Project – Network Simulation
CSE 5346/4346

Project Overview

This is a comprehensive project designed to be completed by 4 phases, and intended to demonstrate network performance and quality of service (QoS) characteristics by employing a sophisticated network simulation program. You will use the NS-2 network simulation program to perform experiments that will help you understand the behavior of the TCP and UDP traffic, and traffic engineering mechanism under various network situations. The project is to be completed INDIVIDUALLY. You may discuss approaches and NS-2 operation with your classmates, but the work submitted must be yours alone.

In this project, you are asked to measure and compare the performance metrics of TCP and UDP connections over the specified no-Multi-Protocol Label Switching (MPLS) and MPLS-based network topology. You must analyze and evaluate the performance impact of mixing TCP and UDP traffic and the effect of using MPLS traffic trunks under specified different scenarios. Finally, you will be able to verify that the total network performance improves significantly with proper traffic engineering.

Following are a few useful NS-2 guide/tutorial and documents, which include valuable information on NS-2 as well as some useful simulation examples:

1. A comprehensive NS-2 information website The Network Simulator - ns-2
2. Marc Greis' Tutorial for the UCB/LBNL/VINT Network Simulator "ns"
3. A simpler tutorial from WPI.
4. NS-2 manual: ***http://www.isi.edu/nsnam/ns/ns-documentation.html***
5. A couple of test examples of queue and traffic control are available on gamma2 ***/opt/ns-allinone-2.30/ns-2.30/tcl/test***

Note: To run NS-2, you need to setup path. If you are using gamma2, cygwin under Windows or Linux, add the following lines to your shell file (e.g., *.bash_profile*) under your home directory.

```
export PATH=/opt/ns-allinone-2.30/bin:$PATH
export LD_LIBRARY_PATH=/opt/ns-allinone-2.30/otcl-1.12:/opt/ns-allinone-2.30/lib:$LD_LIBRARY_PATH
export TCL_LIBRARY=/opt/ns-allinone-2.30/tcl8.4.13/library
```

You can use NS-2 from **gamma2** or NS-2 running on your personal computer. You may find the following directories useful for this project on gamma2 and the ns manual on the website.

Phase 1. *(Due: Wednesday, February 13th)*

Objective

The purposes of this phase are: 1) to familiarize the student with network simulation using NS-2, which is a widely used network research tool; 2) to help the student master how to configure a network topology using NS-2.

You must be able to finish the following steps.

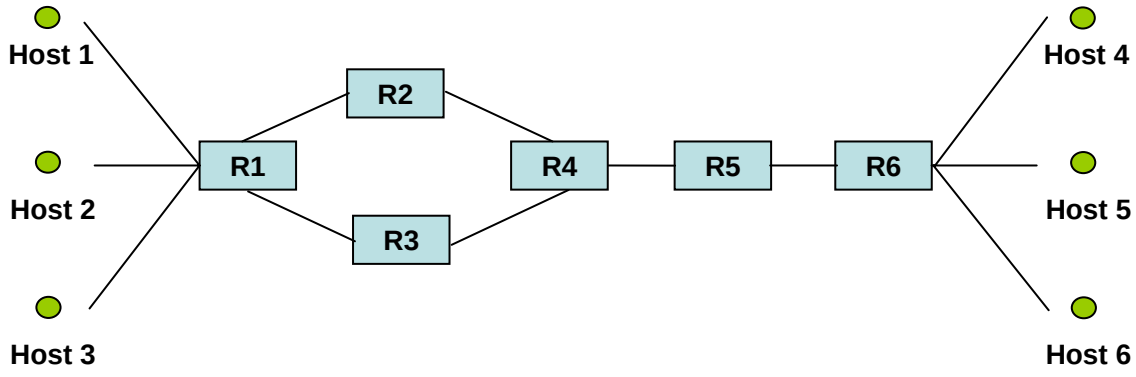
Step 1. Set up your system environment to run NS-2. You may want to use the gamma2 server or install NS-2 in your own machine. You can find the details in *GTA's Tutorial slides* on the class website.

Step 2. Run the example file, ***ns_simple.tcl*** (included below) in order to verify that your NS-2 environment setup is correct. Understand completely how the code works.

How to run your simulation?

% ns file_name

Step 3. Establish the following network topology. There are 6 routers (designated R1 through R6) and 6 hosts (designated Host 1 through Host 6). All links are full duplex links.



Step 4. Establish one TCP traffic flow from Host 2 to Host 5, another TCP flow from Host 3 to Host 6 and one UDP flow from Host 1 to Host 4. You are free to experiment with various settings for traffic/network parameters in order to be familiar with NS2 (i.e., packet size, rate, queue parameters, etc.)

Step 5. Mail your tcl file, named "*phase1_your last name.tcl*" to choe@uta.edu. Please do not use other email account for your submission. Provide your Student ID and Full Name at the beginning line as a comment. ***The submission must be received prior to the beginning of class on the due date, or it will be counted as a late submission.*** You should receive a reply e-mail after your submission. If you don't, contact to TA to confirm your submission.

File name: ns_simple.tcl

```
#Create a simulator object
set ns [new Simulator]

#Open the NAM trace file
set nf [open out.nam w]
$ns namtrace-all $nf

#Define a 'finish' procedure
proc finish {} {
        global ns nf
        $ns flush-trace
        #Close the NAM trace file
        close $nf
        #Execute NAM on the trace file
        exec nam out.nam &
        exit 0
}

#Create four nodes
set n0 [$ns node]
set n1 [$ns node]
set n2 [$ns node]
set n3 [$ns node]

#Create links between the nodes
$ns duplex-link $n0 $n2 2Mb 10ms DropTail
$ns duplex-link $n1 $n2 2Mb 10ms DropTail
$ns duplex-link $n2 $n3 1.7Mb 20ms DropTail

#Set Queue Size of link (n2-n3) to 10
$ns queue-limit $n2 $n3 10

#Monitor the queue for link (n2-n3). (for NAM)
$ns duplex-link-op $n2 $n3 queuePos 0.5

#Setup a TCP connection
set tcp [new Agent/TCP]
$tcp set class_ 2
$ns attach-agent $n0 $tcp
set sink [new Agent/TCPSink]
$ns attach-agent $n3 $sink
$ns connect $tcp $sink
$tcp set fid_ 1

#Setup a FTP over TCP connection
set ftp [new Application/FTP]
$ftp attach-agent $tcp
$ftp set type_ FTP

#Setup a UDP connection
set udp [new Agent/UDP]
$ns attach-agent $n1 $udp
set null [new Agent/Null]
$ns attach-agent $n3 $null
$ns connect $udp $null
$udp set fid_ 2

#Setup a CBR over UDP connection
set cbr [new Application/Traffic/CBR]
```

```
$cbr attach-agent $udp
$cbr set type_ CBR
$cbr set packet_size_ 1000
$cbr set rate_ 1mb
$cbr set random_ false


#Schedule events for the CBR and FTP agents
$ns at 0.1 "$cbr start"
$ns at 1.0 "$ftp start"
$ns at 4.0 "$ftp stop"
$ns at 4.5 "$cbr stop"

#Detach tcp and sink agents (not really necessary)
$ns at 4.5 "$ns detach-agent $n0 $tcp ; $ns detach-agent $n3 $sink"

#Call the finish procedure after 5 seconds of simulation time
$ns at 5.0 "finish"

#Print CBR packet size and interval
puts "CBR packet size = [$cbr set packet_size_]"
puts "CBR interval = [$cbr set interval_]"

#Run the simulation
$ns run
```

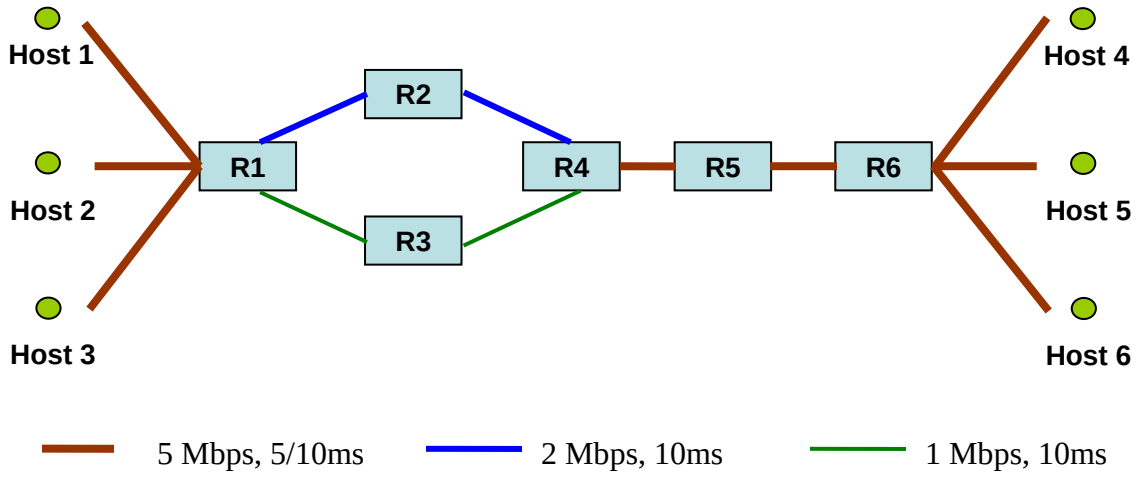
Phase 2. *(Due: Wednesday, March 5th)*

Objective

The purposes of this phase are: 1) to learn how to trace and monitor simulation results with graphical tools, such as *nam*, *xgraph*, etc.; 2) to help the student master the concepts and practices that are discussed in the first part of the course – traffic congestion control/avoidance of TCP and UDP.

You must be able to finish the following requirements.

1. Modify your first file for the following requirements and name it "*phase2_your last name.tcl*".



i. Packet size of TCP flow from Host 2 to Host 5 is 476B.
ii. Packet size of TCP flow from Host 3 to Host 6 is 1500B.
iii. Link capacity and delay between R1-R2-R4 are 2Mbps and 10ms, respectively.
iv. Link capacity and delay between R1-R3-R4 are 1Mbps and 10ms, respectively.
v. Link capacity and delay between R4-R5 and R5-R6 are 5Mbps and 10ms.
vi. Link capacity and delay between each host and a router are 5Mbps and 5ms, respectively.

2. Generate enough traffic over the network to have a *congested* situation. Measure the throughput of each TCP and UDP traffic flow and plot a graph of measured throughput.

4. Gradually increase the rate of the UDP flow and compare the throughputs of all flows.

5. Mail your **analysis report and simulation script file(s)** to choe@uta.edu. The file name format is phase2_last name.*. *Follow the instruction of "Accepted file formats for papers/reports" on Syllabus.* If applicable, submit your result analysis scripts

also. The report is a comprehensive (i.e., complete, detailed and well-written) project report, which includes the following:

a. Detailed configuration information of your network (client types, traffic generators, performance metrics, etc.).
b. Detailed explanation of your simulation.
c. Annotated graphs to support your findings.
d. A conclusion which summarizes your key findings.

A hard copy of your project report should be submitted to Gergely Záruba prior to the beginning of class on the due date.

Phase 3. *(Due: Monday, April 7th)*

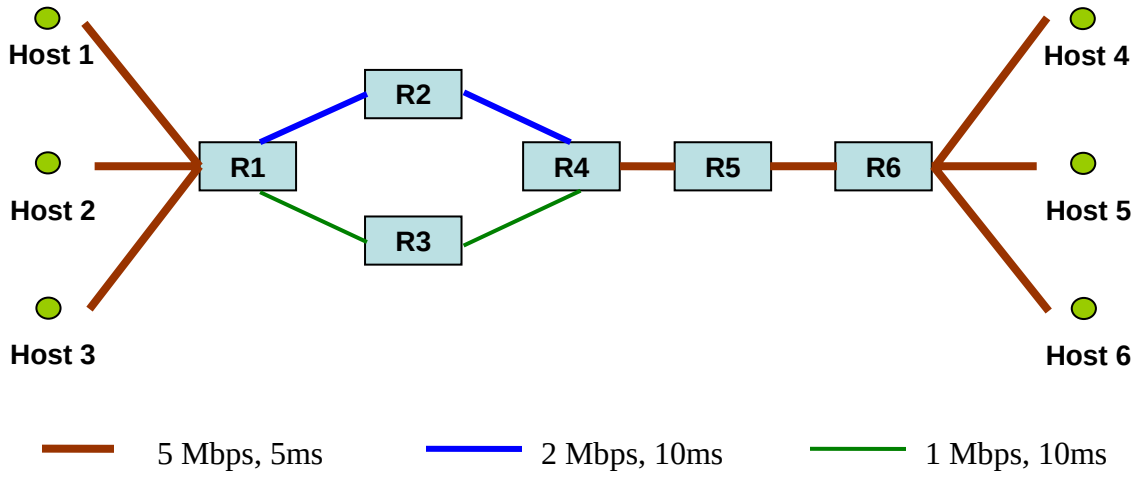
Objective

The purposes of this phase are: 1) to help the student master the concepts and practices that are discussed in the second part of the course – quality of service and traffic management; and 2) to provide the student with an understanding of the current state of the art in quality of service research in the networking field.

It is recommended that you review the Differentiated Service using NS2 guidelines/ tutorials linked on the class website (NS Simulator for beginners - Chapter 7, NS manual - Chapter 9) before starting Phase 3.

Complete the following requirements:

1. Configure the following network topology and name it "*phase3_your last name.tcl*".



All queues between two routers have a queue size limit of **50**, a minimal threshold of **15** and maximal threshold of **50**. Start the **DV** routing protocol on all routers.

2. Introduce enough traffic to ensure that the network operates under an **overload (congested) situation** during some periods in your simulation. If your network is underloaded, you will not be able to satisfy the objectives of this lab.

3. The simulation should run at least 60 seconds. You are free (encouraged) to experiment with various settings for traffic/network parameters as long as your simulation satisfies the specified requirements.

4. Establish one TCP traffic flow from Host 2 to Host 5. This traffic flow has to satisfy the QoS requirement, **an end-to-end throughput of at least 1.6Mbps** (can be higher), in order to provide useful information for its applications.

5. Establish another TCP flow from Host 3 to Host 6. This flow has to satisfy the QoS requirement, **an end-to-end throughput of 0.7Mbps**.

6. Establish one UDP flow from Host 1 to Host 4. There is no QoS requirement for this traffic but try to get as much throughput as possible.

7. You must use the **Differentiated Service modules** provided in ns2 to satisfy the above QoS requirements.

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8. Plot a graph of measured throughput for each flow.

9. Mail your **analysis report and simulation script file(s)** (file name format: phase3_last name.*) to choe@uta.edu. If applicable, submit your result analysis scripts also. The report is a comprehensive (i.e., complete, detailed and well-written) project report, which includes the following:

    a. Detailed configuration information of your network (client types, traffic generators, performance metrics, etc.).
    b. Detailed explanation of your simulation.
    c. Annotated graphs to support your findings.
    d. A conclusion which summarizes your key findings.

**** A hard copy of your project report should be submitted to Gergely Záruba prior to the beginning of class on the due date.***

**** Please keep your results for comparison in Phase 4.***

Phase 4. *(Due: Monday, April 28th)*

Objective

The purpose of this phase is to help the student master the concepts and practices of traffic engineering that are discussed in the course.

In case that you use gamma2 server, you will find example scripts in the following directory**.** ***/opt/ns-allinone-2.30/ns-2.30/tcl/ex/***

Complete the following requirements:

1. Add MPLS modules to the Phase 3 network topology and name it "*phase4_your last name.tcl*".

2. The simulation should run at least 60 seconds. You must ensure that the highest load results in a **congested path**.

3. Establish one TCP traffic flow from Host 2 to Host 5. This traffic flow has to satisfy the QoS requirement, **an end-to-end throughput of at least 1.6Mbps** (can be higher), in order to provide useful information for its applications.

4. Establish another TCP flow from Host 3 to Host 6. Set up explicit routing path, R1→ R3 → R4 → R5 → R6 for this flow. To satisfy the QoS requirement for this flow, **an end-to-end throughput of 1.0Mbps is required**.

5. Establish one UDP flow from Host 3 to Host 6. There is no QoS requirement for this traffic, but try to get as much throughput as possible while satisfying other objectives.

6. As the second scenario, set up a partial explicit routing path, R4 → R5 → R6, for the second TCP flow from Host 3 to Host 6. Compare the result with the first scenario (above) that used explicit routing path from R1 to R6.

7. You must use the either **MPLS or Differentiated Service modules** provided in NS/2 to satisfy the above QoS requirements.

8. Measure **packet loss ratio** and **end-to-end delay** for each flow.

9. Plot a graph of the measured performance metrics of each flow and compare the results.

10. Mail your **analysis report and simulation script file(s)** (file name format: phase4_last name.*) to choe@uta.edu. If applicable, submit your result analysis scripts also. The report is a comprehensive (i.e., complete, detailed and well-written) project report, which includes the following:

a. Detailed configuration information of your network (client types, traffic generators, performance metrics, etc.).

b. Detailed explanation of your simulation.
c. Annotated graphs to support your findings.
d. A conclusion which summarizes your key findings.

A <u>hard copy</u> of your project report should be submitted to Gergely Záruba prior to the beginning of class on the due date.