Human mobility analysis by collaborative radio landscape observation

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University of Minho
Guimarães, Portugal

AGILE'2012, 15th International Conference on Geographic Information Science

Outline

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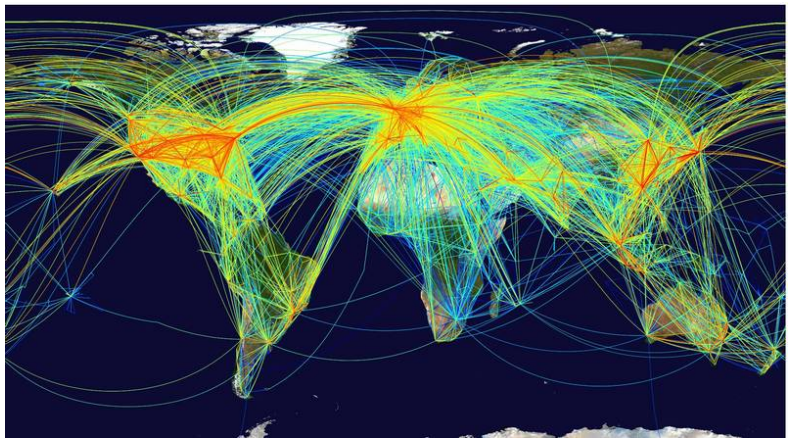

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- Utilize the information to **create reports about their mobility**.

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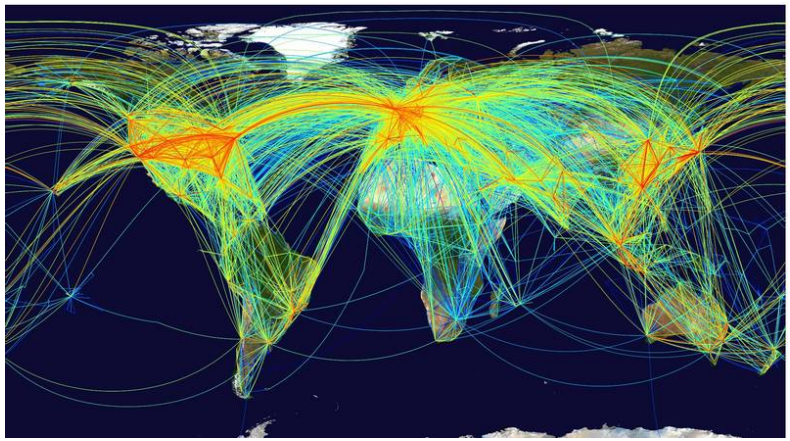

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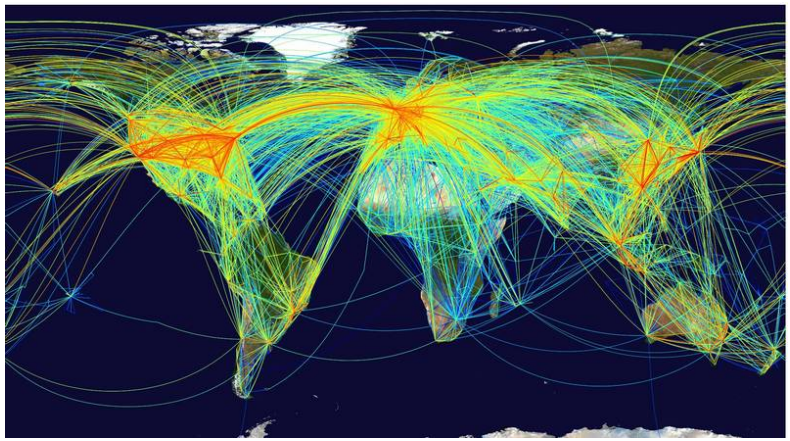

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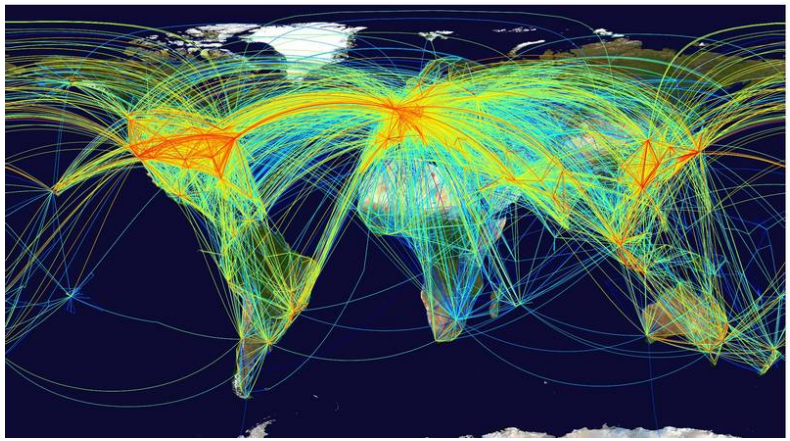

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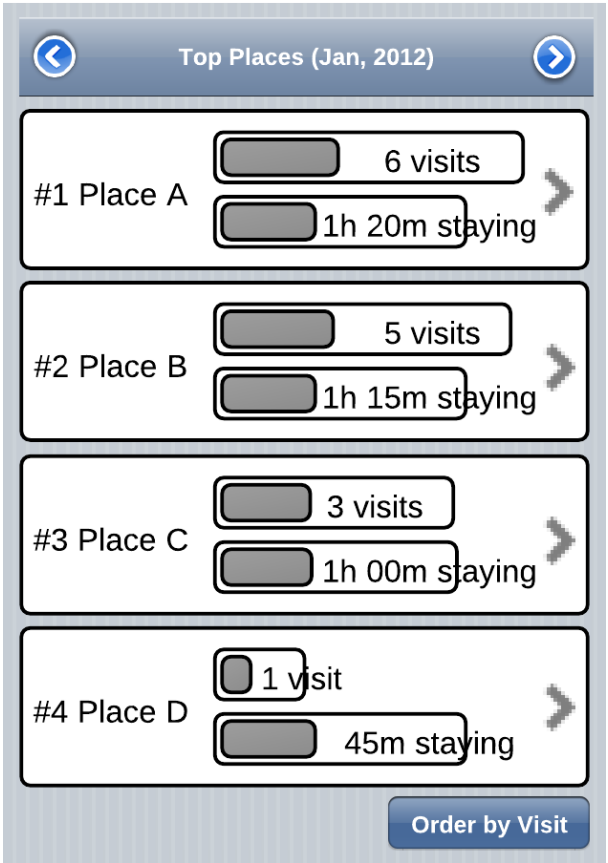

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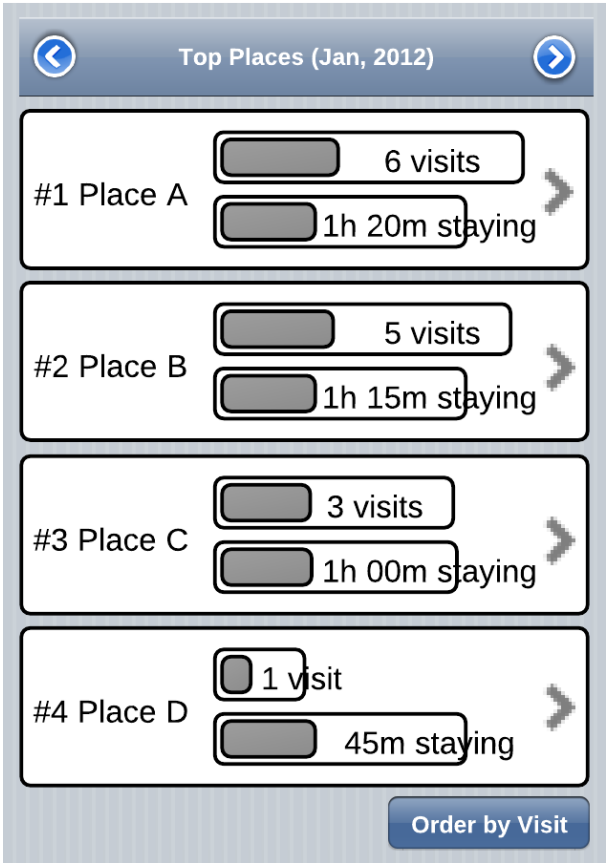

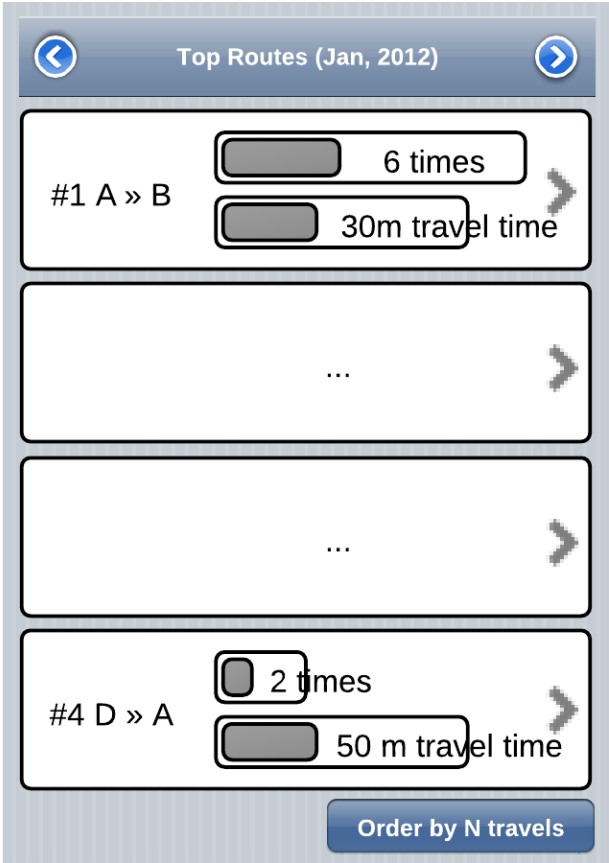

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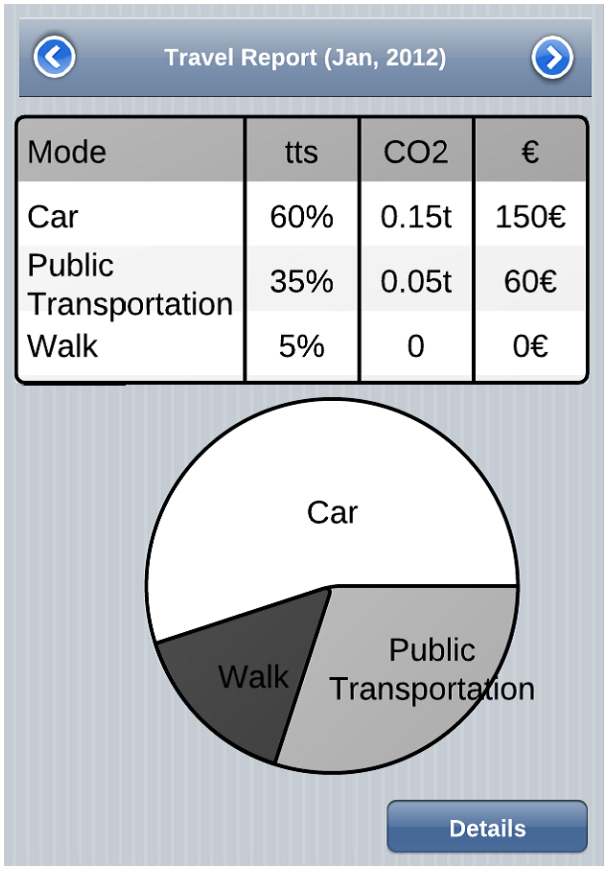

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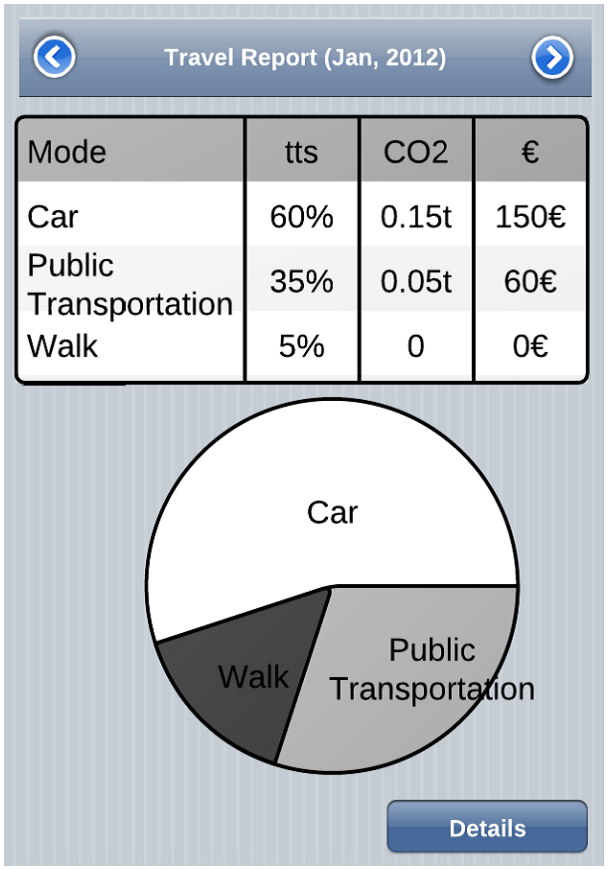

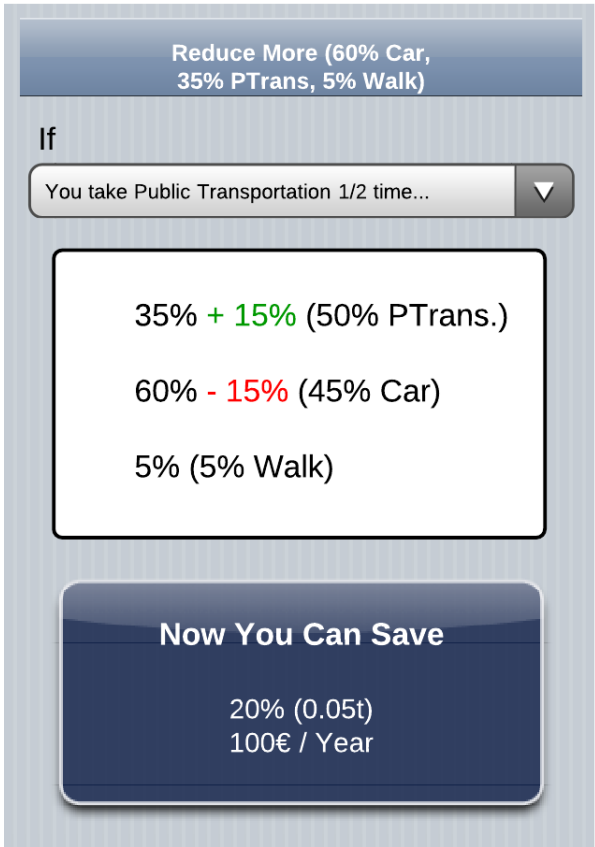

Transportation Systems Efficiency.

- Greener approach to transportation.
- Help users save money and help the environment.

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What Is Known from the Literature?

1. Humans follow reproducible patterns with deep regularity.
2. It is possible to discover daily-life routines of users.
3. Individuals spend around 87% of their time indoors.
4. Increasing popularity on the use of wireless networks.
5. Several indoor localization strategies exist.

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Specific Goals

1. Use GSM and WiFi networks to infer the mobility patterns in a symbolic space, without necessarily knowing the geographic coordinates of places.
2. Infer the logical space structure from the radio landscape and use it to provide spatial context to the mobility patterns.

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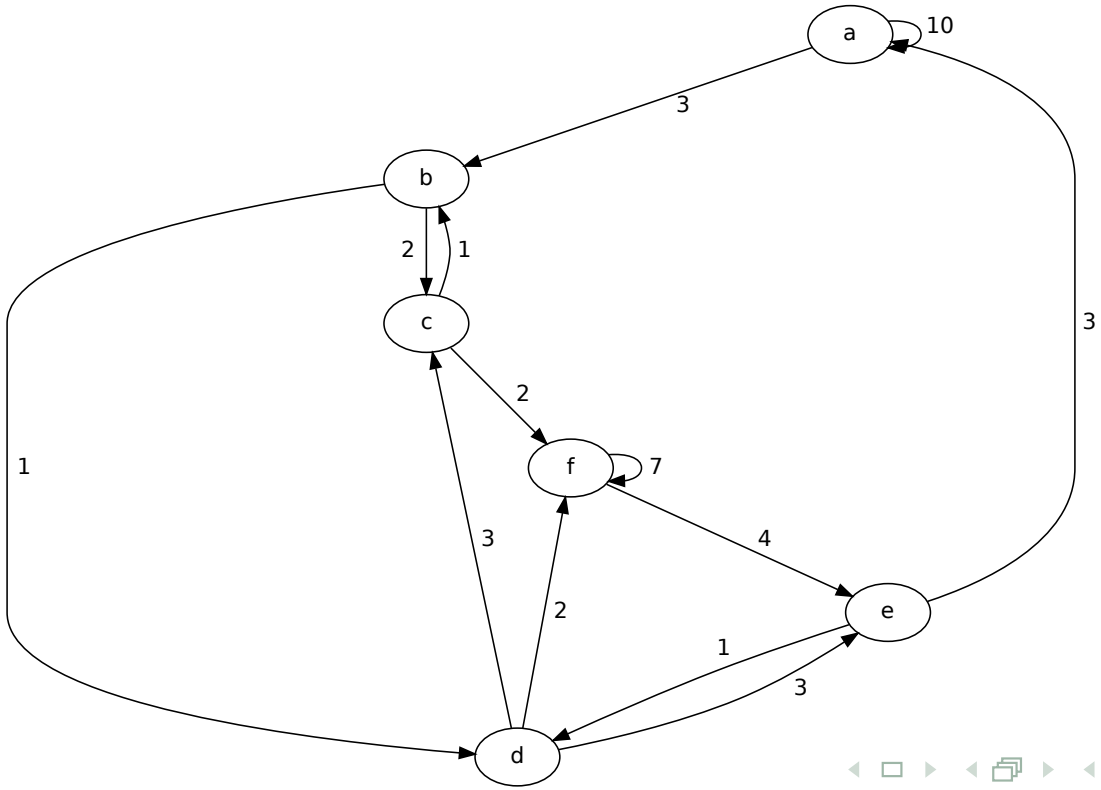
Representation of Mobility.

Challenges

1. Place learning.
2. Trip detection.



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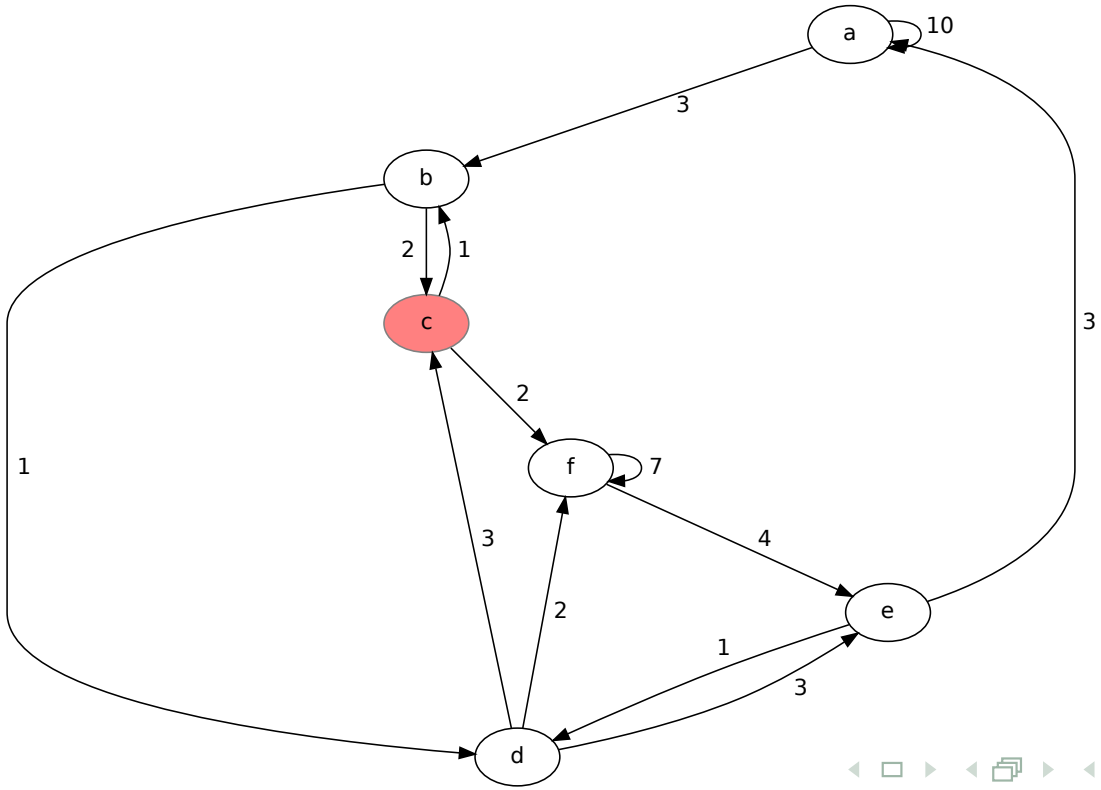

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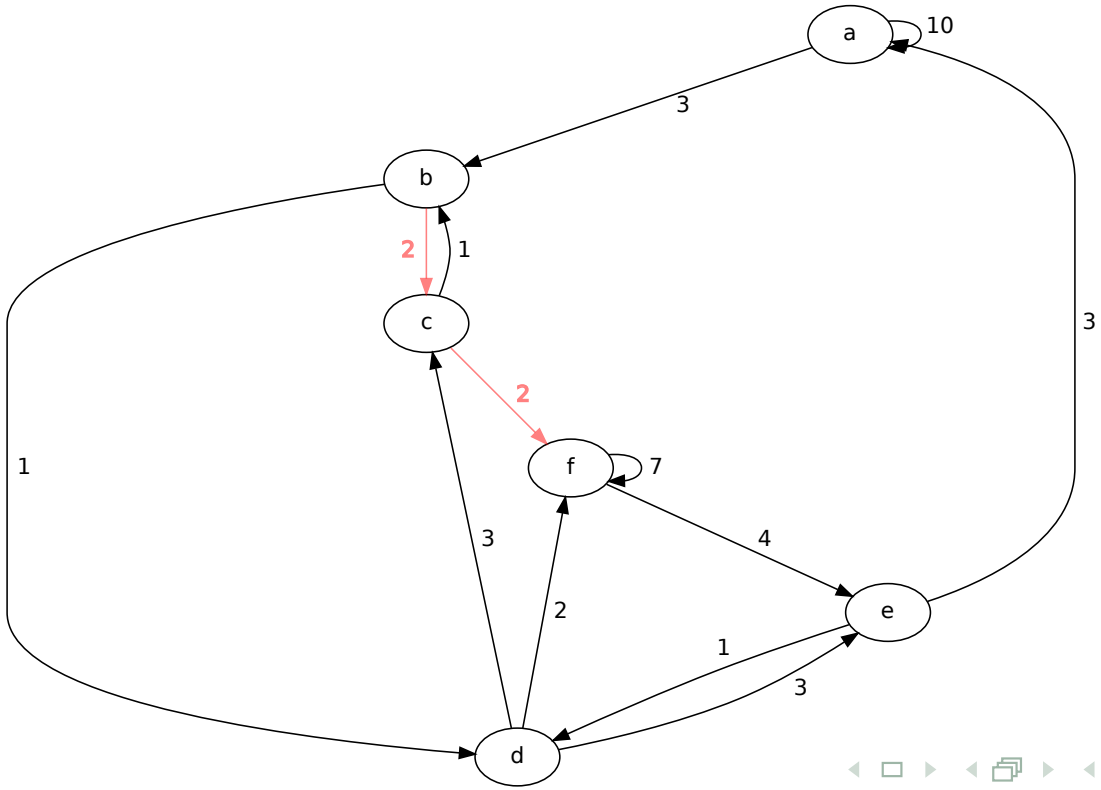

Creating the Mobility Maps.

$$O = \{(mID_1, t_1, BSs_1), \cdots (mID_{Ns}, t_{Ns}, BSs_{Ns})\}$$

$$BSs_i = \{(bsID_{i,1}, RSSI_{i,1}), \cdots (bsID_{i,Nbs_i}, RSSI_{i,Nbs_i})\}$$

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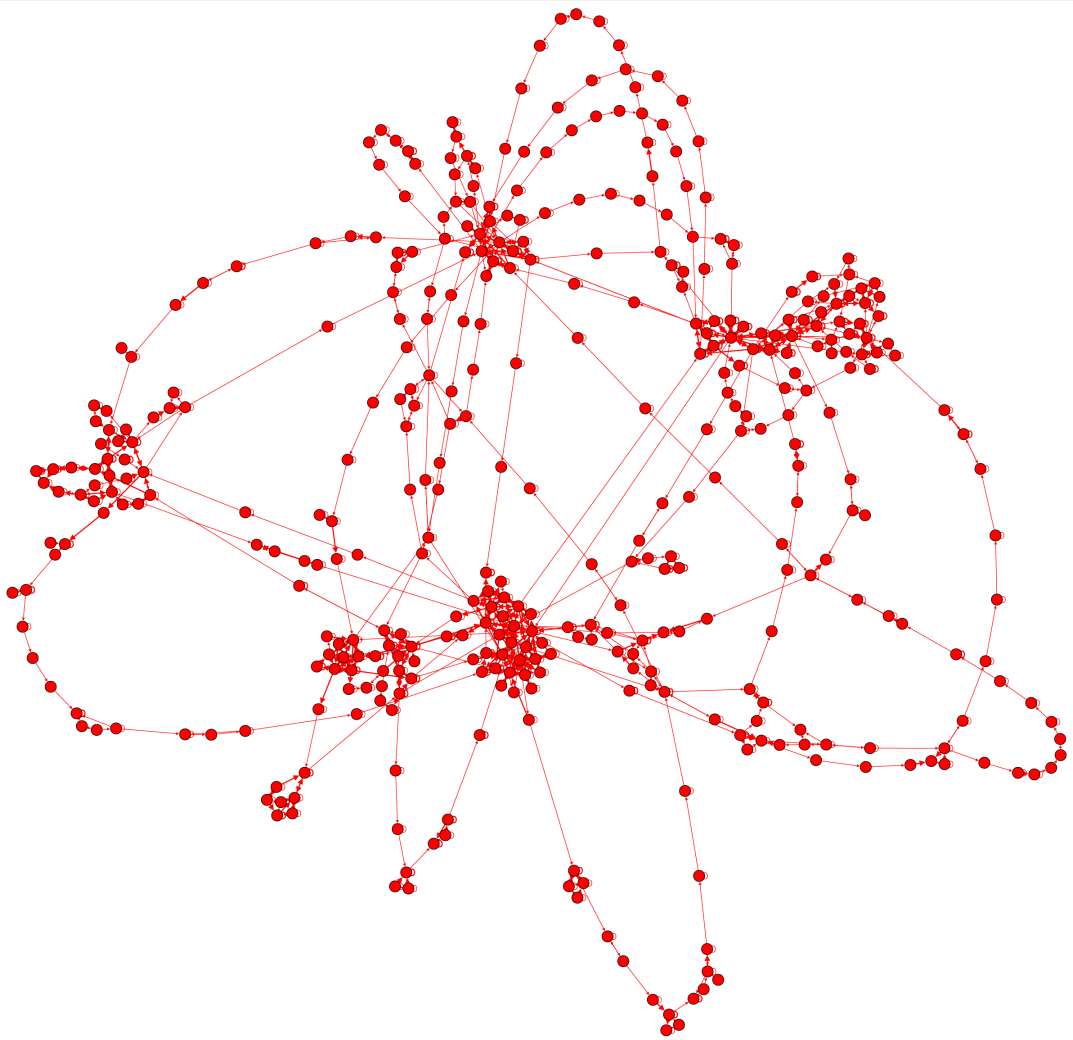
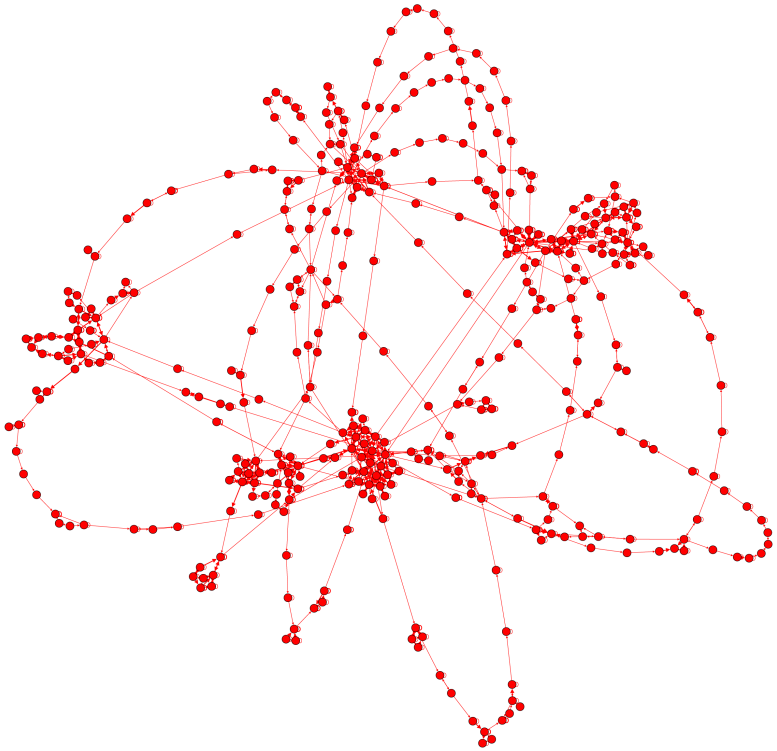
Example of a Real Personal Mobility Map.



93.629 observations obtained during 22 days. 404 nodes and 1.183 edges.

Mobility Maps.
The Good and the Bad

- Successfully shows the aggregated movements of the user and the trajectories he follows.
- Lack of spatial context.



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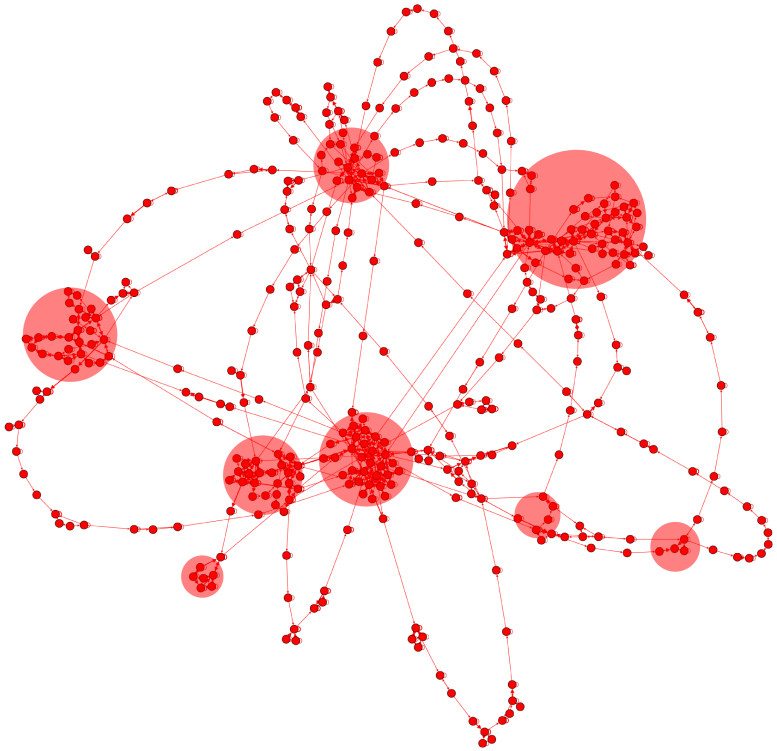

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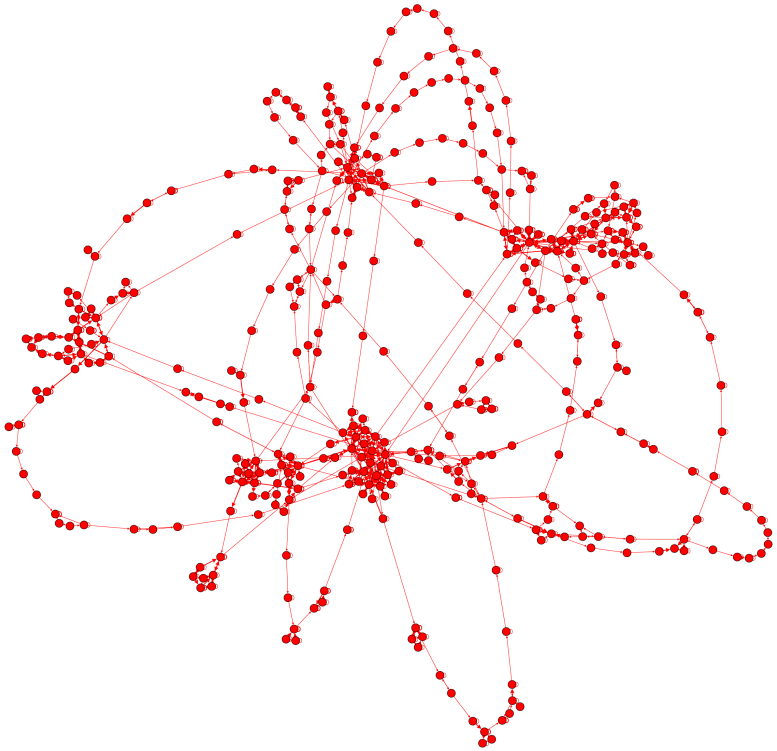

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Adding Spatial Context with WiFi.

$$G_p = \{N_p, E_p\}$$

- Nodes N_p are all the APs in all the observations:

$$N_p = \bigcup_{i,j=1}^{N_s, Nbs_i} bsID_{i,j}$$

- Edges E_p only between simultaneously visible APs.

$$E_p = \left\{ \bigcup_{i} (bsID_{i,j}, bsID_{i,m}) : j \neq m \right\}$$

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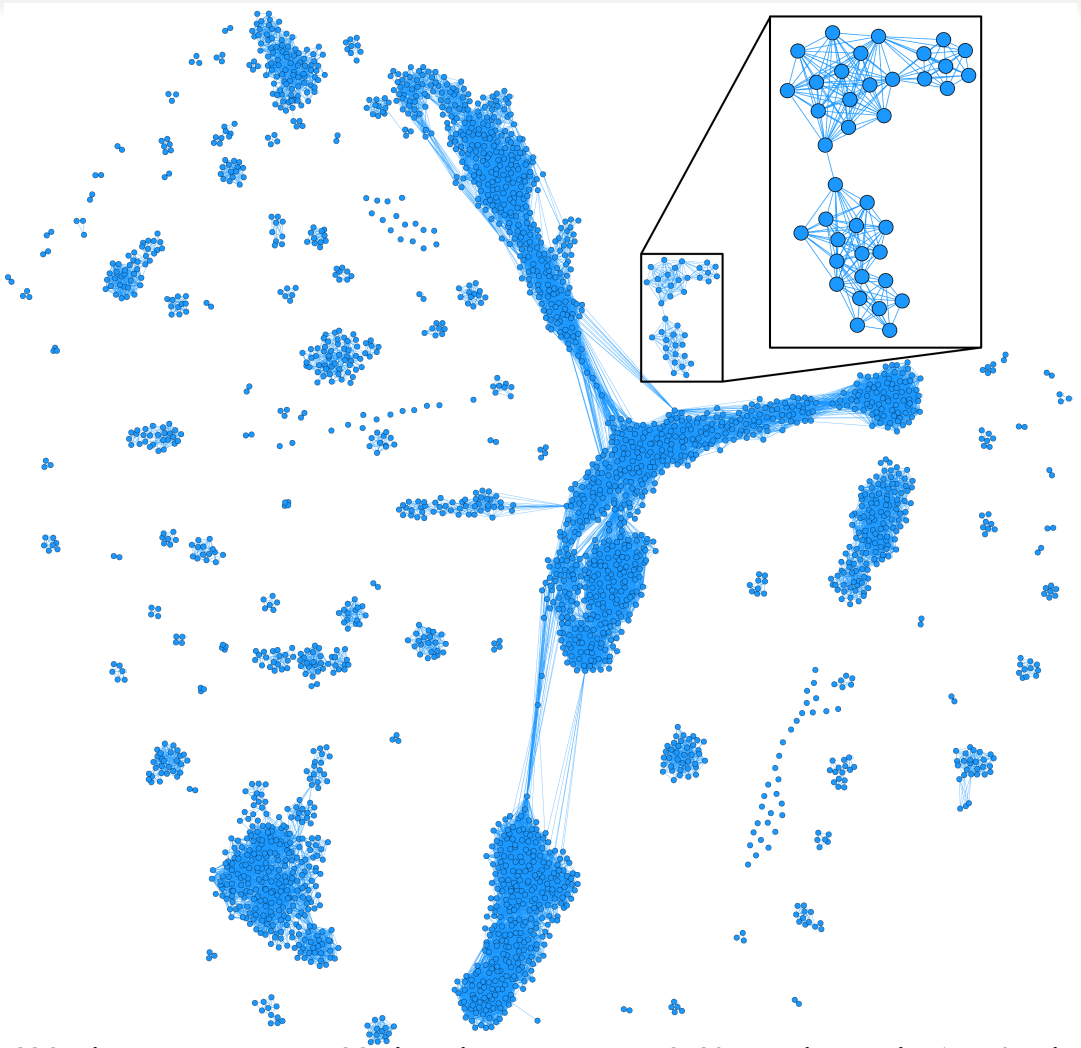
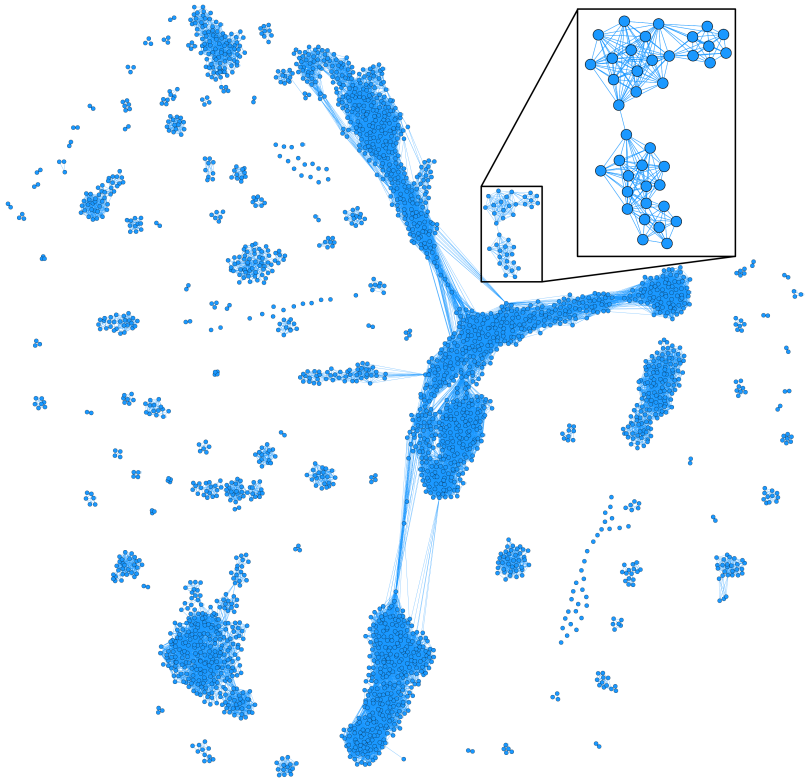


93.629 observations over 22 days by two users. 2.607 nodes and 41.470 edges.

WiFi Proximity Maps.

The Good and the Bad

- Short range neighborhoods are described successfully.
- A number of disconnected subgraphs exists.
- Long range is not easily captured.



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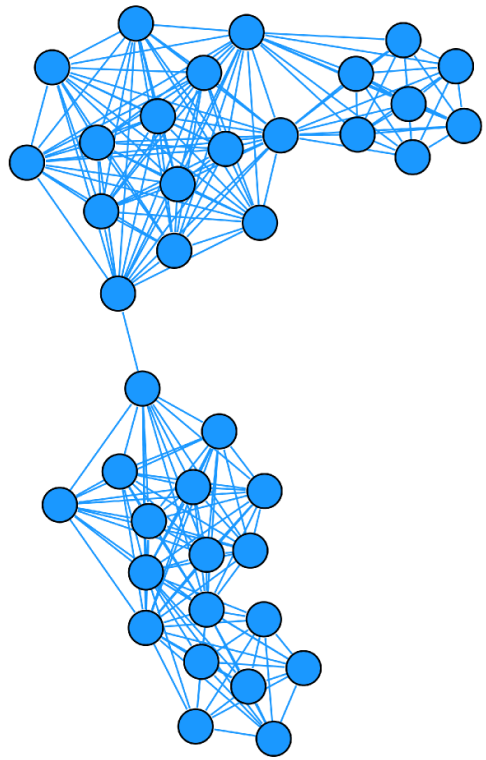

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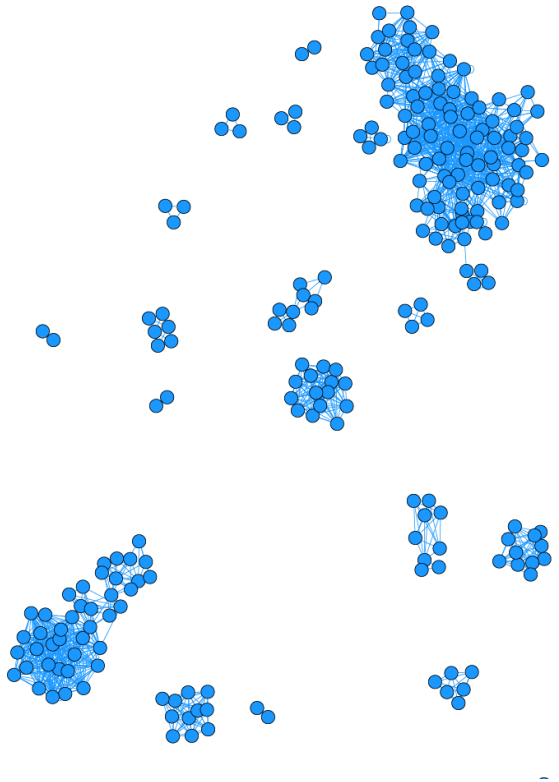

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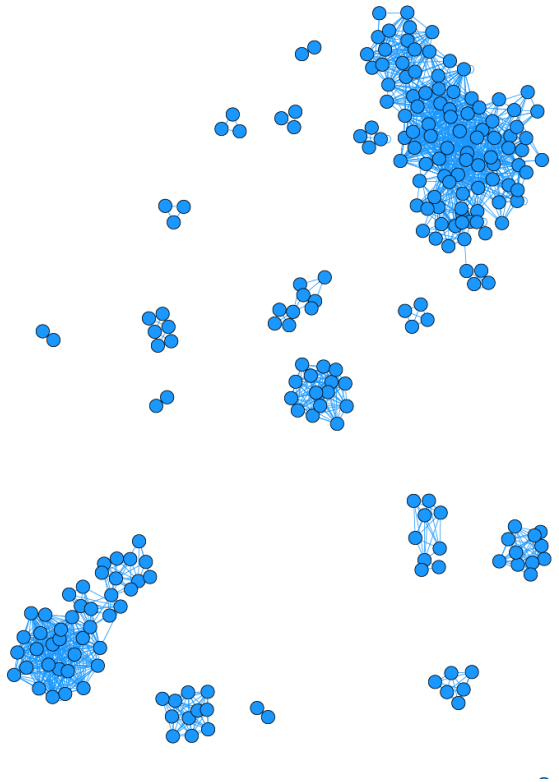

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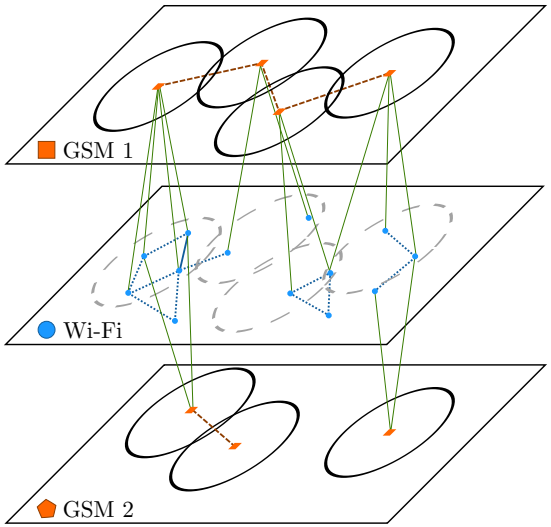

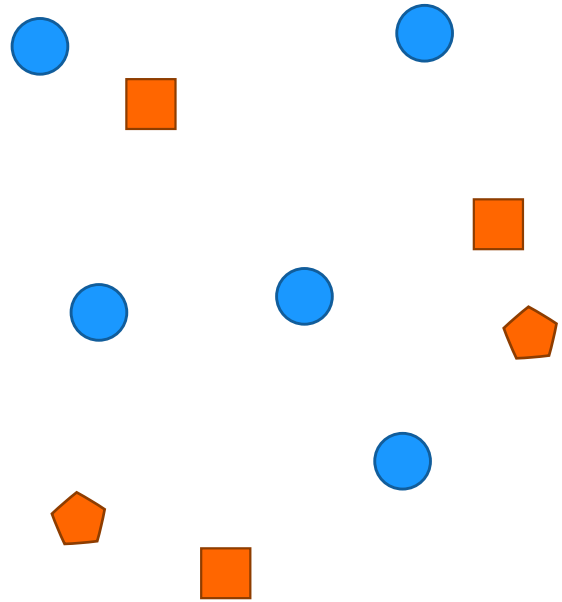

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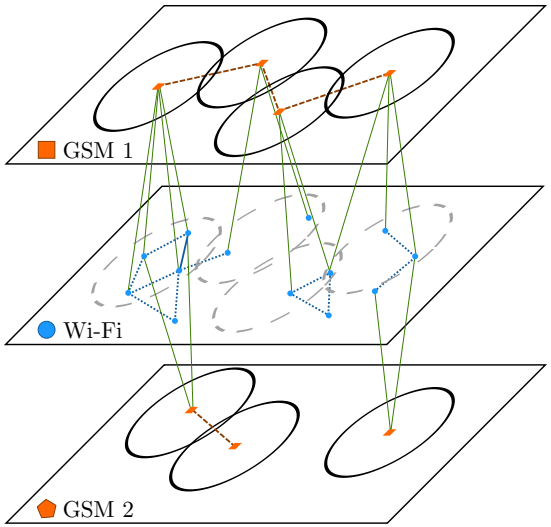

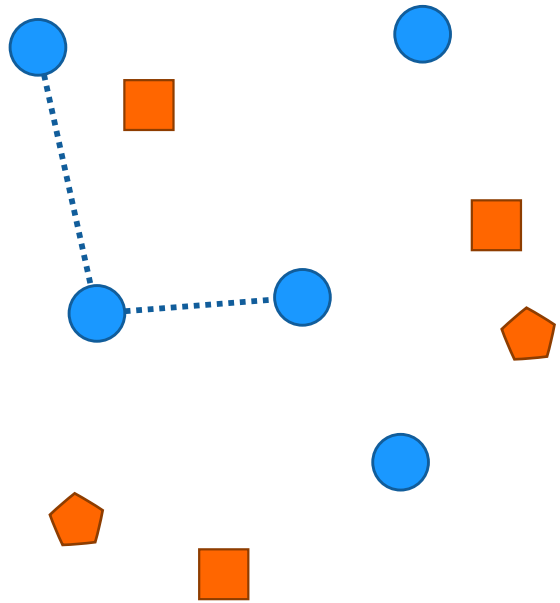

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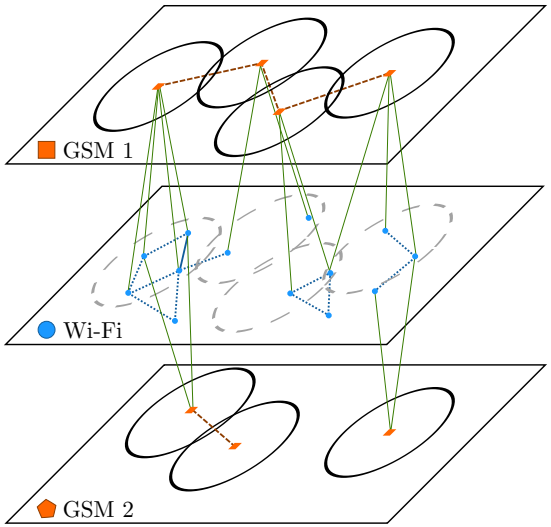

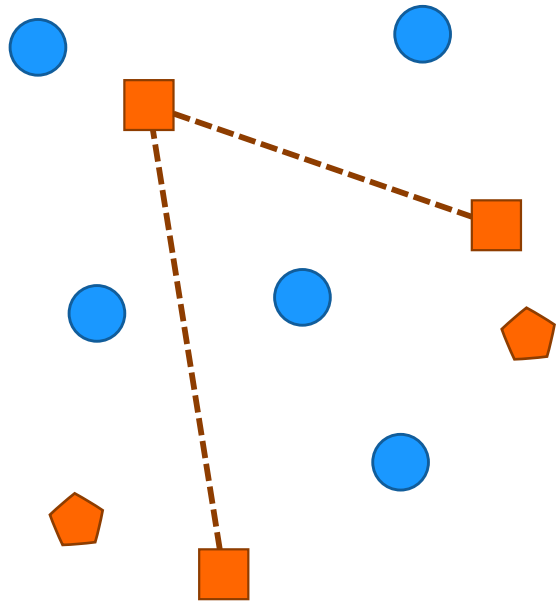

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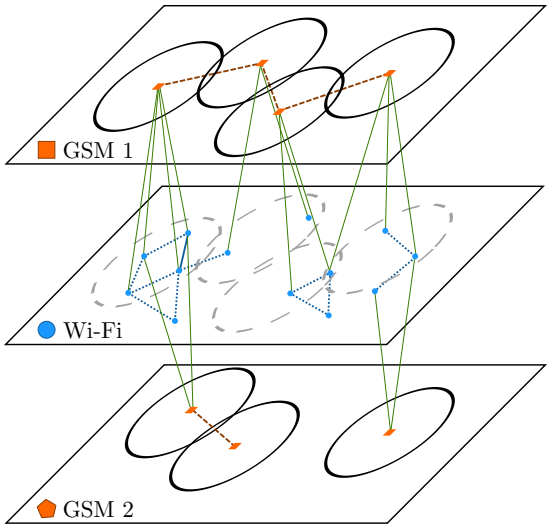

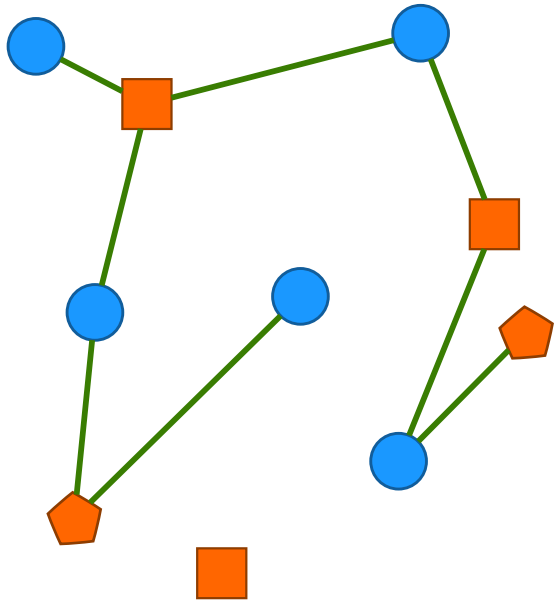

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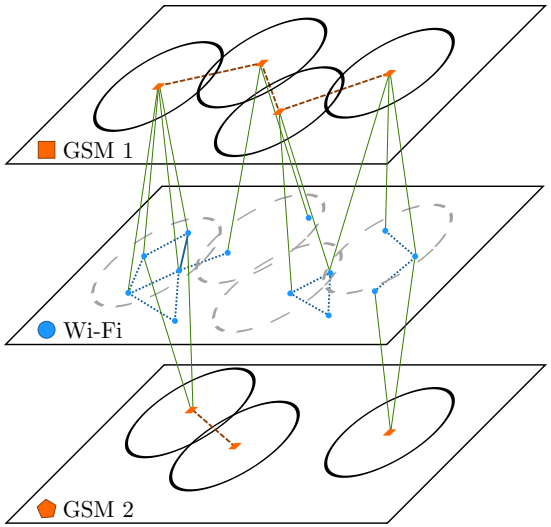

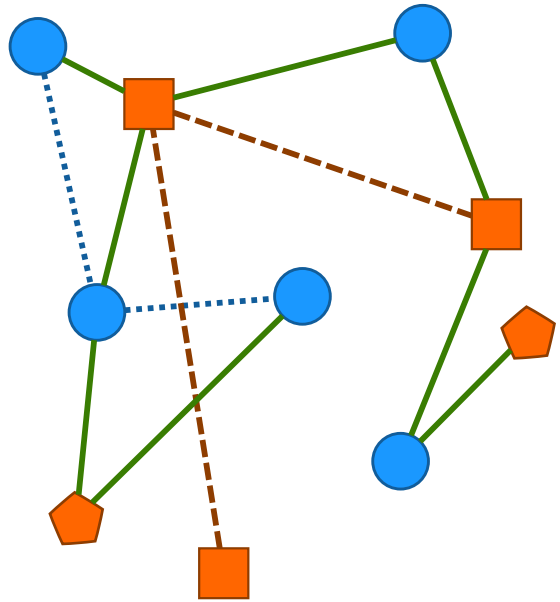

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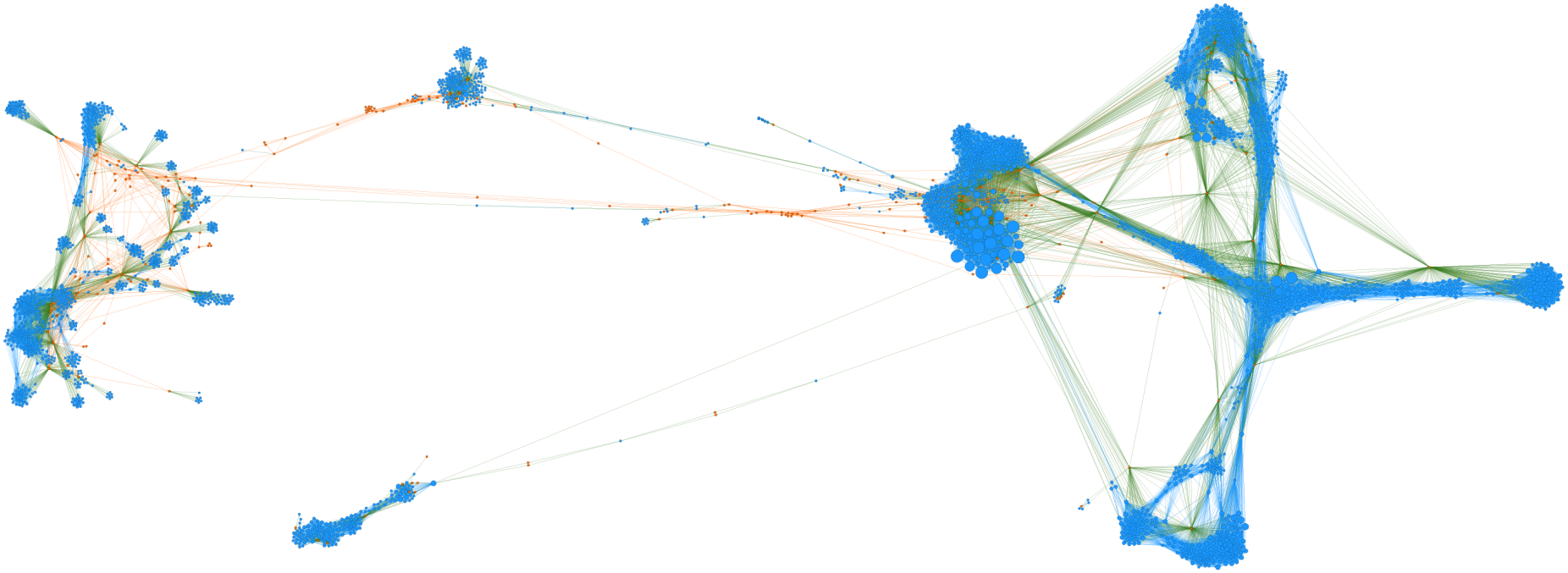

93.629 WiFi observations over 22 days by two users. 2.607 WiFi nodes and 41.470 edges.

346.150 GSM observations over 22 days by two users. 353 GSM nodes and 644 GSM edges. 6.289 mixed edges.

Puting Everything Together

No Spatial Content

Spatial Relations

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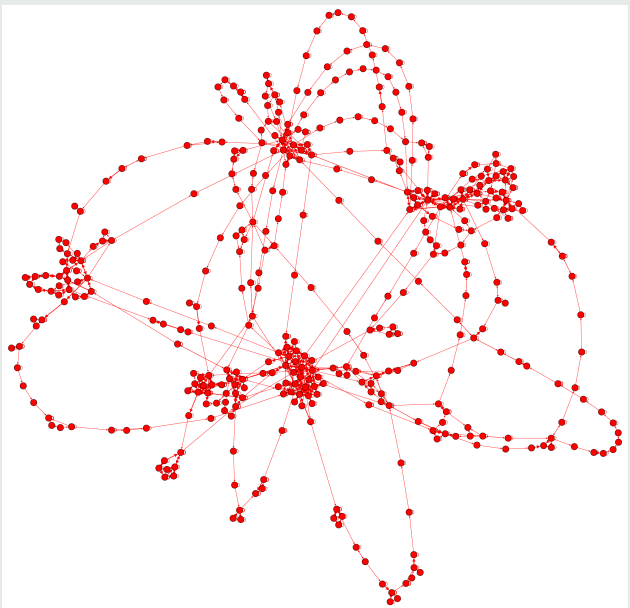

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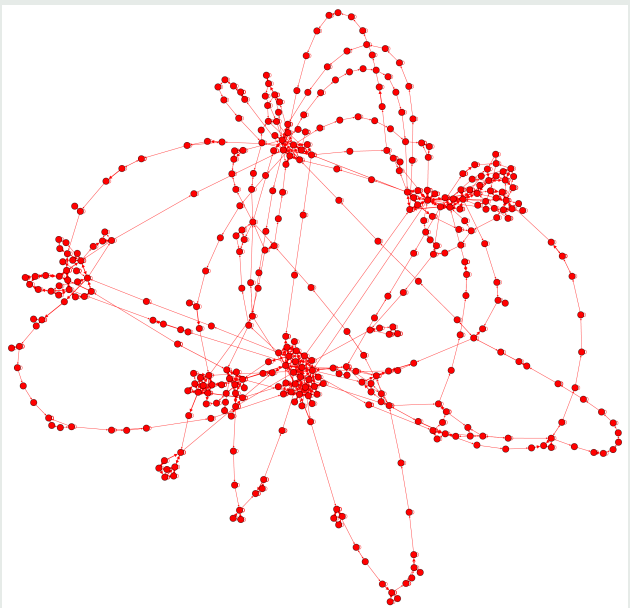

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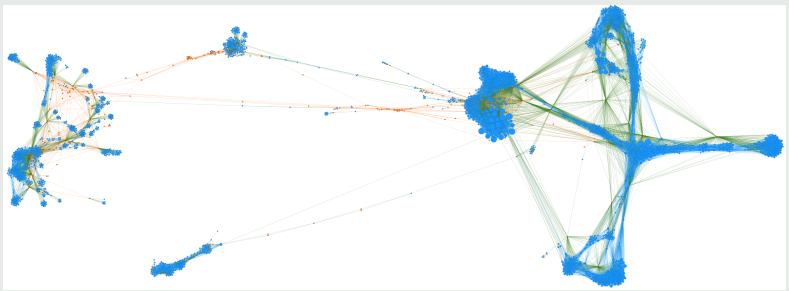
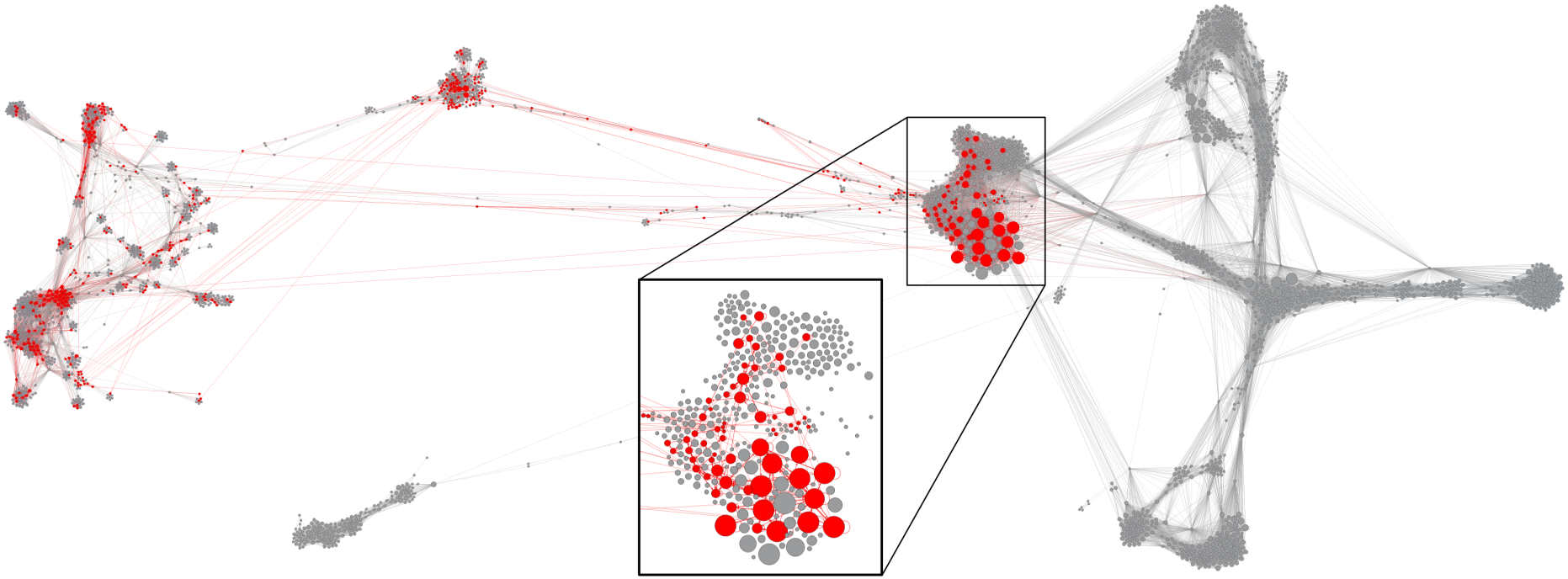
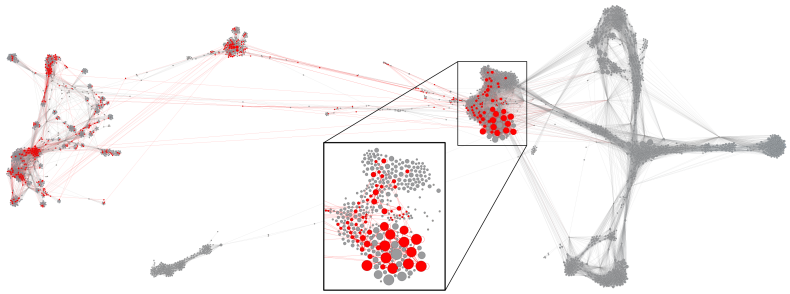


Personal Map overlaid on the GSM/WiFi proximity map



What We Learnt

- Clear view of places.
- Clear view of trips among places.
- Popularity of places.



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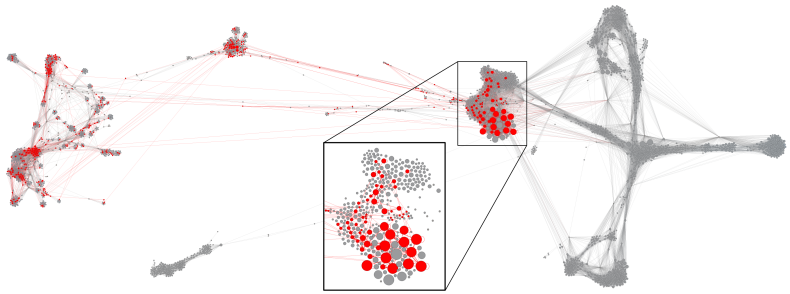

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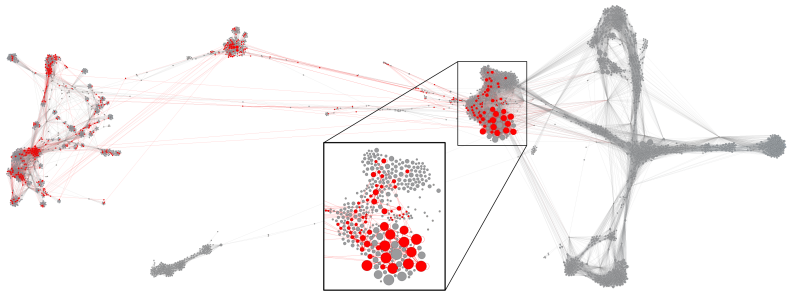

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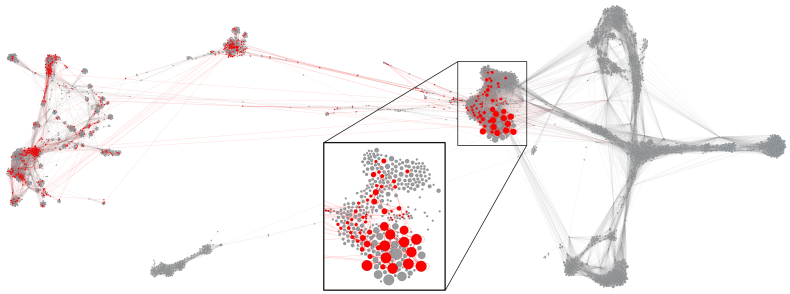

Summary

- The combined analysis of mobility and proximity maps is much more informative than mobility alone.
- Merging the Proximity Graphs of multiple users, Proximity Maps with larger detail can be built.
- Multiple spatial proxies (WiFi/GSM) complement each other to greatly improve the accuracy of the spatial representation.

- Outlook
  - Deal with mobile APs.
  - Suitable metric for the edges of the Proximity Graph.

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Questions?