Influence of Mobility Models in Performance Evaluation of MANET Routing Protocols

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ABSTRACT
A Mobile Ad-Hoc Network (MANET) is a self-configuring network of mobile nodes connected by wireless links to form an arbitrary topology without the use of existing infrastructure. Battlefields, disaster relief activities, underdeveloped territories, classrooms are a few scenarios where MANET can be used. Ensuring effective routing is one of the major challenges in adhoc networks. To thoroughly and systematically study the Mobile Ad hoc Networks, it is important to study its routing protocol and evaluate its protocol performance. A very interesting aspect is understanding how users' mobility patterns impact on the performance of routing protocols. In this paper, we have studied the effects of two totally different mobility models on the performance of three popularly used routing protocols Dynamic Source Routing (DSR-Reactive Protocol) and Destination-Sequenced Distance-Vector (DSDV-Proactive Protocol) and AODV. The widely used mobility model Random Way Point has been compared with City Section mobility model by implementing in NS2. Several experiments have been carried out to study the relative strengths, weakness and applicability of protocols to these mobility models. Our results show that the protocol performance may vary drastically across mobility models and performance rankings of protocols may vary with the mobility models used.

Keywords-- MANET, DSR, DSDV, AODV, Mobility, Simulation

1.INTRODUCTION
Recently, the mobile ad hoc network (MANET) technology has received increasing attention from military, industry and academia owing to developments in radio communications and advancements in wireless networking. A MANET consists of a collection of wireless mobile nodes that are dynamically connected and can communicate with each other without the requirement for any pre-existing or centralized infrastructure. There is no static infrastructure such as base stations. Each node in the network also acts as a router, forwarding data packets for other nodes. Because a MANET can be deployed rapidly and operated with no single point of failure in the whole network, the MANET technology is expected to play a crucial role in the next-generation military networks [2]. One of the major features of a MANET is multi-hop packet transmission due to the limited coverage of the radio transceiver on each node, i.e., a packet usually travels multiple hops to reach the destination node. In addition, the network topology of a MANET changes dynamically due to node mobility. Since a multi-hop route depends on the underlying network topology, packet routing protocols for MANETs are required to deal with changes in the network topology. Thus a routing protocol in a MANET contains two tasks in general: updating network topology information and finding the optimal route to a destination node. Updating network topology information is required because nodes move and the network topology is constantly changing. The updating process consumes network resources, which is referred to as routing overhead induced by node mobility.

The performance of a MANET routing protocol, such as packet end-to-end delay, throughput, and routing overhead, is significantly influenced by node mobility. The node mobility is the most important factor that contributes to the challenge of scalable and efficient routing in MANETs, as it directly contributes to the route breakage. Some research has been carried out for evaluating the impact of different node mobility patterns on various MANET routing protocols, either analytically or through simulations [2, 3, 4, 6].

Mobility pattern, in many previous works was assumed to be Random Waypoint. In NS-2 simulator distribution, the implementation of this mobility model is as follows: at every instant, a node randomly chooses a destination and moves towards it with a velocity chosen uniformly randomly from [0, Vmax], where Vmax is the maximum allowable velocity for every mobile node [5]. Most of the simulations using the Random Waypoint model are based on this standard implementation.

In the future, MANETs are expected to be deployed in myriads of scenarios having complex node mobility and connectivity dynamics. For example, in a MANET on a battlefield, the movement of the soldiers will be influenced by the commander. In a city-wide MANET, the node movement is restricted by obstacles or maps. The node mobility characteristics are very application specific. Widely varying mobility characteristics are expected to have a significant impact on the performance of the routing protocols like DSR [9], DSDV [10] and AODV [11]. The Random Waypoint model is widely accepted mainly due to its simplicity of implementation and analysis. Random Waypoint is a well designed model but it is insufficient to capture the real life node movement. In many cases, the movement of a mobile node may be restricted along the street of a city. A geographic map may define these boundaries. The movement pattern of a mobile node may be influenced by and correlated with nodes in its neighborhood. Like, in some scenarios including battlefield communication and museum touring, certain specific 'leader' node in its neighborhood may influence the movement pattern of a mobile node. Another example is on a freeway to avoid collision; the speed of a vehicle cannot exceed the speed of the vehicle ahead of it. Such real life limitations are not considered in Random Waypoint model.

To show the impact of mobility I have compared Random Waypoint model with a real life scenario mobility model- city section model [5] for evaluating the routing protocols.

2.OVERVIEW OF MANET ROUTING PROTOCOLS
Many routing protocols for ad hoc networks have been proposed so far, each one offering some advantage over the previous

approach. These algorithms differ in the approach used for searching a new route and/or modifying a known route, when hosts move. The ad hoc routing protocols may be generally categorized as table-driven (pro-active) and source initiated on-demand driven (reactive). The simulation results reported in several papers[1] show that normally on demand routing protocols have higher packet delivery ratio and need less routing messages than table-driven routing protocols. In this work we have used three common routing protocols for performance analysis DSDV (pro-active) and DSR, AODV (reactive).

A. Destination-Sequenced Distance-Vector (DSDV)

Perkins and Bhagwat introduced Destination-Sequenced Distance-Vector (DSDV) [10], one of the earliest ad hoc routing protocols. As many distance-vector routing protocols, it relies on the Bellman-Ford algorithm. Every mobile node maintains a routing table which contains the possible destinations in the network together with their distance in hop counts. Each entry also stores a sequence number which is assigned by the destination. Sequence numbers are used in the identification of stale entries and the avoidance of loops. In order to maintain routing table consistency, routing updates are periodically forwarded throughout the network. Two types of updates can be employed; full dump and incremental. A full dump sends the entire routing table to the neighbors and can require multiple network protocol data units (NPDUs). Incremental updates are smaller (must fit in a single packet) and are used to transmit those entries from the routing table which have changed since the last full dump update. When a network is stable, incremental updates are forwarded and full dump are usually infrequent. On the other hand, full dumps will be more frequent in a fast moving network. In addition to the routing table information, each route update packet contains a distinct sequence number assigned by the transmitter. The route labeled with the most recent (highest number) sequence number is used. The shortest route is chosen if any two routes have the same sequence number.

B. Dynamic source routing (DSR)

Johnson et al. propose one of the most widely known routing algorithms, called Dynamic Source Routing[9] which is an ‘‘on-demand’ ’algorithm and it has route discovery and route maintenance phases. Route discovery contains both route request and route reply messages. In the route discovery phase, when a node wishes to send a message, it first broadcasts a route request packet to its neighbors. Every node within a broadcast range adds their node id to the route request packet and rebroadcasts. Eventually, one of the broadcast messages will reach either the destination or a node which has a recent route to the destination. Since each node maintains a route cache, it first checks its cache for a route that matches the requested destination. Maintaining a route cache in every node reduces the overhead generated by a route discovery phase. If a route is found in the route cache, the node will return a route reply message to the source node rather than forwarding the route request message further. The first packet that reaches the destination node will have a complete route. DSR assumes that the path obtained is the shortest since it takes into consideration the first packet to arrive at the destination node. A route reply packet is sent to the source which contains the complete route from the source to the destination. Thus, the source node knows its route to the destination node and can initiate the routing of the data packets. The source caches this route in its route cache. In the route maintenance phase, route error and acknowledgements packets are used. DSR ensures the validity of the existing routes based on the acknowledgements received from the neighboring nodes that data packets have been transmitted to the next hop. Acknowledgement packets also include passive acknowledgements as the node overhears the next hop neighbor is forwarding the packet along the route to the destination. A route error packet is generated when a node encounters a transmission problem which means that a node has failed to receive an acknowledgement. This route error packet is sent to the source in order to initiate a new route discovery phase. Upon receiving the route error message, nodes remove from their route caches the route entry using the broken link.

C. Ad hoc on-demand distance vector (AODV)

The AODV routing protocol was developed by Perkins and Royer [11] as an improvement to the Destination-Sequenced Distance-Vector (DSDV) routing algorithm. AODV aims to reduce the number of broadcast messages forwarded throughout the network by discovering routes on-demand instead of keeping complete up-to-date route information. A source node seeking to send a data packet to a destination node checks its route table to see if it has a valid route to the destination node. If a route exists, it simply forwards the packets to the next hop along the way to the destination. On the other hand, if there is no route in the table, the source node begins a route discovery process. It broadcasts a route request (RREQ) packet to its immediate neighbors and those nodes broadcast further to their neighbors until the request either reaches an intermediate node with a route to the destination or the destination node itself. The route request packet contains the IP address of the source node, current sequence number, the IP address of the destination node and the last known sequence number. An intermediate node can reply to the route request packet only if it has a destination sequence number that is greater than or equal to the number contained in the route request packet header. When the intermediate nodes forward route request packets to their neighbors, they record in their route tables the address of the neighbor from which the first copy of the packet has arrived. This recorded information is later used to construct the reverse path for the route reply (RREP) packet. If the same RREQ packets arrive later on, they are discarded. When the RREP packet arrives from the destination or the intermediate node, the nodes forward it along the established reverse path and store the forward route entry in their route table by the use of symmetric links. Route maintenance is required if either the destination or the intermediate node moves away and it is performed by sending a link failure notification message to each of its upstream neighbors to ensure the deletion of that particular part of the route. Once the message reaches to source node, it then re-initiates the route discovery process.

3.MOBILITY MODELS

In order to thoroughly simulate a protocol for an ad hoc network, it is imperative to use a mobility model that accurately represents the mobile nodes that will eventually utilize the given protocol. Only in this type of scenario it is possible to determine whether or not the proposed protocol will be useful when implemented. Currently there are two types of mobility models used in the simulation of networks: traces and synthetic models [5]. Traces are those mobility patterns that are observed in real life systems. Traces provide accurate information, especially when they involve a large number of participants and an appropriately long observation period. However, new network environments (e.g. ad hoc networks) are not easily modeled if traces have not yet been created. In this type of situation it is necessary to use synthetic models. Synthetic models attempt to realistically represent the behaviors of mobile node without the use of traces. A mobility model should attempt to mimic the movements of real mobile nodes. Changes in speed and direction must occur and they must occur in reasonable time slots. For example, we would not want mobile nodes to travel in straight lines at constant speeds throughout the course of the entire simulation because real mobile nodes would not travel in such a restricted manner. Different synthetic entity mobility models for ad hoc networks are:

- Random Walk Mobility Model (including its many derivatives): A simple mobility model based on random directions and speeds.
- Random Waypoint Mobility Model: A model that includes pause times between changes in destination and speed.
- Random Direction Mobility Model: A model that forces mobile nodes to travel to the edge of the simulation area before changing direction and speed.
- A Boundless Simulation Area Mobility Model: A model that converts a 2D rectangular simulation area into a torus-shaped simulation area.
- Gauss-Markov Mobility Model: A model that uses one tuning parameter to vary the degree of randomness in the mobility pattern.
- A Probabilistic Version of the Random Walk Mobility Model: A model that utilizes a set of probabilities to determine the next position of a mobile node.
- City Section Mobility Model: A simulation area that represents streets within a city.

In this work we have used two models for performance comparison, Random Waypoint Mobility Model and Citi Section Mobility Model.

A. Random Waypoint Mobility Model

The Random Waypoint Mobility Model includes pause times between changes in direction and/or speed. 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 mobile node chooses a random destination in the simulation area and a speed that is uniformly distributed between [minspeed, maxspeed]. The mobile node then travels toward the newly chosen destination at the selected speed. Upon arrival, the mobile node pauses for a specified time period before starting the process again. The Random Waypoint Mobility Model is also a widely used mobility model.

B. City Section Mobility Model

In the City Section Mobility Model, the simulation area is a street network that represents a section of a city where the ad hoc network exists [5]. The streets and speed limits on the streets are based on the type of city being simulated. The City Section Mobility Model provides realistic movements for a section of a city since it severely restricts the traveling behavior of mobile nodes. In other words, all mobile nodes must follow predefined paths and behavior guidelines (e.g. traffic laws).

Maps are used in this model. The map is composed of a number of horizontal and vertical streets. Each street has two lanes for each direction (North and South direction for vertical streets, East and West for horizontal streets). The mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At an intersection of a horizontal and a vertical street, the mobile node can turn left, right or go straight. This choice is probabilistic: the probability of moving on the same street is 0.5, the probability of turning left is 0.25 and the probability of turning right is 0.25.

In the real world, MNs do not have the ability to roam freely without regard to obstacles and traffic regulations. In addition, people typically tend to travel in similar patterns when driving across town or walking across campus. Enforcing that all MNs follow predefined paths will increase the average hop count in the simulations compared to other mobility models.

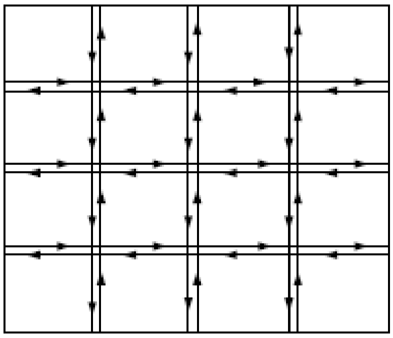

Figure 1. City Section mobility model

4.SIMULATION SETUP AND RESULTS

Since MANETs are not currently deployed on a large scale, research in this area is mostly simulation based.

In this paper NS-2 Simulator has been used to study network behavior under different mobility models. NS began as a variant of the real network simulator in 1989 and has evolved substantially over the past few years Furthermore; NS has a tool for the visualization of the generated trace files, entitled NAM (Network AniMator). The routing protocols used for simulation are available with NS-2. The simulator provides a mobility generator tool that can be used for many scenarios. Performances of DSDV, DSR and AODV were compared across two mobility models, the Random Waypoint Model and City Section Model, with CBR traffic and varying node speed and load. The following metrics are chosen to compare the different routing protocols:

Packet delivery fraction - The ratio of the data packets delivered to the destinations to those generated by the CBR sources.

Average end-to-end delay of data packets - This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times.

Normalized routing load - The number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission.

TABLE 1 SIMULATION PARAMETERS

Parameter	Value
Simulation time	300 seconds
Topology size	1000 m x 1000 m
Number of mobile nodes	40
Pause time	0, 100
Speed	1, 5, 10, 15, 20, 30, 40, 50 m/s
Traffic type	CBR
Number of Connections	1, 5, 10
Packet rate	4 packet/sec
Packet size	512 bytes

Here the protocol evaluations are based on the simulation of 40 wireless nodes forming an adhoc network moving about over a 1000m x 1000m flat space for 300 seconds of simulation time with CBR traffic. Standard 802.11 MAC layer was used and transmission range in each simulation was 250 mtr. Each run of the simulation accepts as input a scenario file that describes the exact motion of each node and another communication file, which details the traffic flows in the network during the simulation period. In City section model initially the nodes are placed randomly on different lane. The movement was controlled as per the specification of the model. If a node moves beyond the area it is reinserted at the beginning position in the opposite lane on the same street.

After generating different scenario file and traffic load communication file with varying parameters, simulation is performed. To measure the ability of a routing protocol to react to different mobility model the routing metrics are evaluated for a variety of movement patterns (scenario file) for the mobile nodes as well as variety of traffic loads (communication file).To have a fair comparison of capabilities and the weaknesses, both mobility models are tested with identical parameters.

After each simulation, trace files recording the traffic and node movements are generated. These files need to be parsed in order to extract the information needed to measure the performance metrics.

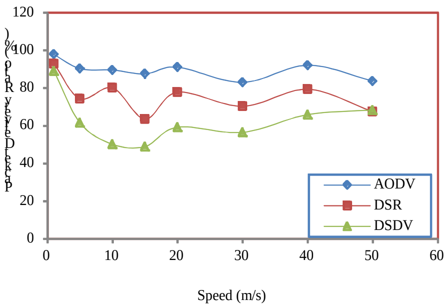

Figure 2. RWP- packet delivery ratio vs. speed

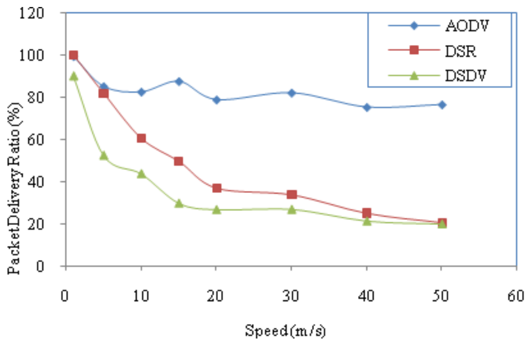

Figure 3. City Section- packet delivery ratio vs. speed

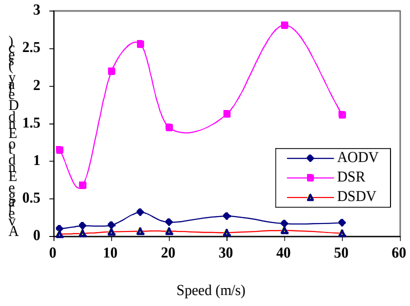

Figure 4. . RWP- average end to end delay vs. speed

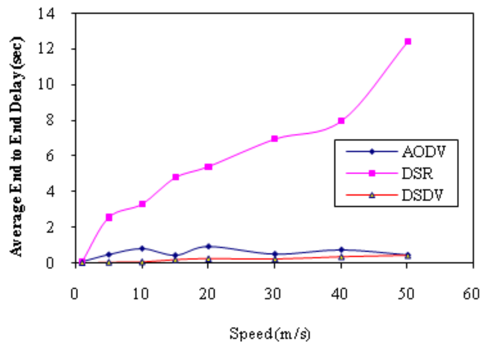

Figure 5. City Section- average end to end delay vs. speed

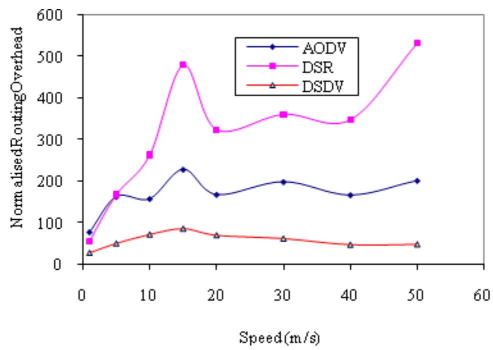

Figure 6. RWP- normalized routing overhead vs. speed

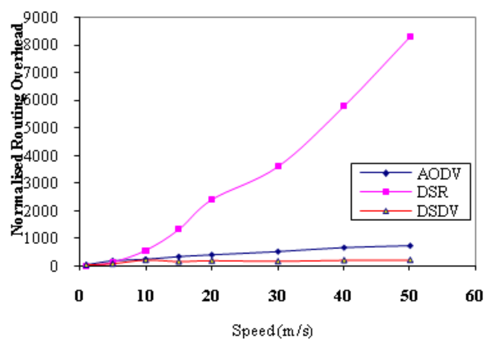

Figure7. City Section- normalized routing overhead vs. speed

5.CONCLUSION

On evaluating the performance of DSR, AODV and DSDV across the Random Waypoint and City Section mobility model it is observed that the mobility model may drastically affect protocol performance. On using DSR as an illustrative example it shows a difference of 40% in packet delivery ratio from Random Waypoint to the City Section model.

It is observed that DSR, DSDV and AODV achieve the high packet delivery ratio and the least overhead with Random Waypoint model and incur low packet delivery ratio and high overhead with city section model. The reason for low packet delivery ratio in City Section Model is that in this model the higher number of hop counts causes more link breakage.

The results of this work clearly show that City Section model has low packet delivery ratio and high routing overhead as compared to Random Waypoint model. These simulation results give the real picture of the performance of MANET routing protocols when deployed in an urban area. Hence it is important to choose an appropriate mobility model (or models) for a given performance evaluation.

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