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Comparative study and performance investigation of MANET routing protocols

Balqees AL-Hasani, Bassam M.S. Waheed

Department of Computer Engineering, University of Technology, Iraq

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Abstract

MANETs (Mobile Ad-Hoc Networks) are fast-developing networks that gaining popularity in the recent period. They play an important part in a variety of applications, and as a result, they got a lot of attention. Routing remains a challenging problem in a MANET since it lacks infrastructure due to its self-configuration nature in addition to the frequent changes in topology due to node mobility. The requirement in MANET routing protocols is to send and receive information among the nodes with the best route with lower delay. Routing protocols are responsible for the efficient delivery of messages between mobile nodes with a focus on the use of limited resources. This paper investigates a group of the most prominent routing protocols of MANET and compares their performance in regard to different parameters such as (end-to-end delay, throughput, average jitter, and routing overhead). The protocols' performance is evaluated under different operating conditions, such as the terrain size that reflect different node density for various terrain dimensions. The amount of data exchanged is varied also through varying the number of bit-rate connections for the same network size. Results of the developed scenarios for the investigated protocols with the considered parameters are collected with the aid of the QualNet v5.2 network simulator.

Keywords: MANET, Routing Protocols, AODV, OLSR, ZRP
2020 MSC: 18M35, 68M10, 90C35

1 Introduction

A mobile ad hoc network (MANET) is a collection of mobile nodes (MNs) such that each node works as a host and router in the same time to establish the communication paths across the wireless network. A mobile ad hoc network composes a scheme of wireless mobile nodes that are vigorously self-organize into randomly and provisionally network topologies. Such network construction comes in fashion letting subscribers to effortlessly internetwork in fields without any existing network or communication substructure. The MANETs can work either in individual fashion or associated to the larger internet. As mentioned before, each mobile node in MANET function as router so that routing paths between the nodes in as ad hoc network may be comprised of multiple hops and according to this feature the name of multi-hop wireless ad hoc networks has emerged. While several complications still to be overcome before large-scale MANETs come in widespread use, small-scale ad hoc networks are deployed since not short time [23][32]. Fig.1 shows the architecture of MANET.

*Corresponding author
Email addresses: balqeesraad@gmail.com (Balqees AL-Hasani), bassamacm@gmail.com (Bassam M.S. Waheed)

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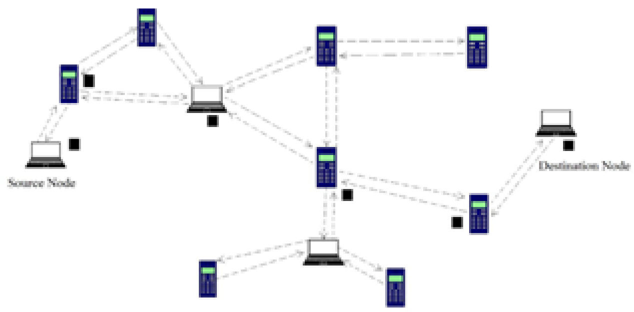


Figure 1: Architecture of MANET [23]

Due to the restricted resources available in MANETs, developing an effective and reliable routing scheme has proven to be a difficult task. To make optimum use of the limited resources while remaining flexible to the changing network conditions such as network size, traffic density, and network partitioning, an intelligent routing strategy is necessary. Therefore, an efficient routing protocol is required to provide certain level of QoS for various applications of MANET.

As a result, selecting the appropriate protocol is crucial. The protocol's performance will have a direct impact on the MANET system's performance. Many routing methods have been developed to gain control of the routing process, each with a considerable influence on network and router resources. On the other hand, different operating conditions for a MANET might make a difference in results, therefore assessing the routing protocol performance should be based on various scenarios each with different operating parameters, As a result, evaluating the routing protocol's performance should be done using a variety of scenarios each with its own set of operational parameters. [35].

This paper is regular as follows: Section 2 introduces MANET routing protocols focusing on proactive, reactive, and hybrid routing protocols, and a detailed explanation for the protocols investigated in this paper; Section 3 provides a comprehensive summary of the related works; Section 4 shows the performance parameters; After that, in Section 5, we'll look at simulation and performance analysis, this section introduces the simulation tool and settings, as well as a full discussion of the simulation's outcome; Finally, the conclusion that comes in section 6 gives.

2 MANET Routing Protocols

Because of the ever-changing topology of MANETs caused by nodes mobility, routing challenges are the generality of critical and significant issues in networks. Developing a routing protocol that fulfills the requirements of the MANET system criteria is a difficult task and must also operate efficiently in a dynamic topology network. In MANET systems, many protocols have created and have achieved a specific level of routing functionality [10]. Many efforts have been made to improve routing protocols for the purpose of increasing network performance by suggesting modifications to the existing protocols in order to enhance their outcome in terms of overhead, through-put, data delivery, etc. However, routing protocols in MANET can be categorized into three different classes in terms of collecting and keeping routing information, these classes are: proactive, reactive, and hybrid [26]. Fig.2 shows the categories of ad-hoc routing protocols.

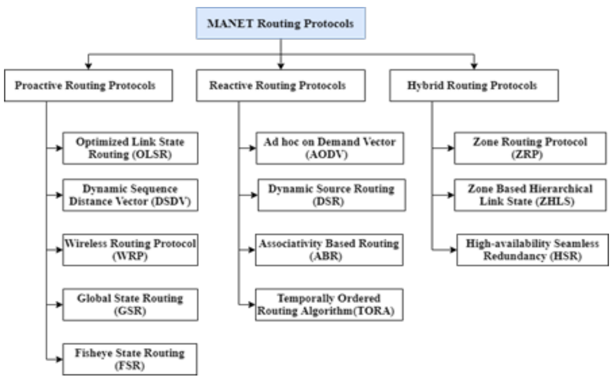


Figure 2: Categories of routing protocol in MANET [21]

2.1 Proactive Protocols

The procedure for routing in proactive protocols is based on established routing tables that contain routes to all destinations, and these routes are updated via periodic update messages. Routing tables are distributed around the network on a regular basis through specific updating messages. Due to their periodic or regular updating strategy, proactive protocols can cause extra overhead and collisions across the network which may lead to affect the network throughput negatively [5]. The following are some examples of common and popular proactive protocols: the Optimized Link State Routing Protocol (OLSR), Landmark Ad Hoc Routing (LANMAR), Topology broadcast based on reverse-path forwarding (TBRPF), and Destination-sequenced distance vector (DSDV). In this work, the OLSR protocol is considered for investigation and to compare its performance with the two other protocols selected from the reactive and hybrid categories, in this context the Ad-hoc On-demand Distance Vector (AODV) routing protocol and the Zone Routing Protocol (ZRP) are chosen to represent the two remaining routing protocols categories respectively.

• Optimized Link State Routing Protocol (OLSR):

OLSR is a point-to-point routing protocol based on the traditional link-state algorithm. According to the protocol, each node keeps a record of the network's topology by transmitting periodically link state signals. OLSR uses a multipoint replaying (MPR) procedure to minimize the size of each control message and the number of rebroadcasting nodes during each route up-to-date. To do this, each node in the network selects a set of neighboring nodes to re-transmit its packets at each topology update. This group of nodes is referred to as multipoint relays of that node. Any node not in the set can read and process each packet, but it cannot be re-transmitted. To choose the MPRs, every node broadcasts a list of its 1-hop neighbors on a regular basis using hello messages, in this way all the 2-hop neighbor information will be available at every node. Thereafter, each node chooses a subset of its 1-hop neighbors as a forwarder set that must cover all its 2-hop neighbors [2]. For example, in Fig.3, the source node selected the MPR nodes which represent the dark grey nodes in the drawing, because this group of nodes cover all nodes that are 2-hops away from the source of the broadcast. By using it is topological information from the topology table and neighbors table, each node determines an optimal route to every known destination and saves this info in a routing table. As a result, the paths to each destination are available immediately when the data transfer starts.

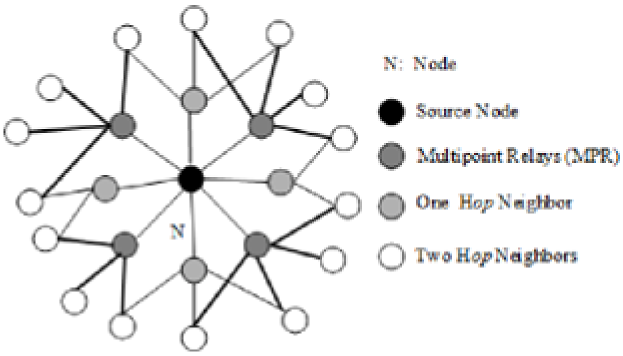


Figure 3: Multipoint relay [29]

2.2 Reactive Protocols

In reactive protocols (on-demand routing protocols), a route to the destination is calculated when there is a need to initiate data transfer between certain pair of nodes as source and destination. To achieve this task, the source node floods the network with control packet dedicated for this purpose known as the route request packet (RREQ). Reactive protocols, in contrast to proactive protocols, have lower overhead and require lower routing information (determined the route only when necessary); when the network topology is altered, which occurs frequently in MANET systems, they produce large number of control packets during the discovery process. As a result, there is a higher message overhead. The delay in obtaining the path is also not suitable for applications that require QoS (e.g. interactive audio and video)[5]. Examples of popular reactive protocols are Ad hoc on Demand Vector (AODV), Dynamic Source Routing (DSR), Location Aided Routing (LAR), and Temporally Ordered Routing Algorithm (TORA).

• Ad-hoc On-Demand Vector (AODV):

AODV is a MANET reactive routing protocol with two main phases: route discovery and route maintenance. To discover and maintain paths, the AODV protocol uses four types of messages: Route Request (RREQ) packet, Route Reply (RREP) packet, Route Error (RERR) packet, and HELLO packet. As shown in Fig.4a, the source node broadcasts a route request RREQ message to its next-hop neighbors. When an intermediate node receives the RREQ message and has no route to the destination, it builds a reverse route with the source. After modifying the received RREQ packet, it will forward the RREQ packet to its next-hop neighbors. This process is repeated until the destination is reached or an intermediate node with a path to the destination receives the RREQ packet. When the destination or intermediate node receives the RREQ packet, it builds a reverse route to the source node and then unicasts an RREP packet to the source through the reverse route, as shown in Fig.4b. When the source receives the RREP packet, it selects the shortest path with the fewest hops and begins to dispatch data packets to the destination [11]. When a link break occurs, Routing Error Messages (RERR) are generated to fix the current route or discover a new route. When a node receives a RERR, it looks at the routing table and removes all routes that contain bad nodes. While the hello messages are sent by AODV periodically to confirm that the link is still active[24].

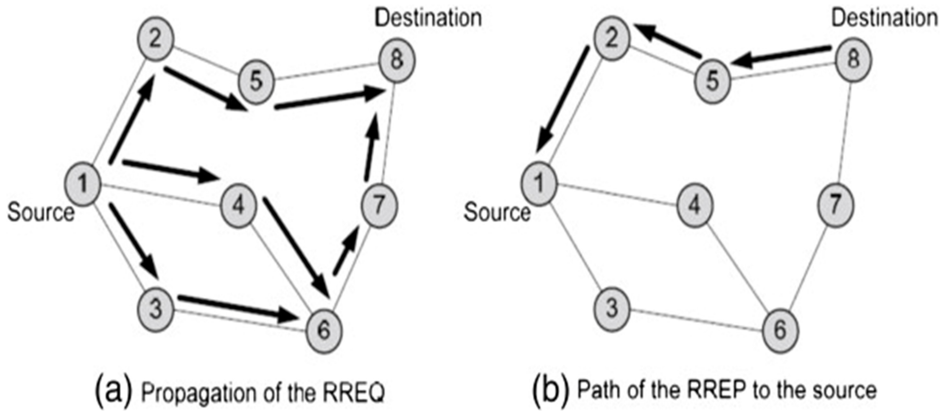


Figure 4: AODV route discovery process [9]

2.3 Hybrid Protocols

In hybrid protocols is use the capabilities of both reactive and proactive protocols, allowing to create a protocol making use from the benefits of both. Hybrid protocols include the characteristics of both proactive protocols and reactive protocols [5]. An example of a hybrid protocol is Zone Routing Protocol (ZRP).

• Zone Routing Protocol (ZRP):

In ZRP, the nodes have a routing zone, which defines a region (in hops) within which each node must maintain proactive network communication. As a result, routes are immediately available for nodes within the routing zone. Routes are determined on-demand (i.e. reactively) for nodes outside the routing zone, and it can employ any on-demand routing protocol to identify a route to the desired destination. When compared to pure proactive protocols, the advantage of this protocol is that it has greatly reduced the amount of communication overhead. This is because, in order to calculate a route to a node outside the routing zone, the routing just needs to travel to a node on the needed destination's boundaries (routing zone's edge). Because the boundary node would maintain routes to the destination proactively (i.e., the boundary node may complete the route from the source to the destination by sending a reply back to the source with the appropriate routing address) [19]. The drawback of ZRP is that it can operate as a pure proactive protocol for large routing zone of routing zone, but as a reactive protocol for small routing zone [27].

3 Literature Review

Routing protocols operate at the network layer, and a variety of protocols have been developed to connect a source node to a destination node (i.e. DSR, AODV, DSDV, OLSR, etc.). Several major pieces of literature work on the comparison of MANET routing protocols are investigated in this work, considering as well the future directions of researchers in this domain.

Sreya et al. [37] have compared and analyzed four routing protocols, which are OLSR, DSDV, AODV and DSR under different conditions. Protocols were simulated using NS3. AODV had the highest average receive rate and the highest average packets received, according to their obtained results. The highest power was found to be consumed by DSR. The DSDV protocol was discovered to use the least amount of power and to have the lowest packet receive rate and average packets received.

Yuxia et al.[5] have compared two main types of MANET proactive routing protocols DSDV (Destination Sequence Distance Vector) and FSR (Fisheye State Routing) and two the well-known reactive protocols AODV and DSR (Dynamic Source Routing) under various simulation scenarios deployed in a terrain area of 500m*500m for a number of nodes 5, 10 , and 30 nodes respectively. The reactive type's AODV protocol outperforms the other routing protocols in terms of throughput and average end-to-end delay, while the reactive type's DSR outperforms the other routing protocols in terms of packet delivery ratio. As the network increases in size, reactive protocols particularly the AODV routing protocol become more dominant in all performance categories for the rest of the protocols, whereas packet size has little impact. The authors aimed to demonstrate the routing protocols' performance in real-world MANET applications in the future.

Roy et al. [26] have conducted a comparative study of AODV, DSDV, and DSR protocols to trace performance metrics include end-to-end delay, packet delivery ratio, and throughput under different data rates. The network scenario was established within terrain of 500m*500m for 50 nodes. The simulation findings show that AODV can be used in low-delay networks, whereas DSR may be employed in restricted networks where higher throughput and PDR are critical requirements. As future work, the authors have suggested demonstrating the advantages and disadvantages of other accessible routing protocols and suggested a new routing protocol for MANETs that will solve the problems of existing routing protocols.

Jair et al. [12] have studied three routing protocols that were evaluated for behavioral and performance analysis in the urban environment. The NS2 simulator was used to test proactive, reactive, and hybrid protocols. The proactive OLSR protocol achieved the highest reduction in overhead, whereas the AODV reactive approach performed better in terms of transfer rate at the TCP level. In addition, the hybrid protocol ZRP yielded the best results in terms of latency reduction and delivery rate increase.

Abdalftah et al. [1] have compared and analyzed QoS parameters for different interactive routing protocols AODV, DSR (Dynamic Source Routing), and TORA (Temporally Ordered Routing Algorithm) while considering variable node density in the MANET network. network load, retransmission attempts, end-to-end delay, media access delay, throughput, and other metrics are utilized when assessing node density and version of IEEE 802.11g WLAN standard using OPNET modeler 14.5 in terrain area 1000m*1000m to 25, 50, 75 and 100 nodes. In terms of media access delay, load, end-to-end delay, data drop retry, and retransmission attempts, AODV outperforms the other protocols. However, DSR had been outperforming the competition in terms of throughput and traffic routing. As a result, the conclusion demonstrates that each protocol operates differently in different environments since distinct parameters have been adjusted in various conditions. As a result of our simulation results, we can conclude that AODV outperforms the competition.

Ashadi et al. [17] have concerned with the performance evaluation of reactive routing protocols, such as AODV, as well as proactive routing protocols, including DSDV and OLSR. The protocols performance has been investigated in terrain areas of 100m*100m, 200m*200m, 300m*300m, 500m*500m, and 1000m*1000m respectively for nodes populations equal to 20, 30, 50 70 and 100 nodes. Each protocol's performance is evaluated with QoS metrics, that includes packet delivery ratio, throughput, packet loss, and end-to-end delay. In every QoS parameter, OLSR outperforms AODV and DSDV, according to the simulation results. The authors attributed their results to the employment of dominant pruning approach represented by the multipoint relay (MPR) for packets forwarding, so that the packet delivery ratio and throughput rise by increasing the number of nodes, simulation area and simulation speed. As a future work, authors aim to examine the impact of environmental variables on the performance of the routing protocol in a wireless network using alternative propagation models rather than the Friis model.

Dodi et al. [33] have analyzed the energy usage in MANET between the OLSR and ZRP protocols. The terrain area of the simulated scenario was1000m*1000 m for 20 nodes. Based on the simulation results of the ZRP and OLSR for energy consumption, authors found out that the OLSR which symbolizes the Proactive approach has yielded an energy consumption less than that required by the ZRP under the same simulation parameters, but on the other hand, they revealed that in case the destination nodes in ZRP are located outside of the sender nodes radius area, the protocol shows higher efficiency for delivering packets. This occurs because the ZRP employs the reactive mechanism in this case, where, the successful delivery of packets assists to avoid consecutive transmissions, hence energy usage in ZRP is more efficient than OLSR under the latter condition.

Mohammed et al. [15] have evaluated and compared the performance of two routing protocols, AODV and OLSR in the MANET network. Authors have developed network scenario to run seven times by using different network densities with number of nodes: 10, 20, 30, 40, 50, 60, 70 and the terrain area of the suggested scenario was equal to 500 m*500 m . Authors have examined the impact of changing the number of nodes on protocol performance by tracking evaluation parameters, such as throughput, packet delivery ratio, and average end-to-end delay. The simulation results indicate that the number of nodes or network size have a significant impact on routing protocol performance, they indicated the AODV outperforms the OLSR in several aspects, especially in regard to overhead and throughput.

Manisha and Mehajabeen [20] have compared the performance of the AODV and ZRP routing protocols with various node speeds according to various metrics such as average end-to-end delay, throughput, queue length and their dropped packets. The terrain area for the simulated network scenarios were 2000m*2000m and 2500m*2500m for 70 and 80 nodes respectively. The simulation results showed that the proposed model using AODV has reduced the delay time in compare to the ZRP protocol. Dynamic adoption of different conditions in AODV has increased the throughput value of the network and reduced the queue length as compared to the ZRP algorithm. In comparison to the scenario with the ZRP protocol, the other scenario that was applying the AODV has shown an increment in packet drop count, which means the ZRP outperforms AODV regarding this issue.

Kashif et al. [22] have aimed to mitigate the impact of network traffic (FTP, E-Mail, and HTTPA discrete) on routing protocols (AODV, DSR and OSLR) in MANETs using Optimized Network Engineering Tool (OPNET) version 14.5 network simulator. Authors planned to trace the performance metrics of throughput, delay, and network loading to find the most efficient and suitable routing protocol. The terrain area of the MANET network simulation was selected as 1500 m*1500 m for 100 nodes. Their results indicate that the DSR protocol has the largest time delay compared to AODV and OLSR. Nonetheless, throughput was regarded the most important criterion in determining overall performance when compared to reported bandwidth, because it is the actual amount of data that nodes successfully receive. OLSR has performed fairly well in the simulation in regard to the overall performance. Finally, OLSR showed decent efficiency in dealing with high congestion and enhanced its scaling by efficiently transmitting packets over highly trafficked networks compared to DSR and AODV.

Gurpreet and Rajat [31] have evaluated the performance of the three routing protocols ZRP, DSR and OLSR for the sparse network case with very low node density in terms of throughput and delay. Authors have employed the random waypoint mobility model in their developed scenarios. The NETSIM simulator is used for a simulation time of 100 sec by using 5 and 10 nodes which are randomly placed within a terrain area of 500m*500m. In both scenarios, nodes 1 and 5 were employed as the source and destination nodes for sending and receiving data in each scenario. According to the results, ZRP is a more reliable protocol in terms of delay and throughput than OLSR and DSR.

Manish et al. [18] have evaluated mobility and scalability of different routing protocols: DSR, AODV and OLSR in different network sizes with a varying mobility rate. The terrain areas selected for simulating the established scenarios were 1000m*1000m, 1400m*1400m and 1725m*1725m with 20, 40,and 60 nodes respectively. In all of the tested scenarios, OLSR outperformed DSR and AODV in that it has the shortest network latency when there is high mobility and a large number of nodes. Even after employing cache, DSR's performance was not satisfactory in both metrics. When it comes to throughput, OLSR outperformed both DSR and AODV. AODV is directly behind OLSR in regard to throughput while produced very low amounts of overhead due to its reactive approach in routes establishment. As future work, authors have suggested including other protocols such as ZRP which belongs to the hybrid routing category. During the research, many characteristics such as the number of nodes, network area, mobility, and pause duration were varied and tested. Other variables, such as data rate and traffic applications, remain constant. It would be interesting to investigate how these factors affect the routing protocols' behavior.

Sampoornam and Raaga.[28] have compared the performance of routing protocols: Bellman-ford, AODV, DSR, ZRP, and DYMO (Dynamic MANET On-demand). The metrics evaluated were throughput, delay, average jitter, the total number of packets enqueued, the total number of packets dequeued and the total number of packets dropped in the queue. The scenario Simulation time was selected as 30 seconds for 10 nodes and the terrain area for the simulated network scenario was 1000m*1000m. The simulation results show that, the ZRP protocol performs well in terms of throughput, average delay, average jitter, and the total number of packets enqueued even in the fault node.

Hashim et al. [13] have evaluated OLSR and AODV routing protocols in a wide variety of scenarios via NS2 simulator, that is under different numbers of nodes, different node speed, and different data rates. After analyzing the simulation data, it was discovered that OLSR performs better in terms of average end-to-end delay, making it ideal for delay-sensitive applications. whereas the AODV outperforms in terms of throughput and packet delivery ratio, making it ideal for applications that rely on throughput.

Rachna and Indu. [14] have compared AODV and OLSR routing protocols. The terrain area of the network simulation is 1000m*1000m with 20, 30, 50, 70, and 100 nodes. NS-2 simulator was used to construct and simulate several scenarios with varied numbers of nodes. According to their obtained results from the simulation runs, the OLSR outperformed AODV in terms of the average end-to-end delay because route searching from routing tables takes less time than establishing them I n on-demand fashion as in AODV, performance the best throughput, and has a higher package delivery rate for a different number of nodes. but OLSR has higher memory overheads due to a large number of routing tables.

Nahid et al. [8] have introduced a thorough examination and analysis of two types of MANET optimized routing protocols: reactive (DSR, AODV) and proactive (DSDV, OLSR) for a terrain area of 750m*750m while nodes numbers were equal 10, 20, 30, 40 and 50 nodes respectively. The simulation time was selected as 150 seconds, when all nodes are sources of traffic, proactive protocols always consume more energy than reactive protocols, and DSDV consumes more energy than OLSR in regard to proactive protocols. These protocols have much higher throughput and relatively low delay when the network is dense. Because of its lower energy consumption, OLSR provides a good choice for high density scenarios. On the other hand, reactive protocols are more efficient in low-density networks, while AODV offers the best performance with less delay and greater throughput.

4 Performance Parameters

The main focus of this paper is given to investigate the performance of the considered routing protocols. The QualNet simulations have run out to trace a selected set of performance parameters. The parameters traced in this work for the evaluation of the considered routing protocols are:

1. **Average End-to-End Delay(s)**: represents the amount of time it took the packet to transit from source to destination, measured in seconds[30].

$$\text{Average End-to-End Delay} = \frac{\sum(\text{arrive time} - \text{send time})}{\text{Number of connection}}$$

2. **Average Packet Delivery Ratio**: The number of packets received by the destination is divided by the number of packets generated by the source. This average describes the rate of packet loss in a network, which limits the network's throughput [30].

$$\text{Packet Delivery Ratio} = \frac{\text{total number of relived packets}}{\text{total number of transmitted packet}}$$

3. **Average Throughput (bit/s)**: is the average rate of data packets successfully received by the node per unit time. In a communication system, high average throughput is always desirable [36].

$$\text{Average Throughput} = \frac{\text{total number of byte relived}}{\text{total time of transmission}}$$

4. **Average Jitter(s)**: is the difference in time between the arrival of data packets caused by changes in route, congestion, and other factors. The average jitter is commonly used as a metric to measure a network's reliability and consistency. For a routing protocol to work well, the average jitter should be low [36].

$$\text{Average Jitter}(s) = \frac{\sum(\text{arrive time} - \text{send time})}{\text{total number of transmit packet}}$$

5. Routing overhead: It is the number of routing packets used due to frequent failures of links that lead to frequent path failures and path rediscoveries [30].

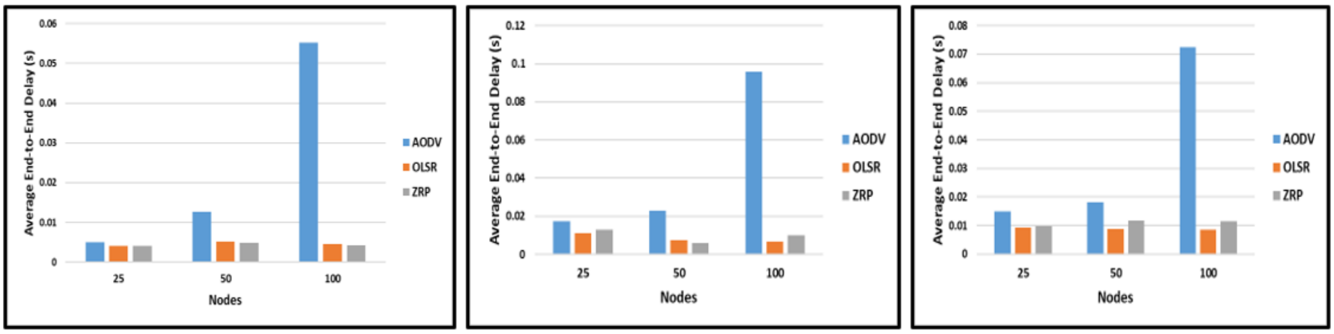
5 Simulation And Performance Analysis

This section illustrates the details of the network scenarios conducted with QualNet v5.2 simulators. This includes the values of various selected parameters for the conducted scenarios as shown in Table 1. According to the table, the simulation time was selected 600 sec for all tested scenarios, whereas the network size was varied from 25, 50 and 100 nodes against different terrain size for each simulation run and according to the values presented in the table.

Table 1: Network load simulation parameters

Parameters	Values
Simulation Time	600 sec
Terrain area	500m*500m, 750m*750m, 1000m*1000m
Numbers of Nodes	25, 50, 100 (nodes)
Packet Size	512 bytes
Routing Protocols	AODV, OLSR, ZRP
Traffic Type	CBR
Node speed	0 -5 m/sec
Node pause-time	10 sec
Mobility model	Random-waypoint
MAC layer protocol	IEEE 802.11 b/g/n

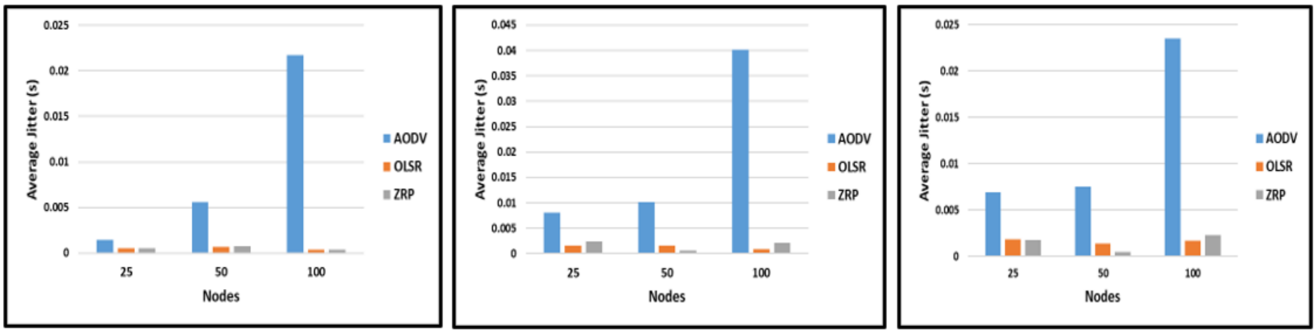
The following are the results of network load experiments:



a =500m*500m b =750m*750m c =1000m*1000m

Figure 5: Average end-to-end delay of the considered protocols

Fig.5 shows the average end-to-end delay of the protocols AODV, OLSR, and ZRP for scenarios with network size of 25, 50 and 100 nodes respectively. Part-a from the figure shows the results obtained for network scenarios of 25, 50, 100 nodes established in terrain of 500m*500m. Parts b and c from the figure increment the terrain size to 750m*750m 1000m*1000m respectively, while changing the network size in the same sequence followed in part a. For the scenarios established within the different considered terrain sizes in parts a, b and c, and for the case of 25 nodes, the performance of the three protocols seems close to each other and no big variance is noticed. In the case of terrain area equal to 750m*750m, AODV had the highest delay as compared with OLSR and ZRP since the AODV discovers routes just in on-demand fashion when there is traffic between certain source and destination nodes, this behavior cause a delay in information transfer from the source node to destination node and this behavior remains the same for the terrain case of 1000m*1000m, that's AODV still keeps the highest delay, whereas the OLSR and ZRP provides a noticeable lower delays. Such behavior obviously renders AODV inappropriate for multimedia applications that do not tolerate relatively high durations of delay. This delay in AODV can be attributed to the expanding ring search feature that broadcast the RREQ packets with Time-to-Live (TTL) value in ascending manner [3]. Actually, this can prohibit network-wide flooding with RREQ packets but on the other hand, if the destination is located beyond the initial values of TTL scope, then several attempts of RREQ broadcast are required that incurs additional delay, this is of course in addition to the reactive approach of AODV in routes establishment which certainly slower than the table-driven protocols in data transferring [7].

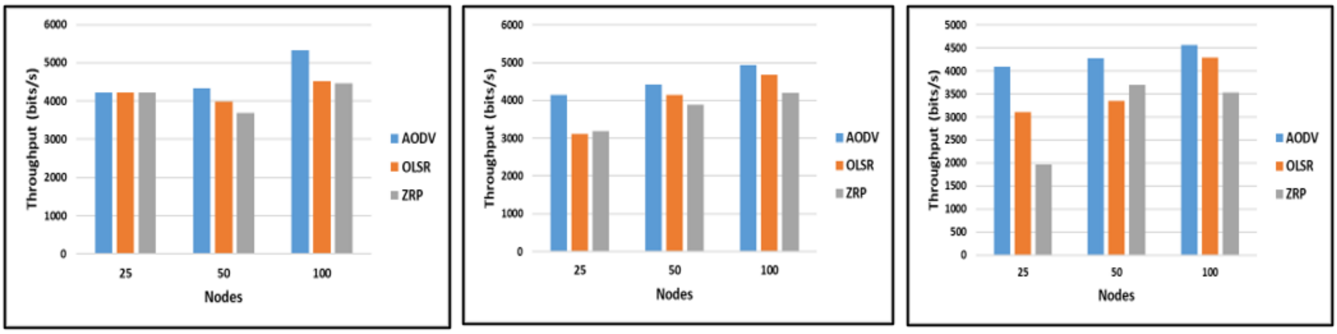


a =500m*500m b =750m*750m c =1000m*1000m

Figure 6: Average jitter(s) against network size variation

Fig.6 illustrates the variation in average jitter against the network size for AODV, OLSR, and ZRP routing protocols and as expressed previously in the Fig. 5, the network size takes three values (25, 50, 100) nodes for each considered terrain size. The jitter is a measure for packet latency variation over time across the network, this means for ideal performance, the routing protocol would generate zero jitter, that's provide packets reception without any latency variation [4].

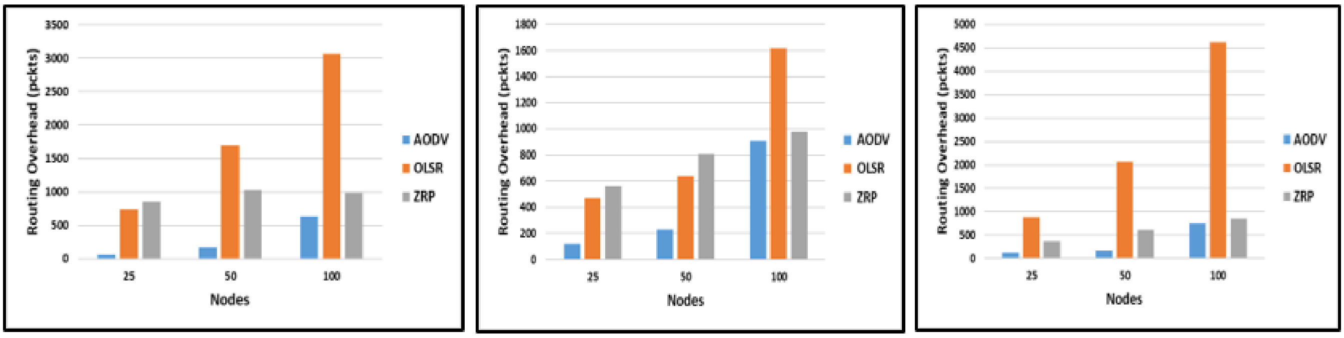
It can be seen from the figure, that the proactive routing protocols, OLSR explicitly and ZRP implicitly, depending on its proactive design component, provide a noticeable performance in regard of jitter variation that range from (2 to 3) msec whereas the AODV come notably behind them although its performance for many cases still within the acceptable bounds. These bounds are adopted from the real-time applications which are very sensitive to jitter, namely: video and audio on-demand, telephony and video conferencing [16]. According to the fact that a human eye can recognize the changes in video stream comes below 30 frames per second, a jitter with this range can bring profound impact on the video quality. A remote logging applications also is sensitive to jitter, that's update on the monitor will be displayed with some blow-ups if the connection has much jitter [25]. Therefore, according to the results obtained, OLSR and ZRP are preferred over the AODV for real-time or multimedia applications, where, the protocols maintain the same performance in regard to jitter for all considered network densities and terrain sizes.



a =500m*500m b =750m*750m c =1000m*1000m

Figure 7: Throughput (bits/s) against network size

Fig.7 presents the obtained values for throughput versus the variation in network size with the same considered values of 25, 50 and 100 nodes as in the cases of the previously considered metrics, while parts a, b and c from the figure corresponds to the terrain areas of 500*500, 750*750 and 1000*1000 respectively. For all established scenarios, AODV provides superior performance in comparison to ZRP and OLSR, where this can be attributed to a better link reliability in AODV that in turn reduces the packet loss, since AODV uses a special dedicated type of control packets route error (RERR) in case of link breakage. This feature allows the AODV to locally repair the breakages without a need to reinitiate a route "establishing" a route through a new RREQ flooding [34]. Such an approach will save the network from being immersed with control packets due to successive flooding actions. The reduced overhead will minimize the rate of packet collisions and hence improve the packet delivery ratio [13].



a =500m*500m b =750m*750m c =1000m*1000m

Figure 8: Routing overhead in the considered scenarios

One of the easiest graphs to interpret is that one in Fig.8 which corresponds to the overhead incurred by the considered routing protocols. No doubt AODV will be the best in this track due its reactive approach in creating and maintaining routes that's avoid transmitting periodic update packets which save a lot in regard of overhead. On the other hand, OLSR which has pure proactive strategy will suffer from linear increase in overhead with increment in network density. That's because the rise in node degree "no. of neighbors" with ramp up in network density. a higher degree means a lengthy topology control message broadcast by nodes in OLSR that is rise the chance of collisions [6]. However, researchers try to alleviate the impact of these collision by trying to add jitter "random waiting time" that nodes should wait before broadcasting their control messages. The ZRP protocol as it belongs to the hybrid category, it provides a trade-off between the reactive and proactive approaches in all the traced performance metrics and overhead is not under exception. It mediates the order between AODV and OLSR with a performance closer to that of AODV in several occasions.

6 Conclusion

One of the main challenges for MANET is to design a dynamic routing protocol with acceptable performance and low overhead. In this paper, the QualNet v5.2 network simulator is used to examine a set of the most well-known routing protocols for MANETs: AODV, OLSR, and ZRP, to see which ones are best for supporting the unique properties of ad hoc networks. We were able to simulate these protocols using a varied number of nodes and terrain areas. It can be seen from the results that no one protocol outperforms the others in all scenarios and evaluation criteria since each one of them was developed with different methodology for initiating and keeping routes in the wireless ad-hoc environment, while the OLSR can provide an excellent average delay compared to AODV, it cannot meet the scalability requirements due to extra amount of overhead produced with the increase in network density. on the other hand, AODV has its limitations for real-time applications because the higher amounts of jitter but it has prominent saving in regard to overhead and well suited to reduce the packet loss ratio. The ZRP provide a good option to achieve decent performance within different metrics unless the targeted application requires certain levels of performance in throughput and overhead. As a future work, additional routing protocols can be considered beside these ones, namely DSR, DSDV, LAR and TORA. The multicasting and energy efficient routing protocols are tempting to investigate due to their approaches in satisfying the crucial needs of MANETs.

References

[1] A.K.S. Ali and U.V. Kulkarni, *Comparing and analyzing reactive routing protocols (aodv, dsr and tora) in QoS of manet*, IEEE 7th Int. Adv. Comput. Conf. (IACC), IEEE, 2017, pp. 345–348.

[2] U. Aliyu, H. Takruri, M. Hope and A. G. Halilu, *DS-OLSR–disaster scenario optimized link state routing protocol*, 12th Int. Symp. Commun. Syst. Networks Digital Signal Process.(CSNDSP), 2020, pp. 1–6.

[3] F.A. Al-Zahrani, *On Modeling Optimizations and Enhancing Routing Protocols for Wireless Multihop Networks*, IEEE Access **8** (2020), 68953–68973.

[4] S. Aswale and V.R. Ghorpade, *Geographic multipath routing based on triangle link quality metric with minimum inter-path interference for wireless multimedia sensor networks*, J. King Saud Univ.-Comput. Inf. Sci. **33** (2021), no. 1, 33–44.

[5] Y. Bai, Y. Mai and N. Wang, *Performance comparison and evaluation of the proactive and reactive routing protocols for MANETs*, Wireless Telecommun. Symp. (WTS), 2017, pp. 1–5.

[6] F. Chbib, A. Khalil, W. Fahs, R. Chbib and A. Raad, *Improvement of olsr protocol by using bacis up mpr and routing table mechanisms*, Int. Arab Conf. Inf. Technol.(ACIT), IEEE, 2018, pp. 1–6.

[7] H. Choi and J. Lee, *Local flooding-based on-demand routing protocol for mobile Ad Hoc networks*, IEEE Access **7** (2019), 85937–85948.

[8] N. Ebrahimi Majd, N. Ho, T. Nguyen and J. Stolmeier, *Evaluation of parameters affecting the performance of routing protocols in mobile ad hoc networks (MANETs) with a focus on energy efficiency*, Future Inf. Commun. Conf., Springer, Cham, 2019, pp. 1210–1219.

[9] M.H. Eiza, Q. Ni, T. Owens and G. Min, *Investigation of routing reliability of vehicular ad hoc networks*, EURASIP J. Wireless Commun. Network. **2013** (2013), no. 1, 1–15.

[10] M.A. Elsadig, Y.A. Fadlalla and A. Altigani, *Performance analysis of popular manet protocols*, 9th IEEE-GCC Conf. Exhib. (GCCCE), IEEE, 2017, pp. 1–5.

[11] A.M. El-Semary and H. Diab, *BP-AODV: Blackhole protected AODV routing protocol for MANETs based on chaotic map*, IEEE Access **7** (2019), 95197–95211.

[12] J.J. Ferronato and M.A.S. Trentin, *Analysis of routing protocols OLSR, AODV and ZRP in real urban vehicular scenario with density variation*, IEEE Latin Amer. Trans. **15** (2017), no. 9, 1727–1734.

[13] A.A. Hashim, M.M. Farhan and S. Alshybani, *Performance evaluation of OLSR and AODV routing protocols over mobile ad-hoc networks*, First Int. Conf. Intell. Comput. Engin. (ICOICE), IEEE, 2019, pp. 1–8.

[14] R. Jain and I. Kashyap, *Experimental load analysis of AODV, OLSR in MANETS*, IIOAB J. **9** (2018), 78–82.

[15] M.A. Jubair, S.H. Khaleefah, A. Budiyono, S.A. Mostafa and A. Mustapha, *Performance evaluation of AODV and OLSR routing protocols in MANET environment*, Int. J. Adv. Sci. Eng. Inf. Technol. **8** (2018), no. 4, 1277–1283.

[16] A. Ksentini, M. Jebalia and S. Tabbane, *IoT/cloud-enabled smart services: A review on QoS requirements in fog environment and a proposed approach based on priority classification technique*, Int. J. Commun. Syst. **34** (2021), no. 2, e4269.

[17] A. Kurniawan, P. Kristalina and M.Z.S. Hadi, *Performance analysis of routing protocols AODV, OLSR and DSDV on MANET using NS3*, Int. Electron. Symp. (IES), 2020, pp. 199–206.

[18] M. Kumar, C. Sharma, A. Dhiman and A.K. Rangra, *Performance variation of routing protocols with mobility and scalability in MANET*, Next-Gen. Networks, Springer, Singapore, 2018, pp. 9–21.

[19] E. Kurode, N. Vora, S. Patil and V. Attar, *MANET routing protocols with emphasis on zone routing protocol–an overview*, IEEE Region 10 Symp. (TENSYMP), IEEE, 2021, pp. 1–6.

[20] M. Mehra and M. Fatima, *AODV and ZRP Analysis for Congestion in MANE*, Int. J. Res. Engin. Sci. Manag. **3** (2020).

[21] A. Nabou, M.D. Laanaoui and M. Ouzzif, *The effect of transmit power on MANET routing protocols using AODV, DSDV, DSR and OLSR in NS3*, Int. Conf. Adv. Intell. Syst. Sustain. Dev., Springer, Cham, 2018, pp. 274–286.

[22] K. Nisar, I.A. Lawal, U.I. Abdulmalik, A.A. Mu'azu, B.S. Chowdhry, S. Khan and S. Memon, *QoS analysis of the MANET routing protocols with respect to delay, throughput, and Network load: Challenges and open issues*, IEEE 14th Int. Conf. Appl. Inf. Commun. Technol. (AICT), IEEE, 2020, pp. 1–8.

[23] B. Rana, and D. Rana, *Energy efficient load balancing with clustering approach in MANET*, Int. Conf. Energy Commun. Data Anal. Soft Comput.(ICECDS), IEEE, August 2017, pp. 2019–2024.

[24] Q. Razouqi, A. Boushehri and M. Gaballah, *Performance analysis for diverse simulation scenarios for DSDV, DSR and AODV MANET routing protocols*, 13th Int. Comput. Engin. Conf. (ICENCO), 2017, pp. 30–35.

[25] A.S. Roque, N. Jazdi, E.P. Freitas and C.E. Pereira, *Performance analysis of in-vehicle distributed control systems applying a real-time jitter monitor*, IEEE 18th Int. Conf. Ind. Inf. (INDIN), 2020, pp. 663–668.

[26] A. Roy and T. Deb, *Performance comparison of routing protocols in mobile ad hoc networks*, Proc. Int. Conf. Comput. Commun. Syst., Springer, Singapore, 2018, pp. 33–48.

[27] P.K. Sahu, B.M. Acharya and N. Panda, *QoS-aware unicasting hybrid routing protocol for MANETs*, Intell. Cloud Comput., Springer, Singapore, 2021, pp. 631–640.

[28] K.P. Sampoornam and G. Raaga Darshini, *Performance analysis of Bellman Ford, AODV, DSR, ZRP and DYMO routing protocol in MANET using EXATA*, Int. Conf. Adv. Comput. Commun. Engine.(ICACCE), IEEE, 2019, pp. 1–5.

[29] E. Setijadi, I. Purnama and M. Hery, *MPR selection to the OLSR quality of service in MANET using preferred group broadcasting*, IAENG Int. J. Comput. Sci. **46** (2019), no. 2.

[30] A. Sharma and R. Kumar, *Performance comparison and detailed study of AODV, DSDV, DSR, TORA and OLSR routing protocols in ad hoc networks*, Fourth Int. Conf. Parallel, Distribut. Grid Comput.(PDGC), IEEE, 2016, pp. 732–736.

[31] G. Singh and R. Khurana, *Performance evaluation of DSR, OLSR and ZRP using NetSim simulator*, Int. J. Adv. Res. Comput. Sci. **8** (2017), no. 3, 346–349.

[32] S.K. Singh and J. Prakash, *Energy efficiency and load balancing in MANET: a survey*, 6th Int. Conf. Adv. Comput. Commun. Syst. (ICACCS), IEEE, 2020, pp. 832–837.

[33] D.W. Sudiharto, N.R. Pradana and S. Prabowo, *The comparative analysis of energy consumption between OLSR and ZRP routing protocols*, J. Commun. **14** (2019), no. 3, 202-209.

[34] T.H. Sureshbhai, M. Mahajan and M.K. Rai, *An investigational analysis of DSDV, AODV and DSR routing protocols in mobile Ad Hoc networks*, Int. Conf. Intell. Circuits Syst. (ICICS), IEEE, 2018, pp. 281–285.

[35] A. Tiwari and I. Kaur, *Performance evaluaron of energy efficient for MANET using AODV routing protocol*, 3rd Int. Conf. Comput. Intell. Commun. Technol. (CICT), IEEE, 2017, pp. 1–5.

[36] R.K. Upadhyay, S. Kumar and J. Wasim, *Performance of MANET routing protocols with varying mobility speed and group mobility model*, Vidyabharati Int. Interdisciplin. Res. J. **2021** (2021), 28–32.

[37] S. Vemuri and S. Mirkar, *A performance comparison of MANET routing protocols*, Innov. Power Adv. Comput. Technol. (i-PACT), IEEE, 2021, pp. 1–5.