Analysis of the Interaction between Routing Protocols and MANET Parameters

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ABSTRACT
Routing protocols for a Mobile Ad-hoc Network (MANET) have been of great interest for many years as the underlying Internet routing protocols are mainly intended to support the permanent infrastructure network. This research makes an attempt to conducting a realistic and quantitative performance analysis of several key routing protocols in the same framework within MANET, which eventually helps better understand the protocols' comparative merits and suitability for deployment under different stressful and dynamic scenarios. The four routing protocols that are considered in the analysis are Optimized Link State Routing (OLSR), Ad-hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Temporary Ordered Routing Algorithm (TORA). The research asserts the fact of superiority of proactive protocol, over reactive and hybrid ones when routing the same traffic in the network. As the simulation results demonstrate, OLSR protocol has been reckoned to be a very effective and efficient routing protocol for MANET, which ensures its particular suitability, irrespective of network size and mobility. Nonetheless, among the reactive protocols, AODV performs well in a medium and high density network, with particular reference to a case where end-to-end delays are very critical.

General Terms
Performance evaluation, Routing protocols.

Keywords
MANET, OLSR, AODV, DSR, TORA.

1. INTRODUCTION
A Mobile Ad-hoc Network (MANET) is a collection of mobile devices dynamically forming a communication network without any centralized control and pre-existing network infrastructure. Lately, MANET has become increasingly popular due to its potential application in many domains. For instance, such a network can be helpful in a rescue operation or in a military battlefield, where there is not sufficient time and resources to configure a wired network or to set up a wireless network with fixed infrastructure [1]. MANET represents a complex distributed system and allows inserting the routing functionality into the mobile nodes, where the nodes must work together in a distributed manner to enable routing among them. Mobile nodes employed in such a network can join or leave the network freely and arbitrarily with no restriction, thus providing a flexible and seamless communication among the users. However, due to free and random movement of mobile nodes, the network's wireless topology may change frequently and unpredictably. As a result, the routing mechanism experiences a host of problems by being more susceptible to errors than the traditional wired network. In particular, member nodes can be affected by churn leading to routes disappearing and re-appearing, which in turn leads to sudden packet losses and higher message delays in the network. Hence, routing becomes a vital issue and a major challenge in this type of network.

The underlying Internet routing protocols are mainly intended to support the permanent infrastructure network; eventually, the properties of those protocols are found to be inappropriate for MANET. Consequently, a variety of MANET routing protocols has evolved over recent time. However, all routing protocols developed for MANET may not lead to adequate performance because of some unique MANET characteristics including, among others, dynamic topology, scarce bandwidth, power constraint and intermittent connectivity [2]. Meanwhile, the creation of an ad-hoc network with a larger scale and a higher mobility rate has become an ideal choice, especially in the field of military and vehicular networks. In what follows, there is a pressing need for a scalable ad-hoc routing protocol to support the networks that are larger by one or several orders of magnitude and speed. However, the extension of network size and mobility rate may cause more stresses and frequent link failures in the network, which subsequently may result in a huge degradation on the routing performance. Hence, it is now widely recognized that determining the specific MANET routing protocol(s) that can perform efficiently in various stressful and dynamic scenarios would be an important contribution to the existing stock of research. More specifically, it is important to contemplate how well various network parameters (i.e. node size and node mobility) and routing protocols interact in MANET, and to what extent each of the individual parameters would affect the routing performance when they are extended up to a certain degree.

Following the above background and problem statement, the study undertakes an analysis towards a comprehensive performance evaluation of several existing routing protocols, and uncovers the pros and cons of the protocols in terms of their suitability for deployment under different MANET scenarios. The study includes two reactive protocols, such as Ad-hoc On-Demand Distance Vector (AODV) [3] and Dynamic Source Routing (DSR) [4], one proactive protocol such as Optimized Link State Routing (OLSR) [5], and one hybrid protocol such as Temporally Ordered Routing Algorithm (TORA) [6]. These protocols are considered important since they cover a range of design choices, including source routing, hop-by-hop routing, periodic advertisement, and on-demand route discovery. The choice of these four protocols is also motivated by the fact that all of them have been proposed in the Internet Engineering Task Force (IETF) working group.

Although MANET has been considered as a convincing candidate for better wireless services, research to enhancing its functionality is still in its infancy. Some studies (e.g. [7], [8], [9]) had been conducted to evaluate the performance of MANET routing algorithms. However, the simulation parameters and performance metrics used by the authors of those researches are substantially different from those used in our simulations. In [5] the author simulated different routing protocols in various mobile scenarios and with different traffic patterns. The experimental results illustrated that the hybrid SBR protocol outperforms OLSR and AODV in networks with high mobility and a small number of data sinks. In [4] Noorani used Network Simulator-2 (NS-2) and conducted a performance study between two reactive routing protocols under TCP Vegas. The results in the research demonstrated the superiority of AODV over DSR protocol. However, the simulation was done only for different pause times. Node speed and also node number were kept constant in the experiment. The authors in [10] conducted a performance evaluation of routing protocols and showed that the proactive protocol has the favorable delay, throughput and goodput, however, at the cost of a higher routing load. In [11] the delay characteristics of different routing protocols were investigated, where both the static and mobile network topology with 3, 5 and 10 nodes had been realized. In [12] the performance of DSR and TORA routing protocols were compared, where DSR had been chosen as a protocol preferable to TORA. The study, however, was conducted considering fixed number of nodes and lower network congestions. In [13] a performance investigation of MANET routing protocols was made through measuring throughput, delay and routing traffic. The authors considered random waypoint mobility model to generate the mobility rates with different relative speeds rather than with absolute speeds and pause times. However, from their study, it is a bit unclear as to at what extent the protocols are impacted by the dynamics of MANET. Besides, the study was limited to realizing low load traffic in the network. One can observe the difference in that our study presents the scalability of the protocols by employing heavy congestions with high load traffic for both FTP and HTTP. The rest of the paper is organized as follows. Section 2 of this paper describes the existing routing protocols used in the study. Section 3 presents the simulation environment, while a discussion on the results obtained upon running the simulation experiments is documented in section 4. Finally, the conclusions along with exploring avenues for future research are drawn in section 5.

2. ROUTING PROTOCOLS

A routing protocol is mainly used to discover the shortest and most efficient path(s) during the data transmissions in MANET. Moreover, the routing algorithm establishes the communications and formalizes agreement among nodes, which is essential to the overall performance of the network. This section continues with a short description of different MANET routing protocols and presents a comparison among them.

2.1 OLSR

OLSR works as a proactive (table-driven) routing protocol i.e. frequently exchanges topology information with other nodes of the network. The responsibilities of OLSR are to minimize the required number of control packets' transmission and also to shorten the size of the control packets.

2.2 AODV

AODV utilizes an on-demand technique in order to discover the routes. The route between two endpoints is formed as per requirement of the source node and maintained as long as the route is demanded. Moreover, the protocol uses a destination sequence number to recognize the most recent path and to guarantee the freshness of the routes.

2.3 DSR

DSR maintains an on-demand approach and often prevent the control packets from consuming much bandwidth. Like other on-demand routing protocols, DSR does not provide the transmission of any periodic hello packet (beacon).Instead, it establishes the route by flooding a route request packet in the network.

2.4 TORA

TORA is known as a hybrid protocol, which can simultaneously support both table-driven and on-demand approach in multi-hop wireless networks. TORA is implemented on the top of the Internet MANET Encapsulation Protocol (IMEP).

3. EXPERIMENTAL DESIGN

This section describes how the study is carried out. More specifically, it deals with the analytical framework, including the methodological issues, such as network scenarios and parameters, evaluation procedure and methods of assessments.

The research is conducted using a discrete event simulation software known as Optimized Network Evaluation Tool (OPNET) [14], which is just one of several tools provided from the OPNET Technologies suite. In order to undertake the experimental evaluation, the most recently available version, namely OPNET Modeler 16 has been adopted in our study.

Specific network layer protocols demand on an own set of performance metrics to evaluate the network efficiency. In order to evaluate the performance of the routing protocols, end-to-end delay and throughput are considered as performance metrics in our study. With the introduction of a variety of network parameters, end-to-end delay and average throughput are substantially affected by the routing algorithm; hence, such parameters often play an important role in the selection of an efficient routing protocol in any communication network.

The network models of the current study are designed, in the OPNET simulator, by taking help of different network entities. The network entities used during the design of the network model are wireless server, application configuration, profile configuration, mobility configuration and workstations (nodes). These model objects are basically a series of network components that allow attribute definition and tuning. Application configuration is an essential object that defines the transmitted data, file size and traffic load. More often, it supports common applications, namely, HTTP, FTP, Database, Email, Print and so on. We have chosen FTP and HTTP applications for data traffic analysis where each application is considered with heavy traffic load (individually), in line with the requirement for bandwidth utilization. On the other hand, profile configuration is employed to create the user profiles whereas these profiles are specified on different nodes for generating the application traffic. For instance, an FTP profile is created in a profile configuration entity in order to support the FTP traffic, which is generated by an application configuration entity.

Table 1. General parameters

General parameters	Value
Area	1000x1000 square meters
Network size	30, 60 and 100 nodes
Data rate	5.5 Mbps
Mobility model	Random way point
File size	High load
Traffic type	FTP, HTTP
Mobility speed	10, 20 and 30 m/s
Simulation time	600 seconds
Address mode	IPv4

Table 2. Wireless LAN parameters

Wireless LAN parameters	Value
Channel settings	Auto
Transmit power(W)	0.005
Fragmentation threshold (bytes)	1024
Buffer size (bits)	256000

Table 3. AODV parameters

Parameters	Value
Active route timeout (seconds)	3
Hello interval (seconds)	Uniform (1, 1.1)
Allowed hello loss	2
Node traversal time (seconds)	0.04
Timeout buffer	2

Table 4. DSR parameters

Parameters	Value
Route expiry time (seconds) in route cache	300
Expiry timer (seconds)	30
Max request period (seconds)	10
Max buffer size (packets)	50
Max maintenance retransmissions	2

Table 5. OLSR parameters

Parameters	Value
Hello interval (seconds)	2.0
TC interval (seconds)	5.0
Neighbor hold time (seconds)	6.0
Topology hold time (seconds)	15.0

Table 6. TORA parameters

Parameters	Value
OPT transmit interval (seconds)	300
IP packet discard timeout (seconds)	10
Beacon period (seconds)	20
Max beacon timer (seconds)	60
Max retries (number of attempts)	3
Max IMEP packet length (bytes)	1,500

One of the other important entities is the mobility configuration, which is used for the purpose of determining the mobility model of the nodes. Moreover, it has to select several appropriate parameters such as speed start time, stop time, pause time and the like, to properly control the movement of the nodes in the network. The reason for configuring the mobility object is to allow the nodes to move within the specific allocated network area, which is chosen as 1000 square meters in our simulation network model. In other words, the traffic generated from outside this specific range, if any, will not be taken into account. In order to configure the nodes with a mobility option, a widely used mobility model known as the default random waypoint mobility is used for all simulation purposes in the present study. The combination of pause time and velocity sets up relative degrees of mobility between mobile nodes in the simulated network. To symbolize the mobile behavior of the nodes, the speed of the node is initially set to 10 m/s with a pause time of 50 sec to observe the network behavior with low mobility. At some later stage, the speed is increased to 20 and 30 m/s with the same pause time so that the nodes can travel with greater speed in the network. The reason for increasing the node speed is to observe the impact of mobility on network performance. The server module is basically a WLAN server, which is configured to support and control the application services (i.e. FTP and HTTP) based on the user profile. The connection speed is set at 5.5 Mbps in our study. Finally, all mobile nodes are configured to generate FTP and HTTP traffic randomly, with the ability to route the data packets to the desired destinations.

Table 1 demonstrates the general parameters used in the process of all simulation experiments of the study. Meanwhile, the parameters used for wireless LAN configuration are portrayed in Table 2. The buffer size is set to 256,000 bits because a medium flow of application has been intended to be generated in our experiment. Likewise, in order to avoid the potential problem related to manual error, the channel setting is fixed at that which is auto-assigned. The channel setting parameter is important since it specifies the bandwidth of the radio channel for physical layer transmissions. This auto-assigned option sets the bandwidth to 22 MHz. Finally, Table 3, Table 4, Table 5 and Table 6 are presented to show the parameters utilized to configure the proposed existing routing protocols.

4. RESULTS AND ANALYSIS

This section outlines how well the mentioned four routing protocols respond to the performance differentials (i.e. throughput and end-to-end delay) when subjected to different network stresses and topology changes. We considered total simulation time as 600 seconds over which the performance statistics are collected. During the course of each experiment, five replications are run with different constant seeds in OPNET simulator in a bid to ensuring the simulation accuracy. The constant values of the seeds are used since it minimizes the variance of the simulation results and thus allows a better comparison of the protocols.

4.1 Varying Node Size

The routing performance is evaluated using TCP Selective Acknowledgment (SACK) since this is considered as a newer and widely deployed TCP version. To observe the impact of node variation on the performance of routing protocols, the target applications are run with various network sizes (30, 60 and 100 nodes). Since it is more realistic to generate at least a low mobility rate among the nodes in MANET instead of keeping those fully static, a moving speed of 10 m/s with an average pause time of 100 sec is set to allow the mobile nodes to move slowly in the network. Throughput refers to the amount of traffic successfully received by the destination node. The routing efficiency can be predicted by observing the overall throughput achieved by the network. Fig. 1, Fig. 2 and Fig. 3 demonstrate the average throughput of OLSR, DSR, AODV and TORA against node sizes representing small, medium and large network, respectively. In our simulation, the start time of profile and application generation is set to 100 sec and 5 sec, respectively. Therefore, no application traffic transmits up to 105 sec of the simulation time. This period is often known as the warm up time. For OLSR protocol, in spite of that, one can observe that the graph starts before the completion of the warm up time. This is because during the warm up duration, OLSR has to transmit control messages in the network so that the routes can be available prior to starting the data transmission.

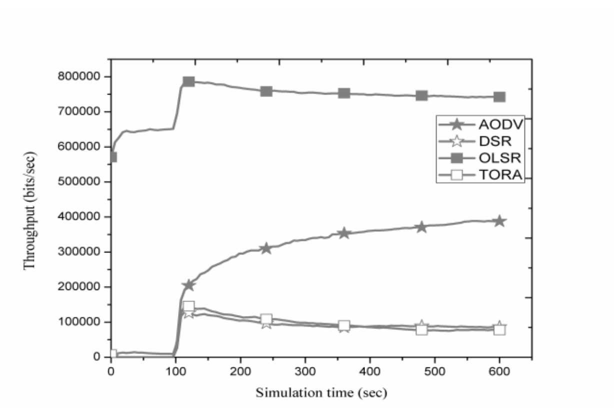

Fig 1: Average throughput for small size network (30 nodes)

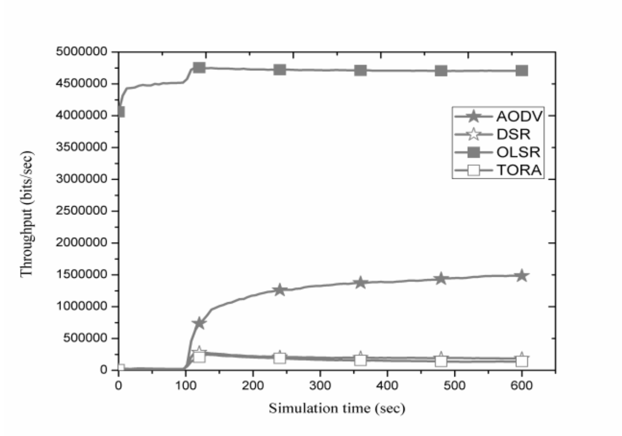

Fig 2: Average throughput for medium size network (60 nodes)

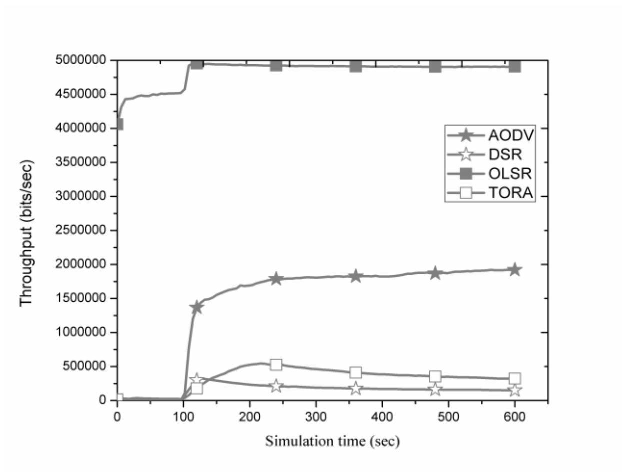

Fig 3: Average throughput for large size network (100 nodes)

In a small network, all the four protocols achieve relatively a less amount of throughput, however, with a slightly higher value in the case of OLSR. In such a network, the throughput values are found to be of lesser quantity due to the small number of nodes (i.e. 30 nodes) available for routing the packets to the destination. Over and above, all such 30 nodes are not easily obtained at a time in a dynamic environment as the nodes frequently join and leave the network in a network session.

The throughput of all the protocols is found to experience an increase for any further increases of nodes (i.e. 60 and 100 nodes), although the increase of throughput is a bit limited in the case of DSR and TORA protocol. Considering all three sizes of the network, OLSR can be reckoned as the most effective one among the four protocols. The significant performance achieved by OLSR can be considered due to the proactive characteristics of this protocol. OLSR continuously maintains and updates the routing information with the help of Multipoint Relay (MPR) nodes, resulting in the minimization of the routing overhead and maximization of the network throughput [5]. In addition, the independency of network size and network traffic also causes OLSR protocol to receive more data packets. In a high density network, the amount of OLSR hello messages becomes larger since all these messages contain a neighbor list. This will result in more network overhead. Hence it is evident that if the hello message interval would have been increased in the network, OLSR could have performed a better result even than the current one. The event of increasing hello interval decreases the periodic broadcast of the hello messages, thereby resulting in less congestion in MANET. However, the end-to-end reliability can be decreased by increasing the hello message interval. As a consequence of that, an optimized configuration is often required to demonstrate the trade-off between end-to-end reliability and network throughput. Meanwhile, among the reactive protocols, AODV adapts well to large networks compared to DSR. This is attributed to the fact that AODV follows hop-by-hop routing mechanism and eliminates the source routing overhead in the network, whereas DSR follows a source routing mechanism and the byte overhead in each packet drastically affects the total byte overhead when the size of the network increases. Similarly, in a stressful network TORA is also found to increase unnecessary overhead due to the fact of utilizing its adaptation feature (i.e. updating path information and route establishment). And to update the routing information TORA has to transmit a large number of control packets as it indirectly maintains a proactive approach. Thus, this feature eventually decreases the throughput in a TORA based network.

End-to-end delay for a data packet is measured from the time it is created to the time it is received. High end-to-end delay indicates more broken links and frequent re-routing during the transmission of the data packet. The packet end-to-end delay is shown in Fig. 4, Fig. 5 and Fig. 6.

When analyzing the packet end-to-end delay against different sizes of network, the results using OLSR protocol are of particular importance as it establishes quick connections between nodes without making significant delays. Like other routing protocols, OLSR does not use much time in route discovery mechanism. The routes are available beforehand in OLSR when the data transmission is needed, thereby resulting in the lowest end-to-end delay. Even with a higher density of the network, OLSR delay is hardly found to experience any significant increase. On the other hand, the delays experienced by TORA and DSR, especially in larger networks, are found to be of much higher. One of the factors responsible for the poor performance of TORA is related to it's formation of temporary loops within the network, where the collisions of the MAC layer are held by the transmitted routing packets. Consequently, the links to neighbor nodes are broken by IMEP. Besides, in response to link failures, TORA sends more updated packets, whereas an acknowledgment of the re-transmitted update packet might not be received, resulting in a serious congestion of the network [8]. As a result, an extremely high delay is introduced in the network, which is further enhanced with an increase in the network size. Meanwhile, DSR adopts a reactive approach, where the data packets keep on waiting in buffers until a route is discovered enroute to the destination. Apart from that, DSR follows a source routing mechanism where the complete route information is included in the packet header, causing an increase in the packet length, and thereby an increase in the delay experienced by the packets in DSR network. Finally, Unlike in DSR and TORA, the performance of AODV is not found to significantly decrease with the changing of network sizes. In medium and large network, in particular, the delay growth of AODV can be considered rather reasonable.

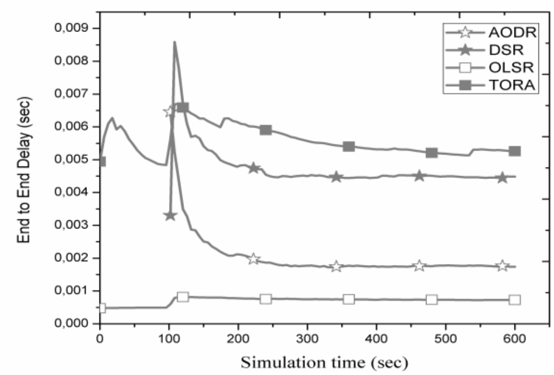

Fig 4: End-to-end delay for small size network (30 nodes)

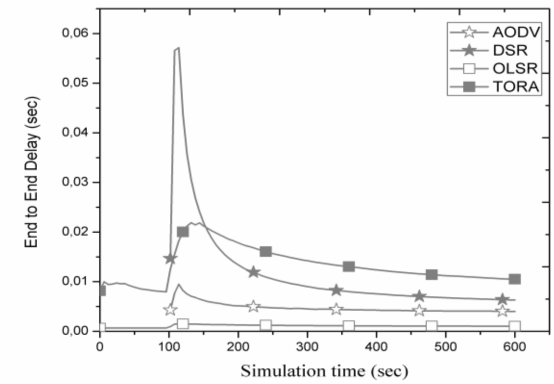

Fig 5: End-to-end delay for medium size network (60 nodes)

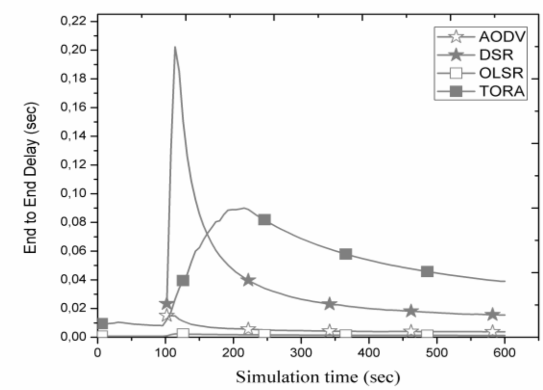

Fig 6: End-to-end delay for large size network (100 nodes)

4.2 Varying Node Mobility

This section presents details of the experiments carried out to evaluating the routing performance whilst the node mobility is varied in a MANET environment. The scenarios considered in the analysis consist of 60 nodes moving with node speeds of 10, 20 and 30 m/s. The pause time is set to 50 sec for all node speeds. The ultimate goal of such experiments is to explore how the protocols scale as the rate of topology changes in the network.

With the incidence of increased mobility rates, frequent changes of the nodes occur, subsequently causing frequent changes in the link states and further more packet losses. Fig. 7 represents the AODV throughput, generated when the mobility rate is of 10 m/s, 20 m/s and 30 m/s. With the lower mobility rate (i.e. 10 m/s), the performance of AODV is found to be considerably enhanced as the network topology remains almost constant for a low speed network. When the speed increases (i.e. 20 m/s) AODV throughput keeps on rising gradually, however, with a lower rate than that of the 10 m/s network. As the speed changes to 30 m/s, a slight decrease is noticed in AODV throughput, although the performance tends to show improvement towards the end of the simulation period. For AODV, the routing tables are more frequently updated in response to topology changes in the network, resulting in fewer packet drops and less performance degradation. Meanwhile, from Fig. 8, it is apparent that DSR attains a lower amount of throughput even when the node speed is set to 10 m/s. The throughput continues to fall with the further increases in the mobility rates (e.g. 20 and 30 m/s). However, the decrease of the throughput is somewhat noticeable, not dramatic. The routes stored in DSR cache can be used effectively with a lower node speed. But in the presence of a high node speed, one can observe a drop in DSR throughput because of it's yet dependence on the cache routes, which are more likely to become stale at higher speeds. Similarly, Fig. 9 shows that the performance of TORA deteriorates with the increase in mobility rate, even though it provides a multipath routing mechanism. In responding to topological changes (due to high mobility), the route adaptation feature of TORA increases the network overhead and causes fewer amounts of throughputs to be achieved by the network. Now turning to Fig. 10, it is evident that OLSR protocol attains a higher throughput, followed by those with AODV, DSR and TORA.

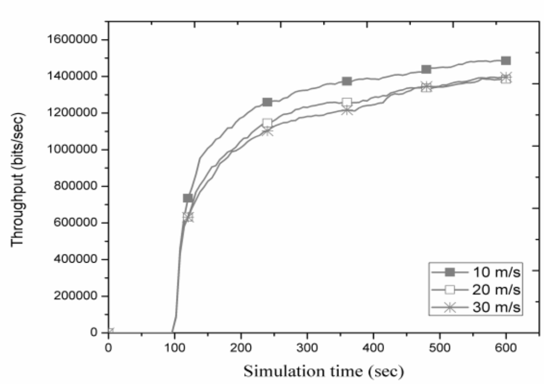

Fig 7: Average throughput for AODV

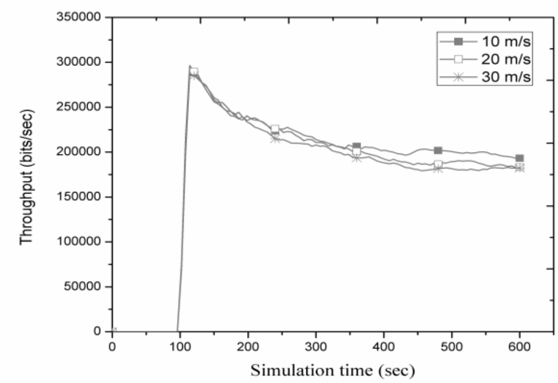

Fig 8: Average throughput for DSR

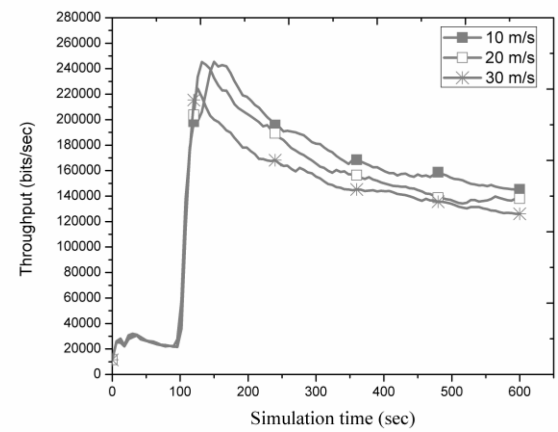

Fig 9: Average throughput for TORA

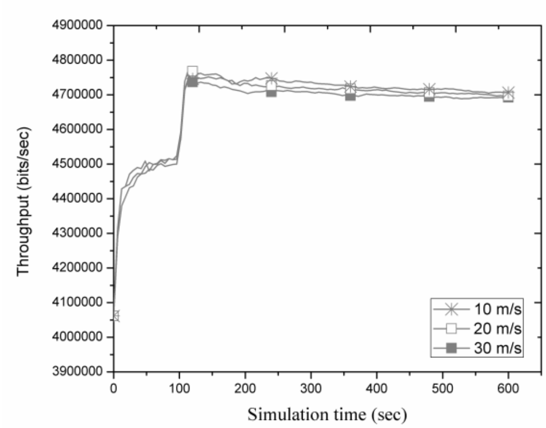

Fig 10: Average throughput for OLSR

Throughout the entire simulation, OLSR is found to maintain a consistent throughput. Even with higher mobility rates in the network, OLSR keeps its performance almost at a steady level. In our views, the superiority of OLSR is due to its ability of promptly detecting the route failures and carrying out continuous searches for the routes to all possible destinations, thereby updating the routing information quickly. In such event, a fewer number of packets are likely to have been dropped, resulting in more data packets successfully received in the network.

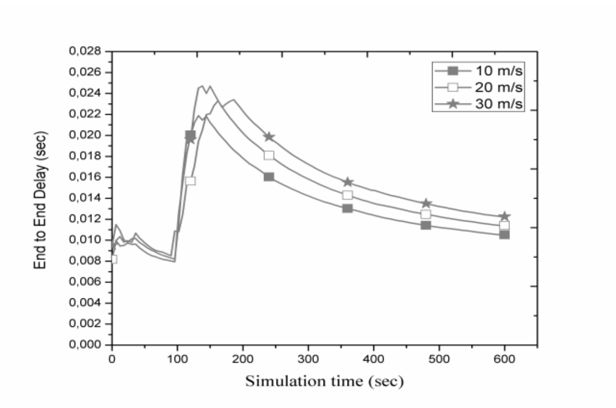

Fig 11: End-to-end delay for TORA

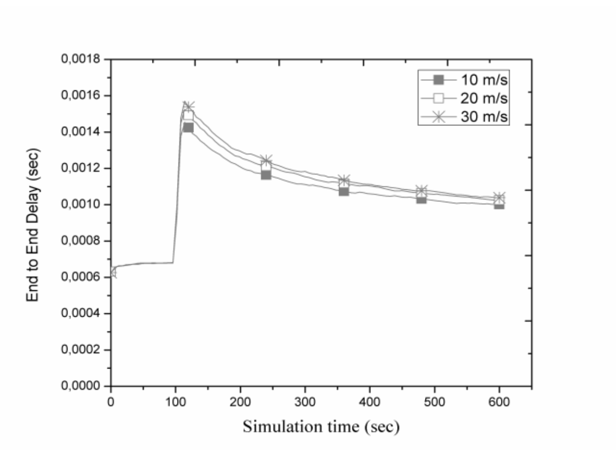

Fig 12: End-to-end delay for OLSR

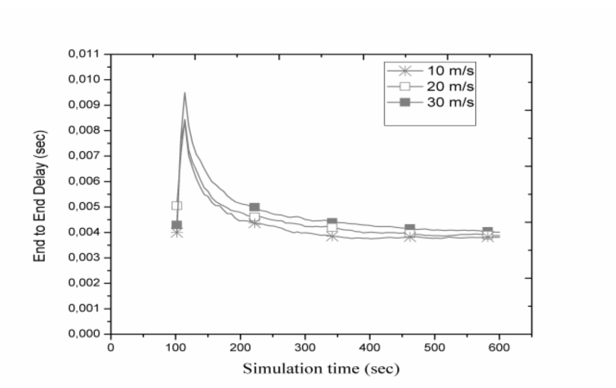

Fig 13: End-to-end delay for AODV

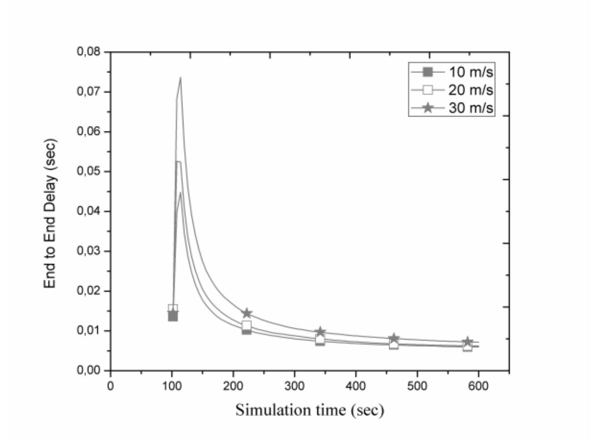

Fig 14: End-to-end delay for DSR

Fig. 11, Fig. 12, Fig. 13 and Fig. 14 display a graphical representation of a comparative analysis on the end-to-end delay results derived from various mobility scenarios. The advantages used by TORA are due to the fact it can maintain multipath capability nature. However, as one can observe, an extremely high delay is introduced in TORA network (Fig. 11), which is further worsened with higher mobility rates. In [6], it is stated that the time required for TORA to complete its initial route discovery mechanism is much higher. This might affect the performance in the event of occurrence of a network partition owing to the high mobility. Thus, the overhead of finding and maintaining multiple paths appears to have outweighed the potential benefits. Meanwhile, being a link state protocol, OLSR provides the shortest path routes and does not explicitly show its reaction to link failure. OLSR consistently maintains a lower rate of end-to-end delay (Fig. 12), as opposed to those of other routing protocols. Still, one can observe the impact of mobility from the results. Following this, with the node speeds of 10, 20, and 30 m/s, the delays of 1.11, 1.13 and 1.16 ms, respectively, are achieved by OLSR.

In contrast, the shortest paths are not maintained by reactive protocols and hence more delays are likely to be induced in AODV (Fig. 13) and DSR (Fig. 14) based networks. Among two reactive protocols, DSR does not trigger the route discovery mechanism so often due to the presence of the abundant route caches at each node. For DSR, a route discovery is not initiated unless all cached routes are broken. However, it has a high probability for these caches to become stale in high mobility scenario. In addition, the interference to data traffic is increased in DSR network due to the generation of a high MAC overhead during the route discovery mechanism [15]. This MAC overhead causes a significant degradation in delay results. AODV, on the other hand, is not able to preserve the unused routes in the network. Instead, the protocol searches for the new routes only when they are needed. This strategy usually generates less control traffic. But at the same time, it increases the overall end-to-end delay in the network since packets remain waiting at buffers until they are transmitted through the new routes.

The route expiration depends on the route timeout value so that an increase in route timeout value would cause the expiration of the route at a longer interval. Thus AODV performance can be improved by increasing the value of the active route timeout. Nevertheless, shorter active route timeout of AODV is necessary to compensate the frequent topology changes. A link breakage is not detected until the connection to a node along the route expires. The active route timeout of AODV was set to a smaller value (i.e. 3 sec) in our study. This eventually causes AODV to quickly re-establish a new route in response to a link failure and hence to produce less end-end-delay value than that of the other reactive protocol DSR.

5. CONCLUSION

In this research, an investigation is made into aspects as to how well OLSR, AODV, DSR and TORA adapt to different network conditions in MANET, particularly with respect to extension of network size and variation of mobility rate. The key observations of the research are as follows.

OLSR performs quite well in our simulation. It achieves the highest amount of data packets and the lowest amount of end-to-end delay. It is encouraging to note that OLSR performance is not degraded to a much extent even in the presence of a high mobility and larger number of nodes in the network. On the other hand, AODV performs well in a medium and a high node density, with particular reference to a case where end-to-end delays are very critical. However, it is not found to be able to outperform OLSR, either in terms of delay or throughput. The performance of AODV degrades as the node speeds are increased in the network; however, it is not as much extreme as it is found in other reactive protocols such as DSR. An extremely higher delay is induced in a DSR-based network, which further increases as the number of nodes and mobility rates get higher. In addition, DSR suffers from achieving a significant throughput as a means of dropping more data packets in such a network. The use of DSR, however, can be restricted to a small size and low mobility network. Last but not least in importance, the simulation results reveal that the higher the mobility rates and the node sizes, the worse is the performance of TORA in a mobile ad-hoc network. The generation of enormous control traffics as well as the dependence of an underlying protocol such as IMEP makes TORA’s use not very encouraging.

In our study, we have considered two network factors (node size and mobility); the pursuit of future research may include aspects relating to evaluation of the MANET performance under other important factors like network load and transmission range. In addition, in our research a comparative analysis on four MANET routing protocols (i.e. OLSR, AODV, DSR and TORA) has been carried out to evaluate their performance, the outcomes of which would be useful in many other situations. However, there are other protocols such as DSDV, ZRP and SSR that can be pursued in any future research. Furthermore, since a MANET is formed without centralized controls, it is posing vulnerable to security attacks. Hence, in any future study, such security issues in an ad-hoc network can be pursued.

6. REFERENCES

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