6. FUZZY BASED RANDOM EARLY DETECTION QUEUE MANAGEMENT TECHNIQUE FOR CONGESTION CONTROL AND REDUCTION OF QUEUING DELAY

6.1 INTRODUCTION

The sensitivity analysis carried out to verify the efficiency of an Enhanced Round Robin Packet Scheduling Strategy (ERR-PSS) and that strategy is implemented as an integrated component to the modified AODV (LM-PSAODV) with an objective of the reduction in IPD while transmitting the multimedia applications from source to destination discussed in chapter 5. The limitation of bandwidth and the subsequent queue size limitations in links that lead to congestion at the link level on delivery of time critical multimedia applications. In this chapter, the proposed Fuzzy Logic-based Random Early Detection (FL-RED) queue management technique aims to reduce the queuing delay by controlling the congestion through effective management of link queue size while transmitting the delay sensitive applications. Delay is one of the significant performance metrics in the wired or wireless network over real-time applications. The proposed FL-RED queue management algorithm is tested with the existing Random Early Detection (RED) queue management algorithm in a simulation environment on varying node density. The performance of the FL-RED algorithms is meticulously examined and analyzed in terms of the performance metric namely queuing delay for the delivery of delay-sensitive application from source to destination. The methodology of FL-RED queue management technique, results and analysis are described in this chapter.

Currently, more research has aimed to transmit the multimedia applications in Mobile Ad-hoc Networks (MANETs). Cross-layer design is an emerging approach to improve the overall network performance. For the smooth transmission of real-time applications over MANET requires the sufficient resource like bandwidth, but due to limited bandwidth availability in MANET requires good channel conditions. Congestion is the significant problem that will occur when a link is carrying more data than its capacity. The effect of this will be queuing delay or packet loss. Congestion control means controlling the traffic. One of the techniques to control the congestion is through effective queue management. This proposed work aims to provide an effective queue management technique using Fuzzy Logic-based Random Early Detection (FL-RED) with less routing overhead and loop-free path. It offers reduced queuing delay and average end to end delay, which is the requirement for delay sensitive applications. In this work, an enhanced algorithm of RED is used to achieve the benefits of AQM. The fuzzy logic concept is applied with RED algorithm for more accurate calculation in order to permit the packets into the link.

It is noticed that using RED has greatly improved all the performance measures. The reason is that RED monitors the average queue size and randomly drops packets when congestion is detected. The research in the area of QM shows an improvement in performance by implementing the state of the art active queue management technique like RED and REM.

6.2 ASSUMPTIONS AND METHODOLOGY OF FL-RED QUEUE MANAGEMENT TECHNIQUE

The idea is to allow the real-time traffic over MANET without congestion; the queue size can be handled in an efficient way. Hence the queuing delay and the average end to end delay can be reduced using the proposed FL-RED. There is scope for contribution to enhance the performance through cross layered approach using the proposed effective queue management strategy. Deployment of fuzzy based random early detection (FL-RED) technique as a queue management scheme for congestion control and reduction of queuing delay in delay sensitive applications.

6.2.1 FL-RED Queue Management over Multimedia Traffic

The objective of the FL-RED Queue Management over multimedia traffic is to reduce the queuing delay by controlling the congestion through effective management of link queue size in the transmission of delay sensitive applications.

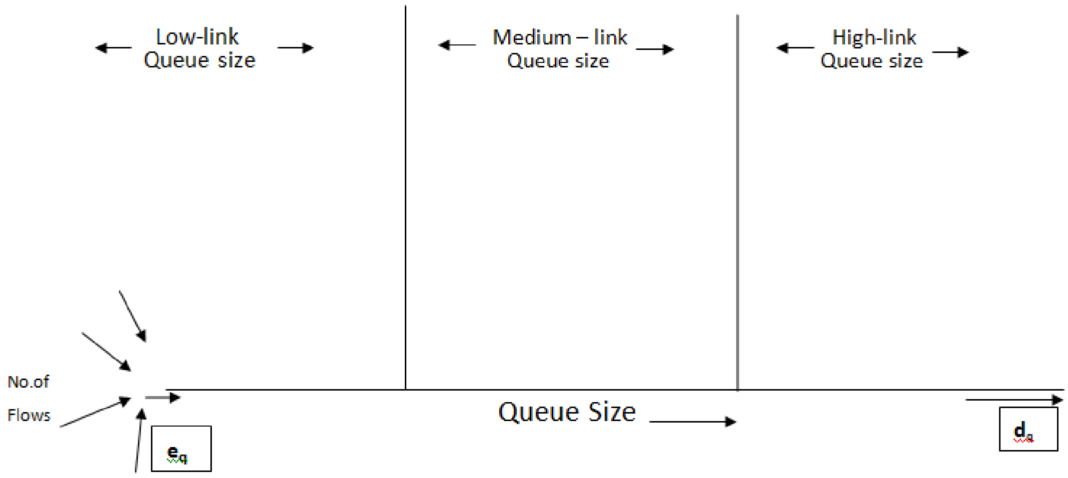

Figure 6.1: Queue Management using Fuzzy Logic Random Early Detection Technique

In this work, an enhanced QM technique is carried out to improve the MANET performance. In this strategy, the User Datagram Protocol (UDP) is used as the transport protocol. The Figure 6.1 shows the management of queue size using Fuzzy Logic Random Early Detection Technique.

6.2.2 Methodology for Queue Management

The limitation of bandwidth and the subsequent queue size limitations in MANET links that lead to more queuing delays on delivery of time critical multimedia applications. The proposed FL-RED queue management strategy aims to reduce the queuing delay by controlling the congestion through effective management of link queue size.

The step by step procedure of the proposed Fuzzy based Random Early Detection queue management algorithm for congestion control and reduction of queuing delay is:

Step 1: Set the parameter values for the transmission range, data rate, simulation time, topology size, number of mobile nodes, traffic type, MAC protocol, routing protocols, mobility model and type of service for the experimentation of MANET routing. Set the source nodes as 'S_i' and destination nodes as 'D_j'.

Step 2: Express the current queue size q(t) in terms of fuzzy variables moderate or full. q(t) is defined as moderate, if it is less than 75% of the link's capacity/bandwidth, otherwise q(t) is defined as full.

Step 3: Express the rate of enqueue (e_q) in terms of fuzzy variables zero or low or high. e_q is defined aszero if the data entered into the queue per unit time (Sec.) is less than 25% of the link's capacity. e_q is defined aslow if the data entered into the queue per unit time (Sec.) is between 25% and 50%, otherwise, e_q is defined as high. Express the rate of dequeue (d_q) in terms of fuzzy variables zero or low or high. d_q is defined as zero if the data departed from the queue per unit time (Sec.) is less than 25% of the link's capacity. d_q is defined as low if the data departed from the queue per unit time (Sec.) is between 25% and 50%, otherwise, d_q is defined as high.

Step 4: Estimate the packet dropping probability 'p' for every packet based on the size of the queue q(t), the rate of enqueue (e_q) and the rate of dequeue (d_q) and express as a fuzzy variable zero or low or medium or high applying the following fuzzy rules.

Step 4 a: If q(t) is moderate in size and e_q is low then p is zero.

Step 4 b: If q(t) is moderate in size and e_q is zero then p is zero.

Step 4 c: If q(t) is moderate queue size and e_q is high then p is low.

Step 4 d: If q(t) is full in size and e_q is zero then p is low.

Step 4 e: If q(t) is full size and e_q is low then p is medium.

Step 4 f: If q(t) is full queue size and e_q is high then p is high.

Step 4 g: If q(t) is moderate in size and d_q is zero then p is medium.

Step 4 h: If q(t) is moderate queue size and d_q is high then p is zero.

Step 4 i: If q(t) is full in size and d_q is high then p is medium.

Step 4 j: If q(t) is full size and d_q is low then p is medium.

Step 4 k: If q(t) is full queue size and d_q is zero then p is high.

Step 5: Permit the packet to enter into the queue if 'p' is low or medium.

Step 6: Predict the congestion over the link early if 'p' is high then do not allow the packets into the link and call the route repairing mechanism to propagate the Route Error (RERR) message for the establishment of an alternate path to reach the destination.

6.3 SIMULATION ENVIRONMENT

The proposed FL-RED queue management algorithm is tested with the existing Random Early Detection (RED) queue management algorithm in a simulation environment on varying node density. The Simulation Parameters value for the experimentation of FL-RED algorithm is presented in Table 6.1. The AODV and LM-PSAODV are used as the routing protocols for the performance analysis of the queue management algorithms.

Table 6.1: FL-RED Simulation Parameters

PARAMETERS	SETTINGS
Transmission Range	250 m
Bandwidth	2 Mbps
Simulation Time	300 s
Pause Time	0 Second
VoIP data rate	512 Kbps.
Topology Size	1000 m X 1000 m
Number of Mobile nodes	200
Traffic Type	VoIP (Voice over Internet Protocol)
MAC Protocol	IEEE 802.11
Interface queue type	RED, FL-RED
Routing Protocols	AODV, LMPSAODV
Transport Protocol	UDP
Mobility Model	Random Waypoint
Service	Video Transmission

The proposed FL-RED queue management algorithm is tested with the existing Random Early Detection (RED) queue management algorithm in a simulation environment. In this strategy, the queuing delay is the performance metric for the evaluation of FL-RED queue management algorithm.

6.4 RESULTS AND ANALYSIS

The performance of the queue management algorithms is compared in terms of queuing delay as the performance metric for the delivery of delay-sensitive application from source to destination on varying node density.

6.4.1 Queuing Delay using AODV and LM-PSAODV Routing Protocols with Different AQM Techniques on Varying Node Density

Queuing delay is the significant parameter for delay sensitive application is concerned and it must be as low as possible for better transmission. It is evaluated on varying number of nodes as 25, 50, 100 and 200. Table 6.2 depicts the effect of queuing delay on varying node density using different routing protocols and queue management techniques for the experimentation of FL- RED algorithm.

Table 6.2: FL-RED - Effect of Queuing Delay on varying node density using different Routing Protocols and Queue Management Techniques

Number of Nodes	Queuing Delay (ms)		
	AODV with RED	LM-PSAODV with RED	LM-PSAODV with FL-RED
25	0.064	0.052	0.03
50	0.062	0.045	0.04
100	0.073	0.06	0.05
200	0.095	0.08	0.06

When the number of node increases proportionally the queuing delay also increases in all the three scenarios (AODV with RED, LM-PSAODV with RED and LM-PSAODV routing protocol with FL- RED queue management strategy) due to the node's mobility, speed, number of packets and routing. However, this increase is proportionally lesser, in the case of LM-PSAODV routing protocol with FL- RED queue management strategy. The reason is that, in the proposed queue management strategy to manage the queue size effectively based on, not only the packets in the queue but also the rate of enqueue (e_q) and the rate of dequeue (d_q) are considered. Hence, congestion at link level managed effectively and it leads to significant reduction in queuing delays.

Figure 6.2 illustrates the effect of queuing delay on varying node density using different routing protocols and queue management techniques.

The LM-PSAODV with FL-RED technique using Round Robin Packet Scheduling Strategy (RR-PSS) has improved the MANET routing performance by 37% and 25% in terms of reductions in queuing delay compared to the 'AODV with RED' and 'LM-PSAODV with RED' technique respectively for the sample node density of 200.

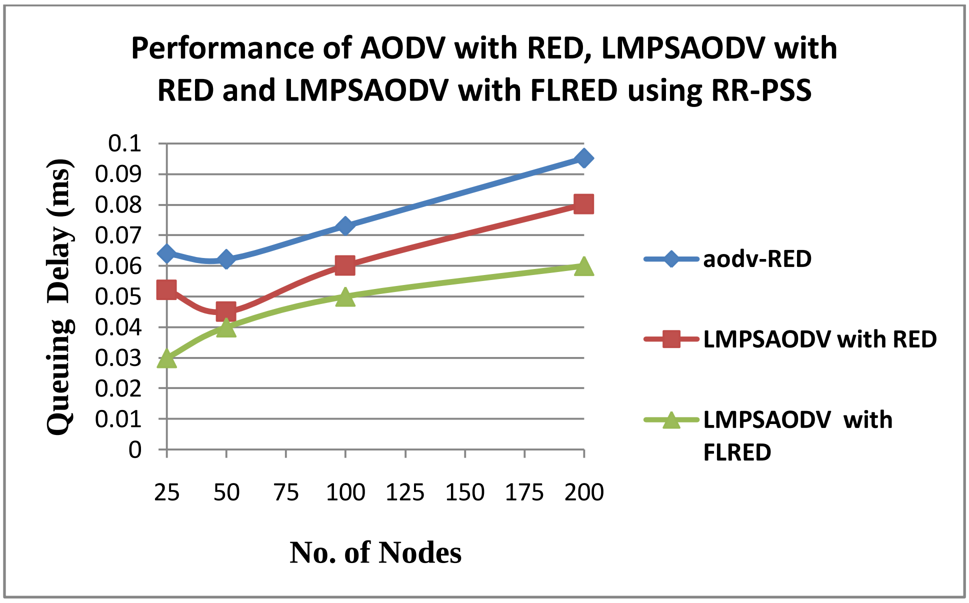

Figure 6.2: FL-RED Effect of Queuing Delay on varying node density using different Routing Protocols and Queue Management Techniques

Providing QoS in MANETs for the transmission of real-time applications require performance improvement in routing and end to end delivery. Hence there is a necessity to integrate the routing and queue management strategies to reduce the end to end delay with the available resources for better achievement in time-critical multimedia applications.

6.5 INTEGRATED ROUTING AND QUEUE MANAGEMENT FRAMEWORK

The objective of an integrated routing and queue management framework (IRQM) is to introduce a MANET framework for the successful end to end delivery of time-critical multimedia applications with a cross-layer integration of the LM-PSAODV routing, ERR-PSS scheduling and FL-RED queue management strategies.

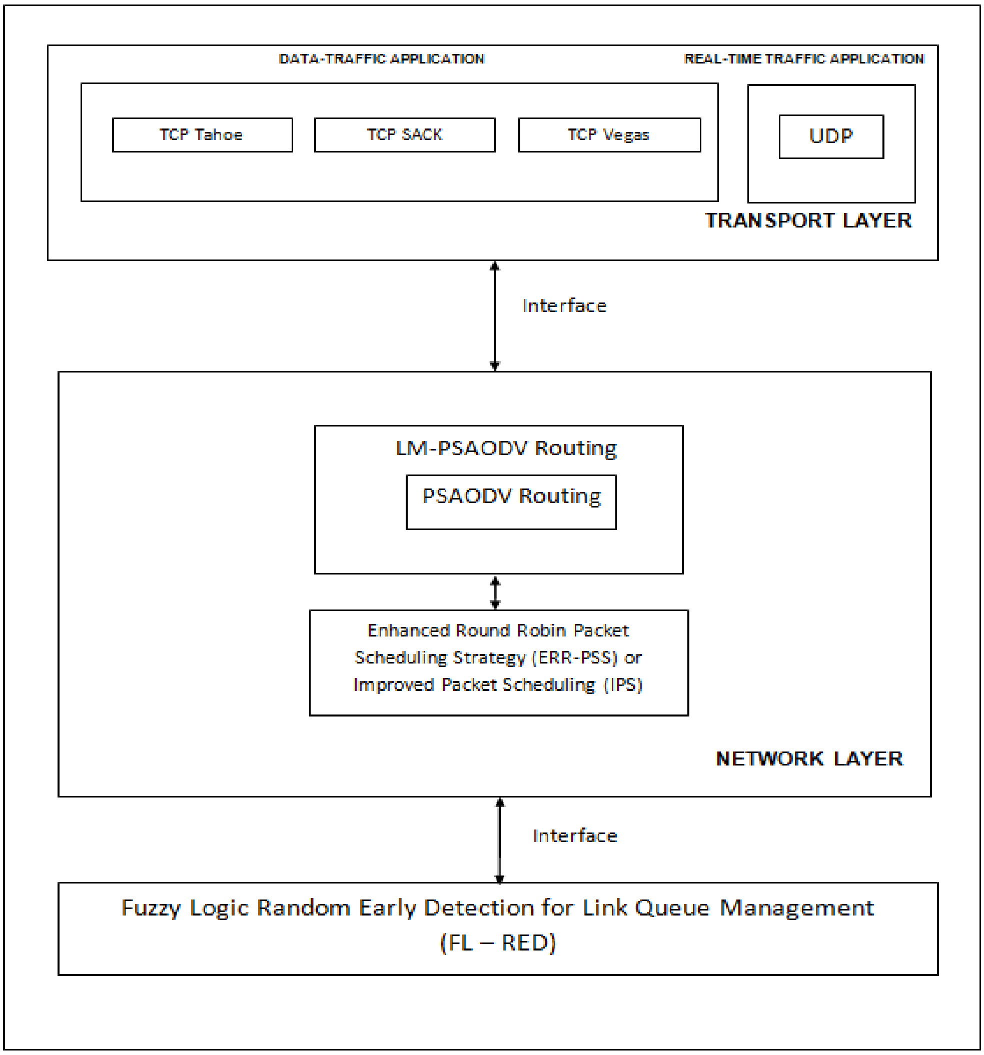

Figure 6.3: Integrated Routing and Queue Management framework

Figure 6.3 shows the Integrated Routing and Queue Management framework. The development of IRQM resulted in a comprehensive reduction of routing overhead, packet drops, inter-packet delay, queuing delay and end to end delay providing QoS in MANETs for the transmission of the real-time application. The Simulation Parameters value for the experimentation of IRQM framework is presented in Table 6.3.

Table 6.3: IRQM - Simulation Parameters

PARAMETERS	SETTINGS
Transmission Range	250 m
Bandwidth	2 Mbps
Simulation Time	600 s
Pause Times	0, 10, 20 and 30 seconds
VoIP data rate	512 Kbps (Kilobits per second)
Topology Size	1000 m X 1000 m
Number of mobile nodes	200
Traffic Type	VoIP
MAC Protocol	IEEE 802.11
Interface queue type	RED, FL-RED
Routing Protocols	AODV, LMPSAODV
Transport Protocol	UDP
Mobility Model	Random Waypoint
Service	Video Transmission

6.5.1 Methodology for IRQM Framework

In this framework, for the successful end to end delivery of time-critical multimedia applications, a cross-layer approach is applied for the route establishment, packet forwarding and link's queue management as described below

Step 1: LM-PSAODV routing protocol is applied for the establishment of the loop-free multipath from source to destination with minimal packet drops.

Step 2: The ERR-PSS scheduling strategy is integrated into the LM-PSAODV-established routing paths for the reduction of inter-packet delays in such a way that the time-critical-information packets are scheduled priority wise and forwarded in a round-robin manner among the multiple source-destination pairs in the ad hoc network.

Step 3: FL-RED queue management strategy is now integrated with the LM-PSAODV routing and ERR-PSS forwarding policies for effective management of link's queue size and congestion control to achieve the necessary reduction in queuing delay required for better multimedia transmission.

Step 4: In the integrated routing and queue management framework (IRQM) the User Datagram Protocol (UDP) is used as the transport protocol for the end to end delivery of multimedia files. The effect of an average end to end delay is measured in a simulated environment for four different scenarios with the run of 600 Seconds varying the pause times as 0, 10, 20 and 30 seconds.

6.5.2 Average End to End Delay on Varying Pause Times

End to end delay is an important performance metric, particularly for the multimedia application. It is evaluated on varying pause times as 0, 10, 20 and 30 Seconds. Table 6.4 depicts the effect of end to end delay on varying pause time using different routing protocols and queue management techniques for the experimentation of IRQM framework.

Table 6.4: IRQM - Effect of End to End delay on varying Pause Time using different Routing Protocols and Queue Management Techniques

Pause Time (s)	Avg. End to End Delay (Sec.)		
	AODV with RED	**LM-PSAODV with RED**	**LM-PSAODV with FL-RED and ERR-PSS (IRQM)**
0	0.3	0.2	0.15
10	0.3	0.25	0.2
20	0.25	0.19	0.1
30	0.25	0.15	0.08

The IRQM enhances the performance by 46% reduction in the average end to end delay compared to the LM-PSAODV routing with RED queue management technique for the sample pause time of 30 Seconds.

Figure 6.4 elucidates the effect of end to end delay on varying pause time using different routing protocols and queue management techniques.

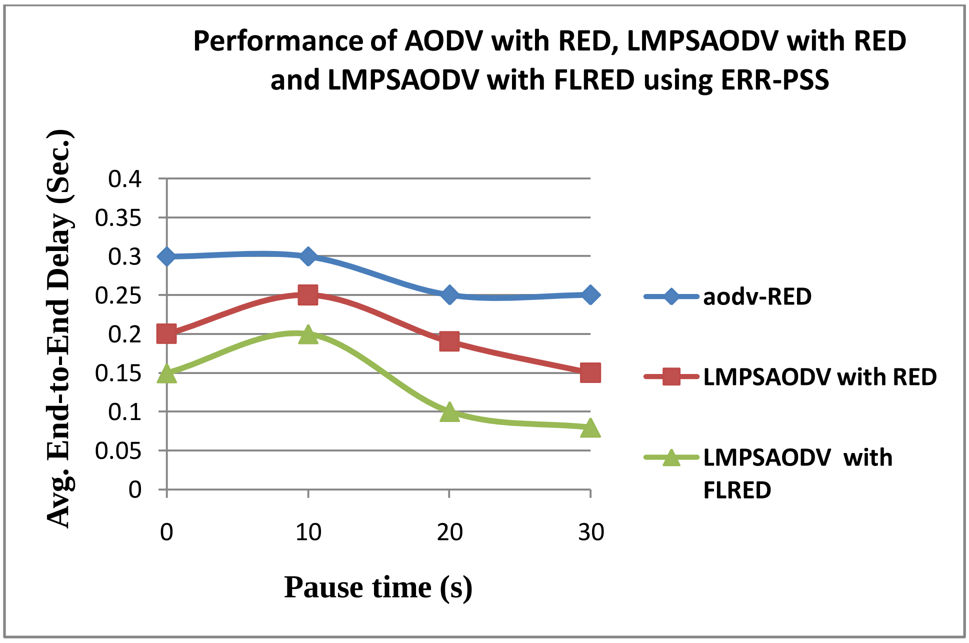

Figure 6.4: IRQM - Effect of End to End delay on varying Pause Time using different Routing Protocols and Queue Management Techniques

From the results obtained, it is observed that the IRQM framework performs better in the reduction of an average end to end delay compared with existing both the 'AODV routing with RED queue management' and 'LM-PSAODV routing with RED queue management'. The reason is that the IRQM framework uses the features of Loop-free multipath routing, Improved Packet Scheduling and proposed queue management strategy that lead reduction in end to end delay.

6.6 CONCLUSION

In this chapter, the Fuzzy Logic-based Random Early Detection (FL-RED) queue management technique is proposed for the effective management of link queue size, which reduced the queuing delay by controlling the congestion while transmitting the delay sensitive applications. The proposed queue management strategy is implemented and evaluated to manage the link queue size in an efficient manner, it estimate the packet dropping probability 'p' for every packet based on the size of the queue q(t), the rate of enqueue (e_q) and the rate of dequeue (d_q) to reduce the queuing delay.

The LM-PSAODV routing with FL-RED queue management technique using Round Robin packet scheduling strategy has improved the MANET routing performance by 37% and 25% in terms of reductions in queuing delay compared to the 'AODV with RED' and 'LM-PSAODV with RED' technique respectively. The simulation results have revealed that the proposed queue management strategy performs better than the existing queue management strategy in terms of queuing delay by varying number of nodes over delay sensitive applications in MANET environment.

To reduce the end to end delay with the available resources for better achievement in time-critical multimedia applications the LM-PSAODV routing, ERR-PSS and FL-RED queue management algorithms are integrated as a framework namely 'Improved Routing and Queue Management' (IRQM). The IRQM enhances the performance by 46% reduction in the average end to end delay compared to the 'LM-PSAODV routing with RED queue management technique'. It is observed from the results that the IRQM framework performs better in the reduction of an average end to end delay than both the 'AODV routing with RED queue management' and 'LM-PSAODV routing with RED queue management'. Thus, the development of IRQM framework confirms the suitability of support for video traffic applications in the challenging MANET environment and it provides better routing and effective management of link queue size.