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Mobility Models vs. Routing Protocols in MANETs: A Review

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Abstract - There are several research works that have studied the impact of mobility models on the performance of routing protocols in MANETs. This paper presents a review of such works done in the last several years. The routing protocols commonly used are DSDV, AODV and DSR. The commonly used mobility models are Random Way Point (RWP), Gauss Markov (GM), Manhattan Grid (MG) and Reference Point Group Mobility (RPGM). Typical performance metrics used are Packet Delivery Ratio (PDR), end to end delay and throughput. Almost all research works have used NS-2 as a simulation tool. The survey may serve as a guideline for choosing a routing protocol for a given mobility model and MANET parameters.

Keywords - MANETs, Routing Protocols, Random Way Point, Gauss Markov, Manhattan Grid, Reference Point Group Mobility Model.

I. INTRODUCTION

A Mobile Ad hoc Network (MANET) consists of many mobile nodes which communicate with each other in absence of any fixed infrastructure and centralized administration. Each mobile node acts as a receiver and a router. Each node has processing capability and limited battery power. MANET is used in several applications some of which are: event meetings, battlefield communication between moving vehicles and soldiers, emergency rescue operations during natural calamities, conferences, etc.

The performance of the network is affected by the battery power, transmission range, and the data traffic model, the buffer space for the message storage, the computing power and most importantly the mobility model used. It is essential that the mobility model selected for performance evaluation truly reflects the movement of nodes in the MANET. A given protocol may perform well if the mobility of the node in a given scenario is correctly modeled. In the absence of realistic mobility of the nodes the results are not true representative of the performance of the network. For example, in the military platoons and emergency relief services the mobile nodes operating in battlefield/ disaster areas will be better represented by a group mobility model rather than an entity mobility model.

In this paper, we review several research work which have experimented the impact of mobility models on the performance of the routing protocols. Before moving on to the literature review, we give a brief description of the routing protocols and some entity and group mobility models.

1.1 MANET ROUTING PROTOCOLS

There are many routing protocols which describe the path to transmit the data from source to destination. Here, we introduce one protocol each from the proactive, reactive and hybrid category.

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OLSR (Optimized Link State Routing Protocol)

This protocol is driven by a table and link state. As the protocol maintains the table and link information in advance it is a proactive protocol. There are three mechanisms in OLSR applied for routing: path selection using shortest path first algorithm [1], control packet using multi point relay (MPR) and Hello message for neighbor sensing. Each node selects MPR resulting in accessibility of all of its two hops neighbors. The Hello and topology control (TC) messages are used to discover and broadcast link information to all the nodes in MANET. This topology information is used by individual nodes, by using shortest hop forwarding paths [1], to compute next hop destinations.

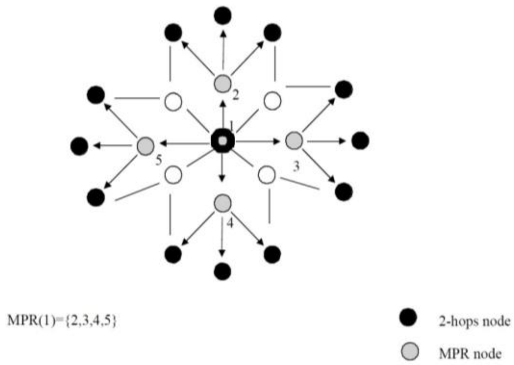

Figure 1: OLSR Routing Protocol [2]

DSR (Dynamic Source Routing Protocol)

DSR is a reactive protocol for MANETS therefore not table driven. DSR has two phases: Route Discovery and Route Maintenance. It is based on source routing. All routing information is maintained and updated at all the nodes of the MANET. If the message reaches its destination a route reply is generated which has inserted into it the route request initially contained in the route record.

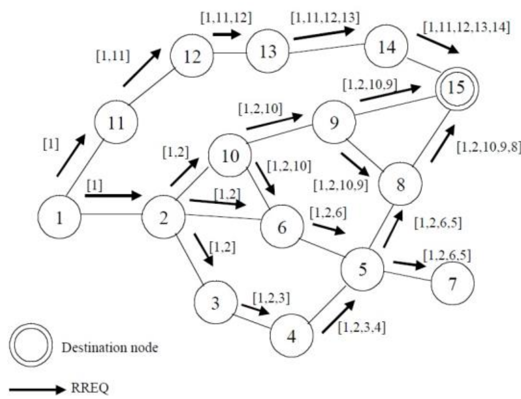

Figure 2: DSR Routing Protocol [2]

ZRP (Zone Routing Protocol)

ZRP provides an optimal balance between purely reactive and proactive protocols. At the intra cluster level it applies between nodes, and at the inter cluster level applies between clusters. Two sub protocols are combined to form ZRP. Inside the routing zones the Intra zone Routing Protocol (IARP) [3] is used. Between routing zones, Inter-zone Routing Protocol (IERP) is used. A node uses IARP to communicate with the other nodes of its zone. A node communicates with the nodes of the other zones using IERP. Therefore, IARP functions as a Proactive Routing Protocol while IERP functions as a Reactive Routing Protocol. IERP initiates route discovery process when needed or on demand thereby slowing down the route finding process. Border cast Resolution Protocol (BRP) [1, 4] minimizes the delay in route finding by IERP.

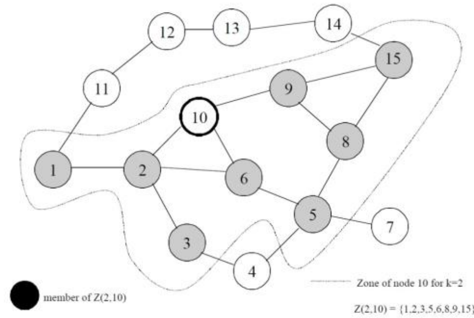

Figure 3: ZRP Routing Protocol [2]

1.2 MOBILITY MODELS IN MANET

The nodes of a MANET are mobile. The nodes keep moving with time. Therefore, with some velocity and acceleration the position of a node changes with time. Model that accurately mimics the mobility of the node is therefore highly desirable. Only then the performance of a protocol may be correctly evaluated. Therefore, the accurate representation of the mobility by the models plays an important role in the performance evaluation of the routing protocols. The endeavor should be to find a model which truly represents the movement of the nodes. A model which is not a true representative of the movement of the nodes will lead to wrong results from the analysis using a simulator.

There are two types of mobility models: traces and synthetic models [5]. The patterns observed in real life come under the traces mobility models. The information provided by the traces is very accurate especially if the number of participants and the observation period is large. If the traces have not yet been created for the new environments, it is very hard to model the mobility. In such cases the synthetic mobility models are used. The synthetic models are an attempt to represent realistically the behavior of the mobile nodes without the use of traces. There are two types of Synthetic Models: Entity Mobility Models and Group Mobility Models.

1.2.1 Entity Mobility Models

The characteristic of Entity Mobility Models is that the nodes move independently of the other nodes in the MANET. The commonly used entity mobility models are: Street Section MM, Probabilistic version of Random Waypoint MM, Gauss-Markov MM, Boundless Simulation Area MM, Random Direction MM, Random Waypoint MM and Random Walk MM. Presented below are various entity mobility models that have been used in the performance evaluation of routing protocols.

Random Waypoint

In Random Waypoint Model the nodes have a pause time before the changes in direction and speed. The pause time is the time a node remains stationary in a position and starts transmission. At the end of the pause time, the node chooses a speed from the range of maximum and minimum speed and selects a new location within the specified simulation area [4]. The mobile nodes, in the defined area, choose a new location by moving at a selected speed as shown in Figure 4. The process described above is repeated with a short pause occurring between repetitions.

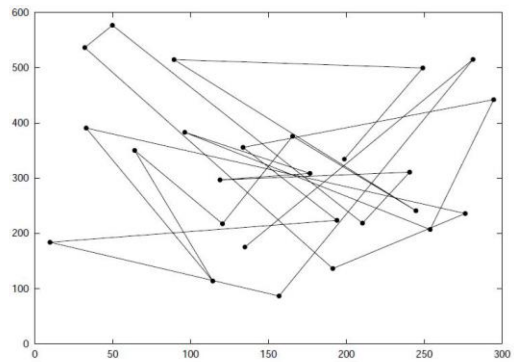

Figure 4. Travelling Pattern of an MN using the Random Waypoint Mobility Model [7]

Manhattan Grid

The Manhattan Grid Model [7] has a matrix form with defined row and column values. The node is restricted to move on the grid points only as shown in Figure 3. The paths of movements are also predefined. The number of block in the grid and the path between them are defined by the –x and –y parameters. For example, "\-x 3 –y 2" generates the paths as shown in Figure 5. The Manhattan Grid supports two more parameters. The first parameter is for deciding or changing the minimum speed of the mobile node. By the second parameter, the maximum pause time period and the pause probability can be set.

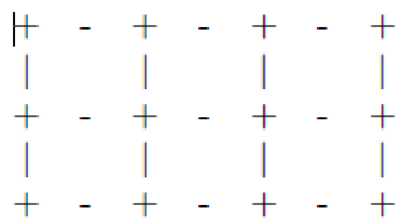

Figure5. Manhattan Grid Mobile Node Travelling Pattern [7]

City Mobility Model

In the City Mobility Model, the streets of a city define the simulation area. This simulated city area represents the section of a city where the mobile node traces its path, i.e., the movement of the mobile nodes is confined within the simulated area of the section of a city. The speed of a node is dependent upon the type of street. The city section mobility pattern is shown in Figure 6. [8] [9].

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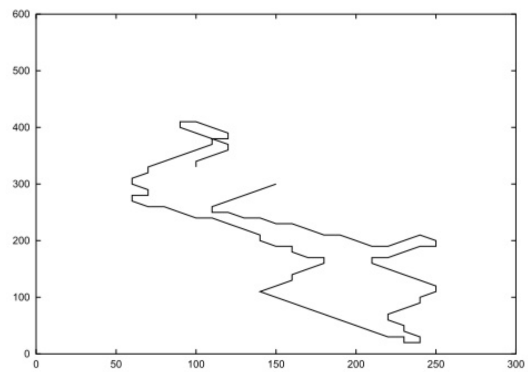

Figure 6. Travelling Pattern of an MN using City Section Model [16]

Gauss Markov Model

The Gauss Markov Model of mobility is so designed that it adapts to varying levels of randomness via a tuning parameter. The speed and direction at the nth level is calculated based on a random parameter and the speed and direction at the n-1th level as shown in the expression below.

$$V_n = \beta V_{n-1} + (1-\beta)\Omega + \sqrt{(1-\beta)^2}\, x_{n-1}$$

x_{n-1} is a random variable from the Gaussian distribution. β is a tuning parameter for randomness variance and Ω is a constant that represents the mean value of speed and direction.

1.2.2 Group Mobility Models

In Group Mobility Models the nodes of the network are assumed to form groups (of nodes), and the whole group moves, i.e., all the nodes in the group move together. The various types of Group Mobility Models are described next.

Reference Point Group Mobility Model (RPGM)

The RPGM model shows the group of mobile nodes that moves as an individual. It is also based upon the random motion of nodes. The logical center of the group defines the motion of the group. For the calculation of the group motion vector, the logical center is required. The speed and the direction of the group movement are defined by the group center.

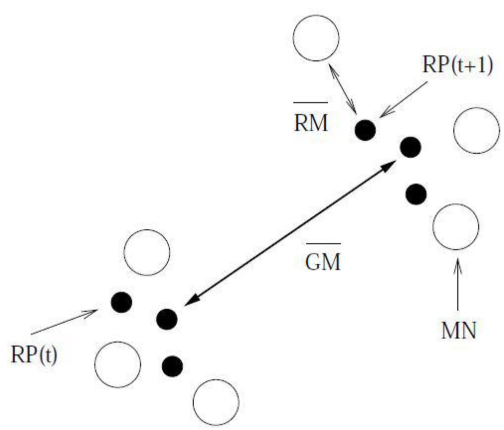

Figure 7. Movements of three MNs using RPGM Model [9]

The reference points for random movements of nodes are defined within the group. When a point moves from location t to t+1 the location of the node is reported to the group's logical center. RP (t+1) is calculated each time when reference points are updated and added to the random vector as shown in Figure 7.

Nomadic Mobility Model

As observed in earlier times the nomadic societies tend to move from one place to another. This is the basis of nomadic mobility model. The nodes collectively move from one point to another in a group. An individual node follows entity mobile model which specifies the individual movement of the node with respect to its reference point. This is shown in Figure 8. The group moves to a new area when the point of references changes. The group starts wandering in the new area.

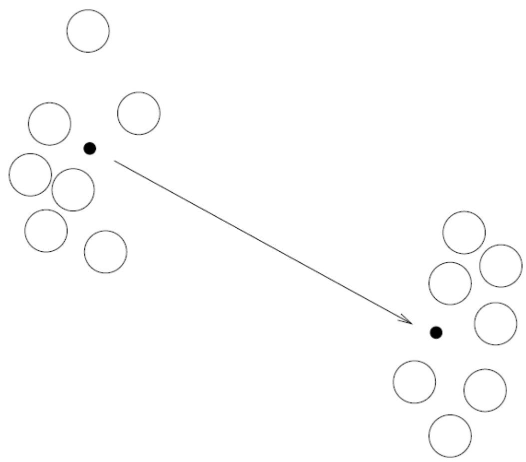

Figure 8. Movements of seven nodes in Nomadic Mobility Model [9]

Pursue Mobility Model

A particular target is tracked by the mobile nodes in Pursue Mobility Model. For each mobile node, the new position is calculated by using the following expression:

New Position = Old Position + Acceleration (Target – Old Position) + Random Vector

The acceleration specifies the rate of change of velocity by which the mobile nodes are pursuing the target while the random vector specifies the offset for each mobile node. To maintain tracking, the randomness of a mobile node is limited as shown in Figure 9.

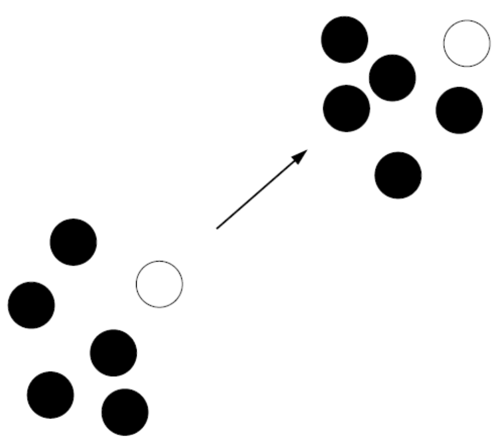

Figure 9. Movement of six MNs using the Pursue Mobility Model [9]

Column Mobility Model

In this model, the mobile nodes move around a given column. The column moves in a forward direction. This is similar to a group of students walking to their classroom in a single line. The model is particularly useful for searching. The Column Mobility Model is shown in Figure 10.

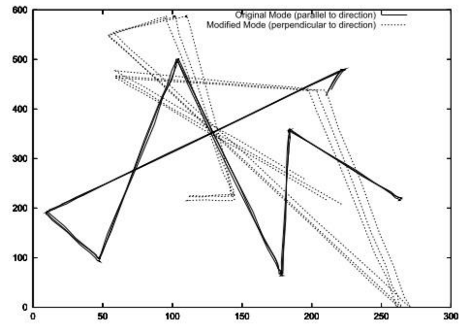

Figure 10. Travelling Pattern of MNs using the Column Mobility Model [9]

II. LITERATURE REVIEW

There have been several works in the recent past on the performance evaluation of various routing protocols. However, the majority of the works have adopted the Random Mobility Models [10-12]. The Random Mobility Model is not based on the scenarios encountered in real life. For this reason, despite the advantages of using MANETs, these have not been used extensively. In [13] the authors compare various proactive, reactive and hybrid routing protocols. Using the Random Waypoint Mobility model the authors compare the performance of AODV, OLSR and ZRP protocols using Qualnet 4.5. Ashish et al. [14] have done performance evaluation of Dynamic Source Routing (DSR), Fisheye State Routing (FSR) and Optimized Link State Routing (OLSR) in variable pause time using Qualnet simulator. The protocols were compared based on the parameters: Throughput, Average end to end delay, Average Jitter and the Packet delivery ratio. Sunil et al. [15] used NS-2 and 700x700m^2 routing area to have the clear impact of the mobility on routing performance. They analyzed AODV, TORA, OLSR, DSDV, DSR routing protocols of MANETs. The results showed the impact the realistic mobility models (RPGM, CMM, and RWP) had on the performance of the selected routing protocols. Gupta et al. [16] stressed upon the need to have a realistic mobility model. They compared AODV and DSDV protocols under Freeway Mobility Model, the Reference Point Group Mobility Model and the Random Waypoint Mobility Model. The throughput of the protocols was compared under the mobility models specified above. The following paragraphs give the summary of the research works experimenting the mobility model vs. performance of the routing protocols of MANET.

Bahuguna and Mandoria [17] compared the performance of routing protocols under different mobility models. They considered DSDV, DSR and AODV protocols. And, considered the Random Waypoint, Gauss Markov and Manhattan mobility models. Bonn Motion-2.0 was used to generate the scenario files for the three mobility models. These scenario files are used in NS-2 version 2.34 to gauge the performance of routing protocols. The following parameters were used for the simulation:

Parameter	Value
Simulation Time	1500 s
No. of simulated Nodes	20,30,40
Area size of topography x(m) X Y(m)	2000 x 2000 m
Traffic type	FTP
Packet size	40-1500 Bytes
Simulated Routing Protocols	AODV, DSDV and DSR
MAC Layer Protocol	IEEE 802.11
TCP source	Node (1)
TCP destination	Node (20),(30),(40)

The protocols were compared based on the throughput, average delay and packet delivery ratio. The results showed that the three performance metrics vary for different mobility models. This clearly established that the choice of mobility model has an impact upon the performance of the routing protocols.

Almomani et.al. [18] studied the effect of Random Waypoint Mobility Model and Boundless Mobility Model on the performance of Greedy Routing Protocol, Greedy Perimeter Stateless Routing Protocol, Directional Greedy Routing Protocol and Mobility Based Adaptive Greedy Forwarding. The performance evaluation metrics considered were Packet Delivery Ratio (PDR), End-To-End Delay(E2E-D) and Routing Overhead. In their simulation with varying number of nodes they found that the performance of the routing protocols using Boundless Mobility Model (BDM) is much better than the performance of Random Waypoint Mobility Model (RWP). In simulations with small number of nodes the RWP model negatively impacted the performance of the protocols. With the increased number of nodes, the performance of RWP and BDM mobility models was found to be similar. BDM model exhibited higher performance compared to RWP mobility model in both dense and sparse networks. When the speed of the nodes was increased from 5 to 10, 20, 30 and 40 m/s the BDM performed better than RWP. Overall, the results with two different scenarios showed that BDM model outperformed the RWP model. The BDM model produced the highest delivery ratio, lowest end to end delay and better control overhead compared to RWP. The authors suggested further study of the BDM model to see whether it is suitable for real life implementations.

Manzoor and Sharma [19] presented a survey of the research considering mobility models versus routing protocols. Majority of the research work studied in this paper strengthen the thinking that the mobility has a marked effect on the performance of the routing protocols. In this survey the research paper by Bhavyesh Divecha et al. is cited. They observed the impact of mobility models on the MANET routing protocols. The performance of the routing protocols varied widely across the mobility models. They suggested that only the most appropriate mobility model for the given scenario should be applied for the better performance of the MANET. They further pointed out that DSR gives good performance for highly mobile nodes. This is because DSR is fast in discovering new routes to destination. Another work by Mona Ghassemian et al. is cited in the survey. The authors evaluated different routing protocols with respect to different mobility metrics. They concluded that if the mobility model that precisely mimics the node mobility is used then the results are reliable. The work by R. Manoharan et al. is also cited. This work analyzed the effect of the mobility models on multicast routing protocols. They also concluded that the mobility patterns also have an impact upon the performance of the routing protocols. They did not find a clear winner among the protocols as the performance is affected by the mobility model used. Another research work by Sabina Barakovic et al. concluded that if the nodes had low mobility then DSDV, AODV and DSR had similar performance. Whereas with greater mobility DSR outperformed the other two protocols. The same conclusion was drawn by the researchers previously mentioned. In the end of the survey the authors conclude that the protocols can perform efficiently if the topology/ mobility information is available accurately. The researchers can use the most appropriate model for the situation at hand thereby increasing the performance of the network.

Sharma et al. [20] studied the factors that impact the performance of a MANET. They found that the mobility model is a factor that affected the performance of a network in a significant way. To illustrate how the choice of the mobility model affected the performance of MANET the authors ran simulation with different mobility models and routing protocols, and considered the performance metrics such as packet delivery ratio, dropped packets, normalized routing load and end-to-end delay. The routing protocols considered were OLSR (Optimized Link State Routing Protocol) from Proactive category, DSR (Dynamic source routing protocol) from the reactive category and ZRP (Zone Routing Protocol) from hybrid category. The mobility models considered were RWP (Random Waypoint), Nomadic, GM (Gauss Markov) and RPGM (Reference Point Group Mobility). The authors found, through simulation, that OLSR with nomadic mobility gave better performance in small networks. The observations showed that OLSR with RPGM model had lowest end to end delay. However, there was exponential increase in delay as the number of nodes increased. The simulation results of DSR with RWP gave higher packet delivery ratio compared to Gauss Markov model. RPGM gave higher packet delivery ratio than the nomadic model. For ZRP with RPGM model the packet delivery ratio improved with the size of the network. The RPGM was the most recommended model with ZRP. The authors concluded that because of the random mobility of the nodes of a network the routing became a complex issue. The results from the simulation suggested that a single protocol could not achieve optimal performance for all mobility models. It was suggested that a protocol suitable to the network environment should be chosen. Similarly, a mobility model best suited to the protocol and the network environment should be chosen.

Wahed et al. [21] have tried to analyse the behaviour of proactive (AODV) and reactive (DSDV and OLSR) routing protocols with different node movement speeds with respect to RPGM and Manhattan Grid (MG) mobility models using the NS-2 simulator. The performance metrics used were average end to end delay, average throughput and packet delivery ratio. BonnMotion 2.0 was used as a tool to generate the mobility scenarios for RPGM and MG with different node speeds of 10 to 50 m/s. For the performance analysis in RPGM mobility model a simulation for 50 nodes (5 groups of 10 nodes each) was conducted. It was observed that AODV is better than DSDV and OLSR in terms of packet delivery ratio. In the performance analysis of the MG mobility model it was observed that the packet delivery ratio for the AODV protocol is higher than the DSDV and OLSR protocols. The authors concluded that the relative ranking of routing protocols varied depending on the mobility model used. Their simulation results suggested that that the AODV protocol performed significantly better than the OLSR and DSDV protocols. Only the end to end delay metric of the OLSR and DSDV protocols was better than the AODV protocols for the RPGM mobility model.

Bharadwaj and Singh [22] state that the Important design issue in MANETs is the efficient and effective use of routing protocols with different types of mobility models to achieve the optimum value of performance parameters. They considered AODV, DSR, DSDV and AOMDV routing protocols with Gauss Markov, Manhattan Grid and Random Walk mobility models. The comparison was done based on the Average Delay, The Packet Delivery Ratio and Normalized Routing Load. The authors found that in small networks the packet delivery ratio is nearly 90% for all routing protocols in all three of the mobility models. When the number of nodes was increased there was a marked decrease in the packet delivery ratio, most significantly for AODV. DSDV, DSR and AOMDV achieve good packet delivery ratio in large networks for Random Walk and Gauss Markov models, however, for Manhattan Grid model the PDR is degraded. In Gauss Markov and Random Walk models AODV did not do well for any network size but all other protocols performed well. For average delay, AODV, DSR and DSDV had comparatively lower delays whereas AODV had higher delay. DSDV had significantly better Normalized Routing Load in medium and large networks compared to the other protocols for the Gauss Markov, Manhattan Grid and Random Walk models. The authors concluded that DSDV/AODV had better performance for small networks under the Gauss Markov model. Large networks performed better with DSDV protocol under the Manhattan Grid model. MANET protocols generally provided optimum performance for small networks of around fifty nodes in an area of 700 X 700 m^2. The performance of Random Walk model provided initial view to gauge the quality of the routing protocols.

Shukla et al. [23] considered a number of mobility models with MANET routing protocols to offer research a more experienced choice of mobility model for the specified routing protocols. A relative analysis of some of the existing mobility models is presented in a variety of simulation settings. The parameters like throughput, end to end delay and packet delivery ratio are considered. The protocols used for simulation are: Destination Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR) and Ad-Hoc On Demand Distance Vector (AODV). The mobility models considered in the simulative study are: City Section Mobility Model and Manhattan Mobility Model. Network Simulator NS-2 version 2.35 is used for the simulative study. The authors conclude that the performance of a mobility model was greatly influenced by the network protocol. The City Section Model and the Manhattan Model yield a relatively larger number of hops for minimum-hop routes and a relatively smaller lifetime for stable routes. The Manhattan mobility model exhibited improved performance as compared to the City Section mobility model.

Kumari et al. [24] state that the mobility of nodes affects the performance of the Mobile Ad-hoc Networks. In case of table driven protocols, the mobility of nodes means greater traffic control overhead for maintaining routes, while in the case of on demand protocols the mobility means overhead in maintaining routes. The authors discuss the impact of mobility, and point out its importance in real scenarios for pedestrian and vehicular speed using DSDV and DSR protocols. The authors have considered the source node movement, the destination node movement and all nodes movement, using different mobility period, and tried to judge the Quality of Service parameter for such scenario. The simulation parameters used are:

Parameter	Value
Simulator	NS-2
Protocols Used	DSDV & DSR
Simulation Time	20, 50, 100. 500msec
Simulation Area	800m x 800m
Transmission Range	200-300m
Node Movement Model	Random Waypoint
Bandwidth Used	3 Mbps
Traffic Type	BER
Data Payload	Bytes/packet

The authors conclude that for source node movement DSDV gave far better performance than the DSR routing protocol. For destination node movement, DSR gave better throughput than DSDV. And, for all nodes movement, DSR is more efficient than DSDV. With increase in simulation time, with all nodes movement, the performance of DSDV had marked degradation.

Zuahiri et al. [25] state that the performance of a routing protocol is affected by the selection of the mobility model. A routing protocol may perform inferiorly for some mobility model while the same protocol may be effective for some other mobility model. Hence, analysis of a routing protocol is usually based on inadequate information leading to the inaccurate conclusion. The authors have selected three mobility models. Each model is distinctive in terms of the movement of the node. The protocols analyzed was the Ad Hoc On Demand Distance Vector (AODV) and the mobility models considered were Gauss Markov, Reference Point Group Mobility (RPGM) and Manhattan. Extensive simulation runs were done and results were compared between each mobility model. NS-2 was used for simulation. Maximum speed of the nodes was set to 0 m/s, 10 m/s and 20m/s. The number of source and destination pair was set to 6 that were selected from a group of 50 nodes. The selected source node transmitted data packets at a randomly chosen start time and finished at 250 seconds of simulation time. In each experiment traffic was set to be transmitted at a rate of 4 packets / sec. Each packet was fixed to 512 bytes. The simulation results showed that at higher speed, routes became more unstable and potentially broke, resulting in unidirectional links. The Gauss Markov model produced more unidirectional links compared with RPGM and Manhattan models. The results clearly showed that the choice of mobility model had an impact on the performance of the routing protocol.

Pal et al. [26] have studied the effect of node speed on Throughput, Packet Delivery Fraction (PDF) and Normalized Routing Load (NRL) under the Random Waypoint Model (RWP), the Reference Point Group Mobility Model (RPGM) and the Manhattan Grid Mobility Model (MGM). The authors used Bonn-Motion tool to generate the scenarios. They had taken 30 mobile nodes in an area of 1000m X 1000m for a period of 1000 seconds. It was observed that with the Random Waypoint Model, mobile nodes had a higher probability of being near the center of the simulation area. Due to this the initial 3600 s were omitted to cope with the boundary effects of the node movement simulation. The authors used NS-2 for simulation. The source and destination were chosen randomly. The minimum speed Vmin was set to a positive value while the maximum speed of a node was set between 10 m/sec and 50 m/sec. The authors had selected constant bit rate (CBR), exponential traffic and Pareto Traffic model as traffic source in simulation. Under AODV routing protocol the PDF for all traffic sources was quite high in RWP mobility model. The DSR protocol was not suitable for Pareto and Exponential traffic. The NRL was found to be very high for both AODV and DSR under the RWP model. The throughput for AODV and DSR was almost the same. Under the RPGM mobility model the majority of the communications took place between the nodes of the same group. Communications outside the group were rare. The PDF for all traffic sources under RPGM model was almost comparable, the NRL was higher for Exponential and Pareto traffic models. The throughput of AODV under RPGM model decreased with the increase in the node speed for CBR traffic pattern. The PDF under the MHG model was higher for all traffic sources as the link breakage was less in MHG compared to RWP. NRL was higher for Exponential and Pareto traffic sources. The throughput for AODV under MHG model decreased with the increasing speeds of the mobile nodes. The authors concluded that the PDF for AODV routing remained the same across all traffic patterns. The NRL decreased in DSR due to the high number of control packets for route establishment in the network. The throughput decreased with increasing node speed for all traffic models for DSR and AODV routing.

Singh and Dutta [27] have tried to identify the system dynamics using the path length between the source node and the destination node over a fixed area. They have used Gauss Markov mobility model, Random Way Point mobility model, Reference Point Group mobility model and Manhattan Grid mobility model under Destination Sequenced Distance Vector routing (DSDV), Ad hoc On demand Distance Vector routing (AODV) and Dynamic Source Routing (DSR) protocols. The path length between two particular nodes is chosen as a metric for all mobility models and all routing protocols. The authors used Bonn-Motion for generating mobility scenarios. Four mobility patterns were generated with 70 nodes moving in an area of 1200m X 1200m for a period of 1000 seconds after ignoring the first 3600 seconds of node movement for each mobility pattern. The first 3600 seconds were skipped to mitigate the boundary effects. The minimum speed V_{min} was set to 0.5 m/s and the maximum speed V_{max} was set to 10 m/s. The cbrgen tool of NS-2 was used to generate Constant Bit Rate (CBR) traffic. The NS-2 tool was used for simulation. Awk scripts were applied to traces to get the path length values. The path lengths were analyzed for the four mobility models discussed earlier, and AODV, DSDV and DSR protocols were used. The results for the Gauss Markov model showed that the path length was lower for DSDV compared to AODV and DSR routing. The DSDV is a table driven protocol; the routes are periodically updated to maintain the shortest path, hence the shortest path length in DSDV. Under Manhattan Grid Mobility Model, the average path length was found to be higher for AODV as compared to DSDV and DSR as was the case for Gauss Markov mobility model. However, the differences in the path lengths for the protocols were not prominent. The reason is that the Manhattan Grid mobility model is restrictive and forces lane movement, therefore, the overhead of the link break is comparatively low. Under the Reference Point Group Mobility model the average path length was found to be lower for DSDV as compared to DSR and AODV. The path length was almost constant for DSDV. The path length was also constant for AODV but with a higher value. For DSR, however, the path length showed a strong fluctuation. Under Random Way Point mobility model, the path length was lower for DSDV as compared to DSR and AODV. The authors concluded that DSDV achieved the shortest path length across all mobility models considered.

Umang et al. [28] have stressed the importance of mobility management in mobile ad hoc networks. They have reviewed and classified the mobility models taking real life applications into account. The mobility of nodes is considered as an important issue due to ad hoc characteristics such as dynamic network topology, multi hop nature, limited bandwidth, security, etc. This necessitates the need for effective mobility management scheme that provides seamless mobility in ad hoc networks. Seamless mobility paves the way for effective communication and easy access among the nodes of the network. In ad hoc networks, the mobility models depict the movement patterns of mobile users and the changes in their speed, direction, acceleration and location with time. The authors suggest mobility models to be used in real life applications. Such as, entity based mobility model is suitable for shopping mall, Delhi metro, railways, campus life, airport and aircraft monitoring whereas group based mobility models are suitable for military, conference, agriculture, thief tracking system and disaster relief scenarios.

Timcenko et al. [29] considered performance of MANET routing protocols with respect to entity and group mobility models. The three widely used routing protocols, DSDV, AODV and DSR were considered. The mobility models used were: RPGM, RWP, GM and MG. NS2 version 2.32 was used for simulation. Comparisons were performed based on end to end delay, packet delivery fraction (PDF) and routing protocol overhead (RPO) metrics. The node speed was varied in the 5 – 10 m/s range. The PDF was superior in case of RPGM model compared to entity models. In 20 nodes network the reactive protocols (AODV and DSR) performed better than DSDV. For 100 nodes the performance of RPGM was not good. More nodes on the path from source to destination contributed to the increased packet loss. RWP model performed better for high density networks. The worst results were obtained for MG model primarily because due to the severe restriction on the node movement irrespective of the node density. Average end to end delay with nodes speed in the range 1.5 – 25 m/s was superior for DSDV. Irrespective of the applied model, DSR suffered from high delays when the speed of the nodes was increased. For lower speed values, AODV suffered from higher delays than DSR. For the network size of 100 nodes the RPGM had improved delay performance. This was because increasing the number of mobile nodes reduces the sparse network effect. In the 20 nodes network AODV performed better than DSDV at lower speeds due to its on demand nature. MG model experienced considerably higher average delays with the increase of network size. This happened because MG model has high temporal and spatial dependence. The Routing Protocol Overhead (RPO) with node speeds in the range of 1.5 – 25 m/s was lowest for DSR for all mobility models. AODV performed better than DSDV at lowest speed level since it is an on demand protocol. For higher speeds AODV had to generate more routing packets since there were more route changes resulting in higher RPO. RPGM and RWP had similar RPO performance. With GM model, AODV suffered from highest RPO when speed reached 5 m/s as the topology changes were very frequent. Authors concluded that the relative ranking of routing protocol varied depending upon the mobility model. The ranking had dependence on node speed as well. This was due to the link failures as a result of mobility. Each protocols reacted differently during link failures. The proactive protocol DSDV gave the most stable performance with all mobility models. The protocol performed the best with entity models that have lower level of randomness, particularly MG and GM. AODV performed best with RPGM. But with increased speed AODV experienced the highest RPO. DSR showed the lowest routing protocol overhead. DSR performed best with RWP model.

Murthy and Das [30] did performance evaluation of DSR and AODV protocols under the Random Way Point (RWP) and Reference Point Group Mobility Model (RPGM) mobility models. Performance metrics considered were Packet Delivery Ratio (PDR), Average Routing Overhead (ARH), Average End to End Delay (AEED) and throughput. The simulation was done for 900 seconds for a network area of 800 m X 500 m with 250 m transmission range. The first scenario compared the mobility models for 5, 10, 15, 20 and 25 nodes with fixed speed 15 m/s. The second scenario evaluated the mobility models with different node speeds of 5, 10, 15 and 20 m/s for a fixed number of 50 nodes. Random Way Point Model had the lowest routing overhead and was considered better for routing communication. RWP also performed better in delivering packets to the destination. The authors concluded that Random Way Point is the best model and it outperformed the Reference Point Group Mobility model for the scenarios considered in the study.

Mann and Mazhar [31] have studied MANET routing protocols vs mobility models. The protocols the authors have considered are: Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Dynamic MANET on demand (DYMO), Optimized Link State Routing (OLSR), and Destination Sequenced Distance Vector (DSDV). The mobility models considered are: Random Way Point (RWP), Reference Point Group Mobility (RPGM) and Column Mobility Model (CMM). The performance metric used are: Packet Delivery Ratio (PDR), Average Delay (D_{avg}) and Normalized Routing Load (NRL). Four terrain sizes 500 X 500 m^2, 700 X 700 m^2, 1000 X 1000 m^2 and 1200 X 1200 m^2 are considered. The number of nodes are selected as 25, 50, 75 and 100. Small networks are specified as consisting of 25 to 50 nodes with area 500 X 500 m^2 and 700 X 700 m^2. The medium size networks are specified as consisting of 75 nodes with area 1000 X 1000 m^2. And, the large networks are specified as consisting of 100 nodes with an area 1200 X 1200 m^2. In small networks the PDR was more than 90% for all routing protocols. A decrease in PDR was observed as the size of the network was increased. OLSR, DYMO and AODV achieved good PDR in large networks. In RPGM and CMM models, the increase in network area and the number of nodes had a significant impact on OLSR, DYMO and AODV performance. DSR gave good performance in small networks but gave low PDR in medium and large networks. For routing in large networks where RWP is suitable, AODV closely followed by DYMO is suitable. AODV, OLSR and DYMO perform better for group mobility applications. The AODV, DYMO and OLSR had comparatively lower delays. For large networks, however, the delay for OLSR is higher than DYMO. Under RWP model the reactive protocols had lower average delays compared to the proactive protocols. The exception to this was DSR for medium and large networks. All protocols had low NRL for small networks. The increase in NRL was observed with the increase in the network size. The authors concluded that the mobility model had significant impact on routing performance. The network performance degraded with the increase in network size and the number of nodes. However, the degree of degradation varied with protocols and mobility models combinations.

Barakovic et al. [32] considered the effect of mobility on DSDV, AODV and DSR protocols. Node mobility scenario is created for 50 nodes, topology boundary of 500 X 500 m^2 and simulation time of 100 seconds. In one set of scenario, the duration of pause time was varied. Values of pause time were taken as 0, 10, 20, 40 and 100 simulation seconds. The movement speed was 20 m/s. In the second scenario the value of pause time was kept unchanged while the speed was changed from 10 to 50 m/s. Packet Delivery Ratio (PDR), Average End to End Delay and Normalized Routing Load (NRL) were taken as the performance metrics. The results showed that AODV and DSR achieved high values of PDR. In low mobility and low load scenarios, all three protocols performed in a similar way. DSR outperformed AODV and DSDV with increased mobility and load. It is attributed to the aggressive use of caching and the lack of mechanism to expire stale routes. Authors have suggested as future work that the routing protocols should be examined with other metrics such as power consumption, fault tolerance, number of hops, jitter, etc. with respect to various mobility models.

Kumar and Rajesh [33] did performance evaluation of AODV, DSDV, DSR and TORA protocols with Random Waypoint, Random Walk and Random Direction mobility models. The packet delivery ratio and end to end delay were compared with respect to mobility speed, traffic and network size. The simulation results showed that in Random Waypoint the network became sparse and the traffic load became high. In such scenario the performance of DSDV and TORA decreased sharply. DSDV performance was closer to AODV under the network size metric. TORA performance under Random Waypoint model was not good. Hence, AODV was the best suited protocol under the Random Waypoint model. In Random Walk model AODV performed better than DSR, TORA and DSDV. Also, the AODV protocol performs better for the Random Direction model than DSDV, DSR and TORA.

Agrawal et al. [34] experimentally evaluated the packet delivery fraction and end to end delay with DSDV protocol using NS2 simulator. The performance of DSDV protocol was evaluated with Random Waypoint, Reference Point Group Mobility, Gauss Markov & Manhattan mobility model at varied network load and speed. The results of simulation suggested that DSDV and RPGM mobility model performed the best at increasing network load and speed of nodes. However, the average of all PDFs for different speeds was found to be decreasing with respect to network load. DSDV with Manhattan mobility showed the worst performance at all the network scenarios compared to the other mobility models. The results showed that the performance of the MANETs was largely dependent on the pattern of mobility. Experimental outputs suggested that DSDV with RPGM had best performance for PDF and end to end delay. Thus the selection of RPGM model is the better option keeping all other parameters constant. The experiments also suggested that parameters such as traffic patterns, node density and initial pattern of nodes also affected the performance and need to be investigated under differing scenarios.

It is quite evident from the above discussion that the realistic mobility models have a large impact on the performance evaluation of routing protocols in MANETs. The Mobility Models differ in their applicability in different scenarios. If the mobility of the nodes under a given scenario is modeled accurately the results of the protocols will be reliable. The extensive analysis of mobility models should be done to gauge their appropriateness to the given scenario.

III. SUMMARY & CONCLUSIONS

This survey provides an overview of the performance of mobility models and routing protocols combinations under different MANET parameters. We have started by introducing proactive, reactive and hybrid protocols. Various entity and group mobility models are then introduced. The research work of several authors are summarized next.

The conclusion to draw from this survey is that the choice of a mobility model does impact the performance of MANET. For same network simulation parameters and the same routing protocols, different mobility models perform differently thereby stressing the need for the most appropriate mobility model selection.

The survey also gives an idea about which protocol to use for the given mobility model & network parameters.

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