**Network Throughput Simulator**

Developed by Leo Barnabas Mariadoss Anthoniraj for use in networking classes taught by George Blank at NJIT. ***If you have problems installing the program, see the installation instructions at the end of this document***.

This simulator is to illustrate delays in a network. Users can select values for packet size, transmission speeds, link distances, processing delays and queuing delays. The simulator will then calculate the transmission delay, propagation delay, processing delay, queuing delay, and nodal delay at each node, and the total end-to-end delay from source to destination.

The simulated network consists of a sending Host, an Ethernet LAN link to an Ethernet switch, another Ethernet LAN link to a Router, a fiber backbone link to a second Router, an Ethernet LAN link to a WiFi Access Point, and a radio link to a destination Host. There are 5 links and six nodes. The nodes are the sending Computer, the Switch, the two Routers, the Access Point, and the destination Computer. If you mouse over the diagram, you will see the identification of the node.

The **Transmission Delay** is the time it takes to put a signal on a link. The formula is **L/R**, where **L** is the length of the packet in **bits**, and **R** is the carrying capacity of the link in **bits per second**. Four choices are given for packet size, 80 bytes, 1280 bytes, 1500 bytes, and 2347 bytes.

80 bytes (640 bits) is the minimum size of a TCP packet on an IPv6 network, consisting of a 20-byte TP header, a 40-byte IPv6 header and a 20-byte header for Ethernet or WiFi. TCP sends packets without data to establish a connection before data is transferred, so header only packets are very common.

1280 bytes are specified as the minimum value for the Maximum Segment Size (MSS) on an IPv6 network. A network must be able to carry packets at least this large to use IPv6.

The MSS for an Ethernet network varies from 1500 bytes to 1536 bytes, and 1500-byte (12,000 bit) packets are common on Ethernet.

The MSS for WiFi is 2347 bytes. Note that since IPv6 does not allow fragmentation, messages sent over mixed networks are limited to the smallest MSS on the various links.

Common **Transmission Rates** are given for different technologies in the simulator. For **Ethernet** there is a choice of 10 million, 100 million or 1 billion bits per second (10 Mbps, 100 Mbps or 1 Gbps). For **WiFi**, choices given are 11 Mbps (802.11b), 54 Mbps (802.11a and 802.11g), 200 Mbps (802.11n), 600 Mbps (822.11n+) and 867 Mbps (802.11ac single channel). For **Optical Fiber**, transmission rates given are 50 Mbps (OC1 is 50.112 Mbps), 148 Mbps (OC3 is 148.608 Mbps) and 9510 Mbps (OC 192 is 9.51 Gbps).

**Propagation Delay** is calculated as **d/s**, where **d** is the distance traveled in **meters**, and **s** is the speed through the propagation medium in **meters per second**. Radio waves for WiFi are assumed to propagate at the speed of light, rounded to 300 million meters per second. Electrical signals in copper wire and light pulses in optical fiber are assumed to propagate at approximately two-thirds of the speed of light, rounded to 200 million meters per second.

**Queuing Delays** are the delays encountered when a packet has to wait in a buffer at a router or switch for other packets that have arrived earlier to be put on a link before they can be transmitted. Queuing delays are minimal in Ethernet switches, so values that can be selected are no delay, or 10 or 20 microseconds. Queuing delays in Routers are very common, and can be the most significant delay in end-to-end transmission. Values that can be selected are no delay, 50 microseconds, and 10 or 100 milliseconds.

**Processing Delays** are the time required to add headers and trailers, compute checksums, interpret information in headers, and similar processing at each node. Processing delays tend to be largest in hosts, smaller in access points and routers, and minimal in switches, but they are not of major concern in a course in networking. So the user is given a choice of 1 or 10 microseconds or 1 millisecond, and that delay is applied at each node.

**Nodal Delays** are the sum of all the delays encountered at a single node, like a host, switch, access point or router.

The **End-to-End Delay** is the total time it takes a transmission to be sent from the source to the destination, and is the sum of the Nodal Delays. The **End-to-End Delay** is given in **microseconds**, **milliseconds** and **seconds** as a way of reminding the user that specifying the units for delays is important. A millisecond is a thousandth of a second, while a microsecond is a millionth of a second. Operations inside a CPU can occur in picoseconds (billionths of a second), so a network is orders of magnitude slower than the processing in a computer.

**Glossary**

Users of this program should also be aware of the distinction between **bits** and **bytes**. File sizes and message lengths are normally given in bytes, while transmission speeds are given in bits. Multiply bytes by 8 to get bits. Another important distinction is between the prefixes ***Mega*** for million and ***Giga*** for billion. A **Megabit** is a million (1,000,000) bits, while a **Gigabit** is a billion (1,000,000,000) bits. Transmission speeds are given in Megabits per second and Gigabits per second.

Note that *Mega* and *Giga* actually have a different definition for file sizes than they do for transmission speeds. Historically, dating back to the invention of the telegraph nearly 200 years ago, transmission speeds are gived as decimal numbers, while file sizes since the invention of the computer are normally given as binary numbers. Thus a **Megabit** is 1,000,000 bits while a **Megabyte** is 1,048,576 (220) bytes or 8,388,608 bits. A **Gigabyte** is 1024 Megabytes or 1,073,741,824 (230) bytes. A **Kilobyte** is 1024 (210) bytes.

*NOTE: In the United States, a billion is a thousand million. In Great Britain, this used to be called a milliard and a billion was a million million. (1,000,000,000,000). This “long scale” billion is now obsolete, and a thousand million is now the common usage for “billion” in the U.S. and Europe.*

**Installation Instructions**

The program is provided as a Java Archive (JAR) file. You must have the Java runtime package installed on your computer. Java security restrictions normally prevent you from running programs downloaded from the Web. You must set your system preferences to allow the program to run.

**How to Run the Program on a Macintosh computer**

Go to the **Apple** Icon and select **System Preferences**. Click on the Java icon. The Java Control Panel will open in a separate window. Select the Security tab. Change the Security level from the default of Very High to High, which is currently the lowest possible setting. If you have problems installing the program, you may have to go to the **Advanced** tab and permit **Application Installation** (Install if hinted) and **Secure Execution Environment** (Allow user to grant permissions…) and **Mixed Code** (Enable – Show Warning if Needed). You may also want to create an entry on your exception list to allow programs from *https:/web.njit.edu/* to run on your system.

You still will not be able to run a program from the Download in the Browser. Instead, you need to right click on the Download and select **Show in Finder**. You also will not be allowed to run it directly from Finder. Instead, right click on the program and select **Open**. You will be told that the program was downloaded from the Web. You can then choose to run it anyway.

**How to Run the Program on a Windows computer**

From the **Start Menu**, select **Control Panel** and search for **Java**. This will bring you to the **Java Control Panel**. Open the Java Control Panel and Select the **Security** tab. Change the Security level from the default of Very High to High, which is currently the lowest possible setting. You may also want to create an entry on your exception list to allow programs from *https:/web.njit.edu/* to run on your system.

You should now be able to right click on your program and run it from your browser or a folder on your computer. You will have to acknowledge the warning that it was downloaded from the Web and indicate that you trust the program.

**Screen Print Image of Simulator**

