

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

Utilization:

- $a = \frac{T_{prop}}{T_{trans}} = \frac{\text{propagationDelay}}{\text{transmissionDelay}}$
- $\text{propagationDelay} = \frac{\text{Distance}}{S}, S = 2 \times 10^8 \text{ m/s}$
- 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 $Tq = \frac{T_s(2-\rho)}{2.(1-\rho)}$; T_s 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 $Tq = \frac{T_s}{(1-\rho)}$, buffer occupancy: $q = \frac{\rho}{(1-\rho)}$
- TCP:
 - slow start CongWin+=1 per ACK,
 - congestion avoidance CongWin+=1 per RTT,
 - EstimatedRTT(k) = $(1-\alpha) \cdot \text{EstimatedRTT}(k-1) + \alpha \cdot \text{SampleRTT}(k)$, $0 < \alpha < 1$
 - DevRTT = $(1-\beta) \cdot \text{DevRTT} + \beta \cdot |\text{SampleRTT} - \text{EstimatedRTT}|$, $0 < \beta < 1$
 - 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: $\Pr[X=k] = (\lambda^k/k!) e^{-\lambda}, E[X]=\text{Var}[X] = \lambda$
- Exponential distribution: $f(x) = \lambda e^{-\lambda x}, F[x] = 1 - e^{-\lambda x}, \Pr[X > x] = 1 - F[x] = e^{-\lambda x}, E[X] = 1/\lambda$