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Fault-tolerance Enhancement in Mobile Ad-hoc Networks Using Backup Nodes

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Abstract

Due to limitations in computing resources of mobile nodes, Mobile Ad-hoc Networks (MANETs) are very fault-prone. So far, redundancy at different levels of the network has been considered an efficient strategy to enhance the fault-tolerance of networks. Indeed, ad-hoc networks are extremely redundant; therefore, natural redundancy to fault tolerance enhancement has a great impact on the network performance. In this paper, a fault tolerant algorithm for MANETs has been proposed that by assigning backup node(s) to each node tries to increase in fault-tolerance. For this reason, the proposed algorithm chooses the backup nodes from among those nodes having the same movement route. The nodes movement route can be determined or predicted through the backup nodes table. Choosing backup nodes is done based on the time of nodes adjacency. Experimental results taken from NS-2 simulator indicated that in comparison to other algorithms, the proposed algorithm increases by 1) the package delivery rate in relation to the percentage of fault, and 2) the package delivery rate in relation to various mobile nodes` pause time.

***Keywords**: Backup Nodes, Mobile Ad-hoc Networks, Fault-tolerance, Redundancy.*

1. Introduction

A mobile ad-hoc network (MANET) is established at environment without requiring any infrastructures. Communication between mobile nodes is made through radio signals [1-2]. Due to limitations in transceiver unit of nodes and decrease in the network energy consumption, mobile nodes are unable to make a direct connection with each other. In this regard, multi-hop communication is natural in MANETs. In a typically MANET, each node acts as both a router and a host during the network lifetime [3-4]. The aim of MANETs is improving the network development in which a set of nodes creates the communicative infrastructures of the network. The network topology in a MANET is made up of the nodes which are constantly moving in across the network. Of course, mobile nodes are able to enter or leave the network at any possible time [5]. Most applications of MANETs are in those fields requiring dynamic configuration, and where the use of wired networks is not available [6]. Nowadays, these networks are increasingly being used by the users in those environments in which the users share information dynamically using mobile devices [7-8]. However, MANETs are faced with such challenges as the lack of a permanent infrastructure, i.e. central control unit [10], limitations in energy supply of mobile nodes [10], multi-hop communications from a source node to a destination node [9], unreliable wireless communication links [11], harsh environmental conditions [11-12], etc.

In MANETs, fault occurrence can be considered in two ways 1) fault occurrence in mobile nodes operation, and 2) fault occurrence in transferred data. The main source of fault in MANETs can be considered as the restriction of hardware resources in the mobile nodes. Besides, unreliable wireless communications as well as the movement of the nodes are likely to make missed data transfer [10]. On the other hand, MANETs are highly redundant networks [10]. The high redundancy of MANETs causes any point in the network to be covered by several nodes and most likely there must be several different paths between the source and the destination nodes in the network.Therefore, the effective use of natural redundancy in MANETs can increase the networks fault tolerance against nodes and wireless links faults. Although fault tolerance in MANETs is a very essential issue, there is insufficient research in this area. A lot ofresearches have been done that have focused only on increase in fault tolerance against transferred data by multi-path routing [17].

This paper proposes an efficient algorithm to the network fault tolerance enhancement against fault occurrence on the nodes operation. Indeed, the proposed algorithm unlike most related work increases the network fault tolerance against faulty nodes. To fault tolerance enhancement against the mobile nodes operation, the proposed algorithm uses natural redundancy of MANETs to select various bake up nodes for each node. Back up nodes selection to mobile nodes is a fundamental challenge for researcher, due to random movement of mobile nodes. In this regard, the proposed algorithm tries to predict the mobile nodes movement path. Thus, the proposed algorithm chooses the mobile nodes with same movement path as back up nodes for each other. Of course, selecting the backup nodes with same movement route leads to increase in time of backup nodes adjacency. So, the proposed algorithm does not require to backup nodes updating at short time interval.

This paper has been organized as following: In Section I, previous related works have been presented and discussed. In Section II, the proposed fault tolerance algorithm is explained. The results of simulation of the proposed algorithm are then presented in Section III. Finally, in Section IV, obtained results and future works are explained.

2. Related Works

Fault tolerance is the capability of systems that allows them to perform properly even when faults have occurred [27-28].The aim of increasing the fault tolerance of the systems is to provide the network users with reliable services even in case of happening. Researchers have tried to find the most appropriate alternatives for the removed nodes from among the remained nodes by choosing an interface node. Indeed, the interface node is responsible for coordinating nodes to find an alternative for the removed nodes. The first node which is informed of the removal of another node is considered as the interface node. The main disadvantages of this method are first exchanging too much of data for finding the best alternative node, and second the focused perspective of this method on the interface node [27]. Therefore, the main aim of increasing fault tolerance is ensuring consistent delivery of services to users. Using nodes redundancy in MANETs in such applications as emergency applications, military applications, and medical care applications plays a very important part in increasing networks fault tolerance, where the placement of nodes in the environment is of high importance [27], [28]. Hence, in the above-mentioned applications, as soon as a fault happens in one of the nodes, a backup node is replaced for the removed node and the data of the removed node are assigned to the new backup node [22]. In these applications, for some reasons which have already been mentioned, it is likely for the nodes to be faced with a fault at any time. Therefore, the backup nodes which are naturally presented in MANETs must always be used in order to increase the networks fault tolerance [11]. However, due to the random movement of nodes within the network, this issue has become a big challenge for the researchers. In [23] the intended network, services are shared among several groups which constitute a connected set K together. When a fault happens in any nodes, other remained nodes are used as a backup node for the removed node [22].

3. Proposed Algorithm

The happening of faults in MANETs can be quite persistent and transient. Besides, faults can originate from hardware or software sources [11]. Transient faults are usually removed on their own immediately after they happen in the network. Therefore, like almost all other studies in this area, the present paper is aimed to increase the fault tolerance of the network against persistent faults. Mobile nodes persistent faults within a path can happen due to such causes as disappearing of the nodes because of their movement, terminating energy sources of the nodes, environmental disasters like fire and flood, damaging the nodes by human beings or animals, etc [13]. In order to increase fault tolerance of the networks, most researchers have only focused on the faults happening in the transmitted data. This happens when increasing network ability against node faults is directly related to the increase of network tolerance against transmitted data faults [14]. Thus, selecting backup nodes can be an effective strategy in order to increase network fault tolerance in most MANETs.

Considering the fact that MANETs are always in motion and these networks are very dynamic, so the selection of backup nodes is a big challenge for all researchers. To solve this problem, the adjacent nodes are to be taken as backup nodes. On the other side, defining different algorithms for these networks need to take place with the least amount of redundant data transmission. In order to reduce the amount of redundant data transmission within the network, the proposed algorithm uses the following strategies:

- Backup nodes can be used either as cold or hot in order to be replaced for the primary nodes. In the cold backup method, immediately after a fault happens in the primary node, the backup node is replaced for the primary node. In hot backup method, backup nodes are replaced for the primary nodes during certain time intervals alternatively [16]. It has been shown that the cold backup method has less data over head and it is more efficient than the hot backup method. Therefore, the proposed algorithm applies the cold backup nodes to replace with primary mobile node.
- Nodes with the same route require less data exchange compared to the nodes which have just been placed in the primary nodes route. Therefore, the proposed

algorithm uses those nodes as the backup nodes which most likely have the same route as the primary node. For this reason, the nodes are informed of the adjacent nodes in specified time intervals and after receiving data from the adjacent nodes, each node attempts to insert new data in its backup nodes table, as shown in table 1.

The proposed algorithm also defines a backup nodes table for each and every mobile node in order to assign backup nodes to them. Table 1 shows the structure of a typically backup table of mobile nodes. This table is used to store the information related to the adjacent nodes in each mobile node. In this table, $Node.ID$ represents the ID belonging to the adjacent node. $Time$ Field represents the period of time when the two nodes have been adjacent. $Re-select$ Field represents the number of times that each node has been waiting to receive data from the adjacent nodes in order to specify their current state. $Status$ Field represents the enabled or disabled status of the adjacent nodes. In order to update the backup table, the following instructions should be followed step by step:

Table 1. The structure of a backup table in mobile nodes.

Node. ID	Time	Re-Select	State
10	12.54	0	1
5	0	0	1
7	22	1	0

a. In order to be informed of the current status of adjacent nodes, mobile nodes attempt to send a hello message to them at certain time intervals.
b. Before sending hello message to adjacent nodes, each node sets the status field value of all the rows in the table equal to zero. The reason is being able to identify enabled or disabled status of all adjacent nodes right after the backup table is updated.
c. As soon as the adjacent nodes receive the hello message, the ID is transmitted to the node which has sent the hello message. The sender node searches the received IDs in its backup table right after the receiving the response. After searching the nodes IDs in the backup table, one of the following issues may occur :
    1. The new $Node.ID$ may not be found in the backup table. In this case, receiver node inserts the new nodes ID into the backup table.Obviously the time when the two newly nodes have been adjacent to each other must be zero. Besides, the value of $re-select$ field for this sample of nodes is zero and the value of the status field is considered as active or one. In table 1, it is supposed that node 5 has the following condition. This table specifies the nodes which have recently been placed next to the current node.
    2. The new $Node.ID$ already exists in the backup table and the value of $re-select$ field of the node is zero. Obviously, in this case the adjacency time of the two nodes and also the nodes adjacency status field are changed from inactive, i.e. zero, to active and no change is required in the value of $re-select$ field. This has happened for the node 10 in table 1. This state

indicates that the new node has already been adjacent to the current node and that the adjacency time of the two nodes must increase.

3. No response is sent from the nodes which have already been inserted in the table. This may happen due to the fact that the new node and the current node have not been adjacent yet or may originate from an occurrence of faults in the transmitted data resulting in unsuccessful transmission of data. Using the adjacent nodes field in the backup nodes table enables us to separate nodes having this status. In such cases, the value of status field of mobile nodes is zero, i.e. inactive, in the backup table. For those nodes with such states, the proposed algorithm gives them another chance to specify the status of all adjacent nodes. This is because it is possible that either the transmitted data has been lost while transmitting or the new node may be far away from the current node in a way that it is out of access for the current node for a while. In both of the above-mentioned states, it is likely that several new nodes with similar conditions may become adjacent to the current node again. For this reason, mobile nodes usually add one unit to the $re - select$ field of the new nodes when the time given to the hello message is up. If in the process of sending a hello message a response is received from the nodes with zero value for their $re - select$ field, the proposed algorithm sets the value of re-select field equal to zero again and tries to upgrade the time and status fields of the node again.

At the end of each sending hello message stage, the proposed algorithm removes the rows from the backup table with the $re - select$ field value of 2 and inactive status field. This happens because after allocating 2 chances to each node, the nodes most likely move to other points of the network and are no longer adjacent to the current node. Therefore the value of $re - select$ field must always be 0, 1 or 2.

The nodes movement route is the most essential and effective parameter to be used to choose the backup nodes in MANETs. This is possible using the nodes movement history which enables the researchers to predict the movement route of the nodes. The movement of nodes is pretty random to all points of the network [17]. This makes it almost impossible to predict the future movement route of the nodes. Regarding the backup table, there must be a plethora of possibilities about the movement of the nodes. For instance, the nodes which have been adjacent for a long time will most likely have the same movement route in future. On the other hand, the nodes which have recently been adjacent will probably move in the same direction for a long period of time. For the sake of increasing the accuracy of guesses made about the same movement route of the nodes, both the above-mentioned probabilities are taken into account. According to the pseudo code of the proposed algorithm in figure 1, after nodes are informed of their adjacent nodes status, the backup table of mobile nodes is sorted as ascending and descending based on the duration of adjacency only for those nodes with active state field. The selection of backup nodes for each node will be as a set of paired nodes. Hence, for each node a pair of two adjacent nodes is taken as the backup nodes; one of which with the highest adjacency time and the other with the least adjacency time. If a fault happens in the operation of each node, the selected backup nodes are replaced for the removed node.

Considering the random movement route of the nodes, the proposed algorithm is making an attempt to predict the nodes movement route. Thus, after completing the backup table, the proposed algorithm selects a pair of nodes as the backup nodes for the mobile nodes. As soon as a fault happens in the performance of the nodes, firstly the node having the most duration of adjacency is chosen as the backup node. If a fault or problem happens for the first backup node, the backup node with the least adjacency time is replaced for the primary mobile node. Undoubtedly, there are some priorities in assigning the nodes as the backup nodes for the primary mobile node. Therefore, the selection of the main backup node to be replaced for the primary node is done based on those priorities.

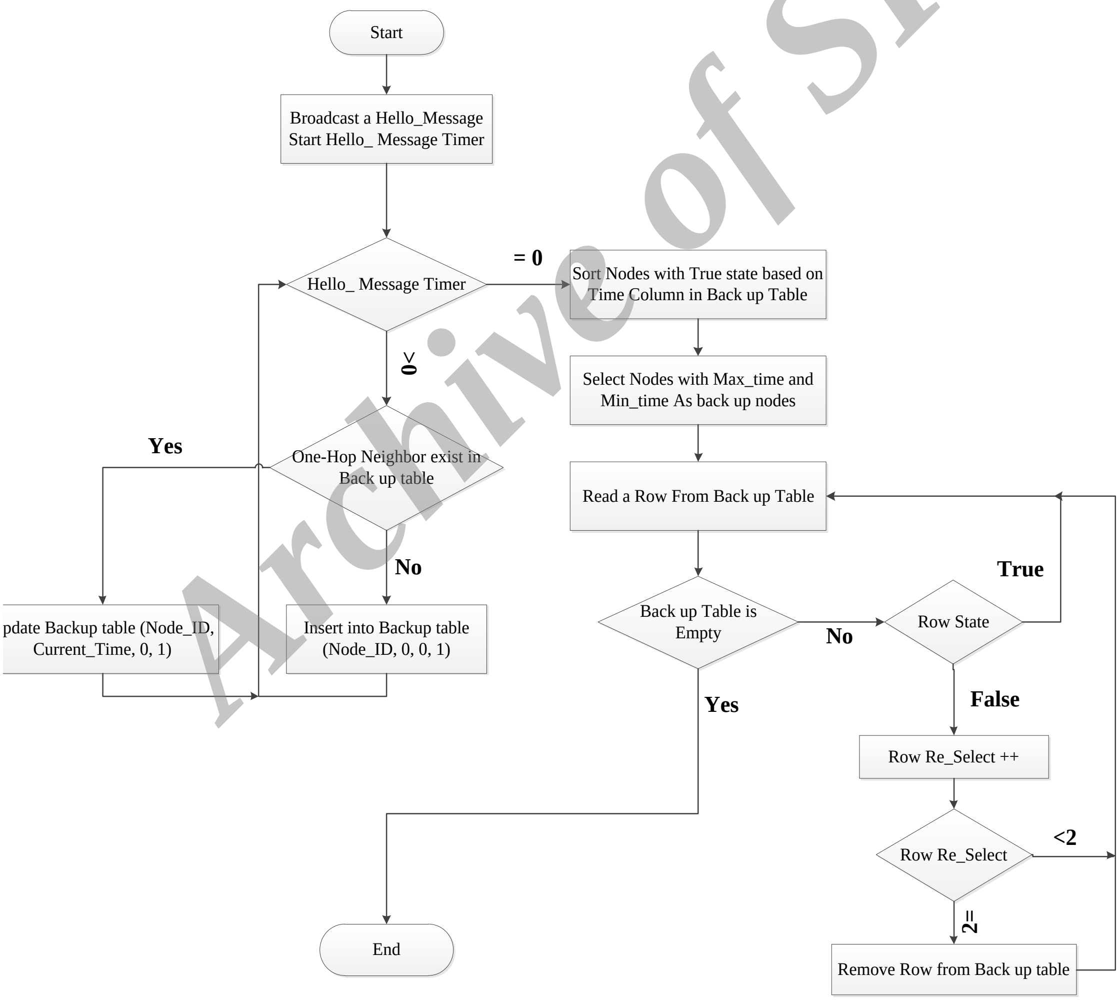

Figure1: Pseudo code of the proposed algorithm.

Figure 1 shows pseudo code of the proposed algorithm. According to this figure, it can be seen that backup nodes are selected based on backup table of mobile nodes. Backup nodes with high probability has same route with their primary node, because the proposed algorithm predicts the nodes movement within the network. Of course, the proposed algorithm chooses several backup nodes for each node. In this regard, the backup nodes can use along with the primary nodes for a long time. The proposed algorithm is a distributed algorithm and it can be used for MANETs with high dynamics.

4. Simulation Results

In this section, the performance of the proposed fault tolerant algorithm is evaluated by NS 2.35 simulator. Different parameters that are used in our simulations are taken according to table 2 [24]. For this sake, 50 mobile nodes in a $2000m \times 2000m$ terrain are randomly distributed. The speed and the movement of all the nodes will change by the change of the pause time. The pause time parameter, in mobile ad-hoc networks, has inverse relationship with the network dynamically. The mobility model of the nodes in the simulated environment is also a random model. Besides, the range of data transmission of the nodes is considered to be 250 meters. All the implemented scenarios for the purpose of simulation run for 900 seconds.

Another parameter that needs to be taken into account for the simulation of mobile ad-hoc networks is the traffic generation model for the data that exists between the mobile nodes. To generate traffic between mobile nodes, the model presented in [24] has been used. In this model, four pair of nodes has been used as the source and the target nodes for sending and receiving data. The source nodes attempt to make packages at certain time intervals and send them to the target nodes regularly. The used traffic generation model in the proposed algorithm is known as CBR and the scheduling of time of sending data by the source nodes is defined according to table 3. Table 3 fields are the source node address, the target node address, the number of packages sent by the source node, the size of packages sent by the source node, time intervals between sending packages, the beginning time, and the finishing time of sending packages by the traffic generation model respectively. With choosing and setting various efficient parameters in simulation scenarios, the implementation process of the proposed algorithm begins.

Table 2.Parameter values inthe simulation

Terrain	$2000m \times 2000m$
Simulation time	900 s
Number of nodes	50
Mobility model	$random\ way\ point$
Speed of the mobile nodes	$0\ to\ 10\ m/s$
MAC protocol	$IEEE$ 802.11
Radio propagation range	250 m
Radio propagation model	$Two\ Ray$
Channel Type	$Wireless\ Channel$

Table 3.Timing of traffic TGTFG generation between nodes

source	destination	items to send	item size	interval	start time	end time
18	16	10000	512	5 S	70 S	100 S
10	27	10000	512	2.5 S	82.49S	199 S
21	0	10000	512	0.8 S	91.39S	248 S
14	17	10000	512	1.1 S	107.8S	274 S
18	16	10000	512	5 S	70 S	100 S

Figure2 shows the effect of the number of faulty nodes on the number of received packages in the target node. It can be observed that with the increase of the percentage of the faulty nodes, the number of received packages both in the proposed algorithm and DSR [25] and also AntHocNet [24] decreases. It is noteworthy that since two backup nodes are chosen in the proposed algorithm, the percentage of package delivery in our algorithm is more than two others. Figure 3 indicates the cost of updating the backup nodes against the percentage of faulty nodes. From figure 3 it can be seen that the exchange rate growth of the redundant packages for among 0% to 50% of the faulty nodes in the proposed algorithm is almost 10%; while this is about 30% in DSR and AntHocNet. This is because the proposed algorithm uses several pairs of nodes as the backup node at the same time. Therefore, updating the backup tables occurs only when no backup nodes are available. According to figure 3, the decrease of the number of times when nodes are updated causes the number of redundant packages exchange to decrease as well. According to figure 4, increase in pause time leads to mobility and the dynamicity of the network decreases too. The pause time is in indirect relationship with the dynamicity of the network. In other words, the more is the pause time, the less is the dynamicity and the mobility of the network. The decrease of dynamicity of the network in the proposed algorithm increases the accuracy of the backup tables in the mobile nodes. It can be realized from figure 4 that with the increase of nodes pause time, the exchange of data in the proposed algorithm decreases.

Figure 5shows themean network energy consumption versus number of faulty nodes. Based on this figure, it can be seen that increase in number of faulty nodes leads to increase in network energy consumption. The network traffic to make decisions about backup nodes as well as insert information about neighborhood nodes in backup table increase with increase in number of faulty nodes. Sending, receiving and processing of data packets are the main resources of energy consumption in MANETs respectively. Therefore, Figure 6 shows the mean network energy consumption versus pause time. Increase in pause time leads to decrease in the network dynamically. This phenomenon decreases changes in backup table. Of course, in proposed algorithm, backup nodes are along primary nodes for a long time. So, the network traffic to gather information about backup nodes decreases. Based on figure 6, the network energy consumption decreases when the pause time parameter increases.

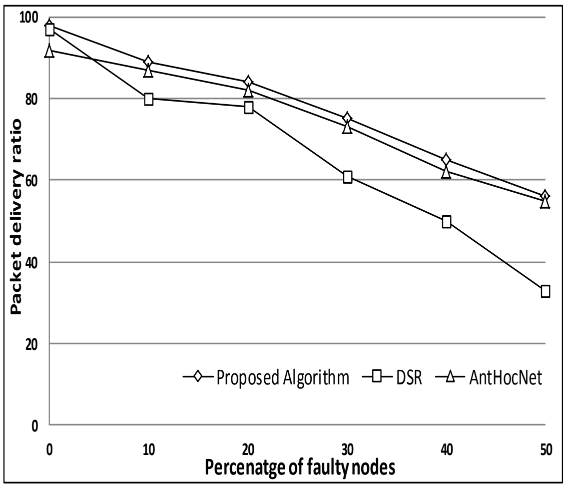

Figure 2.Effect of number faulty nodes vs. packet delivery ratio.

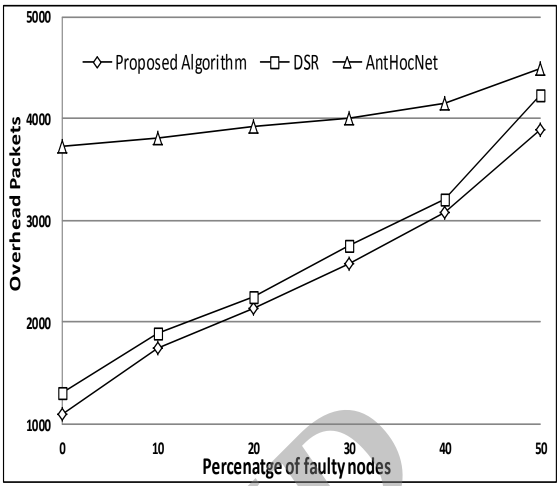

Figure 3.Effect of faulty nodes on the exchange ratio of overhead packages.

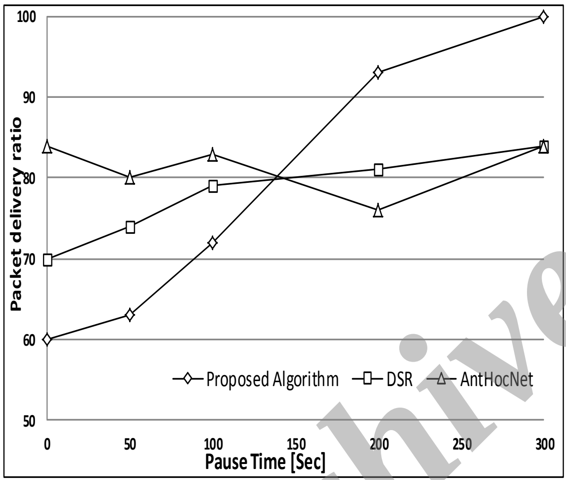

Figure 4.Effect of pause time vs. Packet delivery ratio.

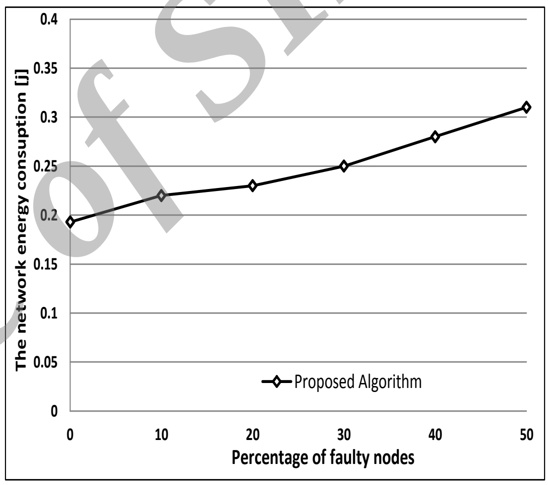

Figure 5. The network energy consumption vs. percentage of faulty nodes.

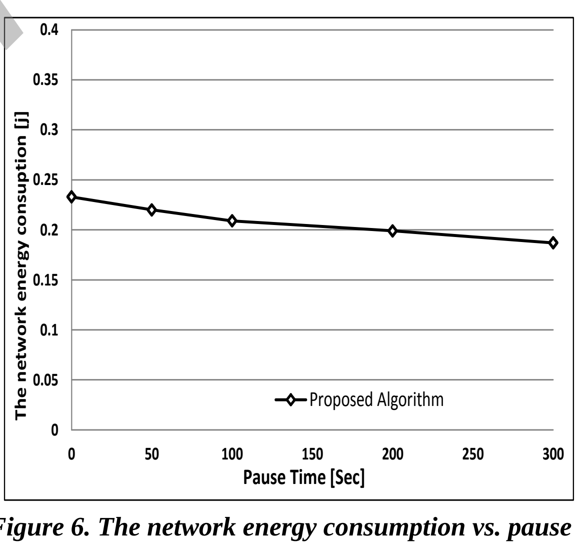

Figure 6. The network energy consumption vs. pause time.

5. Conclusions and Future Works

In this paper, a fault tolerant algorithm for mobile ad-hoc networks was proposed. Proposed algorithm chooses backup nodes for each node to fault tolerance enhancement. For backup node selection, the proposed algorithm uses the nodes with the same movement route as the backup nodes. Determining and predicting the nodes movement route has been doneby using backup nodes table. Backup nodes tables include the history of nodes adjacency which is the basis on which backup nodes are assigned to the current nodes. Backup nodes tables contain the time of node adjacency as well as one hop neighborhoods. Backup nodes tables change after nodes movement and new nodes are inserted within this table. The proposed algorithm makes decision about backup nodes based on backup nodes table. It chooses nodes with same movement route from backup nodes table as backup node. The proposed algorithm increases the network performance as well as the network energy consumption and packet delivery ratio.

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