National University of Computer and Emerging Sciences (Lahore Campus)

Quiz 1: Computer Networks and the Internet (Chapter 1)

Name: ______________ **Roll No:** ______________ **Section:** BSE-6B1 (Spring 2026)

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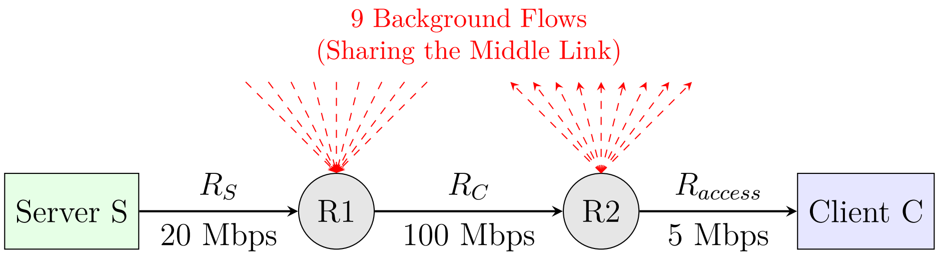
1. (5 points) **Throughput and Bottleneck Analysis**

   Consider the file transfer scenario shown below. Server S sends a file to Client C through two intermediate routers $R1$ and $R2$.

   - Link $S \rightarrow R1$: Rate $R_S = 20$ Mbps.
   - Link $R1 \rightarrow R2$: Shared link, Rate $R_C = 100$ Mbps. This link is shared by 9 other background traffic flows (assume all are working at full capacity).
   - Link $R2 \rightarrow C$: Rate $R_{access} = 5$ Mbps.
   - The 9 background flows consume exactly 10 Mbps each of the middle link ($R1 \rightarrow R2$).



   Calculate the throughput for the file transfer from S to C. Show the available bandwidth for each link and identify the bottleneck link.

   Solution: The end-to-end throughput is determined by the bottleneck link, which is the link with the minimum available bandwidth along the path.

$$\text{Throughput} = \min(R_S, R_C, R_{access})$$

   - **Link $S \rightarrow R1$ (R_S):** Capacity is 20 Mbps. No background traffic.
     Available = 20 Mbps.
   - **Link $R1 \rightarrow R2$ (R_C):** Total Capacity is 100 Mbps.
     Background traffic = 9 flows × 10 Mbps/flow = 90 Mbps used.
     $R_C = 100 - 90 = 10$ Mbps available for our flow.
   - **Link $R2 \rightarrow C$ (R_{access}):** Capacity is 5 Mbps.
     Available = 5 Mbps.

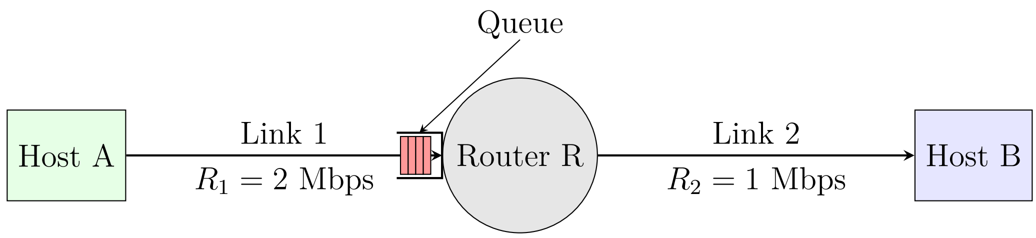
$$\text{Throughput} = \min(20, 10, 5) = \mathbf{5\ Mbps}.$$

   The bottleneck is the client's access link (R_{access}).

2. (10 points) **Nodal Delays and Queuing Dynamics**

Consider a packet-switched network where Host A sends a burst of $N = 10$ packets back-to-back to Host B via a single Router R.

- **Link 1 (A $\rightarrow$ R):** Transmission Rate $R_1 = 2$ Mbps. Propagation Delay $d_{prop1} = 10$ ms.
- **Link 2 (R $\rightarrow$ B):** Transmission Rate $R_2 = 1$ Mbps. Propagation Delay $d_{prop2} = 10$ ms.
- **Packet Size:** All packets have a length $L = 2000$ bits.
- **Processing Delay:** Negligible at Router R ($d_{proc} \approx 0$).
- **Queuing:** Router R has a buffer. Since $R_1 > R_2$, packets arrive at R faster than they can be transmitted to B, causing a queue to build up.



(a) (4 points) Calculate the **Transmission Delay** per packet for Link 1 (d_{trans1}) and Link 2 (d_{trans2}). Notice that a queue builds up at Router R.

Solution:

$$d_{trans1} = \frac{L}{R_1} = \frac{2000}{2 \times 10^6} = 0.001 \text{ s} = \mathbf{1 \text{ ms}}$$

$$d_{trans2} = \frac{L}{R_2} = \frac{2000}{1 \times 10^6} = 0.002 \text{ s} = \mathbf{2 \text{ ms}}$$

(b) (6 points) Calculate the **Queuing Delay** experienced specifically by the **10th packet** at Router R.

Solution: Queuing delay is the time a packet waits in the buffer before it starts being transmitted.

$$d_{queue} = \text{Time Service Starts} - \text{Time Packet Arrives}$$

1. Arrival time of 10th packet at R:

Host A sends packets back-to-back. The 10th packet finishes transmission at A at $10 \times d_{trans1} = 10 \times 1 = 10$ ms. It travels over Link 1.

$$T_{arrival\_10} = 10 \text{ ms} + d_{prop1} = 10 + 10 = \mathbf{20 \text{ ms}}$$

2. Start of service time for 10th packet at R:

The router transmits packets 1 through 9 before handling packet 10. Transmission of Pkt 1 starts at $t = 11$ ms. Time to transmit 9 packets $= 9 \times d_{trans2} = 9 \times 2 = 18$ ms.

$$T_{start\_10} = 11 \text{ ms} + 18 \text{ ms} = \mathbf{29 \text{ ms}}$$

3. Queuing Delay:

$$d_{queue\_10} = T_{start\_10} - T_{arrival\_10} = 29 \text{ ms} - 20 \text{ ms} = \mathbf{9 \text{ ms}}$$