IMPACT OF RANDOM MOBILITY MODELS ON OLSR

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ABSTRACT

In ad hoc networks, routing plays a pertinent role. Deploying the appropriate routing protocol is very important in order to achieve best routing performance and reliability. Equally important is the mobility model that is used in the routing protocol. Various mobility models are available and each can have different impact on the performance of the routing protocol. In this paper, we focus on this issue by examining how the routing protocol, Optimized Link State Routing protocol, behaves as the mobility model is varied. For this, three random mobility models, viz., random waypoint, random walk and random direction are considered. The performance metrics used for assessment of Optimized Link State Routing protocol are throughput, end-to-end delay and packet delivery ratio.

KEYWORDS

OLSR, Mobility model, Random Waypoint, Random Walk, Random Direction

1. INTRODUCTION

Wireless networks can be classified into infrastructure based and infrastructure less networks. In the case of infrastructure based networks, Access Points are used for communication. They act as routers for the nodes within their communication range. Whereas, in infrastructure less networks, also known as, ad hoc networks, nodes act as routers. That is, such networks do not have predesignated routers and nodes connect in a dynamic manner. A node cannot connect to all other available nodes using single hop as the transmission range of nodes is limited and hence data is transmitted using multi hop. A mobile ad hoc network (MANET) is a type of ad hoc network in which nodes can change locations. It is a self configuring infrastructure less network of mobile devices connected by wireless links [1].

The routing protocols in MANET are broadly classified into three categories, namely, proactive protocols, reactive protocols and hybrid protocols. Proactive protocols, also known as table-driven protocols, maintain routing information in the routing table of each node. The routing table is populated in a proactive manner and the routing table information is transmitted to other neighboring nodes at fixed time intervals. Few examples of proactive routing protocols are Optimized Link State Routing (OLSR) Protocol, Destination-Sequenced Distance-Vector (DSDV) Routing Protocol.

Reactive routing protocols are also known as demand driven protocols. In these protocols, prior route information to other nodes is not maintained. Whenever a node (source node) needs to transmit data to a destination node, the route is determined on demand. The node initiates a route discovery process only if it has data destined to a particular node. For other nodes for which no data is to be transmitted, routes are not computed. Examples of reactive routing protocols are

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Dynamic Source Routing (DSR) Protocol, Ad hoc On-Demand Distance Vector (AODV) Routing Protocol etc.

The third category, hybrid routing protocols, are a combination of both proactive and reactive routing protocols. For example, proactive routing may be used to communicate with neighbors and reactive may be used to communicate with distant nodes. Examples of hybrid routing protocols are Zone Routing Protocol (ZRP), Core Extraction Distributed Ad Hoc Routing (CEDAR) Protocol etc.

The performance of the varied routing protocols may be dependent on various factors; one such key parameter that could impact routing protocols is the mobility model. The mobility model is the one that is used to describe the pattern in which mobile users move. It also describes how the location and velocity of the nodes change over time. Based on the mobility model being used, the performance of a routing protocol can vary.

In this paper, we assess the impact of the various random mobility models on OLSR protocol using the performance metrics, throughput, end-to-end delay and packet delivery ratio. The rest of the paper is organized as follows. The OLSR protocol and the various mobility models are briefly discussed in section 2. Section 3 consolidates the related work on the performance of routing protocols using various mobility models. The simulation environment, performance metrics and the simulation results are discussed in section 4. Section 5 concludes the paper.

2. OLSR AND MOBILITY MODELS

2.1. Optimized Link State Routing (OLSR) Protocol

OLSR protocol is a proactive type of routing protocol. It uses Multipoint Relay (MPR) sets for routing. For each node, a set of its neighbor nodes that have symmetric links are selected as MPRs, which alone forward the control traffic. When a node is selected as multipoint relay, it announces this information in the control messages at periodic intervals. Using this, routes are formed from a given node to various destinations. Nodes that belong to MPR set cover all symmetric strict 2-hop neighbor nodes.

In OLSR, HELLO messages and topology control messages are used. HELLO messages are transmitted at regular intervals and they are never forwarded. The HELLO messages help in link sensing, neighbor detection and MPR selection signaling. Link-state information of each and every node is transmitted to all other nodes in the network via the topology control messages. This helps the nodes to compute their routing table. Topology control messages are sent using the MPRs.

2.2. Mobility Models

Mobility models are generally classified into five categories [2]. They are random mobility models, mobility models with temporal dependency, mobility models with spatial dependency, mobility models with geographic restrictions and hybrid mobility models. This classification is summarized in figure 1 [1, 2].

In random mobility models, the nodes move independently by choosing a random direction and speed. In the case of mobility models with temporal dependency, the movement of nodes is affected by their movement history. In the mobility models with spatial dependency, the movement of nodes is correlated in nature. If the mobility model limits the movement of nodes owing to streets or obstacles, then such models fall under mobility models with geographic restriction [1]. In hybrid mobility models, mobility models with spatial dependencies, temporal dependencies and geographic restrictions are integrated [2].

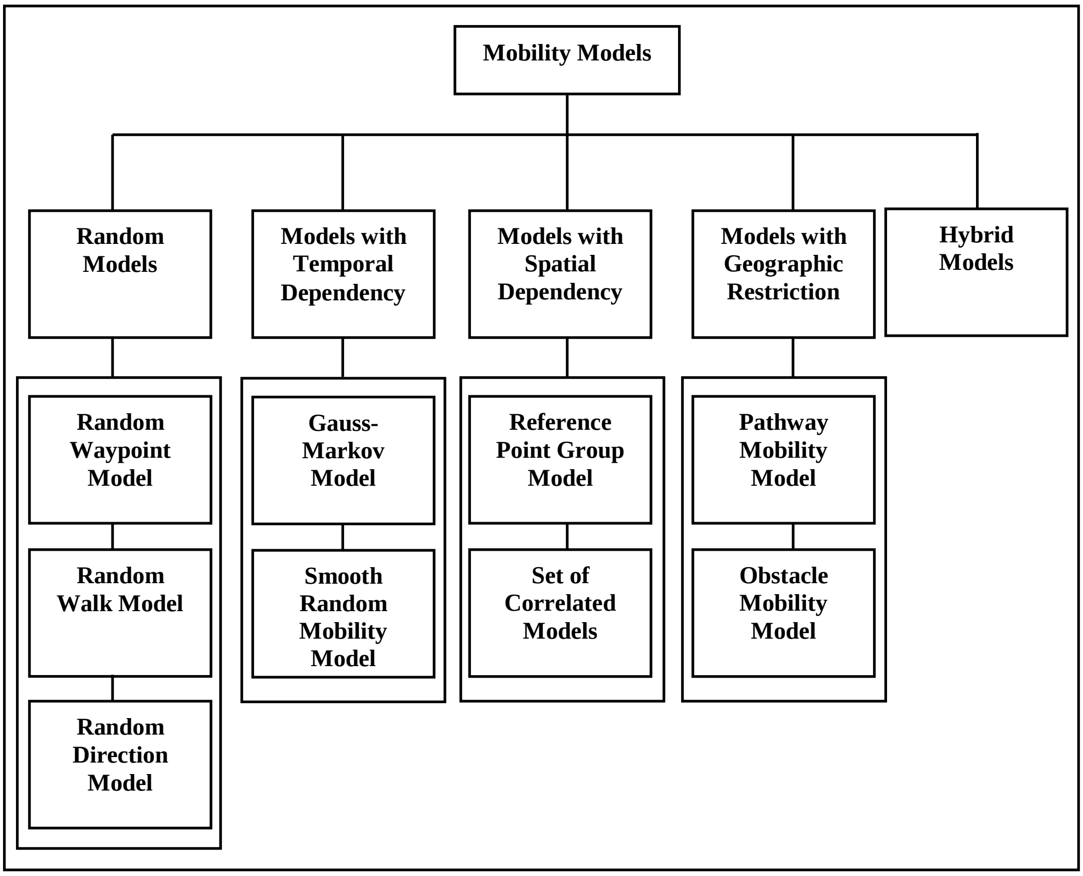

Figure 1. Classification of mobility models in MANET

Of the various mobility models, three random mobility models, viz., Random Waypoint, Random Walk and Random Direction model are considered in this study to assess the performance of OLSR under varying mobility pattern. In the next section we elaborate on these three mobility models.

2.2.1. Random Waypoint Mobility Model

In the Random Waypoint Mobility Model, a node selects a random position (x, y) in the simulation area. This point serves as the destination point. A velocity (v) is chosen from a uniformly distributed range [minspeed, maxspeed]. The node travels to the destination point with speed v. Upon reaching the destination point, the node pauses for a specified pause time. Then again the node repeats the above process by choosing a new destination and speed [3].

2.2.2. Random Walk Mobility Model

In random walk mobility model, nodes move by randomly choosing a speed and direction in constant time intervals (Δt). The speed is determined from the range [minspeed, maxspeed] and the direction $\theta(t)$ is chosen from the range [0, 2Π]. The node moves with the velocity vector ($v(t) \cos\theta(t)$, $v(t) \sin\theta(t)$). When the node reaches the simulation boundary, it bounces back to the simulation area. The angle of bouncing is θ(t) or Π – θ(t). This effect is called as border effect. This model is also referred to as the Brownian Motion Mobility Model or Brownian Walk. Random Walk model can also be considered as Random Waypoint model with zero pause time [1, 3].

2.2.3. Random Direction Mobility Model

In the case of Random Direction Mobility Model, a node chooses a random direction uniformly within the range [0, 2Π]. The velocity is also chosen uniformly from within the range [minspeed, maxspeed]. Node then moves in the chosen direction until it arrives at the boundary of the simulation area. At this point the node pauses for a specified pause time and again selects a new direction from within the range [0, Π]. Since the node is on the boundary of the simulation area, the direction is limited to Π [3].

3. RELATED WORK

Various studies have been conducted so far to assess the performance of routing protocols in the context of different mobility models.

A survey of various mobility models in cellular networks and multi-hop networks has been carried out in [4]. Reference point group mobility model has been applied to two different network protocol scenarios, clustering and routing. The performance of the network with different mobility patterns and for different protocols has been studied. It is found that the performance of the protocols varies with different mobility patterns used. In AODV and Hierarchical State Routing (HSR), the throughput improves when the communications are restricted within the scope of a group, whereas DSDV is not affected by group mobility and localized communications.

The performance of DSR and AODV with reference to varying network load, mobility and network size has been analyzed in [5]. DSR is found to outperform AODV in small networks with low load and/or mobility, whereas AODV is more efficient with increased load and/or mobility. However routing load is less in DSR compared to AODV. It is observed that using congestion-related metrics and aged packets removal can improve the performance of both DSR and AODV. The authors conclude that the interplay between routing and MAC layers affects the performance of the protocols significantly.

The authors in [6] have studied the performance of DSR using random walk, random waypoint, random direction and reference point group mobility models. It is observed that the performance of the protocols varies with the different mobility models and even with the same mobility model but with different parameters.

To create realistic movement scenarios, the authors in [7] have used obstacles to restrict node movement and wireless transmissions. Also pathways have been constructed using Voronoi path computation. It is observed that the obstacles and pathways affect the performance of the protocols. AODV has been used to study the performance of routing protocol using obstacle model and random waypoint mobility model. It is observed that the mobility model chosen affects connectivity of the nodes, network density, packet delivery and routing overhead.

Various protocol independent metrics have been proposed to capture mobility characteristics including spatial and temporal dependence and geographic restrictions in [8]. Random waypoint, group mobility, freeway and Manhattan mobility models have been used to study the performance of DSR, AODV and DSDV. The results indicate that different mobility patterns affect the performance of the routing protocols. The mobility pattern influences the connectivity graph which affects the performance of the protocol. A preliminary investigation of the common building blocks of routing protocols was also attempted.

In [9] the authors introduced GEMM, a tool to generate mobility models that happen to be more realistic and heterogeneous. They have compared the performance of AODV, OLSR and ZRP with various mobility scenarios. It is observed that GEMM can generate more realistic mobility patterns than random waypoint. Mobility pattern influences the performance of the protocols.

In [10] the authors observe that high node degree can be both an asset and a liability. On one hand high node degree can affect scalability. On the other hand high node degree provides multiple routing options.

The performance of DSR and AODV using various mobility models has been studied in [11]. They observe that the mobility pattern affects the performance of routing protocols and that mobility metrics, connectivity and performance are related. When relative speed increases with similar average spatial dependency, there is decrease in link duration and hence routing overhead increases and throughput decreases. In the case of similar average relative speed, the spatial dependence increases and the link duration increases, and hence there is an increase in the throughput and a decrease in the routing overhead. DSR and AODV have highest throughput and least overhead when reference point group mobility model is used. They conclude that mobility pattern influences the connectivity graph which impacts the performance of the routing protocol.

In [12] the performance of AODV routing protocol using pursue group and random based entity mobility models is studied. Pursue group mobility model has performed better than random based entity model.

The effect of mobility models on the performance of the protocols has been analyzed in [13] both analytically and through simulation. They present an analytical framework for the characterization of link and use it to describe lifetime of the path and stability of the topology. The framework describes link, path and topology dynamics as a function of node mobility. They find that there is a diminishing effect on the protocols with increase in mobility.

The performance of On-Demand Multicast Routing Protocol, Multicast Ad hoc On-Demand Distance Vector Routing Protocol and Adaptive Demand driven Multicast Routing Protocol have been studied using random way point, reference point group and Manhattan mobility models in [14]. It is evident from their results that with different mobility patterns the ranking of protocols differ.

In [15] the authors have used Levy-Walk mobility model and Gauss-Markov model to compare Adhoc On Demand Multipath Distance Vector (AOMDV) and OLSR routing protocols. They observe that AOMDV gives higher packet delivery and throughput, whereas OLSR has less delay and routing overhead in the context of varying node density. Also OLSR performs better than AOMDV under Levy-Walk mobility model.

The authors in [16] have studied the performance of AODV, DSR, DSDV, OLSR and Dynamic MANET On-Demand (DYMO) routing protocols using various mobility models. A fair comparison of the capabilities and limitations of different mobility patterns has been attempted.

The performance of AODV and DSR using reference region group mobility model has been examined in [17]. The reference region group mobility model is used to mimic group operations such as group partitions and mergers. It is found that the group partitions have an impact on the performance of the routing protocols. Frequent group partitions can downgrade the performance of both the routing protocols under consideration. Comparatively AODV is able to tackle better the group operations than DSR. Further AODV is more adaptive to high speed environment, while DSR is more suitable for networks with less mobility.

The authors in [18] have compared different hierarchical (position and non-position based) protocols using different mobility models. Position based routing protocols have performed better compared to their counterparts with reference to packet delivery. It is observed that non-position based routing protocols provide low packet delivery ratio and high packet loss. Further the authors conclude that the network performance can be enhanced in the presence of a recovery mechanism.

The authors in [19] have studied the impact of swarming behavior of nodes on the performance of routing protocols both analytically and through simulation, and they have also proposed a Markov swarm mobility model to characterize time-dependent changes in the network topology. They observe that owing to swarm movement of nodes in a collaborative manner, the routing overhead and average end-to-end delay is significantly reduced.

In [20] the authors have evaluated structured and unstructured content discovery protocols with various mobility models. It is evident from their work that movement patterns which exhibit more uniform distribution of nodes provide better efficiency. Limitations reduce the efficiency of the network. Increase in node speed does not have a considerable effect on path availability. They conclude that path availability is the most important factor affecting the efficiency of content delivery protocols. Hence mobility is not of much concern in implementation of efficient overlay networks. In the case of structured protocols which are not efficient for MANETs, the mobility has a negative effect on performance. Performance is dependent on stability and optimality of overlay in the case of structured protocols. In the case of unstructured protocols, alternative paths can be replaced in the case of link failure and hence unstructured protocols perform better.

Three distinctive mobility models in terms of node movement behaviour have been studied by the authors in [21]. A new measurement technique called probability or route connectivity has been used. This metric quantifies the success rate of route established by the routing protocol.

The performance of DSR, Location Aided Routing (LAR) and Wireless Routing Protocol (WRP) have been studied with reference to random waypoint mobility model, reference point group mobility model, Manhattan Grid mobility model and Gauss-Markov mobility model in [22]. It is found that the performance of routing protocols varies significantly with the mobility model being used and also the node speed affects the network performance. Location-based routing protocols exhibit good performance with various mobility patterns.

The authors in [23] have compared the performance of AODV, OLSR and DSDV with respect to reference point group mobility and random waypoint mobility models. It is found that, in the case of random waypoint mobility model, AODV shows maximum packet delivery ratio, least routing load and MAC load. As mobility increases, OLSR performs better with respect to delay. In reference point group mobility model, AODV has higher packet delivery ratio and lowest routing load, whereas OLSR exhibits least delay and maximum MAC load.

The performance of AODV and DSDV using random waypoint, reference point group mobility, Freeway and Manhattan mobility models have been analyzed in [24]. It is observed that AODV has stable performance in all the mobility models studied. It performs best with group mobility model and freeway model. Performance of DSDV is unstable with random waypoint, Freeway and Manhattan mobility models. Performance is best in the case of Reference Point Group Mobility model for both the protocols. AODV has high throughput and low end-to-end delay, whereas both AODV and DSDV have relatively same packet delivery ratio. DSDV suffers from high packet drop compared to the other protocol under consideration.

In [25] the authors have compared AODV, DSR, OLSR, DSDV and Temporally Ordered Routing Algorithm (TORA) routing protocols using reference point group mobility (RPGM), column mobility model (CMM) and random waypoint (RWP) mobility models. The results show that reactive protocols perform better than proactive protocols with reference to packet delivery ratio, end-to-end delay, normalized routing load and throughput. OLSR has got the minimum delay whereas it is maximum in the case of DSR. Throughput is found to be maximum in AODV. DSDV performs better in the case of packet dropper whereas it is worst in the case of AODV. Increasing the number of nodes impacts the performance which varies based on protocols and mobility models. DSR shows degradation as the number of nodes increases. TORA's performance is very minimal.

In [26] the authors have studied AODV, DSR, LAR and OLSR routing protocols with random waypoint, reference point group mobility, Gauss Markov and Manhattan Grid mobility models. They report that there is significant impact on the performance of the routing protocols based on the mobility model being used. The protocols have exhibited considerable difference for different mobility models. The choice of the mobility model has most impact on DSR and OLSR.

The performance of AODV, OLSR and gathering-based routing protocol (GRP) using random waypoint and vector mobility models has been evaluated in [27]. OLSR performs better in terms of throughput and end-to-end delay. In all the routing protocols studied, vector mobility model outperforms random waypoint mobility model.

The effect of random waypoint mobility model and group mobility model for both constant bit rate and variable bit rate traffic has been studied in [28]. They have used AODV, OLSR and ZRP for comparison. With respect to throughput, end-to-end delay and jitter, OLSR performs better than AODV and ZRP. Performance of ZRP is found to be the least among the three protocols.

In [29] the authors have studied the performance of random waypoint and vector mobility model with reference to AODV, OLSR and GRP. They have concluded that OLSR performs better in terms of throughput and end-to-end delay. It is also observed that AODV has lesser network load in both the mobility models used for simulation.

The performance of OLSR, TORA and ZRP with reference to random waypoint mobility model, reference point group mobility model and Manhattan mobility model has been analyzed in [30]. They have concluded that different factors such as pause time, node density and scalability affect the performance and efficiency of the protocols. They also state that no single protocol gives optimum efficiency.

In [31] the authors have evaluated the performance of AODV, DSR and DSDV with respect to different network loads and various mobility models. They found that the performance of routing protocols varies with different mobility models. DSR protocol exhibits better performance with random waypoint mobility model but in the case of Manhattan Grid Mobility model its performance is fair. The end-to-end delay is lowest in the case of RPGM model and it exhibits best performance in DSDV. The authors observed that DSR routing protocol with random waypoint mobility model is better compared to the other combinations.

The authors in [32] have analyzed the performance of AOMDV using random waypoint, random direction and probabilistic random walk mobility models. Their results show that packet delivery ratio decreases with increasing node mobility in all the mobility models. Average end-to-end delay is also affected with varying node speed. With reference to packet delivery ratio and average end-to-end delay, AOMDV performs better with random waypoint mobility model.

In [33] the authors have examined the performance of AODV, DSR, OLSR, DSDV and TORA with reference to reference point group mobility model, column mobility model and random walk mobility model. It is found that delay is least in the case of OLSR and maximum in DSR. AODV shows high throughput whereas DSDV performs better with reference to packet dropper. Performance of DSR declines with increase in the number of nodes, while that of TORA is very poor compared to the other protocols under consideration.

The impact of mobility models and traffic patterns on AODV, DSDV and OLSR has been studied using both CBR and TCP traffic patterns with respect to reference point group and Manhattan Grid mobility models in [34]. The performance metrics used are packet delivery ratio, throughput and end-to-end delay. It is observed that the relative ranking of protocols varies based on the mobility model, node speed and the traffic patterns used. The authors conclude that AODV performed better with TCP-Vegas compared to the two other protocols under consideration. Also the performance was better with TCP traffic patterns compared to CBR traffic pattern. The end-to-end delay was better in DSDV and OLSR when CBR traffic pattern and reference point group mobility model is used.

Performance of AODV, OLSR and TORA using random walk mobility model and random waypoint mobility model is compared in [35]. Different types of traffic have been used to arrive at the results. They conclude that OLSR gives best performance in terms of throughput and load, but has higher delay than the other two protocols. In the case of mobility model, random waypoint mobility model is found to be better than random walk mobility model in all the three routing protocols that have been compared.

Random waypoint and reference point group mobility models have been used to study the performance of DSR, OLSR and TORA in [36]. The results show that reactive protocols are better than proactive protocols in terms of packet delivery fraction, end-to-end delay and throughput. DSR has performed better than OLSR and TORA, whereas performance of TORA is the least among the three protocols considered. OLSR has exhibited average performance in both the mobility models whereas DSR has performed better in random waypoint mobility model.

In this paper, we assess the impact of random waypoint, random walk and random direction mobility models on OLSR protocol with reference to performance metrics, viz., throughput, end-to-end delay and packet delivery ratio.

4. SIMULATION RESULTS

4.1. Simulation Environment and Performance Metrics

Simulations have been carried out using NS3, a discrete event network simulator [37]. Random waypoint, random walk and random direction mobility models have been used to evaluate their impact on OLSR. Simulation is run for a total of 300 seconds using 50 nodes spread over an area of 1000m x 1000m. The speed of the nodes is varied from 10m/s to 50m/s in steps of 10m/s and the pause time is 10 seconds. The packet size is 512 bytes and the channel capacity is 5.5 Mbps. The MAC protocol used is 802.11b.

Three performance metrics, viz., throughput, end-to-end delay and packet delivery ratio (PDR) are examined. Throughput refers to the average rate at which data packet is delivered successfully from one node to another. It is usually measured in bits per second. End-to-end delay is the time taken for a data packet to reach its destination. It is the difference between the time a packet is sent and the time the packet is received. Packet delivery ratio is the ratio of data packets successfully delivered to the destinations to those generated by the sources. It is calculated by dividing the number of packets received by the destination by the number of packets sent by the source.

4.2. Result Analysis

4.2.1. Performance of OLSR using the three mobility models over varying node speed

The simulation results obtained using OLSR with random waypoint, random walk and random direction mobility models over varying node speed are shown in figures 2, 3 and 4. Figure 2 presents the results of throughput for varying node speed from 10 m/s to 50 m/s. From the figure, it is evident that the performance of OLSR with respect to throughput using random waypoint and random walk mobility models is almost similar with very little difference. But as the node speed increases the throughput using random waypoint mobility model is found to be consistent whereas random walk shows decline in the throughput. In the case of random direction mobility model, as the node speed increases there is substantial drop in the throughput.

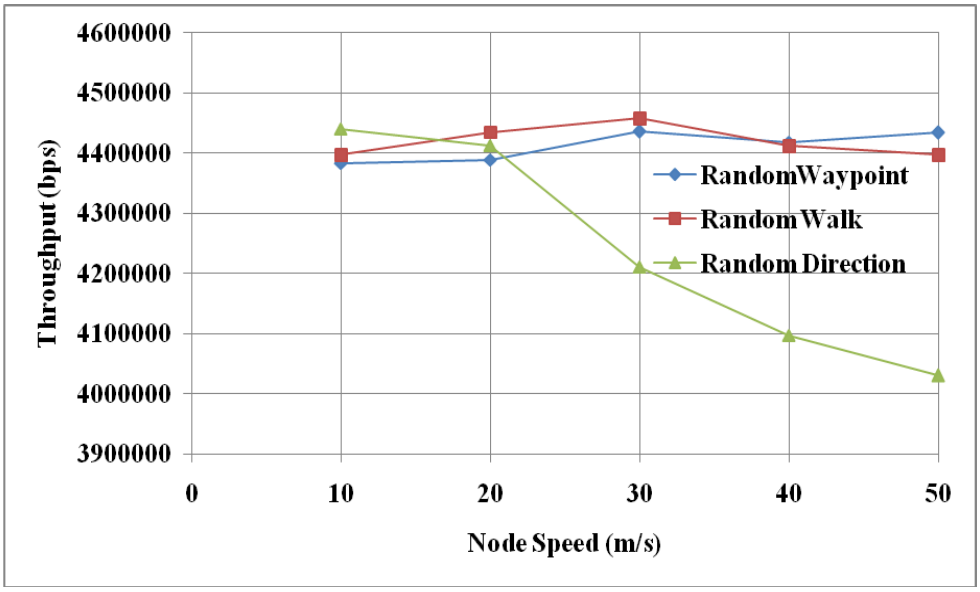

Figure 2. Throughput of OLSR using three mobility models over varying speed

The delay incurred by OLSR protocol using the three mobility models under consideration is shown in figure 3. With reference to end-to-end delay, the OLSR protocol using random waypoint mobility model exhibits least delay and it is consistent with increase in speed. In the case of random walk mobility model, delay is greater than random waypoint mobility model, but it is far better than random direction mobility model, which exhibits high end-to-end delay as the node speed increases.

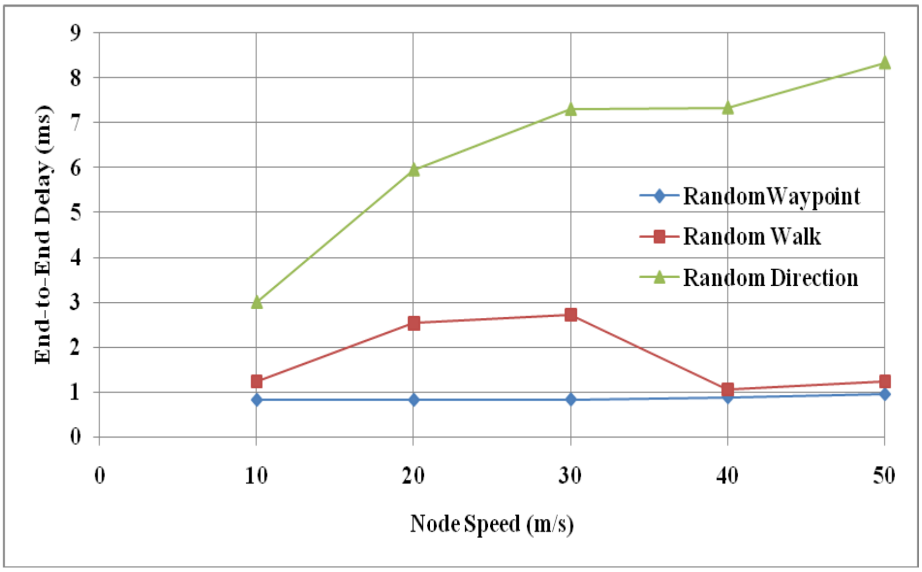

Figure 3. End-to-end delay in OLSR using three mobility models over varying speed

Figure 4 depicts the packet delivery ratio of OLSR protocol under the three mobility models. As is evident from the figure, random direction mobility model provides better packet delivery ratio than the other two mobility models, but at the cost of low throughput and high end-to-end delay. Among the other two mobility models, random walk provides better packet delivery ratio than random waypoint. The performance of random waypoint mobility model with reference to packet delivery ratio improves with increase in node speed, whereas random walk exhibits inconsistent packet delivery ratio with varying speed.

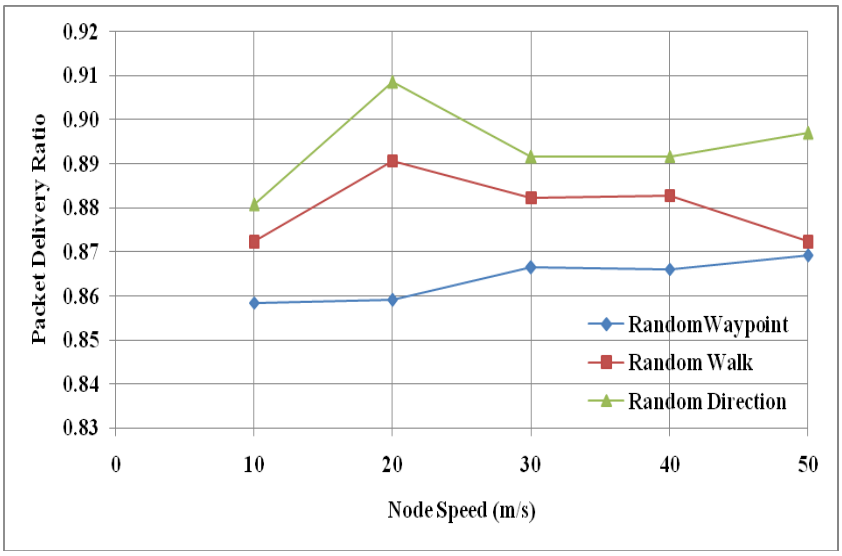

Figure 4. Packet Delivery Ratio in OLSR using three mobility models over varying speed

4.2.2. Performance of OLSR using the three mobility models over the simulation time

The results obtained for node speed 50m/s over the entire period of simulation time with respect to throughput, end-to-end delay and packet delivery ratio is depicted in figures 5, 6 and 7 respectively. As is evident from figure 5, random waypoint mobility model and random walk mobility model are comparatively similar with reference to throughput. But the throughput using random waypoint mobility model is consistent, while that of random walk shows gradual decline over time. End-to-end delay, as shown in figure 6, is lowest in the case of random waypoint mobility model and highest when random direction mobility model is used. Random walk is better than random direction with respect to end-to-end delay and with the passage of time decrease in end-to-end delay is observed. From the results of packet delivery ratio shown in figure 7, random direction seems to outperform the other two mobility models under consideration, but it exhibits low throughput and high end-to-end delay. Random walk mobility model provides better Packet Delivery Ratio than random waypoint mobility model.

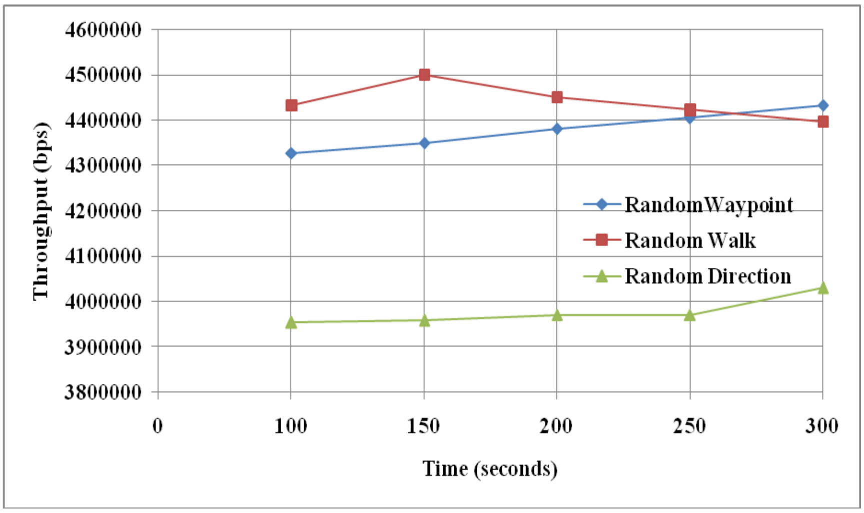

Figure 5. Throughput of OLSR using three mobility models over simulation time

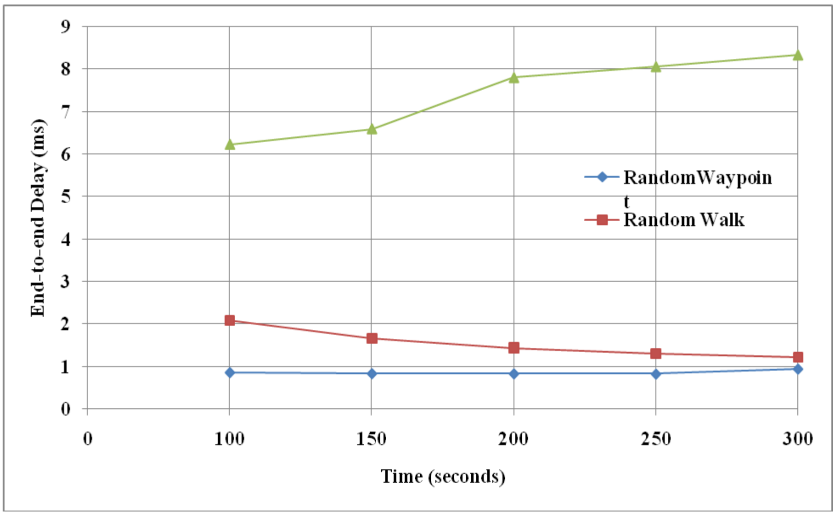

Figure 6. End-to-end Delay in OLSR using three mobility models over simulation time

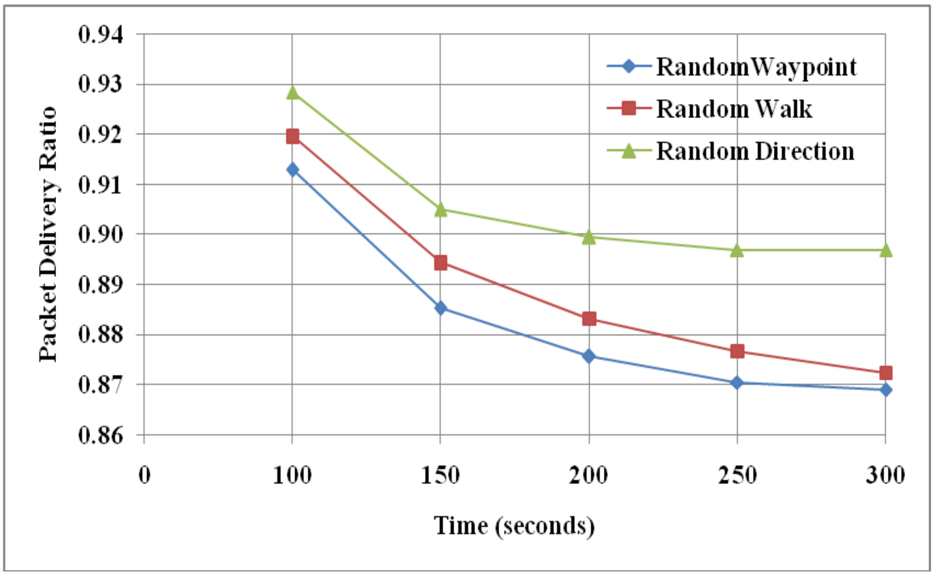

Figure 7. Packet Delivery Ratio in OLSR using three mobility models over simulation time

5. Conclusion

The impact of the various random mobility models, viz., random waypoint, random walk and random direction, on OLSR protocol with respect to throughput, end-to-end delay and packet delivery ratio has been examined. From the simulation results, it is clear that each of the mobility models outperforms the other two with respect to any one of the parameters throughput, end-to-end delay and packet delivery ratio. Considering the three parameters together, the performance of random direction mobility model does not seem to be better than the other two mobility models. It provides better packet delivery, but at the cost of lower throughput and higher end-to-end delay. As far as random walk and random waypoint is considered, OLSR with random waypoint provides good throughput and low end-to-end delay. But with respect to packet delivery ratio, random walk outperforms random waypoint mobility model.

It is evident from the results that the performance of OLSR under various metrics varies from one mobility model to another. There is significant impact of the mobility model on the routing protocol. In the future, random waypoint can be compared with group mobility models to see its effect on the routing protocol.

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