ISSN 1746-7659, England, UK
Journal of Information and Computing Science
Vol. 4, No. 2, 2009, *pp*. 083-092

A Fuzzy Based Approach for Multicast Tree Computation in Wireless Multimedia Networks

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(*Received August 26, 2008, accepted November 11, 2008*)

Abstract. Group communication in wireless multimedia networks must consider the Quality of Service (QoS) parameters for efficient and quality aware multicast route computation. QoS parameters such as bandwidth, channel reliability, buffers, delays, jitters, etc. play a vital role in wireless multimedia networks. Multicast tree development for group communication must press for more than one or two QoS parameters for better services. This paper proposes a scheme for constructing a multicast tree based on a spanning tree by employing a fuzzy controller. Fuzzy controller uses three fuzzy input parameters namely, link bandwidth, link delay and link reliability for the construction of multicast spanning tree. The scheme is simulated to test its effectiveness in terms of multicast tree computation time, iterations required for multicast tree computation, packet delay and packet delivery ratio.

Key words: Fuzzy logic, Spanning tree, Multicast route, Wireless multimedia networks

1. Introduction

There is a potential demand for applications of group communications that include video conferencing, e-learning, collaborative works, etc. In order to support these applications, flexible and efficient multicast routing algorithms are needed to compute reliable and Quality of Service (QoS) aware multicast tree. Multicast is the delivery of information to a group of destinations simultaneously using the most efficient strategy to deliver the messages over each link of the network only once, creating copies only when the links to the destinations split. Determining an optimal path for multicast tree for a group is a challenging issue in wireless multimedia networks. Wireless networks pose several constraints like channel reliability, bandwidth limitations, battery life, etc., while developing a multicast tree. Deriving a spanning tree based on certain parameters from the network topology is one of the solutions for multicast tree computation. The tree can be computed considering one or more parameters such as cost, bandwidth, delay, jitter, reliability, etc.

Employing fuzzy controllers for multicast tree development facilitates soft QoS guarantees to multimedia applications. Fuzzy control is a technique based on the principles of fuzzy set theory. Fuzzy control systems are designed to mimic human control systems better than the classical control systems by incorporating the expert knowledge and experience in the control process. This paper proposes a fuzzy based multicast spanning tree computation scheme by considering bandwidth, delay and reliability of the link as input fuzzy parameters and link weight as an output parameter. Using link weights, scheme makes a decision to prune some of the links that do not satisfy the QoS and builds Multicast Spanning Tree (MST) for the multicast group using remaining unpruned links. The MST developed on this basis is probably better than other schemes since it considers multiple parameters and their soft values.

Rest of the paper is organized as follows. Section 2 explains related works in multicast routing. In section 3, explanation of fuzzy based MST development scheme is given. Section 4 describes the simulation procedure, simulation model and results. Section 5 concludes the paper.

2. Related works

Some of the works on multicast routing in wireless networks are briefly explained in this section. The work presented in [1] considers the problem of multicast routing in delay tolerant networks [DTN] and develops an algorithm depending upon the topological knowledge and group membership. The scheme presented in [2] constructs a reliable multicast tree that minimizes recomputation time of the multicast tree as and when the multicast route is updated due to mobility. The scheme presented in [3] considers the cost of the link and end to end delay of the link as two independent parameters for construction of multicast tree. A multicast routing optimization based on genetic algorithms (GA), which finds the low cost multicast tree with bandwidth and delay constraints is presented in [4]. The optimized multicast tree development using delay is given in [5], which shows the effect of cost on the multicast tree in multimedia network.

The work presented in [6] uses a fuzzy controller to develop routing path which uses delay and queue length as fuzzy inputs and link cost as fuzzy output. An algorithm developed on fuzzy number model based on GA to solve the QoS problem in multicast routing is presented in [7]. A fuzzy logic technique is developed in [8] for efficient QoS routing that allows multiple constraints to be considered in simple and intuitive way. The algorithm presented in [9] for security-level is an adaptive fuzzy logic based algorithm that can adapt itself with the dynamic conditions of mobile hosts, which can improve security of mobile ad hoc networks. The scheme given in [10] presents a genetic algorithm using fuzzy selection to address the problem of QoS under delay constraints. The algorithm finds a multicast tree with minimum cost under delay constraints.

A distributed clustering algorithm [11] based on the use of mobility metric for selection of cluster heads demonstrates that it heads to more stable cluster formation than the lowest-id clustering algorithm. In [12], two efficient source based multicast routing algorithms are explained and the objective of each routing algorithm is to minimize the multicast tree cost while maintaining a bound on delay. Managing the group members by the control messages according to the mobility reduces packet loss and message traffic [13]. A comparative study on routing strategies including shortest path routing is done in [14]. Improvement in handoff and routing is shown in [15], which caches packets at the base station and perform local retransmissions across the wireless link to alleviate the problems caused by high bit-error rates.

In [16], QoS routing algorithm for unicast flows which has a very low call establishment overheads is presented. It is an extension of existing IP routing protocol with some modifications. The MST developed using fuzzy triangular values for the cost is given in [17]. A fuzzy logic based multicast tree construction idea is given in [19] that is based on fuzzy parameters bandwidth, reliability and delays. A fuzzy adaptive cache expiration policy using the defuzzified 'Yes' decision dynamically adapts a static cache timeout value for finding reliable routing path [20].

3. Proposed work

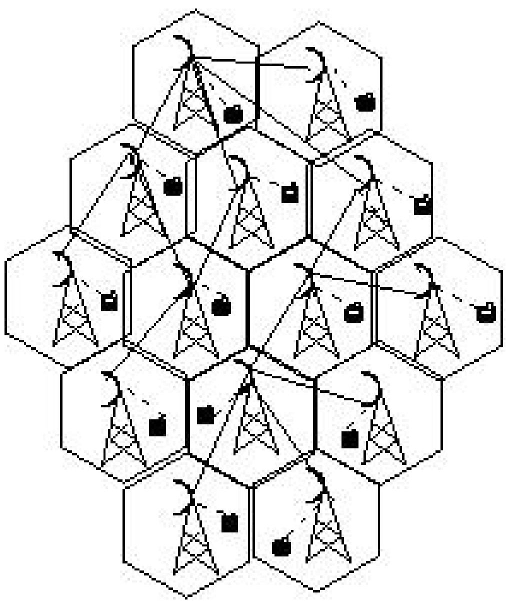

Figure 1: Network environment.

The paper proposes development of Multicast Spanning Tree (MST) depending on the fuzzy parameters link reliability, link bandwidth and link delay. These fuzzy parameters are employed to decide the link weight. If link weight is greater than some value 'x', then it is accepted otherwise rejected. Using the acceptable links, MST is constructed on the basis of maximum link weight for multicast routing. The scheme can be extended to reconstruct MST whenever there is a mobility, node failure and change in membership.

The scheme is applied to wireless network environment as shown in figure 1. The wireless network consists of several cells. Each cell covers a certain area and has a base station for transmission and reception of the packets. Wireless users may be located anywhere in any one of the cells that become the members of a group. The base station to base station links are wired and are characterized by sufficient bandwidth, low to moderate delays and moderate to high reliability. The users in each cell have wireless interface with the base station. Wireless interface is characterized by limited bandwidth, less reliability and moderate to higher delays.

3.1. Fuzzy based multicast routing scheme

In this section, we present the fuzzy logic based MST development scheme, as shown in figure 2. It comprises of link connectivity database, fuzzy based link status computation unit and MST computation unit. The details are as follows.

- Link connectivity database: it consists of values of the parameters such as link connectivity, link reliability, residual link bandwidth, link delay and link weights developed by fuzzy unit (acceptable or not-acceptable).
- Fuzzy based link weight computation: it fuzzifies the parameters link reliability, link residual bandwidth and link delay and generates the defuzzified output parameter called link weight using mean of maximum method [9]. Later, updates the link connectivity database.
- MST computation unit: this unit computes the MST by using the link connectivity and maximum link weights. It considers only acceptable links for computation.

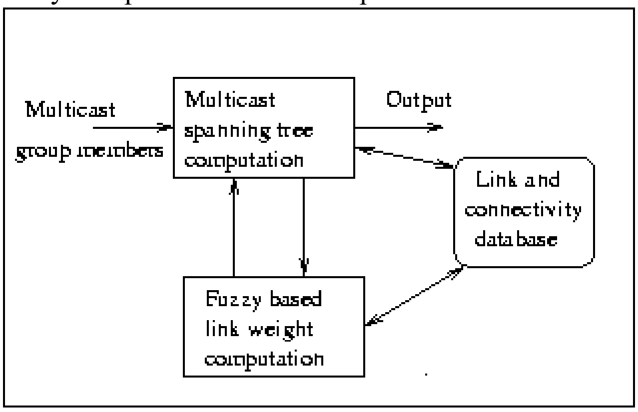

Figure 2: Fuzzy based multicast route computation.

We assume that every base station has the information of all the links of the network and its area. The wireless user who forms the multicast group initiates the MST computation by extracting the link database from its nearest base station.

3.1.1 Fuzzy Parameters

Fuzzy controller is used for minimizing uncertainty present in the network due to mobility of the hosts or constrained network resources. The proposed scheme employs bandwidth, reliability and delay of the link as fuzzy parameters. They have been represented by membership functions as shown in figure 3.

- Residual bandwidth of the link: for bandwidth B_k (k^{th} Link Bandwidth), its linguistic values are small (b0 to b2), medium (b1 to b3) and large (b2 to b4).
- Delay of the link: for delay of the links D_k (k^{th} link), its linguistic values are small (d0 to d2), medium (d1 to d3) and large (d2 to d4).
- Reliability of the link: for link reliability R_k(k^{th} link), its linguistic values are less (l0 to l2), medium (l1 to l3) and high (l2 to l4).

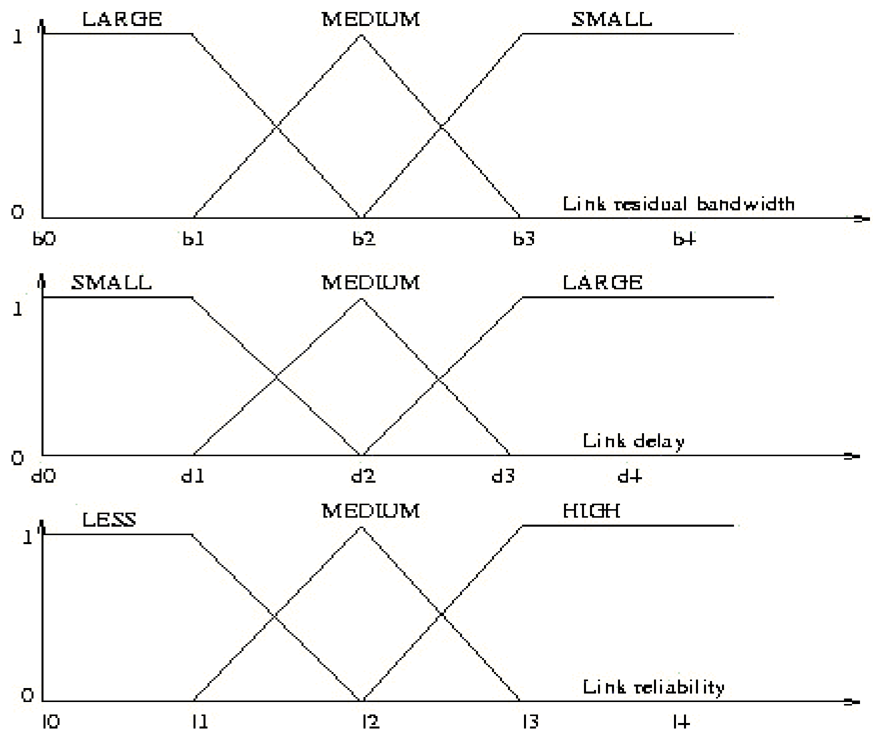

Figure 3: Membership function for input parameters.

Fuzzy based link weight (LW)computation unit considers a fuzzy set of dimension $G(B) * G(D) * G(R)$. The values assigned to fuzzy variables depend on the network administrator, i.e., he/she can assign in the range 1 to 10. The unit generates link weight (acceptable or not-acceptable) by using defuzzifier and inference engine. The defuzzifier method used is mean of maximum, in which maximum of two fuzzy values are selected and mean of them are evaluated.

3.1.2 Fuzzy Controller for link weight computation.

Fuzzy controller consists of fuzzification, inference and defuzzification steps as depicted in figure 4. The details are given below.

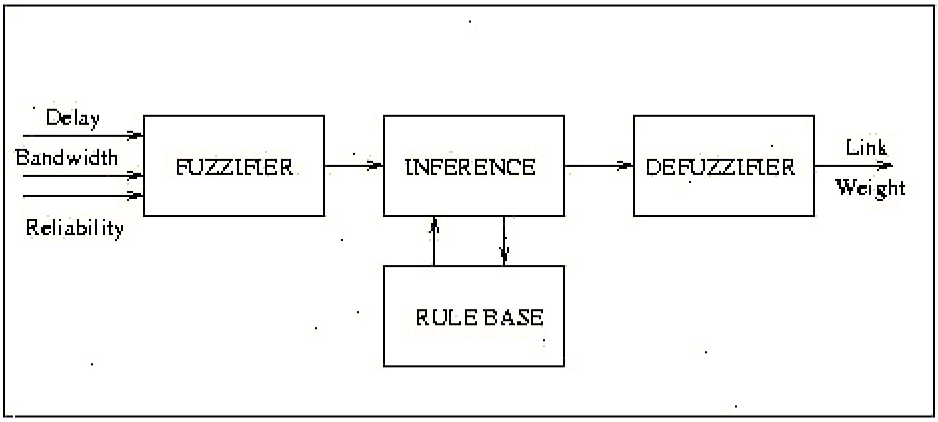

Figure 4: Fuzzy Controller for link weight computation.

3.1.3 Fuzzification

Fuzzy based link weight computation unit considers three parameters for fuzzification: residual bandwidth of link, link reliability and link delay. In the fuzzification step, a measured value (called crisp input) is converted into linguistic values (such as small, medium, large), each of which is represented by a fuzzy set. Each fuzzy set is associated with a membership function and is used to characterize how certain the crisp input belongs to the set. For a given crisp input, the membership function returns a real number in [0,1]. The value closer to 1, more certain the input belongs to the set. A single crisp value can take more than one linguistic value; if the membership values overlap [9]. The membership values are assigned using intuition method. Intuition method is simply derived from the capacity of humans to develop membership functions through their shown innate intelligence and understanding. Intuition involves contextual and semantic knowledge about an issue; it can also involve linguistic truth values about the environment knowledge.

3.1.4 Inference and Defuzzification

Since there are three linguistic values for B_k, D_k and R_k, the total number of rules is 27. The rule-base is in a form called functional fuzzy system where each rule *i* is written as follows.

Rule i: IF (B_k is SMALL and D_k is LARGE and R_k is LESS) THEN {if (*LW*> x) then acceptable else not_accepted}

Link resdual bandwidth	Delay of link	Link reliability	Link weight
L	L	LS	Depends upon fuzzy input parameter. Defuzzified output value, if > then X then link is classified as accepted link
L	L	M	
L	L	H	
L	M	LS	
L	M	M	
L	M	H	
L	S	LS	
L	S	M	
L	S	H	
M	L	LS	
M	L	M	
M	L	H	
M	M	LS	
M	M	M	
M	M	H	
M	S	LS	
M	S	M	
M	S	H	
S	L	LS	
S	L	M	
S	L	H	
S	M	LS	
S	M	M	
S	M	H	
S	S	LS	
S	S	M	
S	S	H	

Figure 5: Fuzzy rule base table.

Link weight values are decided based on membership functions G(B), G(D), and G(R). To decide an appropriate output function, the strength of each rule must be considered. For this reason, the output membership function is a complicated function and mean of maximum method [9] is used for defuzzification. This method finds the maximum point of the fuzzy output membership functions, then evaluates the mean of it and finds acceptable or not acceptable links. The fuzzy rule base with 27 rules is shown in figure 5. The defuzzified output parameter gives flexibility to the network administrator to find the best link for developing MST among the existing links.

3.1.5. Algorithms

Algorithm 1: Fuzzy based MST computation

Nomenclature: Let N = 1,2,...,n be the set of nodes (vertices) of the network, M = 1,2..,m be the number of edges in the network (graph), E=1,2..,e be edge (link) list.

Begin

1. Request for MST for the multicast group computation;
2. Get the information about the links and connectivity;

3. Call algorithm 2;
4. Remove all the links with link weight < x, Creat edge list (links) E;
5. Create topology using E and N vertices;
6. Create MST as follows;

   6.1 Set k=0, count=0;

   //count=initial number edges

   // k= first edge of MST

   6.2 While (count ≠ n-1) and (E ≠ null) do

   Begin

   6.2.1 Select an edge(u,v) from E with maximum link weight;
   6.2.2 Find the root for the vertex u, say i;
   6.2.3 Find the root for the vertex v, say j;
   6.2.4 If (i ≠ j) Then {
   -Select the edge(u,v) as the edge of MST;
   - Increment k and count;
   - Merge the two trees with roots i and j;
   - Delete the edge(u,v) from the list;}

   End
7. Stop

End.

Algorithm 2: Computation of link weight

Nomenclature: m= number of links

Begin

1. For k= 1 to m do

   Begin

   a. Initialize fuzzy controller with residual bandwidth, delay and reliability of 'kth' link;
   b. Find the membership function of bandwidth, delay and reliability for 'kth' link;
   c. Defuzzifiy and compute link weight using Dk, Rk and Bk;

   end;
2. Return link weight;
3. Stop;

End.

3.2. Example

For illustration of the proposed scheme, consider multicast group members connected through wired as well as wireless connection as shown in figure 6. A, B, C, D, E and F are the basestations and A', B', C', D', E' and F' are the wireless nodes (multicast group members). AA', BB', CC', DD', EE' and FF' are the wireless links. AB, BC, CD, DE and EF are wired links.

Each link is assigned a normalized value (1 to 10) for bandwidth, delay and reliability as shown in figure 7(a). These parameters are fuzzified and later defuzzified using mean of maxima method. Consider an edge AB, where 7 and 4 are maximum values. Defuzzified value for the edge is given by equation 1.

$$Fuzzy\_weight_{AB} = (7 + 4)/2 = 5.5 \quad (1)$$

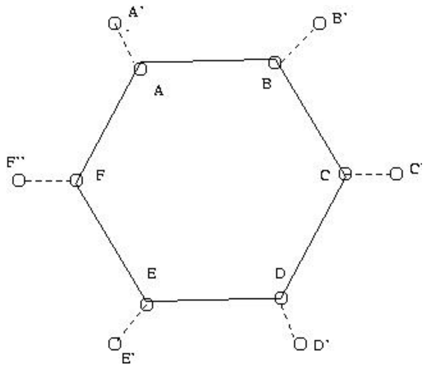

Figure 6: Multicast group topology

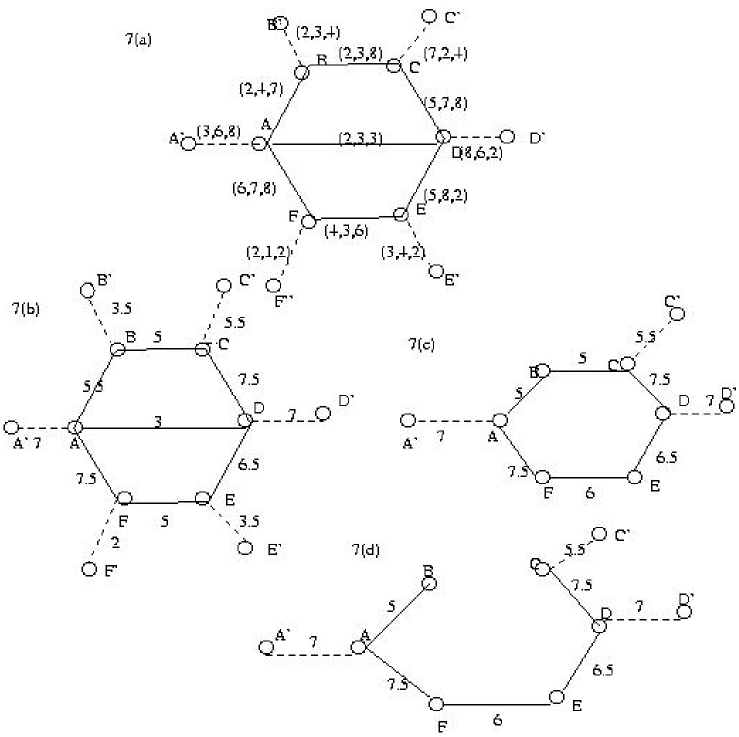

Figure 7: MST of the scheme

The defuzzified value for each edge is evaluated in a similar way. The edges with fuzzy link weights are shown in figure 7(b). We select the edges with fuzzy weight less than 5 (x=5) and prune them from the topology, as they do not satify the QoS criteria, which is shown in figure 7(c). Then a spanning tree is constructed as per Algorithm 1 as shown in figure 7(d).

3.3. Simulation Procedure

To illustrate some results of the simulation, we have taken the following inputs: A=400 sq.kms, bs= 50, max = 7 mbps, wmax = 15 mbps, da = 2 ms., db = 10 ms., wda = 10 ms., wdb = 20 ms., rx = 0.5, ry = 0.9, wrx = 0.1, wry = 0.8, mg = 2 to 50, p = 50 and x = 5. The linguistic values for residual bandwidth is given as follows; small (b0 = 1mbps to b2 = 5 mbps), medium (b1 = 3 mbps to b3 = 7mbps), large (b2 = 5mbps to b4 = 10mbps). The linguistic values for delay are; small (d0 = 1 ms. to d2 = 5ms), medium (d1 = 5ms. to d3 = 12ms.) and large (d2 = 12ms. to d4 = 20ms.). The linguistic values for link reliability are; less (lo = 0.1 to l2 = 0.4), medium (l1 = 0.25 to l3 = 0.6) and high (l2 = 0.4 to l4 = 0.9).

Simulation procedure is as follows.

- Generate a network with random placement of nodes and edges along with the link parameters.
- Generate a multicast group with several nodes.
- Apply proposed scheme to compute link weights.

- Remove links with weights less than ’x’ and reconstruct the network topology.
- Construct MST using maximum value of link weight.
- Evaluate the performance parameters

3.4. Results

The proposed work is simulated extensively on a Pentium-IV desktop by using C programming language. The performance parameters considered for evaluation of the proposed model are as follows.

- *Convergence iterations*: It is defined as the number of iterations required to develop MST.
- *Convergence time*: It is defined as the time required to construct MST.
- *Packet delivery ratio*: It is defined as the ratio of number of packets received to the total number of packets generated.
- *Packet delay*: It is the time taken by the source packet to reach the destinations.
- *Percentage of pruning of the links*: It is defined as the ratio of total number of links that are pruned in fuzzy scheme to the total number of links in the initial topology.

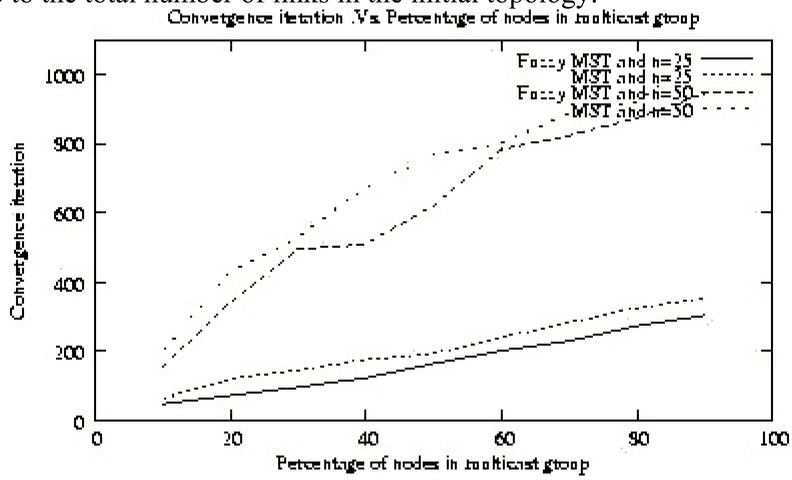

Figure 8: Convergence iterations .Vs. Percentage of nodes in multicast group

The iterations required to converge for building a MST is shown in figure 8. Convergence iterations increase with the increase in multicast group size. Proposed scheme has less number of iterations as compared to traditional MST construction that uses kruskal’s algorithm. The reason is, the links that do not have required parameters are pruned while constructing MST.

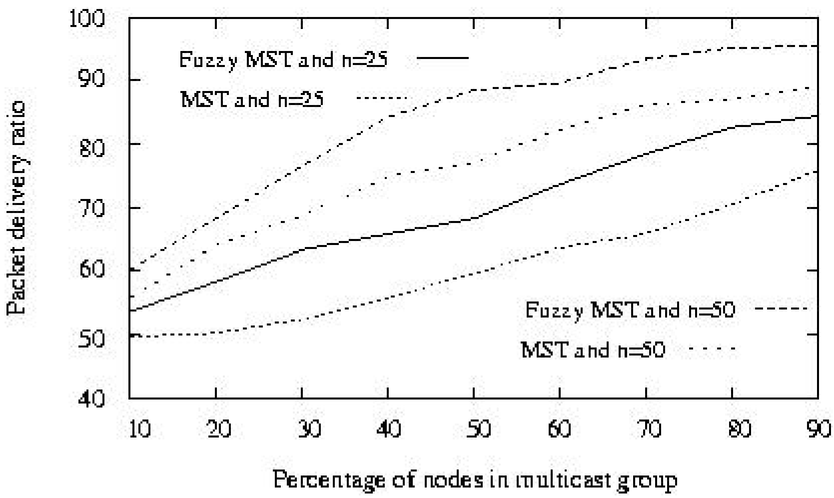

Figure 9: Packet delivery ratio .Vs. Percentage of nodes in multicast group

Figure 9 depicts that the packet delivery ratio increases with increase in multicast group size. It is observed that fuzzy based MST construction scheme performs better packet delivery as compared to traditional MST construction scheme. This is because, the proposed scheme chooses links based on QoS availability for MST construction.

The MST convergence time for different group sizes are shown in figure 10. The convergence time required for fuzzy based MST construction scheme is less because it considers the links with required parameters and hence computations are reduced.

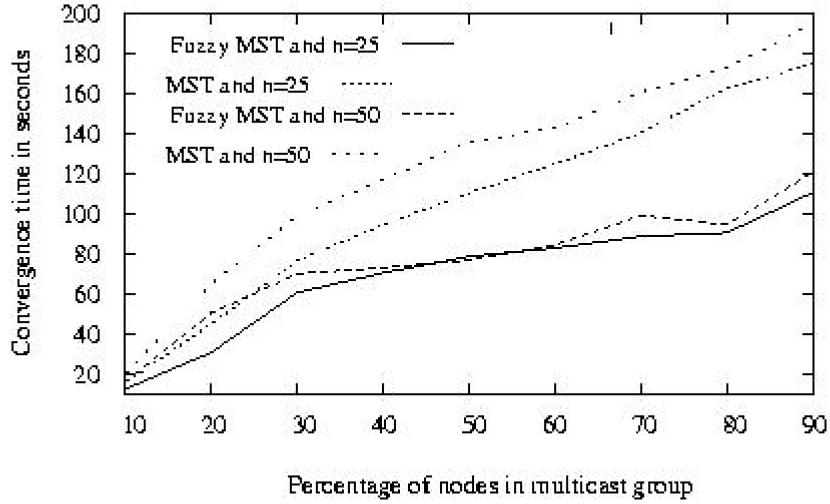

Figure 10: Convergence time .Vs. Percentage of nodes in multicast group

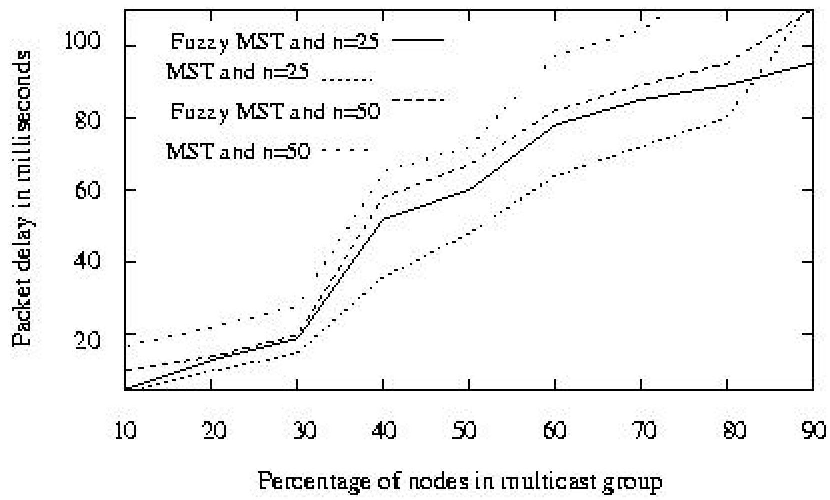

Figure 11: Packet delay .Vs. Percentage of nodes in multicast group

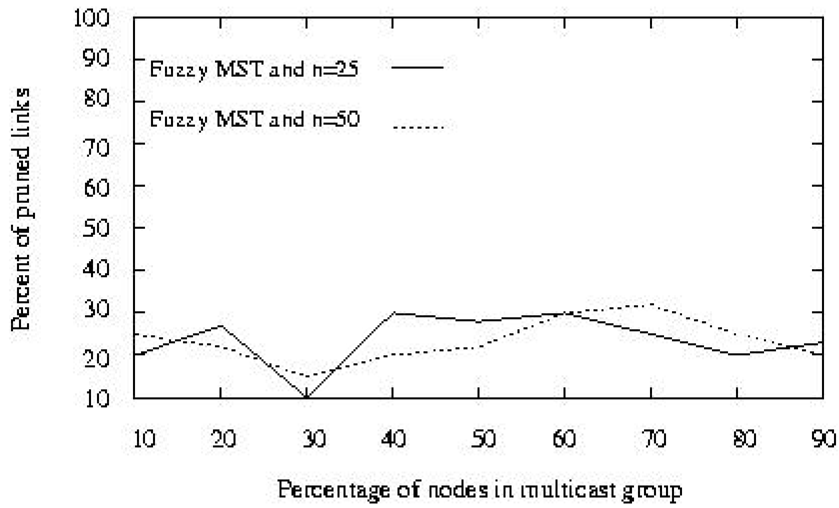

Figure 12: Percentage of pruned links .Vs. Percentage of nodes in multicast group

Packet delay for the fuzzy scheme and MST scheme with different group size are given in figure 11. The delay in case of fuzzy based MST construction scheme is less because links are selected that have lesser delays during MST construction. Percentage of pruned links (that are not-acceptable) with increase in multicast group size are shown in figure 12. QoS based pruning of links makes the proposed scheme more reliable and efficient.

4. Conclusions

In this paper, we proposed a scheme for MST construction based on QoS parameters by employing a fuzzy controller. The main objective is to increase the reliability and packet delivery ratio. The novelty of the proposed scheme is based on MST construction by using acceptable links computed by employing fuzzy controller that considers fuzzy parameters link reliability, link delay and link residual bandwidth. It is observed that the proposed scheme performs better than traditional MST construction scheme (Kruskal's algorithm) in terms of convergence iterations, convergence time, and packet delivery ratio and packet delays. The scheme can also be extended to provide good QoS by considering application specific parameters as well as perform reconstruction of the tree with the user/node mobility and node failures and channel failures.

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