Indoor Positioning Systems

First name: _____

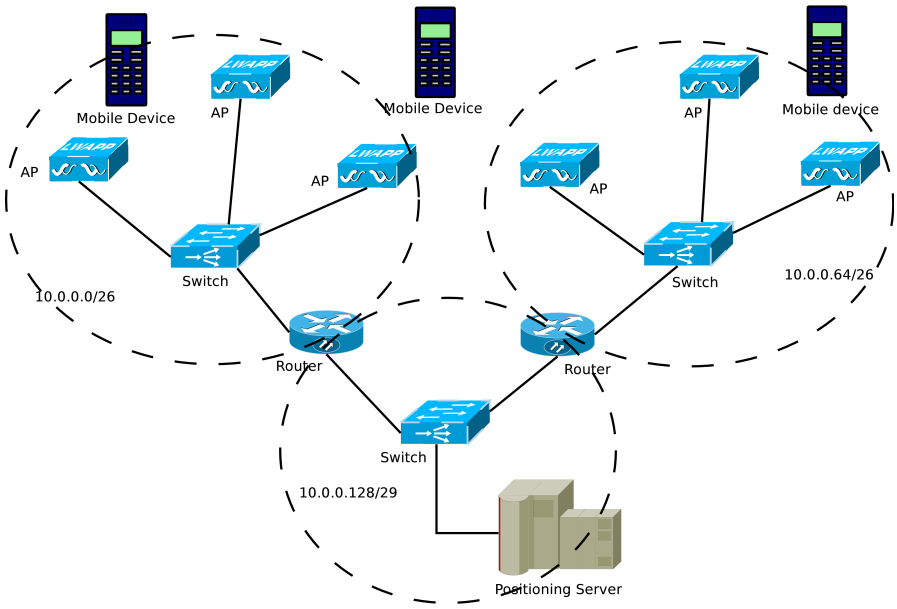
Last name: _____

Documents allowed: personnal notes on a R/V A4 paper sheet
Algorithms either in pseudo-code or C++
EACH PART ON A SEPARATE SHEET OF PAPER!

Part I: Wi-Fi based systems (10 pts)

Knowledge questions (2 pts – answers on this sheet)

1. Look at the exhibit:



In its positioning requests, what should a mobile device transmit to the server? (2 answers)

- its hostname
- its IP address
- its MAC address
- its location
- a positioning request code

2. Give the expression of euclidean distance between two vectors V_1 and V_2 whose elements are V_{1i} and V_{2i} with $1 \leqslant i \leqslant N$

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3. Give an example of transmission with the following values of FromDS and ToDS flags:

FromDS	ToDS	Transmission
0	0	
0	1	
1	0	
1	1	

4. What is the formula to compute the Friis index value in FBCM system for one point P, one access point A and distance d between A and P. P receives a RSSI of -76 dBm on its 2.1 dBi antenna. A has an output power of 20 dBm, a frequency of 2.417 GHz, an antenna gain of 5 dBi. Give the formal expression and the result of numerical application.

Exercises

Ex1 (5 pts)

We consider that we have an API containing the following functions:

```
double rssi_distance(const map<string, double> &m1,
                     const map<string, double> &m2);

Point closest_in_rssi(const map<string, double> &m,
                      const map<Point, map<string, double> > &db);

map<double, Point> kclosest_in_rssi(const map<string, double> &m, int k,
                                    const map<Point,
                                    map<string, double> > &db);

Point kWeightedAverage(const map<string, double> &m, int k,
                       const map<Point, map<string, double> > &db);

Point viterbi_like(const Point &viterbi_data[n][k]);

Point fast_viterbi_like(const boost::multi_array<Point, 2> &viterbi_data);

double compute_friis_index(const double rssi_value, const double distance,
                           const AccessPoint &ap,
                           const double &client_antenna);

map<string, double> fbcm_calibrate(const map<Point,
                                   map<string, double> > &calib_data,
                                   const map<string, AccessPoint> &aps,
                                   const double &client_antenna);
```

And the following data structures:

```
typedef struct _Point {
  double x;
  double y;
  double z;

  double distance (const Point &p);
} Point;

typedef struct _AccessPoint {
  string mac_address;
  double output_power;
  double antenna_gain;
  Point coordinates;
  long frequency;
} AccessPoint;
```

You have to design and setup a positioning system based on hybridation of FBCM and RSSI map based systems. Your boss asks you to provide a quick algorithm of the core function i.e. positioning request solver. The function receives a RSSI sample from the mobile device. It already has its RSSI map database. You have to take into account the past locations through a viterbi like algorithm. Write the algorithm.

Ex2 (3 pts)

Given the following tracks, build a 2nd order markov model which represents the movements. Do not forget states B and F (state before entering the system and state when gone out of the system)
Track 1: 1 → 2 → 3 → 4 → 5
Track 2: 1 → 2 → 4 → 3 → 5
Track 3: 1 → 2 → 4 → 5 → 4
Track 4: 2 → 3 → 1 → 4 → 5

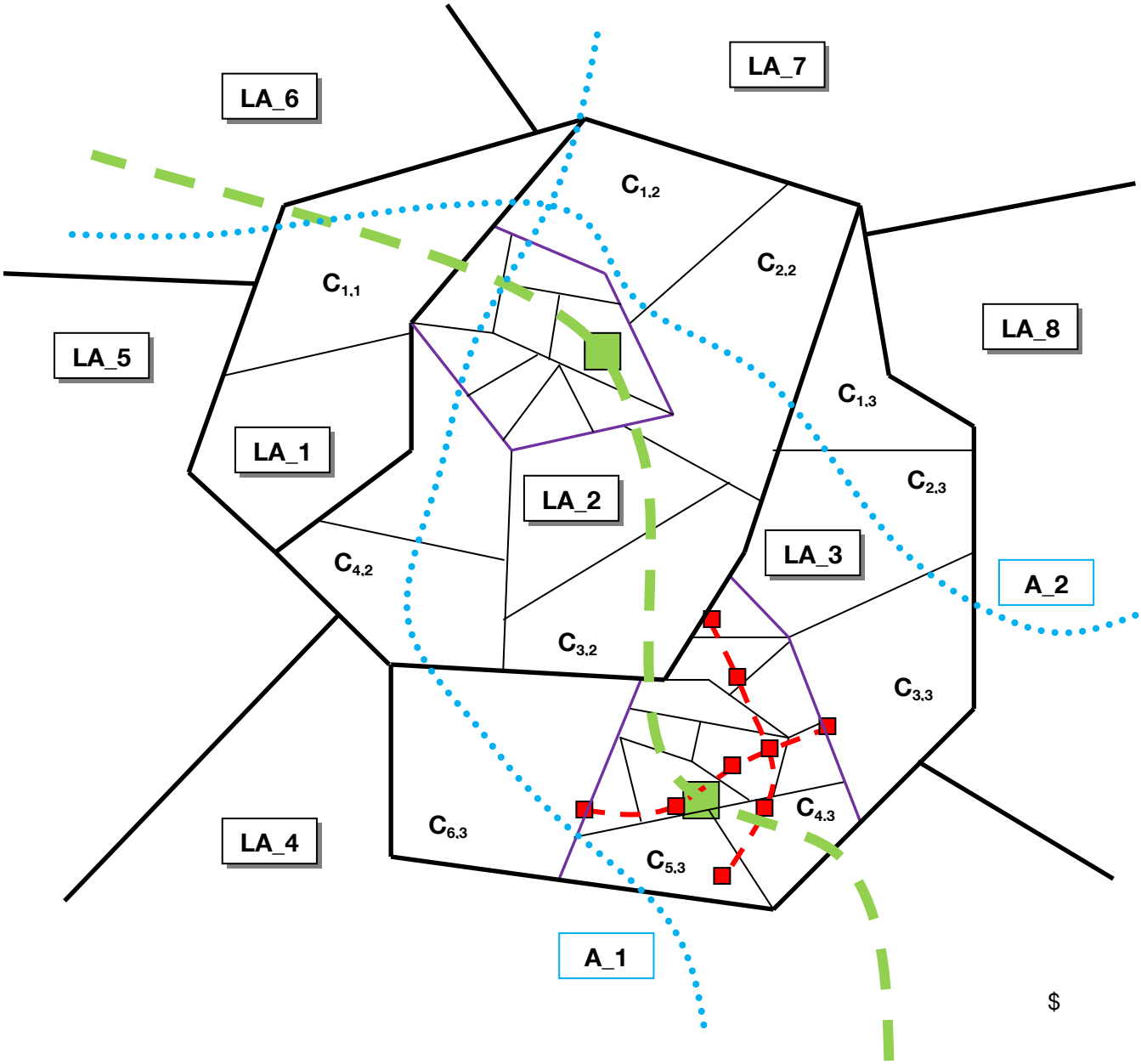
You have to provide the states labels and the probabilities on the edges. (2 pts)

You observe the following movement: 1 → 2. Where is the mobile device most likely to head then? (1 pt)

LO53 Final Exam

Indoor and outdoor positioning using mobile phone data

Name :



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1. Overview

This graph represents a fictive area covered by a 2G cellular network operated by Orange. This area is divided into 8 Location Areas denoted from LA_1 up to LA_8, those LA are divided into cells. The transport network provided on this territory is made of

- one TGV line with two stops drawn in green
- two highways in blue
- two suburban train lines with 9 stops in red

We had access to a database made of signaling events that have occurred on this territory on Monday the 10th of October 2011.

Question 1.a: Based on your knowledge of the GSM network architecture, identify urban area(s)? Explain your choice

Answer 1.a:

Question 1.b: Describe six signaling events that can be used to study the mobility of inhabitants and tourists travelling within this fictive territory.

Answer 1.b:

Question 1.c: In order to count a number of Orange subscribers travelling on a territory during a day, would you rather count

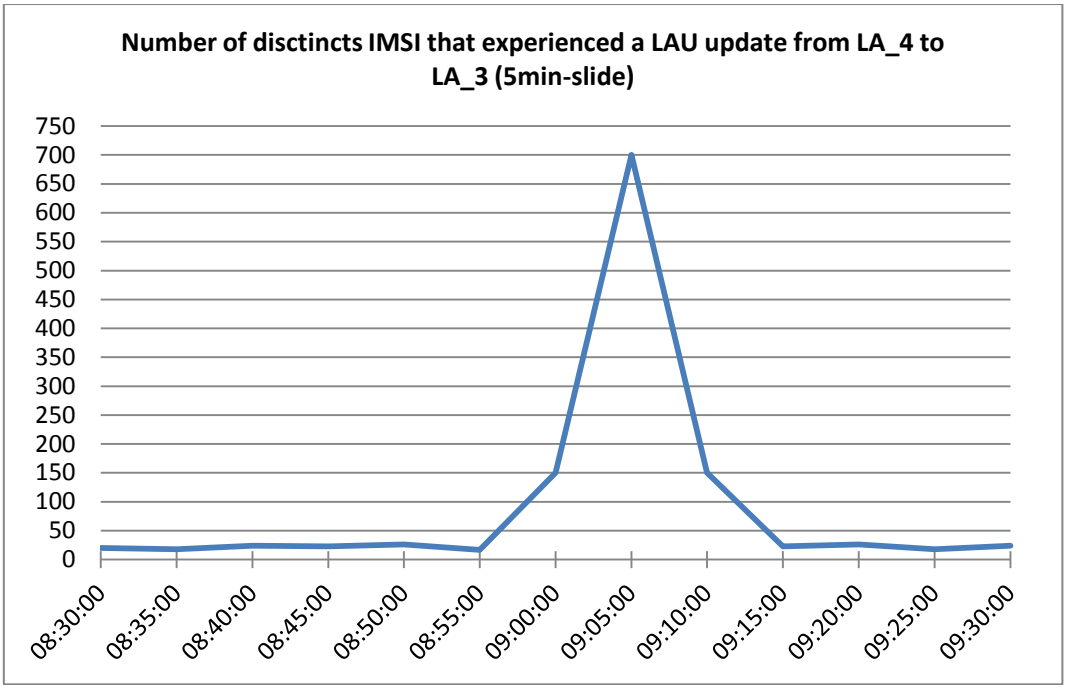
- the number of events that occurred during the day
- the number of IMSI within each event
- the number of distinct IMSI during a day

2. Mobility using the TGV

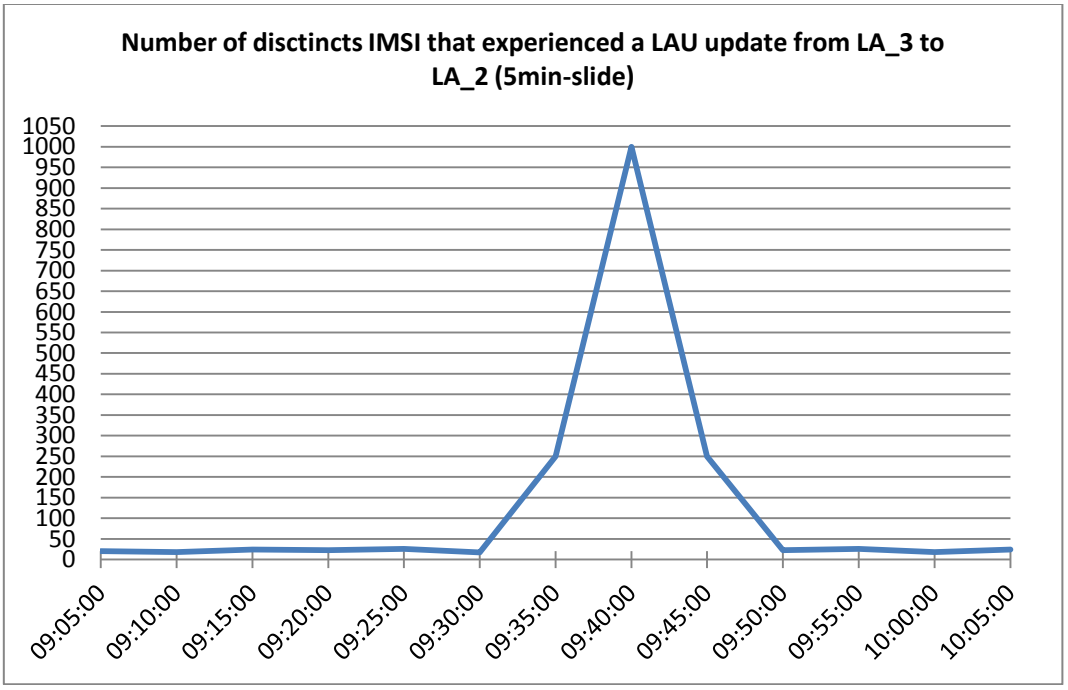
We will consider a time delay of 10 minutes around the instant time the TGV crosses the bordure between two LAs.

We have used the following SQL commands to draw graph 2a.

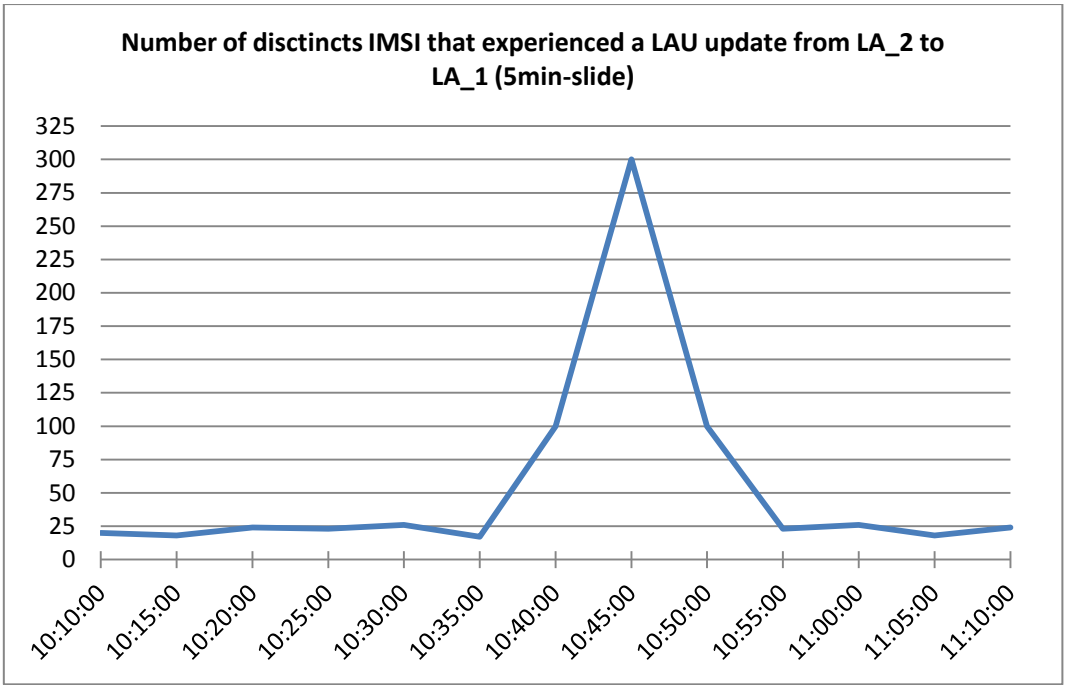
```
SELECT count(distinct IMSI)
FROM  tab_fictive_territory
WHERE  LAC = LA_3 AND Old_LAC = LA_4
GROUP BY time_sec/300
```



Graph 2a



Graph 2b



Graph 2c

Question 2a: Based on the 2a, 2b and 2c graphs, give the time the TGV crossed each LA bordures.

Answer 2a

Let us denote the city in the south of the territory "city_south" and the city located in the north "city_north"

Question 2b: According to graphs 2a, 2b and 2c, give the direction in which the TGV is riding in the morning?

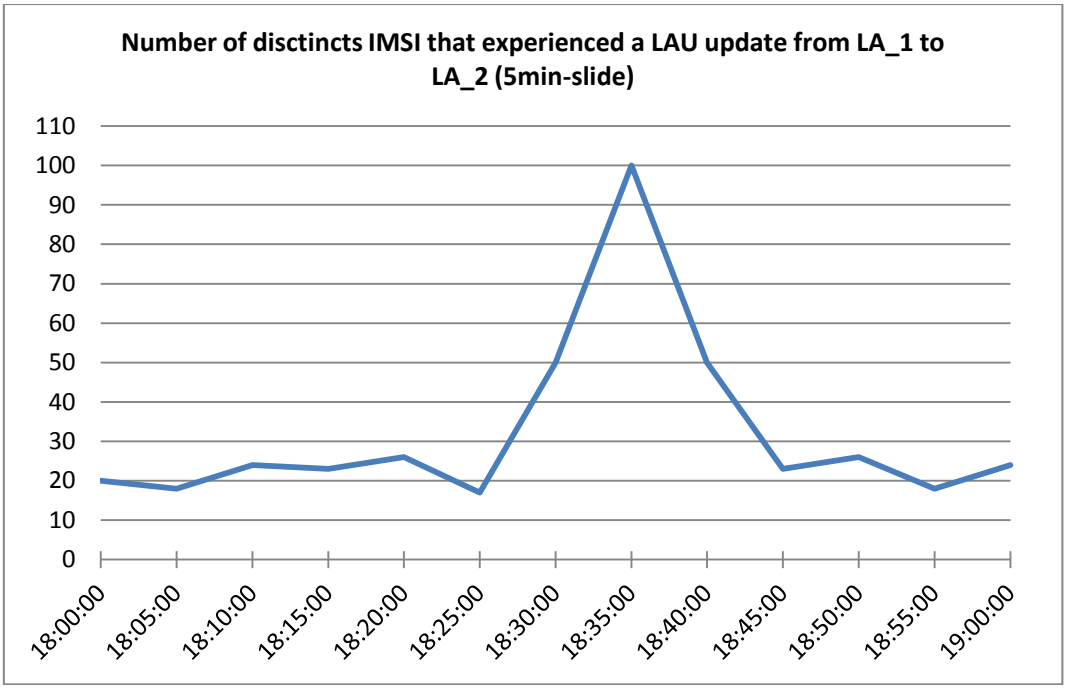
Answer 2b

Question 2c: Fill the following tab (yellow cell)

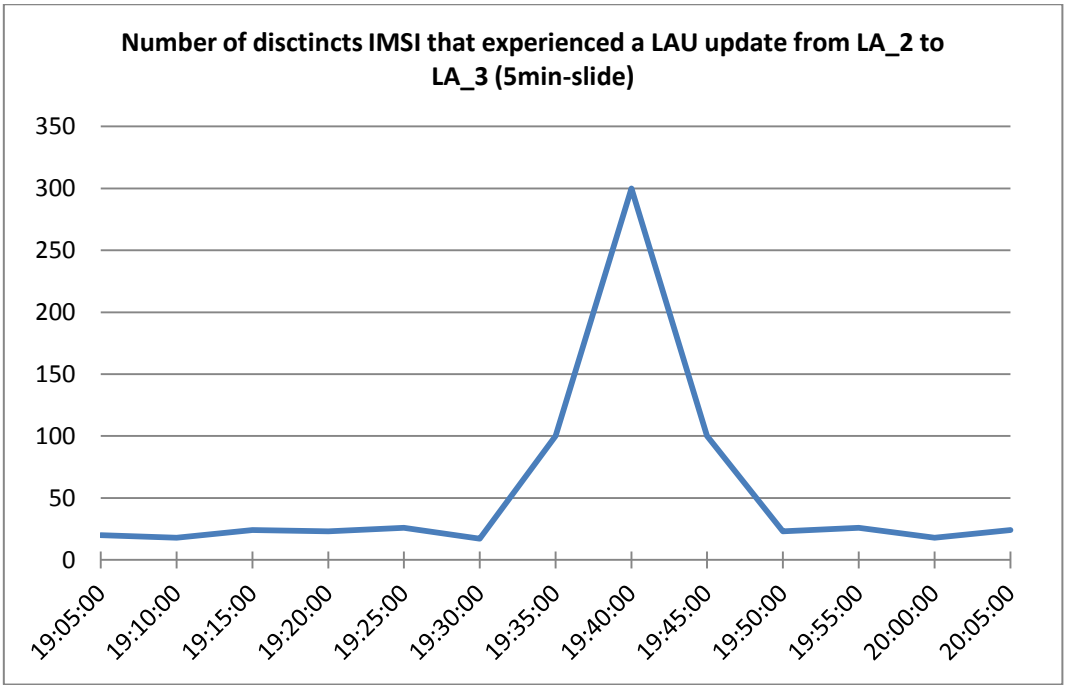
IMSI	Start_event	End_event	Rejection Cause	LAC	Old_LAC	Cell
20801_____	LUREQ	LUACC	-	LA_2		$C_{3,2}$
20801_____	LUREQ	LUACC	-	LA_2	LA_4	
	LUREQ	LUREJ	PLMN	LA_8	LA_3	$C_{1,3}$

We have used the following SQL commands to draw graph 3a.

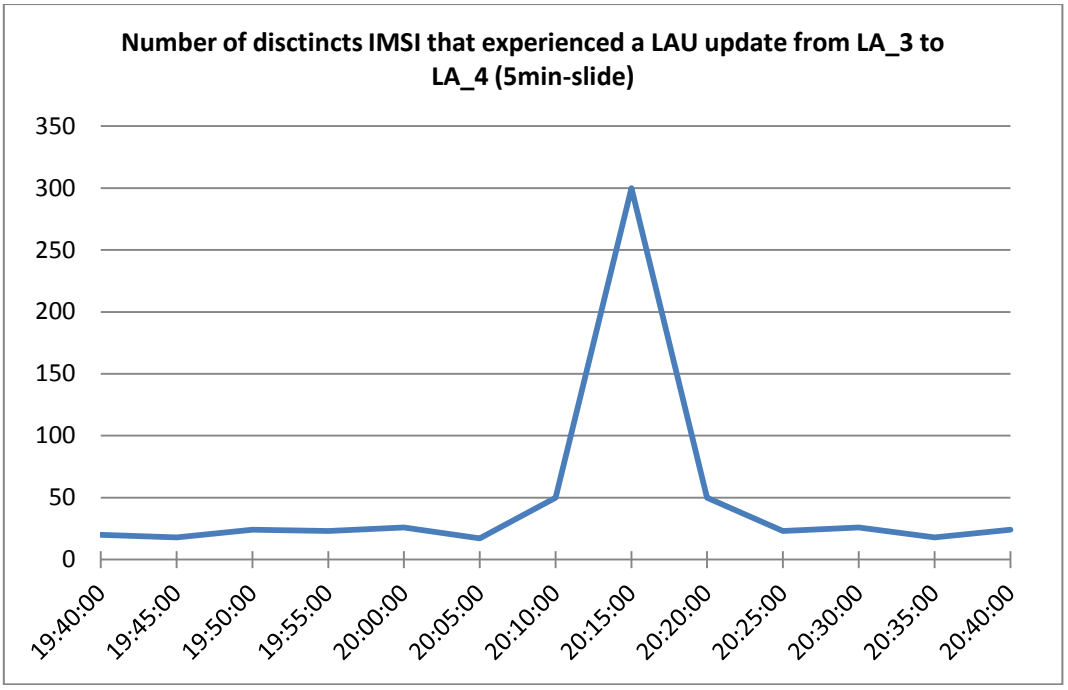
```
SELECT      count(distinct IMSI)
FROM        tab_fictive_territory
WHERE       LAC = LA_2      AND      Old_LAC = LA_1
GROUP BY    time_sec/300
```



Graph 3a



Graph 3b



Graph 3c

Question 2d: Which is the flow of Orange mobile phones that have travelled from city_south to city_north on Monday morning?

Answer 2d:

Question 2e: Which is the flow of Orange mobile phones that have travelled from city_north to city_south on Monday evening?

Answer 2e:

By analyzing another dataset of signaling events that occurred on Friday the 14th of October 2011, we have got:

- Orange mobile phone flow on Friday morning from city_south to city_north : 500
- Orange mobile phone flow on Friday evening from city_north to city_south : 1500

Question 2f: Which is the part of daily travelers and the part of weekly travelers from the people owning a cell phone and an Orange subscription that have travelled between city_south and city_north?

Answer 2f:

The LGV is operated by the SCNF. They gave us the annual flow of passengers that have ridden the TGV between city_south and city_north : 938 000 passengers/year. This flow does not differentiate direction in which the line is ridden.

This fictive territory is not very attractive in terms of recreational activities. Therefore, the SNCF have ensured that 90% of the annual passengers flow travel with a work/study trip motivation from Monday to Friday.

Question 2g: Calculate the Orange market share upon the sample of population who are regular passengers of the TGV between city_north and city_south. We will assume that there is 365 days a year and 52 weeks a year and no holiday.

Answer 2g:

3. Mobility on roads

The A_1 highway is another edge of the transport network to link city_south and city_north.

Question 3.a: By using the signaling events explain a way to differentiate traveler's board on the TGV and travelers on the road.

Answer 3.a:

Question 3.b: Explain a way to estimate the time it takes to cross LA_3 while driving on the A_2. Which events you would use? Why?

Answer 3.b:

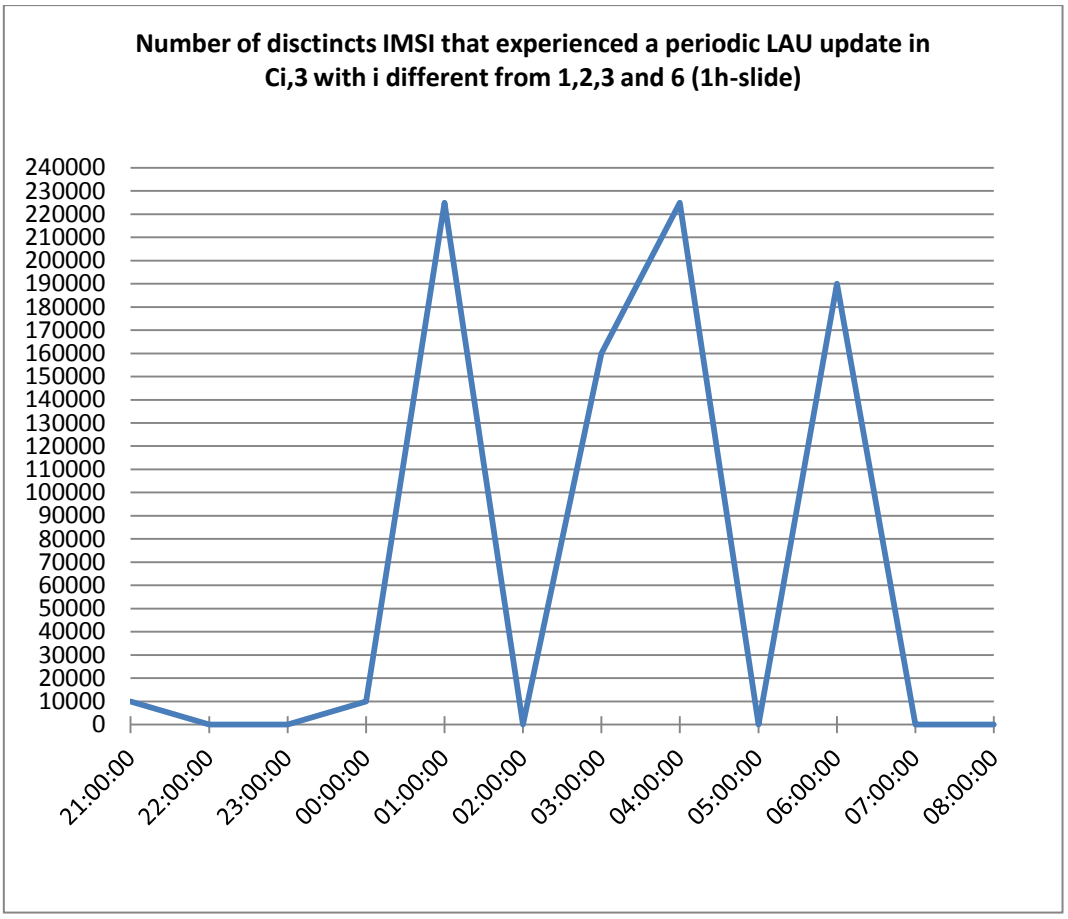
4. Urban mobility

Question 4: Which conditions are necessary to observe trips onto one public transit system in a city? Precise conditions regarding both the telecommunication network and the transport network.

Answer 4:

5. Immobility

We can observe periodic LAU in the LA_3 from 9pm until 8am. We have considered only LAU_P that have occurred in the cells Ci,3 with i≠{1,2,3,6}



Graph 5

A study gives us the way inhabitants of city_south are using their cell phones at night.

Cell phone usage	% of city_south inhabitants
Turn off mobile from 22:00 to 06:00	15%
No activity on mobile from 22:00 to 06:00	45%
No activity on mobile from 18:00 to 6:00	2%
No activity on mobile from 00:00 to 08:00	30%
No activity on mobile from 03:00 to 09:00	8%

Tab 5

"No activity on mobile from X to Y" means last activity (calls or mobility activity) occurred at X.

Question 5.a: Which category of cell phone users are is not represented onto the graph 5?

Answer 5.a:

Question 5.b: For each category of cell phone users that are represented onto the graph 5, give the number of LAUP that should be observed?

Answer 5.b:

Question 5.c: How many inhabitants live in city_south? Detail the method you are using to access this value

Answer 5.c: