Faculty of Arts and Science
University of Toronto
CSC 457 - Principles of Computer Networks, Fall 2020

Cover sheet for Assignment 3

Due Friday Nov. 6, 11:00pm

Complete this page and attach it to the front of your assignment.

Name: Grant Wong
(Underline your last name)

Student number: 1000549445

I declare that this assignment is solely my own work, and is in accordance with the University of Toronto Code of Behavior on Academic Matters.

Signature:

CSC457: Written Assignment 3

Grant Wong

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Question 1

(a) When there are m packets in the buffer then a new packet is dropped and lost with the probability

$$p_m = \frac{1-\rho}{1-\rho^{m+1}}\rho^m$$

meaning the probability that a new packet is lost is p_m and the rate that new packets are dropped is given by $p_m\lambda$.

(b) Throughput is defined by the arrival rate minus the loss rate, that is,

$$\lambda - p_m\lambda = \lambda(1-p_m)$$

(c) It is such that $p_m << 1$ if and only if $p^{m+1} << 1$ which implies for part (a) the result

$$p_m = (1-\rho)\rho^m$$

(d) From Little's formula the expected delay $T = \frac{N}{\lambda'}$ and with $\lambda' = (1-\rho)\lambda$ as well as $N = \sum_{n=1}^{m} np_n$ implies that

$$T = \frac{\sum_{n=1}^{m} np_n}{(1-\rho)\lambda}$$

Question 2

(a) Each packet is comprised of N bits and each bit has a bit transfer error probability of P_{bit} so the probability P_{packet} that a packet from host A arrives error-free at switch C is

$$P_{packet} = (1-P_{bit})^N$$

(b) If host A takes k transmission attempts to have the kth packet accepted at switch C then the first $k-1$th packets arrive with an error and the kth packet arrives error-free which is expressed as

$$P_k = (1 - P_{packet})^{k-1} P_{packet} = \left(1 - (1 - P_{bit})^N\right)^{k-1} (1 - P_{bit})^N$$

(c) Denote $E[T_{AC}]$ to be the total delay for one hop from host A to switch C and denote for $E[T_{CB}]$ in an analogous way. Note that from our assumptions that $E[T_{AC}] = E[T_{CB}]$. Now, expressing $E[T_{AC}]$ we have

$$E[T_{AC}] = \sum_{k=1}^{\infty} E[T|k] P_k = \sum_{k=1}^{\infty} k \frac{N}{R} P_k = \sum_{k=1}^{\infty} k \frac{N}{R} (1 - P_{packet})^{k-1} P_{packet}$$

then using the infinite series result $\sum_{i=1}^{\infty} i(1-a)^{i-1} = \frac{1}{a^2}$ for $|1-a| < 1$

$$= \frac{N}{R} \frac{P_{packet}}{P_{packet}{}^2} = \frac{N}{R} \frac{1}{P_{packet}} = \frac{N}{R} \frac{1}{(1 - P_{bit})^N}$$

The total delay $E[T]$ is given by

$$E[T] = E[T_{AB}] + E[T_{CB}] = 2 \frac{N}{R} \frac{1}{(1 - P_{bit})^N}$$

(d) In end-to-end ARQ transmitting a packet from host A to host B error-free has the probability $P'_{packet} = (1-P_{bit})^N (1-P_{bit})^N = (1-P_{bit})^{2N}$. The average delay is then

$$E[T'] = 2 \frac{N}{R} \frac{1}{P'_{packet}} = 2 \frac{N}{R} \frac{1}{(1 - P_{bit})^{2N}}$$

(e) In computing $E[T']$ we note that $P'_{packet} = P_{packet}{}^2$.

	$P_{packet} = 0.99$	$P_{packet} = 0.2$	$P_{packet} = 0.002$
$E[T]$	$2.02N/R$	$10N/R$	$1000N/R$
$E[T']$	$2.04N/R$	$50N/R$	$500000N/R$

(f) From the result of (e) we can determine which type of ARQ, i.e. hop-by-hop or end-to-end, to use based on the bit error probability P_{bit}. If it is high (as is in the case of a wireless transmission) then hop-by-hop significantly reduces the expected delay, however, if it is low (as is in the case of optical transmission) then end-to-end yields only a small increase in expected delay. Meaning, one should use hop-by-hop with a high P_{bit} but end-to-end with a low P_{bit}.