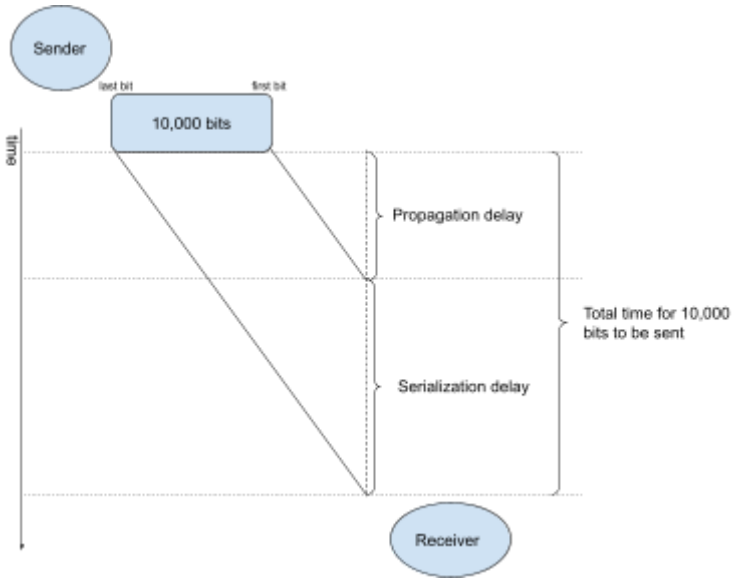
Before Today: Datagrams, User Datagrams, Reliable byte streams on top of unreliable service abstraction
Today: Packet Switching
Logistics:

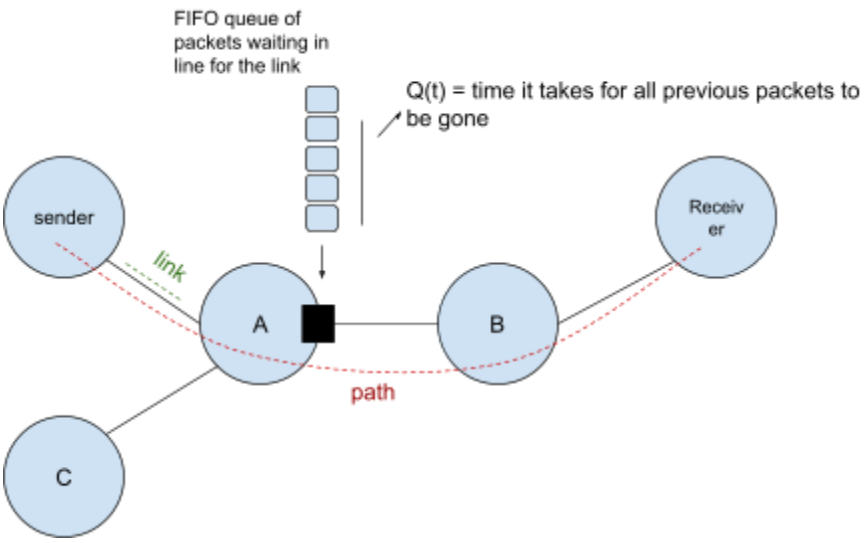
- Come to the lab
- Help each other out both in the lab and on Ed
- Extra credits will be given in upcoming checkpoints for new test cases

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
  - Any phone call has a real direct electrical circuit
  - 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 (packetization) delay:** $t_p = \frac{size\ of\ packet}{link\ rate\ (bits\ per\ second)} = \frac{p}{r}$
  - **Total time to send a packet across a link:** $t = t_p + t_l = \frac{p}{r} + \frac{l}{c}$

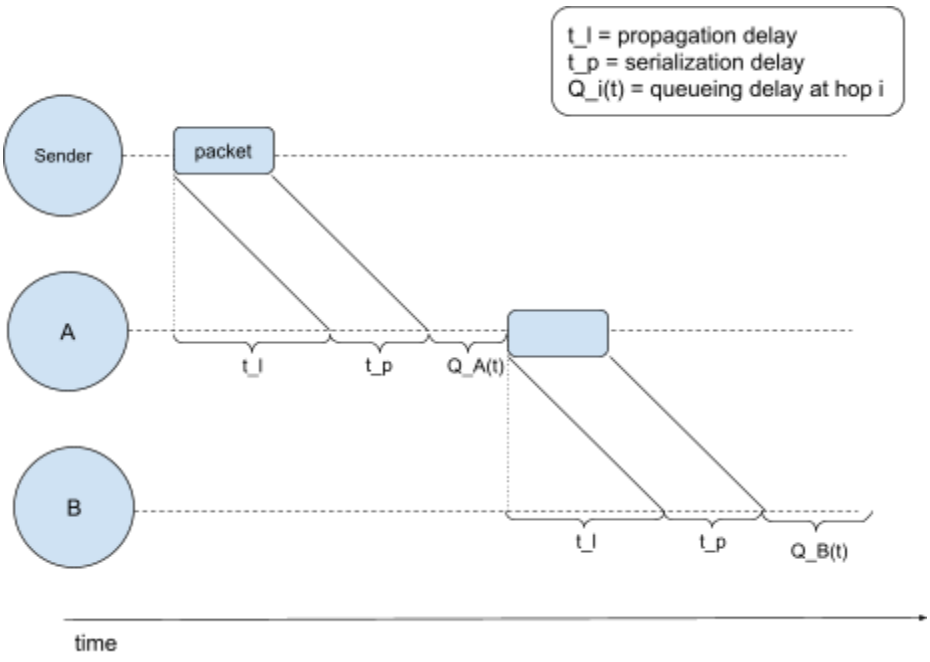


- The path between sender and receiver consists of multiple links



- 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**:

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



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