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Cross-Layer Based Delay Latency Reduction Technique For Multipath Routing In MANET

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Abstract

In MANET multipath routing, delay reduction is a challenging issue. In order to overcome this, we propose to develop a Cross-layer Based Delay Latency Reduction Technique for Multipath Routing in MANET. For this, we estimate a cross layer metric namely Expected Path Delay and use it along with LET, PLRT, LPER, LRSS and RBP in route selection. The EPD depends on data rate received, current queue size, from the MAC and SNR from the PHY layer. The transmission and route maintenance delays due to collisions are overcome by using flexible packet delivery delay control mechanism using Two Hop Relay (2HR) algorithm.

Introduction

MANET

A mobile ad hoc network (MANET) is a multi-hop wireless network are composed of autonomous nodes may act as a host and as a router that communicate with each other without the need of fixed infrastructure by forming dynamic topology such that the mobile nodes can easily join or move in the network and access data randomly at any time with absence of access points or base station and maintaining connections in a decentralized manner. The network over radio links are caused due to the self-organization, self-configuring and self adapting of the mobile nodes[1].The infrastructure less property and the easy deployment along with the self-organizing nature makes them useful for many applications like military applications, mobile social networks, emergency deployment, intelligent transportation systems and fast response to disasters [2]

Challenges

- Dynamic topology
- Unreliable wireless channel
- Node mobility
- Channel contention
- Insecure medium
- Limited Bandwidth [3]

Efficient Delay (or) Latency Reduction Technique for Routing in MANET

Delay aware reduction technique make path selection between source and destination based on the delay metric over the discovered links during routing discovery process and routing table calculations [4]. Delay is the amount of time taken for a packet to reach the destination which is obtained from the sum of all the link delays. Delay in MANETs consist of many types such as compression and decompression delay, processing delay, packetization delay, queuing delay, propagation delay, media access delay, acknowledgment and retransmission delay, jitter delay, end-to-end delay and routing delay at each node [3].

End-to-end delay comprises the delay incurred at each link along the path that refers to the total time experienced by a single packet travelling in a MANET from source node to destination node. Communication delay of a packet across an ad hoc network is the latency consumed by a packet to reach the destination from the source. Node delay involves the protocol processing time at node for link and link delay is the latency consumed by the packet to travel from one node to another node along link. Propagation delays are negligibly small and almost equal for each hop along the pathrelated to propagating bits through wireless media. Compression and decompression delay is related to transmitting audio files. Processing delay occurs while the node processes the packet for transmission [5] [6].

Need for delay reduction technique in MANET

Delay metric of each path will be recorded inside the routing table, and it will be used to select the optimum path from the available paths that carries the lowest value of delay to use it as an active route between the source and destination instead of minimum hop count or other metrics and utilizes the available paths effectively by reducing the power consumption. Selecting such paths will be used to assign routes and make the stream of data especially the real-time stream better in terms of less delay for delivered data [4] [7]. If route selection criterion is least path delay with minimum required bandwidth instead of simple mini- mum hop count, then it will be able to maintain the required QoS constraints throughout the session [8]

Reduction of delay or latency may speed up the communications since it enables a message to reach all neighbors of its transmitter simultaneously in a single transmission and increases the packet delivery ratio [9]. Determination of link capacity and available bandwidth and path delay contributes success for real time delay sensitive applications such as VoIP and videoconferencing. The acceptable QoS parameters are normally measured in terms of end-to-end delay, delay variation (jitter) and packet loss rate. So the need of delay reduction technique is the important metric for supporting QoS [3]

Challenges

- Transferring real-time traffic over MANETs is a big challenge due to the high requirements of bandwidth, time delay, and latency for such traffic [4]
- Delay is an important QoS parameter where challenging network environments are considered, either because of variations of node speed, packet sent rate or the lack of infrastructure, or because of temporary disconnection and high latency that adds more delay to network [5]
- The increase of delay time can be due to congestion and/or collision and also other factors such as the length of the route and interference level along the route path. However, it is important for MANETs to avoid network congestion and collision, in order to optimize MANETs' throughput and performance in general [6]
- Due to the range of possible medium contention of a mobile node is wide, medium contention times can affect the end-to-end delay considerably [8]
- When selecting the path based on minimum number of hops per route without considering the node's queue status and channel conditions causing congested nodes along the path which translates into longer delays and more dropped packets
- Load balancing causing heavily loaded nodes with longer queues will cause longer delays along the path between source and destination [9]

Literature Review

Mahadev A. Gawas et al [9] have proposed a Cross Layer Delay aware Node Disjoint Multipath AODV (CLDM-AODV) based on delay constraint using variation of a node-disjoint Multipath QoS Routing protocol that employed cross-layer communications between MAC and routing layers to achieve link and channel-awareness in which the proposed algorithm selected only node disjoint routes that contented the end-to-end delay specified in the route request. For computing end-to-end delay, the algorithm appraised internode packet processing delay at each node on a regular basis by updating the path status in terms of lowest delay deserved at each intermediate node.

V. R. Budyal and S. S. Manvi [10] have proposed an intelligent agent based on-demand delay aware QoS routing scheme in MANETs that selected QoS and the delay satisfied paths from a source to the destination with intermediate node's state information available at source node. The scheme used a static neuro-fuzzy agent at the source node to optimize membership functions of fuzzy parameters that decided whether nodes on the path satisfy required delay requirement according to user delay requirement of the fuzzy inference system (FIS).A fuzzy Q-learning static agent at the source node is employed to optimize the consequent part of if-then rules of FIS and mobile agents are used to maintain and repair the path.

Muhammad Imran Malik et al [11] have proposed Latency Aware Routing Mechanism to Maximize the Life Time of MANET by addressing the latency issues intrinsically present in the AODV together with retaining the efficient use of battery power. They have used received Log-Likelihood ratios (LLR) at each node as the decisive parameter whether or not to participate in communication. If there was a real time traffic, the nodes functioned at high transmission power and in case of non real time traffic the transmission power was low. Though considers both latency and power, since node had to make the routing decision and used larger transmission ranges to minimize the number of hops between the source and the destination so the overhead will be more. Along with this, the queuing and retransmission are delays are not considered.

MuathObaidat et al [12] have proposed QoS Multipath Routing Protocol called QMRP by modifying the process of route discovery, route selection and route maintenance of AODV. The QMRP protocol selected multiple node-disjoint paths based on which path satisfy the lowest delay using the computation value of Expected Path Delay that have taken SNR into account from the physical layer, data rate and queue size from the MAC layer then pass these values to the routing layer where delay computation takes place and also congested nodes are avoided by choosing paths based on minimum EPD by considering current delay, expected delay and queuing delay encountered at each node into the computation of the EPD when establishing paths between a source–destination pair.

Jiajia Liu et al [13] have proposed group-based two-hop relay algorithm with packet redundancy for enabling the packet delivery delay to be flexibly controlled in a large region where each packet is delivered to at most distinct relay nodes and can be accepted by its destination if it is a fresh packet to the destination and also it is among packets of the group the destination is currently requesting then developed a general theoretical framework to capture complex packet delivery process based on the multidimensional Markov chain, which covers the available frameworks for conventional two-hop relay analysis that enables not only the mean value, but also the variance of packet delivery delay to be derived analytically with a careful consideration of the important medium contention, interference, and traffic contention issues.

David Espes and ZoubirMammeri [14] have proposed a cross-layer TDMA-based routing protocol to meet delay and bandwidth requirements while optimizing network throughput using weight function by minimizing the number of neighbors associated with paths. For that, selection of the best path is enabled by intermediate nodes which compute a cost function based on end-to-end delay, bandwidth and the number of neighbors of all the nodes included in the path to decrease the impact of paths on the network. Then the path with the lowest weight is selected by the destination. ChhaganLal et al [15] have proposed an Adaptive Cross-Layer Routing Protocol for Delay-Sensitive Applications over MANETs that selected node-disjoint routes for a source destination pair using adaptive low routing overhead admission control. ADAMR protocol originated the SAC process by sending a request to the underlying network layer that consisting of its required delay constraints to discover all the available routes towards the destination node. Then the source node stored the best two routes into its routing table from all the discovered node-disjoint routes that satisfy the specified delay requirements before admitting the data session. If ADAMR is incapable to discover any route satisfying the given delay constraints, SAC prohibited the applications data transmission request and assigned a timer to that application. After the timer expires the application can re-request for admission.

Problem Identification and Proposed Solution

In [16], we have proposed a joint design of routing and resource allocation using QoS monitoring agent in MANETs. In this joint design, depending on the bandwidth request, a QoS monitoring agent checks the available bandwidth and allocates the resources temporarily for the real-time flows. In case of QoS changes or route breakages, the monitoring agent sent a feedback to the source, which contains the estimated amount of resources to be reserved or the route failure information. The sender adaptively adjusts the reservations or data rate when there is a QoS change or selects another efficient route when there is a route or link failure.

In [17], we have proposed a stable and energy efficient routing technique. In the proposed method, Quality of Service QoS) monitoring agents collect and calculate the link reliability metrics such as Link Expiration Time (LET), Probabilistic Link Reliable Time (PLRT), Link Packet Error Rate (LPER) and Link Received Signal Strength (LRSS). A Cross-Layer Metric (CLM) which combines all these four metrics in a unit weight function, reduces the average number of route reconstruction and increases the lifetime of the unreliable links. In addition, residual battery power (RBP) is implemented to maintain the energy efficiency in the network.

But both the works fails to consider the various delay involved like queuing delay, transmission delay, propagation delay etc. So as an extension to these works, we propose to design a delay reduction technique for routing in MANET.

In the stable multipath routing, in addition to the cross-layer metric (CLM), the Expected Path Delay EPD metric [12] can be included. It comprises various parameters data rate received, current queue size, from the MAC and SNR from the PHY layer.

The available two-hop relay routing protocols with out-of-order or strictly in-order reception cannot provide a flexible control for the packet delivery delay. To reduce the transmission and route maintenance delays due to collisions, flexible packet delivery delay control mechanism [13] is proposed. Here packets waiting in the local queue of the source node are divided into consecutive groups that are transmitted to at most distinct relay nodes simultaneously. The destination accepts if it is a fresh packet to the destination and also it is among packets of the group the destination is currently requesting.

Overview

We propose to develop a Cross-layer Based Delay Latency Reduction Technique for Multipath Routing in MANET. For this, we estimate Expected Path Delay Metric and use it along with LET, PLRT, LPER, LRSS and RBP in route selection. The EPD depends on data rate received, current queue size, from the MAC and SNR from the

PHY layer. The transmission and route maintenance delays due to collisions are overcome by using flexible packet delivery delay control mechanism using Two Hop Relay (2HR) algorithm.

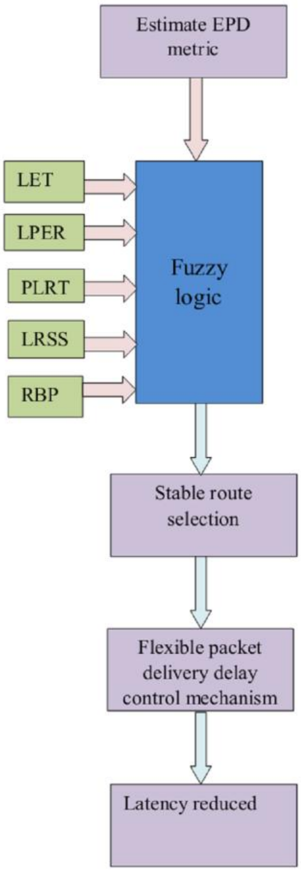

Figure 1: Block Diagram of The Entire Scheme

Estimation of Expected Path Delay

In [17], Quality of Service (QoS) monitoring agents collected and calculated the link reliability metrics such as Link Expiration Time (LET), Probabilistic Link Reliable Time (PLRT), Link Packet Error Rate (LPER) and Link Received Signal Strength (LRSS). In addition to these metrics, here we add Expected Path Delay metric (EPD) which is the cumulative delay up to and including the node itself. This metric is also given to fuzzy as one of the inputs along with other metrics so as to assist in route selection criteria. EPD is incremented with their computed delay and node with lowest EPD is chosen for route selection [12].

EPD consists of various parameters as data rate received and current queue size from MAC and SNR from PHY layer which is reflected in actual transmission out rate. EPD is computed as

$$\mathrm{E}PD = \sum\nolimits_{i=0}^{n}\left[\overline{\mathrm{Qd}}_{\mathrm{i}} + \frac{\Delta\delta*(dr_i + l - act\_Tx_{out(i)})}{act\_Tx_{out(i)}}\right] \tag{1}$$

where $\overline{\mathrm{Qd}}_{\mathrm{i}}$ is the average queuing delay at a node and is given by

$$\overline{\mathrm{Qd}}_{\mathrm{i}} = Q*\overline{\mathrm{Qd}}_{\mathrm{j\text{-}1}} + (1-Q)*\overline{\mathrm{Qd}}_{\mathrm{j}} \tag{2}$$

where Q is the queue occupancy and is given by

$$Q = \frac{Q_{size} - Q_{length}}{Q_{size}} \tag{3}$$

I : a node along the path

Q_{size} : Size of queue at node i

Q_{length} : Length of queue at node i

J : the current period

dr_i : is the data rate calculated based on all traffic received at node i, this parameter is passed from MAC

$\Delta\delta$: Time difference between current time and an arbitrary time after introducing new load into the network. This can vary based on how long routes are expected to remain active based on mobility and active route timeout value

For simplicity, let $\Delta\delta = 2\sec$ (4)

l : Proposed new traffic load added by source which initiate a new route discovery process into the network

$act\_Tx_{out(i)}$: Actual Transmission out from a node extracted from MAC layer and based on

$\max\_Tx_{out(i)}$: Maximum data rate a node can transmit and given by

$$\max\_Tx_{out(i)} = dataTx\_rate*\xi*(1-BER) \tag{5}$$

$dataTx\_rate$: Rate at which a node can transmit/receive

ξ : Network Efficiency factor, typically between 0.7-0.8

BER : Bit Error Rate

Fuzzy Based Reliable Route Selection Algorithm

Fuzzy Logic system 1 (FLS)

The Fuzzy Logic System (FLS1) demonstrated in fig.2 involves the selection of optimal path for data transmission by considering the inputs LET, PLRT, LPER, LRSS, RBP and EPD. These inputs are fuzzified to obtain the appropriate optimal path.

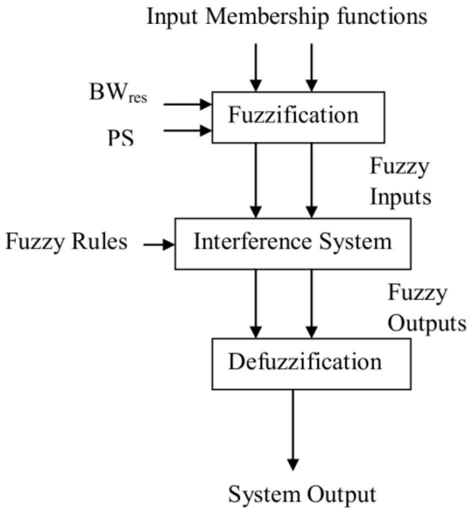

Figure 2: Fuzzy Logic System (FLS1)

The fuzzy logic system is determined in the following steps:

- **Fuzzification:** The process of getting the crisp inputs from the chosen input variables and estimating the degree to which the inputs belong to each of the appropriate fuzzy sets are termed as fuzzification.
- **Inference system**: Here the fuzzified inputs are taken and applied to the antecedents of the fuzzy rules. It is then applied to the consequent membership function. Finally, the outputs of all rules are merged.
- **Defuzzification:** In this step, the merged output of the aggregate output fuzzy set is taken as input and a single crisp number is obtained as output.

Fuzzification

This involves fuzzification of input variables LET, PLRT, LPER, LRSS, RBP and EPD. The crisp inputs are taken from these variables and these inputs are given a degree to appropriate fuzzy sets. The crisp inputs are combination of LET, PLRT, LPER, LRSS, RBP and EPD. The output variable Route Selection Probability (RSP) is also represented as a triangular fuzzy set. We take three possibilities, high, medium and low for input and output variables.

Figures 3, 4, 5, 6, 7, 8 and 9 shows the membership function for the variables LET, PLRT, LPER, LRSS, RBP, EPD and RSP respectively. This utilizes the triangulation functions as they are widely used in real-time applications owing to their computational efficiency and uncomplicated formulas.

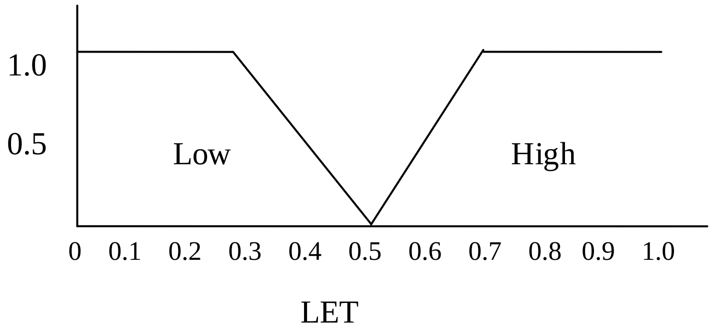

Figure 3: Membership function for LET

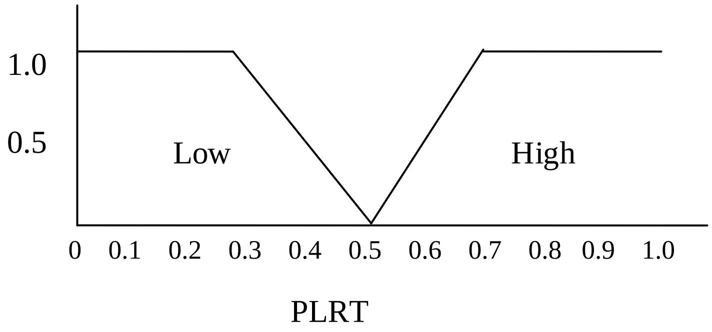

Figure 4: Membership function for PLRT

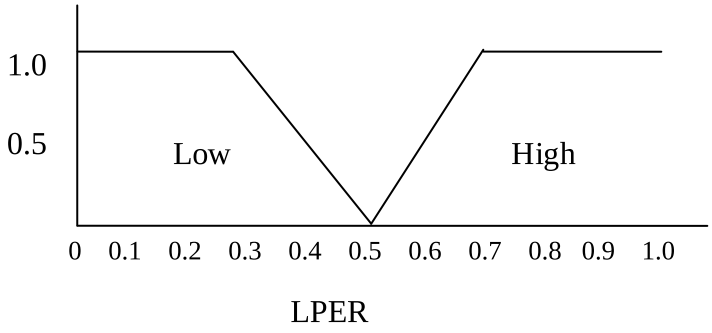

Figure 5: Membership function for LPER

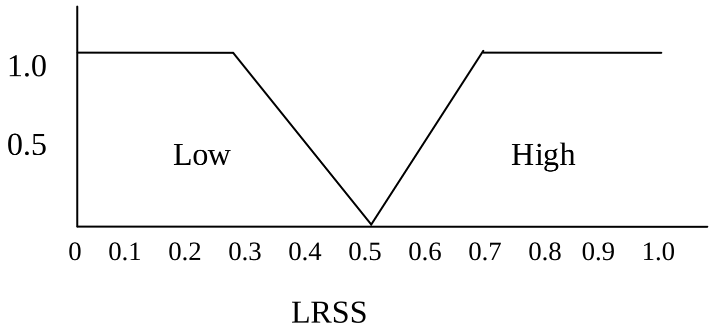

Figure 6: Membership function for LRSS

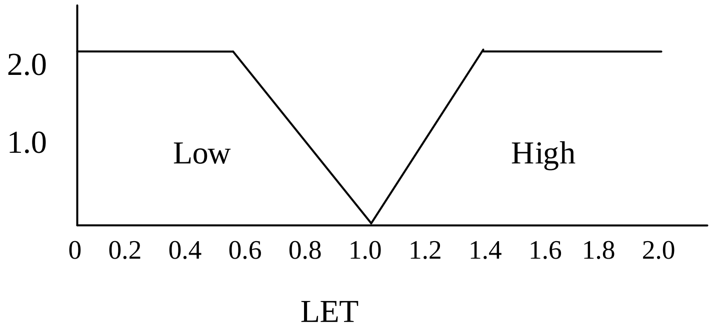

Figure 7: Membership function for RBP

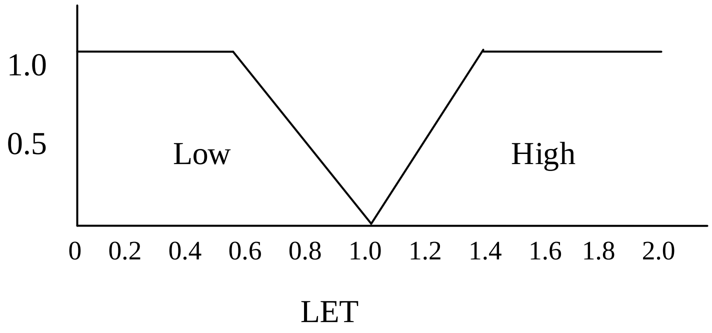

Figure 8: Membership function for EPD

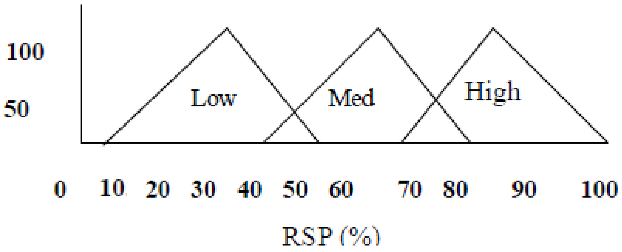

Figure 9: Membership function for RSP

Table 1: Fuzzy Rules

S.No	LET	PLRT	LPER	LRSS	RBP	EPD	RSP
1	Low	Low	Low	Low	Low	Low	Low
2	Low	Low	Low	Low	Low	High	Low
3	Low	Low	Low	Low	High	Low	Medium
4	Low	Low	Low	Low	High	High	Medium
5	Low	Low	Low	High	Low	Low	Medium
6	Low	Low	Low	High	Low	High	low
7	Low	Low	Low	High	High	Low	High
8	Low	Low	Low	High	High	High	Medium
9	Low	Low	High	Low	Low	Low	Low
10	Low	Low	High	Low	Low	High	Low
11	Low	Low	High	Low	High	Low	Low
12	Low	Low	High	Low	High	High	Medium
13	Low	Low	High	High	Low	Low	Low
14	Low	Low	High	High	Low	High	Low
15	Low	Low	High	High	High	Low	Medium
16	Low	Low	High	High	High	High	Low
17	Low	High	Low	Low	Low	Low	Low
18	Low	High	Low	Low	Low	High	Low
19	Low	High	Low	Low	High	Low	Low
20	Low	High	Low	Low	High	High	Medium
21	Low	High	Low	High	Low	Low	Low
22	Low	High	Low	High	Low	High	Low
23	Low	High	Low	High	High	Low	Medium
24	Low	High	Low	High	High	High	Low
25	Low	High	High	Low	Low	Low	Low
26	Low	High	High	Low	Low	High	Low
27	Low	High	High	Low	High	Low	Low
28	Low	High	High	Low	High	High	Low
29	Low	High	High	High	Low	Low	Low
30	Low	High	High	High	Low	High	Low

31	Low	High	High	High	High	Low	Low
32	Low	High	High	High	High	High	Low
33	High	Low	Low	Low	Low	Low	Medium
34	High	Low	Low	Low	Low	High	Medium
35	High	Low	Low	Low	High	Low	High
36	High	Low	Low	Low	High	High	High
37	High	Low	Low	High	Low	Low	High
38	High	Low	Low	High	Low	High	Medium
39	High	Low	Low	High	High	Low	High
40	High	Low	Low	High	High	High	Low
41	High	Low	High	Low	Low	Low	Low
42	High	Low	High	Low	Low	High	Medium
43	High	Low	High	Low	High	Low	High
44	High	Low	High	Low	High	High	High
45	High	Low	High	High	Low	Low	Medium
46	High	Low	High	High	Low	High	Low
47	High	Low	High	High	High	Low	High
48	High	Low	High	High	High	High	Low
49	High	High	Low	Low	Low	Low	Low
50	High	High	Low	Low	Low	High	Medium
51	High	High	Low	Low	High	Low	Medium
52	High	High	Low	Low	High	High	Medium
53	High	High	Low	High	Low	Low	Medium
54	High	High	Low	High	Low	High	Low
55	High	High	Low	High	High	Low	High
56	High	High	Low	High	High	High	Low
57	High	High	High	Low	Low	Low	Low
58	High	High	High	Low	Low	High	Low
59	High	High	High	Low	High	Low	Low
60	High	High	High	Low	High	High	Low
61	High	High	High	High	Low	Low	Low
62	High	High	High	High	Low	High	Low
63	High	High	High	High	High	Low	Medium
64	High	High	High	High	High	High	Low

Table 1 demonstrates the designed fuzzy inference system. This illustrates the function of the inference engine and method by which the outputs of each rule are combined to generate the fuzzy decision.

For example

Let us consider Rule 7.

If LET is low, PLRT is low, LPER is low, LRSS is high, RBP is high and EPD is low

Then

The route selection probability is High

End if

Similarly, consider Rule 21.

If LET is low, PLRT is high, LPER is low, LRSS is high, RBP is low and EPD is low

Then

The route selection probability is Low

End if

Defuzzification

The technique by which a crisp values is extracted from a fuzzy set as a representation value is referred to as defuzzification. The centroid of area scheme is taken into consideration for defuzzification during fuzzy decision making process. The formula (6) describes the defuzzifier method.

$$\text{Fuzzy\_cost} = [\textstyle\sum_{allrules} f_i * \alpha(f_i)] / [\textstyle\sum_{allrules} \alpha(f_i)] \qquad (6)$$

Where fuzzy_cost is used to specify the degree of decision making, f_i is variable for fuzzy all rules and $\alpha\ (f_i)$ is its membership function

The output of the fuzzy cost function is modified to crisp value as per this defuzzification method. The defuzzified output gives the route selection probability in terms of percentage.

Hence, the route with high percentage of route selection probability is selected as the optimal route, which will be stable and energy efficient.

Flexible Packet Delivery Delay Control Mechanism

The flexible packet delivery delay control mechanism is accomplished with the help of 2HR- (r,g) algorithm [13]. Under this algorithm, we estimate expected packet delivery delay.

2HR-(r,g) Algorithm:

Let the traffic between source-destination pair be flow. Here we consider a tagged flow without loss of generality and denote its source node and destination node as S and D respectively. If r is the packet redundancy limit and g is the group size for (2HR- (r,g) for short), as in Fig. 10, with the 2HR- (r,g) algorithm, the source node S will deliver at most r copies of a packet to distinct relay nodes. Meanwhile, the destination D may finally receive the packet from one relay node R.

Each node can be a potential relay for other n-2 flows (except the two flows originated from and destined for itself). In order to support 2HR- algorithm operation, we make an assumption in which each node maintains n individual queues at its buffer:

1. one local queue to store the locally generated packets at the node and to wait for their copies (up to r copies for each packet) to be dispatched,
2. one already-sent queue to store packets whose r copies have already been dispatched but not yet confirmed their reception status (from destination node), and
3. n-2 parallel relay queues to store packets of other flows (one queue per flow).

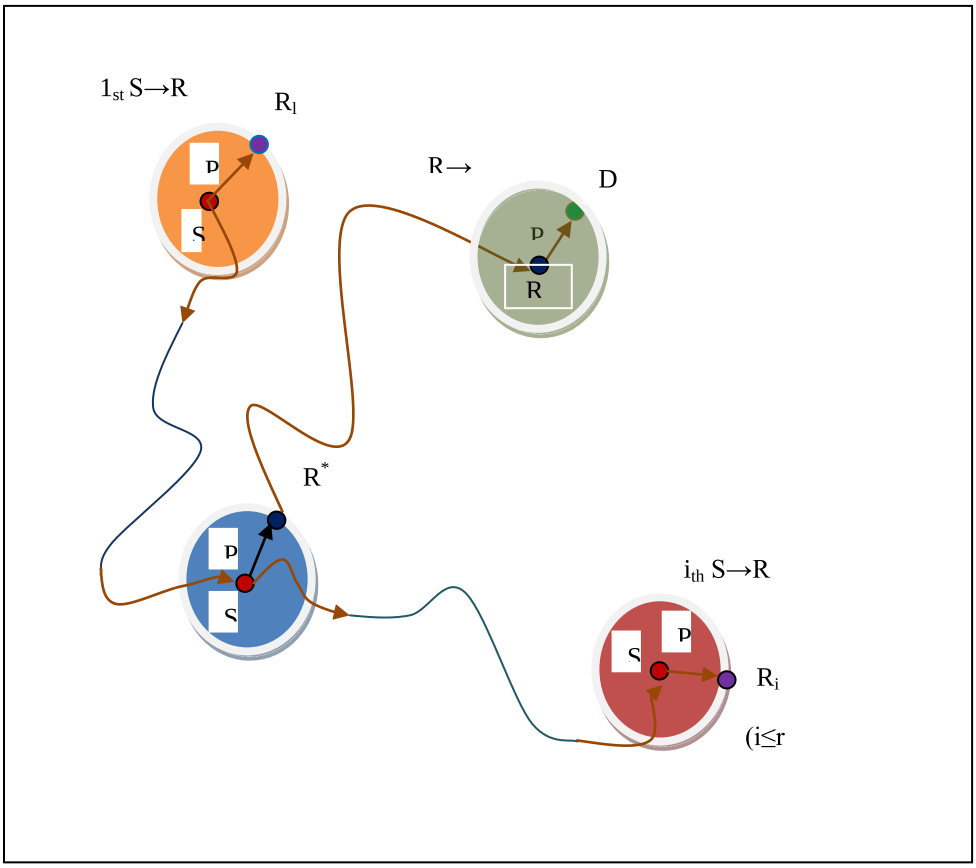

Figure 10: Illustration of the 2HR-(r,g) relay algorithm

The group-based transmission in the 2HR-(r,g) algorithm is enabled by the below steps

- The source node divides packets waiting at its local queue into consecutive groups, g packets per group, and labels each packet P with a send group number Sg(P) and a sequence number Sn(P) $(1 \le Sn(P) \le g)$.
- The node D also maintains a request group number Rg(D) and an indicator vector In(D) . The In(D) is a g-bit binary vector to record the reception status of current requesting group at D, where the *i*th bit $In_i(D)$ is set as 0 (resp. 1) if the *i*th packet of the current requesting group has (resp. has not) been received.

Then we assume that each relay node will carry at most one packet for any particular group. Before proceeding to 2HR-(r,g) algorithm

- **Fresh packet** : A fresh packet is the packet which is not yet received by its destination. Otherwise it is a non fresh packet.
- **Fresh node** : For a tagged packet group, a node other than S and D is said to be a fresh node if it carries a fresh packet for the group
- **Non fresh node** : If the node either carries a non fresh packet or carries no packet for the tagged group, it is called a non fresh node.

2HR-(r,g) Algorithm:

Whenever the source S gets a chance to transmit for the tagged flow, it operates as follows.

Step 1:

If node D is among S's one-hop neighbours

(**Source-to-Destination**)

1. The source S checks whether the node D is among its one-hop neighbours. If yes, it initiates a handshake with D to get its Rg(D) and In(D).
2. Then, it tries to transmit a fresh packet directly to D, in which the packet to be transmitted is chosen as follows
    - It first checks its local queue, starting from its head-of-line packet P_h, to find a fresh packet.
    - If fresh packet is not found, it tries to retrieve a fresh packet from the already-sent queue.

Step 2:

If the node D is not among node S's one-hop neighbours, it randomly chooses any of the following two operations to perform.

(**Source-to-Relay**)

1. It first randomly selects one node (say R) from its current one-hop neighbours, and then initiates a handshake with R to check whether the node R is a nonfresh node. If so, it delivers a new copy P_h of to R; otherwise, it remains idle for this time-slot.
2. Each time S sends out a copy of P_h it checks whether r copies of P_h have already been delivered. If so, it puts P_h to the end of the already-sent queue and then moves ahead the remaining packets in the local queue.
3. At the relay node R , P_h is put at the end of its relay queue dedicated to the node D. Thus, each packet may have at most r+1 copies in the network (including the one in the already-sent queue of its source node).

(**Relay-to-Destination**)

1. It acts as a relay and randomly selects a node (say B) from its one-hop neighbours as the receiver.
2. It first initiates a handshake with B to get the Rg(B) and In(B), then checks its relay queue specified for B whether there exists a fresh packet of group Rg(B).
3. If so, it delivers this packet to B and deletes all packets with $Sg \leq Rg(B)$ from its relay queue for B; otherwise, it remains idle for this time-slot.

Observations from 2HR-(r,g) algorithm

1. Once the node D currently requests for packets of group i, then any fresh packet belonging to the group i is eligible for reception at the node. If all the packets of the group have been received, the node D begins receiving packets

of the next group i+1. Thus, the 2HR-(r,g) algorithm guarantees that the intergroup packet reception is strictly in group order while the intragroup packet reception is totally out of order.

2. The 2HR-(r,g) algorithm is flexible and general since its packet delivery process can be flexibly controlled by a proper setting of the redundancy r and group size g. Actually, the new algorithm covers all the available two-hop relays as special cases, like the out-of-order ones with redundancy $(r > 1, g = \infty)$ or without redundancy $(r = 1, g = \infty)$, and the strictly in-order ones $(r \geq 1, g = 1)$.

Overall algorithm:

1. Expected Path Delay Metric (EPD) is estimated based on data rate received and current queue size from MAC and SNR from PHY layer which is reflected in actual transmission out rate.
2. This metric is given as input to fuzzy logic in addition to metrics LET, PLRT, LPER, LRSS and RBP.
3. The stable route selection is done based on the output of the fuzzy logic.
4. Then we use Two Hop Relay (2HR) algorithm to reduce transmission and route maintenance delays due to collisions.
5. The flexible packet delivery delay control mechanism controls packet delivery process by proper setting of the redundancy r and group size g.

Simulation Results

Simulation Model and Parameters

We used the NS-2 [18] to simulate our proposed Cross-layer Based Delay Latency Reduction (CBDLR) based routing protocol. During the simulation, the number of nodes is varied from 25 to 50 and the speed is varied from 5 to 25m/s. The simulated traffic is Constant Bit Rate (CBR).

Our simulation settings and parameters are summarized in table 2.

Table 2: Performance Metrics

No. of Nodes	25,30,35,40,45 and 50
Area Size	1000 X 1000m
Mac	802.11
Routing Protocol	CBDLR
Radio Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512 bytes
Antenna	OmniAntenna
Rate	50Kb
Initial Energy	10.1 J

The proposed CBDLR protocol is compared with the QoS-Aware Multipath Routing Protocol (QMRP) [12]. We evaluate mainly the performance according to the following metrics.

Average Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets transmitted.

Delay: It is the time taken by the packet to reach the receiver.

Energy: It is the average energy consumed for the data transmission.

Drop: It is the total number of packets dropped.

A. In the first experiment, we varying the number of nodes as 25, 30, 35, 40, 45 and 50 for CBR traffic.

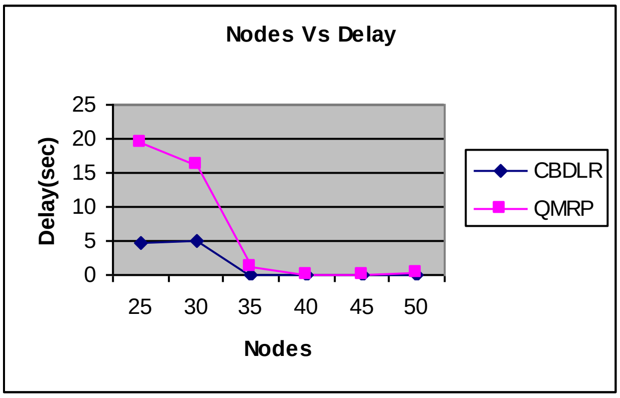

Figure 11: Nodes Vs Delay

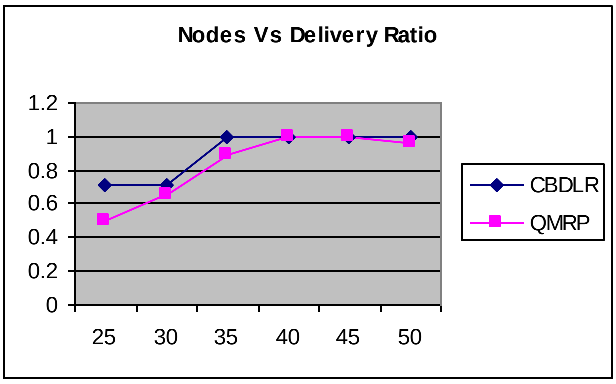

Figure 12: Nodes Vs Delivery Ratio

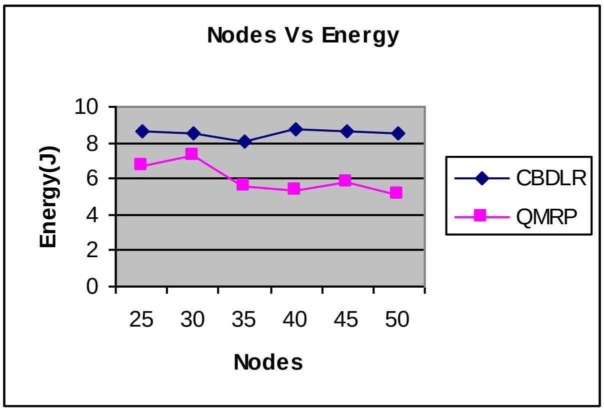

Figure 13: Nodes Vs Drop

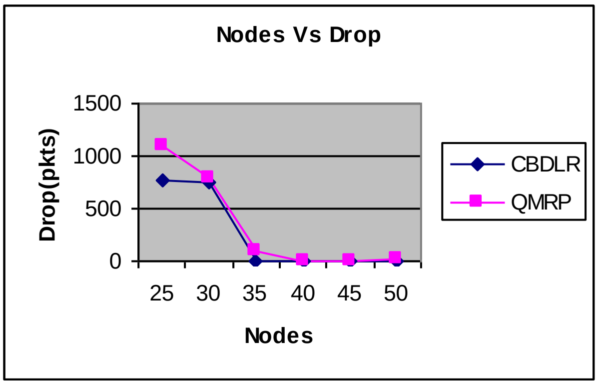

Figure 14: Nodes Vs Drop

Figures 11 to 14 show the results of delay, delivery ratio, energy and drop for the packet sending rate 25, 30, 35, 40, 45 and 50 in CBDLR and QMRP protocols. When comparing the performance of the two protocols, we infer that CBDLR outperforms QMRP by 83.2% in terms of delay, 8.7% in terms of delivery ratio, 30.2% in terms of energy and 51.2% in terms of drop.

B. In the Second experiment, we varying the Speed as 5, 10, 15, 20, and 25 for CBR traffic.

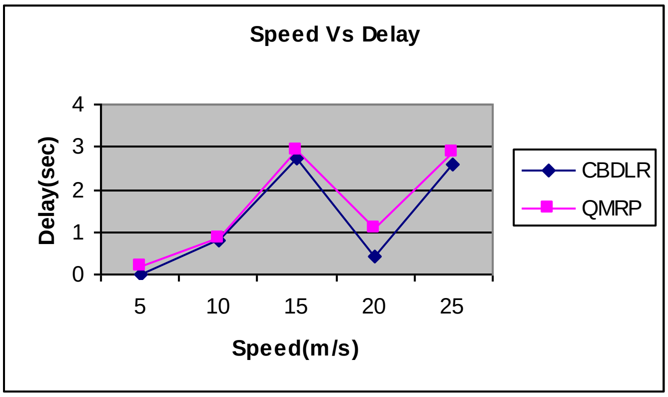

Figure 15: Speed Vs Delay

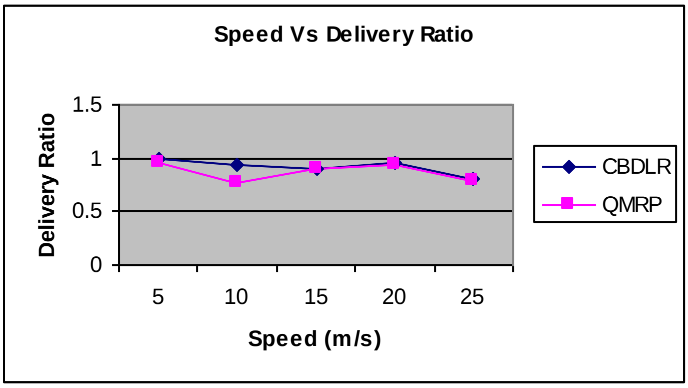

Figure 16: Speed Vs Delivery Ratio

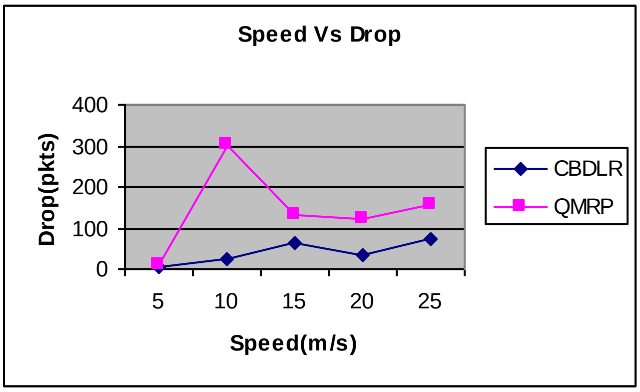

Figure 17: Speed Vs Drop

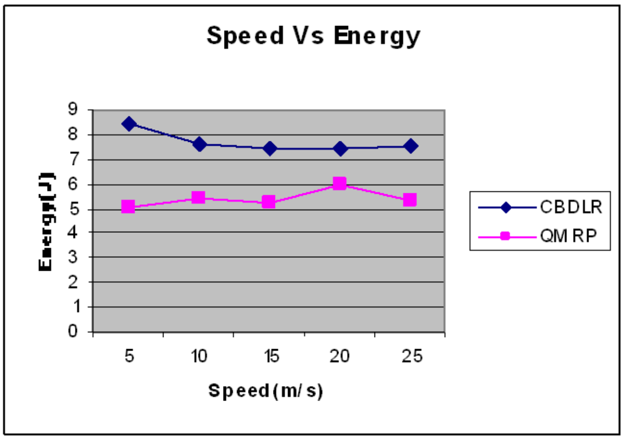

Figure 18: Speed Vs Drop

Figures 15 to 18 show the results of delay, delivery ratio, energy and drop for the speed 5, 10, 15, 20 and 25 in CBDLR and QMRP protocols. When comparing the performance of the two protocols, we infer that CBDLR outperforms QMRP by 34.4% in terms of delay, 6% in terms of delivery ratio, 69% in terms of energy and 29.4% in terms of drop.

Conclusion

We proposed to develop a Cross-layer Based Delay Latency Reduction Technique for Multipath Routing in MANET. For this, we estimated Expected Path Delay Metric and use it along with LET, PLRT, LPER, LRSS and RBP in route selection. The EPD depends on data rate received, current queue size, from the MAC and SNR from the PHY layer. The transmission and route maintenance delays due to collisions are overcome by using flexible packet delivery delay control mechanism using Two Hop Relay (2HR) algorithm.

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