Student Name	Date 16/09/09

NETWORKS AND PROTOCOLS

Laboratory 1

Objective

This experiment is an introduction to OPNET. You will become familiar with the structure of OPNET models and some aspects of the behaviour of Packet Switched networks.

You will configure network nodes and select statistics to be collected during simulation runs.

Lab Procedure:

Preliminary

Go to the course web page and download the zip file *Lab2_network.zip*.

Extract the zip file into the directory **op_models** in "**Documents & Settings/netengineer**".

Select **File > Model Files > Add Model Directory**.

Select **Program Files/OPNET/11.0.A/Models/tutorial_ref/modeler**. ***Note: Change the version of OPNET accordingly ***

Click OK.

Confirm the selection and include all sub-directories. Do not select it as default directory.

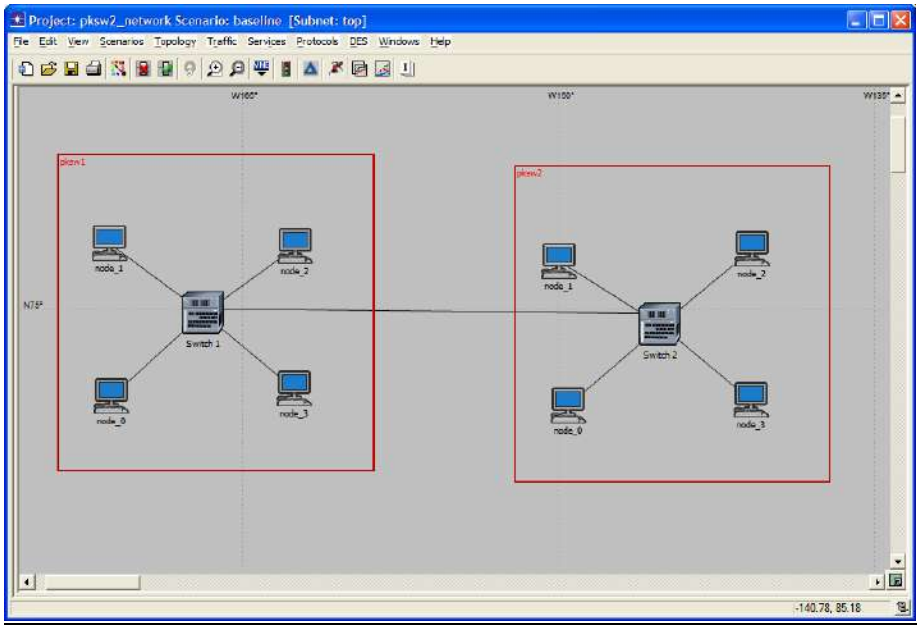
***Note: Follow the above instruction strictly ***

Choose **Manage Model Files,** then **Refresh Model Directories.** Then choose **Open** and select the project *pksw2_network* that you have just installed in **op_models**.

Save the project under a new name, e.g. <**your initials_pksw2**>. ***Note: You can create sub-directory to save your work and give a different but meaningful name ***

You have a model of Packet Switched network, made of 2 interconnected networks, pksw1 and pksw2.

In each network, a packet switch switches packets between its links based on a destination address contained in the packet.



Step 1: Links

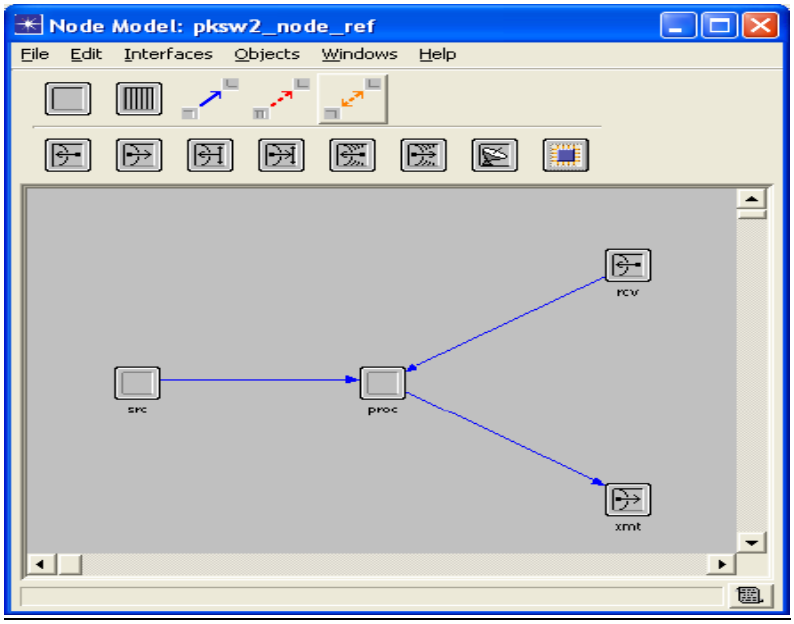
The links are duplex links: packets can be transmitted while other can be received.

Right-click on the link between the 2 switch nodes, and select Edit Attributes. Check that the data rate is 9600 bits/sec; enter the value if necessary.

Right-click on one of the links between a node_*x* and a switch, and select Edit Attributes. Check that the data rate is 9600 bits/sec; enter the value if necessary.

Step 2: Node_x

Right click on one of the nodes called *node_x*, and select **Edit Node Model**. Observe the structure of the node.



Module *src* is a packet generator; right click on the module and select “Edit Attributes”.

Observe the main characteristics of the packet generation: Packet size, Packet inter-arrival time (time between successive packets). As the module *src* is used by all nodes node_x, these characteristics are common to all nodes of this type.

Left-click on Packet Size in the value column: you are offered the possibility to change the distribution of the size and its average value. Set the packet size to a constant distribution and a value of 2400 bits.

Left-click on Packet Inter-arrival time in the value column: you are offered the possibility to change the distribution of the time and its average value. Set the distribution to “exponential” distribution and the average value to 1 second.

Note: arrival of packets in a packet switching node in data communications, or calls in a telephony switch, does not happen at a fixed deterministic rate, but is commonly described as a type of random process called Poisson process which is characterized by the way the possible values of the inter-arrival times are distributed (i.e. exponentially).

Close the view for the “src” attributes and **save** the module.

Module proc: In the *proc* module, packets are received from the generator (*src*) or from the packet switch, via the *rcv* module.

Packets received from the generator are allocated a destination network address (pksw1 or pksw2), and a destination node address.

In this simple example, a network address is randomly selected, so that:

- half the packets arriving from sources inside pksw1 (resp. pksw2) are forwarded by the packet switch to destinations within pksw1 (resp. pksw2)

- the other half of packets arriving from sources inside pksw1 (resp. pksw2) is forwarded to destinations within pksw2 (resp. pksw1).

A destination address (node) is then randomly selected using a uniform distribution between the 4 possible hosts within a network.

The packet is then sent to the packet switch using the transmitter module *xmt*.

Step 3: Packet switch:

On reception of a packet, the packet switch analyses the address and, depending on the network destination, the packet switch forwards locally (i.e. in the same network, pksw1 or pksw2) to the host address, or sends the packet on the link to the other network.

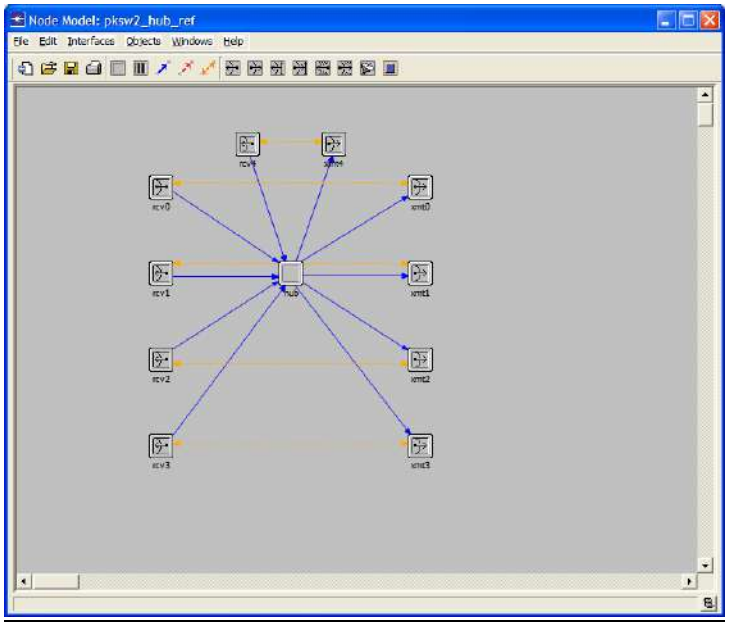
In the Packet switch as well as in the node_x modules, the *rcv* and *xmt* modules are a transmitter and receiver module, essentially characterized by the bit rate at which they send or receive bits, and, for the xmt modules, a certain buffer capacity (capacity to store packets before they are transmitted, when the link is already being used to transmit another packet). Initially, all transmitters and receivers should operate at 9600 bits/sec.

Right click on the node called *switch1*, and select **Edit Node Model**. Observe the structure of the node.

Right-click on the *rcv4* modules and select *Edit attributes*; expand *Channel – Row 0*, to verify the data rate. Change the data rate to 9600 bits/sec if it is not set to this value.

Right-click on the *xmt4* modules and select *Edit attributes*; expand *Channel – Row 0*, to verify the data rate and the buffer capacity in packets. Change the data rate to 9600 bits/sec if it is not set to this value. Note the buffer capacity.

Save and close the Packet switch view.



Step 4:

Based on the parameters obtained in previous steps, you must calculate the expected values for the throughput (bits/s, and pk/s) and utilization, for the pksw1 to pksw2 link one way.

⇨ *(Step4) Document Results*

Note: You know how many packets are transmitted per second by each source node, and how many bits there are per packet on average.
You know how many source nodes are transmitting packets in one network.
You know what proportion of packets generated in one network is forwarded to the other network, via the pksw1 to pksw2 link.
You know the capacity of the links.

Step 5: Choose Statistics

Right-click anywhere in the network view, and select:

Choose individual DES statistics>Global statistics>*ETE delay*,

Select the link between pksw1 and pksw2, right click on it, and select, for one direction:

Choose individual DES statistics>Point-to-Point> *Queuing Delay*, *Throughput (bits/sec)*, *Throughput (packets/sec), and Utilization*.

Note: After selecting **Queuing Delay**, right-click on it and select "**Change Collection Mode**". In the new panel, check the **Advanced** box, and select "**all values** " in the top drop down menu.

OPNET can capture a statistic by collecting the values taken by a characteristic of a network in different ways: over a period called a bucket, the sum, the max, the sum/time, … of the values taken may be calculated and stored, or all values taken may be recorded.

Select the packet switch node in pksw1 and right click on it. Select:

Choose individual DES statistics > Module statistics > xmt4.channel[0] > point-to-point transmitter > Queue size (packets).

Note:When selecting **Queue size**, right-click and select "**Change Collection Mode**". In the new panel, check the **Advanced** box, and select "**all values** " in the top drop down menu.

ETE = End To End delay: mean latency measured between creation of the packet and reception in destination node

Queuing delay: Measurements taken from the time a packet is available for transmission to the time the last bit of the packet is transmitted (i.e. buffer time + transmission time).

Queue size (packet switch): number of packets present on average in the transmitter module of the packet switch before transmission to the other network.

Click OK. Save the project (under the name chosen in step 1).

In **Scenarios**, select **Manage Scenarios**. Rename the scenario S1. Left-click in the Results column and select "**collect**", set the duration equal to 5 hours and click OK.

The simulation executes, simulating 5 hours of operation. Allow the simulation sequence to complete before clicking Close.

Questions:

1- After completion right-click on the network view, and select *View results*. Find and click on the pull down menu showing "*As is*", and select "*average*" instead.

Select the ETE delay in *Global Statistics*.

Click on "Show" to open a window with a particular statistics, and click and drag the arrow to open a zoom window around an area of interest, to read an estimate for the performance. Note the result.

⇨ *1(a) Document Results*

In *Object statistics*, observe the statistics between pksw1 and pksw2: Throughput, Queuing delay and Utilization.

Note the results for the pksw1 to pksw2 link.

⇨ *1(b) Document Results*

Compare the calculated results (in Step 4) with those obtained by simulation: investigate any significant difference.

⇨ *1(c) Document Results*

2- In scenario S1, observe the statistics for the Queue size in pksw1/packet switch/xmt4/ channel[0]/point-to-point transmitter. Look at the statistics for both *time_average* and *As Is*.

Note the maximum number of packets at any time in the queue, and the average number over time.

Calculate the transmission time for a packet.

⇨ *2(a) Document Results*

Compare with the queuing delay (see definition in Step 5) between pksw1 and pksw2, observed with "*average*" display. Explain the possible origin for the difference.

⇨ *2(b) Document Results*

3- Create a new scenario, S2, using the *Duplicate Scenario* option in the *Scenarios* menu. In the packet generator, change the values of the packet size to 4800 and the inter-arrival time to 2 seconds. Simulate, and report the ETE (Global).

⇨ *3(a) Document Results*

Calculate and report the expected values for the throughput (bits/s, and pk/s) and utilization, for the pksw1 to pksw2 link one way

⇨ *3(b) Document Results*

Then in *Object statistics*, observe the statistics for the pksw1 to pksw2 link: Throughput, Queuing delay and Utilization. Note the simulation results.

⇨ *3(c) Document Results*

Compare the calculated results with those obtained by simulation: investigate any significant difference.

⇨ *3(d) Document Results*

4- Create a new scenario, S3, using the *Duplicate Scenario* option on S2. In the packet generator, change the values of the inter-arrival time to 1 seconds and the packet size to 5000 bits. Run the simulation.

Observe the ETE (Global), Throughput, Queuing delay, Queue size and Utilization (between pksw1 and pksw2, one way). Suggest an explanation that matches the observed results.

Hint: note how many bits network pksw1 attempts to send over to network pksw2 per second, and compare the pksw1 to pksw2 link capacity.

⇨ *4(a) Document Results*

5- Create a new scenario, S4, using the *Duplicate Scenario* option on S3. Double the capacity of the link between the 2 packet switchs:

- Right click on the link between the 2 packet switches, and select **Edit Attributes**; change the data rate to 19200.
- In one of the 2 packet switchs select **Edit Node Model**, then select successively the *rcv4* and *xmt4* modules and right-click to select **Edit Attributes**. Change the data rate to 19200 in *rcv4* and *xmt4 (channel/row 0)*.

Simulate and report the ETE (global), Throughput, Queuing delay, Queue size and Utilization (between pksw1 and pksw2, one way).

⇨ *5(a) Document Results*

Explain the effect of increasing the data rate on the packet switch-to-packet switch link, on the queuing delay and queue size.

⇨ *5(b) Document Results*