



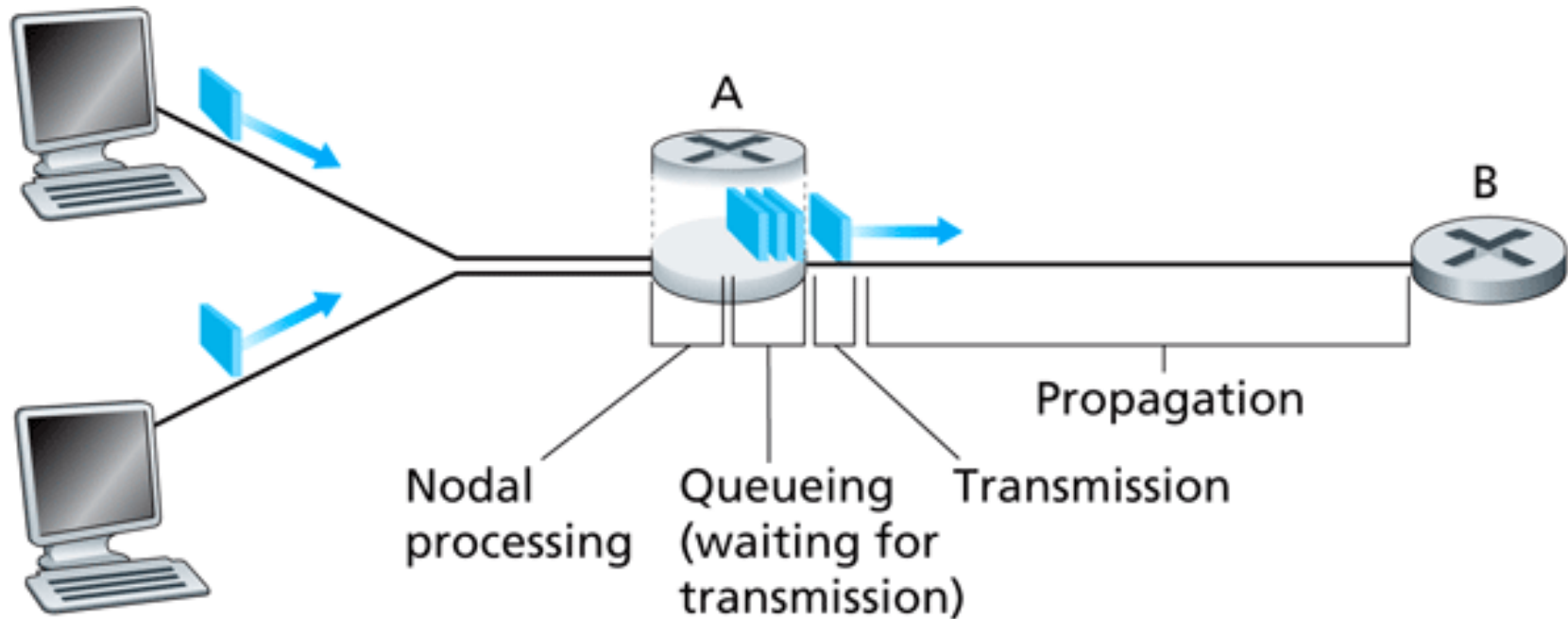
# Computer Networks

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# Delays in Switching



**Figure 1.12** ♦ The nodal delay at router A

# End-to-End Delay

- N-1 Routers

- $N(D_{\text{proc}} + D_{\text{trans}} + D_{\text{prop}})$

- Why N if N-1 routers?

- There is exactly one packet switch between a sending host and a receiving host. The transmission rates between sending host & switch and between switch & receiving host are  $R_1$  and  $R_2$ , respectively. Assuming that the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length  $L$ ? (Ignore queueing, propagation and processing delays).

1.  $1 + L/R_1 + L/R_2$
2.  $L/R_1 + L/R_2$
3.  $(2 * L/R_1) + (2 * L/R_2)$
4.  $L/R_1 * L/R_2$



- How long does it take a packet of length 1,000 bytes to propagate over a link of distance 5,000 km, propagation speed  $2.5 \times 10^8$  m/s, and transmission rate 1 Mbps?

(enter numeric part of answer only in ms)



- How long does it take to transmit a packet of length 1,000 bytes over a link of distance 5,000 km, propagation speed  $2.5 \times 10^8$  m/s, and transmission rate 1 Mbps?

(enter numeric part of answer only in ms)



- A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. At packet arrival, one other packet is half transmitted on this outbound link and three other packets are waiting to be transmitted. Suppose all packets are 1,000 bytes and the link rate is 1 Mbps. What is the queuing delay for the packet?

(enter numeric part of answer only in ms)

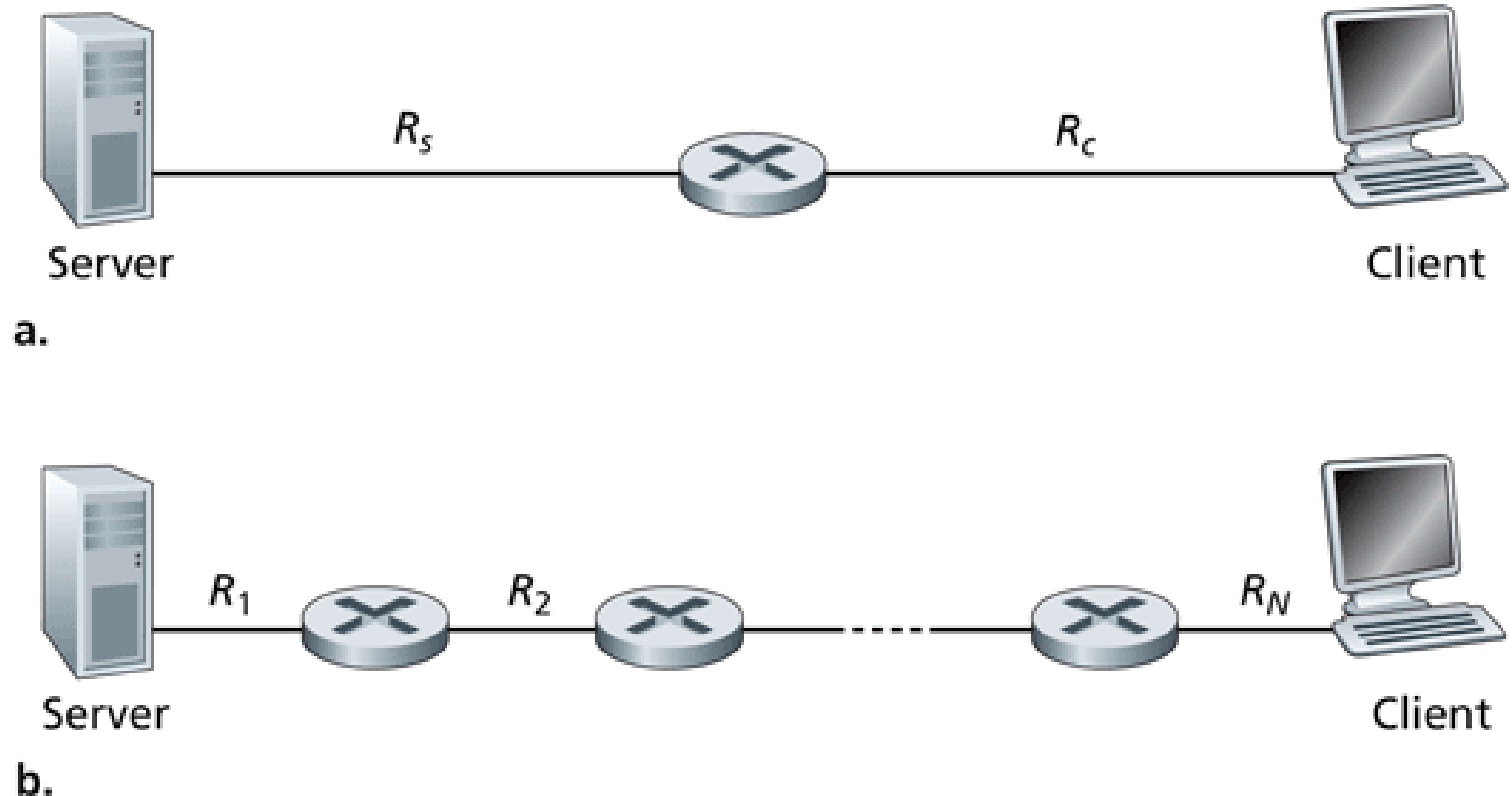


# Throughput

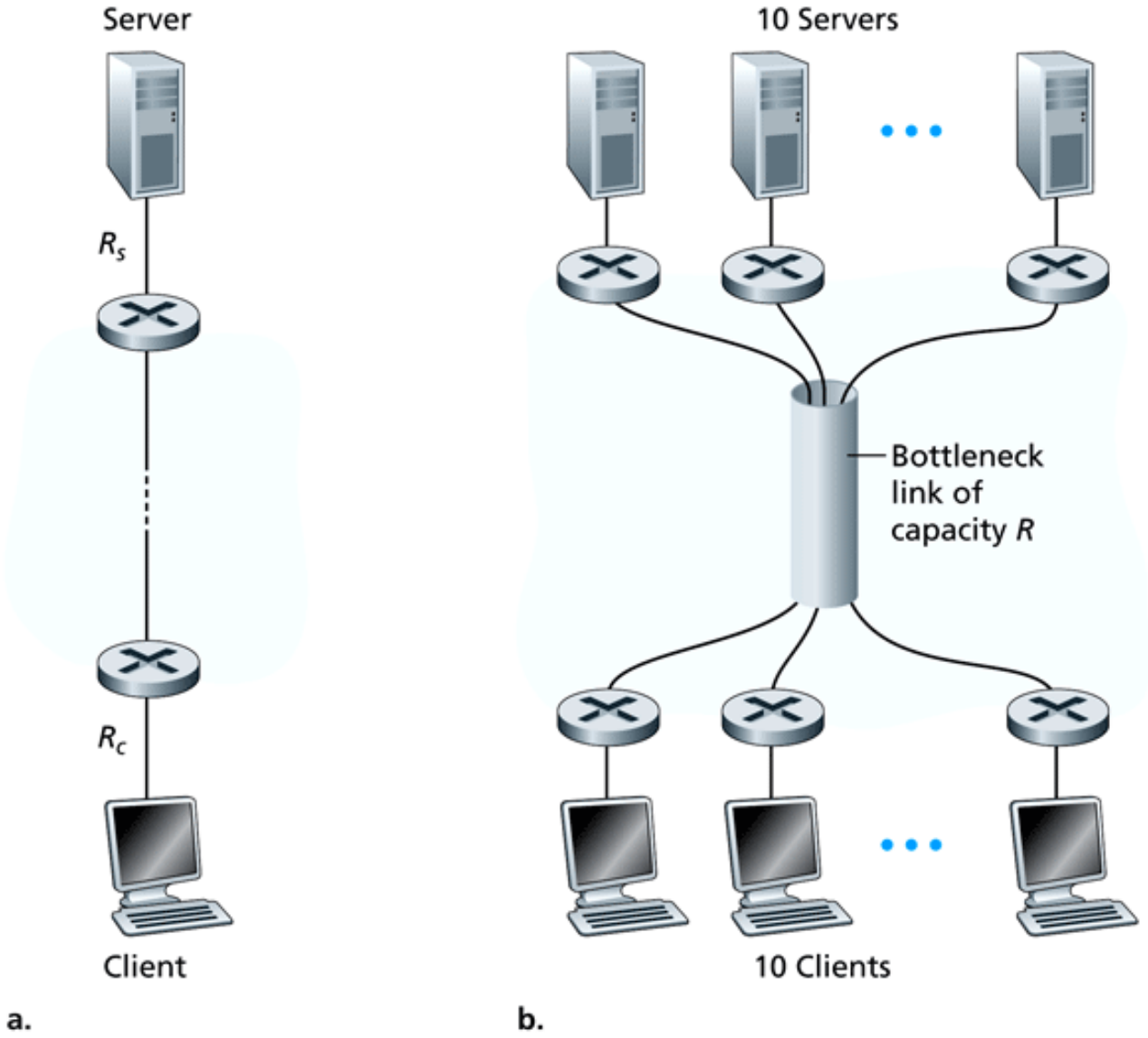
- Instantaneous throughput
- Average throughput
- Bottleneck link



# Throughput Example



**Figure 1.15** ♦ Throughput for a file transfer from server to client



**Figure 1.16** ♦ End-to-end throughput: (a) Client downloads a file from server; (b) 10 clients downloading with 10 servers.



# Traceroute

- Sends ICMP packets
- Switches/routers respond to source
- Show network delay times

# Calculate throughput

- Homework

- Download the file “big file” on course web page and calculate your throughput