Spring 2021 – Cooperative Communications and Networks

Assignment 1

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Due: see course webpage

– Numerical Questions –

Q1) [SNR, 10%] A receiver measured the received SNR equal to 5dB and the thermal noise power equal to $N_0 = 10^{-14}$ Watts. What is the received power strength in Watts?

Q2) [Shadow fading, 10%] The path loss due to distance is deterministic but it becomes non-deterministic when shadowing comes into play. Determine the probability that the path loss due to both distance and log-normal shadowing with zero mean and variance 5^2 dB at distance of 500 m is below 118 dB, given the path-loss exponent $\nu = 4.35$ and the reference distance $d_0 = 1$ m.

Q3) [Distribution, 40%] The following question helps you to recall some basics learned from Probability. It also builds the foundation of Monte Carlo Simulation (will be discussed later), an important tool to study the performance of wireless communications systems using simulations.

Suppose X is an indicator variable that characterizes whether a transmitter has sent a bit successfully.

$$X = \begin{cases} 1, & \text{if a bit is sent in error} \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

a) Let P_e denote the probability of transmission error. Derive the mean and variance of X in terms of P_e.

b) Suppose the transmitter sends n bits among which the number of erroneous bits is denoted as Y. Derive the mean and variance of Y.

c) The average rate of transmission errors can be found as $\hat{P}_e = Y/n$ (which is also known as the *sample mean* or the *empirical mean*). Derive the mean and variance of $\hat{P}_e$.

d) When n goes large, $\hat{P}_e$ can be approximately normal. Derive the 95% confidence interval for $\hat{P}_e$.

Hint: Think of X, Y, and $\hat{P}_e$ as random variables and try to figure our their statistical distributions. It would be easier if you normalize $\hat{P}_e$ to be a standard normal distribution with zero mean and variance of one.

– Simulation –

Q4) [Random Generator, 30%] Write a computer program to generate the normal distribution with mean $\mu = 0$ and variance $\sigma^2 = 1$.

a) Verify the accuracy of your random generator by plotting the probability mass function (PMF) of empirical results and comparing it with the theoretical one. In your figure, clearly indicate the simulation and theoretical curves.

b) Describe the programming software you use (name and version) and what commands/functions are used to generate random samples. Also, show the number of samples you generated to obtain the statistics.

The generation of random samples is used in nearly every simulation for communications networks, e.g., signal transmission at the physical layer, channel access and routing protocols at the MAC layer, and packet delivery at the link layer.

Hint: The PMF is commonly plotted as histogram.