# Introduction to Wireless and Mobile Networking — Homework 3

Student ID: b03901032   Name: Jason Kuo 郭子生
Github: https://github.com/awinder0230/2017-Spring-Wireless-and-Mobile-Networking

**Problem Description:**

19 base stations are located in an urban area with temperature 27, which form a 19-cell map shown in Fig. 1. The coordination of the central BS is (0, 0) and ISD (inter site distance) is 500 m. The channel bandwidth is 10MHz. All BSs use the same carrier frequency (frequency reuse factor =1).The power of each base station is 33dBm. The power of each mobile device is 23dBm. The transmitter antenna gain and the receiver antenna gain for each device, including base station and mobile devices, are 14 dB. The height of each base station is 1.5m, which is located on the top of a 50m high building. The position of each mobile device is 1.5m high from the ground. Consider the path loss only radio propagation (without shadowing and fading). Use Two-ray-ground model as the propagation model for your simulation.

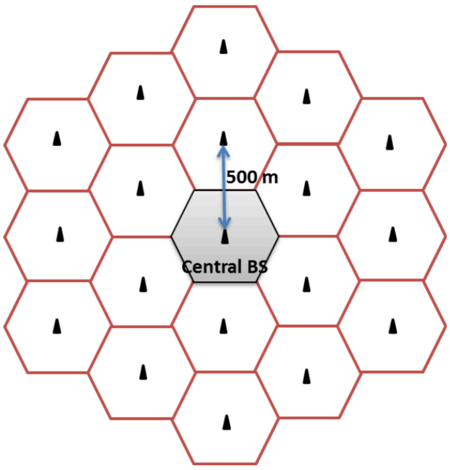


Figure 1.   19-cell map

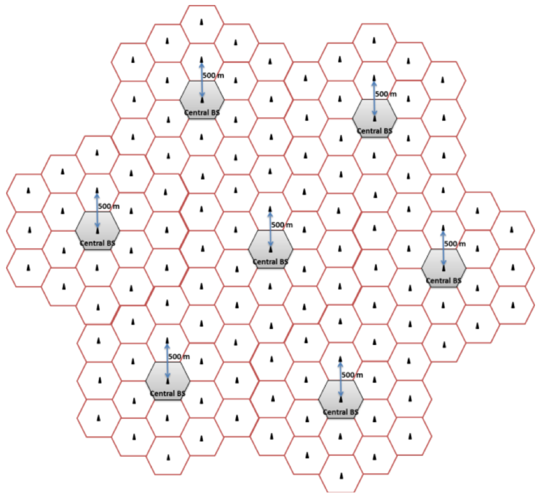

Figure 2. extended cell map

In this problem, only uplink case is considered. 100 mobile devices do uplink communication and moves based on random walk mobility model as described below. Since the 19-cell map is symmetric, if the mobile device reaches the map boundary, it will enter the opposite cell as shown in Fig. 2. That is, from the mobile device perspective, the map seems to extend.

Random walk mobility model:

a) The mobile device chooses the moving direction between [0, 2] uniformly.
b) The mobile device chooses the velocity between [minSpeed 1m/s, maxSpeed 15m/s] uniformly.
c) Based on the chosen direction and velocity, the mobile device moves t seconds, in which t is chosen uniformly between [minT = 1s, maxT = 6s].
d) Upon arriving the destination, the mobile device chooses another direction, velocity and travel time again according to step a, b and c.

The initial locations of all the 100 mobile devices are decided uniformly in the 19-cell map.
Total simulation time is 900 seconds.

**Submission Files:**
- report: b03901032_hw3_report.pdf
- readme: b03901032_hw3_readme.pdf
- codes:
  - main.m
  - gen_hexagon.m: a function to generate hexagon with radius r center at (x,y).
  - gen_hexrand.m: a function given hexagon, generate random dots inside the hexagon.
  - received_power_dB.m: given BS power, BS height, MS height, distance, transmitter gain, and receiver gain, compute received power in dB based on two-ray-ground model.
  - SINR.m: a function a function given signal, interference, and noise power, calculate SINR.
  - thermal_noise_power.m: a function given temperature and bandwidth, calculate thermal noise power.
  - two_ray_ground_model.m: given distance, height of transmitter and receiver, calculate gain of channel.
  - dB_2_watt.m: a function convert units from dB to Watt.
  - dBm_2_watt.m: a function convert units from dBm to Watt.
  - watt_2_dB.m: a function convert units from Watt to dB.
  - MobileDevice.m: class definition of mobile devices.
  - BaseStation.m: class definition of base stations.

**Usage:**
1. Put all the *.m codes under the same directory.
2. Open Matlab and run main.m to get the simulation result.

**Design:**
1. **Class:**
   I define 2 classes, **MobileDevice** and **BaseStation**, in this assignment. The philosophy of this design is by considering the problem is quite object oriented, thus, classes would simply the process of coding. In class MobileDevice, it has several properties, such as its position, velocity, time left for current velocity, and the current base station id which it is uplinking to. The constructor of MobileDevice initialize its position, and the method **randomWalk** updates its velocity according to constraints in problem description. In class BaseStation, it has properties such as id, central position, cell border, and total received power from all mobile devices, which makes the computation of SINR easier. The constructor of BaseStation initialize its position and base station id.

2. **Simulation:**
   Simulation is implemented by a for loop. In each loop, I first compute the total power received of each base station. The total power is calculated by summing all the transmission power from each mobile devices based on two-ray-ground model. Next, for each mobile device, find the best SINR it has, and updates its registered base station id if necessary. Finally, update locations of mobile devices according to their velocities.

3. **Extend Cell Maps:**

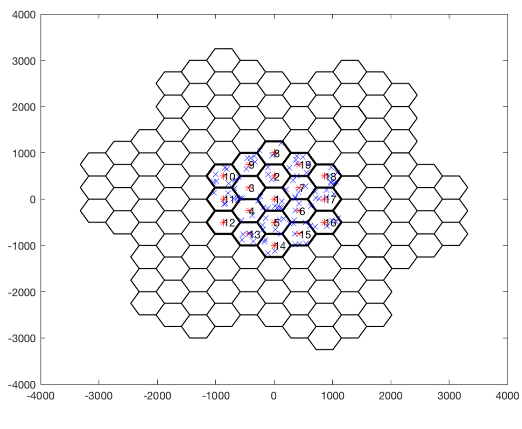

Figure 3. extended cell map

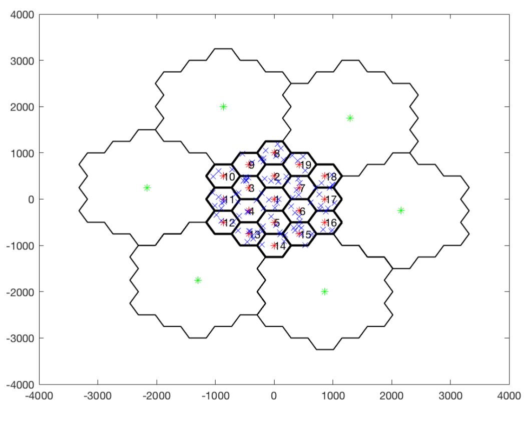

Figure 4. extended cell map with union border

According to problem description, if a mobile device goes straight up starting from the center of 19 cells, after crossing the upper border of cells (cell 8 in Fig. 3.), it will end up showing at the border in the bottom of cell 16 in Fig. 3. To implement this feature, I extend cell map from 19 central cells to the one shown in Fig. 3, which has 19 x 7 cells in total. Next, union each 19 cells into a larger area, which is shown in Fig. 4. with its center in green. In this way, if a mobile device roams away out from 19 central cells, we can update its location by computing the distance between the mobile device and the center of union area which it is located in. Add this distance to the center of 19 cells, which is (0,0) in fact, would turn out to be the new location that the mobile device should be updated to.

**Result:**

**B-1, B-2**

Please give a figure to describe how you arrange cell IDs to Fig. 1. Please plot a map with all mobile devices in their initial location. Describe how you decide the initial location.

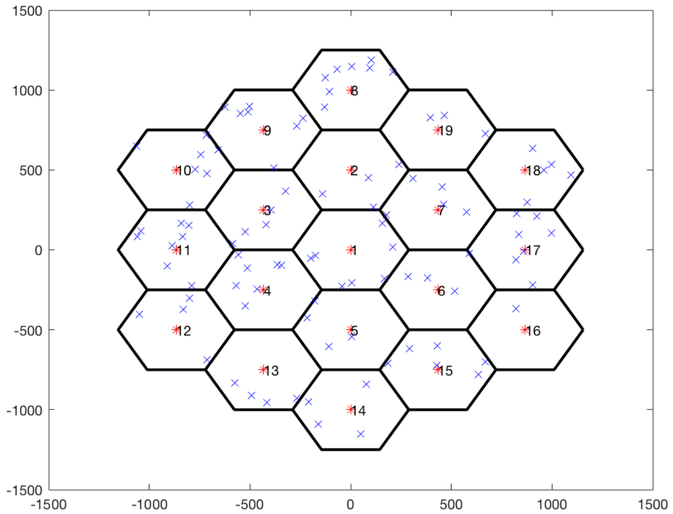


Figure. B-1

Red * depict base stations, blue x depict mobile devices, and numbers label ids of each cells. Mobile devices are distributed uniformly within 19 cells. To accomplish this randomness, I randomly choose an integer from 1 to 19 by Matlab function **randi**. Next, in cell with id same as this integer, randomly generate a point in the cell by function **gen_hexrand**, and assign a mobile device to this point. Function gen_hexrand is define in the file named gen_hexrand.m. In gen_hexrand, randomly choose a point within a square which covers the whole cell. If this point is also located in the cell then return; otherwise, randomly pick a next point until the point is in the hexagonal cell.

**B-3, B-4**

Based on B-1, please list all the time when the handoff event occurs and the related cell ID. How many handoff events happen during the total simulation time? The criteria to decide when the handoff events occur SHOULD be SINR-based. You SHOULD describe your criterion clearly in your report.

As describe above in section ‘design’, for each base station, I first compute total power received from mobile devices at the beginning of each simulation loop, and the power is then being saved in each BaseStation object as its property. Next, for each mobile device, find the largest SINR among the transmission between itself to 19 cells. SINR is computed as following: S is the power received by a specific base station from the mobile device. I is the total power received by a specific base station minus S. N is computed by thermal noise model. Finally, SINR is computed by S / ( I + N ). After calculating 19 SINRs, find the one with the largest SINR value. Handover occurs only when the newly computed SINR is calculated from a base station which is different from the current one. Update property regBS of object MobileDevice as well as append the event to table whenever handover occurs. The result of simulation is in the output file from main.m named output.csv.

Total Handoff/Handover Event: 3895 Times