Ubiquitous computing and smarter cities: capturing and modeling urban mobility

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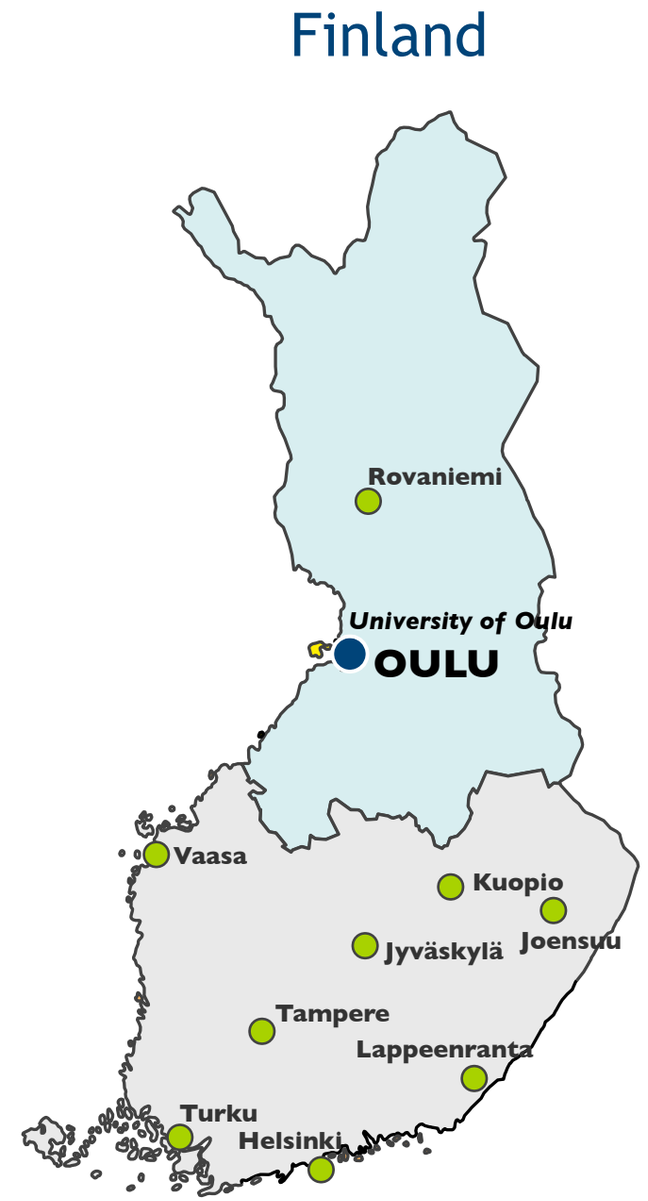
University of Oulu

29 March 2012, Zurich, Switzerland

University of Oulu

- Founded in 1958
- 6 faculties
- 16 000 students
- 2900 employees
- Total funding EUR 226 million
- Four research focus areas:
  - Information Technology
  - Biosciences and Health
  - Cultural Identity and Interaction
  - Environment, Natural Resources and Materials



Active exchange programs

Department of Computer Science and Engineering

- Ubiquitous computing (MediaTeam)
- Machine vision
- Intelligent systems
- Biomedical engineering

CSE

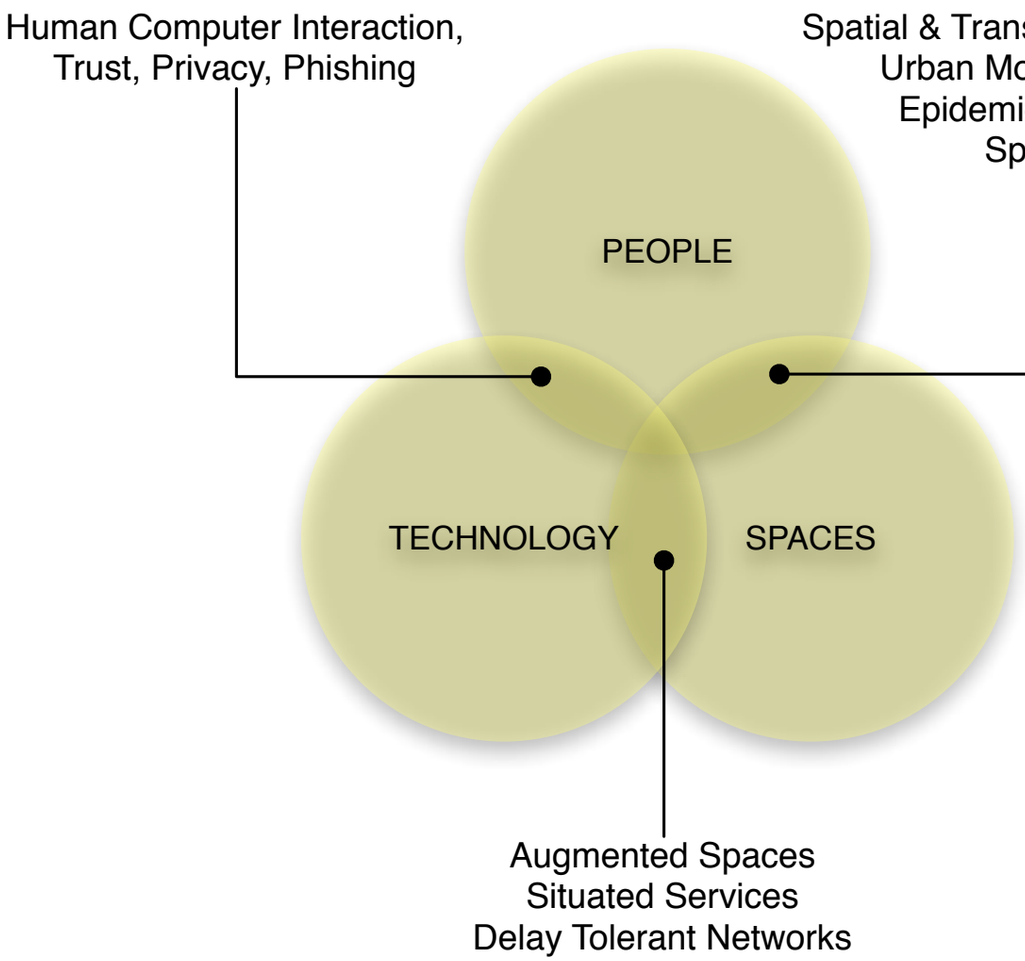
Department of **Computer Science and Engineering**

Tietotekniikan osasto

UNIVERSITY of OULU
OULUN YLIOPISTO

Impact

Ongoing work



Social and complex networks

Sensing for public transport

Security and privacy

Instrumenting mobile platforms

Public interactive displays

Outline

- Overview of infrastructure
- Sensing/contacting bus passengers
- Multimodal traffic sensing
- Associating across multiple datasets

Research infrastructure

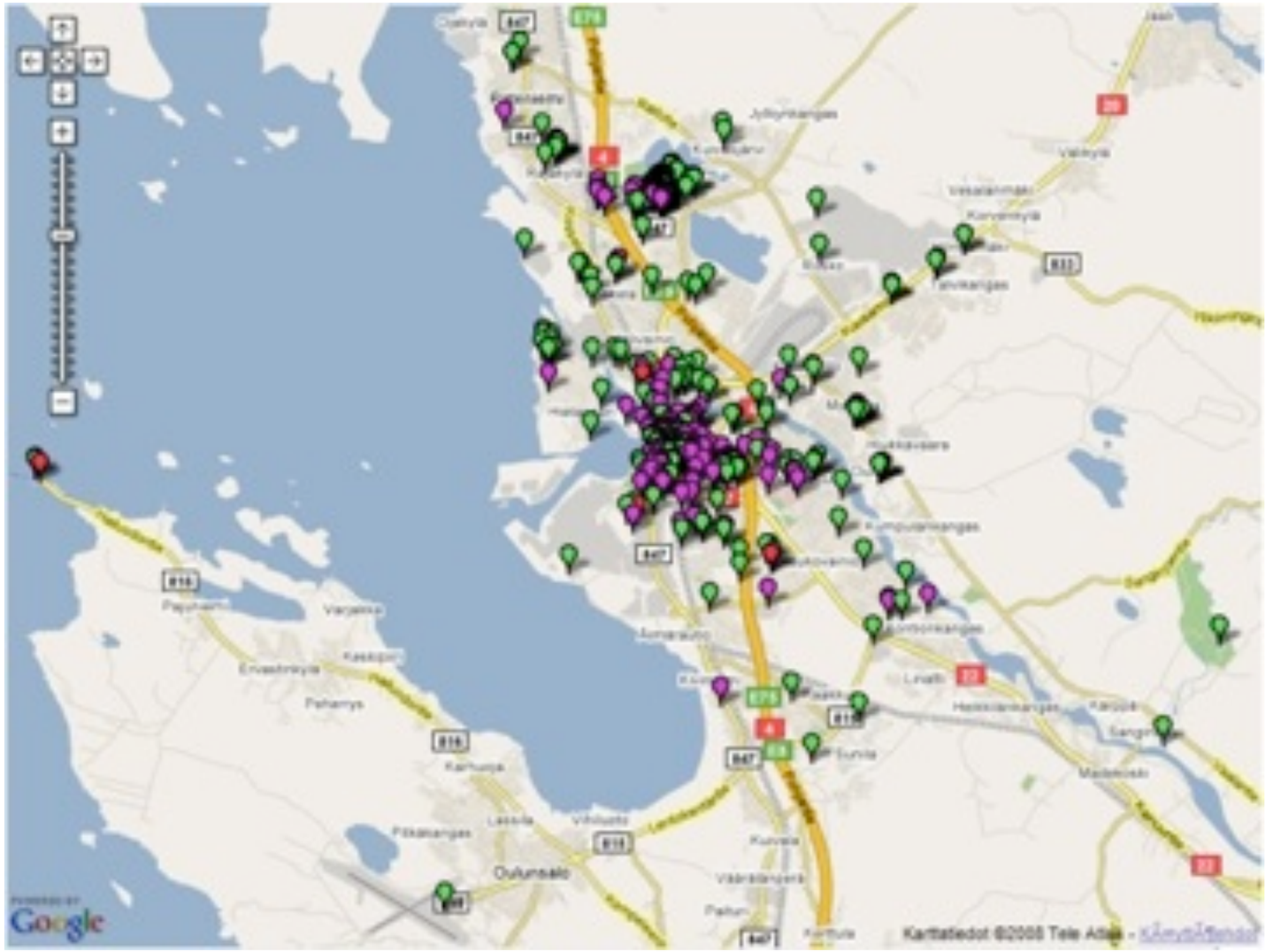

Main Library
Toripolliisi
Valve
Oulu10
Rotuaari N
Rotuaari W
Rotuaari C
Rotuaari E
Rotuaari S
Science Centre Tietomaa
Oulu Swimming Hall
Ouluhalli Sports Hall
Outdoor hotspot
Indoor hotspot

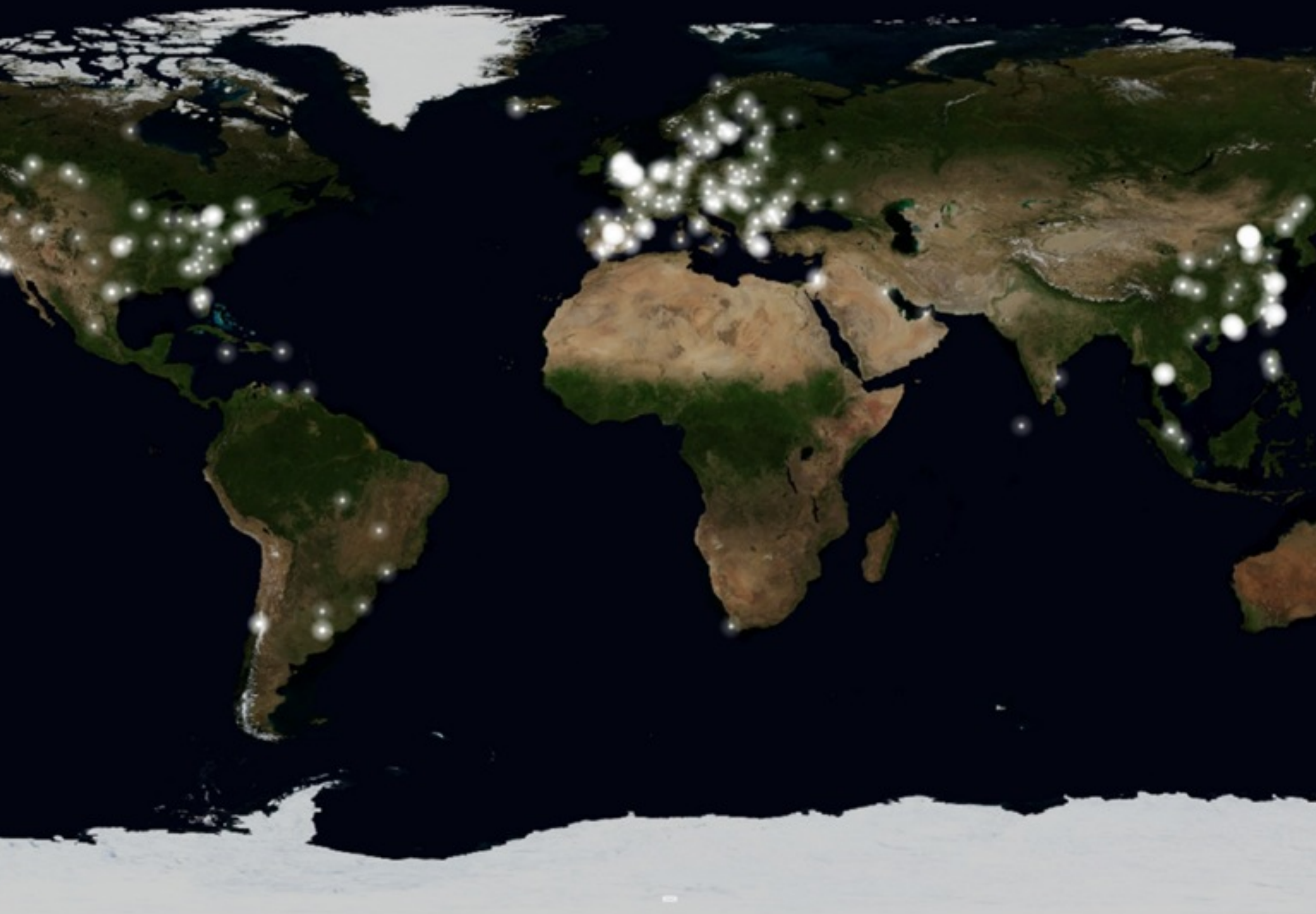

Cameras
57" Full HD LCD panel
6 mm safety glass with capacitive touch screen foil
NFC/RFID reader
panOULU WLAN AP
panOULU WSN AP
panOULU BT AP
Control PC
Loudspeaker
500 GB RAID 1 disk

Interface


Check our partners services!
Katso Oulun asunto-tarjonta ETUOVI.COM
Etuovi.com
Browse apartments for sale in Oulu.
Veripalvelu
Read about Finland's Red Cross' Blood Service and learn how to donate blood.
WWF-yleiskuvaus
Please donate to WWF Finland.
Oulun seudun Ammattikorkeakoulu
Learn about studies at the Oulu University of Applied Sciences.
UBI Hotspot services
Select the service You wish to use
Categories
News
Services
City
3rd Party
Fun & Games
Multimedia
Help & Survey
New cool stuff
Cityguide
Make a video call to the tourist office and get information about Oulu
Restaurants
Browse the restaurants in the downtown area of Oulu
Event Calendar
Browse future events and download event information to your mobile device
Rotuaari Renovation
Learn about the renovation process of Rotuaari
Ilo asuu ipanassa
Service Directory
City of Oulu
login

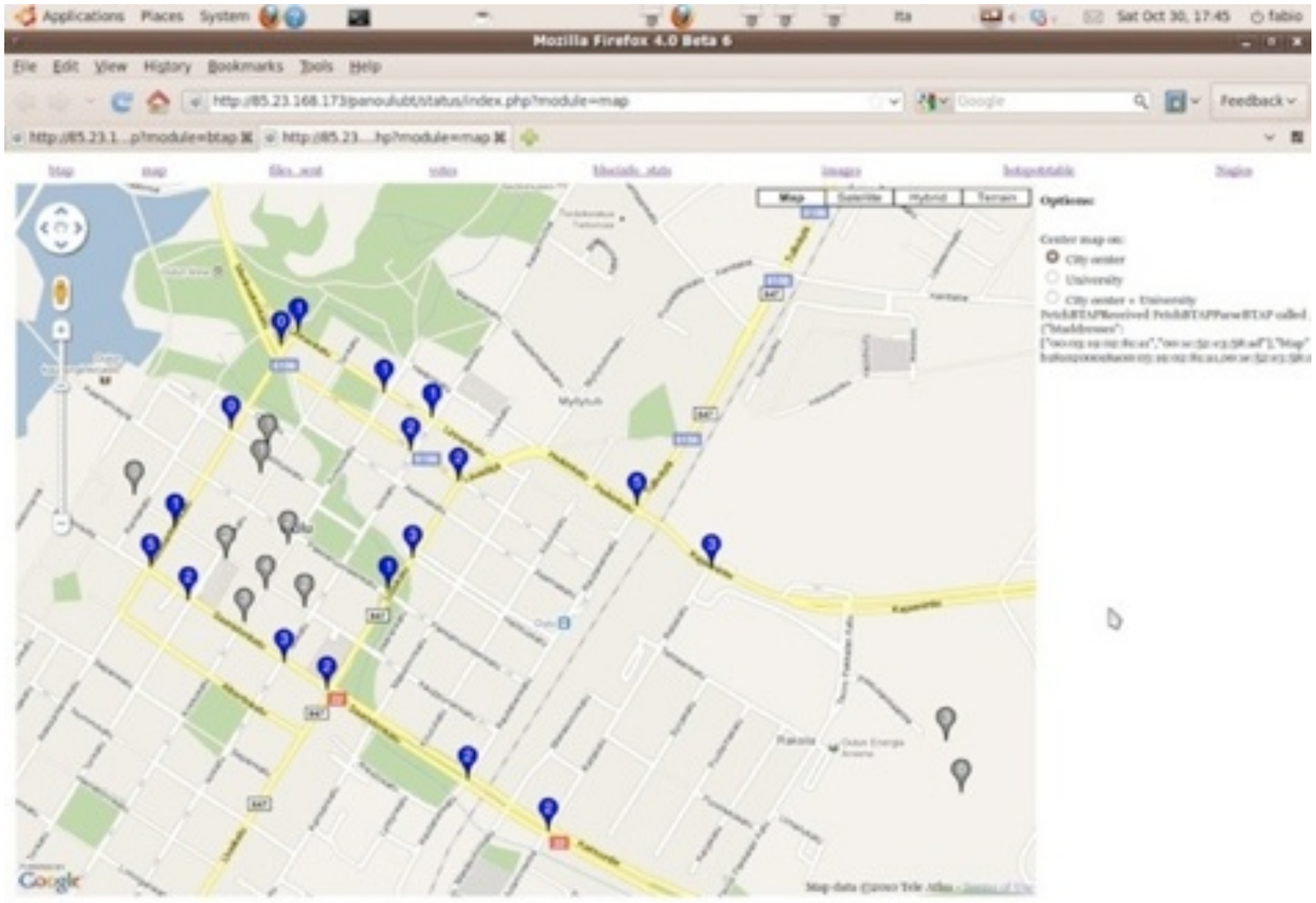
panOulu WiFi





Thursday, March 29, 12

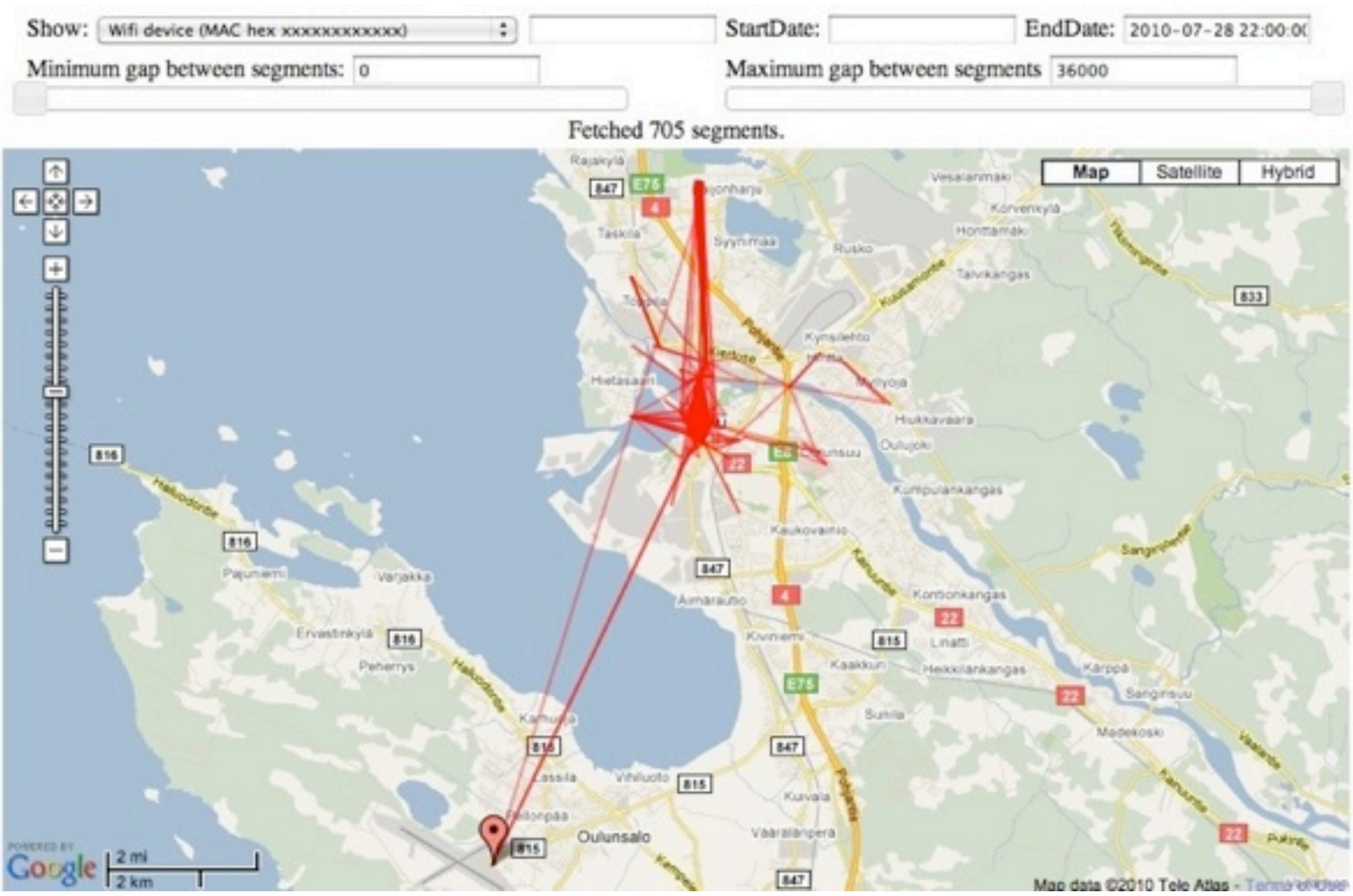
Bluetooth network



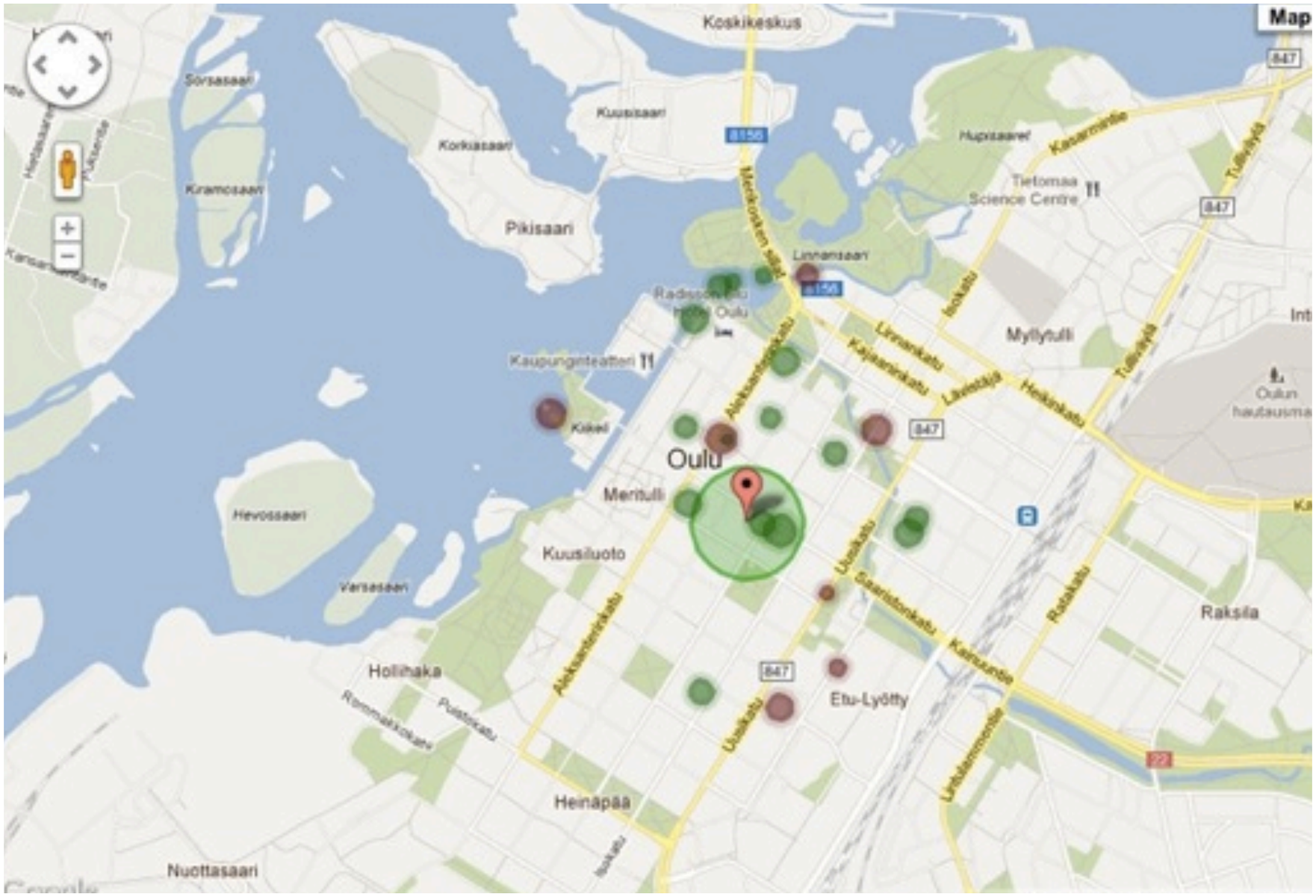
3D Oulu

Which half is real?

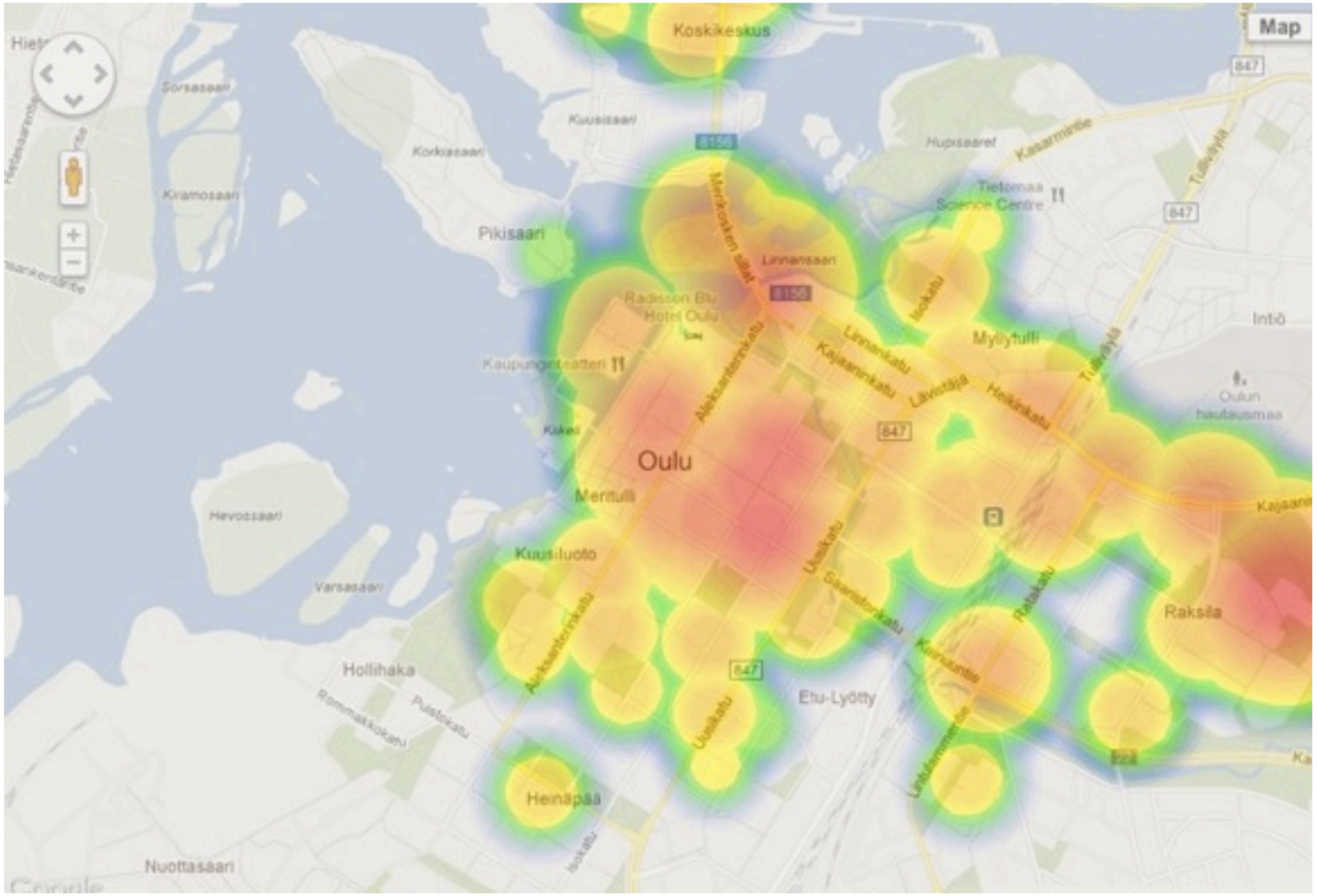
Reconstructing movement



Catchment areas



Where is it busy now?

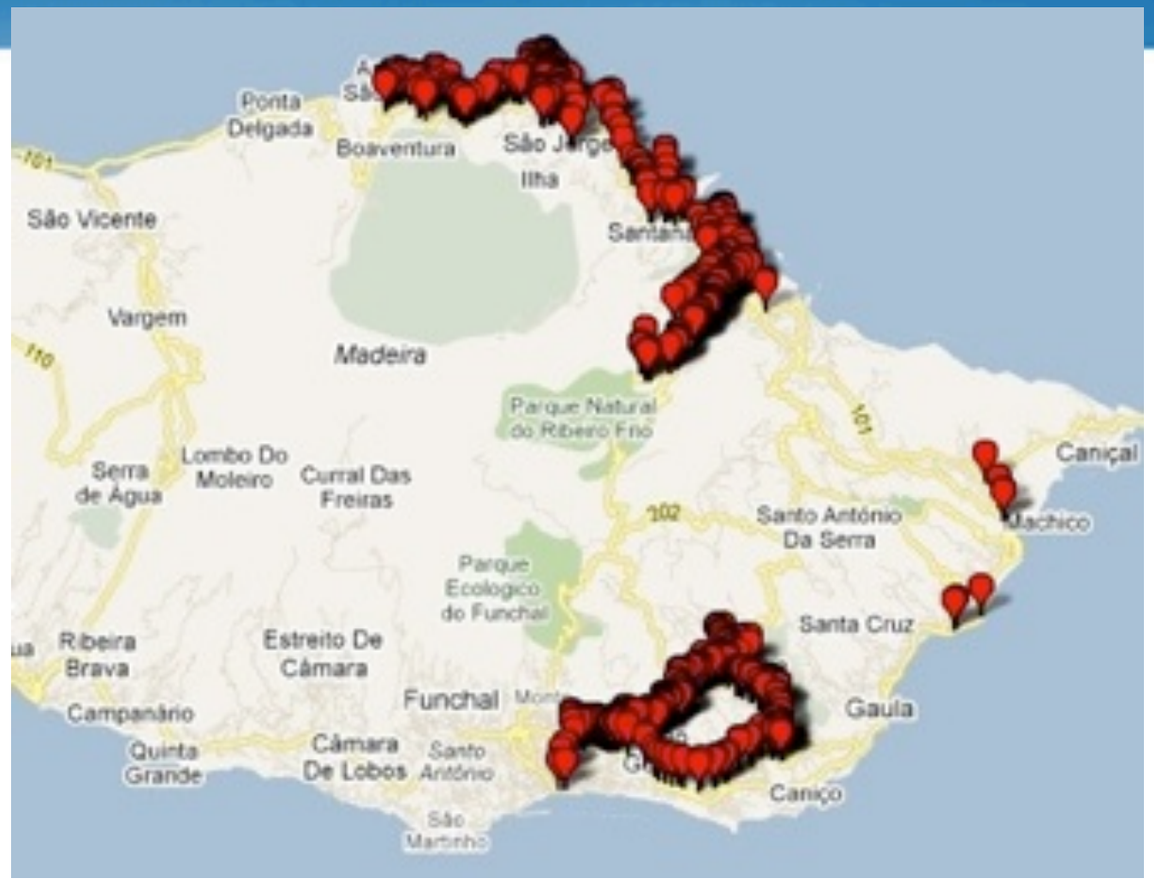


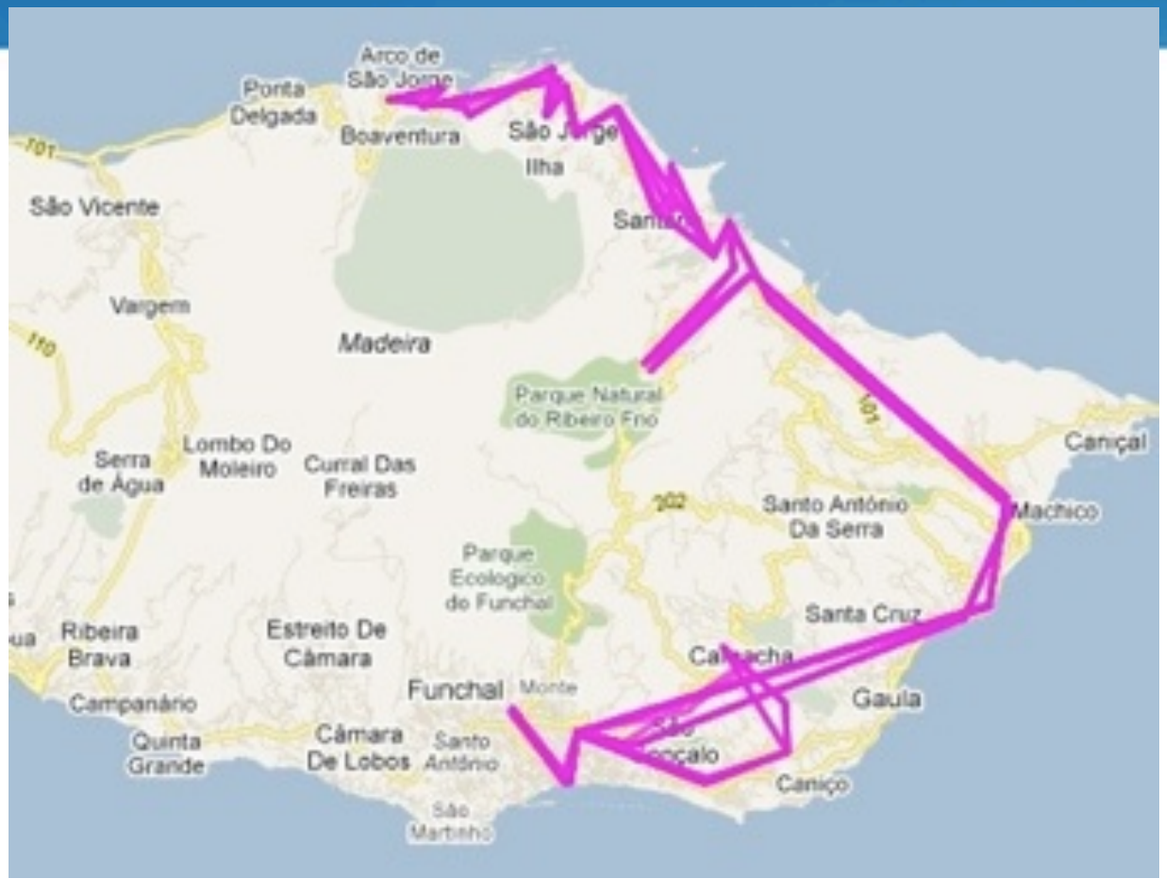
Live demo?

Click and pray!

Intelligent sensing for public transport

Kostakos, V., Camacho, T. and Mantero, C. (2010). Wireless detection of end-to-end passenger trips on public transport buses. **IEEE Conference on Intelligent Transportation Systems**, pp. 1795-1800.


Ponta Delgada
Boaventura
São Jorge
Ilha
São Vicente
Vargem
Madeira
Parque Natural do Ribeiro Frio
Serra de Água
Lombo Do Moleiro
Curral Das Freiras
Caniçal
Machico
Santo António Da Serra
Parque Ecologico do Funchal
Santa Cruz
Ribeira Brava
Estreito De Câmara
Funchal
Gaula
Campanário
Quinta Grande
Câmara De Lobos
Santo António
Caniço
São Martinho


Arco de São Jorge
Ponta Delgada
Boaventura
São Jorge
Ilha
São Vicente
Vargem
Madeira
Parque Natural do Ribeiro Frio
Serra de Água
Lombo Do Moleiro
Curral Das Freiras
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Machico
Santo António Da Serra
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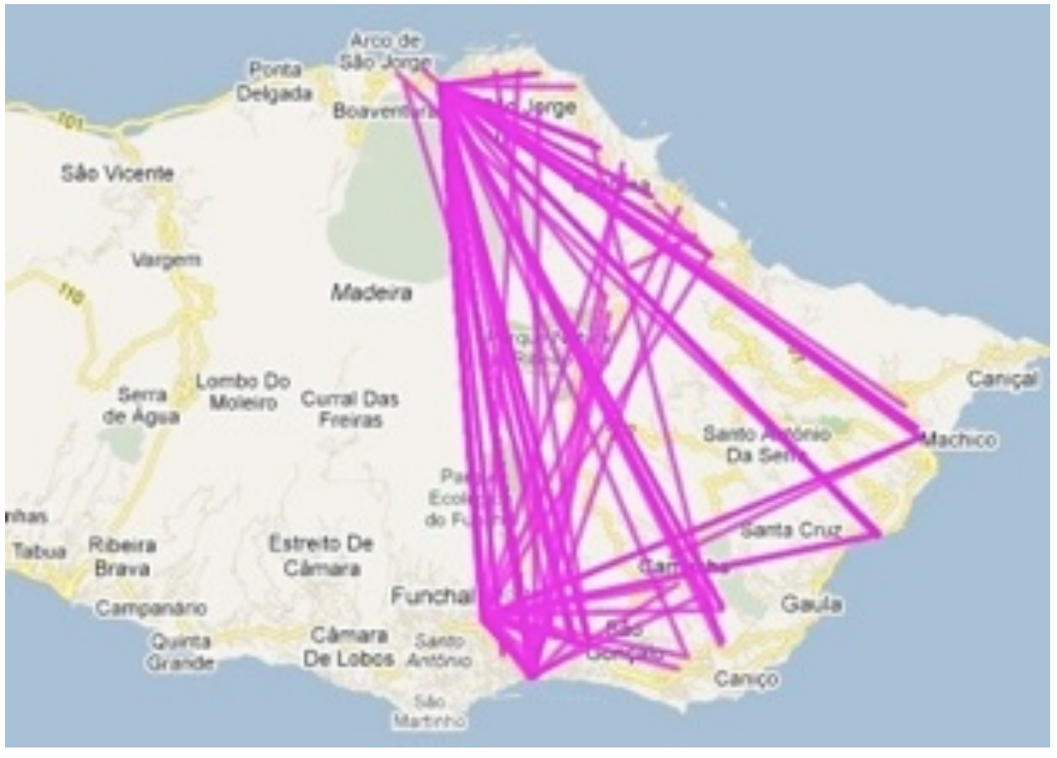
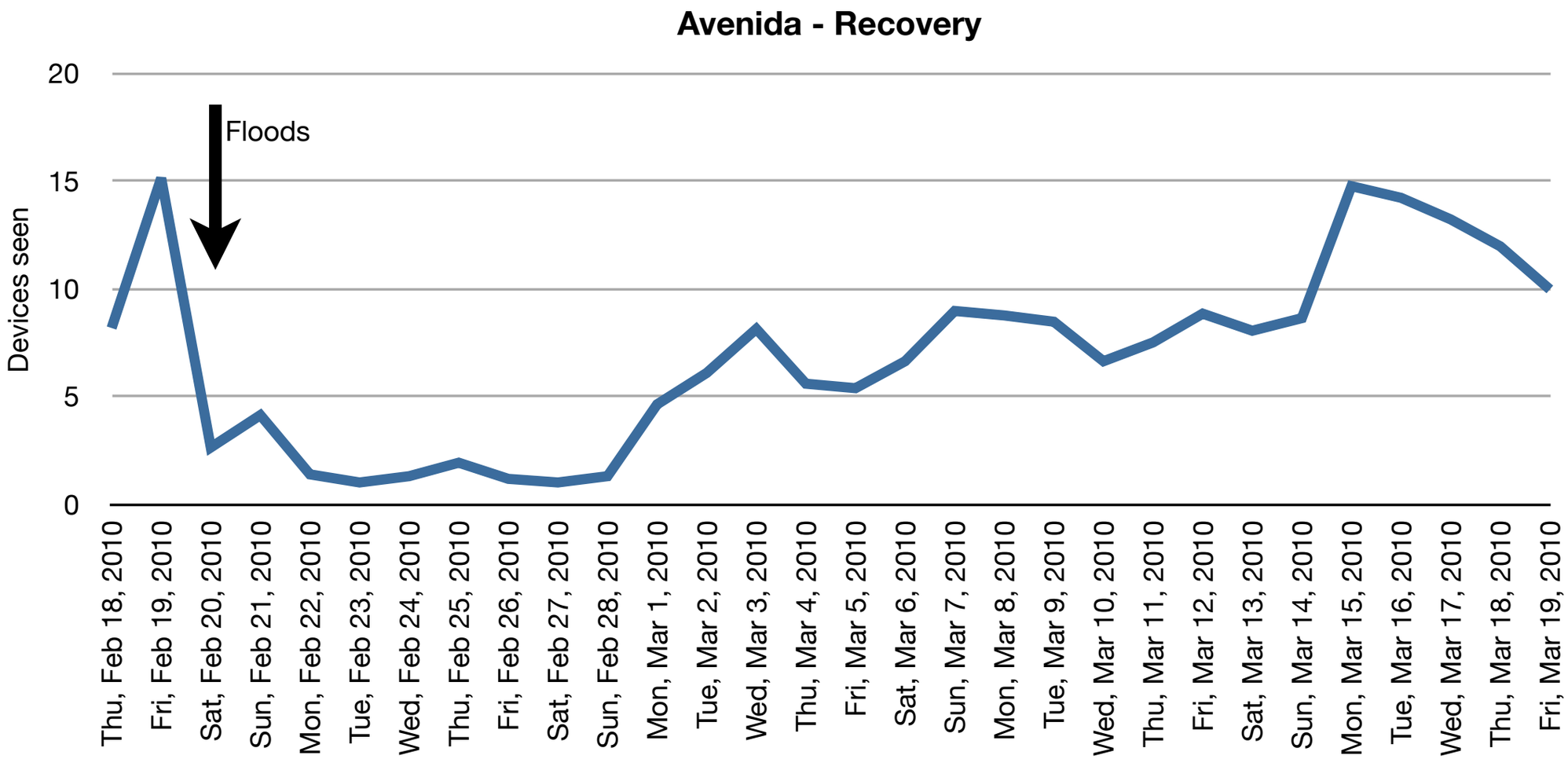
Santa Cruz
Ribeira Brava
Estreito De Câmara
Funchal
Gaula
Campanário
Quinta Grande
Câmara De Lobos
Santo António
Caniço
São Martinho


Arco de São Jorge
Ponta Delgada
São Vicente
Vargem
Madeira
Serra de Água
Lombo Do Moleiro
Curral Das Freiras
Caniçal
Machico
Santo António Da Serra
Santa Cruz
Tabua
Ribeira Brava
Estreito De Câmara
Funchal
Gaula
Campanário
Quinta Grande
Câmara De Lobos
Santo António
Caniço
São Martinho

Thursday, March 29, 12

Thursday, March 29, 12

Thursday, March 29, 12

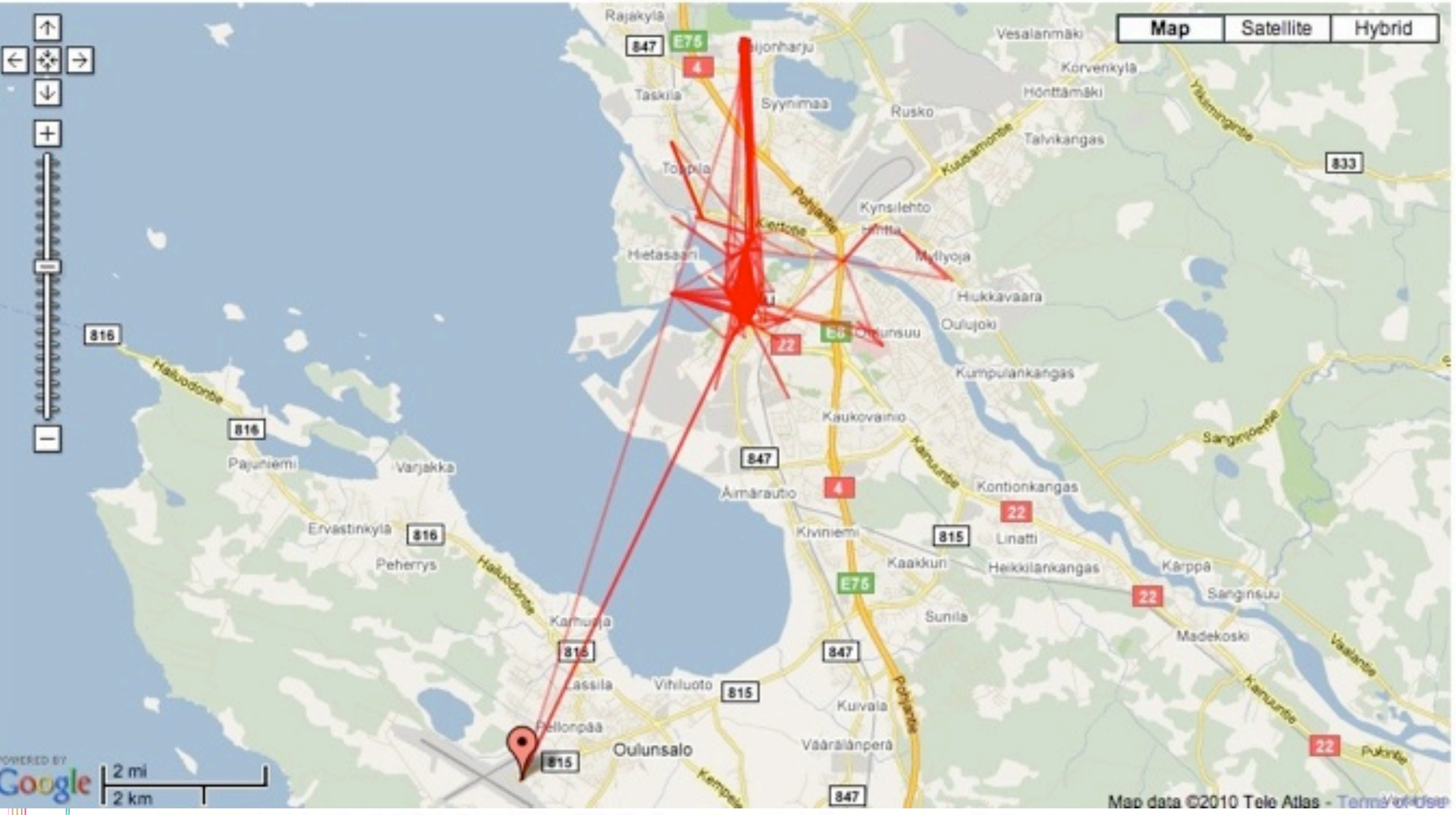


Camacho, T., Kostakos, V., and Mantero, C. (2010). A Wireless Infrastructure for Delivering Contextual Services and Studying Transport Behavior. **IEEE Conference on Intelligent Transportation Systems**, pp. 943-948.

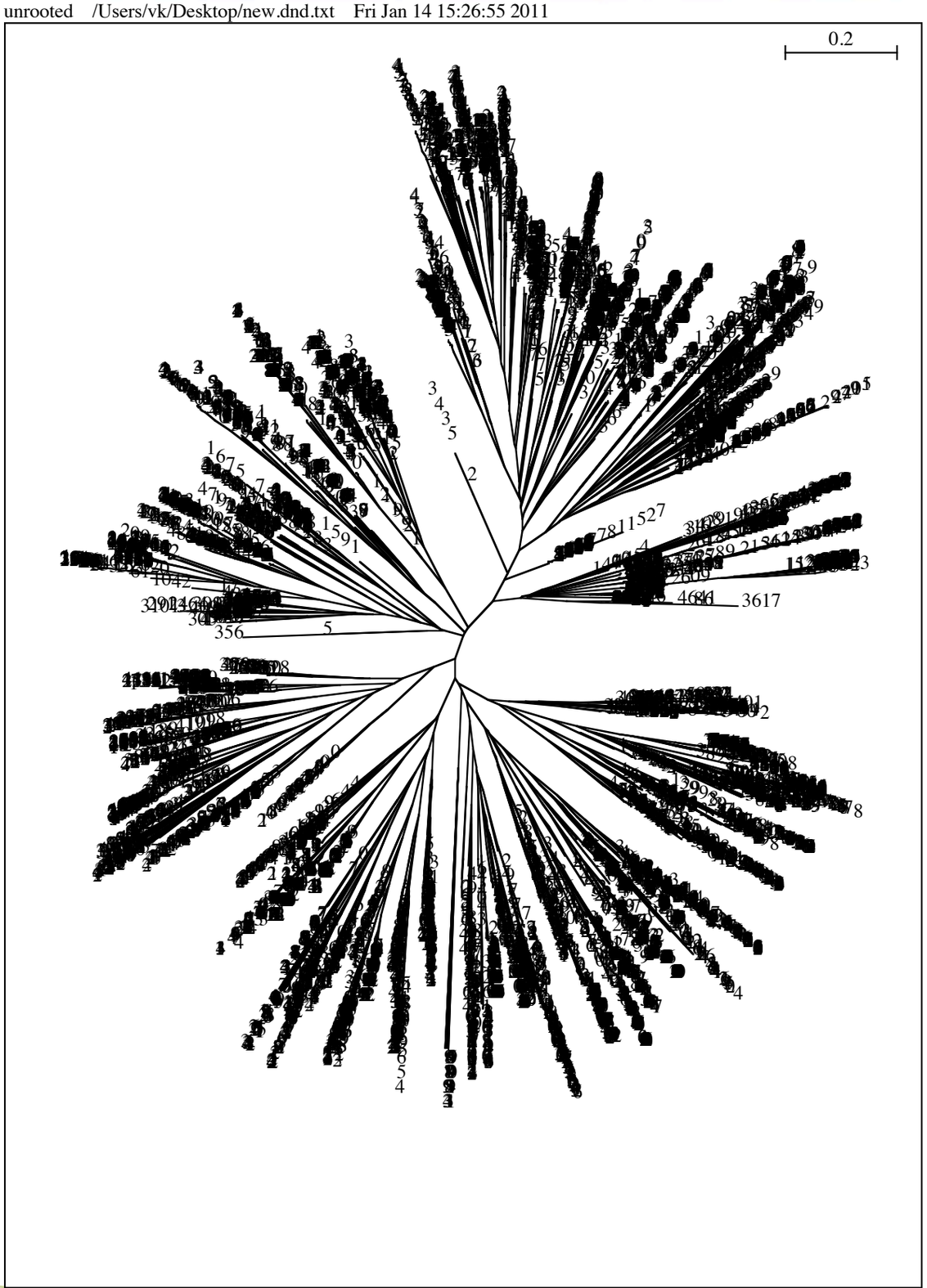
Show: Wifi device (MAC hex xxxxxxxxxxxx) StartDate: EndDate: 2010-07-28 22:00:0(

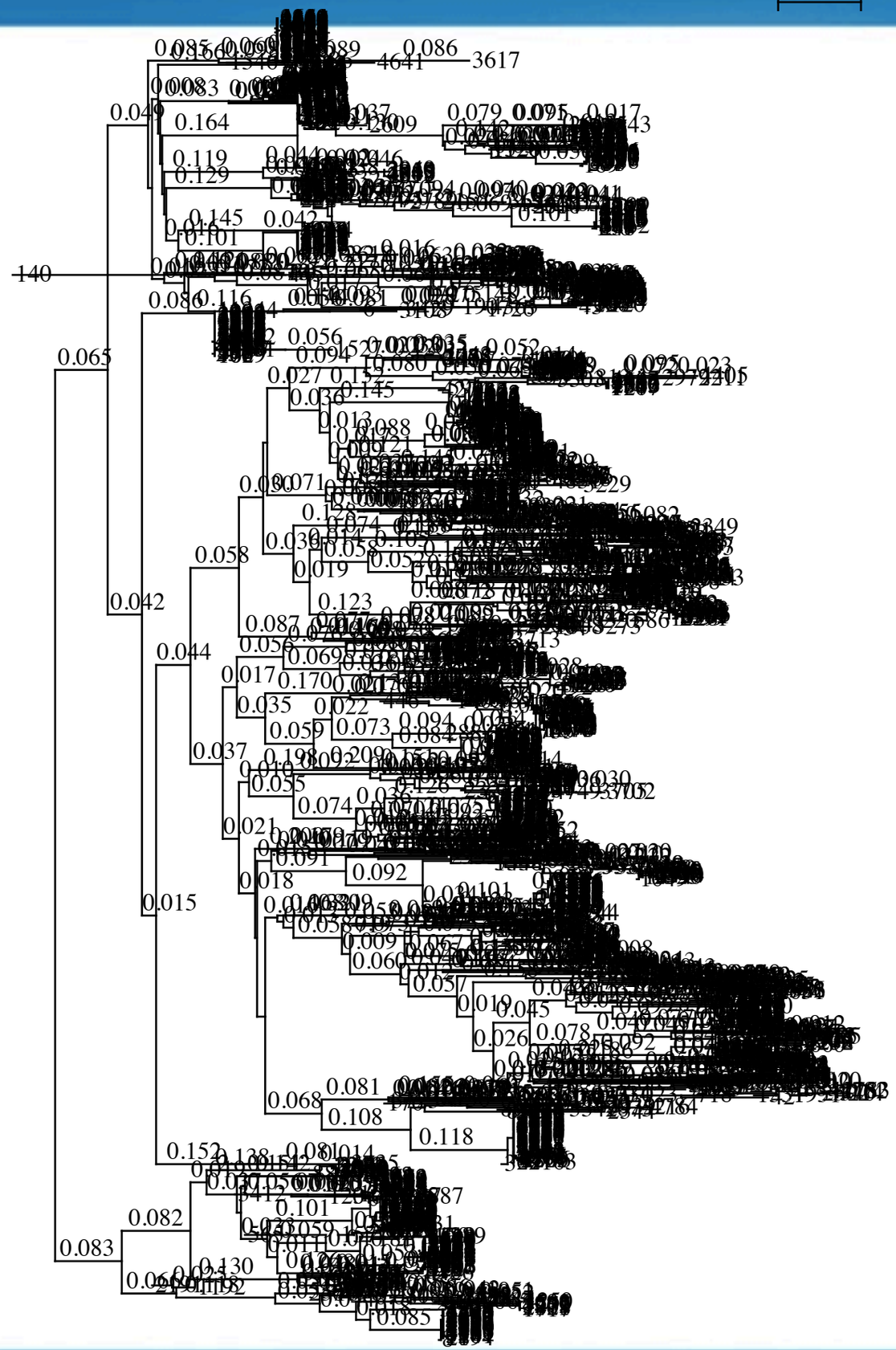
Minimum gap between segments: 0 Maximum gap between segments 36000

Fetched 705 segments.

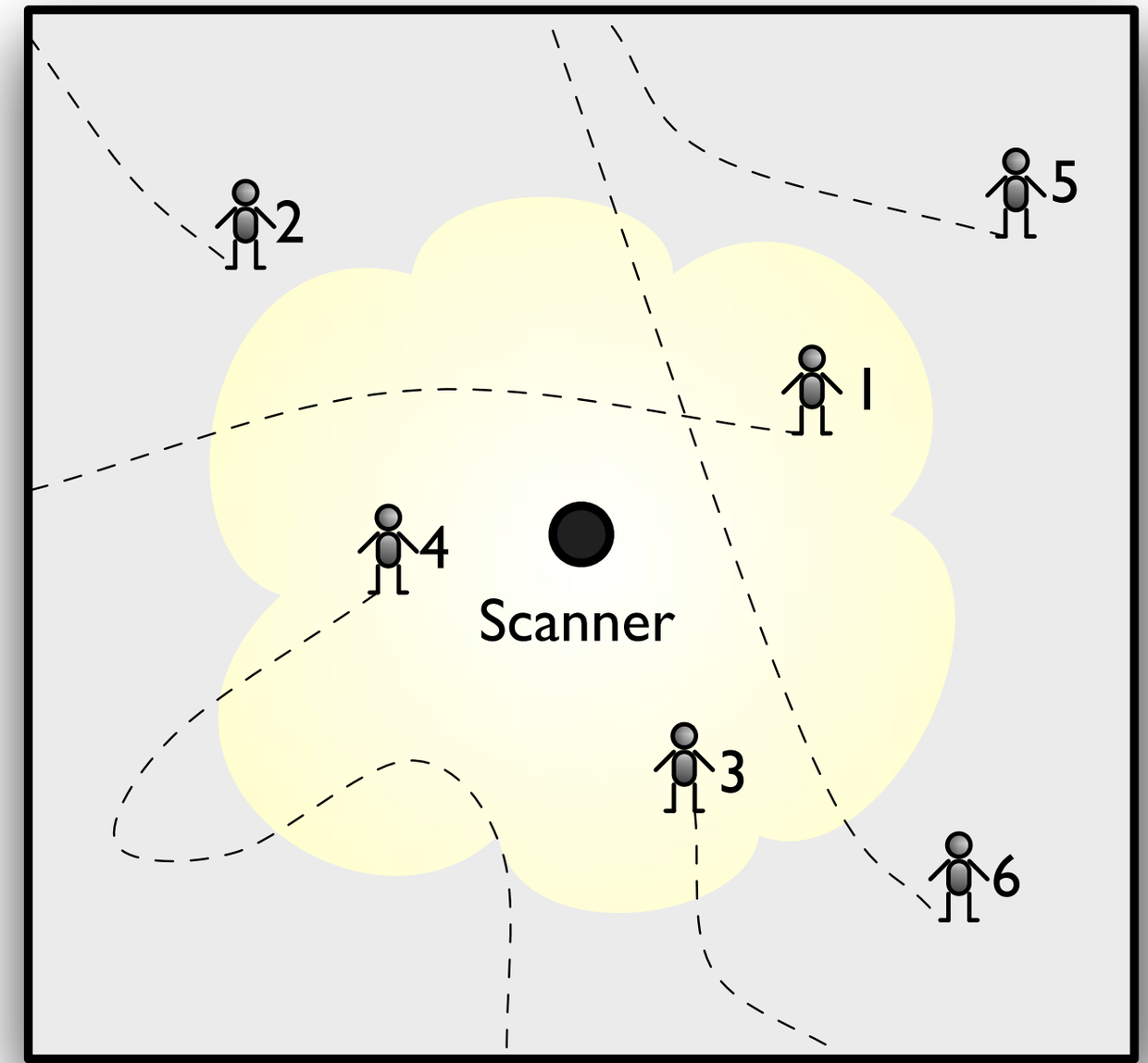


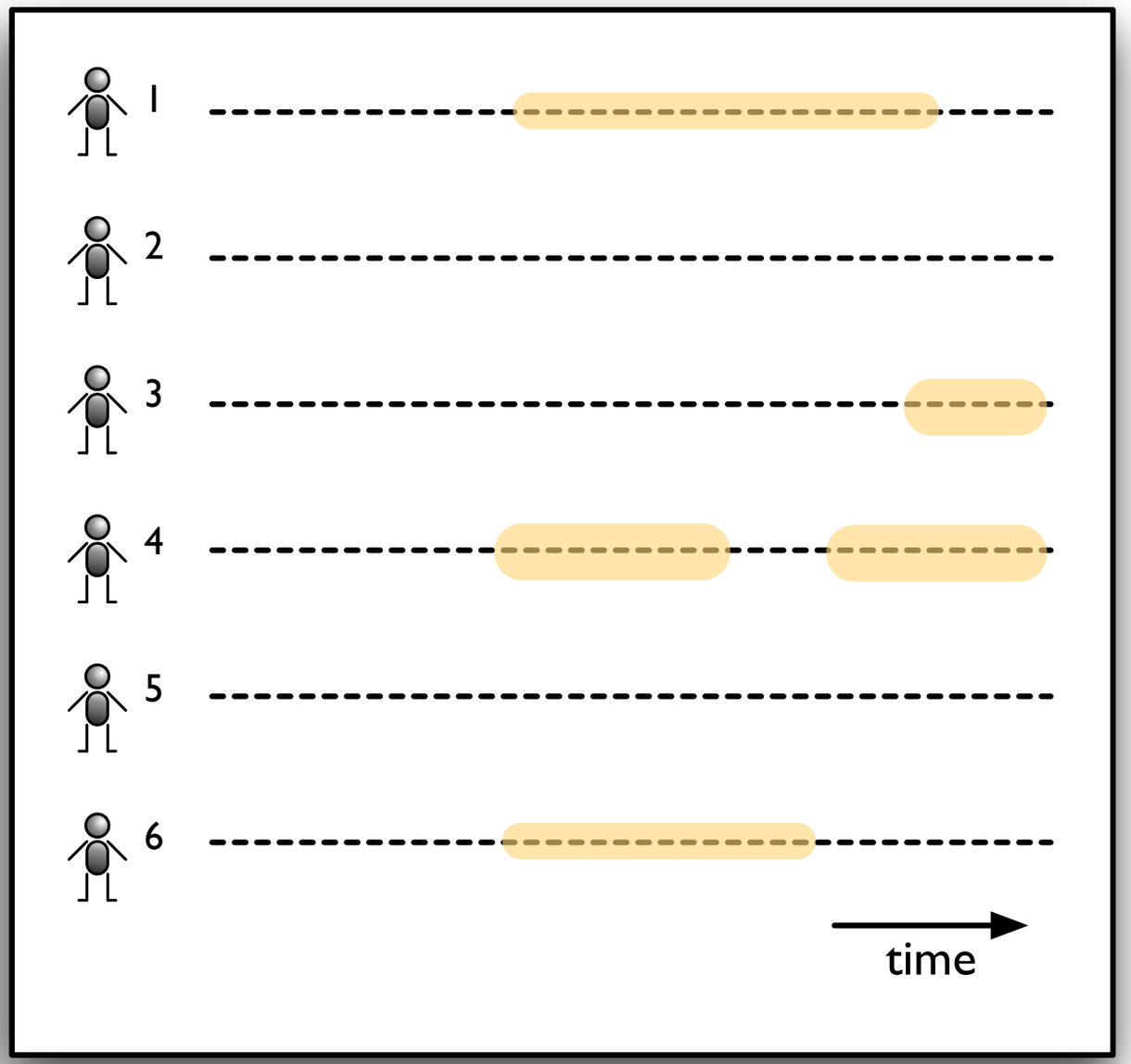
unrooted /Users/vk/Desktop/new.dnd.txt Fri Jan 14 15:26:55 2011

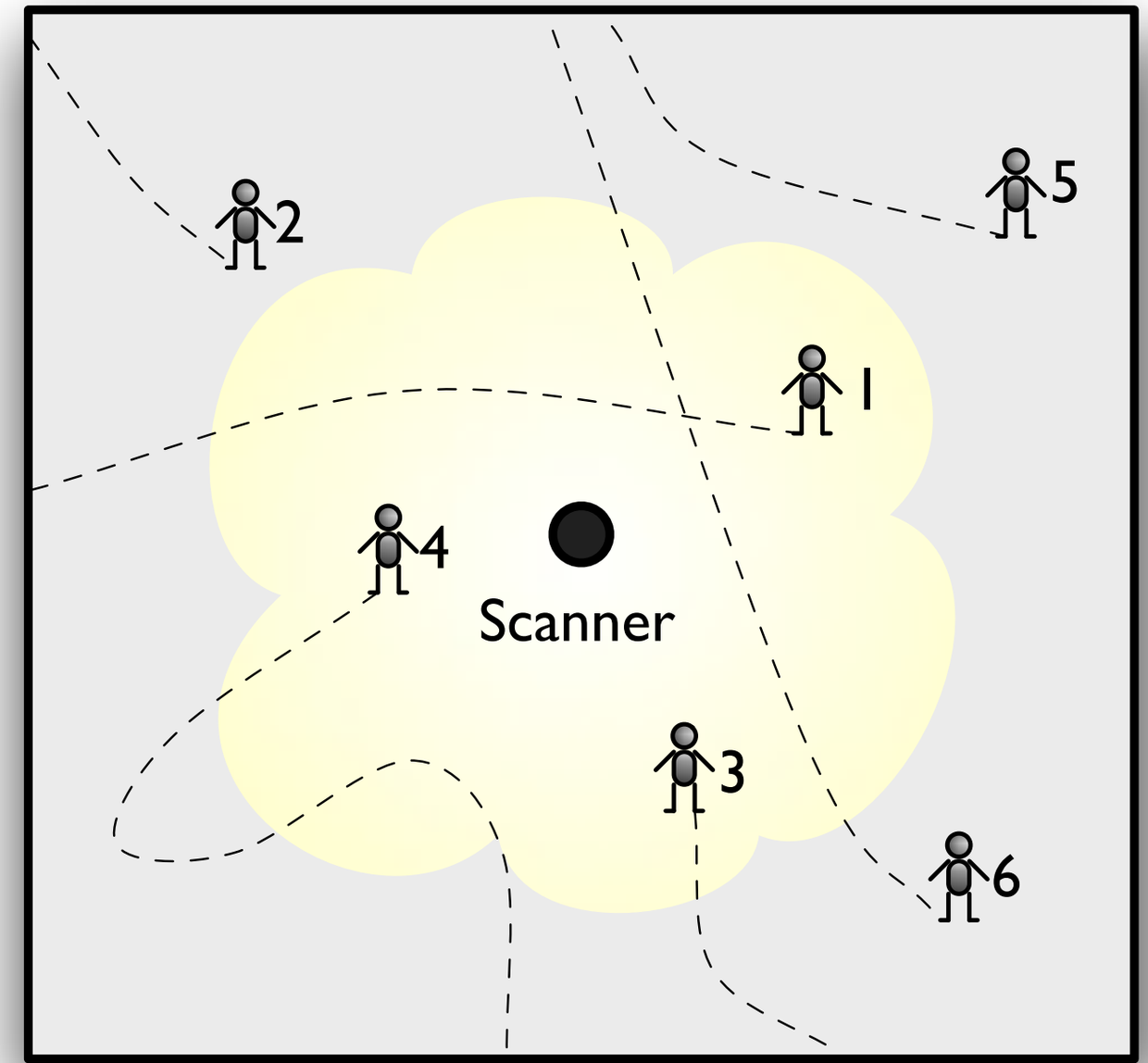


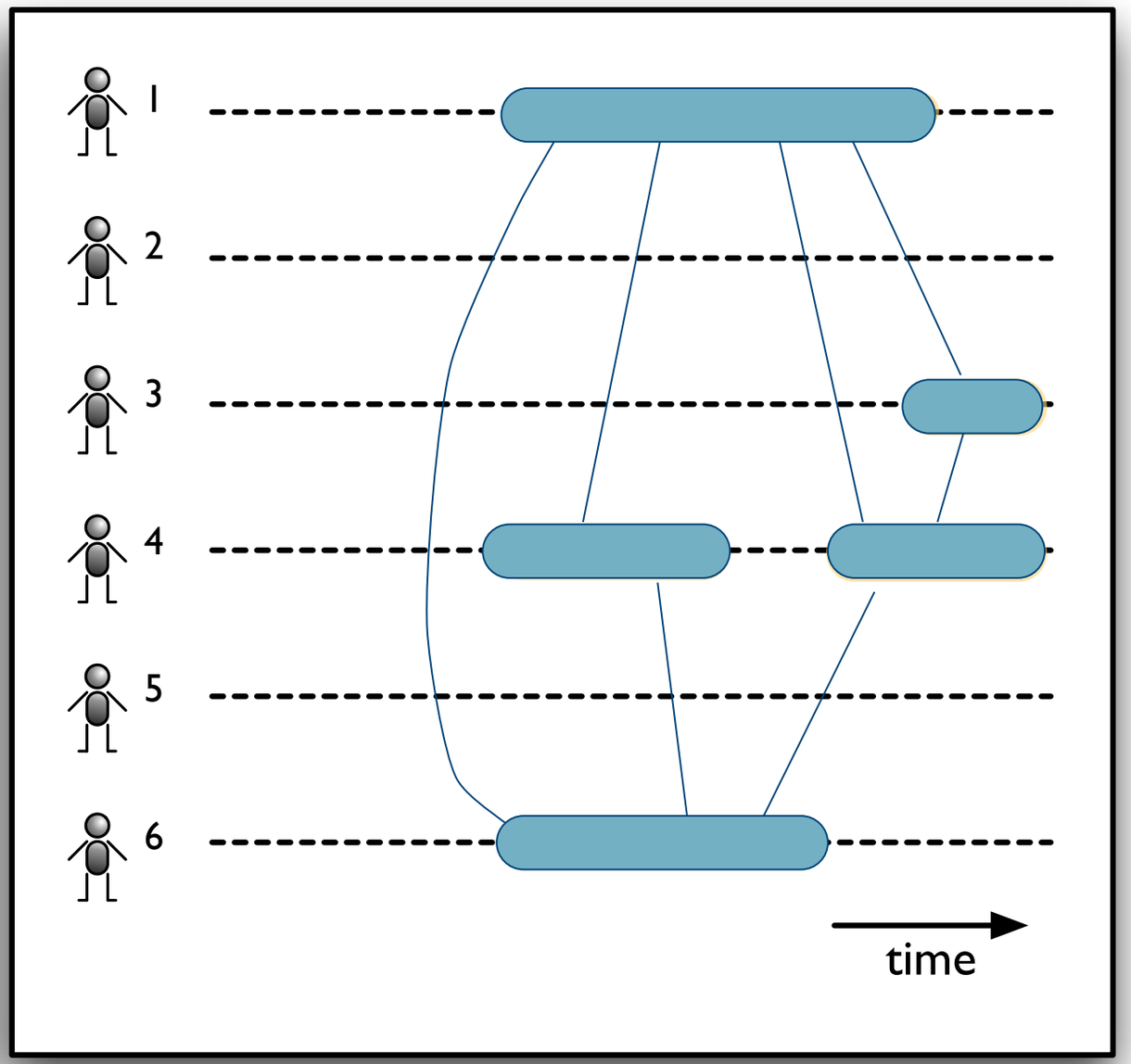


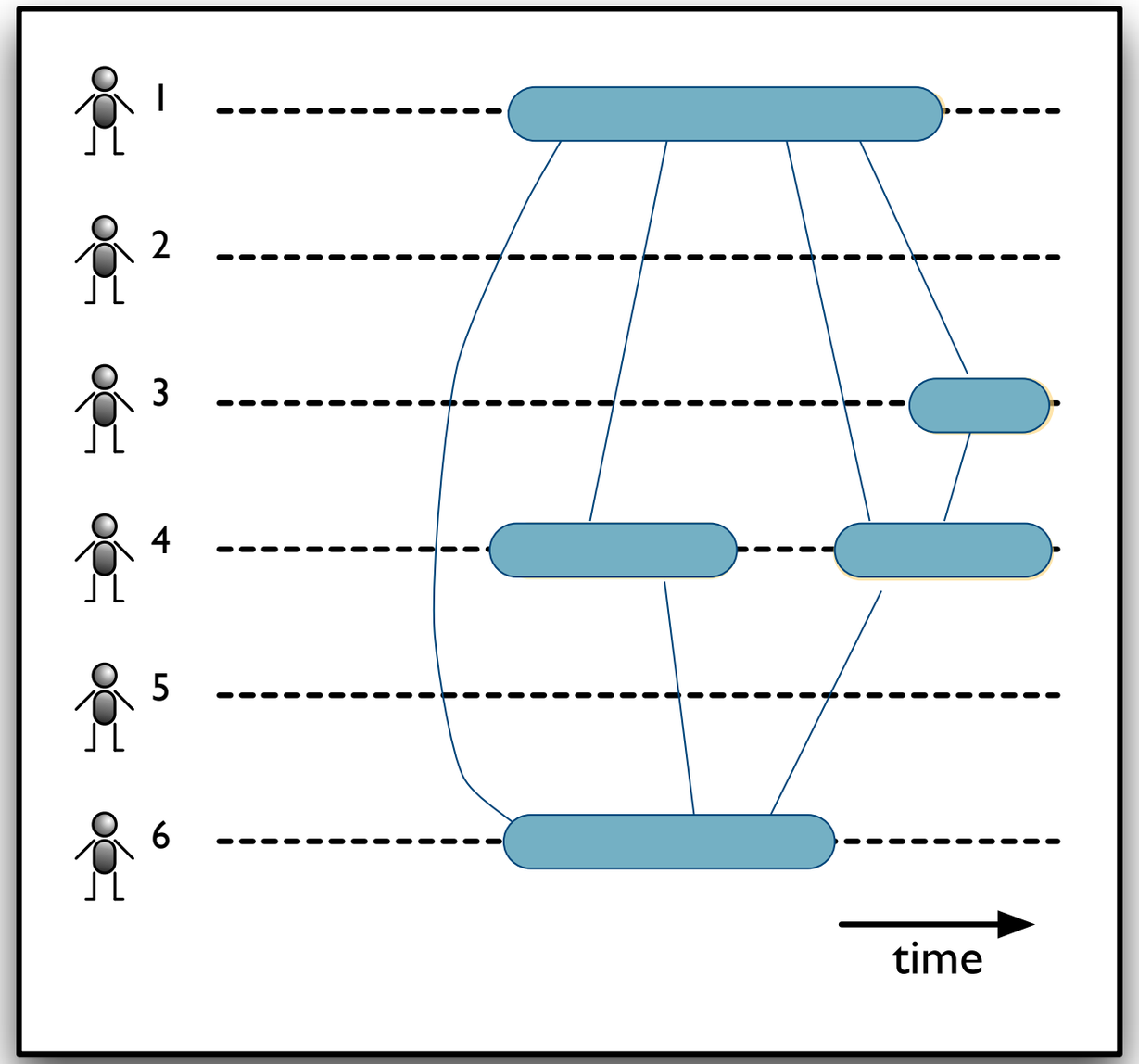
Urban social networks

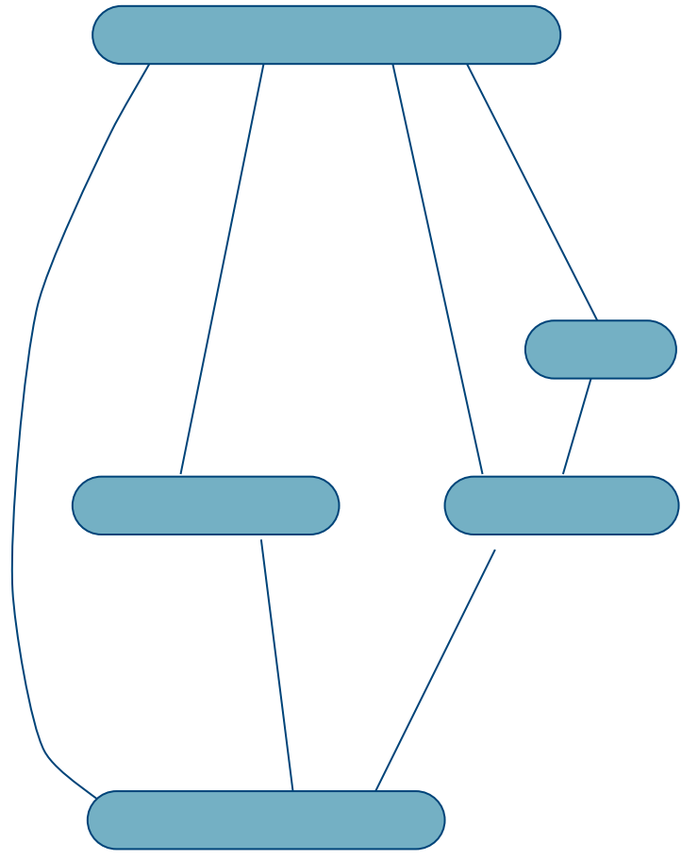


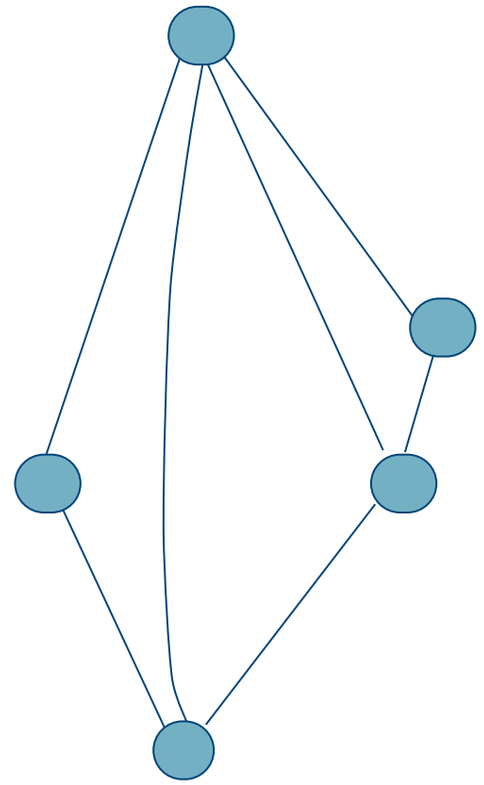


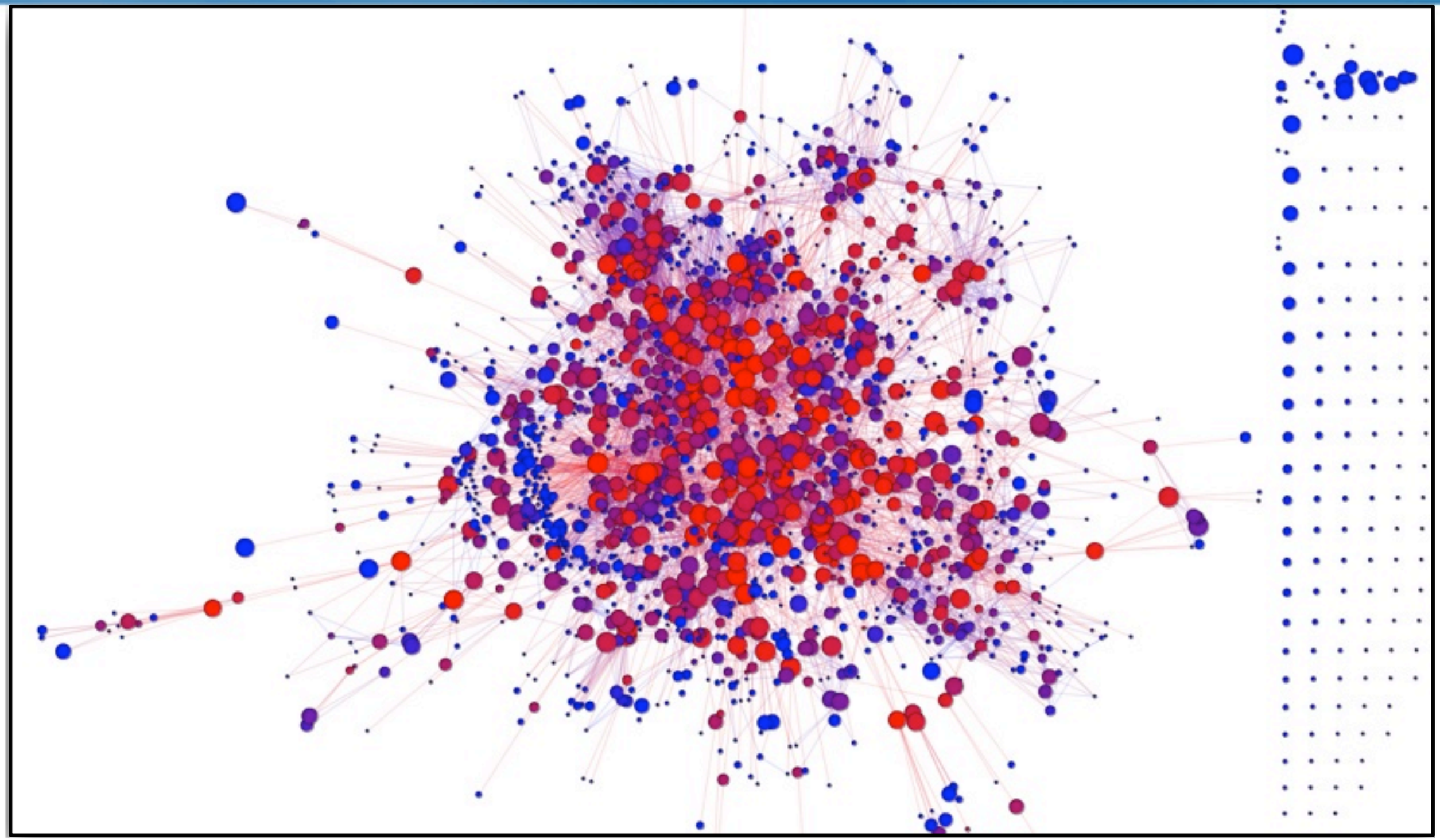

2
5
1
4
Scanner
3
6


1
2
3
4
5
6
time

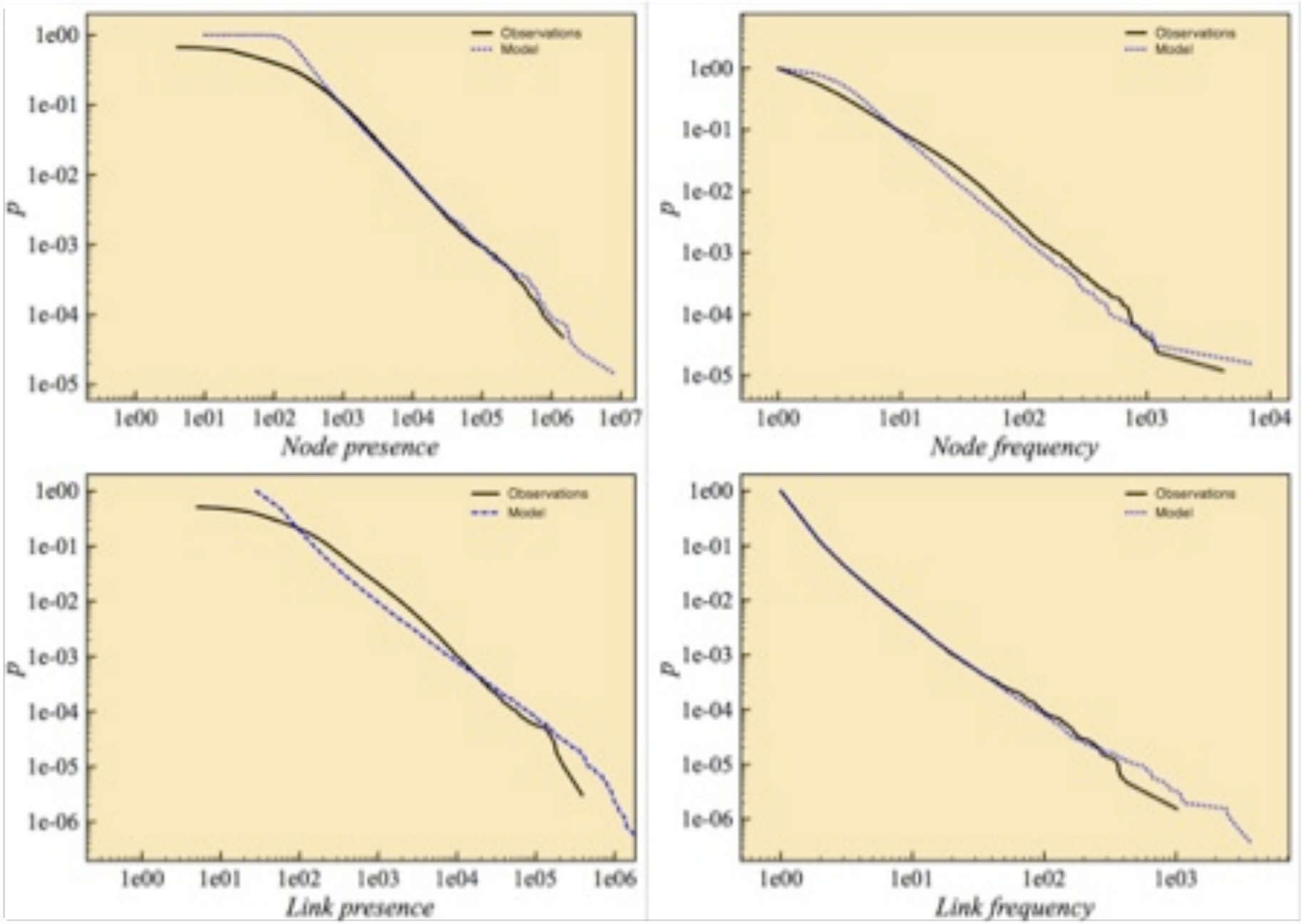

1
2
3
4
5
6
time





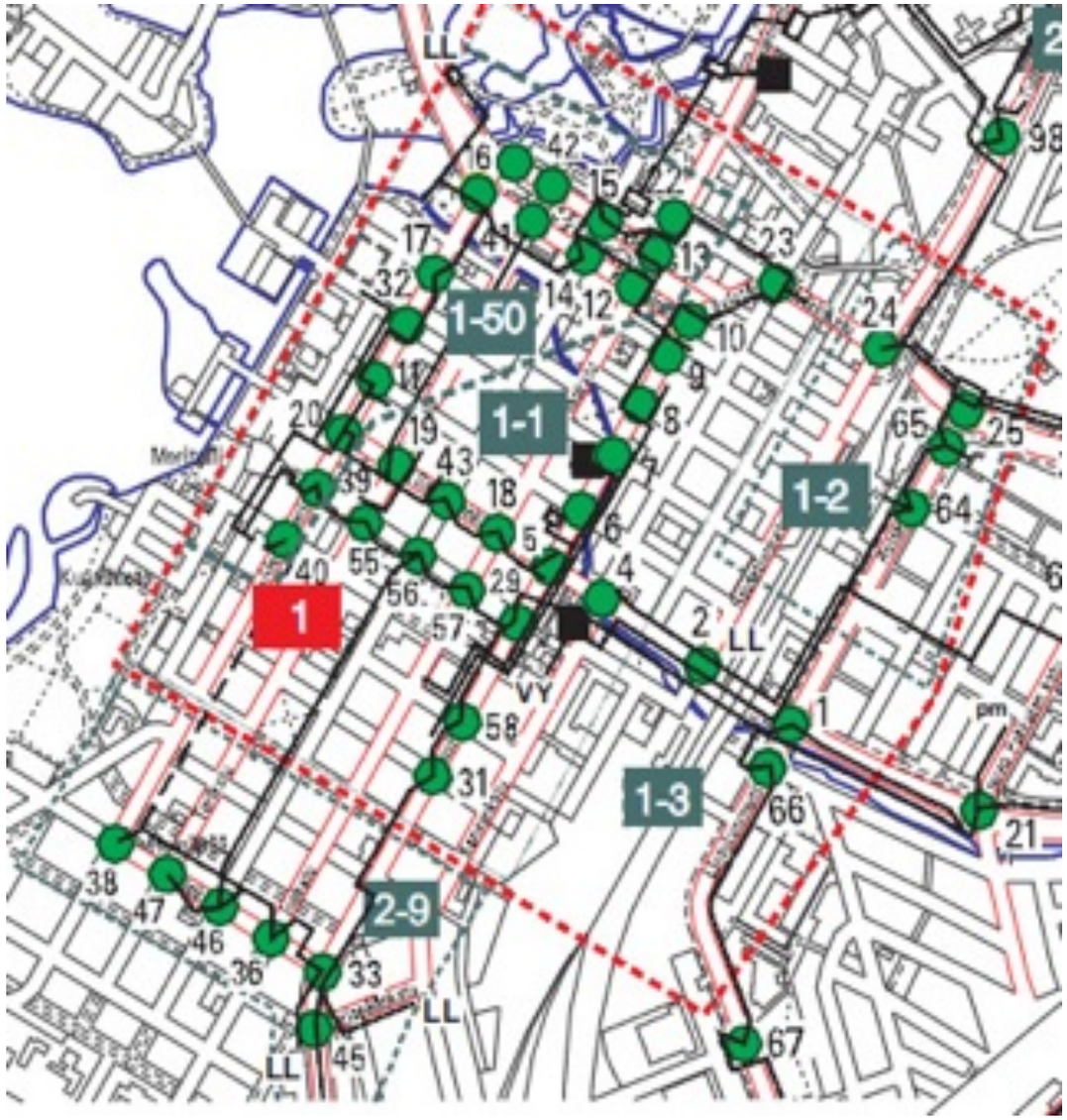


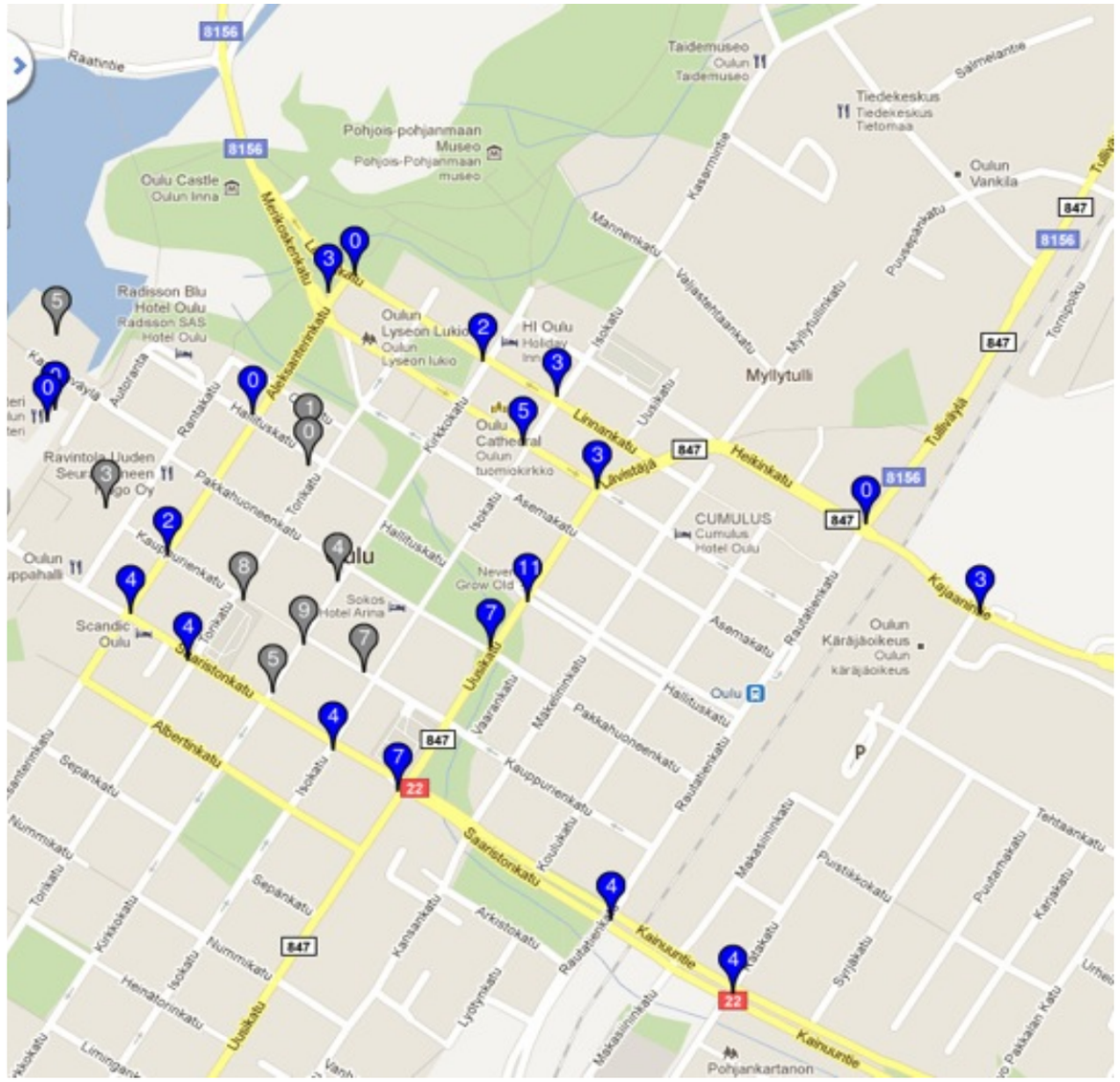
Kostakos, V., Nicolai, T., Yoneki, E., O'Neill, E., Kenn, H. and Crowcroft, J. (2009). Understanding and measuring the urban pervasive infrastructure. **Personal and Ubiquitous Computing**, 13(5):355-364.

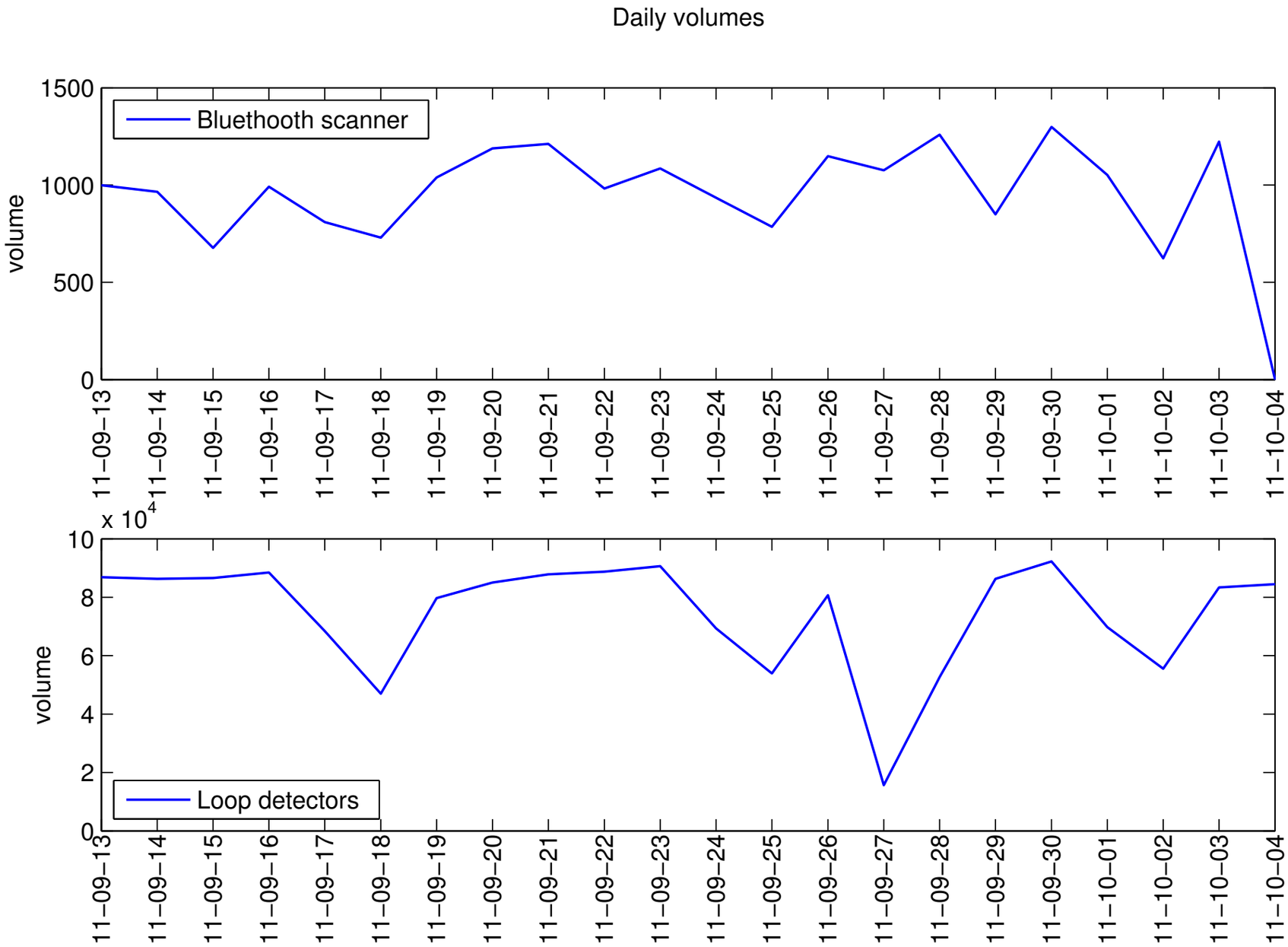


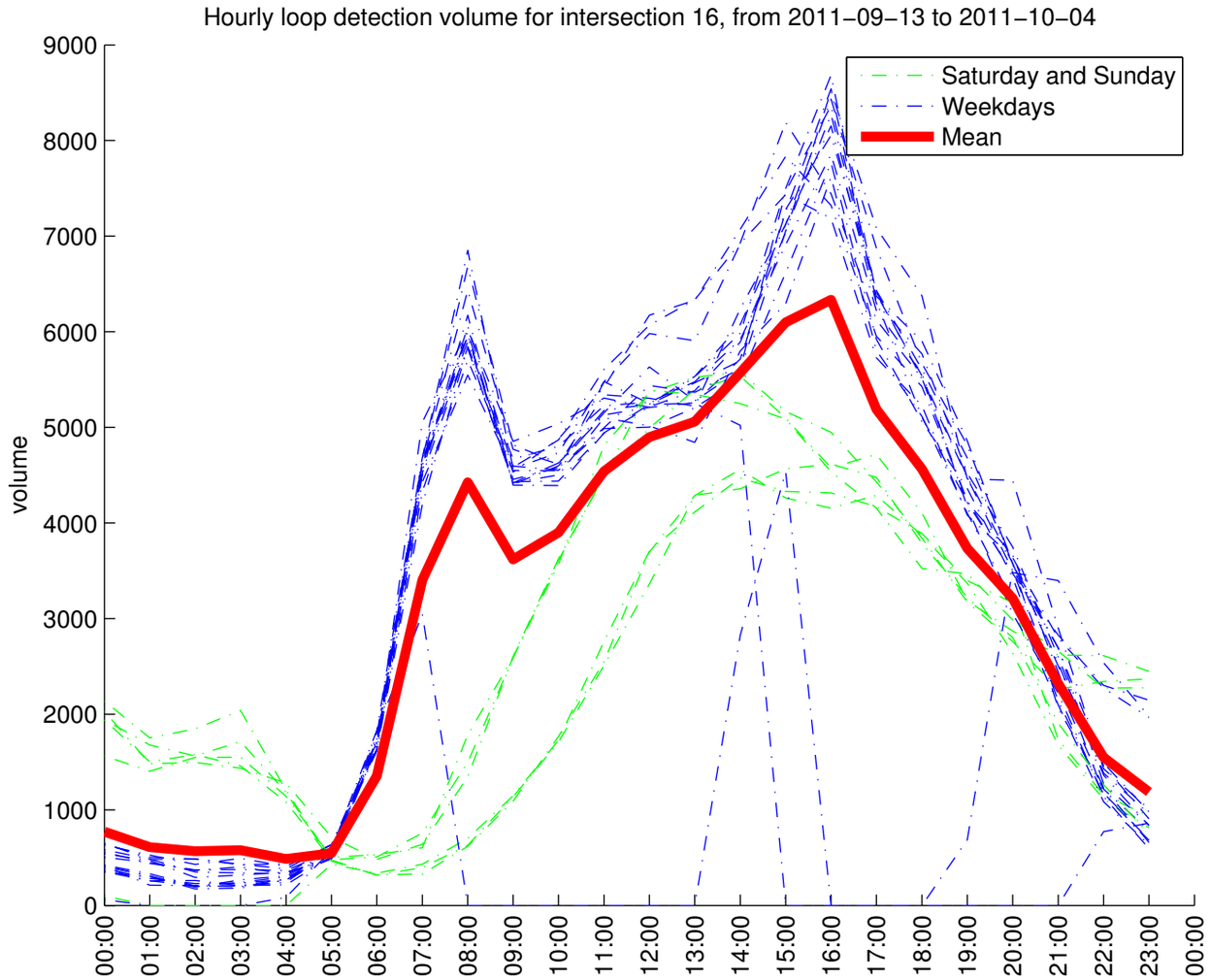
Kostakos, V., O'Neill, E., Penn, A., Roussos, G., Papadongonas, D. (2010). Brief encounters: sensing, modelling and visualizing urban mobility and copresence networks. **Transactions on Computer Human Interaction,** 17(1):1-38

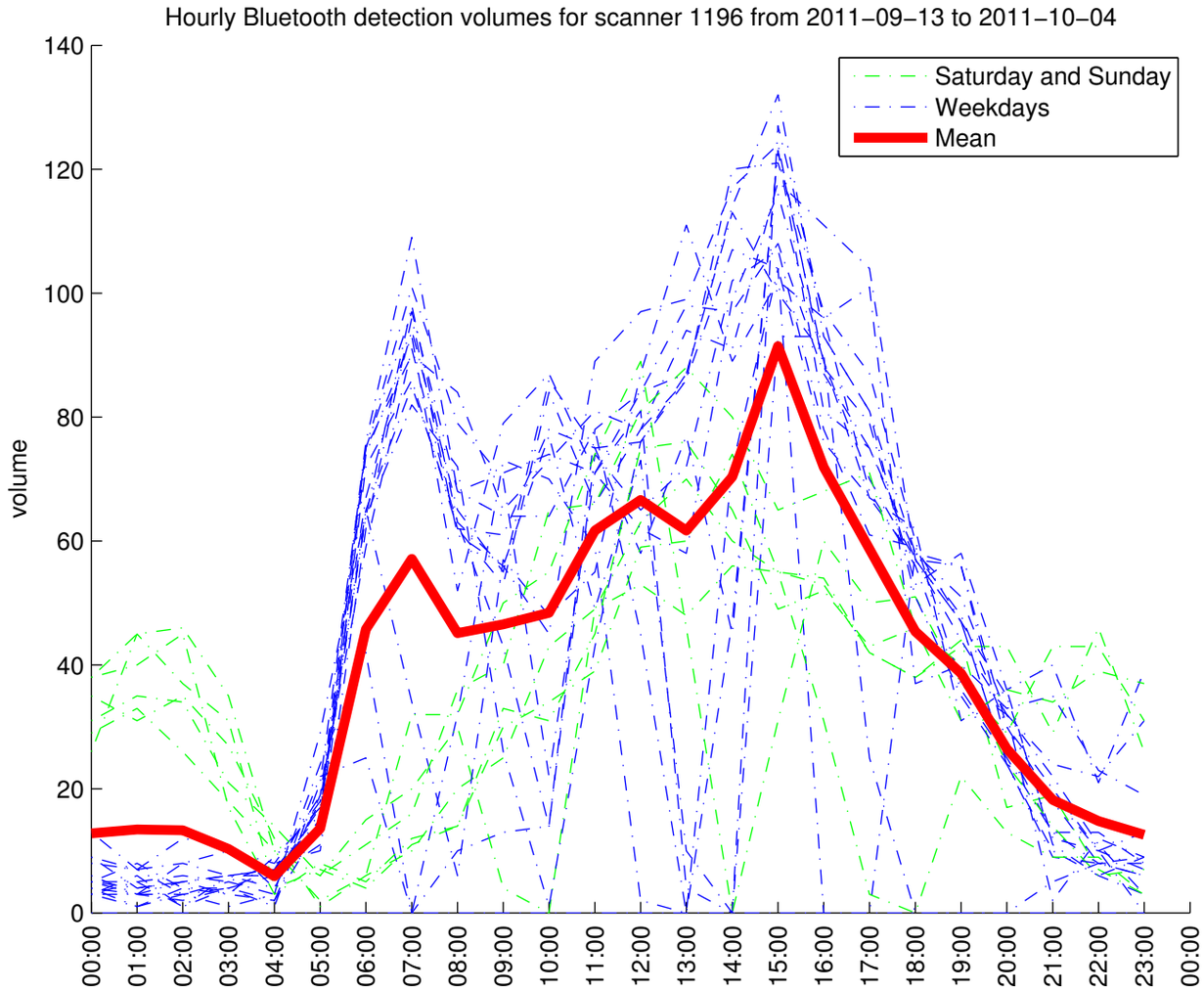
Multimodal vehicular traffic sensing

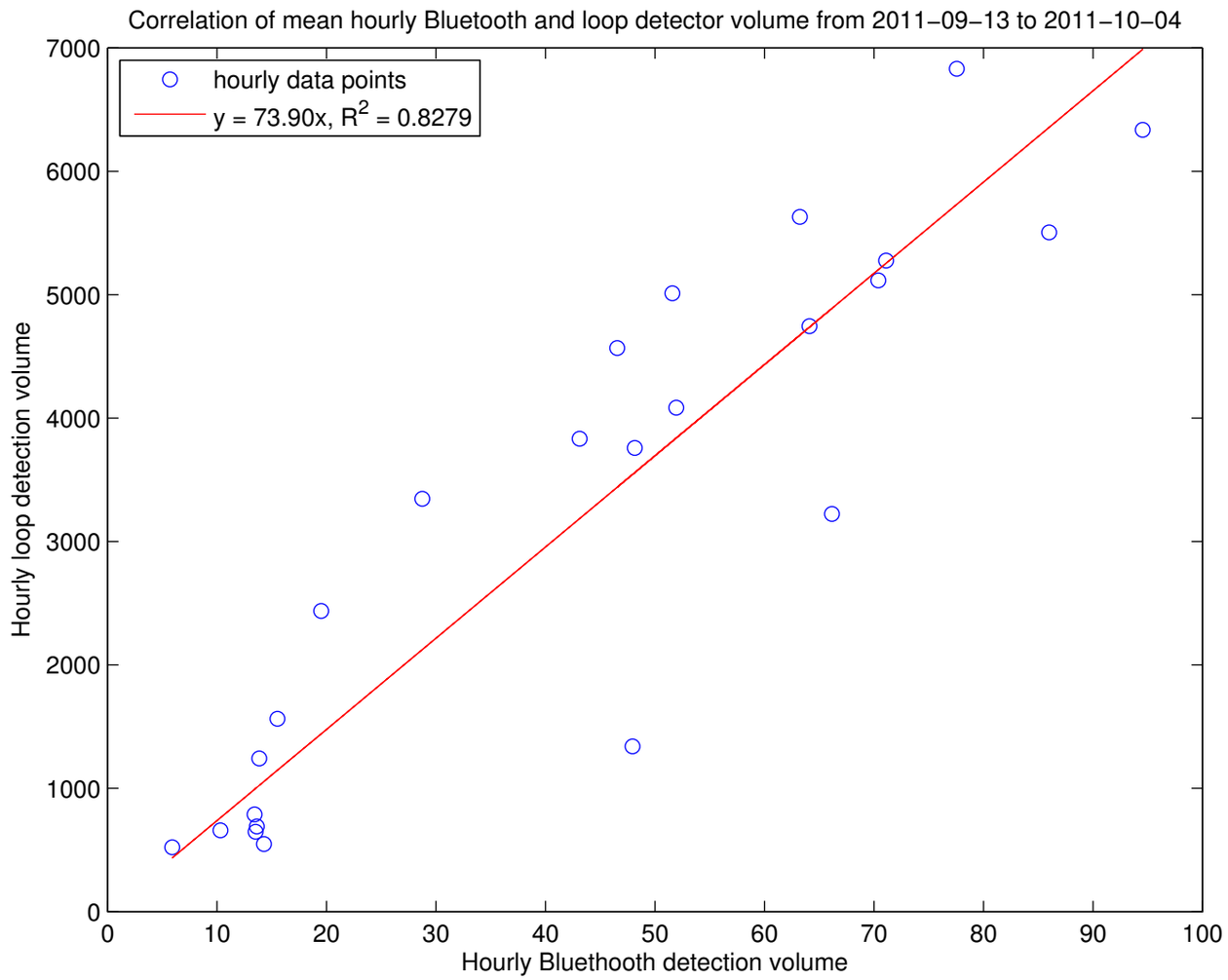


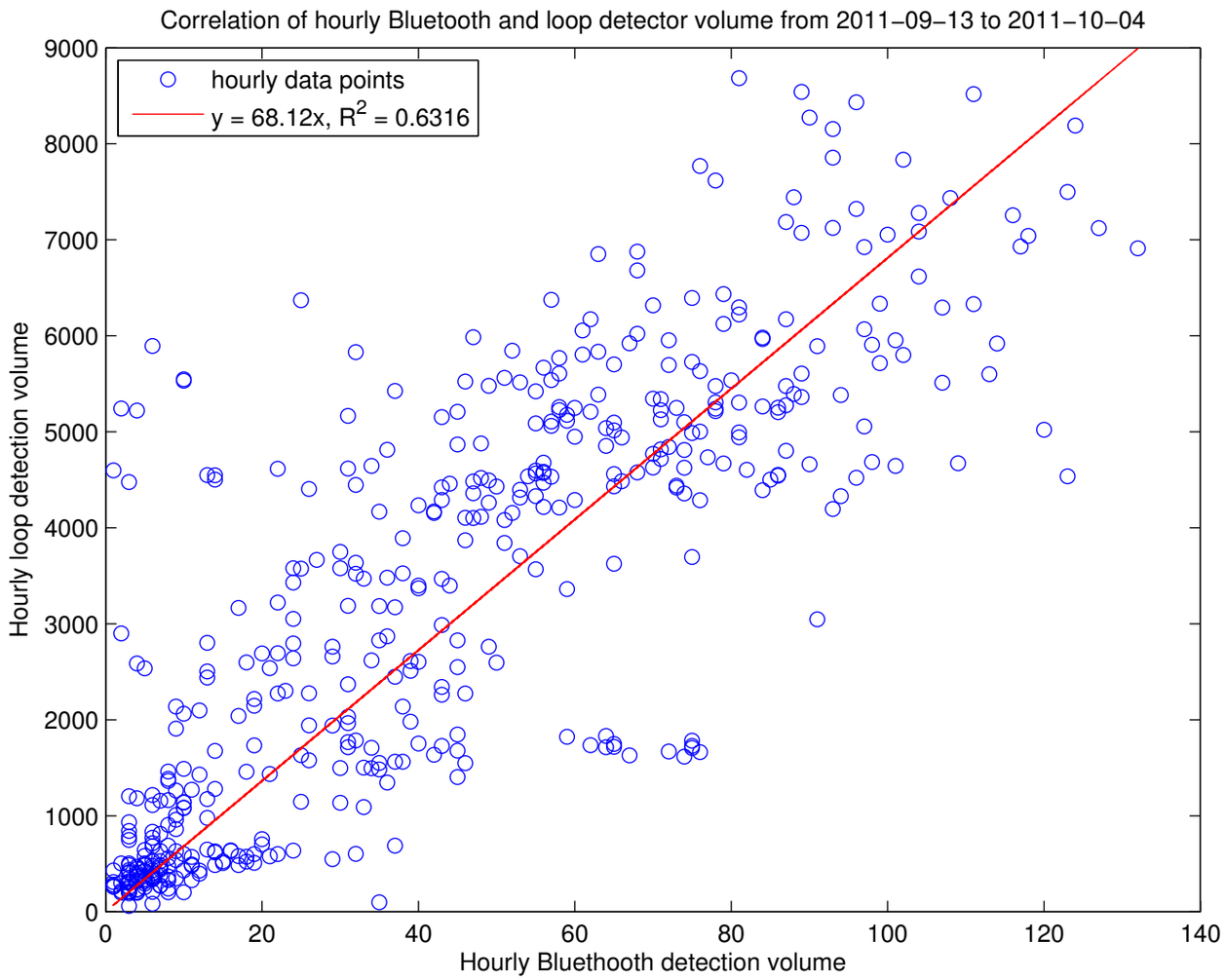


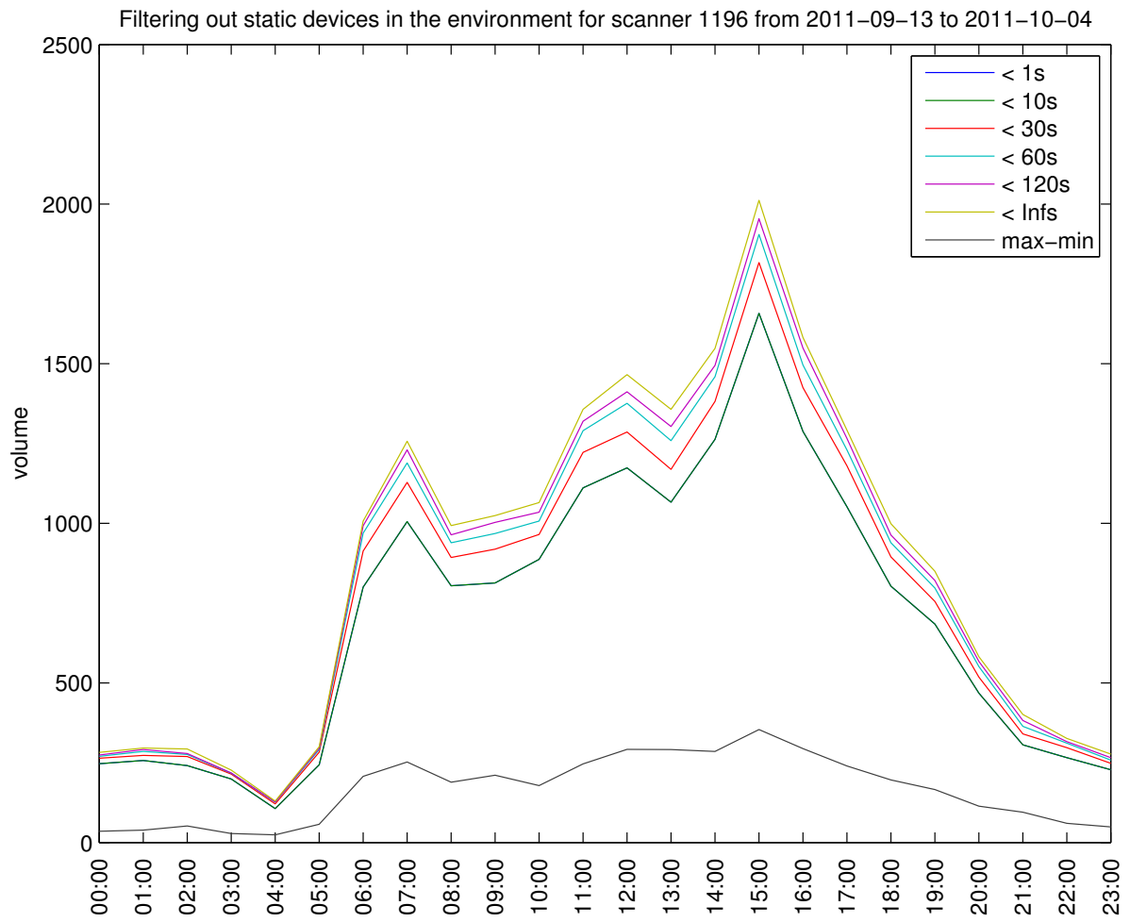

Daily volumes
Bluethooth scanner
volume
1500
1000
500
0
x 10^4
11–09–13
11–09–14
11–09–15
11–09–16
11–09–17
11–09–18
11–09–19
11–09–20
11–09–21
11–09–22
11–09–23
11–09–24
11–09–25
11–09–26
11–09–27
11–09–28
11–09–29
11–09–30
11–10–01
11–10–02
11–10–03
11–10–04
Loop detectors
volume
10
8
6
4
2
0

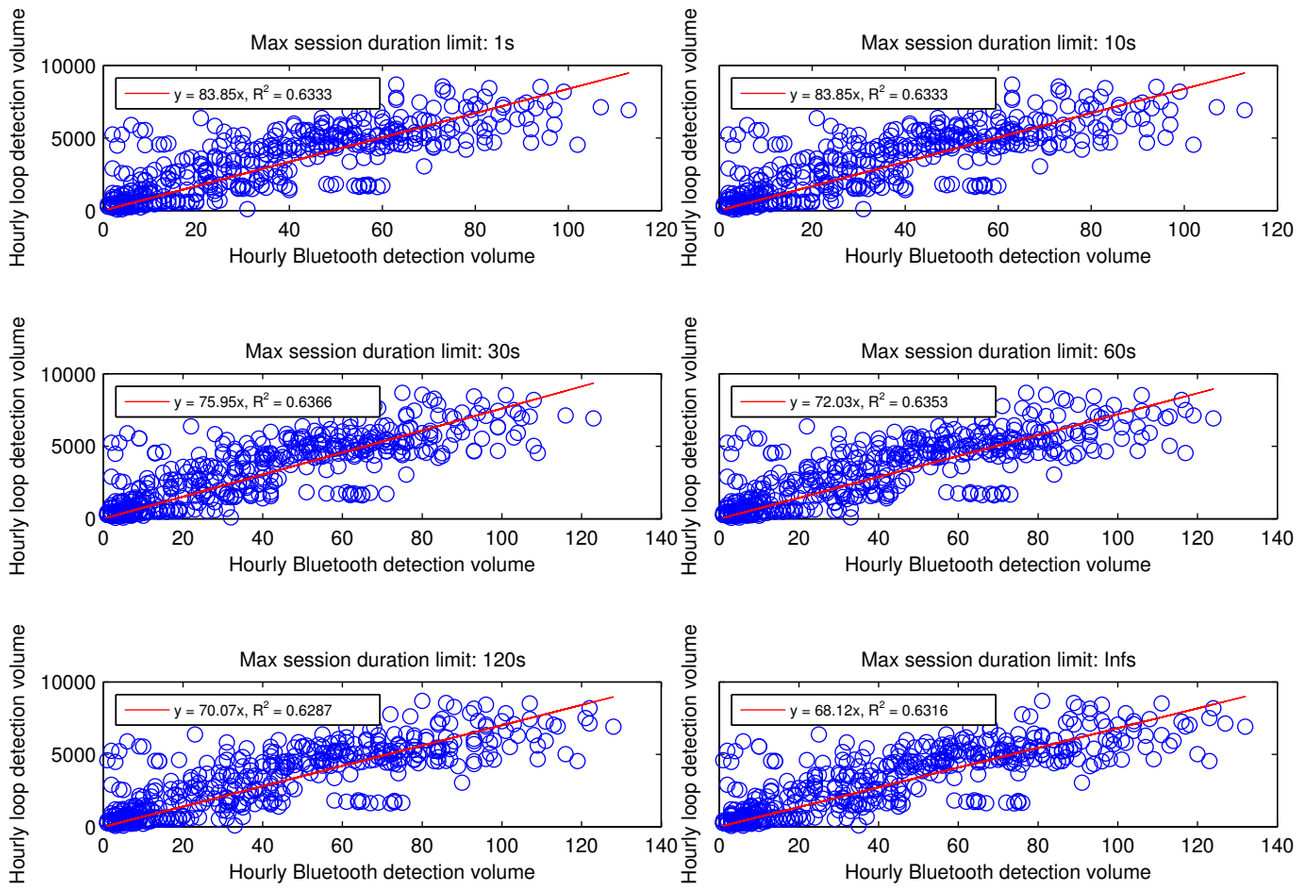

Hourly loop detection volume for intersection 16, from 2011−09−13 to 2011−10−04
volume
Saturday and Sunday
Weekdays
Mean
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00

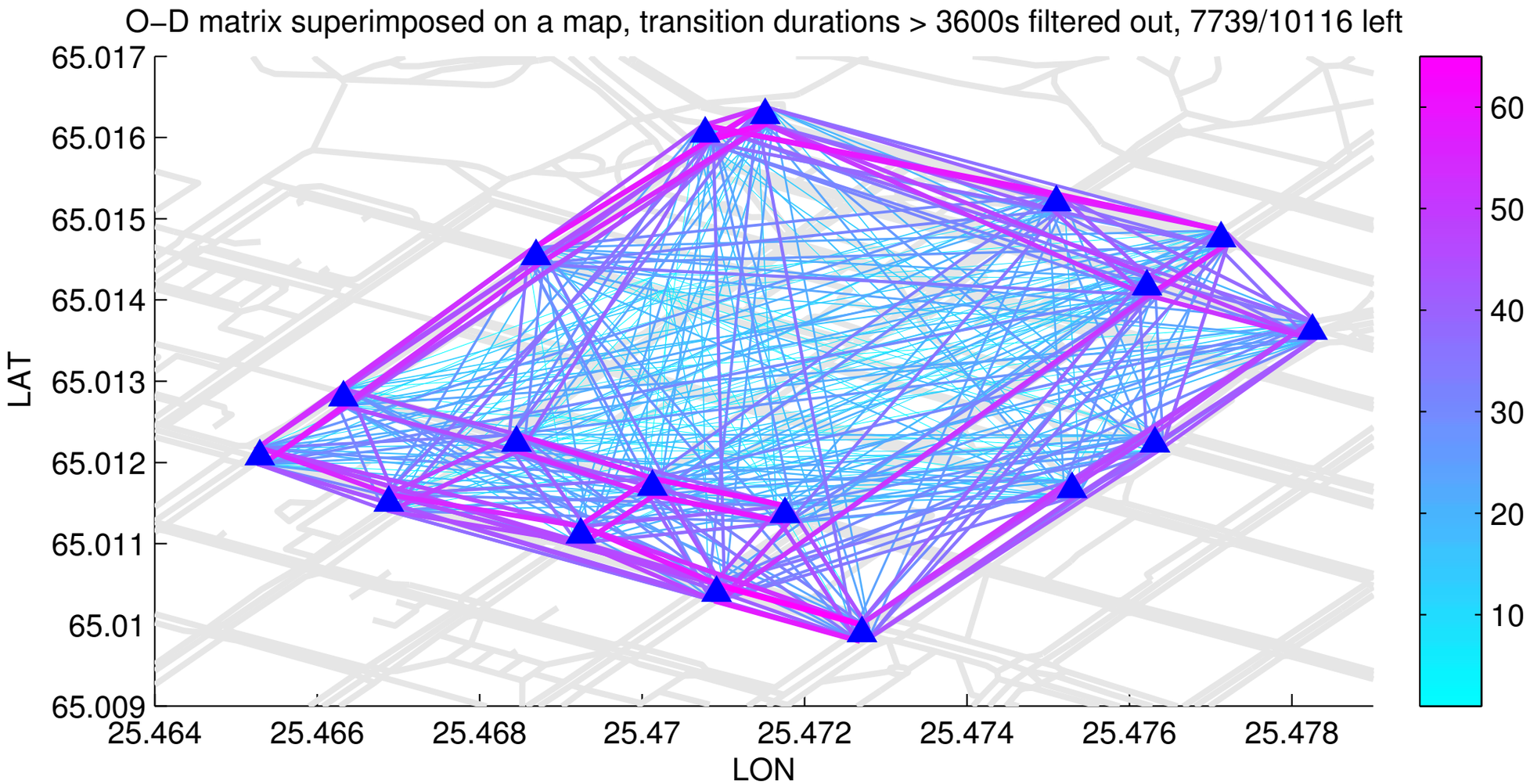

Hourly Bluetooth detection volumes for scanner 1196 from 2011−09−13 to 2011−10−04
volume
Saturday and Sunday
Weekdays
Mean
140
120
100
80
60
40
20
0
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Correlation of mean hourly Bluetooth and loop detector volume from 2011−09−13 to 2011−10−04
hourly data points
y = 73.90x, R2 = 0.8279
Hourly loop detection volume
Hourly Bluethooth detection volume
0
1000
2000
3000
4000
5000
6000
7000
0
10
20
30
40
50
60
70
80
90
100

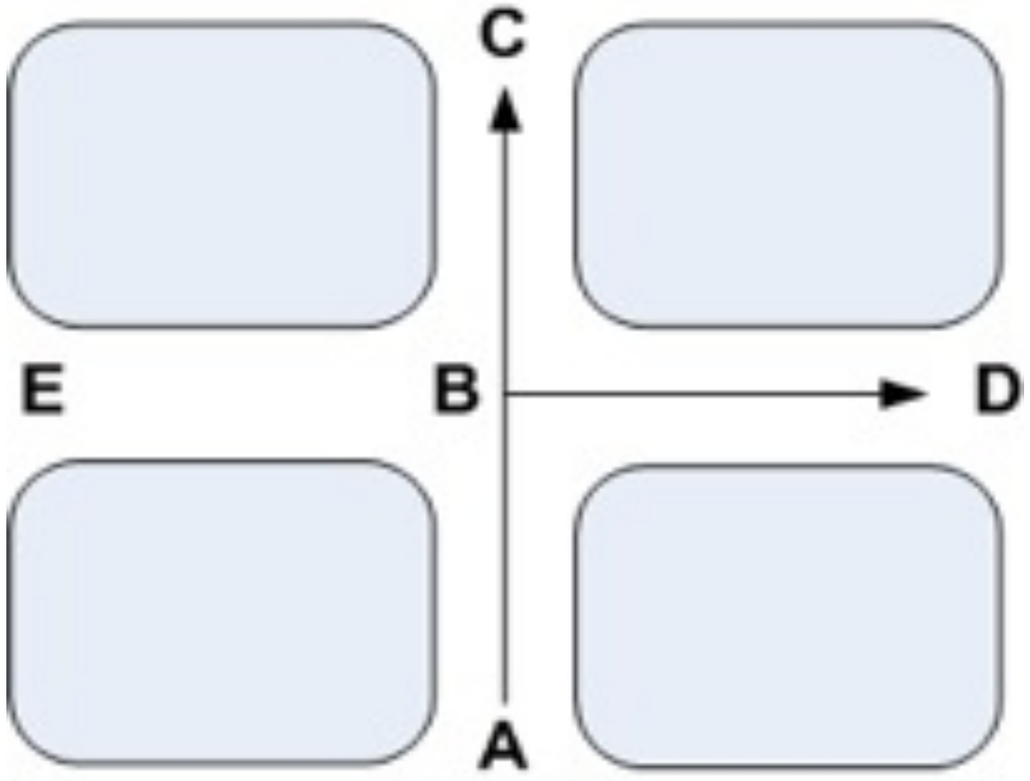

Correlation of hourly Bluetooth and loop detector volume from 2011−09−13 to 2011−10−04
hourly data points
y = 68.12x, R2 = 0.6316
Hourly loop detection volume
Hourly Bluethooth detection volume
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
0
20
40
60
80
100
120
140


Filtering out static devices in the environment for scanner 1196 from 2011−09−13 to 2011−10−04
volume
< 1s
< 10s
< 30s
< 60s
< 120s
< Infs
max−min
2500
2000
1500
1000
500
0
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Max session duration limit: 1s
y = 83.85x, R² = 0.6333
Max session duration limit: 10s
y = 83.85x, R² = 0.6333
Max session duration limit: 30s
y = 75.95x, R² = 0.6366
Max session duration limit: 60s
y = 72.03x, R² = 0.6353
Max session duration limit: 120s
y = 70.07x, R² = 0.6287
Max session duration limit: Infs
y = 68.12x, R² = 0.6316
Hourly loop detection volume
Hourly Bluetooth detection volume


O–D matrix superimposed on a map, transition durations > 3600s filtered out, 7739/10116 left
65.017
65.016
65.015
65.014
65.013
65.012
65.011
65.01
65.009
LAT
25.464
25.466
25.468
25.47
25.472
25.474
25.476
25.478
LON
60
50
40
30
20
10

Calculating turning ratios

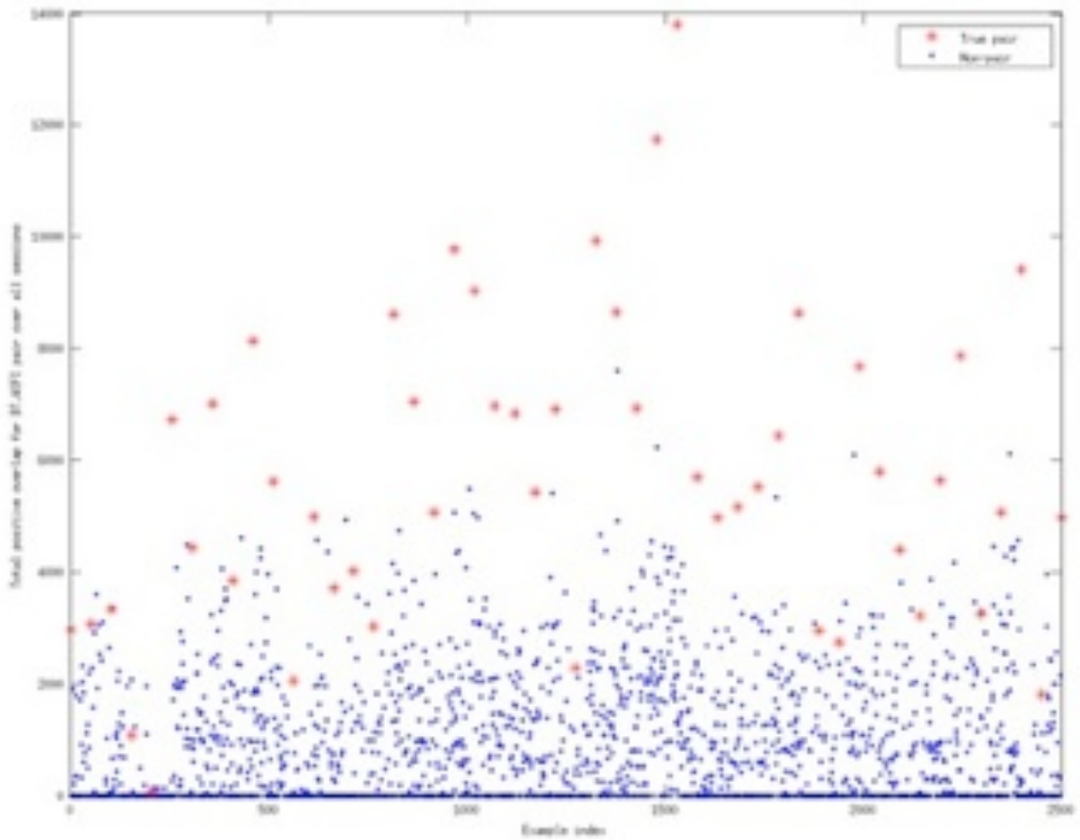


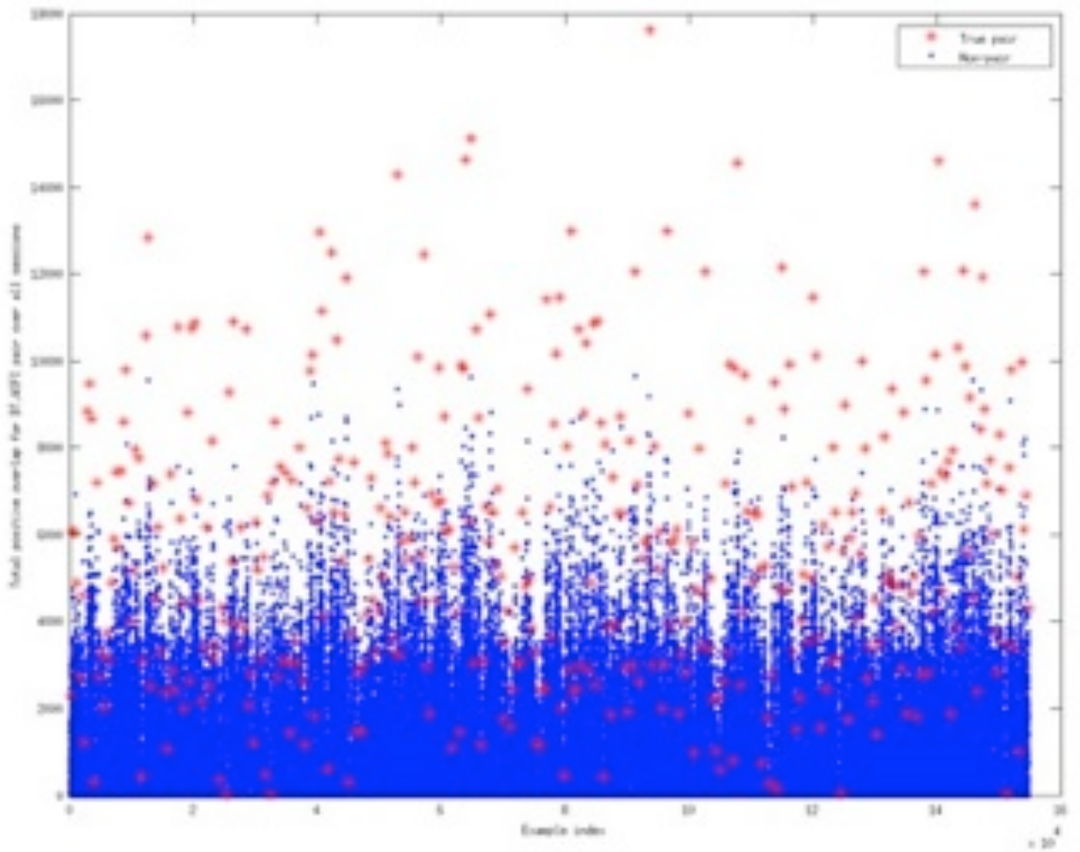
Test	Duration	Method	Turning ratio (std)	Error %
1	1 day (10 samples)	Bluetooth Loop detectors	0.3996 (0.1418) 0.4972 (0.0259)	9.76%
2	1 week (3 samples)	Bluetooth Loop detectors	0.4361 (0.0386) 0.5036 (0.0135)	6.82%
3	3 weeks (1 sample)	Bluetooth Loop detectors	0.4498 (-) 0.4850 (-)	3.52%

Linking BT and WiFi IDs

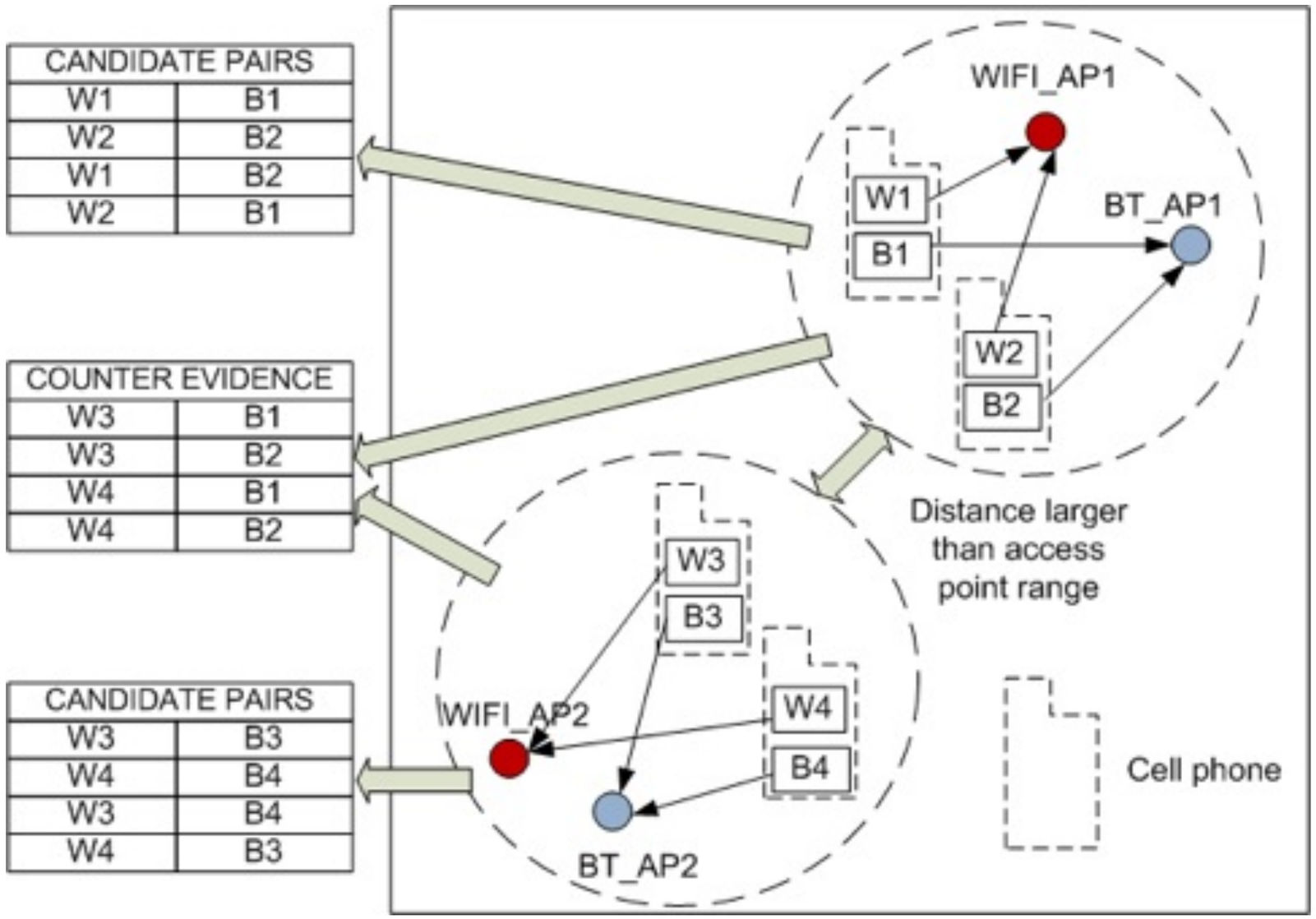

20
18
16
14
12
10
8
6
4
2
0
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00

More activity => More noise

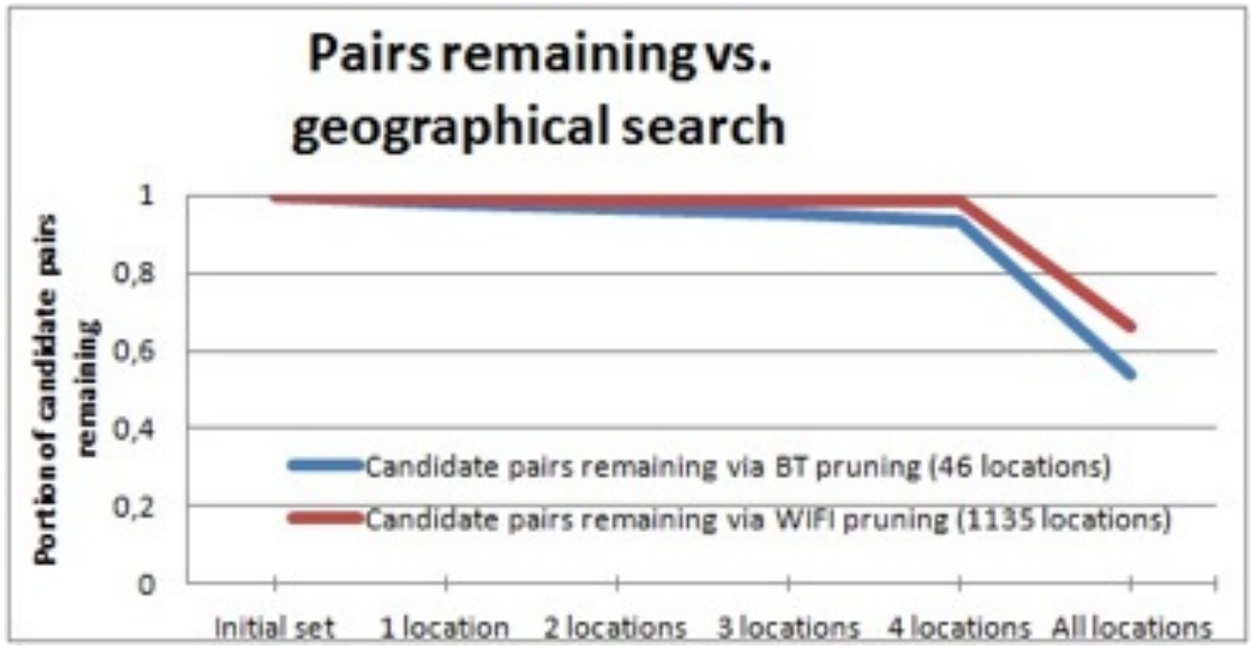


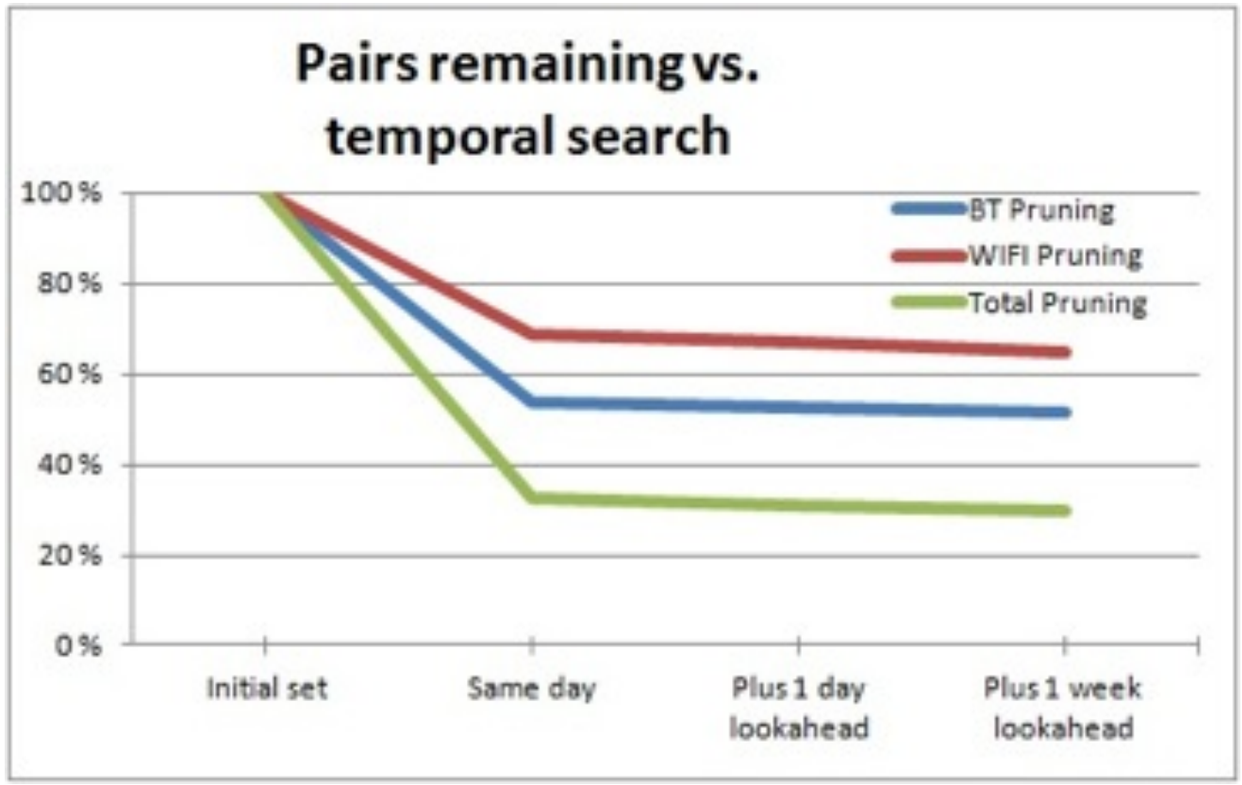


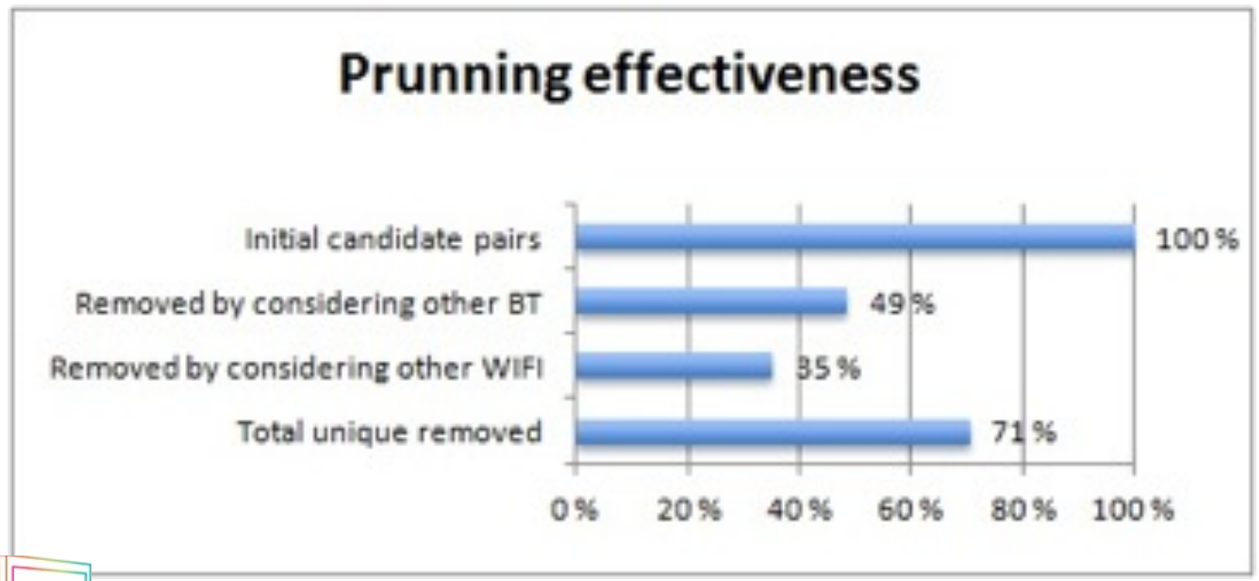
Looking for Counter-evidence



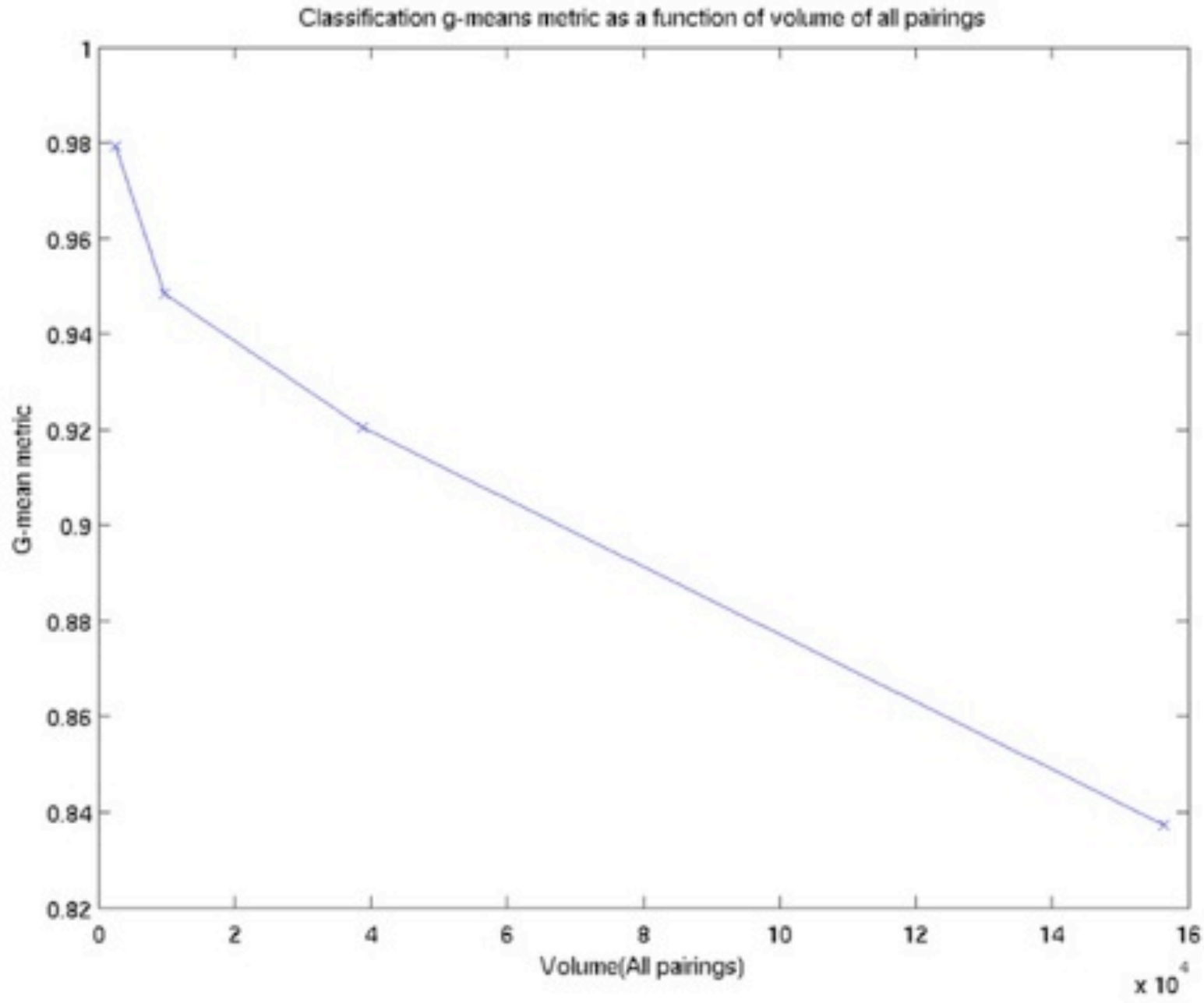
Effectiveness of counter-evidence







Classifier performance



The end

- 3rd Ubi Summer School 2012
  - http://www.ubioulu.fi/en/UBI-summer-school-2012
- Researcher in Residence program
  - Soon to be announced
  - UbiChallenge: http://www.ubioulu.fi/en/UBI-challenge
- Special issue of IJHCS on Social Networks and Ubiquitous Interactions.
- Or just come visit!

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