International Journal on Emerging Technologies **10**(3): 472-479(2019)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Design and Implementation of an Algorithm for Mitigating the Congestion in Mobile Ad Hoc Network

Harsh Pratap Singh[1], Jitendra Sheetlani[2], Nagesh Salimath[3] and K. Murali Gopal[4]
[1]Research Scholar, Sri Satya Sai University of Technology and Medical Sciences, Sehore, (Madhya Pradesh), India.
[2]Associate Professor, Sri Satya Sai University of Technology and Medical Sciences, Sehore, (Madhya Pradesh), India.
[3]System Analyst, PDA College of Engineering, Kalaburgi (Karnatka), India.
[4]Associate Professor, GIET University, Gunupur, India.

(Corresponding author: Harsh Pratap Singh)
(Received 26 June 2019, Revised 29 August 2019, Accepted 25 September 2019)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Wireless mobile ad-hoc network is a recent trend of communication network that work in dynamic behaviour with the help of multiple node co-operation. Because of the limited capacity of the bandwidth every node may transmit the packet at the same time due to this congestion arises which incur long delay and high packet loss which cause the performance degradation of the network. Number of researcher gives the idea for minimization and controlling the congestion in efficient manner but they cannot fulfill all aspect of network parameters. In this paper, the aim is to design a mechanism to control the congestion as well as gives improved performance with respect to every parameters of network under dynamic behaviour. In this paper apply the local route revamp and node reliability methodology for route establishment process and analogous time CTS/RTS mechanism are used to resolve the collision while multiple nodes are contend for the channels assignment. In the second methodology we minimize congestion with using the intermediate queue aware based data rate control technique so our network performance overall improve. The experimental analysis of proposed approach is done using various performance metrics such as Packet Delivery Ratio (PDR), Normalized Routing Load (NRL), throughput and average delay. The result taken in different scenario and analyzed the performance in all respect of network parameter, that conclude our proposed approach is more reliable than the existing AODV protocol which improves the PDR approximately 15%, throughput about 5-6%. The proposed approach also minimizes the network routing load and average delay than the existing approach.

Keywords: MANET, AODV, PDR, RTT, CTS, RTS, Collision, Congestion, PDR, NRL.

I. INTRODUCTION

MANET is an accumulation of mobile hubs or nodes that can collaborate with one another without utilizing wires. In this, node inside the transmission range can convey legitimately else they can utilize different nodes to send packet (PKT) [10, 11]. Sending of MANET is low-cost and because of this it is the significant anxiety of research. The use of MANET ranges from huge scale mobile systems to diminutive, static systems restricted by the power resources. The principle targets of the MANET directing convention are- amplify organize lifetime, energy effectiveness, arrange throughput and defer minimization. To accomplish these goals, many directing protocols have been proposed for MANETs. The routing protocols in MANETs are arranged into three classes: proactive routing protocols, reactive routing protocols and hybrid routing protocols [12, 13, 17]. A few difficulties looked by MANET are dynamic topology, requirements on resources, the executives of data transfer capacity and PKT communicate overhead, which makes trouble to configuration directing protocols. MANET empowers the change of data among the various disengaged system or all the more prevalently versatile clients. In MANET every cell phone functions as a switch and help each other for effectively conveying the information. MANET experiences high transmission error rate because of the high transmission conflict and congestion. Congestion happens in the system when a hub or connection conveys a lot of information that debases the system administration quality. Congestion can happen because of different reasons like when the info traffic rate surpasses the limit of the yield line, slow processors, when switch's support (Buff) is restricted and furthermore because of moderate connections. Congestion Control is the system that can either maintain a strategic distance from Cong, before it occurs, or evacuate Congestion, after it has occurred. Following are the Congestion Control Algorithms utilized in MANET.

A. Drop Tail Algorithm

This algorithm is used in case of routers. It works on first-in-first out (FIFO) based queue of limited size. In this algorithm, a network part can Buff auto sized amount of PKT and it drops those PKT that can't be buffered. If Buff is full for a long time, the network is congested. This algorithm does not fairly distribute the buffer space among the traffic flow and also leads to global synchronization.

B. Random Early Detect (RED) Algorithm

RED [14] is tailored for TCP connection across IP routers. RED maintains two threshold values Max_Thres and Min_Thres. Initially RED calculates the ave-rage queue length (AQL). Then it checks if the average is less than Min_Thres then it accepts the PKT and if the average is more than Max_Thres then it drops the PKT. RED is improved than Drop-tail as it does not

retain unfair distribution of Buff space to handgrip the bursty traffic.

The major drawback of this algorithm is the queue size varies with the level of congestion. In this research work, proposes a node reliability and rate control mechanism is used to control the congestion over the network on AODV protocol. The simulation of the proposed scheme is done using the network simulator NS-2 and uses the performance metrics such as PDR, NRL, throughput and average delay for the comparative analysis between the existing approaches and proposed. The results of propose approach shows that they minimizes the congestion and improves the PDR and throughput of the AODV protocol.

The remaining section of this paper is organized as follows. Section II describes Literature Survey about congestion control. Section III describes proposed methodology for congestion control and IV describe Experimental Setup and Result Analysis and concluding remarks in section V.

II. LITERATURE SURVEY

In MANET a node works as a host just as a router as there is no central head to disperse the coming traffic, some middle of the road node get overwhelming traffic and the circumstance emerge that the node isn't capable or to store the coming data packet. In such condition node begin to drop the data packet. In the event that these occasions happen much of the time, at that point it is called congestion. It is essential to stay away from congestion breakdown in remote multi-bounce arranges so as to perform productive congestion control. For this reason numerous creators have proposed different congestion control algorithms trying to stay away from bundle misfortunes and to guarantee solid conveyance of packets from source to goal. This part reviews past work in which congestion control strategy has been applied to improve the exhibition in MANET.

Mallapur *et al.,* [1] investigated a proficient routing strategy called multipath load balancing method for congestion control (MLBCC) in MANETs to productively adjust the heap among the different ways by decreasing congestion. For a proficient progression of circulation, a node accessibility degree standard deviation parameter is presented. The aftereffects of their examinations demonstrated execution enhancements as far as normal start to finish delay, bundle conveyance proportion and packet drop proportion in correlation with AOMDV and FMLB. Sharma and Pawar [2] proposed another methodology named as CRAODV for congestion control in MANETs and contrast the equivalent and the EDMR algorithm. It initially distinguishes the few system angles, some of which are one of a kind to MANET arranges that influence congestion, study congestion side effects for various Wireless Network congestion types and in addition, since congestion influences different system parameters, these are additionally analyzed. Their reproduction result demonstrated better execution as far as packet drop proportion. Vadive and Bhskaran [3] proposed a versatile dependable and congestion control routing convention to determine congestion and course mistakes utilizing sidestep course determination in MANETs. The congestion is recognized based on usage and limit of connection and ways. At the point when a source node distinguishes congestion on a connection along the way, it conveys traffic over elective ways by considering the way accessibility limit and utilizing a traffic parting capacity. In the event that a node can't resolve the congestion, it flag its neighbors utilizing the congestion sign piece. By utilizing recreation, we demonstrate that that the proposed convention is solid and accomplishes more throughputs with decreased bundle drops and overhead. Suraj *et al.,* [4] examined a novel way to deal with versatility forecast utilizing development history and existing ideas of hereditary algorithms, to improve the MANET directing algorithms. The proposed lightweight hereditary algorithm performs exception expulsion based on heuristics and parent determination utilizing the weighted roulette wheel algorithm. The procedure proposed another way to deal with versatility expectation which doesn't rely upon probabilistic strategies and which is totally founded on hereditary algorithms Suraki *et al.,* [6].

A cross-layer approach is proposed in vehicle, system, and MAC layers in which Fuzzy Logic System is utilized in middle of the road and goal nodes as a unique apparatus for controlling the congestion issue in MANETs. In the system layer, DSR routing algorithm is utilized and messages traded among nodes are placed into the ACK packets. The reenactment results demonstrate that in this strategy, start to finish deferral is decreased more for UDP packets and less for the TCP bundle. Besides, organize throughput expanded and packet misfortune rate marginally improved. Aimtongkham *et al.,* [7] proposed an algorithm Congestion Control and Prediction Schemes Using Fuzzy Logic System with Adaptive Membership Function in Wireless Sensor Networks. System congestion is a key test in asset compelled systems, especially those with constrained transfer speed to suit high-volume information transmission, which causes troublesome nature of administration, including impacts, for example, packet misfortune and low throughput. With a few elements, for example, jump tally, remaining energy, buffer occupancy, and sending rate, we apply fuzzy rationale frameworks to decide legitimate loads among those variables notwithstanding enhancing the weight over the participation capacities utilizing a bat algorithm. The reenactment results show the prevalent exhibition of the proposed strategy as far as high throughput, low packet misfortune, adjusting the general energy utilization, and drawing out the system lifetime contrasted with cutting edge conventions. Arora *et al.*, [8] Flexible congestion control utilizing fuzzy rationale for Wireless Sensor Networks. In WSNs, congestion is by all accounts an unusual stage brought about by the packets crash and the over-load arrange. To accomplish these targets, Flexible Congestion Control Plot (FCCFA) is proposed. FCCFA utilizes the shut circle congestion control strategy to control the traffic rate as needs be by utilizing three parameters. The Type-2 Fuzzy Logic System is utilized to gauges the alteration rate to deal with the vulnerability of information. Inherent notification system is utilized to inform the prompt nodes without squandering any energy. The recreated outcomes give the confirmation of our guarantees and upgrades. Kamatchi [9] proposed an algorithm energy adjusted plan and congestion control dependent on the chain of importance utilizing remote sensor systems Wireless Sensor Organize (WSN) comprises of an outsized scope of device nodes. The limited assets and many to-one communication model ordinarily end in congestion and unequal energy utilization. They will in general blessing a congestion the board and energy adjusted

subject bolstered the pecking order (CcEbH) Raikwar and Gupta [15].
Link failure increases the network congestion and overhead so that our proposed threshold based AOMDV routing minimizes network congestion and balance the network load. Ad hoc on demand multipath distance vector routing approach select the more than one route for communication where each selected path contain the maximum queue size and processing capability node with low mobility that increases the network reliability and minimize the network congestion. In this paper proposed enhance AOMDV routing simulate in different mobility condition and compare with exiting TALB-AOMDV routing through the network simulator-2. Result shows that proposed approach outperform as compare to existing TALB-AOMDV routing in every respect of network parameter in any condition. Meshram *et al.*, [16] presented Agent-based Congestion Control Protocol (ACCP) for wireless sensor networks. The traffic rate analysis on each node. It is based on the priority index and the congestion degree of the node. The parameter such as latency and throughput are investigated.

A. Motivation

Congestion in mobile ad hoc network in light of the fact that the sender may engage in sending packets over and over. It is profoundly attractive that transmission ought to be as proficient as would be prudent, negligible loss and delay transmission to monitor the constrained resources. It is better that some techniques are used to preclude the network from the congestion [5]. But prevention from congestion is not always possible and very problematic due to dynamic topology in MANET. When congestion occurs, through-put of the network is reduced. In MANET routing protocol, it can choose intermediate nodes in which some nodes generally drop the packets. If such type of nodes can be identified and replaced with some selected reliable nodes for forwarding the traffic, congestion delinquent can be abridged. It would be better if the selected intermediate node through the routing protocol can also watch the performance and cooperate properly in the network. With the concept, in this work we must find reliable node to forward packets and remove congestion using traditional AODV routing protocol concept for path establishment, also try to discover the time complexity of node for reliability.

B. Objective

The aim of this work is to control the congestion problem for improving the performance in MANET through the enhancement of AODV routing protocol. In this work the traditional AODV with the concept of local route discovery mechanism is proposed. When the route detected by the AODV is used for the transmission of data packets, intermediate nodes not only forward the packet, they also check their reliability status and apply local route discovery procedure to find an alternative path when node performance become poor, even the link is not broken. In proposed work node reliability shell be measured with the Packet Delivery Ratio (PDR) of a node.
Whenever the reliability (packet delivery ratio) become lower from the fixed threshold value, a local route discovery procedure has to be started to search other available path by the predecessor of that node instead of the sender which generally search a fresh path only when the detected route have been destroyed due to node movement or route failure. In this way by selecting reliable path utmost of the time network performance will be increased and it is also helpful in controlling congestion problem. The foremost objective of congestion control is to limit the delay and buffer overflow to deliver the enhanced performance of the network.

III. PROPOSED METHODOLOGY

In the recent research of mobile ad-hoc network dramatically change the communication scenario because dynamic routing provide flexible to move communicator device anywhere in any time with the help of intermediate nodes. However some challenges occur (congestion or collision) due to nature of unstructured behaviour of the network topology, which increase unreliability of communication network.
In this paper we proposed efficient congestion aware and control mechanism that improve the all aspects of network performance of mobile ad-hoc network. In this proposed work divided into three sub module and collaboratively provides efficient approach of congestion minimization with minimum overhead. These modules are route established, route reliability and Collision/Congestion resolves and link reliability.

A. Route Established

In this section describe about how the route initially established and resolve the route brake problem while the node continues change their topology. In this algorithm initial step to define the input parameter i.e. number of mobile nodes, sender receiver nodes, step time etc. than the execute algorithm with some constraint. In the next stage check the route table for established link are update or not if found that link are updated then we check the new link from lk to lm. If the link is break than local route repair technique is call and established the new path from lk, to lk+2 with efficient manner and minimized reroute broadcasting by sender node.

$S(t + 1) = s(t) + k$ if congestion not detected (1)

$(t + 1) = s(t) * 1$ is congestion detected (2)

where s(t) data sending rate at time slot t

k (k > 0) additive increase parameter.

l (0 < l < 1) multiplicative decrease factor.

Algorithm 1: Route Established Initialization:

M: mobile nodes
S: Sender nodes
R: Receiver nodes
I: {i_1, i_2,…..i_j, i_{j+1},……. i_{n-1}, i_n} intermediate nodes
L:{ l_1, l_2,….. l_k, l_{k+1},……. L_{m-1}, l_m} i.e $l_1 = i_1 \rightarrow i_2$ link between nodes
Step time: {1,2,……..100}
λ= 0 step change
While λ <=100
Do
Check route-table(S, i_j, R)
If l_k update && R! exist **then**
Check path l_k to l_m
If$i_j$toi_{j+1} route break **then**
Local-route-repair (l_k, l_{k+2},R)
End if
End if
λ = λ+10
End do

B. Route Reliability

In our proposed work apply the AODV (ad-hoc on demand distance vector) routing for route establishment from source to destination node. In this section detailed describe about how the route are reliable form work, for that some parameter is initialized those are trust value of the nodes, number of packet receives, forwarded etc. and execute them very first call the route established phase and calculate the trust value of each nodes whose participated in the established route. That trust value is calculate from the total number of data forwarded out of total number of packet receives multiply by hundred that is packet delivery ratio of node (PDR). If the PDR value is greater than the seventy percentages it means route is reliable else unreliable and call the local route repair mechanism and minimized the route packet overhead of the network. This work persistently works in every ten seconds of step time.

M (O): MANET abstract view, where O set of nodes
q: number of nodes
ri, i = 1,….,q
ri reliability values of nodes
gij: path from i to j node, i, j {0,1} 1 if path exist else 0
G is matrix of gij

$$\alpha_{o,}\ o = 1, \ldots . |A| \quad (3)$$

where $\alpha_{o,}$ state of the network
A: set of all possible configuration

$$\beta = \frac{f}{n-1} \quad (4)$$

where β link existence probability
f average number of neighbors per node

$$P(\alpha_o = 1) = \beta^{e1}\,(1-\beta)^{e2} \quad (5)$$

where $P(\alpha_o = 1)$ probability existence of each configuration
$e1$ and $e2$ linked and unlinked pairs respectively

$$2LR\alpha_o = P(\alpha_o = 1)\prod g_{ij,\ r_i} \quad (6)$$

where $2\ LR\alpha_o$ two node link reliability configuration
r_i reliability of node i and shortest path

Algorithm 2: Route Reliability Initialization:

T: trust value
r: no. of receives
f: no of forward
pdr: packet delivery ratio
S: Sender nodes
R: Receiver nodes
λ= 0 step change
for j in {0..n}
do
While λ<=100 **do**
Route-established S to R
//call Algorithm 1
$T_j \leftarrow (i_j, r, f)$
$pdr_j = (f/r)*100$
if(pdr_j < 70) **then**
Local-route-repair (l_k, l_{k+2},R)
else
correct route
end if
λ= λ+10
done
end do

C. Collision and Congestion Resolve

Mobile ad-hoc network are frequently change their topology due to mobility of nodes, so that multiple senders are detect common shortest path and arises the problem of congestion or collision. Than the problem of collision is resolve through the request to send (RTS) and clear to send (CTS) message technique and congestion resolve through the utilization of queue and delay measuring method. The first problem collision resolves, while multiple senders sends the route request packets through same link but that request packets receives by the intermediate nodes in some discrete delay differences than the intermediate node broadcast the CTS wining message by sender number, whose receives first come first serve bases and intimate all the remaining senders for wait next round trip time or completion of communication of first wining sender so collision are not occur on the network. Another issue of congestion that initially aware based on queue utilization of each intermediate nodes and while the queue demand is exceeded as compare to queue limit than the queue size increase based on demand but that increases the network delay and delay minimized through acknowledge delay difference based and sender control the data rate based of delay variation.

$$P = \sum_{i=1}^{n}(e_i - s_i) \quad (7)$$

$$d = \frac{P}{C} \quad (8)$$

where *P:* packet duration, e_i: packet receives time, s_i: transmission time of packet, *d*: average delay, *C:* number of packets

Algorithm 3: Collision/Congestion resolves and link reliability Initialization:

RTS_n: request to send
CTS_n: clear to send
S_n: sender nodes
R_n: receiver nodes
RTT: round trip time
Delay= 0
Max-delay: 3*RTT
q_n: queue in nodes
I: {i_1, i_2,…..i_j, i_{j+1},……. I_{n-1}, i_n} intermediate nodes
ac k_n: acknowledgement
While S_n send RTS_n msg to i_j **do**
i_j receives RTS_n by S_n
ifRTS_i receives time < RTS_{n-1} receives time **then**
broadcast (CT S_i msg to all S_n)
S_i send data by granted channel
Store(RTT, delay)←RTT,delay
End do
If q_i = full then
Packet drop
delay increase
resolve (congestion, link)
end if
resolve(congestion, link)
if delay> max delay **then**
RTT time increase
new RTT = ack_i– ack_{i-1}
Send data by(new RTT)
decrease q_i
else
RTT ←RTT
Send data by RTT value
End if

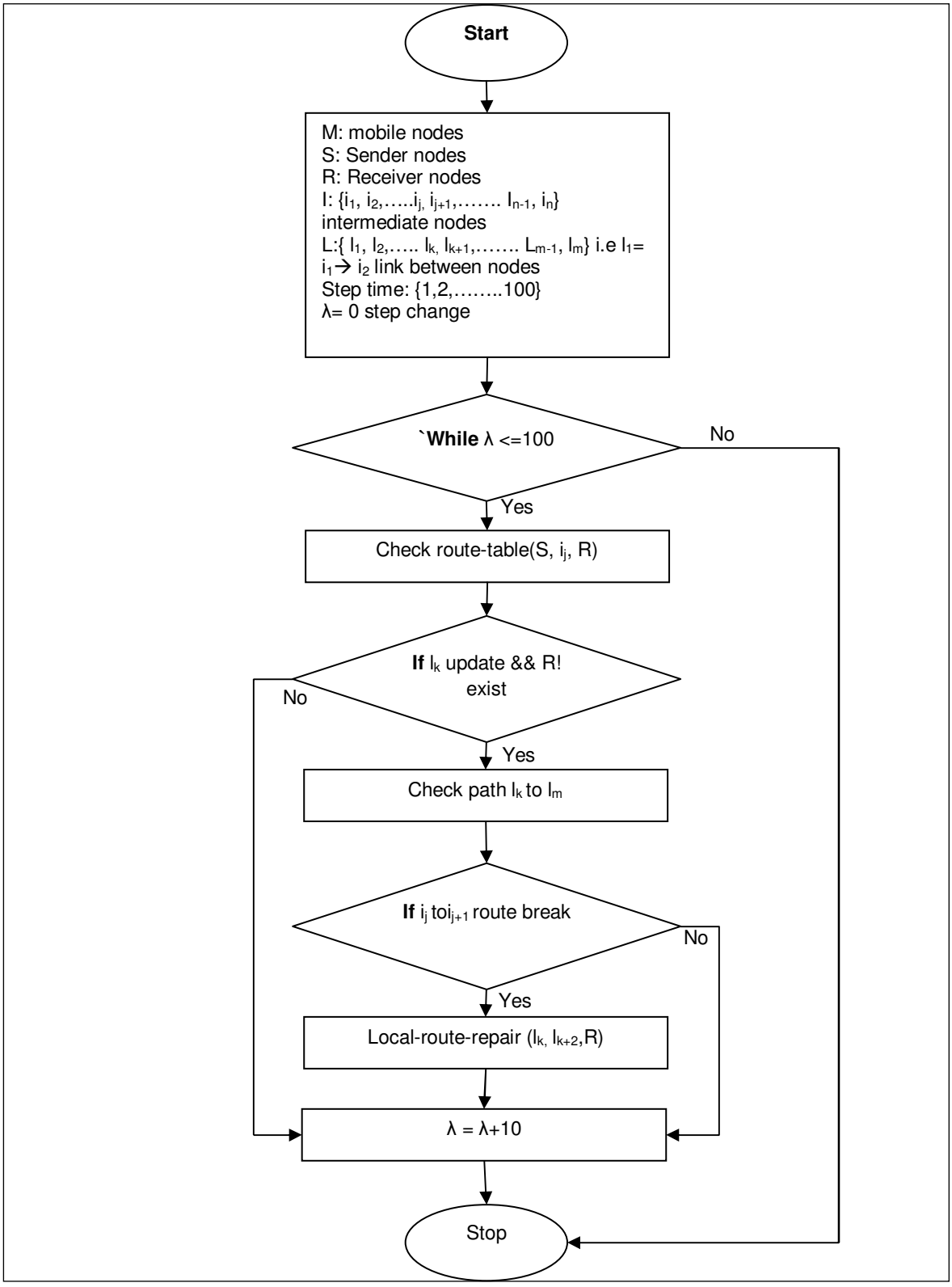

Fig. 1. Block diagram of proposed work.

IV. EXPERIMENTAL SETUP AND RESULT ANALYSIS

The simulation parameters are mentioned in Table 1 is considered for simulation of existing AODV, network in Enhanced AODV for congestion and collision resolve. The parameters are considered similar for both routing cases because similar environment in both cases gives better justification for performance parameter.

The work is done in NS-2 simulator version 2.31. The number of nodes is considered for simulation is 10, 25, 50, 75 and 100 with random movement in a simulation area of 800 m*800 m.

Table 1: Simulation Setup.

Parameters	Type
Physical Medium	Wireless Physical
Propagation Modes	Two Ray Ground
Antenna Type	Omni Directional Antenna
Simulation Area	800*800 m^2
Simulation Time	100 seconds
Frequency	914e+6 Mhz
MAC Layer	802.11
Routing Protocol	AODV, Enhanced AODV
Queue Type	Drop tail/ Priority Queue
Channel Sensing Mechanism	CTS/RTS
Traffic Type	CBR
Agent Type	TCP/UDP
Node Mobility	Random

A. Data Packet send analysis

In the simulation scenario deploy the network with the help of network simulator-2 and use the AODV routing for route establishment. The graph shows that comparative analysis of existing methodology and proposed congestion and collision prevention methodology in different network size i.e. 10, 25, 50, 75 and 100 nodes. From the result we conclude that proposed time data sending is always greater than the existing methodology because clear to send are minimized the collision and queue awareness increases the efficiency of the network meanwhile performance of the network are increased.

B. Data Packet receive analysis

Mobile ad-hoc network is a collective form of mobile nodes that established the routing in on demand bases so the network performance is vary time to time and data receiving is also effected that not depended number of intermediate mobile nodes. In this graph shows the comparative analysis of data receives by the genuine receiver at the time of existing AODV routing and proposed AODV with queuing methodology. Where the x-axis's shows number of mobile nodes and y-axis's shows the number of packets receives by the receivers, through the result conclude that proposed methodology every time receives higher data packets as compare to existing AODV routing that means our performance is better than the existing AODV routing.

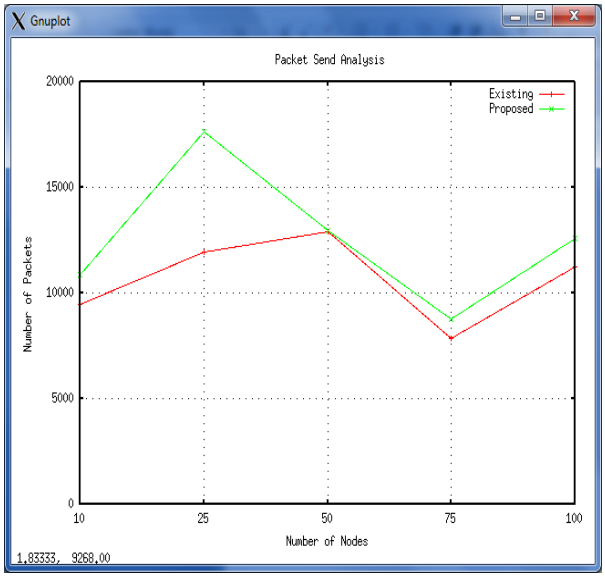

Fig. 2. Data Packet send analysis.

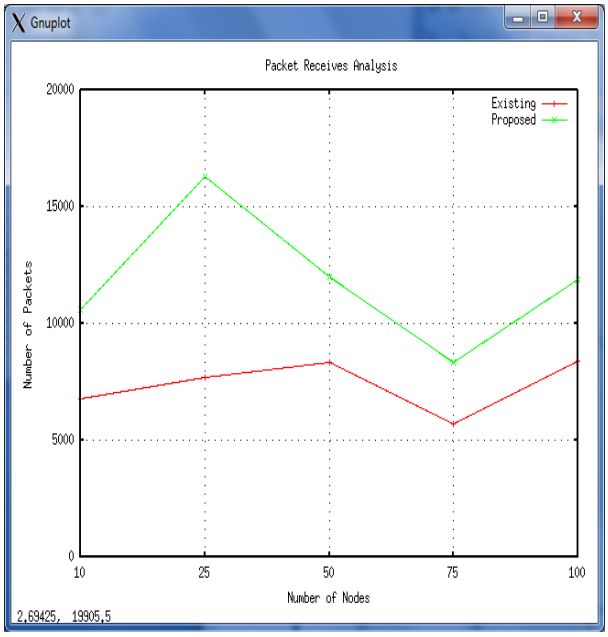

Fig. 3. Data Packet receive analysis.

C. Analysis of Data Drop

Ad-hoc network are a temporary network where routes are frequently switch, based on node mobility and channel availability which arises the problem of data dropping. During the communication data are drop from various reasons i.e. channel not available, MAC error, route error, congestion problem, collision etc. while the data dropping greater that means network performance is poor. In our proposed work, aim to minimize the data drop from the network with the help of CTS/RTS mechanism as well as rate control mechanism and simulation result are validate the proposed work. In this graph shows the data drop in different scenario and compare with existing to proposed approach, that result concludes that proposed approach case data drop is less than the existing AODV.

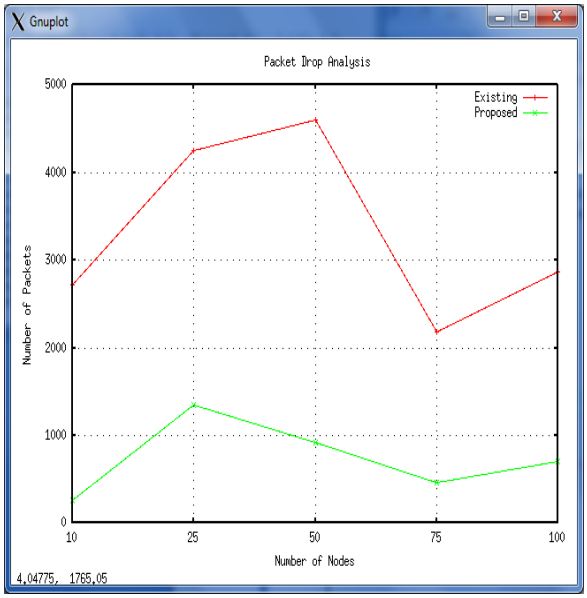

Fig. 4. Analysis of Data Drop.

D. Packet Delivery Ratio Analysis

Packet Delivery Ratio (PDR) is analyzed in the form of percentage of data receiving by the genuine receiver. While the network is reliable than PDR is higher, in this graph we compare the PDR performance in both cases at the time of 10, 25, 50, 75 and 100 nodes. That graph inference that proposed mechanism gives performance greater than the 90% and another side existing AODV gives performance lower than the 80% in every simulation case. PDR is depends on the network behaviour and it's a important parameter for measuring network performance, that matrix fluctuated or degrade while network congested of jam arises.

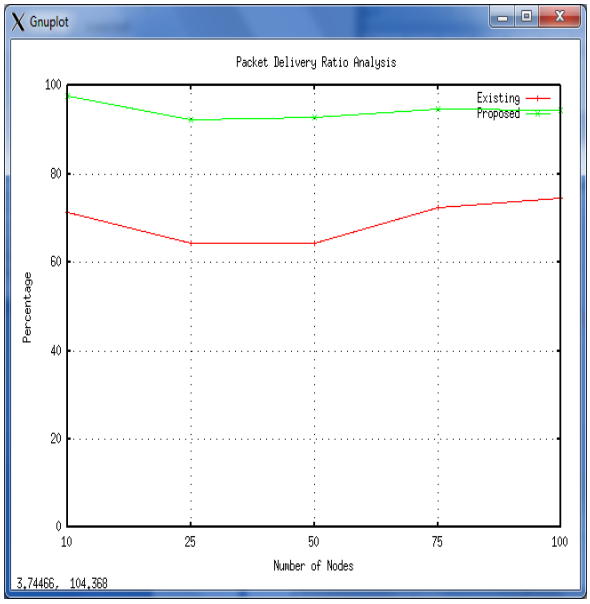

Fig. 5. Packet Delivery Ratio Analysis.

Normalized Routing Load:

Normalized Routing Load (NRL) is a ratio between numbers of data receiving packet with the numbers of route search packet, while the NRL is lower, that means network overhead is minimum and network channel is maximal utilized by data receiving, rather than routing flood. In this graph proposed approach gives lower routing overhead it means channel utilization by routing packet is lower, but the existing case that overhead is greater, causes channel utilization is greater.

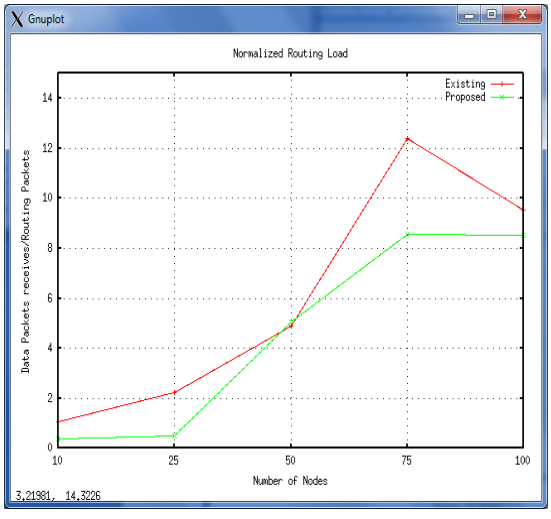

Fig. 6. Normalized Routing Load.

E. Throughput Analysis

Throughput of the network is measure kilobit per seconds, which is the data packets, receives per seconds. Throughput directly proportional to PDR, while PDR is greater than throughput is also higher. In this simulation result every time our proposed mechanism gives higher throughput as compare to existing AODV routing. Result also conclude that while the network size is small than throughput is higher because limited number of nodes share the common channel and gives better throughput, but other hand network size is increases than the sharing of communication channel by various sender in similar time is increases that degrade the performance of network throughput.

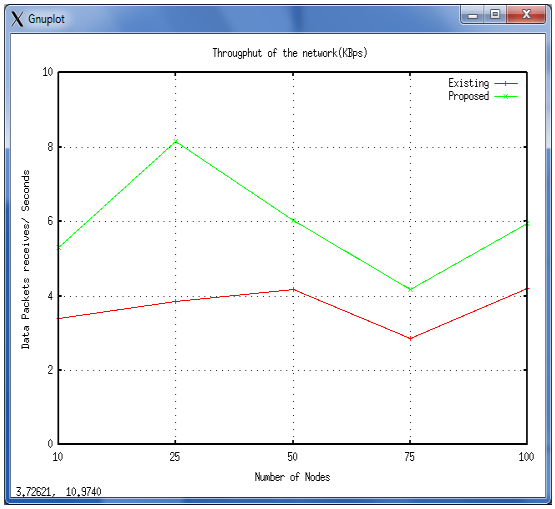

Fig. 7. Throughput Analysis.

F. Average Delay

Delay depends on round trip time or end-to-end communication time, delay is calculate by sum of link delay, queuing delay, processing delay and propagation delay and it's measure in millisecond. Network delay increase while congestion occur in the network that minimized by data rate minimization in per unit time or minimizing waiting time of packets in the intermediate queue, so in our proposed work the waiting time of queue is minimize with the help of queue aware and data rate control. That result shows the proposed approach gives better result with respect to average delay of per data packets as compare to existing AODV routing in all scenario.

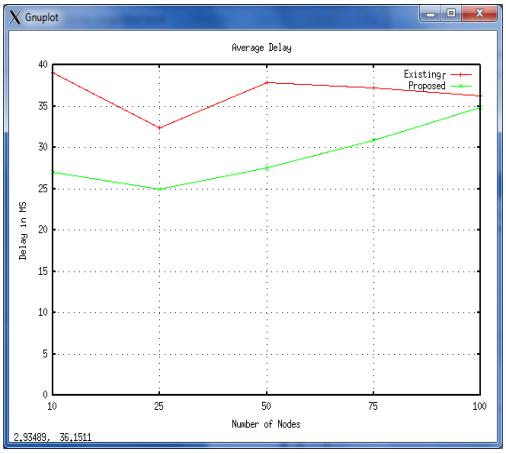

Fig. 8. Average Delay.

V. CONCLUSION

Mobile ad-hoc network face the problem of congestion because unknown number of senders simultaneously sends the data without aware the channel utilization as well as bandwidth capability so maximal data are drop by the congestion. That problem resolve with the help of rate control and clear to send and request to send methodology. In this paper describe the proposed algorithm and how the congestion is controlled. Before design proposed work we study number of research paper in the field of newer congestion control methodology and its impact under dynamic environment. Finally we take the simulation scenario in different node cases with basic behaviour of routing is AODV and get the result using network simulator ns-2.31. The result of the proposed approach minimizes the congestion which improves the PDR upto 10% and throughput about 5-6% than the existing approach. This approach also reduces the routing load and average delay which should be minimum for the transmission of the packets over network for reducing the packet loss.

VI. FUTURE SCOPE

In future work, we need to include another measuring parameters quality of service (QoS) like energy aware route selection with the combination of network bandwidth allocation calculation.

ACKNOWLEDGEMENTS

We would like to thank the unspecified referees of the paper for their valuable recommendations and constructive comments which helped us in refining the quality of the paper.

Conflict of Interest. The authors declare that there are no conflicts of interest regarding the publication of this paper.

REFERENCES

[1]. Mallapur, S. V., Patil, S. R., & Agarkhed, J. V. (2015). Multipath load balancing technique for congestion control in mobile ad hoc networks. In *2015 Fifth International Conference on Advances in Computing and Communications (ICACC)* (pp. 204-209). IEEE.

[2]. Sharma, A., & Pawar, K. (2016). CRAODV: A new approach for congestion control in mobile ad-hoc network. In *2016 Symposium on Colossal Data Analysis and Networking (CDAN)* (pp. 1-5). IEEE.

[3]. Vadivel, R., & Bhaskaran, V. M. (2017). Adaptive reliable and congestion control routing protocol for MANET. *Wireless Networks*, *23*(3), 819-829.

[4]. Suraj, R., Tapaswi, S., Yousef, S., Pattanaik, K. K., & Cole, M. (2016). Mobility prediction in mobile ad hoc networks using a lightweight genetic algorithm. *Wireless Networks*, *22*(6), 1797-1806.

[5]. Kumar, D. Ramya, I. & Roberts, M. (2010). Queue Management In Mobile Ad-hoc Networks (MANETs). IEEE/ACM International Conference on Cyber*, Physical and Social Computing Green* Com-CPS Com pp. 943-946.

[6]. Suraki, M. Y., Haghighat, A. T., & Gholipour, M. (2018). Fuzzy Cross-Layer Congestion Control in Mobile Ad Hoc Networks. *International Journal of Computer Science and Network Security*, *18*(1): 155-165.

[7]. Aimtongkham, P., Nguyen, T. G., & So-In, C. (2018). Congestion Control and Prediction Schemes Using Fuzzy Logic System with Adaptive Membership Function in Wireless Sensor Networks. *Wireless Communications and Mobile Computing*.

[8]. Arora, M., Upadhyaya S., & Kashyap, N. (2018). Flexible congestion control using fuzzy logic for Wireless Sensor Networks. *International Journal of Computer Sciences and Engineering, 6*(5), 492-499.

[9]. Kamatchi, S. (2017). Energy-balanced scheme and congestion control based on the hierarchy using wireless sensor networks. *International Journal of Scientific & Engineering Research*, *8*(5), 78-83.

[10]. Arya, K. V., & Rajput, S. S. (2014). Securing AODV routing protocol in MANET using NMAC with HBKS Technique. In *2014 International Conference on Signal Processing and Integrated Networks (SPIN)* (pp. 281-285). IEEE.

[11]. Rajput, S. S., & Trivedi, M. C. (2014). Securing zone routing protocol in MANET using authentication technique. In *2014 International Conference on Computational Intelligence and Communication Networks* (pp. 872-877). IEEE.

[12]. Azzedine Boukerche, Begumhan Turgut, Nevin Aydin, Mohammad Z. Ahmad, Ladislau Blni & Damla Turgut, (2011). Routing protocols in ad hoc networks: A survey. *Elsevier Journal of Computer Networks*, Vol. *55*, pp. 3031 3080.

[13]. Johansson, P. (1999). Routing Protocols for Mobile Ad-adhoc Networks-A Comparative Performance Analysis. *Proc. IEEE/ACM MOBICOM'99,* Aug. 15-19, pp. 195-206.

[14]. Teng, Y., Wang, H., Jing, M., & Lian, Z. (2012). A study of improved approaches for TCP congestion control in Ad Hoc networks. *Procedia Engineering*, *29*, 1270-1275.

[15]. Raikwar, P., & Gupta, H. (2018). Network Congestion Minimization using Enhanced AOMDV Routing in MANET. *International Journal of Electrical, Electronics and Computer Engineering, 7*(2): 51-56.

[16]. Meshram, S., Chavan, P., & Jawale, S. (2015). Congestion Control using Active agent in Wireless Sensor Network. *International Journal of Electrical, Electronics and Computer Engineering*, *4*(1), 120-124.

[17]. Singh, H. P., & Singh, R. (2017). Exposure And Avoidance Mechanism of Black Hole and jamming attack in mobile Ad hoc Network. *International Journal of Computer Science, Engineering and Information Technology, 7*(1), 14-22.

How to cite this article: Singh, H. P., Sheetlani, J., Salimath, N. and Gopal, K. M. (2019). Design and Implementation of an Algorithm for Mitigating the Congestion in Mobile Ad Hoc Network. *International Journal on Emerging Technologies*, **10**(3): 472–479.