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Increasing the Performance of Reactive Routing Protocol using the Load Balancing and Congestion Control Mechanism in MANET

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Abstract: Nowadays, routing and the improvement of reliability along with the load balancing and congestion control are the most important and challenging concepts in ad-hoc networks. However, there are some constraints in the bandwidth and the communication range due to the different utility of routing in the Mobile Ad Hoc Network (MANET). These restrictions, in addition to the dynamic network topology, are causing more complexity of routing and data transmission. These problems make the use of conventional methods inefficient, especially in the congestion and traffic control. So, there is a need to propose new solutions for these kinds of networks. This study has used the multipath routing based on the original protocol Ad-Hoc On-Demand Multipath Distance Vector (AOMDV). It proposes an appropriate protocol for the congestion control and balances the favorable loads in the routes. The proposed algorithm is based on different parameters that prepare the fittest multi-paths based on the most efficient routes from the source to the destination, and then it makes a proper traffic distribution pattern in the middle routes based on the congestion analysis of the routes. Simulation results with NS2 shows improvements in the throughput, packet delivery ratio and delay in comparison to the Load Balancing Maximal Minimal Nodal Residual Energy (LBMMRE), Multipath Load Balancing Technique for Congestion Control (MLBCC), and AOMDV routing protocols.

Keywords: MANET, AOMDV, Reactive routing, Congestion control, Load balancing

1. Introduction

The MANET is an autonomous system consisting of mobile nodes that are connected to each other wirelessly and each node acts as either an end node or a router for other nodes. MANETs have advantages over traditional wireless networks, which include the simplicity and speed of development and are not dependent on any fixed structure [1, 2 Due to the need for no specific infrastructures, these networks have received much attention from researchers in various domains, including military applications, environmental monitoring using wireless sensor networks, medical and healthcare, vehicular ad hoc communications, rescue operations, road safety, personal and household networks, official applications such as meeting and conferences, educational applications, and so on. In contrast, these networks have some restrictions, including the limited bandwidth in communication on the wireless channel, the power of the node's battery, the limited radio range, the lack of a central controller, the dynamic network topology as well as multi-hop paths between each pair of the source and the destination nodes. The lack of a central controller to enforce control in the network has caused a decentralized and fully distributed network traffic management based on the collaboration of all network nodes [3]. Since MANET has a limited bandwidth and communication range compared to other wireless networks, routing is one of the most challenging aspects of MANET. The function of routing algorithms used in these networks should be distributed, loop-free and on-demand. Supporting for bidirectional communication can also increase the efficiency of the routing protocol. On the other hand, because of the energy constraints of equipment used in MANETs, the routing should be done in such a way that the energy consumption is minimized. In cases where the paths are cut off for different reasons, the ability to explore multiple paths between nodes reduces the scope of reactions to congestion which no longer requires the discovery of a new path. The low bandwidth of devices in MANET means there will be a high probability of congestion in the network. Also, failure to use load balancing algorithms will result in a sharp increase in latency and such factors. So, these constraints make it necessary to provide new approaches, particularly about traffic control and congestion [4, 5]. In recent years, several routing protocols for MANET have been proposed with an emphasis on load retention, including the AODV protocol [6] and DSR [6], which use the number of hops as a route selection method.

The idea to reduce the negative impacts of congestion has led to attracting the interest to study load balancing routing protocols in order to distribute and balance the load and congestion through the appropriate route in the routing stage. However, no method has been proposed for optimal distributing and load balancing based on analysis of current congestion conditions in network paths, which is a limitation. The main objective of load balancing protocols is to direct the load traffic from the routes and nodes that are not currently in congestion and can reduce the negative effects of congestion on the network, by increasing the packet loss rate, end-to-end delay, the energy consumption, and ultimately by reducing the throughput of the network. Accordingly, the purpose is to provide an efficient method for controlling the traffic optimization in MANET by studying the nature of traffic load in MANET, packet delays, and its dependence on the volume and traffic balancing in order to improve the network performance against the traffic generated in the most optimal modes possible. The proposed scheme first uses multi-path routing based on the AOMDV [6] protocol and according to the proposed algorithm

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identifies the most efficient route to the destination. Then, it tries to distribute and balance the network load by analyzing the congestion of the buffer of nodes in these paths.

The rest of the paper is organized as follows: Section two presents a brief overview of the research in the field of congestion control, distribution, and load balancing. In the third section, the proposed method is presented. The fourth section provides models of the network and the simulation of the proposed method with the results. Finally, section five outlines the conclusions and the future suggested areas of research.

2. Related Works

MANET routing protocols can be divided into three categories: Proactive, Reactive, and Hybrid routing protocols the main difference of which is in the stored information and how to transmit this information [6, 7]. The purpose of the MANET routing protocols is to select the optimal routes that have the lowest latency and packet loss that will cause congestion in one or more paths. Obviously, if the routing protocol fails to manage the correct load distribution in specified paths, congestion will certainly occur which will have a lot of negative effects on the network and will reduce the network performance. Therefore, several routing protocols have proposed to distribute the load fairly. Previous related works can be categorized into two areas of efficient routing or congestion management which have not been simultaneously considered in these studies. Marina1 et al. [8] have developed the function of the AOMDV protocol based on the AODV-base protocol that is a reactive protocol. However, this approach does not support the congestion control using the connections on the network. M. Lee et al. [9] proposed a method based on spatial tree formation when discovering the path and attempted to transmit it efficiently with the least amount of packet loss through the selection of paths with the highest energy in the network. In this method, controlling the total network congestion is not considered and as it only supports reducing the loss of packet to prevent congestion. MA Moustafa et al. [10] have proposed a three-stage protocol called MSR that focuses on proper load distribution with step-by-step acknowledgment, which suffers from the increase of overhead and congestion in terms of how the protocol operates in the packet distribution process in the source. The method presented by S. Muhammad et al. [11] focuses on the concept of congestion control with an increased reliability. In this approach, the performance of single-path and multi-path protocols have been investigated in terms of the demand. It seeks to increase the efficiency of the transmission path and a reduction of the lost data and retransmissions. Yet, there is no proposed way to analyze the traffic load and network congestion. I. Jawhar et al. [12] have provided a protocol called RAS based on the DSR-based protocol, the main idea of which is to select the most reliable transmission path to reduce the packet loss and to focus on the number of shortest paths between the source and destination with maximum efficiency. There is no way to analyze the traffic load and the network congestion in this method. The AOMDV-LB method is one of the efficient ways for the congestion control and the load balancing methods developed by Rama et al. [13] in 2015 for the use in MANET. The function of this protocol is also based on the AOMDV protocol and aims to control the congestion and load balancing in order to increase the network lifetime and the throughput. The limitations of this protocol are as follows: the average congestion of paths to select the optimal route will not be always responsive. Besides, one of the proposed methods for finding the most efficient route is the reference [14], which can calculate the efficiency of the transmission path based on end-to-end delay, the delay of each hop and the reduction of probability of packet loss, to control congestion. As the delay parameter is considered in calculating the path efficiency, the selected path not only is efficient in terms of reducing retransmissions and congestion but also is efficient and optimal in terms of the delay. In [15], the proposed LBMMRE protocol evaluates the built-in routes based on the node's maximum residual energy and the actual number of packets that can be transmitted. The results from the evaluations indicate that the protocol improves the packet delivery and decreases the number of dead nodes, which in turn reduces the probability of the network partitioning. The disadvantages of this protocol are the more end to end delays than other protocols and the lack of analysis congestion in the network. In [16], an efficient routing technique called the Multipath Load Balancing Technique for Congestion Control (MLBCC) has been introduced in which more efficient load balancing between multiple paths is noted by reducing the congestion control. The MLBCC has a congestion control mechanism and a load balancing mechanism during the data transfer process. The congestion control mechanism detects congestion in paths at a time interval (T) by using the arrival and departure rates. The load balancing mechanism uses link cost and path cost to select a gateway node to distribute the load efficiently by selecting the most favorable path for an efficient flow of distribution. The simulation results of MLBCC indicates the performance of this protocol in improving the control overhead, the delivery packet rate, the average latency, and the packet loss rate compared to the Fibonacci multilevel load balancing. The protocol has not been able to improve the packet loss rate as a result of the improper transfers. In [17], a new approach to load balancing in the AOMDV routing protocol in MANET has been proposed which can improve the network performance by selecting routes while using temporary load distribution on the mid-nodes as well as the load distribution on free nodes during data transmission. The proposed protocol outperforms AOMDV in higher loads because the AOMDV only uses a path at a time. On the other hand, the TALB-AOMDV protocol distributes the traffic between different routes, which leads to distribute loads between more nodes, the better use of resources, and ultimately an increase in network lifetime and the balanced energy consumption. Although the proposed protocol will improve end-to-end delays, the packet delivery rate, and throughput, it has not performed any congestion control analysis. The proposed routing protocols for MANET have failed to manage the traffic in the routes optimally, and they always face the lack of optimal congestion control, proper distribution, and load balancing in the paths. In this paper, a multi-path routing protocol based on the AOMDV protocol for controlling congestion, distribution and optimum load balancing is presented in the paths.

3. Method

In this section, an approach is presented to increase the congestion control capability, support the distribution and load balancing, to adapt to the network layer and its features, which can be implemented on routing protocols as an engineering solution. Figure 1 shows the flowchart of the proposed method based on which the proposed method can be implemented in three general stages as follows: A-Routing process based on the discovering of efficient routes B- Checking the congestion criterion C. Considering the distribution and load balancing in routing.

Routing process based on the discovering of efficient routes. Providing an efficient method for the optimal control over congestion, distribution, and load balancing require a proper routing process. It should be noted that the function of the previous protocols was based on the reliable transmission through the routes with the least delay which led to the increasing congestion in the middle paths. In this regard, at this phase of research, an efficient routing method that can perform the congestion control along with considering other network criteria as well as providing an efficient way of routing has been proposed. Targeted routing to reduce the network congestion include considering the reliability criteria (reception rates, delays, the energy of nodes and route congestion) for which a method has been developed that can consider congestion effectively. According to [18], the packet acceptance rate between two nodes A and B means the packets received by node A to the total packets sent by node B that is calculated through (1).

$$PRR = \begin{cases} 1 & d < D_1 \\ \left[\frac{D_2-d}{D_2-D_1} + X\right]_0^1 & D_1 < d < D_2 \\ 0 & d > D_2 \end{cases} \qquad (1)$$

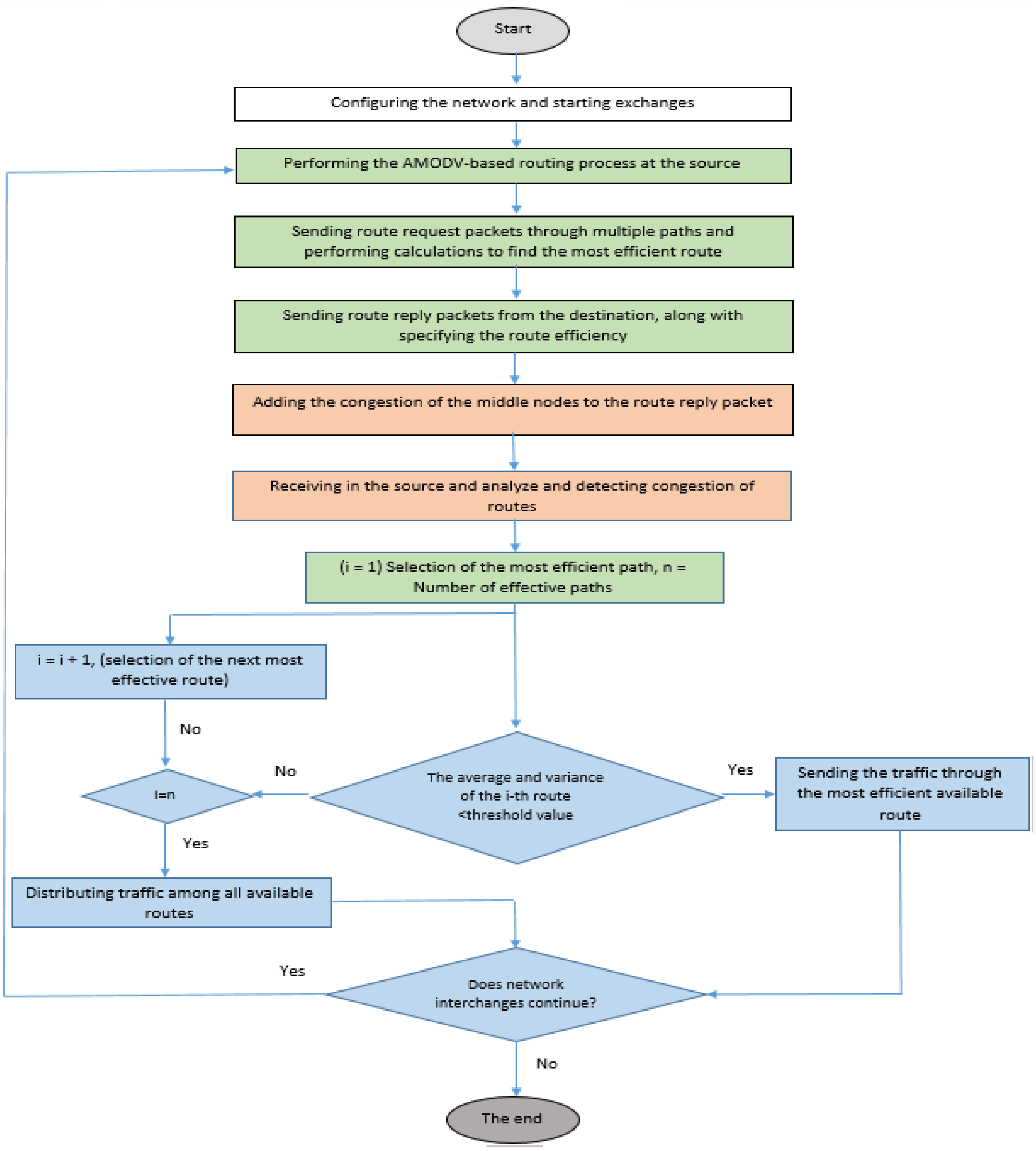

Fig. 1. Flowchart of the proposed method

In (1), X is a Gauss variable with σ^2 as the variance. D1 is a desirable radio range that if a node exists in this range, it will definitely arrive at the destination. But D2 is an undesirable radio range that if a node exists in this range, it will never arrive at the destination. If the distance between the two nodes (d) is less than D1, all packets arrive at the destination and the packet acceptance rate is 1. If the distance between two nodes is greater than D2, the broken link means the sent packets do not arrive at the destination. While, there is a weakened radio range between D1 and D2, which if the node is located in it, the probability of delivering the packet at the destination will follow Gaussian functions. Now, if the distance between the nodes is between D1 and D2, the packet acceptance rate is obtained from the second part of (1). In the proposed method, the path efficiency parameter shown with E is obtained from (2) which expresses the routing criterion and is in line with the aims of the research [19].

$$E = \frac{E_{eff}}{delay} \tag{2}$$

In (2), E_{eff} and delay represent the energy efficiency of the path and the amount of delay required to send the packet from the source to the destination, respectively. E_{eff} of (6) is calculated and obtained:

$$E_{eff} = \frac{E_r}{E_e} \tag{3}$$

E_r and E_e is respectively the end-to-end acceptance rate of the path and the energy consumed to transport a package to the destination where E_r is obtained from (4):

$$E_r = \prod\nolimits_{k \neq destination\ n} pr_{i,i+1} \tag{4}$$

In the above equation, $pr_{i,i+1}$ is equal to the packet acceptance rate between node i and the neighbor node i + 1. Figure 2 shows the concept expressed among the network nodes. According to the presented figure, the calculation of the route acceptance rate (end-to-end) is equal to multiplying the acceptance rates of hop-by-hop of the path from the source to the final destination.

To calculate the E_e criterion, it is first necessary to calculate and obtain the required energy to receive the packet in the first transmission from (5) [20].

$$E_e^1 = (prr_{i,i+1}(E_e^i + b) + a(b + E_e^2)) \tag{5}$$

With regard to the recursive functions presented in [20], it is shown that the amount of energy required to receive a packet per transfer period is obtained by using (6):

$$E_e^{k+1} = (prr_{i,i+1}(E_e^i + b) + ab) \tag{6}$$

The repeat rate for retransmission (R) is dependent on MAC layer; thus, if the protocol used in the MAC layer is IEEE 802.15, then this rate for retransmissions is 3, and if the IEEE 802.11 standard is used, this will be 16. In the proposed solution, IEEE 802.11 has been used [20]. In (6), $prr_{i,i+1}$ is obtained from (1). E_{ei} is the energy consumed from the source node to the i + 1 node and b is equal to the amount of energy required to process the package. The value of a is equal to 1-$pr_{i,i+1}$. Finally, the energy used to send the packet to the base station is obtained by using (7) [20].

$$E_e = \frac{(prr_{i,i+1}(E_e^i + b) + ab)(1 - a^{R+1})}{1 - a} \tag{7}$$

By replacing and calculating E_e and E_r in (3), the path efficiency is equal to (8) [20].

$$E = \frac{\prod_{k \neq destination\ n} pr_{i,i+1}}{delay(prr_{i,i+1}(E_e^i + b) + ab)(1 - a^{R+1})}(1 + a) \tag{8}$$

Equation (8) is proposed as the routing criterion in reference [20] but in [18], the value of node's residual energy has been added to the e criterion to increase the routing efficiency. In this work, in each node, an independent parameter called e_i is considered which is the node's residual energy and is calculated and updated by the node itself in the periods and intervals specified alternately. The value of this parameter is equal to the energy capacity of the node's power supply in the network. Over time and network processes, the remaining energy of the node decreases, so at the end of the energy consumption, the value of this parameter will be close to zero. Therefore, by adding this parameter in the routing criterion, the path efficiency will be equal to (9), which will increase the network's efficiency:

$$E = \frac{\prod_{k \neq destinaion\ n} pr_{i,i+1}}{delay\ (prr_{i,i+1}(E_e^i + b) + ab)(1 - a^{R+1})}(1 - a) * e_i \tag{9}$$

The value of (9) is the proposed routing criterion in reference [18]. As we have seen, various studies have been proposed to improve the routing process or to find the most efficient route, each of which is complementary to the previous one. The proposed method attempts to complete this process and increase the routing efficiency by considering the bandwidth criterion in the proposed equation because the bandwidth is always one of the most fundamental and at the same time one of the most important criteria in the congestion control methods [21-24]. This criterion expresses the amount of the free space for transferring relative to the total media space. So, in the proposed method, it will be possible to select paths as the most efficient paths that have better bandwidth and exchanges by analyzing the bandwidth of the intermediate nodes. Also, the choice of such a path will reduce the probability of a congestion because the path with the high bandwidth will allow faster and better data exchange and ; hence, can reduced congestion. Therefore, the proposed equation is for efficient multi-path routing with the aim of finding the best and most efficient exchange paths based on (10).

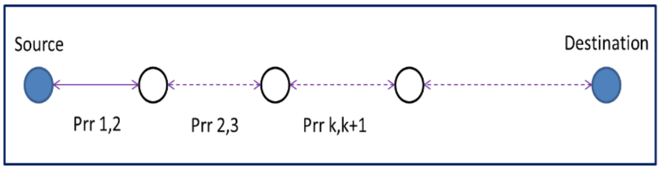

Fig. 2. The receive rates for middle nodes in a route from the source to the final destination

$$E = \frac{\prod_{k \neq \mathrm{destinaion}\ n} pr_{i,i+1}}{\mathrm{delay}\left(prr_{i,i+1}\left(E_e^i + b\right) + ab\right)\left(1 - a^{R+1}\right)} \tag{10}$$

$$(1 - a) * e_i * \mathrm{Band\ Width}_i$$

The bandwidth analysis from (11) and the bandwidth of the path will be obtained from (12) [29]:

$$\mathrm{Band\ Width} = \frac{\sum_{i=1}^{n} Ii}{Tb} * BW_{\mathrm{Total}} \tag{11}$$

$$\mathrm{Route}_{BW} = \prod_{k \in \emptyset, k \neq \mathrm{destinaion}\ n} BW_k \tag{12}$$

I_i is the idle time (empty opportunity) which is equal to the interval between the time of the previous occupancy of the channel and the current occupancy of the channel; n is the number of slots empty; BW is the remaining bandwidth of all available channels. In the proposed method, during routing, the efficiency of the mid-network path is analyzed based on the AOMDV-base protocol and the multiple paths along with the efficiency of each path to the source. As a result, the most efficient path for the purpose of controlling congestion and distribution and appropriate load balancing in the network will be selected.

Checking the congestion criterion. At this stage of the proposed method with the aim of optimal control and management of the traffic congestion, and the improvement of distribution and load balance in the network paths, the criterions of traffic analysis and the congestion of the middle paths, have been utilized. In order to analyze and decide the amount of the congestion of the middle paths, the path response phase used in the original AOMDV protocol is used for the optimal distribution in the network. In so doing, when the route reply packet is sent from the destination to the source, after reaching each middle node, the amount of traffic congestion and the traffic load of the node buffer is added to the Route Reply Packet (RREP) in a separate field. The congestion of the middle nodes in the available routes added to the route reply packet is calculated and evaluated based on (13). This process is performed for all the middle nodes until, eventually, the packet is received at the source node. Then, after receiving the packet, the source starts to analyze the field added to it (as it contains the amount of node's congestion) using the proposed equations below. In (14), M represents the average of the total buffer volume and in (15), ∂ represents the amount of congestion variations in the middle nodes. Based on this assessment, the source will decide which route is proper for transmission.

$$\mathrm{Congestion(i)} = 1 - \left(\frac{\mathrm{use\ of\ Queue}}{\mathrm{All\ of\ Queue}}\right) \tag{13}$$

$$M = \frac{\sum_{i=1}^{n} \mathrm{Congestion(i)}}{n} \tag{14}$$

$$\partial^2 = \frac{\sum_{i=1}^{n} (\mathrm{Congestion(i)} - \mu)}{n} \tag{15}$$

In the second step, the congestion criterion is considered in order to control the target of congestion and traffic in the network. Also, the quality of service will be improved by relying on the transfer of information from a reliable route using the congestion analysis. In so doing, selecting a node with a lower volume load will empty the capacity of the network; hence, the load volume at the level of the neighboring nodes will be uniformly distributed. On the other hand, the traffic analysis criterion is the basis for distributing traffic at the network, balancing congestion in the middle nodes, and ultimately reducing the overall congestion of the network. Consequently, using the above equations, the congestion of the paths can be analyzed. For example, the lower average and the rate of change leads to the better choice of route. Now, considering these two values as well as the efficiency of the paths, the third step of the proposed method which is the distribution and load balancing in the network will be performed.

Regarding the aforementioned distribution and load balancing in routing, the purpose of presenting the current research is to provide a solution with the highest distribution and load balancing in the network context and to prevent the negative effects of increasing congestion. In the previous steps, the most efficient routes were identified by analyzing various criteria. Additionally, the amount of congestion in the middle paths as well as the congestion of the intermediate nodes were separately identified and analyzed. The purpose of adding this step from the proposed method to the current research is to provide the optimal and most efficient distribution and load balancing the network and to avoid creating and increasing congestion in the network. As a result, this congestion control can have the highest level of sustainability. Accordingly, the congestion of an efficient route may increase or it may have a high variation that would lead to congestion. In this case, the most efficient exchange route is checked for the rate of congestion and the congestion variations of the middle nodes. If the result indicates that there is a high congestion (more than a threshold value) or indicates a high variation in the congestion of the middle nodes in the route, the source node selects the second efficient path for the interchange as the first route has a high congestion. The reason for this is that in different conditions of the network, the congestion of routes or the congestion of the middle nodes of the routes may increase or fluctuate, separately, which will cause congestion. The result of congestion analysis and changes values of route congestion, and distributing loads based on these factors, will be the exchanging the traffic through the most efficient route selected. It is worth mentioning that the use of such a mechanism will reduce the volume of congestion from the middle paths of the network and will provide a more favorable distribution and balance in the network. Also, it should be noted that if the congestion of all the middle paths is high and in fact, the overall congestion of the network is very high, the function of the proposed method is based on the distribution of traffic from all existing routes. Also, determining the threshold value associated with MANET can be easy or strict. For example, if a network has a high exchange volume and a high traffic network, it is considered as a *strict* one (the more it tends to one, it will become more strict.), and it is considered as the *easy* one if the exchange rate is low and in sum, a small amount of traffic in the network will be seen (the more it tends to zero, it will become easier). In the current research, after the repeated simulations and the independent variable consideration which is related to the number of nodes as well as some other parameters such as the number of injected packets in the network and the type of traffic and the node's transmission power, the threshold value of 3/2 was set based on which the distribution and the load balancing is done in efficient routes.

4. Evaluating the Proposed Model

In this section, the simulation details, the testing environment and the evaluation of the proposed protocol in terms of the performance metrics are presented. Besides, a comparison of the proposed routing protocol and MLBCC, LBMMRE, and AOMDV protocols based on parameters of throughput, packet delivery ratio, end-to-end delay, and routing overhead has been made. The proposed model analysis of this paper has been developed and expanded based on the NS2 simulator. The NS2 enables users to design and study wireless networks, telecommunications networks, devices, and protocols in networks. The parameters used in the simulations performed along with the amount assigned to each parameter is given in Table 1.

The average throughput is the total number of packets that have been successfully delivered from the source node to the destination node and can be better with the growing node density. Figure 3 illustrates a comparison among the proposed protocol, MLBCC, LBMMRE, and AOMDV routing protocol, in terms of the average throughput based on the mobility scenario by varying number of nodes.

Table 1. Simulation Parameters

Parameter	Setting
Simulator	NS-2.34
Terrain dimension	1000 m x 1000 m
Number of nodes	50
MAC protocol	IEEE 802.11
Radio range of a node	Random
Traffic Type	Constant Bit Rate (CBR)
	5 m/s
Number of infusion nodes to network	4
Packet size (Byte)	512
Simulation Time (Second)	900
Number of Simulation runs for each scenario	10
The threshold of trust degree value	0/5
The threshold of trust degree value	0/5
maximum number of connections	35
Channel type	Wireless channel
Propagation model	Two-ray rayleigh fading
Antenna Type	Omni directional
Pause time (s)	25
Mobility model	Random waypoint model

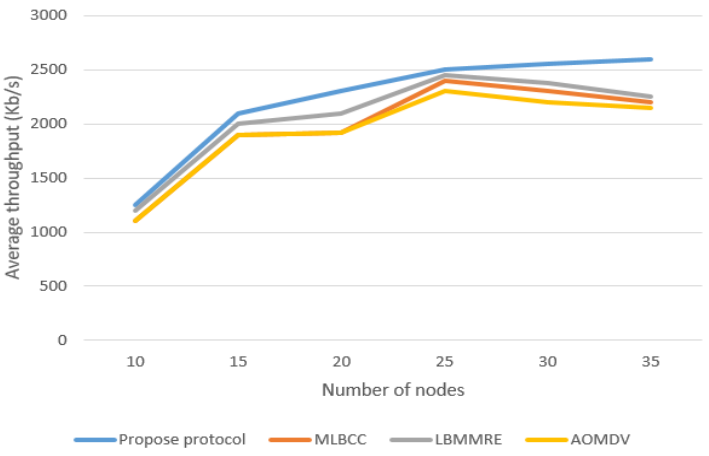

Fig. 3. Comparing among proposed protocol, MLBCC, LBMMRE and AOMDV in terms of average throughput

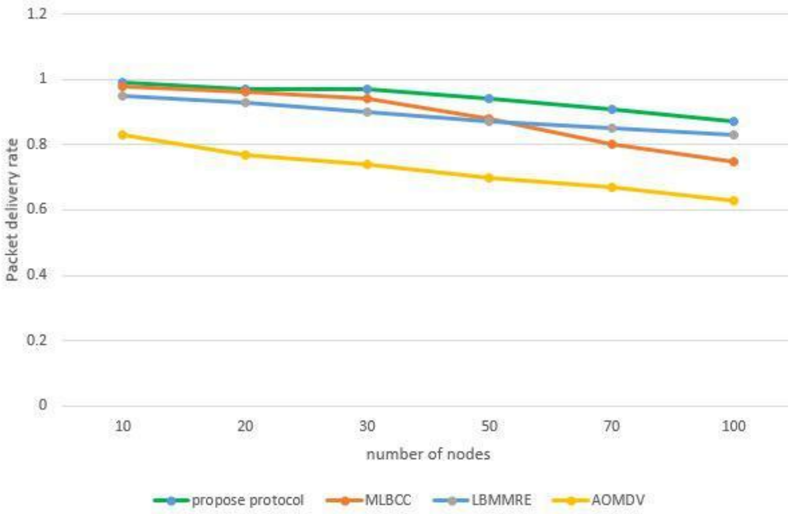

Fig. 4. Comparison of packet delivery ratio of the proposed protocol with that of AODV, MLBCC, and LBMMRE Protocols

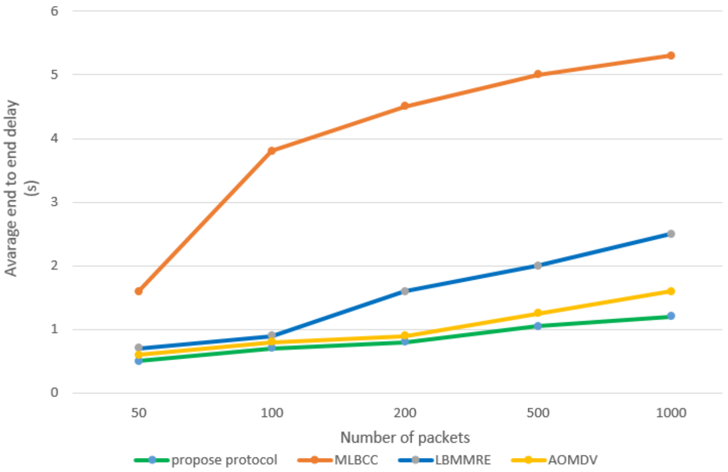

Fig. 5. Average end-to-end delay with proposed protocol and other routing protocols

The numbers of nodes varied as 10, 15, 20, 25, 30, 35, respectively. Figure 3 shows that mobility affects the throughput of the proposed protocol, MLBCC, LBMMRE, and AOMDV differently. To randomly change the topology, at a low density from 10 to 15 numbers of connections, the throughput of four protocols is almost similar. At a high density of 35 nodes or more, our proposed protocol has a higher throughput than others but the average throughput decreases for AODV, MLBCC, and LBMMRE routing protocols as the possibility of the link failures increases. The most efficient routes will be determined on the basis of different criteria (congestion, delay, and loss of packet) and by the order of priority in the source. Besides, the source has been allowed to perform the optimal load distribution process on the most efficient routes based on the amount of the congestion of the middle paths. For this reason, the optimal control of the congestion and the optimal distribution of the load according to the network conditions have led to an increase in the receive rate.

Figure 4 demonstrates how many 512-byte data packets each protocol delivers successfully. It can be seen that the packet delivery ratio is generally lower for the higher packet size. The proposed protocol presented a higher packet delivery ratio than MLBCC, LBMMRE, and AOMDV for all the numbers of nodes. According to Figure 4, the improvement of the proposed method based on averaging, compared to the MLBCC, LBMMRE, and AOMDV is 6.16%, 5.3%, and 19%, respectively. Figure 5 shows the average end-to-end delay with different numbers of packets. LBMMRE suffered the highest average end-to-end delay which is followed by AOMDV and MLBCC. This is because the main goal of LBMMRE is to deliver the maximum possible amount of the data safely.

Also, Figure 5 shows the delay of network exchanges in the proposed method compared to the three approaches mentioned. Performing exchanges from different and also favorable routes as well as preventing traffic injections and increasing the delay in a route has led to an improvement in the delay of exchanges in the proposed method compared to the three other ways. It should be noted that another reason for this improvement is the use of a delay criterion to select the optimal route in the proposed method.

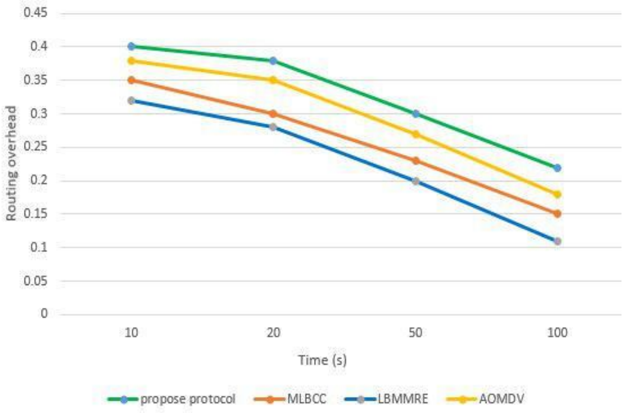

Fig. 5 routing overhead with respect to time between proposed protocol, MLBCC, LBMMRE and AOMDV

Therefore, by choosing the most efficient routes, distributing loads in these routes, and reducing the negative impacts of congestion, the delay of the exchanges will be achieved. The percentage improvement in the proposed method based on averaging compared to the MLBCC, LBMMRE, and AOMDV is 14%, 30.1%, and 23.6% respectively.

Figure 6 shows the overhead of the control packages added to the proposed method in comparison to other methods relative to the performance. Regarding the performance of the proposed method in the routing process and adding the delay and congestion criteria to the Route Reply packet (RREP) of the routes by the middle nodes, the overhead of control and the routing packets in the proposed method have increased compared to the three other methods. The increasing amount is 19% more than MLBCC, 22% more than LBMMRE, and 10% more than AOMDV. Thus, given to the improvements made by the proposed method and according to the obtained results, this amount of overhead can be ignored.

Conclusions and Future Studies. In this research, one of the most important network issues under the topic of congestion control and distribution and load balancing is investigated and the significance of this issue in MANET is expressed in terms of its applications in various fields. The proposed approach is aimed at improving the congestion control and load balancing and distribution, which is in line with the features of MANET and the traffic on the middle paths, and is well suited for the implementation on routing protocols. The implementation is based on one of MANET's most famous protocols known as AOMDV, the results of which indicated the effectiveness of the proposed method. In the future works, it is possible to develop the proposed method using other criteria to be used in other networks such as VANET and WSN. It is also possible to optimize the proposed method considering its limitation to reduce the overhead and to increase the efficiency of the proposed method in future studies.

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