Multipath Routing Protocol Based on Cross-Layer Approach for MANET

https://doi.org/10.3991/ijim.v11i1.6175

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Abstract—Mobile Ad-hoc Networks (MANETs) involved in many applications, whether smart or traditional and for both civilian and military uses, and that because of their special features, where it does not depend on any infrastructure during its working, as well as the nodes in MANETs have a freedom of movement with the ability to self-configure, in addition, to working as a router or client at the same time. Moreover, MANETs considered as an infrastructure less network, so the cost of this type of networks is less in comparison to other traditional networks. On the other hand, the routing considered one of most important challenges in MANETs due to the perpetual motion and randomness of the nodes that can causing a continuous change of the network topology and thus to all paths between nodes, where finding valid paths between the nodes is the core task of routing protocols. Recently, it has been argued that the traditional layered architecture is ineffective to deal with receiving signal strength related problems. In an effort to improve the performance of MANETs, there has been increased in protocols that rely on cross-layer interaction between different layers. In this paper, a Cross-layer design among Network, MAC and Physical layers based on Threshold Multipath Routing Protocol (CTMRP) is proposed. The CTMRP is designed for decision maker based on threshold value of average paths signal for efficient transmission of the Text, image, audio and video as well as sending the data via multiple paths, which mitigate the negatives effects causes from forcing the nodes to send the data via single. The Route Discovery Delay, Number of RREQ Messages, Number of RREP Messages, End-to-End Delay, Packet Delivery Ratio (PDR), and Throughput were selected as the main performance evaluation metrics. The results show that the proposed algorithm has better performance and lead to increase stability of transmission link.

Keywords—MANETs; DSR protocol; Multipath; Threshold, Cross layer, Broadcasting.

1 Introduction

Communications is a key necessity in life and that depend on them most are sectors, whether commercial, industrial, agricultural, educational, and others like, whether civilian or military activities. From these essential services, we can conclude that one of the most important reasons for success in the aforementioned activities is to provide an effective communications system in terms of speed, security, compatibility, and reliability. Communications are divided into two basic types namely: wired and wireless communications and each one of them can be divided into different subtypes. This paper proposed a new approach that focuses on providing an effective communication system to improve the performance of MANET, which is one of the types of wireless network that uses related techniques of routing protocols.

Most of the previous researches had been carried out to determine the performance of MANETs, where numerous researches show that MANETs performance is not constant, due to the high mobility of the nodes, low coverage problem, network load and network size [1,2]. The desired end of any wireless communications system is the exchange of data with high reliability and speed while ensuring the lowest rate of errors and problems that may arise during the operation of the network. Due to the different composition and work of the MANET, they face special challenges and obstacles stemming from the nature of the wireless nodes, which relies on self-configuration and play the role of the router and the client at the same time without having to rely on any infrastructure or base station6.

In [3] proposed a mechanism to provide load sharing to transfer data between the source and the destination, and by allowing transmission of packets through multipath. The proposed idea in this paper is based on the measure of the signal strength of each path for comparing signal strength with the noise, however, in case the value of the signal strength is greater than the noise, then this path is considered one of the best available paths that will use to send the data. The results showed the reduction in the overhead, delay, congestion, as well as increasing data transmission between source and destination. In [4] proposed a mechanism to choose the best route that have been discovered through the process of route discovery, while according to the standard DSR algorithm, the minimum hop count is the only metric for choosing the best path, but other metrics has been added in this proposed study, such as: maximum residual energy, maximum available bandwidth, minimum load, where the priority to choose the best path is the path with the maximum energy and minimum hop count, but in case there are routes which have the same energy and hop count, then it should be taking into consideration the maximum available bandwidth and network load respectively. In [5] proposed a mechanism to reduce the flooding of RREQ messages in the route discovery phase. In this study authors proposed an algorithm for adding an additional condition before re-broadcasting the RREQ message by the intermediate nodes, where each intermediate node, upon receipt the RREQ message will check three parameters: its own residual battery, received signal strength, and speed. The node will only re-broadcast the RREQ message if its measured parameters have values within the predefined threshold value, otherwise, it will be dropped. The results from the proposed study show an enhancement in the performance of the networks in terms of residual battery, average end to end delay, average jitter and throughput.

In this paper, an Efficient Multipath Cross-Layer design among Network, MAC and Physical layers, called Signal Strength Based Stability (CTMRP) is proposed that considers the signal strength to select path for reliable data transmission across the network. It reduces the link failures as well increase the lifetime of Network through the distribution of traffic load. The DSR was chosen because it offers the best performance in overall compared with the other routing protocols, especially in small to medium-sized networks and with nodes speed from slow to medium [6]. The proposed mechanism will be clarified in detail in the methodology section depend on an update the DSR protocol algorithm.

1.1 Mobile Ad hoc Nnetwork

Mobile ad hoc networks (MANETs) are infrastructure less wireless networks, where it characterized in a number of properties, such as self-configuring, self-forming, self-healing network, random mobility for the nodes, transmission through multiple hops, in addition, to the decentralized nature which improves the scalability [7]. The devices in MANETs have the freedom to move randomly in all directions, which play the roles of both the client and router together during sending or receiving the data in the network, where it must depend on in its own information to take the decisions to choose the paths which lead to the destination, which that create the challenges on finding and updating that information constantly [8, 9].

The fundamental objective of MANET is to permit a gathering of communication nodes to set up and keep up a network among themselves, without the backing of a base station or a focal controller. The absence of infrastructure in MANET requires the nodes to perform the network setup, administration, and control among themselves. Every node must act as a router and data forwarder in addition to playing the role of a data terminal [10].

1.2 Routing Protocols

As there are different types of networks, there are different types of routing protocols also which have similar aspects in the main task which is the routing, but they differ in a way to work, where each one has a special algorithm is different from the other. Routing protocols are originally designed for wired networks which are not adequate and sufficient to ad hoc networks, although there is a big difference in term of wired network topology that is more of stability compared with the topology of the Ad hoc networks which changes constantly [11]. When designing a routing protocol that will work within the ad hoc network environment, it should be noted that the ad hoc network has to work within a limited bandwidth, in addition to limited resources in terms of node storage capacity, CPU capabilities, and energy resource since it depends mainly on batteries [12]. We can infer from the above, the fundamental differences between routing protocols for wired networks that consume large amounts of bandwidth and resources of the nodes, like memory capacity, processor capabilities, also deal with the fixed and stable devices, topologies and routing protocols for ad hoc networks [13, 14, 15]].

1.3 Dynamic source routing protocol (DSR)

The DSR protocol is classified as one of the reactive routing protocol used in multi hop wireless Ad-hoc networks. It consist two main stages one is route discovery, second is route maintenance. The route discovery stage begins when the source node want to send the data to a node not exists in its routing table. The route maintenance stage begins when one of the identified routes is broken or failed 16, 17].

Figure 2 shows the node S, initiating a route discovery by flooding RREQ message to all its neighbors' nodes. When the intermediate nodes receive the RREQ message and after each of them applied all the required checks, then each node rebroadcast the RREQ to all neighboring nodes in all directions. The process continued whereby other intermediate nodes perform the same process until the RREQ message reach to the destination node D.

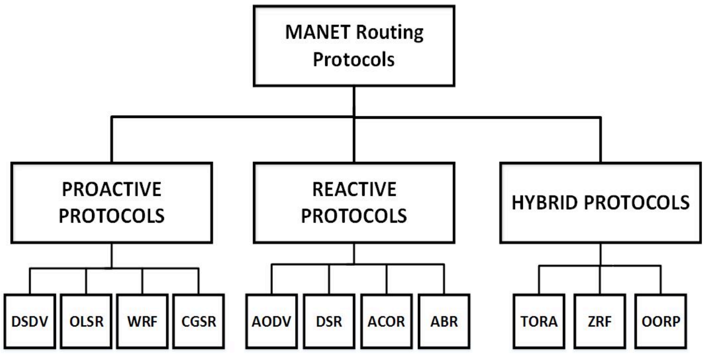

Fig. 1. MANETs routing protocols classifications

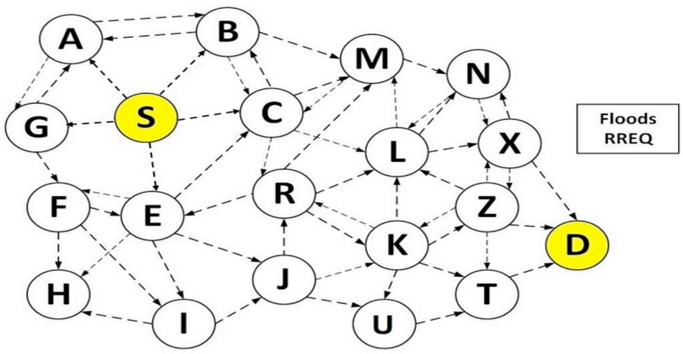

Fig. 2. Propagate RREQ for Intermediate nodes in DSR protocol

When the source node S receives the required routes through the reply message RREP, it keeps these routes in its cache memory to be used, when next times its want to send to the node D. The default mechanism for arranging the routes and choosing the best one is according to the minimum hop count [18]. The path with a minimum number of hops can be a low performance path in terms of bandwidth, speed, delay, security, and congestion, and especially the routes between spaced nodes. Furthermore, the hop count factor will totally ignore the other most important factors like distance and signal strength, which will cause an increased in the probability of sending the messages via stale or less quality routes than other available routes. However, this will certainly lead to what has been previously mentioned such as an additional consumption of bandwidth, increase the overhead, delay and latency.

Finally, even if there are many paths available to the destination the source node sends all the packets via single path, and this result into a number of drawbacks, as follows:

- Routing that involve sending all packets from source to destination going along the same way is called single path routing and this type of routing need high transmission power for those nodes included in transmission.
- Due the fact that all packets must be transmitted in sequential manner from source to destination along a single path that causes more delay for data transmission.
- Malicious node eventually might partake in the data transmission which results in packet drops and security issues.
- Noise data transpire in high rate because of the fluctuation in radio connection that happen in transmission between nodes that are part of the transmission.

According to IEEE 802.11 architecture and protocols, The Point Coordination Function (PCF) is used in infrastructure networks, where an Access Point (AP) is used to co–ordinate access to the radio spectrum. Of more interest to ad hoc networks is the Distributed Coordination Function (DCF) which is used when there is no Access Point (AP) available, and individual 802.11 nodes must contend with each other for access to the media in a distributed fashion.

The DCF provides the basic access methods of the 802.11 MAC protocol and is based on a Carrier Sense Multiple Access with Collision Avoidance (CSMA / CA) scheme. The PCF is implemented on top of the DCF and is based on a polling scheme. It uses a Point Coordinator that cyclically polls stations, giving them the opportunity to transmit. Since the PCF cannot be adopted in the ad hoc mode, it will not be considered hereafter. According to DCF, before transmitting a data frame, a station must sense the channel to determine whether any other station is transmitting. If the medium is found to be idle for an interval longer than the Distributed Inter Frame Space (DIFS), the station continues with its transmission.as shown in figure 3.

2 Proposed Method

Several researchers have focused on study the effective path calculation based on their considered route selection metric (distance, number of hop, etc.) to find the most suitable path to forward packets. More optimized algorithms can be design by allowing Physical and MAC layers to provide information to Network layer. The Physical layer information can be used for signals values (Threshold), and scheduling information can be analyzed by MAC layer. Network layer can facilitate in best path selection based on information received from PHY and MAC layers. Figure 4, shows the overall proposed cross layer architecture with different parameters at different layers. When Route Reply receive, source node calculates average signal strength value for each path, if signal is equal to or greater than threshold value forward message via multipath, otherwise select route with minimum number of hope.

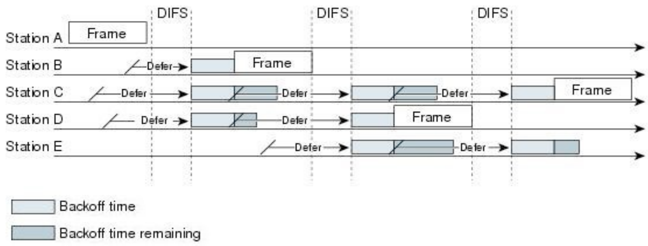

Fig. 3. Basic Access Mechanism

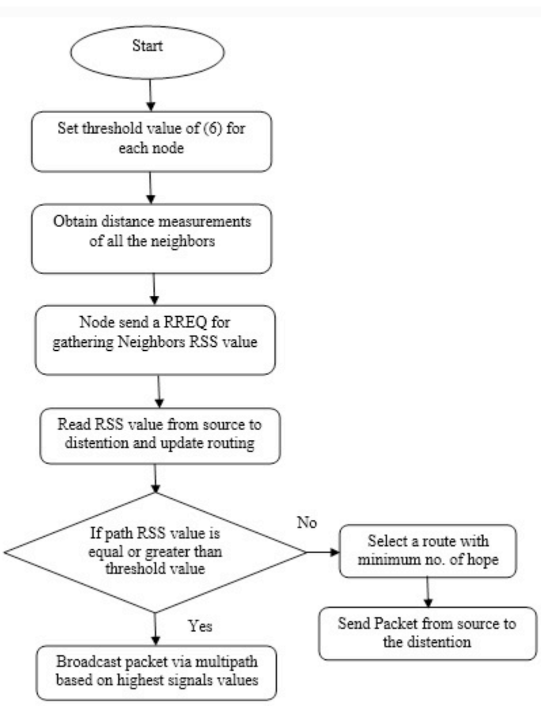

Fig. 4. Route Request messages

The proposed method provides to perform adjustments in the mechanism of arrangement the routes in cache memory according to best signal strength (SS) of path, where the total SS of the path is the sum of SS of every node on the path. By using this new mechanism we can save more than one path, the source node S will choose the path with highest and ignoring the minimum number of hop count default factor. It allows the nodes to send data through multiple paths, as shown in Figure 5.

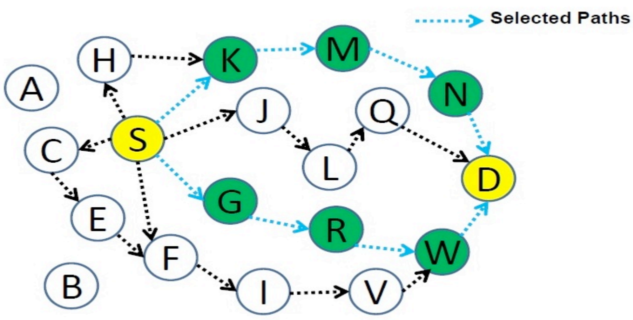

Fig. 5. The positive effects after apply the proposals

3 Implementation

In the phase of practical implementation of the proposed algorithms, it has been relying on designing a program that simulates the MANET network characteristics and DSR routing protocol. According to what mentioned previously, it has been using the programming language of MATLAB in the design and implementation of simulation program to apply the proposed algorithms in addition to standard DSR protocol algorithms and then the comparison of the results.

3.1 The Simulation Scenarios

There are three basic levels have been identified and defined in the prototype, which defines the various scenarios under study in this research in order to achieve the desired objectives. The first level involves the algorithms that will be studied, where we have within this level standard algorithms of DSR protocol as well as the proposed algorithms in this research. Whereas, the second level relates to the size of the network, which is determined by the number of nodes in the network, where there is in this level three different sizes of the network of 5, 10, and 20 nodes. Finally, the third level determines the speed of movement of the nodes; in this level three different speeds of 1 m/s, 5 m/s, and 10 m/s.

3.2 The Simulation Performance Metrics

The performance metrics is considered of the most important elements of any program to simulate the networks which they form indicators and evidence of the efficacy of the network and achieving its functions within the targets set. The importance of the performance metrics is derived being give us the evidence of the success of the proposed ideas, and that when comparing the results of the proposed algorithms with the results of standard algorithms of DSR protocol in MANET networks. There are five performance metrics within this designed simulation that are related to the modified and proposed algorithms in this thesis, which they are:

- Route Discovery Delay: It is the delay time elapsed in route discovery process from the first moment which the source node initiates the route discovery process until it receives the responses from the destination node.
- Number of RREQ Messages: It is the total number of RREQ messages which distributed from all nodes in the network during route discovery process until reaching the destination node.
- Number of RREP Messages: It is the total number of RREP messages which sent from the destination node to the source node as a response to the RREQ messages during the route discovery process.
- Delay (End-to-End): It is the delay time elapsed to send a specific size of data from the source node until reaching to the destination node.
- Packet Delivery Ratio (PDR): It is the ratio of the traffic received to the traffic sent in the network.
- Throughput: It is a rate of successful data delivered to destination node over the communication channels in network.

4 Results and Discussions

This section presents the results obtained from the simulation program for all scenarios, where will provide and discuss these results for each of the selected performance metrics separately, and then will be thrown an analytical look at these results as a whole for both standard and enhanced algorithms. Figures 5 – 10 show the obtained results for the five performance metrics.

According to what has been explained previously, DSR protocol depends on the blind broadcast in standard algorithm to all nodes in the process of route discovery, so it is natural increasing the number of RREQ messages when increasing the number of nodes in the network and this, of course, which will increase the delay of route discovery process also. Moreover, the increase in the number of nodes in the network will give further paths, which can be explored between the source and the destination nodes in the network, which explains the increasing number of RREP messages when increased the size of the network, which in turn contributes to increasing the value of the delay as well.

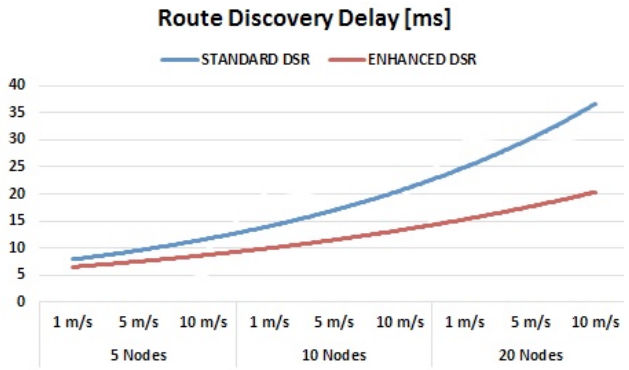

Fig. 6. Route discovery delay results for all scenarios

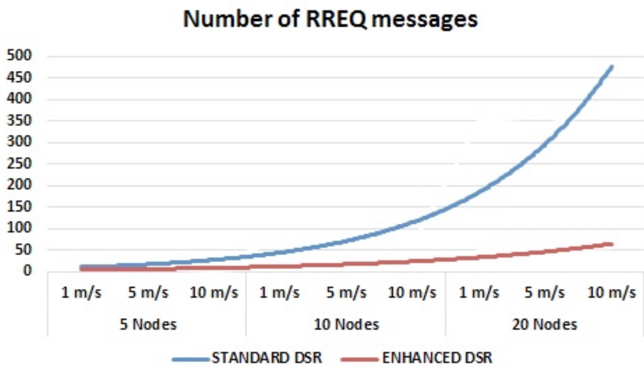

Fig. 7. Number of RREQ messages for all scenarios

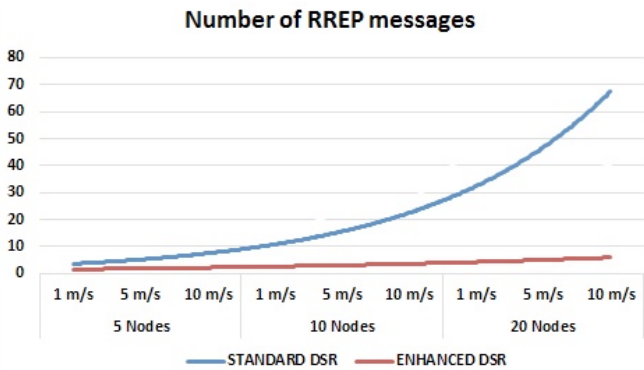

Fig. 8. Number of RREP messages for all scenarios

On the other hand, has been canceled the dependence on the blind broadcast in the enhanced algorithm, and adopted instead on the filtering the transmission according to the signal strength of the nodes and prediction the position of the nodes. This is what leads to the reduction of the number of nodes that exchange RREQ messages, which gives the same effect of reducing the size of the network, which means that when applying the enhanced algorithm on the big network, the results will be better than applying the standard algorithm on the small network in general as shown in the obtained results.

The calculation of the end-to-end delay value depends on three basic factors, where these factors are: the volume of data transmitted the rate of transmission, in addition to the number of nodes in the path. We've been relying on our study on the fixed volume of data with fixed transmission rate, which means that the only variable, which controls the value of the end-to-end delay, is the number of nodes in the path between the source and the destination. There are two main reasons which caused that the enhanced algorithm gives end-to-end delay value less than the standard algorithm:

- The number of nodes in the discovered paths between the source and destination are less than it is in the standard algorithm due to the adoption of the enhanced algorithm on filtering transmitter in route discovery process rather than the blind broadcast in the standard algorithm as explained previously.
- The data is sent over only one path in the standard algorithm, while it is sent through multi paths (if any) in the enhanced algorithm, which leads to split the data into parts (depending on the number of paths available to send) and send them together in parallel across this paths, which of course will lead to a decline in the value of the end-to-end delay by as much as 70%.

Naturally, the increasing the value of the end-to-end delay when increasing the size of the network, because it will lead to an increase the number of nodes in the path between the source and the destination especially the greater the distance between them. The calculated value of the PDR mainly depends on the volume of data transmitted in addition to the value of data received, which will decrease when increased the number of nodes, due to increasing the probability of packet loss with collisions which will lead to decrease the data received in the destination. The PDR in enhanced DSR is greater than in standard DSR, due to the end-to-end delay is less in enhanced DSR in addition to sending data via multi paths which will increase the delivery ratio of the data with decreasing the probabilities of collisions and packet loss, all that increase the volume of data received in the destination node which in turn increase the PDR in enhanced DSR.

Logically, the value of throughput will increase when increasing the size of the network, because that the load in network will increase when increasing number of nodes, and that in turn will increase the throughput, as well as, for the same reasons mentioned in PDR, the throughput in enhanced DSR is greater that in standard DSR. With regard to the extent of the effect of increasing the speed of the nodes on the performance metrics values, where this effect ranges from low to medium influence, where when increasing the speed of the nodes, will lead to change faster in the nodes' location in the network. This will cause a number of events, such as the connection

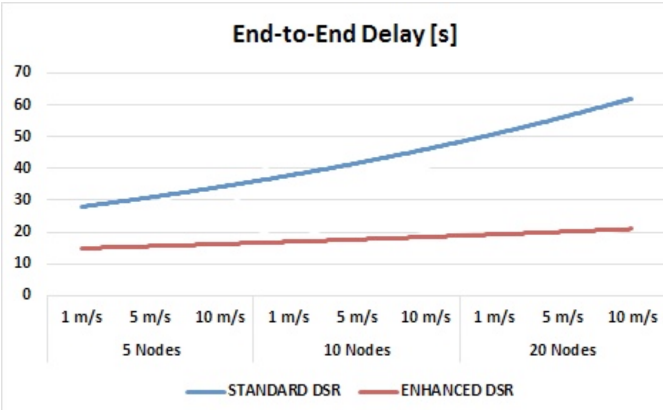

Fig. 9. End-to-End Delay for all scenarios

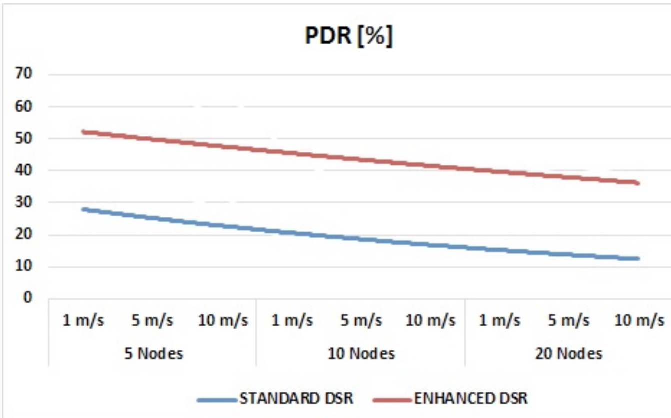

Fig. 10.PDR in all scenarios

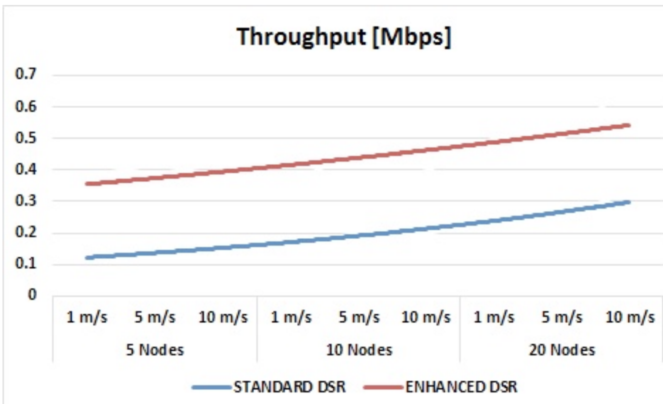

Fig. 11. Throughput in all scenarios

loss between two nodes, which will lead to the failure of all the routes that rely on them, and also, some of the signal strength of the nodes may become a good signal after it was with the low signal strength and vice versa, leading to a continuous change in the process of route discovery and its results for both standard and enhanced algorithms.

5 Conclusion

The constant motion of the nodes is one of the key challenges faced by MANET networks. The negative effects of not dealing with this challenge, such as: High consumption of bandwidth, overhead, delay and latency. The proposed modified algorithm for DSR protocol providing for performing three adjustments, and are: firstly, perform adjustments in the mechanism of re-send the intermediate nodes to RREQ broadcast messages to neighboring nodes according to the signal strength. Secondly, perform adjustments in the mechanism of arrangement the routes in cache memory, according to best signal strength (SS) of routes. Finally, allowed to the node to send the data through multi paths rather than single path. The simulation results show that the enhanced algorithm gives results better than the standard algorithm in terms of the routing traffic, delay

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Submitted 26 August 2016. Published as resubmitted by the authors 13 October 2016.