Introduction to Wireless and Mobile Networking — Homework 3

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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.
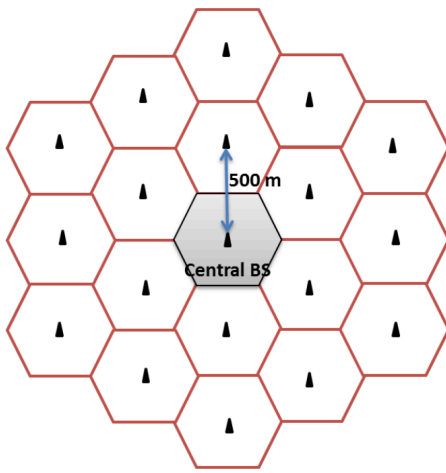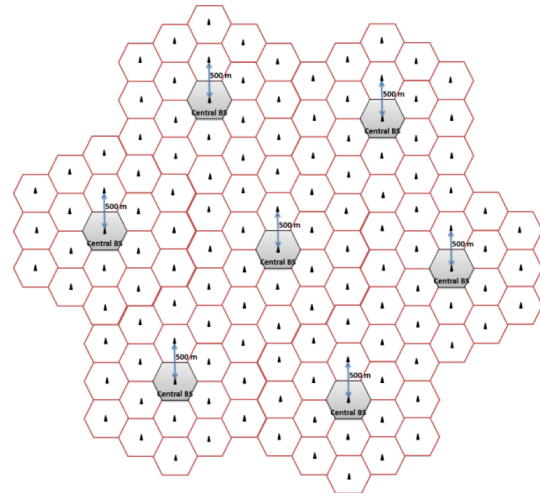

Figure 1.   19-cell map

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:**
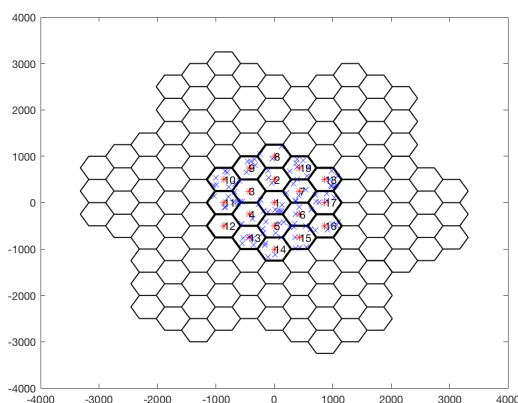
Figure 3. extended cell map
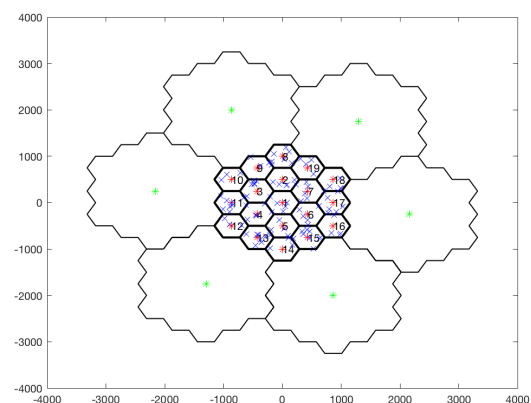
Figure 4. extended cell map with union border

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.
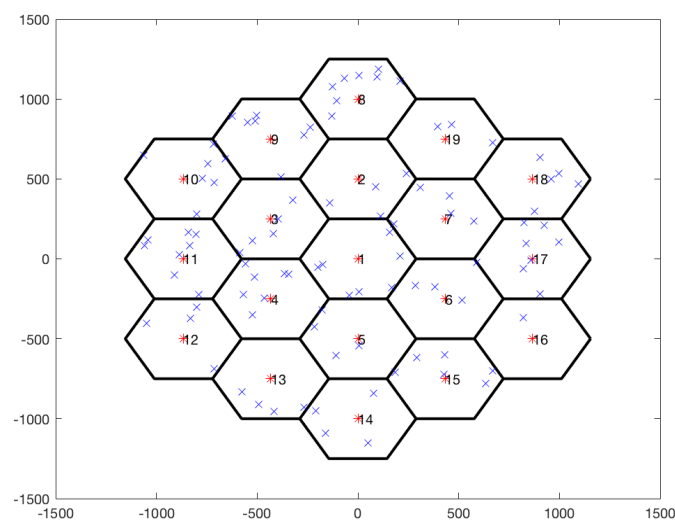
Figure. B-1

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 listed down below.

Handoff/Handover Event: 3895 Times
T: Time
S: Source Cell ID
D: Destination Cell ID

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
1	13	5	191	9	3	377	17	18	551	17	6	717	7	19
1	6	16	191	7	18	377	9	2	551	15	16	717	13	12
2	16	17	191	8	19	377	11	12	552	17	7	718	8	16
2	10	18	191	7	2	377	8	15	552	3	9	718	2	19
2	12	10	192	14	15	377	17	18	552	15	6	718	3	10
2	16	17	192	7	2	378	13	1	552	15	5	719	14	13
2	1	12	192	8	19	378	14	13	552	1	4	719	18	7
2	13	14	192	17	3	378	17	10	552	18	7	719	12	11
2	2	1	193	10	3	378	6	5	553	4	5	719	15	9
2	7	19	193	18	17	379	15	5	554	13	7	719	16	11
3	13	5	193	7	2	379	1	4	554	7	6	720	18	7
3	9	10	193	3	2	380	19	17	554	5	14	720	15	8
3	14	15	193	13	4	380	15	5	554	12	19	720	12	11
3	2	19	193	8	19	381	9	2	554	13	14	720	14	13
3	10	11	194	14	13	381	18	17	554	9	8	721	7	2
4	3	1	194	6	16	381	10	11	554	1	6	721	14	15
4	1	4	194	3	11	381	14	5	555	11	4	722	5	15
5	2	19	194	4	11	382	9	2	555	15	9	722	14	13
5	1	5	194	3	11	382	15	5	555	11	4	722	8	9
5	10	11	195	14	15	382	16	6	556	5	14	722	3	2
5	12	4	195	4	11	382	11	12	556	9	2	722	12	11
5	1	4	195	4	11	383	1	3	556	4	13	723	4	3
6	14	5	196	8	15	383	4	5	557	4	5	723	7	19
6	10	11	196	14	15	383	14	2	558	1	4	723	12	13
6	6	1	196	7	19	384	13	12	558	4	11	724	7	1

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
6	10	11	197	7	3	384	13	5	559	3	9	724	16	17
6	9	8	197	6	4	384	6	17	559	5	15	724	2	7
6	12	4	197	6	16	385	16	17	559	4	11	724	13	11
6	16	17	197	7	19	385	6	17	559	6	7	725	13	5
7	18	17	198	17	6	385	13	12	559	6	15	725	19	13
7	1	4	198	14	15	385	2	9	560	7	19	725	13	5
7	16	15	199	15	16	386	2	9	560	7	2	725	12	13
8	1	4	200	13	4	386	8	2	560	9	2	726	3	4
8	9	10	200	13	4	386	2	9	560	6	7	726	7	19
8	5	15	200	12	4	386	2	3	560	9	15	726	16	17
8	18	17	201	4	3	386	17	18	560	9	2	726	7	19
8	19	18	201	13	4	387	1	5	560	5	13	726	11	16
9	15	5	201	17	11	388	9	15	561	6	15	726	16	11
9	1	5	201	11	4	388	11	3	561	18	7	726	6	16
9	9	8	201	2	7	388	17	18	561	4	11	727	6	15
9	11	16	201	18	13	388	11	10	561	6	7	727	4	1
9	9	10	202	3	15	388	12	17	561	16	11	727	19	2
9	16	7	202	2	3	389	17	6	561	8	12	727	5	15
9	9	10	202	13	4	389	12	19	561	6	7	728	5	15
10	1	5	203	16	6	389	7	17	561	6	5	728	6	16
10	9	8	203	2	3	389	1	3	562	14	9	728	6	15
10	1	5	203	2	3	390	4	5	563	9	2	728	3	10
11	4	12	203	3	1	390	11	10	563	4	3	729	6	17
11	9	8	203	3	4	390	4	5	563	13	12	729	16	15
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12	4	1	203	7	1	390	15	8	565	7	17	730	2	7
12	15	16	204	3	1	391	17	6	565	1	4	730	11	13
13	12	13	204	3	1	391	19	7	565	9	2	731	8	16
13	8	12	204	16	15	392	18	5	565	7	18	732	19	2
13	4	12	204	12	4	392	1	5	565	16	15	732	2	8
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13	10	9	205	8	9	393	11	10	565	14	9	733	1	5

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
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14	4	1	205	15	14	394	3	11	566	10	17	734	2	7
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14	8	9	205	19	8	394	11	10	567	9	3	734	13	12
14	12	8	206	6	15	394	6	15	567	19	7	734	11	12
14	1	7	207	6	7	394	2	7	567	9	8	735	9	10
15	1	12	207	11	3	395	5	12	567	7	6	735	13	12
15	12	11	207	19	8	395	3	4	568	12	4	735	7	1
15	4	1	207	16	6	395	5	4	568	7	17	736	7	18
16	12	11	207	4	12	395	18	10	568	15	6	736	15	14
17	14	13	207	19	18	395	17	6	569	7	17	736	15	14
17	11	16	207	19	7	395	5	6	569	11	10	736	9	3
17	19	12	208	8	9	396	5	4	569	15	16	736	9	2
17	8	16	208	7	18	396	11	10	569	19	7	736	7	2
17	10	11	208	19	18	396	12	17	569	14	15	737	9	3
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18	13	14	209	4	13	396	3	1	570	5	4	737	16	11
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19	8	16	209	6	16	397	3	9	571	7	18	738	17	18
19	18	19	209	7	18	397	5	4	571	2	7	738	19	7
19	12	16	210	8	7	397	19	8	571	15	14	738	12	11
19	16	17	210	4	13	398	15	6	571	13	12	738	2	8
19	16	8	210	11	17	398	19	7	571	16	12	738	12	13
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19	1	5	210	6	5	398	8	12	572	11	10	738	10	3
19	16	17	210	18	19	399	5	15	572	7	17	739	16	15
19	9	8	210	3	10	399	9	10	572	2	9	739	17	6
20	1	12	210	18	19	399	9	3	573	17	18	739	17	11
20	18	17	210	4	13	399	8	9	573	19	7	739	16	11
20	1	19	211	7	19	400	13	12	573	12	4	739	12	11

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
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21	12	11	211	15	6	400	11	12	574	19	7	740	19	8
21	11	17	211	4	13	400	12	4	574	9	8	740	10	17
21	12	11	211	7	19	400	2	9	574	10	17	740	8	9
21	8	9	212	6	16	401	6	16	574	17	6	741	17	6
21	1	7	212	6	5	401	10	18	574	9	8	741	3	9
21	14	5	212	15	6	401	12	16	575	12	11	741	12	13
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23	5	14	213	6	5	402	4	1	576	13	4	742	15	5
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23	8	9	213	8	19	403	9	2	576	6	17	742	15	14
24	10	9	213	17	18	404	15	6	576	17	16	742	12	13
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25	17	18	214	16	6	404	5	14	577	15	14	742	7	17
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26	19	2	215	15	14	405	15	6	578	4	1	743	16	15
26	19	18	215	19	2	405	9	14	578	10	17	743	5	1
26	8	16	215	1	4	406	15	6	578	7	19	743	3	11
26	11	16	216	5	6	406	3	9	579	7	19	743	13	11
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27	16	17	216	15	9	407	15	6	579	9	10	744	15	5
28	17	7	216	1	3	407	19	7	580	12	19	744	5	13
28	11	16	216	17	6	407	7	2	580	17	6	744	11	10
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28	8	2	216	19	18	408	15	6	580	4	7	745	7	19
28	8	2	216	6	16	408	16	12	580	7	13	745	12	13
28	1	5	216	13	14	409	12	13	580	4	3	745	13	4
29	13	5	217	15	14	409	7	1	581	9	10	745	11	17

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
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30	16	15	217	5	6	409	15	6	581	5	4	746	17	11
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31	5	1	217	19	2	410	6	14	582	17	6	746	11	10
31	9	2	218	10	18	410	6	5	582	8	2	746	16	17
32	16	17	218	12	8	410	7	19	582	7	6	746	6	17
33	5	4	218	9	15	410	6	14	582	7	19	746	1	2
33	5	4	218	5	6	410	4	1	583	6	1	747	17	10
34	18	7	218	19	2	411	6	5	583	7	6	747	1	4
34	7	2	218	19	18	411	12	13	583	18	19	747	7	19
35	11	4	218	1	6	411	6	5	583	4	13	748	11	16
35	11	3	219	8	2	411	5	13	583	17	6	748	3	9
35	15	8	219	15	6	411	10	9	583	17	7	749	13	4
35	5	15	219	17	6	411	6	16	584	10	9	749	11	10
36	17	11	219	5	6	411	4	1	584	19	13	749	11	4
36	5	15	219	19	2	411	12	17	584	14	5	749	6	5
36	16	15	220	8	9	411	4	1	584	7	18	750	3	11
36	18	7	220	7	6	411	9	2	585	8	12	751	11	10
36	13	5	220	9	12	411	6	17	585	6	1	751	17	11
36	16	15	220	11	3	412	16	17	585	14	5	751	11	3
36	18	7	221	6	17	412	4	12	585	8	19	751	7	19
37	18	7	221	2	9	412	1	7	585	6	17	752	13	12
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37	16	15	221	4	12	413	14	5	587	5	13	754	9	15
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38	17	7	222	18	13	413	12	13	587	10	9	754	14	13
38	9	8	222	18	19	413	6	16	587	11	10	754	4	13
39	13	12	223	11	3	413	1	13	587	18	17	755	5	13
39	17	7	223	1	4	413	7	2	587	6	15	755	14	13

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
40	17	7	223	6	17	414	10	17	588	3	9	755	18	17
40	4	5	224	15	6	414	4	12	588	6	16	755	11	12
40	7	19	224	15	6	414	13	5	588	14	13	755	15	10
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41	7	18	225	6	5	415	10	11	588	4	3	755	11	12
41	7	18	225	6	5	415	6	16	588	7	19	756	4	5
41	17	7	226	2	19	415	6	16	589	7	17	756	15	16
41	17	7	226	18	13	416	13	5	589	11	12	757	5	6
41	2	8	227	15	6	416	14	10	589	5	13	757	11	17
42	7	5	227	7	6	416	16	9	589	13	19	757	16	17
43	10	3	227	3	4	416	6	5	589	8	2	757	11	13
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43	2	19	227	6	14	417	12	4	590	13	14	759	16	15
44	5	4	227	15	6	417	7	17	590	18	13	760	18	7
44	5	1	227	16	11	417	6	1	591	6	17	760	4	13
44	7	17	227	15	6	417	1	3	591	5	13	760	3	11
44	7	17	228	15	6	418	9	3	591	11	12	760	10	14
44	14	5	228	10	11	418	1	4	591	4	5	760	13	12
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44	7	18	228	9	2	419	13	4	591	11	10	760	18	7
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45	14	5	229	6	15	419	18	7	592	15	5	761	7	19
45	15	16	229	11	6	420	12	4	592	16	17	761	8	2
45	19	18	229	6	16	420	10	11	592	13	14	761	9	3
45	14	5	229	9	8	420	9	16	592	6	1	761	18	13
45	7	19	229	2	6	420	8	2	592	8	2	761	5	6
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163	8	9	348	11	16	528	6	5	700	19	8	872	10	3
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163	16	15	349	4	11	529	6	5	701	18	13	872	1	2
163	17	18	349	5	1	529	11	10	701	8	6	872	11	10
164	12	11	349	4	13	529	3	7	701	4	11	873	14	13
164	11	4	349	14	19	530	7	19	702	8	2	873	16	15
165	18	19	350	14	15	530	15	6	703	6	16	873	8	9
165	18	13	350	12	13	530	12	13	703	6	16	873	8	9
165	13	4	350	7	19	530	9	8	703	10	18	874	18	7
166	2	3	350	11	4	531	6	15	703	6	17	874	12	16
166	6	15	350	9	8	531	7	3	704	10	9	874	8	19
167	11	16	350	14	13	532	10	17	704	14	13	874	1	3
167	9	10	350	5	13	532	4	13	704	4	11	875	1	2
168	4	11	350	11	3	532	6	15	704	17	6	875	16	15
168	18	19	350	2	7	532	6	15	704	4	13	876	7	19
168	10	11	351	9	8	533	3	9	704	17	7	876	5	1
168	18	19	351	17	16	533	6	17	705	18	13	876	1	2
168	18	10	351	18	19	533	11	3	705	17	6	876	19	2

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169	16	17	352	14	15	533	6	17	705	18	7	879	8	9
169	16	6	353	9	8	533	10	17	705	19	18	879	15	16
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170	2	3	354	4	13	533	15	9	706	8	9	880	17	16
170	4	5	354	8	9	533	6	16	706	10	11	880	10	14
171	11	12	354	18	19	534	5	15	706	8	2	880	7	1
171	6	5	355	3	10	534	9	2	706	17	18	880	14	1
171	6	1	355	10	11	534	19	8	706	18	13	880	10	14
171	13	19	355	14	13	534	14	13	706	8	2	881	3	2
171	9	15	355	5	1	534	5	15	706	12	13	881	9	15
171	1	7	356	3	2	535	10	3	707	9	6	881	3	4
171	6	17	356	16	11	535	19	7	707	8	9	882	15	1
172	8	19	356	13	19	535	6	15	707	12	13	882	7	18
173	2	8	356	19	12	535	8	15	707	6	15	882	2	1
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174	19	12	357	17	16	536	14	13	707	8	9	883	15	6
174	14	5	357	13	14	536	9	15	708	12	13	883	19	14
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174	4	12	358	3	11	537	3	12	708	6	16	883	2	1
175	2	7	358	8	9	537	5	13	708	8	9	884	17	18
175	19	18	358	11	12	537	5	4	708	17	6	884	7	2
175	2	7	358	17	7	538	16	15	708	2	13	885	7	19
176	2	3	358	3	10	538	3	2	708	13	14	885	14	13
176	11	12	359	12	8	538	9	2	708	17	6	885	8	2
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177	18	7	360	16	6	539	8	7	709	1	3	886	12	11
178	16	6	360	13	1	539	8	9	709	6	16	886	17	1
178	5	14	361	19	13	539	14	9	709	13	11	886	2	9
178	10	18	361	16	6	540	3	12	709	18	7	886	3	10

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179	2	7	361	16	6	540	4	12	709	18	7	886	2	16
179	4	1	362	1	5	541	19	7	710	9	16	886	9	2
180	19	18	362	8	9	541	4	13	710	18	7	887	15	16
180	11	3	362	19	7	541	19	7	710	6	16	887	14	5
180	6	12	362	1	5	541	12	8	710	18	7	887	1	7
180	10	14	363	13	19	542	14	15	710	13	11	887	8	2
180	12	4	364	16	17	542	15	12	710	5	6	888	9	14
180	10	9	364	16	15	542	12	17	711	9	3	888	10	3
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180	1	6	365	17	11	543	12	11	711	18	11	888	10	11
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181	11	4	366	4	1	543	14	13	712	6	16	889	1	4
182	9	8	366	10	9	543	14	13	712	9	8	889	11	4
182	12	6	367	14	15	544	12	8	712	2	8	890	1	17
182	18	8	367	2	3	544	7	1	712	6	16	890	2	1
182	7	8	367	16	15	544	15	5	713	13	14	890	13	12
182	11	10	367	4	1	545	2	8	713	9	8	891	19	7
183	14	10	367	11	3	545	7	19	713	13	12	891	1	15
183	11	4	367	12	11	545	3	4	713	9	3	891	10	9
183	8	13	367	7	2	545	7	19	713	13	14	892	10	11
183	19	8	368	13	1	546	7	1	714	6	15	893	6	15
183	12	4	368	12	11	546	2	3	714	11	3	893	12	4
184	14	18	368	19	18	546	4	13	714	7	19	893	1	15
184	6	4	368	10	9	546	13	5	714	1	4	894	15	9
184	4	13	369	4	1	546	8	7	714	9	3	895	3	9
185	4	11	369	8	9	546	15	16	714	11	3	895	9	3
185	4	13	369	12	8	546	13	14	714	13	12	895	9	2
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185	3	9	369	18	19	547	9	10	714	11	3	896	14	13

T	S	D	T	S	D	T	S	D	T	S	D	T	S	D
185	15	6	370	13	5	547	2	9	715	6	15	896	16	12
186	9	8	371	15	14	547	9	10	715	13	12	896	16	15
186	5	4	372	13	12	547	4	12	715	3	10	896	2	9
186	13	8	372	18	17	548	15	6	715	13	5	896	4	12
187	12	6	373	9	8	548	13	4	715	6	15	897	9	15
187	4	13	373	18	17	548	7	19	715	18	7	897	19	7
187	5	6	373	9	8	548	2	9	715	11	12	897	10	9
187	9	3	374	13	5	548	12	4	715	6	16	897	18	14
187	10	3	374	11	16	548	13	14	715	13	12	898	6	15
188	1	7	374	11	4	549	15	5	716	7	19	898	19	8
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189	6	16	375	1	4	549	13	5	716	6	16	898	19	8
189	14	15	375	16	15	549	12	11	716	13	12	898	15	5
189	17	6	375	3	2	550	13	14	717	11	3	899	16	19
189	6	17	375	2	19	550	15	5	717	6	7	899	13	5
190	1	4	376	1	4	550	15	16	717	11	12	899	2	8
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190	11	4	376	1	6	551	17	7	717	3	10	900	12	19