Realistic Mobility for Mobile Ad Hoc Network Simulation

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Abstract. In order to conduct meaningful performance analysis of routing algorithms for Mobile Ad Hoc Networks (MANETs), it is essential that the mobility model on which the simulation is based reflects realistic mobility behavior. However, current mobility models for MANET simulation are either unrealistic or are tailor-made for particular scenarios. We introduce GEMM, a tool for generating mobility models that are both realistic and heterogeneous. These models are capable of simulating complex and dynamic mobility patterns representative of real-world situations. We present simulation results using AODV, OLSR and ZRP, three MANET routing algorithms and show that mobility-model changes have a significant impact on their performance.

Keywords: Mobility Model, MANET, GEMM

1 Introduction

Mobile ad-hoc network (MANET) routing protocols have received considerable recent attention. The standard way to evaluate these protocols is simulation, key to which is a model of node mobility. Typically, a simple abstract mobility model such as random waypoint [6] or random walk [1] is used [5,7]. By virtue of their simplicity, these random models do not attempt to reflect real human mobility. The hope, however, is that a simple model captures enough of the key characteristics of human mobility to make protocol evaluations meaningful.

Humans, of course, rarely move randomly. Consider, for example, a typical public park. Park users will be unevenly distributed over this landscape. Some of them will be stationary and others will move at different characteristic speeds: walkers, joggers and bikers, for example. The course that mobile users take will not be random. Some will move to attraction points such as snack bars, restrooms, play areas, etc.

While some previous works have observed that routing algorithm performance may be influenced by choice of mobility model [9], most research continues to use random waypoint. In order to provide a framework for producing more realistic mobility models, we have developed a tool called GEMM, that generates mobility scenarios capturing some key features of typical human mobility. We use GEMM to re-examine three MANET routing algorithms: AODV [3], OLSR [2] and ZRP [4], representative of the three popular routing approaches.

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We compare algorithm performance for random waypoint and several more realistic models generated by GEMM. Our evaluation shows significant performance differences between random waypoint and the alternatives, thus confirming that this random approach is insufficient for accurate simulation.

2 Related Work

Numerous studies have evaluated MANET routing protocols using the *random waypoint* mobility model. Maltz et. al. compared DSDV, TORA, DSR and AODV [5,6]. Das et. al. evaluated DSDV, TORA, DSR and AODV with exponential distance distribution with mean 5m and no pause time [7]. Variations of the *random waypoint* model have been proposed such as *random walk* [1], *random direction* and *boundless simulation area* mobility model. *Gauss-Markov* is a model in which a node's next position is determined incrementally based on its current position and velocity [8].

Several researchers have explored the use of customized models designed to be more realistic than random waypoint. Johanson et. al. proposed three mobility scenarios: *conference*, *event coverage* and *disaster area* [9]. Sanchez explored several custom-made group mobility models such as *column* , *pursue* and *nomadic community* mobility model [10]. Although tailor-made models are useful, significant development effort is required for each simulation scenario and each scenario has limited applicability.

3 GEMM

When setting out to model human mobility realistically, one must consider how humans move and what features of this behavior are important enough to capture.

3.1 Developing a Realistic Mobility Model

Motivated by studies of human walking [11], we observe that mobility can be fairly expressed using four characteristics: attraction points, activities, roles and group behavior.

Attraction points. An attraction point is a destination of interest to multiple people. On a university campus, for example, students may tend to move among locations such as classrooms, cafeterias, pubs, etc. Attraction points are described by a 5-tuple consisting of *x-y coordinates*, *popularity*, *radius* and *type*.

Activities. An activity is the process of moving to an attraction point and remaining there for some period of time. Activities can be parameterized by by a 6-tuple consisting of *minimum and maximum trigger time and duration*, *destination* and *type*.

Roles. A role characterizes the mobility tendencies intrinsic to different classes of people. For example, university students spend much more time moving among classrooms than professors; some people bike others walk, etc. A real environment consists multiple user classes each taking on different roles. Roles are specified by a 5-tuple consisting of *weight*, *minimum and maximum speed* and *activity set*.

Group Behavior. Group behavior captures the way that people influence each others mobility. People may tend to cluster in groups, match each others velocity or avoid colliding with each other [12]. This is specified by a four-tuple consisting of *collision-avoidance*, *inertia*, *velocity-matching* and *group-centering probabilities*. Each probability is expressed as the fraction of nodes that exhibit the specified group behavior.

3.2 Design and Implementation of GEMM

The basic framework is that each node is statically assigned a distinct role. This role specifies a set of activities that nodes perform, chosen randomly during the simulation. Each activity consists of moving to a new location and specifies zero or more attraction points as possible destinations.

GEMM is implemented in Java conforming to the BonnMotion API and uses its output-file format [13]. The input to GEMM is a set of parameter settings and the output is a detailed mobility scenario that can be used directly by either the NS2 [14] or Glomosim [15].

4 Evaluation

This section compares the performance of three MANET routing algorithms using random waypoint and a set of more realistic scenarios generated by GEMM.

4.1 Experimental Setup

In order to conduct comparison studies with GEMM, we select OLSR, AODV and ZRP, which are representative of *proactive*, *reactive* and *hybrid* routing algorithms respectively. The goal of our simulation experiments is to assess the impact of different aspects of realistic mobility scenarios on the ability of the MANET routing protocols to successfully deliver data packets. Simulations were conducted using Glomosim [15].

We adopt a simulation environment similar to [5], where 50 mobile nodes move about in an area of 1500m x 300m. Each node in the simulation has a radio transmission range of 250m. We report packet delivery ratios for pause times of 0, 30, 60, 120 and 300 seconds. The data traffic characteristics are based on constant bit rate (CBR).

4.2 Attraction Points

The goal of this first set of simulations is to illustrate the ways in which attraction points change routing algorithm behavior. In these simulations node speed is chosen uniformly between 0 and 20m/sec as in [5].

Mobility scenarios. We used GEMM to generate the following mobility scenarios.

RWP. The standard random waypoint model.
OAP-RTO. Nodes move to a single attraction point, pause and return to their original position.
TAP-RTO. Nodes randomly choose among three attraction points, pause and return to their original position.
TAP. Nodes randomly choose among three attraction points, pause and move to another randomly chosen attraction point.

Figure 1 shows the packet delivery ratios for OLSR, AODV and ZRP respectively, for all four mobility scenarios. The first and most important thing to notice is that there are substantial differences among the mobility scenarios. Furthermore, each algorithm reacts differently to mobility-model changes. These differences indicate that the choice of mobility has a big impact on comparisons among competing algorithms.

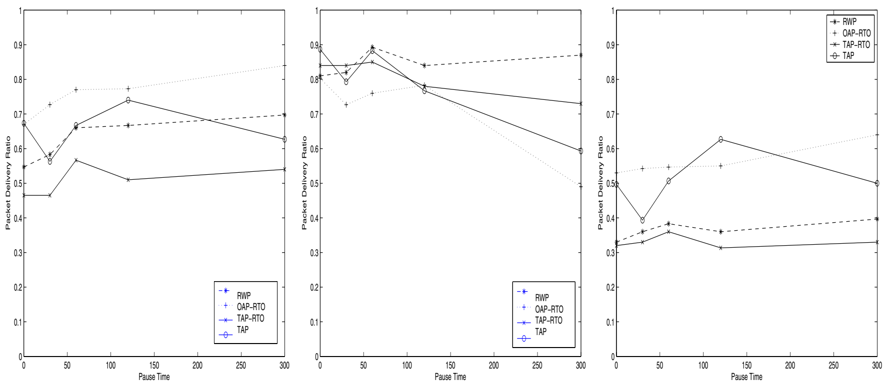

Fig. 1. Attraction-point packet delivery ratio for OLSR and AODV and ZRP

4.3 Impact of Speed Variation

We now turn to simulations using realistic human walking and bicycling speeds of 1-1.6 m/s and 4-11 m/s respectively. We add the suffix **HS** to model names to signify walking speed and **MIXED** to signify a mix of 20% bikers and 80% walkers.

Figure 2 shows the normalized packet delivery ratio attained by three routing algorithms, OLSR, AODV and ZRP, for these six scenarios (OAP-RTO-HS, OAP-RTO-MIXED, TAP-RTO-HS, TAP-RTO-MIXED, TAP-HS and TAP-RTO-MIXED). The normalization is done with respect the earlier scenarios with nodes having maximum speed 20m/s. For instance, the packet delivery ratio for

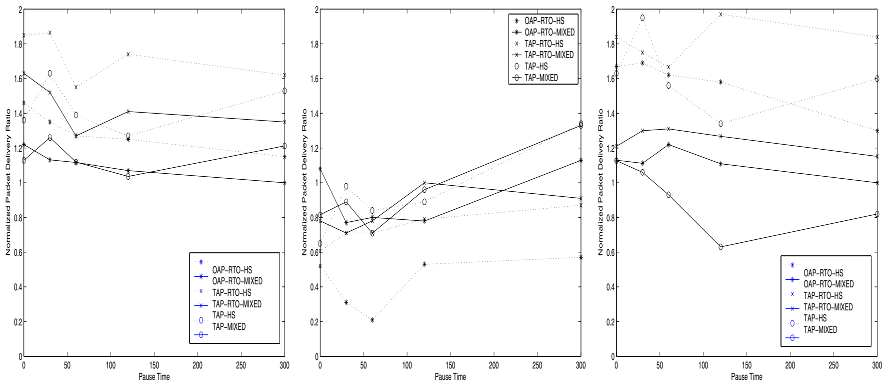

Fig. 2. Speed-variation normalized delivery ratio for OLSR and AODV and ZRP

OAP-RTO-HS is normalized with respect to OAP-RTO. Again the key thing to observe from these graphs is that performance differs substantially among the mobility models.

4.4 Group Mobility Behavior

Finally we turn to group mobility. For this simulation we generated group mobility variants of the mixed walking/biking scenarios. For these models, we set all four group parameters to 100%, indicating that every node acts with all four group behaviors. We add a **-GM** suffix to these models names.

The results are shown in Figure 3, which gives packet delivery ratio normalized to the non-group variant of each scenario. Again we see that group settings seem to matter, though less so than for speed variation, particularly for AODV.

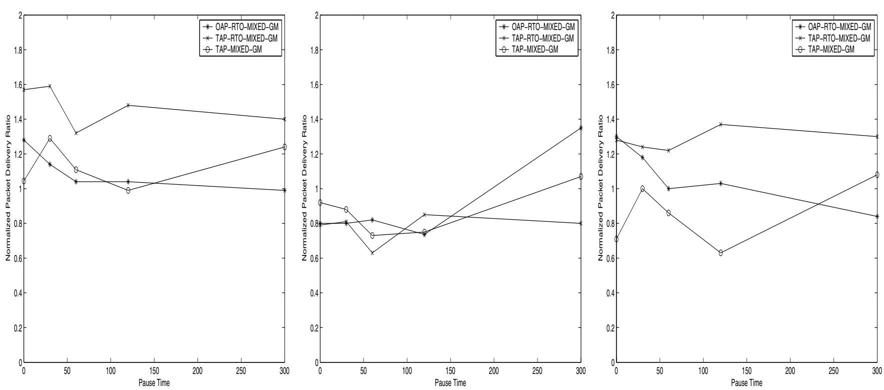

Fig. 3. Group mobility normalized packet delivery ratio for OLSR and AODV and ZRP.

5 Conclusion

This paper describes a tool we have built, called GEMM, that generates mobility scenarios suitable for MANET routing algorithm simulation using either NS2 or Glomosim.

We simulated three algorithms, AODV, OLSR and ZRP, using a variety of mobility scenarios designed to be more realistic than random waypoint. Our results show that the algorithms we studied behaved significantly differently under the models generated by GEMM than under random waypoint. We have also shown that GEMM can be used to generate models that are arguably more realistic.

We believe that generic approaches such as GEMM provide substantial benefit with the evaluation of MANET protocols. Our work also points out the danger of choosing a routing algorithm based on unrealistically simple mobility models.

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