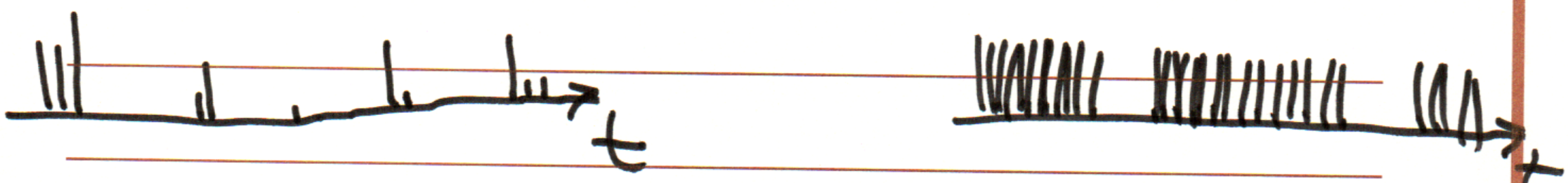
# Traffic Types

- Bursty
- Streamy




# Performance Measures

- Delay (Latency) (sec)
  - Deterministic
    - Transmission Delay
    - Propagation Delay
  - Random
    - Processing delay
    - Queuing delay
- Throughput (bps)

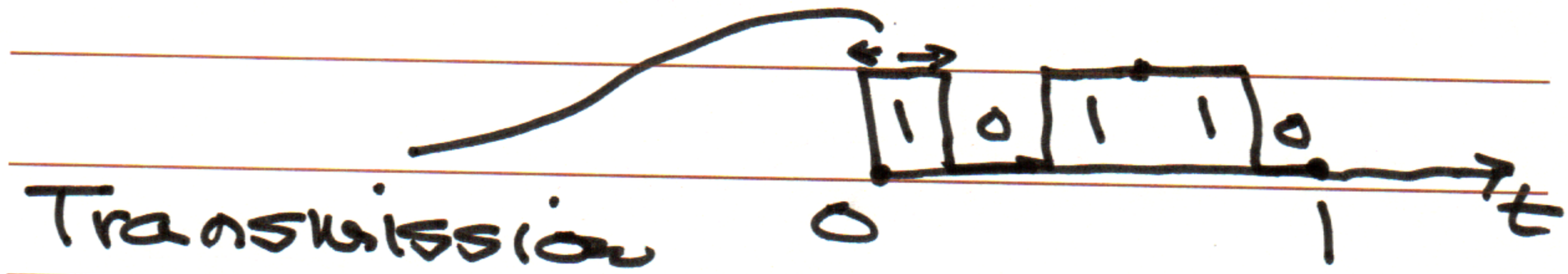
① Transmission Time :

Time elapsed from the moment you T/x the first bit till the moment you T/x the last bit of your message.

$$T_t = \frac{\text{Message length (bits)}}{\text{Data (bit) Rate (bps)}}$$

$$R_b$$

eg. 5 bps




$$T_b = \frac{1}{R_b}$$

② Propagation Delay

Time elapsed from moment you transmit a bit (any bit) till moment this bit is received.

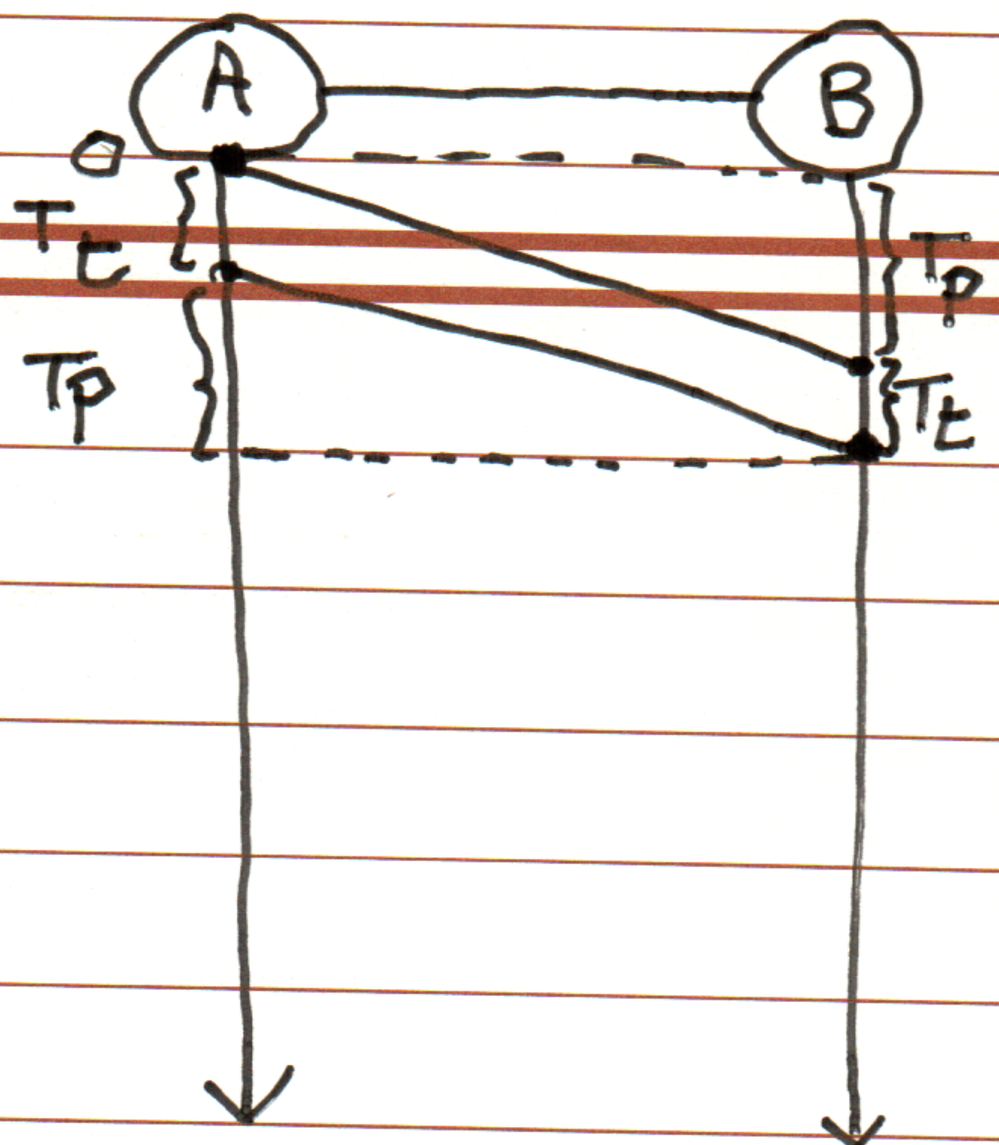
$$T_p = \frac{\text{length of the link (m)}}{\text{Velocity of propagation (m/sec)}}$$

↓

$\approx$ speed of Light

$3 \times 10^8$ m/sec

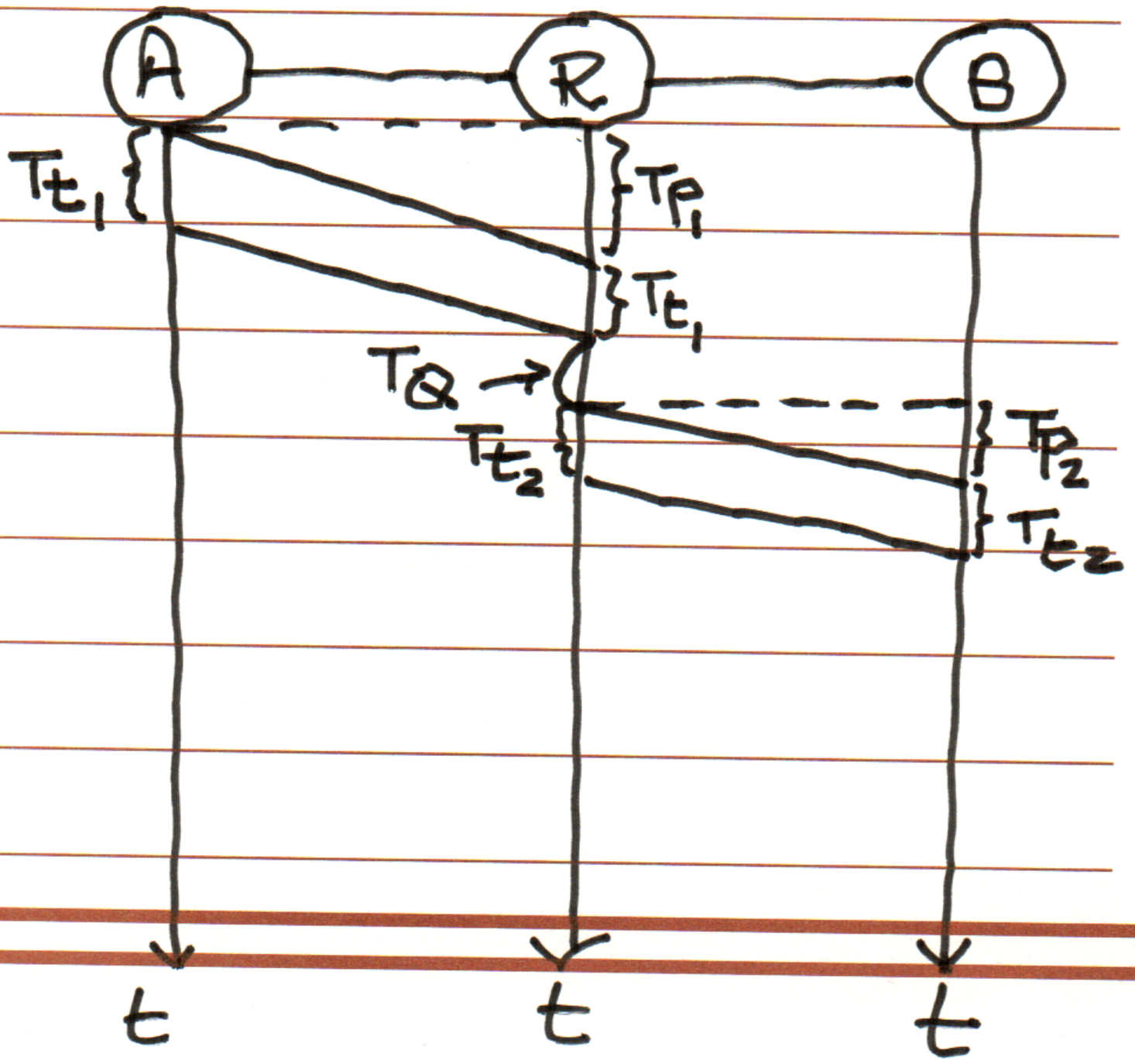
Timing Diagram




End-to-End delay = Time elapsed from moment you send the first bit of your packet till the last bit is received.

$$T_{End\text{-}to\text{-}End} = T_t + T_p$$

# Two-hops, one packet

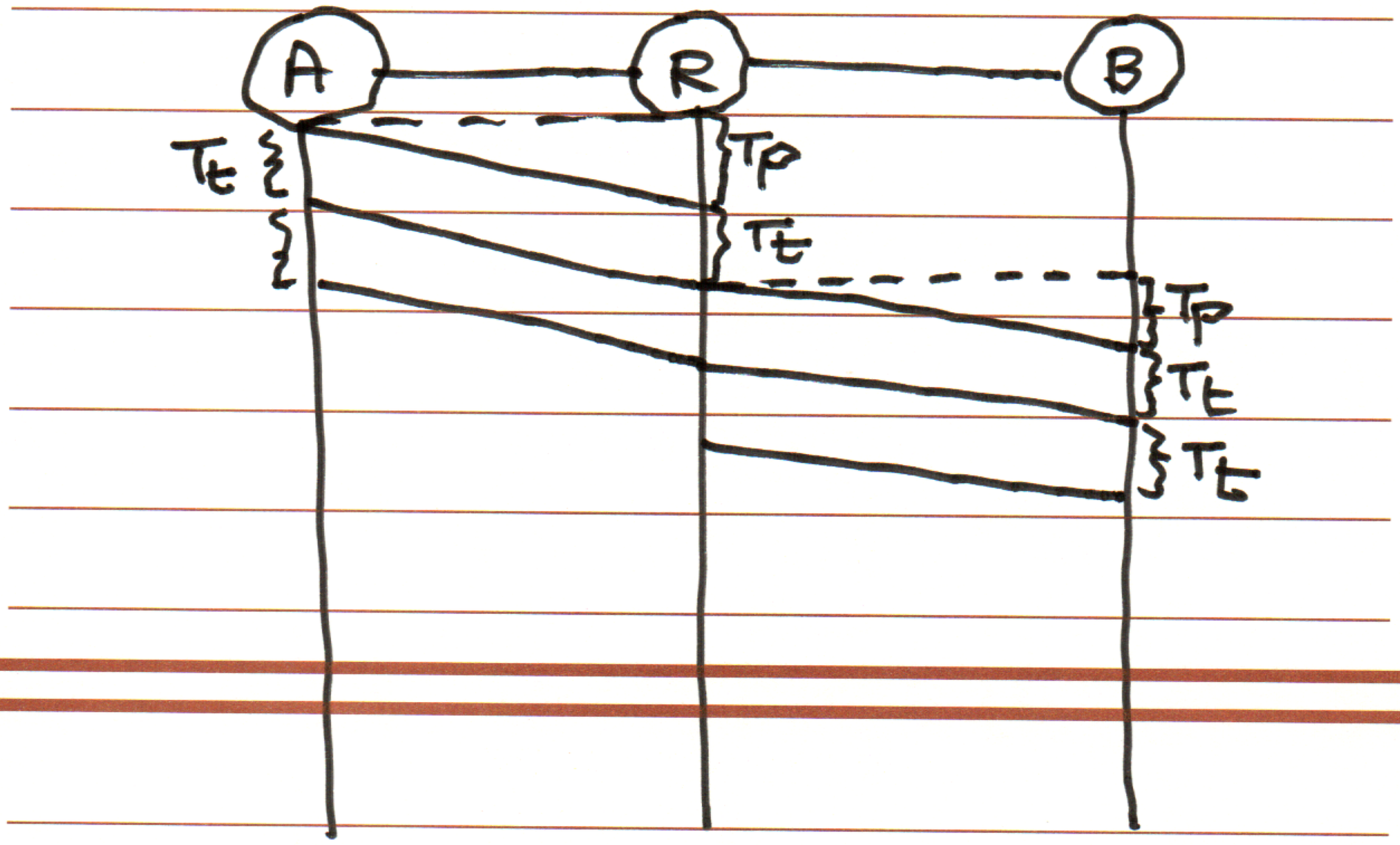



$$T_{end\text{-}to\text{-}end\ delay} = T_{P_1} + T_{t_1} + T_Q + T_{P_2} + T_{t_2}$$

if $T_{t_1} = T_{t_2}$ $T_{P_1} = T_{P_2}$

$$End\text{-}to\text{-}End\ ~~packet\ delay~~ = 2T_t + 2T_p + T_Q$$

Ex: Two-hops, Two packets (Back-to-Back)
No queuing, same length links

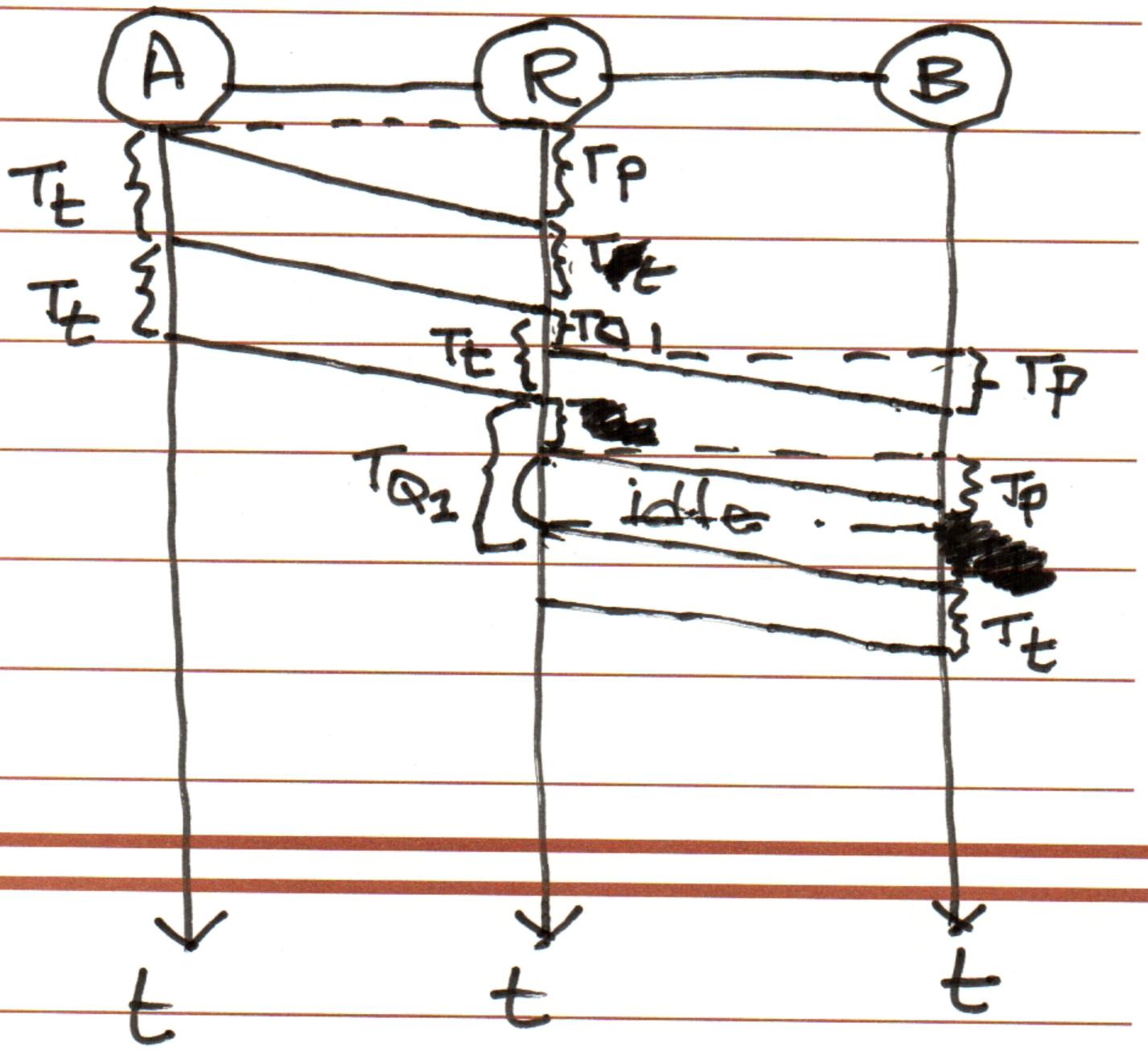



$$T_{End\text{-}to\text{-}End} = T_p + T_t + T_p + T_t + T_t$$

$$= 3T_L + 2T_p$$

@ home: Find the End-to-End delay with N packets and M Links.

# Two hops, Two packets with Queuing delay



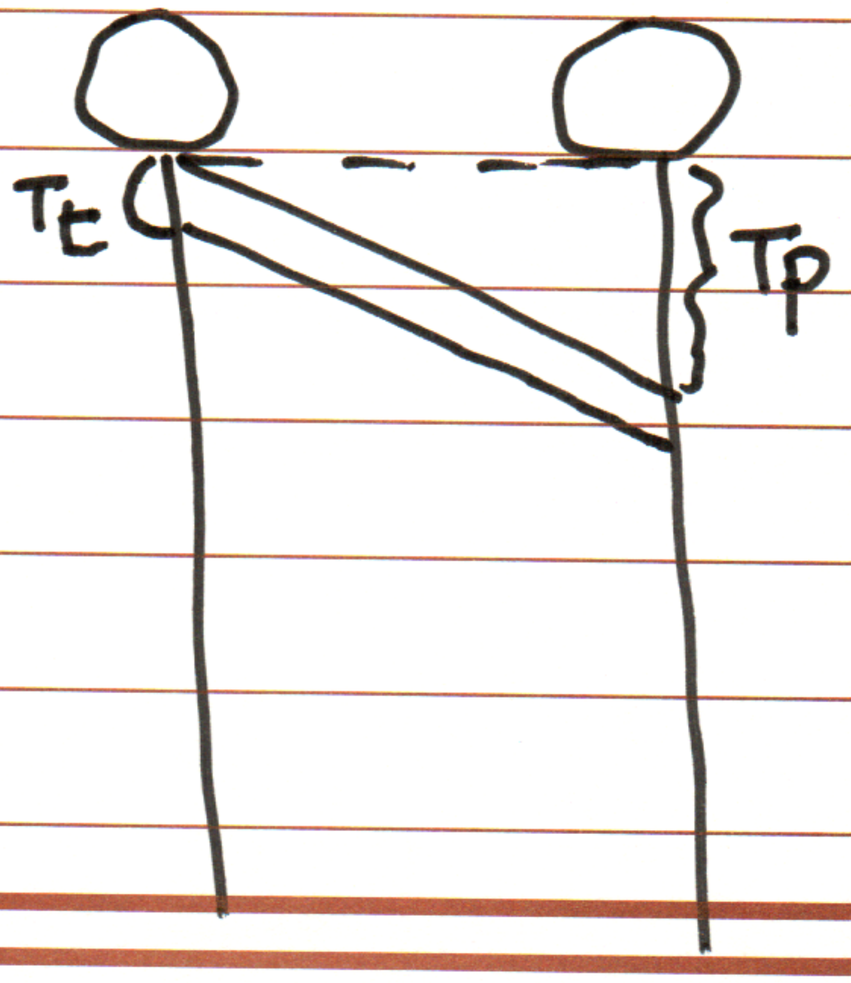

End-to-End delay $= T_p + T_t + T_{Q_1} + T_p$

$+ T_t + T_{idle} + T_t$

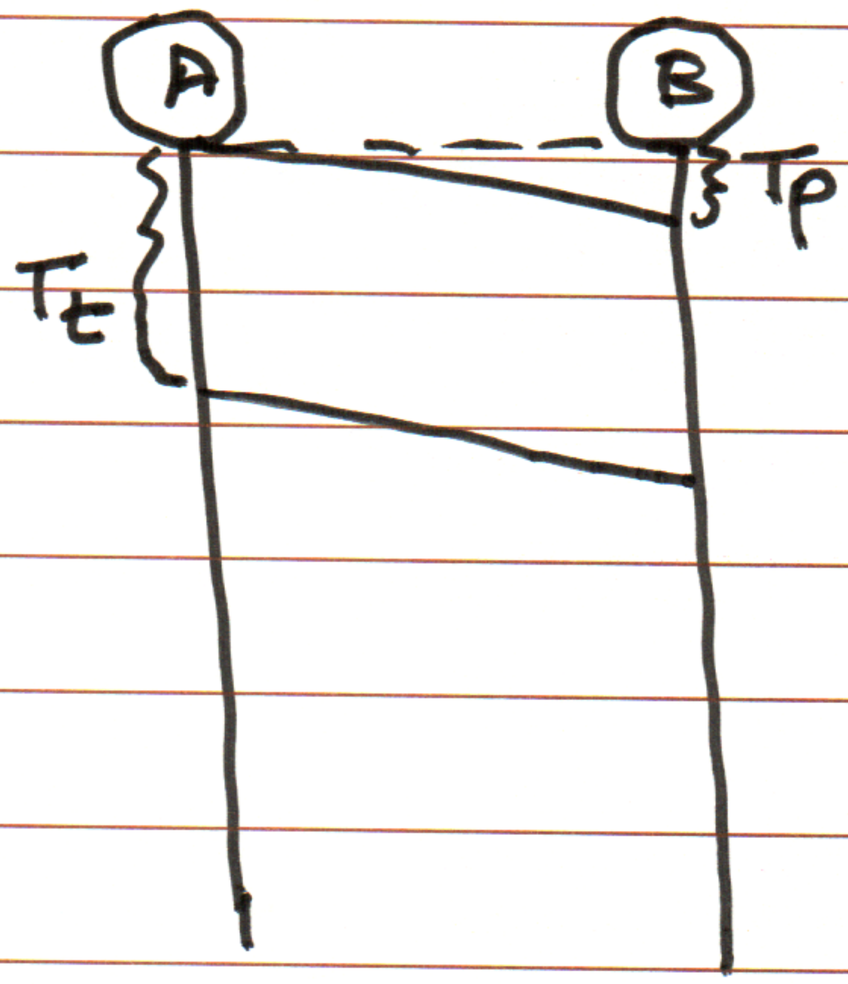
$= 3T_t + 2T_p + T_{Q_1} +$

$T_{idle}$

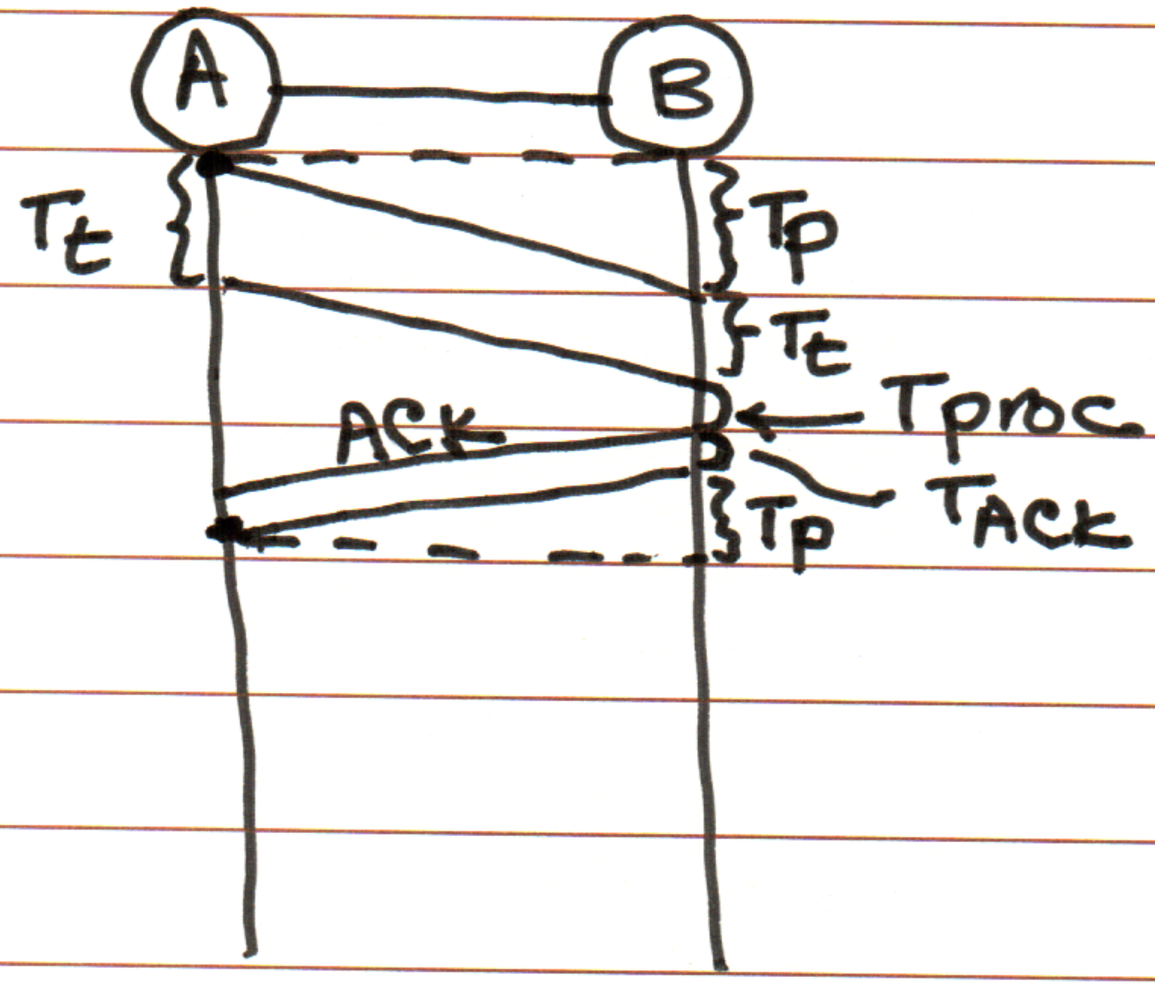
which is Larger $T_t$ or $T_p$ or they have nothing to do with each other.




$T_p > T_t$

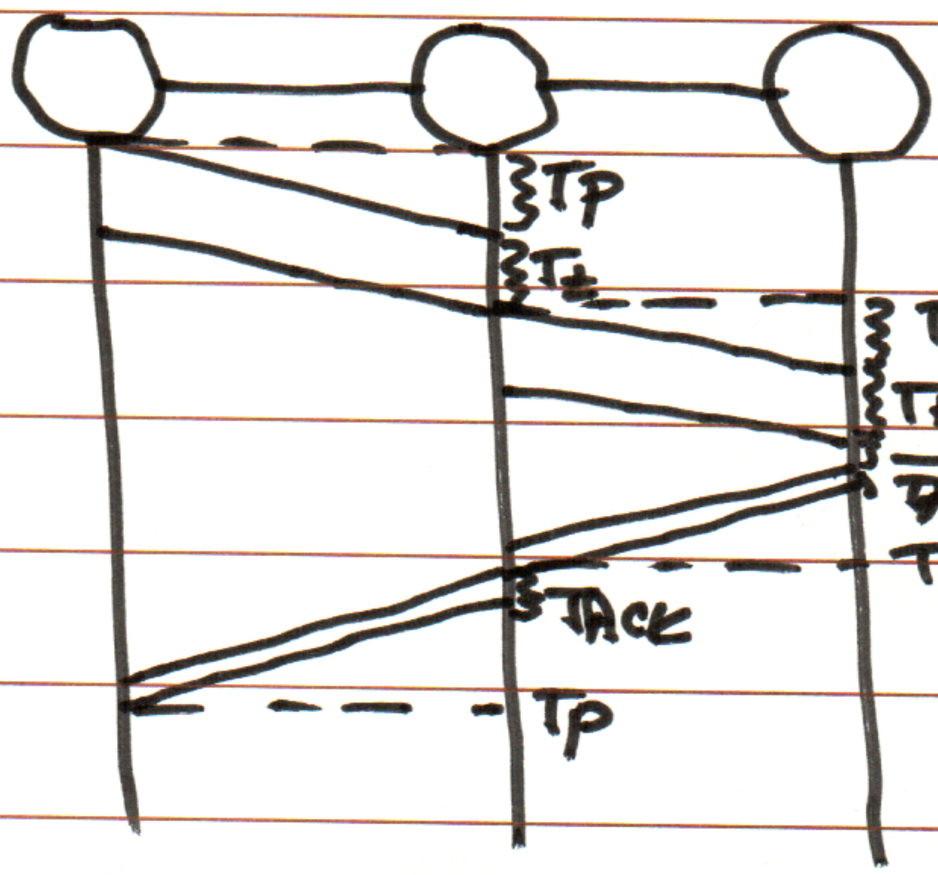


# RTT: Round Trip Time (a.k.a response time).

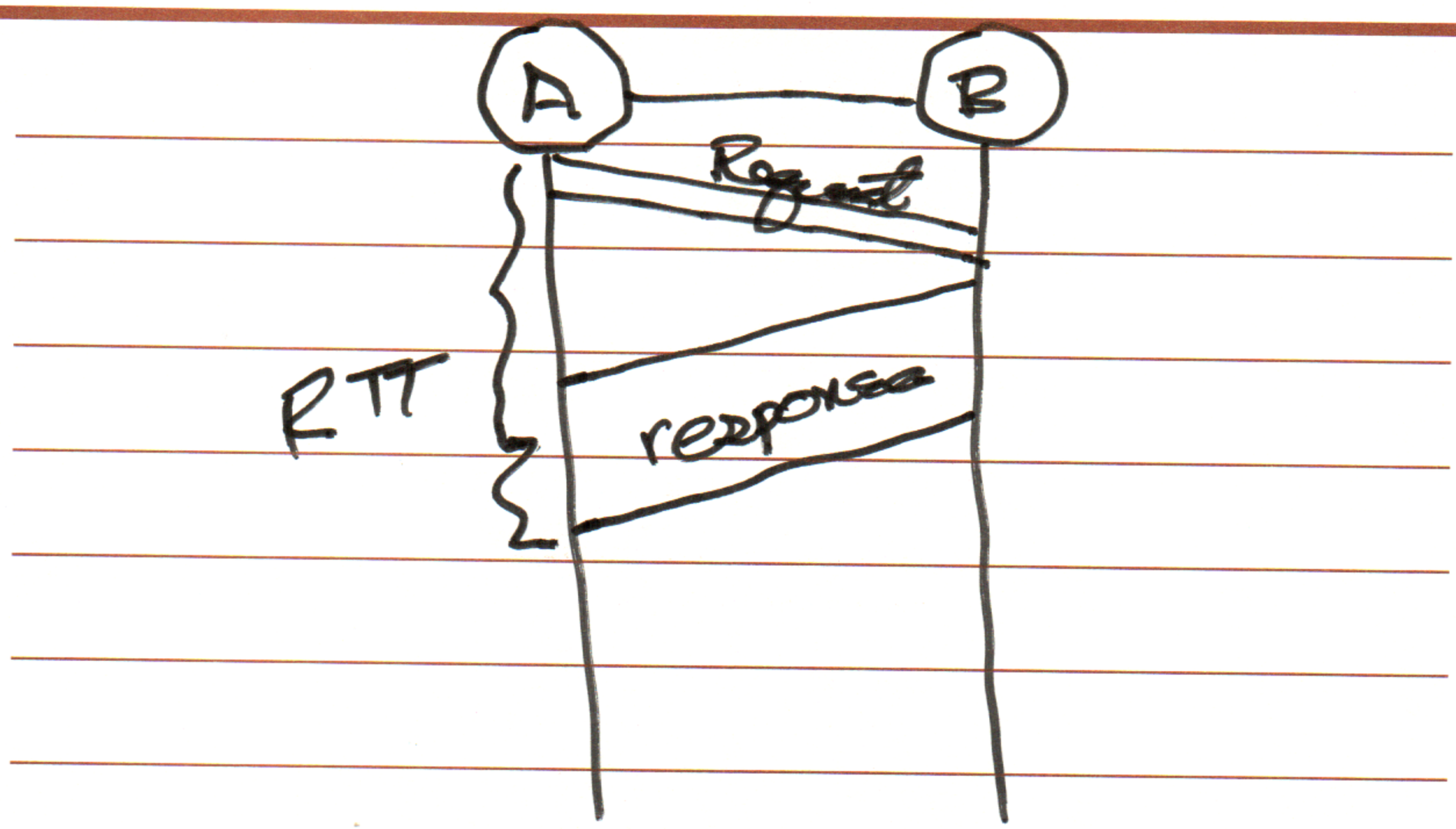



$RTT = T_p + T_t + T_{proc} + T_{ACK} + T_p$ (most of times ignored.)

$= T_t + 2T_p$




$RTT = T_p + T_t + T_p + T_t + T_{proc} + T_{ACK} + T_p + T_{ACK} + T_{proc} + T_p$

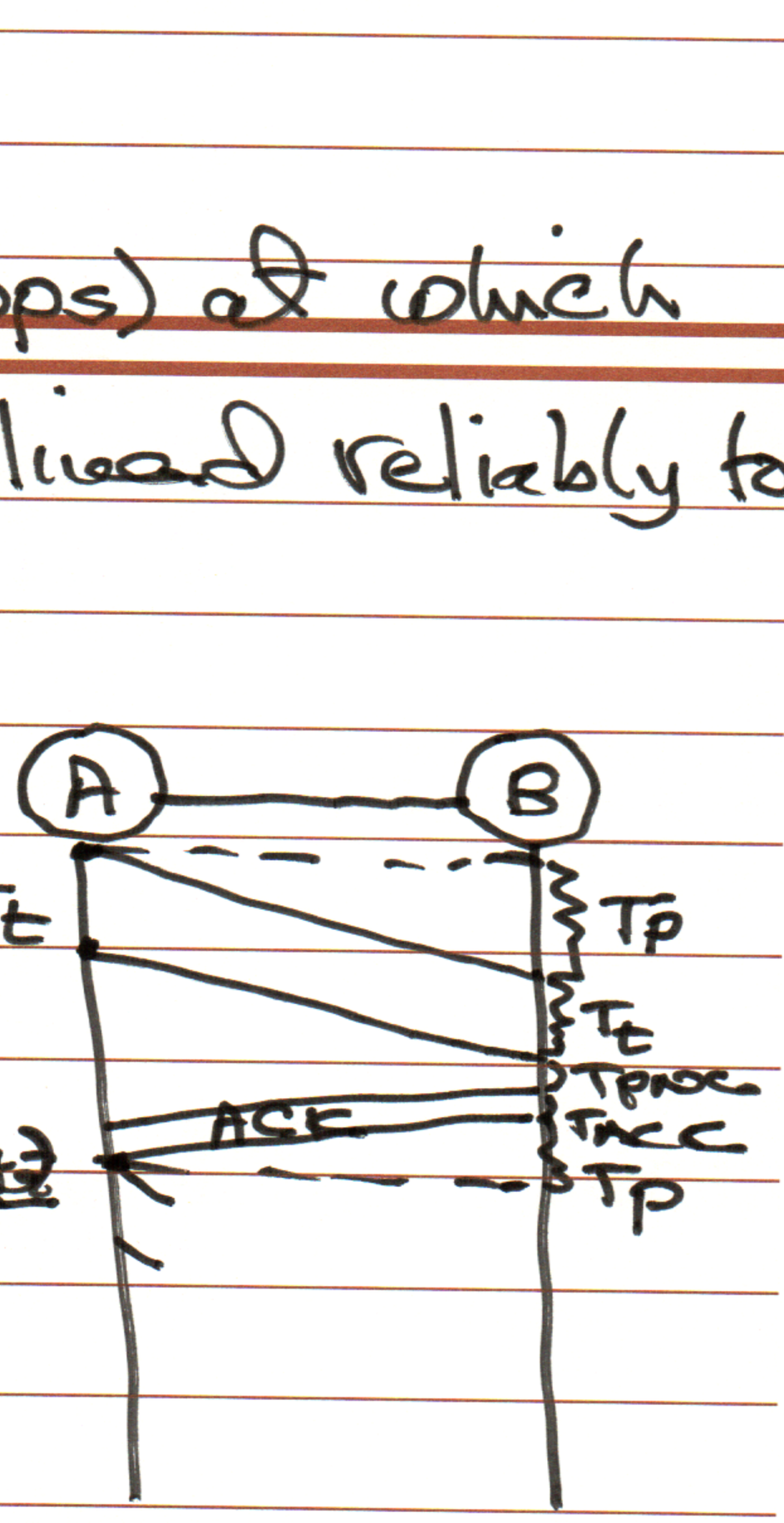



## Throughput :

The rate (in bps) at which packets are delivered reliably to the receiver.

Data Rate

$$R_b = \frac{\text{Length of Packet } T_t}{T_t}$$

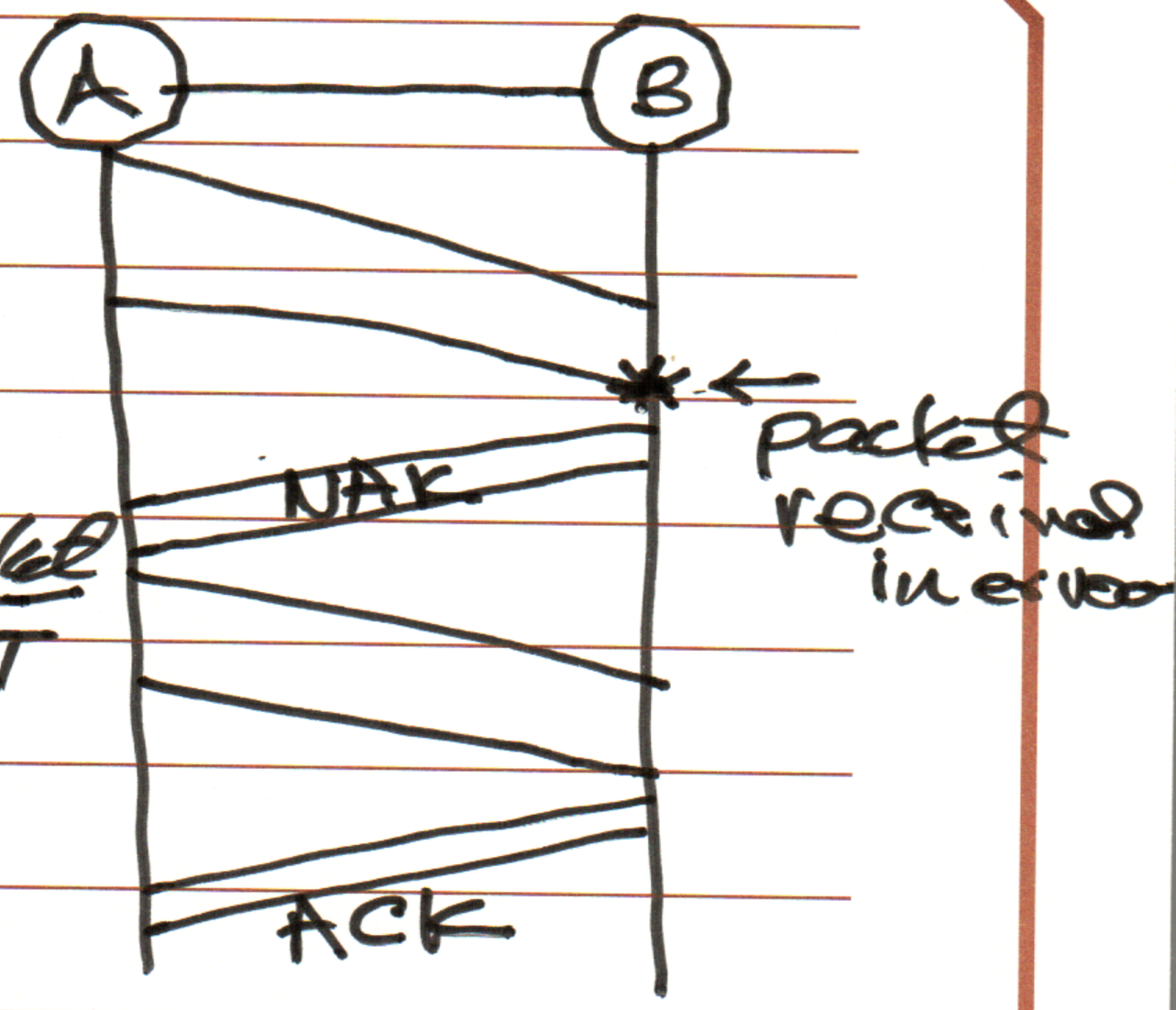



$$\text{Throughput} = \frac{\text{length of packet}}{RTT}$$

$$\eta = \text{Link utilization}$$

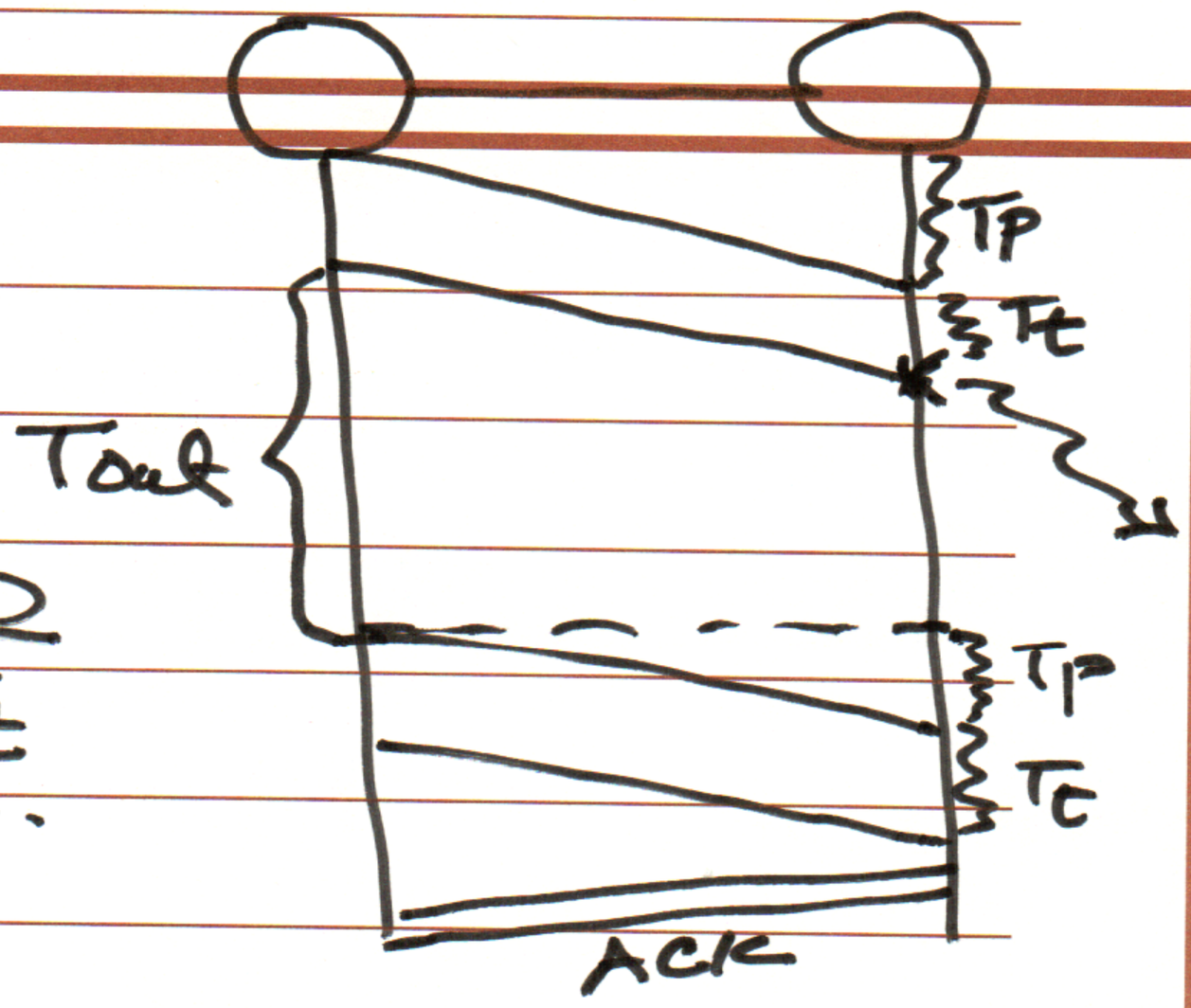
$$= \frac{T_t}{RTT}$$

$$R_b = \frac{\text{length of packet}}{T_t}$$




$$\text{Throughput} = \frac{\text{length of packet}}{2RTT}$$

$$\text{Throughput} = \frac{\text{length of Packet}}{T_p + T_t + T_{out} + T_t + T_{ACK} + T_p \ldots}$$

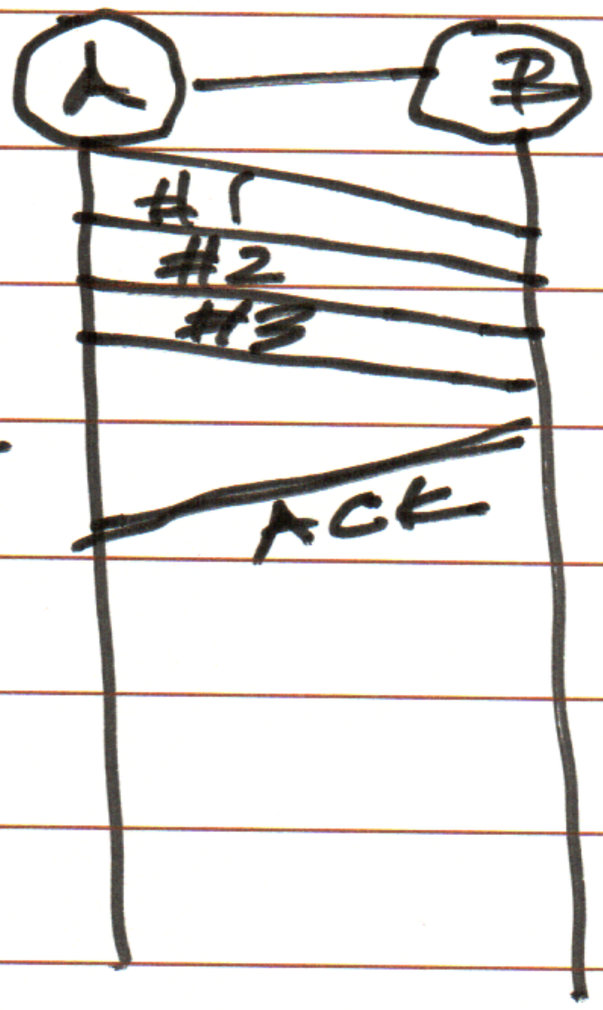



Link utilization

$$\eta =$$

Throughput

$$= \frac{(3)(\text{Packet Length})}{RTT}$$




$$\eta = \frac{3T_E}{RTT}$$

↑

in % (No units).

one way propagation delay.

BW x Delay Product:

(bps) (s) = Bits

The max. # of bits that will fill the pipe.

The delay is usually taken as RTT (twice the propagation delay).