CS/ECE 438: Computer Networks **Spring 2026**

Homework 1

Handed Out: January 22, 2026 *Due: 11:59pm, February 13, 2026*

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- Homework assignments must be submitted online through GradeScope. No handwritten solutions will be accepted. LaTeX formatting is recommended, but not enforced.
- Each question is worth the same number of points (e.g., 10 points). Show your work for full credit. You will not receive points for a correct answer with no work shown. Partial credit may be awarded for correct reasoning even if the final answer is incorrect.
- Please come to office hours if you have questions about the homework.
- While we encourage discussion within and outside of the class, cheating and copying is strictly prohibited. Copied solutions will result in the entire assignment being discarded from grading at the very least and a report filed in the FAIR system.

1 Network Overview

RFC 1149 proposes a new and interesting physical layer for use with IP: Carrier Pigeons. A pigeon can carry 512 GB of data on a micro SD and travels 75 kmph. If you are 300 km away from the destination server, how many pigeons do you need to achieve a higher data rate than a direct 40 Gbps Ethernet connection? Justify your answer.

2 Probability Overview

The Fighting Illini Women's Basketball team makes it to the playoffs every year. There are seven rounds in the tournament, and the Illini must win each round to advance to the next. The Illini score k^2 points in the k-th round if they win that round. If they lose a round, they do not gain any points for that round. The Illini have an 80% chance of winning each game they play.

Let m be the (statistical) mean number of points scored by the Illini in a tournament, and let n be the mean number of games played per tournament. Use cycle analysis to find:

1. What fraction of years do the Illini make it to the final round (Round 7)?
2. m
3. n
4. m/n. Note that this ratio is the Illini's long-term rate of points per game.

3 Store-and-Forward Switching Latency

Consider two machines, A and B, connected by a 10 Mbps Ethernet link with two store-and-forward relay switches on the path between them. Suppose that no other machines are using the Ethernet, that each of the links between the machines and switches, as well as between each adjacent switch, introduces a propagation delay of **10 ms**, and that a switch begins transmitting a packet immediately after receiving the last bit of the packet.

1. What is the total transfer time for a single 1400 Byte packet, measured from the transmission of the first bit at A to the receipt of the last bit at B?
2. What is the effective bandwidth for the transmission of a large file from A to B? Assume packets of size 1400 Bytes are used, where 100 Bytes are headers. Assume continuous sending (pipelining) with no waiting for acknowledgments.
3. What is the effective bandwidth if, after each transmission of a 1400 Byte packet, node A must wait for a 50 Byte acknowledgement from B before sending the next packet?

4 Circuit vs. Packet Switching

Suppose users share a 100 Gbps link. Also suppose each user requires 400 Mbps when transmitting, but each user only transmits 10% of the time ($p = 0.1$). Whether a user is transmitting or not is an independent random variable with uniform distribution.

1. When circuit switching is used, how many users can be supported?
2. For the remainder of this problem, suppose packet switching is used. Suppose there are 2000 users. Write an equation for the probability that at any given time, exactly n users are transmitting simultaneously.
3. What is the probability that the link will get overloaded? Write your answer as a summation (you do not need to compute the final decimal value).

5 Bandwidth-Delay Product

For each of the following links, calculate the bandwidth $\times$ delay product in bits using one-way delay.

1. 40 Gbps Ethernet, with a one-way delay of 5 μs.
2. 1.5 Gbps wireless link, with a one-way delay of 0.1 μs.
3. 8 Gbps link through a satellite in geosynchronous orbit, approximately 36,000 km high. Assume the only delay is speed-of-light propagation delay ($c = 3 \times 10^8$ m/s).

6 Noisy Channel Data Rates

The decibel is a measure of the ratio between two signal levels: $N_{dB} = 10 \log_{10}(P_2/P_1)$, where N_{dB} = the number of decibels, P_1 = the input power level and P_2 = the output power level.

A telephone line is known to have a loss of 40 dB. The input signal power is measured as 0.5 watt and the output noise is measured as 7 μW.

1. Using this information, calculate the output signal-to-noise ratio (SNR) in dB.
2. What is the capacity of this phone line with a frequency range of 600 Hz – 2500 Hz?
3. If the attenuation rate of this phone line is 5 dB/km, and the minimum output signal is 0.005 watt, given the input signal from part 1, how long can the phone line be before it requires a repeater?

7 Encoding

1. **Bit and baud rates.** Suppose it is possible to send 1024 different types of signals on a link, and that there is no noise. How many bits per second (bps) can such a link achieve at 8200 baud?
2. **SNR.** What signal-to-noise ratio (in dB) is needed to put a 23 Gbps carrier on a 650 MHz line? (Note: for line speeds in networking, giga-, mega-, kilo- indicate powers of 1000, not 1024.)

8 Encoding and Channel Capacity

1. **Encoding.** Show the NRZ, Manchester, NRZI, and 4B/5B encoding signals (the resulting NRZI signal for 4B/5B), using a diagram similar to that in the class slides, for the data bit sequence:

   `1011 0011 1010 0001`

   To be definite, suppose the NRZI signals begin at low voltage.
2. **Channel Capacity.** In 1962, Bell Labs introduced the first version of their Transmission System 1 (T-1). Subsequent specifications carried multiples of the basic T1 data rates. What signal-to-noise ratio is needed to put a T3 (672 channel) carrier on a 25 MHz line? (T3 data rate = 44.736 Mbps.)

9 Modulation

1. A modem constellation diagram has data points at the following coordinates:

   (3, 3), (3, 1), (3, -1), (3, -3), (1, 3), (1, 1), (1, -1), (1, -3), (-1, 3), (-1, 1), (-1, -1), (-1, -3), (-3, 3), (-3, 1), (-3, -1), (-3, -3)

How many bps can a modem with these parameters achieve at 8200 baud?

2. A modem constellation diagram has data points at (6, 15) and (8, 20). Does the modem use phase modulation and/or amplitude modulation? Explain your answer.

10 WHOIS Utility

The Unix utility `whois` can be used to find the domain name corresponding to an organization, or vice versa. The information is provided by a domain name registration service provider. This utility is commonly shipped with Linux.

Read the online man page for `whois` and experiment with it.

1. Perform a `whois` query for the following domains:

   - `youtube.com`
   - `tiktok.com`
   - `uber.com`
   - `nytimes.com`
   - `openai.com`

   For each domain, list:

   - The **Registrar**
   - The **Creation Date** (or activation date)
   - The **Expiration Date** (if present)