Before Today: Datagrams, User Datagrams, Reliable byte streams on top of unreliable service abstraction
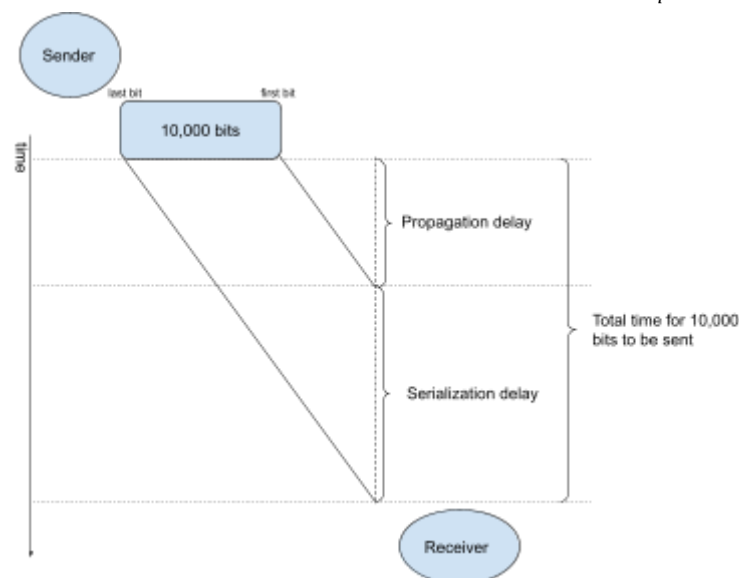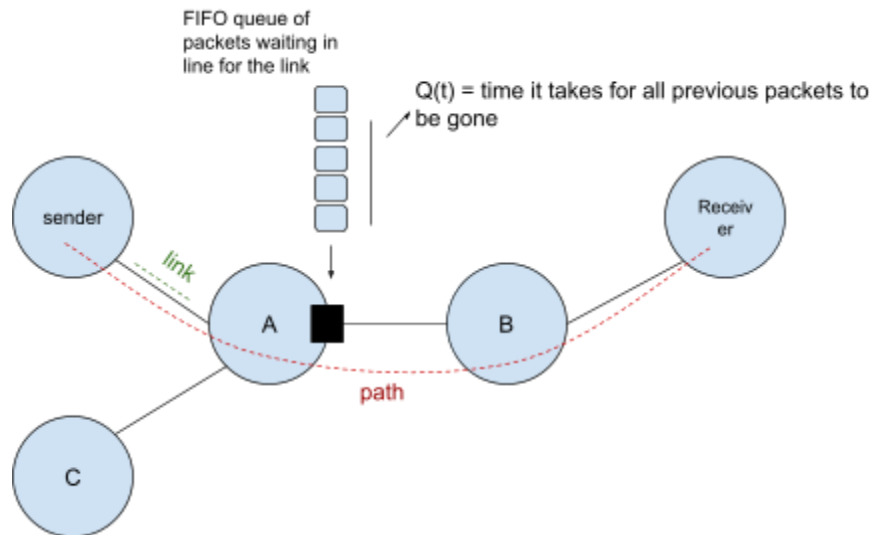Today: Packet Switching
Logistics:
- Come to the lab
- Help each other out both in the lab and on Ed
- Extra credits will be given in upcoming checkpoints for new test cases

How does end point drop a "postcard" to its destination?
- Circuit-switched networks (e.g. telephones)
    - Each telephone is connected to a center office
    - And a staff worked in the office would connect the wires upon customers' request
    - If the person you want to call does not belong to the same office as you, there are circuits between main offices
    - <u>Any phone call has a real direct electrical circuit</u>
    - BUT: setting up and tearing down circuit is expensive, it works for telephone calls, but would not make sense if you only want to send a short piece of data
- Packet Switching
    - The time it takes for the first bit to be received – **Propagation Delay:**
      $t_l = \frac{l}{c}$ (l = distance, c = light speed in that medium) (seconds)
        - $c = 2 \times 10^8 \, m/s$ in cable
    - The time it takes for the whole packet to be received after the first bi t is received
      — **Serialization delay:** $t_p = \frac{size\ of\ packet}{link\ rate\ (bits\ per\ second)} = \frac{p}{r}$
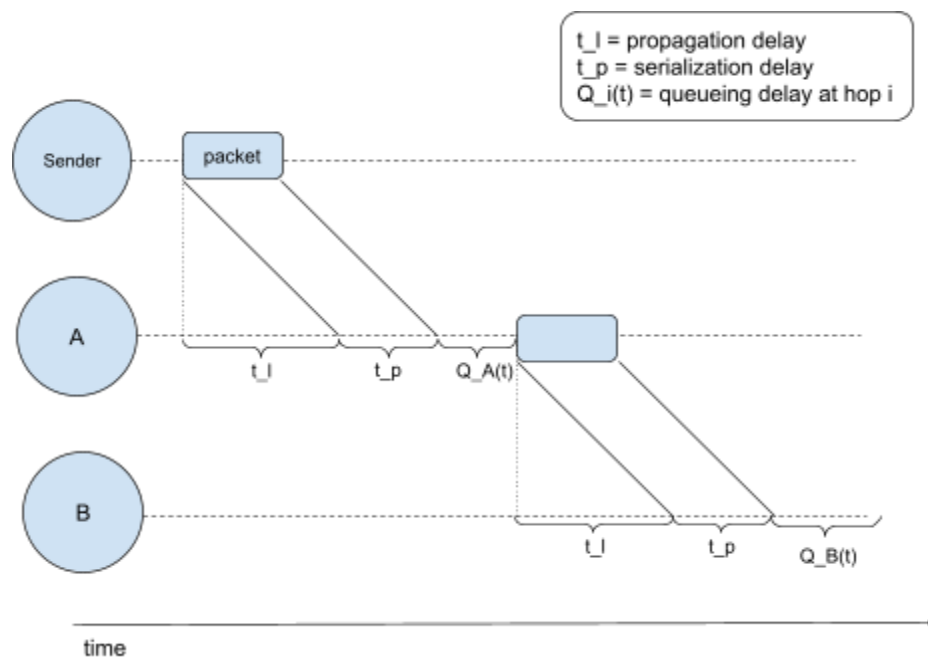   - **Total time to send a packet across a link:** $t = t_p + t_l = \frac{p}{r} + \frac{l}{c}$

    - The path between sender and receiver consists of multiple links

FIFO queue of packets waiting in line for the link

Q(t) = time it takes for all previous packets to be gone

sender

Receiver

link

A

B

path

C

-
- Each hop on the link receives the whole packet before sending it out, and therefore each hop would have propagation delay + serialization delay
- And there is **Queueing delay** if the link is busy (a packet needs to wait in line at the FIFO queue).
- TIme until packet begins transmission on a link — **Queueing delay**:

$$Q(t) \; = \; \Sigma \; serialization \; delay \; of \; any \; packet \; before \; this \; packet \; in \; the \; queue$$

t_l = propagation delay
t_p = serialization delay
Q_i(t) = queueing delay at hop i

Sender

packet

A

t_l   t_p   Q_A(t)

B

t_l   t_p   Q_B(t)

time

-
- **End-to-end delay**: $\sum\limits_{i \in \{hops\}} (t_p + t_l + Q_i(t))$