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The joint impact of mobility models, percentage of transmitting/receiving nodes, and nodes density in the scenario on MANET routing protocols

By

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Abstract:

A Mobile Ad-hoc network (MANET) is a multi-hop wireless network where all nodes cooperatively maintain network connectivity without a centralized infrastructure, and nodes change their positions dynamically. Most studies in MANETs are focused on scenarios with special characteristics. These are: Random waypoint mobility model, 40% transmitting/receiving nodes, and high density of mobile nodes in the scenario area. Our framework aims to evaluate the impact of mobility models, network density, and different percentages of transmitting/receiving nodes on the performance of MANET routing protocols. In this paper a study 27 different scenarios which aim to study the joint effect of different densities of mobile nodes in the scenario area; Three different mobility models; as well as different percentages of transmitting/receiving nodes. Each scenario is evaluated for both the location aided routing (LAR) and ad-hoc on demand distance vector (AODV) routing protocols. Performance evaluation metrics included packet delivery ratio, overhead, and the average end-to-end delay. These metrics were evaluated for a speed of the mobile nodes in the range from 1 to 40 meters/sec. We analyzed the results and compiled a catalogue for MANETS that can be used to deploy the best suitable routing protocol for each scenario of choice.

Keywords:

Mobile ad hoc network, mobility, routing protocols, density, percentage.

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1. Introduction:

Virtual Classrooms, battlefield, and environmental monitoring for early disaster warnings are a few examples where mobile ad-hoc network (MANET) can be used. MANET is a multi-hop wireless network where all nodes cooperatively maintain network connectivity without a centralized infrastructure while changing their positions dynamically. This connectivity is maintained by having a continuous route between source and destination nodes. Each node in a MANET serves as a data node while participating in the network routing role. Different routing protocols were proposed form MANETs; these include Ad hoc On demand Distance Vector (AODV) [1] routing and Location Aided Routing (LAR) protocols [2]. Invariably, the performance of routing protocols is evaluated using simulations. Many factors may affect the simulated performance; the speed of motion of the nodes in the network; the density of the nodes in the scene, the mobility models of the nodes, and the average percentages of transmitting/receiving nodes.

Although there is a wealth of literature on the performance of MANET routing algorithms, most of this literature is limited to the assumption of *random waypoints* mobility model. Indeed, there is significant research on appropriate modelling of MANET nodes mobility. Many models were developed to mimic different environments [3-5]. These models range from simple models assuming random motion in random directions to the more structured Manhattan grid mobility model [5] which emulates the motion of nodes in the streets. Moreover, the network node density is usually chosen to be medium. Using results obtained under such assumptions to predict the performance of the same routing protocols in different environments can be misleading. Therefore, in this paper we expand the range of mobility models, network densities and percentages of transmitting / receiving nodes and show that the relative performance of the routing protocols may change in different environments. Our results shed light on the suitability of certain routing protocols in certain environments.

Specifically, we study the joint effect of the aforementioned parameters on the performance of the networks, which lead us to build 27 different scenarios. We applied these scenarios to evaluate two commonly used routing protocols for MANET which are LAR and AODV. The evaluation criteria used to evaluate the performance are packet delivery ratio, the overhead, and the average end-to-end delay for different average speeds of motion of the nodes in the range 1 to 40 meters/second.

The rest of the paper is organized as follows: in Section 2 we introduce an overview on the factors affecting MANET routing and used for our study to build the different scenarios. In Section 3 we present the experimental setup and results. Finally, the paper is concluded in Section 4.

2. Factors Affecting MANET Routing:

We introduce the factors that affect the performance of MANET which are two routing protocols, mobility models, node density in the network, percentage of nodes performing data communication in the following subsections.

2.1. Routing protocols:

We performed our study based on the two commonly used MANET routing protocols which are ad-hoc on demand distance vector routing protocol (AODV) [1] and location-aided routing (LAR) [2].
AODV is an on-demand protocol which initiates route-request only when needed. When a source node (***S***) needs a route to certain destination node (***D***), it broadcasts a route-request packet (RREQ) to its neighbors. Each receiving neighbor checks its routing table to see if it has a route to the destination. If it does not have a route to this destination, it will re-broadcast the RREQ packet and let it propagate to other neighbors. If the receiving node is the destination or has the route to the destination, a route reply packet (RREP) will be sent back to ***S***. Routing entries for ***D*** are created in each intermediate node on the way RREP packet propagates back. Data traffic is then routed according to the information provided by these entries.
LAR is an on demand source unicast routing protocol. LAR sends location information in all packets to hopefully decrease the overhead of a future route discovery. LAR uses location information of the mobile nodes to flood a route request packet for the destination in forwarding zone instead of the entire ad-hoc network. This forwarding zone is defined by location information on ***D***. Two methods used by intermediate nodes between ***S*** and ***D*** to determine the forwarding zone of a route request packet. In the first method called LAR box, a neighbor of S determines if it is within the forwarding zone by using the location of ***S*** and the expected zone for ***D***. In the second method called LAR step, an intermediate mobile node (MN) determines if it is within the forwarding zone if it the MN is closer to ***D*** than the neighbor that sent the route request packet. In our work we apply the LAR box method.

2.2. Mobility models

We model the motion of the nodes in the MANET using three mobility models which are random way point, Gauss-Markov, and Manhattan grid mobility model.
The random waypoint mobility model includes pause times between changes in direction and/or speed [3]. A mobile node begins by staying in one location for a certain period of time (i.e., a pause time). Once this time expires, the MN chooses to move to a random destination in the simulation with a random constant speed drawn from a uniform distributed between (minspeed, maxspeed). Upon arrival, the mobile node pauses for a specified time period before starting the process again.

The Gauss-Markov mobility model [4] is designed to adapt different levels of randomness via one tuning parameter. Initially each mobile node MN is assigned a current speed and direction. At fixed intervals of time *n*, a movement occurs by updating the speed and direction of each MN. Specifically, the value of the speed and direction at the n^{th} -instance is calculated based upon the value of speed and direction at the $(n\text{-}1)^{\text{th}}$-instance and a random variable is generated using the following equations:

$$d_n = \alpha d_{n-1} + (1-\alpha)d^c + \sqrt{(1-\alpha^2)}d_{x_{n-1}} \quad (1)$$

$$s_n = \alpha s_{n-1} + (1-\alpha)s^c + \sqrt{(1-\alpha^2)}s_{x_{n-1}} \quad (2)$$

where s_n and d_n are the new speed and direction of the MN at time interval *n*; α is a tuning parameter, $0 \leq \alpha \leq 1$, used to vary the randomness; s^c and d^c are constants representing the mean value of speed and direction as $n \rightarrow \infty$; s_{xn-1} and d_{xn-1} are random variables with a Gaussian distribution. Totally random values (or Brownian motion) are obtained by setting $\alpha = 0$ and linear motion is obtained by setting $\alpha = 1$. Intermediate levels of randomness are obtained by varying the value of α between 0 and 1.

The Manhattan grid mobility model [5] emulates movement of mobile nodes on streets. The mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At an intersection the mobile node can turn left, right or go straight, with probability 0.25, 0.25 and 0.5, respectively. Velocity of a node at a time slot is dependent on its velocity at the previous time slot and is restricted by the velocity of the node preceding it on the same lane of the street, as in the freeway model. Thus, the Manhattan mobility model has high spatial dependence and high temporal dependence.

2.3. Network density

Given that the number of nodes in a terrain is N_m and each node has a coverage area (radio rage) A_n, we define the network density as the ratio of the total area coverage of all nodes in the network and the area of the terrain (scenario) A_s as follows:

$$d = \frac{N_m A_n}{A_s} \quad (3)$$

We define three density ranges *d*:
Low density for $d \in [1, 5]$; Medium density for $d \in [6, 8]$ and High density for $d \geq 9$.
In this paper we used *d*= 4, 8, and 10 for low, medium, and high density respectively. We define the coverage area of a node (A_n) as the area of possible mutual communication with other nodes. This area is parameterized by the radius of radio transmission range r_t. Simply we have

$$A_n = \pi r_t^2 \quad (4)$$

For any given r_t determined by a device, *d* and A_s defined by a scenario, one can obtain the number of nodes N_m using (3) and (4) as

$$N_m = \frac{dA_s}{\pi r_t^2} \tag{5}$$

2.4. Percentage of transmitting/receiving nodes

This percentage defines the number of sources and destinations. In our work we use three percentages of transmitting/receiving nodes which are 80%, 40%, and 20%.

3. Simulation environment and Experimental work

The tools used to perform all scenarios are: Bonnmotion software [6] used for generating the mobility models and Glomosim: Global mobile information system simulator [7]: which is the simulator used in mobile ad-hoc network simulation for different scenario parameters.

3.1. General Scenarios Parameters

All scenarios have the following general parameters:

- Duration of Simulation is 900 seconds.
- The physical terrain is 1500×1500 m^2.
- Transmission range of nodes is 300 m.

In high density scenario (d=10), the number of nodes is 80, in medium density scenario (d=8) number of nodes is 55, and in low density scenario (d=4) the number of nodes is 32 in the scenario. The Bandwidth is assumed to be 2 Mb/sec using MAC protocol 802.11, using IP network protocol and constant bit rate CBR used to send data through network. A packet is assumed to be 64 Bytes and the data rate is 4 packet/second. For each scenario we vary the average maximum speed to have values of 1 m/s, 5m/s, 10 m/s, 20 m/s, 30 m/s, 40 m/s. For each scenario setup we run the simulation three times and take the average out of the three results. For each of the average end-to- end delay, packet delivery ratio (PDR), and the overhead.

3.2. Specific scenario parameters

For each scenario there are parameters that tune the three mobility models which are described as follows:

Gauss Markov mobility model: update frequency =2.5 sec, angle standard deviation= 0.392699, speed standard deviation=0.5 m/sec.

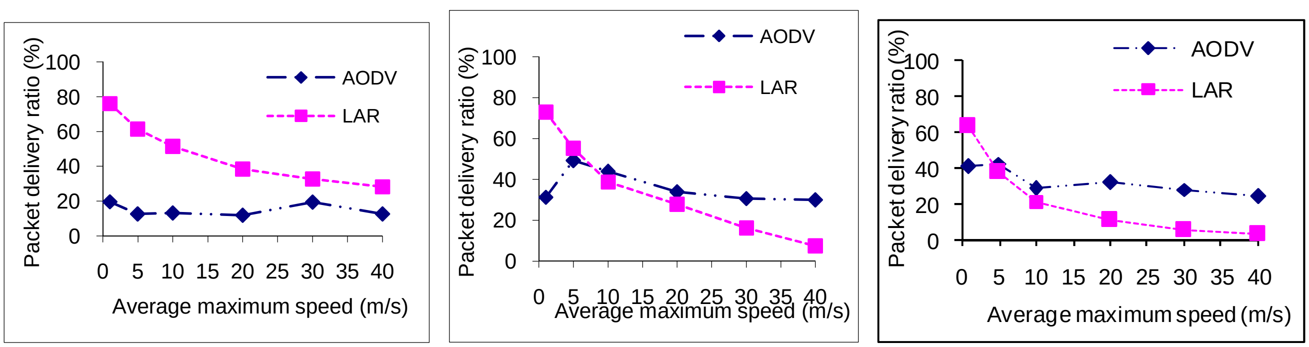
Random way point mobility model: minimum speed=0m/s, Pause time= 5 sec. Manhattan grid mobility model are: X blocks=15, Y blocks=15, update distance=5, turn probability=0.5, speed change probability=0.2, and speed standard deviation=0.5.

3.3. Simulation results and comparisons

In this paper, we performed 54 different scenarios with the following combinations denoted as follows: Scenario ≡{scenario density, mobility model, routing protocol, percentage of transmitting/receiving nodes}. We present in this section the results of 54 scenarios where in each figure there is a comparison between the AODV and LAR routing protocol thus having a total of 27 graphs. We grouped the graphs having the same values of scenario density, and percentage of transmitting/receiving nodes but for different mobility models in one figure for ease of interpretation, thus we have a total of 9 figures. The results are split in three sub-sections based on the density of the nodes and thus each sub-section has 3 figures. These sub-sections are for high, medium, and low density.

3.3.1 High density

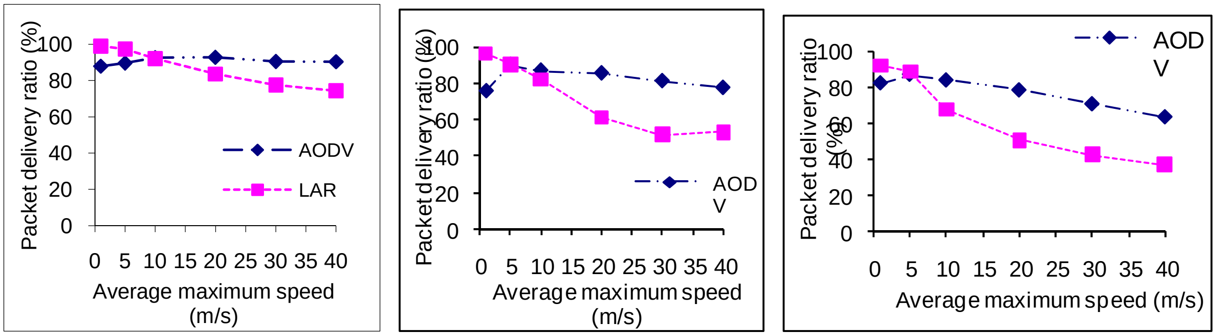
All figures 1, 2, and 3 shows the packet delivery ratio of LAR and AODV routing protocols according to the increase of node's average maximum speed. Three mobility models are used and shown in (a) random waypoint, (b) Gauss-Markov, and (c) Manhattan grid mobility model. The percentage of transmitting/receiving nodes is 80%, 40%, and 20% and shown in figures 1, 2, and 3 respectively.



(a) (b) (c)

Figure (1): *Packet delivery ratio of scenarios: {high density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 80%}*

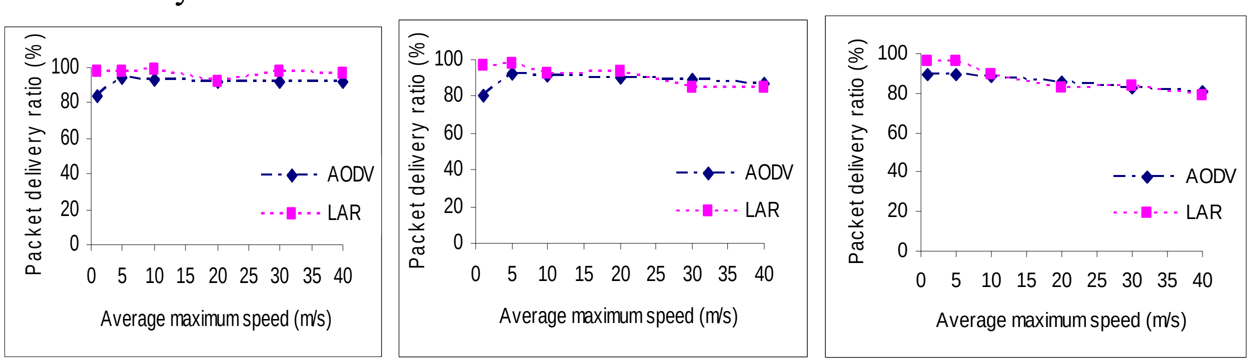
Figure 1 shows that LAR routing protocol demonstrates better performance than AODV. LAR uses location information which limits the broadcasted zone of route control packets. This characteristic leads to better performance in PDR rate. As the node's average maximum speed increases, the PDR of both protocols decreases. This is due to the fact that, at higher speeds, more frequent link breakage may occur and therefore the packet loss rate increases. For Gauss-Markov in Fig. 1(b) and Manhattan mobility in Fig. 1(c) LAR shows better performance than AODV at lower speeds. This behavior is due that, in the cases of Manhattan and Gauss mobility models, the request and expected zone of source node, when using LAR, is the whole simulation area and information about speed is not available. Therefore, in some results, especially at higher speeds, higher densities and higher percentage of transmitting/receiving nodes, the AODV shows better performance than LAR. This is due to the fact that all network nodes are located within the request zone, which in turn causes an increasing in transmission traffic. And, at higher speeds, the change of location information is very fast, which results in more frequent link breakage, therefore the packet loss rate increases.



(a) (b) (c)

***Figure 2:** Packet delivery ratio of scenarios {high density, (a) Random waypoint, (b) Gauss Markov , and (c) Manhattan grid, (LAR, AODV), 40%}*

In Figure 2, as the node's average maximum speed increases, more frequent link breakage may occur and therefore a packet loss rate increases. In these figures, LAR shows a better PDR than AODV. At lower speeds. AODV shows a better PDR than LAR At higher speeds. Because of LAR uses location information, it can limit the broadcasted zone of route control packets. This characteristic can lead to better performance in PDR. At higher speeds, the change of location information becomes very fast, and LAR broadcasts more zone of route control packets. This leads to bad in packet delivery ratio.



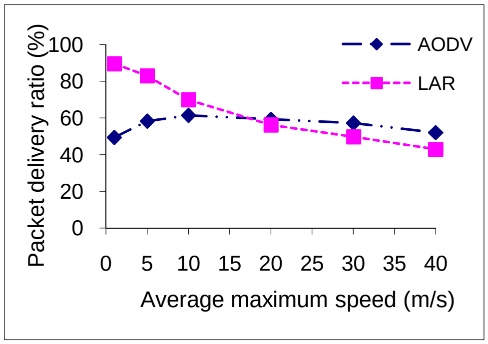
(a) (b) (c)

***Figure 3:** Packet delivery ratio of scenarios {high density, (a) Random waypoint, (b) Gauss Markov , and (c) Manhattan grid, (LAR, AODV), 20%}*

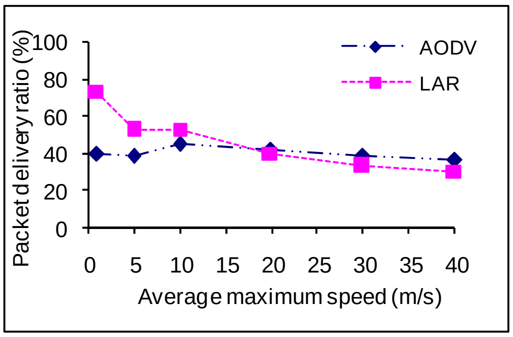
In Figure 3 ,the percentage of transmitting/receiving nodes of 20% which is a low traffic case that leads to a decrease in collision, congestion, and packet loss rate. Therefore, both AODV and LAR demonstrate well at the same performance.

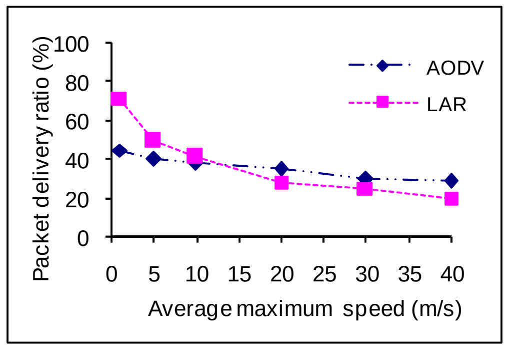
3.3.2 Medium density

All figures 4, 5, and 6 show the packet delivery ratio of LAR and AODV routing protocols according to the increase of node's average maximum speed. Three mobility models are used and shown in (a) random waypoint, (b) Gauss-Markov, and (c) Manhattan grid mobility model. The percentage of transmitting/receiving nodes is 80%, 40%, and 20% and shown in figures 4, 5, and 6 respectively. In the same way, the results can be discussed as in the case of high density.



(a)



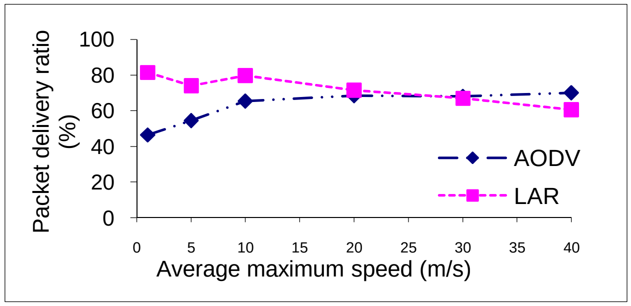


(b) (c)

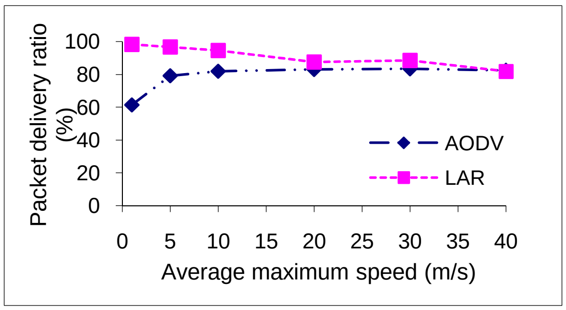
Figure (4): *Packet delivery ratio of scenarios: {Medium density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 80%}*

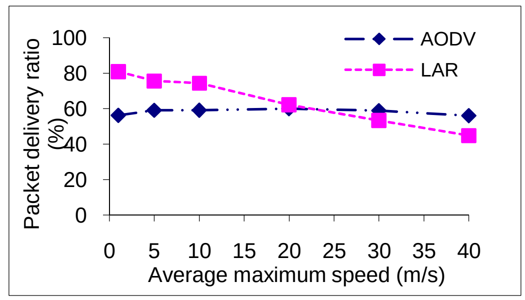
3.3.3 Low density

Figures 7, 8, and 9 show the packet delivery ratio of LAR and AODV routing protocols according to the increase of node's average maximum speed. Three mobility models are used and shown in (a) random waypoint, (b) Gauss-Markov, and (c) Manhattan grid mobility model. The percentage of transmitting/receiving nodes is 80%, 40%, and 20% and shown in figures 7, 8, and 9 respectively. From the figures, LAR shows better performance than AODV. This is due to the fact that, at low density, the number of nodes is very low, compared to the simulation area, which in turn results in, especially at lower speeds, communication loss with some nodes. Therefore, the packet loss rate increases. LAR uses location information to discover the route by broadcasted request zone and determined expected zone. This LAR characteristic helps in delivering the packets from the source to destination in a manner more efficient than AODV.



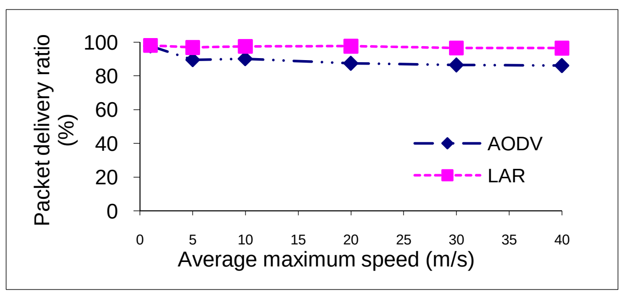
(a)



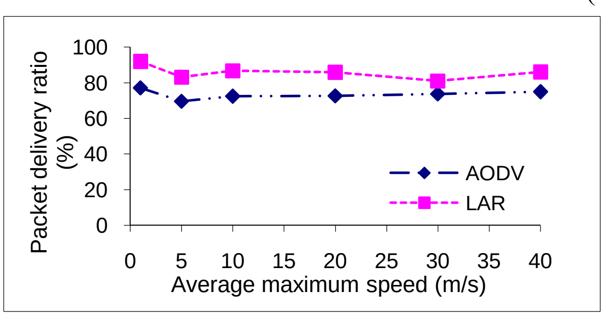


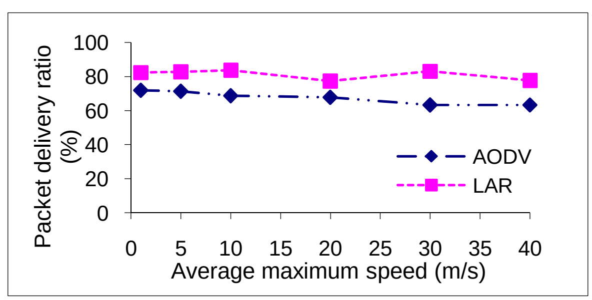
(b) (c)

Figure (5): *Packet delivery ratio of scenarios: {Medium density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 40%}*



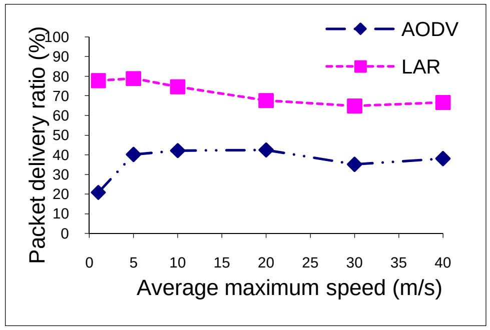
(a)



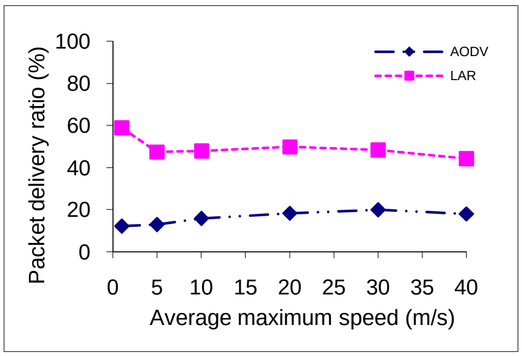


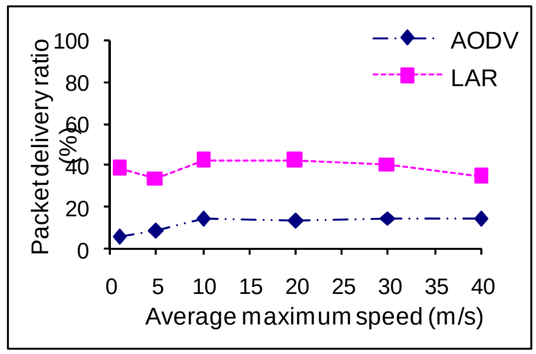
(b) (c)

Figure (6): *Packet delivery ratio of scenarios: {Medium density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 20%}*



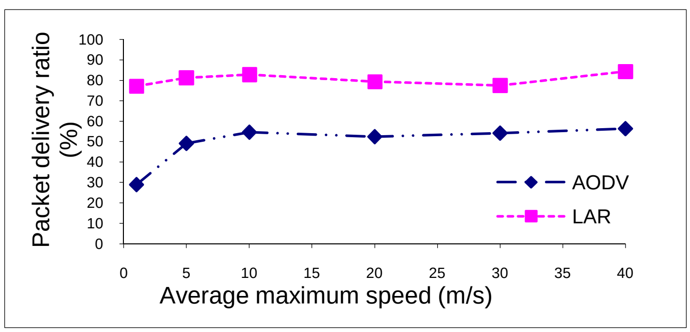
(a)



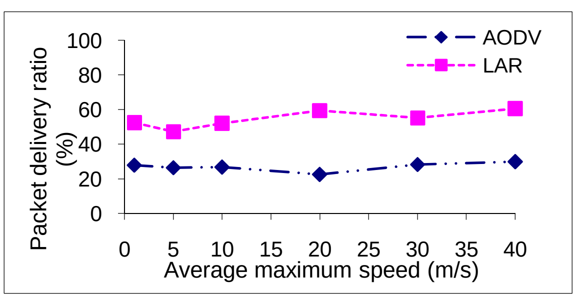


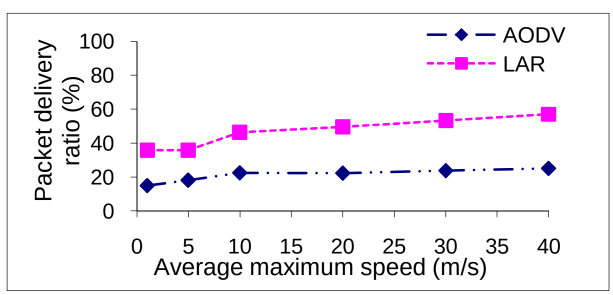
(b) (c)

Figure (7): *Packet delivery ratio of scenarios: {Low density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 80%}*



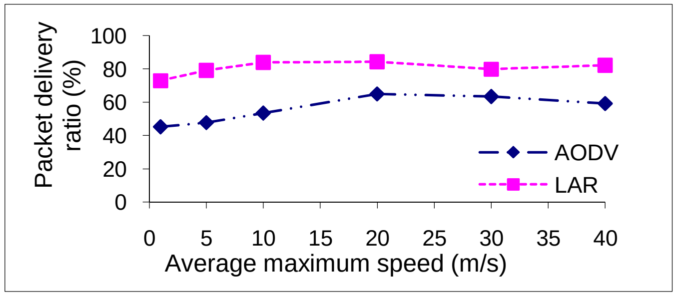
(a)



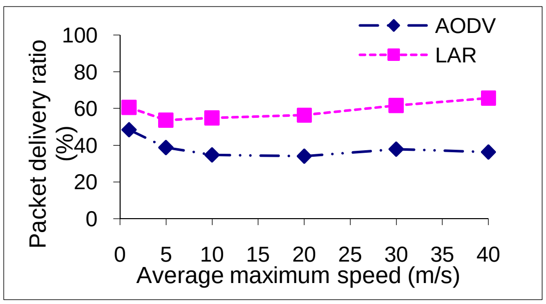


(b) (c)

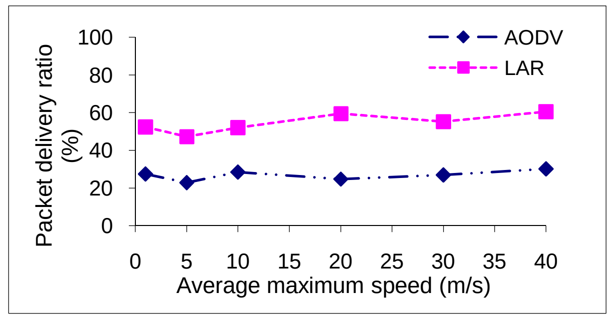
Figure (8): *Packet delivery ratio of scenarios: {Medium density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 40%}*



(a)



(b)



(c)

Figure (9): *Packet delivery ratio of scenarios: {Low density,(a) random waypoint, (b) Gauss Markov, and (c) Manhattan grid, (LAR, AODV), 20%}*

3.4. Best performing protocol for the different scenario cases

Although in our study we obtained results for the overhead and end-to-end delivery delay, we only presented the results for packet delivery ratio (PDR) in the figures for its importance as a performance measure and due to space limitation in the paper.
The summary of our study is shown qualitatively in table 1.

Table1: *Best performing routing protocol selection for different scenarios*

High density	Higher speeds	AODV is better than LAR unless for random way point mobility model at cases of 20% and 80% transmitting/receiving nodes
	Lower speeds	LAR is better than AODV unless for Manhattan grid mobility model.
Medium density	Higher speeds	AODV is better for 80% and 40%, LAR is better for 20% transmitting/receiving nodes
	Lower speeds	LAR performance is better than AODV
Low density	LAR performance is better than AODV in general	

4. Conclusions and future work

In this paper, we studied the impact of mobility models, network density, and different percentages of transmitting/receiving nodes on the performance of MANET routing protocols. We studied 27 different scenarios based on the factors that affect the routing in MANET. These scenarios reflected the joint effect of different densities of mobile nodes in the scenario area; three mobility models were chosen: random waypoint, Gauss Markov, and Manhattan grid, and three percentages of transmitting/receiving nodes were used: 80%, 40%, and 20%. Each scenario was evaluated for both the LAR and AODV routing protocols. We analyzed the results and compiled a catalogue for MANETS that can be used to deploy the best suitable routing protocol for each scenario of choice.

In general we found that at low speeds LAR gives better performance, compared to AODV because LAR uses location information which decreases routing overhead. AODV gives better performance at higher speeds, especially in high and medium density scenarios, where the update of node location data is fast. However, at low density, LAR gave better performance, because it uses location information (request zone, expected zone), which increases the probability of the arrival of packets to the destination nodes. For every mobility model, the mobile node has a special behavior of movement that affects the nodes distribution densities in the localized area in the scenario. Increasing the percentage of transmitting/receiving nodes degrades network performance. The AODV results are more stable than LAR results (especially at high speeds). LAR depends on location information while AODV depends on ID sequence, source address, and destination address.

Future work could address the implementation of physical test bed and comparing its results with the simulated results. This will allow the practical validation before deploying the real MANET networks.

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