User Manual for IMPORTANT Mobility Tool Generators in ns-2 Simulator

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I  Overview

These mobility generator tools are used to generate a rich set of mobility scenarios used to evaluate the protocol performance in Mobile Ad Hoc Network. The tools include the Reference Point Group Mobility (RPGM) model, Freeway Mobility Model and Manhattan Mobility Model.

The trace files generated by these tools are compatible with the format required by ns-2. Thus, the user could directly input the trace files generated by this generator into the ns-2 simulator and run the simulations.

After modification of appropriate parameters, this set of mobility generators are able to create various mobility scenarios with different mobility characteristics, as stated in details in the following sections.
II Mobility Models

2.1 Random Waypoint (RW) Model:

The Random Waypoint model is most commonly used mobility model in research community. In the current network simulator (ns-2) 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 $[0, V_{\text{max}}]$, where $V_{\text{max}}$ is the maximum allowable velocity for every mobile node.

After reaching the destination, the node stops for a duration defined by the 'pause time' parameter. After this duration, it again chooses a random destination and repeats the whole process again until the simulation ends. In our framework, the RW model acts as the 'baseline' mobility model to evaluate the protocols in Ad Hoc Network.

The Random Waypoint model is provided by the setdest tool in the standard ns-2 distribution, thus we do not provide it in our release.

2.2 RPGM Model:

Group mobility can be used in military battlefield communication. Here, each group has a logical center (group leader) that determines the group's motion behavior. Initially, each member of the group is uniformly distributed in the neighborhood of the group leader. Subsequently, at each instant, every node has a speed and direction that is derived by randomly deviating from that of the group leader.

Important Characteristics:

Each node deviates its velocity (both speed and direction) randomly from that of the leader.

The movement in group mobility can be characterized as follows:

(1) $V_{\text{member}}(t) = V_{\text{leader}}(t) + \text{random()} \times SDR \times \text{max\_speed}$

(2) $\theta_{\text{member}}(t) = \theta_{\text{leader}}(t) + \text{random()} \times ADR \times \text{max\_angle}$

where $0 \leq SDR,ADR \leq 1$. SDR is the Speed Deviation Ratio and ADR is the Angle Deviation Ratio.

SDR and ADR are used to control the deviation of the velocity (magnitude and direction) of group members from that of the leader. Since the group leader mainly decides the mobility of group members, group mobility pattern is expected to have high spatial dependence for small values of SDR and ADR.
2.3 Freeway Mobility (FW) Model:

This model emulates the motion behavior of mobile nodes on a freeway. It can be used in exchanging traffic status or tracking a vehicle on a freeway.

Important Characteristics:
In this model we use maps. There are several freeways on the map and each freeway has lanes in both directions. The differences between Random Waypoint and Freeway are the following:
(1) Each mobile node is restricted to its lane on the freeway.
(2) The velocity of mobile node is temporally dependent on its previous velocity. Formally, vec{V_{i}}(t+1) = vec{V_{i}}(t) + random() * vec{a_{i}}(t)
(3) If two mobile nodes on the same freeway lane are within the Safety Distance (SD), the velocity of the following node cannot exceed the velocity of preceding node. Formally, for all {i}, for all {j}, for all {t}, if D_{i,j}(t) < Safety_Distance, then vec{V_{i}}(t) < vec{V_{j}}(t), if j is ahead of i in its lane.

Due to the above relationships, the Freeway mobility pattern is expected to have spatial dependence and high temporal dependence. It also imposes strict geographic restrictions on the node movement by not allowing a node to change its lane.

2.4 Manhattan Mobility (MH) Model:

We introduce the Manhattan model to emulate the movement pattern of mobile nodes on streets defined by maps. It can be useful in modeling movement in an urban area where a pervasive computing service between portable devices is provided.

Important Characteristics:
Maps are used in this model too. However, the map is composed of a number of horizontal and vertical 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 with certain probability. Except the above difference, the inter-node and intra-node relationships involved in the Manhattan model are very similar to the Freeway model.

Thus, the Manhattan mobility model is also expected to have high spatial dependence and high temporal dependence. It too imposes geographic restrictions on node mobility. However, it differs from the Freeway model in giving a node some freedom to change its direction.
III Usage and Description of Mobility Generators

3.1 RPGM Model (in the directory /rpgm)

Once the program is run, the users will be asked for the value of several key parameters.

(1) Firstly, the user will be asked about the ‘number of groups’ used in the mobility scenarios. Here, if user is going to use single group mobility model, please input 1; otherwise, please input the desired number, e.g., 4 for our INFOCOM2003 paper.

(2) Then, parameter 'the number of nodes in each group' will be asked.

(3) Later, the values of Speed Deviation and Angle Deviation will be asked.

(4) To work appropriately, the RPGM model needs the trace file (we call it as 'checkpoint file') of the group leaders of each group. The file names will be asked. If single group model is used, only one checkpoint file for group leader is needed; if multiple group model (e.g., 4 groups) is used, then four checkpoint files for the group leaders of each group are required. Please just input the filename as following the instruction.

The ‘checkpoint file’ is needed to be created by users. It represents the movement trace of the group leader. It could be manually created by the users according to the predefined trace of movement trace, or easily converted from the random waypoint model. The format of this ‘checkpoint file’ is described in Appendix A.

In sub-directory /rpgm/checkpoint1 and sub-directory /rpgm/checkpoint2, we provide two sets of the checkpoint files for single group mobility model and multiple group mobility model respectively.

(5) Finally, the user needs to input the file name of the generated trace file.

If the users would like to generate more rich mobility scenarios, please refer the source code and change it appropriately.

3.2 Freeway Model (in the directory /fwy)

Once the program is run, the users will be asked for similar questions as in RPGM model.

In FW model, a map file is also needed for the Freeway mobility generator to work appropriately. When the user is asked, the file name of this map file should be typed. The
format for the map file is described in Appendix B. In the sub-directory /fwy/mapset1 and /fwy/mapset2, two sets of maps used for freeway model are provided.

The users are also asked for the value of acceleration speed. By changing this parameter, the users are able to adjust the mobility behavior. In our INFOCOM2003 paper, we use the following setting:

\[
\text{Acceleration\_speed} = 10\% \times \text{MAX\_VELOCITY}.
\]

3.3 Manhattan Model (in the directory /man)

Once the program is run, the users will be asked for similar questions as in RPGM model.

(1) First, the overall number of mobile nodes in the simulation field is asked.

(2) Second, The Max and Min allowed velocity of mobile nodes are asked respectively. The users can input their desired values.

(3) Then, the users are also asked for the value of acceleration speed. By changing this parameter, the users are able to adjust the mobility behavior. In our INFOCOM2003 paper, we use the following setting:

\[
\text{Acceleration\_speed} = 10\% \times \text{MAX\_VELOCITY}.
\]

(4) In MH model, a map file is also needed for the Manhattan mobility generator to work appropriately. When the user is asked, the file name of this map file should be typed. The format for the map file is described in Appendix C. In the sub-directory /man/mapset1 and /man/mapset2, two sets of maps used for manhattan model are provided.

(5) Finally, the filename of output trace files are asked.
Appendix A: The format of Checkpoint file for RPGM model

[Format:]
=================================================================================================
<ini_x0> <ini_y0>
<destination_x1> <destination_y1> <duration_time_t1>
<destination_x2> <destination_y2> <duration_time_t2>
<destination_x3> <destination_y3> <duration_time_t3>
<destination_x4> <destination_y4> <duration_time_t4>
...
...
...<destination_x(n)> <destination_y(n)> <duration_time_t(n)>
=================================================================================================

Here,

<ini_x> and <ini_y> are the initial positions of the group leader at the beginning of simulation.
<destination_x1> and <destination_y1> are the position of the destinations at the next movement,
<duration_t1> is the time to move from current location (x0,y0) to (x1,y1). Similarly,
<destination_x2> and <destination_y2> are the position of the destinations of next movement after it reaches the position (x1,y1), <duration_t2> is the time to move from current location (x1,y1) to (x2,y2).

This procedure is repeated until the simulation is finished.

Please refer to the samples in /rpgm/checkpoint1 and /rpgm/checkpoint2.
Appendix B: The format of Map file for FW model

[Format:]
=======================================================================
FREEWAY
FREEWAY_NUM <total_number_of_freeways>
LANE_NUM <total_number_of_lanes>
LANE_BEGIN  <freeway_id>  <lane_id_in_this_freeway>  <lane_id_in_all_freeway>
  <direction>  <number_of_phases_of_this_lane>
  PHASE  <phase_id>  (<phase_start_x0,phase_start_y0>)(<phase_end_x1,phase_end_y1>)
     <v_min>  <v_max>
  PHASE  <phase_id>  (<phase_start_x1,phase_start_y1>)(<phase_end_x2,phase_end_y2>)
     <v_min>  <v_max>
...
...
LANE_BEGIN  <freeway_id>  <lane_id_in_this_freeway>  <lane_id_in_all_freeway>
  <direction>  <number_of_phases_of_this_lane>
  PHASE  <phase_id>  (<phase_start_x0,phase_start_y0>)(<phase_end_x1,phase_end_y1>)
     <v_min>  <v_max>
  PHASE  <phase_id>  (<phase_start_x1,phase_start_y1>)(<phase_end_x2,phase_end_y2>)
     <v_min>  <v_max>
...
...
LANE_BEGIN  <freeway_id>  <lane_id_in_this_freeway>  <lane_id_in_all_freeway>
  <direction>  <number_of_phases_of_this_lane>
  PHASE  <phase_id>  (<phase_start_x0,phase_start_y0>)(<phase_end_x1,phase_end_y1>)
     <v_min>  <v_max>
  PHASE  <phase_id>  (<phase_start_x1,phase_start_y1>)(<phase_end_x2,phase_end_y2>)
     <v_min>  <v_max>
...
...
=======================================================================

In FW model, several freeways co-exist in the simulation field and mobile nodes are moving on the lanes of the freeways. For each freeway, it has several lanes in both directions. (Certainly, users are able to define a freeway with only one direction). Please note, each lane should be separated with other lanes by some distance. That is to say, when design the map file, the lanes are not supposed to be overlapping. For each lane which is not necessary to be a straight line, so it may have several phases while each phase is a straight line. By connecting several phases together, the users are able to define a non-straight freeway in the simulation field.
The map starts with required word 'FREEWAY', then some parameters are placed.  
<total_number_of_freeways> is used to define how many freeways exist in the simulation field,  
<total_number_of_lanes> is used to count totally how many lanes exist in the field.  
For each lane, it begins with keyword 'LANE_BEGIN', and then several parameters are listed here,  
<freeway_id> is the id of the freeway where this specific lane belongs,  
<lane_id_in_this_freeway> is the id of this lane on this freeway,  
<lane_id_in_all_freeway> is the id of this lane in the overall simulation field, please note, these two parameters are not same.  
<direction> is the direction of this lane. For example, if one direction of a lane is defined as positive value 1, then the lane on the opposite direction must be defined as the negative value -1.  
<number_of_phases_of_this_lane> represents how many phases this lane has.

Once the general parameters of the lane has been described, the map file will describe the parameter for each phase. It starts with keyword 'PHASE', and the meaning of parameters are described as follow:  

<phase_id> is the id of this phase on this lane of this freeway.  
<phase_start_x0,phase_start_y0> describes the position of starting points of this phase  
<phase_end_x1,phase_end_y1> describes the position of the ending points of this phase. Please note, generally speaking, the starting point of next phase should be the ending point of this phase.  
<v_min> <v_max> defines the maximum and minimum allowed velocity on this phase.  
For each lane, several phases are defined. For each freeway, several lanes are defined; For the whole simulation field, several freeways are defined.

For more questions, please refer to the samples in directory /fwy/mapset1 and /fwy/mapset2.
Appendix C: The format of Map file for MH model

[Format:]

MANHATTAN
HOR_STREET_NUM <num_of_horizontal_street>
VER_STREET_NUM <num_of_vertical_street>
LANE_NUM <overall_num_of_lanes>
LANE <street_id> <lane_id> <direction> <start_x0> <start_y0> <end_x0> <end_y0>
<total_number_of_crosspoints_in_this_lane> <vmin> <Vmax>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x>
<position_y>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x>
<position_y>
...
LANE <street_id> <lane_id> <direction> <start_x0> <start_y0> <end_x0> <end_y0>
<total_number_of_crosspoints_in_this_lane> <vmin> <Vmax>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x>
<position_y>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x>
<position_y>
...
LANE <street_id> <lane_id> <direction> <start_x0> <start_y0> <end_x0> <end_y0>
<total_number_of_crosspoints_in_this_lane> <vmin> <Vmax>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x>
<position_y>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x>
<position_y>
...
...

In MH model, several horizontal and vertical streets co-exist in the simulation field and mobile nodes are moving on the lanes of the streets. For each street, it has several lanes in both directions. (users can also define a street with only one direction). Please note, each lane should be separated from other lanes by some distance. That is to say, while designing the map file, the lanes are not supposed to overlap. However, the vertical and horizontal streets may cross with each other at the crosspoints. At the crosspoints, the mobile nodes are suppose to move ahead, turn left or turn right with certain probability.
Similar to Map file of freeway model, the map file of Manhattan model starts with keyword 'MANHATTAN'.
Then, `<num_of_horizontal_street>` and `<num_of_vertical_street>` give the number of horizontal and vertical streets in the simulation field.
For each lane street, it starts with the keyword 'LANE', and the meaning of the parameters are described as follow:
`<street_id>` is the id of the street where this lane belongs,
`<lane_id>` is the unique id of this lane,
`<direction>` is the direction of this lane, for example, if lane is towards right and up, its value is 1; otherwise, it is -1,
`<start_x0> <start_y0>` are the position of the starting point of this lane,
`<end_x0> <end_y0>` are the position of the ending point of this lane,
`<total_number_of_crosspoints_in_this_lane>` indicates how many crosspoints exist in this lane,
`<vmin> <Vmax>` defines the max and min allowed velocity of nodes on this lane. Please note, the values here should be consistent with the input parameters.

For each crosspoint, it starts with keyword 'CROSSPOINT', the parameters are described as:
`<crosspoint_id>` is the unique id of this crosspoint
`<street_id>` is the unique id of the street to which this crosspoint belongs
`<lane_id>` is the unique id of the lane to which this crosspoint belongs
`<direction>` is the direction of the street to which this crosspoint belongs
`<position_x> <position_y>` is the exact position of this crosspoint.