A Novel Method for Avoiding Congestion in a Mobile Ad Hoc Network for Maintaining Service Quality in a Network

Khalid A. Alattas
kaalattas@uj.edu.sa
Department of Computer Science and Artificial Intelligence, College of Computer Science and Engineering, University of Jeddah, Jeddah, Saudi Arabia.

Summary
Under the mobile ad-hoc network system, the main reason for causing congestion is because of the limited availability of resources. On the other hand, the standardised TCP based congestion controlling mechanism is unable to control and handle the major properties associated with the shared system of wireless channels. It creates an effect on the design associated with suitable protocols along with protocol stacks through the process of determining the mechanisms of congestion on a complete basis. Moreover, when bringing a comparison with standard TCP systems the major environment associated with mobile ad hoc network is regraded to be more problematic on a complete basis. On the other hand, an agent-based mobile technique for congestion is designed and developed for the part of avoiding any mode of congestion under the ad-hoc network systems.

Keywords: Mobile Based Ad hoc Network Systems, traffic switching, Congestion, TCP, Mobile Agents.

1. Introduction

Mobile-based ad hoc network systems are determined as the combination of higher-level mobile nodes. It is responsible for the formation of a strong system of the network without the usage of ant standardised support devices or any mode of central admission which is available under the conventional network systems. On the other hand, to carry out the routing protocols and network control operations, the available nodes in the network generate application traffic along with the user [1]. Under the mobile-based ad hoc network systems, the major reason behind the cause of congestion is due to the availability of limited resources. However, the problem of congestion occurs within the shared network platforms during the point of time when the multiple users contend for
access to the same resources [2]. In this network systems, the operational aspects associate with the system of packet transmission which has a negative effect due to the problem of the collision, fading and interference. The major reason behind this aspect is relied with dynamic and radio topology [5]. Furthermore, the problem of congestion under the mobile-based ad hoc network systems lead to packet loss and higher delay in transmission.
It has led to major time consumption and energy loss for the part of enhancing a better level of operational aspects for the network systems on a complete basis. Consequently, congestion control is responsible for referring to network techniques and mechanisms which are used for the part of controlling the function of congestion [3]. It also enables in the area of controlling that in turn, implies to the loads below the range of network capacity. The major functional perspectives is relating with the process of congestion handling that can be distributed and divided into a strong system of network recovery. For example, it includes the process of restoring and the operational state of the network during the point of time [4]. Both of these aspects leads to yielding the demand exceeds the congestion avoidance and capacity. The other important functions involve the process of managing and anticipating the process of congestion such that it never occurs further. However, it is strongly stated that the routing protocols are popular as the network-based layer protocol systems which play an important role in the area of traffic switching and path determination [3].
Moreover, the methods associated with the system of routing is divided and distributed to non-adaptive and adaptive routing. However, under the system of adaptive routing method, the decisions are made for every packet [5]. In addition, the decisions for routing are based upon the topology and condition that present under the network. On the other hand, under the non-adaptive based routing method, the decisions are not made regularly. Once the destination is decided for the router, all the packets are sent to the same destination in that route. Therefore, it makes a comparison with the adaptive routing system in which the routes are not associated with any mode of topology or condition. On the other hand, during the current times, there are numerous research areas used by mobile agents [6]. Through the advanced application of the mobile agents, it enables the nodes to get connected to the dynamic based network topology systems within the required point of time [8]. It includes an important process based upon multiple aspects such as data communication applications, distributed systems, monitoring, intelligent systems, and computer languages. However, the major deployment is associating with mobile agents on a complete basis includes

Manuscript received September 5, 2021
Manuscript revised September 20, 2021
https://doi.org/10.22937/IJCSNS.2021.21.9.18

a certain mode of advantage [9]. It includes the process based on network traffic reduction, filtering and remote searching along with availing advanced mode of fault tolerance and inducing robustness.

2. Related Work

The respective section on a complete basis provides an accurate model of understanding regarding the already performed work within the same field. In this, the important application of a routing protocol uses the multi-agents for the part of detracting the congestion of network within the mobile-based ad hoc network systems [11]. Consequently, the chosen context is discussed and evaluated in the proceeding section. However, in this, the application of protocol based on dynamic routing is extended through the protocol related to mobile agents. The main reason is to make the respective application more effective under network congestion combat [13]. On the other hand, under this, the implementation of metric associated with congestion aware is strictly adopted for bringing a clear estimation about the MAC overhead, data rate along that in turn, helps to prevent the issue of buffering [15]. Moreover, to make better accuracy for the current and future perspectives, higher capacity links are used to introduce improvement under the system of channel utilisation.

However, with relation to the same, a routing protocol is associated with congestion is designed for the mobile-based ad hoc networks [7]. However, it is evaluated that CARM has designed and developed a link for the part determining the approach associate with the system of data classification. The application of the same is known as a supportive segment in the area of preventing any mode of route mismatch [10]. The respective system on a complete basis was implemented and adopted under multi rate-based network for ad hoc. Some of the important application of the same include a QoS-aware for the mobile-based ad hoc network systems interlinks with the measurement of linking quality and mobility sortilege.

The implementation of the respective software application has becoming a supportive part in the area of rending higher level of reliability along with enhancing stronger mode of communication [17]. However, it has a stronger mode of the link between the actual energy competency on a complete basis. During the absence of any mode of delay, there is a stable approach under the developed algorithms through the application of the approach based on Lyapunov Function [20]. However, TCP congestion is the major important application that strongly controls the operation in a well-defined manner on the internet.

Moreover, in this, it is strictly evaluated that mobile-based ad hoc network platforms systematically exhibits some unique properties [17]. On the other hand, in the presence of any mode of delay, the application of hop-by-hop approach is more suitable. Hence, it can be strongly stated that the process of congestion within the mobile-based ad hoc network system on a complete basis may lead to packet loss and delay in the transmission process [19]. The other operational aspects associate with the same leads to higher energy recovery and time consumption.

The protocols associate with the system of routing which is adaptive to the status of congestion under the mobile-based ad hoc network systems [21]. This is a supportive part in the area of bringing better mode of improvement within the execution of network. On the other hand, the important application of the design interlinks with the cross-layer medium, physical access control along with routing used the major application of (RSS) Received Signal Strength [22]. It is used as a base for the interaction parameters for the part of patronaging the energy. The other important segments associate with the same that include the creation of a reliable route along with enhancing the rejection of unidirectional link within the mobile-based ad hoc networking systems.

However, under this, the advanced application of newly adopted protocol application is introduced for the part of bringing a better system of improvement within the existing on demand-based routing protocols [26]. During the point of time when the network topology changes the available routing protocols constructs a protocol based on multiple routing for the part of transmitting the databases on a dynamic basis. It is performed through the process of enabling and designing the backup routes which will be more beneficial for the current and future perspectives [27]. Moreover, to make the functioning more effective (CBCC) “Cluster Based Congestion Control” is developed and designed for undertaking further functioning [29]. The beneficial part is that it includes certain distributed and scalable cluster mechanisms for the part of supporting the congestion control within the mobile-based ad hoc network control systems. The upcoming section is based on the congestion problem provides accurate mode on idea regarding the mechanism of congestion control through the application of mobile agents.

3. The Congestion Problem

Today the mobile network deployment and the successful operation is becoming an ever-increasing challenge [24]. These challenges are forcing to the existing technology to become upgraded further and provide the necessary solution for the successful development of the overall network.

The mobile network has been formed for establishing the strong, as well as an efficient network providing the communication to the respective customers [28]. This aspect is known as the main problem to be understood and necessary measures are required on this occasion. The main

problem associates with the network is congestion [26]. Congestion is the issue which may appear at any time during the transmission of the data packets from the sending end to the receiver. This problem may be taken in the form of performance degradation of the whole network due to the huge traffic load, especially on the main path of the data packets or due involvement of some other factors which cannot be ignored in any cases [29].

It is the issue of non-transformation of one or more data packets from the sender to the desired point of reception due to the low efficiency of the network. Data loss due to heavy load on the data path/huge traffic involvement, data loss due to a high level of noise in the path of the data transmission also be the reason for low data transfer and may degrade the quality of the overall performance of the network.

A. Reason for congestion problems

The reasons for the congestion problem in the mobile network which has been arranged in the form of ad hoc may be a lot. Some of them have been discussed below:

- *Restricted range of wireless transmission*

One of the major issues may be the transmission range of the data packet established in the whole network [21]. Due to the low range of the network design and based on that, the arrangement of the different nodes of the mobile network, the loss of data packet, huge load on the path for traffic will be a common problem [22]. In a particular MANET, there is a particular topology that has been used for the overall design of the network and successful transition of the data packets from the sending end to the destination without any type of harm of the data. Now the routing protocol should ensure the network data transfer capability and based on that, data transfer may be delayed [21].

This data transfer capability and the overhead of the whole network make the overall routing very difficult within the whole network [24]. So, there may be a routing error in the whole network and due to that, some of the valuable data may get lost or sometime the whole network may exhibit a high level of delay in the data transfer.

- *The fluctuation of the connectivity*

It may be the other problem of successful data transfer. In any type of MANET connection, sometimes there may be connection loss, fluctuation of the speed of data transfer and so on. This connection loss or fluctuation can be due to mediation, impeding and other problems [26]. This dispute may generate the case of data congestion.

- *Broadcasting nature*

The broadcasting nature of the overall network may be the prime factor of developing the congestion problem. The broadcasting of the whole network differs from the basic connection of the different nodes and it involves all the possible nodes in the path of straight transmission of the data [28]. All the devices in the path of the data transfer can be affected by the broadcasting technique and data may get crossed linked by any other data in the case of common medium access.

- *Cost of connection and efficiency of connectivity*

Before the successful deployment of the overall MANET in a particular place, there should be a clear and detailed calculation of the overall cost of the deployment of the whole network. This cost involves the number of nodes to be deployed, several efficient nodes, broadcasting zoned to be covered and so on [25]. Now based on the overall cost of deployment of the different nodes work that has been designed, there may be the problem of proficiency of arrangement of the network and making more fixation on the different nodes of the network [24]. Also, there may be a problem with the cost limitation for the overall arrangement. These all disputes result in low transmission efficiency as well as the congestion problem.

- *Physical security*

This is one of the major problems in producing a congestion problem. Most MANET networks are associated with the physical security problem and due to that, data transfer may face a lot of problems and ultimately it may transfer low amount or wrong data to the destination port [23]. This security may be due to the security of the layer of the nodes. Employing a low level of security will result in a significant level of loss of data, routing problems and most importantly the congestion in the network path.

- *Node mobility*

Node mobility may be another reason for the creation of congestion in the network. This node mobility may be due to the variability in power consumption, the technique of hopping used in the overall network [22]. In a MANET, there are many nodes deployed in different places. Now all the nodes may not consume the same power from the installed battery and so their mobility may be different. To the different mobility rate, some of the nodes may get overloaded and this will result in congestion.

B. Impact of congestion

The overall impact of congestion can be broadly taken into the fact of loss of data packets, a long delay in the overall transmission of the data, and some other issues. Overhead may be another impact of the factor of occurrence of the congestion problem.

Under this, it can be strongly stated that the network consisting of the shared resources enhance the stronger mode of competition in the area of determining the actual bandwidth of the links [24]. However, for the part of preventing any mode of overloading factor in the network, the most important part includes the process of adjusting the available data [23]. On the other hand, the packets which arrive at the router which cannot forward the information

are dropped. On the other hand, the higher and excessive mode of packets which arrives at the actual bottleneck of the network will enhance the strong system of packet drops on a complete basis.

However, the respective packet drops which are being already dropped may have already travelled longer way within the network [22]. The respective process on a complete basis has led to higher-level consumption of energy. Consequently, the packets which are already lost may trigger a larger mode of retransmissions. It is the accurate sign that a larger number of packets can be easily sent within the network in a limited point of time [21]. Under this, it is understandable that several congestions associated with the network may completely deteriorate network throughput. In this, the most important segment is based on developing suitable congestion control systems for the part of preventing any mode of discrepancies in the future [29]. On the other hand, the negative part of the same may lead to network collapse.

However, it is evaluated that congestion is regarded as the major reason behind causing packet loss under MANET's. It on a complete basis may include a reduction in packet loss, any mode of failure and mobility within the protocol of adaptive routing under the available network layer [28]. On the other hand, the process of congestion within the non-adaptive mode of routing within the MANET's leads to the above-demonstrated issues:

- The first and foremost part is associated with a longer delay. Moreover, it can be stated that it takes the longest point of time for detecting congestion through the application of procedure associate with congestion control [27]. Under this condition, it will be more beneficial to use the most reliable route.
- The second major complication is associated with a higher level of overload. During the point of time when the new route is detected, it takes a longer time for communicating and processing. If the routing associated with multipath is applied through the application of other alternative routes [26]. It will require larger efforts in the area of maintaining multipath.

The above-demonstrated segment in the paper provides accurate information regarding the controlling measures required to be adopted for the part of determining congestion under the ad hoc network system [29]. It includes the application of the path which is being selected already.

However, through the application of the network with the shared resources under which the multiple senders compete for the link bandwidth as mentioned earlier the most important part is associated with the process of adjusting the data. It plays an important role in the area of preventing any mode of network overload for current and future perspectives. Moreover, under the multi-rate based ad hoc network systems the complete route associated with the same is limited through certain constituent links [31]. The above-demonstrated figure provides accurate information regarding the application of numerous data rates through links. For example, A -> B -> C -> D -> F -> H, it is regarded as the mismatched routes which are highly data rated.

During the point of time when the larger scale traffics is transmitted through the application of the route, the major benefits having consisted of the multi rated links are highly compromised [29]. There is a higher-level potential for congestion through the application of any node that heads the links through the application of a slower rate of data when bringing a comparison with the previous links. Due to the availability of higher data rate the nodes which forward the traffic to lower data rate node, there is a higher chance of having buffering in the data paths. However, it can be determined that routes are the most important segment in the area of combatting congestion.

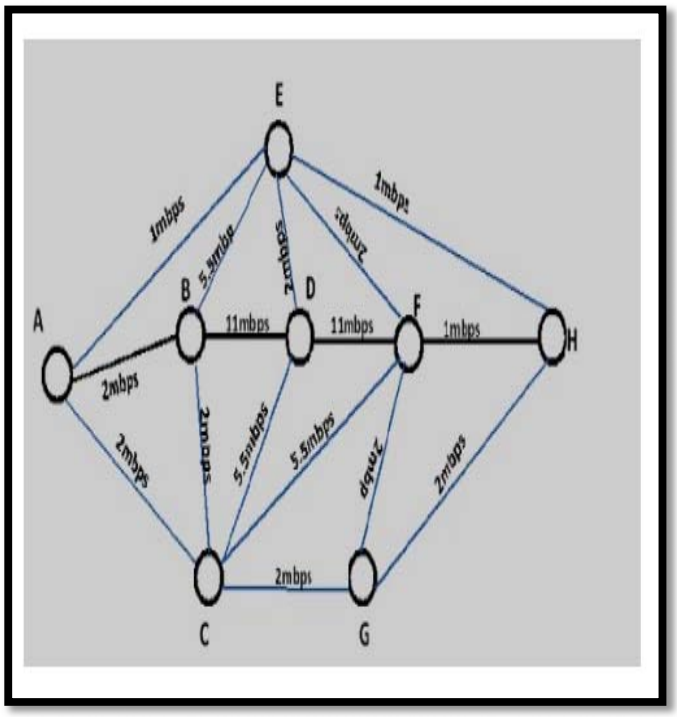

Figure 1: An example for 802.11b multi-rated Ad hoc network (Source: [28])

4. Proposed Work

The process of congestion present under the wireless network is different when bringing a comparison with the wired networks. Some of the major causes of congestion are demonstrated below:

- The major throughputs present within the nodes get reduced on a complete basis. The main reason is that the available nodes that are present within the complete range of other attempts to transmit the data on a direct basis [27]. On the other hand, it results in certain complications for current and future perspectives.
- The buffering used for the part of holding the packets are transmitted which overflows within the available node. It may also result in certain loses.

On the other hand, the discovery process of the routes under the MANET's protocols may not bring any mode of consideration for the status based on Queues. It happens during the point of time before routing the nodes to their actual destination. The negative part is that it results in packet drops and higher delays for the advanced traffic systems [15]. The other important part includes any mode of failure to conduct the process of transmission within the already queued traffic sources. However, in this, the major performance associated with the mobile-based ad hoc network system is influenced through congestion problems [19]. On the other hand, the schemes associate with the congestion may include a strong mode of routing algorithm along with the scheme for determining the control of the flow.

Moreover, according to the research conducted earlier, the problems associate with flow control and routing are not evaluated. For the part of achieving advanced performance along with better control for congestion, the most important part is to consider both flow control and routing equally [22]. The router shifts to the parameters set to get a reasonable trade-off between queuing delay and loss rate. If the factory fixes the number of flows a router is handling is fixe. An ideal router will change its queuing configuration according to the increase and decrease in the load. The above problem can be segregated into three parts:

- An active flow should be understanding by the predefined mechanism.
- An option should be provided to drop rate based and target queue length on the flow count.
- There should be a mechanism to target on FIFO queue.

In wireless network evaluation of congestion control mechanism is performed on various network parameters like dynamic queue length and an increasing number of senders is done through simulation [26].

- *Performance Matrices*

Different performance metrics and statistics are used to analyse a MANET routing protocol. This section need to talk about the matrices need to evaluate the performance are:

- *End-to-end delay*

The total amount of delay occurs in the entire network in every hop while moving towards the destination is termed as end-to-end delay. The general definition is that the time taken to transfer a package in the network is the called end-to-end delay [28]. The week signal strength in each node and tearing of certain connection is responsible for the certain type of delay in the MANETs. The end-to-end delay on a given network could determine the consistency of a routing protocol.

- *Network Throughput*

It is defining as the process data is a transfer from the sender to destination in a communication network. In more details, it can be explained as the rate at which the message is sender to the receiver is called network throughput.

- *Packet delivery ratio*

It is defining to find out the accuracy and efficiency of the MANET network protocol. It is the last performance metric to judge the network strength [29]. It determines the network strength by estimating the rate of losing packet. The packet delivery ratio is also high as network throughput in probability.

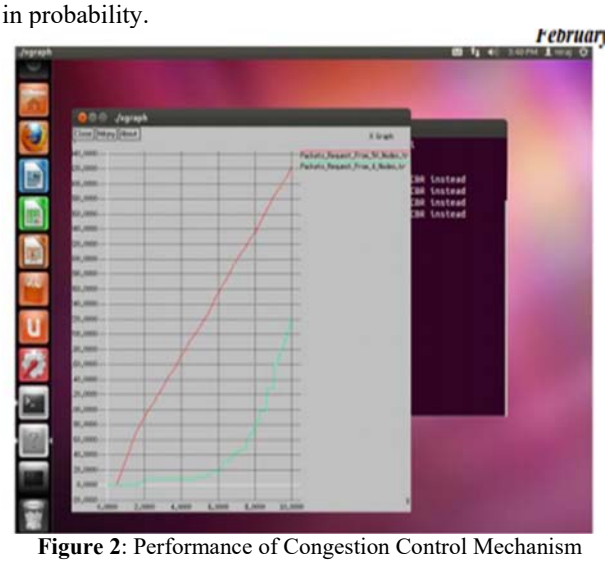

Figure 2: Performance of Congestion Control Mechanism (Source: [29])

The above examples depict that the number of a packet per sender is 70 packet and 4.1 is the maximum permitted sender. Therefore 280 is the maximum number of packet limit that can be queued in the buffer [21]. The above figure shows the depicted results graphically. The red represents the 50 senders is sending the buffering request which in hand implemented to enhance the maximum size approximately to 420 packets. The above scenario is seen because of no application of the congestion control on the network. The 4 sender gives a buffer in green line which is

approaching the maximum size of 220 packets or less. It is less than the buffer capacity of the queue. The buffer capacity of the queue here is 280 packets [27]. The diagram shows the method to target queue length, count active flow and fall rate to impose the target on the First in the first out queue.

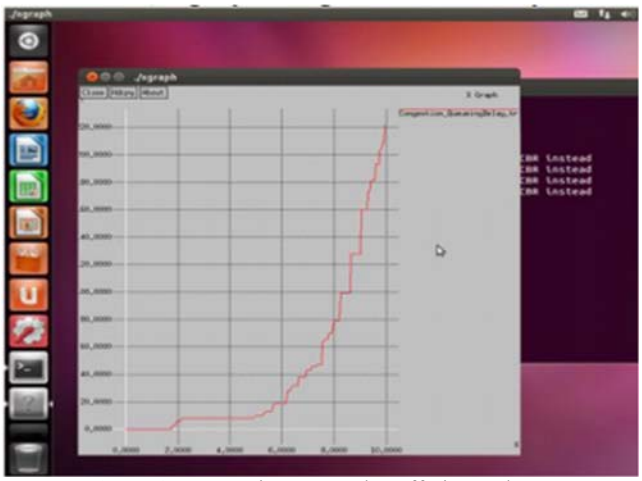

Figure 3: Congestion Network Buffering Delay (Source: [27])

The above diagram shows the congested network by buffering delay. Maximum 220 packets go into queuing delay. It happens was no congestion control is applied. Above case arises as soon as 50 senders are allowed to send the packets [28]. The problem arises in the presence of the fix buffering capacity of the queue. The rest 220 packets can set on the queue. Buffering delay also shows the congested delay.

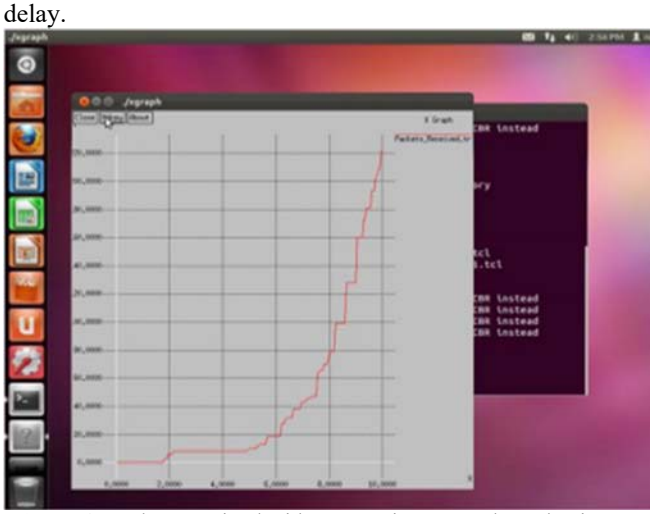

Figure 4: Packet Received with Congestion Control Mechanism (Source: [29])

The above image shows the graph of all active sender sending the number of the package. The above graph has no package loss. The number of package request in total is 220 and packets received is equal to the package request.

However, for the part of ensuring competitiveness and consistency in the future, an agent-based architecture for congestion control is designed and developed. Under the respective architecture, all the major nodes associated with the information and mobile regarding the system based on network congestion is distributed and collected through mobile agents. In this, every node has a routing table which stores the information of the routes for each destination [28]. MA begins from each node and at the same point of time, it moves towards adjacent nodes. On the other hand, MA on a complete basis update routing table for each node where they visit. Consequently, the application of agent congestion routing is explained through the above-developed figure.

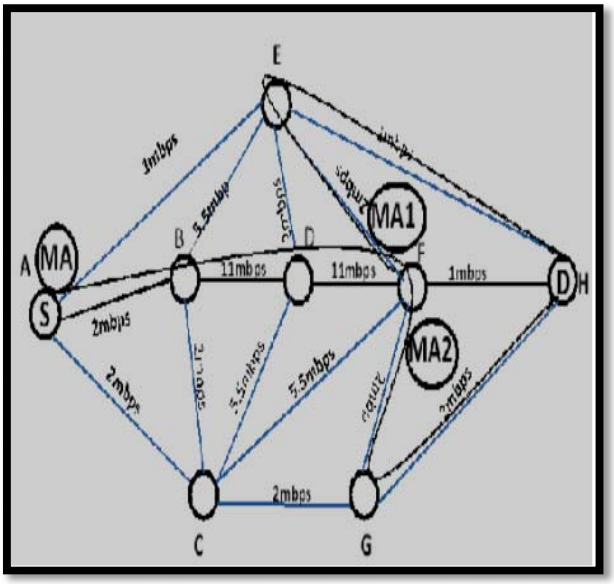

Figure 5: Congestion Control Process (Source: [28])

Under the multi rated ad hoc networking systems the data routes may lead to certain routes which consist of numerous links having differentiated data rates. If the lower-level data rated links follow the higher-level data rated links the available packets will automatically build-up at the nodes which heads towards the lower-level data rated links. However, the operational aspects associate with the same may lead to a higher level of delays and buffering [29]. On the other hand, the nodes are strongly classified into numerous categories. It completely depends on the condition where the traffic belongs to the background. The next major process includes measuring the effectiveness through checking the buffering status [27]. Through the respective classification, the node having intensive delay is regarded to be the priority factor such that more traffic can be received through enhancing lower priority nodes. On the other hand, the congestion level associated with every node

is updated regularly. It is made during the point of time when there is a traffic type change along with the point of time when it is propagated to the neighbours.
Some of the major steps which are applied for the part of evaluating the mechanism of congestion control is determined below:
Step 1: The source is indicated through S. It is used for the part of checking the available hop neighbour. For example, A - E, A - B, A-C.
Step 2: The path is selected by the mobile agents for the part of moving towards the actual destination D from the available source node which is S [26].
Step 3: Now the actual occurrence of congestion is determined by the mobile agents F-H nodes. It is because of the nodes having a higher level of a data rate which is from S - B - DF. It forwards the complete traffic to lower-level data rate nodes which is F.
Step 4: The next step includes the process of checking the actual number of the available hop neighbours E or G along with cloning the mobile agents to the respective neighbour which is MA1 & MA2.
Step 5: In this, MA1 moves to the actual destination which is D along with node H in the form of hop-by-hop manner within the path P1 along with MA2 under P2. Then MA1 calculates the rate of data within the path P1. At the same point of time, MA2 will calculate the rate of data associated with P2 [24].

P1 data rate = Data size / Channel delay (E node)

P2 data rate = Data size / Channel delay (G node)

Step 6: The path is selected by the sources through the application of higher data rates associated with P2 (S-B-D-F-G-H) along with the process of sending the data through the corresponding path.

5. Conclusion

The total storage and number of active flows controlled the congestion loss in the network bust. The thesis successfully stated that the wireless network had spread like cancer because of the easy installation, cheap cost, flexible infrastructure and sensing application. However, the wireless data had to contain huge data with utmost care [24]. The particular part of the subnet became overloaded it then results in the congestion. It occurred due to the speed difference in the receiving package and forwarding package. The reason for which one of the above two can only happened at a time. The general definition was that the time taken to transfer a package in the network, called end-to-end delay. During the point of time when the network topology changed the available routing protocols constructs a protocol based on multiple routing for the part of transmitting the databases on a dynamic performed through the process of enabling and designing the backup routes which was more beneficial for the current and future perspectives [25]. The week signal strength in each node and tearing of certain connection was responsible for the certain type of delay in the MANETs.
The above thesis had depicted a few of the congestion control techniques. The thesis had stated a simple counting algorithm. The algorithm used one bit of state per-flow from the instructions per sender. It was performed through the process of enabling and designing the backup routes which was more beneficial for the current and future perspectives [26]. Moreover, to make the functioning more effective (CBCC) “Cluster Based Congestion Control” was developed and designed for undertaking further functioning. The algorithm kept the count of congestion feedback by sending feedback. It could be done by varying the number of packets per sender which was in proportion to the queue length. it can be strongly stated that the network consisting of the shared resources enhance the stronger mode of competition in the area of determining the actual bandwidth of the links [28]. However, for the part of preventing any mode of overloading factor in the network, the most important part included the process of adjusting the available data. This helped to remove the congestion after the congestion has occurred. The report had only applied on of the technique here.

References

[1] Agrawal, R., Sharma, P. and Malviya, V., 2017. A novel method for queue management using the RED technique in a mobile ad hoc network. In *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)* (pp. 175-180). IEEE.
[2] Alameri, I.A., Onaizah, A.N. and Koondhar, I.A., 2020. Optimized image processing and clustering to mitigate security threats in mobile ad hoc network. *Telkomnika*, *18*(1).
[3] Alnumay, W., Ghosh, U. and Chatterjee, P., 2019. A trust-based predictive model for mobile ad hoc network in Internet of Things. *Sensors*, *19*(6), p.1467.
[4] Aouiz, A.A., Hacene, S.B. and Lorenz, P., 2019. Channel busyness based multipath load balancing routing protocol for ad hoc networks. *IEEE Network*, *33*(5), pp.118-125.
[5] Fan, X., Cai, W. and Lin, J., 2017. A survey of routing protocols for highly dynamic mobile ad hoc networks. In *2017 IEEE 17th International Conference on Communication Technology (ICCT)* (pp. 1412-1417). IEEE.
[6] Hamdi, M.M., Audah, L., Rashid, S.A., Mohammed, A.H., Alani, S. and Mustafa, A.S., 2020. A review of applications, characteristics and challenges in vehicular ad hoc networks (VANETs). In *2020 International*

Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA) (pp. 1-7). IEEE.

[7] Kannan, K. and Devaraju, M., 2017. Congestion Avoidance in Mobile Ad-Hoc Network Through Decision Matrix Analysis Based Priority Routing for Quality of Services. *Journal of Computational and Theoretical Nanoscience*, *14*(11), pp.5413-5417.

[8] Kokkonis, G., Gounopoulos, E., Tsiamitros, D., Stimoniaris, D. and Fragulis, G.F., 2020. Designing interconnected haptic interfaces and actuators for teleoperations in mobile ad hoc networks. *International Journal of Entertainment Technology and Management*, *1*(1), pp.43-63.

[9] Kumar, A., Varadarajan, V., Kumar, A., Dadheech, P., Choudhary, S.S., Kumar, V.A., Panigrahi, B.K. and Veluvolu, K.C., 2020. Black hole attack detection in vehicular ad-hoc network using secure AODV routing algorithm. *Microprocessors and Microsystems*, p.103352.

[10] Kushwah, R., Tapaswi, S. and Kumar, A., 2019. A detailed study on Internet connectivity schemes for mobile ad hoc network. *Wireless Personal Communications*, *104*(4), pp.1433-1471.

[11] Lee, K.E., Park, J.G. and Yoo, S.J., 2021. Intelligent Cognitive Radio Ad-Hoc Network: Planning, Learning and Dynamic Configuration. Electronics, 10(3), p.254.

[12] Majeed, J.H., Habeeb, N.A. and Al-Azzawi, W.K., 2021. Performance investigations of internet protocol versions for mobile Ad-hoc network based on qualnet simulator. *Indonesian Journal of Electrical Engineering and Computer Science*, *21*(1), pp.497-504.

[13] Mikarić, B., Rančić, D. and Ilić, S., 2020. Routing protocols in Mobile Ad-hoc Networks. *Przegląd Elektrotechniczny*, *96*.

[14] Moqimi, E., Najafi, A. and Ajami, M., 2020. An Enhanced Dynamic Source Routing Algorithm for the Mobile Ad-Hoc Network using Reinforcement learning under the COVID-19 Conditions.

[15] Mukherjee, A., Keshary, V., Pandya, K., Dey, N. and Satapathy, S.C., 2018. Flying ad hoc networks: A comprehensive survey. *Information and decision sciences*, pp.569-580.

[16] Muralidhar K, Madhavi K. Setting Up Ad Hoc Computing as a Service in Mobile Ad Hoc Cloud Computing Environment. International Journal of Interdisciplinary Telecommunications and Networking (IJITN). 2021;13(1):1-2.

[17] Qiu, T., Chen, N., Li, K., Qiao, D. and Fu, Z., 2017. Heterogeneous ad hoc networks: Architectures, advances and challenges. Ad Hoc Networks, 55, pp.143-152.

[18] Rasheed, A., Gillani, S., Ajmal, S. and Qayyum, A., 2017. Vehicular ad hoc network (VANET): A survey, challenges, and applications. In *Vehicular Ad-Hoc Networks for Smart Cities* (pp. 39-51). Springer, Singapore.

[19] Rath, M., Pattanayak, B.K. and Pati, B., 2017. Energetic routing protocol design for real-time transmission in mobile ad hoc network. In *Computing and Network Sustainability* (pp. 187-199). Springer, Singapore.

[20] Rath, M., Rout, U.P., Pujari, N., Nanda, S.K. and Panda, S.P., 2017. Congestion control mechanism for real time traffic in mobile adhoc networks. In *Computer communication, networking and internet security* (pp. 149-156). Springer, Singapore.

[21] Regin, R. and Menakadevi, T., 2019. Dynamic clustering mechanism to avoid congestion control in vehicular ad hoc networks based on node density. *Wireless Personal Communications*, *107*(4), pp.1911-1931.

[22] Regin, R. and Menakadevi, T., 2020. A novel clustering technique to stop congestion occur vehicular ad-hoc networks using node density based on received signal strength. *Peer-to-Peer Networking and Applications*, pp.1-11.

[23] Sahnoun, A., Habbani, A. and El Abbadi, J., 2017. EEPR-OLSR: an energy efficient and path reliability protocol for proactive mobile Ad-hoc network routing. *International Journal of Communication Networks and Information Security*, *9*(1), p.22.

[24] Sarkar, D., Choudhury, S. and Majumder, A., 2018. Enhanced-Ant-AODV for optimal route selection in mobile ad-hoc network. *Journal of King Saud University-Computer and Information Sciences*.

[25] Shafigh, A.S., Veiga, B.L. and Glisic, S., 2018. Cross layer scheme for quality of service aware multicast routing in mobile ad hoc networks. *Wireless Networks*, *24*(1), pp.329-343.

[26] Shantaf, A.M., Kurnaz, S. and Mohammed, A.H., 2020. Performance Evaluation of Three Mobile Ad-hoc Network Routing Protocols in Different Environments. In *2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)* (pp. 1-6). IEEE.

[27] Sharma, V.K. and Kumar, M., 2017. Adaptive congestion control scheme in mobile ad-hoc networks. *Peer-to-Peer Networking and Applications*, *10*(3), pp.633-657.

[28] Srivastava, A., Gupta, S.K., Najim, M., Sahu, N., Aggarwal, G. and Mazumdar, B.D., 2021. DSSAM: digitally signed secure acknowledgement method for mobile ad hoc network. *EURASIP Journal on Wireless Communications and Networking*, *2021*(1), pp.1-29.

[29] Sundar, R. and Kathirvel, A., 2020. Aggressively delivered mechanism over variable-length density using a simulated annealing algorithm in mobile ad hoc network. *Transactions on Emerging Telecommunications Technologies*, *31*(12), p.e3863.

[30] Thiagarajan, R., Babu, M.R. and Moorthi, M., 2020. Quality of Service based Ad hoc On-demand Multipath Distance Vector Routing protocol in mobile ad hoc network. *Journal of Ambient Intelligence and Humanized Computing*, pp.1-9.
[31] Veeresh, P., Sam, R.P. and Bin, C.S., 2019. Reliable fault tolerance system for service composition in mobile Ad Hoc network. *International Journal of Electrical & Computer Engineering (2088-8708)*, *9*(4).
[32] Zhang, D.G., Cui, Y.Y. and Zhang, T., 2019. New quantum-genetic based OLSR protocol (QG-OLSR) for Mobile Ad hoc Network. *Applied Soft Computing*, *80*, pp.285-296.

KHALID A. ALATTAS received the B.Sc. degree in computer science from King Abdulaziz University, Saudi Arabia, the M.Sc. degree in telecommunication networks from New York University, NY, USA, and the M.Sc. and Ph.D. degrees in computer science from the University of Louisiana at Lafayette, USA. He is currently an Assistant Professor at the College of Computer Science and Engineering, University of Jeddah, Saudi Arabia. His research interests include networks, machine learning, data analytics, robotics, and unmanned vehicles. He serves as a reviewer for many international journals.