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Useful formulae: [Note that you may not need all of these formulae. Use as needed]

Utilization:

- $a = \frac{Tprop}{Trans} = \frac{propagationDelay}{transmissionDelay}$
- $propagationDelay = \frac{Distance}{S}$, $S=2x10^8 m/s$
- For stop-and-wait: $u = \frac{1-p}{(1+2a)}$, where p is the probability that a frame is in error.

Utilization for sliding-window mechanisms with window of w:

- Go back N: $u = \frac{1-p}{1+2ap}$, if w fills the pipe, or $u = \frac{w(1-p)}{(1+2a)(1-p+wp)}$ otherwise
- Selective repeat: $u = (1-p)$, if w fills the pipe, or $u = \frac{w(1-p)}{(1+2a)}$ otherwise
- M/D/1: queuing delay $Tq = \frac{Ts(2-\rho)}{2.(1-\rho)}$; Ts is service time & ρ is link utilization
- M/D/1: average queue length or buffer occupancy $q = \lambda.Tq = \rho + \frac{\rho^2}{2.(1-\rho)}$
- M/M/1: queuing delay $Tq = \frac{Ts}{(1-\rho)}$, buffer occupancy: $q = \frac{\rho}{(1-\rho)}$
- TCP:
  - slow start CongWin+=1 per ACK,
  - congestion avoidance CongWin+=1 per RTT,
  - EstimatedRTT(k)= (1-α)*EstimatedRTT(k-1) + α*SampleRTT(k), $0<\alpha<1$
  - DevRTT= (1-β)*DevRTT+ β*|SampleRTT – EstimatedRTT|, $0<\beta<1$
  - TimeoutInterval = EstimatedRTT + 4*DevRTT

ATM ABR rate-based congestion control:

- Increase: Rate = min(PCR, Rate + PCR x RIF)
- Decrease: Rate = max(MCR, min[ER, Rate – Rate x RDF])

Probability distributions and stochastic processes:

- Geometric distribution: ***x*** is the number of Bernoulli experiments until success, $Pr[X=k]=q^{k-1}p$, $E(X)=1/p$
- Binomial distribution: ***x*** is the number of successes in ***n*** Bernoulli experiments/trials
  $P(X=k) = \binom{n}{k} q^{n-k} p^k, \binom{n}{k} = \frac{n!}{(n-k)!k!}$, E[X]=np

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- Poisson Distribution: $Pr[X=k]= (\lambda^k/k!)\ e^{-\lambda}$, $E[X]=Var[X]= \lambda$
- Exponential distribution: $f(x)=\lambda e^{-\lambda x}$, $F[x]=1-e^{-\lambda x}$, $Pr[X>x]=1-F[x]=e^{-\lambda x}$, $E[X]=1/\lambda$