Lab Exercise 6: Throughput, IP Fragmentation and Routing

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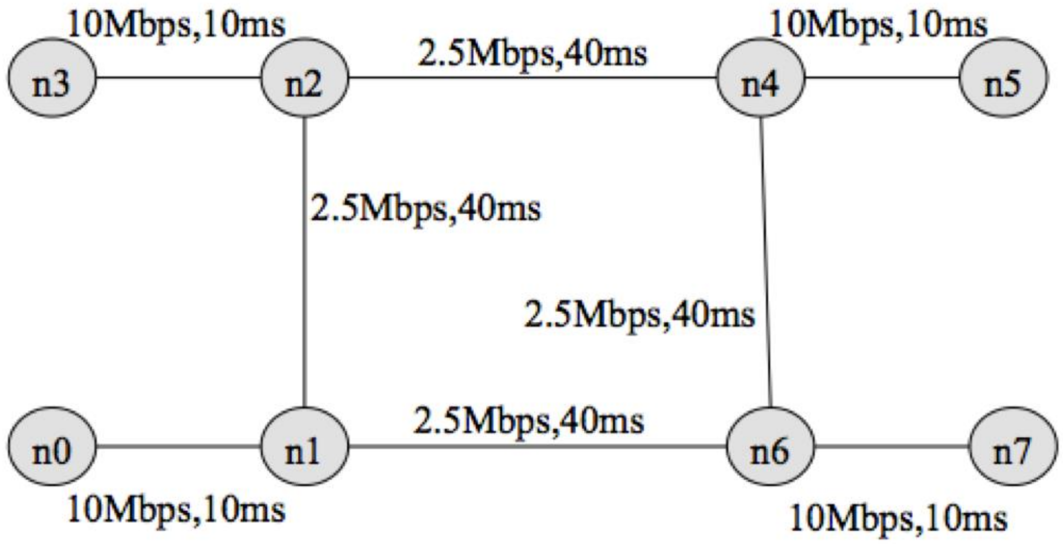
Exercise 1: Setting up NS2 simulation for measuring TCP throughput

Consider the topology shown in the following figure where bandwidth and delay for each link is shown.



You have been provided with a stub tcl file exercise2.tcl . Your task is to complete the stub file so that it runs with ns and produces two trace files tcp1.tr and tcp2.tr, and nam.out. Check the animation for the simulation using nam.out file. Next write a script named "throughput.plot" (referenced from within exercise2.tcl in procedure finish( )) to plot the throughput received by host n5 for two flows terminating at n5. Uncomment the line (#exec gnuplot throughput.plot &) to execute gnuplot. You have been provided with the throughput plot TCPThroughput.png produced by gnuplot for comparing your final output.

">>" in the stub file indicates that one (or more) lines need to be added. Remove the ">>" and insert the required code.

Consider the following traffic pattern for your simulation.

FTP/TCP Source n0 -> TCP Sink n5 : start time: 0.5 sec End time: 8.5 sec

FTP/TCP Source n3 -> TCP Sink n5 : start time: 2.0 sec End time: 9.5 sec

FTP/TCP Source n7 -> TCP Sink n0 : start time: 3.0 sec End time: 9.5 sec

FTP/TCP Source n7 -> TCP Sink n3 : start time: 4.0 sec End time: 7.0 sec

You have to submit your completed tcl file (exercise2.tcl) and the script (throughput.plot) for producing the throughput plot. Comment on the throughput behaviour observed in the simulation by answering the following questions.

Question 1: Why the throughput achieved by flow tcp2 is higher than tcp1 between time span 6 sec to 8 sec?
Flow tcp1 is competing with flow tcp4 on link n1-n2 and link n2-n4. Flow tcp2 has less RTT and it gets higher share of the bandwidth on link n2-n4, which is recorded at n5.

Question 2: Why the throughput for flow tcp1 is fluctuating between time span 0.5 sec to 2 sec?
Flow tcp1 is using Slow Start mechanism

Question 3: Why is the maximum throughput achieved by any one flow capped at around 1.5Mbps?
Between 0.5 – 2.0 sec, tcp1 is the only flow active, but it is still in the SS phase and have to compete with the other flows starting at 2.0 sec before it can discover the maximum bandwidth.

Exercise 2: Understanding IP Fragmentation

(Include in your report)

We will try to find out what happens when IP fragments a datagram by increasing the size of a datagram until fragmentation occurs. You are provided with a Wireshark trace file IPfrag_trace that contains trace of sending pings with specific payloads to 8.8.8.8. We have used ping with option (– s option on Linux) to set the size of data to be carried in the ICMP echo request message. Note that the default packet size is 64 bytes in Linux (56 bytes data + 8 bytes ICMP header). Also note that Linux implementation for ping also uses 8 bytes of ICMP time stamp option leaving 48 bytes for the user data in the default mode. Once you have send a series of packets with the increasing data sizes, IP will start fragmenting packets that it cannot handle. We have used the following commands to generate this trace file.

Step 1: Ping with default packet size to the target destination as 8.8.8.8

```
ping -c 3 8.8.8.8
```

Step 2: Repeat by sending a set of ICMP requests with data of 2000.

```
ping -s 2000 -c 3 8.8.8.8
```

Step 3: Repeat again with data size set as 3500

```
ping -s 3500 -c 3 8.8.8.8
```

Load this trace file in Wireshark, filter on protocol field ICMP (you may need to clear the filter to see the fragments) and answer the following questions.

Question 1: Which data size has caused fragmentation and why? Which host/router has fragmented the original datagram? How many fragments have been created when data size is specified as 2000?

Because MTU is 1500 bytes, both 2000 and 3500 bytes payload would cause fragmentation. 192.168.1.103 has fragmented the original datagram, and 2 fragments have been created when data size is specified as 2000.

Question 2: Did the reply from the destination 8.8.8.8. for 3500-byte data size also get fragmented? Why and why not?

Yes, since the MTU for the last link is 1500 bytes, we cannot be sure who fragmented the original 3500 bytes reply.

Question 3: Give the ID, length, flag and offset values for all the fragments of the first packet sent by 192.168.1.103 with data size of 3500 bytes?

Packet 39: ID=0x7a7b, length=1500, flag=0x01(MF bit on), offset=0

Packet 40: ID=0x7a7b, length=1500, flag=0x01(MF bit on), offset=1480

Packet 41: ID=0x7a7b, length=568, flag=0, offset=2960

Question 4: Has fragmentation of fragments occurred when data of size 3500 bytes has been used? Why and why not?

No fragmentation of fragments has occurred for the reply from 8.8.8.8 for data size of 3500. We cannot be sure the fragmentation from 192.168.1.103 to 8.8.8.8 since the reassembly is only done at the destination.

Question 5: What will happen if for our example one fragment of the original datagram from 192.168.1.103 is lost?

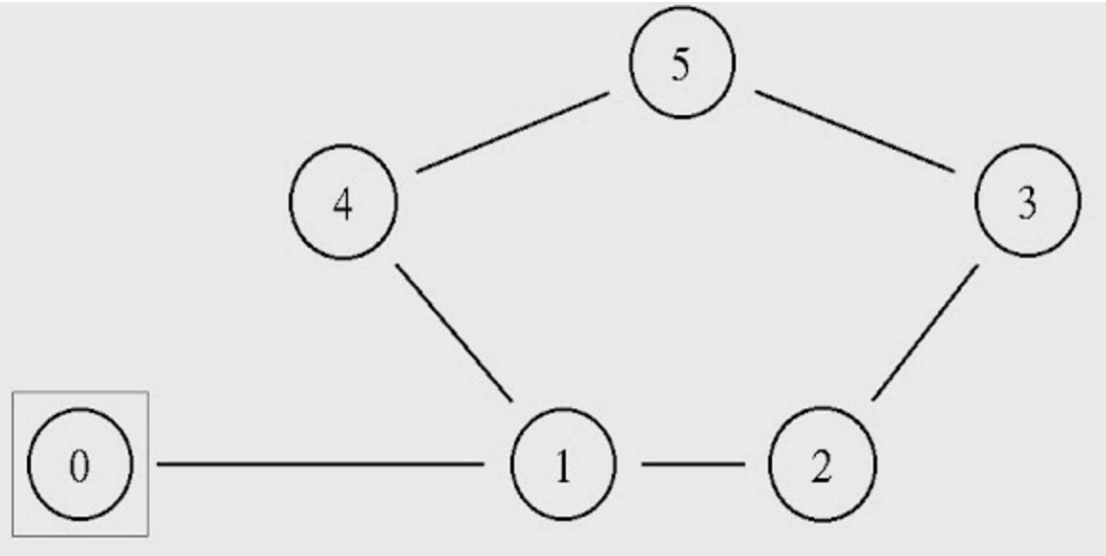
The fragments would be incomplete, and the receiver would discard.

Exercise 3: Understanding the Impact of Network Dynamics on Routing

(include in your report)

In this exercise, we will observe how routing protocols react when network conditions change (e.g., a network link fails) using a ns-2 simulation.

The provided script, tp_routing.tcl takes no arguments and generates the network topology shown in the figure below.



You can run the simulation with the following command:

```
$ns  tp_routing.tcl
```

Step 1: Run the script and observe the NAM window output.

Question 1: Which nodes communicate with which other nodes? Which route do the packets follow? Does it change over time?

Note: You can also answer the above question by examining the simulation setting in the script file.

Step 2: Modify the script by uncommenting the following two lines (line No 84 and 85):

```
$ns  rtmodel-at  1.0  down  $n1  $n4

$ns  rtmodel-at  1.2  up  $n1  $n4
```

Step 3: Rerun the simulation and observe the NAM window output.

NOTE: Ignore the NAM syntax warnings on the terminal. These will not affect the simulation.

Node 0 -> Node 5 (0-1-4-5)

Node 2 -> Node 5 (2-3-5)

It does not change over time.

Question 2: What happens at time 1.0 and at time 1.2? Does the route between the communicating nodes change as a result of that?

Step 4: The nodes in the simulation above use a static routing protocol (i.e., preferred routes do not change over time). We are going to change that, so that they use a Distance-Vector routing protocol. Modify the script and uncomment the following line (Line No 16) before the definition of the finish procedure.

```
$ns rtproto DV
```

Step 5: Rerun the simulation and observe the NAM window output.

At time t=1.0, link 1-4 goes down, node 0 – node 5 not changed, node 0 cannot reach node 5

At time t=1.2, link 1-4 goes up, node 0 can reach node 5, node 1 can reach node 4

Traffic between node 2 and node 5 does not affected.

Question 3: Did you observe any additional traffic as compared to Step 3 above? How does the network react to the changes that take place at time 1.0 and time 1.2 now?

Step 6: Comment the two lines (Lines 84 and 85) that you had added to the script in Step 2 and uncomment the following line (Line 87) instead:

```
$ns cost $n1 $n4 3
```

Step 7: Rerun the simulation and observe the NAM window output.

The DV routing protocol discovers a different route (0-1-2-3-5) when link 1-4 goes down. When 1-4 goes up, the routing protocol is 0-1-4-5.

Question 4: How does this change affect the routing? Explain why.

Step 8: Comment line 87 and Uncomment the following lines (Lines 89 and 90):

```
$ns cost $n1 $n4 2
$ns cost $n3 $n5 3
```

and uncomment the following (Line 29), which is located right after the finish procedure definition:

```
Node set multiPath_ 1
```

Step 9: Rerun the simulation and observe the NAM window output.

The cost of link 1-4 increase to 3, the cost of 0-1-4-5 is 4, and the cost of t0-1-2-3-5 is 4. Therefore, the flow between node 0 and node 5 now uses route 0-1-2-3-5, because it has the lowest cost.

Question 5: *Describe what happens and deduce the effect of the line you just uncommented.*

For node 0 and node 5, the total cost does not change. But from node 2 to node 5, there are two routes of equal total cost (2-3-5 and 2-1-4-5). Since the network is using multipath routing, node 2 will split traffic equally on both paths.