International Conference on Complex, Intelligent and Software Intensive Systems

MixMobGen - a realistic *Mix*ed traffic *Mob*ility *Gen*erator for ad hoc network simulations

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Abstract

Recently, performance evaluation of ad hoc network protocols is done using realistic mobility and traffic models, thus improving the validity and credibility of wireless simulation studies. In this paper we design and implement MixMobGen, a mobility generator for ad hoc vehicular applications, which takes into account mixed vehicular conditions. This is the first mobility model that takes into account, both, slow and fast vehicles. While speed for highway traffic has been modeled following a normal distribution, two studies on the mixed traffic show that speed follows a multimodal or bimodal distribution, instead. In this paper we a) design and implement MixMobGen, a realistic mobility generator that models mixed traffic conditions. b) evaluate protocol performance in 802.11 network protocols using NS 2 simulator.

1 Introduction

Synthetic mobility models are mainly used to evaluate the protocol performance in wireless networks. The synthetic mobility models [1] are very useful, since they are easy to implement and mathematically tractable. However, the study at Uppsala University [2] shows that the wireless protocol performance in real test beds drops by 30% from the ones in the simulation platforms. The main reason for the disparity is the use of synthetic simulation models, including mobility models, which do not closely model the environments where the wireless networks will be deployed.

The authors of [3] issue a ‘A call to arms: It’s time for REAL mobility models’, thus they design and implement a more realistic pedestrian mobility model. Also, to further improve the validity and credibility of the simulation studies the authors of [4, 5] show that mobility and traffic are interconnected, as well as, provide a more realistic traffic model. The studies show that under more realistic mobility and traffic models the simulation protocol performance better reflects the protocol performance of real deployments.

In addition, more realistic vehicular mobility models are implemented [6, 7, 8, 9, 10, 11, 12]. For example, the authors of [10] implement a more realistic vehicular model by using the publicly available TIGER (Topologically Integrated Geographic Encoding and Referencing) database from the U.S. Census Bureau, giving detailed street maps for the entire United States of America, and model the automobile traffic on these maps. First, the model can be very complex, since it needs to query the database for every location. Second, the database does not provide any speed limit information for each location. Lastly, the model makes assumptions about the speed distribution and other pertinent parameters. Specifically, the models do not take into account mixed traffic conditions [13, 14].

The focus of this paper is the design of the mixed traffic mobility model generator. While highway traffic is characterized by fast moving vehicles and the speed follows normal distribution, under the mixed traffic conditions the speed distribution is multimodal [13]. In addition, the direction of movement is not random, but rather it is activity based. For example, the data collected by [14] show that the wireless devices are clustered around popular loca-

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978-0-7695-3575-3/09 $25.00 © 2009 IEEE
DOI 10.1109/CISIS.2009.157

tions ,i.e, work place, shopping, other errands. Furthermore, the data supports the property of the dynamic membership, which was first introduced on the pedestrian realistic mobility model [3]. The dynamic membership suggests that the wireless nodes are dynamic, thus join and leave the network at random times.

The contributions of this paper are the design and implementation of a mixed traffic mobility generator, MixMobGen. MixMobGen draws its characteristics from two real data sets. In addition, it provides simulation performance evaluations of two most used ad hoc wireless protocols, namely AODV [15] and DSR [16]. This paper is organized in four more sections. The next section provides a quick review of the main parameters of the synthetic mobility models. In Section 3 we show the design and implementation of MixMobGen, which is a more a realistic mobility generator that models mixed traffic conditions in NS 2 simulation environment [17]. Section 4 shows simulation evaluations of MixMobGen in the 802.11 networks. The last section concludes and presents future work.

2 Synthetic Mobility Models Parameters

Many synthetic mobility models are implemented and used to evaluate the protocol performance of ad hoc networks. The models are divided into two main groups, namely entity and group mobility models. The most used synthetic mobility model is the Random Walk Model (RWM) [18], which is a representative of the entity mobility model and works as follows:

1. Each node is assigned a randomly distributed initial location $(x0; y0)$

2. Each node randomly picks up a destination independent of their initial positions and moves toward it with speed chosen uniformly on the interval $(v0; v1)$

3. Nodes pause upon reaching each destination

4. The process is repeated until the user entered simulation time is over.

The main characteristics of a synthetic mobility model are summarized hereby:

Initial Distribution of the Wireless Nodes distributed uniformly in the simulation area and all the nodes are active at the start of the simulation until the simulation ends.

Speed selected from a uniform distribution (on pedestrian cases) or gaussian on vehicular models.

Pause set to some constant or withdrawn from a uniform distribution.

Direction of Movement continues change of direction, however the wireless nodes do not move this way.

3 MixMobGen Mobility Generator

MixMobGen is based upon the data collected by the Indian Institute of Technology [13] and from the Battelle Memorial Institute [14]. Both data sets systematically have collected mixed traffic data. MixMobGen is the first mobility model, we are not aware of any other one, that captures mixed traffic conditions by realistically implementing the speed as a bimodal distribution, the direction of movement based on a probability transition matrix, and the wireless nodes to poses the dynamic membership property (join and leave the simulation at some random time).

3.1 Data Sets Descriptions

The first data set [13] was collected on 17 different sections of the national and state highways in different parts of India. The sections were chosen to have a wide variation of fast vs. slow moving vehicles. The data collected on each section involved 2 hours of a typical weekday. (Please refer to Figure 1 for a summary of the traffic sample size on each section). For example, as shown in the Figure 1, the sample size on section 6 is $1,407$ vehicles.

On each section, different ratios of fast moving vehicles vs. slow moving vehicles were captured. The hypothesis of the study was:

Hypothesis: Speed Data distribution on mixed traffic conditions does not follow normal distribution.

The collected data supported the hypothesis on 13 out of the 17 (77%) sections (As shown in Figure 2). For example, the red bars that represent the sections 1, 3, 8, 12 show that the null hypothesis was rejected on only four sections due to the fact that data was better modeled by unimodal distribution, but supported on the other 13 sections. Furthermore, the graph shows that the bimodality of the data is not correlated to the volume of the fast vs. slow moving vehicles. For example, bimodality is supported when the ratio of slow moving vehicles was 14% on section 11 or as high as 31% on sections 5, 6, and 7. Analogously, the distribution was unimodal at low ratio of slow moving ,i.e., 19% on section 1 or at high ratio , i.e., 39% on section 8.

The second data set [14] covered the Lexington area of approximately 461 square miles with a total population of approximately $350,000$. The sample was comprised of 100 households and included data collected via GPS mounted systems in the cars, which provides useful information for the mobility parameters that could not be extracted from

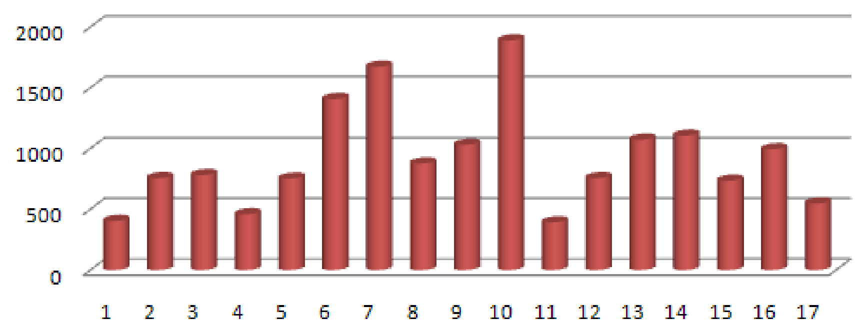

Figure 1. Number of the vehicles sampled on 17 sections.

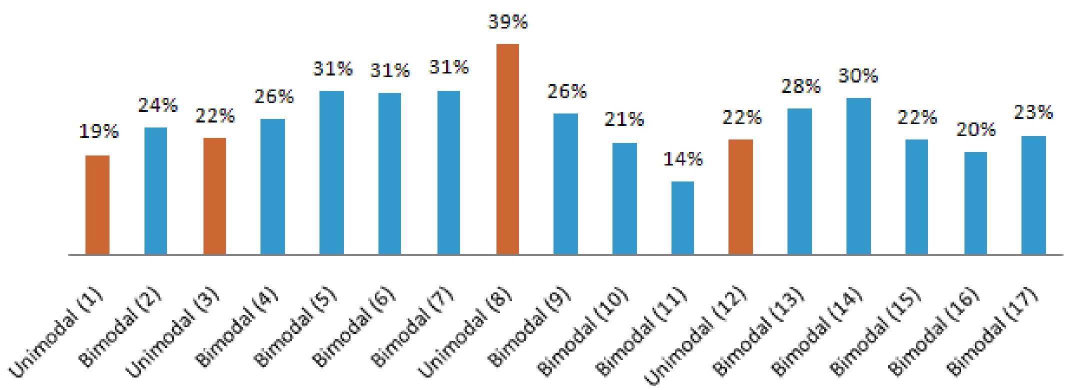

Figure 2. Ratio of the Slow Moving Vehicles and the Speed Distributions.

the first data set, including direction of movement, trip start times, and dynamic membership properties.

The second data set reveals that the direction of movement is not random, but rather it is based on person's activities. For example, while traveling on local streets the purpose of the trips was classified as follow:

Work Place 10%

Social/Recreational Activity 13.8%

Eat Out 15.8%

Shopping 14.9%

In addition, it emphasizes that nodes posses dynamic membership, thus are not in the simulation during the entire simulation time, but rather a fraction of the simulation time.

3.2 MixMobGen Parameters

In this section we discuss the parameters of the MixMobGen and the implementation choices in NS 2.

3.2.1 Speed Distribution

Speed distribution is extracted from the first data set [13], which shows that on the 13 out of the 17 of the sections the speed of mixed traffic is best modeled by bimodal distribution. For example, on the Table 1 we show 13 data points collected at section 6.

We assessed many distributions to graph the data, however we adopted the interpolation [19] method, which is the process of defining a function that takes on specified values at specified points (As shown in Figure 3). The figure and the study supports that the speed distribution is bimodal with the mean to be *12.5* on the first peak and the mean to be *37.5* on the second peak.

3.2.2 Direction of Movement

Wireless devices are carried by humans, thus the human movements would be the best approximation to the mobility patterns of the mobile nodes. We are aware that humans do not move at random, but rather based on activities. The data collected on Lexington area supports that humans move based on activities and the findings are summarized

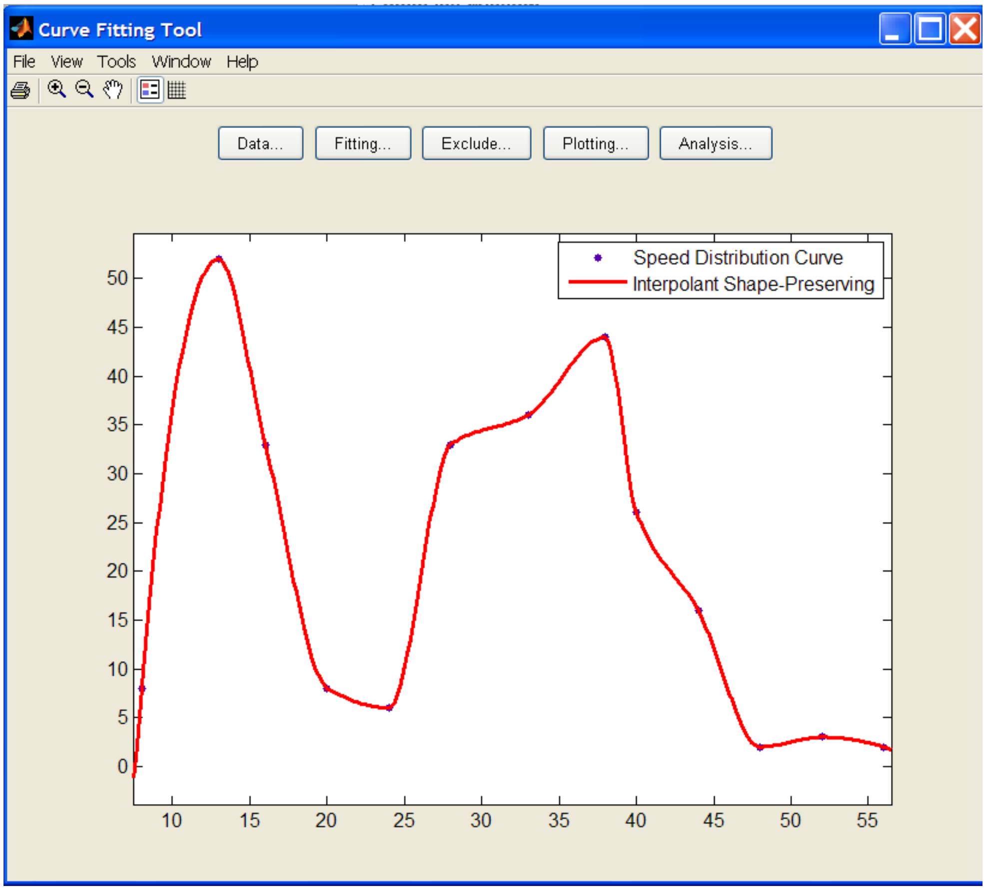

Figure 3. Shape-preserving interpolation curve on the data collected in section 6.

Table 1. Speed Distribution Data

Speed (kmph)	Probability Density
8	8
13	52
16	33
20	8
24	6
28	33
33	36
38	44
40	26
44	18
48	2
52	3
56	2

in Figure 4. We implemented this feature by introducing a $Transitional\_Destination\_Prob\_Matrix$, which places a weight of 0.1 on the Shopping and Other Errands activities, or a weight of 0.26 on the Return Home activity.

3.2.3 Dynamic Membership

The length of the trips, as well as, the start times of the trips were collected. In Figure 5 we see that 50% of the trips were on length of $[0, 9]$ minutes, 30% of the trips were on length of $[10, 19]$ minutes, 10% of the trips were on length of $[20, 29]$ minutes, 4% of the trips were on length of $[30, 39]$ minutes, 2% of the trips were on length of $[40, 49]$ minutes, and 4% of the trips were on length of $[50, +]$ minutes.

In the implementation phase we introduced the array $Start\_time\_of\_Trip$, which has the percentage of the nodes that become active at time 0 (of the simulation). For example, 27% of the nodes become active at time 0), 5, 10, and (increments of 5 until the full hour is reached). In addition, we introduce the array the $Active\_time\_of\_Nodes$, which presents the weights of the trip lengths.

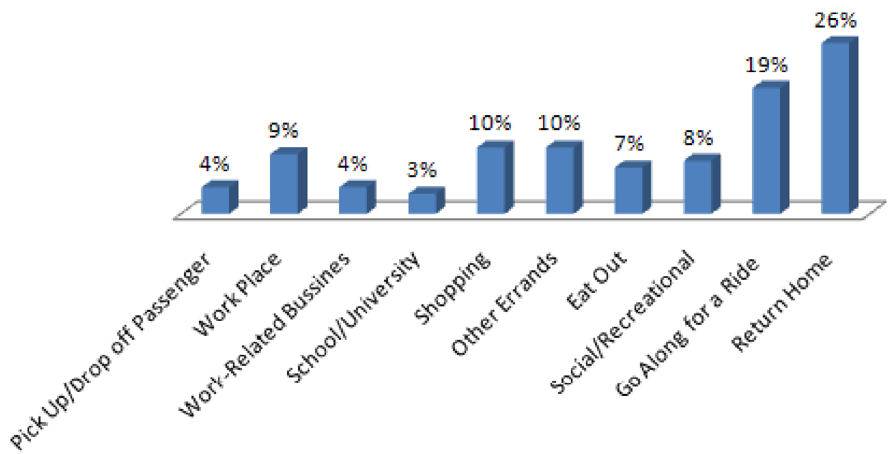

Figure 4. Destinations (As % of trips).

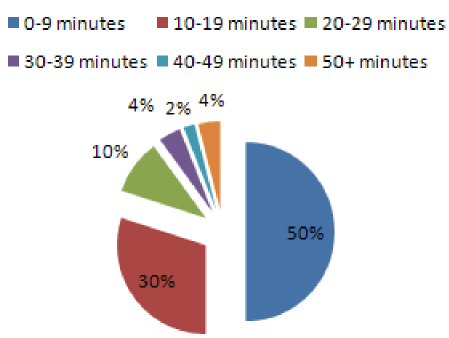

Figure 5. Length of Trips.

3.3 Algorithm of MixMobGen

The simulation duration time (T) and the number of nodes (N) are the inputs entered by the user. First, 11 popular locations are defined, i.e, Shopping, Errands, University, and Work. In MixMobGen the nodes are distributed based on the weights defined on the $Transitional\_Destination\_Prob\_Matrix$. The nodes active state is determined by the values on the arrays $Start\_time\_of\_Trip$ and $Active\_time\_of\_Nodes$. The algorithm of the $MixMobGen$ is presented by Algorithm 1.

Algorithm 1 : $MixMobGen$.

Input: Simulation Time (T); Number of Nodes (N);

Compute $Transitional\_Destination\_Prob\_Matrix$
Compute $Start\_time\_of\_Trip$ as a function of N
Compute $Active\_time\_of\_Nodes$ as a function of N, T
INITIALIZATION
for each node ϵ N **do**
  InitialLocation from the $Transitional\_Destination\_Prob\_Matrix$
  Speed (S) from the BimodalSpeed Distribution
  ActiveTime from the $Active\_time\_of\_Nodes$
  TripStartTime from $Start\_time\_of\_Trip$
end for
for each node ϵ N **do**
  Select Destination (D) to move to from the $Transitional\_Destination\_Prob\_Matrix$
  Move toward D with speed S from Initial Location
  if upon reaching D the node is still ACTIVE **then**
    Select new Destination and Speed
    Move toward the new destination with the new speed
  end if
end for

Output: Mobility Patterns File

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4 Simulation Evaluations

The MixMobGen mobility tools were used to generate mobility. We used the RealTrafficGen to generate traffic. In the routing layer AODV [?] and DSR [16] were selected, since they are the most used ones in the performance evaluations studies. The propagation model is the two-ray-ground [20]. The parameters that were not varied in the simulations were the number of nodes set to 40, simulation area $900m \times 1200m$, simulation time set to $900s$, the IEEE 802.11 [21] as the protocol for the medium access control (MAC) layer model.

We summarize in Table 2 the parameters used in the simulation.

In addition, the derived parameters that are calculated from the number of nodes (40); the simulation area ($900m\times$

Table 2. Simulation Parameters.

Parameter	Value (s)
Routing	AODV and DSR
MAC	802.11
Number of Nodes	40
Simulation Area	$1200m \times 900m$
Simulation Time	900 s
Propagation Model	Two-Ray-Ground
Radio Range	250 m
Traffic	Constant Bit Rate
Mobility	MixMobGen

$1200m$); and the transmission range (R=250m) are provided below (for further explanations on each of the derived parameters we refer the reader to [22].)

Node Density: Number of nodes divided by the simulation area. In our case it is $(900 \times 1200)/40$, thus 1 node for $27,000m^2$.

Coverage Area: Area with the transmission range as radius. In our case it is $\Pi * R^2$=$196,349m^2$.

Maximum Path Length: The diameter of the rectangle $900m \times 1200m$ equals to 1500.

The network Diameter: The maximum path length divided by the transmission range, which in our case turns out to be 6 $Hops$.

Network connectivity no edge effect: The coverage area by the node density, which turns out to be 7.27 $Hops$.

The performance metric used in the simulation is defined hereby.

Availability as a performance metric to take into account the dynamic membership.

Availability: We define Availability as the ratio between the number of packets sent by the source and the number of packets received by the destination, while the node is active.

MixMobGen shows that nodes are clustered around the main activities and their probabilities that are defined by the $Transitional\_Destination\_Prob\_Matrix$. For example, Figure 6 shows the visualization of MixMobGen on 40 nodes.

The mobility file is generated under MixMobGen, while the traffic file is generated under Constant Bit rate traffic model with three different sources $(10, 20, 30)$ sources, resp., 40 nodes, and the rate of generating packets was set to 4 packets. Each data point represents an average of *fifty* runs with different traffic and different randomly generated mobility scenarios.

In order to account for the the dynamic membership we use the performance metric of Availability, which is the ratio between the number of packets sent by the source and the number of packets received by the destination, while the node is active. The results of the experiments are summarized in Tables 3. The results, also, include the 95% confidence intervals (CI) for validation of the experiments.

5 Conclusions

In this paper we presented the design and implementation of the MixMobGen mobility generator, which models mixed-traffic mobility patterns. Also, simulation evaluations of 802.11 networks show that under more realistic mobility models simulation protocol performance drops by 30%, thus better reflecting the performance obtained in real test beds. In the future, we plan to augment the generator and allow to switch between different modes of movement (pedestrian, highway, mixed traffic). For example, the mobility generator should adjust automatically to pedestrian mobility patterns, fast moving traffic, and mixed traffic. We are working to present Knob Mobility Generator, which based on the context can automatically adjust to the proper mobility model.

Furthermore, MixMobGen and RealMobGen suggest that mobility models that are extracted from real user data posses mobility characteristics that are rather different from the synthetic mobility models. When we evaluate the protocol performance using realistic mobility models, the performance drops significantly from the evaluations done when using synthetic mobility models. In the future we plan to address the main mobility characteristics of ad hoc simulation models, including dynamic membership, direction of movement, and speed distribution.

Lastly, the realistic mobility models shed new light into the ad hoc protocol design, as well. For example, the realistic mobility models show that nodes tend to cluster around popular locations. When the nodes are within the cluster they tend to be less mobile, but when they are between the clusters the nodes tend to be more mobile. However, none of the popular protocols captures this reality. In the future, we are going to address ad hoc protocol design based from on the real data sets collected fro real world scenarios.

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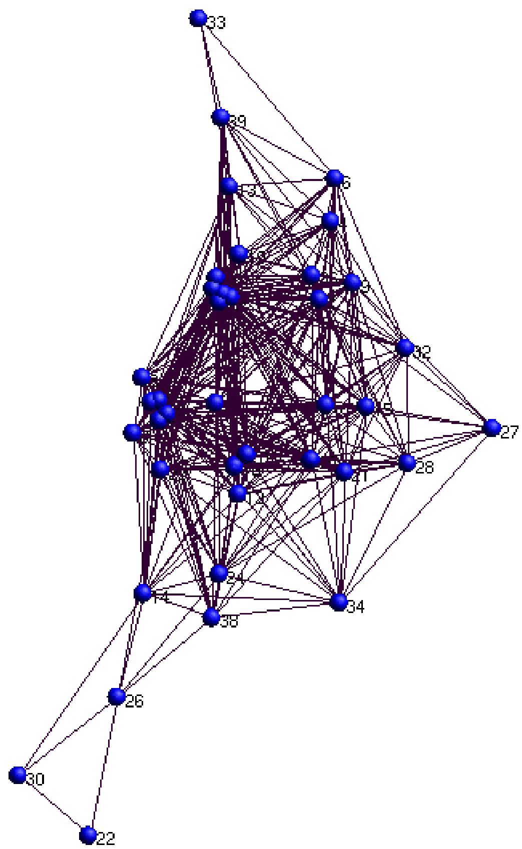

Figure 6. MixMobGen on 40 Nodes.

Table 3. Performance evaluation under MixMobGen.

Number of Sources	Availability: AODV	95% CI: AODV	Availability: DSR	95% CI: DSR
30	55.65%	55.65 ± 4.03	56.11%	56.11 ± 4.16
20	66.64%	66.64 ± 4.22	66.48%	66.48 ± 4.68
10	68.49%	68.49 ± 4.14	70.02%	70.02 ± 4.00

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