| 1 | 2 | 3 | Total |
|---|---|---|---|
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**University of Toronto**
Department of Computer Science

# Midterm

CSC 458/2209: Computer Networks — Fall 2003

Last Name:
First Name:
Student ID:

Student: undergraduate ☐ graduate ☐

- You have 50 mins to complete the midterm
- The midterm is closed book. You can use a basic (non-programmable) calculator.
- Show **all** steps for the derivations of your results.
- When we can't read it, we don't grade it.

## Useful Formulas

Poisson process:

$$P\{N(T) = n\} = e^{-\lambda T} \frac{(\lambda T)^n}{n!}$$

$$E[N(T)] = \lambda T$$

Exponential distribution:

$$P\{s \leq t\} = 1 - e^{-\mu t}$$

$$E[s] = \frac{1}{\mu}$$

Series:

$$\sum_{n=0}^{\infty} \rho^n = \frac{1}{1-\rho}$$

$$\sum_{n=0}^{K} \rho^n = \frac{1-\rho^{K+1}}{1-\rho}$$

$$\sum_{n=1}^{\infty} n(1-p)^{n-1} p = \frac{1}{p}$$

$$\sum_{n=0}^{\infty} \frac{\alpha^n}{n!} = e^{\alpha}$$

Little's Theorem:

$$N = \lambda T$$

$M/M/1$ Queue:

$$p_n = (1-\rho)\rho^n, \qquad n = 0, 1, 2, ...$$

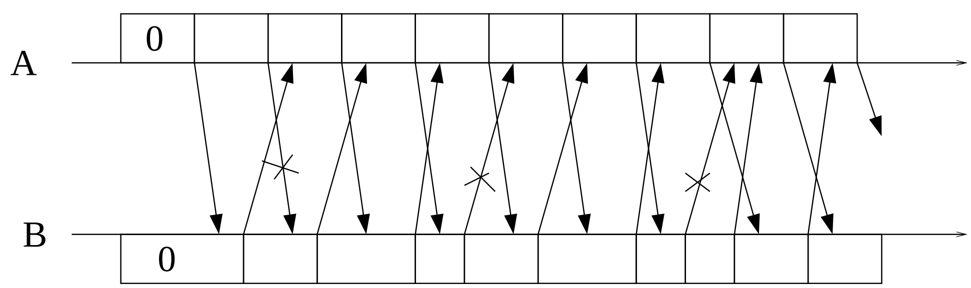
$$N = \frac{\rho}{1-\rho}$$

$$T = \frac{1}{\mu - \lambda}$$

**Question 1: (50 points total) ARQ Protocols**

(a) (20 points) In the figure below, the two peer processes implement **Selective Repeat ARQ** with **n=3**. Fill in the values for SN and RN, indicate the window size at $A$ and $B$, as well as the packets delivered to the next higher layer.

Use the convention that $B$ always acknowledges the last error-free packet from $A$, and when $A$ has to retransmit packets it starts with the $SN$ at the beginning of the window and retransmits packets that have not yet been acknowledge by $B$ in order of their sequence number.

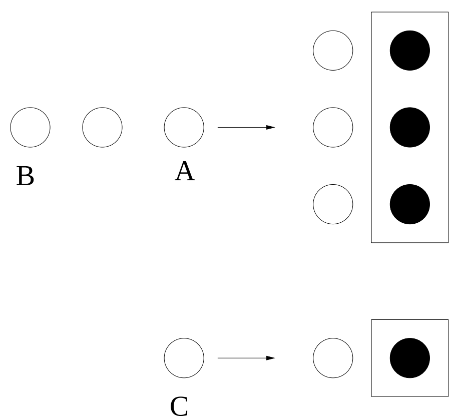


(b) (15 points) For the **Stop-and-Wait ARQ** protocol that we discussed in class, give an example which shows that the protocol **does not** work properly if we only use sequence numbers $SN$, but not request numbers $RN$.

(c) (15 points) Give an example where **Selective Repeat ARQ with modulus** $m$ fails if $m = 2n - 1$. Use $n = 3$ for your example.

**Question 2 (30 points total)**

Consider a bank with two queues, 1 and 2. Queue 1 is served by three clerks and queue 2 is served by one clerk. Two customers, $B$ and $C$, enter the bank at the same time and find all of the 4 clerks busy, each serving one customers, and two customers waiting in queue 1. Customer $B$ joins queue 1, and customer $C$ joins queue 2. All Customers (including $A$, $B$ and $C$) have independent, identical, **exponential distribution of service time with a mean of 6 minutes**.



(a) (15 points) What is the probability that customer $B$ leaves the bank before customer $A$?

(b) (15 points) What is the probability that customer $C$ leaves the bank before customer $A$?

**Question 3 (20 Points total)**

An important issue for wireless devices is energy-efficiency. One way to achieve this is by only initiate a data transmission when there are at least $K$, $K > 1$, packets in the system. In this question, we model and analyze this situation.

Consider a wireless application which generates data packets according to a Poisson process with rate $\lambda$. Data packets are stored in a buffer to be transmitted over a wireless link. The packet transmission delay is exponentially distributed with mean $1/\mu$. When the buffer empties out, then the device does not start sending again until $K$ packets are in the system. Once service begins it proceeds normally until the system becomes empty again.

(a) (5 points) Draw the state-transition diagram.

(b) (15 points) Let $p_0$ be the probability that the system is empty. Find the steady-state probabilities $p_n$, $n = 1, 2, ...,$ of having $n$ packets in the system as a function of $p_0$.