Comparative Study of the Impact of Different Mobility Models on the Performance of a Mobile Ad-hoc Network Under Increasing Loads.

Tommaso Liardo
Edinburgh Napier University
40452307

***Abstract*— In this paper, the impact of different mobility models on the performance of a Mobile Ad-Hoc Network with an increasing number of nodes will be discussed. It will also be looked at possible benefits and drawbacks when varying between mobility models with different number of nodes in the MANET. The software used for the simulations from which the data is collected is OMNET++ and Throughput, PDR and Delay are the performance metrics examined. By comparing the obtained values, I will conclude how much the different models impact the performance of the network when the loads increase.**

I. INTRODUCTION

A Mobile Ad-hoc Network (MANET) is an autonomous, de-centralized, ad-hoc wireless networking system consisting of independent nodes that move dynamically, changing network connectivity (and thus, topology) without a static or fixed preexisting infrastructure [1]. It is essential for MANETs to implement routing protocols that can rapidly respond to the sudden and unpredictable topological changes in the network, but such protocols must also keep the amount of control traffic at a minimum as the bandwidth is limited.

The figure 1 describes a Mobile Ad-hoc Network, while Other MANET characteristics include [2]:

- Multi-hop routing: By forwarding packets through intermediate nodes, each node is able to communicate with other nodes that are outside of its communication scope.
- Independent nodes: Any node can work as a host as well as a router.
- Limited power devices: All participating nodes have less CPU capability, limited power and memory.

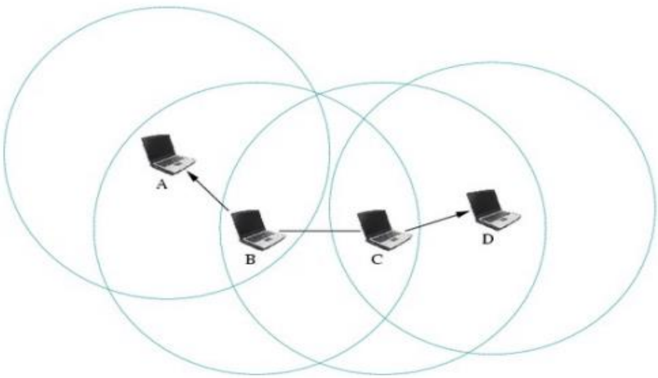

Figure 1. MANET

The Medium Access Control protocol (MAC), IEEE 802.11 standard, is used to regulate the access to the shared channel in order to increase the efficiency when sharing the limited bandwidth. The routing protocols that MANETs implement are divided into 3 main categories: “Proactive” (Table-Driven protocols), “Reactive” (On demand protocols) or “Hybrid” protocols (using the best features of both) depending on when and how a node acquires routing information. Possible applications of MANETs include military applications, disaster recovery efforts after natural disasters, students using laptops to participate in a lecture.
Mobility models allow to imitate the behavior of nodes during the performance simulations; therefore, the results are greatly correlated with the mobility model. In this study, a closer look is given to the linear mobility model and the random waypoint mobility model.

In this paper, I will describe the theoretical characteristics of the MANETs routing protocols in section II and the mobility models in section III, with particular focus on the DSDV protocol, the Linear Mobility model and the Random Waypoint Mobility model. I will then present the simulation scenario in section IV; simulation results are discussed and compared in section V. Section VI defines the conclusion of this paper.

II. ROUTING PROTOCOLS

Because of the MANETs unpredictable topology and limitedness of resources, routing protocols have many challenges to face. The Internet Engineering Task Force (IETF) working group is responsible to analyze and observe the performance and problems of ad-hoc networks. The MANET routing protocols are described as follows.

Proactive or table-driven protocols maintain routes to *all* nodes, even those to which no packets are sent. Routing information is updated periodically and each node maintains one or more tables that contain the latest routes to any node inside the network. Examples of proactive protocols include the Destination Sequenced Distance Vector protocol (DSDV) and the Optimized Link State Routing (OLSR).

Reactive or on-demand protocols attempt to establish routes when communication requests occur. When a node tries to communicate with another, it begins a route discovery mechanism to find the route to the destination. Once the route has been established, it maintained until either the destination becomes inaccessible, or until the route is no longer used or expired [3]. Reactive protocols obtain routes by flooding the route packets throughout the network and maintain routes only if they are needed. By avoiding periodic updates, reactive protocols reduce routing overhead. Known reactive protocols include the Dynamic Source Routing (DSR) and the Ad-hoc On-demand Distance Vector Routing (AODV).

Hybrid protocols such as the Temporally Ordered Routing Algorithm (TORA) and the Zone Routing Protocol (ZRP) draw advantages from using the best features of both the reactive and proactive protocols.

A. Destination-Sequenced Distance Vector (DSDV)

DSDV is a hop-by-hop distance vector protocol based on modifications made to the Bellman-Ford algorithm. Each node maintains a routing table that has entries for every destination in the network, as well as the number of hops required to reach each one of them. A sequence number is assigned to each entry in order to identify stale entries and to avoid the formation of loops. Routing table updates will be sent periodically in order to maintain consistency in a dynamically changing topology.
Routing information is distributed between nodes by sending full dumps frequently and smaller incremental updates more frequently. Routing information is advertised by broadcasting or multicasting the packets which are transmitted periodically and incrementally as the topology changes.
DSDV requires regular updates of its routing tables, which consumes battery power and bandwidth even when the network is idle. On topology changes, a new sequence number is necessary before the network can re-converge [3].

Advantages of DSDV include the following:

- DSDV is an efficient protocol for route discovery.
- Route discovery latency is very low.
- Loop-free paths are guaranteed in DSDV.

Disadvantages of DSDV include:

- To maintain network topology at each node, DSDV needs to send a lot of control messages.
- DSDV generates a high volume of traffic for high-density and highly mobile networks [4].

III. Mobility models

In the simulation environment, a mobility model is required to imitate the movements of the mobile nodes that will implement the given protocol. Such models are essential in determining the performance in a MANET.
The mobility models were designed for imitating the behavior of mobile users: how their speed, acceleration and location can vary at every moment in the simulation scenario.
Mobility models can be "single" or "group" mobility models. Single mobility models describe the movement of entities that are independent of each other, while group mobility models describe the motion of group members that are dependent on each other [4].
They can also be defined as "trace-based", "deterministic", "stochastic", and "combining" models, and they're described as follows.

- Deterministic: Mobility models that describe motion through non-random mathematical models. These include models such as the Linear model, circle model, and rectangle model.
- Trace-based: Mobility models that reproduce recorded motion as observed in real life. These may include the Bonn Motion mobility model, the Ns2 mobility model and the Ansim mobility model.
- Stochastic: Also known as random mobility models, these models use mathematical models involving random numbers, where nodes are free to move in any direction. Examples include the Random Waypoint model and the Random Walk model.
- Combining: Also called hybrid models, they allow more complex motion to be formed by combining several other mobility models. The Super Positioning model is an example [4, 5].

A. The Linear Mobility Model

This model describes linear motion with a constant speed or acceleration, and is set through parameters for speed, acceleration and starting angle. Once the simulation starts, the hosts will move along the area in a straight line, with constant speed, a random starting angle, and will bounce back from the boundaries reflecting the wall at the same angle [7].

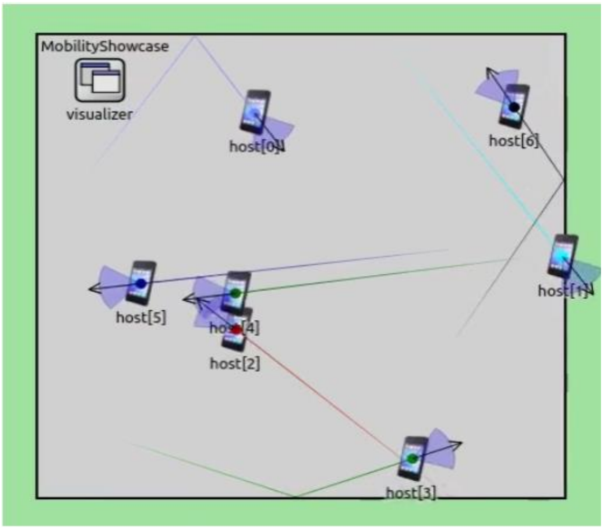

Figure 2. Linear Mobility Model

B. The Random Waypoint Mobility Model

According to this model, a mobile node begins by residing at one specific location for a set period of time called `waitTime`. As soon as this `waitTime` expires, the node selects a random destination (distributed uniformly over the simulation area) and moves towards it at a random speed (between `minSpeed` and `maxSpeed`) and wait for another `waitTime` before moving again. This model is widely used for researches.

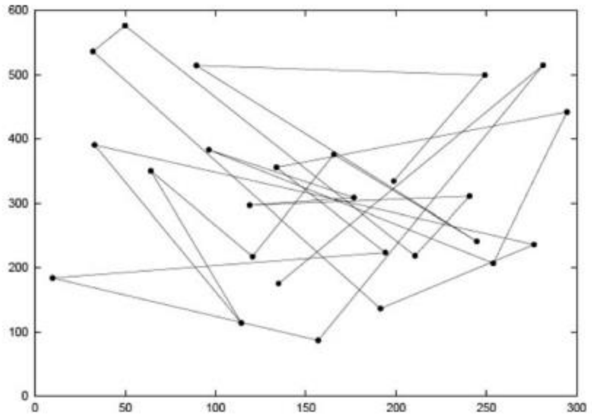

Figure 3. Traveling pattern of a mobile node using the random waypoint mobility model.

IV. SIMULATION SCENARIO

OMNET++ is a simulation library and framework primarily used for building network simulators [6] adopted for the simulations presented in this paper. The parameters setup is explained as follows.

Table 1. Simulation parameter setup

Parameter	Value
Simulation Time	60 Seconds
Number of nodes	5,10,15,20,25,30, and 35
Packet send Interval	0.05 Seconds
Environment Size	1000m x 1000m
Traffic Type	CBR (UDP)
Maximum Speed	10mps
Packet Size	512 Bytes
Mobility Model	Linear Mobility, Random Waypoint Mobility
Routing Protocol	DSDV

Both simulations will use the same parameters but two different mobility models. The first simulation is based on a linear mobility model, while the second is based on a random waypoint mobility model. For each model, the simulation will increase the number of nodes by five, starting from an initial host number of 5 and ending with a final host number of 35, for 60 seconds each time. The `sendInterval` value determines the interval at which the 512-Bytes UDP packets are sent, which in this case is 0.05 seconds. The size of the environment is 1000m x 1000m, and nodes will move at a speed of 10mps. Both simulations will use the DSDV routing protocol.

The impact of the two different mobility models on the performance of the MANET is observed by comparing three performance metrics: Throughput, Packet Delivery Ratio (PDR), and Network Delay.

A. Throughput

This value represents the number of successful messages sent or received in a communication channel. The throughput is calculated through the following formula:

$$Throughput = \frac{Total\ delivered\ packets * Packet\ size * 8}{Total\ time\ of\ the\ simulation}$$

Throughput is a great indicator of network performance because is directly correlated to packet loss, which is a common indicator of possible issues in the network.

B. Packet Delivery Ratio (PDR)

PDR is the value that corresponds to the ratio between the number of packets received and the number of packets sent. It indicates reliability. PDR is calculated as follows:

$$PDR = \ Received\ Packets/Sent\ packets$$

C. Network Delay

It is expressed as the difference in time between the moment all the packets are transmitted, and the moment the packets are *actually* received. It is calculated using the following formula:

$$Network\ Delay = \frac{\sum[Time\ Received - Time\ Sent]}{Total\ number\ of\ packets\ received}$$

Its value is represented in milliseconds, and includes the delay that may be caused by the route acquisition process, intermediate nodes processing, etc.

V. RESULTS, COMPARISON AND DISCUSSION

Figure 4 shows throughput variations on node density increase for both models. For each model, the network throughput increases with the number of nodes, with the linear model keeping a lower throughput than the random waypoint mobility model across almost all node variations. However, the linear mobility model simulations show that there is a sudden spike in the throughput above 30 nodes. The random waypoint mobility model's throughput is three and a half times higher at 25 nodes, but also 14.61% lower at 35 nodes.

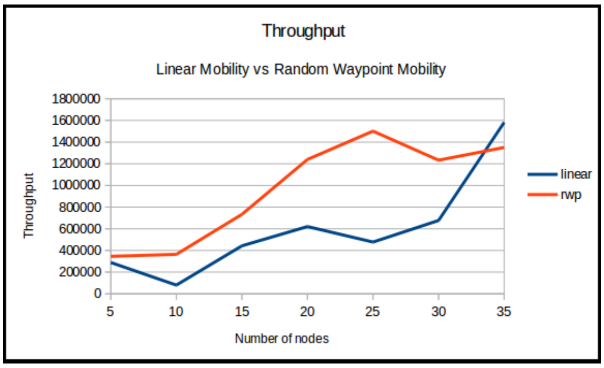

Figure 4. Network Throughput vs Node Density

Figure 5 depicts the PDR versus node density. Again, each model maintains a similar trend over the entire simulation, where the linear model shows a lower PDR across almost all densities but a sudden increase above 30 nodes that brings its value above the random waypoint mobility's PDR. The linear model's PDR is -49.56% lower on average, but it is 17.11% higher at 35 nodes.

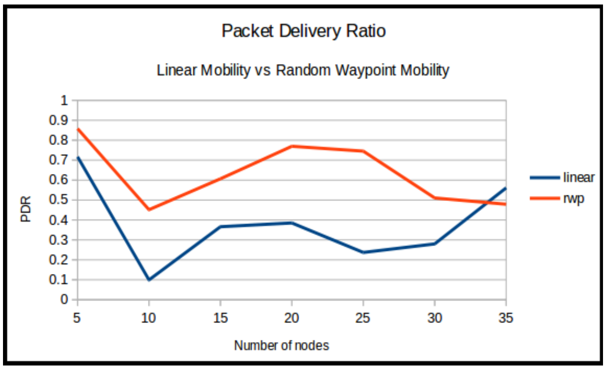

Figure 5. Packet Delivery Ratio vs Node Density

Figure 6 describes the network delay variations versus node density. In this particular case, both values are very similar (almost identical at the beginning), with slight variations above 20 nodes where the linear model maintains a lower delay value, but with another spike after 30 nodes that brings its value above the random waypoint mobility model's delay by 10.56%.

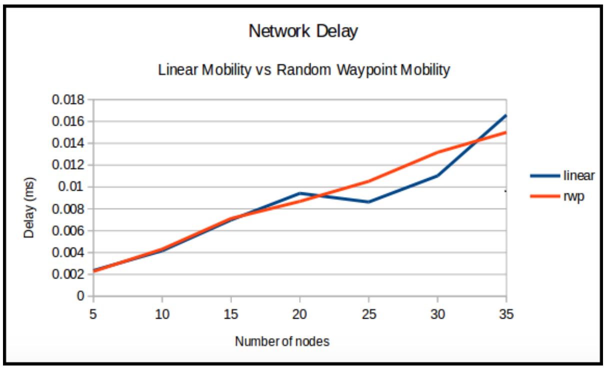

Figure 6. Network Delay vs Node Density

VI. CONCLUSION

In this paper I provided a comparative description of the impact of two different mobility models, linear and random waypoint, on the performance of a mobile ad-hoc network. I have highlighted the difference between the following performance metrics: Throughput, PDR and Network Delay for both models.

Both simulations produced similar results, which is understandable considered that there is not a lot of difference in performance when there are few hosts participating in the network. The resulting data shows clearly that the linear mobility model offers a better performance when implemented in a scenario with less than 30 nodes, but also falls off very quickly above 35 nodes, and that makes the random waypoint mobility model more reliable and efficient for scenarios with an increased number of nodes participating in the network. However, the random waypoint mobility model tends to have higher variations in performance evaluations when simulated for shorter times, and because of this it would be suggested to run simulations with longer simulation times (more than 1000 seconds) and/or save the locations of mobile nodes past the initial high variability in order to use them as possible starting point of the mobile nodes in future simulations [4].

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