Efficient Fuzzy-based Multi-constraint Multicast Routing With Multi-criteria Enhanced Optimal Capacity-Delay Tradeoff

N.Sivapriya, T.N.Ravi

Abstract— In Mobile Ad-hoc Network (MANET), a mobility of the nodes may impact the node capacity and delay during transmitting the data from source to the destination in the network. To avoid this, Multi-criteria Enhanced Optimal Capacity-Delay Tradeoff (MEOCDT) was proposed with Time-limited Neighbor Detector using Multi-criteria Node Rank metric that detects the neighbors and optimal paths for reliable forwarding node. Though this technique improves link stability and node reliability, the computational complexity was high. Hence in this paper, an Efficient Fuzzy-based Multi-constraint Multicast Routing (EFM2R) method is proposed with MEOCDT to reduce the computational complexity of optimal node selection. The major objective of this technique is to solve the uncertainty issues in the consideration of multiple network metrics such as delay, bandwidth, Link Stability Factor (LSF) and residual energy. In this technique, the fuzzy logic method is proposed to convert the considered network metrics as a single metric called fuzzy cost or communication cost. Then, the path with minimum fuzzy cost is selected as an optimal route to transmit the data from the source to the destination node in the network with reduced delay. Finally, the simulation results show the performance effectiveness of the proposed technique compared to the existing technique in terms of throughput, routing overhead, delay, packet delivery ratio.

Index Terms— Fuzzy logic, MEOCDT, Multi-constraint multicast routing, Multi-criteria node rank, Residual energy

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1 INTRODUCTION

Mobile Ad-hoc Network (MANET) is one of the types of decentralized wireless networks consisting of a number of mobile nodes. Those mobile nodes can communicate with each other directly or indirectly through wireless connections. Each node in the network may act as a host and a router to find and maintain the routing paths to the other nodes since there is no centralized administrator in the network. The primary characteristics are including bandwidth and energy constraints, cooperation and its dynamic topology. This type of network is used in defense, healthcare monitoring systems, disaster management, etc.

A successful data transmission mainly depended on the quality of the selected route. If the quality of routing path was not efficient, then the packet reception can be affected by the node's mobility and insufficient resources [1]. As a result, different routing protocols have been designed to transmit the packets from the source to the destination node. Mostly, Ad-hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols were applied to reduce the number of hops on the selected routing path. However, QoS performance of the network was not efficient. Therefore, Optimal Capacity-Delay Tradeoff (OCDT) were considered [2] to improve the link stability. In this method, a correlation of node mobility was considered to set up the complete upper bound of Capacity-Delay Tradeoff(CDT). Also, achievable — lower bound was discovered based on the optimal scheduling parameters on a specific constraint. This method was enhanced by considering QoS-aware routing metric [3] to improve the link stability efficiently. In this scheme, the forwarding node was selected based on the Link Stability Factor (LSF) which was computed by considering the contention count, received signal strength and hop count. Moreover, the neighbor node detection was achieved by using a time-limited neighbor detector that allows the nodes to detect the neighborhood nodes. Here, the optimal neighbor nodes were selected by using Multi-criteria Node Rank (MNR) [4]metric that consists of residual energy, LSF and nodes' mobility. However, this scheme has a high computational complexity to detect neighbor nodes and improve the routing path quality.

Hence in this paper, an efficient fuzzy based multi-constraint multicast routing method is proposed. In this work, different network metrics such as delay, bandwidth, LSF and residual energy are considered. These network metrics are converted into a single metric namely fuzzy cost based on the fuzzy logic method. Based on this method, uncertainty issues in the computed network metrics are solved to select an optimal path from source to the destination node. Once the fuzzy cost is computed, the path with minimum fuzzy cost is chosen as an optimal path for data transmission. Thus, the packets are transmitted through the selected path successfully.

The rest of the paper is structured as follows: Section II presents the literature survey related to the multipath route discovery and routing protocols in wireless ad-hoc networks. Section III explains the proposed methodology. Section IV illustrates the experimental results of the proposed method. Finally, Section V concludes the research work.

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2 LITERATURE SURVEY

A Mobility-based Multicast Routing (MMR) algorithm [5] was proposed for MANET. The main aim of this algorithm was alleviating the flooding issue in multicast routing protocols. In this algorithm, the expected relative mobility of each host was used for predicting its realistic motion characteristic by sampling its movement parameters during different epochs. The Minimum Steiner Connected Dominating Set (MSCDS) issue was defined in the stochastic graphs where the relative mobility of each host was considered as its weight. Then, a distributed Learning Automata-based (LA) algorithm was proposed to solve such stochastic issue. However, the performance efficiency was required further improvement.

An efficient route discovery algorithm [6] was proposed for improving the efficiency of On-Demand Multicast Routing Protocol (ODMRP). In this algorithm, multicasting mechanism was improved by controlling flooding mechanism according to the delay characteristics of the contributing nodes. Moreover, the contributing nodes were modelled as M/M/1 queuing systems. However, packet delivery ratio was less when the node's mobility was increased.

A link-state QoS routing protocol [7] was proposed based on the Optimized Link Stable Routing (OLSR) protocol to establish the stable and sustainable Multipoint Relays (MPR) between all nodes in the MANET. In this scheme, a stability function was used as the primary route selection criterion based on the computation of the mobility degree of a node relative to its neighbor. In addition, QoS metrics such as packet loss and response time were guaranteed by this scheme. However, it requires the other parameters like path overhead, residual energy, etc., for evaluating the path availability.

An Improved Ant colony-based Multi-constrained QoS Energy-saving Routing (IAMQER) [8] was proposed in wireless ad-hoc networks. In this method, an optimal path from the source node to the destination node was obtained by using ant colony algorithm. This algorithm was performed based on the analysis of local node information such as queue length, number of forwarding data packets and residual energy, the relationship between the network throughput and the energy consumption of a node. Moreover, the transmission power of a node was adjusted dynamically based on the distance between the nodes. But, it requires further improvement to satisfy more network requirements.

Design of Load Balanced Multicast Routing Protocol (LBMRP) [9] was proposed to reduce the overhead and increase the lifetime of MANET. In this scheme, all mobile nodes were randomly classified into three groups and a tree was constructed for each group for transmitting the data efficiently. Based on this scheme, path stability of multicast routing was increased during the route discovery process. However, the energy consumption and packet delivery delay were high.

Network coding-based energy-efficient multicast routing algorithm [10] was proposed for multi-hop wireless networks. Initially, the energy metric and energy efficiency metric of multi-hop networks were analyzed. After that, the network coding was used for improving the network throughput. In addition, three basic structures of network coding were proposed to solve the random network topology. Moreover, a flexible energy-efficient multicast routing algorithm was presented for exploiting the proposed network structure in order to reduce the energy consumption. However, the complexity of this algorithm was high.

QoS routing was enhanced [11] in MANET by using metaheuristic approach in MANET. The main aim of this approach was to satisfy the QoS constraints in the network based on the Cuckoo Search (CS) algorithm. In this protocol, QoS path was selected according to the best fitness value which was computed by using three parameters such as routing load, residual energy and hop count. This algorithm was applied on Ad-hoc On-demand Distance Vector (AODV) protocol for route reply where multiple paths were available. However, the robustness of this protocol was less.

An Intelligent Energy-aware Efficient Routing (IE2R) [12] was proposed for MANET. In this protocol, Multi-Criteria Decision Making (MCDM) technique was used based on entropy and Preference Ranking Organization METHod for Enrichment of Evaluation-II (PROMETHEE-II) method in order to find an efficient path. Moreover, MCDM technique was combined with an Intuitionistic Fuzzy Soft Set (IFSS) method for efficiently reducing uncertainty related to the mobile node. However, path discovery latency was high. Since the path was discovered only after the flow was initiated.

3 PROPOSED METHODOLOGY

In this section, the proposed Multi-criteria Enhanced Optimal Capacity-Delay Tradeoff - Efficient Fuzzy-based Multi-constraint Multicast Routing (MEOCDT-EFM2R) technique is explained. The fuzzy logic system consists of four components such as fuzzifier, inference engine, fuzzy rule base and defuzzifier. Initially, different network metrics such as delay, residual energy, LSF and bandwidth are computed. Once all the metrics are computed, they are given as input to the fuzzy logic system. The proposed MEOCDT-EFM2R converts them into a single metric named fuzzy cost with minimized computational complexity. Based on this fuzzy cost value, an optimal path is selected to transmit the packets from source to the destination node.

Input Fuzzification: In this phase, the considered input variables such as delay (d), residual energy (E_r), Link Stability Factor *(lsf)* and bandwidth (b) are fuzzified. Normally, a linguistic variable is decomposed into a set of linguistic terms. Based on the knowledge base rule, the three linguistic values of each input variables are minimum, average and maximum. For the output variable i.e., fuzzy cost, the linguistic values are very minimum, minimum, average and maximum.

Membership Function: Membership functions are used in the fuzzification and defuzzification processes for mapping the crisp input to fuzzy input and vice-versa. In the fuzzification process, the crisp inputs are converted into a fuzzy input set i.e., linguistic values by using triangular membership function.

Fuzzy Knowledge Base Rule: A rule base is constructed for controlling the output variable. A fuzzy-rule is IF-THEN rule which contains antecedent and consequent statement including either "AND" or "OR" operator.

In this proposed technique, network metrics uncertainty issues are controlled by the fuzzy logic system to select an optimal multicast routing path for data transmission from the source node to the destination node. The multicast routing path is selected based on minimum fuzzy cost value. The relationship between fuzzy cost function and the network performance metrics is defined as follows:

$$Fuzzy\ Cost = F(d, b, lsf, E_r) \quad (1)$$

Here, the network metrics are computed by using the following equations (2)-(6) respectively.

$$d(R(s,t)) = \sum_{i=1}^{n} delay[e_i, e \in R(s,t)] \quad (2)$$

$$b(R(s,t)) = \sum_{i=1}^{n} bandwidth[e_i, e \in R(s,t)] \quad (3)$$

$$LSF_i = \frac{SS_{norm_i}}{HC_{norm_i}} - |CC_{norm_i} - CC_{med}| \quad (4)$$

$$E_r(L(n_i, n_{i+1})) = E_{int}(n_i) - [E_t(n_i) + E_r(n_i)] \quad (5)$$

$$E_r(R(s,t)) = \sum_{i=1}^{n} E_r[L(n_i, n_{i+1})] \quad (6)$$

In the above equations, SS_{norm_i} is the normalized received signal strength, HC_{norm_i} is the normalized hop count, CC_{norm_i} is the normalized contention count at any node, CC_{med} is median contention count, R is the path from source node s to the destination node t, e is the transmission channel between two nodes and n is the number of nodes in the specific routing path, L is the link, E_{int} is the initial energy, E_t is the energy used for transmission and E_r is the energy utilised for receiving data. The optimal routing path will be selected by the source node using the minimum fuzzy cost value. Some fuzzy rules of the proposed technique are shown in Table 1.

Table 1. Fuzzy Knowledge Base Rules

Input				Output
Delay	**Residual Energy**	**LSF**	**Bandwidth**	**Fuzzy Cost**
Minimum	Minimum	Minimum	Minimum	Very Minimum
Minimum	Minimum	Average	Average	Minimum
Minimum	Average	Average	Minimum	Minimum
Average	Average	Minimum	High	Average
Maximum	Maximum	Maximum	Maximum	Maximum
Maximum	Average	Minimum	Average	Average
Average	Maximum	Average	Maximum	Maximum

After that, the data packets are transmitted to the destination node through the selected optimal routing path based on the following functions:

Multicast Route Discovery Phase: If source node wants to forward a data packet to the destination node, then it will initiate the route discovery process to discover a multicast routing path. The source node transmits an RREQ packet across the network and the nodes located in its communication range will receive the RREQ. This packet consists of different information $\{s_{add}, t_{add}, U_{id}, RP_{info}, d, b, E_r, lsf\}$ where s_{add} refers source address, t_{add} refers destination address, U_{id} refers message unique id used for identifying the duplicate RREQ packets and RP_{info} is used for recording the entire routing path information.

Multicast Route Reply Phase: The RREP packets are generated while RREQ packet is received. The generated RREP packets are transmitted to the source node. The RREP consists of the following information $\{s_{add}, RevPath_{info}, U_{id}, fuzzy\ cost, t_{add}\}$ where $RevPath_{info}$ refers to the reverse path to carry the RREP packet. Once RREP packet is received by the source node, the data packets are transmitted to the destination through the selected optimal path efficiently.

MEOCDT-EFM2R Technique

1. Initialize;
2. Construct the network consists of ***i*** number of nodes;
3. Assign each node with a sub-region R_i;
4. Create a set of node and detect its neighbors at time ***t***;
5. Determine the correlated mobility with contention count;
6. Discover a reliable forwarding node;
7. For (each node v_i)
8. {
9. Compute MNR metric based on residual energy and mobility;
10. Calculate link cost function using MNR metric;
11. Rank the nodes based on MNR metric;
12. Select top ***k*** nodes as optimal neighbor nodes;
13. Scan its locations and their paths in R_i;
14. Broadcast a RREQ packet from the source node;
15. If(receiving node of RREQ is a destination node)
16. {
17. Compute network metrics using (2)-(6);
18. Compute a fuzzy cost using (1);
19. Select the optimal path with minimum fuzzy cost;
20. Transmit RREP packet to the source node;
21. else
22. Rebroadcast the RREQ packet;
23. }
24. If(receiving node of RREP is a source node)
25. {
26. End
27. else
28. Rebroadcast the RREP packet;
29. }

4 Results and Discussions

In this section, the performance effectiveness of the proposed MEOCDT-EFM2R technique is evaluated and compared with the existing MEOCDT technique by using Network Simulator version 2 (NS2.35). The comparison is made in terms of throughput, routing overhead, Packet Delivery Delay (PDD), end-to-end delay, Energy Cost per Packet (ECP), Packet Delivery Ratio (PDR), Average Route Lifetime (ARL), Average Energy Consumption (AEC), total packets dropped, network lifetime. The simulation parameters are given in Table 2.

Table 2. Simulation Parameters

Parameters	Value
Number of nodes	40
Node's speed	0.01m/s
Network simulation area	1500 X 1500sqm
Frequency	2.4GHz
Radio range	250m
MAC Protocol	IEEE 802.11
Packet size	512 bytes
Packet type	RTP/UDP
Transmission Power	15dBm
Number of channels	2
Channel capacity	2 Mbps
Transmission rate	4 Mbps
Packet interval	2 ms
Traffic source	CBR
Node mobility	0-20m/sec
Mobility model	Random way point
Propagation model	Free space propagation
Traffic rate	4 packets/sec
Initial energy	50J

4.1 Throughput
It is defined as the number of bits received at the destination within a given time.

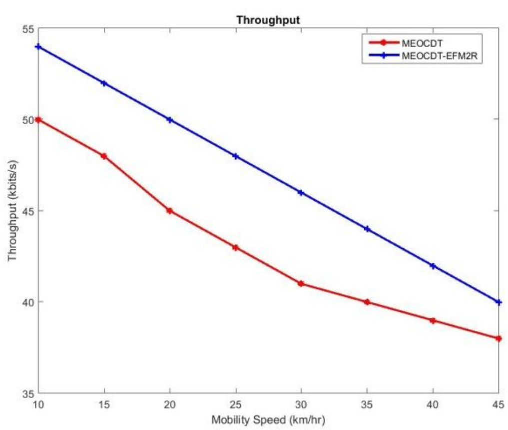

Fig.1 Comparison of Throughput

Fig. 1 shows the comparison of proposed and existing techniques in terms of throughput for different mobility speeds. In the graph, x-axis denotes the mobility speed in km/hr and y-axis denotes the throughput values in kbps. From the analysis, it is evidently clear that the throughput of the proposed MEOCDT-EFM2R technique is higher than the existing technique.

4.2 Routing Overhead
It is defined as the total number of routing packets in the network.

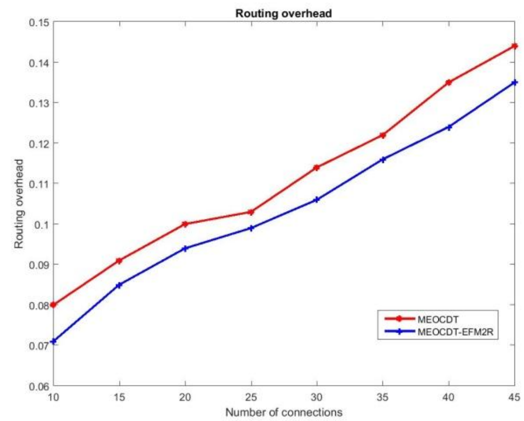

Fig. 2 Comparison of Routing Overhead

Fig. 2 shows the comparison of proposed and existing techniques in terms of routing overhead for different number of connections. In the graph, x-axis takes number of connections and y-axis denotes the routing overhead values. From the prior analysis, it is concluded that the routing overhead of the proposed technique is reduced than the existing technique.

4.3 Packet Delivery Delay (PDD)
It is defined as the average amount of time taken for data packets transmitted from source to the destination.

Fig. 3 Comparison of PDD

Fig. 3 shows the comparison of proposed and existing techniques in terms of PDD for different mobility speeds. In the graph, x-axis denotes the mobility speed in km/hr and y-axis denotes the PDD values in seconds. Here, it is shown that the PDD of the proposed MEOCDT-EFM2R technique is decreased than the existing technique.

4.4 End-to-end Delay
It is defined as the time elapsed between transmitting the data packet from the source and receiving it at the destination.

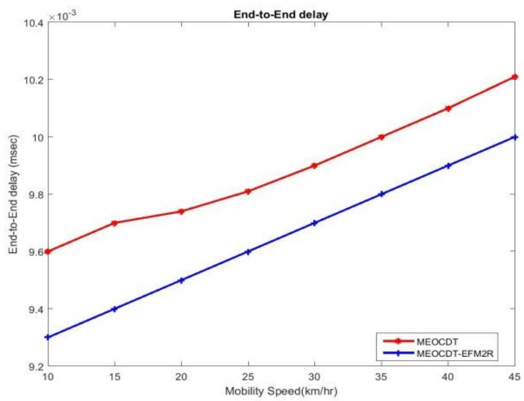

Fig. 4 Comparison of End-to-end Delay

Fig. 4 shows the comparison of proposed and existing techniques in terms of end-to-end delay for different mobility speeds. In the graph, x-axis denotes the mobility speed in km/hr and y-axis denotes the end-to-end delay values in milliseconds. From former the analysis, it is proved that the end-to-end delay of the proposed MEOCDT-EFM2R technique is minimum than the existing technique.

4.6 Packet Delivery Ratio (PDR)
It is defined as the ratio between the total number of data packets received and transmitted over the communication medium.

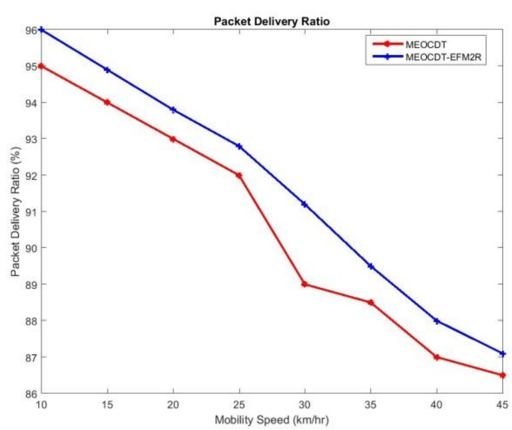

Fig. 5 Comparison of PDR

Fig. 5 shows the comparison of proposed and existing techniques in terms of PDR for different mobility speeds. In the graph, x-axis denotes the mobility speed in km/hr and y-axis denotes the PDR values in %. The present analysis firmly declares that the PDR of the proposed MEOCDT-EFM2R technique is increased than the existing technique.

5 CONCLUSION

In this paper, EFM2R technique is proposed for a MANET with MEOCDT technique to enhance the multicast routing path selection. The uncertainty issues in the network metrics are resolved by using fuzzy linguistic values. In this technique, the considered network metrics such as delay, bandwidth, etc., are converted into fuzzy linguistic value namely fuzzy cost. After the computation of fuzzy cost, the path with minimum fuzzy cost is chosen as an optimal path for data transmission from source to the destination node. This technique reduces control overhead, uncertainty issues and packet loss. Finally, the network performance is simulated by using NS2-simulator and compared with the existing technique that illustrates a better improvement in the proposed technique.

REFERENCES

[1] Mohandas,R., Krishnamoorthi,K. ,Sudha,V.,"Energy Sensitive Cluster level Security Selection Scheme for MANET", Wireless Personal Communications, 2019, vol. 105, no.3, pp. 973-991.

[2] Jia, R., Yang, F., Yao, S., Tian, X., Wang, X., Zhang, W., & Xu, J.,. "Optimal Capacity–Delay Tradeoff in MANETs with Correlation of Node Mobility", IEEE Transactions on Vehicular Technology, 2017, vol. 66, no. 2, pp. 1772-1785.

[3] Priya Sethuraman, Tamizharasan, P.S., Kannan Arputharaj, "Fuzzy Genetic Elliptic Curve Diffie Hellman Algorithm for Secured Communication in Networks", Wireless Personal Communications, 2019, vol. 105, no.3, pp. 993-1007.

[4] Pratapa Reddy,A. , Satyanarayana,N., "Energy-efficient stable Multipath routing in MANET", Wireless Network, 2017, vol. 23, no. 7, pp. 2083-2091.

[5] Torkestani, J. ilA., & Meybodi, M. R., "Mobility-based multicast routing algorithm for wireless mobile Ad-hoc networks: A learning automata approach", Computer Communications, 2010, vol. 33, no.6, pp. 721-735.

[6] Kharraz, M. A., Sarbazi-Azad, H., & Zomaya, A. Y., "On-demand multicast routing protocol with efficient route discovery", Journal of Network and Computer Applications, 2012, vol. 35, no. 3, pp. 942-950.

[7] Moussaoui, A., Semchedine, F., & Boukerram, A., "A link-state QoS routing protocol based on link stability for Mobile Ad hoc Networks", Journal of Network and Computer Applications, 2014, vol. 39, pp. 117-125.

[8] Wang, Y. L., Mei, S. O. N. G., Wei, Y. F., Wang, Y. H., & Wang, X. J., "Improved ant colony-based multi-constrained QoS energy-saving routing and throughput optimization in wireless Ad-hoc networks", The Journal of China Universities of Posts and Telecommunications, 2014, vol. 21, no. 1, pp. 43-59.

[9] Yadav, A. K., & Tripathi, S.,"DLBMRP: design of load balanced multicast routing protocol for wireless mobile ad-hoc network", Wireless Personal Communications, 2015, vol. 85, no. 4, pp. 1815-1829.

[10] Jiang, D., Xu, Z., Li, W., & Chen, Z., "Network coding-based energy-efficient multicast routing algorithm for multi-hop wireless networks", Journal of Systems and Software, 2015, vol. 104, pp. 152-165.
[11] Mandhare, V. V., Thool, V. R., & Manthalkar, R. R., "QoS Routing enhancement using metaheuristic approach in mobile ad-hoc network", Computer Networks, 2016, vol. 110, pp. 180-191.
[12] Das, S. K., & Tripathi, S., "Intelligent energy-aware efficient routing for MANET", Wireless Networks, 2016, vol. 24, no. 4, pp. 1139-1159.