Useful formulae:

- Delay for distrbuting copies of a file with F bits to N clients, with u_s upload server bandwidth, d_{min} minimum download bandwidth, and u_i upload bandwidth for client i:
  - for "client-server" (CS) model: $D_{CS} \geq max\left\{\frac{NF}{u_s}, \frac{F}{d_{min}}\right\}$
  - for "peer-to-peer" (P2P) model: $D_{P2P} \geq max\left\{\frac{F}{u_s}, \frac{F}{d_{min}}, \frac{NF}{u_s+\sum_{i=1}^{N} u_i}\right\}$
- $transmissionDelay\ (Ttrans) = \frac{L\ (bits)}{R\ (bps)}$
- $propagationDelay\ (Tprop) = \frac{Distance}{S}$, S≈2x10^{8}m/s (electromagnetic speed in copper)
- $a = \frac{Tprop}{Ttrans} = \frac{propagationDelay}{transmissionDelay}$
- Utilization for stop-and-wait: $u = \frac{1-p}{1+2a}$, where p is the error probability in a frame/segment
- Utilization (u) for sliding-window mechanisms with window of w:
  - Selective repeat: $u = (1-p)$, if w fills the pipe, otherwise $u = \frac{w(1-p)}{1+2a}$
  - Go-back-N: $u = \frac{1-p}{1+2ap}$, if w fills the pipe, otherwise $u = \frac{w(1-p)}{(1+2a)(1-p+wp)}$
- $Network\ Power = \frac{Throughput}{Delay}$
- TCP congestion window management equations:
  - slow start: *cwnd*+=1 per Ack
  - congestion avoidance: *cwnd*+=1 per RTT
  - fast recovery: *cwnd*+=1 per duplicate Ack
- TCP *RTT* and *RTO* estimates:
  - EstimatedRTT(k)= (1-α)*EstimatedRTT(k-*1*) + α*SampleRTT(k), 0<α<1
  - DevRTT= (1-β)*DevRTT+ β*|SampleRTT – EstimatedRTT|, 0< β <1
  - Retransmission timeout (*RTO*) = EstimatedRTT + 4*DevRTT
- TCP average throughput (Tput), for a long-lived connection with window size W bytes:
  - $average\ Tput \approx \frac{0.75\ .W}{RTT}$, at steady-state where W causing loss is roughly constant
  - for high speed long pipes (with high W):
    - $average\ Tput = \frac{1.22\ .MSS}{RTT\ \sqrt{L}}$, where L is the segment (or packet) loss rate