Assignment 3

Due November 25^{th} 2009

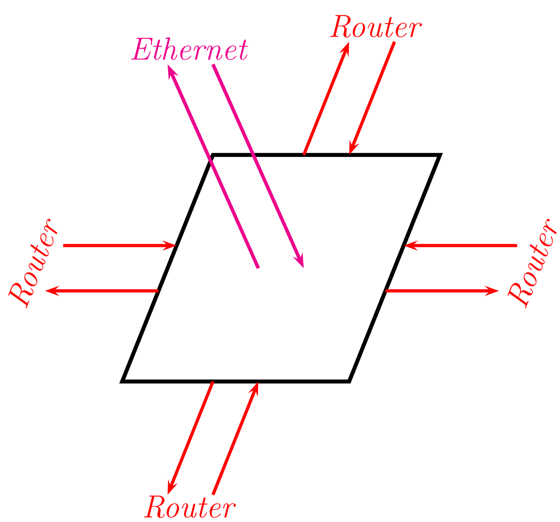
Discrete simulation of computer systems. Modelling input. Processing output.

The problem

In this assignment you will model the behaviour of simplistic network routers with the objective of discovering the relationship between traffic patterns and packet loss.

A router

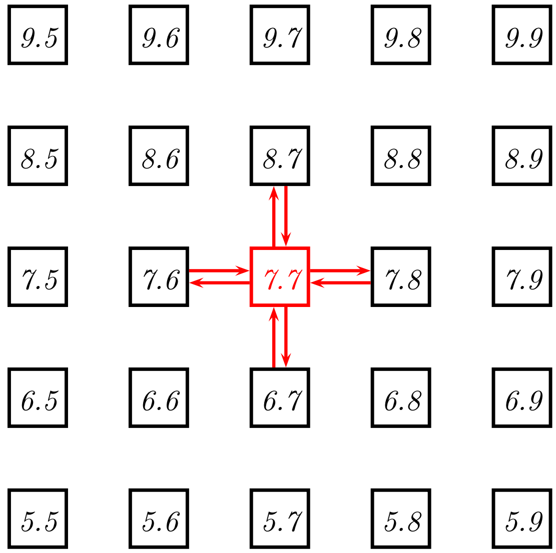
A (very) simplified 4×4 router looks like this:



This router is connected to 4 other routers and to an Ethernet switch.

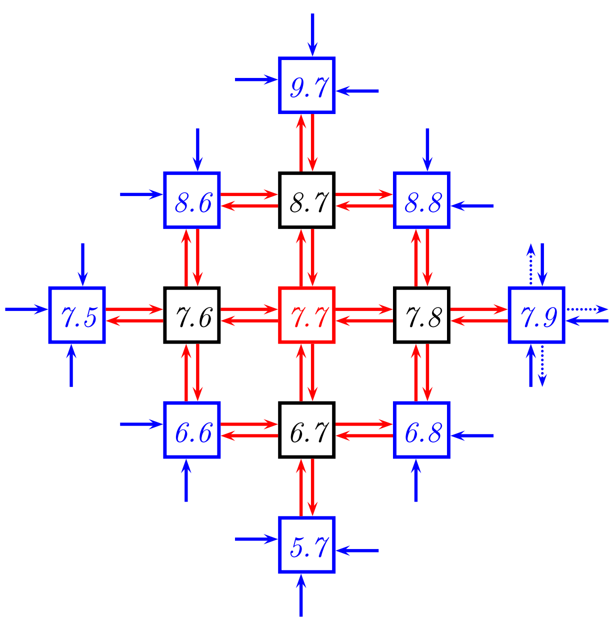
Note that the links are unidirectional, so that traffic can flow simultaneously to and from a neighbouring router (same applies to the Ethernet switch).

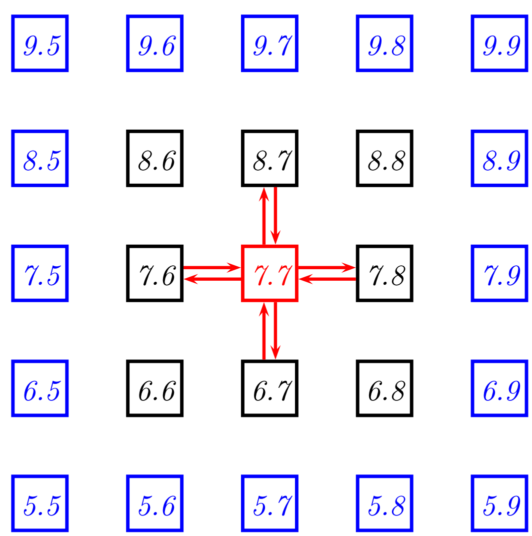
All the routers are identical. For simplicity, all the routers have addresses in the form of a pair $x.y$ with **our** router having the address *7.7*. The routers form a grid which is shown in part:



Packets arrive through all the 5 input links. Initially all the packets appear at the Ethernet link of some router. The random variable describing the interarrival times is unknown and will have to be modelled based on the empirical sample that is available in file **Ethernet**. This file contains a sample of interarrival times of packets showing up at the **Ethernet link** of one sample router.

Your model will include only a small set of routers. This set could look like one of the two diagrams below[1]





Note that the routers can be divided into two groups: the inner and the outer routers. The inner routers receive packets sent by their neighbouring routers. The traffic coming through

[1]Some arrows are missing from the diagrams due to excessive laziness.

the blue links needs to be modelled. We need to create a random variable modelling the interarrival times of packets coming through one blue link and assume that all blue links have identical traffic patterns. This random variable is unknown and will have to be modelled based on the empirical sample that is available in file **ExternalWorld**. This file contains a sample of interarrival times of packets showing up at one **incoming link** of one sample router.

It is not trivial to render the exact decision process that makes packets pass through the blue links. Some arbitrary decisions might be necessary here.

Note also that the outgoing blue links are irrelevant.

Each packet has several attributes:

a length which is a variate from an unknown distribution. Some sample points are available in Packet lengths; use these points to model the distribution of lengths. The lengths are in bits and include packet headers. Please remember to choose an upper bound on packet size that does not exceed 4800 bits.

a source address which is uniformly distributed over the two dimensional grid (0,0) to (10,10).

a destination address which is modelled in the same way as the source address but must be different from it and must be such that one of the modelled routers is between the source and the destination.

When a packet reaches a router, the following steps are performed by the router:

1. The destination address is checked. If it matches the router's own address, the packet is moved to the Ethernet interface.
2. Otherwise, the packet is moved to an output link. The output link is chosen in the following way:
   - **Only links leading to routers closer to the packet's destination are considered.**
   - If there are two such links, the one with a less full buffer is chosen. A link with a full buffer cannot be considered. In the case of a tie, a link is chosen at random.
   - If no link can be chosen (the eligible links have full buffers), the packet is **dropped**.

   The operation of moving a packet to an output link is instantaneous.

The internals of a router

The router has a separate output buffer associated with each outgoing link. The size of this buffer is $\mathcal{B}$ bits, a simulation parameter.

When a packet is being transmitted (inserted into a link), it still occupies space in the buffer. The space is released the very moment the last bit of the packet is sent.

Parameters and constants

The model has two parameters:

$\mathcal{B}$ the buffer size in bits. Possible values range from 4800 bits to 48000 bits

Traffic intensity τ by which all the interarrival times are to be multiplied. τ should be decreased until clear overload is seen from the simulation output.

The simulator will use the following constants:

P the propagation delay of a link (time between the moment a bit leaves one router and the moment when it reaches the next) equal to $100ns$. There is no propagation delay for bits sent to an Ethernet switch.

R the transmission rate (the time it takes to send one bit) equal to $10n$.

Simulation

Your task is to model the behaviour of "out" router (7.7). The following properties are of interest:

Packet loss as a function of τ. This is the ratio of bits deleted divided by bits that the router received.

Delay in router as a function of τ. This is the time that elapsed between the moment a bit reached the router and the moment it was sent out.

Throughput as a function of τ. Throughput is defined (this assignment **only!**) as the number of bits transmitted out of router 7.7 (into any of the 5 output links). per unit of time.

All these properties will be modelled as a function of the buffer size $\mathcal{B}$.

What to do?

You are to write a simulator that simulates the behaviour of 7.7 and all the routers located not farther than 2 hops away from it (you can simulate a larger grid, if it is more convenient).

The inputs to the outer routers are to be modelled as stochastic processes; the inputs to the inner routers are to simulated accurately. You will have to put some thought into ways of capturing the possibility of a packet going from 1.1 to 9.9 passing through the simulated area (this will be a stochastic model).

Submission rules

You will deliver your assignment work in person at a time scheduled in advance (a sign–up sheet will be available). You must bring with a filled copy of the self–evaluation form.

A simplistic simulator traffic inside one router will be available. It will be of little use other as a means of clarifying doubts.

Grading

The assignment is worth 20 marks which are distributed as follows:

	action	marks
1	One router: one input link works	2
2	One router: all input and output links work	2
3	Two routers work together	2
4	The input processes are modelled	4
5	7.7 moves packets to/from its 5 neighbours	2
6	A grid of routers works together	2
7	Output statistics are collected correctly	2
8	Confidence intervals are built	4
9	Graphic presentation of simulation output done	2

Part 4 requires a standard test (such as χ^2). Part 8 must use Student's. Part 9 will have $\frac{1}{\tau}$ as its x–axis.

This assignment must be full of errors. A reward of 1 mark will be given to the first student who points out a relevant error.

Assignment 3

Self evaluation form

Name: ______________________ Student ID# ______________ Total: [ ]

Step	Done correctly	Not done	Other (explanation)
1			
2			
3			
4			
5			
6			
7			
8			
9			

1	2	3	4	5	6	7	8	9
2	2	2	4	2	2	2	4	2