

Code simulates a network topology using the **NS-3** simulator, setting up a network with **routers**, **workstations** (end devices), and **UDP Echo applications** that generate traffic between these workstations. The simulation is configured to measure **flow statistics** such as **throughput**, **packet loss**, **delay**, and **jitter**. It also generates a **NetAnim** visualization of the network topology for analysis.

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## 1. Network Topology Overview

The network in this simulation consists of:

- **4 Routers (R1, R2, R3, R4).**
- **7 Workstations (A, B, C, D, E, F, G).**
- **Routers (R1, R2, R3, R4) are connected in a loop:**

`R1 <--> R2 <--> R3 <--> R4 <--> R1.`

- **Workstations (A-G) are connected to routers:**
  - A, B to R1.
  - C, D to R2.
  - E, F to R3.
  - G to R4.

The workstations send traffic to each other, and the routers route the traffic.

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## 2. Logging Setup

The simulation logs information about the **UDP Echo client** and **UDP Echo server** applications.

These lines enable logging at the **INFO** level, meaning details about the application operations (such as packet transmissions and receptions) will be printed.

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### 3. CreateLink Function (Helper Function)

The **CreateLink** function sets up the **point-to-point links** between the nodes (routers and workstations):

#### Parameters:

- **node1, node2:** The two nodes (routers or workstations) to connect.
- **capacity:** Data rate of the link (e.g., "3Mbps").
- **delay:** Propagation delay of the link (e.g., "1ms").
- **baseAddr:** Base IP address for the link.
- **dropRate:** Optional rate for packet drops (default 0.0 means no packet drops).

#### Function Steps:

- **DataRate** specifies the link's bandwidth (e.g., "3Mbps").
- **Delay** specifies the propagation delay for the link (e.g., "1ms").
- **Point-to-Point Helper Setup:** This part sets the link's data rate and delay:

**Error Model for Packet Drops:** If a **dropRate** is specified (greater than 0), an error model is created to simulate packet loss:

**Assign IP Addresses:** The **Ipv4AddressHelper** assigns IP addresses to the devices:

#### Output:

This function returns the interface container containing the IP addresses assigned to the link.

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### 4. Main Simulation Logic

#### Initial Parameters:

- **Packet Size:** 256 bytes (for UDP packets).
- **Simulation Time:** 60 seconds.
- **Propagation Delay:** 1ms.
- **Packet Drop Rate:** 0.1%.

### Traffic Matrix:

A **traffic matrix** is created to define the average number of packets exchanged between workstations. The matrix is **7x7**, where `trafficMatrix[i][j]` represents the number of packets sent from workstation `i` to workstation `j`.

### Node Creation:

- **Routers:** 4 routers (`R1`, `R2`, `R3`, `R4`).
- **Workstations:** 7 workstations (`A`, `B`, `C`, `D`, `E`, `F`, `G`).

### Install Internet Stack:

The **internet stack** is installed on both routers and workstations to enable IP-based communication.

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## 5. Link Creation Between Nodes

### Routers:

- Point-to-point links are established between the routers, with specified **data rates**, **delays**, and **drop rates**:

### Workstations:

- Each workstation is connected to a router through point-to-point links:
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## 6. Application Setup: UDP Echo Client-Server

The **UDP Echo Client** sends traffic from one workstation to another. The **UDP Echo Server** listens for this traffic.

- **Client Setup:** For each workstation pair (`i`, `j`) in the traffic matrix, the client sends `trafficMatrix[i][j]` packets to the server at workstation `j`:
  - **Server Setup:** The server listens for incoming traffic:
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## 7. Flow Monitoring and Statistics

- The **Flow Monitor** is used to track packet flows, measure performance, and gather statistics like throughput, delay, and jitter:

After the simulation, flow statistics are printed:

### Statistics:

- **Tx Packets:** Transmitted packets.
  - **Rx Packets:** Received packets.
  - **Lost Packets:** Difference between transmitted and received packets.
  - **Throughput:** Calculated as  $(\text{Received Bytes} * 8) / (\text{Time taken})$  in kbps.
  - **Average Delay:** Average delay for packets in seconds.
  - **Average Jitter:** Average variation in delay between received packets.
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## 8. Simulation Execution and Cleanup

The simulation is run for 60 seconds and then the flow statistics are displayed. The simulation is stopped using:

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### Conclusion:

The code sets up a **custom network topology** with routers and workstations, simulates traffic between workstations using UDP Echo applications, and collects network performance statistics. The network's behavior is visualized with **NetAnim**, and the **Flow Monitor** is used to measure throughput, delay, jitter, and packet loss during the simulation. The **traffic matrix** defines how much traffic is generated between each pair of workstations.