Introduction to Network Simulator

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Mobility models: Introduction

- Mobility models are an essential part in the simulations of mobile networks.
- They are used in the simulations of mobile ad-hoc networks, vehicular ad-hoc networks, cellular networks, etc.
- They can be created either through traces collected over some observation periods in real life or they can be synthetic, i.e. created to mimic a given movement patterns of mobile nodes.
- Synthetic mobility models can be divided into two groups:
  - `Entity mobility model` where the movements of mobile nodes are independent of each other.
  - `Group mobility model` where mobile nodes belonging to a given mobility group have the same movement patterns.

Mobility models: Introduction

- For mobile ad-hoc network, several mobility models have been proposed for both groups.
- Hereafter, we will consider two commonly used entity mobility models: `Random Waypoint` model and `Random direction` models.
- These models can be defined and used in 1-D, 2-D or 3-D dimension space.
- References:
  - "`Performance comparison of multi-hop wireless ad hoc network routing protocols`", *J. Broch, D. Maltz, D. Johnson, Y.-C Hu, and A. Jetcheva, 1997*.
  - "`A Survey of Mobility Models for Ad Hoc Network Research`", *T. Camp, J. Boleng, and V. Davies, 2002*.

Random waypoint mobility model

- Random waypoint mobility model (RWP): A travel path consists of a series of trips.
  - Initially at time 0, each mobile node is assigned a uniform location in the area.
  - At the beginning of each trip, the mobile chooses a random destination, i.e. next waypoint M_n, uniformly in the area and a next speed V_n uniformly in $[V_{min}, V_{max}]$, independently of past and present values.
  - Then, it travels toward the newly chosen destination at constant speed V_n.
  - Upon arrival to M_n, the mobile pauses for a fixed or random period of time.
  - Once this time expires, it starts the process again.

Random direction mobility model

- Similarly, random direction mobility model (RD), a travel path consists also of a series of trips. RD has two variants: with `Reflection` or with `Wrap around`.
  - Initially at time 0, each mobile node is assigned a uniform location in the area.
  - At the beginning of each trip, the mobile chooses a random direction θ uniformly between $[0, 2\pi]$, a next speed V_n uniformly in $[V_{min}, V_{max}]$, and a travel time τ, exponentially distributed with a given mean.
  - Then it travels in the direction θ for a duration τ at speed V_n.
  - Similarly, upon arrival to M_n, the mobile pauses for a fixed or random period of time, then again, a new direction, speed and travel time are chosen at random.
  - When a node reaches a boundary, it is either reflected or wraps around the area so that it reappears on the other side.

References on RWP and RD models

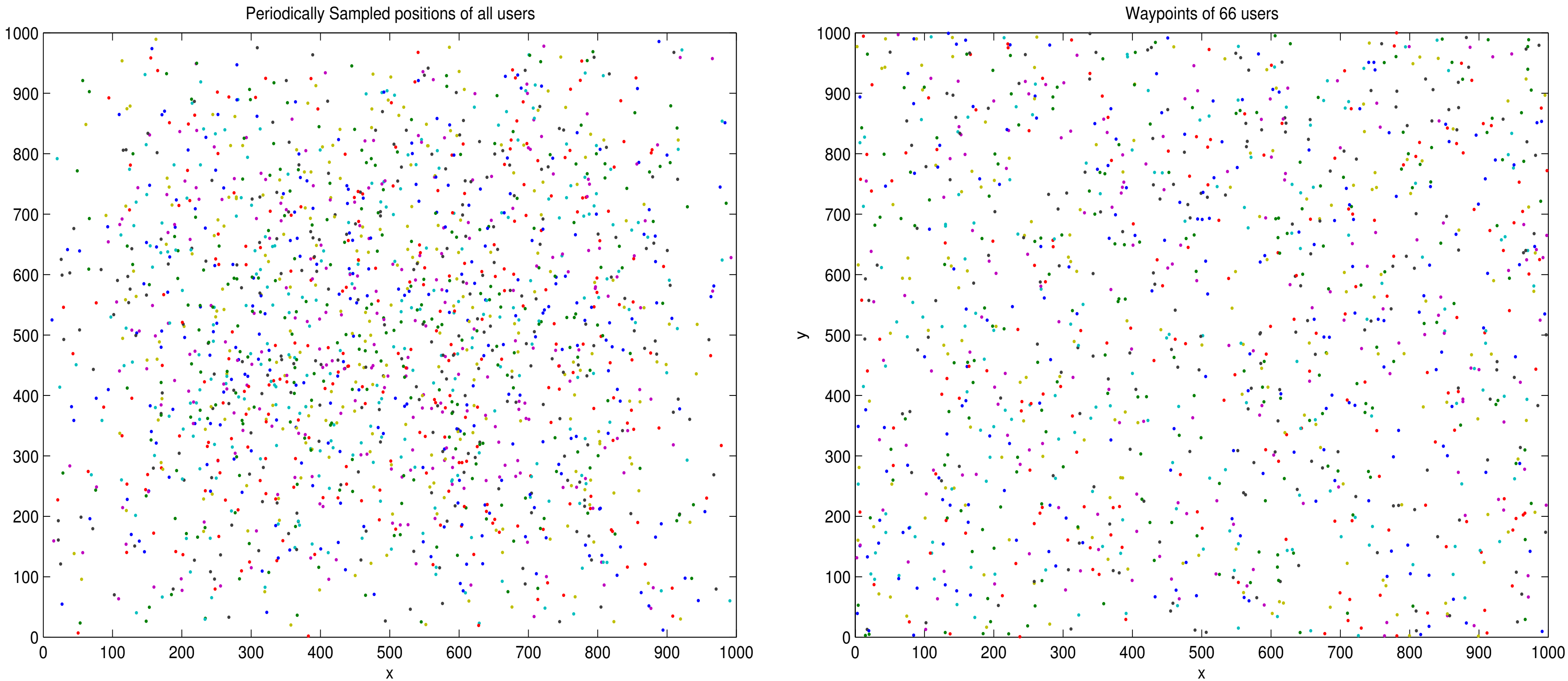
- Some references on RWP and RD models:
  - "`The Node Distribution of the Random Waypoint Mobility Model for Wireless Ad Hoc Networks`", *C. Bettstetter, G. Resta, and P. Santi, 2003*.
  - "`Random Waypoint Considered Harmful`", *J. Yoon, M. Liu, and B. Noble, Infocom 2003*.
  - "`Stationary Distributions for the Random Waypoint Model`", *W. Navid and T. Camp, 2004*.
  - "`Perfect Simulation and Stationarity of a Class of Mobility Models`", *J.-Y. Le Boudec and M. Vojnovic, Best Paper Award Infocom 2005*.
  - "`Properties of Random Direction Models`", *P. Nain, D. Towsley, B. Liu and Z. Liu, Infocom 2005*.

Properties of RWP

- The stationary distributions of location and speed in the random waypoint mobility model `change` with simulation time and differ significantly from the initial uniform distribution.
- In the random waypoint mobility model, the probability of a mobile choosing a new destination that is located in the center of the simulation area, or a destination which requires travelling through the middle of the simulation area, is high.
- Hence, in RWP, nodes are `clustered near the center` of the simulation area, distance between nodes is shorter, performance is better.

Properties of RWP (cont'd)

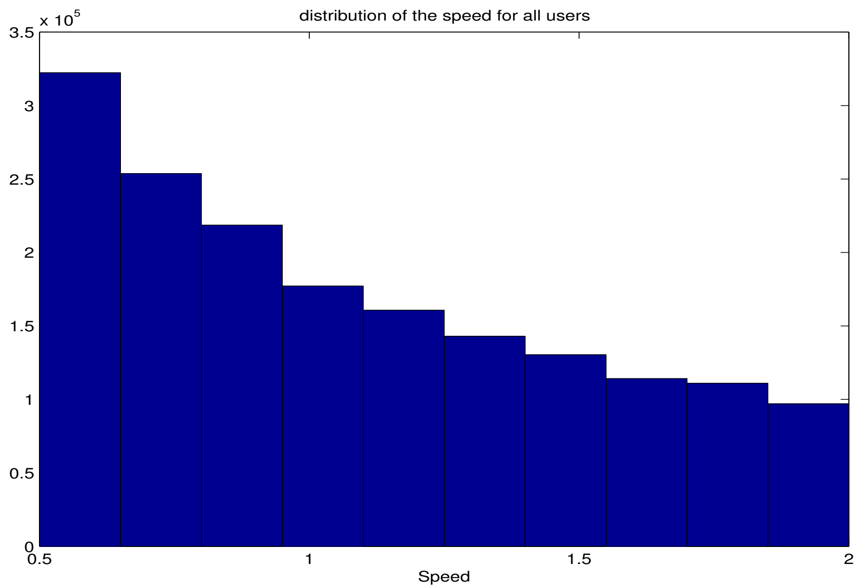
- The stationary distribution of the location of a node sampled at random time instants is more concentrated near the center of the region [a].

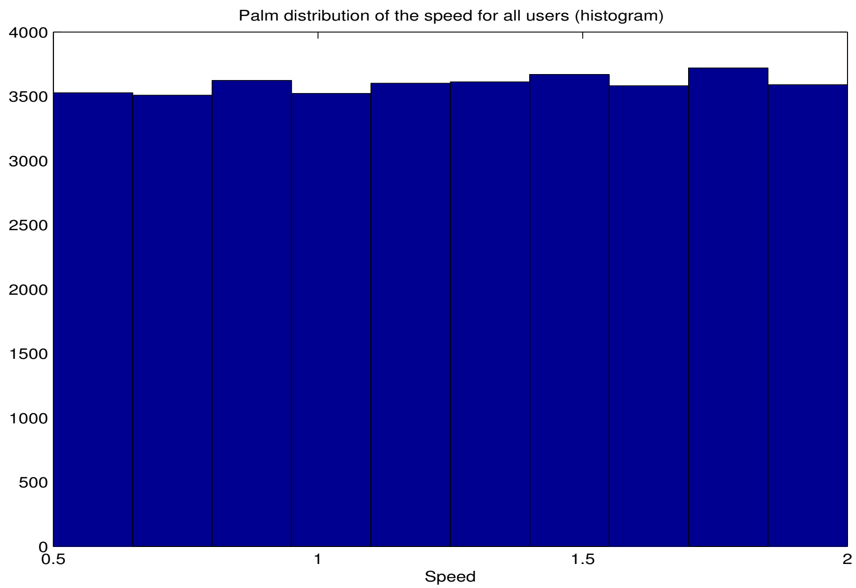


[a] Figure taken from "Understanding the Simulation of Mobility Models with Palm Calculus", by J.-Y. Le Boudec, EPFL technical report.

Properties of RWP (cont'd)

- The stationary distribution of the speed of a node sampled at a random time instants is a decreasing function of the speed: higher probabilities to observe low speeds [a].
- V_{min} needs to be strictly positive to ensure that the average speed over time does not go to zero.





[a] Figure taken from "Understanding the Simulation of Mobility Models with Palm Calculus", by J.-Y. Le Boudec, EPFL technical report.

Properties of RWP (cont'd)

- To avoid this initialization problem of the RWP, there are several solutions.
  - Discard the initial 1000-seconds of simulation time produced by the random waypoint mobility model in each simulation trial.
  - Generate random variables according to the stationary distributions of location and speed and use these variables as the initial values of position and speed. This method is implemented by an open-source tool which can generate perfect simulations for RWP model. The format of the output is that used by NS-2 (with adequate node name choice !).
  - The tool can be downloaded at `http://icawww1.epfl.ch/RandomTrip/` or at `http://www.cs.rice.edu/ santa/research/mobility/`
`(Special attention needs to be taken to ensure independent values during each run of the`

Random direction mobility model

- For RD, the stationary distributions of location and direction of a node have been shown to be uniform irrespective of being reflecting or wrapping around the boundaries.
- Hence, a node moving according to the RD and sampled at random time instants can be found anywhere in the area with the same probability.

Mobility support in NS

- Node mobility in NS can be created by direct Tcl commands or can be provided by an external mobility generator tool which creates a file defining the movement of the nodes.
- Using Tcl commands :
  - We need to provide the initial coordinate locations of the nodes with `$node_(i) set X_`
  - We need also to specify the coordinates of next location as the well as the speed (the waypoint mobility model) using the command `setdest`:

    `$ns_ at time "$node_(i) setdest next_Xcoord next_Ycoord next_speed"`

    Note that when nominating the nodes, the names should be in the format `node_( )` in order to follow the format used by the mobility files of NS.

Mobility support in NS (cont'd)

- Using external mobility generator tools: Mobility files can be generated using some tools like `setdest` which is an independent tool provided with NS (`.../ns/indep-utilities/cmu-scen-gen/setdest/calcdest`), or the previously mentioned tool of the EPFL to generate perfect mobility files according to the RWP, RD, and random walk models.
- Once created in the proper format, the file can be included simply in the Tcl script after the node creation part using:
  `source "fileName"`
- The file can also be defined among the optional parameters at the beginning of the script file and also included using `source`:
  ```
  set opt(cp) "fileName"
  source $val(cp)
  ```

Nam for wireless networks

- The network animator Nam can also be used to visualise the node movements within the network area. However, packet transferts between the nodes cannot be displayed.
- To set up a Nam trace file, we need first to define a trace file, then to setup Nam to use that file through the command `namtrace-all-wireless`:

```
set namtrace [open namtrace-out.nam w]
$ns_ namtrace-all-wireless $namtrace $opt(x)
$opt(y)
```

Some comments

- Unwanted output during simulation run time results from a `printf` command (line 160) in `.../ns/mobile/propagation.cc` file when FreeSpace propagation model is used.
- At the end of the simulations, it is recommanded to reset the internal network components of mobile nodes:
  `$ns_ at stopTime "$node_($i) reset"`
- Note the packet fragmentation procedure at the level of Mac layer.
- Source transmission rate and packet size.

Simulating a wireless scenario

- Write a Tcl, an Awk and a Bash scripts to the following scenario. There is a wireless network of $1000 \times 1000\ m^2$ of N nodes. The nodes move in the area according to some mobility model. We assume that N is an even number, and that half of the nodes are traffic sources for the other half. Source nodes run `CBR` applications which send 1000-$Byte$ packets at the rate of $1.6\ Mb/s$. All the sources start sending data simultaneously at $t_{init} = 20s$, and they stop also simultaneously at $t_{end} = 500s$. Assume that the channel capacity is $2\ Mbits/s$ and the propagation model is that of a free space model. Set queue length of each node to 100. No routing protocol is considered.

Simulating a wireless scenario (cont'd)

1. Set the physical parameters of the nodes in such a way that their transmission ranges are equal to $100\ m$.
2. Write an Awk script that computes that throughput of the network as well as the packet delivery ratio.
3. Include the Awk script at the end of the Tcl script and print its output in a separate file.
4. Write a Bash script that run the previous Tcl for a given number of runs.
5. Run separately the Bash script for two scenarios with N equal to 10: In the first, the nodes move according to the RWP model while in the second they move according to the RD with reflection.
6. Compute the mean total maximal throughput in $bits/s$ and the mean packet delivery ratio of the network obtained under each mobility model for 30 simulation runs. Compute also the confidence interval. Conclude.

Simulating a wireless scenario (cont'd)

- The parameters for RWP are as follows: `speed mean = 7, speed delta = 5, pause time = 0.0, pause time delta = 0.0.`
  The parameters for RD are as follows: `speed mean = 7, speed delta = 5, pause time = 0.0, pause time delta = 0.0, travel time = 50.0, travel time delta = 49.0.`