Simulating a channels in Matlab

In this assignment channel models from communication theory will be used to simulate a network. Note that the communication theory models are not exactly designed for networks, but there are no models for networks.

Recall that the channel is made up of four parts

$$H = 10\log_{10}\left(\left(\frac{\lambda}{4\pi}\right)^2\right) - a \times 10\log_{10}(d) + 10\log_{10}\left(\frac{1}{W}\sum_{i=1}^{W} X_i\right) + Y$$

where

- d is the distance between the receiver and transmitter,
- α is the attenuation exponent and is between 1.3 and 6,
- X_i are exponentially distributed random variables with mean equal to 1,
- W is the number of bands,
- Y is a Gaussian distributed random variable with mean 0 and standard deviation σ equal to between 4 and 11.

Problem 1: Make a histogram of the channels.

In Matlab a single realization of the channel gain can be made as follows:

$a = 2.3$; % set the attenuation exponent
$d = 100$; % set the distance between the receiver and transmitter
$W = 1$; % set the number of bands
$s = 11$; % set the standard deviation
$X = mean\,(exprnd\,(1, W, 1))$; % make the fast-fading part
$Y = normrnd\,(0, s, 1, 1)$; % make lognormal shadowing part
$H = 10 * 2 * \log 10\,(0.125/(4 * pi)) - a * 10 * \log 10\,(d) + 10 * \log 10\,(X) + Y$;

Now make a vector of realizations and make a histogram.

$a = 2.3$; % set the attenuation exponent
$d = 100$; % set the distance between the receiver and transmitter
$W = 1$; % set the number of bands
$s = 11$; % set the standard deviation
for i=1:10000
    $X = mean\,(exprnd\,(1, W, 1))$; % make the fast-fading part
    $Y = normrnd\,(0, s, 1, 1)$; % make lognormal shadowing part
    $H\,(i) = 10 * 2 * \log 10\,(0.125/(4 * pi)) + a * 10 * \log 10\,(d) + 10 * \log 10\,(X) + Y$;
end
hist(H,[-175:5:0])
title(sprintf('histogram of channel gains with a=%.1f d=%.0f W=%.0f s=%.0f',a,d,W,s))
mean(H)
std(H)

Repeat the above for different values of a, W, and s.

Turn in: Determine for which values of s does W play a role. That is, if $s = 11$, is there any difference between $W = 1$ and $W = 100$? For which values of s is $W = 1$ different from $W = 100$? Include plots to support your answer. Does the value of α play a role?

Problem 2: Check connectivity

Here we want to check if it is possible to reach all nodes in the network via multihop communication.

1. Generate the locations of the nodes. We will assume that the nodes are in a 100m $\times$ 100m area. Let P be the vector of location.

   ```
   P=zeros(1,2);
   for i = 1 : 100
       P(i,:) = rand(1,2)*100;
   end
   ```

2. Now find the channels between all node pairs

   ```
   H=zeros(size(P,1),size(P,1));
   for i = 1 : size(P,1)
       for j = 1 : size(P,1)
           if (i==j)
               H(i,j) = 0;
           else
               d = (P(i,1)-P(j,1))^2 + (P(i,2)-P(j,2))^2;
               X = mean(exprnd(1,W,1)); % make the fast-fading part
               Y = normrnd(0,s,1,1); % make lognormal shadowing part
               H(i,j) = 10*2*log10(0.125/(4*pi)) - a*10*log10(d) + 10*log10(X) + Y;
               H(j,i) = H(i,j);
           end
       end
   end
   ```

3. We will say that a node can communicate with a neighboring node is the channel gain is greater than Thresh. Check how many nodes a typical node can communicate with for different values of Thresh.

   ```
   Thresh = -90; % dBm
   hist(sum(H>Thresh,2)/2);
   ```

   The previous line is a bit tricky. Note that H'>Thresh is a matrix of zeros and ones. The sum(...,2) command will sum along rows, and finds the number of ones in each row, which is the number of nodes a particular node can communicate with. We then take the histogram of that.

   Turn in: Make a few plots with several different values of Thresh.

4. Find which nodes can be reached from node 1 via one hops.

   ```
   B = H<Thresh;
   U=[1,zeros(1,size(P,1)-1)];
   V = (U*B) > 1;
   ```

   Then V is a vector of zeros and ones with the ith element set to 1 if the ith node is a neighbor of node 1. **Turn in:** Explain why this is true.

5. Find which nodes can be reached from node 1 via two hops.

   ```
   B = H<Thresh;
   U=[1,zeros(1,size(P,1)-1)];
   U = (U*B) > 1;
   U = (U*B) > 1;
   ```

6. Find which nodes can be reached from node 1 via any number of hops. The fraction of nodes that are reachable is sum(U)/length(U). **Turn in:** make a plot of fraction of nodes reachable as a function of Thresh.
7. **Turn in:** Make several other plot that show the same thing, but for different values of W, σ, α, the number of nodes. Make some conclusions