OPNET Software for Teaching and Research at Rowan University

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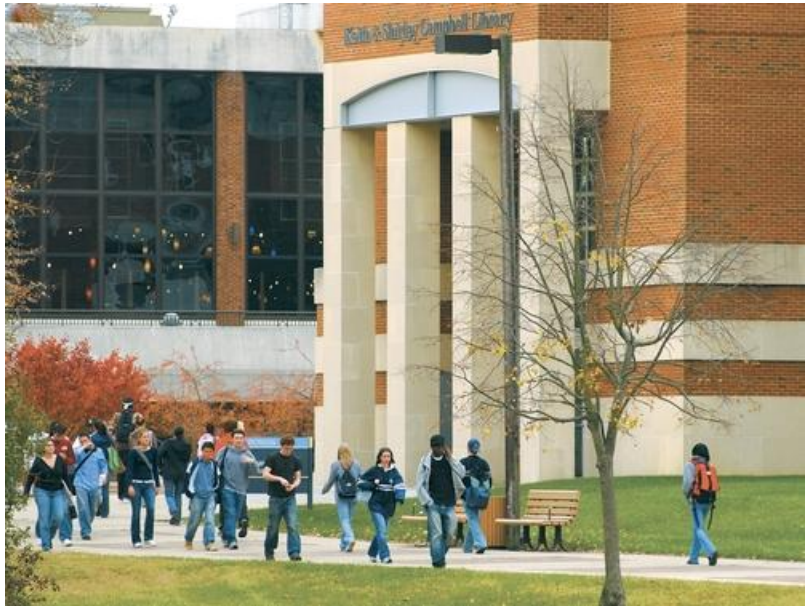
About Rowan University

- Founded 1923
- Located in Glassboro, NJ
- Provides undergraduate and graduate education
- Over 11,000 students
- Student-faculty ratio 15:1



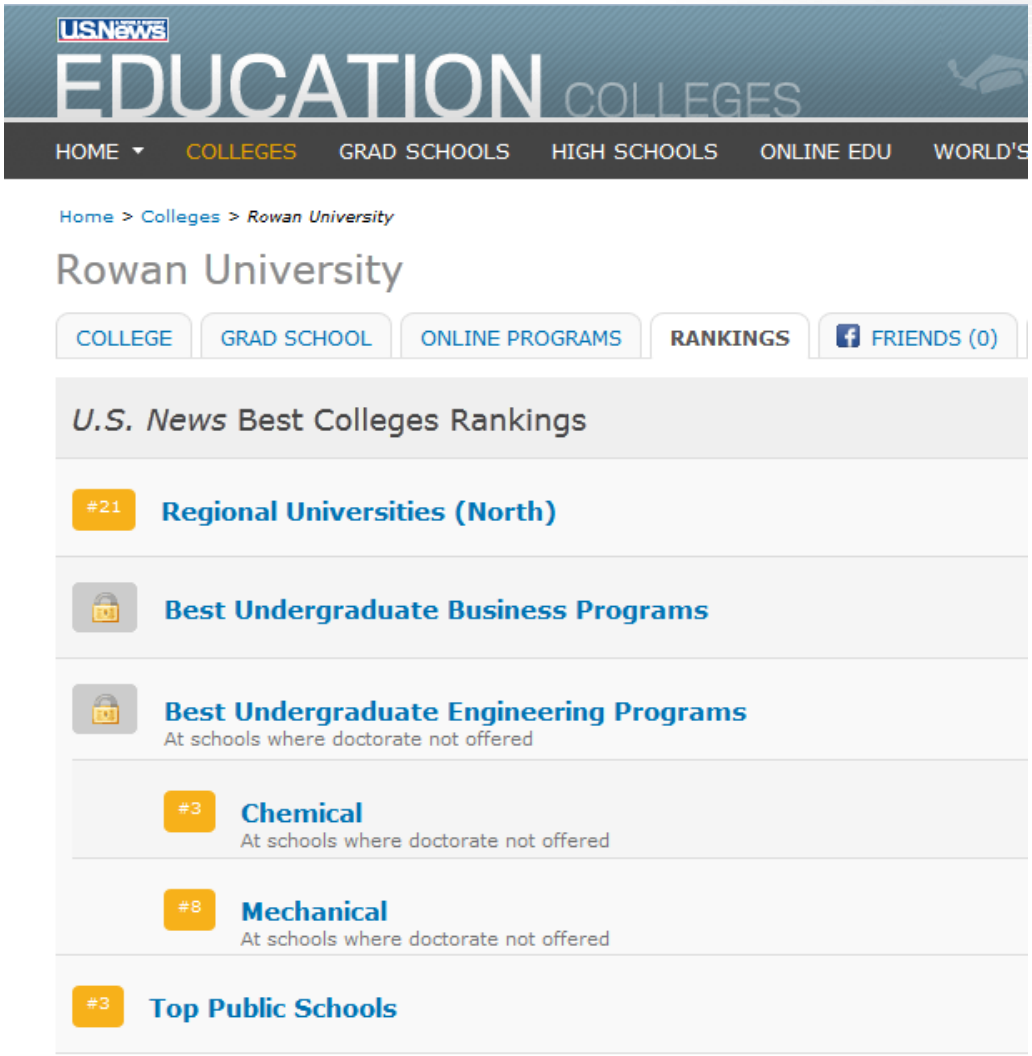
About Rowan University

US News & World Report

- Rowan University is in the "Top Tier" of Northern Regional Universities

Cooper Medical School of Rowan University

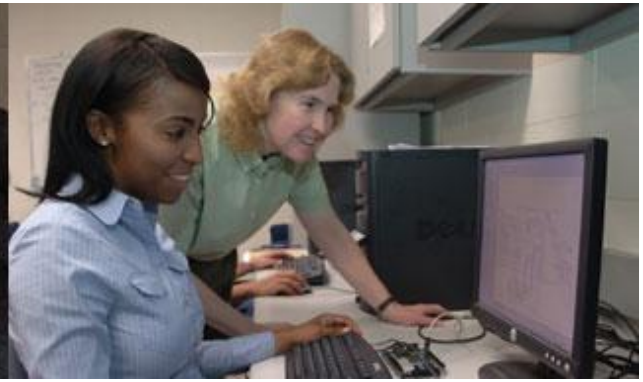
- Opens Fall 2012
- First medical school of South Jersey



About Computer Science Department at Rowan University

- 11 full-time faculty
- Over 250 undergraduate students
- Around 25 graduate students
- M.S., B.S./M.S. programs
- No Ph.D. program
- Using OPNET since Fall 2003





Introduction: Why Use OPNET In Undergraduate Education?

- More effective, hands-on undergraduate education
- Ability to illustrate and try theoretical concepts with OPNET software
- New type of student
  - Task-oriented
  - Likes to try things out
  - Interested in hands-on activities rather than pure lecture
- Computer Science is active learning discipline
  - OPNET is a tool that enables active learning in the classroom

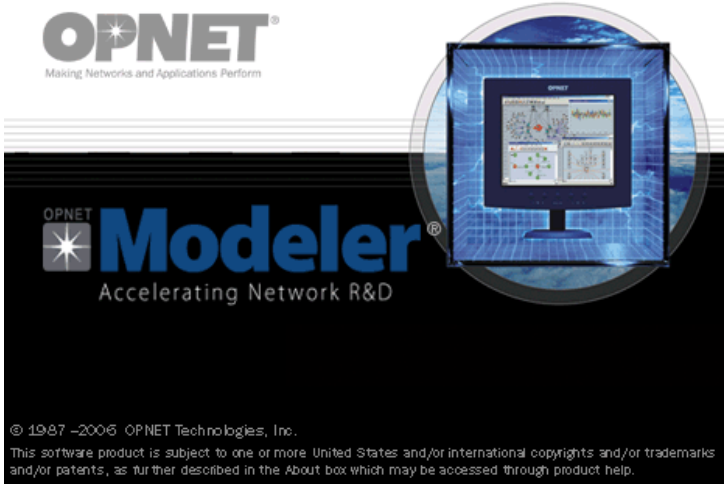
Introduction: Why Use OPNET In Undergraduate Education?

- Can help illustrate networking concepts
  - Various network phenomena
  - Performance comparison
  - Network configuration
- Students can work with networks and devices that are generally physically unavailable at univeristy
- Actively involves students in learning process
- Increases student's interest in the subject
- Helps students understand the concepts discussed in class

Introduction

- Challenges of using OPNET in undergraduate education
  - Time and difficulty of learning all needed aspects of the software
  - Frequent software updates
- What OPNET software is appropriate for undergraduate education?
  - OPNET IT Guru
  - OPNET Modeler
  - ACE and Wireshark
- How to use OPNET in undergraduate education?
  - In class examples
  - Laboratory assignments
  - Research projects

OPNET Products For Undergraduate Education



- IT Guru and Wireshark
  - Relatively simple to use
  - Can be easily integrated into classroom
- Modeler
  - Steep learning curve
  - Can be used for independent research projects
- ACE
  - Specific to application
  - Can be used for independent research projects

Using OPNET In Undergraduate Education

- Appropriate for undergraduate and graduate networking courses
- Plan for introducing OPNET in the classroom:

1. Introduction to modeling and simulation with OPNET
   - **Topics**: What is modeling and simulation? Why is it needed? Overview of OPNET architecture and file structure.
   - **Duration**: 1 lecture.
2. Using OPNET Software
   - **Topics**: working with scenarios and projects, creating network topology, developing and deploying network applications, configuring individual network technologies, configuring and executing simulation model, and collecting and interpreting the simulation results.
   - **Duration**: 2 lectures
3. Advanced Topics:
   - **Topics**: coincide with material covered in class
   - **Duration**: as needed, ½ or ¼ of the lecture period.

Using OPNET In Undergraduate Education

- Important OPNET topics to be covered in class:
  - Creating scenarios/projects
  - Configuring Network Topology
  - Specifying traffic sources
    - Explicit Traffic Sources
    - Traffic Demands
    - Standard and Custom applications (e.g. applications and profiles)
  - Running simulation and collecting/analyzing results
  - Configuration of specific advanced technologies
- Good idea to
  - Provide several in-class examples
  - Give homework or laboratory assignments to reinforce understanding

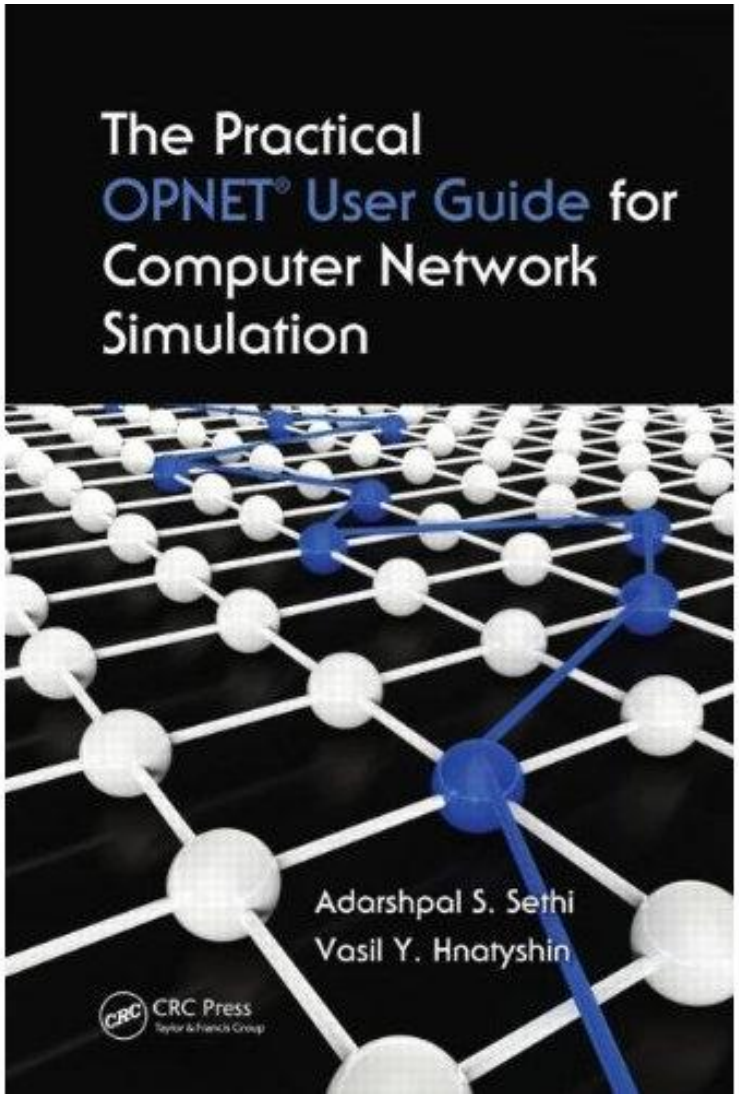
OPNET Laboratory Assignments

- Frequent issues with available OPNET laboratory assignments:
  - Written for free educational version of OPNET IT Guru (i.e., version 9.1)
  - Laboratory assignments are tedious
    - Consist of exact step-by-step instructions
    - Easy to make a mistake or skip the step
    - Hard to debug
    - Do not teach students how to use OPNET software
    - Do not challenge the students
    - Students are focused on precisely following the steps instead of thinking about what they are doing

The Practical OPNET® User Guide for Computer Network Simulation

- We try to address these issues in the book which comes out in Fall 2012
- The book is divided into two portions:
  - Main part:
    - Careful account of available OPNET features and
    - Detailed description of steps for creating simulation using OPNET software
  - Practical laboratory assignments part:
    - Contains laboratory assignments which illustrate various OPNET features discussed in the main portion of the book
    - Each lab separates the design and objectives of the simulation study from the specifics of OPNET GUI.
    - Each lab contains references to the main part of the book which contains the instructions for configuring the necessary OPNET features

The Practical OPNET® User Guide for Computer Network Simulation



The Practical OPNET User Guide for Computer Network Simulation

- **Adarshpal S. Sethi**
- **Vasil Y. Hnatyshin**

Hardcover:	527 pages
Publisher:	Chapman and Hall/CRC (September 4, 2012)
Language:	English
ISBN-10:	1439812055
ISBN-13:	978-1439812051

The Practical OPNET® User Guide for Computer Network Simulation

- The Practical OPNET® User Guide for Computer Network Simulation
  - One of the first books to provide a comprehensive description of OPNET® IT Guru and Modeler software
  - Explains how to use this software for simulating and modeling computer networks.
  - The included laboratory projects help readers learn different aspects of the software in a hands-on way.
- Quickly Locate Instructions for Performing a Task
  - The book begins with a systematic introduction to the basic features of PNET, which are necessary for performing any network simulation.
  - The remainder of the text describes how to work with various protocol layers using a top-down approach.
  - Every chapter explains the relevant OPNET features and includes step-by-step instructions on how to use the features during a network simulation.

The Practical OPNET® User Guide for Computer Network Simulation

- Gain a Better Understanding of the "Whats" and "Whys" of the Simulations
  - Each laboratory project in the back of the book presents a complete simulation and reflects the same progression of topics found in the main text.
  - The projects describe the overall goals of the experiment, discuss the general network topology, and give a high-level description of the system configuration required to complete the simulation.
- Discover the Complex Functionality Available in OPNET
  - By providing an in-depth look at the rich features of OPNET software, this guide is an invaluable reference for IT professionals and researchers who need to create simulation models.
  - The book also helps newcomers understand OPNET by organizing the material in a logical manner that corresponds to the protocol layers in a network.

The Practical OPNET® User Guide for Computer Network Simulation

- Features
  - Provides detailed descriptions of the most commonly used OPNET software features
  - Illustrates how to develop and configure models for every layer of the TCP/IP reference model
  - Contains extensive examples that show how to set up and configure many nontrivial features of OPNET software
  - Presents detailed answers to commonly asked “how-to” questions
  - Includes laboratory assignments that cover all layers of the TCP/IP reference model and enable readers to experiment with various software features described in the text

The Practical OPNET® User Guide for Computer Network Simulation

- Practical laboratory assignments:
  - Do not provide step-by-step instructions
  - State assignment tasks in a form of objective (e.g. create the following topology, configure the protocol as follows, etc).
  - First few laboratory assignments are dedicated to teaching basic OPNET features
  - Remaining assignments concentrate on advanced OPNET features and specific networking technologies
  - The majority of the laboratory assignments are complete separated from OPNET GUI

Chapter List

- Chapters 1 – 4: Introduction to modeling with OPNET
- Chapters 5 – 7: Working with Applications
- Chapter 8: The Transport Layer
- Chapters 9 – 11: The Network Layer
- Chapter 12: Data Link and Physical Layers
- 14 laboratory assignments
  - Illustrate OPNET features discussed in the main chapters
- Index

Introductory Chapters

- **Chapter 1: Getting Started with OPNET**
  - Intro to IT Guru/Modeler, Managing Preferences, Documentation, Files and Directories, Projects and Scenarios
- **Chapter 2: Creating Network Topology**
  - Object Palettes, Adding/Deleting Nodes/Links, Rapid Configuration Tool, Configuring Links, Failure/Recovery of Elements, Subnets, Annotation
- **Chapter 3: Configuring Network Topology**
  - Object Attributes, Editing Attributes, Configuring Object Properties, Promoting Attributes
- **Chapter 4: Configuring and Running a Simulation**
  - Simulation Statistics, Configuring and Running a Simulation, Viewing Results, Analysis Panels, DES Log

Working with Applications

- **Chapter 5: Standard Applications**
  - Types of Traffic Sources, Configuring Standard Applications: Database, E-mail, FTP, HTTP, Print, Remote Login, Video Conferencing, Voice, Using Symbolic Node Names, Application Statistics
- **Chapter 6: Advanced Traffic Generation Features**
  - Custom Applications, Tasks and Phases, Example of Custom Application, Explicit Packet Generation Sources, Application Demands and Traffic Flows, Statistics for Custom Applications
- **Chapter 7: Specifying User Profiles and Deploying Applications**
  - Specifying and Configuring User Profiles, Deploying User Profiles with and without the Application Deployment Wizard, Common Mistakes in Profile Configuration and Application Deployment

Transport and Network Layers

- **Chapter 8: The Transport Layer**
  - Using TCP and UDP in OPNET, Supported TCP Features, TCP Configuration Attributes, Transport Layer Statistics
- **Chapter 9: The Network Layer: Introduction to IP**
  - Managing IP Addresses, IP Configuration Attributes, ICMP, IP Statistics and Reports
- **Chapter 10: Advanced IP Protocol Features**
  - NAT, IP Multicast, IPv6, Quality of Service (QoS): Global and Local QoS Profiles
- **Chapter 11: Network Layer: Routing**
  - Deploying Routing Protocols, RIP, OSPF, Routing Statistics, Viewing Routing Tables

Lower Layers

- **Chapter 12: Data Link and Physical Layers**
  - Deploying and Configuring Simulation Models with Data Link Layer Technologies, Link Model Attributes and Statistics, Ethernet, Token Ring, Wireless LANs (WLANs), MANET, Specifying Node Mobility, Wireless Network Deployment Wizard

Example:
Simulation Statistics in OPNET

- Described in Chapter 4, Sections 4.1 and 4.2
- What is a statistic?
- Scalar vs vector data collection
- Statistic categories: object statistics (e.g. node/link) vs global
- Statistic collection modes: all values, sample, bucket
- Deciding which statistics to collect
- The Choose Results Window
- Selecting statistics for a single object /whole scenario / global
- Statistic Information and Data Collection panes
- Statistic Draw Styles
- How to specify and change collection modes

Step-by-Step Instructions: Selecting Statistics for a Single Object

- Right-click on the object of interest located within the **Project Editor**.
- From the pop-up menu, select **Choose Individual DES Statistics** which will open a **Choose Results** window with the statistics available for the selected object.
- Browse the statistics tree within the **Choose Results** window by clicking on the plus or minus signs to expand or collapse statistic categories until the statistic(s) of interest is/are located. Expanded statistics will have the plus sign changed to minus.
- Click on the checkbox of an individual statistic to select it. Repeat the process until all statistics of interest have been selected. To select all statistics in a sub-category, click on the corresponding checkbox.
- Click **OK** to close the window and save the changes. The chosen statistic(s) will be collected only for the selected object.

Step-by-Step Instructions: Alternate Methods for the Same Task

Select Multiple Objects in the Project Workspace

- Approach #1: Left-click on the project workspace and then drag the mouse over the area where the objects of interest reside.
- Approach #2: While holding the *Ctrl* key, left-click on the objects that you would like to select.
- Approach #3: Right-click on one of the objects to be selected and then from the **Object Pop-up Menu** (Section 3.2.2), choose the option **Select Similar Nodes**. This operation will select all objects in the current scenario that have the same model.
- Approach #4: Choose **Edit > Select All in Subnet** in the top-level pull-down menu. This will select all objects in the current subnet.
- Approach #5: Choose **Edit > Select Objects …** in the top-level pull-down menu. This will open a **Define Selection** window that allows you to find and select nodes in the whole scenario, including all subnets, based on certain criteria such as object type or availability of an attribute.

List of Practical Laboratory Assignments

1. Introduction to OPNET (traffic generation parameters)
2. Simple Capacity Planning (traffic flows)
3. Introduction to Standard Applications
4. HTTP Performance
5. Modeling Custom Applications
6. Influence of the Maximum Transfer Unit (MTU) on Application Performance
7. Transport Protocols – TCP vs. UDP

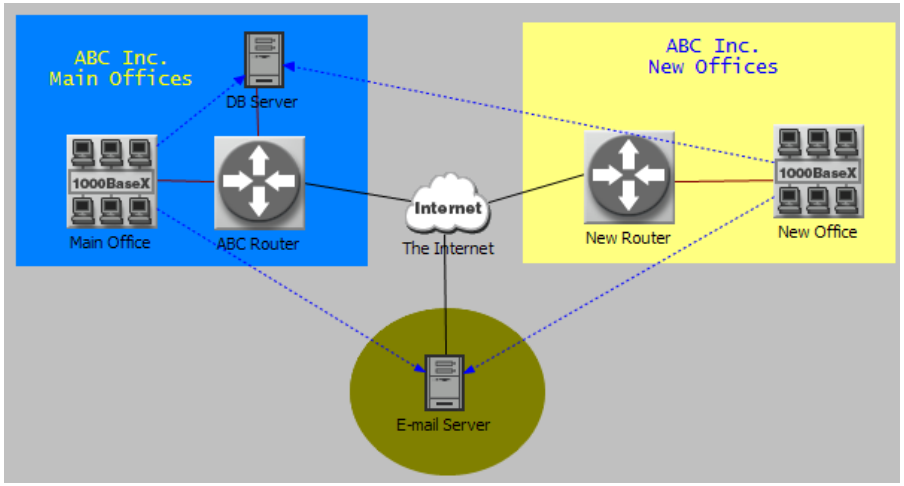
List of Practical Laboratory Assignments

8. TCP Features
9. IP Addressing and Network Address Translation (NAT)
10. Routing with RIP
11. Routing with OSPF
12. Providing Quality of Service Support
13. Ethernet
14. Wireless Communication

Example of Laboratory Assignment:
Simple Capacity Planning

- Assignment:
  - *ABC Inc., a small private company, is in the process of expansion and would like to add another office located on the other end of town. The company plans to double the new office size in the future. In this laboratory assignment you will help ABC Inc. to determine the best option for provisioning the links connecting their offices to the Internet.*

- Network configuration:



Object Name	Object Model
DB Server	*ethernet_server* node object
E-mail Server	*ppp_server* node object
Main Office New Office	*1000BaseX_LAN* node object
ABC Router New Router	*ethernet4_slip8_gtwy* node object
The Internet	*ip32_cloud* node object
Main Office <-> ABC Router Link DB Server <-> ABC Router Link New Office <-> New Router Link	*1000BaseX* link object
ABC Router <-> The Internet Link New Router <-> The Internet Link	*PPP_DS1_int* link object
The Internet <-> E-mail Server Link	*PPP_DS3* link object

Example of Laboratory Assignment:
Simple Capacity Planning

- Configuration Steps:
  - Create a new project and empty scenario named **Assignment 02** and **ABC_Network** respectively (Section 1.6.2).
  - Create the network topology as shown in Figure L2.1. Make sure that you use node and link models as specified in Table L2.1 (Section 2.4).
  - Verify link connectivity (Section 2.6.2).
  - Add and configure traffic demands (Section 6.6). Add and configure four **ip_traffic_flow** demand models as follows:
    - All demands should be configured to have 1.0% of traffic modeled as explicit traffic (attribute **Traffic Mix**).
    - All demands should start transmitting data at time 100 seconds.
    - All demands should continue transmitting data until the end of simulation.
    - **Main Office → DB Server** and **New Office → DB Server** IP demands transmit data at constant rates of 1200 Kbps and 100 packets per second respectively.
    - **Main Office → E-mail Server** and **New Office → E-mail Server** IP demands transmit data at constant rates of 800 Kbps and 10 packets per second respectively.

Example of Laboratory Assignment: *Simple Capacity Planning*

- Configuration Steps:
  - Configure your simulation to collect the following statistics:
    - All **Demand** Statistics (Section 6.8).
    - All **Link** statistics in the category **point-to-poin**t (Section 4.2.3).
  - Execute the simulation for 1 hour (Section 4.3.7) and then examine the following collected statistics (Section 4.5):
    - Traffic sent by each of the traffic demands.
    - Utilization on all the links connected to The Internet node.
    - Traffic received by each of the demand destinations.
    - End-to-end delay experienced by the demand packets. Note that if you did not configure your demands to generate traffic explicitly (i.e., set Traffic Mix attribute to a value greater than 0%), then this demand statistic will report no data.

Example of Laboratory Assignment: *Simple Capacity Planning*

- End of the lab questions:
  - What was the traffic sending rate by each demand? Did the simulation results correspond to the demand configuration?
  - What was the utilization on the links connected to The Internet? Why? (Hint: What are the capacities of 1000Base-T, DS-1 and DS-3 links? What are the transmission rates of each demand?)
  - What was the rate at which traffic arrived at each demand's destination? Why?
  - What was the packet end-to-end delay for each of the demands? Why?
  - In your opinion, what is the problem with the current network configuration? Which link in the network is the bottleneck?

Challenges Of Using OPNET

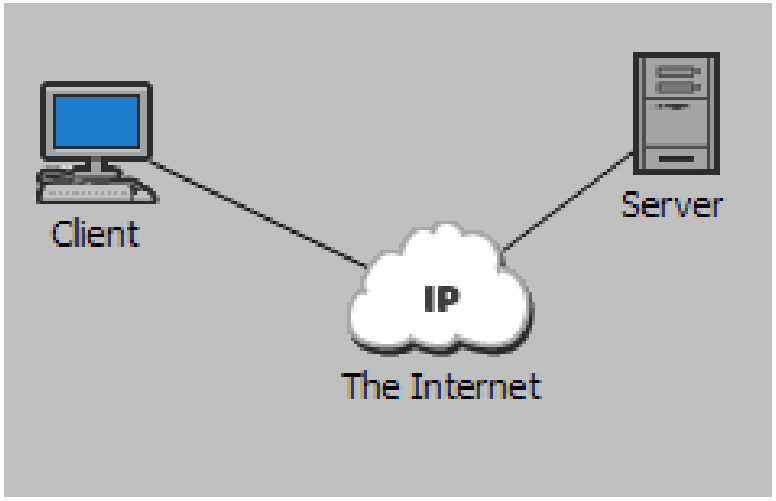
- OPNET frequently releases new versions of its software
- However, new releases
  - Contain few GUI changes
  - Are mostly backward compatible
  - Configuration steps used in previous releases are still applicable
- Thus
  - Most of the described features and configuration steps will be available and applicable to the new software releases
  - The majority of laboratory assignments will remain unchanged

QUESTIONS?

Example of Laboratory Assignment:
TCP Features: Nagle's algorithm

- Assignment:
  - *Nagle's algorithm addresses the issue of small packet size. Instead of immediately transmitting small data packets, each of which would carry 40 bytes of TCP and IP header information, Nagle's algorithm suggests buffering the data until the application provides more data to transmit or until all of its outstanding packets have been acknowledged. In this portion of the assignment, you will examine how Nagle's algorithm influences the application delay and the amount of traffic sent over the wire.*

- Network configuration:



Object Name	Object Model
Client	*ppp_wkstn* node object
Server	*ppp_server* node object
The Internet	*ip32_cloud* node object
All links in the network	*PPP_33K* link object

Example of Laboratory Assignment: *TCP Features: Nagle's algorithm*

- Configuration Steps:
  - *Create a new project and an empty scenario named **Assignment 08** and **Nagles Algorithm**, respectively (Section 1.6.2).*
  - *Create the network topology as shown in Figure L8.1 using node and link models specified in Table L8.1 (Sections 2.3 and 2.4). Verify link connectivity (Section 2.6.2).*
  - *Add **Application Config** and **Profile Config** node objects.*
  - *Create a **Remote Login** application, let us call it **Telnet**, which generates 1 byte commands to and from the terminal (Section 5.4.6).*
    - *To simplify the data analysis, use a constant distribution to specify the size of the command.*
    - *Promote the attribute **Inter-Command Time (seconds)** by clicking the button **Promote**.*
  - *Configure a profile, let us call it **Telnet User**, that runs the **Telnet** application with the default setting (Section 7.2).*
  - *Deploy the defined profile in the network so that **Client** operates as source and **Server** is a **Remote Login** server for the **Telnet** application (Section 7.4).*

Example of Laboratory Assignment: *TCP Features: Nagle's algorithm*

- Configuration Steps:
  - *Specify the node configuration as follows:*
    - *Set packet latency in The Internet node to 100 milliseconds by specifying the value of the attribute **Performance Metrics…Packet Latency (secs)**.*
    - *Promote the attribute **TCP…TCP Parameters...Nagle Algorithm** at both Client and Server nodes.*
  - *Configure the simulation to collect the following statistics:*
    - ***Response Time (sec)** from the Client Remote Login node statistic category.*
    - *All **point-to-point link** statistics.*
  - *Specify the values of the promoted attributes as follows:*
    - *Set the value of the **TCP Parameters...Nagle Algorithm** attribute to **Disabled** and **Enabled**.*
    - *Set the value of the attribute **Inter-Command Time** to **exponential (0.1)** and **exponential (10)**.*
  - *Run the simulation for 1 hour.*

Example of Laboratory Assignment:
TCP Features: Nagle's algorithm

- End of the lab questions:

Examine the application response time and display a graph for the following four situations:

- *Nagle's algorithm is disabled and inter-command time is set to 0.1 seconds.*
- *Nagle's algorithm is enabled and inter-command time is set to 0.1 seconds.*
- *Nagle's algorithm is disabled and inter-command time is set to 10 seconds.*
- *Nagle's algorithm is enabled and inter-command time is set to 10 seconds.*

•How does the application response time vary when Nagle's algorithm is enabled and when it is disabled? Why?

•Which of the above four scenarios resulted in the lowest and in the highest application response time? Why?

Example of Laboratory Assignment:
TCP Features: Nagle's algorithm

- End of the lab questions:

Examine the throughput on the link between **Client** and **The Internet**, display a graph that compares the link throughput in the above four scenarios, and answer the following questions:

- How does the link throughput vary when Nagle's algorithm is enabled and when it is disabled? Why?
- Which of the above four scenarios resulted in the lowest and in the highest throughput on the link between **Client** and **The Internet**? Why?