NS3-based Simulation of a Computer Network

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Introduction

This report details the simulation of a computer network using the NS3 simulator. The network comprises 4 routers and 7 end devices interconnected to evaluate performance metrics such as delay, jitter, queue lengths, and packet drop rates. The simulation code was written in `.cc` files and executed using NS3's scratch module.

Assumptions

The following assumptions were made for the simulation:

- The network consists of 11 nodes, including 4 routers and 7 workstations/servers.

- Packets are generated following a Poisson distribution based on the traffic matrix.

- Each packet is 2048 bits in size.

- The propagation delay is fixed at 1 ms for all links.

- The packet drop rate is set to 1%.

- The network operates for a total of 1 simulated minute.

- Routes are predefined and static, with routing tables populated using the command:

    ```
    Ipv4GlobalRoutingHelper::PopulateRoutingTables();
    ```

- The topology used is the same as the one provided in the assignment, including 4 routers and 7 end devices.

Network Topology and Parameters

The simulated network consists of:

- **Nodes:** 4 routers and 7 end devices.

- **Links:** Point-to-point links with:

- Router-to-router links having capacities of 3 Mbps and 2.5 Mbps.
- End device-to-router links having capacities of 1 Mbps.

- **Packet Size:** 2048 bits.

- **Traffic Matrix:** The traffic between different nodes was set according to the following matrix:

Table 1: Traffic Matrix (Packets per Second)

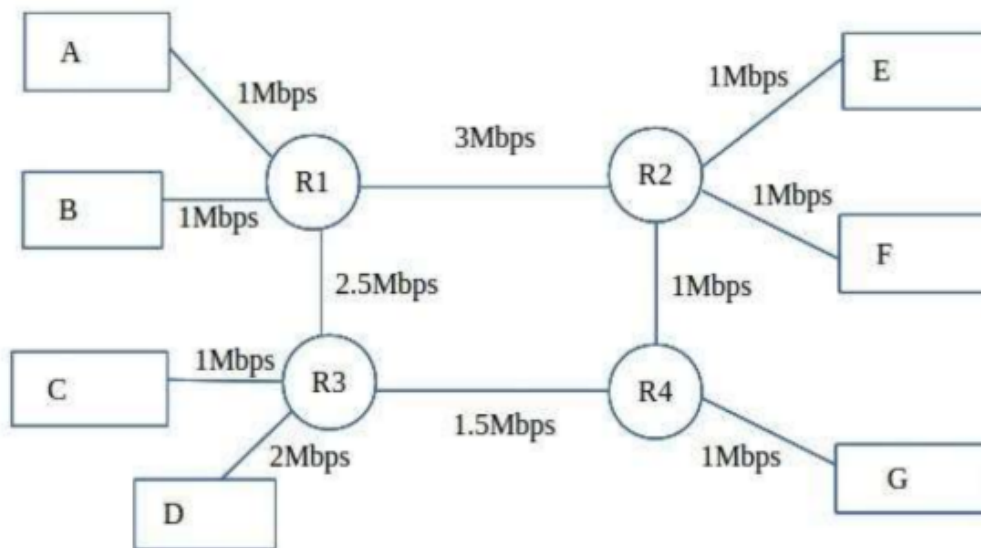| Source/Dest	A	B	C	D	E	F	G
A	0	40	50	204	44	29	67
B	33	0	40	50	34	44	29
C	29	78	0	100	54	98	26
D	120	19	144	0	67	95	65
E	34	88	91	54	0	23	11
F	40	50	34	44	29	0	45
G	34	70	13	88	89	65	0

Figure 1: Network Topology (Same as Assignment)

Routing and Simulation Configuration

Routing

The routing table was generated using the command:

```
Ipv4GlobalRoutingHelper::PopulateRoutingTables();
```

Initialization of Parameters

- Traffic matrix as shown above.

- Packet size: 2048 bits.

- Drop rate: 1%.

- Simulation time: 60 seconds.

- Base port numbers for assigning UDP ports.

NS3 Configuration

The simulation was run on Linux OS using the NS3 scratch module:

```
./ns3 run scratch/scratch-simulator.cc
```

Results and Observations

The performance metrics were observed for a simulation time of 1 minute. Below are the results:

End-to-End Delay

Table 2: Average End-to-End Delay Matrix (ms)

Source/Dest	A	B	C	D	E	F	G
A	NaN	339.77	452.96	425.92	443.80	435.54	595.45
B	328.80	NaN	444.09	501.27	434.81	495.53	654.33
C	429.15	427.51	NaN	333.42	534.23	523.45	601.50
D	466.97	556.62	353.68	NaN	525.30	522.09	477.82
E	417.71	452.61	526.21	526.94	NaN	348.70	552.13
F	440.47	463.04	571.47	586.15	347.62	NaN	513.13
G	567.27	564.85	487.92	468.12	501.53	536.79	NaN

Jitter

Table 3: Jitter Matrix (ms)

Source	A	B	C	D	E	F	G
A	NaN	20.24	32.67	8.86	43.70	46.53	56.02
B	0.00	NaN	32.08	35.82	49.76	47.94	92.71
C	12.14	12.68	NaN	16.10	42.45	37.10	54.91
D	33.19	37.47	28.68	NaN	50.43	44.32	53.21
E	2.22	23.09	27.86	35.99	NaN	46.66	93.18
F	30.37	51.95	48.80	36.59	49.79	NaN	65.36
G	33.99	30.72	56.90	34.68	38.62	52.66	NaN

Packet Drop Matrix with Source-Destination Labels

The table below represents the packet drop matrix, with rows indicating the source router (A to G) and columns indicating the destination router (A to G).

Source \ Destination	A	B	C	D	E	F	G
A	0	4	6	22	5	3	7
B	3	0	5	6	4	5	3
C	3	8	0	10	6	9	2
D	13	2	15	0	7	10	7
E	4	9	10	6	0	3	1
F	5	5	4	5	3	0	5
G	4	7	1	9	9	6	0

Table 4: Packet Drop Matrix

Rounting table

Source	A	B	C	D	E	F	G	R1	R2	R3	R4
A	-	R1	R1	R1	R1	R1	R1				
B	R1	-	R1	R1	R1	R1	R1				
C	R3	R3	-	R3	R3	R3	R3				
D	R3	R3	R3	-	R3	R3	R3				
E	R2	R2	R2	R2	-	R2	R2				
F	R2	R2	R2	R2	R2	-	R2				
G	R4	R4	R4	R4	R4	R4	-				
R1	A	B	R3	R3	R2	R2	R2	-	R2	R3	R2
R2	R1	R1	R1	R1	E	F	R4	R1	-	R1	R4
R3	R1	R1	C	D	R1	R1	R4	R1	R1	-	R4
R4	R2	R2	R3	R3	R2	R2	G	R2	R2	R3	-

Table 5: Routing table showing shortest paths between sources and destinations.

Queue Lengths at Routers

Table 6: Router Queue Statistics

Router	Average Queue Size	Maximum Queue Size
Router0	27.59	306
Router1	27.20	153
Router2	25.15	51
Router3	28.54	306

NetAnim Visualizations

Below are screenshots captured from NetAnim, showing the data packet flow, routing dynamics, and packet drops.

Figure 2: NetAnim Visualization (Placeholder for Image)

Conclusion

The simulation successfully evaluated the network's performance based on end-to-end delays, jitter, and queue lengths. The results align with expected behavior, demonstrating NS3's capability for simulating complex network scenarios. Future improvements could include testing with variable link capacities and dynamic traffic patterns.

References

1. NS3 Documentation: `https://www.nsnam.org/documentation/`

2. Assignment Guidelines: Programming Exercise 4.