Simulation, Emulation and Benchmarks

Outline

- Introduction
- Simulation
- Emulation
- Benchmarks

Introduction

- On small networks, you can use network monitoring to help with capacity planning or diagnose problems or predict the network's reaction to new hardware or software.
- However, as networks grow, their numerous devices and connections make understanding the network impossible and testing live production systems is fraught with danger as most companies rely heavily on an always available network.
- Too many conversations among too many devices via too many network routes occur simultaneously for us to accurately predict how one application's traffic will affect another part of the network.
- Simulation, emulation and benchmark testing can all help with the design, development or management of networks.

Simulation

- To simulate your production network, you need to construct a reasonable representation of the network's topology
- Including the physical devices and logical parameters that comprise the network
- Determine how much traffic is on your network during the period you want to emulate, specify a question you want the simulation to answer and finally, you need to run the model through a simulator.
- Don’t forget the old axiom “garbage in garbage out”- you must ensure that as much detail as possible is included in the model otherwise the results will be worthless.
- Validation of models is essential, preferably against real systems or at least against other simulators.

Question

- Before you run a simulation, you must devise a specific question that you want the simulation to answer.
- You might want to ask a change-analysis question.
- You might want to analyze what would happen if you changed your network's WAN links, LANs, or routers or added a new application to your network.
- You might want the simulation to answer a question about the network's fault tolerance.
- For example, you might want to determine how the failure of a specific device or group of devices such as LANs, WAN links, or an entire facility of your organization - would affect application demands.

Answering these questions can help you in capacity planning, rollout validation, disaster recovery, and life cycle management.

Tweaking

- After you decide which question you want your simulation to answer, you might need to tweak the network model's topology and traffic to make sure the simulation addresses your question.
- Simulators automatically alter a network model to test its fault tolerance; they have built-in utilities that emulate the failure of network devices.
- You can select devices from a menu, and your simulation will predict what effects that device's failure would have on your production network.
- However, you must manually alter your model for your simulation to answer a change-analysis question. To add or move servers or users, you must change the volume of bytes an application produces in the model or add network devices or demands to the model before running your simulation.

Simulators

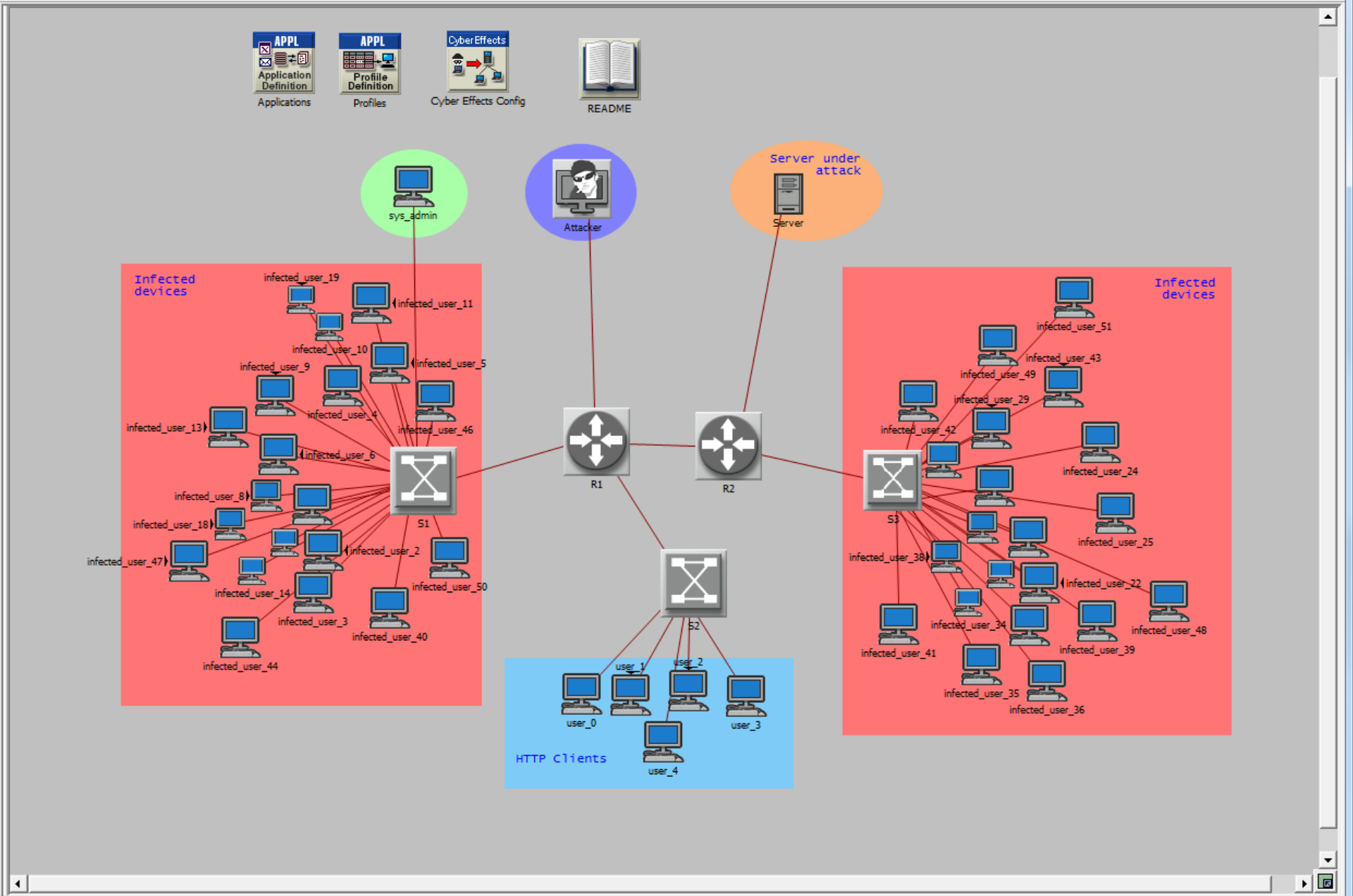
- A network simulator is software that predicts the behaviour of a computer network.
- After you develop a model of your network and define the question you want to answer, you're ready to run simulations.
- Simulators have traditionally run on powerful UNIX workstations, but some simulators are now available for different platforms: Unix, MacOS, Windows, etc.
- Most commercial simulators are expensive and running them requires training.

Commercial Network Simulator

- *Riverbed Modeler* (aka *OPNET*) is *a popular*, but *expensive,* commercial packages, that allow networks to be simulated.
- Used to assist with the research and design of new networks or
- to model an existing network and help predict the effect of changes on network performance (change simulation or What-If Analysis).
- Riverbed Modeler Academic Edition available for free for students and staff (with very limited capabilities)

Project: Cyber_Effects Scenario: DDoS_attack [Subnet: top.Campus Network]

File Edit View Scenarios Topology Traffic Protocols DES Windows Help



31.14, 17.96

Open Source Simulator

- There are a number of open-source or free software developed by various research agencies
- NS-2 (network simulator 2) by the VINT (Virtual Internetwork Testbed) project (http://www.isi.edu/nsnam/ns/)
- NS-3 (https://www.nsnam.org/)
- OMNet++ (https://omnetpp.org/)
- Specific simulator: CloudSim, IoTSim, DCSim, GreenCloud, etc.

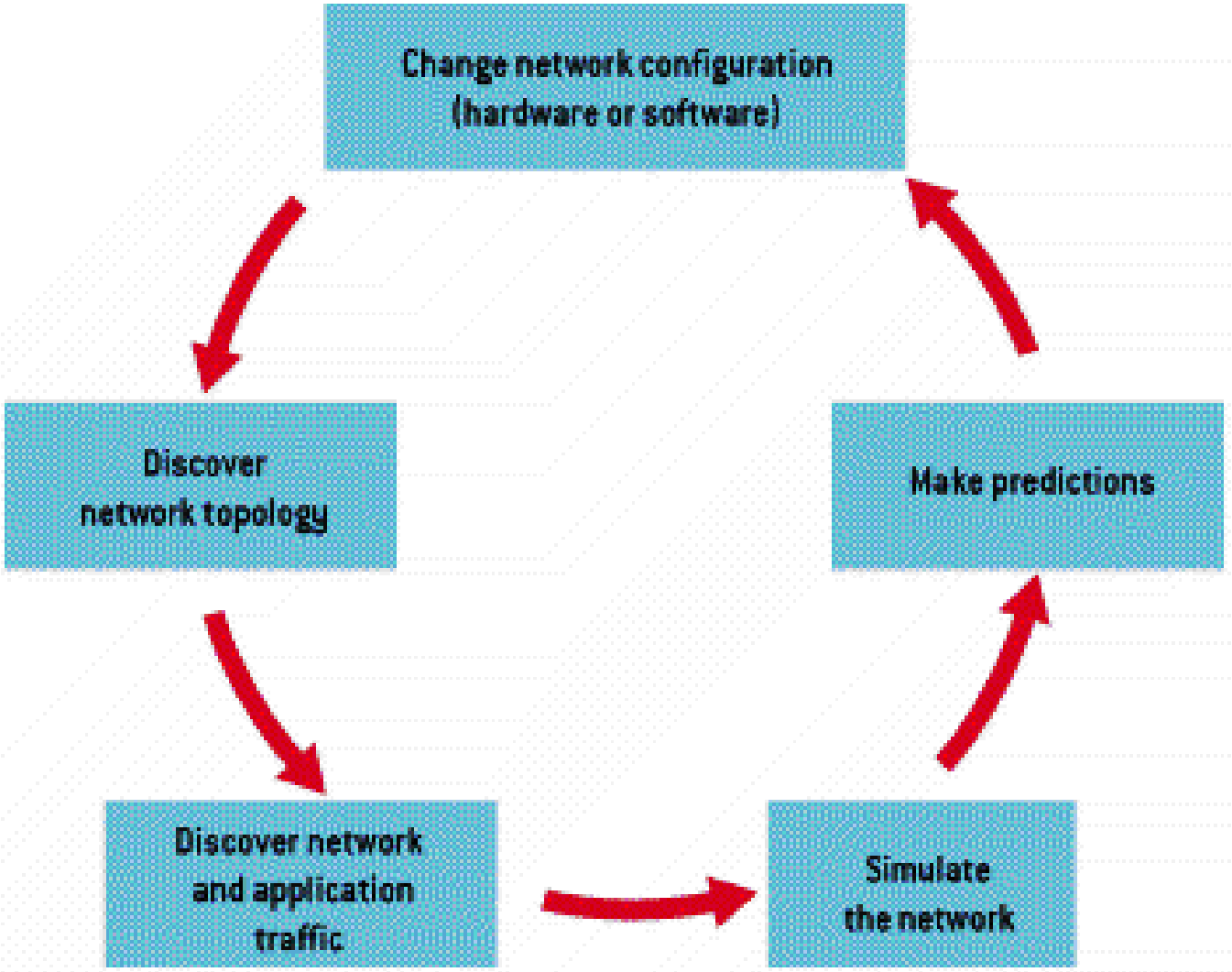
Discrete or Analytical?

- Simulators use a discrete-event or an analytical approach to model network traffic.
- Discrete-event simulation (DES) models the operation of a system as a discrete sequence of events in time.
- Each event occurs at a particular instant in time and marks a change of state in the system.
- Between consecutive events, no change in the system is assumed to occur; thus the simulation can directly jump in time from one event to the next.
- This contrasts with continuous simulation in which the simulation continuously tracks the system dynamics over time.
- Because discrete-event simulations do not have to simulate every time slice, they can typically run much faster than the corresponding continuous simulation.
- The analytical approach makes assumptions about network traffic before a simulation.

Apps and Traffic

- You can use simulation to estimate the effect that deploying a new application will have on a production network.
- Until you deploy the application, probes on your network won't capture the application's traffic.
- To measure a new application's effect on a simulation, you first must add the application to one machine on the production network or (preferably) to a lab network.
- Then, you can gather basic information about the application's individual conversations so that you can identify the following information for every conversation on the network:
- The network protocol, the application that generates the conversation, the conversation's source and destination computers, the number of packets and bytes that travel in each direction, total round-trip latency for the application, and the duration of the conversation.

Life Cycle Management

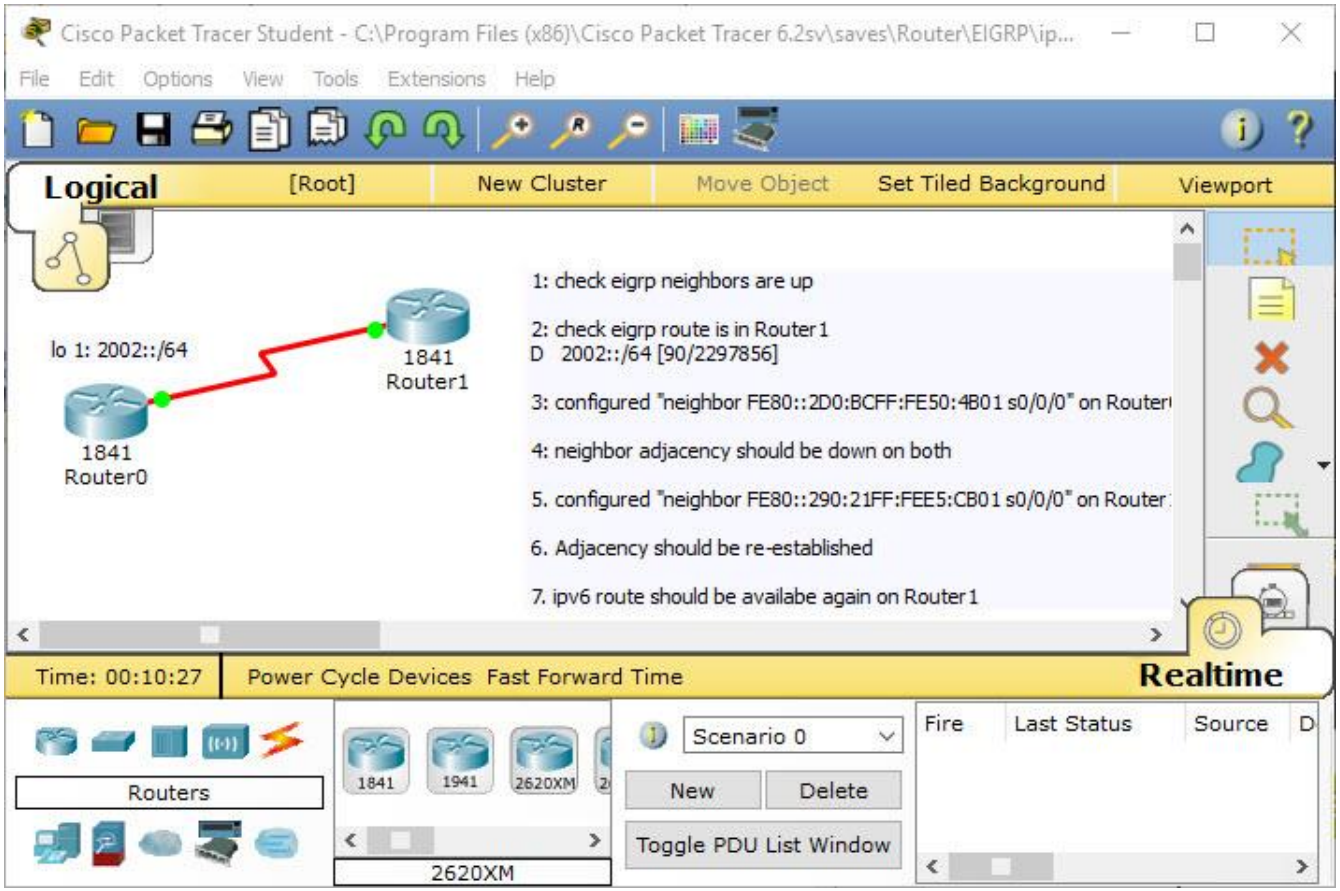


Visualisation Tools

- The problem with simulators is that they can produce an overwhelming amount of information and results that describe dynamic events can be difficult to interpret when viewed statically.
- Programmes such as *nam* help with this problem by animating the network simulation to show the packet movement, dropped packets, queues and congestion to get a better idea of what is happening.
- *Packet Tracer* from Cisco is a useful too to help understand how networks function - you must understand how networks work before you can use a network simulator effectively.

Packet Tracer

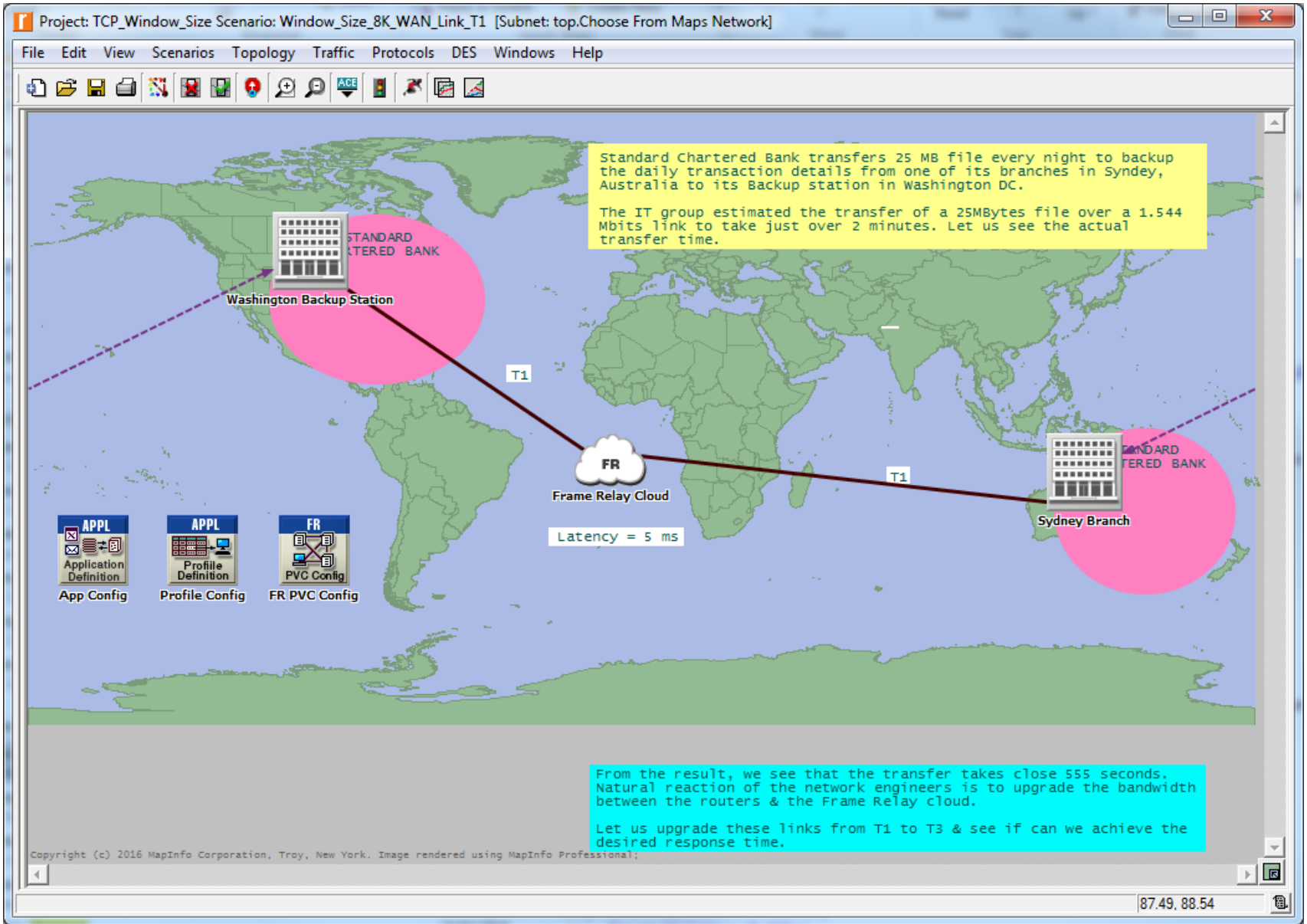
- Cisco Packet Tracer is a network simulation program that allows students to experiment with network behaviour and ask “what-if” questions.



Change Simulation or 'What-IF Analysis'

- Simulators such as *Riverbed Modeler* allow models (or simulations) of existing or planned networks to be created.
- You can do 'what-if analysis' or change simulation (called scenarios in *Riverbed Modeler*) on pre-existing network models.
- e.g. you can look at how latency (delays) and bandwidth affects application performance over a WAN (see Panko Lab5)

Panko Lab 5: Simulating effects of TCP window size on File transfer



Emulation

- An alternative to simulation modeling is to have a test network that allows you to try out changes to topology, upgrades and new applications without affecting the production network.
- The main problem however is how to generate traffic that emulates the real world production network.

Emulators

- A network emulator is a device that sits on a network and mimics the behaviour of network devices such as routers or parts of the system such as subnets.
- Actual traffic measurements are made under the control of the emulator.
- Emulators lie between simulators and live systems.
- They allow experiments with a high degree of reproducibility.
- For example, an emulator might duplicate or approximate the behaviour of an attached network device.

Case for Emulation

- Network simulation involves use of theoretical mathematical models and is prone to error because they cannot fully take real world behaviour into account.
- Emulation uses an empirical approach and can use live applications such as VoIP to generate the traffic or import real data from a production network into the emulation network

Emulating apps over a WAN

- Once the emulated WAN is defined, you can activate your emulation and exchange data through various applications such as VoIP, as you would do on the real WAN.
- You can then observe and analyze the effects of the different WAN settings on the quality and stability of the applications or products that you are testing

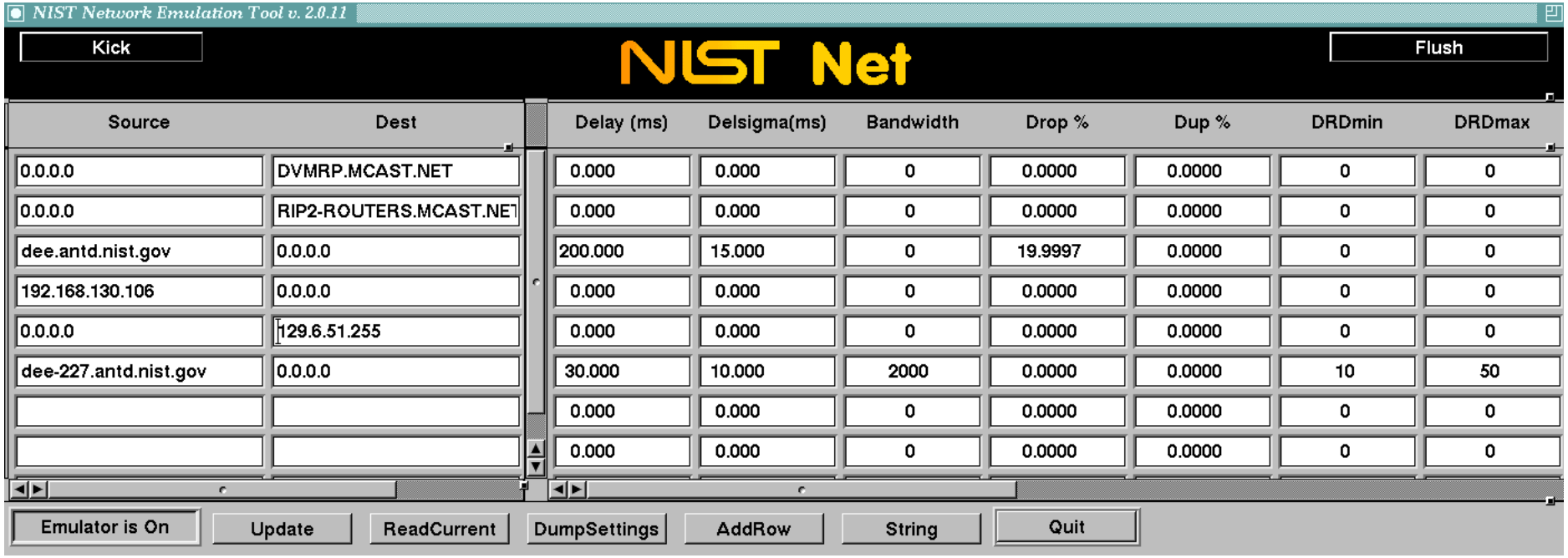
Some available Emulators

- *NISTNet* open source emulator for Linux
- INE commercial emulator for Windows
- Shunra commercial WAN emulator for Windows
- *WANem* open source WAN emulator for Windows

NIST NET

- The NIST Network emulation tool (NIST Net) is a general purpose tool that can be used to emulate the dynamics of an IP network.
- NIST Net allows you to use a LINUX system configured as a router to emulate a number of different network scenarios.

NIST NET Console



WANem

- Wide Area Network Emulator
- TCS - Performance Engineering Research Centre (PERC) has released WANem which can emulate real networks in a development or test environment.
- Emulates on a LAN to help developers to better understand the application behaviour of various networks such as WANs

Testing Mode

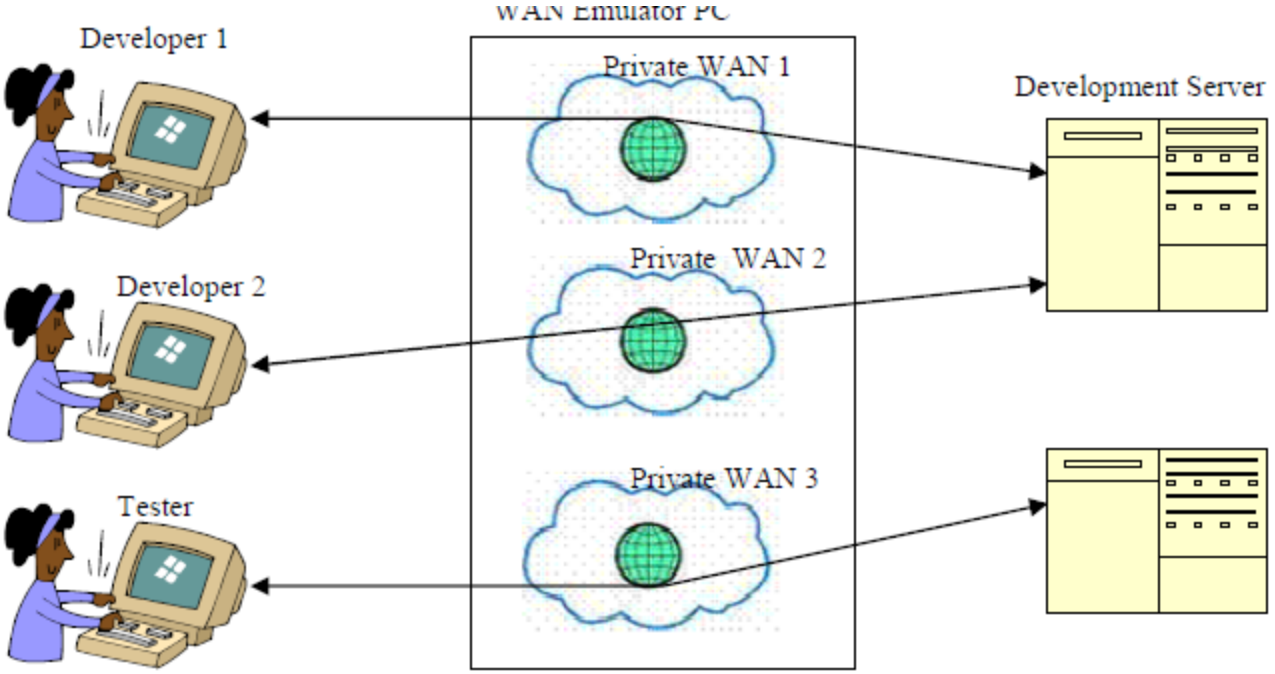
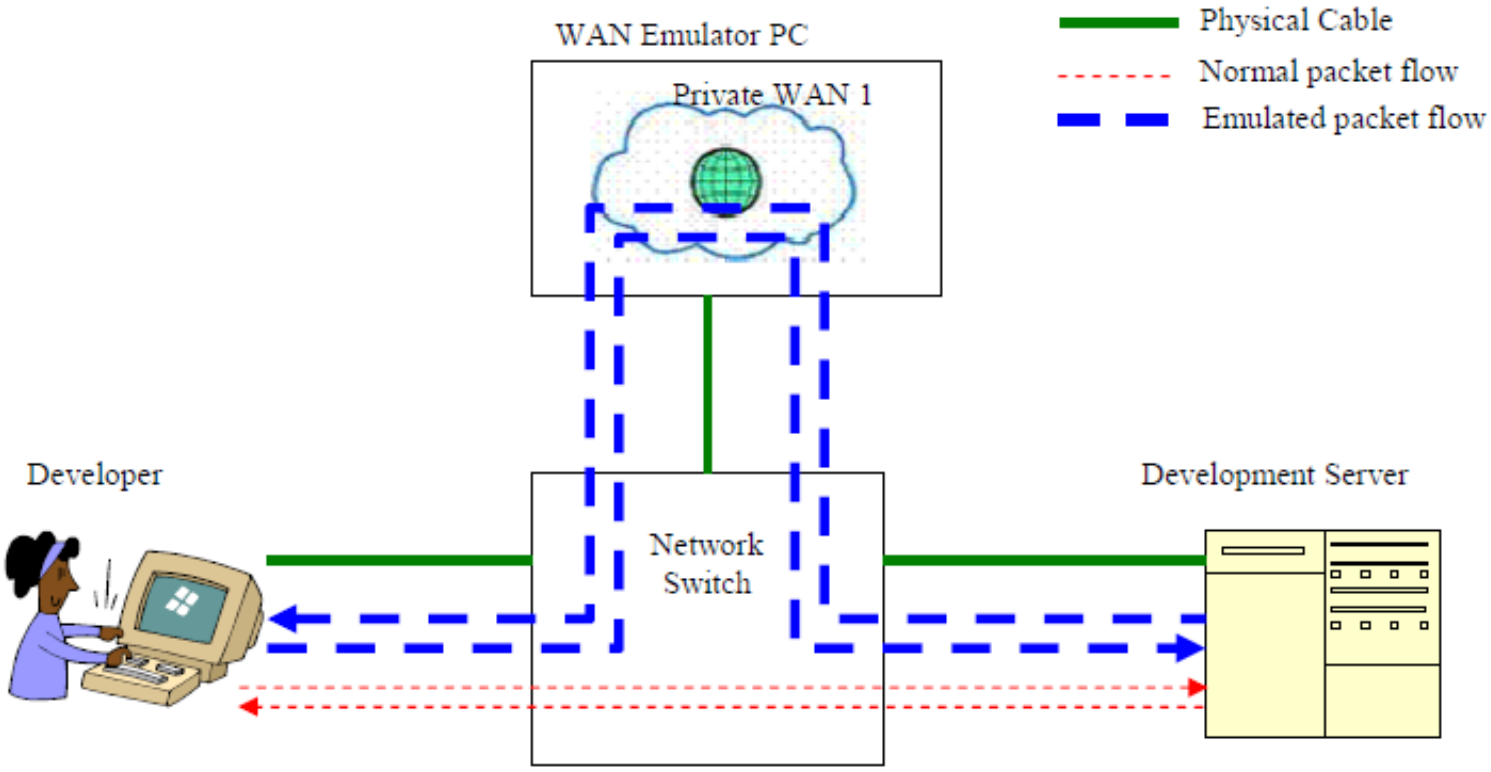


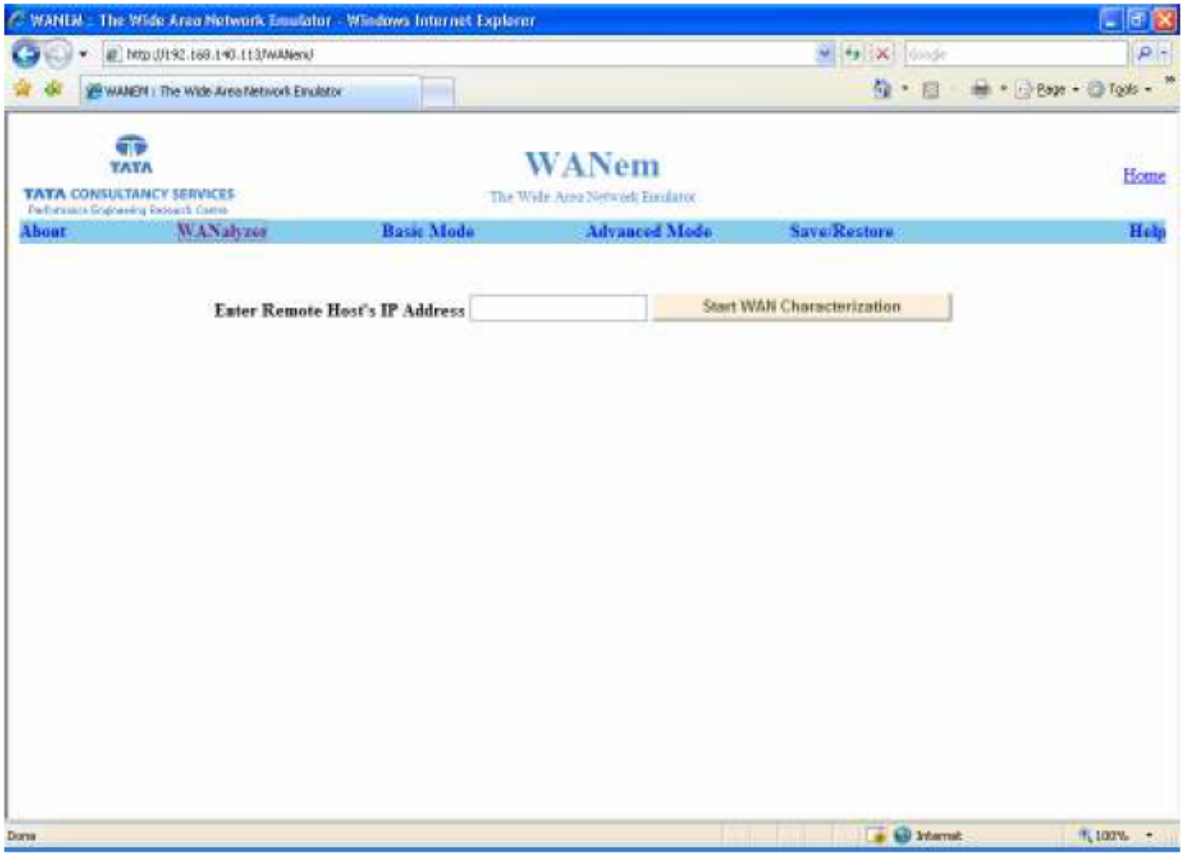
Figure 1 Unit Testing Mode

Using WANem


Physical Cable
Normal packet flow
Emulated packet flow
WAN Emulator PC
Private WAN 1
Developer
Network
Switch
Development Server

WANanalyzer

To measure the WAN characteristics between the WANem box and the remote machine, one needs to enter the IP address of the remote machine. If the remote machine is reachable then WANalyzer will measure the WAN characteristics and produce the results as shown



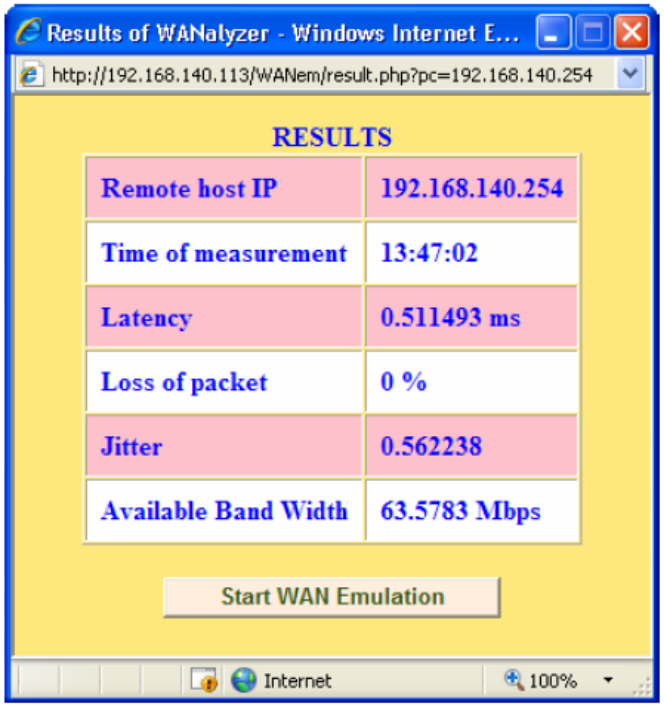
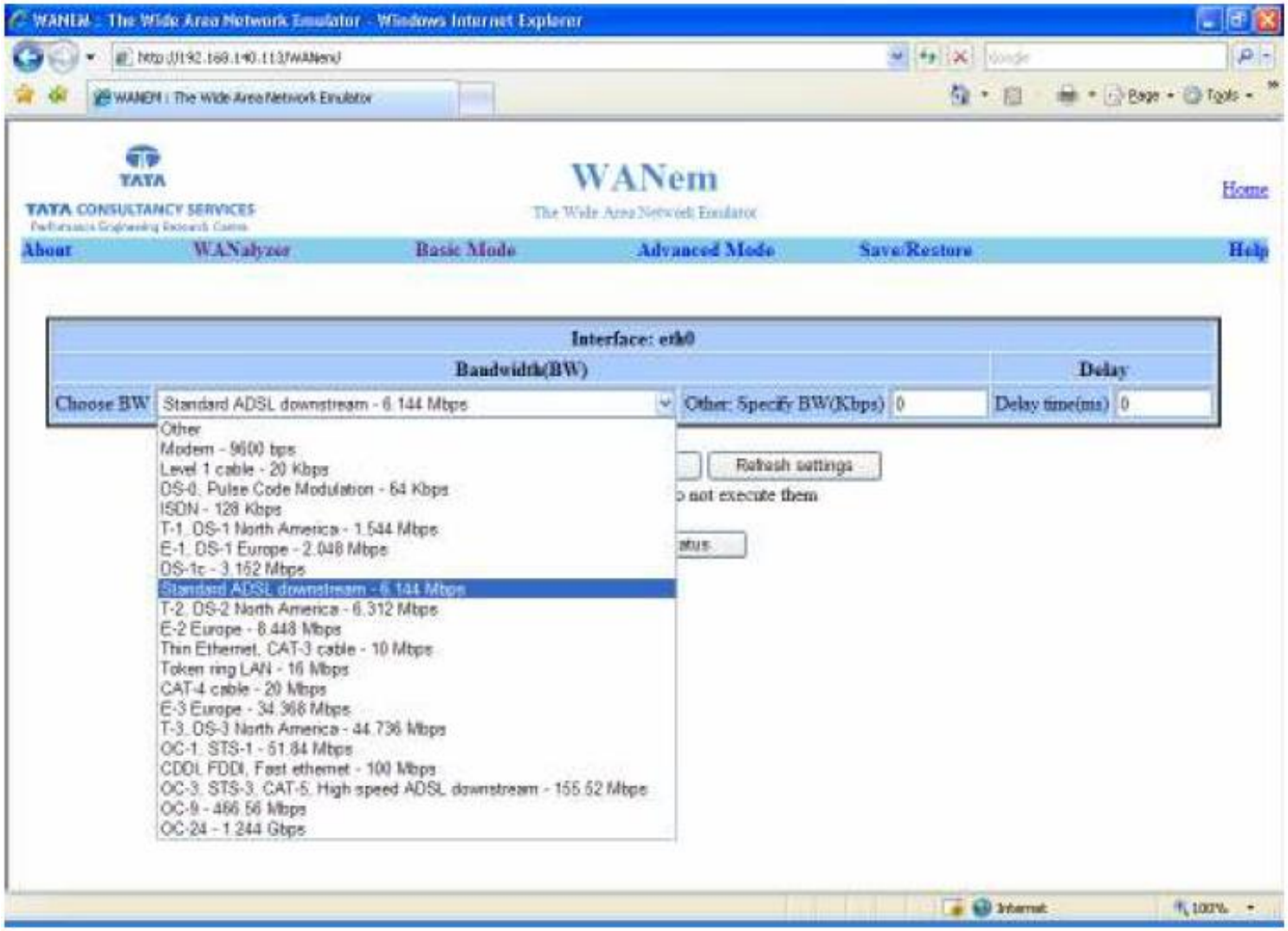
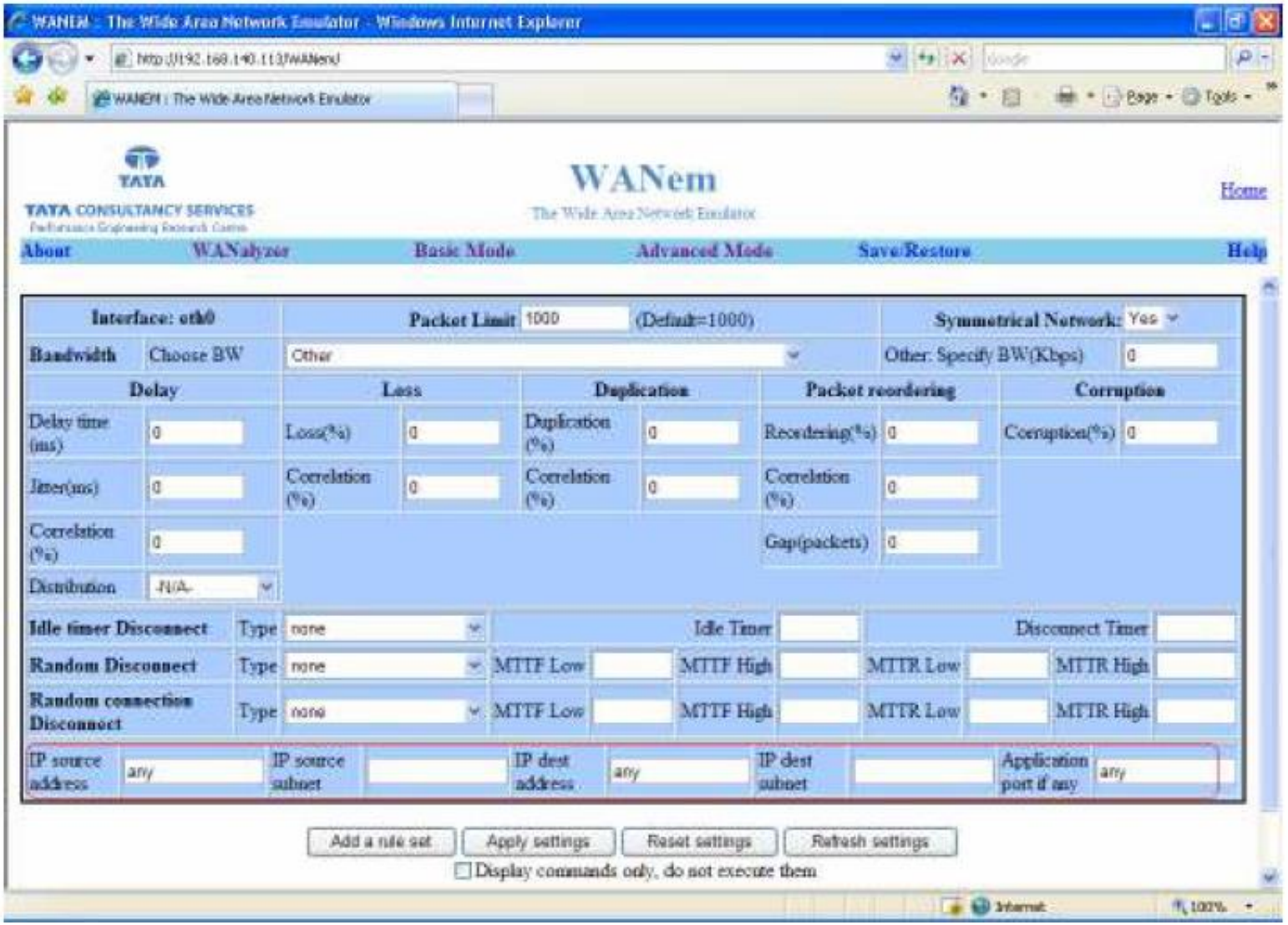


Figure 5 WANalyzer GUI – with result window

WANem Basic Mode

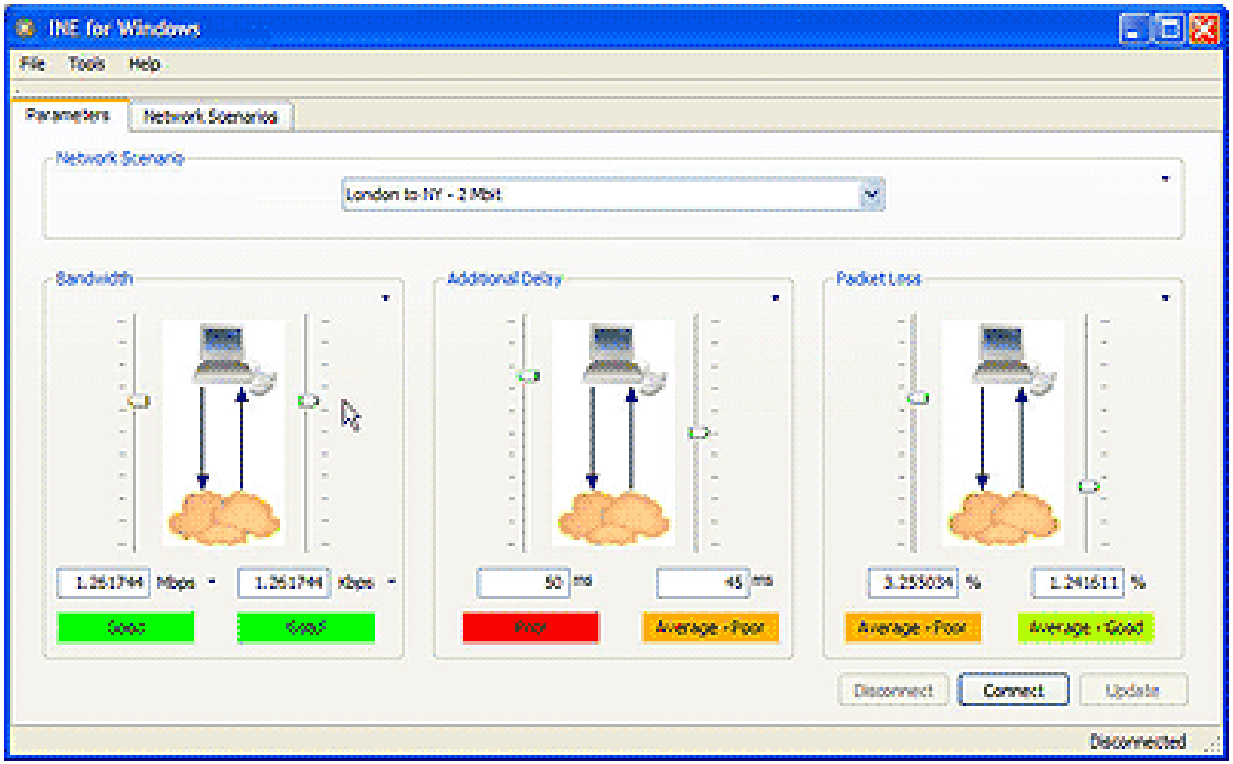


WANem Advanced Mode



INE and NE-ONE

- iTrinergy Network Emulator (INE and NE-ONE Emulator): enable you to realistically recreate a wide variety of network conditions like latency, jitter, packet loss/error/reordering and bandwidth restrictions so that you can simulate environments such as Wide Area Networks (WANs), Wireless LANs, GPRS, 3G, IP over Radio / Radio over IP(RoIP), Satellite or MPLS networks.



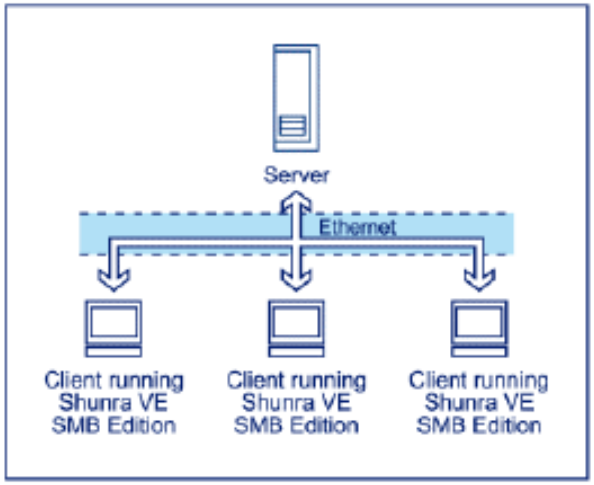
SHUNRA

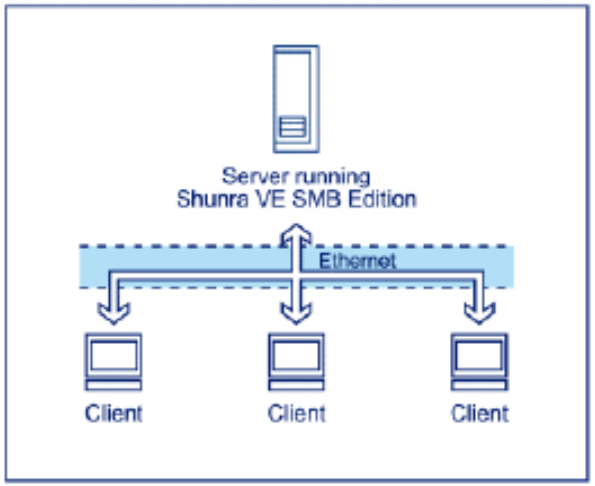
- Wide area networks such as the Internet and complex Intranets are characterized by the variety of network infrastructures they support.
- Making sure that communications products function well and have reasonable response times in such a varied environment is a difficult task.
- Parameters such as physical distance, time of the day, connection speed, and the quality of the Internet services can greatly affect the speed and efficiency of data transfer.
- By emulating a WAN, Shunra VE SMB Edition reduces much of the pain and expense associated with the testing of applications under wan conditions.

Shunra VE SMB

- Shunra VE SMB Edition emulates a point-to-point WAN in the laboratory.
- The software is used to introduce network parameters such as bandwidth, latency, and packet loss that characterize WANs, to a LAN environment.
- Also included is VE Network Catcher Lite, which can be used to record real WAN data and incorporated into Shunra VE SMB Edition for emulation purposes.
- For the academic tester Shunra VE SMB Edition also offers standard mathematical algorithms and the ability to import any model from a simple text file.
- Once the emulated WAN is defined, you can activate your emulation and exchange data through various applications such as VoIP, as you would do on the real WAN.
- You can then observe and analyze the effects of the different WAN settings on the quality and stability of the applications or products that you are testing

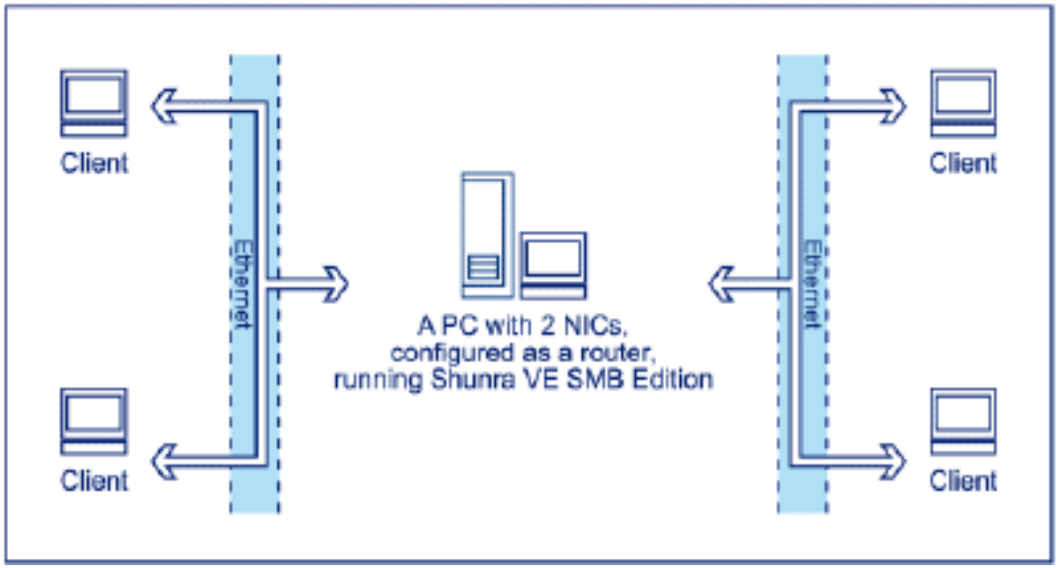
Shunra Network Configuration





The objective of the test is **to create individual WAN conditions for the different clients**, where each client represents an entity such as different branches of an organization, which are situated in different geographical locations. This configuration assumes that each client-branch has access to the server through a different WAN environment.

The objective of the test is to **check the data flow that enters and exits a server.** Shunra VE SMB Edition software needs to be installed on the server machine. Your network will include client machines that communicate with that server and Shunra VE SMB Edition will affect the data flow between them as if it passed through the real WAN. The following figure illustrates the single server configuration:

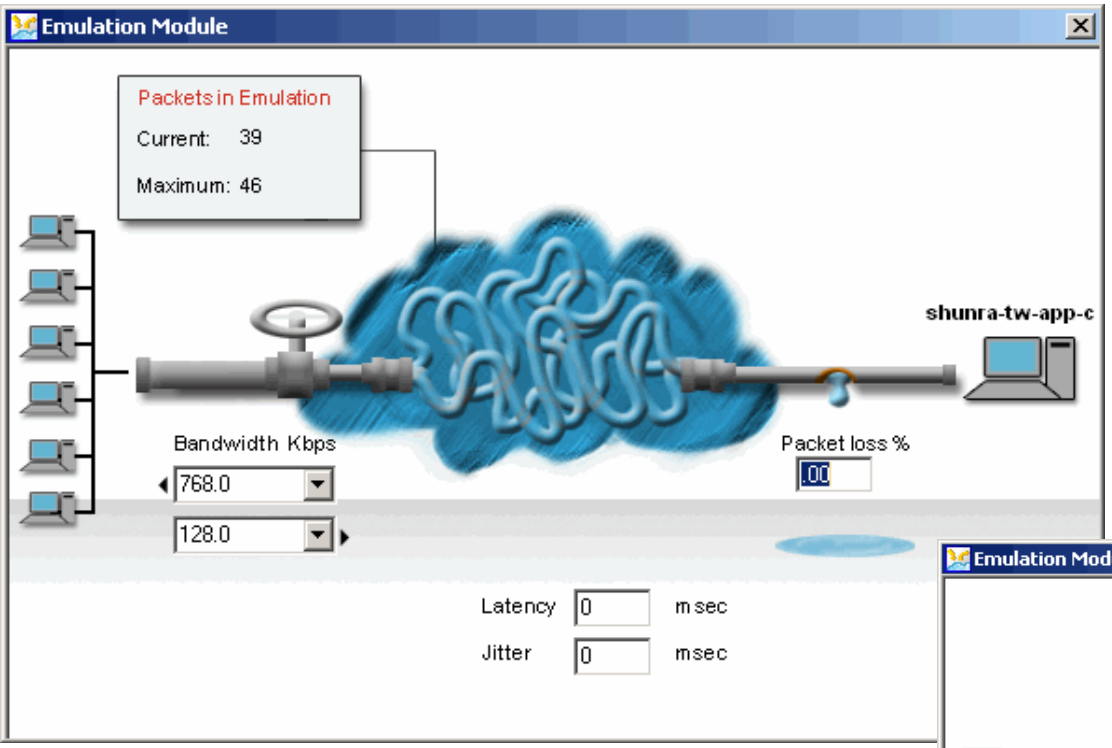


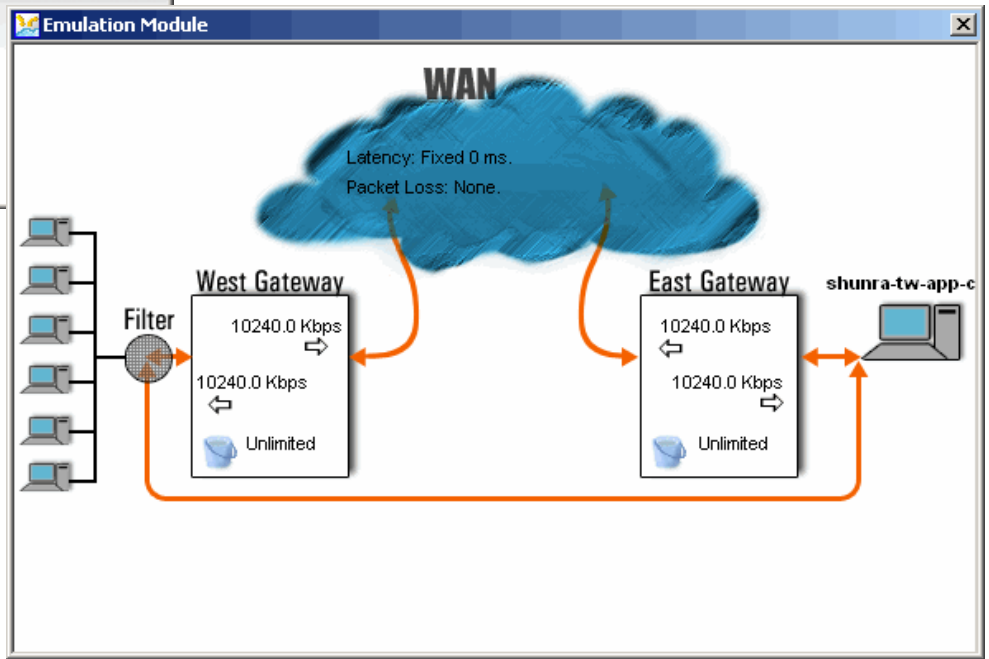
The router model **is a flexible configuration that allows you to create a stand-alone test unit based on Shunra VE SMB Edition.**
You can use the unit to run a variety of tests that involve different clients and servers without the need to install Shunra VE SMB Edition on the clients or the servers themselves.

Emulating a Network with Shunra

- This section reviews how use Shunra VE SMB Edition to impair network traffic and view data regarding the results of this impairment.
- To emulate the network, you enter network parameters (such as expected packet loss, or the latency of the emulated WAN).
- The parameters are entered through Shunra VE SMB Edition graphical user interface.
- You must enter the parameters on each machine, where Shunra VE SMB Edition is installed.

Shunra Example Screens





Load Generation

- Before you can emulate network traffic, you need to learn how information flows on your network.
- Monitoring your network and collecting traffic requires special tools that captures data or communicates with SNMP or Remote Network Monitoring (RMON) agents.
- To test realistic performance of a network you need to generate large amounts of data to see how the network devices respond to the increase in load.

Stress Testing

- A number of programmes and network analysers have the ability to generate traffic to test network performance.
- These range from custom packet generators that allow you to create packets with a great deal of control as to what is injected onto the network to load generators that are used to stress test the network and do not give much control.

Load Generation Tools

- Commercial:
  - Ixia Chariot
  - Load Runner
  - Rational Performance Tester
  - WebLOAD
- Open source:
  - The Grinder
  - Siege
  - JMeter
  - iPerf
  - D-ITG

Benchmarks

- Benchmarks are values that are used to measure the performance of products such as processors, video cards, disc drives, applications or whole systems.
- They are popular performance indicators that allow companies to compare themselves with the competition.
- They are used by sales and marketing to promote products but the real purpose of benchmarks is to indicate the level of performance you can expect when using the product.
- Benchmarking is the process of comparing one's business processes and performance metrics to industry bests and best practices from other companies.

Benchmark Providers

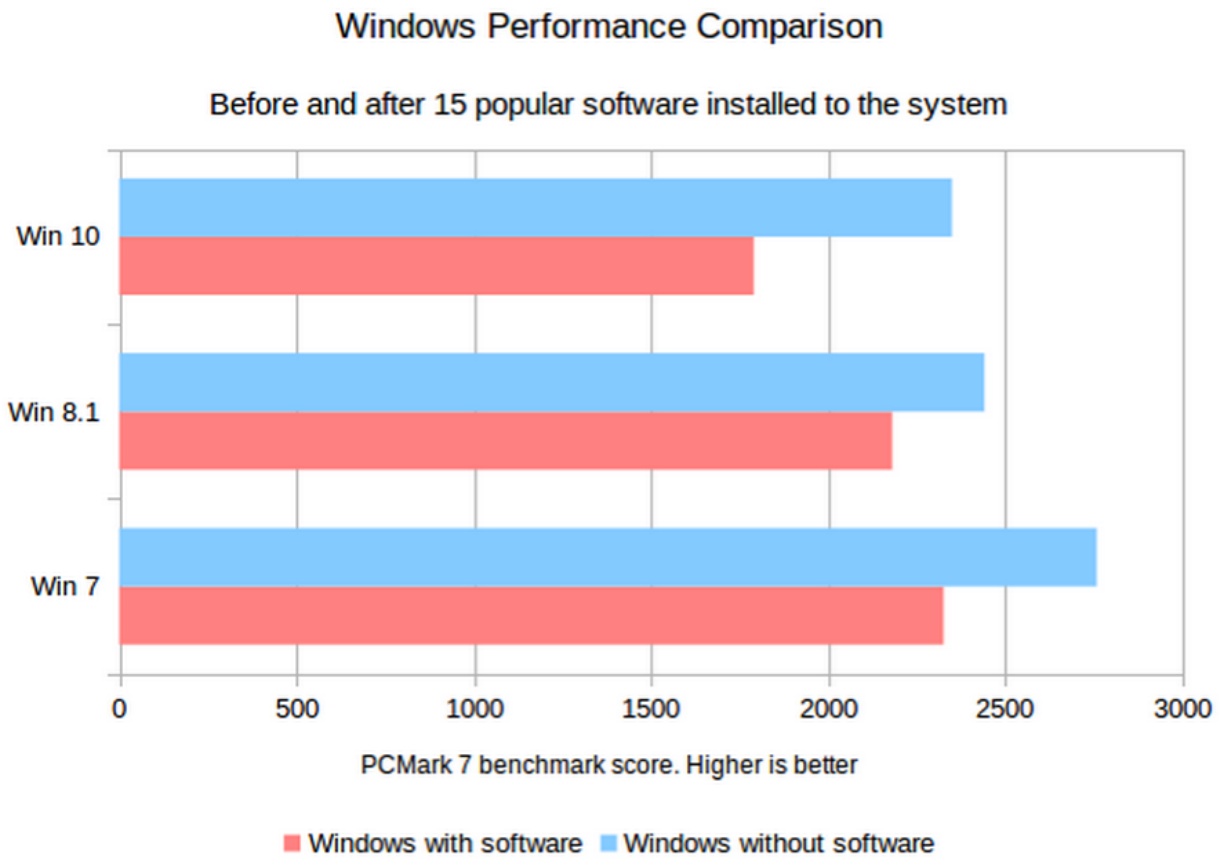
- Most benchmark programs are provided by the vendors themselves but they can originate from a variety of other sources as well
- Magazines or benchmark organizations such as Ziff-Davis WinBench suite (inc. Winstone standard workloads)
- SiSoft's Sandra for instance provide comprehensive tests of all aspects of a computer system
- Veritest's NetBench for instance is designed to test client/server performance of file servers and WebBench for web servers.
- Linpack and High Performance Linpack (HPL) to test CPU and HPC performance.
- Speed test sites for evaluating Broadband performance such as SpeedTest.net are available

Example Benchmark

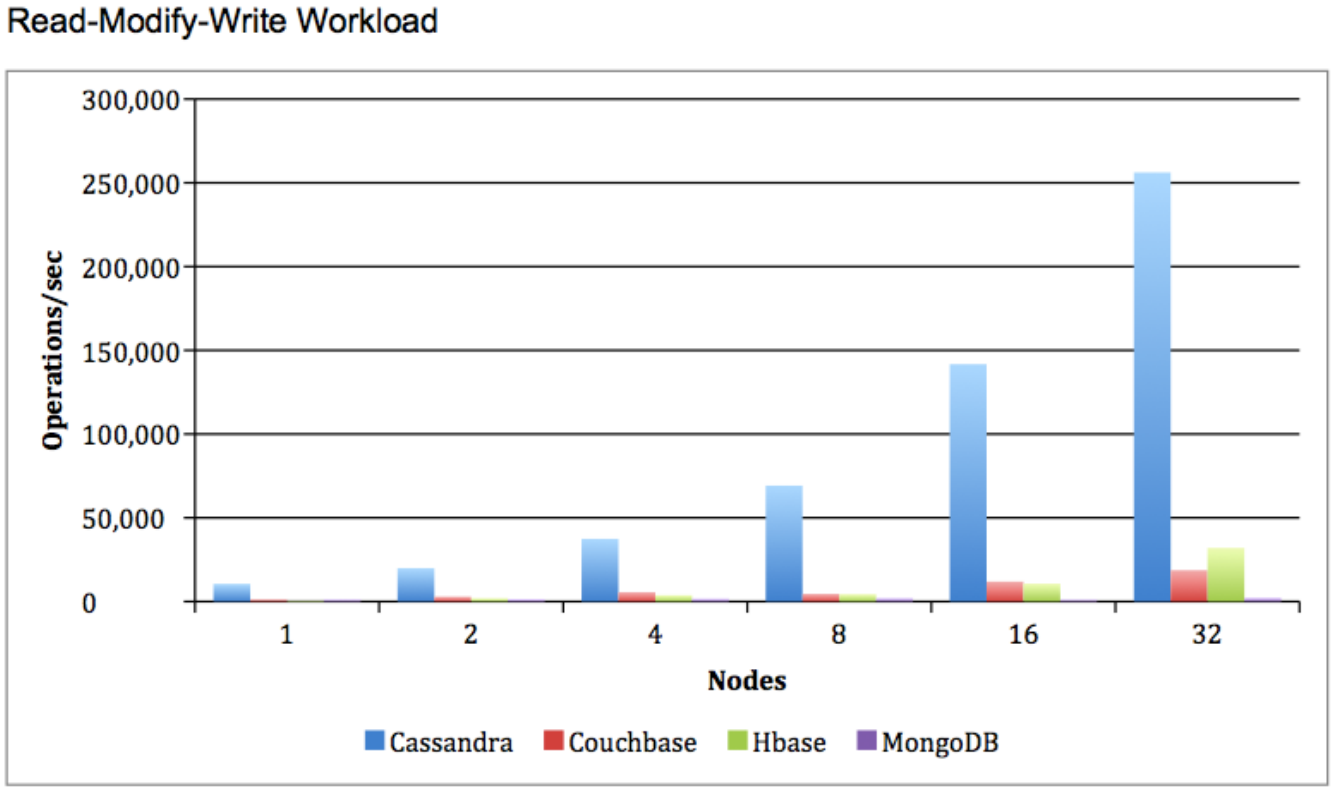
PC Performance Benchmark - SiSoftware Sandra Lite	
OS	Total Score
Windows 7	1.167 kPT
Windows 8.1	1.232 kPT
Windows Technical Preview	1.229 kPT

Game Performances - Fraps				
Need For Speed Carbon - Medium(preset) - 1024*768				
OS	Frames per minute	Min	Max	Average
Windows 7	999	12	21	16.650
Windows 8.1	986	13	20	16.433
Windows Technical Preview	995	14	19	16.583

Example Benchmark

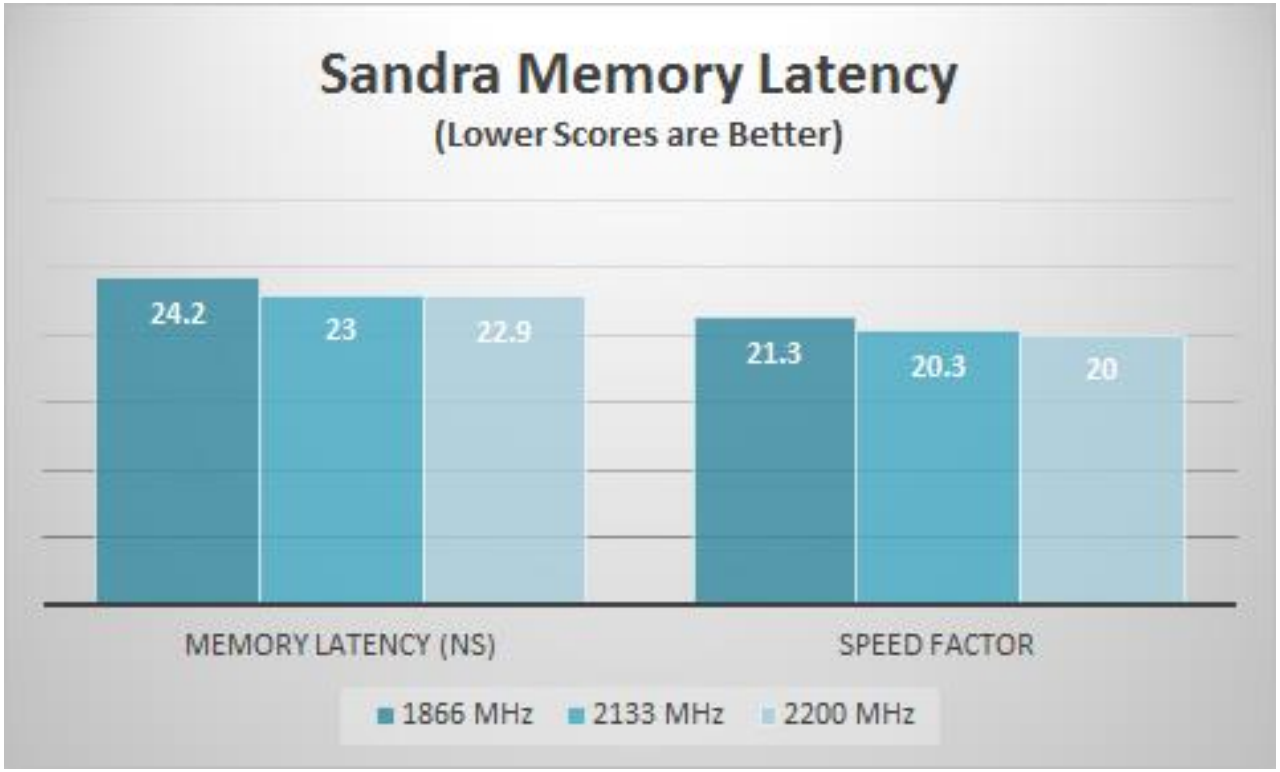


Example1 Workload Benchmark

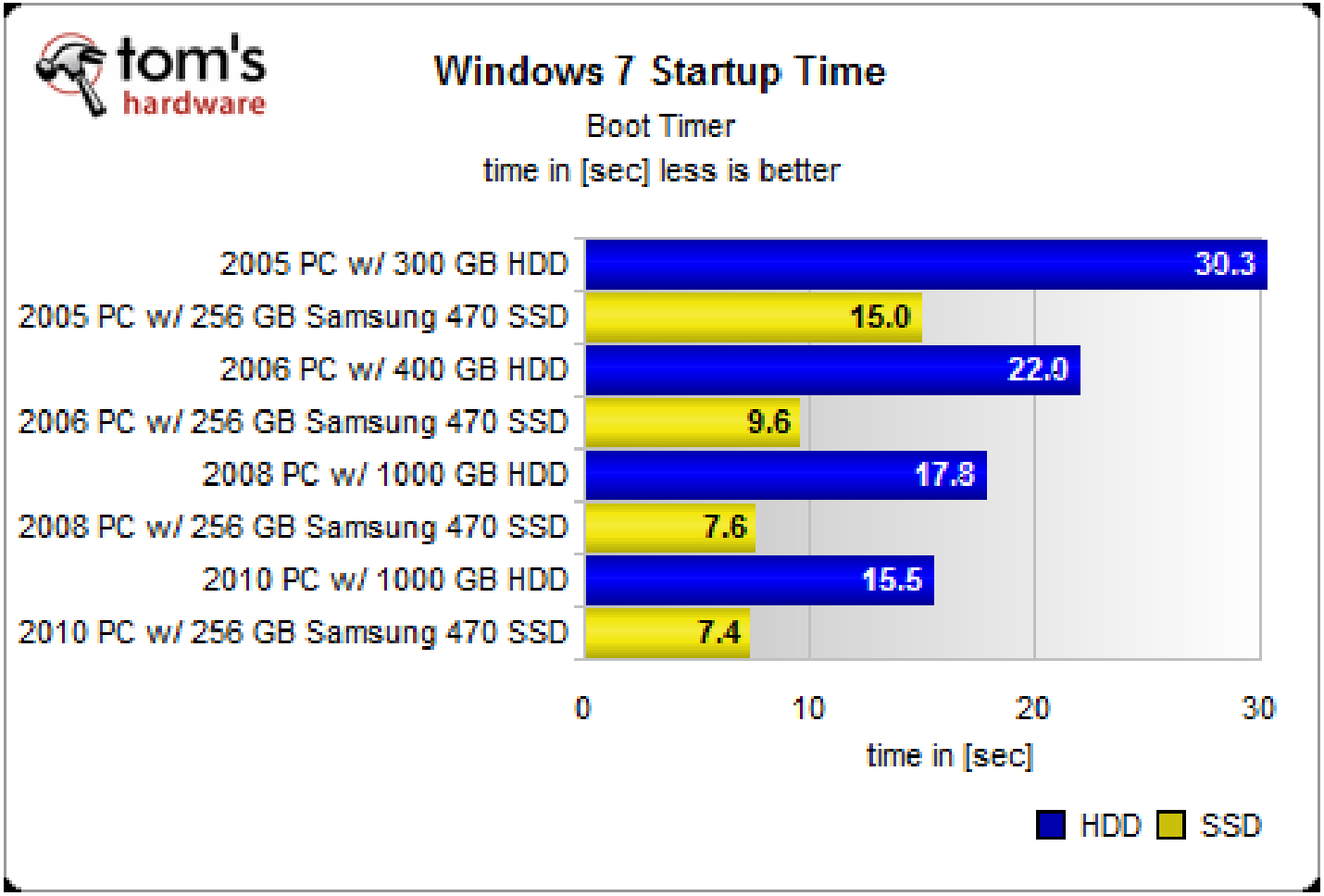


Nodes	Cassandra	Couchbase	HBase	MongoDB
1	10,555.73	1,326.77	519.35	1,261.94
2	19,919.52	2,928.64	1,949.13	1,480.72
4	37,418.16	5,594.92	3,773.06	1,754.30
8	69,221.07	4,576.17	4,412.47	2,028.06
16	141,715.80	11,889.10	10,654.14	1,114.13
32	256,165.66	18,692.60	31,989.63	2,263.69

Example 2 Latency Benchmark

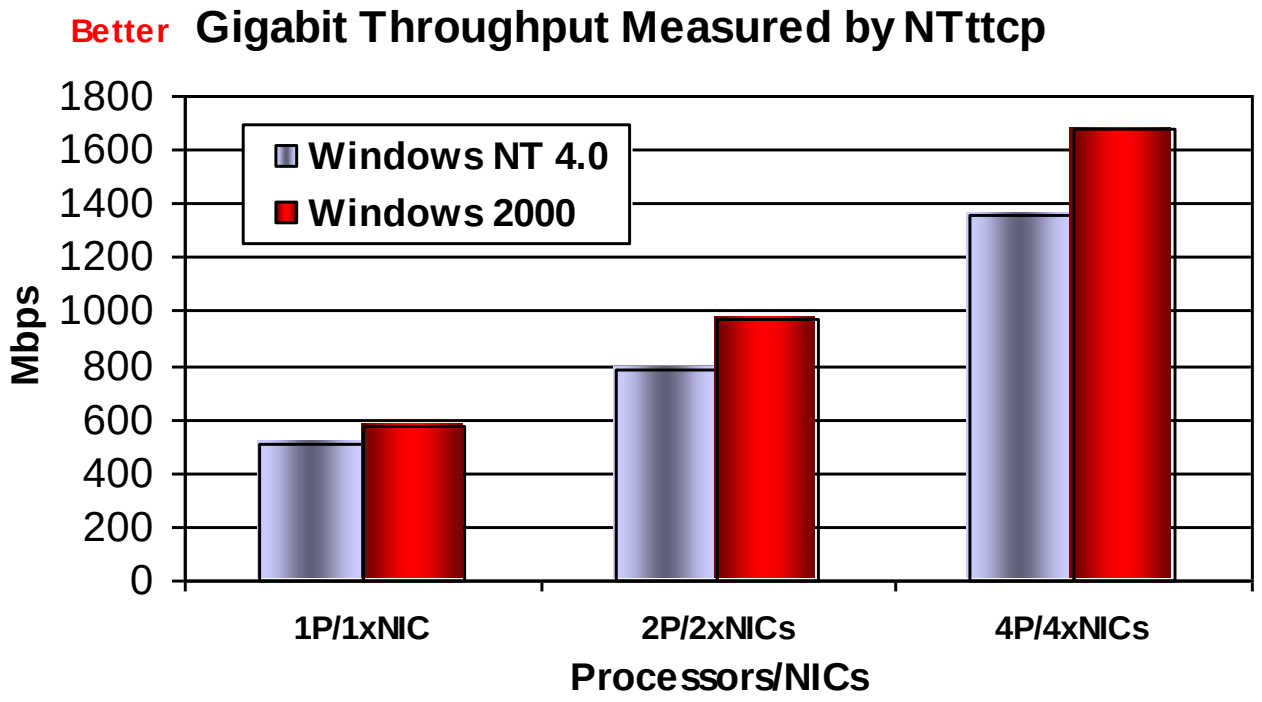


Start-up Time



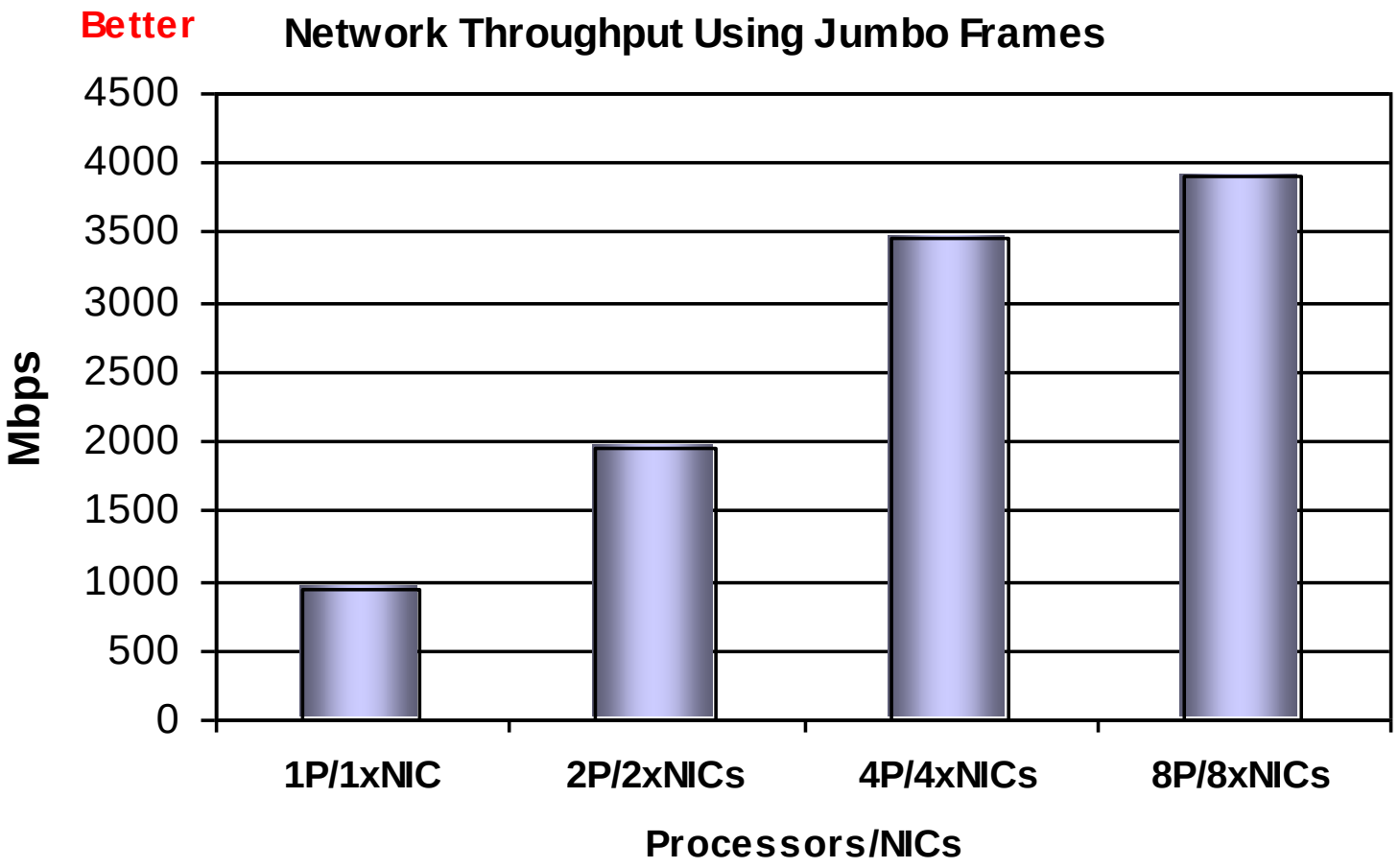
TTCP Benchmark

Bar chart comparing gigabit throughput on systems with different processor/network adapter (NIC) configurations.



The above results above were generated using a standard frame size of 1.5 KB

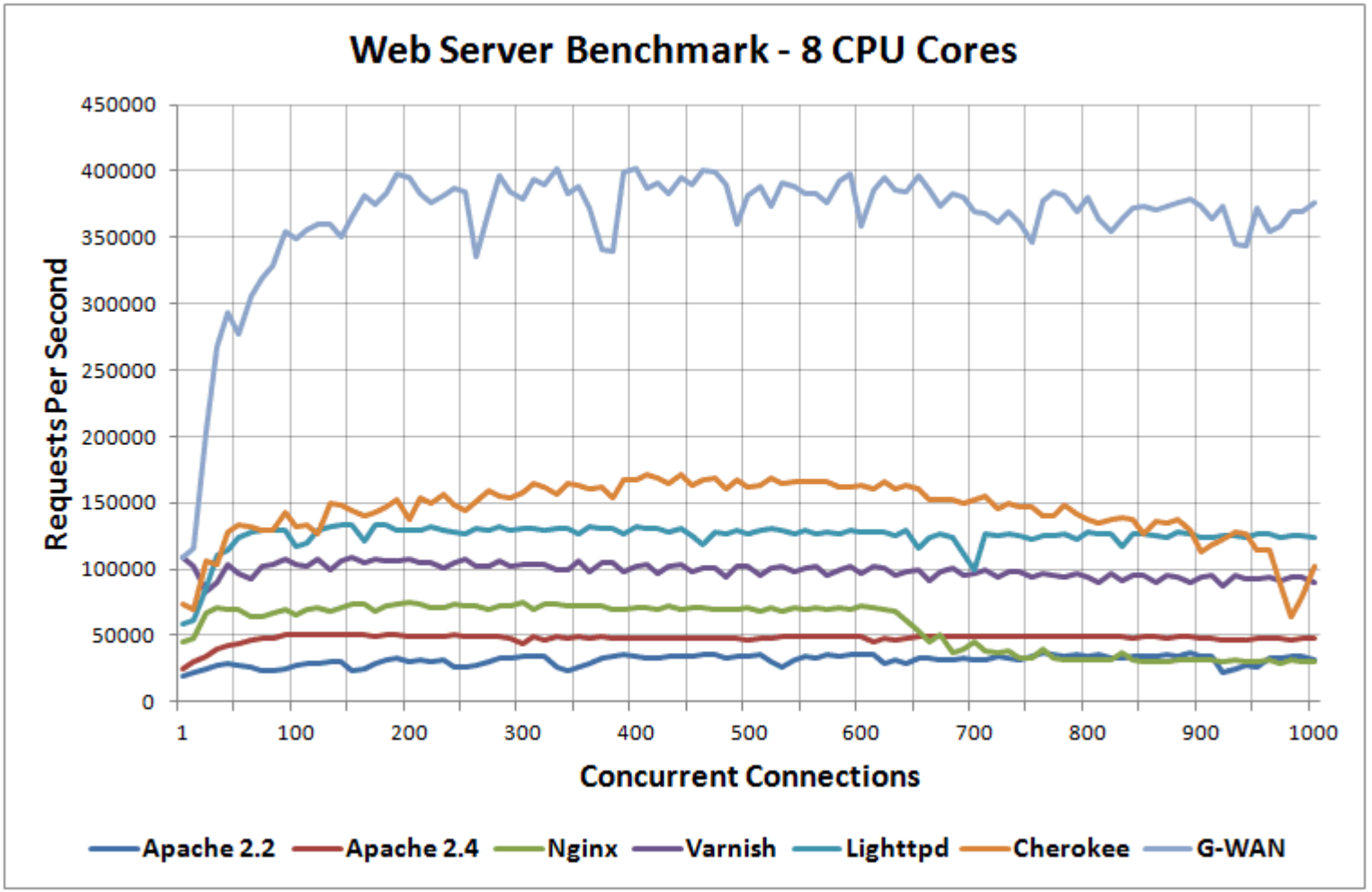
Large Frame Size



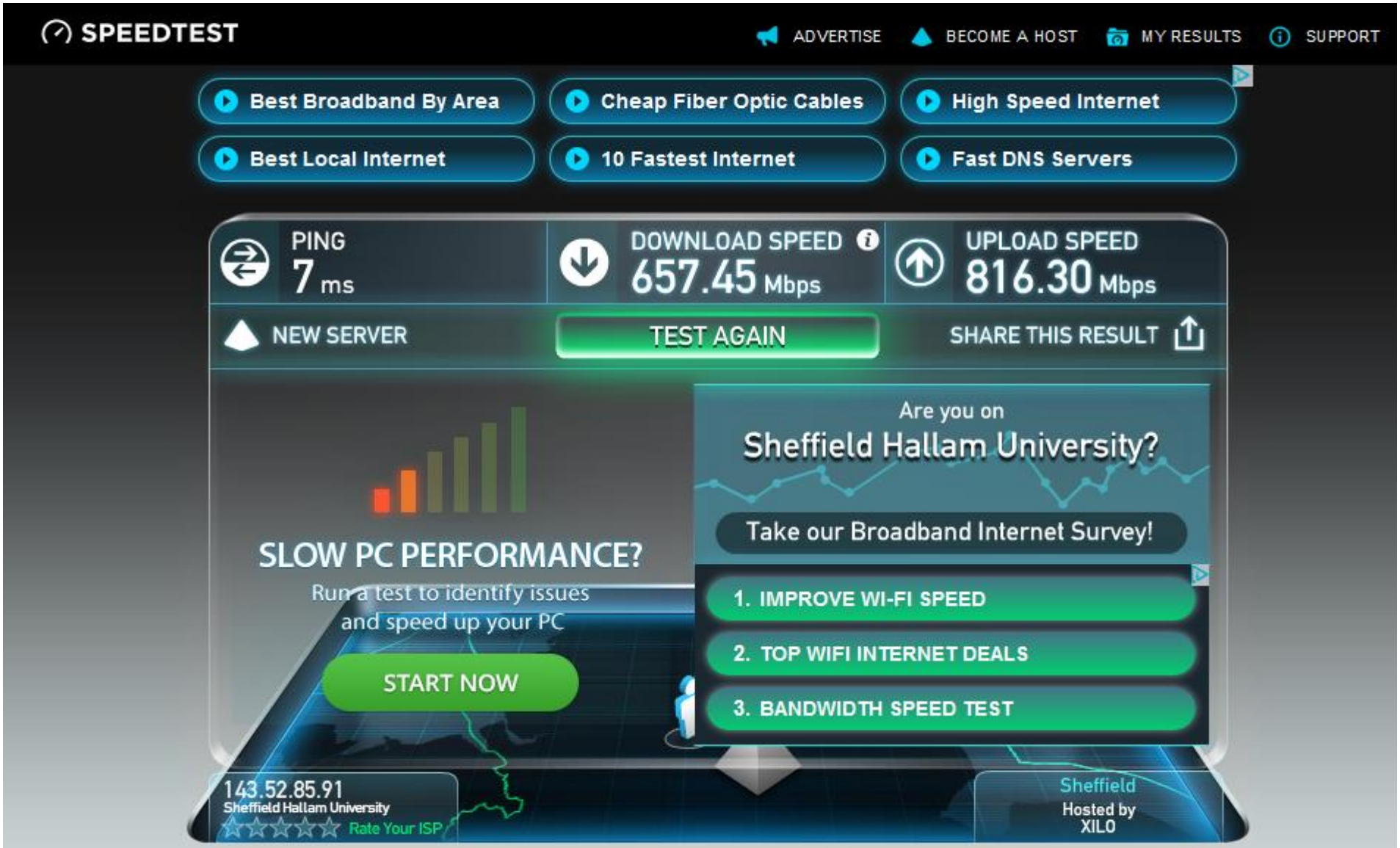
Analysis

- Using jumbo frames (9 KB frame size), Windows 2000 can deliver close to 4 Gbps of network throughput, which is the maximum supported by hardware currently available.
- With four processors and four network adapters, the hardware is very close to the maximum I/O it can support.
- So when additional CPUs and network adapters are added, the network throughput doesn't increase as much when moving from two CPUs/two network adapters to four CPUs/four network adapters.

Web Server Benchmark



Broadband Speed Testing



Broadband Quality Test

Study Resources

- Modeling and simulation of IEEE 802 11 using OMNeT++ https://www.youtube.com/watch?v=JCjVdXYsvJY
- Understanding CPU characteristics https://www.youtube.com/watch?v=UI6Xmum0i90
- Measuring Throughput with Wireshark and Riverbed https://www.youtube.com/watch?v=HYs1azeDnZ4