Simulation of Realistic Mobility Patterns for Mobile Ad Hoc Networks

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Abstract: -Due to the difficulties associated to real tests, the evaluation and comparison of the performance of ad hoc networks are usually based on simulations. Simulations require the settings of several parameters as the traffic patterns, the radio propagation channel or the mobility model that the nodes follow. Several mobility models have already been proposed in order to describe the real behaviour of mobile users. The Random WayPoint is one of the most extended mobility patterns employed in the MANET research activities. Although its popularity, some lacks are present in it. One of the main drawbacks is related to its inability to consider obstacles in order to restrict the positions of mobile devices. In this paper, we analyse the importance that this characteristic has on the performance of real ad hoc network scenarios. The results show that, although the absolute values of the different metrics employed for the computation of network performance are different, the tendencies of the general behaviour are similar.

Key-Words: Mobility Model, MANET, Random WayPoint, Voronoi, ad hoc routing.

1 Introduction

Wireless devices are becoming popular and common elements in our days. This popularity in conjunction with the great amount of web Services that are utilized nowadays has enabled the mobile or pervasive computing. In this paradigm, Mobile Ad hoc NETworks (MANET) are receiving significant attention as they ease the connection of wireless devices without any pre-installed infrastructure. Although the initial concept of MANET goes back to 1970 with the DARPA project, there is still much research work to be performed in order to analyse and evaluate critical configurations in ad hoc networks as the ad hoc routing protocols, the security schemes or the supports for the integration of MANET into the Internet. Due to the great variety of conditions on which the MANET can be deployed, most of these research activities are accomplished by means of simulations. In this sense, several abstractions and simplifications should be considered in order to model the most significant factors that describe the environment where the mobile devices are expected to operate as well as their behaviour. Thus, the environment is usually modeled by radio propagation and interferences phenomena simplifications. On the other hand, the user activities can be captured by his mobility and the traffic that its device is generating or receiving.

A great variety of mobility models have been presented in the literature. In this sense, entity and group mobility models have been proposed. In the entity mobility pattern, movements of nodes are independent of the movements of the rest of the nodes that belongs to the same network. On the other hand, in the group mobility models, the movements of different nodes are correlated. One of the most extended individual mobility models is the Random WayPoint (RWP) [1]. According to this pattern, the nodes of an ad hoc network move along a straight line between two destination points (waypoints) placed in a finite space. In this literature, this space is normally bi-dimensional and restricted to a rectangular area of dimensions x_{max} and y_{max}. Once a node reaches a destination point, a new one is uniformly selected from this area. The speed for a movement is also chosen from a uniform distribution in the interval $[v_{min}, v_{max}]$. Both speeds and waypoints are generated independently of all the previous destinations and speeds. In addition, the model allows nodes to pause between two consecutive trips for a certain period of time. This period (Pause Time) is habitually fixed to a constant value. By varying the values of x_{max}, y_{max}, v_{min},

v_{max} and the pause time, it is possible to control the movement conditions of the simulated scenario.

Although its popularity, the Random WayPoint is often considered unsuitable for ad hoc networks due to its inability to capture the real users conducts. In this paper, we study the impact that utilizing more realistic mobility patterns has on the network performance. For this purpose, we employ the obstacle Mobility Model. In order to ease future work based on the Obstacle Mobility Model, a graphical tool has been included in the Network Simulator in order to compute synthetic traces that correspond to this realistic pattern.

The rest of the paper is structured as follows. Section 2 describes the related work. In Section 3, the Obstacle Mobility Model is explained. Section 4 presents the PatAdHoc, a tool for the generation of movement traces that follow the Obstacle Mobility Model. The ns-2 is utilized to analyze the impact of employing more realistic mobility models in simulations, as shown in Section 5. Finally, the paper is concluded in Section 6.

2 Related Work

Most of the research activities concerning ad hoc routing protocols have been accomplished by means of simulations. This methodology is extendedly employed due to the great variety of scenarios where ad hoc networks can be deployed. In simulations, it is imperative to represent the node movements by traces. In this sense, real or synthetic traces can be utilized [2]. As real traces are difficult to capture and do not usually correspond to generic scenarios, synthetics mobility patterns were developed.

The Random WayPoint in one of the most extended mobility pattern. However, this abstract random model does not represent the behaviour of nodes in real-world scenarios, since people and vehicles neither move in open and unobstructed areas nor follow random trajectories. However, we do not really know whether these variables influence the network behaviour. If we have a look in the work presented in [3], it seems to be proved that the utilized mobility model has a deep impact in the performance of ad hoc routing protocols. For this reason, realistic mobility scenarios have to be developed and used to understand the performance of ad hoc routing protocols in real world.

Aiming at helping the researchers to generate synthetic mobility patterns with different mobility models, some tools have been developed as Bonnmotion [4] and GEMM [5]. These tools return a file with the mobility traces that are included in the simulation scripts as input parameters in network simulators like Glomosim [6] or NS-2 [7]. Bonnmotion allows the utilization of some mobility models like Random Waypoint, Manhattan Grid or Reference Point Group, whereas GEMM provides a specific mobility model that employs some parameters like attraction points, activities or habits to generate the patterns. However, these tools do not include the effects of obstacles in real scenarios. The obstacles restrict the mobility of the nodes and make the patterns more realistic, since people and vehicles usually move following provided paths, like roads, pathways and corridors. For this reason, we have developed PatAdhoc, a graphic tool that allows the generations of mobility traces taking into account the presence of obstacles in the terrain. It is based in an obstacle mobility model described in [8]. With this pattern, the performance of ad hoc routing protocols in real world can be evaluated more accurately.

3 Obstacle Mobility Model

Most of the environments where ad hoc networks are expected to be deployed contain a great variety of obstacles, like buildings, mountains or cars. These obstacles block and limit the node movements. Besides, nodes do not move randomly among the obstacles, but usually follow existing pathways that, for example, interconnect buildings and lead into buildings. This obstacle mobility model takes into account the presence of obstacles and pathways to create a realistic mobility model.

Firstly, users have to define the scenario, giving the dimensions of the rectangular terrain and placing the obstacles. These can be modelled with complex polygonal shapes specified as an ordered sequence of its vertices or corners, where each vertex is defined by its coordinates. Non-linear shapes can be approximated by polygons, improving the quality of approximation with the numbers of vertices in the polygon. Additionally, each side of an obstacle may possess more than one point through which the nodes can enter or leave it, like for example a building, where there are some doorways in the same side.

Once the scenario is defined, it is necessary to compute the potential paths that exist in the presence of the specified obstacles. For this purpose, we employ the Voronoi Diagram of the obstacles corners, which provides pathways that generalize the idea that the paths usually lie in the middle of the two adjacent obstacles.

The Voronoi diagram of a set of points in the two-dimensional plane (in this case, the set of obstacles corners $C = \{c_1, c_2, ..., c_N\}$ where N represents the total number of corners) is a partition of the plane into convex polygonal cells. There is one cell per obstacle corner, so that every point in a cell is closer to one corner (considered as its corner) than to any other corner. The boundary edges of the cells are straight line segments that are equidistant from their two closest obstacles corners. These edges form the Voronoi graph of C, and represent the set of pathways that the nodes may follow. The vertices of the Voronoi graph in conjunction with the intersections points between the boundary of the simulation area and the Voronoi graph compose the set of vertices of the pathways. It is worth noting that the points of intersection between the obstacles boundaries and the Voronoi graph act as doorways.

Figure 1 shows the Voronoi diagram for a scenario with two obstacles. The set of sites S:

$$S = \{s_1, s_2, ..., s_6\} \cup \{s_7, s_8, ..., s_{12}\} \quad \text{(Eq. 1)}$$

represents the vertices of the pathways, where s1 to s6 are the sites generated by the Voronoi computation meanwhile s7 to s12 are the border sites.

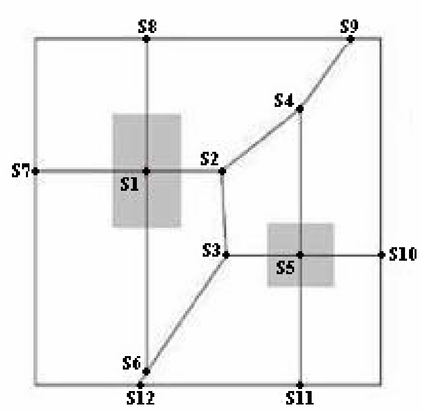

Fig. 1. Example of Voronoi Diagram

Once the Voronoi graph has been computed, nodes are placed in any site contained in S. Then, they choose a random destination within the set S and a random speed from a range previously specified by the user. To reach its destination, each node moves following the shortest path in the Voronoi diagram. Possibly, this path traverses intermediate sites. In order to compute the shortest paths, the use of a shortest path algorithm, like Dijkstra's, is required. In these algorithms, the cost of each path segment is its Euclidean distance. When the node reaches its destination, it rests for a pause time chosen from an input interval and then, repeats the process.

4 PatAdHoc Mobility Simulation Tool

PatAdHoc is a software tool for generating mobility patterns in ad hoc networks with obstacles in order to carry out more realistic simulations with the NS-2 network simulator.

The simulations are more realistic because PatAdHoc bears in mind the existing obstacles within the terrain when it generates the patterns, using the obstacle mobility model explained in the previous section.

This tool has been implemented in Java, so it is independent of the underlying operating system. Therefore, only it is necessary to have a Java Virtual Machine installed in the PC to use it. Figure 2 shows the graphic user interface (GUI) provided by PatAdHoc. The snapshot illustrates the possible applications of the tool. To generate the mobility patterns, as a first step users have to introduce the simulation scenario. There are two ways to do it: by hand, clicking and typing, or loading it from an existing file. The simulation area must be bigger than 10 x 10 m2 and the dimensions must be natural numbers. However, the obstacles corners coordinates have a resolution of 0.1 m. Voronoi diagram (the paths) is calculated and showed each time the user inserts a new obstacle corner. Additionally, scenarios can be saved into a file to be used in the future.

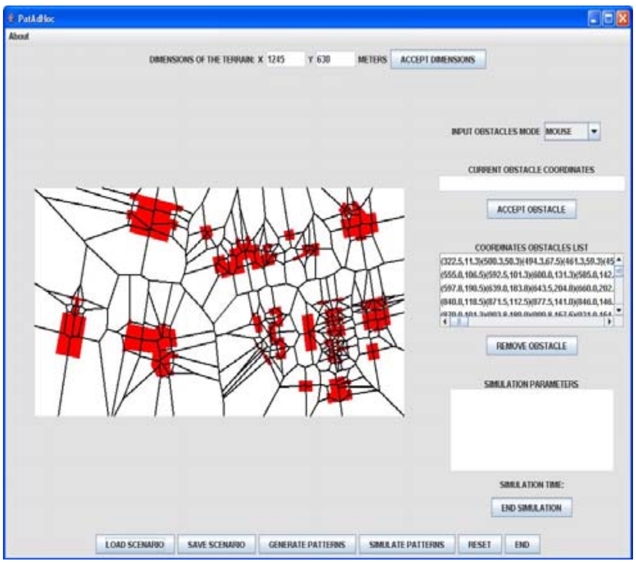

Fig. 2. PatAdHoc Graphic User Interface

Once the scenario has been specified, the user must provide the remaining simulation parameters, like number of nodes, speed range or simulation time. Then, the mobility patterns are generated and saved into a file. In addition, PatAdHoc allows the visualization of these patterns in current time or in the future, with a temporal scale or in real time.
After that, the mobility patterns file can be used as input file in NS-2 to run simulations.

5 Simulation and Results

The goal of these simulations is to prove the impact of using obstacles and pathways on the performance of ad hoc routing protocols. The network performance has been quantified by the estimation of the following metrics:

- Percentage of Lost Packets. It is defined as the ratio between the lost data packets and the data packets generated by the sources in the MANET. In our case, the number of packets that reach the corresponding Internet node is equivalent to the number of data packets received at the Access Routers as neither loss nor delays are assumed in the external Internet route.
- End-To-End Delay. It represents the average value of the time that the received data packets take to reach the destination from their origin. This parameter includes the time that the nodes stay in the internal queues, the retransmissions at the MAC level, and the forwarding through multiple intermediate nodes.
- Normalized Overhead. It corresponds to the ratio between the total control packets and the received data packets. Each hop of any control packet between two nodes is computed as a new control packet.

We compare the performance of popular on-demand AODV routing protocol [9] using the Random WayPoint and the obstacle mobility model. The simulations were run using the NS-2 network simulator [7]. The simulation scenario models the campus of Teatinos of the University of Malaga. Figure 3 shows this environment that represents the existing buildings in this campus in order to create a realistic simulation terrain.
The ad hoc network is formed by 50 nodes, with a transmission range of 250 m. In each simulation, all nodes moved at the same speed, but this speed changed to evaluate different mobility scenarios.
The traffic is associated to 10 CBR sources with a rate of 4 packets/second and 30 bytes/packet, (a similar size to that imposed by the ITU-T G.723 standard of wideband speech codec [10]).

Table 1 summarizes the rest of the parameters utilized in the simulations.
Figure 4, 5 and 6 shows the simulation results. As we can see, the performance of the network degrades when the Random WayPoint is considered as the mobility pattern. This characteristic could be explained by the fact that the Obstacle Mobility Model restricts the potential positions of the mobile users, keeping the devices closer. This proximity could lead to shorter routes and therefore, less losses and interferences are expected. Although the absolute values of the computed metrics differ, the general tendencies are similar when the two mobility models are compared.

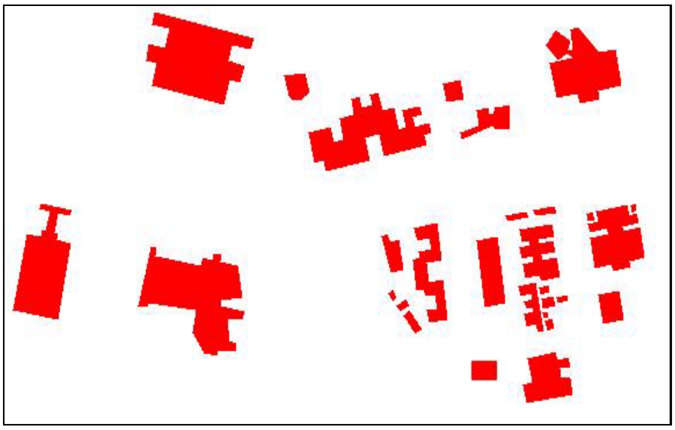

Fig. 3. Scenario for the Simulations. It corresponds to a campus (Teatinos) of the University of Malaga (Spain)

TABLE 1. Simulation parameters

Simulation Area	1245 x 630 m^2
Mobile Nodes	50
Mobility Pattern	Constant speed: [1, 2.5, 5, 7.5, 10] m/s Pause Time = 0 seconds
Traffic Pattern	10 CBR sources Rate = 4 packets/s Packet size = 30 bytes
Simulation Time	3000 s
Transmission Range	250 m
Runs per Point	5
Ad Hoc Protocol	AODV
Internal Queue	64 packets

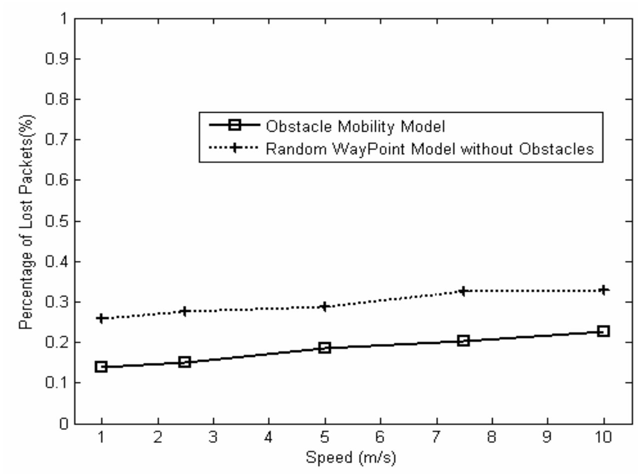

Fig. 4. Percentage of Lost Packets versus the Speed.

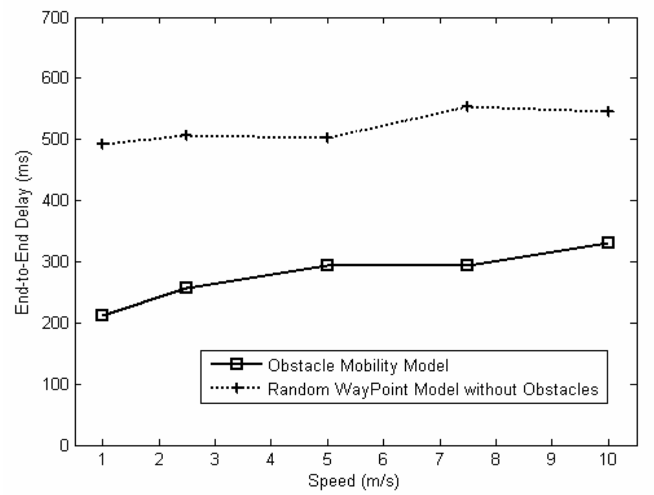

Fig. 5. End-to-End Delay versus the Speed.

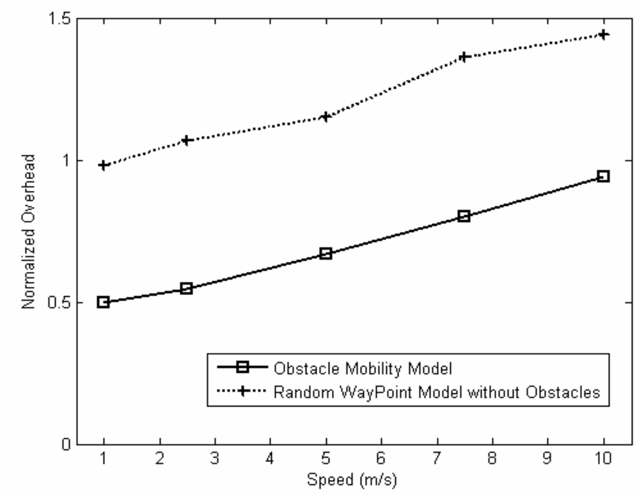

Fig. 6. Normalized Overhead versus the Speed.

6 Conclusions

In this paper, a tool for the generation of realistic mobility traces has been presented. This tool allows the introduction and consideration of obstacles that restrict the movements of mobile users. In order to evaluate the impact of the utilization of realistic mobility patterns, several simulations were run in ns-2. The comparison shows that the absolute values of the computed metrics differ but the tendencies are similar.

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