HW 2 – The Wireless Link

The Wireless Link and ns-3 simulations on it

First Submission Due: Monday, October 16th, 11:59pm Pacific Time Revision Due

Dates will be updated after the grades are released

What you will learn

- Using wireless link models to compute maximum achievable throughput
- Using the ns-3 simulator to simulate the wireless link

Task 1

Consider three nodes A, B and C placed along a straight line, in the order A, B, C. Assume that d(A,B) = 30m and d(B,C) = 20m. All nodes use transmit power 1mW when transmitting.

Assume a log-distance propagation model, with pathloss exponent α=2.8, and pathloss at distance d0=1m as 20dB, noise spectral density N0/2=4 * 10^{-21} W/Hz and bandwidth W=10MHz. Also assume that the rate of reliable information delivery on a link is given by W $\log_2$(1 + SINR). Each node may either transmit or receive at any given time, but not both simultaneously.

[LP] Determine the maximum throughput achievable for the link A□□B and for B□□C.

[HP] Determine the maximum throughput achievable for a flow from node A to node C, when using the route: A□B□C. Note that a node cannot transmit or receive at the same time. Assume that there is no other traffic on the network.

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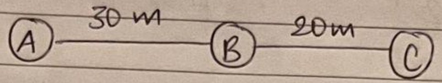
Task 1



$P_s = 1 \text{ mW} = 10^{-3} \text{ W}$

$\alpha = 2.8$

$d_0 = 1 \text{ m}$

$PL_0(d_0) = 20 \text{ dB}$

$\frac{N_0}{2} = 4 \times 10^{-21} \frac{W}{Hz}$ $\therefore N_0 = 8 \times 10^{-21} \frac{W}{Hz}$

$W = 10 \text{ MHz} = 10^7 \text{ Hz}$

Capacity of channel $(C) = W \log_2 (1 + SINR)$

Signal to Noise Ratio $(SINR) = \frac{P}{I + N_0 W} = \frac{P}{N_0 W}$

[LP] Link A—B

$PL(B) = PL_0(d_0) + 10 \alpha \log_{10}\left(\frac{d_{AB}}{d_0}\right)$

$= 20 + 10(2.8) \log_{10}(30)$

$= 61.36 \text{ dB}$

Power received at B → $P_r(B)$

$PL(B) = 10 \log_{10}\left(\frac{P_s}{P_r(B)}\right)$

$\frac{P_s}{P_r(B)} = 10^{PL(B)/10}$

$P_r(B) = P_s \times 10^{-\frac{PL(B)}{10}}$

$= 10^{-3} \times 10^{-6.136}$

$= 10^{-9.136}$

$= 73.11 \text{ nW}$.

$SINR = \frac{P_r(B)}{N_0 W} = \frac{7.31 \times 10^{-10}}{8 \times 10^{-21} \times 10^7} = 9.138 \times 10^3$

$C_{AB} = W\log_2(1+SINR)$

$= 10^7 \log_2(1+9138.75)$

$= 131.577 \times 10^6$ bPs

$= 131.58$ Mbps

Link B – C

$PL_{BC} = PL_0(d_0) + 10\alpha\log_{10}\left(\frac{d_{BC}}{d_0}\right)$

$= 20 + 10(2.8)\log_{10}(20)$

$= \cancel{56}\ 56.43$ dB

$P_r(C) = P_{SB} \times 10^{-PL_{BC}/10}$

$= 10^{-3} \times 10^{-5.643}$

$= 2.275$ mW

$SINR = \frac{P_r(C)}{N_0W} = \frac{2.275 \times 10^{-9}}{8 \times 10^{-21} \times 10^7} = 28.437 \times 10^3$

$C_{BC} = W\log_2(1+SINR)$

$= 10^7 \log_2(1+28437.5)$

$= 147.96 \times 10^6$ bPS

$= 147.96$ Mbps

[HP] Max throughput

$C_{AB} = 131.58 \times 10^6$ bps

$C_{BC} = 147.96 \times 10^6$ bps

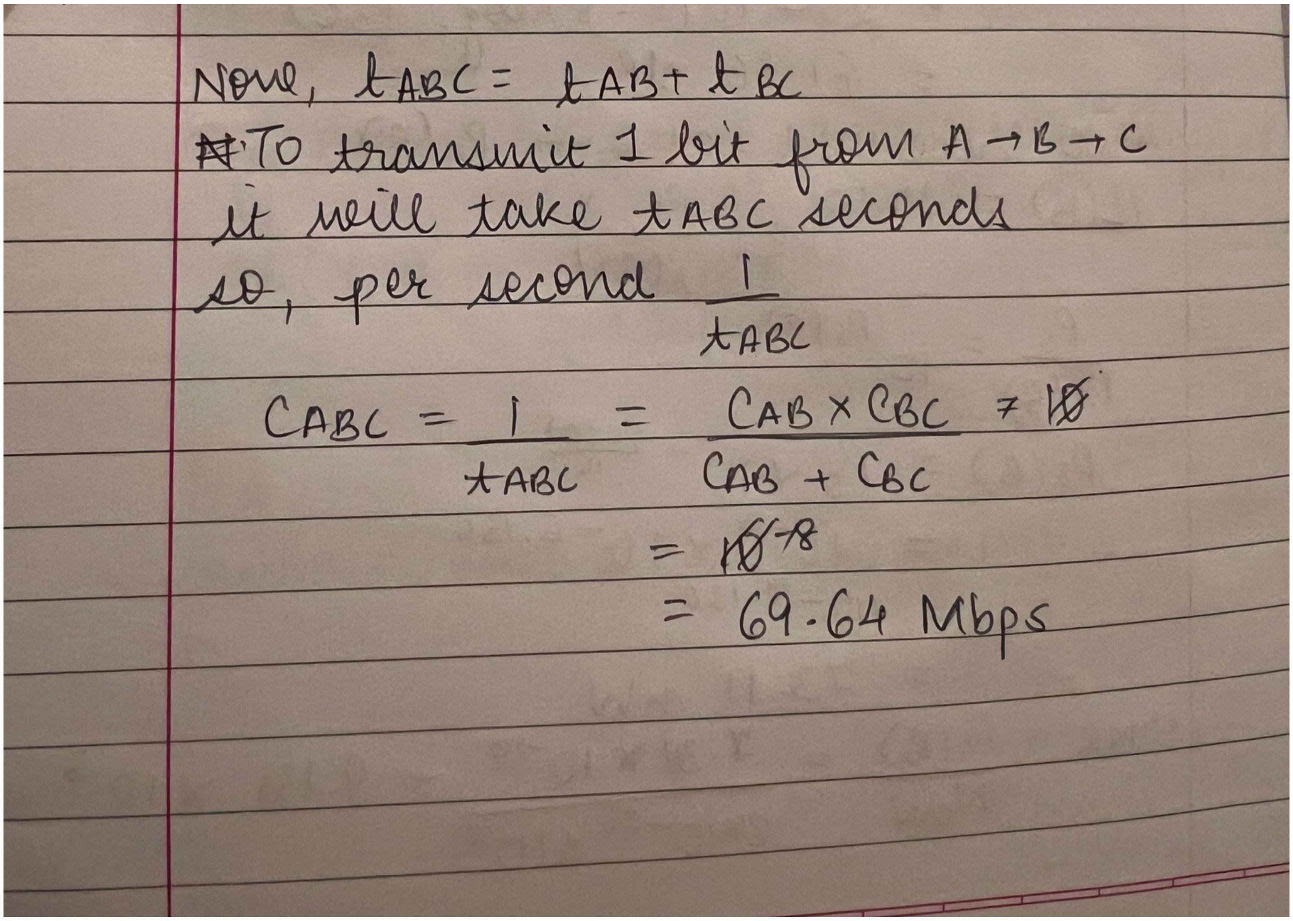
$C_{ABC} = ?$

assuming transmitting 1 bit from A→B→C

time taken to transmit for A→B = t_{AB}

time taken to transmit for B→C = t_{BC}

$t_{AB} = \frac{1}{C_{AB}}$, $t_{BC} = \frac{1}{C_{BC}}$



Now, $t_{ABC} = t_{AB} + t_{BC}$

~~At~~ To transmit 1 bit from A→B→C

it will take t_{ABC} seconds

so, per second $\frac{1}{t_{ABC}}$

$$C_{ABC} = \frac{1}{t_{ABC}} = \frac{C_{AB} \times C_{BC}}{C_{AB} + C_{BC}} \quad 7\ \cancel{10}$$

$$= \cancel{10}^{-8}$$

$$= 69.64 \text{ Mbps}$$

Task 2 – ns-3 simulations

[LP] You will implement the log-normal shadowing model with a Gaussian random variable. Propagation models are found in the module propagation, found in `src/propagation` of the ns- 3 source code. Under `src/propagation/model`, you will find various classes that implement path loss and path delay. You can use the doxygen manual to understand each class.

You will create a new propagation model with new attributes for the random variable. You need to take at least the following attributes as input: loss exponent, random variable for the noise.

Help creating a new model: Follow the guidelines in https://www.nsnam.org/docs/manual/html/new-models.html to avoid errors.

For HW 2, you need to create a new model for log-normal shadowing propagation loss. You will find most standard propagation loss models in `src/propagation/model/propagation-loss-model.cc`. Other propagation models created by researchers can be found in src/propagation/model. You can refer to one of them, e.g., okumura-hata-propagation-loss-model, as a reference.

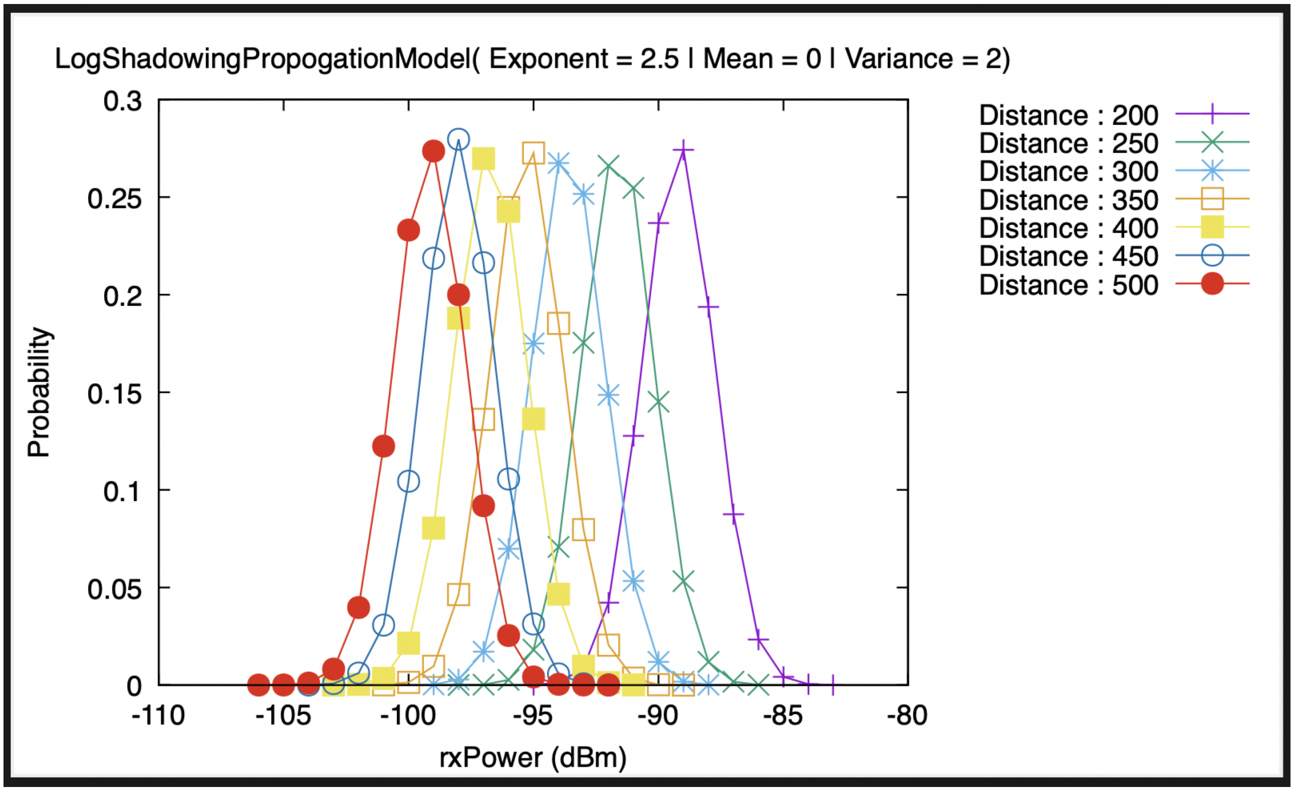
Within propagation-loss-model.cc, your class will be closest to the LogDistancePropagationLossModel class. Feel free to reuse parts of that model in your class.

For the Gaussian random variable, you can use the NormalRandomVariable class. A good reference on how random variables can be used in the propagation model, please refer to the RandomPropagationLossModel for more details. The format for the stringvalue attribute of NormalRandomVariable is "ns3::NormalRandomVariable[Mean=0|Variance=0]", where you can provide your values for mean and variance.

Run a set of simulations to test your propagation loss model, and produce four graphs (see problem 4.1) for this assignment. Go through the sample code in random-propagation-loss- distance-expt.cc attached as a reference.

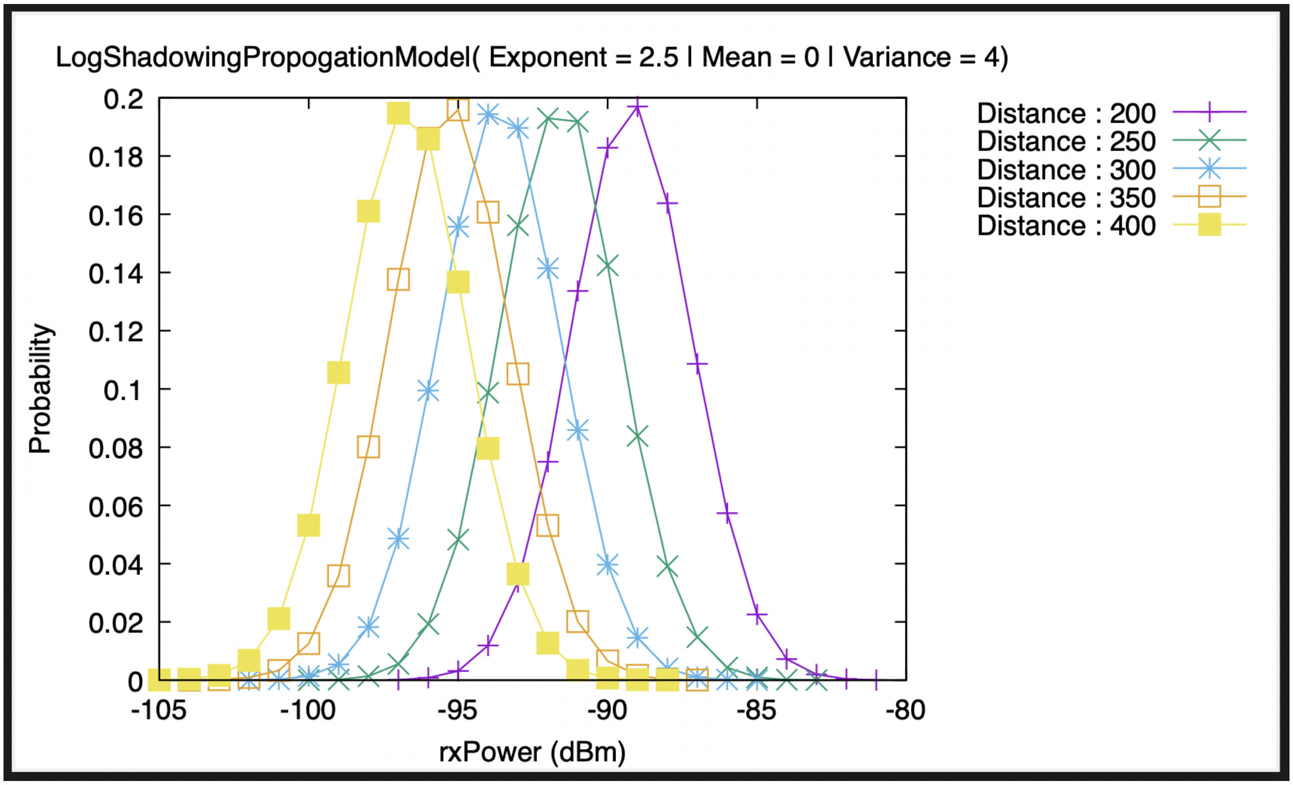
The code runs 100000 samples to determine the received power for a given path loss exponent at different distances and generate a plot. The transmit power is fixed.

The plot file is saved in a .plt, e.g., output.plt. Running gnuplot output.plt creates the plot in a pdf file. Note that you will need to install gnuplot first by running sudo apt-get install gnuplot on Ubuntu. Use the code as a template to generate the plots for your propagation model. Plot a graph showing the probability distribution of the received power for distances 200m to 500m in increments of 50m for path loss exponent 2.5, Gaussian random variable with a mean of 0 and variance 2.

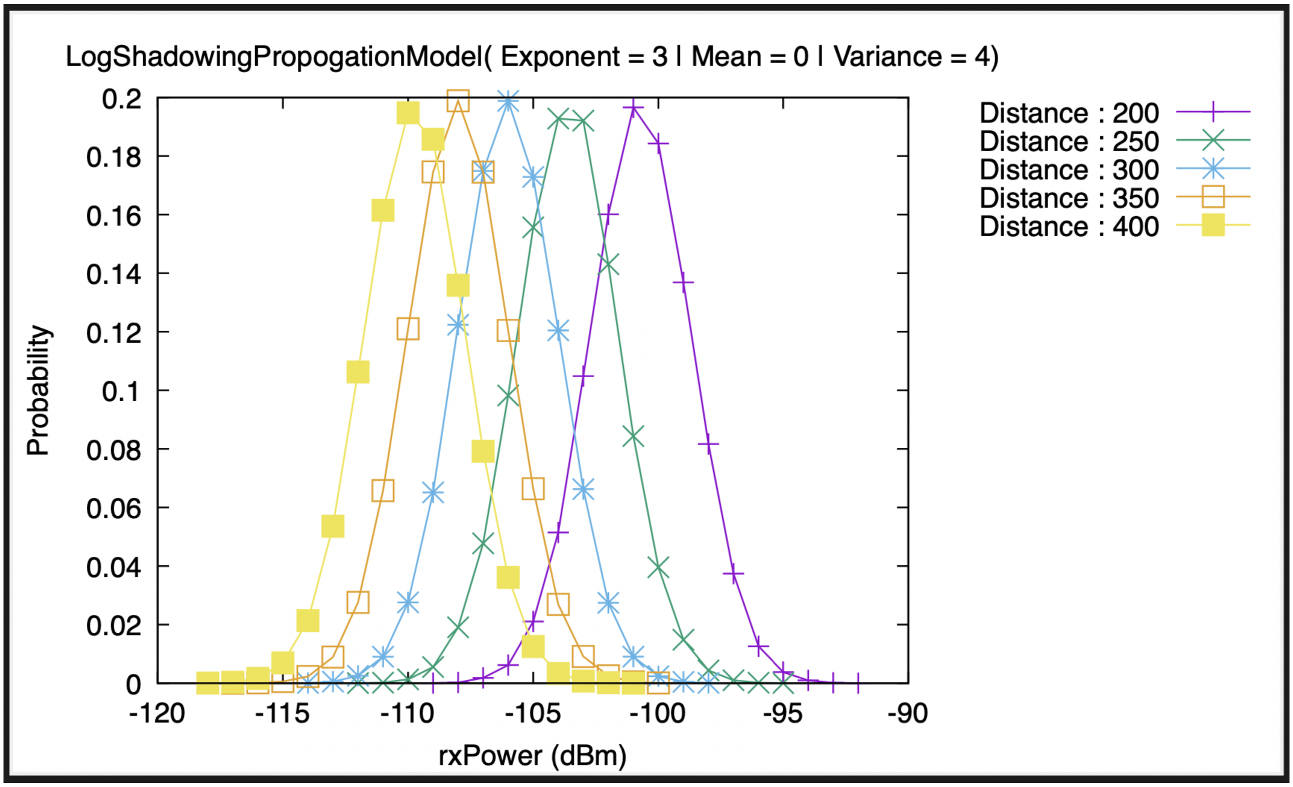


[HP] Plot three more graphs showing the probability distribution of the received power for distances from 200m to 400m in increments of 50m) for the following scenarios with the log normal shadowing path loss model that you wrote:

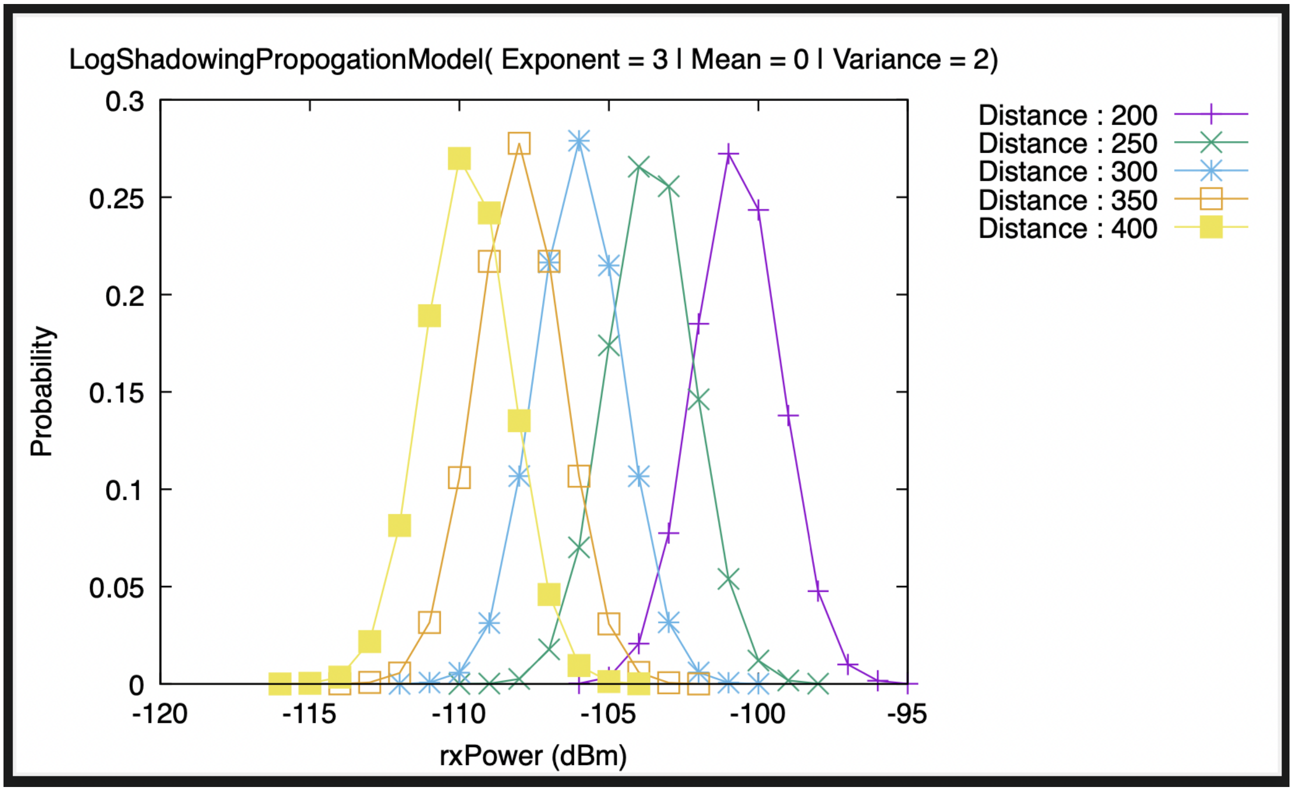
(i) Path loss exponent is 2.5, Gaussian random variable is *N*(0,4)



(ii) Path loss exponent is 3, Gaussian random variable is *N*(0,4)



(iii) Path loss exponent is 3, Gaussian random variable is*N*(0,2)



Answer the following questions:

1. How does the received power change as the path loss exponent increases?

According to our observation, PL is a function of the square of the signal frequency and the distance between the transmitter and receiver. The received power level depends on the path loss. More the path loss, less is the available received power

2. If the receiver needs a signal of at least -95dB to decipher a signal, at approximately what distance do you observe that the receiver can no longer hear the transmitter for scenarios (i), (ii), (iii), and the experiment in the LP question above?

i. According to the graph, approx 500m to 600m the receiver signal would be > -95dB and it will no longer hear the transmitter.
ii. the receiver will no longer hear the transmitter for >200m distance.
iii. According to the graph, 200m is the minimum distance.
[LP] >500m distance

Submission Instructions

- The written part of the completed homework should be in pdf format. Name your file "hw2- answers-<your SJSU ID>".pdf, e.g., hw1-answers-11100111.pdf.
- Compress your ns-3 files and hw2-answers-<your SJSU ID>.pdf in a zip file called hw2-<your SJSU ID>.zip, e.g., hw2-11100111.zip, and submit on Canvas.
- Commit and push your code in github every time you make changes. Your activity on github will be checked to finally assign your grade. Having your code go from 0% to 100% in a short time will attract unnecessary attention.

Specifications

Both tasks have components labeled [LP] and [HP]. If you complete ALL the LP components satisfactorily, you will receive a grade of "low pass" on the homework. If you complete ALL the LP components and at least 1/2 HP components satisfactorily, you will receive a grade of "high pass". If you do not meet the criteria for a "low pass", the submission will be marked as "revision needed".

Note the following statements from the syllabus:

If a student receives a "low pass" or "revision needed" grade, the student may revise and resubmit their homework assignment by using one "token".

For homework assignments, if the student fails to submit their assignment by the posted deadline, their submission will receive a grade of "revision needed". If they fail to submit the assignment by the revision deadline, the submission will receive a grade of "fail".

At most two tokens may be used for the one-day deadline extensions (one token for each one-day extension), including the revision deadlines. Tokens will be automatically removed from your wallet if you submit late and/or resubmit.

VERY IMPORTANT: Include ALL the references you used for this assignment, including names of classmates you discuss with. Failure to cite your sources counts as an act of academic dishonesty and will be taken seriously without zero tolerance. You will automatically receive a "fail" grade in the homework and further serious penalties may be imposed.

NOTE: You can look for help on the Internet but refrain from referencing too much. Please cite all your sources in your submission.

When you submit your assignment, you automatically agree to the following statement. If you do not agree, it is your responsibility to provide the reason.

"*I affirm that I have neither given nor received unauthorized help in completing this homework. I am not aware of others receiving such help. I have cited all the sources in the solution file.*"