A Model for Early Detection and Avoidance of Congestion in MANET

Bhawana Pillai, Deepak Singh Tomar and Ashish Kumar Khare

April 13, 2020

A Model for Early Detection and Avoidance of Congestion in MANET

Bhawana Pillai
Dept.of CSE
LNCTS,Bhopal
bhawanapillai@gmail.com

Deepak Singh Tomar
Dept. of CSE
LNCTS, Bhopal
tomar_deepak01@yahoo.in

Dr. Ashish Khare
Dept. of CSE
LNCTS, Bhopal
Prof.khare@gmail.com

***Abstract*—In a MANET, no architecture is needed to make nodes to communicate with one another. Its constant changes in network topology, as well as the wireless channel's common existence, present significant difficulties. Mobile ad hoc networks (MANETs) are entirely a mobile community by such active location & network topology structure that can be variation immediately in terms of time and application requirement. The mobile node usability factor not only opens doorfor different applications but also provides reasons for network loss. MANETs have different features that make congestion management more difficult. This paper examines a similar approach to congestion solving situations and minimizing loss of packets in wireless networks. The method of using the concept of trust aware with Queue status for bandwidth aware routingis and we have demonstrated our approach to improves system performance and reduces number of packets deposited on the network.**

Keywords*—MANETs, *Congestion control, Packet loss, Congestion controlling techniques.

I. INTRODUCTION

MANET are infrastructure-less networks in which nodes begin to move randomly at various speeds resulted in continually changing topologies of the network. This paper mainly emphasized the congestion problem & key techniques used to it [1]. Due to this changing network topology because of this evolving topology of the network, many problems are found where congestion is one of the problems. Congestion occurs while the load delivered to the network would be more than the resources. A lot of work has been performed in MANET on Congestion Control [2].

The intensive video traffic in MANET results in more transmission falls, longer delays or corresponding reduced QoS quality, probably due to congestion [3]. Its source is told about congestion in network in current congestion control methods such that either packet transmitting speed can be decelerated or an alternative route might not automatically be an ideal route. It should be mentioned that only some methods of congestion management will notify the source aroundissues of congestion as they usage TCP [4].

Congestion happens in a network or internet function as there are queues buffers for routers that carry packets during delivery. This degrades service quality and can also result in delays, loss of data. Multiple factors could cause congestion. So all of a sudden, packet sources start to arrive on 3 or 4 input lines &whollyrequirement that similar output line, queue may develop. When there is not enough space to carry them all, the package would be lost[5]. Despite can database, this problem cannot be solved, as Nagle found that which routers had infinite memory, congestion will only get worse, not better. Congestion may be triggered by sluggish processors. Its purpose of congestion reduction is to limit no. of packets inside the network below rate on that output increases theatrically. High-speed network congestion may frequently occur owing to unexpected variability in the burstiness of traffic flows. We, therefore,we need an effective technique for congestion management [5].

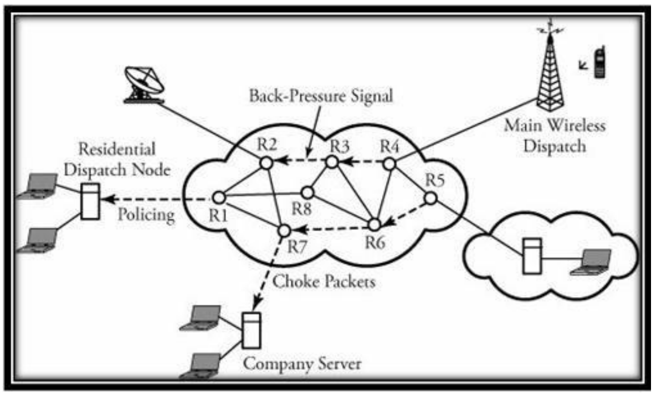

Fig.1. congestion in network

TCP congestion control system cannot control compounds of communal wireless multi-hop channel well[6]. Compared to flexibility, concealed terminal issues, low error-prone wireless links, node instability owing to low power, so on.various circumstances may contribute to packet loss. Alterations in the path, as well as the error-prone wireless network, resulted in delays in the distribution of data and losses of packets. Packet losses will therefore not be misconstrued as results of congestion. Rather than just packet loss or retransmission timeout, appropriate frameworks are needed to identify network congestion. When congestion emerges should the transport protocol reduce the sending speed? It still needs to communicate regularly via lower layers to accommodate increasing network requirements or network topology updates. [8].

II. CONGESTION IN MANET

Congestion [9] is stated in communiqué networks during that portion of the subnet comprises so many packets. Congestion occurs when network load (no. of packets transfer to network) increases network capacity (number of packets whichmay be supported in-network). Congestion outcomes in loss of packets & deterioration of bandwidth, and to restoration of congestion waste of money &energy [10]. It has typically determined on a single router on the Internet if congestion arises, while distributed MANET congestion medium will not overwhelm mobile nodes then will benefit the entire coverage area [11]. Whenever MANET RPs were not aware of the congestion, below issues arise.

- Long delay
- High overhead
- Many packet losses

Step 1. Congestion Types

Congestion may be categorized into4dissimilarforms [12]:

1) Instantaneous Congestion
2) Baseline Congestion
3) Flash Congestion
4) Spiky Delay

Step 2. Congestion Control Techniques in MANETs

Management of congestion applies to the traffic control mechanism or strategies or holds load below capacity. This is a mechanism which only after it occurred, can either stop congestion before it occurs or eliminate congestion. MANETS traffic nonlethal methods are different[13]. These would be the following methods:

CBRRT (Congestion Based Route Recovery Technique) [14]: Throughout this method, parameters like queue size, data rate, or medium access control (MAC) argument are estimated by each node. Comparison is rendered between both the anterior perimeter of these limits& node is labeled to congestion classification such as average, medium to high. The indirect nodes across the route check its congestion state while information is to be conveyed from source to destination.

CFR (Congestion Free Routing) [15]:CFR utilizes non-congested neighbors to explore a congestion-free route through network topology and initiates path discovery process. That path will become a key road from origin to destinations. The nodes which help transfer data packets regularly measure their congestion state at node frequency to preserve the congestion-free status. The main path node of the predecessor is aware of these issues and initiates to a destination an alternative route exploration method. Finally, a modern congestion-free path to the destination is found. CFR, therefore, increased the transmission ratio of packets, reduced delays from end to end or control packets.

CA-AODV (Congestion Adaptive AODV) [16]:CA-AODV is intended primarily to make sure primary route accessibility also routes & to manage the above routes. Because congestion develops between the main route of source and destination nodes at any point in time, the notified node warns about the congestion of its preceding node. The preceding node uses an alternative route to the endpoint node that is not overcrowded.

CARP (Congestion Adaptive Routing Protocol) [17]:CARP is the on-demand routing protocol for MANETs that is highly adaptable to congestion. This attempts to stop first-place congestion. The next node performing on route here alerts its accompanying node if it is likely to also be congested. CRP then utilizes alternate paths named bypass to bypass congestion producing traffic to first uncongested node on the main route.

LSRP (Link State Routing Protocol) [18]: In LSRP, it performs the congestion control algorithm when the congested node submitted the congestion control packet collected inthe source code. Origin node initially prevents packet forwarding over most of the active routes. That origin node establishes a timer for the period of initialization of this new rate. During the whole time, if the source node does not obtain an overloaded packet, if the connection quality of some of the active paths deteriorates, the source node will finally begin loading over that route at the lowest possible level.

AODV-I (Improved AODV) [19]: AODV-I is a protocol for enhanced ad-hoc on-demand vector range routing dependent on congestion-conscious mechanism or route repair. Under AODV-I, when congestion filtering is introduced to the RREQ communicationthat prevents automatic selection of busy nodes after a new route setup. That routing maintenance feature is applied to RREQ response in its place of new routing discovery when the route becomes distracted.

CBCC (Cluster Based Congestion Control) [20]:A specification that consists of scalable & distributed cluster-based systems to enable congestion management in ad-hoc networks. Our strategy's distinguishing characteristic is that it is focused on the network's self-organization via clusters. clusters track congestion in the regional context efficiently and proactively. This mechanism consists of a clustering method, traffic level estimation or correction of traffic speed. Through replacing small quantities of control packets across paths, node levels are balanced or cluster node cooperation is achieved.

ABCC (Agent-Based Congestion Control Protocol) [21]: In this strategy, mobile agents (MA) gather or disseminate information about network congestion. Thus prevent congestion in ad hoc networks, mobile agent-based AODV routing protocol is suggested. Several mobile operators are gathered in an ad hoc network that carries congestion classification for routing details or nodes.

III. LITERATURE SURVEY

Sreelakshmi and S. Sindhu [2019] Proposes Efficient Multipath AODV routing algo to decide if network node relays or is silent in the route process of discovery to transfer data packets via basis to endpoint. Visualization outcomes indicate proposed routing algo to reduce congestion to boost network performance, because not all network nodes want to contribute in route discovery of common source-destination pair[22].

T. A. Haqet al. [2019]The LBCAR (baseline) adaptive load-balanced congestion routing is a normal protocol for MANET congestion management. Even though this protocol does better than CRP or AODV, at high data levels it does not produce effective output. We have suggested a new algorithm that uses data rates higher than those of the defined threshold value for network coding. Studies have produced better outcomes at data transfer levels for the proposed technique similar to the baseline [23].

N. Akhtar et al. [2019]Recommend bandwidth-conscious routing scheme (BARS) which may avoid congestion by tracking available bandwidth capacity in network paths or obtainabledistance for caching information in lines. Until transmitting communications, the number of obtainable&expended bandwidth beside residual cache needsto work out. BARS uses the feedback mechanism to identify the source of traffic & change data rate in the routing route according to the quality of bandwidth or queue. We performed extensive simulations on Ubuntu utilizing NS 2.35 where TCL can be applied for node setup, deployment, usability & message initiation, & C language will be used to change AODV's features..findings were derived as of trace files by Perl scripts to demonstrate BARS ' superiority over introductions in forms of packet delivery ratio, amount or end-to-end latency, &possibility of congested nodes of simple & complex topologies [24].

R. A. Hamamreh and D. Khader[2019] Recommends a modern TCP congestion control solution, TCP DCM+. DCM is the prior version to estimate the available bandwidth utilizing the TCP Westwood model. point of the new protocol is to boost DCM's efficiency or reliability by using TCP Westwood’s modified algorithm to approximate the available bandwidth.Applied topology is modest wired 1-path topology. TCP DCM+ is intended to be appropriateby wired, wireless & networks. Simulationsperformed are done bythe ns-3 simulator [25].

S. Khayatbashi and A. T. Haghighat [2018]Gains in return & losses RREQ packets are transmitted in their proposed method, bearing in mind the features that are consistent with MANETs. RREQ samples are transmitted dependent on a likelihood function that takes account congestion, overlap, connectivity or factors of survival. node with far more available power and communication with less congestion and overlapping area is more likely in the discovery process to transmit the RREQ packets. Similarly to the updated route maintenance scheme (MRM) and the neighboring dynamic connectivity factor routing protocol (DCFP), it was shown that our proposed method works better in an example of normalized overhead routing and energy consumption[26].

A. Amuthan et al. [2017] Proposes Dynamic multi-stage Tandem Queue Modeling Adaptive Congestion Routing (DTQCAR) depends on average blocking threshold projections. Congestion police decision is to maintain the present level of congestion & also to send alert notices to all their neighbors for adaptive packet forwarding change. average threshold rate analysis dependson multi-stage dynamic tandem queue analysis which encourages stochastic possibility. Neighbors trying to trace congestion-free alternative route to the destination, based on elucidated stochastic factors..simulationoutcomes also confirm which somehow average DTQCAR performance in terms of packet distribution ratio was 13%, 17% or 19% under current LBCAR, DCDR & EDAPR congestion control algorithms. [27].

M. Khan et al. [2016] A current algorithm was established using the application of AODV& Cross-layer development methodology. It is alluded to as AODV (CCAODV) solution to Congestion Control. It is used to prevent the MANET connection split. Signal intensity obtained is often used as a variable for cross-layer layout. By using node signal strength, the CCAODV protocol creates a strong and secure path. The intensity of signal depends mainly on parameters like node transmission power the distance between 2 nodes. A cross-layer development method is tested or compared to the AODV routing protocol utilizing Ns 2.35 simulator [28].

N. Sharma and G. Patidar[2016] Domains hybrid congestion reduction or prevents packet loss in wireless networks. A version of Hybrid-TCP (H-TCP) and TCP Reno is preferred Revised Hybrid solution. Suggested Modified Hybrid-TCP version, to predict an effective retransmission period, recognize the level of increase parameter dependent on signal strength or noise factor. Suggested Modified Hybrid-TCP is replicated utilizing the NS2 emulator& assessed by congestion window length, packet distribution ratio, flexibility factor (node speed) throughput. [29].

T. SenthilKumaran and V. Sankaranarayanan [2011] Proposes prevention or efficient routing of congestion by MANET recognized EDAPR. EDAPR primarily generates a database of NHN (non-congested neighbors) neighbors and seeks away via an NHN node to destination. Every key path nodes measure their queue designation at the cluster level on a regular basis. That node senses congestion that will be likely to occur by using early congestion detection methodology or refers to warning messages to NHN nodes. A predecessor NHN node is alert of these problems or, by applying adaptive route function, seeks an alternative path to a direction immediately.EDAPR's efficiency was evaluated to use the Ns-2 simulator to EDAODV and EDCSCAODV. That paper shows significant improvements over routing strategies for EDAODV or EDCSCAODV [30].

IV. PROPOSED METHODOLOGY

A. Problem Description

MANET allows routing a difficult task with features such as complex neural networks or distributed networking. While the nodes acquire more data than they can forward, they need to buffer "redundant" information, so Congestion happens even though the restricted buffer space is complete and extra data (new or old) has to be discarded as a response. This results in a reduction of interaction or energy including node bandwidth and also obstructs the accuracy of effect tracking owing to packet losses. Afterload provided to network outstripsassetsthen this state leads to congestion. Congestion in network capacity could be significantly degraded and the network can fail. A network like MANET which uses shared resources and whether multiple senders are needed to compensate for link bandwidth, data rate being used by the sender will be modified in such a way that the network should not be overloaded.

B. Procedure

First initialize all parameters (that are sender, receiver, bandwidth, Minth, Maxth, buffer_size) then done route discovery by sending hello packet. When a destination has founds then data transmission has started and maintaineda routing table for all routes with trust value. With the reduction of buffer space as well as the average queue width, we can be judged on the percent of all packets discarded. Could predict congestion well during advance, we are using an initial congestion detection method ona node. advanced congestion detection method is queue reduction algoby random early diagnosis (RED) design optimization that uses the congestion status of scientific measurement well in advance within a network. A mobile node may obtain valuabledataaround oncoming traffic based on Queue status. Its incoming traffic develops bursty traffic if the meaning of Queueuerank is high. That Queue rank ' exponential growth means that incoming heavy traffic exceeds the buffer capacity of the mobile node but also that buffer overflow is inevitable.

C. Proposed Algo

Step 1. Start

Step 2. Select sender & receiver among maximum no. of nodes & also set Min threshold (Th)& MaxThvalues for queue length in eq. (1) & (2).

$$\text{Minth} = 25\%\text{buffer size} \quad (1)$$

$$\text{Maxth} = 3 * \text{Minth} \quad (2)$$

Step 3. Generate route from selected sending node to the receiving node.

Step 4. To discover neighbors uses the local bandwidth information.

Step 5. Send “hello” packet to preferred destination & begin timer to count hops & delay, each node sendsa control message to its neighbors. This process repeated up to this point and store routes, congestion status, sequence number, neighbor information, hops count and delay in the routing table.

Step 6. Calculate the available bandwidth and also trust is calculated in data transmission.

Step 7. A data rate identified by the receiving node must be comparable to or below the approved route's available bandwidth route.

Step 8. Estimate of accessible bandwidth, the weighted average of the latest estimation of accessible bandwidth is occupied.

Let

τ_{curr} =&

τ_{prev} = p&accessible bandwidth at time t=0 may be intendedin

(3)

Trust is intended as

$$T = \frac{\cdot}{f} \quad (4)$$

Step 9. Trust is intended by 4 parameters e.g. Route demand for negligence, route response misconduct, path fault misconduct or information delivery misbehavior

Step 10. Check Bandwidth aware to route discovery RREQ packet broadcast an extra message to indicate the minimum amount of bandwidth available.

Step 11. Trying to send node communicates RREQ packet together by min bandwidth cost to its neighboring nodes in the way of development path discovery.

Step 12. The neighbor maintains a table to store the history of a particular node under suspect.

Step 13. Whether queue length is below Minth, then node may be categorized as Zone I (safe zone), >Minth or <Maxth is categorized as Zone II

(probably congested zone) but is classified as Zone III (congested zone) if it is in excess ofMaxth.).

Step 14. Calculate the maximum queue length as a

Avgque=(1- wq)* Avgque + Inst_Que* wq (5)

Whereverwq, queue weight is constant parameter (wq = 0.002) &Inst_Que is instantaneous queue size.

Step 15. PresentQueue_status over average queue size specified by Eq. (6) thatreplicatesthe heaviness of incoming traffic. Created on Queue_status, a mobile node may get valuabledata around incoming traffic.

Queue status = Inst_que –Avgque (6)

Step 16. If Queue_status< minTh, incoming traffic is low & queue is in safe zone.

Step 17. If Queue_status> minTh&Inst_Que< maximum Th, incoming is common& queue is in probableforblockedarea.

Step 18. If Inst_Que> maxTh, incoming traffic is heavy & queue is in congested area.

Step 19. Blockedareas have been identified by the Queue_status and not included for future communication.

Step 20. These store all trusted paths in the table during data transmission.

Step 21. To prevent contact interference, the procedure for preservation of the path will be introduced. The system restores destroyed roads or identifies road breaks during the detection of neighbors.

Step 22. Exit

V. SIMULATION AND RESULTS

NS-2 simulator is the most efficient tool that can be used to check the performance of the MANET. The network area for this simulation is 1000m x 1000m and the number of nosed is 100.

Table I. Parameters of Simulation

Parameter	Value
Simulation time	1000 s
No. of nodes	100
Network size	1000m*1000m
Transmission range	250 m
Packet size	1024 b
Mobility model	Random waypoint
Traffic type	CBR
MAC	IEEE 802.11

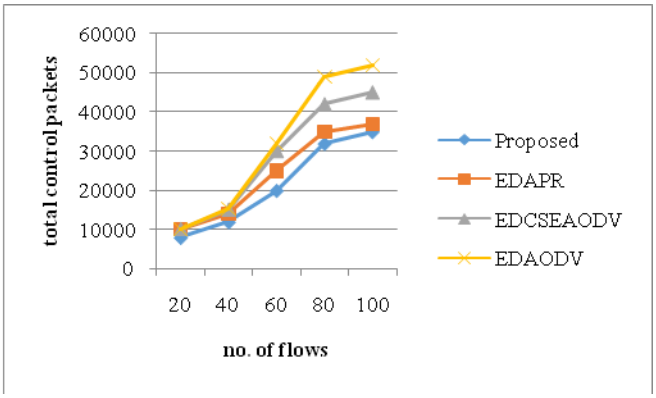

Fig. 2. Routing Overhead in the network

In fig. 2 depict the routing overhead in the network on different-different routing protocol.

Packet Delivery Ratio:proportion of no. of packets transported to corresponding destination to predict congestion well during advance.

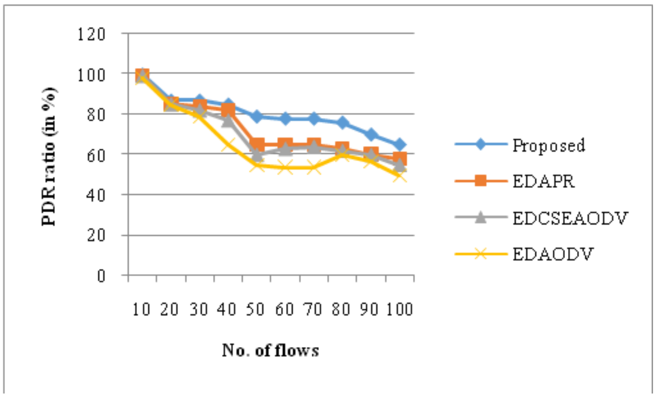

Fig. 3. Packet Delivery Ratio

Fig3presentsthe packet transmission ratio of data rate shifts in various routing environments.

Packet Loss: Full packets for failure throughout delivery.

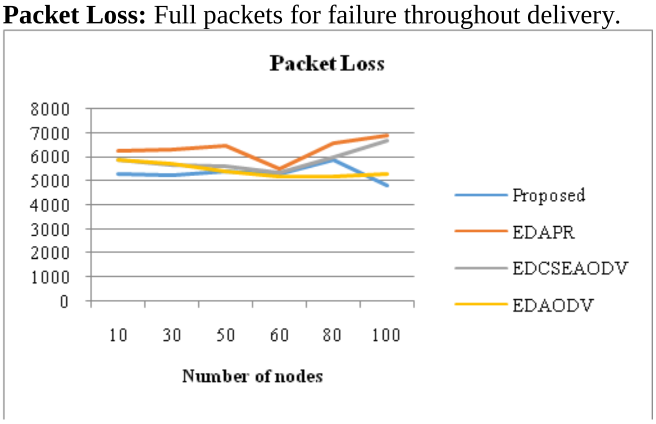

Fig. 4. Packet loss comparison

End-to-End Delay: time to deliver packet as of source to destination.

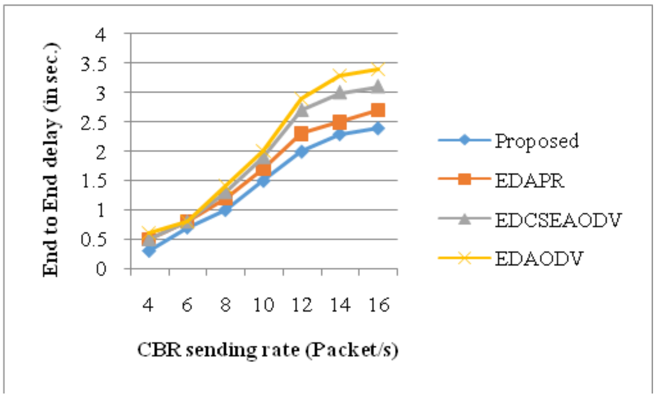

Fig. 5. End to End delay

VI. CONCLUSION

There is no hierarchical network in MANET. Nodes are free to transferabout networks anywhere, so routing is a complicated task. The responsibility for connection loss, intrusion and congestion rests to mobile routers. Congestion is among the keyaims forthe degradation of the performance of the network. After traffic in network enhance over specified capacity, blockingproceeds place. Writersintended a novel algousedgrouping of AODVby using trust aware with queue status bandwidth routing in MANET to know the congested zone for early detection. The simulation part shows the comparison of various parameters among different routing protocols.

References

[1] S. Sharma, Dr.R Agarwal, "AnalysingQos Parameters In MANETS: A Survey, Second International Conference on (RTSTMSD-15), Recent Trends in Science, Technology, Management & Social Development, pp. 82-89, 2015.

[2] Saurabh Sharma, Dipti Jindal, and Dr. Rashi Agarwal, "An approach for Congestion Control in Mobile Ad hoc Networks", International Journal of Emerging Trends in Engineering and Development, Issue 7, Vol. 3, April-May 2017, pp. 217-223.

[3] D. Kliazovich, F. Granelli, Cross-layer congestion control in ad hoc wireless networks, Ad Hoc Networks, 4 (6) (2006) 687-708.

[4] Janhavi, V., &Yuvaraju, B. N. (2014). A unified method to solve the energy depletion and congestion problem using mobile relay in manets. 2014 IEEE 7th Joint International Information Technology and Artificial Intelligence Conference, pp. 330-335.

[5] Sandeep Rana, VarunPundir, Ram Sewak Singh, Deepak Yadav, "Congestion Control in Mobile Ad-Hoc Networks", International Journal of Scientific Research Engineering & Technology (IJSRET) Volume 1, Issue5, August 2012, pp 194-198.

[6] F. Klemm, Z. Ye, S.V. Krishnamurthy, S.K. Tripathi, Improving TCP performance in ad hoc networks using signal strength based link management, Ad Hoc Networks, 3 (2) (2005) 175-191.

[7] S. Iren, P.D. Amer, P.T. Conrad, The transport layer: Tutorial and survey, ACM ComputSurv, 31 (4) (1999) 360-404.

[8] Kanellopoulos, D. (2018). Congestion control for MANETs: An overview. ICT Express,Volume 5, Issue 2, Pages 77-83.

[9] Sukhwinder Singh and Vijay Laxmi, "A Review on Techniques for Controlling the Congestion in MANET", IJCSN - International Journal of Computer Science and Network, Volume 6, Issue 3, June 2017, pp. 340-346.

[10]KaoutarOurouss, NajibNaja, and AbdellahJamali, Mobility Based Investigation of Load Balancing and Energy Efficiency of MANets Routing Protocols", 978-1-4673- 8224-3/15 IEEE.

[11]Anupama Sharma, Abhay Bansal, VinayRishiwal," Performance Enhancement in MMDSR through Information Management", 978-1-5090-3480-2/16,IEEE.

[12]Devi M. and Uthariaraj V.R., "Congestion Based Route Recovery Technique for MANET", Journal of Theoretical and Applied Information Technology (JITIT), Volume 54, No. 1, pp. 73-81.

[13]Bhupinder Kaur and Vaibhav Pandey, "Survey on Congestion Control Techniques in MANETs", International Journal of Advanced Research in Computer Science and Software Engineering 5(5), May- 2015, pp. 1441-1446.

[14]Devi M. and Uthariaraj V.R., "Congestion Based Route Recovery Technique for MANET", Journal of Theoretical and Applied Information Technology (JITIT), Volume 54, No. 1, pp. 73-81.

[15]Kumaran S., "Congestion Free Routing in Ad-hoc Network", Journal of Computer Science, pp. 971-977, 2012.

[16]Ramesh B. and Manjula D.," CA-AODV: Congestion Adaptive AODV Routing Protocol for Streaming Video in Mobile Ad Hoc Networks", I. J. Communications, Network and System Sciences (IJCNS), Volume 4, pp.285- 385, Nov. 2008.

[17]Pingale H., Rakshe A., Jain S.A., and Kokate S.R., "A Study on Congestion Aware Adaptive Routing Protocols in MANETs", International Journal of Advanced Technology & Engineering Research (IJATER), Volume 2, Issue 2, pp. 32-38, May 2012.

[18]Elamathi V. and Dhivya D.,"To Avoid Congestion by using Flooding Approach in Wireless Ad-hoc Networks", International Journal of Engineering and Science and Innovative Technology (IJESIT), Volume 2, Issue 2, pp. 475-480, March 2013.

[19]Xia L., Liu Z., Chang Y., and Sun P.,"An improved AODV Routing Protocol Based on Congestion Control and Routing Repair Mechanism", IEEE 2009, pp. 259-262.

[20]Karunakaran S. and Thangaraj P., "A Cluster-Based Congestion Control Protocol for Mobile Ad-hoc Network", International Journal of Information Technology and Knowledge Management (IJITKM), Volume 2, No. 2, pp. 471-474, Dec 2010.

[21]Sharma K.V. and Bhadauria S.S., "Mobile Agent-Based Congestion Control using AODV Routing Protocol Technique for Mobile Ad-hoc Network", International Journal of Wireless and Mobile Networks (IJWMN), Volume 2, No. 2, pp. 299-314, April 2014.

[22]H. Jhajj, R. Datla and N. Wang, "Design and Implementation of An Efficient Multipath AODV Routing Algorithm for MANETs," 2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2019, pp. 0527-0531.

[23]T. A. Haq, K. Mansoor, and S. Mahmood, "Congestion Avoidance Adaptive Routing Protocol For MANETs Using Network Coding," 2019 International Conference on Communication Technologies (ComTech), Rawalpindi, Pakistan, 2019, pp. 47-52.

[24]N. Akhtar, M. A. Khan, A. Ullah, and M. Y. Javed, "Congestion Avoidance for Smart Devices by Caching Information in MANETS and IoT," in IEEE Access, vol. 7, pp. 71459-71471, 2019.

[25]R. A. Hamamreh and D. Khader, "DCM+: a multi-purpose protocol for congestion control," 2019 IEEE 7th Palestinian International Conference on Electrical and Computer Engineering (PIECE), Gaza, Palestine, 2019, pp. 1-7.

[26]S. Khayatbashi and A. T. Haghighat, "Neighbor-based dynamic multi-factor routing algorithm in MANETs," 2018 9th Conference on Artificial Intelligence and Robotics and 2nd Asia-Pacific International Symposium, Kish Island, Iran, 2018, pp. 74-79.

[27]Amuthan, A., Sreenath, N., Boobalan, P., &Muthuraj, K. (2017). Dynamic multi-stage tandem queue modeling-based congestion adaptive routing for MANET. Alexandria Engineering Journal, Volume 57, Issue 3, pp. 1467-1473.

[28]M. Khan, DhatShital M. and SayyadAjij D., "Cross-layer design approach for Congestion Control in MANETs," 2016 IEEE International Conference on Advances in Electronics, Communication and Computer Technology (ICAECCT), Pune, 2016, pp. 464-468.

[29]N. Sharma and G. Patidar, "Improved Congestion Control Mechanism Using Modified Hybrid-TCP in Mobile Ad-Hoc Networks," 2016 Second International Conference on Computational Intelligence & Communication Technology (CICT), Ghaziabad, 2016, pp. 312-315.

[30]SenthilKumaran, T., &Sankaranarayanan, V. (2011). Early congestion detection and adaptive routing in MANET. Egyptian Informatics Journal, 12(3), 165–175.