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Performance Analysis of Fuzzy based RED for Congestion Control in MANET

Richa Rai[1], Laxmi Shrivastava[2] and Sarita Singh Bhadauria[3]

Department of Electronics and Communication
Madhav Institute of Technology and Science
Gwalior, India
rairicha49@gmail.com, lselex@yahoo.com, saritamits61@yahoo.co.in

Abstract

In today's world, nothing seems to be impossible, due to the astonishing advancements in science and technology. Now days, many humans are dependent on internet for their daily chores. But, congestion is one of the major issues, which affects the performance of such data networks. Thus, in order to control congestion, various schemes have been developed. In this research paper, the active queue management (AQM) scheme i.e. random early detection (RED) AQM algorithm is modified using fuzzy logic MATLAB tool, in such a manner that the efficient and reliable performance of the network can be maintained and improved as well. The results are verified with the help of QualNet 6.1 network simulator.

Keywords*: congestion; congestion control; active queue management (AQM); random early detection (RED); QualNet 6.1; MATLAB; fuzzy logic*

1. Introduction

Humans are living in the era of technology in which, the internet has become one of the primary needs for over one-third of the world population [1, 2]. Internet has such wide range of information and services that it can be employed in various day-to-day life activities [3]. In such electronic data networks [4], congestion may occur if the number of sent packets, i.e. load on the network is larger than the number of packets that the network can handle, i.e. the network's capacity [5]. According to Author [6], Due to the limited bandwidth and increasing demand of large number of internet users, the load on the network exceeds the network capacity, which causes congestion. Congestion deteriorates the performance of such networks in terms of various network performance metrics such as packet delivery ratio, average end-to-end delay, throughput etc. [6]. Therefore, in order to control network congestion, various congestion control mechanisms have been devised. In this research paper, communication or data network is described by the term 'network'.

In this research paper, active queue management (AQM) scheme for congestion control mechanism has been used. Router-based queue management technique is suggested by many researchers as well as the RFC-7567 IETF [7] for early detection of the congestion inside the network, which helps in improving its performance [8]. Author [8] describes that AQM algorithms are implemented on internet router [9], which detects the congestion building up inside the network by continuously analyzing the instantaneous or average queue size. FIFO or Drop-Tail algorithm is the most common one being used by the routers because of its low overhead, but it does not provide optimum performance [8]. Thus, in order to optimize network performance, Random Early Detection (RED) was introduced, which is one of the famous AQM algorithms. Various other variants of RED have also been proposed to optimize network performance [10].In this research paper, fuzzy logic is incorporated with classic RED algorithm to devise a feasible RED variant

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so as to improve network performance in terms of performance metrics such as, end-to-end delay, packet delivery ratio, packet loss ratio, average jitter, *etc*.

2. Random Early Detection (RED) Algorithm

Author [11] describes Random Early Detection or Random Early Drop [12] (RED) as an AQM algorithm used for congestion detection and also congestion avoidance with the help of end-to-end transport protocols in commercially used internet routers [11]. This algorithm was discovered by Floyd and Jacobson in their research paper "Random Early Detection Gateways for Congestion Avoidance" [13]. The basic principle for this algorithm described by Author [13] is that the packets are dropped or marked in random fashion before the buffer is full. Thus, the links tend to renege before the buffer gets full and hence, many packets are dropped. Otherwise, the links continue to transmit at higher transmission rate, which causes more packet loss. In RED algorithm dropping of packets is a function of average queue size, q_a which is the number of packets in the queue [14]. It can be computed with the help of exponentially weighted moving average filter, to reduce the effects of burst traffic or incipient congestion while estimating queue size. Thus, average queue size is given below in (1) as in [13],

$$q_a = (1 - w_q)\, q_a + w_q q_i \quad (1)$$

Where,
q_a = Average Queue Size, which is the number of packets in the queue [14]
w_q = Queue Weight, filter parameter to calculate weight towards instantaneous queue size [14]
q_i = Instantaneous Queue Size, which is current number of packets in the queue [14]

Author [11] explains that the RED algorithm is implemented using a set of parameters:

min_{th} = Minimum Threshold of Queue Size
max_{th} = Maximum Threshold of Queue Size
w_q = Queue Weight
max_p = Maximum Packet Drop Probability

In [13], if the average queue size is greater than the minimum threshold min_{th}, the incoming packets are dropped by the router randomly with the given drop probability. When the queue increases and exceeds the maximum threshold max_{th}, then all the incoming packets are marked. Thus, the RED drop function $d(q_a)$ given in Fig. 1 can be described mathematically as given in (2) below [13]:

$$d(q_a) = \begin{cases} 0, if\ q_a < min_{th} \\ \frac{q_a - min_{th}}{max_{th} - min_{th}} . max_p, if\ min_{th} \leq q_a < max_{th} \\ 1, if\ q_a \geq max_{th} \end{cases} \quad (2)$$

Author [11] describes that the RED algorithm is reactive towards the setting up of these parameters. According to [13], the value of min_{th} and max_{th} depends on the average queue size which is to be achieved by the router.

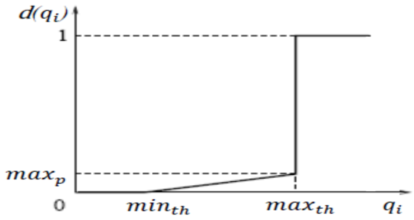

Figure 1. RED Drop Function

Author [11] describes that if the parameters are not properly assigned, oscillations of average queue size limited between min_{th} and max_{th} may occur, leading to instability by not properly utilizing the link. Thus, these parameters should be assigned properly in order to achieve convergence [11] and optimize the performance of the network.

3. Fuzzy Based RED Algorithm

In this research paper, MATLAB's Fuzzy Logic Toolbox [15] is incorporated with classic RED AQM algorithm in order to improve network performance in terms of network performance metrics such as packet delivery ratio, average end-to-end delay, etc. Fuzzy Logic Toolbox is used to design fuzzy inference [16]. In this research paper, Mamdani's fuzzy inference system is implemented. Authors [17, 18] describe the design process of Mamdani system in MATLAB with the help of flow chart shown in Figure 2 below:

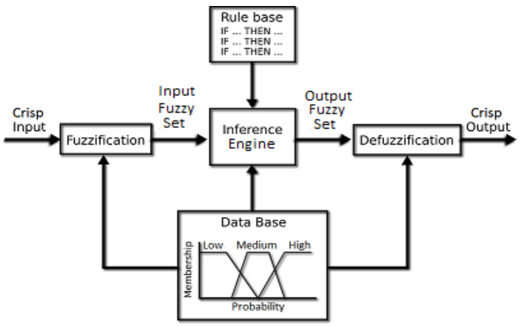

Figure 2. Fuzzy Inference System

Author [19] describes the implementation of Fuzzy Logic Mechanism in RED AQM algorithm quite useful as well as a feasible method to establish relationship between various queue parameters and packet drop probability in order to control congestion thereby optimizing network's performance, which can be verified with the help of various network performance metrics given in the later section.

In this research paper, a multiple input- single output fuzzy inference system is designed. There are two input functions, namely, average queue size which is denoted by 'aql', with fuzzy set linguistic variables used for mapping, called, membership functions [17][18] {Small, Medium, Large, Very Large} [20], shown in Figure 3 and difference between average queue size and instantaneous queue size which is denoted by 'daql', with membership functions {Negative, Zero, Positive} [20], shown in Figure 4. There is one output function, namely, maximum packet drop probability which is denoted by 'mdp', with membership functions {Zero, Low Probability, Medium Probability, Medium High Probability, Medium Medium High Probability, High Probability} [20], shown in Figure 5.

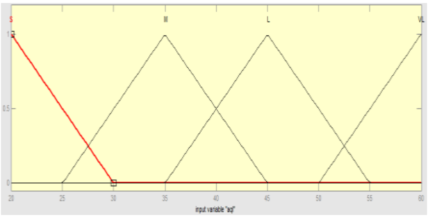

Figure 3. Average Queue Size, 'aql'

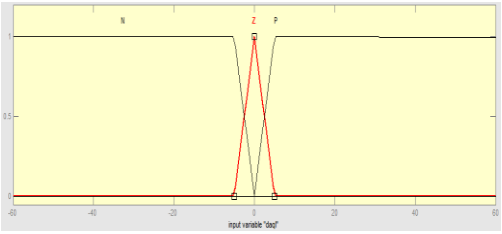

Figure 4. Difference between Average Queue Size and Instantaneous Queue Size, 'daql'

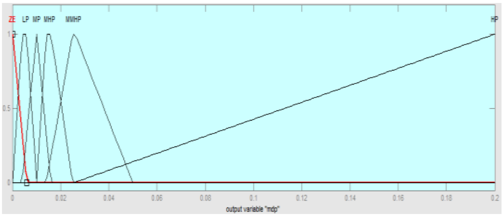

Figure 5. Maximum Packet Drop Probability, 'mdp'

The set of fuzzy rules defined for the designed fuzzy inference system [20] is given in Table I below:

Table 1. Fuzzy Rule Base

Rule	aql	daql	mdp
1.	S	N	ZE
2.	S	Z	LP
3.	S	P	MP
4.	M	N	LP
5.	M	Z	MP
6.	M	P	MHP
7.	L	N	MP
8.	L	Z	MHP
9.	L	P	MMHP
10.	VL	N	MHP
11.	VL	Z	MMHP
12.	VL	P	HP

4. Simulation Environment and Parameters

QualNet 6.1 network simulator is employed in this research paper, for performing simulation on network to analyze its performance and alter the network in such a manner that the modified version of the network provides better results in terms of various network performance metrics [22].

Authors [23][24] describe QualNet 6.1 simulator as a popular modeling and simulation tool for mobile ad hoc networks (MANET), which is an infrastructure less network such that all the mobile nodes in the network behave as routers due to the lack of any network controller and thus, interconnections between the nodes vary on a continuous basis.

Hence, such networks possess high mobility, dynamic topology and self configuration [23][24]. Thus, they require ad-hoc routing protocols for efficient routing i.e. data trans-reception between nodes, [25]. Latin language word ‘Ad hoc’ means ‘for any specific purpose’ [26]. In this research paper, MANET is used for simulation in QualNet 6.1 simulator to inspect whether the modifications employed in the Fuzzy based RED queue parameters, in the network, control congestion better as compared to that of default RED queue parameters in the QualNet 6.1 simulator. In this research paper, comparison is performed by varying the number of nodes from 10 to 50 such that 10 nodes contain 5 CBR connections, 20 nodes contain 10 CBR connections, 30 nodes contain 15 CBR connections, 40 nodes contain 20 CBR connections and 50 nodes contain 25 CBR connections.

Network simulation model parameters are described in Table II given below:

Table 2. Network Simulation Model Parameters

Network Simulation Model Parameters	Value of Parameters
Network Type	Wireless
Radio Propagation Model	Two Ray Ground Propagation
Antenna	Omni Directional
Mobility Pattern	Random Waypoint
MAC	MAC 802.11
Number of Sources	5,10,15,20,25
Number of Queues	3
Number of Nodes	10,20,30,40,50
Routing Protocol	AODV
Pause Time (in sec)	30
Maximum Speed (m/s)	10
Traffic Type(Application/Agent)	CBR/UDP
Simulation Area	1500×1500 m^2
Data Rate	2 Mbps
Packet Size	512 Bytes
Simulation Time (in sec)	900

Default RED queue parameters in QualNet denoted by ‘Without Fuzzy’ and Modified RED queue parameters using fuzzy logic denoted by ‘With Fuzzy’ are described in TABLE III given below:

Table 3. RED Queue Parameters

RED Queue Parameters	Value of Parameters	
	Without Fuzzy	***With Fuzzy***
Minimum Threshold, min_{th}	5	20
Maximum Threshold, max_{th}	15	60
Number of Sent Packets	10	40
Maximum Probability, max_p	0.02	0.0143
RED Queue Weight, w_q	0.002	0.002

5. Results and Analysis

The results obtained after comparing the network performance metrics such as average queue length [14], average end-to-end delay [14, 21], average jitter [14, 21], packet delivery ratio [21], packet loss ratio [21] and throughput [21], in both the cases *i.e.*, ‘Without Fuzzy’ and ‘With Fuzzy’ using QualNet 6.1 simulator, which are shown below:

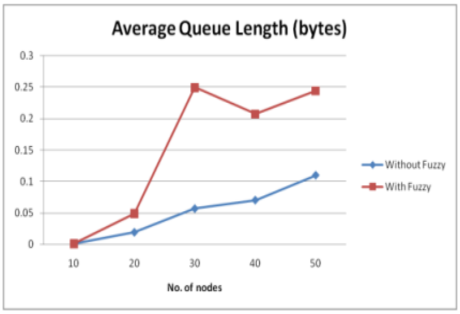

Figure 6. Average Queue Length

It can be observed from Figure 6 that the RED queue maintains the desirable average size of the queue in the internet router, depending upon the respective values of min_{th} and max_{th}, in both cases. This helps in controlling congestion, warding off global synchronization [27] and eliminating bursty network traffic, as much as possible [28].

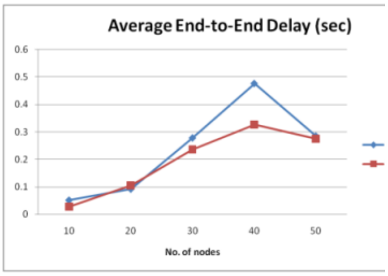

Figure 7. Average End-to-End Delay

From Figure 7, it can be observed that the overall average end-to-end delay in case of 'With Fuzzy' is lower than that of 'Without Fuzzy', which ensures that 'With Fuzzy' case performs better than that of 'Without Fuzzy', thus helping in improving the performance of the network.

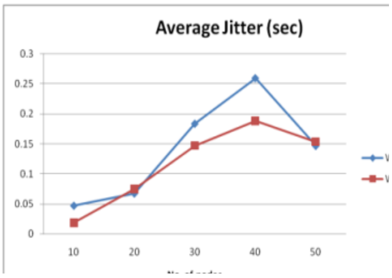

Figure 8. Average Jitter

From Figure 8, it can be observed that the overall average jitter in case of 'With Fuzzy' is lower than that of 'Without Fuzzy', which ensures that 'With Fuzzy' case performs better than that of 'Without Fuzzy', thus helping in improving the performance of the network.

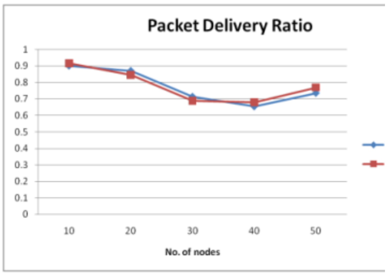

Figure 9. Packet Delivery Ratio

From Figure 9, it can be observed that the overall packet delivery ratio in case of 'With Fuzzy' is higher than that of 'Without Fuzzy', which ensures that 'With Fuzzy' case performs better than that of 'Without Fuzzy', thus helping in improving the performance of the network.

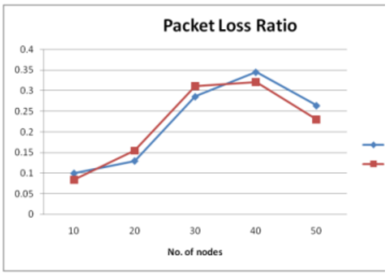

Figure 10. Packet Loss Ratio

From Figure 10, it can be observed that the overall packet loss ratio in case of 'With Fuzzy' is lower than that of 'Without Fuzzy', which ensures that 'With Fuzzy' case performs better than that of 'Without Fuzzy', thus helping in improving the performance of the network.

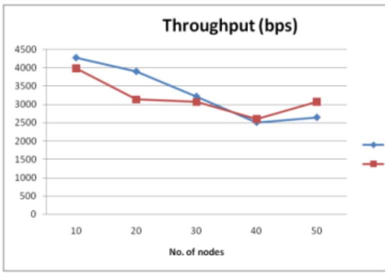

Figure 11. Throughput

Although, in Figure 11, the overall throughput in case of 'With Fuzzy' is lower than that of 'Without Fuzzy', but it can be compensated with adequate decrease in average end-to-end delay [29] and adequate increase in packet delivery ratio (or adequate decrease in packet loss ratio), in order to optimize the network's performance.

6. Conclusion

In this research paper, RED AQM algorithm has been modified, with the help of fuzzy logic MATLAB tool for improving congestion control in any network, which is much needed in this era of technology. The results are verified by comparing the modified fuzzy based RED queue parameters with the conventional RED queue parameters in the QualNet 6.1 network simulator.

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