IT-305 Computer Networks

Autumn Semester 2024

Lab04 – Network Simulation on NETSIM

Aim: To understand and analyze the behaviour of basic network topologies, protocols and devices using NETSIM software, with a focus on performance metrics such as throughput, delay and packet loss in different scenarios.

Introduction to NetSim:

NetSim is a comprehensive network simulation tool developed by Tetcos, designed to simulate various network protocols, devices, and topologies. It is widely used in academia and industry for research, development, and education in computer networks. The tool provides an intuitive graphical user interface (GUI) that enables users to model, design, and simulate network scenarios with ease. The NetSim is a user-friendly interface that allows users to create, configure, and simulate network scenarios visually. The GUI provides drag-and-drop functionality to add devices such as nodes, switches, routers and links to the network simulation. It also includes tools for configuring network parameters, running simulations and analyzing results that simplifies the process of network simulation, making it accessible to users with varying levels of technical expertise. NetSim is a versatile tool that supports a wide range of network technologies, making it an ideal platform for studying and simulating various network protocols, devices and scenarios. Below is a list of the key network technologies that can be explored using NetSim:

1. Internetworks

- Ethernet
- WLAN (Wireless Local Area Network)
- IP (Internet Protocol)
- TCP (Transmission Control Protocol)

2. Legacy Networks

- Aloha
- Slotted Aloha

3. Cellular Networks

- GSM (Global System for Mobile Communications)
- CDMA (Code Division Multiple Access)

4. Mobile Adhoc Networks (MANETs)

- DSR (Dynamic Source Routing)
- AODV (Ad hoc On-Demand Distance Vector Routing)
- OLSR (Optimized Link State Routing Protocol)
- ZRP (Zone Routing Protocol)

5. Wireless Sensor Networks

- IEEE 802.15.4

6. Internet of Things (IoT)

- 6LoWPAN Gateway
- 802.15.4 MAC/PHY
- RPL (Routing Protocol for Low-Power and Lossy Networks)

7. Cognitive Radio Networks

- IEEE 802.22

8. Long-Term Evolution Networks (LTE)

- LTE

9. Software Defined Networking (SDN)

10. Advanced Routing and Switching

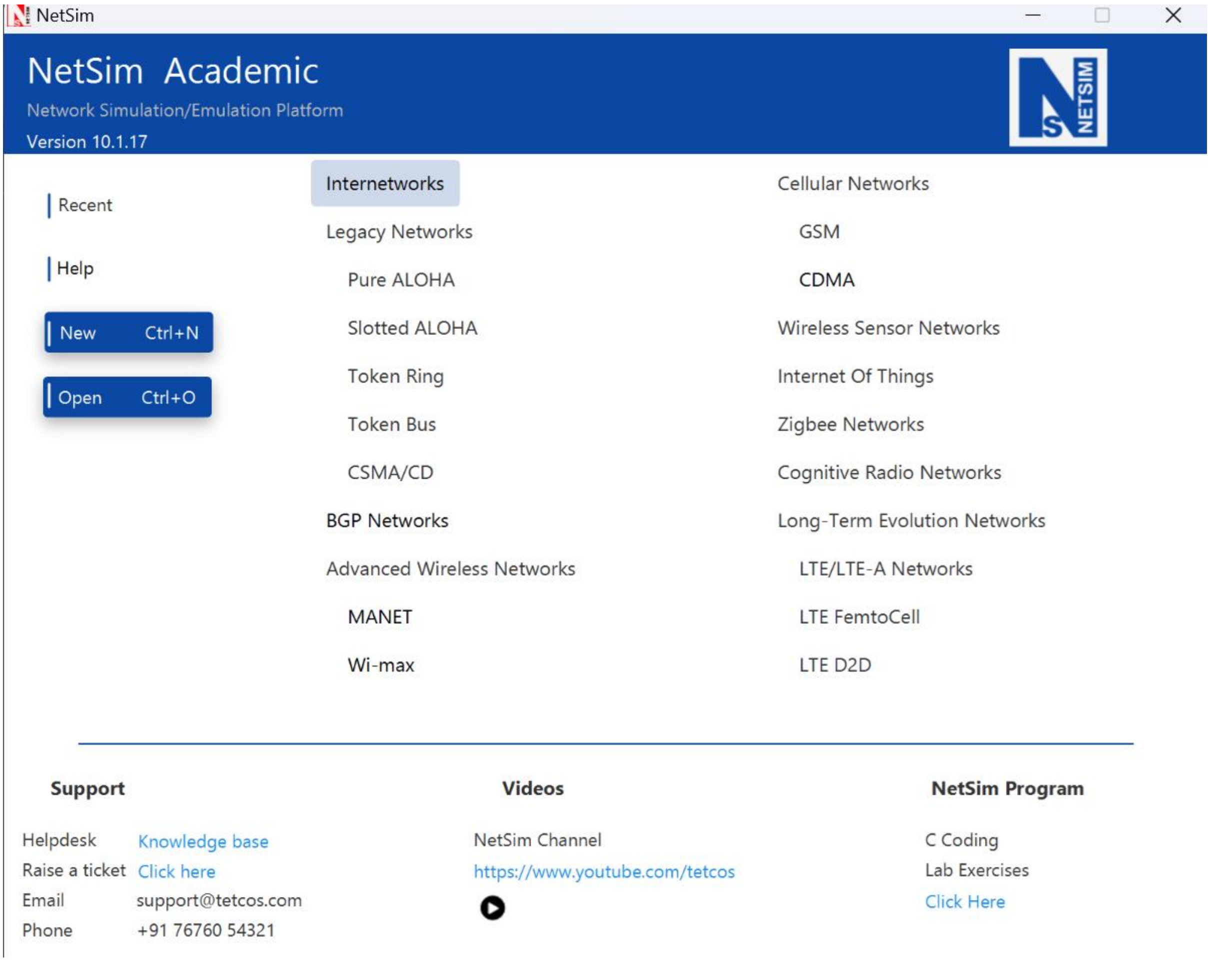
- VLAN (Virtual Local Area Network)
- IGMP (Internet Group Management Protocol)

- PIM (Protocol Independent Multicast)
- L3 Switch
- ACL (Access Control List)
- NAT (Network Address Translation)

11. 5G NR mmWave

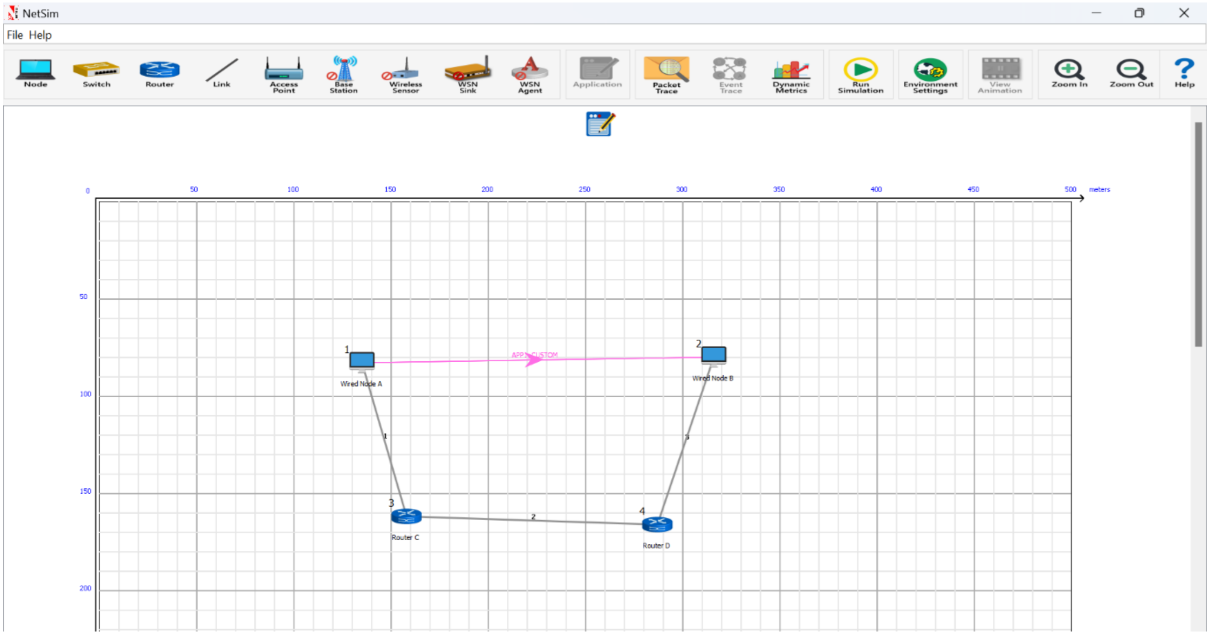
- LTE NR

NetSim home screen will appear as shown below see **Figure 1.1**



[Figure 1.1]

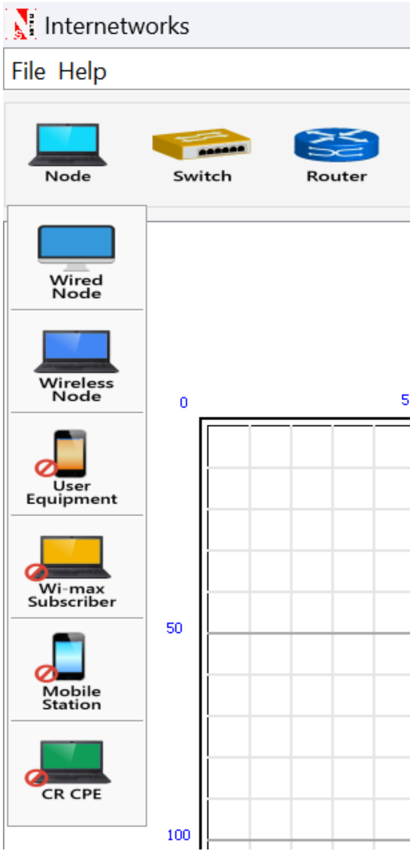
NetSim design window or the GUI see **Figure 1.2**, enables users to model a network comprising of network devices like switches, routers, nodes, etc., connect them through links, and model application traffic to flow through the network. The network devices shown are specific to the network technologies chosen by the user.



[Figure 1.2]

Node

A **Node** represents a network device or an endpoint in a network. Nodes can be computers, servers, mobile devices or any other equipment that can send, receive, or forward data. Each node is characterized by specific parameters, such as IP addresses, protocols in use, and hardware capabilities, which can be configured and analyzed within the simulation. Understanding how different nodes interact is crucial for analyzing the flow of data across a network and optimizing communication efficiency.



[Figure 1.3]

Switch

A **Switch** is a network device used to connect multiple nodes within a Local Area Network (LAN). It operates at the data link layer (Layer 2) of the OSI model, using MAC addresses to forward data to the correct destination within the LAN. Unlike hubs, which broadcast data to all devices, switches intelligently direct data only to the intended recipient, reducing network congestion and improving performance. In NetSim, switches can be configured to study various aspects of network performance, such as collision domains, VLANs, and switching techniques.

[Figure 1.4]

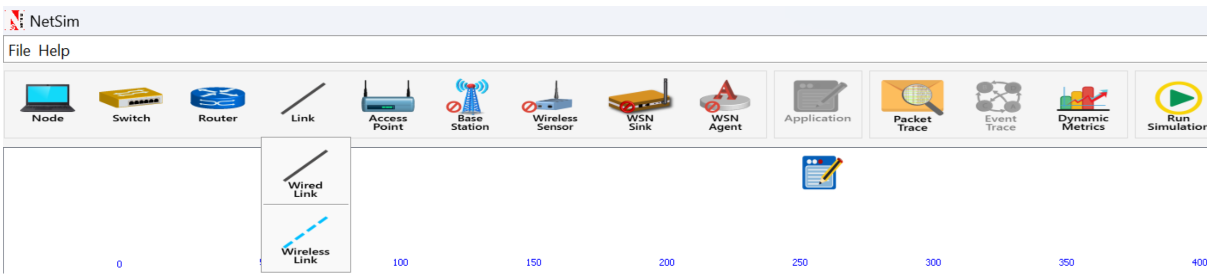
Router

A **Router** is a crucial network device that directs data packets between different networks, such as between a local network and the internet. Operating at the network layer (Layer 3) of the OSI model, routers use IP addresses to determine the best path for data to travel across interconnected networks. In NetSim, routers can be configured to implement routing protocols like OSPF, RIP, or BGP, allowing users to simulate and analyze the impact of different routing strategies on network performance, latency, and reliability.

[Figure 1.5]

Link

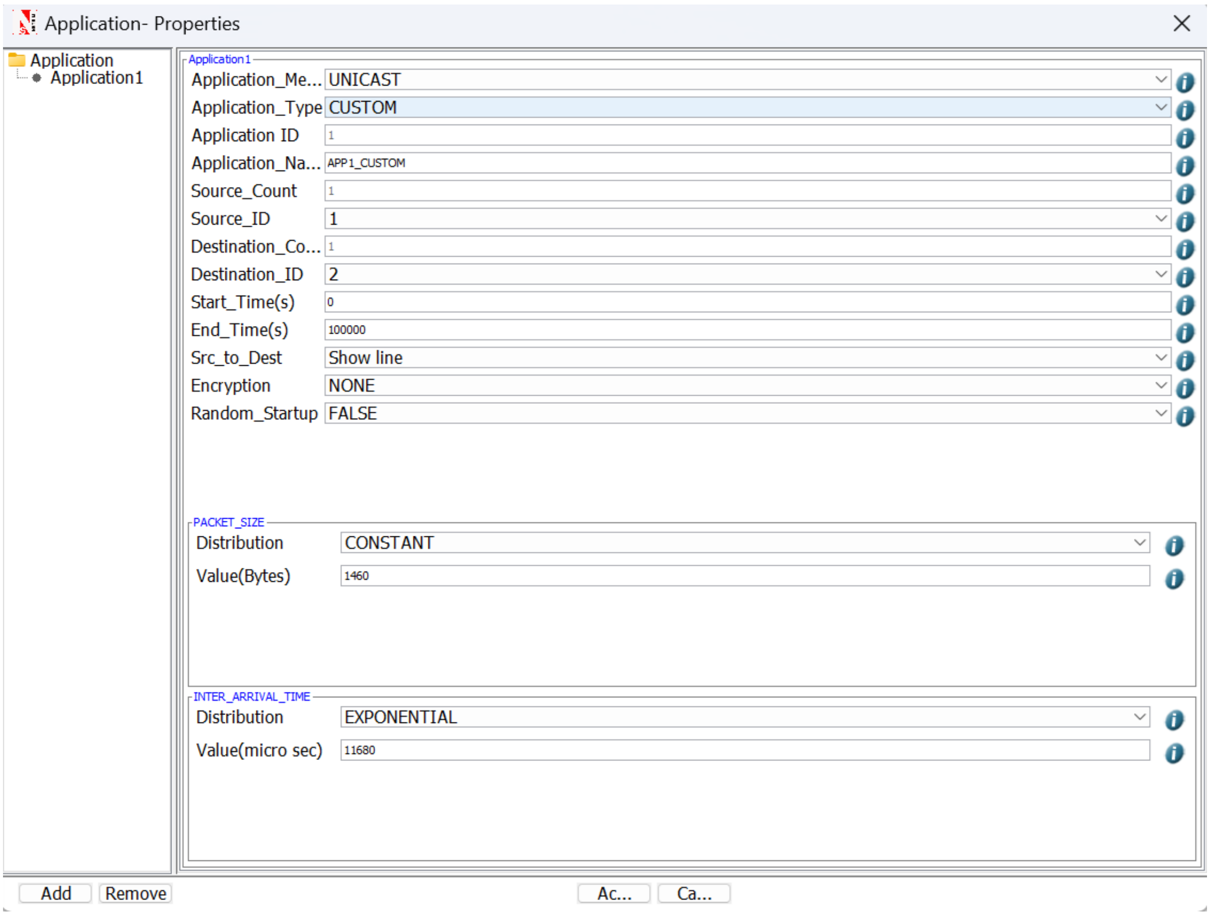
A **Link** represents the physical or logical connection between two nodes, such as between a computer and a switch, or between two routers. Links are characterized by parameters like bandwidth, delay, and error rate, which influence the performance of data transmission across the network. By configuring these parameters, users can simulate various network scenarios, such as high-latency satellite connections or low-bandwidth rural networks and study their impact on overall network performance.



[Figure 1.6]

Application

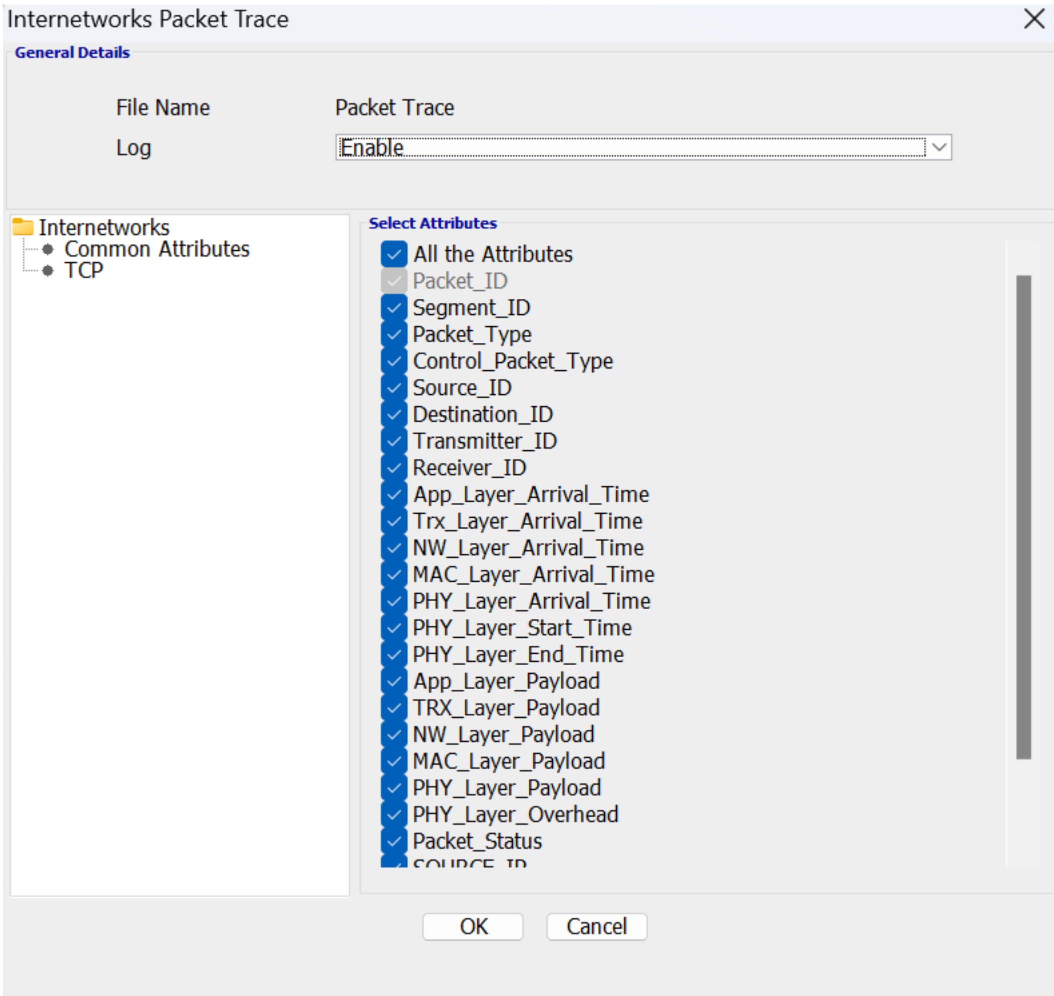
Application refers to the type of network traffic or service being simulated, such as web browsing (HTTP), file transfer (FTP), voice over IP (VoIP), or video streaming. Each application generates data packets according to its specific requirements, like bandwidth, delay sensitivity, and packet size. By simulating different applications, users can evaluate how various types of traffic impact network performance and identify potential bottlenecks or areas for improvement.



[Figure 1.7]

Packet Trace

Packet Trace is a feature that allows users to visualize the flow of data packets through the network in real-time. It provides a detailed view of how packets are routed, switched, and transmitted across the network, showing the path each packet takes and how it interacts with various network devices. Packet Tracer is an essential tool for understanding the inner workings of network protocols, troubleshooting network issues, and verifying the accuracy of simulations. These concepts form the foundational elements of network simulation in NetSim, enabling users to design, analyze, and optimize complex network systems. By understanding and utilizing these components, students can gain deeper insights into the principles of computer networking and apply their knowledge to real-world scenarios.



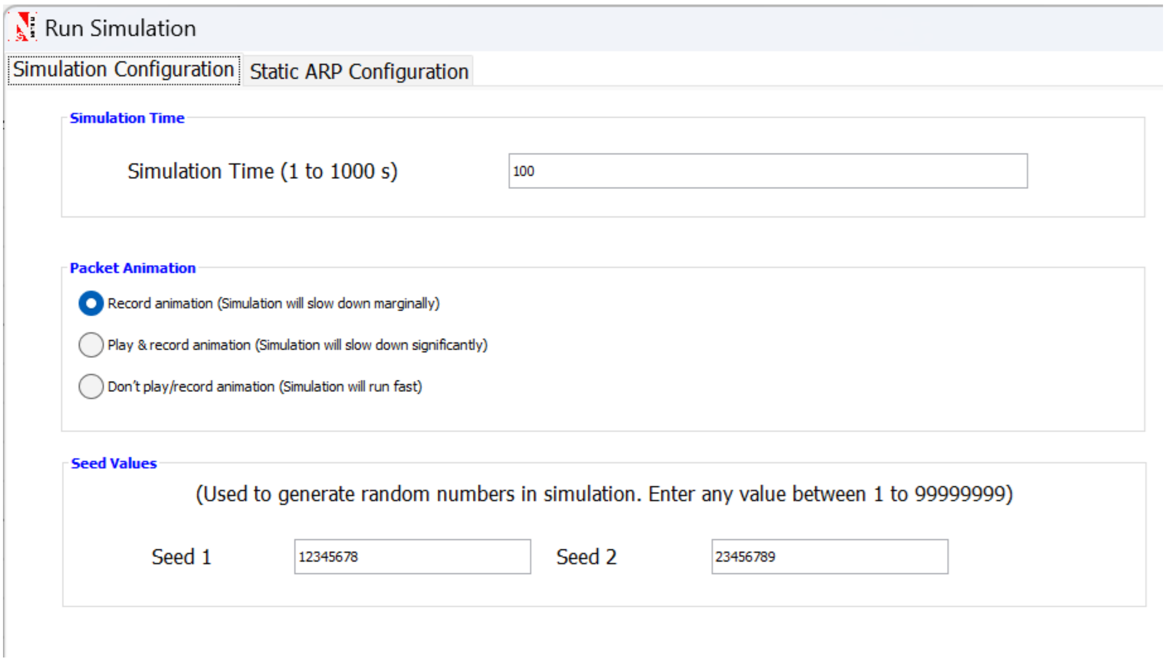
[Figure 1.8]

These selected attributes focus on the key elements needed to analyze packet flow, routing behaviour, and the overall performance of network simulations in NetSim.

Running the Simulation

After configuring your network setup, the next step is to run the simulation. Click on the **Run** icon to access the **Run Simulation** dialog box. In this dialog box, navigate to the **Simulation Configuration** tab, where you can set the **Simulation Time**. This duration determines how long the simulation will run and allows you to observe network behaviour over a specific period. NetSim offers the option to enable packet animation, which allows you to visually track the movement of data packets across the network. This feature is especially useful for understanding how packets traverse the network and interact with various nodes and devices.

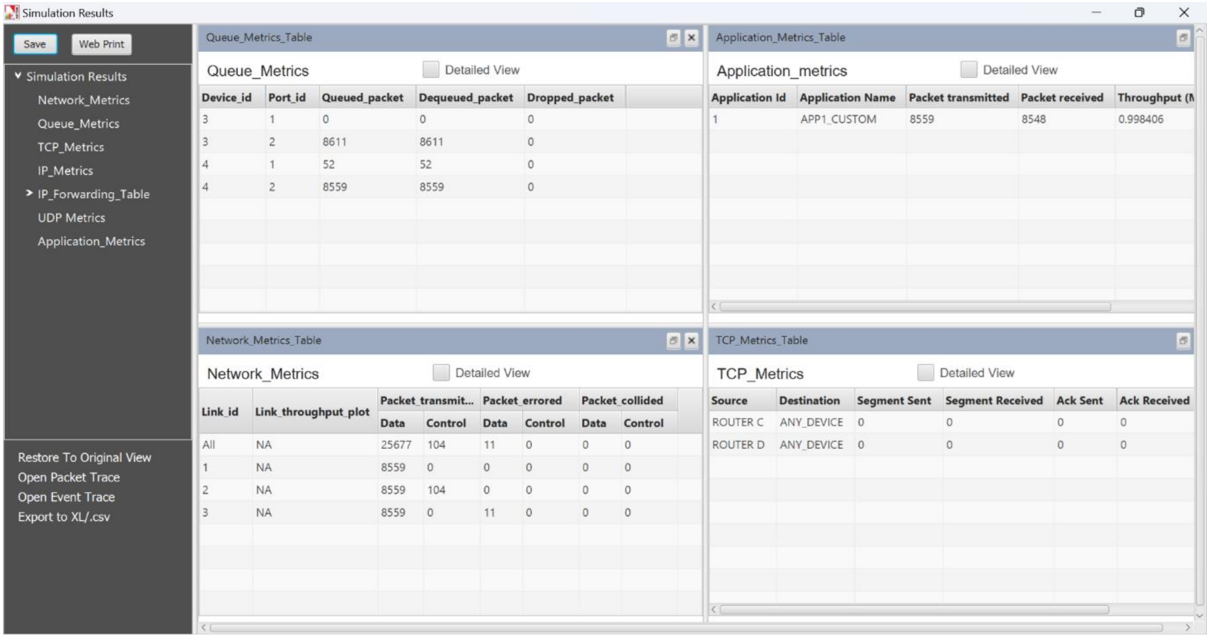
Click on the **Run** button to start the simulation. As the simulation progresses, you will be able to monitor the performance metrics, such as throughput, delay, and packet loss, and analyze how the network handles different types of traffic and configurations. This step is crucial for validating your network design and gaining insights into the effectiveness of various protocols and devices in your network setup.



[Figure 1.9]

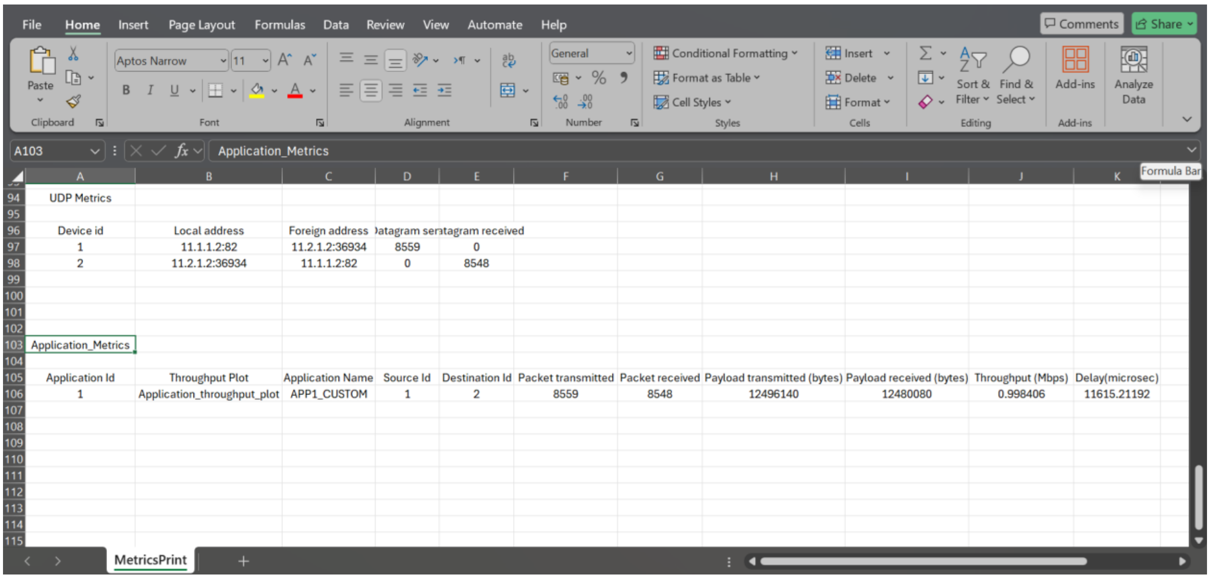
Results Window:

Upon completion of simulation, Network statistics or network performance metrics reported in the form of graphs and tables. The report includes metrics like throughput, simulation time, packets generated, packets dropped, collision counts etc.



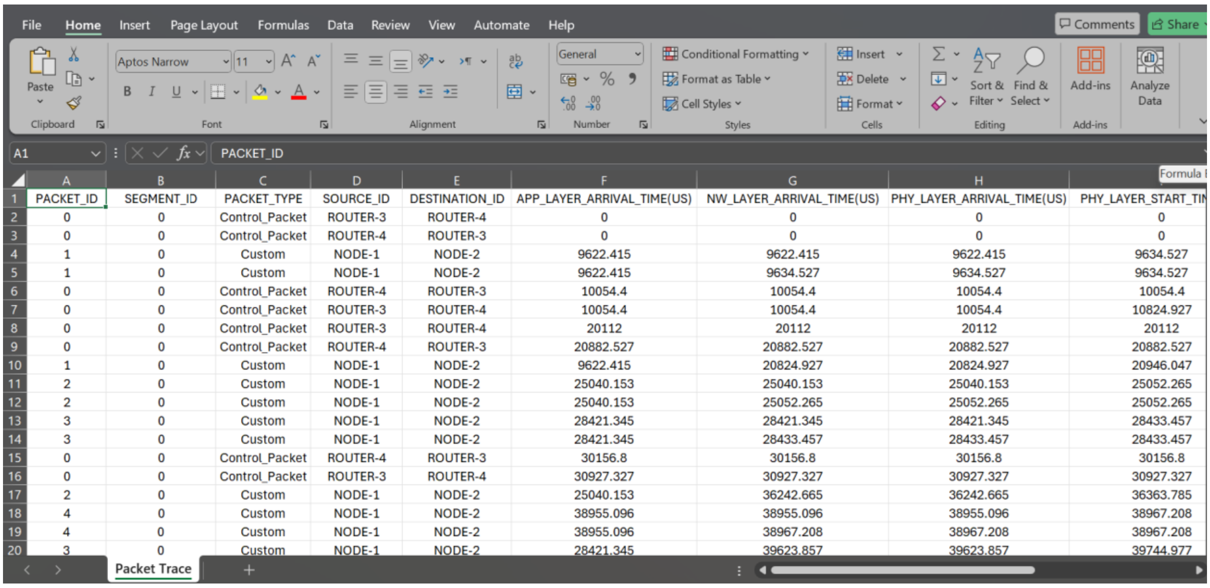
[Figure 1.10]

Export to XL/.csv:



[Figure 1.11]

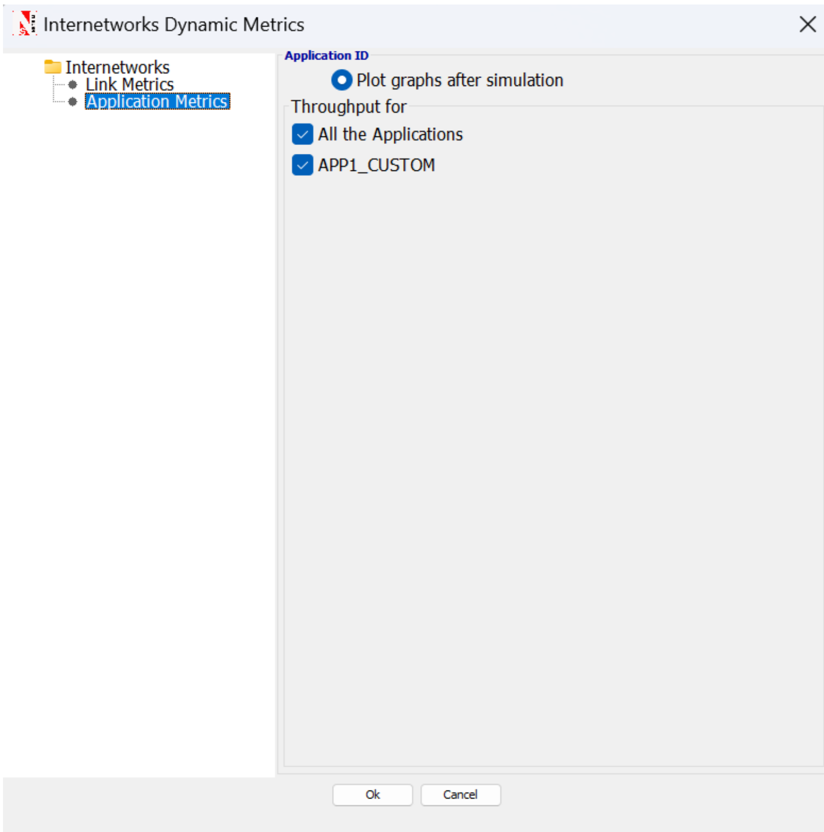
Open Packet Trace:



	A	B	C	D	E	F	G	H	I
1	PACKET_ID	SEGMENT_ID	PACKET_TYPE	SOURCE_ID	DESTINATION_ID	APP_LAYER_ARRIVAL_TIME(US)	NW_LAYER_ARRIVAL_TIME(US)	PHY_LAYER_ARRIVAL_TIME(US)	PHY_LAYER_START_TI
2	0	0	Control_Packet	ROUTER-3	ROUTER-4	0	0	0	0
3	0	0	Control_Packet	ROUTER-4	ROUTER-3	0	0	0	0
4	1	0	Custom	NODE-1	NODE-2	9622.415	9622.415	9622.415	9634.527
5	1	0	Custom	NODE-1	NODE-2	9622.415	9634.527	9634.527	9634.527
6	0	0	Control_Packet	ROUTER-4	ROUTER-3	10054.4	10054.4	10054.4	10054.4
7	0	0	Control_Packet	ROUTER-3	ROUTER-4	10054.4	10054.4	10054.4	10824.927
8	0	0	Control_Packet	ROUTER-3	ROUTER-4	20112	20112	20112	20112
9	0	0	Control_Packet	ROUTER-4	ROUTER-3	20882.527	20882.527	20882.527	20882.527
10	1	0	Custom	NODE-1	NODE-2	9622.415	20824.927	20824.927	20946.047
11	2	0	Custom	NODE-1	NODE-2	25040.153	25040.153	25040.153	25052.265
12	2	0	Custom	NODE-1	NODE-2	25040.153	25052.265	25052.265	25052.265
13	3	0	Custom	NODE-1	NODE-2	28421.345	28421.345	28421.345	28433.457
14	3	0	Custom	NODE-1	NODE-2	28421.345	28433.457	28433.457	28433.457
15	0	0	Control_Packet	ROUTER-4	ROUTER-3	30156.8	30156.8	30156.8	30156.8
16	0	0	Control_Packet	ROUTER-3	ROUTER-4	30927.327	30927.327	30927.327	30927.327
17	2	0	Custom	NODE-1	NODE-2	25040.153	36242.665	36242.665	36363.785
18	4	0	Custom	NODE-1	NODE-2	38955.096	38955.096	38955.096	38967.208
19	4	0	Custom	NODE-1	NODE-2	38955.096	38967.208	38967.208	38967.208
20	3	0	Custom	NODE-1	NODE-2	28421.345	39623.857	39623.857	39744.977

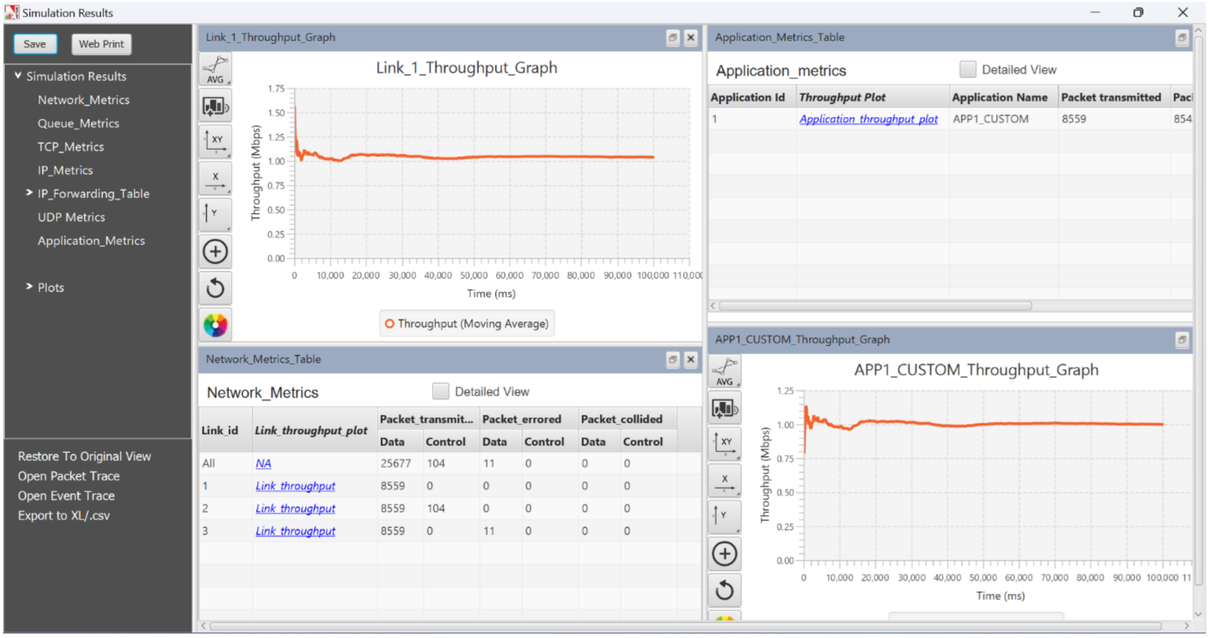
[Figure 1.12]

Dynamic Metrics:



[Figure 1.13]

Plot Graph After Simulation:



[Figure 1.14]

Experiments (To do in the Lab):

To gain a thorough understanding of network performance metrics and analysis, refer to the **NetSim Experiments Manual** available on the Tetcos website. The manual provides detailed guidance on several experiments designed to enhance your understanding of key networking concepts.

Experiment 2: Understanding Measures of Network Performance: Throughput and Delay

This experiment focuses on understanding and measuring two fundamental aspects of network performance: throughput and delay.

Throughput refers to the amount of data successfully delivered over a network in a given period, typically measured in bits per second (bps). It is a key indicator of the network's capacity to handle traffic and is influenced by factors such as network topology, protocol efficiency, and congestion.

Delay, on the other hand, measures the time taken for a data packet to travel from the source to the destination. Delay can be affected by various factors, including propagation delay, queuing delay, and processing delay. In this experiment, the goal is to configure a network in NetSim, simulate traffic, and analyze how different configurations impact throughput and delay. By examining these metrics, one can gain insights into how efficiently the network handles data and where potential bottlenecks or delays might occur.

Experiment 3: Throughput and Bottleneck Server Analysis

This experiment delves into the concept of throughput in the context of bottleneck analysis. A **bottleneck** occurs when a particular node or link in the network becomes a limiting factor, causing a reduction in overall network throughput. This can happen due to a variety of reasons, such as limited bandwidth, high traffic loads, or inefficient routing.

In this experiment, a network with multiple servers is simulated in NetSim, and the performance of the network is analyzed by varying the capacity and configuration of the servers. The experiment involves identifying the server that acts as the bottleneck and understanding how it affects the overall throughput of the network. By adjusting server parameters and analyzing the results, it is possible to learn how to optimize network performance and reduce the impact of bottlenecks.

Experiment 4: Delay and Little's Law

This experiment focuses on analyzing **delay** in the network and understanding its relationship with **Little's Law**, a fundamental theorem in queuing theory. Little's Law states that the average number of items (L) in a queuing system is equal to the average arrival rate (λ) multiplied by the average time an item spends in the system (W): $L = \lambda W$. This relationship is crucial for understanding how delays accumulate in a network.

In the experiment, a network is simulated in NetSim, where traffic is generated, and the delays experienced by packets are measured. By applying Little’s Law, the experiment demonstrates the relationship between the number of packets in the system, the arrival rate of packets, and the average delay. This analysis helps in understanding how traffic intensity and network conditions contribute to delays, and how these delays can be managed or minimized to improve overall network performance.

Exercise:

1. Bottleneck Analysis with Varying Bandwidth on Server Links

Objective: To analyze how changes in server link bandwidth can create bottlenecks and affect overall network throughput.

Instructions:

1. **Network Setup:**
   - Use the network configuration from Experiment 3 (Throughput and Bottleneck Server Analysis) in the NetSim Experiments Manual.
   - Set up a network where multiple servers are connected to a central router, which then connects to several client devices.
2. **Link Configuration:**
   - Begin by setting the bandwidth of all server links to a uniform value, such as 10 Mbps.
   - Run the simulation for 100 seconds and record the throughput for each server-client connection.
3. **Bandwidth Variation:**
   - Gradually reduce the bandwidth of one server link, starting from 10 Mbps and lowering it to 2 Mbps, while keeping the other server links constant.
   - After each change in bandwidth, re-run the simulation and observe the effects on network throughput.
4. **Simulation Settings:**
   - Set the simulation time to 100 seconds.
   - Use partial packet animation to focus on key points of packet flow through the network.
5. **Observation and Analysis:**

- Compare the throughput results for different bandwidth settings.
- Determine the bandwidth level at which the server link becomes a bottleneck.
- Analyze how this bottleneck impacts overall network performance and the throughput of other server-client connections.

6. **Performance Measures:**
   - **Throughput:** Measured in Mbps, representing the average data delivery rate from server to client.
   - **Bandwidth of Server Link:** Measured in Mbps, representing the capacity of the link between the server and router.
7. **Graph Plotting:**
   - **X-axis:** Bandwidth of Server Link (Mbps)
   - **Y-axis:** Throughput (Mbps) for each server-client connection.

Expected Results:

- **Throughput:** As the bandwidth of one server link decreases, the throughput for that server-client connection should decrease. Once the link becomes a bottleneck, it will start affecting the overall network performance, reducing throughput across the entire network.
- **Identification of Bottleneck:** The server link with the reduced bandwidth will likely become a bottleneck, limiting the overall throughput.

2. Exploring the Relationship Between Traffic Intensity and Delay Using Little's Law

Objective: To understand how varying traffic intensity impacts network delay and the average number of packets in the system, as explained by Little's Law.

Instructions:

1. **Network Setup:**
   - Configure a simple network topology with one router connected to three end devices.
   - Set up traffic flows from the devices to the router, varying the packet arrival rates.
2. **Baseline Configuration:**
   - Set an initial packet arrival rate of 50 packets per second.
   - Run the simulation for 100 seconds and record the average delay and the average number of packets in the system.
3. **Varying Traffic Intensity:**
   - Increase the packet arrival rate to 100 packets per second, run the simulation again, and record the same metrics.
   - Further increase the packet arrival rate to 200 packets per second, run the simulation, and record the results.
4. **Application of Little's Law:**
   - Apply Little's Law ($L = \lambda W$), where:
     - L is the average number of packets in the system.
     - λ is the average packet arrival rate (packets per second).
     - W is the average time a packet spends in the system (delay).
   - Calculate the expected delay using the recorded arrival rate and the average number of packets in the system.
5. **Observation and Analysis:**

- Compare the calculated delay using Little's Law with the observed delay from the simulation.
- Analyze how increasing traffic intensity affects delay and the average number of packets in the system.

6. **Performance Measures:**
   - Average Delay (ms): The average time a packet spends in the system.
   - Average Number of Packets (L): The average number of packets in the system at any given time.
   - Packet Arrival Rate (λ): The rate at which packets are sent to the router (packets per second).
7. **Graph Plotting:**
   - **X-axis:** Packet Arrival Rate (λ) in packets per second.
   - **Y-axis 1:** Average Delay (ms).
   - **Y-axis 2:** Average Number of Packets (L).

These graphs should clearly illustrate the relationship between increased packet arrival rates, system delay, and the average number of packets in the system.

Expected Results:

- As traffic intensity (packet arrival rate) increases, delay is expected to rise proportionally. Little's Law should confirm the relationship between arrival rate, the number of packets, and delay.
- The system will show an increase in both delay and the average number of packets as traffic intensity increases, in line with the predictions of Little's Law.

Based on the simulation experiment results, try and answer the following questions:

Q1. How does varying traffic load affect throughput and delay? What is the expected relationship between these metrics?

Q2. How can reducing server link bandwidth create bottlenecks, and how does this impact network performance?

Q3. What effect does decreasing the bandwidth of one server link have on the throughput of other connections in the network?

Q4. How is Little's Law ($L = \lambda W$) used in network performance analysis? Provide an example calculation for delay based on packet arrival rates.

Q5. How does network delay change with increasing packet arrival rates? How can you verify this relationship with simulation data?

Q6. Compare the impact of increasing traffic load versus increasing server link bandwidth on network performance. What key factors should be considered?

Q7. What trends are expected in graphs of throughput vs. traffic load and delay vs. packet arrival rate? How do these graphs aid in understanding network performance?

References:

- ✓ https://www.tetcos.com/documentation/NetSim/v13/NetSim-Experiments Manual/#t=NetSim_Experiment_Manual.htm
- ✓ https://www.tetcos.com/documentation/NetSim/