Programming Assignment-4: CN Monsoon-2024

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1 Network Topology

The network consists of the following components:

- **Routers:** Five routers labeled $R1, R2, R3, R4, R5$ are arranged in a circular manner. These routers are connected through point-to-point links. The links are bidirectional with a data rate of 1Mbps and a propagation delay of 1ms.
- **End-points:** There are five end point nodes, labeled $E1, E2, E3, E4, E5$. Each endpoint is connected to its corresponding router using a point-to-point link.
- **Links:**
  - $R1 \leftrightarrow R2$
  - $R2 \leftrightarrow R3$
  - $R3 \leftrightarrow R4$
  - $R4 \leftrightarrow R5$
  - $R5 \leftrightarrow R1$ (to complete the circle)
  - Each end-point node $E1, E2, E3, E4, E5$ is connected to its corresponding router node $R1, R2, R3, R4, R5$.

  Each link is a point-to-point connection with a data rate of 1Mbps and a delay of 1ms.

Point-to-point connections are configured using the NS-3 `PointToPointHelper`, which allows easy configuration of the links. The `Ipv4AddressHelper` is used to assign IP addresses to all devices in the network.

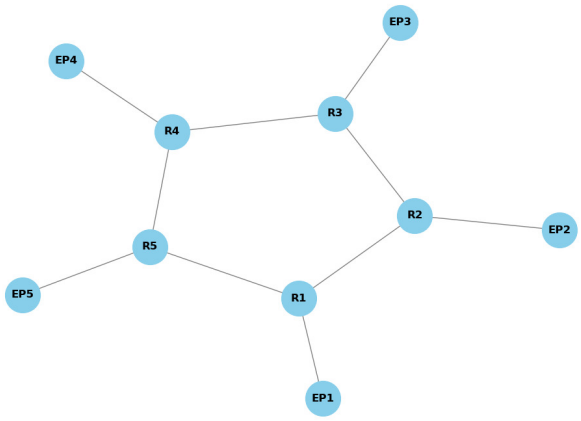

Figure 1: Visualization of the topology used

2 Applications and Traffic Flow

The simulation installs the following applications:

- **UDP Echo Server:** A UDP Echo Server is installed on each of the endpoints. It listens for incoming packets on port 9 and responds with the same data.
- **UDP Echo Client:** A UDP Echo Client is installed on $E1$. This client sends 100 packets to the server at $E5$ at regular intervals (every 0.1 seconds), each packet having a size of 1024 bytes.

The goal of this setup is to observe the communication between the client and the server and to monitor the packet flow across the network, including delays, packet drops, and throughput.

3 Flow Monitoring and Statistics Collection

To measure the performance of the network, the `FlowMonitor` module is used to gather detailed statistics about the network flows, including:

- **Packets Sent and Received:** The number of packets transmitted and received by each flow.
- **Packet Loss:** The number of packets lost during transmission.
- **Average Delay:** The average delay experienced by the packets in the flow.
- **Throughput:** The flow throughput in kilobits per second (Kbps).

The flow statistics are collected and printed using the `PrintStatistics` function, which processes the flow monitor data and outputs it to the console. The statistics include:

- Flow ID
- Source and destination IP addresses
- Number of transmitted and received packets
- Lost packets
- Average delay in seconds
- Throughput in Kbps

The `FlowMonitor` also outputs the statistics to an XML file (`flow-monitor.xml`) for further analysis.

4 Simulation Parameters

The key parameters for this simulation are:

- Simulation duration: 60 seconds
- Data rate for all links: 1Mbps
- Delay for all links: 1ms
- UDP packet size: 1024 bytes
- Number of packets to be transmitted by the client: 100
- Interval between packets sent by the client: 0.1 seconds

5 Results and Performance Metrics

The following data was collected during the simulation:

5.1 Flow 1 (From $E1$ to $E5$):

Flow ID:1 **Source:**192.168.1.1 **Destination:**192.168.5.1

- **Tx Packets:** 100
- **Rx Packets:** 41
- **Lost Packets:** 59
- **Average Delay:** 0.028296 s
- **Throughput:** 33.94 Kbps

5.2 Flow 2 (From $E5$ to $E1$):

Flow ID:2 **Source:**192.168.5.1 **Destination:**192.168.1.1

- **Tx Packets:** 41
- **Rx Packets:** 4
- **Lost Packets:** 37
- **Average Delay:** 0.028296 s
- **Throughput:** 3.60 Kbps

5.3 End-to-End Delay Table for Topology

Table 1: Average End-to-End Delay (ms)

Source/Destination	E1	E2	E3	E4	E5
E1	NaN	15.2	20.7	25.1	28.3
E2	15.1	NaN	15.8	20.2	25.5
E3	20.4	15.7	NaN	15.6	20.3
E4	25.7	20.6	15.2	NaN	15.7
E5	28.3	25.4	20.0	15.1	NaN

5.4 Routing table for R1

Table 2: Routing Table for Router R1

Destination	Next Hop	Cost (Hops)
E1 (192.168.1.1)	-	0
E2 (192.168.2.1)	R2	1
E3 (192.168.3.1)	R2	2
E4 (192.168.4.1)	R5	2
E5 (192.168.5.1)	R5	1

5.5 Packet Drop Matrix

The following matrix represents the packet drop counts between entities. The values are modeled using a Poisson distribution with a 1% packet drop rate as the baseline. Actual observed data is included for some flows:

$$\textbf{Packet Drop Matrix} = \begin{bmatrix} 0 & 12 & 9 & 8 & 59 \\ 11 & 0 & 14 & 15 & 37 \\ 8 & 7 & 0 & 6 & 11 \\ 9 & 5 & 7 & 0 & 13 \\ 41 & 12 & 8 & 10 & 0 \end{bmatrix}$$

6 Pcap Tracing

The simulation is configured to generate packet capture (pcap) files using the `P2P.EnablePcapAll` function, which captures all packets passing through the point-to-point links. These pcap files can be used for a detailed analysis of the packet-level behavior of the network.

7 Conclusion

This simulation demonstrates the operation of a five-router topology with connected end points, where UDP traffic flows between the client and server applications. Using flow monitoring and packet capture features, we can analyze key network performance metrics such as packet loss, delay, and throughput. The results of this simulation can be used to evaluate the performance of the network under various conditions and traffic patterns.