Network Performance Measures

- **Delay (sec)**
  - Goal: minimize delay
  - **Deterministic**
    - **Transmission Delay**
    - **Propagation delay**
  - **Random**
- **Throughput (bps)**
  - Maximize throughput

Transmission Delay

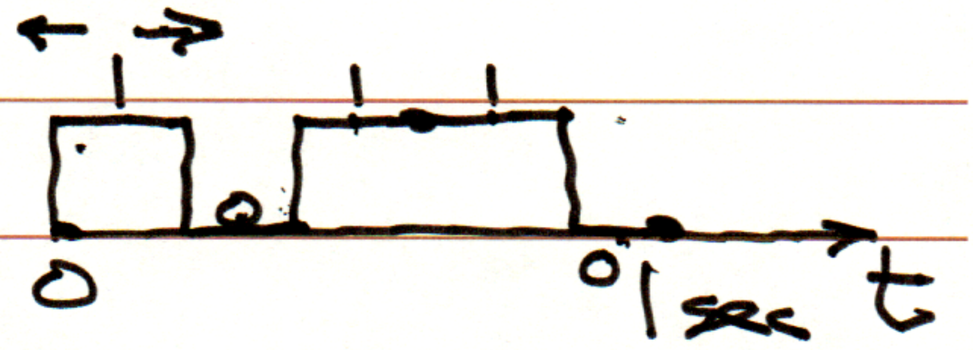
T_t = The time elapsed from the moment you transmit the first of your message till the time you transmit the last bit of your message.

$$T_t = \frac{\text{length of the message (bits)}}{\text{Transmission (Bit rate) rate}}$$ bps

R_b = Bit Rate

10110

= 5 bps



Bit duration (sec)

$$T_b = \frac{1}{R_b} = 0.2 \text{ sec}$$

Propagation Delay T_p is the time elapsed from the moment you transmit a bit till the moment that bit is received.

$$T_p = \frac{\text{length of medium (m)}}{\text{velocity of propagation (m/sec)}}$$

normally the velocity of propagation is ≈ speed of Light

$= 3 \times 10^8$ m/sec

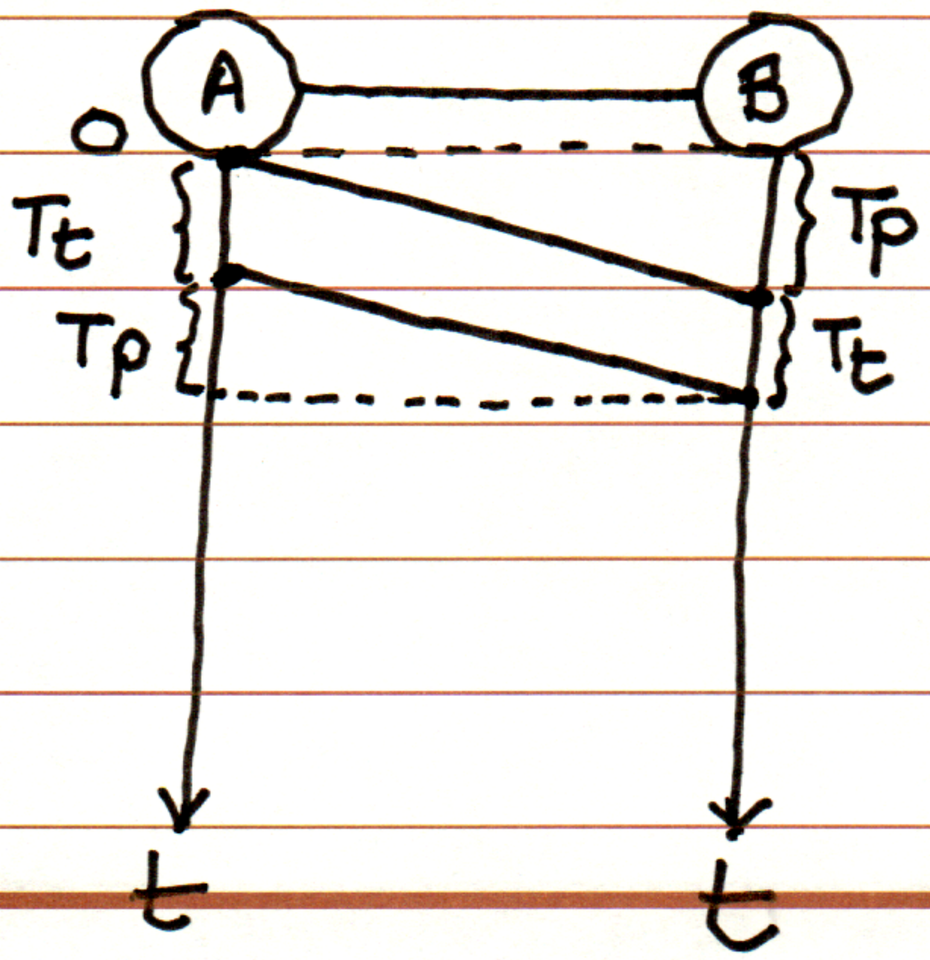
usually ranges from 2×10^8 to 2.5×10^8 m/sec.

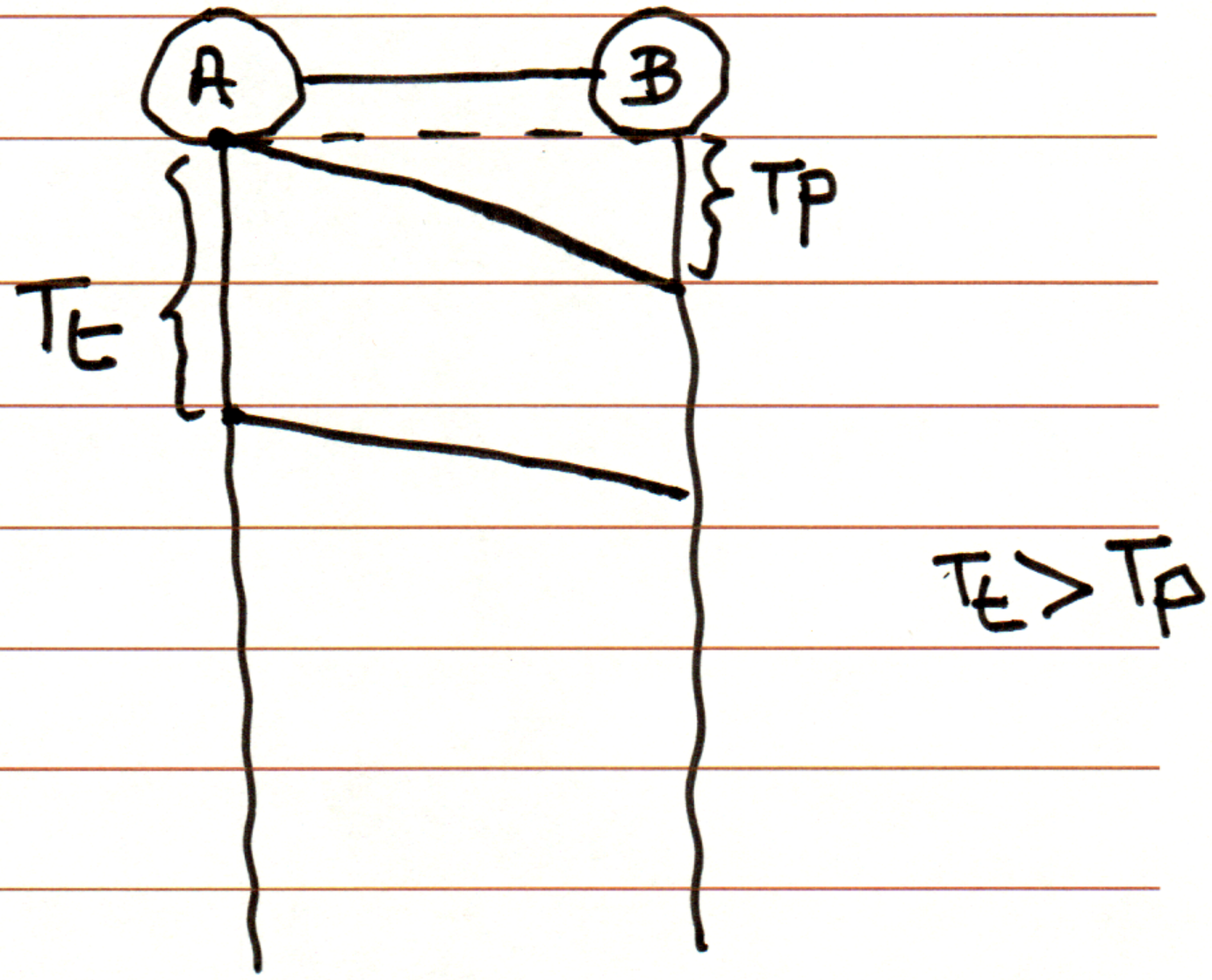
Random Components

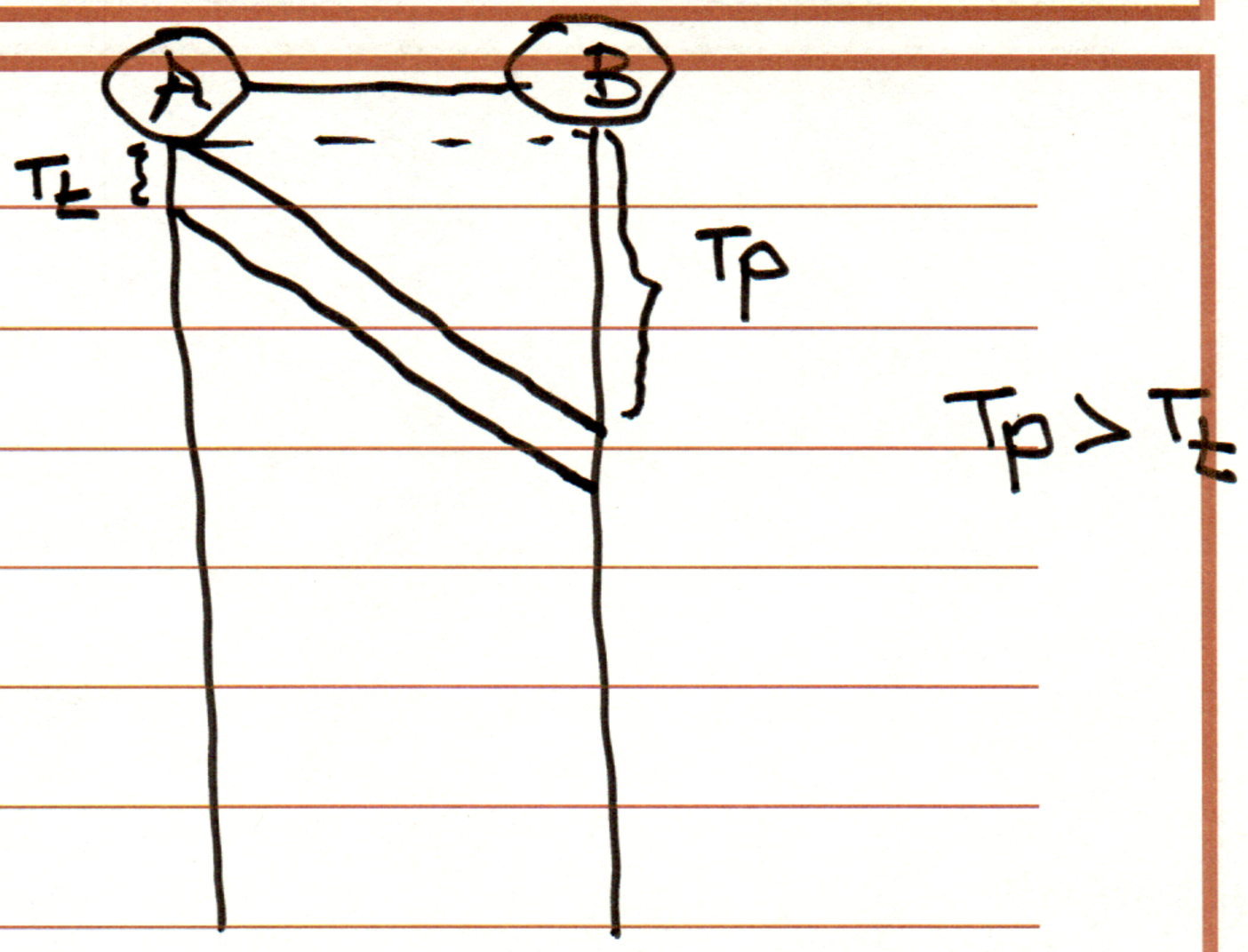
Processing Delay

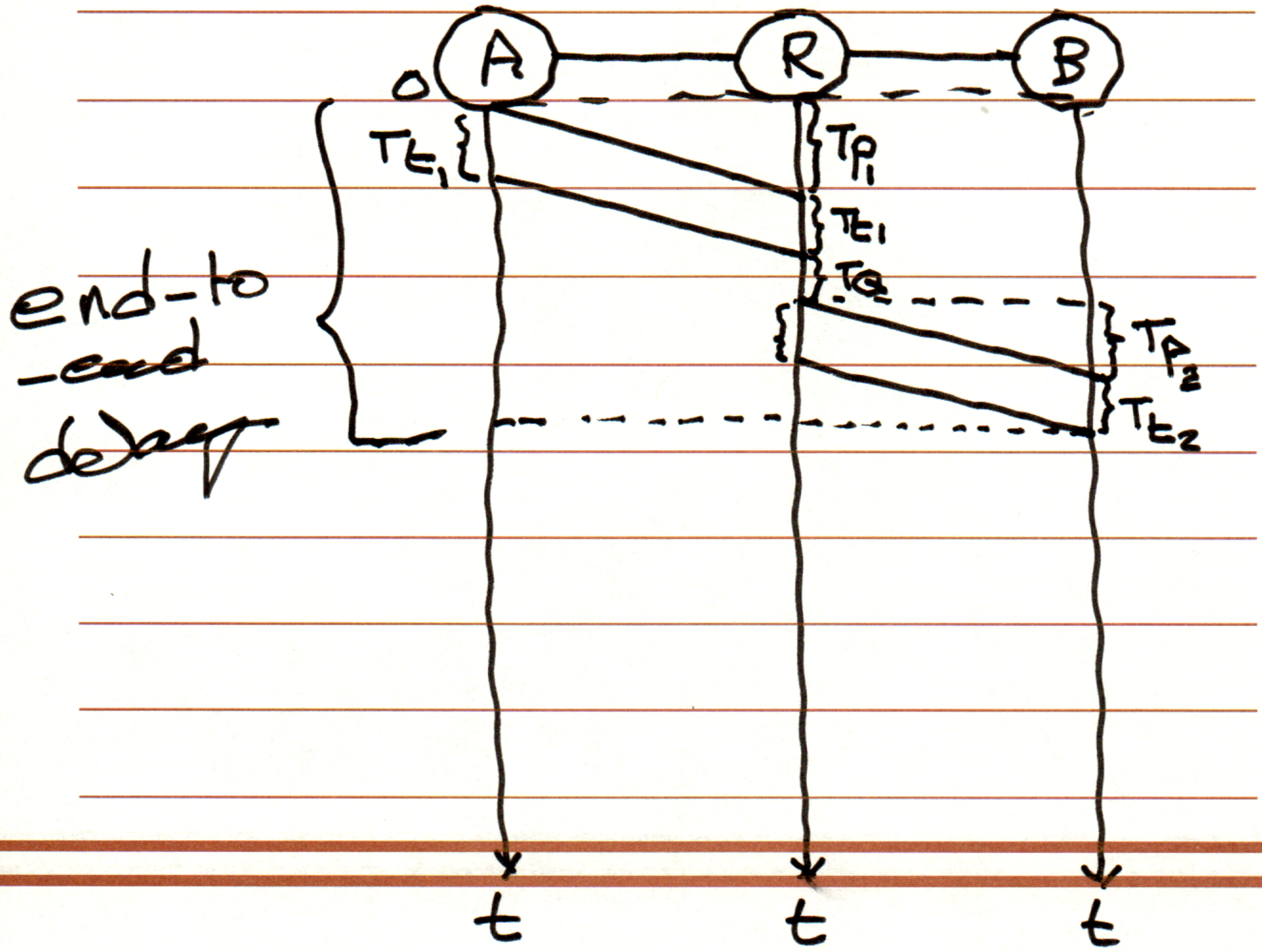
Queuing Delay

Graphical Representation




A
B
Tp
Te
Te > Tp

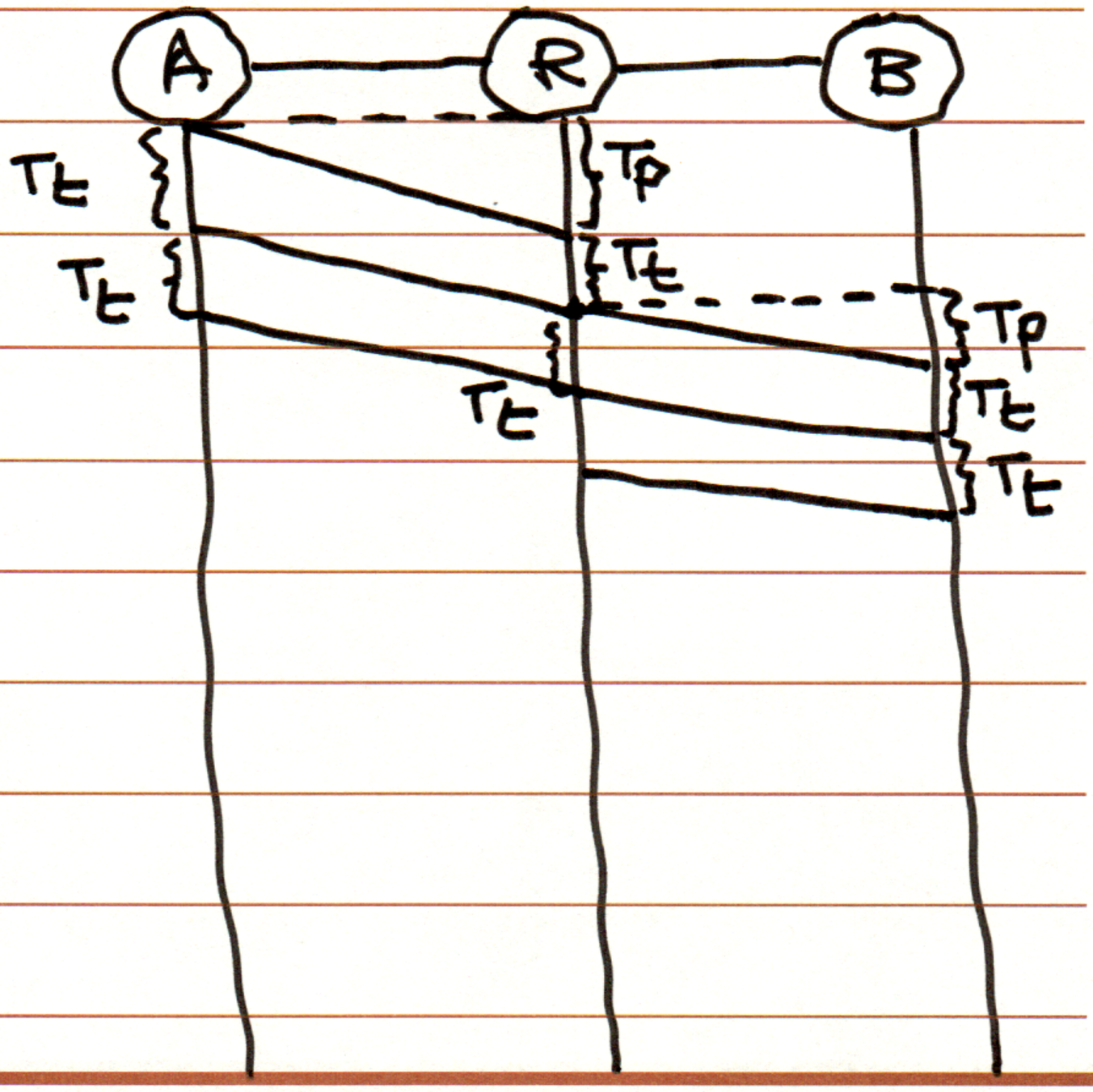

A
B
Te
Tp
Tp > Te



End_to_End delay = The time
(Transfer)
elapsed from the moment you
transmit the first bit of your
message till the moment the last
bit is received.

$$T_{e2e} = T_{P_1} + T_{t_1} + T_Q + T_{P_2} + T_{t_2}$$

$$= 2T_P + 2T_t + T_Q$$



A is transmitting two packets back_to_back

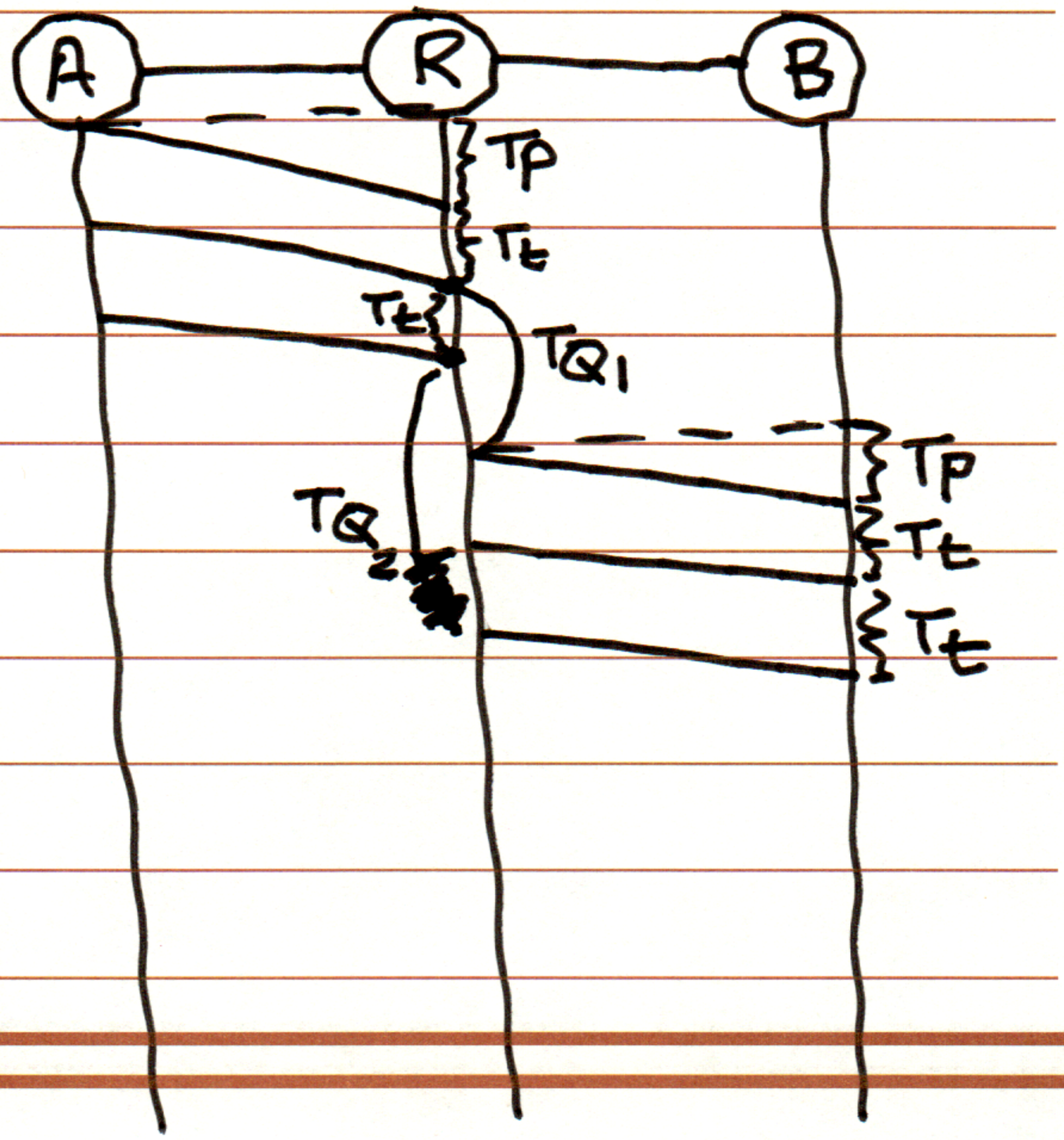
ignore Q_delaying

what is end-to-end delay?

$$= T_p + T_t + T_p + T_t + T_t$$

$$= 2T_p + 3T_t$$

Generalize this case to M back-to-back packets & N Links and no-congestion



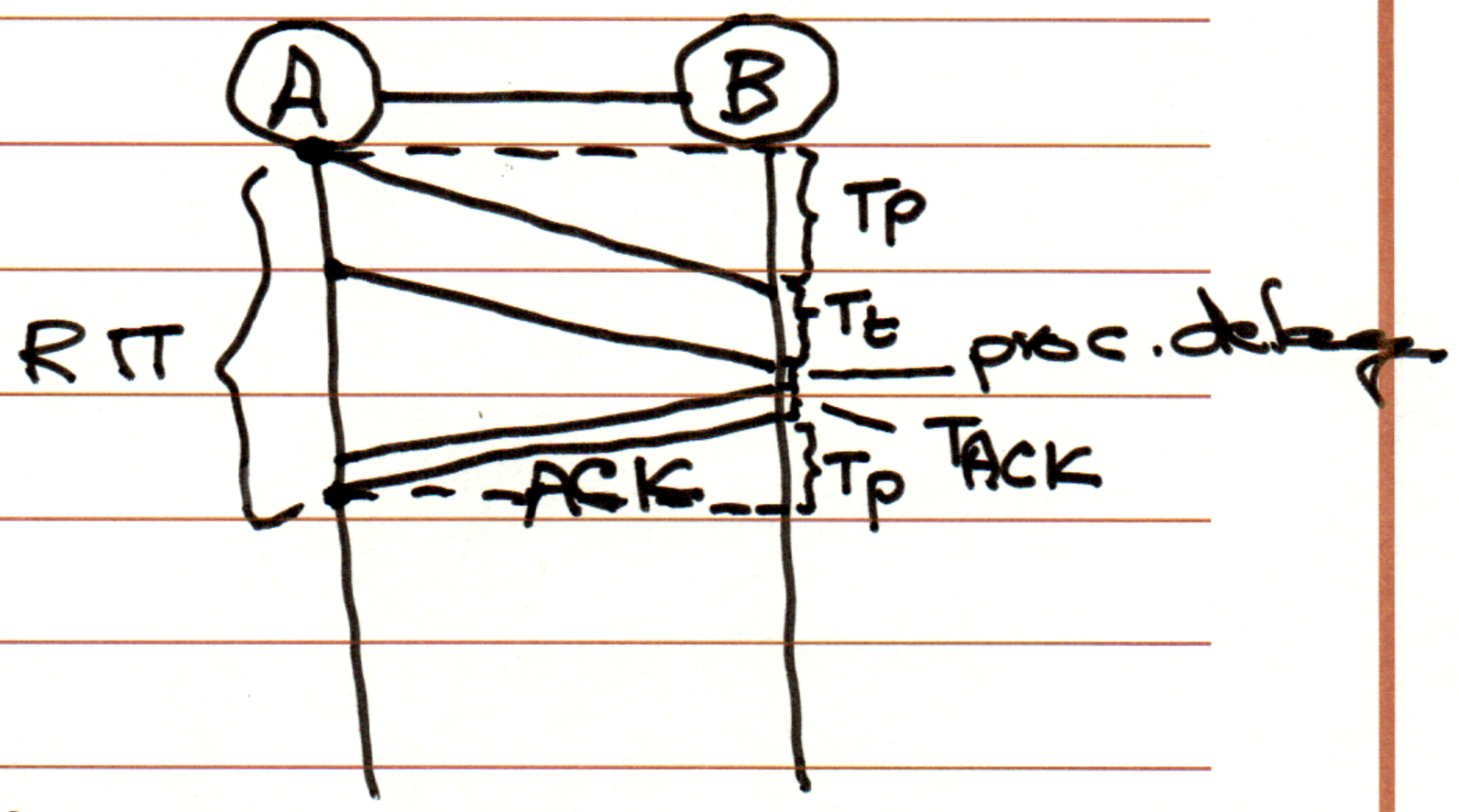
End-to-End delay

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

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

Response Time

RTT: Round Trip Delay (sec)



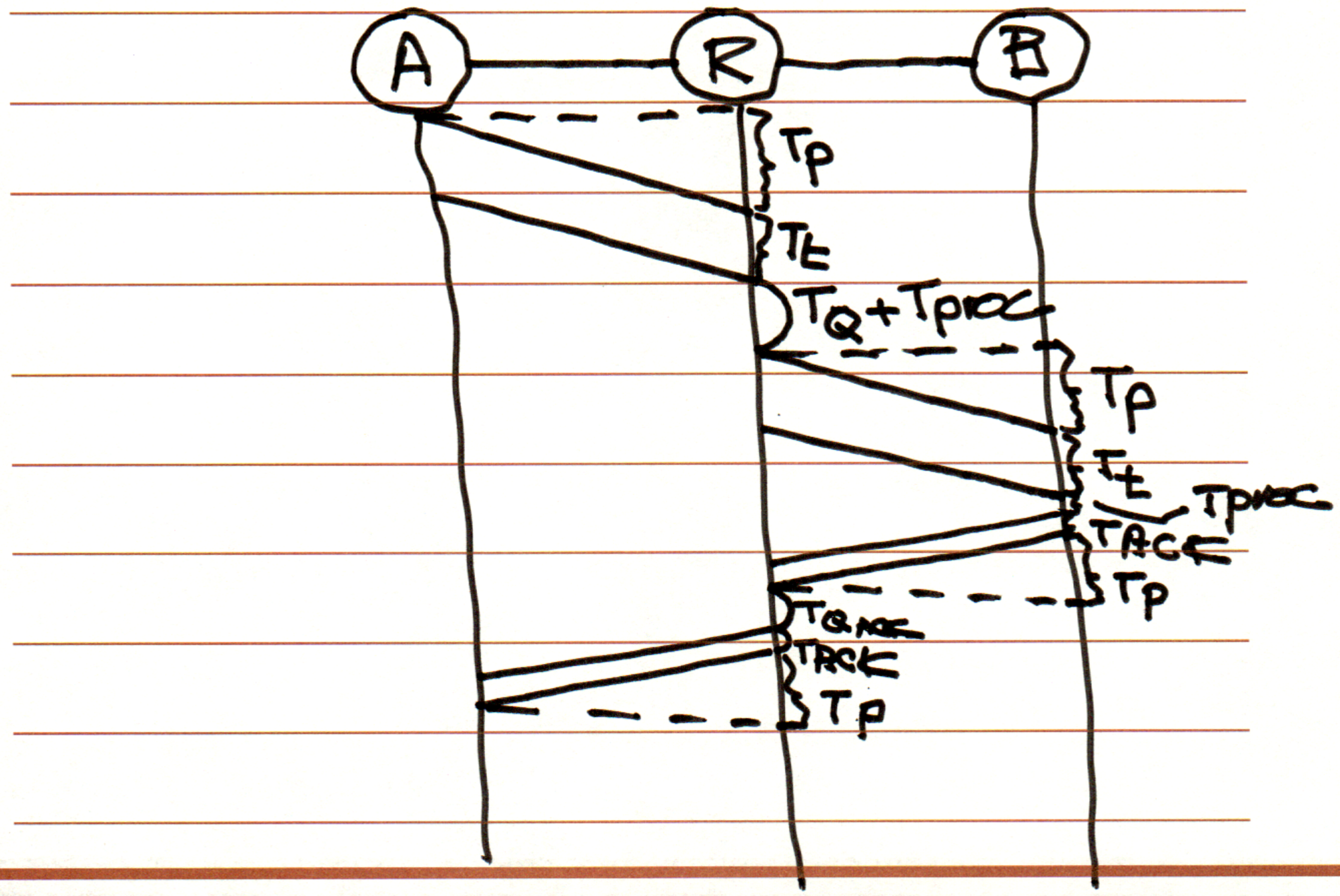
$$RTT = T_p + T_t + T_{proc} + T_{ACK} + T_p$$

$$\simeq 2T_p + T_t$$

So if you start the timer when you send the message

$$RTT \cong 2T_p$$

2 hops



$$RTT = T_p + T_t + T_Q + T_p + T_L + T_{proc}$$

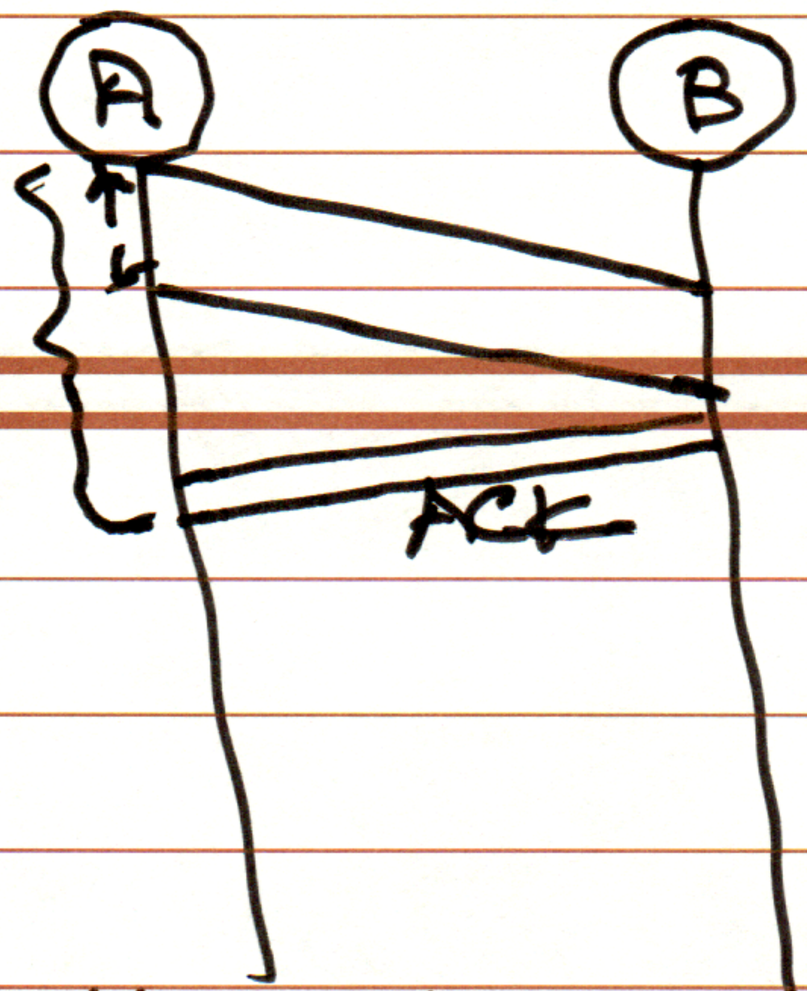
$$+ T_{ACK} + T_p + T_{QACK} + T_{ACK} + T_p$$

$$\simeq 4T_p$$

Throughput (bps)

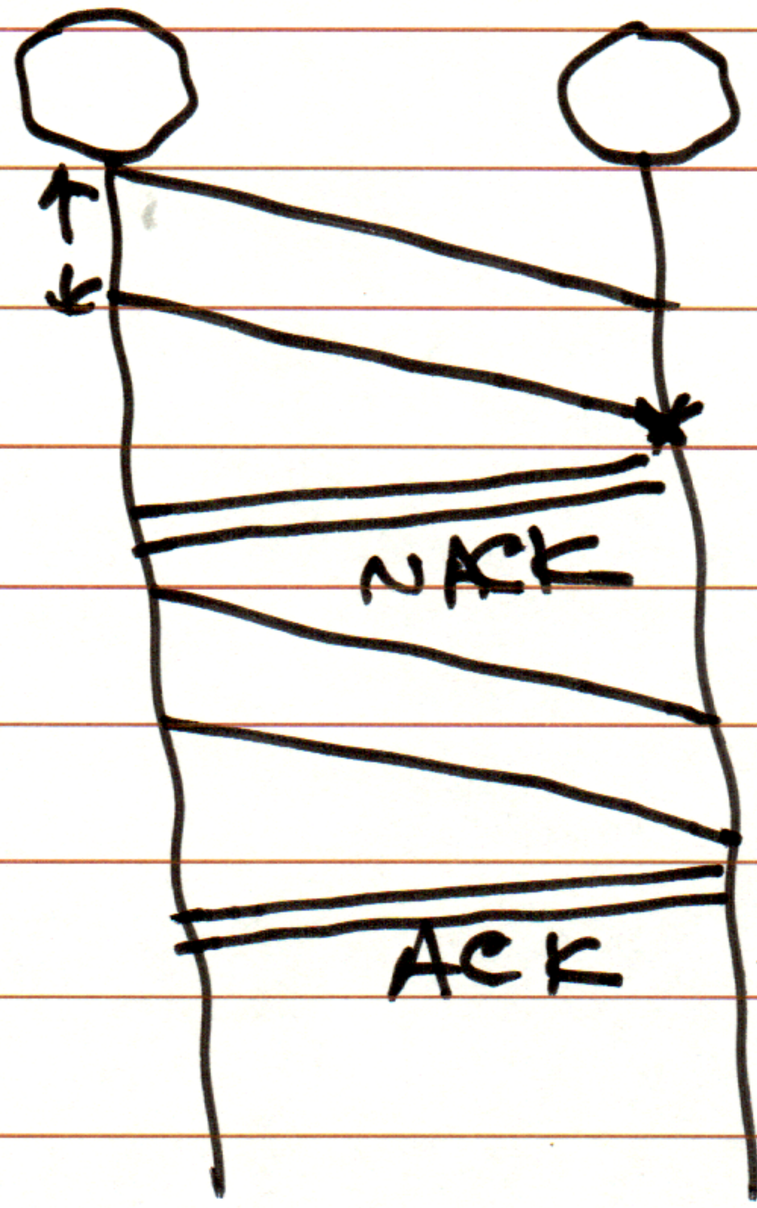
is the rate at which the bits are delivered reliably.

to the receiver.



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

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



$$\text{Bit (Data Rate)} = \frac{\text{length of image}}{t}$$

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