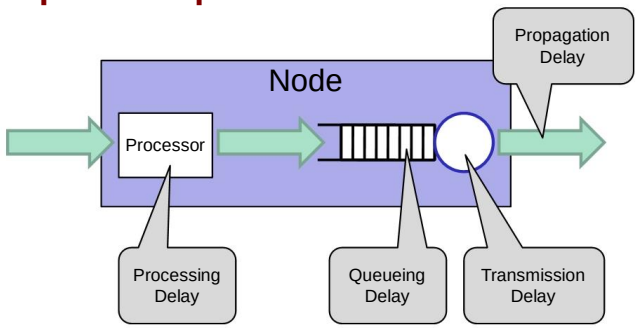
Delay Models in Data Networks

- Packets experience delay on end-to-end path
- Four sources of delay at each hop

Sources of Delay

- Processing Delay
  - Time between when a packet is received and scheduled on an outgoing queue
- Queuing Delay
  - Time packet spends in the outgoing queue
- Transmission Delay
  - Time between when the first and last bits are transmitted
- Propagation Delay
  - Time it takes for the last bit to leave the transmitter and arrive at the receiver

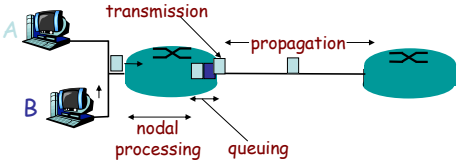
Graphical Representation



Delay in packet-switched networks

nodal processing:
- check bit errors
- determine output link

queuing
- time waiting at output link for transmission
- depends on congestion level of router



Delay in packet-switched networks

Transmission delay:

- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~$2x10^8$ m/sec)
- propagation delay = d/s

Note: s and R are *very* different quantities!