Evaluate the affect of mobility, network size and time on the Performance of Adaptive Routing Protocols*

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***Abstract*—A Mobile Ad Hoc Network (MANET) protocol must be configured correctly to ensure efficient data transfer. Pro permissible performance in MANET needs to optimize the collection conditions to obtain perform with high level of efficacy. One of the most critical of these conditions is the selection of the optimal routing protocol, where routing protocols play an essential role in performance. Also, election the proper values of the parameter in routing protocols plays a key role in MANET. Where MANET comprises several node devices which provided with the battery as a power source. The primary responsibility for MANET nodes is transmitting data based on routing protocols. All MANET routing protocols serve the same function in the network, but they are different in their performance. This paper investigated four routing protocols using the network simulator (NS-2) with various nodes speed, time simulations, network load, and network size. The current study was conducted using the performance metrics such as throughput, end-to-end delay, packet delivery ratio, and normalized routing load to comparative routing protocols performance. The simulation results showed that the Ad Hoc On-demand Distance Vector (AODV) protocol was the best in all previous metrics performance, with the note of a bit of height in the PDR term. In contrast to the Zone Routing Protocol (ZRP) has the lowest performance.**

***Index Terms*—MANET, Routing protocols, Random Waypoint Model, AODV, routing metrics**

I. Introduction

A mobile ad-hoc network (MANET) involves a mobile collection of nodes that communicate directly with each other without a fixed infrastructure [1] [2]. Nodes (or hosts) of MANETs self-organize, keeps moving in any path and at any velocity [3]. Recently developed MANET showed a particular interest in having characteristic features of fast adaptation, reconfiguration, economic viability, and adaptation to flash flood scenarios such as emergency deployment for military service and population health monitoring [4] [5] [6]. The nature of MANET nodes is a dynamic and, wireless links frequently changes, to communication completion. Consequently, the main cons of MANET's is to keep all nodes fully updated with necessary information for routing [7]. The location of MANET nodes and their capability of transmission power (tp) present a significant role in determining network topology. MANET's nodes are run by batteries and have short communication ranges, therefore all unnecessary communications should be avoided to enhance the network lifespan and throughput. The development, management, organization, and overall administration of a MANET are all carried out by the network [8]. To address dynamic topology variations and achieve a quality reliable connection, the choosing of routing protocols is essential in MANET configuration. Therefore, an effective routing protocol is essential to improve MANET connectivity. Selecting the proper routing protocol acts as an essential key in network efficiency, where the current paper primarily aims to investigate and analyze the effect of various protocols (proactive, reactive, and hybrid) on network performance by testing multiple parameters. Very few papers studied scalability and mobility of routing protocols and network parameters. The parameters investigated in the current study includes various number of nodes and various speeds evaluated in the experimental results using network simulator 2 (NS2). Eventually, the optimal protocol is operating more nodes number and changeable speed. We chose the Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) as reactive protocols were through research, and results for several papers proved the efficiency of these protocols. Destination Sequenced Distance Vector (DSDV) has been chosen as a proactive protocol, which is a predecessor of the AODV protocol. The rest structure of the current article is arranged as follows. An overview of the MANET routing protocols is introduced in the second section. While the third section presents the methods of the current project. The simulation Technique outline is explained in the fourth section. Results and discussion presented in the fifth section. Eventually, in the sixth section, the conclusions are presented.

II. MANET Protocols

As mentioned in the literature review, the Wireless ad hoc networks have various designs and categorizing protocols.

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There are several different MANET routing protocols classified summarized in the figure 1 [9]. The various routing

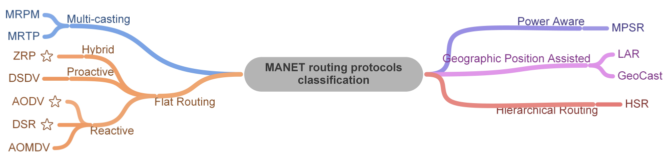

Fig. 1: MANET routing protocols classification.

protocols are mainly based on the distance-vector or link-state, sometimes mix between the distance-vector and link-state but may use different methods and mechanisms in an adaptation context of particular purposes.
MANET routing protocols is classified as proactive, reactive, and hybrid. Proactive protocols actively refresh their routing tables on a regular schedule [10]. Reactive routing protocols adaptively maintain a route and keep it while the path has long been used. Finally, the most common hybrid protocols combine the strengths of both approaches (proactive and reactive) to solving a problem.

1) Proactive Routing Protocols: Proactive protocols use a strategy similar to that of the protocol used in wired protocols. One goal for Proactive routing protocols is to provide the most updated networked path information and discover new paths [9].This enables them to transfer packets optimally because the route is calculated when the packet is forwarded to the node. An example of this type of routing protocol is Destination Sequenced Distance Vector (DSDV).
DSDV: is a MANET routing method that utilizes tables. Following the Bellman-Ford algorithm, several other changes were made and applied to the DSDV algorithm. The routing table has three components: hops number, access nodes, and sequence number commissioned to the destination node. Sequence numbers differentiate routes that have already been declared stable from those in the process of being established and avoid loops [11]. Routing tables are regularly broadcast to all the interconnected neighboring nodes to keep them up to date, or in case there is an essential update done in the table [12]. It is preferable to send updates as a small batches rather than constantly to maintain network stability. The routing table entry also contains a number generated by the transmitter and called a sequence number. The path selects the highest sequence number. In situations where two or more paths have the same sequence number, the one with the better metric (i.e., the path with the shortest length) is chosen [13] [14].

2) Reactive Routing Protocols: The reactive routing protocols are also known as on-demand protocols. If the on-demand protocols are used, the routes are checked only when required [15], this meaning that the paths are only checked when any nodes need to connect—Discovery process of the path, when a path is discovered, or when no path is found at all. In this context, these characteristics make it a reactive protocol. Several MANET routing protocols implement the reactive technique include dynamic source routing (DSR) and ad hoc on-demand distance vector (AODV) [16].
AODV:AODV uses three routing messages for three types of requests: Route Request (RREQ), Route Reply (RREP), and Route Error (RERR). When AODV tries to obtain a path to the destination, it flooding the network with request routing information. If the request is sent to the intended destination successfully, the destination will reply by gives an RREP to the source of this RREQ. However, if it was not, the last node would respond by provides a RERR with to the source of RREQ. Like the DSDV routing protocol, AODV uses the sequence numbers in the interchange information route process []. Every RREQ will be addressed only once, thus minimizing routing overhead. It only tracks the next hop among other features in the route table information [17] [18]. In AODV routing process uses the intermediate nodes. This process is also known as a hop by hop. The intermediate nodes use to transmitting packets between source and destination.
DSR: Path exploration in DSR uses RREQ/RREP packets, the same method as in AODV. In contrast to AODV, the paths are kept in a path cache. Additionally, the DSR is a path-based protocol that keeps data about the entire paths between the source and destination. Instead of forwarding the packet hop by hop like AODV, the packet conveys the whole route from source to destination in DSR.

A. Hybrid Routing Protocols

Hybrid routing combines close reactive routing protocols and proactive routing protocols to mitigate overhead routing and delays in the network resulting from discovery routing operations [19]. Higher reliability and scalability provide the contributions of hybrid routing protocols. The drawback of hybrid protocols is that new routes are being found connectivity issues presented within a network's latency. Zone Routing Protocol (ZRP) is one of the significant protocol type [20] [8].
ZRP: Utilizes reactive and proactive protocols in a hybrid system by using the proactive exploration of nearby nodes and using reactive communication routing protocol features between nodes [21]. A single config factor defines how the ZRP is designed for a given network. ZRP is a combination of two sub-routing protocols called Inter-zone Routing Protocol (IERP) and Intra zone Routing Protocol (IARP) [22].
Source table can be used to recognize a path to the destination zone's entry through a constructive cache table lookup. IARP allows the path to be found by looking in the source zone using the cash routing table when it has already been sent a certain amount of response time. When the source and destination are both in the same area, IARP determines the path and instantly sends the packets. According to these advantage features, IARP is being used in the algorithm of ZRP routing protocols [23].

III. Materials and Methods

A. Mobility Patterns

Random mobility does not impose limits on the nodes' movements in the MANET. In other words, in a random manner, the speed, destination, and orientation are chosen for each node, where each one of these factors is determined on its own and separately for the nodes [24]. MANET has several mobility types: Random waypoint model (RWM), Random walk model, Random direction model, Street random waypoint, Reference point group model (RPGM), Manhattan mobility model and Freeway mobility model. The random Waypoint model (RWM) is a widely employed mobility model. The RWM has two different models the Random Waypoint model and the Random Walk model. Due to the efficiency, plainness, unsophistication, and availability, the RWM has became the MANET standard mobility model. The setdest tool is used to create the node trace of the RWM. The commonly used network simulator NS-2 includes this function. It is advantageous to use mobility models as these imitate the way mobile nodes react to network efficiency. There's a significant correlation between mobility type and network performance [25].

B. Work proposed

Although several articles provided a foundation for further analysis based on essential suppositions, they did not address the fundamental analysis because critical conclusions were not taken to study the results with the different types of routing protocols such as proactive, reactive, and hybrid protocol. The current study investigates the various MANET routing protocols comprised of five aspect speed of nodes, number of nodes (Network overload), mobility, simulation time and network area. Besides, the current study takes into count applied all these aspects with different routing protocol types. MANET routing protocols' efficiency is measured by four parameters: packet drop rate (PDR), end-to-end delay (E2E Delay), throughput, and normalized routing load (NRL). The current study conducted with three different scenarios summarizes in the following section. The presented study examined the MANET routing protocols thirty-five times for each phase to substantiate and prove routing protocol efficiency. The current project used a variant number of nodes between 40 till 100 nodes. The number of nodes between (40 - 80) refers to the small network, while the number between (81 -100) refers to the large network. Figure 2, refers to network typology. In figure 2, nodes are free moving in the network area. Although the wireless communication range will vary across nodes, the data is propagated from source node to destination node. Accurate packet delivery is difficult to be ensured as there are a vast number of links between different parts of the network. This is substantiated in the upcoming section of the current work.

C. performance Parameters

The different routing protocols' parameters analyzed via simulation in the current study. These parameters are:

- **Packet Drop Rate (PDR)**: PDR is described as the" quantity of dropped packets per second". The dropped packets data have extracted and calculated from the simulation trace file. Every dropped packet will increase the unit time counter. Then the extracted data fed into the MATLAB, to plot the line graph for the entire simulation time. The PDR can be calculated by equation (1).

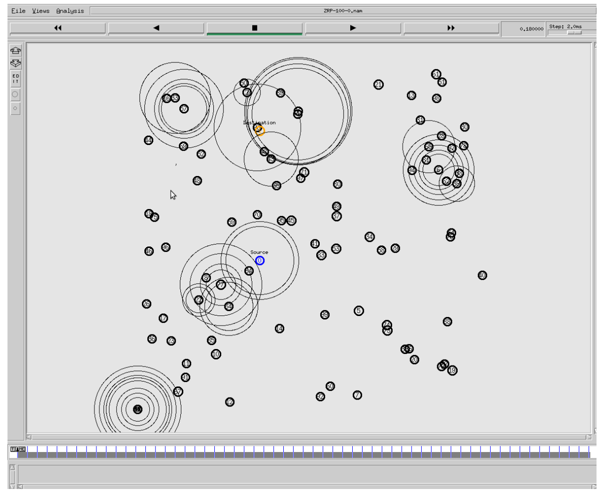

Fig. 2: Network typology.

$$PDR = \frac{\sum \text{Number of packets received}}{\sum \text{Number of packets send by node}} \quad (1)$$

- **Throughput**: A network throughput represents the total number of packets that have been delivered successfully per period unit of time. The optimal protocol is the protocol that generates a higher throughput rate. In other words, throughput is essential in evaluating the effectiveness and scalability of routing protocols, it is calculated by equation (2).

$$\text{Throughput} = \frac{\Sigma \text{ received packets size}}{\text{time}} \quad (2)$$

- **End to End Delay (E2E)**: is the average time that needs to send packets to the final destination. Also, it is defined as the difference between the transit time and the arrival time of the packet and calculated by equation (3).

$$D_{avg} = Tr_{avg} - Ts_{avg} \quad (3)$$

- **Normalized routing load (NRL)**: is the total routing packets of the total data packet that are received at the destination which is called routing load (4).

$$RO = \frac{\sum \text{ Routing packets}}{\sum \text{ Packets received}} \quad (4)$$

IV. Simulation Technique

The current work investigates the behavior of reactive, proactive, and hybrid protocols. These routing protocols are AODV, DSR, DSDV, and ZRP routing protocols are examined.

A. Simulation and Metrics Performance

There are several network simulations tools, such as (NS-2) [26], (NS-3) network simulator [27], and the network simulation software QualNet (QualNet) [28]. NS-2 has been chosen as the protocol simulator for this current study because of its abundance and support of several network protocols.

Four different routing protocols have been selected belonging to other families: AODV, DSR as a reactive routing protocol, DSDV as a proactive routing protocol, and ZRP as a hybrid protocol. By default, NS2 doesn't have ZRP routing protocol, unlike the other routing protocols like AODV, DSR, and DSDV, where those routing protocols are automatically installed with NS2. So, the patches of ZRP routing protocols have been implemented to NS 2.35. This patch is a solution to the ZRP installation. The ZRP routing protocol was out of the NS2 scope of development, so the ZRP protocol had to be added to the NS2 to implement it. Practical simulations were carried out after the patch was added.

In addition, the current work proposed a custom Perl script to calculate metrics such as packet drop rate (PDR), throughput, average end-to-end delay, and network overhead from the trace files. Finally, after these suggested modifications, the protocols and the four MANET routing scenarios are installed and ready to be tested.

The mobility model refers to the movement pattern of the mobile nodes during the simulation study. It plays a significant role in designing and implementing an excellent wireless infrastructure because a routing protocol has performed well in one mobility model, even though it is unnecessary to perform well in other conditions.

Besides, the scripts presented in OTcl, an object-oriented language enhanced version of Tcl modeling and analyzing UDP protocols, routers, and other network items, are used to execute the NS-2 software. Tcl scripts were used to create network scenario simulation, connection settings, nodes movement, and position are implemented in the same fashion. Other modifications were implemented to adjust the transmitting and receiving power at nodes to produce an effective influence per each packet. The simulation study results are produced in a trace file that is included in the stimulation details of the network.

The MATLAB programming language generates graphs. The current study used Random WayPoint (RWP) mobility model in the network simulation parameter.

As mentioned in the section above of "work proposed," where the presented work for three different scenarios included four aspect speed of nodes, network overload, mobility, and network area. More comprehensive details on the simulation parameters and simulation outcomes will be given below. The illustrations are examined and empirically deduced to support how to deal with various protocols for various network conditions and which routing protocol will be adapted, convenient, and appropriate for the MANET network.

B. Result and discussion

The performance analysis results by varying network overload, node speed, and area of the network will discuss in this subsection. The parameters are used in this simulation in the current study represented in table II. For organizational purposes, we analyzed and studied the first and second scenarios together. Table II, indicates the parameter simulation used during the current study in the first and second scenarios. In this simulation, the number of nodes was varied between (40 ,80 ,100), the node speed was 20, 40, and 60, and the network area was 1000 m2 and 1500 m2—the study in the first and second scenarios, conducted for all the different routing protocols used in this work.

TABLE I: Network simulation scenario

Parameters	***Value***
Simulator	Network Simulator 2
Simulation Time	180 seconds
Area of Different Scenarios	1000m x 1000m, 1500m x 1500m
Nodes Speed for different Scenarios	20, 40, 60
Transport Layer Protocol	UDP
Number of Nodes	40, 60, 80, 90, 100
Movement Scenario	Random Way Point (RWP)
Routing Protocols	AODV, DSR, DSDV, ZRP

Routing on the WMN is difficult to achieve because of the node's mobility. The mobility leads to irregular alteration in the network's topology, so selecting a suitable routing protocol is a challenging task. The present work evaluated the effects of mobility on various performance metrics in the current experiment work. The maximum mobile speeds obtained from a limited network, were between 1 m/s to 60 m/s and, the experimental networks were performed on small networks (40, 80 nodes connectivity sets) and large networks (81-100 nodes, connectivity sets).

There have been two different types of experiments and their results are summarized in the following subsections are set to the first and second scenarios.

C. Scenarios 1 & 2

Test 1- the impact of the network size and node speed Figures 3 & 4, illustrates the results of this experiment. The significant metric that stands out in this study is the throughput of AODV routing protocol. Where figures 3 & 4, found that the AODV dominates routing protocols at any condition simulation parameters. The AODV is fulfilled well than other routing protocols. It can be concluded that AODV has an Important throughput when the node's speed is high or low.

Moreover, the throughput of AODV remains higher than other routing protocols even the network was large in 1500 m^2. In addition, the DSR routing protocol produces higher throughput in 1000 m^2, which is inversely proportional with the network area. ZRP has a noticeable improvement in terms of throughput with higher mobility speed and a large network area.

The results of the packet delivery ratio (PDR) analysis are summarised in Figures 5 & 6. In this analysis, ZRP and DSDV have the lowest PDR. Contrary to ZRP and DSDV, this study found significant results related to the AODV routing protocol, where AODV AODV is the leader protocol when the PDR is considered.

Figure 7 & 8, presents the term of end-to-end delay (E2E) metrics reinforce the assumption that the metrics will remain

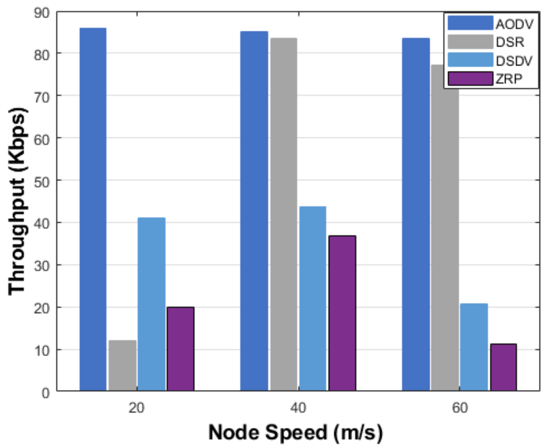

Fig. 3: Throughput based variety - nodes speed - 1000 m^2

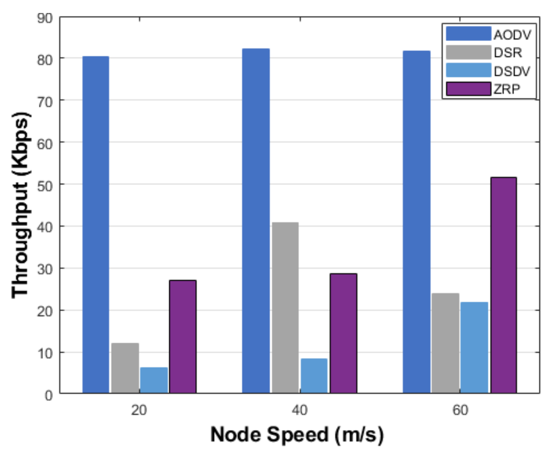

Fig. 4: Throughput based variety - nodes speed - 1500 m^2

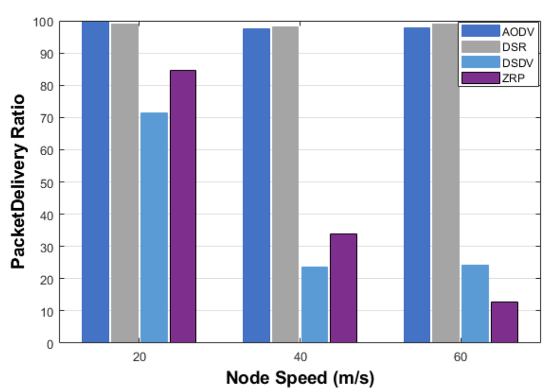

Fig. 5: PDR based variety nodes - max speed - 1000 m^2

constant as the max speed of mobile nodes increases. DSDV performs better than all other routing protocols in this situation, providing the minimum packet delay. DSDV produces acceptable values whether the size of the network was small or large within various mobility speeds. The AODV performed an optimal ratios packet delay, whereas, the ZRP present maximum packet delay.

The figure 9 & 10, Shows that the ZRP routing overhead is more significant than the other routing protocols, the performance getting significantly improved with the increment of the network area and speed of nodes. The overhead routing of the protocols following affects their internal implementation. In a high nodes speed environment, when the nodes numbers are 40, 80, and 100, the results showed that the AODV routing protocol has the lowest routing overhead. However, it is preferable to reduce the routing overhead with a large network with high mobility conditions and scalable nodes. Also, AODV routing protocols present a better effect on the NRL and lowest routing overhead rather than the other routing protocols.summary, the network's speed and size area have a significant and direct impact on network efficiency. The parameters of the network performance acting more stable and improved significantly with the increment nodes speed, but the performance decrease with expanded network area.

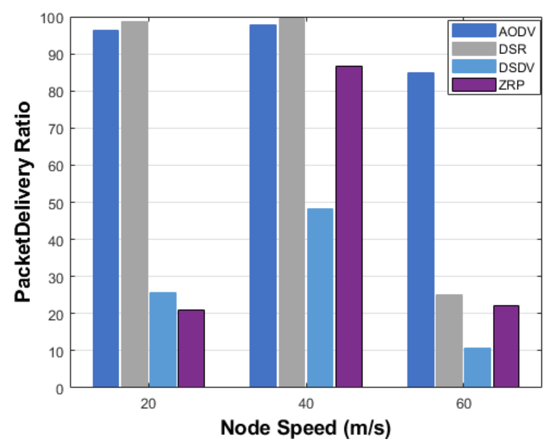

Fig. 6: PDR based variety nodes - max speed - 1500 m^2

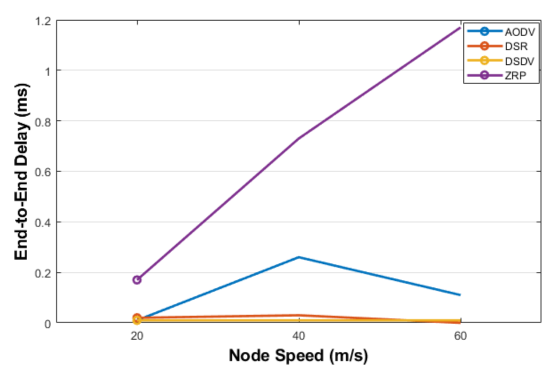

Fig. 7: E2E by different - max speed - 1000 m^2

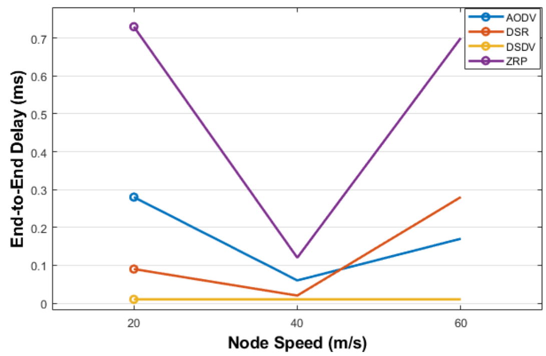

Fig. 8: E2E by different - max speed - 1500 m^2

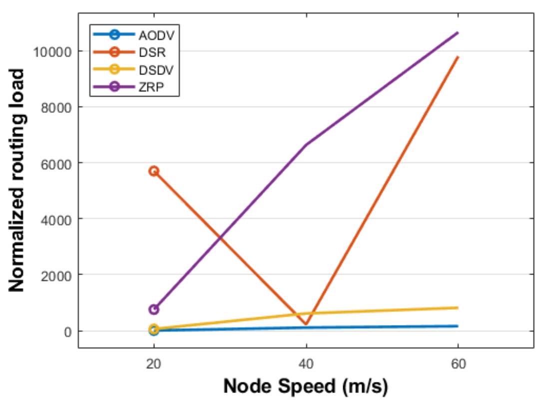

Fig. 9: NRL by different nodes - max speed - 1000 m^2

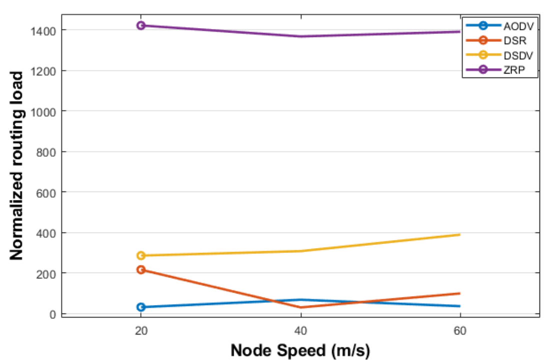

Fig. 10: NRL by different nodes - max speed - 1500 m^2

Test 2 - the impact of the nodes number and network area

The current scenario employs various network typologies. In this study, with different network areas, and maximum nodes number is 100 nodes. The plotted graphs below present the results of AODV and DSR protocols.

Figures 11 & 12, illustrates the throughput four routing protocols for 40, 80, and 100 nodes, respectively. The DSR and DSDV protocols are worse significantly when the number of nodes within the large network area increases. However, the DSR performance remains acceptable in the small and middle network area. The AODV performance is much better than other routing protocols. Noting a slight improvement in the performance of ZRP routing protocol within a large network area. The packet delivery ratio shows in 13 & 14, is very high though AODV is doing much better in this term. In contrast, the DSR, DSDV, and ZRP serve the lowest than AODV, especially with the large network size and higher nodes numbers. Simultaneously, the results of figures 15 & 16, show that the AODV protocol has an insignificant increment in the average end-to-end delay with the network size. In comparison, the ZRP protocols reduced the network performance with an increase in network size and an increasing number of nodes. Terms of normalized routing load (NRL) represented in 17 & 18, the results reveal that AODV performs better than the other three routing protocols. In contrast, the DSR protocol has poor outcomes in terms of routing overhead. Moreover, DSR and ZRP have the most considerable routing load, increasing the network size and nodes.

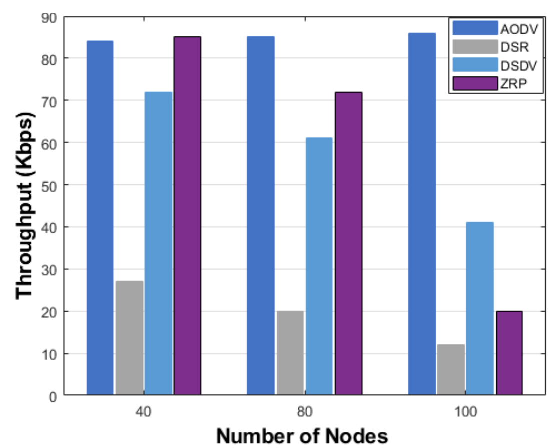

Fig. 11: Throughput vs number of nodes - 1000 m^2

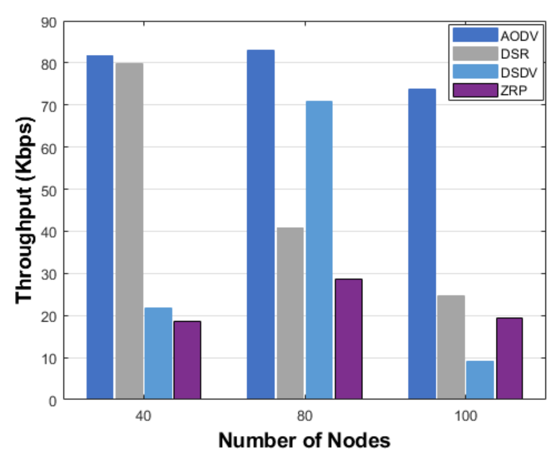

Fig. 12: Throughput vs number of nodes - 1500 m^2

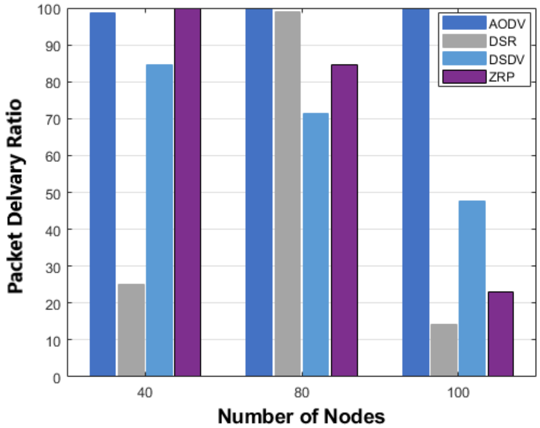

Fig. 13: PDR vs number of nodes - 1000 m^2

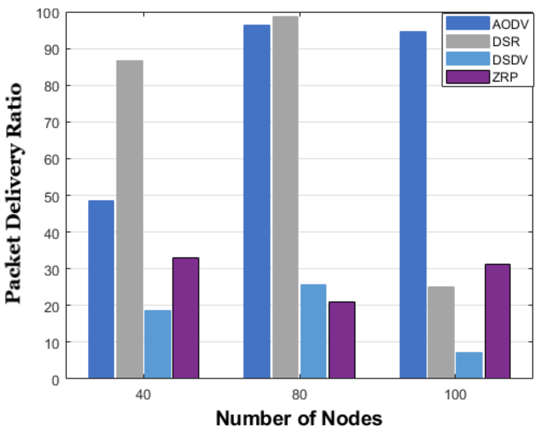

Fig. 14: PDR vs number of nodes - 1500 m^2

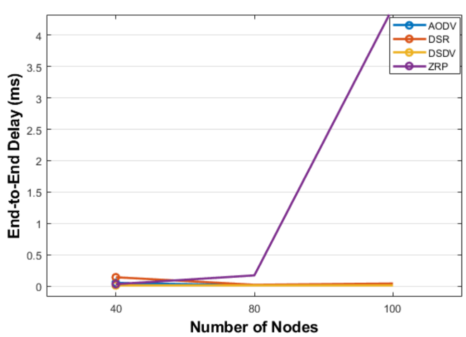

Fig. 15: E2E vs number of nodes - 1000 m^2

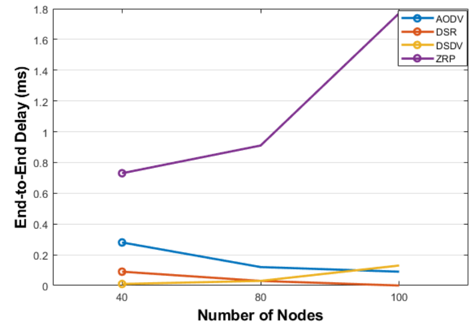

Fig. 16: E2E vs number of nodes - 1500 m^2 area

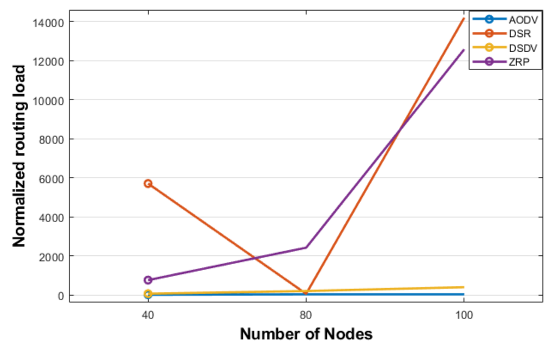

Fig. 17: NRL vs number of nodes - 1000 m^2 area

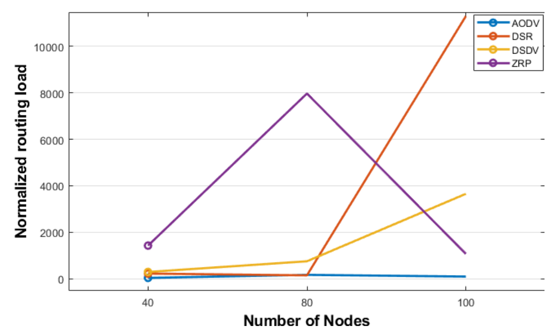

Fig. 18: NRL vs number of nodes - 1500 m^2 area

TABLE II: Network simulation scenario

Parameters	***Value***
Simulator	Network Simulator 2
Simulation Time	180sec, 300 sec
Area of Different Scenarios	1000^m
Nodes Speed for different Scenarios	20
Transport Layer Protocol	UDP
Number of Nodes	100
Movement Scenario	RWP
Routing Protocols	AODV, DSR, DSDV, ZRP

D. Scenario 3

The pivot of the current test in this scenario is the simulation time. In this test, the term of simulation time was the factor of axis study alongside with the node speed of the network. Table II presents the network parameters. Evaluation of the influence of simulation time on the MANET protocols. Four routing protocols have been evaluated and compared to assess their efficiency. They are PDR, end-to-to-end delay, normalized routing overhead, and throughput as shown in figures 19, 20, 21, and 22 sequentially. These protocols are seated to evaluate the performance of routing protocols based on the time alteration. The outcome of the simulation result shows that the AODV is performed better in simulation time than another routing protocol when simulation increases. Expectedly the PDR has the same value during the simulation, even as long or short time. Furthermore, the result showed that the AODV gives a valuable result with the throughput, routing overhead, and end-to-end delay. In contrast, the ZRP has the worst performance when the simulation time increases.

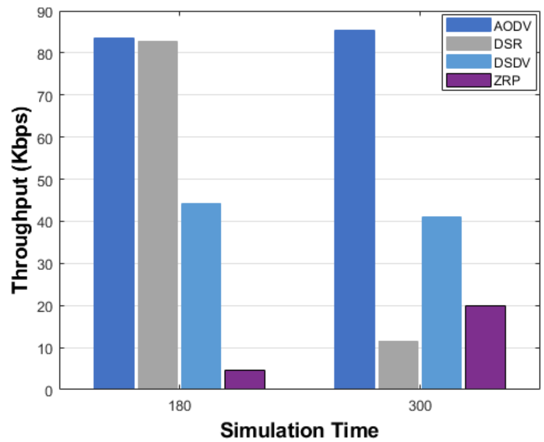

Fig. 19: Throughput based on a variety of simulation time

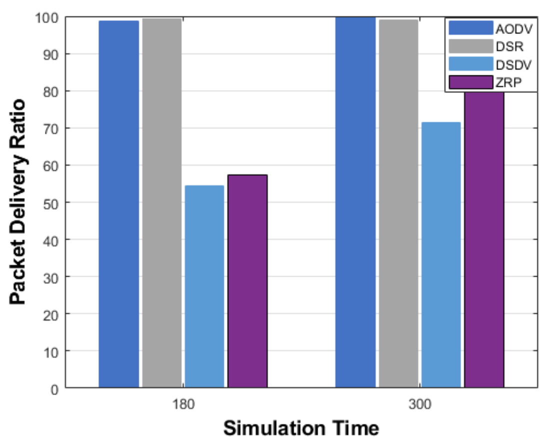

Fig. 20: PDR based on a variety of simulation time

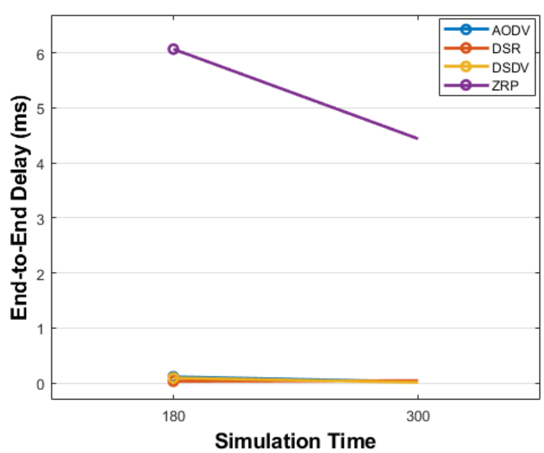

Fig. 21: E2E based on a variety of simulation time

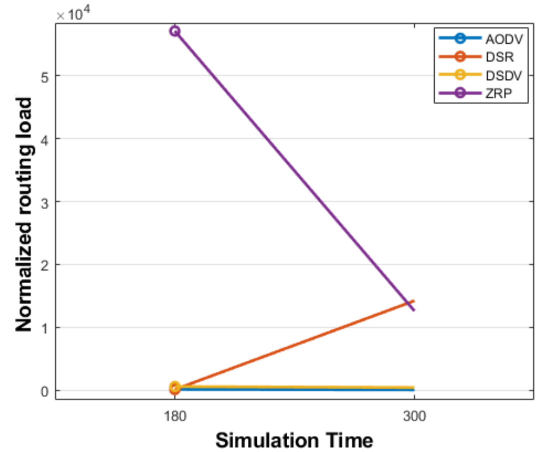

Fig. 22: NRL based on a variety of simulation time

V. Conclusion

The current investigation aimed to assess the performance of routing protocols under different metrics aspects such as throughput, PDR, end-to-end delay, and routing overhead. The current work was undertaken with NS2 simulation and the evaluation of graphics created by MATLAB with alteration the simulation time, number of nodes and network size. The simulation results obtained detailed of different metrics by employing the following routing protocols: AODV, DSR, DSDV, and ZRP. One of the more significant findings emerged from this study is that AODV routing protocols was the best performance in respect of the metrics mentioned above. On the other hand, the evaluation of the PDR was a little more valuable than the different routing protocols. A small to medium-sized network doesn't affect the performance of the routing protocols significantly, even the protocol outcomes were well performance in this type of the network. The results indicated that the vital feature of a successful routing protocol is the ability to scale. In generality, the normalized routing load is responses proportionally with the number of nodes and time simulation besides increasing network area. The normalizing load does not often change when there is increasing in the network size, the number of nodes, and time simulation, especially with AODV protocol, but the performance of the DSR and ZRP protocols was the worst, the NRL as a result of overload and network area.

The current simulation results could assist the researchers in deciding which is the best WMN routing protocol. Where the current results provide some helpful guidance outlines, that may help to select or develop a routing protocol for WMNs. Further investigations and experimentations into PDR are strongly recommended. Also, study similar experimental design to the current project should be carried out on TCP traffic instead of UDP traffic.

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