Congestion Detection and Congestion Control Method Using Fuzzy Logic Control in Mobile Ad-hoc Network

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Abstract- An ad-hoc network is the collection of wireless nodes without any access point or centralized infrastructure. The nodes or routers communicate independently through wireless network without any central control. Congestion occurs when the arrival rate of packets exceeds the departure rate at a link interface. In ad-hoc networks, packets that arrive at a router and are not forwarded owing to limited buffer space are dropped. Under persistent network overload, the high levels of transmission delays and losses experienced by packets result in poor data delivery services to end systems and wastage of resources. Thus it is required to control congestion or more ideally avoid congestion. The first step in congestion control is congestion detection. In this paper, congestion detection method is implemented using fuzzy logic control using input parameters node buffer occupancy at node, energy consumption and channel utilization ratio. The Hello interval is decided according to fuzzy rules. The justification and logic reasoning for framing these rules are described in this paper. The congestion control methods are proposed in this paper and simulation results are analyzed. The performance evaluation of basic AODV and proposed congestion control methods is discussed in this research.

Keywords- *Mobile ad-hoc network, Energy consumption, Fuzzy logic, Congestion control, Channel utilization.*

I. INTRODUCTION

An ad hoc network is a collection of mobile nodes without any centralized access or control point in which each node acts as a router. It is a dynamic network with mobile nodes in which nodes can join and leave arbitrarily [1, 2]. The most important characteristics of mobile ad hoc networks are node mobility and multi-hop shared wireless channel. Using multi-hop wireless channel, data transmission is allowed at the transmission range of each node. Several senders compete for link bandwidth to transmit data packets to the destination. A network with shared resources is required where several transmitters compete for link bandwidth so that the data rate used by each sender would be adjusted. Thus, the network would not be overloaded [3]. Several protocols have been proposed for routing packets in ad hoc networks. The destination node is identified in every data packet. When a node receives this packet, it forwards it to the next-hop for that particular destination, until the packet reaches its destination. The generation and maintenance of routing tables differs from one protocol to another. Every protocol focuses on few constraints and based on these constraints attempts to find the optimal path from source to destination [4]. These constraints may be the number of next-hops, bandwidth etc. Similar to regular networks, routing protocols for ad hoc networks can also be classified as Proactive, Reactive and Hybrid [5]. In proactive routing protocol, every node maintains the network topology information in the form of routing table by periodically exchanging routing information. In contrast to proactive routing protocols which maintain all up-to-date at every node, in reactive routing protocol routes are created only when desired by the source node using a connection establishment process. Some protocols that combine the good properties of both pro-active and reactive protocols were proposed, such. The routing is initially established with some proactive prospected routes and then serves the demand from additionally activated nodes through reactive flooding.

A. Congestion Problem

Network congestion occurs when the amount of data traffic injected into the network by end systems exceeds its transmission capacity [6]. An excessive amount of packets arrive at a congested node and are not forwarded. As a result, a large amount of incoming packets in the network bottleneck causes a lot of packets to be discarded. These packets may have traveled a long way in the network and consumed adequate resources. In addition, packet loss often causes retransmission of packets. This means even more packets are sent into the network. Therefore, network congestion severely degrades the throughput. This leads to heavy packet drops and increased delay. If proper congestion control mechanism is not applied, it can cause the network to collapse resulting in no data being delivered successfully. Congestion seriously affects network performance such as queuing delay, packet loss or the blocking of new connections [7, 8]. Wired networks, in comparison with wireless networks, have less congestion issue due to a fixed infrastructure and dedicated end-to-end links. The limited wireless networks scalability and the mobility causes congestion in this network [9]. In ad-hoc networks, with particular challenges such as frequent changes of topology, investigating congestion control is very important. Congestion control methods regulate the amount of data traffic injected by end systems into communication networks, preventing persistent network overload [10]. The first step in the congestion control method is detection of congestion. This research paper focuses on method of congestion detection where congestion is marked in network using some congestion detection parameters. The routing protocol used in this research is AODV, which is a reactive routing protocol.

The organization of the paper is as follows. The starting section of this paper discusses congestion problem in mobile ad-hoc network. Section II discusses about previous established research work. The proposed research algorithm is explained in section III. Section IV discusses simulation configuration and performance analysis. Finally, Section V presents conclusion.

II. RELATED WORKS

The related research papers based on various congestion control approaches are discussed below:

A fuzzy rate-based congestion control method is proposed in [11] to prevent network congestion. Fuzzy logic congestion control determines the network congestion level based on the probability of congestion. Then, data rate is set based on the level of congestion. The simulation result shows that using the fuzzy method in ad hoc networks with random topology changes is suitable.

In [12], a method is proposed to detect congestion in ad hoc networks based on the average queue length in each node. Based on the average queue length threshold, the node detects the congestion levels and sends a warning message to its neighbors. After that, they an alternative route to the destination is identified. Dynamic congestion estimation mechanism ensures reliable communications in ad hoc networks. However, this method suffers some limitations such as increase in control overhead which is incurred due to congestion notification. Agent-based congestion control technique is proposed in [13], in which network congestion information is collected and distributed by mobile agents. A mobile agent moves towards the edge nodes and mobile agents with their own history of movement update the routing table of the visited node. Mobile agents calculate the data transmission rate of the corresponding nodes and then select the node with highest data rate. The level of congestion for each traffic queue is estimated and priority is assigned to each node based on measurements of the level of congestion. Therefore, a node with no traffic and insensitive delay would have higher priority for receiving more traffic than a low priority node.

In paper [14], a scheme for congestion control based on cross layer scheme is proposed. The cross-layer scheme ensures that information is shared between different layers in the protocol stack. Then congestion is detected at the scale of congestion and packet loss rate is achieved. Finally, congestion control is achieved using the cross-layer approach. The congestion path is determined based on path gain and buffer fullness.

The authors in [15] developed an efficient energy-based congestion control scheme to avoid congestion and to improve the energy efficiency of mobile nodes. Multipath routing is used to prevent congestion that leads to increased network lifetime. The mathematical model is used to calculate the energy consumption of nodes in the network. Therefore, the probability of packet retransmission decreases by calculating the energy level of acknowledgment and data packets.

In research [16], authors present a congestion control and early avoidance congestion control scheme. This scheme is based on the Cross-layer solution between the MAC and network layers in order to detect congestion. The cooperation between nodes is utilized by the sender node to find an alternative route based on Triangular Matrix Table (TMT). This mechanism works on resource control approach instead of rate control approach.

In paper [17], authors presents the early congestion control (ECC) and a mechanism in order to improve TCP performance in wireless networks. They implemented an active queue management (AQM) technique that dynamically changes the value of the window field from TCP headers according to the utilization of the router queue. This method leads to enhance the performance of the TCP protocol by controlling the congestion.

In paper [18], authors propose an adaptive reliable and congestion control routing protocol to resolve congestion and route errors using bypass route selection in MANETs. In this method, the congestion detection is based on utilization and capacity of link and paths. When congestion is detected by a source node on a path, traffic is distributed over alternative paths by considering the path availability threshold and using a traffic splitting function. If a node cannot resolve the congestion, it signals its neighbors using the congestion indication bit.

III. PROPOSED METHODOLOGY

The proposed congestion control method is completed in three steps; the first step is the congestion detection, which finds out the presence of congestion in network, next step is the congestion notification, where congestion information is transferred to neighboring nodes without using additional control packets and finally congestion prevention, where congestion control is employed to prevent congestion. First, the route is identified between source and destination nodes using AODV protocol, by utilizing RREQ and RREP control packets. For discovered route, the congestion level of the node is determined by using the proposed congestion detection technique that is based on the following parameters –

- **Node buffer occupancy** – The buffers are available with nodes where incoming packets are stored for the short term. The state of node congestion can be expressed by the number of packets in node buffer. This parameter can be used as an essential congestion metric to evaluate the network performance. As the number of packets collected in the interface queue is more due to heavy traffic, the congestion is increased resulting in packet drop. The retransmission of these lost packets would increase the traffic and results in congestion.

- **Remaining node energy** - Heavy traffic of packets in the network leads to congestion and high energy consumption at node. This causes fast energy exhaustion at nodes, and as a result, the residual node energy is reduced. Less is the node residual energy; more is the possibility of route failure. As a result, the packets are lost and retransmitted. Thus it aggravates the congestion in network. The remaining node energy can be used to represent node level and link level congestion in network.

Channel utilization ratio – Channel utilization ratio is given as the proportion of time during which channel surrounding the node is marked as utilized. Channel utilization increases when incoming and outgoing queues at the node are busy. It is a measure of congestion in a link.

The congestion status of the node is calculated according to the above mentioned parameters using fuzzy logic controller. The frequency of the periodic Hello messages transmission is decided according to the congestion status of the node. Higher is the congestion at the node, more will be the frequency of Hello packets transmitted by the node to the neighboring nodes. The node will estimate the congestion status of neighboring node by observing the frequency of Hello packets. The fuzzy rules consider node buffer occupancy, remaining node energy and channel utilization ratio as input variables and Hello interval as an output variable. The flow diagram for proposed congestion detection scheme using fuzzy logic is given in Fig. 1. The Hello interval is calculated as low, medium and high depending on input parameters as per the fuzzy rules given in Table 1.

Some of the rules are discussed below:

- When the channel utilization, node buffer occupancy and energy consumption at node exceeds the threshold, then that node becomes congested. There is increased packet drop at node. To have connectivity with the node, the Hello interval should be low.
- When channel utilization, node buffer occupancy and energy consumption at node is low, the node is less congested. The node will continue forwarding the packet without dropping the packet. Thus the Hello interval of the node is high as there are less chances of failure of route.
- When channel utilization, node buffer occupancy and energy consumption is medium, the node is congested as all parameters are approaching towards high value. Thus Hello interval is low and connectivity with congested node is maintained.
- When channel utilization and node buffer occupancy is medium and energy consumption is low, then node is medium congested as the energy consumed in packet processing and transmitting is low. The frequency of Hello packets is neither high nor low but it is transmitted at medium frequency.

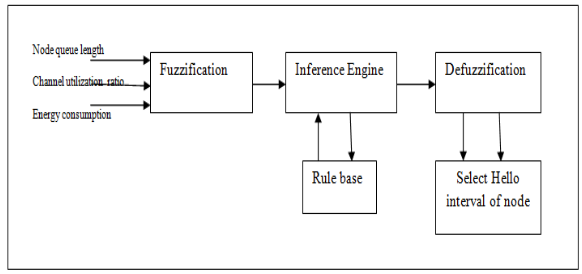

Fig. 1. Flow diagram of congestion detection scheme

TABLE 1: RULE TABLE FOR HELLO INTERVAL

Avg. queue length ↓	**Channel Utilization**								
	Low(L)			**Medium(M)**			**High(H)**		
	Remaining node energy			**Remaining node energy**			**Remaining node energy**		
	L	M	H	L	M	H	L	M	H
L	H	H	H	M	M	H	M	M	H
M	M	M	H	L	L	M	L	L	M
H	L	M	H	L	L	M	L	L	L

After congestion detection and congestion notification to neighboring nodes, the congestion control method is proposed. In case of medium congestion, the congested node is bypassed from the route through alternate non-congested node. When the node is high congested, the network coding of data packets coming from opposite directions at a congested node is performed. Thus one packet instead of two packets is transmitted by a congested node which reduces the data packets in its output queue and reduces the traffic in its neighborhood. Two diverse variants of congestion control protocols, **Adaptive network coding (ANC protocol) and Network coding and local route assistance (NCLR**

protocol) are developed depending on the congestion status of the nodes.

IV. SIMULATION RESULTS AND ANALYSIS:

A. Simulation configuration

The performance of proposed technique is evaluated through NS-2 software. The performance metrics Packet delivery ratio, Throughput and Normalized routing load is measured for the AODV protocol and proposed variants. In the scenario, the simulation parameters taken are given as follows:

- The routing protocol used for performance analysis is AODV. Each node moves towards a randomly chosen destination node with a random speed. The maximum node speed in the scenario is 20 m/s and the total length of the simulation is 100 seconds. The area of the network is $1200*1200m^2$ and size of the data packet is 512 bytes. The transmission range is 300 meters and MAC layer protocol used is 802.11 DCF protocol.
- The node has a maximum queue size of 50 packets and initial node energy is 50J. In our simulation, 2 Mbps is the channel capacity of mobile hosts for our simulation environment.

The performance evaluation is discussed for variation in the number of nodes in a fixed terrain area.The results for performance parameters such as normal routing load, throughput and packet delivery ratio are plotted and compared for different number of nodes.

B. Result Analysis

The performance assessment analysis of basic AODV and proposed congestion control methods ANC and NCLR is discussed in this section. The number of nodes in network is varied as 180, 195 and 210.

The number of control packets transmitted for each data packet received at the destination is called **Normalized Routing Load (NRL)**. The NRL increases with increase in number of nodes as there is increase in traffic. The proposed methods show less NRL as compared to AODV as shown in Fig. 2,3 and 4.

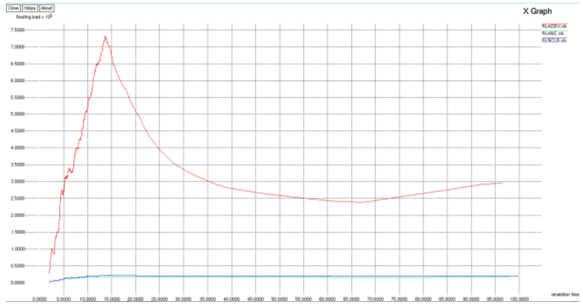

Fig. 2. Graph of Normalized routing load for 180 nodes

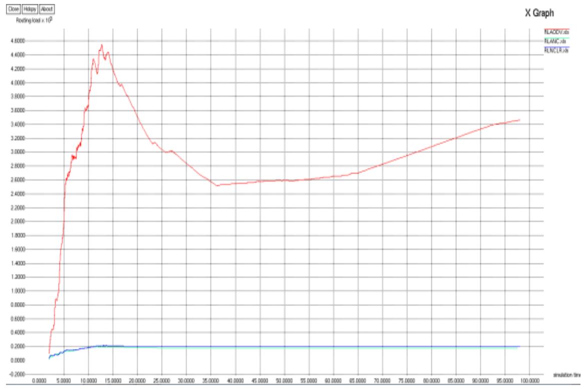

Fig. 3. Graph of Normalized routing load for 195 nodes

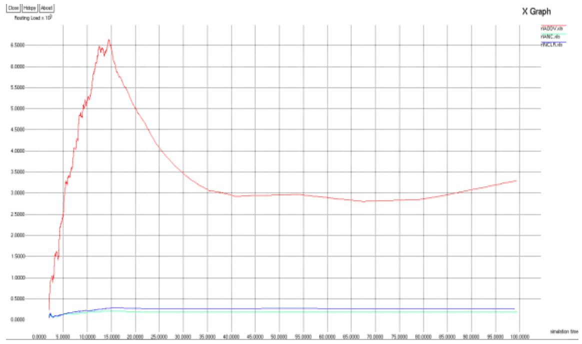

Fig. 4. Graph of Normalized routing load for 210 nodes

Packet delivery fraction is given by ratio of number of received packets to number of packets transmitted in network. With increase in number of nodes, there is increase in traffic so congestion in the network increases. The congestion control methods show enhanced packet delivery ratio as compared to basic routing protocol AODV as shown in Fig. 5, 6 and 7. The NCLR show improved performance than ANC.

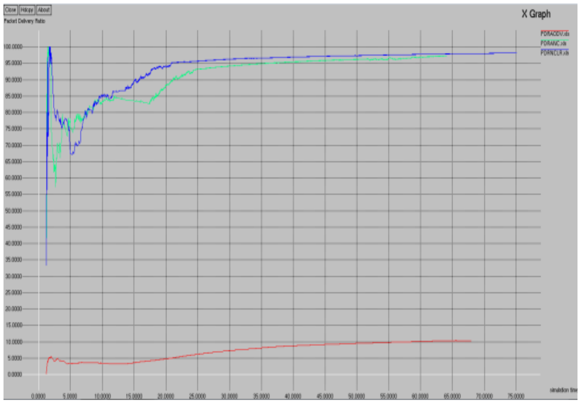

Fig. 5. Graph of Packet Delivery Ratio for 180 nodes

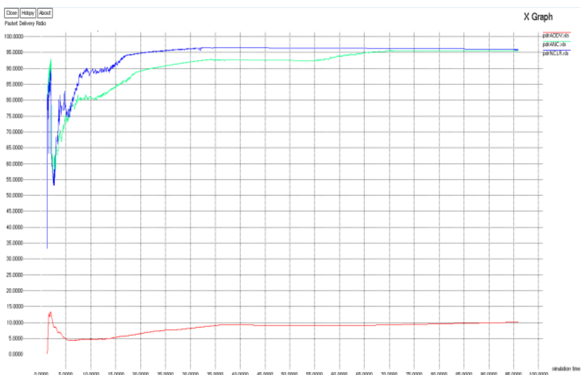

Fig. 6. Graph of Packet Delivery Ratio for 195 nodes

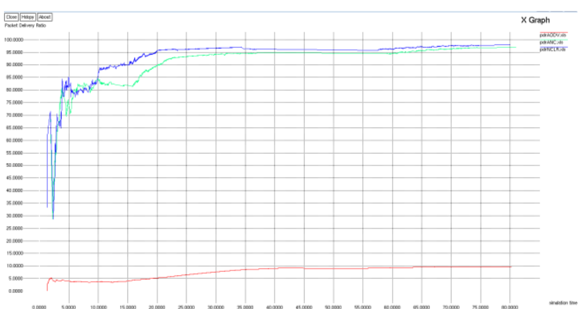

Fig. 7. Graph of Packet Delivery Ratio for 210 nodes

Throughput is defined as ratio of number of data bits received at destination and total simulation period. The proposed congestion control methods ANC and NCLR show better throughput than AODV, as shown in Fig. 8, 9 and 10.

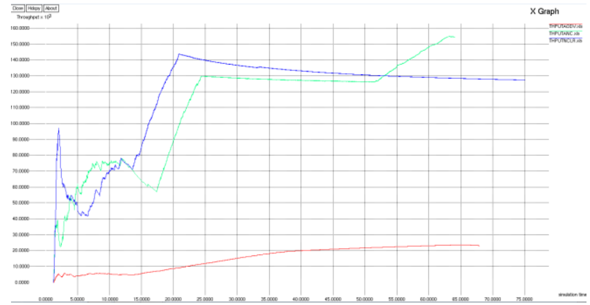

Fig. 8. Graph of Throughput for 180 nodes

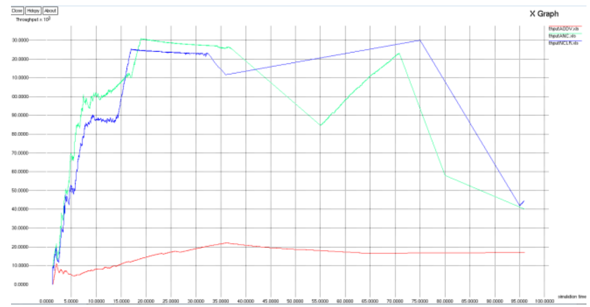

Fig. 9. Graph of Throughput for 195 nodes

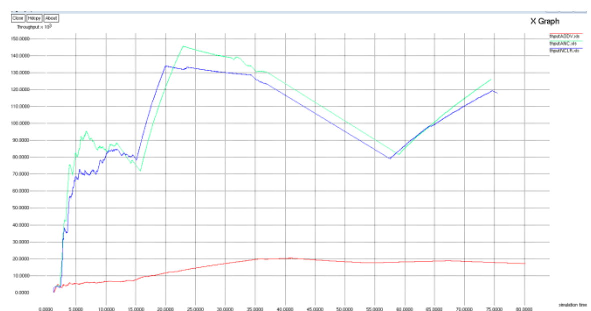

Fig. 10. Graph of Throughput for 210 nodes

V. CONCLUSION

In Mobile ad-hoc network, congestion occurs in the network, when traffic exceeds the resource availability. This paper proposes a congestion detection method using fuzzy logic control. The congestion detection parameters used are node buffer occupancy, energy consumption and channel utilization as these parameters reflect node level and link level congestion efficiently. The network coding and local route assistance scheme is proposed for congestion control, based on congestion status of a node.

In this research, no special control and routing packets are used for congestion notification but adaptive frequency of Hello packets is used for notification of congestion. The frequency of Hello packets is varied according to the congestion. The simulation results demonstrate the validity of proposed methods as compared to AODV. The performance parameters show improved results in terms of throughput, packet delivery ratio and normalized routing load, in case of proposed protocols. Future research can be further expanded to implement proposed algorithm for other routing protocols.

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