Introduction to Wireless and Mobile Networking

Homework 2 Report

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1. Downlink

   1-1. Please plot the location of the central BS and 50 uniformly random distributed mobile devices in the central cell. Don't plot the location of other BSs and other mobile devices in other cells. The unit of x-axis and y-axis should be "meter". The central BS is located at (0, 0). Also, use mark or color to differentiate the central BS from mobile devices.

   For a mobile device located at (x, y) within the service area of the central base station, the restriction on x and y are $|x| \leq 500/\sqrt{3}$ and $|y| \leq 250$. To simplify calculation and random point generation, we omit the shape of the service area of the central base station. By using random number generator and scatter function, we have the following distribution of mobile devices in the central base station:

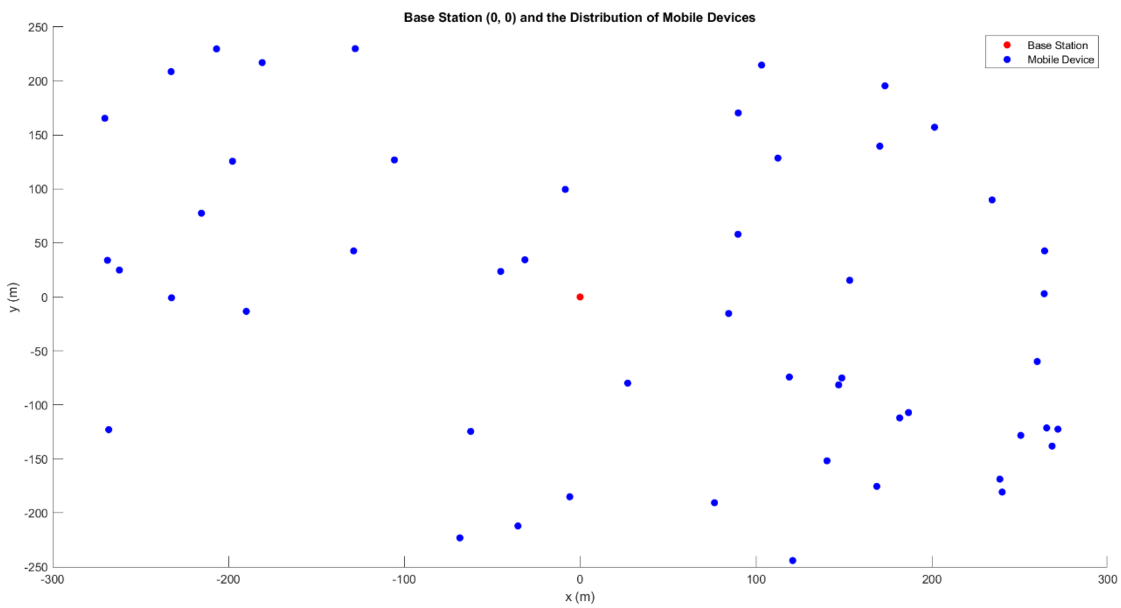

Figure 1. Distribution of mobile devices in the central base station

1-2. Based on the map in 1-1, please plot a figure with the received power (in dB) of a mobile device in a central BS as y-axis, and with the distance between the corresponding mobile device and the central BS as x-axis. Also, write down how to calculate the received power of a mobile device. HINT: There should be 50 points in the figure.

The relationship between transmitted power P_T and received power P_R is given by

$$P_R = P_T \times G_T \times g(d) \times 10^{x/10} \times G_R, \quad (1)$$

where G_T is the transmitter gain, $g(d)$ is the path loss parameter, x is the shadowing variable, and G_R is the receiver gain.

If we only consider path loss using the two-way-ground model, then $x = 0$ and

$$g(d) = (h_t h_r)^2 / d^4, \quad (2)$$

where h_t is the height of the transmitter from the ground, h_r is the height of the receiver from the ground, and d is the distance between the transmitter and the receiver. Since we measure received power in dBm, by taking 10 times of logarithm on both sides, formula (1) becomes

$$10 \log P_R = 10 \log P_T + 10 \log G_T + 10 \log g(d) + x + 10 \log G_R. \quad (3)$$

Here $10 \log P_R$ and $10 \log P_T$ are all measured in dBm, while the rest of the terms are measured in dB. By substituting the given values into (3), we have the following scatter graph:

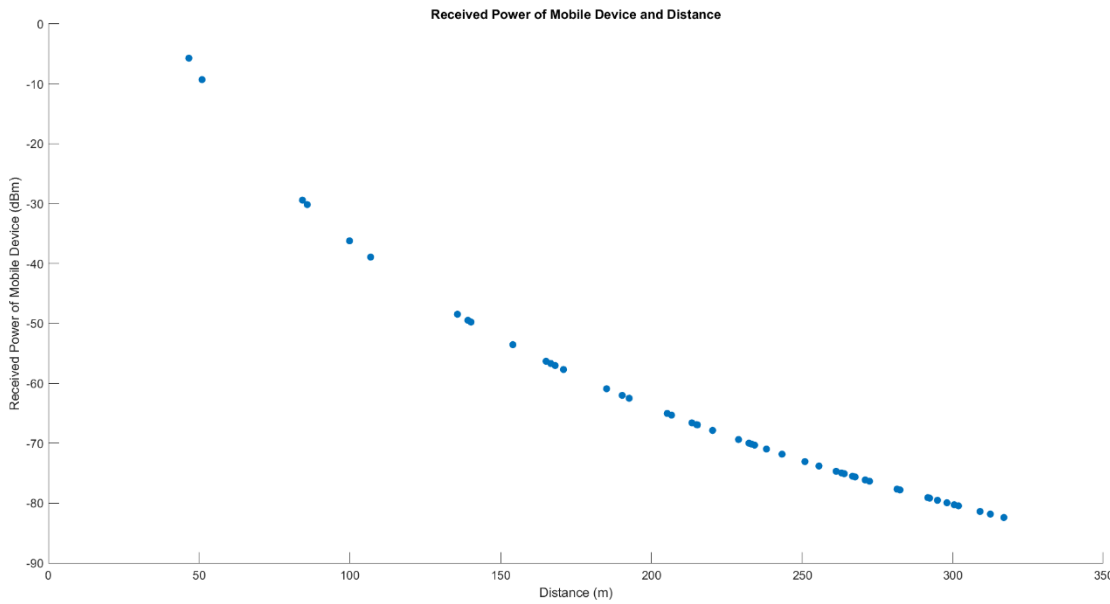

Figure 2. Received Power of each Mobile Device

From Figure 2, we see that if a mobile device is farther away from the central base station, the received power from the central base station decreases.

1-3. According to 1-2, please plot a figure with the SINR (in dB) of a mobile device in the central cell as y-axis, and with the distance between the corresponding mobile device and the central BS as x-axis. Also, write down how to calculate the SINR in your report. HINT: Both thermal noise and received power of a mobile device from other BSs should be taken into consideration.

The thermal noise power is given by

$$P_N = kTB, \tag{4}$$

where $k = 1.38 \times 10^{-23}$ J/K is Boltzmann's constant, T is absolute temperature of the environment (in Kelvin), and B is the bandwidth of the channel. By using $T = 300.15$ K and $B = 10$ MHz, we know that $P_N = 4.14 \times 10^{-14}$ W. The formula for SINR is

$$\text{SINR} = P_R/(P_I + P_N), \tag{5}$$

where P_R is the power of signal and P_I is the power of interference. For each mobile device in the central base station, the interference comes from the outer base stations. Based on the distance between the outer base stations and the central base station, we can divide the outer base stations into 3 classes: $D_1 = 500, D_{sq3} = 500\sqrt{3}, D_2 = 1000$. Each class has 6 base stations. In addition, each class can be split into 3 approximate distances: $D - r, D, D + r$, where r is the distance between the mobile device and the central base station. Hence, we can calculate power of interference as follows:

$$P_I = \sum_{i \in C} 2 \times P_T \times G_T \times [g(D_i - r) + g(D_i) + g(D_i + r)] \times G_R, \tag{6}$$

where the constant 2 comes from symmetry and $C = \{1, sq3, 2\}$. To express SINR in dB, we take 10 times of logarithm on (5), which becomes

$$\text{SINR (dB)} = 10 \log P_R - 10 \log(P_I + P_N) \tag{7}$$

Figure 3 illustrates the relationship between SINR and distance. The values are obtained using (6) and (7). As the distance to the central base station increases, the SINR decreases because the power from the central base station declines significantly.

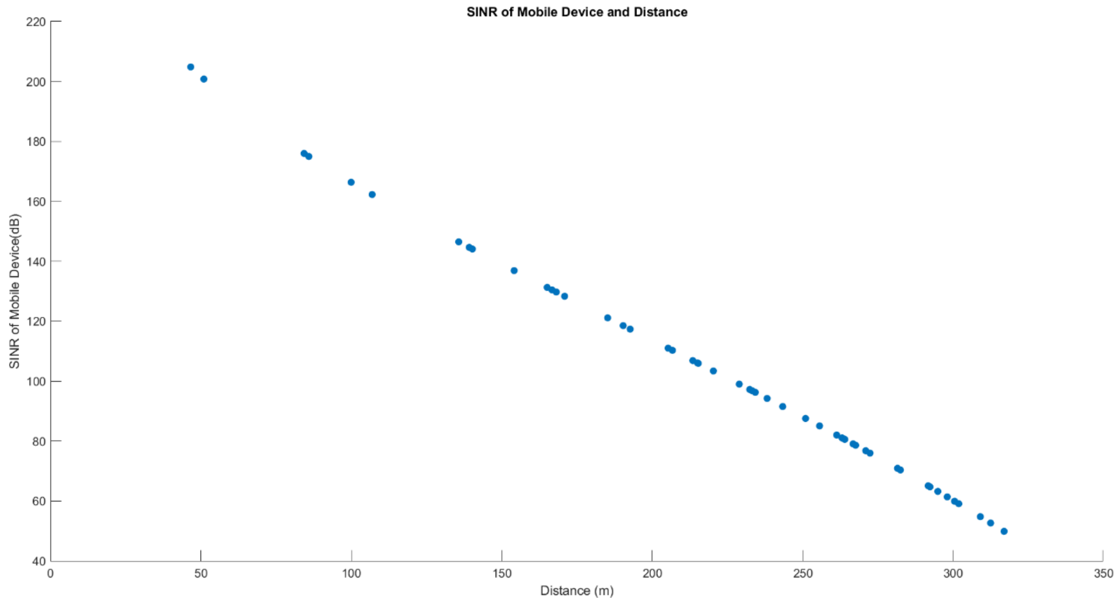

Figure 3. SINR of mobile device and distance

2. Uplink

   2-1. Please plot the location of the central BS and 50 uniformly random distributed mobile devices in the central cell. Don't plot the location of other BSs and other mobile devices in other cells. The unit of x-axis and y-axis should be "meter". The central BS is located at (0, 0). Also, use mark or color to differentiate the central BS from mobile devices.

   This is essentially the same task as 1-1. The scatter graph is given in Figure 4, which is identical to Figure 1.

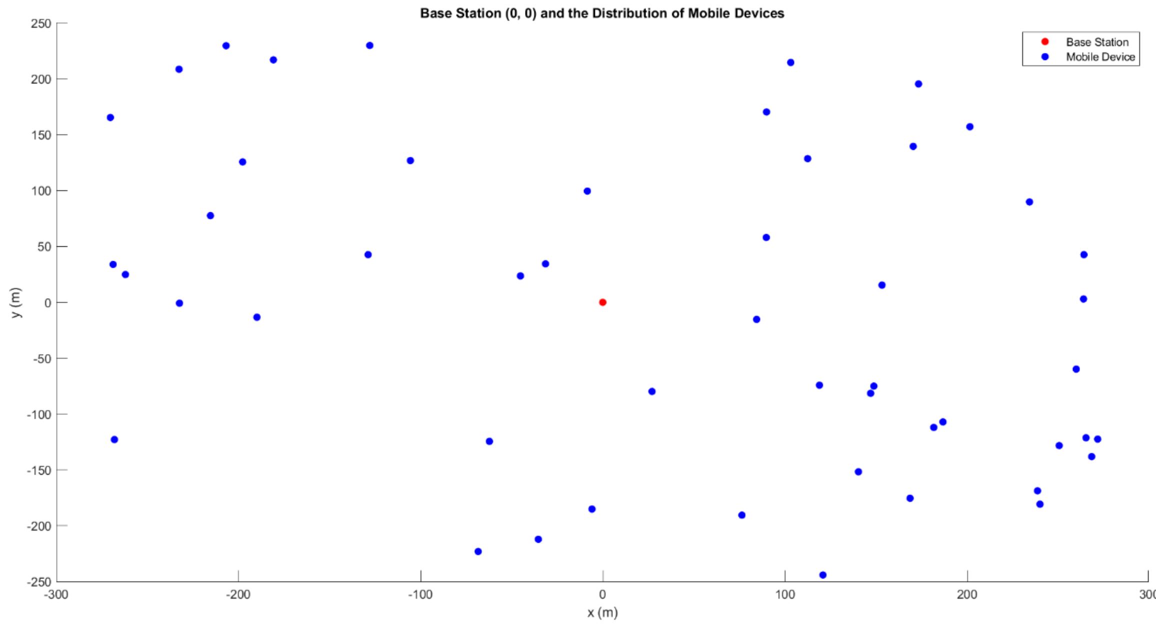

Figure 4. Distribution of Mobile Devices in the Central Base Station

2-2. Based on the map in 2-1, please plot a figure with the received power (in dB) of the central BS from a specific mobile device as y-axis, and with the distance between the corresponding mobile device and the central BS as x-axis. Also, write down how to calculate the received power of the central BS from a specific mobile device.

HINT: There should be 50 points in the figure.

Actually, the power of mobile device is a tenth of the power of the base station, while the other parameters remain unchanged. Hence, the plot of received power of base station is similar to the plot of received power of mobile devices, with the values in the former being 10 dB lower than the latter. The scatter graph of received power of base station is shown in Figure 5:

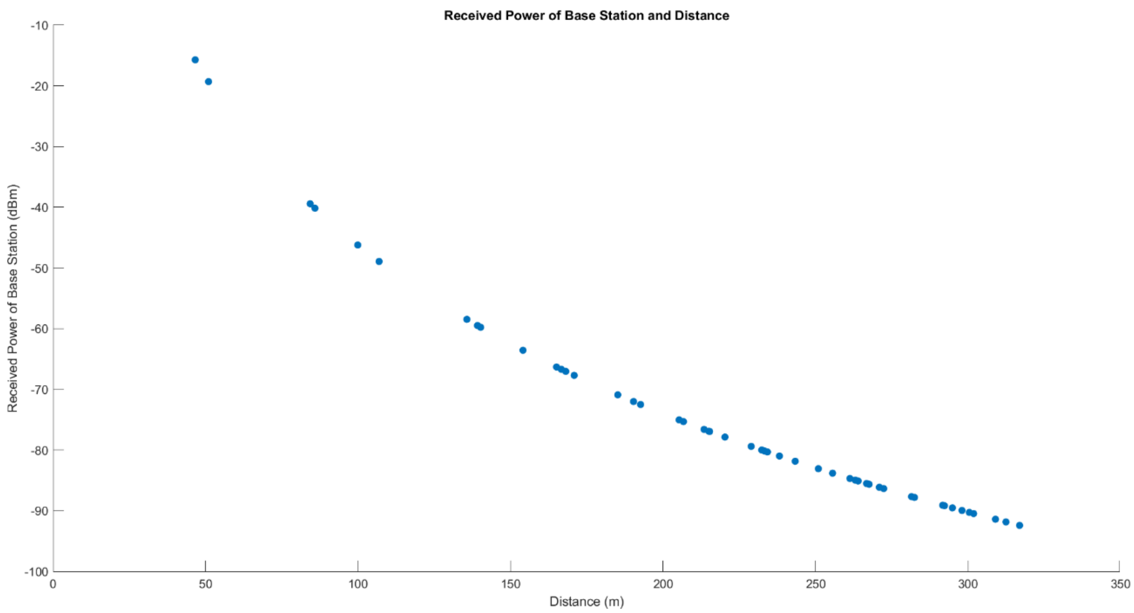

Figure 5. Received Power of the Central Base Station

2-3. According to 2-1, please plot a figure with SINR of the central BS (in dB) as the y-axis and the distance between the BS and the corresponding mobile device (in meter) as the x-axis. Also, write down how to calculate the SINR in your report. HINT: Both thermal noise and received power of the central BS from other mobile devices within the same cell should be taken into consideration. We don't consider the uplink interference from mobile devices in other cells. No need to calculate inter-symbol interference (ISI).

For any device in the central base station, the power of interference comes from the remaining 49 devices. We calculate the total power send to the central base station and subtract the power of the chosen device from it. This gives the total power of interference of a mobile device. By (4) and (7), we can plot the relationship between SINR of a base station and distance, as shown in Figure 6. We can see that, if a mobile device is farther away from the base station, then the SINR of the base station is lower, implying lower quality of transmission.

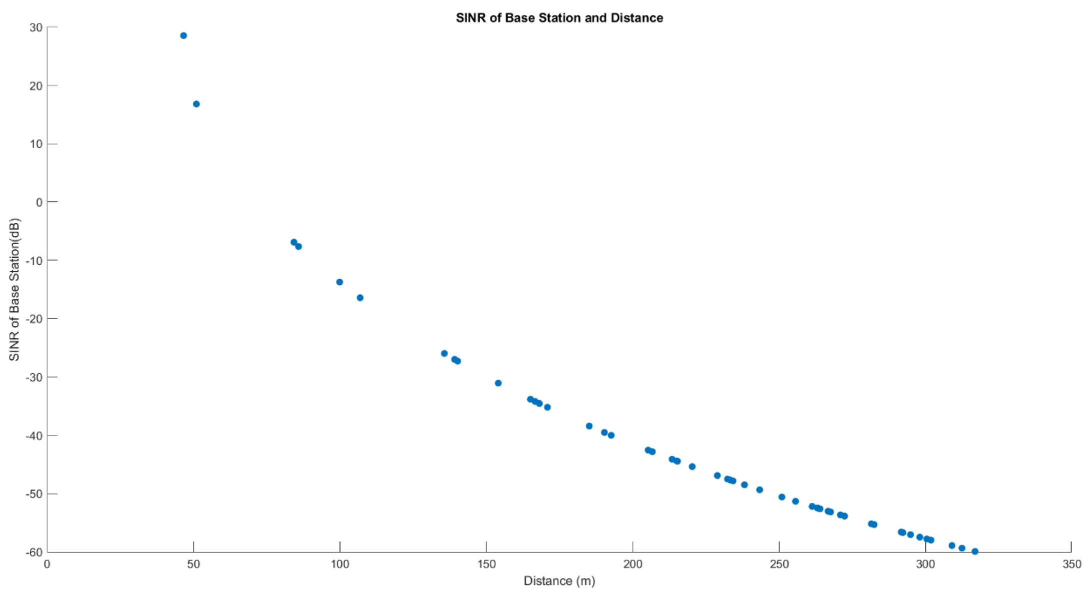

Figure 6. SINR of Base Station and Distance