Comparative Performance Analysis between AODV and OLSR in VANET Environment using NS3

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***Abstract*—The popularity of Vehicular Ad-hoc Networks (VANETs) has increased over the past few years due to the rise of autonomous driving, computer vision, and artificial intelligence. VANETs can vary from sparse to highly dense and are characterized by having a very dynamic topology. These characteristics impose a challenge on the communication between the vehicles. Which in turn led to the need for developing and characterizing a suitable routing algorithm that can quickly adapt to the rapid changes in the topology. In this paper, we present a comparative study using Network Simulator 3 (NS3) between Ad-hoc On-Demand Distance Vector (AODV) and Optimized Link State Routing (OLSR). The metrics used in the study are goodput, packet delivery ratio (PDR) and Mac-Phy overhead. Results show that AODV's performs better at low density networks in terms of PDR. While OLSR outperforms AODV in high density networks in terms of PDR. On the other hand, while OLSR has a smaller overhead than AODV, the overhead values of the two protocols become comparable for high density networks.**

***Index Terms*—VANETs, AODV, OLSR, NS3, QoS**

I. Introduction

Vehicular Ad-hoc Networks (VANETs) fall under the umbrella of Mobile Ad-hoc Networks (MANETs), they are characterized by high mobility and rapidly changing topology. VANETs are mainly used to transmit and receive information between fast moving vehicles. This can include information on the road condition, speed limit, and much more. However, due to the movement of the cars, the topology is always changing, which makes it difficult for traditional routing algorithms to perform well.

There are several proposed architectures for VANETs. as proposed in [1] a VANET network consists of an ad-hoc plane, infrastructure plane, and network plane that connects the whole system to the internet and provide data to other levels. The communication is conducted to and from vehicles via On-Board Units (OBUs) and similarly a Roadside Unit (RSU) to connect the infrastructure. And as proposed in [2] vehicle to vehicle (V2V) communication could use IEEE 802.11P and similar standard for vehicle-to-infrastructure (V2I). Figure 1 shows a normal VANET scenario. Though it is proposed that V2I communication is mainly done through LTE Base Stations due to the lack of availability of IEEE 802.11P RSUs.

Fig 1 VANET scenario illustration. 1. RSU, 2. vehicle with OBU, 3. V2V communication, 4. V2I communication

The Architecture was further classified in [3] as pure cellular Architecture where V2I solely takes place, pure ad-hoc Architecture were all the communications are handled on the ad-hoc plane V2V, lastly a Hybrid Architecture were both V2V and V2I take place coherently. VANETs cannot utilize traditional routing protocols that were developed for static networks; therefore, researchers have developed and evaluated routing protocols for VANETs. In this paper, a comparative study between Ad-hoc On-Demand Distance Vector (AODV) and Optimized Link State Routing (OLSR) with respect to Quality-of-Service (QoS) metrics. This study was conducted using Network Simulator 3 (NS3).

The rest of the paper is organized as follows. Section II contains background about different types of VANET routing protocols, Section III contains a comprehensive literature review for work done to evaluate VANETs protocols performance, Section IV presents the methodology and the plan used to carry out the simulations, Section V presents the results obtained and discussion, and finally Section VI concludes the paper.

II. Background

A. Classification of Routing Protocols

Due to the very dynamic nature of Vehicular Ad-Hoc Networks, there is a variety of routing protocol, each of which aims to solve a bottleneck in VANETs. These protocols are categorized as follows:

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- **Position Based Routing Protocol:** This class of protocols uses Global Positioning System (GPS), so nodes do not need a routing table to convey a message rather have the positional coordinates of the target. Though the system not relying on a routing table is advantageous, it suffers from losing connection in tunnels [4]. Examples of these protocols are DREAM (Distance Routing Effect Algorithm for Mobility) [5] and GPSR (Greedy Perimeter Stateless Routing). This class of protocol has had some attention, including Delay-Tolerant VANETs [6].
- **Topology Based Routing Protocol:** This class of routing protocols has three different categories.
  - **Proactive Routing Protocols:** Every node has a routing table so that whenever a node needs to send a message it can be conveyed through the other nodes via the routing table [4]. Examples of such protocols are Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR) [7].
  - **Reactive Routing Protocols:** These protocols are labeled as being on-demand as the route is discovered whenever a node needs to send a message [4]. Examples of such protocols are Ad-hoc On-Demand Distanced Vector (AODV), Ad-hoc On-Demand Multipath Distance Vector (AODVM) [8], and Dynamic Source Routing (DSR).
  - **Hybrid Routing Protocols**: Combines the features of the two previous categories.

B. NS-3 vs NS-2

The goals of the NS3 project and key differences from NS2 were introduced in [9]. And every version has a release documentation, as shown in [10]. While NS3 simulations could be written in C++ with the availability of simulation scripts using Python, NS2 is written using OTcl and C++. NS3 is advantageous over NS2 in that it has better memory management; thus, more extensive simulations could be conducted using NS3 without overhead on the host device. Also, NS3 could be used as an emulator, meaning that it could be connected to hardware to emulate the application layer of a network, or applications could be connected to the simulator to emulate the hardware and the physical properties of a network. Also, NS3 is aimed at scalability and the production of novel research in the field of networking.

III. Related Work

Researchers have conducted numerous research in the field of VANETs, with each research showing a specific contribution. In this section, a literature review presents the contribution presented in the area with a brief of what this paper aims to achieve compared to the presented one.

Chouhan and Deshmukh presented in [11] a comparative study using NS3 between AODV, DSDV, and OLSR. The comparison was between QoS, i.e., packet delivery ratio and packet loss ratio. The study used a static number of OBUs and RSUs to represent the VANET, a multi-lane unidirectional. mobility model and a Nakagami radio propagation model. For RSUs, DSDV had a consistent result but relatively higher than the other two protocols. Regarding PDR, DSDV performed worst, and OLSR had the highest packet delivery ratio. In this paper, we will present simulations for higher density networks than shown in [11].

Mantoro and Reza in [12] used NS2, MOVE and SUMO (Simulation of Urban Mobility) to study the performance of both AODV and DSDV. The study used a static number of nodes and an Omni antenna model with two-lane traffic. The performance metrics used was throughput and End to End Delay. The results have shown that AODV had better throughput, while DSDV had a lower end to end delay as AODV is a reactive routing protocol. The key difference from this work is using NS3 instead of NS2 and the use of goodput and throughput in analysis.

Hamid and Mokhtar in [13] have conducted an extensive study on AODV, DSDV and OLSR using NS2 and SUMO. The study included varying node number and varying node speeds in an urban environment. The study's outcome by varying node speed was that OLSR had the least delay, while AODV had the highest packet delivery ratio and the highest bandwidth. However, when the node number was varied, OLSR had lowest delay, while AODV had the highest packet delivery ratio and the highest throughput. Work in this paper will not focus on node speeds like [13] instead study the effect of varying the node number in a dense network.

Kashyap, Astya, Nand, and Pandey in [14] conducted a comparative study on AODV and DSR routing protocols using NS2 simulator. Key parameters used for evaluation in this contribution was End to End delay, Throughput and packet delivery ratio. AODV achieved the lowest end to end delay and the highest packet delivery ratio. At the same time, DSR had the highest Throughput. DSDV performed quite similar to AODV regarding the end-to-end delay; however, it had a significantly worse packet delivery ratio.

Vijaya and Rath in [15] Have conducted a study on the performance of AODV, DSDV and DSR routing protocol in a TCP and UDP environment. The simulations were performed using NS2. The study suggests that as the number of nodes increases, the performance of AODV starts to surpass that of DSR. However, the study indicates that DSR imposes lower loads on the network for routing.

Naim and Hossain in [16] conducted an evaluation of performance for AODV, DSDV, and DSR routing protocols. The assessment was based on typical QoS metrics. The traffic type used was TCP. They concluded that AODV has superiority over the other protocols in a parameter such as throughput for static and mobile networks. Simultaneously, DSDV suffered less from link losses, and finally, DSR had the least delay and jitter. In this work we will be using UDP traffic.

IV. Simulation Methodologies

The simulations done in this work were performed using NS3. The simulations were designed to conduct a comparative study between the reactive and proactive protocols AODV and OLSR, respectively using QoS metrics. The following subsections define the QoS metrics used in the simulation, and the procedure and setup used for the simulations.

A. Performance Metrics

Though throughput (Mbps) metric will be used, it is essential to note that the throughput includes the routing packets and data packets simultaneously, which not exactly what we wanted to measure in this work, and so, the following metrics are used.

- **Average Goodput** (Kbps) is the rate of receiving useful application bytes at destination nodes.

- **MacPhy Overhead** is the overhead imposed by the packets used for routing as they do not include application layer data.
  $MacPhyoverhead = (totaltransmittedbytes - totalreceivedapplicationbytes)/totaltransmittedbytes$

- **Packet Delivery Ratio (PDR)** is the ratio between received and transmitted packet.
  $PDR = receivedpackets/transmittedpackets$

B. Procedure

Simulations were carried out according to the scenario shown in Table I.

TABLE I
Simulation Scenario Setup

Parameter	Value
Number of Sinks	10
Number of Nodes	Start 30 Step 2 Stop 98
Mobility Model	Random Mobility Model
Area Node Speed	$1500m * 300m$ 40 kph
Application Data Size	250 *Bytes*
Transmission Power	7.5 *dB*
Simulation Time	300 *Seconds*
Traffic Type	UDP
rate	2048bps

The two protocols are subjected to variation in the node density, starting with 30 nodes in an area of 1500m * 300m and adding two nodes at a time with a maximum number of nodes of 98. The nodes have random mobility with an initial placement, as shown in Figure 2. The application used is an on/off application with a data size of 250 bytes. The variation of each metric will be studied with respect to the number of nodes in the network. The topology aims at simulating an area with a dense network and well RSUs coverage.

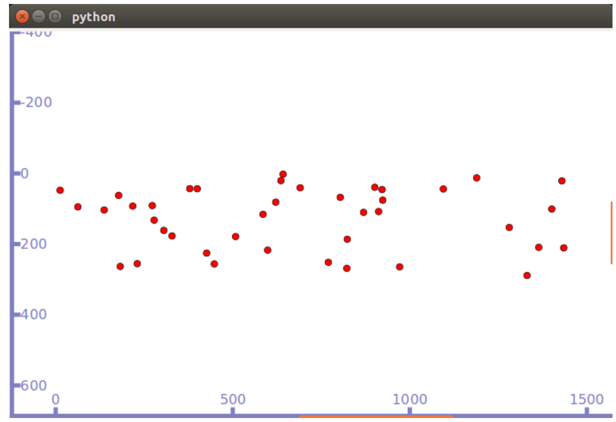

Fig 2 40 node network initial topology

V. Results and Discussion

Results of the simulations from scenarios mentioned in the previous section will be discussed in two parts. First, we discuss the throughput, goodput and PDR, and the second part is concerned about the routing overhead of the protocols.

A. Data rates and PDR

Figure 3 shows the relation between the number of nodes and the throughput for the two protocols AODV and OLSR. It is clear that AODV has a much higher throughput and an increase at a higher rate than OLSR as the effective node density of the network grows higher. Also, OLSR rate of throughput increase is more stable than AODV. However, It is fair to mention that this metric includes the routing packets used by the protocols and the data packets simultaneously.

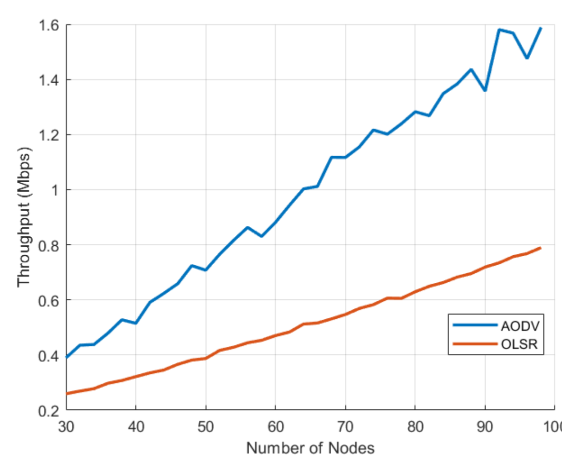

Fig 3 Average Throughput.

Both the goodput metric and PDR metric shown Figure 4, and Figure 5, respectively. The figures show the same trend, where AODV at lower node densities has higher average goodput, and higher PDR as AODV has 16.25 kbps and 0.8 respectively. While OLSR has a goodput of 13.5 kbps and a PDR of 0.63 at 30 nodes. Additionally, we can observe that with we increase node densities, AODV routing protocol performance starts to degrade until the breakeven between AODV and OLSR at 74 nodes both protocols had around 14.5 kbps goodput and 0.73 PDR. For these metrics, at higher node densities, OLSR performs better than AODV with respects to these metrics. However, as it will be shown, both protocols could suffer degradation in other metrics simultaneously.

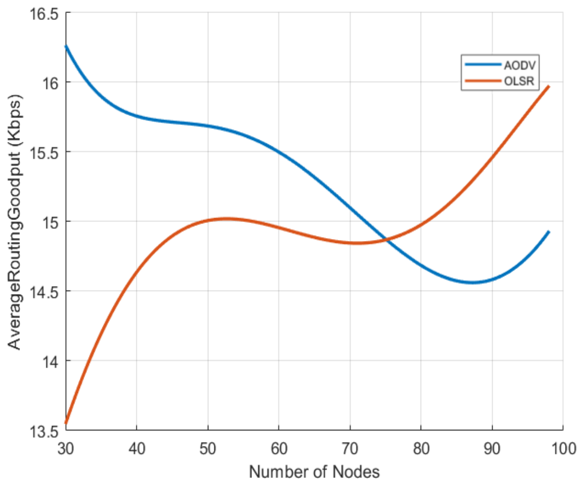

Fig 4 Average Goodput.

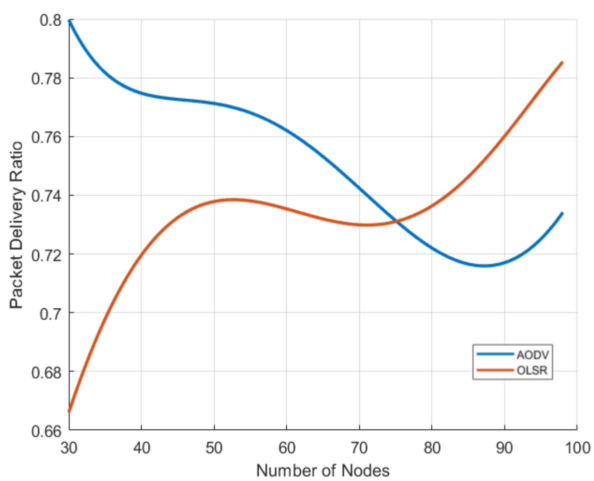

Fig 5 Packet Delivery Ratio (PDR)

B. Routing Overhead

The Mac-Phy overhead for both the protocols is shown in Figure 6. It can be used to illustrate the overhead added by the routing packets on the network. While both AODV and OLSR have an increasing overhead trend with the increase in node density. However, AODV has higher routing overhead; this can be attributed to the fact that AODV is a reactive routing protocol.

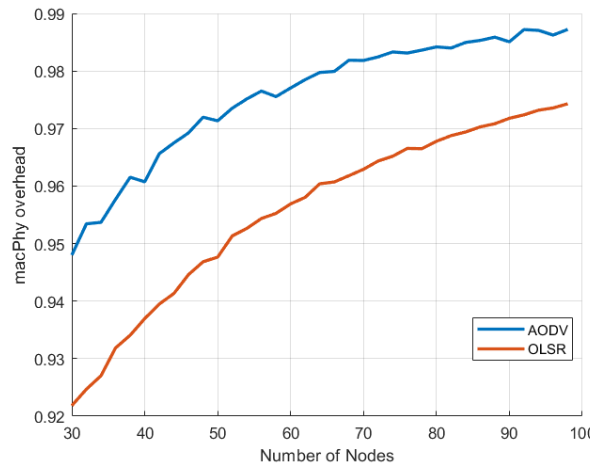

Fig 6 Mac-Phy overhead at different number of nodes.

While Figure 6 shows only the variation with the number of nodes, Figure. 7 shows the Mac-Phy overhead of the network for the discrete simulations having 30, 60 and 90 nodes. While there is a spike initially, this is due to establishing routes in the network for the first time, but then both AODV and OLSR achieves a steady overhead, with OLSR having the lower value for each simulation. it is noted that for increasing densities, the routing overhead for OLSR starts to have closer values to that of AODV.

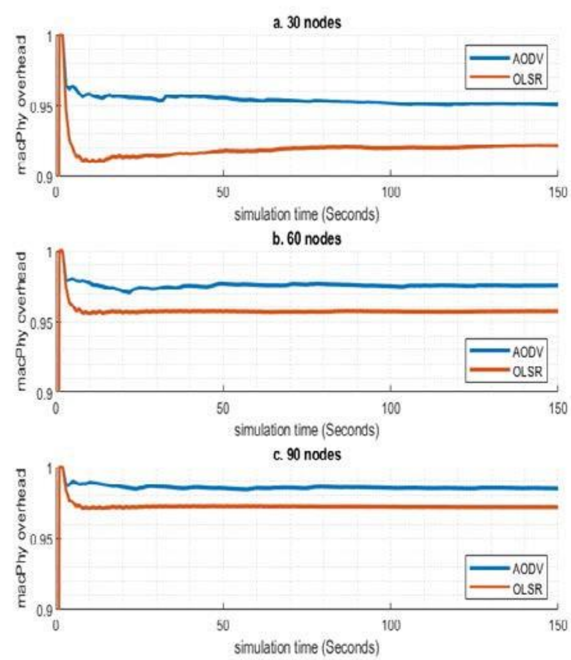

Fig 7 Mac-Phy overhead a. 30 nodes, b. 60 nodes, c. 90 node

VI. Conclusion

This paper presented a comprehensive literature study on the main protocols that have shown performance studies under different scenarios. We also presented the simulation plan used to conduct a comparative study between AODV and OLSR using QoS metrics, namely goodput, PDR and Mac-Phy overhead. The planned simulation's primary outcome was that AODV goodput and PDR are better at lower node densities, while for the same metric, OLSR performs better for high node densities. OLSR has a better and lower routing overhead. However, it starts to approach values of routing overhead of AODV at higher node densities.

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