Simulation of Data Networks S-38.148

CNCL Simulation Exercise

Contents

Chapter 1

Introduction

The purpose of this exercise is to make you familiar with CNCL simulation library. You will learn how to create new simulator blocks with C++ by using the objects and functions provided by CNCL and how to collect statistics from the simulation.

The exercise deals with modelling mobility in adhoc network simulations. Random Waypoint (RWP) mobility model [1] is one of the most often used mobility models. In this exercise connectivity of nodes moving according to this model is studied.

Chapter 2

Background for the exercise

2.1 Random Waypoint Mobility Model

In performance studies of wireless systems, e.g., ad hoc networks, the movement of the users must be modelled. In practice simple synthetic mobility models are often used, since more realistic models are not readily available. Random Waypoint model (RWP) [1] is one of the most widely used synthetic mobility models. In this model, a mobile node basically moves along a zigzag line, where each of the straight line segments is called *a leg*. At each turning point the node chooses a new destination randomly (from uniform distribution in the given area $\mathcal{A}$)and then moves towards the destination at a constant speed, which can be drawn from a given speed distribution at each turning point. The node may also remain stationary for a random think time before starting its movement towards the new destination.

To be exact, the process representing the movement of a node within the simulation area according to the RWP model can be described as follows. Initially, the node is placed into the area at the point P_1 according to a uniform distribution over the simulation area $\mathcal{A}$. Then a destination point (also called waypoint) P_2 is chosen from a uniform distribution and the node moves along a straight line from P_1 to P_2 with constant velocity V_1 drawn independently of the location from a distribution $f_V(x)$. Once the node reaches P_2, a new destination point, P_3, is drawn independently from a uniform distribution over the simulation area and velocity V_2 is drawn from $f_V(x)$ independently of the location and V_1. The node again moves at constant velocity V_2 to the point P_3, and the process repeats. This is illustrated in Figure 2.1.

The simulation area $\mathcal{A}$ can be any convex area. However, in this exercise we will be studying the RWP process in the unit disk. Furthermore, the velocity distributions to be used are: constant velocity and uniformly distributed velocity in the range $[v_{\min}, v_{\max}]$.

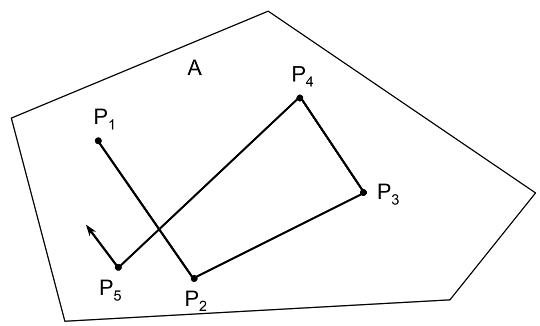

Figure 2.1: Zigzag movement of the RWP process [2].

2.2 Connectivity

In wireless ad hoc network two nodes can communicate directly with each other, if their *transmission radius* is greater than the distance between them. The network is *connected*, if there is a path from every node to every other node. Connectivity is an essential parameter for performance of communication networks, since it tells us whether we can send data to each of the destination nodes. In this exercise, we will study both the probability that the network is connected, i.e., the proportion of time the network is connected, and the mean duration of the connectivity period.

In this exercise we assume that each node has the same maximum transmission radius, which is denoted by d. Then, at an arbitrary time instant, if the distance between two nodes is shorter than the transmission radius, these two nodes are connected with a link. The connectivity of the whole network can be examined for example by the breadth-first search algorithm.

2.2.1 Simulation of connectivity measures

To study connectivity via discrete event simulation, the simulation is carried out by examining the system state (connected/disconnected) between fixed time intervals of length Δ. Thus, the continuous time system will become discretized, but the error from this can be made arbitrarily small by keeping Δ sufficiently small.

Consider a simulation with k nodes with the simulation time being equal to $N{\cdot}\Delta$, and let C_n denote the boolean random variable for weather the network was connected or not during the nth interval,

$$C_n = \begin{cases} 1, & \text{if network is connected at } n\text{th interval,} \\ 0, & \text{otherwise.} \end{cases}$$

Probability of connectivity: Given the number of nodes k and the transmission radius d, the probability of connectivity, $c_{k,d}$ equals the fraction of time the network is connected, and the estimator for it equals

$$\hat{c}_{k,d} = \frac{1}{N \cdot \Delta} \sum_{n=1}^{N} C_n \cdot \Delta = \frac{1}{N} \sum_{n=1}^{N} C_n.$$

Mean length of connectivity periods: To estimate the mean length of the connectivity periods, we need to keep track of "how long" the periods of consecutive connectivity (and disconnectivity) periods are. Let us denote by $\bar{T}_{k,d}$ the mean connectivity length with k nodes, each with a transmission radius d. In the simulation, let T_n denote the length of the nth connectivity period. Thus, the measured variables T_n represent the lengths of the continuous sequences of C_i:s for which $C_i = 1$. More concretely assume that $T_2 = 5 \cdot \Delta$. This implies that in the simulation the second connectivity period consisted of five consecutive sampling periods where the network was connected until it became disconnected again. Thus, the estimator for $\bar{T}_{k,d}$ is simply

$$\hat{T}_{k,d} = \frac{1}{N} \sum_{n=1}^{N} T_n,$$

where N is the total number of connectivity periods observed during the simulation. Note that one actually only needs to record the counts for the connectivity lengths, since we are sampling at fixed intervals.

Chapter 3

Exercise

3.1 Practical Instructions

CNCL is installed in all workstations in computer class B215. Remote login to the workstations is also possible, see the list of workstations from

http://www.ee.hut.fi/unix/hardware.shtml

In order to be able to do the simulation exercise, you have to go through the following steps:

1. Copy the necessary files (source code and Makefile) from the course webpage to your working directory.
2. If your default shell is tcsh, write a shell script including the following line:

   setenv LD_LIBRARY_PATH /usr/lib:/usr/local/lib

   If your default shell is bash, write a shell script with the following:

   LD_LIBRARY_PATH = $LD_LIBRARY_PATH: /usr/lib:/usr/local/lib
   export LD_LIBRARY_PATH

   Execute the script with the command “source usefile”, where usefile is the name of your shell script. By default your shell should be tcsh and these commands should work (you can check your shell type with the command “echo $SHELL”)
3. Edit the source file cncl_sim.c: Implement the required methods and the main program.
4. When you want to compile your program, create first a .depend file with the

command “touch .depend”.

5. Compile the program by “make”.
6. Execute the program with the command “./cncl_sim”.

3.2 General description of the task

The purpose of the exercise is to study how different velocity distributions and the number of nodes in the network affect the connectivity parameters of the network. The system consists of a number of nodes that all move according to the RWP mobility model. Your task is to:

1. Modify the **event_handler()** method in Controller class (and implement other methods if needed) such that the desired data can be collected.
2. Implement the RWP mobility model by modifying the **event_handler()** method in Node class (and by implementing other methods if needed).
3. Implement the main method.
4. Investigate the duration of the periods the system stays connected. You should use two different velocity distributions (constant and uniform distribution) and three values for the number of nodes (2, 5 and 10 nodes).

3.3 Description of the simulator objects

- **Controller** Object contains methods that are used for calculating if the network is connected at a certain time instant. This object controls the program execution and data collection.
- **Node** Object has methods for movement handling.

3.4 Description of the simulator events

In CNCL, objects communicate by sending events to each other. These events will then be handled by the **event_handler()** method of the object. In this exercise the Controller and Node classes can handle events. The used event types are the following:

1. **EV_TIME** Controller’s event to itself every t seconds, where t is a fixed sampling time. The state of the system (connected or not) is studied.

2. **EV_NODE** Node's event to itself when the node arrives to destination point. A new destination point and a new speed are drawn from suitable distributions.

3.5 Results and simulation parameters

After the system has been implemented, you should start collecting results from the simulations: the mean durations of the connectivity periods and the probability of connectivity. As regards the estimated values, you should also show the 95% confidence intervals based on 10 (approximately) independent samples. In practice you can make one long simulation and divide it into 10 parts: from each part you simply estimate the average delay ratio and then use these 10 estimates to calculate the confidence interval (batch means method). Alternatively, you can use completely independent simulation runs. Hint: In simulations, it will be helpful to use a CN-Moments object. Other fixed parameters include:

- Note that the system is not in the steady state at the beginning of the simulation. Implement initial transient control and start data collection after 10 time units.
- The sampling interval (**EV_TIME**) should be less than 0.01 time units.
- The movement area is the unit square.

You should investigate the duration of connection times and the connectivity probability in the following cases:

- **Case1:** Constant velocity $v = 1$. Transmission radius $r = 0.5$. Repeat the simulation with different number of nodes (2, 5, 10).
- **Case2:** Velocity is from uniform distribution $\sim U(0.1, 1.9)$, average speed $\bar{v} = 1$. Transmission radius $r = 0.5$. Repeat the simulation with different number of nodes (2, 5, 10).
- **Case3:** For both velocity distributions, repeat the simulation in 5 node case with several transmission radii $r = \{0.3, 0.4, 0.5, 0.6, 0.7\}$.

In your final report, present your results either in the form of graphs of tables and discuss the following issues: How the number of the nodes affects the connectivity? How transmission radius affects to the connectivity? Does the velocity distribution have an effect on the duration of the connectivity period? Does the velocity distribution have an effect on the probability of connectivity?

3.6 Handout requirements

The following items should be included in your final report:

- All source code with comments
- Graphs of the simulation results
- Brief analysis of the results

3.7 Getting help

The students are **strongly** encouraged to attend the two exercise classes that are organized as "question hours" in the computer class room B215. The idea is that the assistant will be present there to answer your questions and maybe even to help in solving some specific problems. The dates for the question hours dealing with CNCL are:

- Wednesday, November 17, at 13-15 in B215
- Wednesday, December 1, at 13-15 in B215

In case the above is not enough, contact the assistant of the exercise (laura.nieminen@hut.fi).

3.8 Returning

The deadline of the exercise is 14.01.2005 at 16 o'clock. Return your report and codes via e-mail to following address: laura.nieminen@hut.fi

Bibliography

[1] D. B. Johnson, D. A. Maltz, "Dynamic source routing in ad hoc wireless networks", in Mobile Computing (eds. Tomatz Imilinski and Hank Korth), Kluwer Academic Publisheshers, 1996, pp. 153–181.

[2] E. Hyytiä, P. Lassila, L. Nieminen and J. Virtamo, Spatial Node Distribution in Random Waypoint Mobility Model, 2004, submitted for publication