CSC358H5: Principles of Computer Networking — Winter 2025

Worksheet 2: Network Sharing and Encoding

Q0 Knowledge Check (from Week 02 Lecture)

0.a For most networks, the peak of aggregate demand for resources is greater than the aggregate of peak demands.
☐ True ☐ False

0.b Circuit switching is easier to implement than packet switching.
☐ True ☐ False

0.c How does Manchester Encoding make clock recovery easier?

- ☐ By sending a sequence of alternating 0s and 1s before the main frame.
- ☐ By sending a sequence of 1s at the beginning of each frame.
- ☐ By embedding the clock cycle in the signal.
- ☐ By sending the clock signal as a separate signal.

0.d Which encoding scheme do you suggest in order to provide high bandwidth?
☐ Manchester ☐ 4B/5B

0.e What is the maximum overhead in byte-stuffing algorithm (excluding the flags marking the start and end of the frame)?
☐ 25% ☐ 50% ☐ 100% ☐ 125%

Q1 (Encoding) Fill out the blank in the following statement. Justify your answer.

In 4B/5B Encoding that we discussed in the lecture, which uses NRZI encoding as part of its procedure, a signal transition will occur at least every _____ bit times (*i.e.*, clock cycle).

Q2 (Circuit Switching vs Packet Switching) Suppose several users share a 3 Mbps link and each user requires 150 Kbps when transmitting. Assume that the probability that a given user is transmitting at any given point in time is $p = 0.1$. Answer the following questions.

2.a When circuit switching is used, how many users can be supported?

2.b Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously.

2.c Find the probability that there are 21 or more users transmitting simultaneously. How do you interpret the meaning of this probability?

Q3 (Statistical Multiplexing) Consider three flows F_1, F_2, and F_3 sending packets over a link. The sending pattern of each flow is described by how many packets it sends within each one-second interval. Table 1 shows their pattern for the first ten intervals.

Time (s)	1	2	3	4	5	6	7	8	9	10
F_1	1	8	3	15	2	1	1	34	3	4
F_2	6	2	5	5	7	40	21	3	34	5
F_3	45	34	15	5	7	9	21	3	3	34

Table 1: Sending pattern of F_1, F_2, and F_3.

3.a What is the peak rate of F_1, F_2, and F_3? What is the sum of the peak rates?

3.b Now consider all packets to be in the same aggregate flow. What is the peak rate of this aggregate flow?

3.c Which is higher - the sum of the peaks, or the peak of the aggregate? Based on the flow patterns, find the statistical multiplexing gain.

Q4 **(Advanced Statistical Multiplexing Analysis)** This optional question is designed for students with a strong interest in theory. It provides insight into how to determine an adequate buffer size and understand statistical multiplexing gain in a more realistic scenario. While this analysis involves the Central Limit Theorem (CLT), which is beyond the scope of this course, there's no need to worry—you are not expected to know the CLT, and it will not be included in your exams.

Consider N traffic flows. The arrivals from each flow are governed by a random variable X with a geometric distribution. Specifically, in any time slot, the probability that the number of arrivals from a single flow are equal to k kilobytes (kB) is given by

$$p(X = k) = \begin{cases} 0, & k = 0, \\ (1-p)^{k-1}p, & k > 0, \end{cases} \tag{1}$$

where $0 < p < 1$. Assume that the N flows are independent and identically distributed.

In every time slot, the arrivals are entered into a buffer with a given size. If arrivals to the buffer exceed the buffer size, the excess traffic is lost. The buffered data is removed from the buffer before the start of the next time slot.[1]

The objective is to design the size of the buffer such that the probability that a loss occurs does not exceed a given threshold value.

4.a Consider that there is one buffer for each flow, *i.e.*, we have N buffers.[2] Express the total size of all N buffers needed so that the loss probability of each flow does not exceed ϵ.

4.b Consider that there is a single buffer that is shared by all N flows.[3] Use the Central Limit Theorem (CLT) to derive the buffer size needed so that the loss probability does not exceed ϵ.
[**HINT:** A random variable X with Geometric distribution as in (1) has $\mathbb{E}[X] = \frac{1}{p}$ and Var$[X] = \frac{1-p}{p^2}$.]
[**HINT:** Let $\Phi(\cdot)$ denote the cumulative distribution function of the standard normal distribution. To get $1 - \Phi(z) \approx \epsilon$, you may use the approximation $z = \sqrt{|\ln(2\pi\epsilon)|}$.]

4.c Consider the previous parts, find the statistical multiplexing gain?

[1] Hence, the buffer is empty at the beginning of each time slot.
[2] This is similar to circuit switching resource sharing.
[3] This is similar to packet switching resource sharing.