Conceptual analysis of single and multiple path routing in MANET network

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***Abstract*—Mobile ad-hoc network (MANET) has attracted the attention of networking industries owning to their desirable characteristics such as multi-hop routing, self-configuration, self-healing, self-managing, reliability, and scalability. Routing over wireless mobile networks is a critical problem due to the dynamic nature of the link qualities, even when nodes are static. A key challenge in MANETs is the need for an efficient routing protocol that establishes a route according to certain performance metrics related to the link quality. The routing issue in MANETs is generally concerned with finding a good path between the source and the destination pairs. Based on that, there is a demand for the development of a high throughput routing protocol. The impact of a single-path routing protocol and a multi path routing protocol on the performance of MANETs is required to be investigated. In this work, a performance comparison in terms of throughput, packet delivery, routing overhead, and end to end delay of well-known routing protocols such as AODV, AOMDV, and OLSR using network simulator version 2 (NS-2) has been introduced. The simulation results of this work show that the single-path AODV protocol out performance the multi path OLSR and AOMDV protocols in terms of throughput and packet delivery ratio. In addition to that, the single-path routing protocol presents less routing overhead in comparison to the AOMDV and OLSR. While the OLSR and AOMDV demonstrate a relatively better end to end delay in comparison to the AODV protocol.**

***Keywords*—MANET, Routing protocols, AODV, AOMDV, OLSR, routing metrics**

I. Introduction

Information Communication Technologies (ICT) has laid down the foundation of the New World Order (NWO). Since its birth to 5th Generation (5G) [1], wireless networks have shown instrumental growth and development to solve real-world problems. We encounter many different types of wireless networks on day to day basis, for example, Bluetooth, Wireless Local Area Networks (WLAN), 4th Generation (4G) mobile networks, etc. One prime reason for the availability of several wireless technologies is the research and development (R D) which has taken place in this domain [2].

Wireless communication networks are divided into two types (i) infrastructure-based and (ii) infrastructure-less wireless networks [3]. Infrastructure-less wireless networks are also referred to as ad-hoc networks. A literature study shows that several ad-hoc networks are presented, like Vehicular ad-hoc Network (VANET), Mobile ad-hoc Network (MANET), etc. Although most ad-hoc networks share common characteristics and challenges, they also differ in few aspects [4].

In this paper, our core objective is the study of topology-based route selection interventions for mobile ad-hoc networks. This study focuses on single-path and multi-path protocols. A mobile ad-hoc network (MANET) is a brand of no infrastructure-based wireless networks that comprises nodes that can freely change their location and operate in a decentralised manner [5]. The decentralised nature primarily relies on the self-configuration and autonomously of nodes [6]. The self-configuration (also known as auto-configuration) feature of MANET eliminates the need for an administrator to configure them. These properties of MANET differentiate it from the traditional infrastructure-based wireless network. A comparison of the infrastructure-based and infrastructure-less wireless network is presented in Table I [7]. Table 1, presents several striking features of infrastructure-less mobile networks. However, such networks have to deal with different challenges also, such as:

- Limited Range Transmission: Nodes in mobile ad-hoc networks can only communicate with nearby nodes (up to only a few meters). Because mobile nodes cannot carry advanced high-end radios (transceiver) and large antennas.
- Limited Energy: Since mostly mobile nodes are battery operated (do not have a direct electric supply). Due to this reason, power is a significant challenge in MANET. In literature, many researchers have proposed energy-efficient routing protocols for MANET [8]–[10].
- Mobility: In MANET, nodes/devices can move freely anywhere, which leads to network topology changes more frequently. Due to network topology changes, efficient routing becomes a significant challenge.
- Routing: In MANET network can change dynamically at run time, due to which efficient routing interventions are needed to operate in the network.

TABLE I: Comparison of infrastructure-based VS infrastructure-less wireless networks.

Feature	Infrastructure-based	Infrastructure-less
Cost	It needs heavy investment to lay down the required infrastructure such as base station or mobile towers etc.	It is infrastructure-less networks
Deployment	Complex deployment sometimes require experts to design the network	No deployment cost or planning required.
Decentralized Control	Infrastructure-based networks require central server / manager (generally known as Access-Point (AP) to control the network e.g. nodes admission etc.	Adhoc networks do not require any central server for the their management.
Dynamic Nature	Generally less dynamic in nature as nodes communication remain confines to AP	In MANET nodes can become part of the network or leave any time.

- Quality of Service (QoS) or Service Quality: Due to the number of reasons presented above, providing a satisfactory extent of service quality becomes a challenge to deliver. Mobile ad-hoc Networks (MANETs) are being used in many situations where infrastructure-based wireless networks generally fail to deliver or operate efficiently.

Due to the unique features of the MANET, this type of the network has been employed in several services such as video streaming, online shopping, and mobile surgery. On the other hand, MANET could be employed in emergency relief environments owning to their low cost of implementation. In literature review, it has been realised that the employed routing protocol play a crucial role to improve the QoS and scalability of MANET. Several ad-hoc routing protocols have been introduced to transmit information using a single-path in the last few years. In contrast, another type of transmitted data builds on the concept of multi-path. These technologies enable a multi-path to generated among a source and a destination used to transfer information. Anyway, the optimal route is chosen based on the various performance measures known as metrics such as hop count, distance from the source to the destination, remaining energy, etc [11].

The objective of this work is to evaluate the impact of a single-path routing protocol and a multi-path routing protocol on the performance of the ad-hoc networks. In this study, three well known protocols which are AODV, AOMDV, and OLSR have been employed for different network scenarios of different network densities. The AODV represents a single-path routing protocol while the other two protocols represent the multi-path routing protocol.

The rest of this paper is organised as follows: The second section of this paper will present the routing protocols overview. Section III presents the literature review to summaries the key findings of previous research work published in this domain and their limitations in the context of MANET. The simulation Methodology and simulation approach assesses single-path and multi-path routing protocols are discussed in Section IV. Last but not least, simulation findings are rendered and discussed in Section V, and followed by the conclusion in section VI.

II. MANET ROUTING PROTOCOLS OVERVIEW

Routing is when nodes determine the optimally best route/path to forward the packets toward the destination. If a device receives or nodes receives a packet, and the target destination is not an actual destination for which packet was sent, it must route it. All intermediate nodes in ad-hoc networks need to take routing decision for each packet by routing table lookup. Routing protocols populate the routing table. Routing protocols play a significant role in MANET, especially when nodes are mobile and network dynamics change at run-time. In literature, routing interventions are grouped into different classes based on how they operate, build and maintain the routing table. The taxonomy of routing protocols is presented in Fig. 1. Fig. 1, shows an overview of a few set of protocols sharing standard functionality.

The following subsection below critically shows each category of network routing briefly.

A. Position-based Routing Protocols

In this type of routing, each node knows its current position in the grid. This position information is made available to the node using the Global Positioning System (GPS) sensor embedded on the node [12]. In position-based routing protocols, senders are also aware of the position of the prime destination. Senders use location services advertised previously by entire nodes that exist in the network. These routing protocols are also classified into three groups such as reactive, predictive and hybrid.

B. Energy-based Routing Protocols

In MANET and other similar arrangements, nodes are generally battery operated, due to which nodes energy consumption have a significant effect on network lifetime [13]. In literature, researchers have produced different energy-aware routing protocols that make routing decisions based on energy consumption, remaining energy left, etc. In such scenarios, devices are aware of other nodes' utilized energy, which is part of the network and network routing decision is supported with this. For example, nodes having less residual energy will be avoided to become part of forwarding.

C. Heterogeneity-based Routing Protocols

Different types of wireless mobile networks need to collaborate in some scenarios, such as MANET, VANET, etc., as the dynamics of these networks are different. Therefore

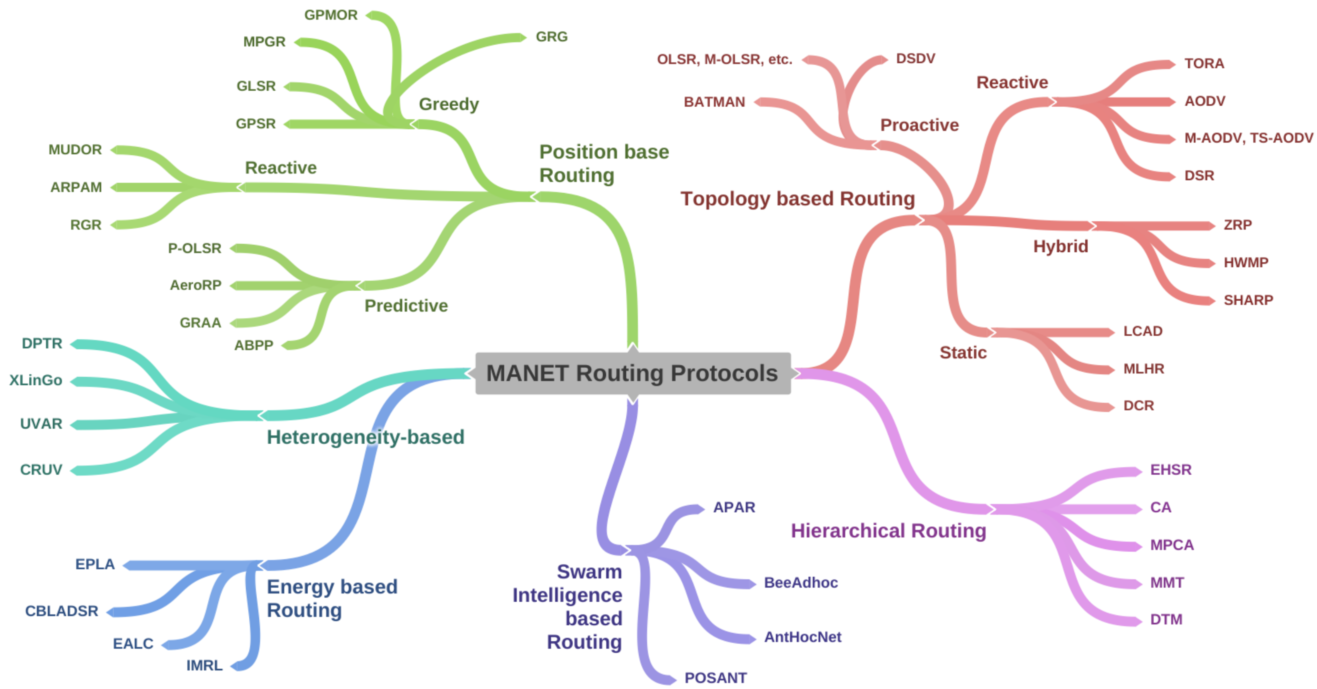

Figure 1: Moile ad-hoc networks - Protocol hierarchy.

researchers have proposed different routing approaches that can be operated in similar conditions as shown in Fig. 1.

D. Swarm Intelligence-based Routing Protocols

Swarm intelligence-based routing protocols are generally inspired by the biological behaviour of different animals, birds, insects, etc [14]. Therefore, they are also known as the bioinspired routing strategy. Several bio-inspired or swarm-intelligence based routing strategies have been proposed in the past research work, e.g. Ant Colony Optimization (ACO) algorithm, BeeAdhoc routing protocol etc [15]. These routing protocols have produced outstanding results in some scenarios.

E. Hierarchical Routing Protocols

Fall under this group usually forms clusters. A cluster can be defined as 'nodes reside in closed proximity' build a cluster [16]. A cluster is formed following a process. Each nearby node participates in the cluster formation process, which is known as the setup phase. During the setup phase, a cluster head is elected by a process known as election. The elected cluster head will remain the leader in that cluster for some fixed number of rounds. When a certain number of rounds have passed, nodes in the proximity go again in the setup phase to elect a new cluster head. In this paper, we will focus on and discuss in detail topology-based protocols. All protocols which build routing table based on sharing topology information are included in this group.

F. Topology-based Routing Protocols

Topology-based routing techniques make use of network topology data in order to build a routing table. This class of routing approach is most widely utilized in ad-hoc networks. Topology-based protocols are divided into the following groups: proactive, reactive, hybrid routing, and static [17]. In mobile ad-hoc networks, a static technique to build routing table is not often used and recommended due to its static nature.

1) Proactive Routing Protocols: A complete routing table is built by all proactive routing protocols in advance at the start of operation. This table aims to establish and maintain a path to every destination node alive in the network/topology [18]. All devices/nodes that speak any proactive routing protocol start to exchange network information initially, which is also known as the setup phase like the Lower Energy Adaptive Clustering Hierarchy (LEACH) protocol [19]–[21]. In the setup, nodes exchange routing messages and calculate the best next hop for every destination. Nodes exchange complete routing table periodically and at each change occurred in the topology due to which it consumes heavy network bandwidth and computational resources of the nodes. However, each node in the network carries a complete 'map' for the network; therefore, the best route to any target is readily available, which reduces route discovery for each packet. It is advised that these protocols should not be operated in large networks or where topology changes more frequently.

Optimized Link State Routing (OLSR)
Link state routing approaches are entirely different from traditional distance vector-based routing options. Link state routing protocol shares the status of their link (cost) with their neighbours. OLSR is also an LS routing strategy that follows the same school of thought [22]. The OLSR routing protocol is a multi-path [23], [24]. OLSR do not broadcast anything. All hello messages are shared only with the neighbours periodically. In case of topology changes, they exchange topology change notification (TCN) only with their neighbours. Furthermore, to reduce routing communication, OLSR selects Multipoint Relay (MPR) nodes from its neighbours. MPR is also responsible for forwarding such messages to other neighbours/peers. A significant amount of network bandwidth is reduced by using this approach.

2) Reactive Routing Protocols: As opposed to proactive methods, reactive routing techniques start route lookup or discovery process when a node receives a request. That is why they are known as reactive. There is no setup phase like in proactive routing protocols, nor they maintain routes for each target. Due to this nature, they are referred to as 'on-demand routing protocols. When a route for a particular target is discovered, then the node only keeps that route for a limited time in the routing table. When no more packet is received for the target node for a specific duration, route entry is removed from the table. The benefits of the reactive protocol are that they generate less routing load, and network size is scalable, meaning they can be used in significant typologies. Reactive protocols may have unpredictable delays.

Adhoc On-Demand Distance Vector (AODV)
AODV is a reactive routing protocol that incorporates DSDV and DSR protocols [25], [26]. It shows adaptive behaviour at each hop which is known as Hop-by-Hop nature. Hop by hop feature in AODV is adapted from the DSR protocol. It utilizes the periodic exchange of messages technique from the DSDV protocol. In the beginning, it initiates route discovery to create a routing path. It tries minimum hop count path to be selected. This feature significantly reduces the overhead and minimizes network congestion. To maintain established links up to date, it exchanges update messages.

Ad-hoc On-Demand Multipath Distance Vector (AOMDV)
AOMDV is a multi-path routing protocol [23], [24], [27]. Multi-path routing protocols discover and maintain multiple paths for the target node [28], [29]. The purpose of keeping multiple paths is to avoid or reduce frequent discovery of routes. AOMDV is based on AODV reactive routing protocol.

3) Hybrid Routing Protocols: Hybrid methods choose the best attributes of both groups, i.e. proactive and reactive. These interventions curtail the limitations and overheads of reactive proactive strategies. The Zone Routing Protocol (ZRP) is a hybrid routing strategy that partitions the area into different segments known as 'zone' [30]. Intra-zone path selection is performed with the help proactive routing approach, and inter-zone is achieved by utilizing reactive interventions.

III. LITERATURE REVIEW

This chapter began by describing a previous research study on routing limitations in mobile ad-hoc networks. Relay routed-DSR is officially implemented to manage data packets effectively. To collect information from neighbour nodes, this novel routing strategy employs a broadcasting mechanism. During the flooding process, redundant paths are discovered, increasing overhead in the network [31]. Preemptive-DSR (PDSR) protocol predicts connection failures, but the mechanism is slow and costly. Due to low signal strength, P-DSR sets a threshold, and warning signals are sent to source nodes [32]. The new variant of AODV, ad-hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol, is the most widely used multi-path routing strategy. The new routing method avoids connection loss and relies on a minimal hop count [33]. Fibonacci multi-path load balancing and multiple AODV are considered to deliver data packets to conserve energy in nodes [34]. However, AODV routing vulnerabilities enable many typical network attacks such as a black hole, grey hole, wormhole, etc., which can easily access data packets and set up malicious nodes within the network [35]. Fig 2, shows a routing study of the AOMDV protocol. Attackers send data packets in a continuous stream to increase the number of false information in the network, directly affecting the system's dynamics [36]. Context-aware routing improves node energy levels, introducing a novel solution that will help to secure channel links. Adaptive routing decision helps to monitor routes [37].

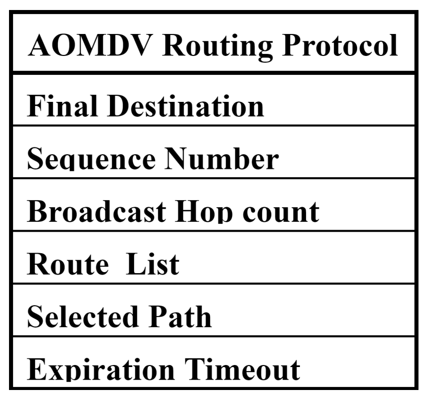

Figure 2: AOMDV protocol.

The idea of meta-heuristics, which improve local monitoring in mobile ad-hoc networks, is computed by mobility aware-Termite [38]. Therefore, extended ad-hoc networks, finding the exact position using GPS-based knowledge predictive-OLSR, show exponential improvement [39], [40]. In a recent study, authors developed an ad-hoc routing protocol to conserve energy at every node [41]. Single-path or multi-path routing strategies can be used in mobile ad-hoc networks. Single-path routing is recommended for forwarding all data packets over the route. However, some significant problems with single-path routing have been found, including an increase in end-to-end delay and slower route discovery time. As a result of these reasons, the single-path routing fails to perform tasks in all environments. Multi-path routing protocols select several routes from source to target. Compared to a single-path, specific metrics such as delay, bandwidth, and throughput have improved [42], [43]. Response surface optimization finalizes the optimal response time during data analysis in AODV and AOMDV [44]. The working concept of AODV routing is visualized in fig 3. While sending an AODV message from one node to another, two steps are usually followed: (i) path exploration and (ii) route repair. For route discovery and maintenance, message data comes in four forms: reply, request, error, and hello packet [44]. Multi-path routing protocols have several advantages. Multi-path routing protocol tends to reduce end to end delay. These protocols utilize network bandwidth more efficiently as compared to single-path routing protocols.

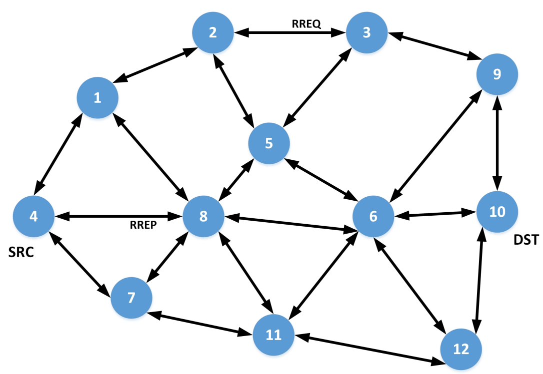

Figure 3: AODV routing protocol.

Since authors maintain multiple paths to the same destination, the traffic will be forward via an alternate path/route without adding a delay factor if a path becomes unavailable. They can perform better network load balancing, which causes homogenized energy consumption in the network. Multiple path/route selection methods also aid in minimizing the packet drop rate of the network. Besides many advantages of multi-path protocols, they also introduce few limitations. Generally, they use the broadcast mode of communication. At times they suffer from good end to end multiple path discovery issues. Since from source to target node, they maintain more than one path; therefore, the data duplication problem also arises in few cases. Limited control information distribution and longer routes. The summary of the pros and cons of multi-path routing interventions are presented in table II.

TABLE II: Multi-path routing protocols advantages and disadvantages.

Advantages	***Limitations***
Reduction in End-to-End Delay	Broadcasting Issues
Efficient bandwidth utilization	Insufficient path discovery
Taking Backup of the system	Data Packet Duplication
Load distribution in entire network	Longer Routes
Less Packet Loss	No Control Information distribution

IV. Materials and Methods

The current section is concerned with the methodology used for this study. The presented paper uses a simulation approach and parameters configured for the successful execution of the work. Overall, the study highlights the need for network simulator 2 (NS-2) to perform the simulation. NS-2 is an open-source discrete event simulator that is widely used in research [45]. The core engine of NS-2 is built in C++ programming language, and the front system, which is used to create simulation topology, uses Object-Oriented Tool Command Language (OTCL). We used the latest version of NS-2, which is 2.35. It generates two types of trace files which are (i) simulation trace and (ii) nam trace. The simulation trace file is further used for data analysis. In contrast, the Nam trace file can be fed into the network animator (Nam) utility to view how the simulation is carried out. Fig. 5, shows how simulation is carried out using NS-2. The MATLAB programing language has been used to generate the graphics and analyse the trace file by formulas and MATLAB. We created three different testbeds or scenarios for our study. In all three scenarios, the basic simulation parameters are the same. However, the main difference in all three testbeds is the number of nodes each.

Scenario 1: In this scenario, we configured our simulation topology as mentioned in Table III. The number of nodes in this scenario was configured to 100.

Scenario 2: In this scenario, we configured our simulation topology as mentioned in Table III. The number of nodes in this scenario was configured to 150.

Scenario 3: In this scenario, we configured our simulation topology as mentioned in Table III. The number of nodes in this scenario was configured to 200.

For each simulation scenarios, performed ten iterations of Simulation. The purpose of this repetitive exercise is to reduce the statistical anomalies/discrepancies in the result. Therefore, 30 total rounds/iterations of the Simulation are carried during this study. The time duration of the Simulation contributes towards an essential role in studying the behaviour of any phenomenon. In Literature, found that most researchers used a low time window. Therefore, the presented paper performed the Simulation for up to 4 minutes or 240 seconds within various network load. The coverage area, also known as the simulation area, also plays a significant role in the study. In order to accommodate hundreds of nodes, built a large coverage area such that nodes can also move freely and easily. The network area for each scenario was configured as 1500m x 1500m in our study. The mobility of nodes affects the performance of a network drastically. Presented paper used Random Way Point (RWP) mobility model in our study. RWP is the most used movement pattern. The velocity (speed) of nodes also play a crucial role. In our topology, all nodes can move with up to 20 $m.s^{-1}$ velocities. As discussed in Section I, we included single and multiple path routing protocols.

This paper suggested to use AODV, AOMDV and OLSR routing protocols. Further, as mentioned above, the Simulation was performed ten times by altering the number of nodes in each iteration. However, the relevant parameters and topology design are summarized in Table III.

TABLE III: Network simulation scenario.

Parameters	***Value***
Simulator software	NS-2
Simulation Time	240 seconds
Area of work	1500 m^2
Nodes Speed	20 m/s
Transport Layer Protocol	UDP
Application Type	Constant Bit Rate (CBR)
Number of Nodes	100, 150 , 200
Movement Scenario	RWP
Routing Protocols	AODV, AOMDV, OLSR

A. *Simulation trace analysis*

During any simulation process, the simulator generates a vast amount of data, as per the configurations in the OTCL TCL scripts. NS-2 can generate data in different trace files for the type of analysis. The two standard trace formats used in NS-2 are (i) simulation trace and (ii) nam trace. The simulation trace file is commonly used for further processing to extract required information that can be used to generate graphical notations and tables. At the same time, the nam trace file is fed into Nam utility which can execute all events chronologically to show the animation type video. The purpose of the nam trace file is to view the simulation in real as shown in Fig. 4.

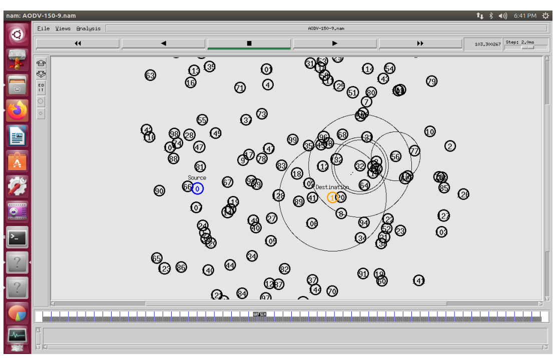

Figure 4: Network topology.

Older NS-2 versions used the old trace format with a different set of issues. One essential weakness in the old wireless trace format is the absence of a type field in the trace file.
Fig. 5, provides an overview of NS-2 structure and code process.
Due to this limitation, programmers have to memorize the field's name as per its position in the trace file. To overcome this problem, NS-2 now comes we a new wireless trace format. The current work used the new wireless trace format. The new wireless trace format has several advantages over the old trace format. Every field in a new format has a type field associated

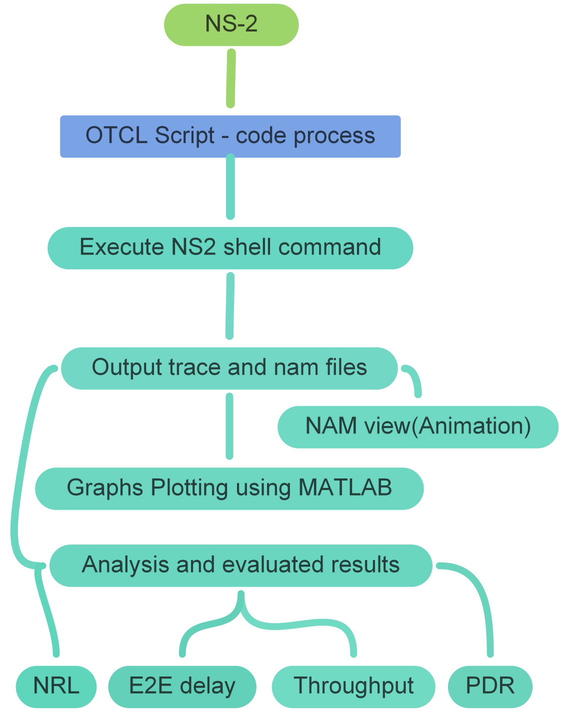

Figure 5: Code process and NS-2 structure.

with it. The benefit of adding a type field in front of a data field is to enhance the effectiveness of data extraction utilities.

V. SIMULATION RESULTS AND DISCUSSION

These rather interesting evaluation results could be due to their relates to critical criteria in MANET networks; as described in the next text. As described in the Section I, we studied four different parameters to gauge the effectiveness and performance of each routing protocol.

- Network Throughput.
- End to End Delay (E2E delay).
- Normalized Routing Load (NRL) / Routing Overhead (RO).
- Packet Delivery Ratio (PDR).

A. *Network parameters*

Throughput: The efficiency of a protocol is measured by its throughput. Higher performance rates indicate optimal results, while low throughput indicates restricted activity in the network [46], [47]. Technically, throughput is described as follows: frames, packets, or bytes efficiently transmitted per unit time are referred to as throughput. Throughput is calculated by using Eq 1.

$$\text{Throughput} = \frac{\Sigma \text{ received packets size}}{\text{time}} \quad (1)$$

E2E delay: Another important metric for network assessment is end to end delay. The time taken by a packet to arrive at its final destination is known as end to end delay [48], [49]. In practice, this means subtracting the time obtained by a data packet when it arrives at its destination from the initial time and calculated by Eq 2.

$$D_{avg} = Tr_{avg} - Ts_{avg} \quad (2)$$

NRL: Normalized routing load or routing overhead is considered as the overhead. It is defined as "Ratio of network control packets to all delivered packets" [50]. NRL / RO for our simulation is presented Fig. 9, and can be measured by using Eq 3.

$$NRL = \frac{\sum \text{Routing packets}}{\sum \text{Packets received}} \quad (3)$$

PDR: Packet delivery ratio is the ratio between packets successfully delivered at the target nodes to the total number of packets sent [51]. The Equation 4, is used to calculate PDR.

$$PDR = \frac{\sum \text{Number of packets received at destination}}{\sum \text{Number of packets send by node}} \quad (4)$$

B. *RESULT ANALYSIS AND DISCUSSION*

In the previous subsection V-A, we presented simulation results. In this section, we will critically analyze them. These are significant results that will describe and discuss sequentially.

1) Network throughput: From Fig. 6, it is evident that the network throughput of the OLSR routing protocol started to drop as the number of nodes decreases. This might be because the OLSR routing protocol selects Multi-Point Relays (MPR) to forward control messages. As node density increases, it had to select several relays in the topology that become the cause of the decreased throughput. The exact figures also show that AODV and AOMDV are less sensitive to changing the number of nodes [52].

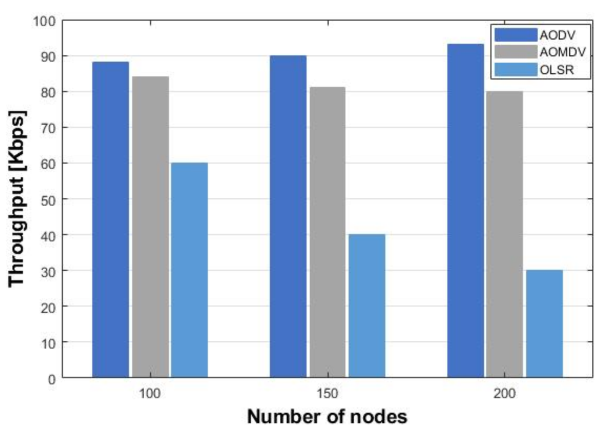

Figure 6: Network throughput based variety nodes number.

Due to the significant importance of the throughput, the presented paper suggested another method known as a standard deviation to double-check the accuracy of results related to the throughput of routing protocols. The table IV, shows the standard deviation study of single and multi path routing protocols for throughput. In the table IV, we calculated the cumulated standard deviation throughput for all three testbeds. Standard deviation measures the amount of deviation from the average figures.

TABLE IV: Standard deviation analysis of routing protocols.

NO. of Nodes	*AODV*	*AOMDV*	*OLSR*
100	83.089	76.752	60.4
150	84.788	78.318	40.1
200	83.911	79.81	30.2
Average	83.92933	78.29333	43.56667
Standard Deviation	0.693735	1.248545	12.57042

These results provide further support for the throughput of protocols. Where the AODV standard deviation for all three cases is far below AOMDV and OLSR protocols. Results suggest that if we further increase or decrease the number of nodes, AODV throughput will be marginally affected. In addition, AOMDV, which is a multi-path routing protocol, also rendered relatively acceptable numbers as compared to OLSR. It suggests that AOMDV protocol throughput will be affected if we change the number of nodes compared to AODV. In contrast, the OLSR has the worst standard deviation value. It means its throughput will be highly affected if we change the number of nodes. Therefore it is not recommended to use in large complex typologies. The Fig. 7, shows the standard deviation of routing protocols.

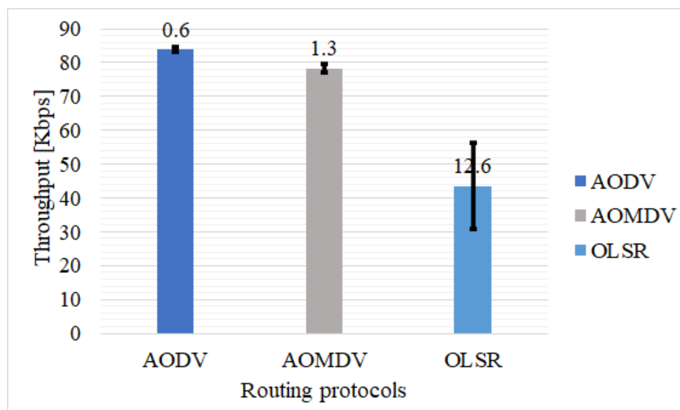

Figure 7: Network throughput based on the standard deviation.

2) E2E delay: Fig. 8 shows a significant increase in the end to end delay for OLSR protocol as node density increases, making it less useful for large and complex topologies. In addition to that, notable improvement in the delay is observed for the AOMDV routing protocol. We observed that initially, AODV and AOMDV delay are higher than OLSR. As the number of nodes increases, they show remarkable improvement.

3) NRL: Fig. 9 proves that reactive routing protocol like AODV has extraordinarily low routing overhead as compared to other two techniques studied in the research, i.e. AOMDV

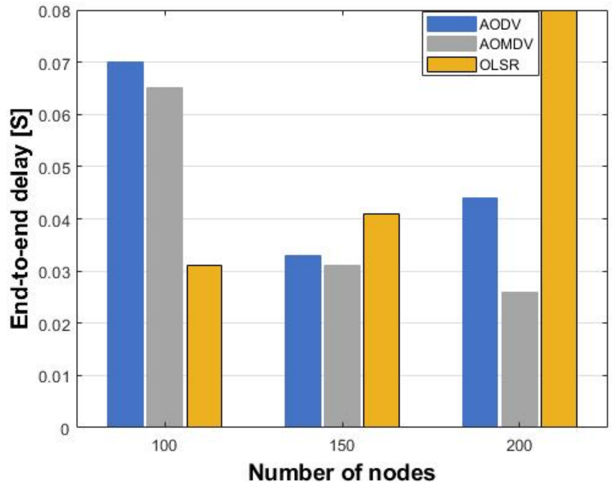

Figure 8: E2E delay of routing protocols.

and OLSR. Rather AOMDV and OLSR have almost similar routing overhead.

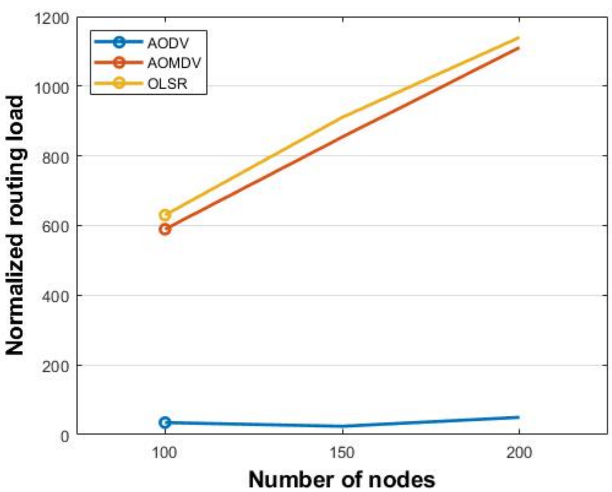

Figure 9: NRL of routing protocols.

4) PDR: The packet delivery ratio graph shows that OLSR has the worst delivery ratio compared to AOMDV and AODV. In addition, another observable pattern that we can analyze, is the effect of an increasing number of nodes. The Fig. 10 shows that AODV is not affected as the number of nodes increases in the network. However, AOMDV and OLSR are affected. The PDR is shown in Fig. 10.

VI. Conclusion

The main goal of this study is to compare and analyse the network performance of different routing protocols in terms of different parameters such as throughput, packet delivery, routing overhead, and end to end delay. The simulation results

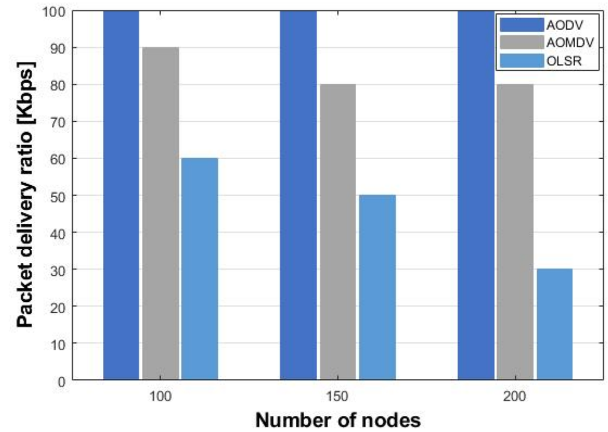

Figure 10: PDR of routing protocols.

reveal that the throughput of the OLSR protocol is highly affected by the varies of the node density in comparison to the AODV and AOMDV protocols. In relation to the throughput, the single-path AODV routing protocol exhibits better network throughput in comparison to the multi path protocols employed in this study. The influence of node density on the performance of the networks has also been investigated in this work. It has been proven in this study as the node density increases, the OLSR protocol reveals a significant increase in the end to end delay. Based on that, it can be stated that the OLSR protocol is not a suitable protocol for high density networks. While the AOMDV shows less end to end delay in comparison to the AODV and OLSR protocols for the examination of the same scenarios. In respect to the routing overhead, the AODV protocol shows less routing overhead comparing to the OLSR and AOMDV protocols.
The future work of this study suggests further investigations of the dynamic behavior of the AODV routing protocol which can lead to a modification to the routing mechanism of the protocol to handle the instability of the link quality.

Acknowledgment

This paper was supported by SGS University of Pardubice project No. SGS_2021_011.

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