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MANET performance evaluation for DSDV, DSR and ZRP

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Abstract
In a mobile ad hoc network (MANET) setting, this study investigates the effectiveness of three routing methods. Mobile nodes in MANETs can connect wirelessly without the assistance of central devices or physical infrastructure. Routing protocols, which come in a variety of forms, including proactive, reactive, and hybrid, are crucial for maintaining communication inside MANETs. This study compares the network performance of the zone routing protocol (ZRP), dynamic source routing (DSR), and the destination-sequenced distance vector (DSDV) when there are between 10 and 50 nodes with a speed of 10 m/s. The study's objective is to learn more about the quality of service (QoS) that these protocols offer. The performance analysis was performed using the network simulator 2 (NS2), and the results reveal that the DSR protocol exhibits superior performance in terms of throughput, packet delivery ratio (PDR), and end-to-end (E2E) delay as the number of nodes increases from 10 to 50. The findings of this study can provide valuable information for the selection and deployment of routing protocols in MANETs.

Keywords
MANET, DSDV, DSR, ZRP, Network performance.

1.Introduction
Numerous nodes, particularly electronic devices like tablets, cellular phones, and video cameras, form mobile ad-hoc networks (MANETs). All of these devices are connected to one another via a wireless connection and is capable of communication [1]. Each mobile node is able to join or leave the network at any time. The mobile nodes are independent and can move at will. As a consequence, the network's topology may change abruptly and without prior notice. To put this in context, MANET may alternatively be described as a group of mobile nodes attached to a distant source that later creates a dynamic topology [2]. In addition to being a router for data sent to and received from the other mobile nodes, each node in the network has the ability to act as a sender, receiver, or intermediary node. The nodes are highly dynamic in real-world settings and rely on battery cells for power due to the MANET usage [3].

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Wireless communication can be provided through MANETs without the need for a strong physical infrastructure.

They use a multi-hop communication approach where the source and destination mobile nodes connect indirectly through intermediary nodes and only consist of a collection of radio equipment. Only nearby nodes can directly communicate with one another.

MANETs allow every device to move around independently and in any direction. MANET supports device mobility as it is a self-aligning network without physical infrastructure. Because of its self-configuring, self-repairing, self-functioning, and self-recovery network, MANET is simple to maintain [4, 5]. Since MANET is a decentralized, infra-structureless network, users can configure dynamically wireless connections without an established infrastructure network [6, 7]. Military operations like tactical networks and complex defence research were where MANET was first use in the context of application. Using MANETs to build a wireless connection that is dynamically adaptable even in the lack of physical infrastructure during disasters was also a practical approach [8]. In addition, several different industries have been using MANET applications recently, including those for robotics, IOT, environmental sensors, homes, and health [9].

Due to its mobility, topology of the MANET change. As a consequence, routing emerges as one of the issues in MANET that needs to be addressed immediately in order to handle data delivery, particularly in cases where the local infrastructure is inaccessible. In MANET, routing is built on a direct technique that allows each node to re-emit the data message, enabling direct network transmission from a source to its particular destination. One of the most important factors in designing a routing system is determining the optimum path to the destination. The nodes can make use of these protocols to aid them in determining the best route for messages to take via the network. It is also employed to create and store up-to-date routing data. Due to mobility, the routing information will need to be modified to adjust for changes in connection connectivity. Moving from one location to another is possible in a number of ways. The routing protocols, which choose a path from source to destination, send the packet to the correct spot [10]. The performance of the MANET routing protocols is influenced by their efficiency [11].

According to [5] and [12], routing in MANETs is a challenging operation that calls for taking into account important variables including dependability, scalability, and real-time communication. Given the dynamic nature of network characteristics, even in situations when nodes are static, this is very difficult. According to [13], establishing a route in MANETs that satisfies particular performance criteria linked to connection quality is a substantial issue. Numerous routing protocols have been created recently to enhance their quality of service (QoS) in the MANET simulation. A routing protocol should ideally be able to provide data to a data center quickly, reduce transmission delays, and offer real-time communication.

Therefore, the purpose of this paper is to compare the performance of three fundamental routing protocols in the proactive, reactive, and hybrid MANET routing classes. The chosen protocols, zone routing protocol (ZRP), dynamic source routing (DSR), and destination-sequenced distance vector (DSDV), will be assessed based on quality of service (QoS) metrics such throughput, packet delivery ratio (PDR), and end-to-end (E2E) delay. To evaluate the effectiveness of these protocols, simulation settings like the number of nodes will be changed. This paper's main contribution is a comparison of the effectiveness of these chosen routing protocols, highlighting the importance of the findings in terms of QoS.

The paper is structured as follows: Section 2 explains the categorization of routing protocols in MANET and previous efforts in this area. In section 3, we have described the approach for evaluating the QoS of three distinct routing protocols in terms of throughput, PDR, and E2E delay, along with the parameter configurations and performance measurements. Section 4 follows with a presentation and explanation of the simulation results. Section 5 discusses the results and identifies their shortcomings. The provided work is finally concluded in section 6, and additional research is advised.

2.Literature review

2.1Classification of routing protocols

In the context of mobile ad-hoc networks (MANETs), the term "ad hoc routing protocol" refers to a protocol that facilitates the determination of routing paths between source and destination nodes. The nodes in ad hoc networks have limited knowledge of their network topology, and thus, due to the constrained resources and the dynamic movement of nodes in MANETs, routing can pose a significant challenge. There are three types of routing protocols: proactive, reactive, and hybrid. Each of these routing protocols has its own unique advantages and disadvantages.

2.1.1Proactive protocol

The proactive protocol is a table-driven protocol that largely depends on link state techniques to provide information about its network neighbors and to keep track of each node's route and course within the network [14]. DSDV is an example of a proactive protocol. Every DSDV node maintains a routing table that contains a list of all destinations and the number of hops needed to reach each one. Each entry has a sequence number next to it. It employs complete dumps or incremental updates to reduce the network bandwidth needed by route updates. The proactive protocol's advantage is that routing computations are made on each node before the data transmission procedure is carried out. Consequently, this process consumes much energy and bandwidth [15]. The process flow for how DSDV provides the routing strategy is shown in *Figure 1*.

2.1.2Reactive protocol

The reactive protocol starts a path discovery process and then determines the shortest path between the communication nodes as soon as the source node has data packets to send to the destination node. Until the information packets reach their destination or the pathway is blocked, a path that has already been established won't change. Many procedures have been taken, such as adding a sequence number [14], to assist users in remembering the new path and preventing repetition. Reactive protocols, such as DSR, operate entirely on demand in every way. It functions in accordance with the principle of source routing. Source routing is a type of routing in which the sender of a packet chooses the entire list of nodes that the packet will pass through before being forwarded. The advantage of reactive protocols is that the path is only established in response to on demand requests. The data will encounter delays as a result of the time taken for the path to be established, which is a drawback of the reactive protocol [15]. *Figure 2* illustrates the process flow for how DSR provides the routing strategy [16].

2.1.3Hybrid protocol

In order to establish a reactive environment that is instantaneously connected to proactive connections within a given range, the hybrid routing protocol in a MANET combines the advantageous components of proactive and reactive routing protocols. A reactive assessment is carried out if the source node wants to send messages to a node outside of this zone. When proactive routing protocols are used, root nodes and routing tables are used to instantly access the paths within a node's coverage area. A node will use the reactive routing technique for route discovery if it is uncertain of the source node's path to its destination [17]. The zone routing protocol (ZRP), which combines the benefits of proactive and reactive routing systems to achieve maximum efficiency and scalability, is an example of a hybrid protocol [18]. ZRP uses proactive protocols within the zones and reactive protocols between the zones, dividing the network into non-overlapping routing zones. Using proactive and reactive protocols accelerates communication while still taking into account network overhead by choosing the most direct path [15]. The flowchart illustrating ZRP's routing system is shown in *Figure 3* [19].

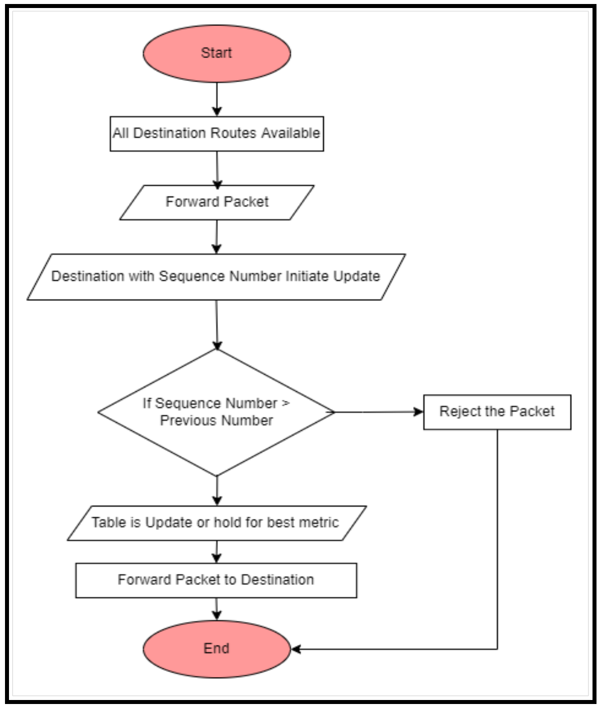

Figure 1 Flowchart of DSDV routing protocol

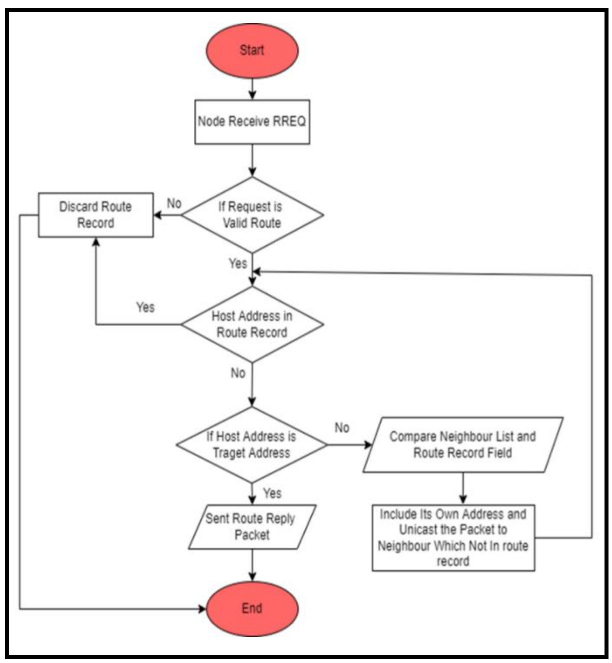

Figure 2 Flowchart of DSR routing protocol

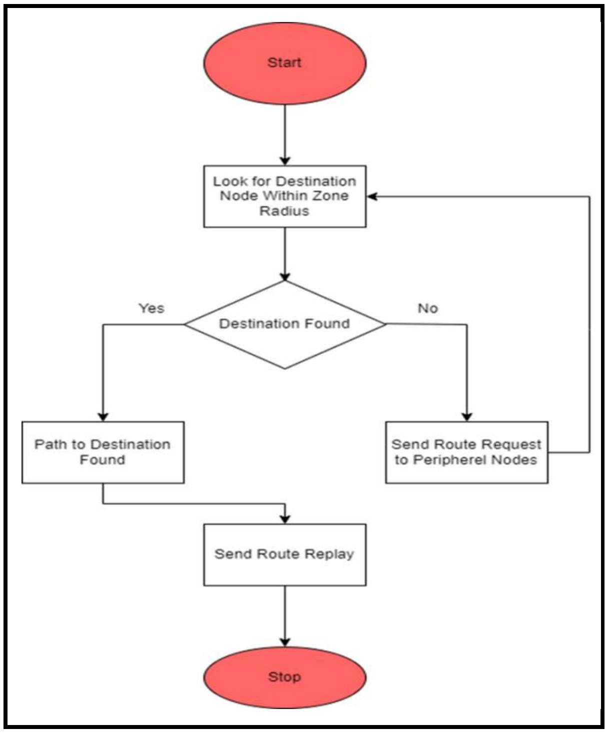

Figure 3 Flowchart of ZRP routing protocol

Table 1 describes the summary of the three routing protocols chosen (DSDV, DSR, and ZRP) in terms of their path route discovery.

2.2Related works

Manimekala [19] used the optimized network engineering tool (OPNET) to assess the effectiveness of the ZRP routing protocol. Three different scenarios were used for the simulations, each with 20, 40, or 60 mobile nodes, with constant simulation time and traffic load. Throughput, load, packet drop rate, and delay were the performance metrics taken into consideration in the analysis. As the number of mobile nodes rises, the results showed that ZRP demonstrates good throughput. With 20 nodes, the burden is negligible, but as the number of nodes increases, the load likewise rises, first increasing slowly. As the number of nodes grows in response to congested traffic, the delay and amount of data loss also grow.

Yahaya et al. [20] examined the effectiveness of DSR, optimal link state routing (OLSR), and the geographical routing protocol (GRP) using the OPNET. For all simulations, the network area was set to 1000 m x 1000 m, with a fixed amount of 20 nodes. The simulation lasted 3600 s, with a 10 m/s mobility speed. Throughput, latency, and network load were the network performance parameters compared. According to the findings, OLSR performed better than the GRP and DSR routing protocols. It is noteworthy, nevertheless, that OLSR's higher performance in MANETs could not always adapt to other networks.

Additionally, Roy and Deb [21] conducted a performance evaluation and comparison of three ad-hoc routing protocols, namely Ad-hoc on-demand distance vector (AODV), DSR, and DSDV, based on throughput, average end-to-end delay, and packet delivery fraction (PDF) at different data rates. The simulation involved 25 uniformly selected nodes with a simulation duration of 100 m/s. The results indicated that DSR is suitable for network scenarios where throughput and PDR are crucial, while AODV is suitable for networks that prioritize low delay.

Moreover, Srivastava [22] conducted a performance comparison between AODV and DSDV by varying the number of nodes from 5 to 25. The node mobility speed was set to range from 0.5 to 1.5 meters per second. The simulation area was 600 meters by 600 meters with a transmission range of 250 meters, and the simulation duration was 200 seconds. The results showed that the DSDV protocol outperforms AODV in terms of packet delivery ratio (PDR), however, as the number of nodes increases, the performance of DSDV in terms of routing overhead becomes inadequate.

Real-time load balancing DSR (RTLB-DSR), a revolutionary routing technology presented by Maleki et al., aimed to raise network QoS [23]. A centrality statistic was created as a result of this work's emphasis on best-effort packet routing. The random waypoint (RWP) mobility model and a 670 m × 670 m simulation area were both used. 900 seconds were spent on the simulation. The RTLB-DSR attempts to route real-time flows through network centres that are less congested while routing best-effort flows at the network edge using a centrality metric. It has been shown that the suggested method is more capable of managing both real-time and best-effort traffic.

Naseem and Kumar introduced an efficient DSDV (EDSDV) protocol to mitigate network congestion in their work [24]. The protocol selects a less congested alternate route instead of utilizing the congested primary route. The simulations were conducted using Network Simulator2(NS2), with a 1000m x 1000m simulation area and a transmission range of 250m. The network consisted of 50 nodes, and the simulation time was varied at 250, 500, 750, and 1000 seconds. The results of the simulation showed that EDSDV achieved shorter E2E latency for packet transfer compared to DSDV. The utilization of an alternate route that was less congested reduced both congestion and the total latency associated with data transfer.

A comparison of the DSR, the temporally ordered routing algorithm (TORA), and the low-energy adaptive clustering hierarchy (LEACH) may be found in [25]. The throughput, average jitter, E2E latency, and PDR of their performance were evaluated. In a 500 m x 500 m simulation region, the nodes' values varied between 10 and 100. DSR's performance is considered superior due to its increased throughput and PDR even as the network's nodes grow in number. When the network is congested, the DSR's overhead increases since it uses a table-driven approach for packet forwarding. Therefore, DSR has a larger average jitter and poorer E2E latency performance. Meanwhile, TORA uses a graph called a directed Acyclic Graph (DAG) to find paths, which saves time. Thus, it has a shorter end-to-end delay than DSR. However, the TORA performs poorly in terms of average jitter and throughput. As for the LEACH, it is the fastest in terms of E2E delay and throughput but is the slowest in terms of PDR.

A study in [26] implemented and evaluated the performance of AODV, DSR, and DSDV in terms of throughput, PDR, end-to-end latency, and average routing load by using NS2. The simulations demonstrated that a routing protocol's performance changes significantly across distinct performance differentials. Both AODV and DSR outperformed DSDV in simulations. It was concluded in the study that in ad hoc networking setups, DSR and AODV perform better than DSDV for constant bit rate (CBR)-based traffic. Therefore, a new protocol for ad-hoc networks may be created utilizing DSR and AODV as a basis, with further research concentrating on optimizing and deploying the new protocol in ad-hoc networks.

Sani et al. [27] examined performance of the transmission control protocol (TCP) in MANET routing systems. PDR, average throughput, and average E2E latency were the performance measures used to assess the DA mobility model's performance during the simulation experiment. The mobility model was put through a range of traffic patterns and a high node density in order to evaluate the routing protocols. The findings showed that in terms of throughput and E2E latency, ad hoc on-demand multipath distance vector (AOMDV) is better than DSR and ZRP. However, DSR outperforms the others in terms of PDR, whereas ZRP outperforms them all in terms of PDR.

For the link and route lifespan in mobile multi-hop networks, Younes and Albawi presented an analytical model [28]. Several distinct network variables were altered throughout the simulation that utilized the RWP model. Data from simulations and the suggested analytical model were contrasted in order to verify it. The obstruction from surrounding nodes also increased when the transmission range was expanded, which reduced network performance.

Four MANET routing protocols, including AODV, DSR, DSDV, and ZRP, were compared in Alameri and Komarkova's work [29], with an emphasis on a number of different variables. Throughput, average E2E delay, PDR, and nodes energy residual are a few of the metrics used to assess the performance of the protocols. The RWP was applied as the mobility model in the investigation. In regards to the overall network performance, the study's findings demonstrated that AODV operated effectively.

Additionally, Neeraj et al. investigated two distinct simulation area types, namely 400 m × 400 m and 500 m x 500 m, to assess the effectiveness of the AODV, DSR, and DSDV routing protocols [30]. The simulation was run with constant values for the pause duration, connection pattern, packet size, connection type, and runtime. The parameters of throughput, E2E latency, energy, normalized routing load (NRL), and PDR were used to assess the effectiveness. The findings showed that AODV excelled over DSDV in terms of throughput but DSDV consumed less energy on average. In terms of PDR, DSR significantly outperforms the other protocols for fewer nodes whereas AODV surpassed them for more nodes.

Brill and Nash in their paper [31] presented a performance comparison between various MANET routing protocols based on their classification which are reactive (AODV), proactive (DSDV), and hybrid (AntHocNet). The simulation ran in a defined area of 3 km x 1 km with 100 nodes and duration of 900 s. The performance was measured in terms total packets sent, PDR, and energy consumption. The simulations demonstrated that AntHocNet consumes the most energy. As opposed to DSDV, which only broadcasts ants across the network when they are needed, the ant colony optimization (ACO) technique broadcasts ants more frequently than DSDV. The protocol makes up for its shortcomings with a superior PDR that outperforms AODV and DSDV.

To improve the effectiveness of the AODV protocol in the MANET, an improvement has been suggested in [32]. By utilizing NS2, the simulation was run while modifying a variety of parameters, including node density, packet count, runtime, highest and lowest speed mobility, and pause time. The enhanced AODV performs better than the default AODV in terms of PDR, throughput, overhead, and E2E latency, according to the findings of the simulation.

A study was done in [33] to examine how the AODV and OLSR performed in relation to the route request parameters. PDR, throughput, delay, packet loss, energy use, and overhead were the QoS parameters taken into consideration for the performance assessment. According to the results, the OLSR protocol has a lower latency than the AODV. However, the AODV performs better than the OLSR in terms of other QoS metrics.

A comparison of the AODV, DSDV, and AOMDV's performance evaluations has been provided in [34]. These protocols were evaluated by taking various values into account for node density, stop duration, and traffic connection rates. In addition, throughput, NRL, PDR, and packet drop were taken into account when evaluating performance. The results show that AODV outperforms DSDV and AOMDV protocols in terms of overall performances. AOMDV has better E2E latency than DSDV. While AODV is very slightly impacted by changes in network architecture, DSDV experiences lower throughput.

In their work [10], Lemma Arega et al. examined the effectiveness of the AODV, DSR, and DSDV protocols based on QoS criteria such as throughput, average E2E latency, PDR, and packet loss ratio. NS2 was used to run the simulations. The simulation findings showed that in terms of network load, DSR exceeded DSDV in regard to overall performance, whilst in terms of network size, DSDV surpassed DSR in terms of its overall performance.

Mohamed et al. [35] conducted an evaluation of the performance between the AODV and the DSDV routing protocols in order to assess the impact of variations in QoS parameters, including throughput, jitter, PDR, and energy consumption. The simulations were performed using the NS3 and the results indicated that DSDV exhibited remarkable performance in networks with moderate load and mobility. However, in scenarios with high network load and mobility, AODV was found to perform better and was determined to be a superior choice compared to DSDV.

To manage a variety of situations, including dynamic environments, network load balancing, and congestion control, an improved hybrid routing protocol (IHRP) has been introduced in [36]. The network situation-based routing modification in the proposed IHRP makes use of the AODV, AOMDV, and OLSR protocols. Regarding the PDR, NRL, throughput, and average E2E latency, the effectiveness of the IHRP and ZRP protocols were compared. In regards to the overall QoS parametric, their studies showed that the IHRP performs significantly better than the ZRP.

Al-Hasani and Waheed [37] investigated how effectively AODV, OLSR, and ZRP performed in several scenarios that represented various node densities for varied terrain sizes. For a similar network size, the number of bitrate connections was modified to represent the volume of data transmitted. Performance metrics such as E2E latency, throughput, average jitter, and overhead were analyzed using the QualNet v5.2 network simulator. Since each protocol was created using a different technique for establishing and maintaining paths in the wireless ad-hoc environment, it is apparent from the findings that no protocol performs better than the others in all scenarios. While OLSR can offer an excellent latency in contrast to AODV, it cannot fulfill the scalability requirement due to the additional overhead produced by a rise in network density. Even though AODV has its limitations for real-world applications due to a higher amount of delay, it nevertheless offers considerable overhead savings and the best packet loss ratio. The ZRP offers a reasonable approach for attaining decent results across various parameters, unless the targeted application requires a specific performance level in throughput and overhead.

The effectiveness of different routing protocols and their impact on MANET with regard to several Qos metrics have been researched in the literature up to this point. According to the study, there are currently no routing protocols that can perform in every QoS parameter. Instead, depending on the chosen case, there is still a chance for them to perform better in some QoS parametric. The performance of the selected routing protocols, DSDV, DSR, and ZRP, was examined in the next section, where we described how the simulation utilizing the NS2 was performed.

Table 1 Path route discovery of DSDV, DSR, and ZRP routing protocols

Routing Protocol	DSDV	DSR	ZRP
Routing Type	Link state	Distance vector	Link reversal
Routing Approach	Proactive	Reactive	Hybrid
Route	Single	Single	Multiple
Routing Mechanism	Flat		
Route Maintenance	Routing Table		
Routing Metrics	Shortest Path		
Update Transmission Frequency	Periodically and as needed.	Periodically.	Periodically and as needed.
Limitation	When the topology of the network undergoes modifications, it is necessary to assign a new sequence number in order for the network to re-establish stability.	High-time processing in obtaining routing information.	Short latency for finding new routes.

3.Methods

In order to determine which routing protocol, classified based on their characteristics, may offer a higher quality of QoS in terms of MANET performance, the study analyzed the performance of the DSDV, DSR, and ZRP. A network simulator tool was utilized for the analysis, as creating a large number of nodes in a real-world environment would not be a practical option. The focus was on examining the QoS parameters of throughput, E2E delay, and PDR, to understand the behavior of these protocols for a real-time monitoring system. The simulation employed the Perl programming language and NS version 2.35 (NS2.35) to gather data such as throughput, PDR, and E2E delay from trace files and other sources. The ZRP protocol was not included in NS2 by default, thus it had to be manually installed and configured.

3.1Simulation setup

We considered these papers [32, 38] as references to setup our simulation model. Thus, we configured the number of nodes as 10, 20, 30, 40, and 50. The simulation area was set to 500 m x 500 m. In each of the simulated scenarios, the RWP mobility model was used with the speed set at 10 m/s with zero pause time. The simulation time was set to 100 s and packet size 512 bytes. CBR was used for the traffic pattern and two-ray ground as the radio-propagation model. Other simulation parameters used such as media access control (MAC) type, interface queue type, network interface type and antenna type were also summarized in *Table 2* below.

Before running the simulation, NS2.35 and network animator (NAM) software were installed on the Ubuntu Linux operating system. To begin, upon the completion of the installation, a tool command language (TCL) script was modified based on the set simulation parameters to meet the requirements of the network under test. Then, the modified TCL script was run using NS2. As a result, outputs which were a trace file and an animation file were generated automatically. The animation file demonstrated a visual simulation of the traffic flow between nodes in the designated network. On the other hand, the trace file contains the movement trace of each node, and their performance can be evaluated using scripting languages such as Aho, Weinberger, and Kernighan (AWK) or PERL.

Table 2 Parameter settings

Parameter	**Specification**
Simulation area (sq m)	500 × 500
Mobility model	Random Waypoint
Routing protocol	DSDV, DSR, and ZRP
Number of nodes	10, 20, 30, 40, and 50
Mobility speed (m/s)	10
Simulation time (s)	100
Pause time (s)	0
Mac type	MAC/802.11
Interface queue type	Queue/Droptail/PriQueue, CMUpriqueue
Network interface type	Phy/WirelessPhy
Antenna type	OmniAntenna
Traffic type	CBR
Radio-propagation model	Two-Ray Ground
Packet size (bytes)	512

3.2Performance metrics

In order to maintain effective communication in MANETs, routing is essential. It is crucial to think about overall performance given the restricted processing and power capability of MANETs. This study concentrates on a handful of the parameters that define the operation of MANETs and lists them, as explained below.

3.2.1Throughput

Throughput in a network refers to the amount of data that is successfully transferred from one point to another in a given period of time [39]. The throughput can be influenced by various factors, such as the type of communication protocol being used, the amount of traffic on the network, and the capacity of the network components such as the bandwidth of the network connection, the processing power of the devices involved, and others. Equation 1 denote the calculation for the throughput:

$$\text{Throughput} = \left(\frac{Pr\ X\ SP}{T}\right) X \left(\frac{8}{1000}\right) \qquad (1)$$

where the throughput is determined in kilo bit per second (kbps), Pr is the packet number received by the destination node, SP is size packet and T is the simulation time. T is referred to the difference value between Stop Time and Start Time. The throughput is a key metric in determining the efficiency and performance of a network, as it reflects the amount of data that can be transmitted over the network in a given time. Thus, the best performance is achieved if this metric is maximum [40].

3.2.2PDR

PDR refers to the fraction of packets sent over a network that are successfully received by their intended receiver [39]. It is a measure of the reliability of a network, as it indicates the proportion of packets that make it from the source to the destination without being lost or corrupted. Equation 2 denote the calculation for the PDR:

$$\text{PDR} = \left(\frac{Pr}{Ps}\right) X\ 100\% \qquad (2)$$

where *Pr* is the number of packets received by the destination node and *Ps* is the number of packets sent by the source node. It is usually expressed as a percentage and can be affected by several factors, such as network congestion, interference, or hardware failures. A high PDR value indicates a reliable network, while a low PDR value may indicate issues with the network's performance or stability. Hence, PDR is an important metric in the evaluation of network performance, as it provides information about the reliability and efficiency of data transmission over the network.

3.2.3E2E delay

The disparity in packet arrival times is known as the E2E delay. The queueing on the interface, the path discovery, or the retransmission processes could all cause packet delays [41]. In [29, 30], E2E latency is described as the total amount of time it takes a packet to successfully reach the sink node. Equation 3 denote the calculation for the E2E delay:

$$\text{E2E delay} = N\ x\ (dproc + dtrans + dprop) \qquad (3)$$

where N is the number of links between routers, dproc is the average processing delay incurred by a router, dtrans is the average transmission delay and dprop is the average propagation delay. The E2E delay returns the time in miliseconds (ms). This metric should be minimized to get better performance [40].

4.Results

Throughput, PDR, and E2E latency metrics are used as QoS parameter metrics to examine the network performance of the chosen routing protocols, DSDV, DSR, and ZRP. *Figures 4 to 6* displayed the results as a graph with a 500 m x 500 m simulation size and 10 to 50 nodes moving at a speed of 10 m/s.

Figure 4 demonstrates that as the number of nodes ranges from 10 to 50, the DSR and ZRP protocols virtually achieve the same output in regard to overall throughput. When compared to the ZRP, DSR's performance does somewhat improve. Otherwise, DSDV has the lowest overall average throughput. Since the DSDV always chooses the route with the fewest hops, despite the route being busy, it has the lowest overall throughput. If the chosen route is busy, the number of packets lost rises. In comparison to the other two routing protocols, the DSR's throughput is stable because it is efficient at controlling traffic congestion despite the increasing number of nodes in the area of the simulated scenario.

According to *Figure 5*, it can be seen that DSR and ZRP had slight differences in terms of PDR when the number of nodes varies from 10 to 40. However, ZRP has a slight decrement when the number of nodes is above 40, while DSR maintains its performance when delivering their packets. On the other hand, as the number of nodes varies from 10 to 50, DSDV has a lower PDR value than DSR and ZRP when sending data. This is due to DSDV refreshes its routing table frequently, consuming bandwidth even though the network is not being used. Thus, for networks with high mobility and number of nodes, DSDV is not suitable to be implemented. In DSR, the overhead of route maintenance is decreased since the routes are only maintained between nodes that wish to interact. Route caching significantly lowers route finding cost, resulting in an improvement in PDR performance. When considering high mobility, density or large-scale area, DSR suits better compared to the other two routing protocols.

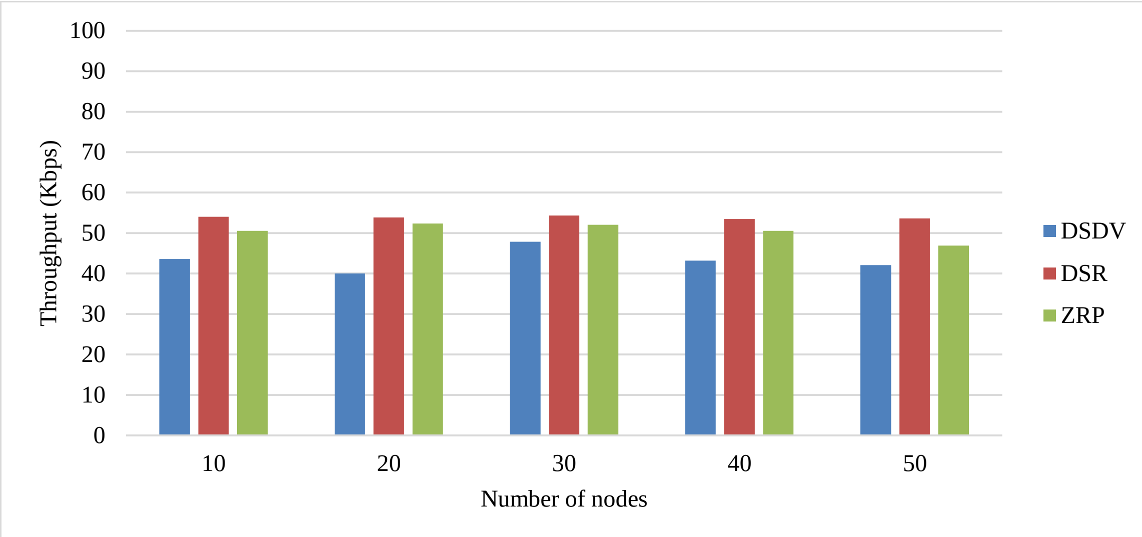

Figure 4 Throughput of DSDV, DSR, and ZRP

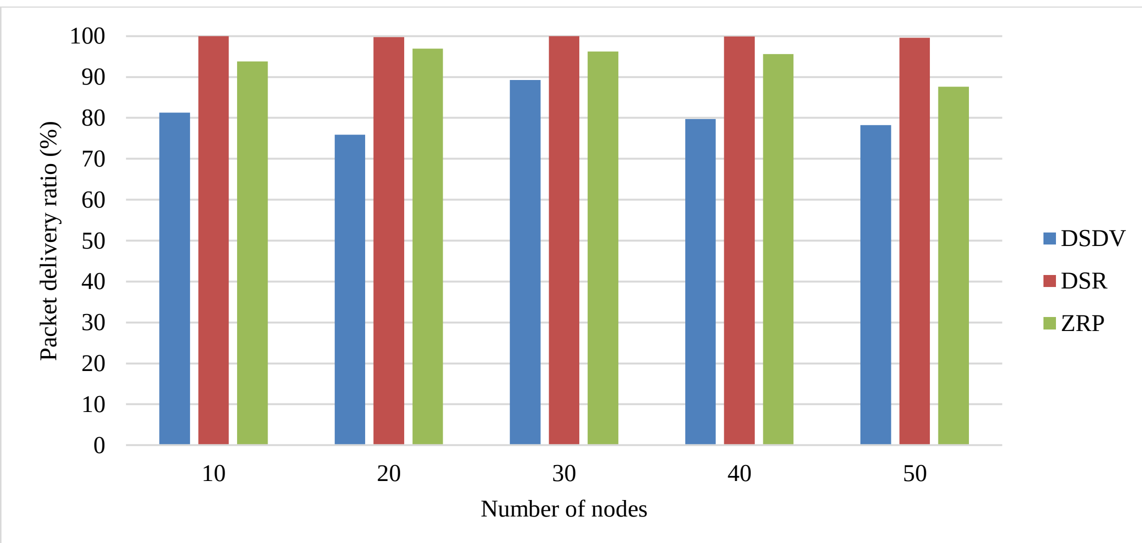

Figure 5 PDR of DSDV, DSR and ZRP

Figure 6 illustrates that for the first 30 nodes, the three routing protocols performed about equally in terms of E2E delay. In contrast to DSR and DSDV, ZRP exhibits a large increment when the number of nodes approaches 50. This is brought on by a routing zone with a high value, which causes packet delays. As the node density increases, DSDV and DSR retain consistent performance of E2E latency. Due to the constant availability of paths to all destinations, DSDV performs fairly in decreasing the delay. Therefore, DSR is a preferable choice when building a fast velocity or high-density nodes, whereas DSDV is appropriate when the latency is the objective with big network scalability.

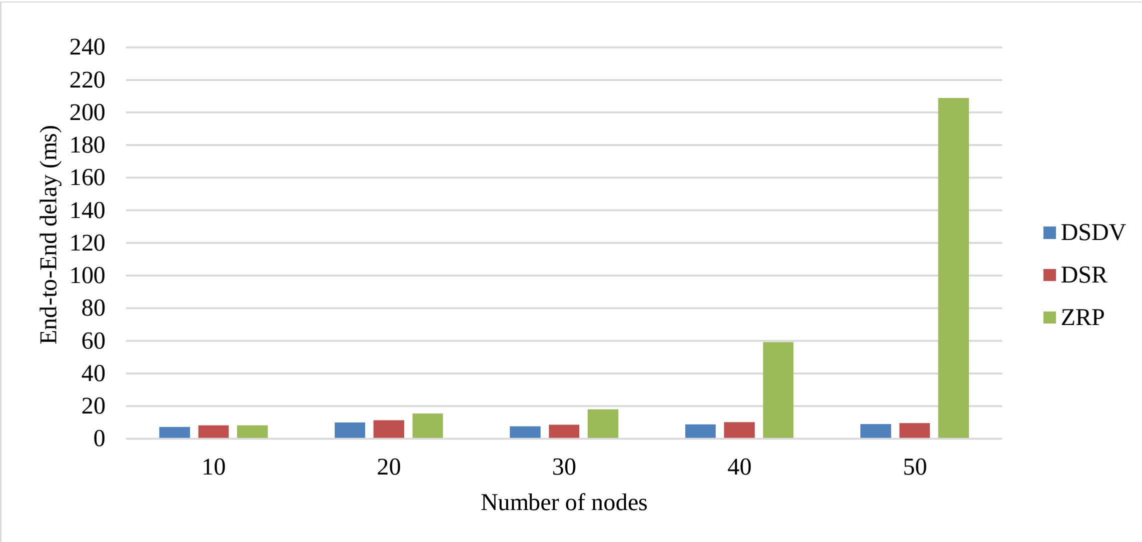

Figure 6 E2E delay of DSDV, DSR, and ZRP

5.Discussion

In this study, we examined the connection between the network density and basic communication performance indicators. In MANET implementations, we evaluated by comparing the proactive DSDV protocol, the reactive DSR protocol, and the hybrid ZRP protocol while varying the density nodes between 10 to 50. Our findings demonstrate that a single protocol cannot meet all the requirements for MANET applications. In terms of throughput and PDR, DSR performed better. However, DSDV was shown to have a minimum E2E delay transmission and may be a preferable choice for faster data transmission. In terms of PDR, DSR outperformed ZRP and DSDV, leading to a more reliable network communication. ZRP may be considered as an alternative when the network scenario involves high mobility speed and node density. However, if E2E delay is the primary metric, ZRP is the poorest choice among the three protocols with a high density of nodes. A lower end-to-end delay reduces the overhead of the network, thereby increasing the communication lifetime between nodes. In terms of overall QoS performance, DSR is the preferred protocol to implement in networks with high numbers of nodes and mobility speed. The reactive protocol showed better results than the proactive and hybrid protocols, with the proactive protocol being less efficient compared to the hybrid protocol.

5.1Limitations of work

Several problems and limitations may occur during the process of project development. The limitation of this study is that it is conducted experimentally and not a field test where we cannot see the real performance of a network.

A complete list of abbreviations is shown in *Appendix I.*

6.Conclusion and future work

To make the optimal decision, many sorts of routing protocols were used throughout the investigation. The characteristics and features of the evaluation parameters affect the results of each test differently. This article compares different ad hoc mobile techniques using simulated experiments. Reactive, proactive, and hybrid methods were selected as the three distinct types. The outcomes of the NS2 simulation demonstrated that DSR displays a better QoS than DSDV and ZRP. Large networks with high throughput and PDR rates can use it. The simulation results indicate that ZRP has high values when the number of nodes increased with a speed of 10 m/s in terms of E2E delay. Further investigation reveals that the throughput and PDR of DSR and ZRP are equivalent. However, ZRP has a greater E2E delay value. In contrast, the DSDV routing protocol is marginally worse to the DSR and ZRP protocols. It is advantageous for streaming applications like voice/video calling and video streaming because there is less E2E delay. Graphs demonstrate how DSDV performs better in terms of energy-saving nodes, potentially extending the life of the network.

For future work, these routing protocols have the potential to be adapted to different contexts by incorporating modifications to mobility models other than random movement. It is important to note that the performance of the routing protocols may vary based on the mobility models and parameters employed. To provide a comprehensive evaluation of performance, additional performance measures such as overhead, packet loss, and energy consumption should also be considered. By adding more nodes, this research can also be applied to real-world networks. Although we only considered quantitative performance criteria in this paper, future work may take qualitative performance indicators like security, scalability, and multicasting loops into account.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Author's contribution statement

Fatin Fazain Mohd Affandi: Formal analysis, writing-reviewing-editing and validation. **Nor Aida Mahiddin:** Supervision, validation, writing-reviewing-editing and funding acquisition. **Ahmad Danial Ahmad Hashim:** Conceptualization, writing-original draft preparation, methodology, software, visualization.

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Appendix I

S. No.	Abbreviation	Description
1	ACO	Ant Colony Optimization
2	AODV	Ad-hoc On-demand Distance Vector
3	AOMDV	Ad Hoc On-Demand Multipath Distance Vector
4	AWK	Aho, Weinberger, Kernighan
5	CBR	Constant Bit Rate
6	DAG	Directed Acyclic Graph
7	DSDV	Destination-Sequenced Distance Vector
8	DSR	Dynamic Source Routing
9	E2E	End-to-end
10	EDSDV	Efficient DSDV
11	GRP	Geographical Routing Protocol
12	LEACH	Low-energy Adaptive Clustering Hierarchy
13	MANET	Mobile Ad Hoc Network
14	NAM	Network Animator
15	NRL	Normalised Routing Load
16	NS2	Network Simulator2
17	OLSR	Optimized Link State Routing
18	OPNET	Optimized Network Engineering Tools
19	PDF	Packet Delivery Fraction
20	PDR	Packet Delivery Ratio
21	QoS	Quality of Services
22	RTLB-DSR	Real-time Load Balancing DSR
23	RWP	Random Waypoint
24	TCL	Tool Command Language
25	TORA	Temporally Ordered Routing Algorithm
26	ZRP	Zone Routing Protocol