معامل التأثير العربي 1.63
العدد 22

مجلة التربوي
Journal of Educational
ISSN: 2011- 421X
Arcif Q3

مجلة التربوي

مجلة علمية محكمة تصدر عن

كلية التربية / الخمس

جامعة المرقب

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يناير 2023م

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	مجلة التربوي Journal of Educational ISSN: 2011- 421X Arcif Q3	معامل التأثير العربي 1.63 العدد 22

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مجلة التربوي
Journal of Educational
ISSN: 2011- 421X
Arcif Q3

معامل التأثير العربي 1.63
العدد 22

Simulation and Analysis of Control Messages Effect on DSR Protocol in Mobile Ad-hoc Networks

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Abstract— In the recent era of technology, the utilize of wireless communications becomes trustworthy as it does not requires an extra cost of establishment, creation, and protection, as well, it offers a better functionality compared to wired communications. One of the most important patterns of wireless networks is Mobile Ad-hoc Network (MANET). In MANETs, the process of discovering and maintaining a route between the sender and the receiver node has several routing concerns as this kind of networks develop and expand. The control messages are one of the majoritysignificantrouting issues within MANET's protocols. In this research, a detailed simulation based performance study and analysis is performed on the control messages of Dynamic Source Routing (DSR) protocol for MANETs. Practically, the control messages of DSR protocol has been studied utilizing various simulation scenarios and by analysing their effects with regard to mobility, offered load and nodes density in the network. Consequently, the experimental simulation results demonstrate that the number of control messages of DSR protocol is affected by mobility more than offered load and nodes density in the network. Besides, according to the experimental analysis, recommendations have been prepared about the effects of the control messages of DSR protocol under a variety of circumstances. Simulations of DSR protocol to analyse and study its performance were executed in Global Mobile Simulator (GloMoSim).

Key words**:** Mobile ad-hoc networks, routing, DSR protocol, control messages.

1. Introduction

The mobile ad-hoc network (MANET) is a type of wireless networks, whichis mobile networkand independent of anyinfrastructure. MANET is dynamically created by wireless mobile nodes that randomly move without the management of anysupport station or any access point. In MANET, mobilenodes have the capability to operate as a host and a router simultaneously, since nodes are able to move freely and systematize themselves with arbitrarymode, which lead to creating network dynamic topology [Al-Shoraand et. al., 2018] [Khudayerand et al., 2020].Basically, to stay connected, each node participates the role of a router and moderatelyshares the job of routing data in the network [Hajlaoui and et al.,2015].In MANETs, there are three ways to create one or more route between source nodes and their destination nodes, which are proactive (table-based) routing, reactive (on-demand) routing and hybrid routing [Malwe and et al.,2022].However, most of the routing protocols in MANETs are each of two:reactive or proactive. Reactive routing protocols (such as: dynamic source routing (DSR) protocol and Ad hoc On-Demand Distance Vector (AODV) routing protocol) [Saima and et al., 2016],[Soujanya and et al.,2011], [Priyaganga and Madhumita, 2016]) and proactive routing protocols (such as Destination-Sequenced Distance Vector (DSDV) routing protocol and Wireless Routing Protocol (WRP)) [Priyaganga and Madhumita, 2015].In the main, reactive routing protocols have to perfunctorily adapt to topology changes to preserve the routes between the source node and its intended destination node.Generally, routing protocols utilize various control messages (packets) for guarantee deliveryof data packets from the source to the intended destination in the network [Clausen and et al., 2018] [Khudayer and et al., 2020].Therefore, reactiverouting protocols (such as

DSR and AODV)presented the construction of routes to the intended destinations reactively via their special route discovery processes. However, the route discovery and maintenanceoperations of reactive protocols have three important control messages: Route Request (RREQ) message, Route Reply (RREP) message and Route Error (RERR) message,which plays a central role in data transmitting task inmobile ad-hoc networks [Mann et al., 2005] [Zhang et al., 2011] [Soundarya et al., 2021].Besides, enormous challenges remain while studying the previousdeclaredfeatures of control messages, since these control messages are affected by severaloperators, for instancemobility, network size and offered load. This article discusses a detailed analysis of control messages created during routing process in DSR protocol.

The rest of the article is presented as next. In section 2, we present the related works. In section 3 we introduce typical DSR routing protocols.Section 4 provides detailed preview of control messages of DSR Protocol.While section 5 presents the research methodology, and section 6 shows the simulation experiments and results. Finally section 7 gives the conclusion.

2. Related Work

Several research works have been conducted related to the analysis of the effect of control messages on the performance of reactive routing protocols (i.e. DSR and AODV) in the past.

Work by [Sathish and Thangavel, 2014]haspresented customized DSR schemefor Reducing RREQmessages overhead in MANETs. It hasproposed animproved flooding (broadcasting) strategy for the route discovery mechanism of DSRprotocol. Practically, the improved scheme is to discover the best next neighbour node,since it aims todecrease the RREQ overhead difficulties.However, the performance of this improved DSR scheme is highregarding toseveral simulation metrics (for instance:control messages routing overhead, and data-packet delivery fraction). The improved DSR scheme adapts rapidly to routing varies via reduction of sending RREQ messages when the range of theMANET is large enough. Consequently, it achieved better than standard DSR and E-DSR.

In [Zhang et al., 2011]a new systematic model for analysing the attributes of control traffic has proposed for control messages issues in MANETs. Itsuggested four systematic indicators, which are utilized to analyse the distribution of control traffic (specifically RREQ messages) in the network,control message (RREQ messages) communication between dissimilar nodes, the rate of RREQ messages along with the fraction of the number of RREQ control messages creating from each intermediate node to that of all RREQ messages transmittedvia this node at dissimilar times, correspondingly. Practically, by utilizing the proposed model, theydiscoveredthree things: firstly, the distribution of the control traffic is symmetricthrough the warm up stage, and whereas the MANETachieves the stabilitystage, the majority of control traffic in the MANETpasses through the middle of the network. Secondly, there are numerousclusters (groups) in each MANET, since the number of RREQ messages transmitted between couple of nodes in thesimilar cluster is bigger than that between couple nodes belonged to two dissimilar clusters. Third and finally, there are backbone nodes, which working as a gateway to transmit RREQ messages between dissimilar clustersin the MANET. The authors that provided this workrecommend to utilizing it to improve and develop efficient routing protocols forMANETs.

Shobha and Rajanikanth [41] suggested an improvement called (Relay Routed DSR) that aimed to decrease the quantity of control packets (i.e. RREQ messages). However,the functions of improved DSRprotocol were consistent with the mobility information, since this informationwascollected in the route discovery stage from the neighbouring nodes,along withutilizes it to choose the intermediate nodes (i.e. nodes between the source and destination) where RREQ messages should be sent during datatransmitting process. Nevertheless, the mobility information of a node obtained in the route discovery stage possibly will not be suitabledue to the velocity of mobile nodes, which sources excessive route discoveries that contribute to more routing overhead in the network.

Another work was conducted by [Mann et al., 2005], it proposes a statistical analysis to determine the traffic volume (data and control messages) in MANETs, which utilize reactive (on-demand) routing protocols. However, it offers an analytical framework that uses for approximating the routing overhead because of node mobility and link failures in the network. Detailed analysis was introduced for calculating the number of control messages (specifically RREQ, RREP and RERR messages). Practically, the authors of this recommended using the presented statistical analysis for choosing an appropriate reactive routing protocol, in addition for designing new and reliable routing protocols for MANETs.

Work by [Malwe et al., 2017] has presented two methods for decreasing the flooding of RREQ messages and estimating the link accessibility. The first method is zone-based, since the broadcast range of each node is separated into the internal, central and external zone established on the received signal power,along withcouple predefined thresholds, while only the nodes inside the centre zone share in the path discovery technique. On the other side, the second method is segment-based; in this method, the link accessibilityfraction for all neighbouringconnections is computed utilizing the present location of the neighbour node and its pointed sector in the transmission variety. On the other hand, this method suffers from message looping and high number of hops toward the target nodein the path discovery technique. However, this method does not suppose the direction of nodes in the particulararea to guarantee the RREQ message can achieve its target node in the network.

3. DSR: Dynamic Source Routing Protocol

Dynamic Source Routing (DSR) is a reactive (on-demand) MANET routing protocol [Khudayer et al., 2020]. In DSR, the nodes do not keep the network topology due to nodes mobility in the network.Fundamentally,when a node desires to send a data packet, initially it runs a route discovery procedure to the destination node, and then it starts sendingdata packets through the discovered route to the desired destination node. On the other hand, each node in the source route (called: intermediate node) is responsible to delivering the transmitted data packets to the next node forward the destination node. In case of failure link in the discovered route, intermediate nodes have to run route maintenance procedure for salvaging data packets during transmitting data packets process. Mainly, routing protocols of MANET (such asDSR protocol) depend on control messages to run all routing processes in the network [Priya, 2014][Johansson et al., 1999].

4. Control Packets of DSR Protocol

In MANETs, DSR protocol consists of three major phases [Vikram et al., 2011]: Route Discovery, Data Forwarding and Route Maintenance. Basically, every routing protocol employs control messages (packets) for finding the efficient route between the source node and the intended destination node. Essentially in reactive protocols (i.e. DSR protocol) there are three main kinds of Control Messages (CP) for route discovery and route maintenance procedure as follows: i) Route Request (RREQ) Message.ii) Route Reply (RREP) Message.iii) Route Error (RERR) Message.

Basically, for transmitting data messages to such a node, the routing system requires to identify one or more routes from the source node to the intended destination node, in addition to discover any faults in the selected route. As mention above, DSR protocol employs its three control messages (RREQ, RREP, and RERR) in its route discovery stage. Basically, source node starts broadcasting RREQ messages to find a route to its destination node in the network, along with waiting RREP messages that carry the discovered source route. As soon as the source node received one or more RREP message, it selects the shortest route and starts transmitting its data messages to the intended destination node. However, when a mobile node moves out of the transmission range in MANET, link failure is the mainly frequent cause for RERR control message creation. In this case, a RERR control message will send to the source node and all neighbored nodes by the intermediate node that discovered the failure link [Malwe et al., 2022]. In particular, DSR protocol is applying route discovery and maintenance procedures to grantee delivering data packets to their targets, sincesource nodes exchange RREQ,RREP and RERRcontrol messages with their neighbour nodes to complete their data transmitting task. These circumstances lead to the problem of broadcasting control-messages storms. Broadcasting control-messages raise control routing overhead along withreduce network performance[Alani et al., 2020].In addition,DSR protocolhasother important issues(e.g. poor scalability and more data packets collusions) due to their excessive use of control messageswithin the network[Dusia et al., 2019].

4.1. Control Messages in DSR Route DiscoveryProcedure

In DSRrouting protocol, source nodes have to operate the route discovery procedurein case ofdo not havea route to the desired destination nodes in their route caches [Zarzoor, 2021] [Satyanarayanaet. Al, 2021].Basically, the route discovery procedure has two key processes of control messages: Route Request (RREQ) and Route Reply (RREP) process. However, the following examples and figures will describe the mechanism of each process in route discovery stage in DSR protocol.Figure (1)describes the RREQprocess of the route discovery procedure inDSR protocol. Basically, if a source node desires to send data packets to the intended destination node but the source route is not offered in the network, it starts by calling a route discovery procedure by broadcasting route request (RREQ) messages to its neighbours nodes in the network. Practically, allneighbour nodesthat receiving a RREQ message requireto re-broadcasting it again to its neighbour nodes;except it is the intended destination node;otherwise it has a cached source route to the intended destination node. However, any middle node that has received the same RREQ message will not re-broadcast it over againin the network. The RREQ message includes a list of all the middle nodes traversed included the source node. In addition,each node receives a new RREQ message, immediately it stores a new route to the source node (i.e. called source route), and then verifies for middle nodes accumulated in the route. Besides, a new source route will be saved in the routes cache for any of the middle nodes, if one did not previously exist.

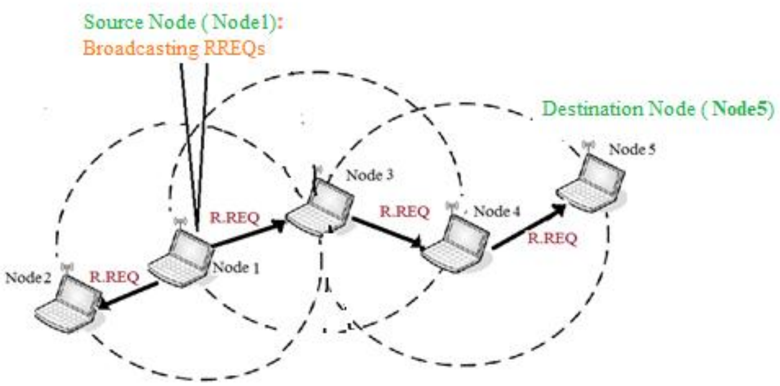

Fig.1: Explains RREQ control message procedure

For instance, a source node (Node1) requires to sending a data packet for the intended destination (Node5). Firstly, the source node (Node1) runs the route discovery procedure by broadcasting RREQ messages in the network. However, whereas the intended destination node(Node5)itself receives a RREQ message, or any an middle node (e.g. Node2, Node3 and Node4) has a route to the intended destination node (Node5) in its routing cache, immediately thenode creates a new RREP messagealong with send it along the reverse route back toward the original source node(Node1). In the RREP process as illustrated in fig.3, the intermediate node (Node4) discovered a cached route from the source node (Node1) to the destination node (Node5), that is: (Node1->Node3-> Node4-> Node5). Basically,the discovered cached route willbe traversed backward to the source node (Node1) via a RREP message. Practically, theoriginal source node (Node1) and all traversed nodes (i.e. Node3 and node4) will cache thereplied route in their routes cache. Generally, it is possible for the RREQ originator (Node1) to receiveone or more RREP message from its neighbour nodes in the network.Inthis situation, the source node (Node1) will select the shortest route to send its data packets, andstores otherreplied routes in its routes cache for future use.

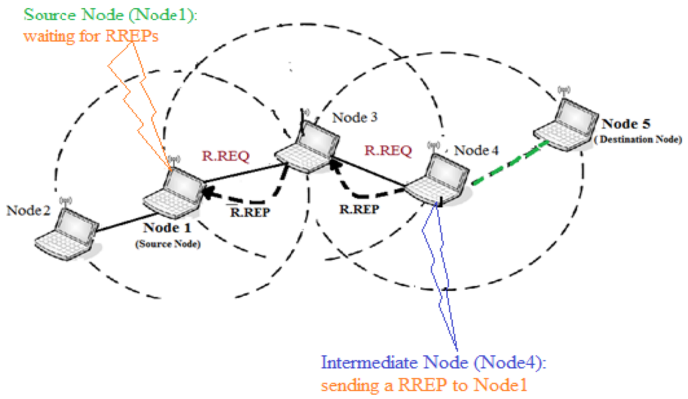

Fig. 2:explains RREP control messages in route discovery procedure

4.2. Control Messages in DSR RouteMaintenanceProcedure

In DSR routing protocol, nodes employs the route maintenance procedure to maintain its source routes, and for salvaging the transmitted data packets in the network. Mainly,the route maintenance procedure has an important reaction (called RERR control messageprocess)for notifying the source and other node that the route is disconnected.Basically, in situation where the source node needs for sending a data packet to the intended destination node, it isutilizing theircached routes, sinceevery node transmitting the data packet has to confirming that the transmitteddata packet has arrived by the next intermediatenode (forward the destinationnode). In case of failure link,the failure-link node sends backward a RERR message to the source node and all neighbour nodes, in addition it has to call route maintenance procedure to salvage the transmitted data packets [Soundarya et. al, 2021]. Each node receives a RERR message has todelete allcached route thatare affected by the detected failure link.Accordingly, it will check its route cache for alternative route, or recall a new route discovery procedurefor transmitting the remained data packets [Ahmed et. Al, 2022].

For instance, the situation that showed in Fig. 3 as below, the failure-link node (Node 4) is not capable to transmit the data packet to the next hop (Node 5) in the active source route, subsequently, it has tosends a RERR control message to the source node(Node 1), which is fornotifying the source node that the link from (Node 4) to the next node (Node 5) is currently “failure”. Responsibly, the source node (Node 1) has to recall a new route discovery for alternative route to the intended destination node (Node 5). On the other hand, the failure-link node (Node 4) has to calls route maintenance procedure for salvaging the data packets that face the failure linkbetween Node 4 and Node 5.

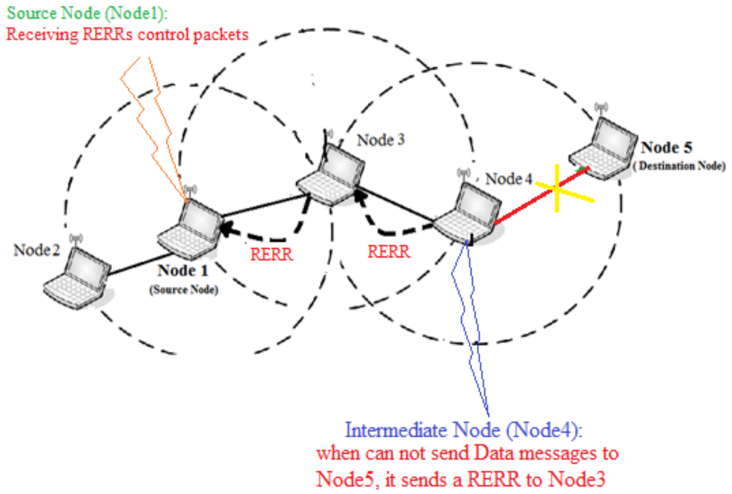

Fig. 3: Explains RERR control messages in route maintenanceprocedure

In particular, DSR protocol is applying route discovery and maintenance procedures to grantee delivering data packets to their targets, since source nodes exchange control messages (i.e. RREQ, RREP and RERR) with their neighbour nodes to complete their data transmitting task. However, some circumstances lead to control-messages storms problem in the network. However, flooding the control-messages raise the control overhead along with reduces network performance [Alani et al., 2020]. In addition, DSR protocol has other important issues (such as poor scalability and more data packets collusions) due to their excessive use of the control messages within the network [Dusia et al., 2019].

5. Research Methodology

5.1. Simulation Environment

The simulations of the mobile ad-hoc network (MANET) are implemented utilizing GloMoSim (Global Mobile Simulator) simulator [Bagrodia, 2000]. Nodes in the simulation area proceed according to famous model called Random Waypoint Mobility (RWM) model [Gowrishankaret. Al, 2007]. For each scenario, the simulation time is 900 seconds, while the simulated MANET region is 2200 m x 600 m rectangle. However, the MAC layer protocol (IEEE 802.11) is employed in all MANET simulations, and the Internet Protocol (IP) is utilized as network layer protocol, whereas the Constant Bit Rate (CBR) traffic sources offer a stable stream of data packets of 512 byte. The simulation parameters of our simulation experiments are illustrated in Table 1.

Parameters	Values
Simulation Area	2200m X 600m
Simulation Time	900 second
Size of Network	30, 40, 45 or 50 nodes
Node Speed	From 0 to10 meter per second
Mobility Model	RWPModel
Traffic Model	CBR Model(4 packets/sec.)
Routing Protocol	DSR
Pause Time	0, 300, 600 or 900 sec.
Number of Sources	5,8,10 or 15 sources
Bandwidth	2 Mbps
Packet Size	512 Byte

Table 1: Simulation Values and Parameters

5.2. Performancemetrics

In our simulations, we have chosen the number of RREQ messages, number of RREP messages, and number of RERR messages as a performance metric during the simulation experiments in order to study and analysis the control messages of DSR protocol, which are as follows:

i)**Number of RREQ messages (No.RREQs)**: it is the total of request control messages that distributed by the broadcasting algorithm, which send via a source node for finding out the route towards the required destination node if it doesnot find any route in its route cache [Miguel et al., 2005] [Jadhav et al., 2014]. Basically, to compute the total of route replay control messages for unsuccessful send data packets, we have used equation as given in (1).

$$\text{No. RREQs} = \sum_{i=1}^{n} \left(\text{number}_{\text{of\_request\_message\_sent}}\right) \ldots\ldots (1)$$

$\boldsymbol{Since}$: $\boldsymbol{n}$ $is the number of nodes that$ $\boldsymbol{received}$ the $\boldsymbol{route request}$ $messages.$

ii)**Number of RREP messages**: it is the total of replaycontrol messages thatcontains the constructed path, which send back by the destination node whenit receives the RREQ message, orany intermediatenodethat hasa route to the destination node in the network [Pura et al., 2010]. Basically, to compute the total of route replay control messages for unsuccessful send data packets, we have used equation as given in (2).

$$\text{No. RREPs} = \sum_{i=1}^{n} \left(\text{number}_{\text{of\_reply\_message\_sent}}\right) \ldots\ldots (2)$$

$\boldsymbol{Since}$: $\boldsymbol{n}$ $is the number of nodes that$ $\boldsymbol{sent}$ the $\boldsymbol{route reply}$ $messages.$

iii)**Number of RERR messages**: it is the total of error control messages that send back by any intermediate node when a link break happens while the source route is active; since the intermediate node upstream of the failurebroadcasts a RERR message to the source node to notify it of the currently unreachable destination node[Saraswat et al., 2015]. Basically, to compute the total of route error control messages for unsuccessful send data packets,we have used equation as given in (3).

$$\text{No. RERRs} = \sum_{i=1}^{n} \left(\text{number}_{\text{of\_error\_message\_sent}}\right) \ldots\ldots (3)$$

$\boldsymbol{Since}$: $\boldsymbol{n}$ $is the number of nodes that$ $\boldsymbol{sent}$ the $\boldsymbol{route error}$ $messages.$

All the presented above quantitative metrics must be based on the same MANETcharacteristics, for instance data packets density, bandwidth, traffic type, energy resources, dimension of simulated area , etc.

6. Simulation Experiments and Results

Practically, we examine different simulation scenarios for our simulation experiments, wherein the MANET's nodes are spread over the simulation region. The simulation scenarios describe: varying number of source nodes (traffic load),varying number of the pause time of nodes (speed)andvarying number of node (network size). To study the outcome of control messages on popular DSRrouting protocol performance, we requireto evaluating the DSR protocolunder a variety of circumstances using different simulation scenarios.

In this work, three simulation scenarios have been run with respect to three parameters (i.e. number of source nodes, pause time of nodes and number of MANET's nodes), whereas every scenario has been run four times with varied 4 values of each parameter. In total, 12 simulations were done for our investigation, while every simulation scenario has been executed for 900 seconds. In the first simulation scenario, varying number of source nodes (offered load) is varied from 4 source nodes to 15 source nodes. In the second simulation scenario, varying pause time of nodes (mobility) is varied from 0 sec to 900 sec. In the third simulation scenario, varying number of MANET's nodes (nodes density) is varied from 30 nodes to 50 nodes. In this section, details of the result analysis are focusing on ratio of each type of control messages (RREQ, RREP and RERR) along with its effects on the performance of DSR protocol in the mobile ad-hoc network.

For analysing our simulation results, we have described the curve line of each scenario to two cases, the 1st case is related to (high and very high rate), and the 2nd case is related to (low and very low rate) of the selected simulation metric in our scenarios. Basically, the simulation scenarios are explained in the subsequent sections:

6.1.1.Scenario 1: Effect of Varying Number of Source Nodes

This simulation scenario changes the number of source nodes (Offered Load), since it aims to explain the impact of number of source nodes on the number of control messages (i.e. RREQ, RREP, RERR messages)in the MANET. Practically,the simulation scenarios are executed for 4, 8, 10 and 12 mobile source nodes. Table 2explains the parameters of the simulation experiment (1)whichvary from the standardparameters that provided in Table 1.

Parameter	Value
Pause time	900s
Number of nodes	50 nodes
Speed of nodes	0-10 m/s
Number of sources	4, 8, 10 and 12 sources

Table 2: The effected parameters of simulation experiment 1

In this simulation scenario, four environments executed using varying number of source nodes. Consequently, the simulation result was collected and illustrated in Fig. 4, whereas the rate and total numbers of control messages successfully broadcast in MANET network are illustrated in Table 3.

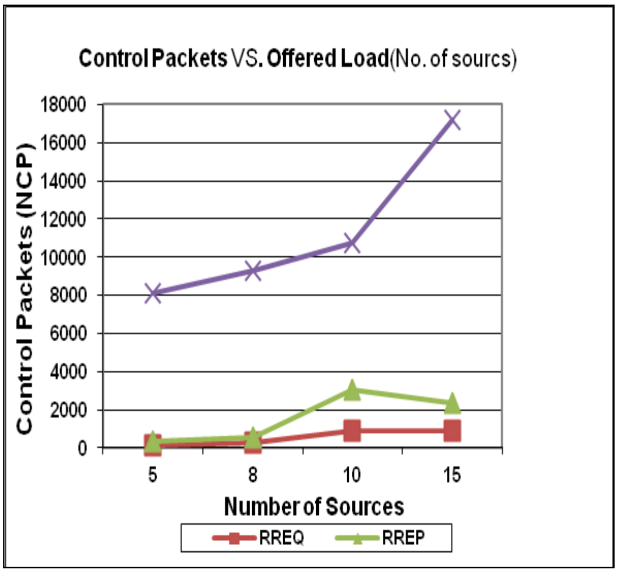

Fig. 4: Control Packets VS. Offered Load

Refer to scenario (1), to examine the behaviour of performance measures; the number of source nodes is varied while all other parameters remain constant as shown in Table 3. The first assumption we can make from the simulation results is that the Number of Sources parameter (offered load) has a significant effect on the control messages in DSR protocol. This effect is much more significant in high and very high offered load network than in low and very low offered load network.

In high and very high offered load network with 10 and 15 source nodes, the ratio of control messages is raising from 14634 to 20428 messages in the simulated MANET, which is expected due to the high number of route discovery processes of sources in this scenario. On the other hand, in low and very low offered load network with 5 and 8 source nodes, the ratio of control messages is raising from 8606 to 10147messages. This because reducing number of sources means reducing number of route discovery processes, which lead to decreasing the total of control messages in the network.

In low and very low offered loaded environment, RREQ messages represent between 1.67% and 2.59% of the total control messages in the network, while RREP messages represent between 3.87% and 5.55%, as well as RERR messages represent between 94.47% and 91.86% of the total control messages in the network. In high and very high offered loaded environment, RREQ messages represent between 5.98% and 4.39% of the total control messages in the network, while RREP messages represent between 20.8% and 11.5%, as well as RERR messages represent between 73.22% and 84.11% of the total control messages in the network. On the other hand, analyzing the simulations' results provides the feeling that decreasing the number of source node (i.e. low and very low offered load networks) regularly improves the performance of the DSR protocol. Consequently, to enhance the performance of the DSR protocol in MANETs, the offered load parameter should be set to low or very low number of source nodes.

Control Messages		Varying Number of Source Nodes			
		5	8	10	15
RREQ Control Messages	No. of RREQ Control Messages	143.4	262.4	874.8	896.8
	RREQ's Rate of total Control Messages (%)	1.67%	2.59%	5.98%	4.39%
RREP Control Messages	No. of RREP Control Messages	332.4	563.2	3043.6	2348.6
	RREP's Rate of total Control Messages (%)	3.87%	5.55%	20.80%	11.50%
RERR Control Messages	No. of RERR Control Messages	8131	9321.8	10715.6	17183.2
	RERR's Rate of total Control Messages (%)	94.47 %	91.86%	73.22%	84.11%
DSR Control Messages	Total of Control Messages	8606.8	10147.4	14634	20428.6

Table 3: Varying Number of Source Nodes VS. Control Messages

6.1.2. Scenario 2: Effect of varying the Pause Time

This simulation scenario changes the pause time (Mobility)of MANET's nodes, since it aims to explain the impact of pause time of mobile nodes on the number of control messages (i.e. RREQ, RREP, RERR messages) in the MANET. Practically, the simulation scenarios are executed for 0, 300, 600 and 900 sec as pause time of the mobile nodes. Table 4 explains the parameters of the simulation experiment (2) which vary from the standardparameters that provided in Table 1.

Parameter	Value
Pause time	0,300, 600 and 900 sec.
Number of nodes	50 nodes
Speed of nodes	0-10 m/s
Number of sources	10 source nodes

Table 4: The effected parameters of simulation experiment 2

In this simulation scenario, four environments executed utilizing varying pause time of nodes (Mobility). Consequently, the simulation result was collected and illustrated in Fig. 5, whereas the rate and total numbers of control messages successfully broadcast in MANET network are illustrated in Table 5.

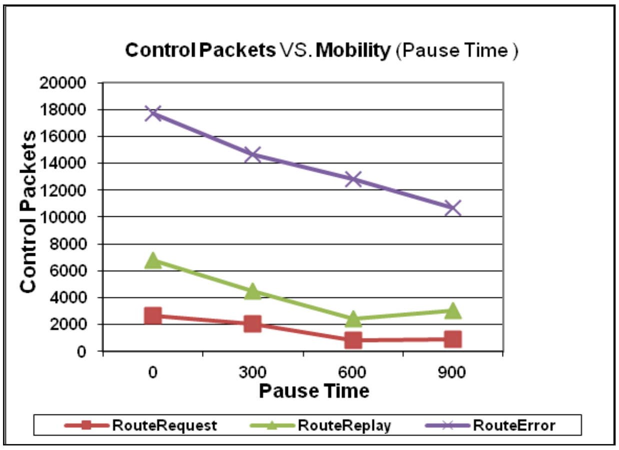

Fig. 5: Control Messages VS. Mobility

Refer to scenario (2), to examine the behaviour of performance measures; the pause time of nodes (Mobility) is varied while all other parameters remain constant as shown in Table 5. The first assumption we can make from the simulation results is that the Pause Time parameter (Mobility) has a significant effect on the control messages in DSR protocol. This effect is much more important in low and very low pause time of nodes than in high and very high pause time of nodes in MANET.

In high and very high pause time network with 600 and 900 seconds, the ratio of control messages is decreasing from 16005 to 14634 messages in the simulated MANET, which is expected due to the minimal node mobility and the successes route replies via route discovery processes in this scenario. On the other hand, in low and very low pause time network with 300 and 0 second, the ratio of control messages is raising from 21214 to 27144messages. This is due to reducing the period of pause time of mobile nodes, which increases the speed of nodes in MANET. Because of this, numerous routes will be broken, along with lots of RERR messages will be propagated in the network. However, there will be gradually raising of the total of control messages in the network.

In high and very high pause time of nodes, RREQ messages represent between 5.16% and 5.98% of the total control messages in the network, while RREP messages represent between 14.96% and 20.8%, as well as RERR messages represent between 79.86% and 73.22% of the total control messages in the network. In low and very low pause time environments, RREQ messages represent between 9.76% and 9.81% of the total control messages in the network, while RREP messages represent between 21.07% and 25.03%, as well as RERR messages represent between 69.17% and 65.16% of the total control messages in the network. On the other hand, analyzing the simulations' results provides the feeling that increasing the pause time of nodes (i.e. low and very low mobility environments) regularly improves the performance of the DSR protocol. Accordingly, to enhance the performance of the DSR in MANETs, the pause time parameter should be set to high or very high period of time.

Control Messages		Varying of Pause Time (Mobility)			
		0s	300s	600s	900s
RREQ Control Messages	No. of RREQ Control Messages	2661.6	2070.6	826	874.8
	RREQ's Rate of total Control Messages (%)	9.81%	9.76%	5.16%	5.98%
RREP Control Messages	No. of RREP Control Messages	6795.4	4469.2	2393.6	3043.6
	RREP's Rate of total Control Messages (%)	25.03%	21.07%	14.96%	20.8%
RERR Control Messages	No. of RERR Control Messages	17687.8	14674.8	12786	10716
	RERR's Rate of total Control Messages (%)	65.16%	69.17%	79.86%	73.22%
DSR Control Messages	Total of Control Messages	27144.8	21214.6	16005.6	14634

Table 5. Varying of Pause Time VS. Control Messages

6.1.3. Scenario 3: Effect of Varying the Number of Nodes

This simulation scenario changes the number of nodes (nodes density) in the MANET. This scenariointends to explain the impact of number of nodes on the number of control messages (i.e. RREQ, RREP, RERR messages). Practically, the simulation scenarios are executed for 30, 40, 45 and 50 sec as number of nodes in the MANET. Table 6 explains the simulation parameters which vary from the standardparameters that provided in Table 1.

Parameter	Value
Pause time	900 sec.
Number of nodes	30, 40, 45 and 50 nodes
Speed of nodes	0-10 m/s
Number of sources	10 source nodes

Table 6: The effected parameters of simulation experiment 3

In this simulation scenario, four environments executed using varying number of nodes. Consequently, the simulation result was collected and illustrated in Fig. 6, whereas the rate and total numbers of control messages successfully broadcast in MANET network are illustrated in Table 7.

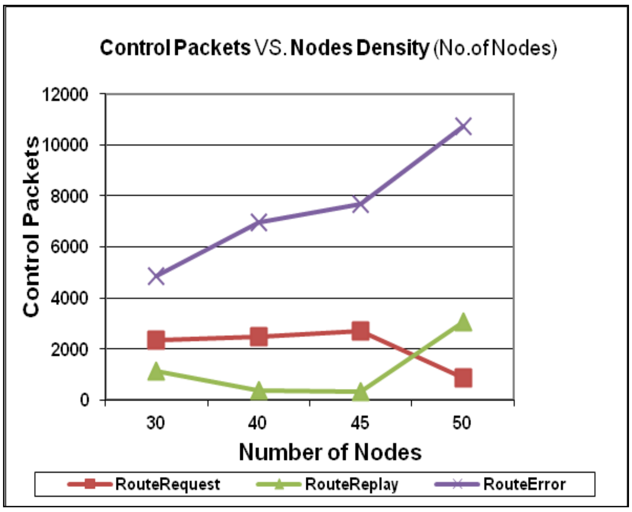

Fig. 6: Control Packets VS. Nodes Density

Refer to scenario (3), to examine the behaviour of performance measures; the number of nodes (i.e. nodes density) is varied while all other parameters remain constant as shown in Table 7. The first assumption we can make from the simulation results is that the nodes density parameter has animportant effect on the number of control messages in DSR protocol. This effect is much more significant in high and very highnodes density than in low and very lownodes density in MANET.

In networks of high and very high nodes density with 45 and 50nodes, the ratio of control messages is increasing from 10763 to 14634messages in the simulated MANET, which is expected due to high nodes density,thismeanswill bebig number of neighbored nodes of the source. Therefore, many RREQ, RREP and RERR messages expected to be broadcastingin the network. In contrast, in low and very low nodes density network with 40 and 30nodes, the ratio of control messages is decreasing from 17140 to 8366messages. This is due to reducing the nodes density in MANET. Accordingly, less RREQ, RREP and RERR messages are expected in the network. However, there will be decreasing of the total of control messages in the network.

In high and very high nodes density environments, RREQ messages represent between 25.25% and 5.98% of the total control messages in the network, while RREP messages represent between 3.17% and 20.79%, as well as RERR messages represent between 71.56% and 73.22% of the total control messages in the network. Whereas, in low and very low nodes density environments, RREQ messages represent between 57.22% and 28.10% of the total control messages in the network, while RREP messages represent between 2.04% and 13.59%, as well as RERR messages represent between 40.73% and 58.29% of the total control messages in the network. On the other site, analyzing the simulation results provides the feeling that increasing the nodes density (i.e. high and very highnodes density environments) regularly improves the performance of the DSR protocol. Consequently, to improve the performance of the DSR protocol in MANETs, the nodes density parameter should be set to high or very high number of nodes.

Control Messages		Varying Number of Nodes (Nodes Density)			
		30	40	45	50
RREQ Control Messages	No. of RREQ Control Messages	2351.4	2474.2	2718.2	874.8
	RREQ's Rate of total Control Messages (%)	28.10%	57.22%	25.25%	5.98%
RREP Control Messages	No. of RREP Control Messages	1137.6	350.6	342	3043.6
	RREP's Rate of total Control Messages (%)	13.59%	2.045%	3.17%	20.79%
RERR Control Messages	No. of RERR Control Messages	4877.8	6982.4	7703.2	10715.6
	RERR's Rate of total Control Messages (%)	58.29%	40.73%	71.56%	73.22%
DSR Control Messages	Total of Control Messages	8366.8	17140.2	10763.4	14634

Table 7. Varying Number of Nodes VS. Control Messages

Table 7 shows there is small effect of number of nodes on performance metrics (RREQ, RREP and RERR control messages) as compared to scenario 1 (effects of number of source nodes), whereas there is massive effect as compared to scenario 2 (effects of pause time).

7. Conclusion

In this paper, a performance analysis of the control messages along with its effects on the performance of DSR protocol has been performed. Whereas ithas beenevaluated using theGloMoSim network simulator.The performance evaluation of DSR protocol has been carried out on the basis of control messages (RREQ, RREP and RERR) that broadcast in the network. However, the performance evaluation has been prepared in three simulation scenarios. In the first scenario, it can be observed that when the offered load of MANET is high, there is positive effect on performance metrics (RREQ, RREP and RERR control messages) of DSR protocol, unlike when the offered load of MANET is low and very low. Whilst in the second scenario, it can be noticed that when the mobility of nodes is high (the pause time is long period), there is negative effect on performance metrics of DSR protocol, unlike when the mobilityof nodes is low and very low. In the last scenario, it can be observedthat when the node density is very high, there ispositive effect on performance metrics of DSR protocol,unlike when the nodes density is very low.Concluding, DSR protocol is working good and more efficientwith respect to its control messages in three MANET environments: high offered load networks, low mobility networks and high density networks.

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