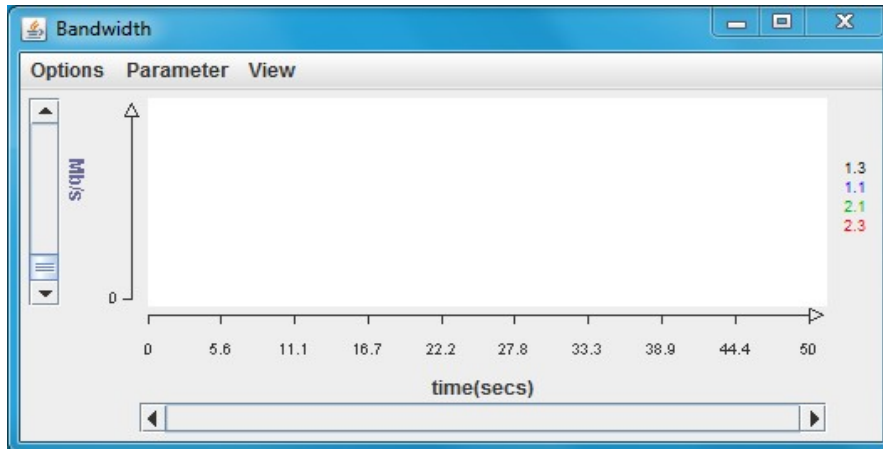
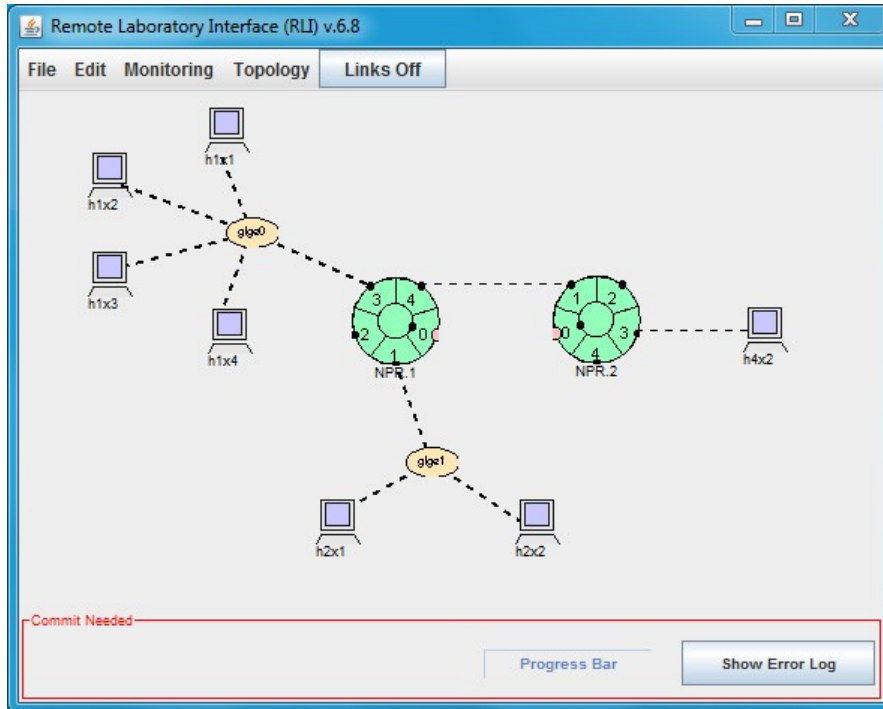


# ECE 671 – Computer Networks

## Fall 2011 – Lab 1-Solution

### Topology



## Part 1: Set IP Address in the Routing Table

Table1. Routing table of NPR1 and NPR2

NPR1					
Port 1		Port 3		Port 4	
Prefix/ mask	Next port	Prefix/ mask	Next port	Prefix/ mask	Next port
192.168.1.0/24	3:0.0.0.0	192.168.1.0/24	3:0.0.0.0	192.168.1.0/24	3:0.0.0.0
192.168.2.0/24	1:0.0.0.0	192.168.2.0/24	1:0.0.0.0	192.168.2.0/24	1:0.0.0.0
192.168.4.0/24	4:192.168.3.2	192.168.4.0/24	4:192.168.3.2	192.168.4.0/24	4:192.168.3.2

NPR2			
Port 1		Port 3	
Prefix/ mask	Next port	Prefix/ mask	Next port
192.168.1.0/24	1:192.168.3.1	192.168.1.0/24	1:192.168.3.1
192.168.2.0/24	1:192.168.3.1	192.168.2.0/24	1:192.168.3.1
192.168.4.0/24	3:0.0.0.0	192.168.4.0/24	3:0.0.0.0

Table 2 Routing table of Hosts

Hosts	Prefix/Mask	Next hop
h1x1, h1x2 h1x3, h1x4	192.168.1.0/24	0:0.0.0.0
	192.168.2.0/24	0:192.168.1.5
	192.168.4.0/24	0:192.168.1.5
h2x1, h2x2	192.168.2.0/24	0:0.0.0.0
	192.168.1.0/24	0:192.168.2.3
	192.168.4.0/24	0:192.168.2.3
h4x2	192.168.4.0/24	0:192.168.4.1
	192.168.2.0/24	0:192.168.4.1
	192.168.1.0/24	0:192.168.4.1

```

jinz@pclcore65:~
[ 3] 0.0-10.0 sec 13.7 MBytes 11.5 Mbits/sec
[jinz@pclcore65 ~]$ ping -c 5 h4x2
PING h4x2 (192.168.4.2) 56(84) bytes of data:
64 bytes from h4x2 (192.168.4.2): icmp_seq=1 ttl=62 time=50.1 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=2 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=3 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=4 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=5 ttl=62 time=50.0 ms

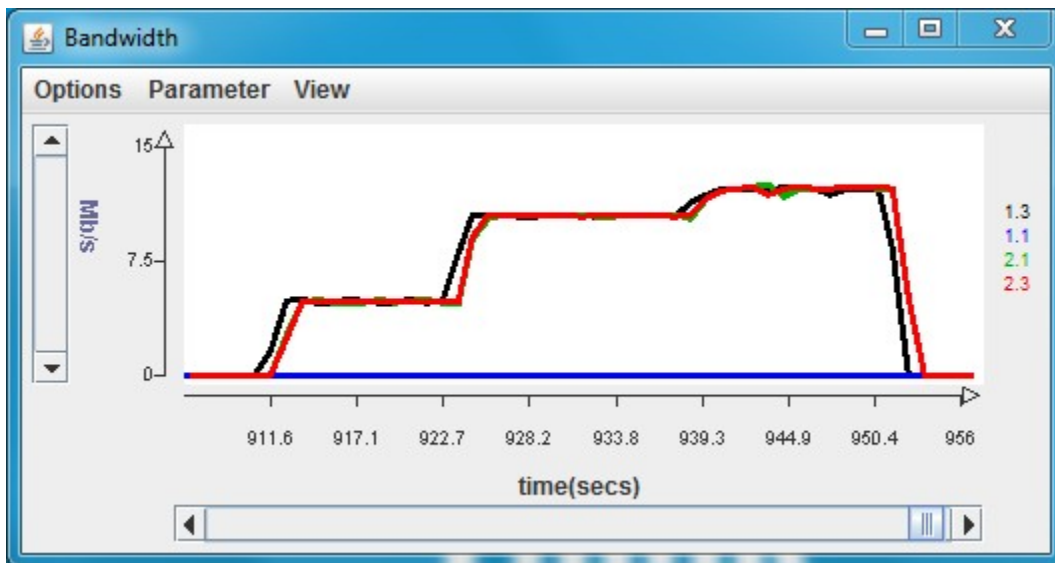
--- h4x2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 3999ms
rtt min/avg/max/mdev = 50.083/50.092/50.111/0.283 ms
[jinz@pclcore65 ~]$ ping -c 5 h4x2
PING h4x2 (192.168.4.2) 56(84) bytes of data:
64 bytes from h4x2 (192.168.4.2): icmp_seq=1 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=2 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=3 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=4 ttl=62 time=50.0 ms
64 bytes from h4x2 (192.168.4.2): icmp_seq=5 ttl=62 time=50.0 ms

--- h4x2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4000ms
rtt min/avg/max/mdev = 50.088/50.090/50.095/0.283 ms
[jinz@pclcore65 ~]$
  
```

Figure 1 check the connection establishment by ping command

## Part 2: TCP Congestion Control

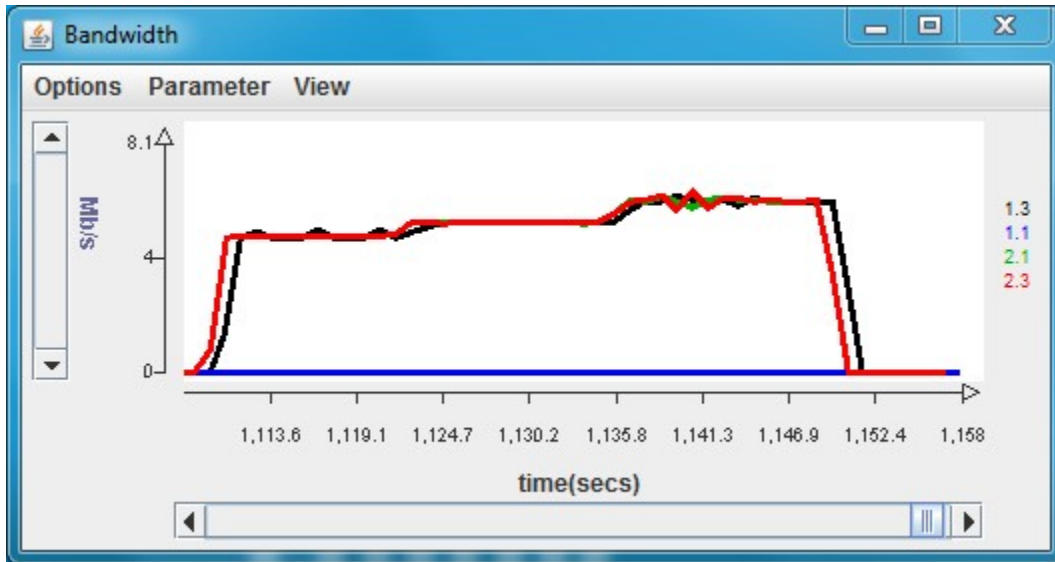
Delay: 50ms



```
jinz@pclcore65:~  
[ 3] 5.0-10.0 sec 432 KBytes 708 Kbits/sec  
[ 3] 10.0-15.0 sec 400 KBytes 655 Kbits/sec  
[ 3] 15.0-20.0 sec 2.56 MBytes 4.30 Mbits/sec  
[ 3] 20.0-25.0 sec 5.52 MBytes 9.25 Mbits/sec  
[ 3] 25.0-30.0 sec 5.48 MBytes 9.20 Mbits/sec  
[ 3] 30.0-35.0 sec 5.52 MBytes 9.25 Mbits/sec  
[ 3] 35.0-40.0 sec 5.52 MBytes 9.25 Mbits/sec  
[ 3] 0.0-40.0 sec 25.9 MBytes 5.42 Mbits/sec  
[jinz@pclcore65 ~]$ iperf -c h4x2 -w 64kB -t 40 -i 5  
-----  
Client connecting to h4x2, TCP port 5001  
TCP window size: 125 KByte (WARNING: requested 62.5 KByte)  
-----  
[ 3] local 192.168.1.2 port 49207 connected with 192.168.4.2 port 5001  
[ 3] 0.0- 5.0 sec 2.74 MBytes 4.60 Mbits/sec  
[ 3] 5.0-10.0 sec 2.74 MBytes 4.60 Mbits/sec  
[ 3] 10.0-15.0 sec 4.79 MBytes 8.03 Mbits/sec  
[ 3] 15.0-20.0 sec 6.00 MBytes 10.1 Mbits/sec  
[ 3] 20.0-25.0 sec 6.00 MBytes 10.1 Mbits/sec  
[ 3] 25.0-30.0 sec 6.57 MBytes 11.0 Mbits/sec  
[ 3] 30.0-35.0 sec 6.97 MBytes 11.7 Mbits/sec  
[ 3] 35.0-40.0 sec 7.05 MBytes 11.8 Mbits/sec  
[ 3] 0.0-40.0 sec 42.9 MBytes 8.98 Mbits/sec  
[jinz@pclcore65 ~]$
```

Figure 2 change of bandwidth when link rate is 5Mbps, 20Mbps, 1Mbps, delay=50ms

Delay 100ms:



```
jzhu@pclcore18:~  
[ 3] 5.0-10.0 sec 3.45 MBytes 5.78 Mbits/sec  
[ 3] 10.0-15.0 sec 3.41 MBytes 5.71 Mbits/sec  
[ 3] 15.0-20.0 sec 3.49 MBytes 5.86 Mbits/sec  
[ 3] 20.0-25.0 sec 3.49 MBytes 5.86 Mbits/sec  
[ 3] 25.0-30.0 sec 3.41 MBytes 5.73 Mbits/sec  
[ 3] 30.0-35.0 sec 3.47 MBytes 5.82 Mbits/sec  
[ 3] 35.0-40.0 sec 3.33 MBytes 5.58 Mbits/sec  
[ 3] 0.0-40.0 sec 27.2 MBytes 5.71 Mbits/sec  
[jzhu@pclcore18 ~]$ iperf -c h4x2 -w 64kB -t 40 -i 5  
-----  
Client connecting to h4x2, TCP port 5001  
TCP window size: 125 KByte (WARNING: requested 62.5 KByte)  
-----  
[ 3] local 192.168.1.1 port 38349 connected with 192.168.4.2 port 5001  
[ 3] 0.0- 5.0 sec 2.59 MBytes 4.35 Mbits/sec  
[ 3] 5.0-10.0 sec 2.74 MBytes 4.60 Mbits/sec  
[ 3] 10.0-15.0 sec 2.90 MBytes 4.86 Mbits/sec  
[ 3] 15.0-20.0 sec 3.03 MBytes 5.09 Mbits/sec  
[ 3] 20.0-25.0 sec 3.00 MBytes 5.03 Mbits/sec  
[ 3] 25.0-30.0 sec 3.38 MBytes 5.66 Mbits/sec  
[ 3] 30.0-35.0 sec 3.50 MBytes 5.87 Mbits/sec  
[ 3] 35.0-40.0 sec 3.45 MBytes 5.79 Mbits/sec  
[ 3] 0.0-40.0 sec 24.6 MBytes 5.15 Mbits/sec  
[jzhu@pclcore18 ~]$
```

Figure 3 change of bandwidth when link rate is 5Mbps, 20Mbps, 1Mbps, delay=100ms

Table 3 result of throughput in different link rate

Link Rate		5Mbps	20Mbps	1Gbps	
Throughput	Delay 50ms	Theoretical result	5Mbps	10.24Mbps	10.24Mbps
		Experiment result	4.61Mbps	10.10Mbps	11.70Mbps
	Delay 100ms	Theoretical result	5Mbps	5.12Mbps	5.12Mbps
		Experiment result	4.61Mbps	5.03Mbps	5.77Mbps

The key point of explanation

- When link rate is 5Mbps, the time need to send 64KB data is

$$t = \frac{64KB}{5Mbps} = \frac{64 * 1000 * 8bits}{5Mbps} = 102.4ms$$

which is larger than the RTT (50ms or 100ms)

So when the link rate is 5Mbps, the throughput is the same as the link rate

- When link rate is 20Mbps or 1Gbps, the time need to send 64KB data is

$$t = \frac{64KB}{20Mbps} = \frac{64 * 1000 * 8bits}{20Mbps} = 25.6ms$$

$$t = \frac{64KB}{1Gbps} = \frac{64 * 1000 * 8bits}{1Gbps} = 0.512ms$$

which is much smaller than the RTT (50ms or 100ms)

So when the link rate is 20Mbps or 1Gbps, the throughput is

$$throughput = \frac{window\ size\ 64kB}{RTT}$$

the results are showed in the table

- The server(receiver) received packets at a rate (4.61Mbps) lower than the capacity of the bottleneck (5Mbps), because there is additional bytes of IP header (20-byte) and TCP header (20-byte to 60-byte) that accounts for an additional 7% in the packet length. This difference means that 7% of the 5Mbps bottleneck capacity is consumed by packet headers and therefore, the receiver will see only about 4.61Mbps at the application level.