Crowd-Sensing: an Internet of Things Approach

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U-Hopper

Advanced School on Service Oriented Computing
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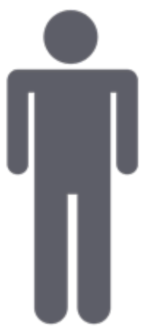
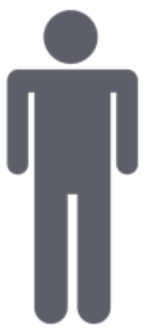
Organization of the Talk

- Crowd-sensing: the why and the how
  - What is *crowd-sensing*
  - Motivating scenarios / Startups
- Architecture and challenges
- Internet of Things
- COMPOSE
- Conclusions

The Context



The Context

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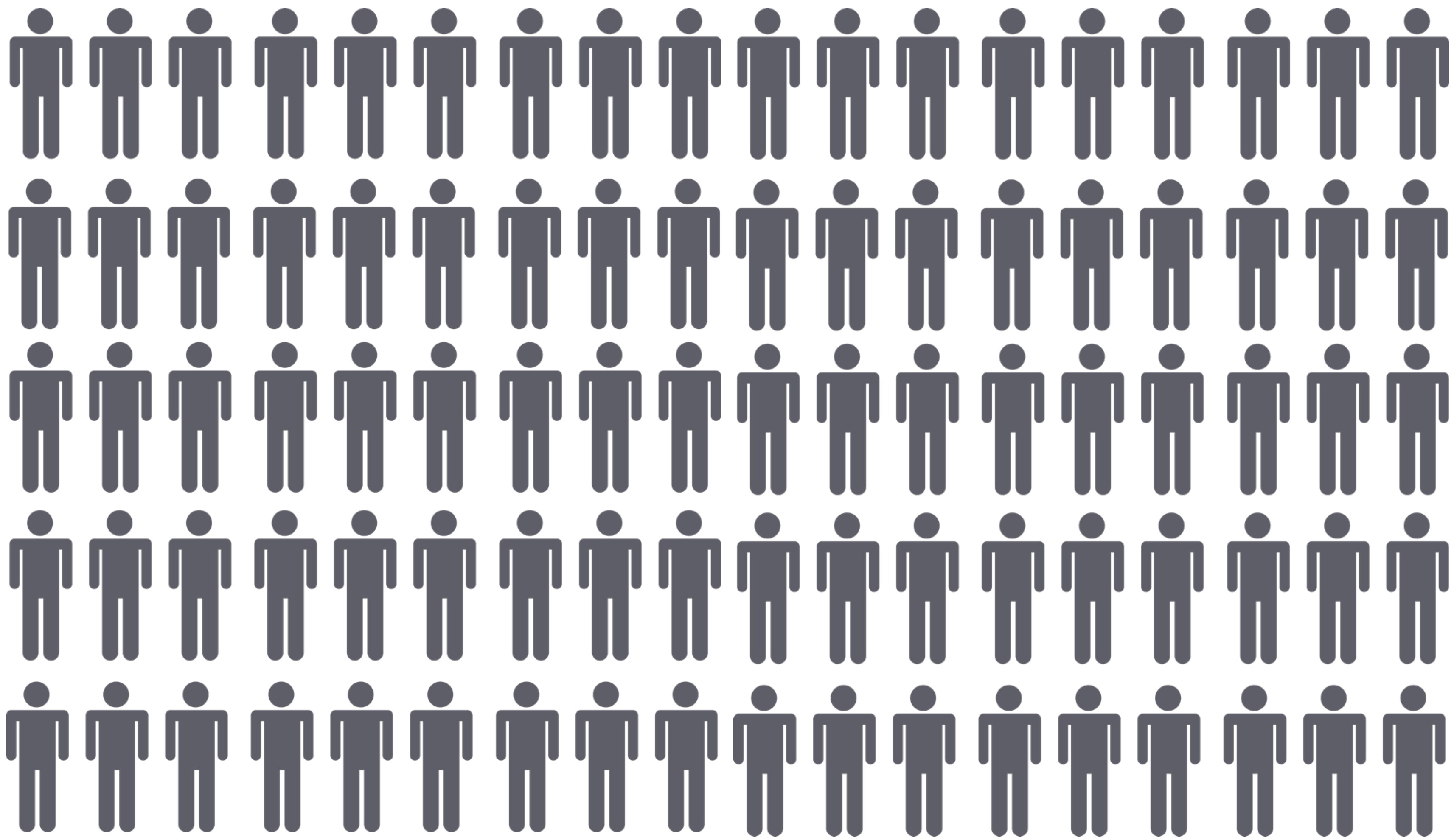
Weather
Passbook
Notes
Reminders
Clock
Stocks
Newsstand
iTunes
App Store
Game Center
Settings
Phone
Mail
Safari
Music

The Context

- bluetooth
- ambient light
- microphone
- pression
- GPS
- WiFi
- accelerometer
- NFC
- gyroscope
- compass
- photo/video
- .....

The Context

The Context



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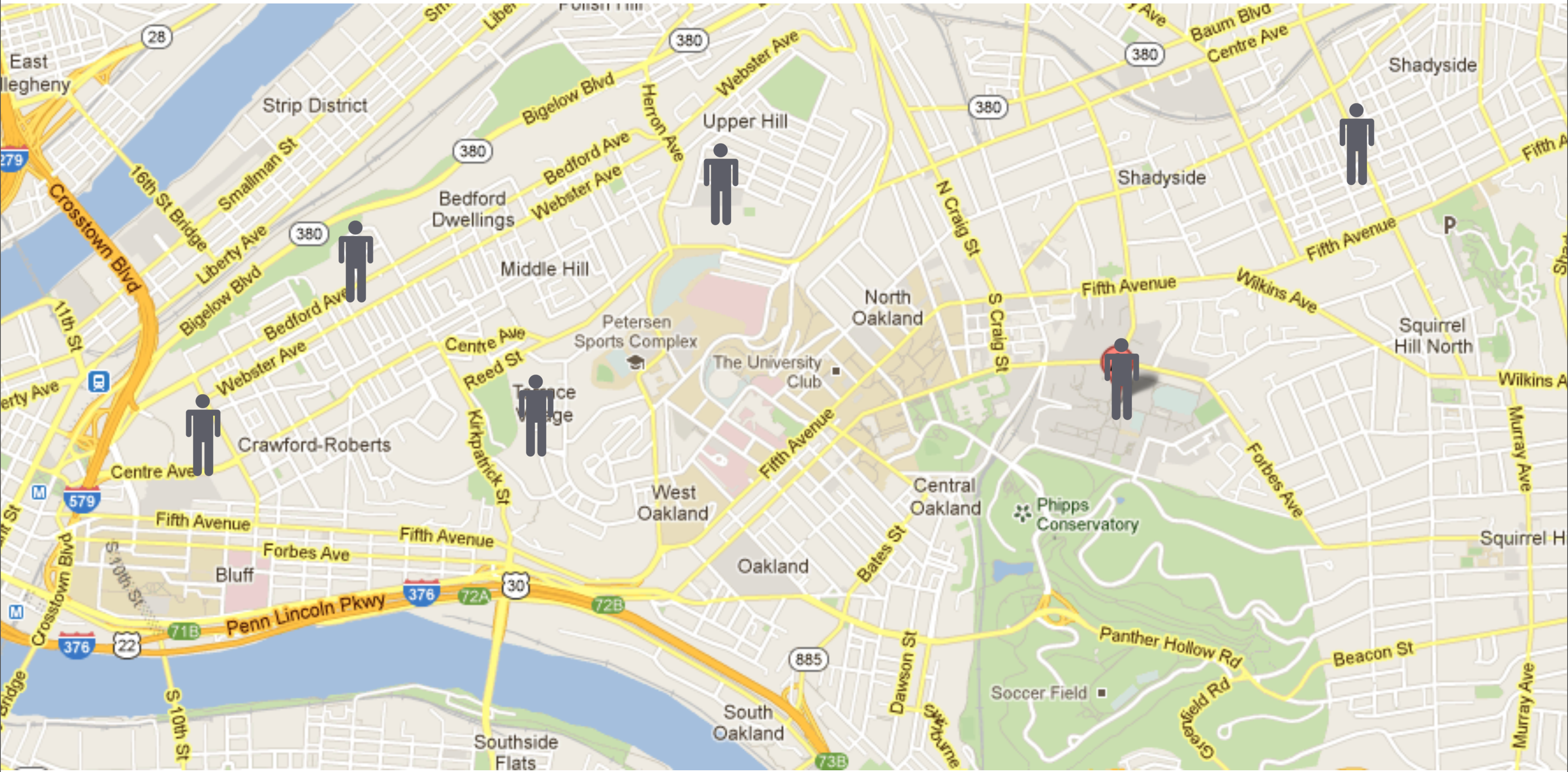
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Club
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Crawford-Roberts
West
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Central
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Phipps
Conservatory
Oakland
Bluff
South
Oakland
Southside
Flats
Soccer Field
Crosstown Blvd
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Murray Ave
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The Context


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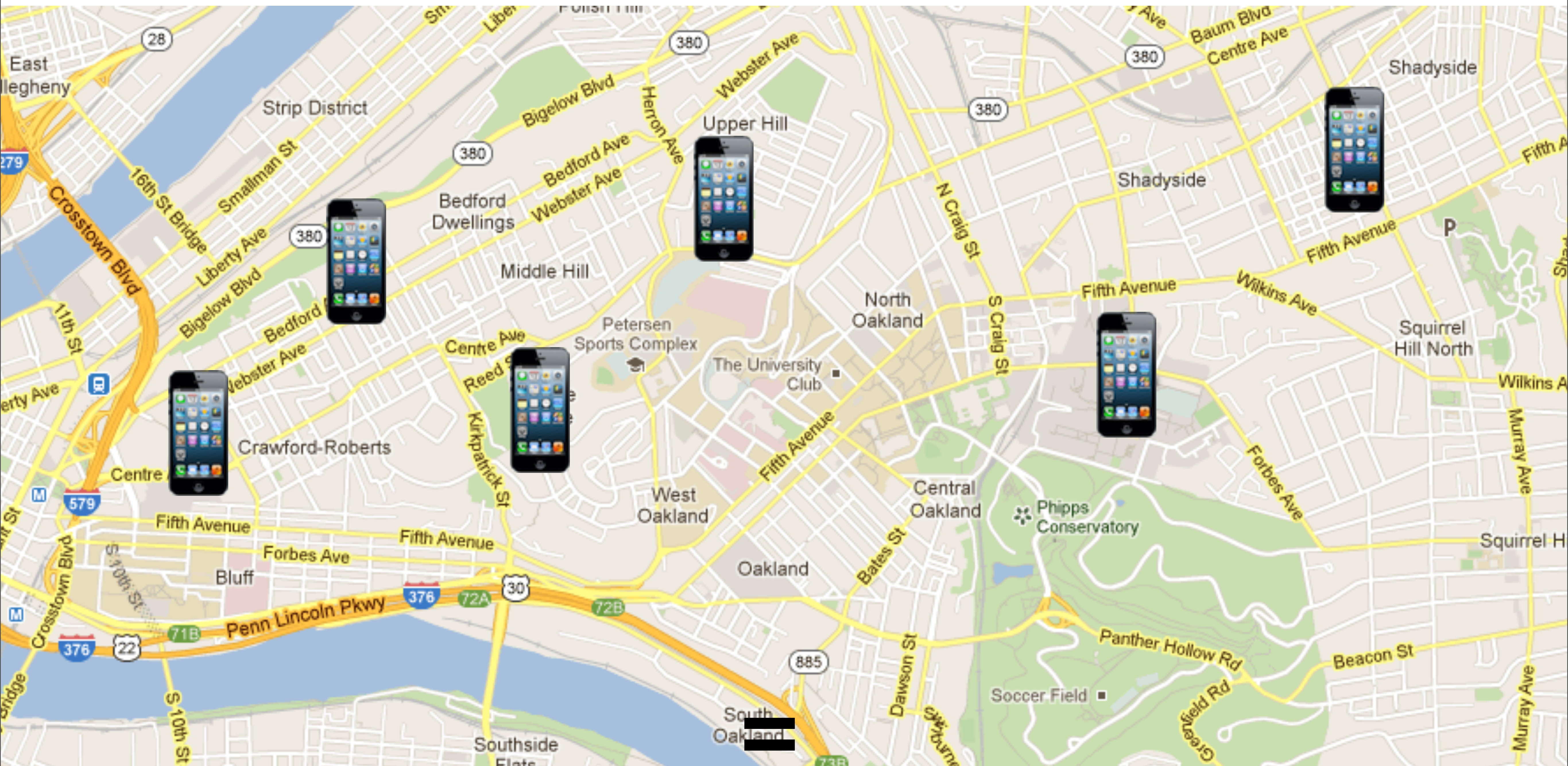
The Context



<u>societal scale</u> ubiquitous sensing infrastructure

CROWD-SENSING:

HOW TO LEVERAGE SUCH A PERVASIVE SENSING INFRASTRUCTURE?

Motivating Scenarios

Motivating Scenarios

- Environmental
  - pollution levels
  - water, wildlife

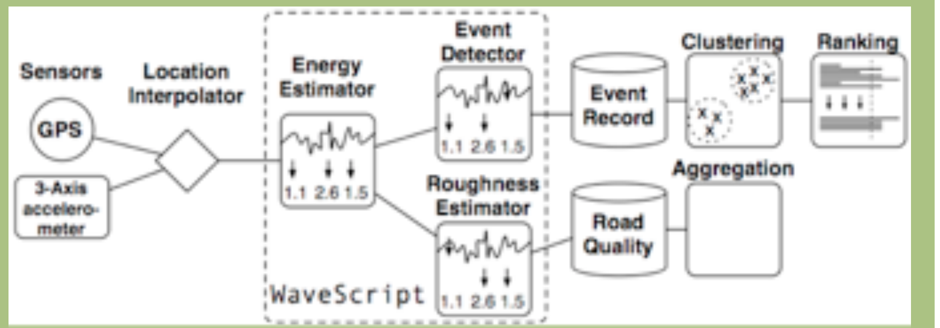
IBM CreekWatch

Motivating Scenarios

- Environmental
  - pollution levels
  - water, wildlife

IBM CreekWatch

- Monitoring Urban Spaces
  - traffic congestion,
  - parking availability
  - road conditions



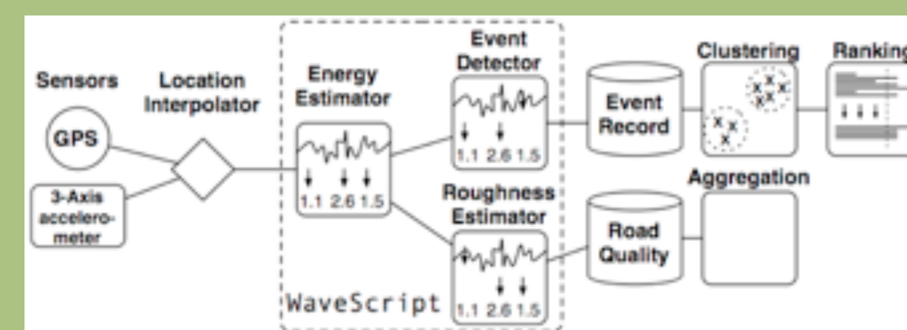
MIT Pothole

Motivating Scenarios

- Environmental
  - pollution levels
  - water, wildlife

IBM CreekWatch

- Monitoring Urban Spaces
  - traffic congestion,
  - parking availability
  - road conditions

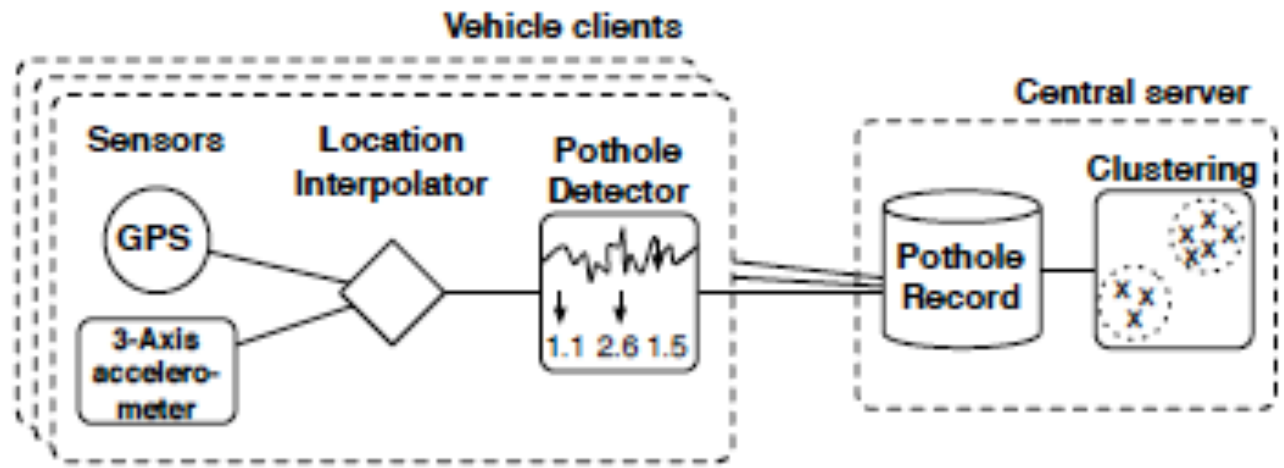


MIT Pothole

- Personal Sensing
  - Bike Net
  - DietSense

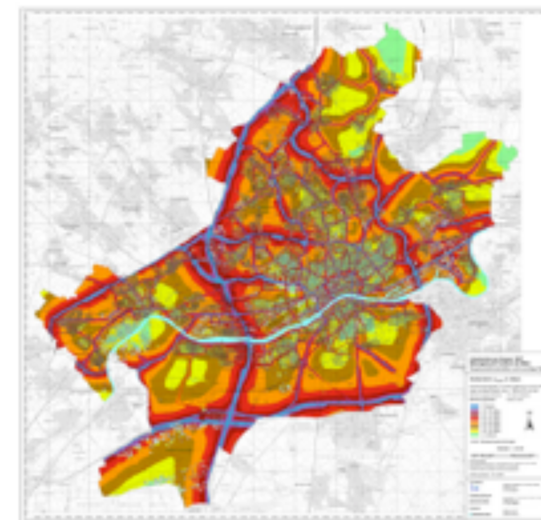
Dartmouth
Bikenet

Pothole Detection



- Objectives
  - measure presence of potholes from geo-localized accelerometers traces
- Challenges
  - Loosely labeled training data
  - Anomalies similar to potholes (e.g., curbs, manholes)
  - False positives

NoiseMap



- Objectives
  - measure noise pollution
- Challenges
  - Incentives
  - Microphone data quality
  - Calibration
  - Combination of heterogeneous sources

BikeNet

Carbon dioxide Map

- Objectives:
  - share cycling experience
  - monitor urban environment
- Challenges
  - privacy
  - data delivery

Mobile Territorial Lab

Exploit smartphones' sensing capabilities to:

- infer individual and social dynamics
- improve personal awareness and self-knowledge,
- empower communities through citizens data (mobility, spending, mood and stress etc.),
- advance knowledge on a given territory

http://www.mobileterritoriallab.eu

Environmental Monitoring

Potholes

Traffic

Biking

Health Monitoring

Urban rhythms

Air quality

Emotional State

Noise Pollution

Stress

Diet

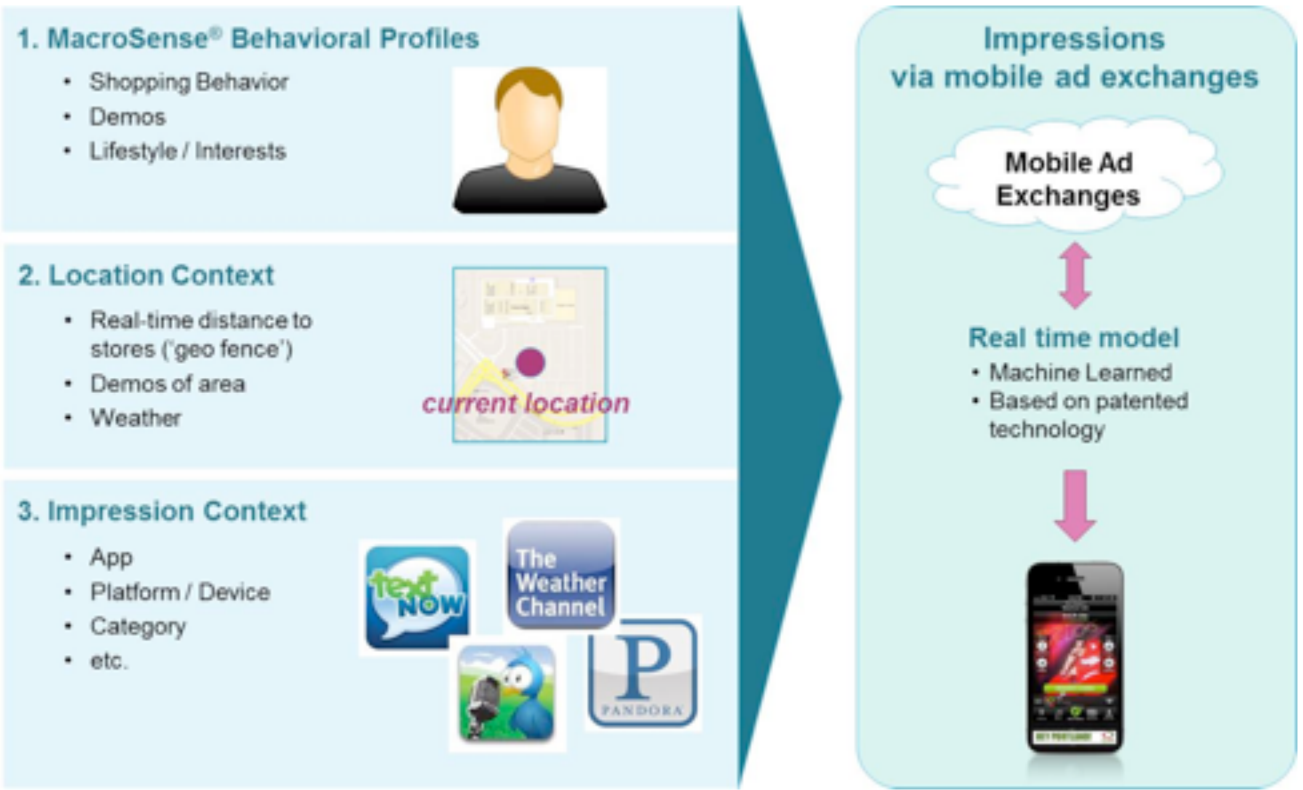
Garbage

Urban sensing

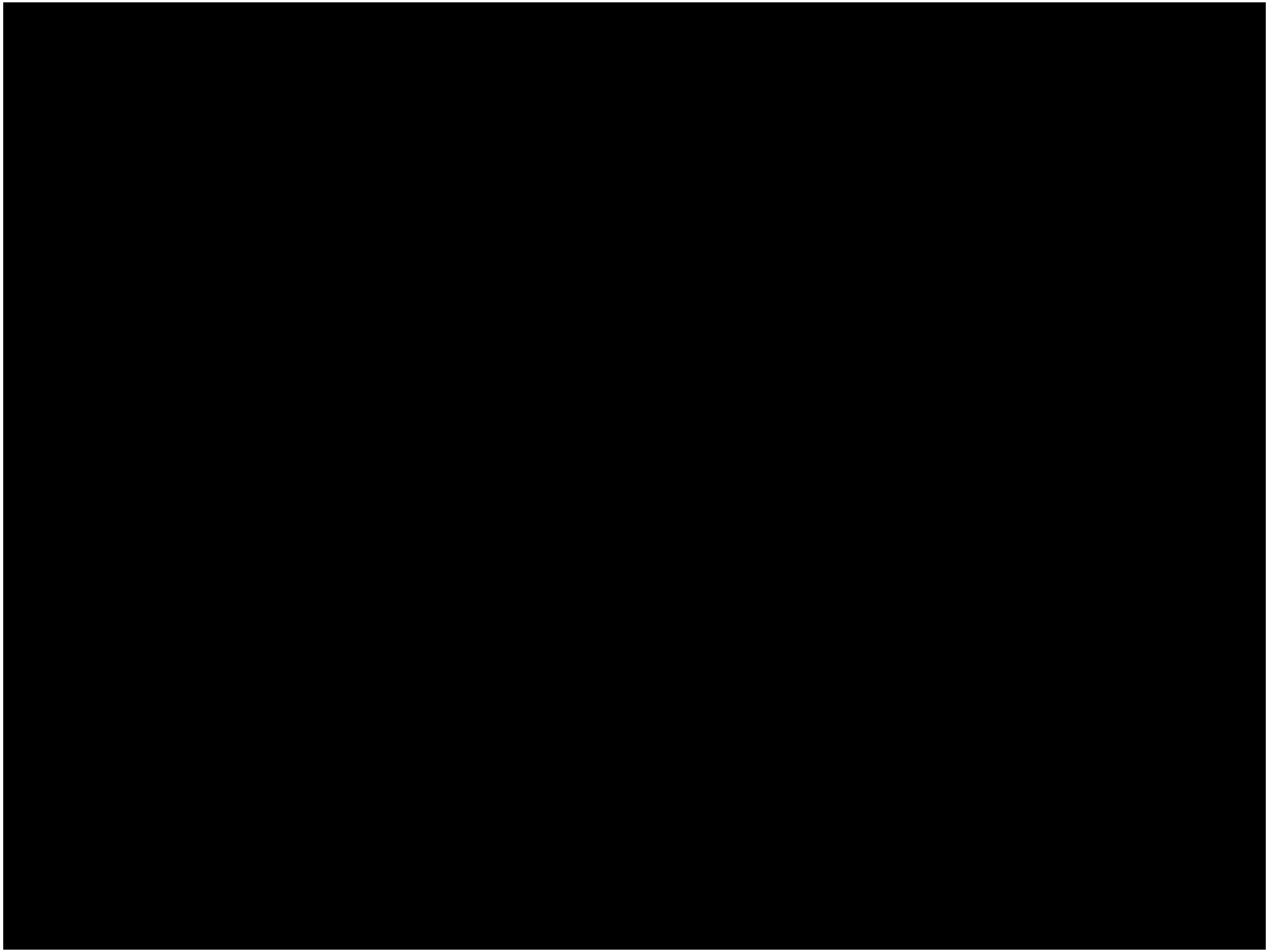
WHAT ABOUT STARTUPS?

Sense Networks

- Transforms raw location data into <u>actionable</u> intelligence
  - from opt-in locations
  - extract behavioral attributes
  - build anonymous profiles
- Example of applications
  - ad-targeting
  - recommend "hot" spots in the city



SenseNetworks in Action

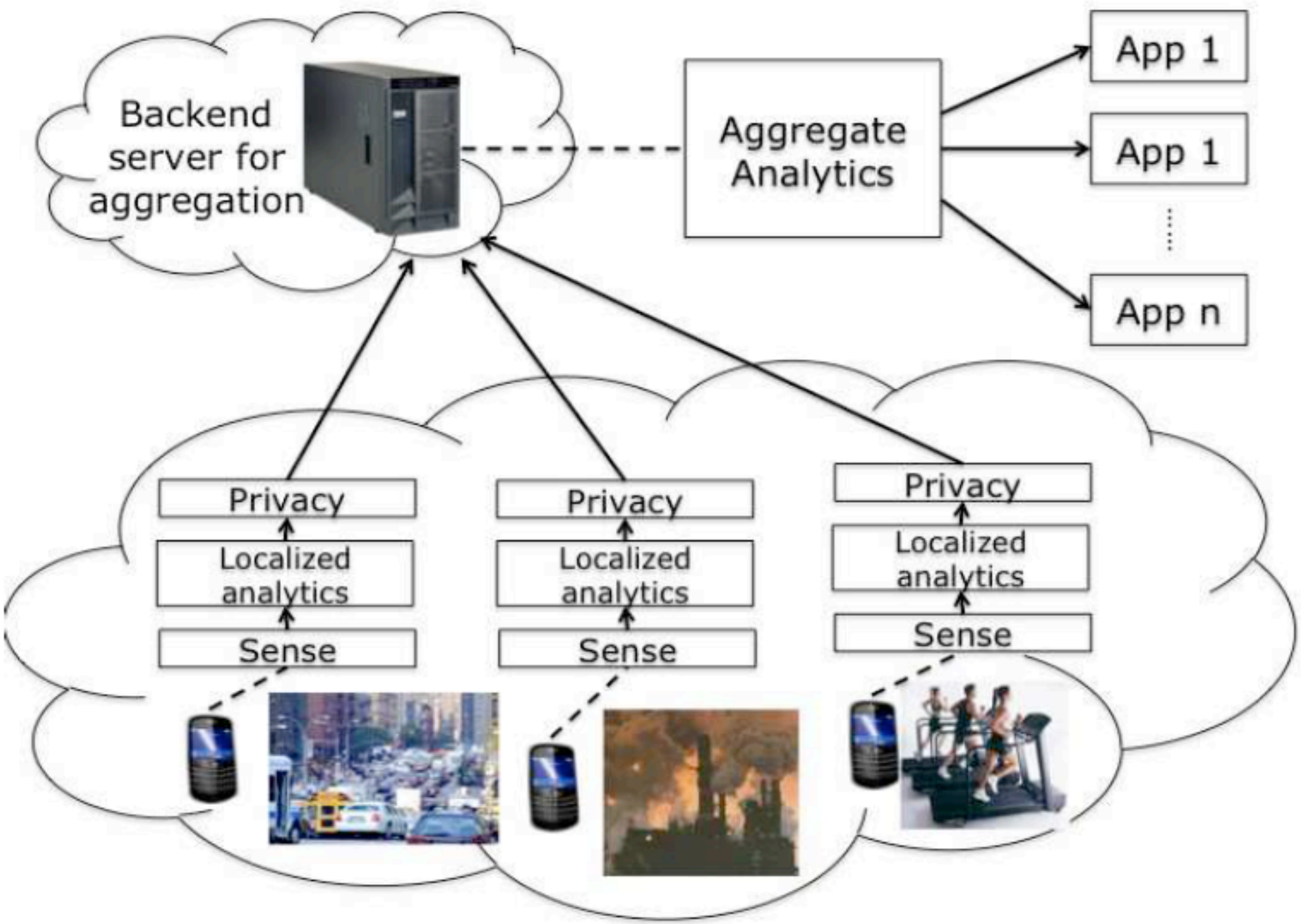


behavio

funf
Open Sensing Framework

An open source, reusable set of functionalities, enabling the collection, uploading, and configuration of a wide range of data signals accessible via mobile phones.

Architecture



source: Mobile Crowdsensing: Current State and Future Challenges, K. R. Fanti, F. Ye, H. Lei

Challenges

- Understanding and interpreting the sensed data
  - from incomplete and sparse data
- Privacy
- Energy efficiency
- Incentive mechanisms
- Program human-based computations/tasks
  - recruitment, incentives, reliability

WHY

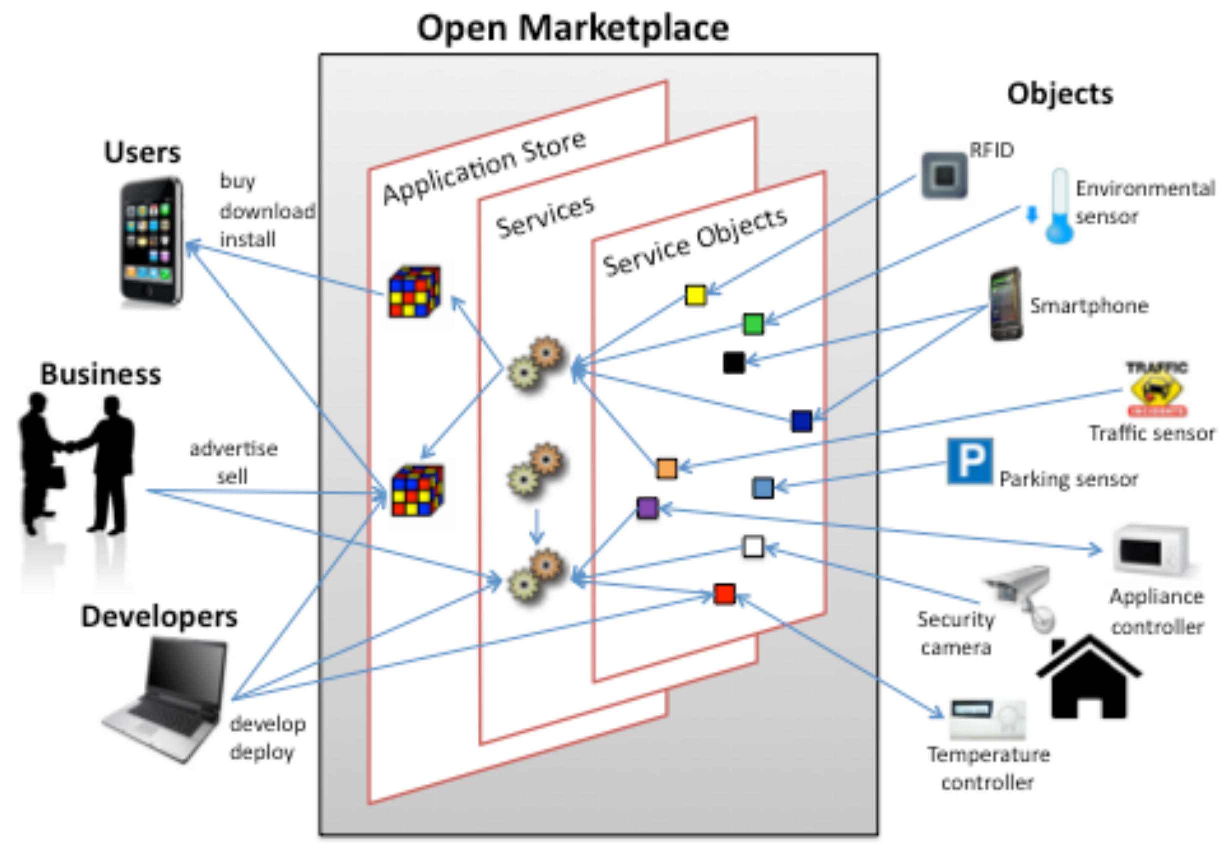
INTERNET OF THINGS?

Internet of Things

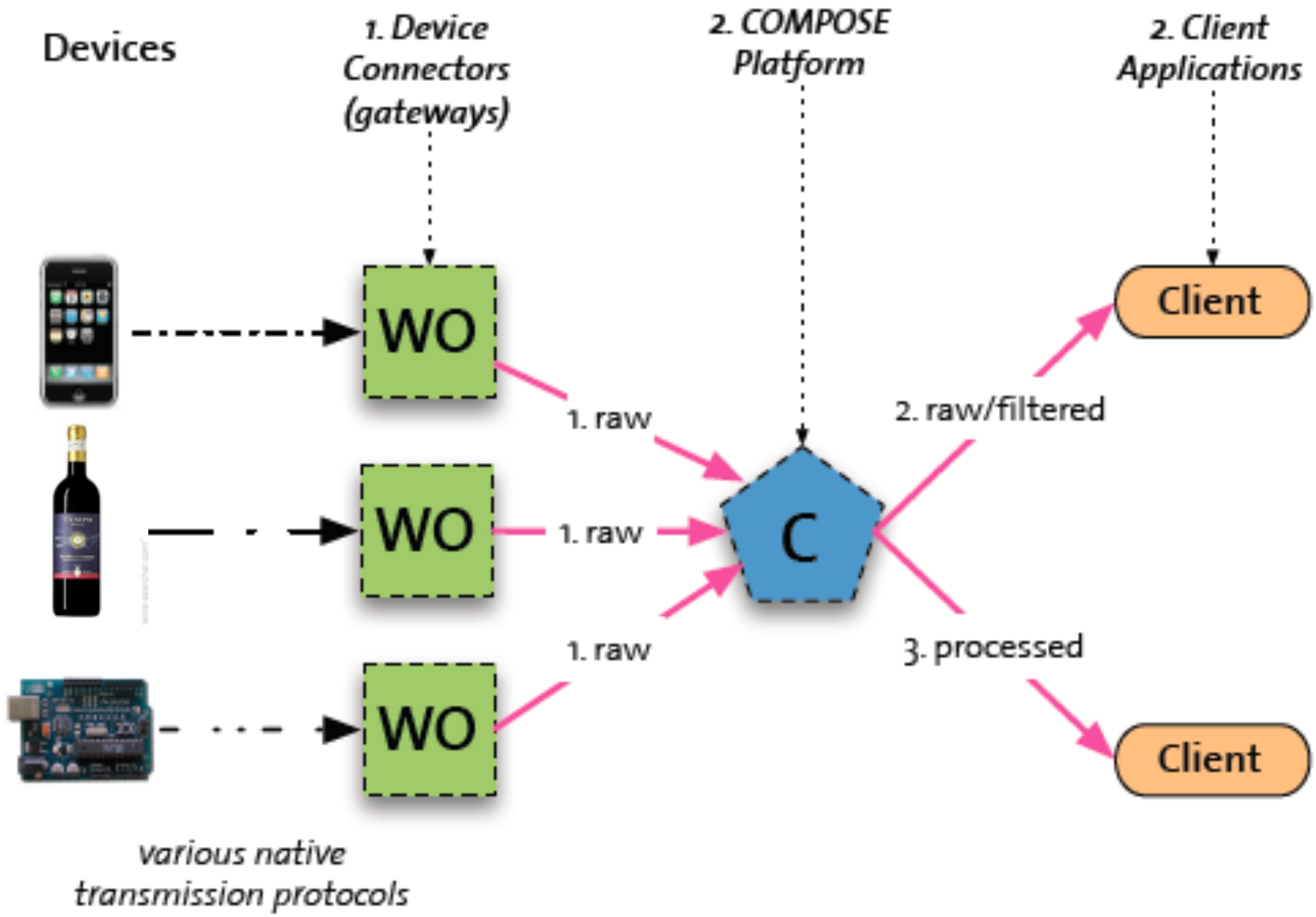
- Project Fact-sheet:
  - Integrated Project
  - Objective: 1.2 (Internet of Services)
  - Number of partners: 12
    - Coordinator: IBM Haifa
    - 2 SMEs, W3C, 4 Research centers, 1 Telco, 2 Universities, 1 Business Dev. company
  - Duration: 3 years
    - Started Nov. 2012
  - Total Cost: 7.4M Euros
    - EC contribution: 5.35M
  - Web site: www.compose-project.eu

COMPOSE Objectives

- Objectives:
  - Design and implement an open and scalable service **Market Place** to easily and securely develop, deploy, share and maintain **services based on Internet-connected** smart objects
  - Cover the whole service lifecycle
  - Become the Appstore/Google Play for Smart Objects



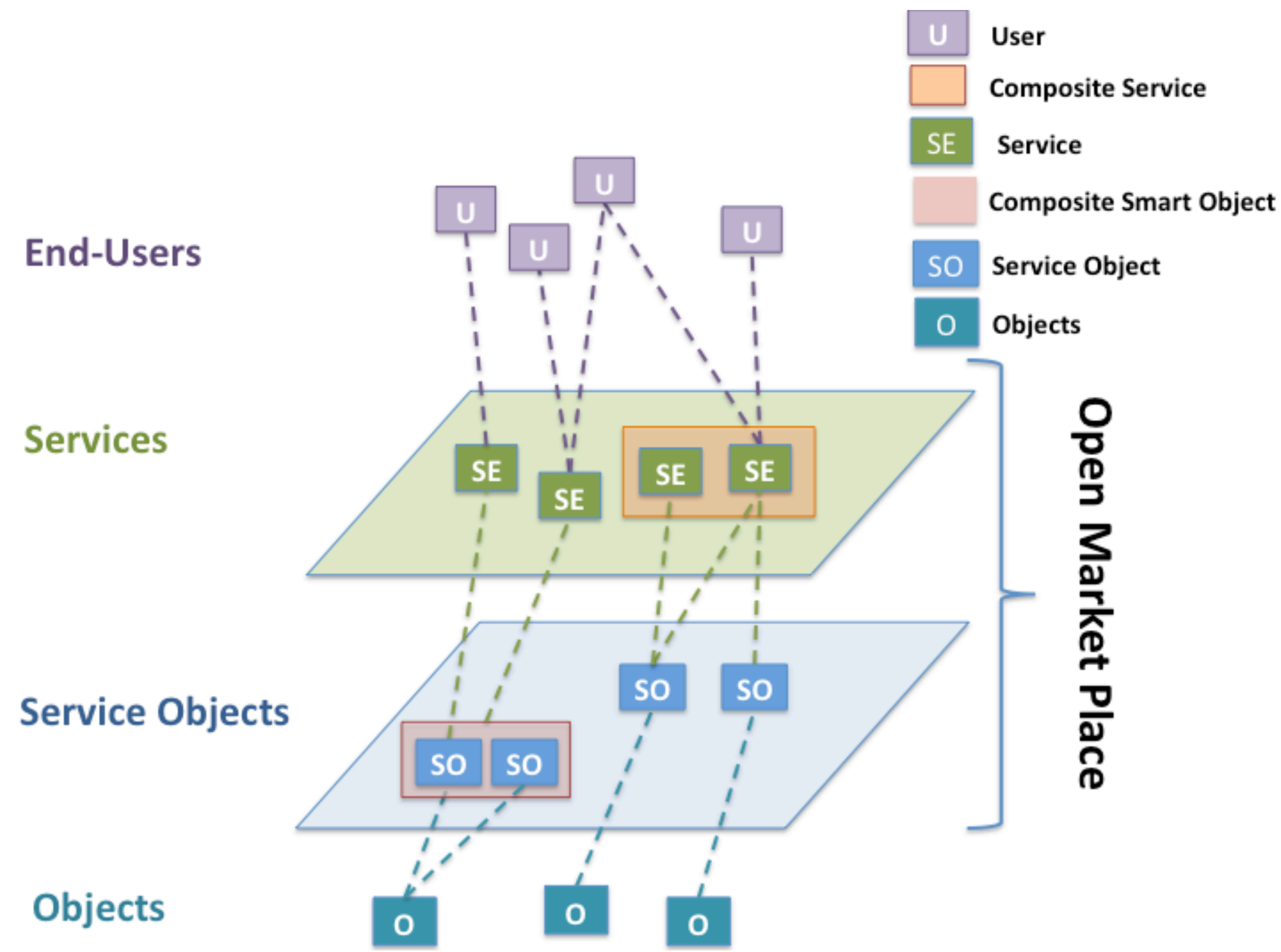
Approach



@Copyright: Vlad Trifa, Evrythng

Technical Approach

- Web-based architecture
- Objects service management:
  - object and interaction virtualization, discovery
  - accounting
  - events stream processing
- Service design and execution
  - discovery, composition, orchestration
  - runtime
- Marketplace support
  - SDK/GUI for developers



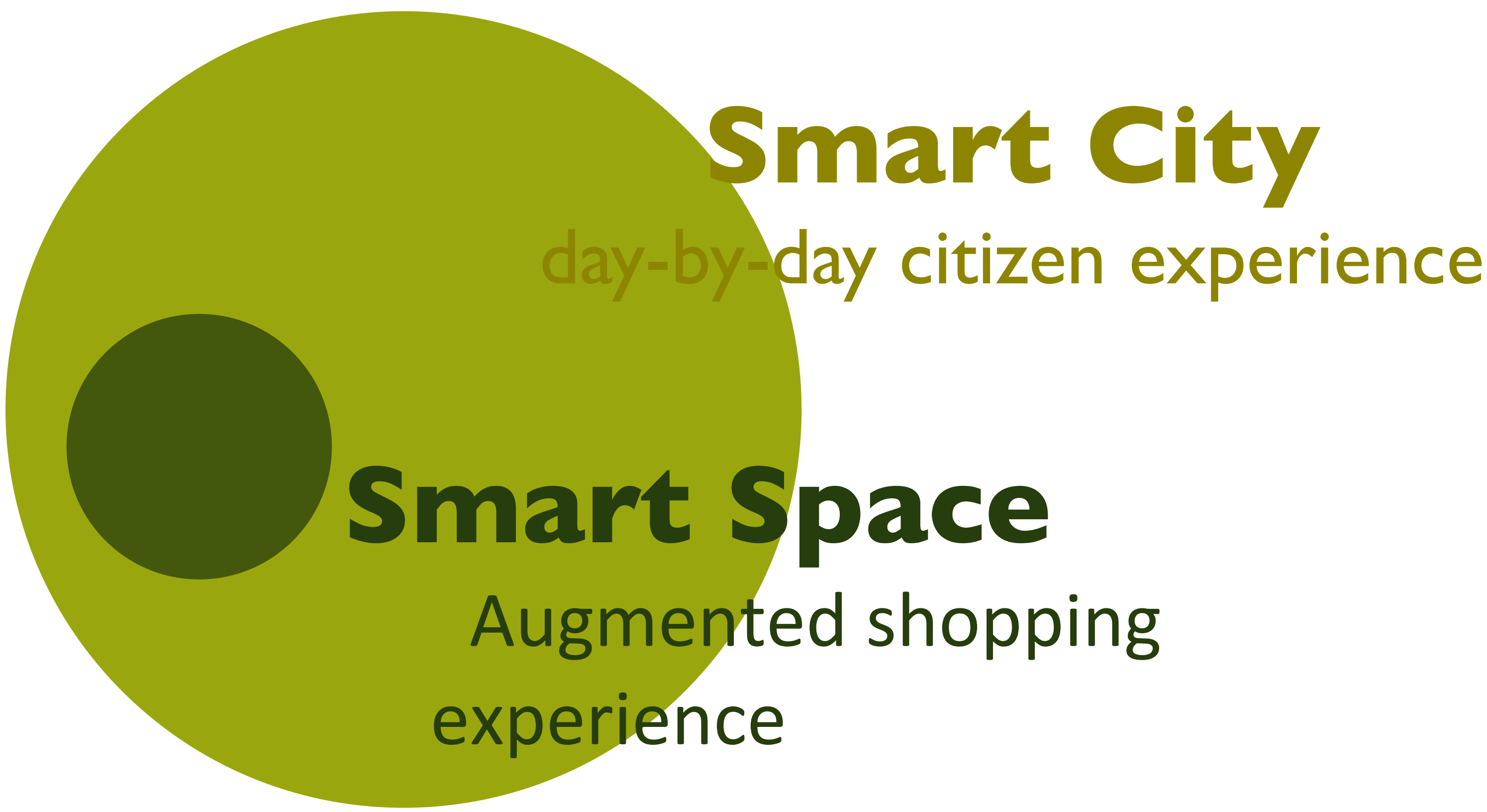
Use-Case Driven

Use-Case Driven

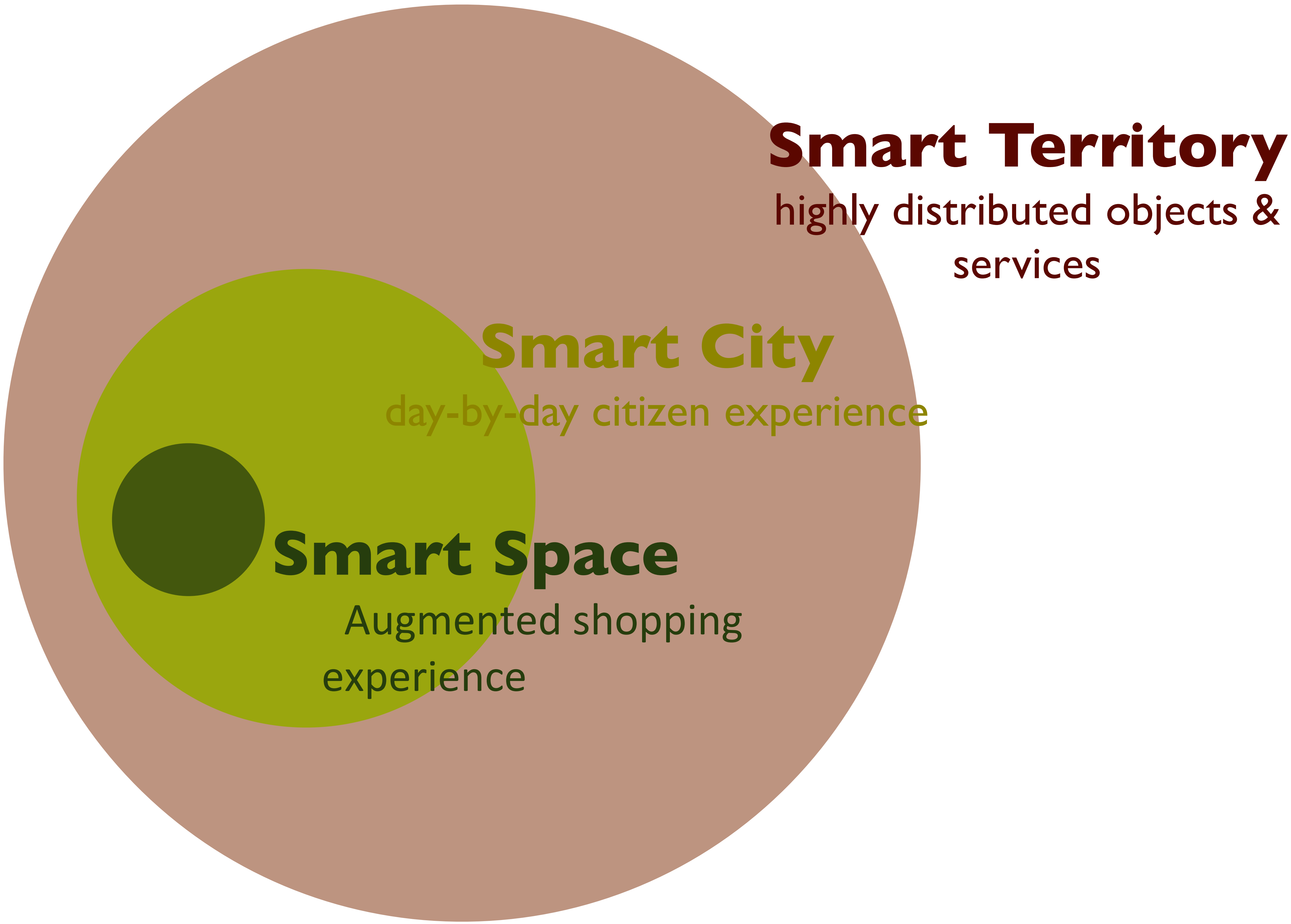
Smart Space

Augmented shopping experience

Use-Case Driven



Use-Case Driven



Issues

- Scalability
  - at the Object level (# of objects generating data)
  - at the Application level (# of app consuming data)
- Dynamic system behavior
  - programmable real-time stream processing
  - unreliable data streams
- Service modeling
- Privacy and security
- Heterogeneity
  - of devices
  - of data streams

TO CONCLUDE

Take-Away Messages

- Smartphones are becoming a primary **source** of data pertaining to users daily patterns and the surrounding environment
  - can be considered as Internet connected (sensing) Objects
- It's "for free"
  - no infrastructural costs
  - (Big) data is there
-

Questions?

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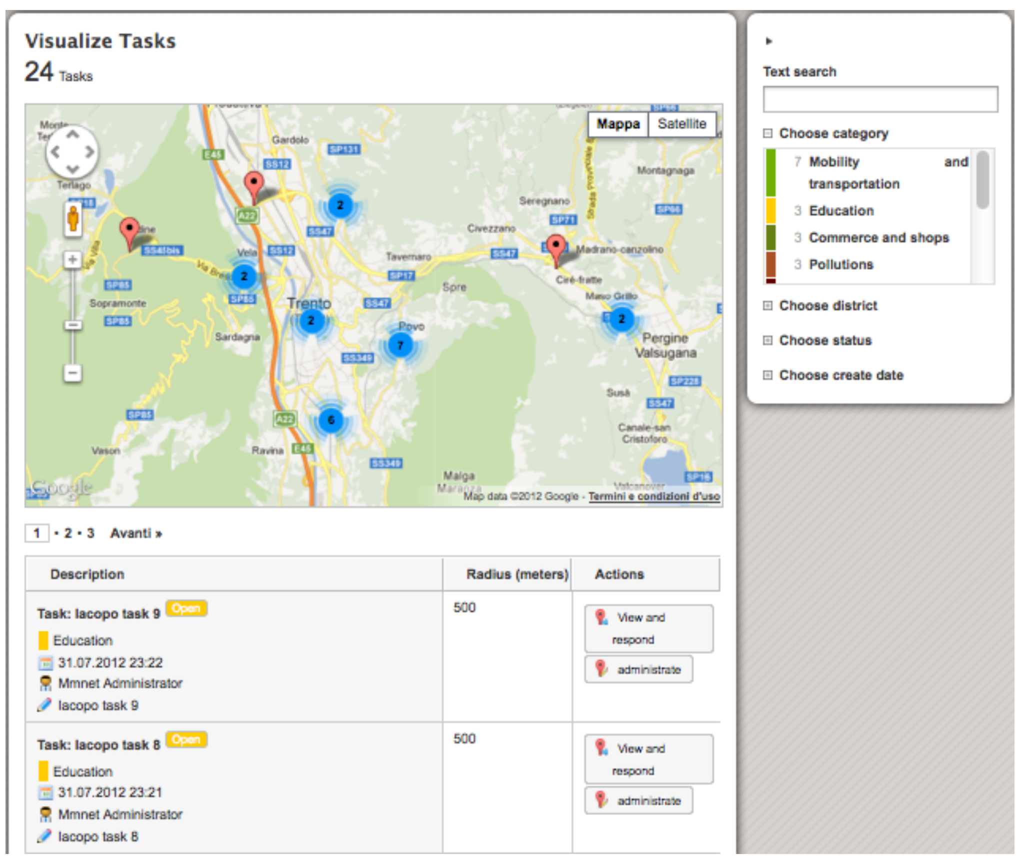
skype: i_carreras

Back-up

MATADOR: server side

Server Side

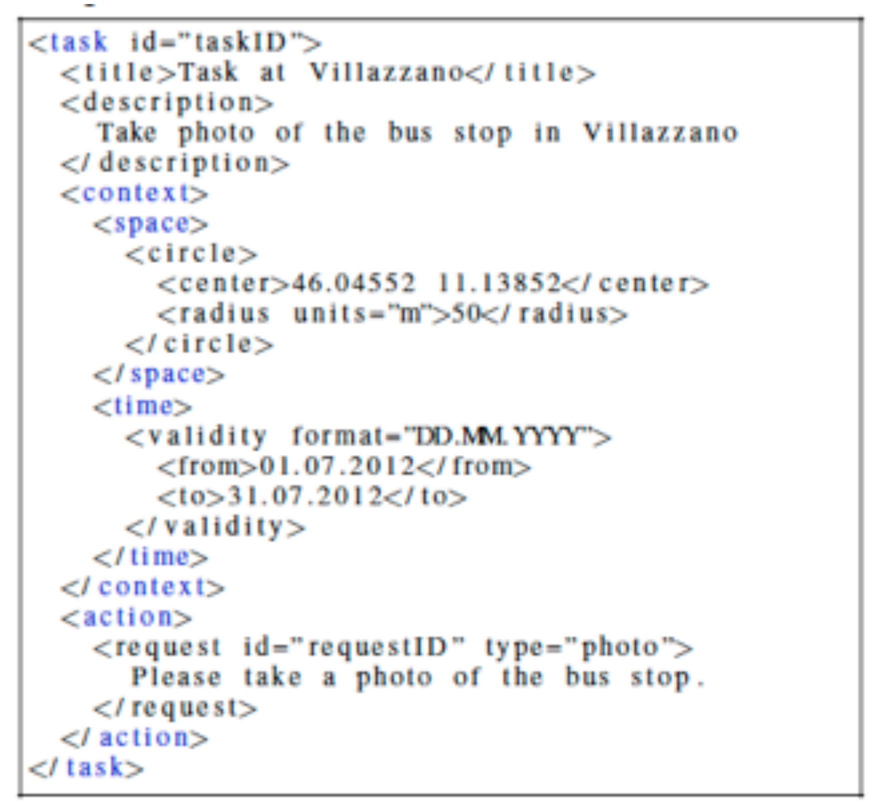
- Create and configure crowd-sensing tasks
- Visualize and analyze data



- Task 1
- Task2

- Task N

Task Response

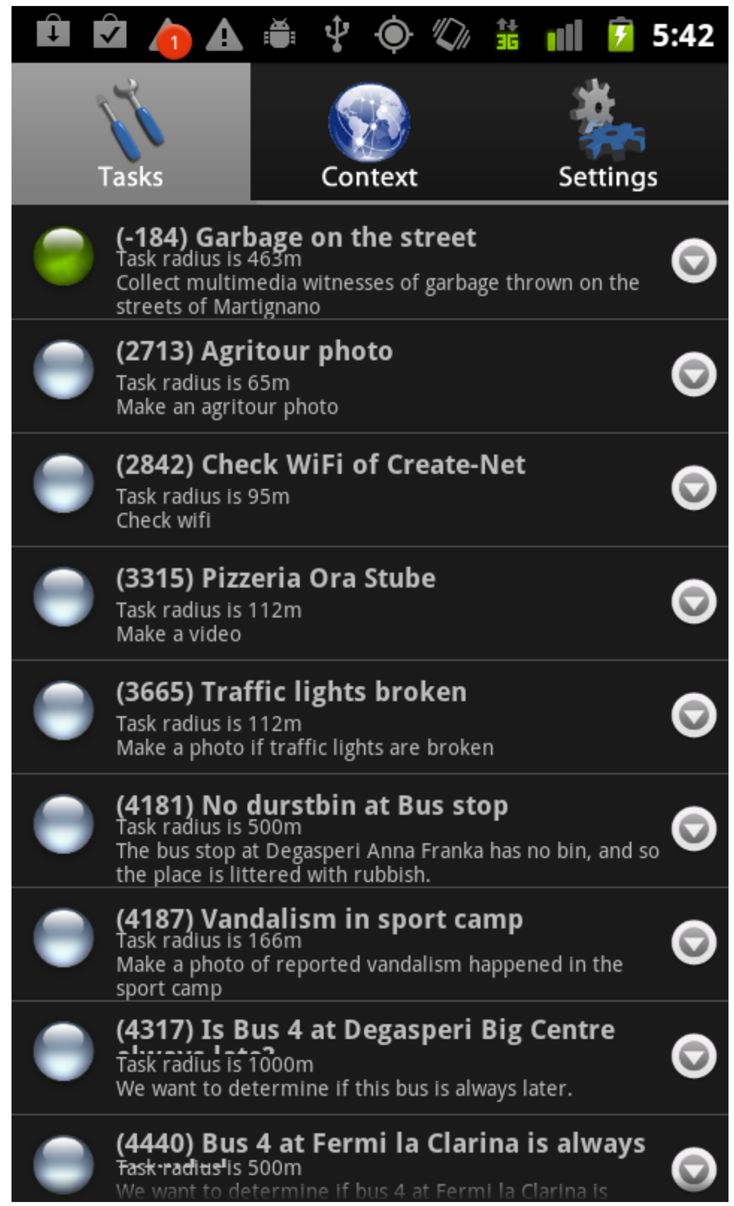


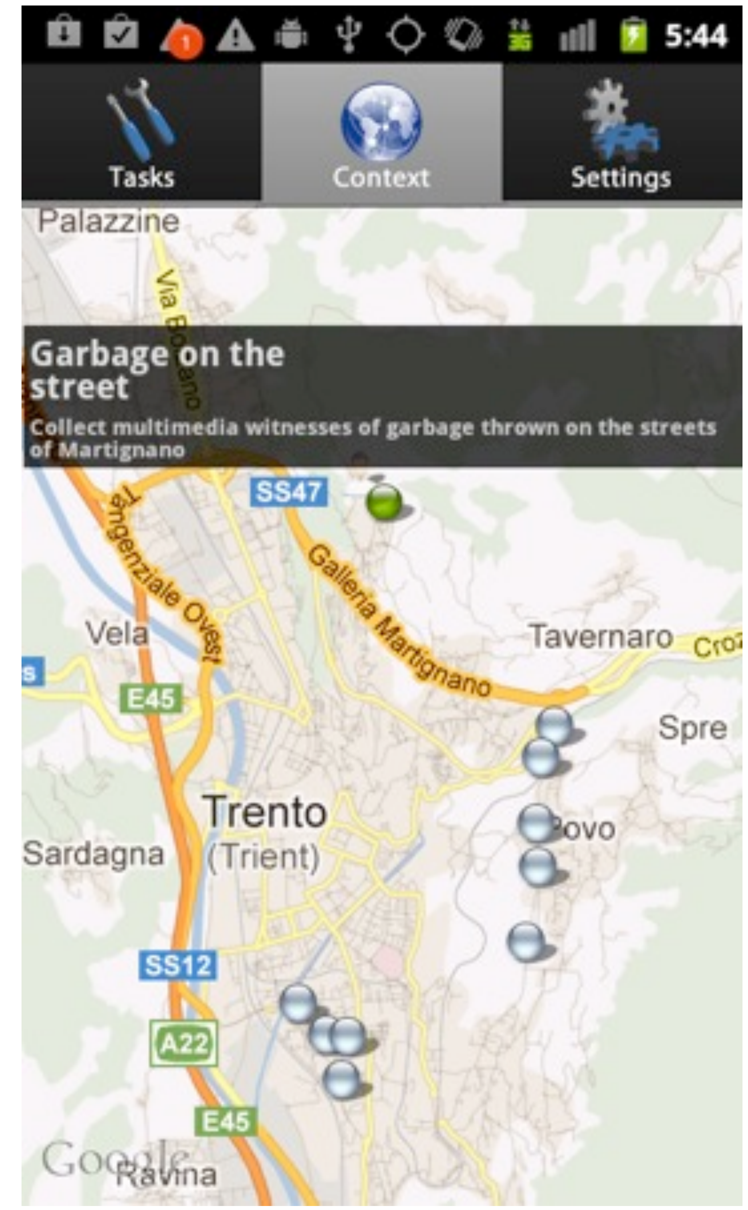
```
<task id="taskID">
  <title>Task at Villazzano</title>
  <description>
    Take photo of the bus stop in Villazzano
  </description>
  <context>
    <space>
      <circle>
        <center>46.04552 11.13852</center>
        <radius units="m">50</radius>
      </circle>
    </space>
    <time>
      <validity format="DD.MM.YYYY">
        <from>01.07.2012</from>
        <to>31.07.2012</to>
      </validity>
    </time>
  </context>
  <action>
    <request id="requestID" type="photo">
      Please take a photo of the bus stop.
    </request>
  </action>
</task>
```

MATADOR: mobile app

Mobile application

- Synchronizes tasks
- Trigger tasks to users
- Deliver results to web application

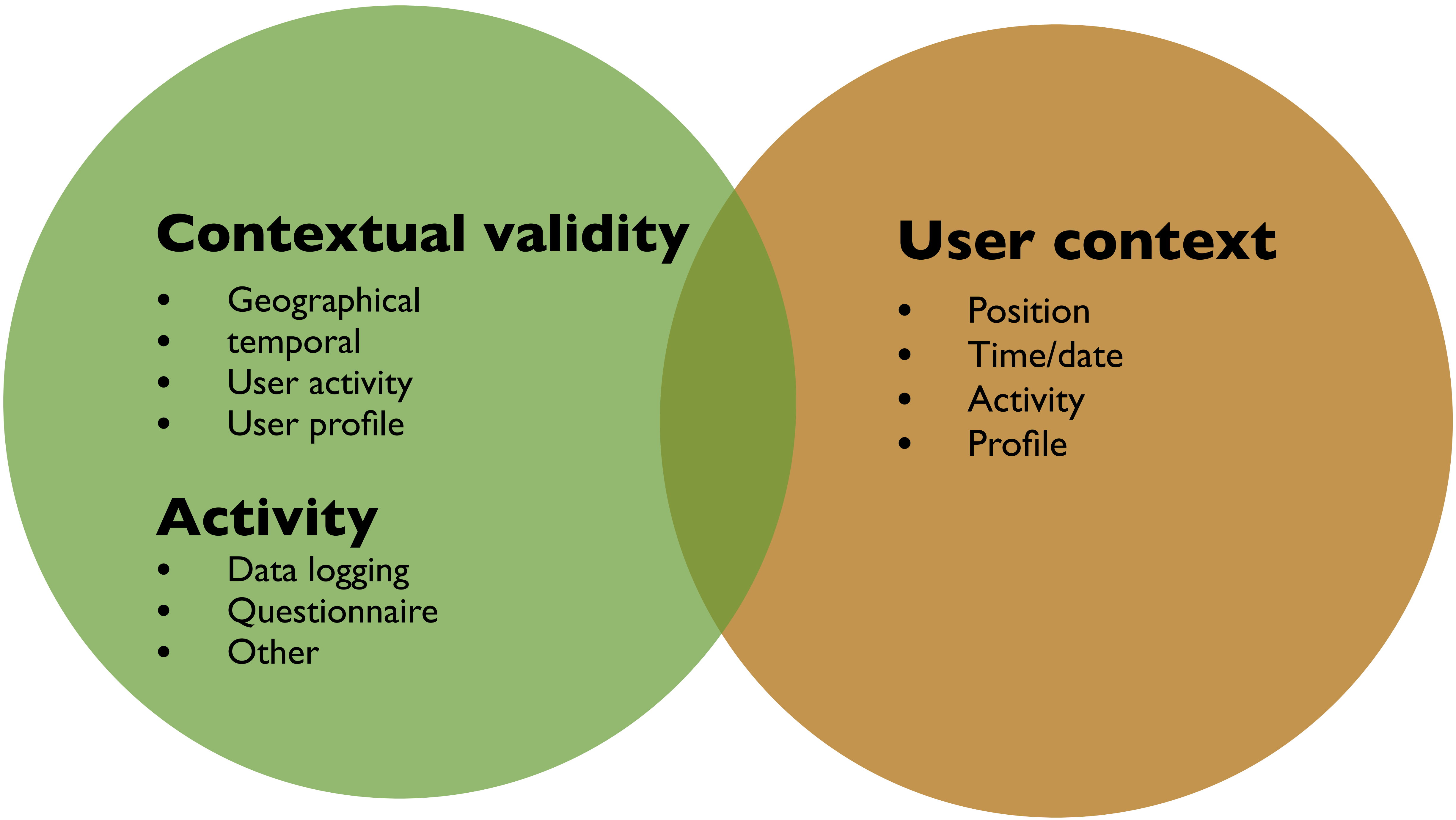




Context-Aware Crowd-

Crowd-Sensing Task

User Context

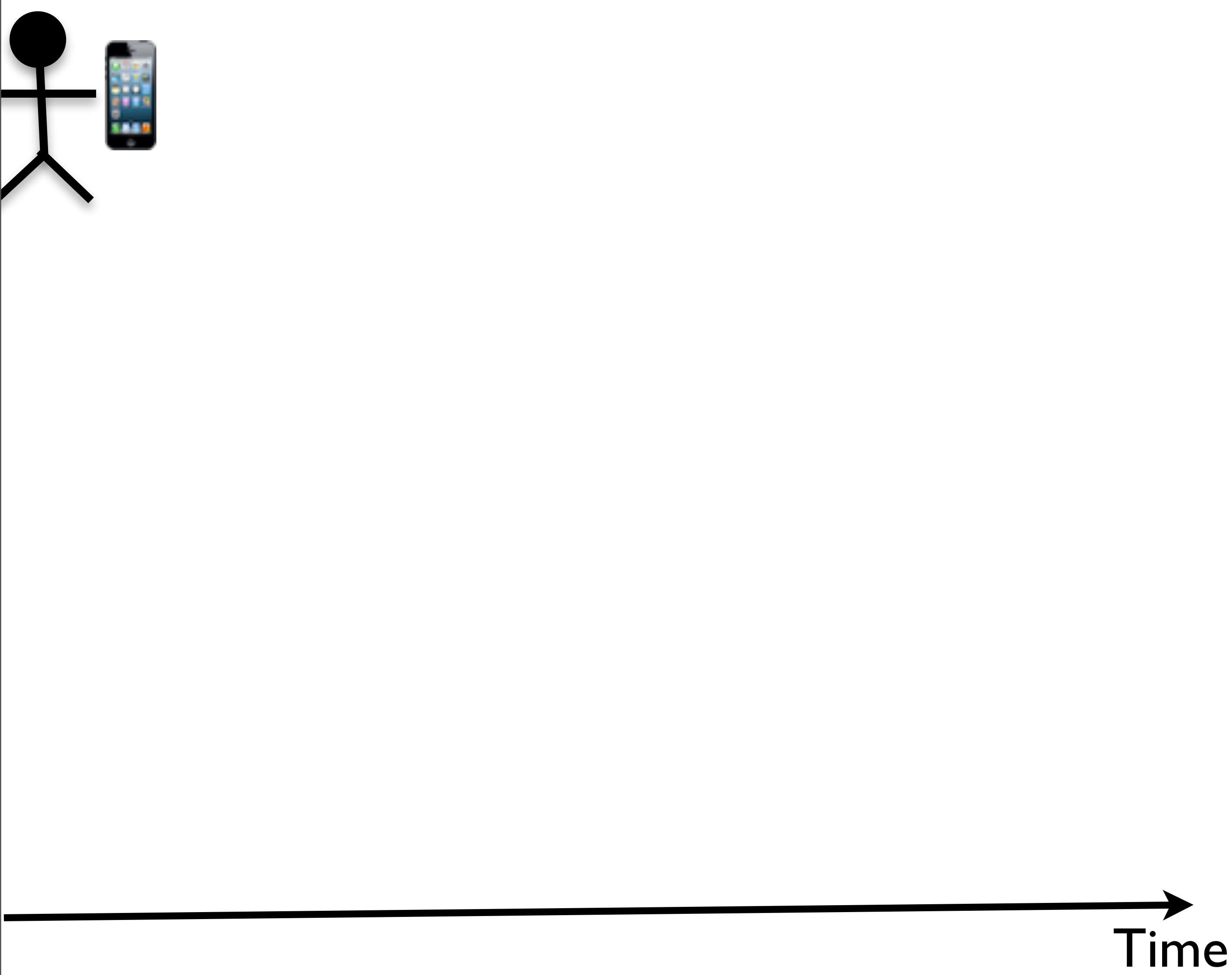


Problem Formulation

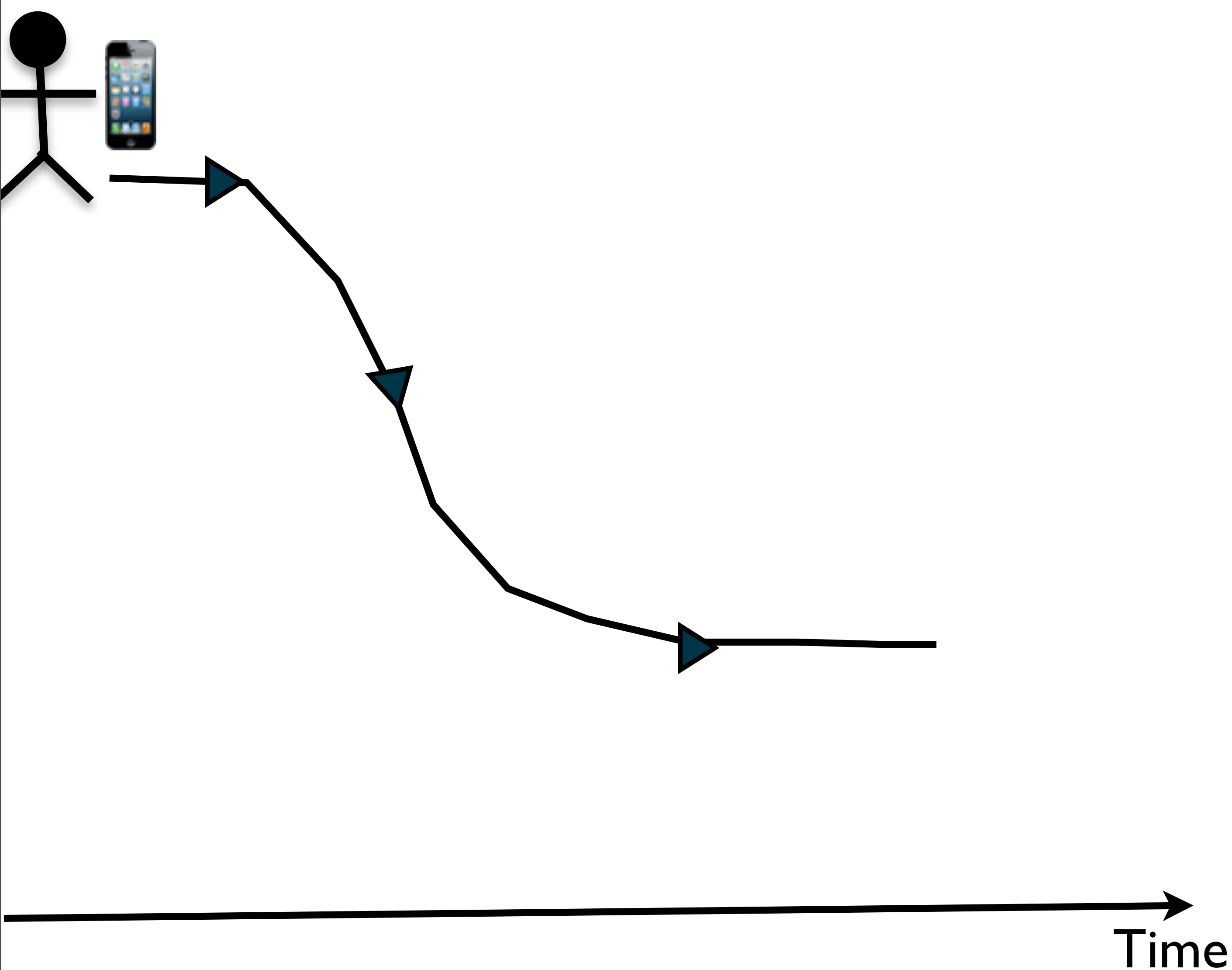
Design a context sampling algorithm which is able

1. Minimize mobile devices' energy consumption
   - Temporal
   - User activity
   - User profile
2. Maximize the # of detected tasks

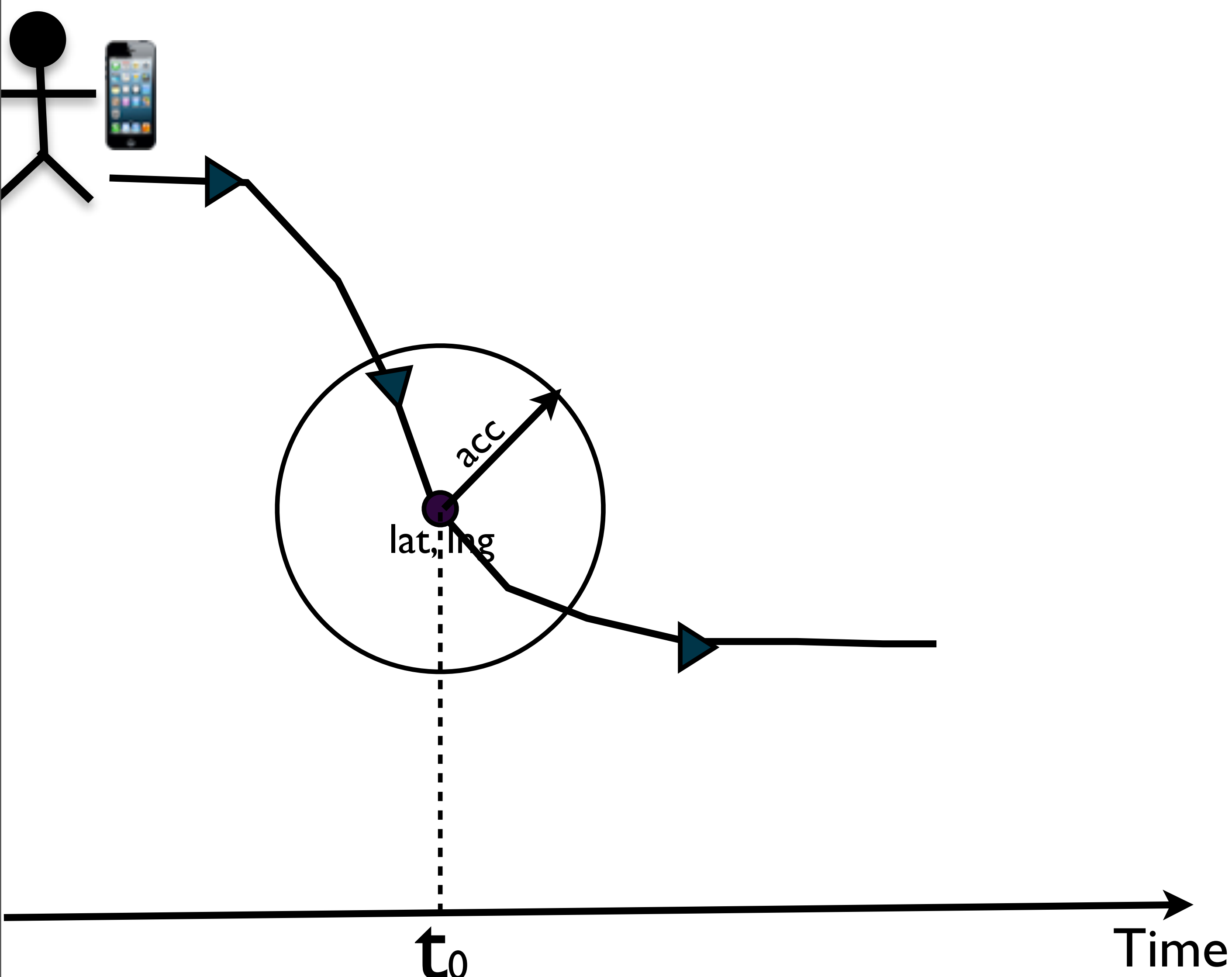
The Algorithm



The Algorithm



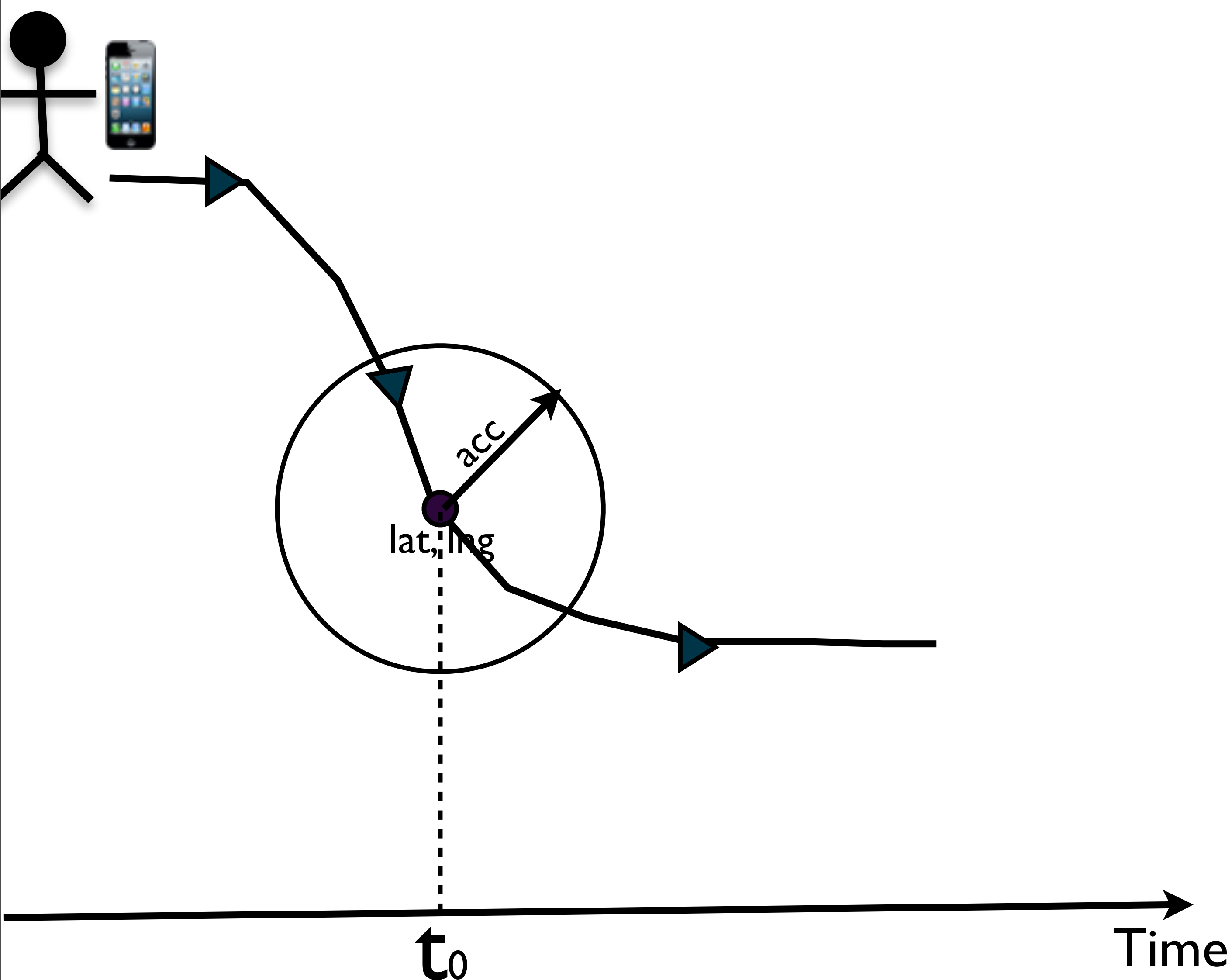
The Algorithm

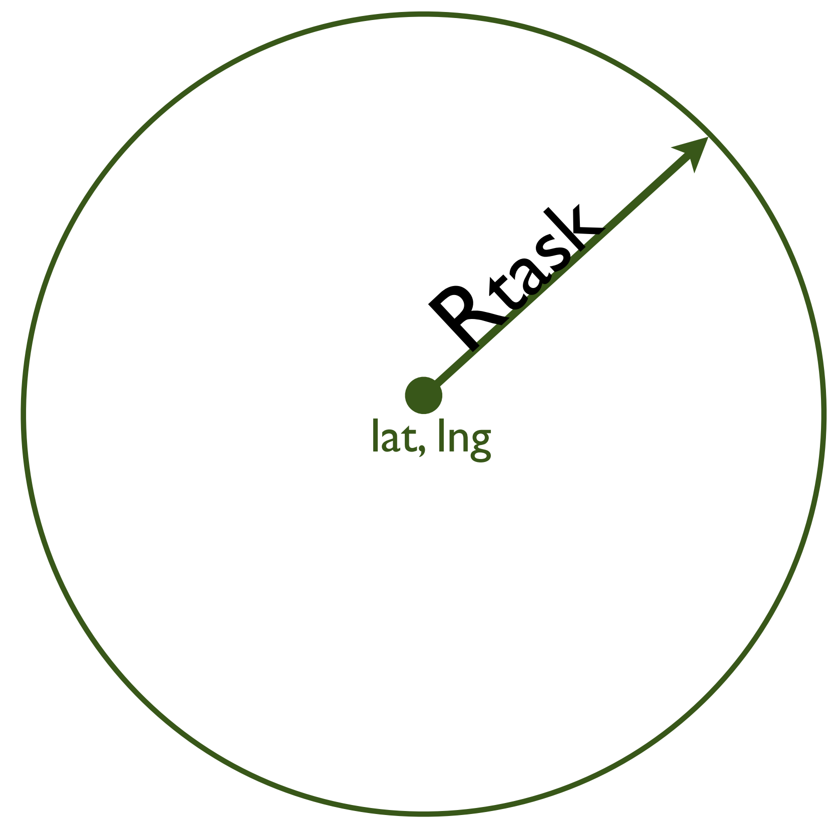


User

- position <lat, lng, acc>
- speed

The Algorithm





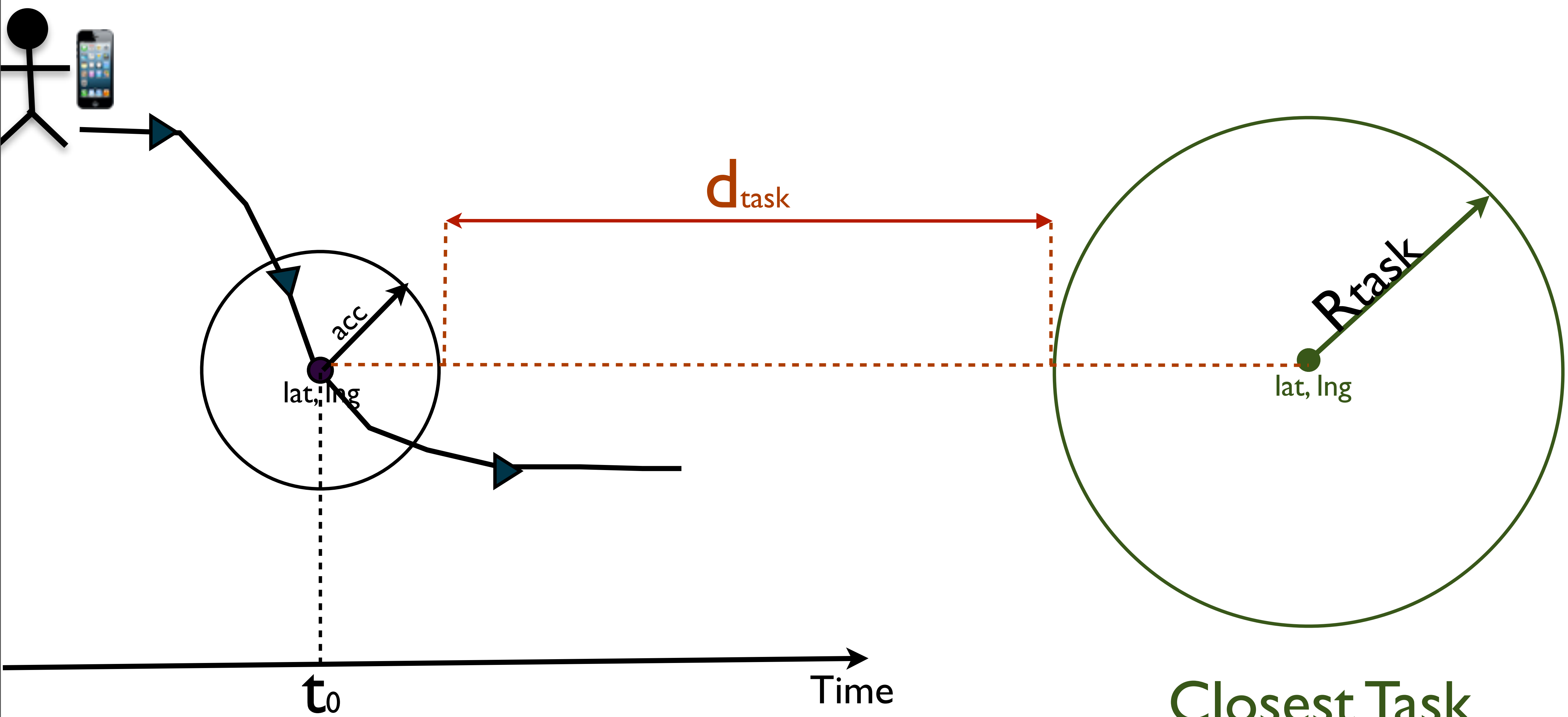
User

- position <lat, lng, acc>
- speed

Closest Task

- Spatial validity
- Temporal validity
- Other features

The Algorithm



User

- position <lat, lng, acc>
- speed

Closest Task

- Spatial validity
- Temporal validity
- Other features

The Algorithm

d_{task} →

v →

Algorithm 1 User context sampling function $f_{sampling}$

$\Delta t_{min} = 10s;$ ▷ Minimum sampling interval

$\Delta t_{max} = 120s;$ ▷ Maximum regular sampling

$\lambda = d^{u,t} = 1.5$ km; ▷ Task detection threshold

function NEXTCONTEXTSAMPLING($\mathbf{c}^u, \mathbf{t}$)

$\quad c_i^u \leftarrow getCurrentUserContext(\mathbf{c}^u);$

$\quad c_{i-1}^u \leftarrow getPreceedingUserContext(\mathbf{c}^u);$

Find the closest task t_j the user is heading to

$\quad t_j \leftarrow getClosestTask(c_i^u, \mathbf{t});$

Approach rate to closest task t_j

$\quad v_i \leftarrow \frac{hvrs^*(c_i^u, c_j^t) - hvrs^*(c_{i-1}^u, c_j^t)}{ts_i - ts_{i-1}};$

$\quad \bar{v} \leftarrow \frac{\sum_{j=i}^{j=i-3} v_i}{3}$ ▷ Average speed over 3 samples

$\quad d^{u,t} \leftarrow f_{dist}(c_i^u, c_j^t);$

Selection of next sampling method

$$\sigma_{i+1} = \begin{cases} GPS & \text{if } d^{u,t} \leq \lambda \\ NETWORK & \text{otherwise} \end{cases}$$

$$\Delta t = \begin{cases} \frac{d^{u,t}}{\bar{v}} \bar{v} & \text{if } \Delta t_{min} < \frac{d^{u,t}}{\bar{v}} < \Delta t_{max} \\ \Delta t_{min} & \text{if } \frac{d^{u,t}}{\bar{v}} < \Delta t_{min} \\ \Delta t_{max} & \text{if } \frac{d^{u,t}}{\bar{v}} > \Delta t_{max} \end{cases}$$

Next sampling time (sec.)

$\quad ts_{i+1}^u \leftarrow ts_i^u + \Delta t;$

$\quad$ **return** $\langle \sigma_{i+1}, ts_{i+1}^u \rangle;$

end function

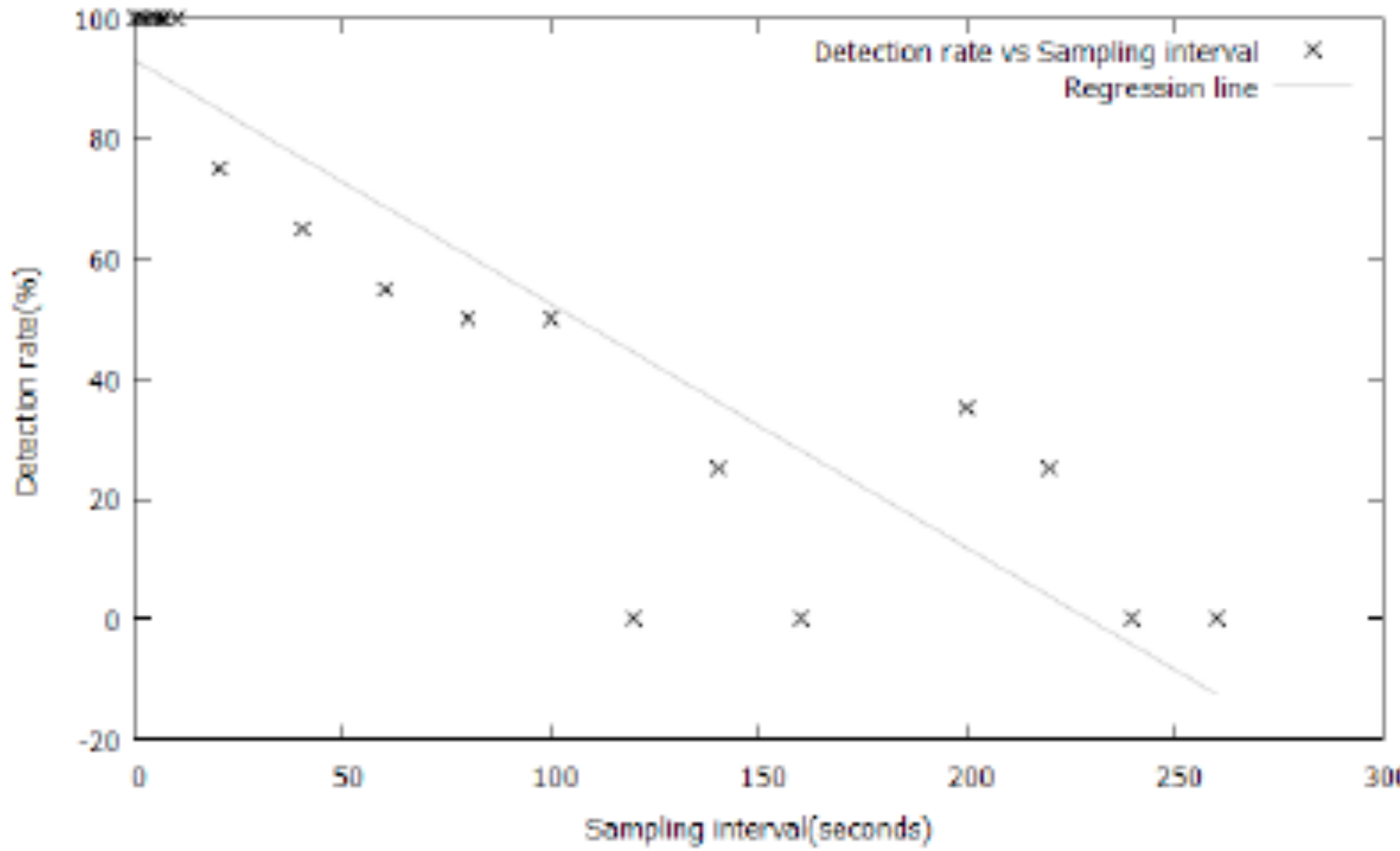
→ Next sampling time

→ Next sampling method GPS vs network

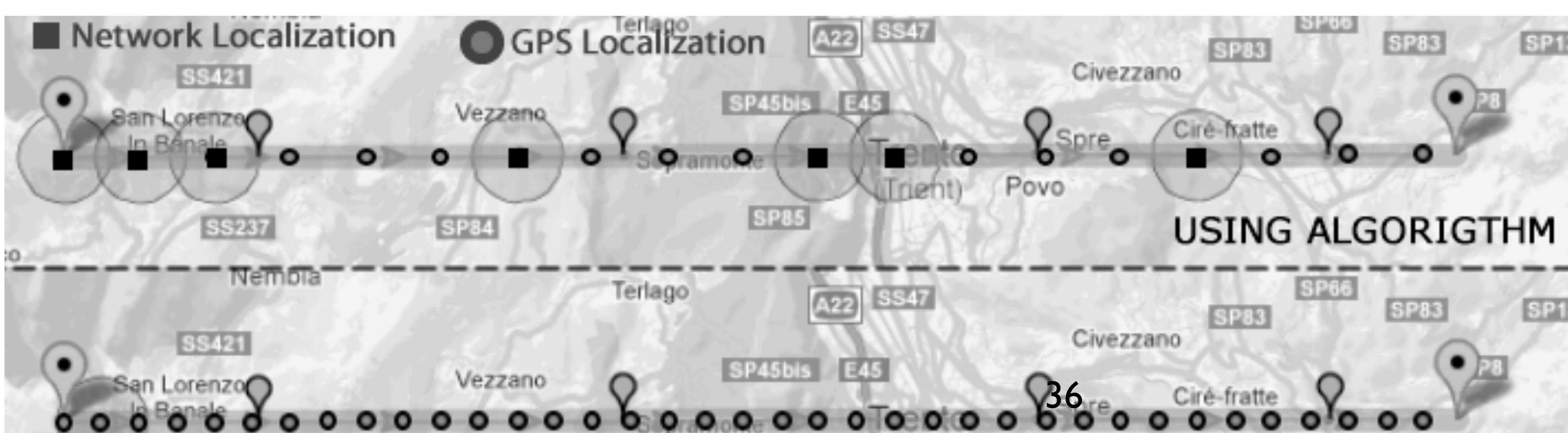
Preliminary Evaluation

Simulation study

- 30 Km route
- 50 Km/h
- NTWacc = 1 Km, GPSacc = 20



Task detection at different <u>constant</u> GPS sampling rates



Visual comparison of constant GPS and MATADOR adaptive context sampling

Field Test

Small scale field test

- 400 Km of driving
- User carrying the MATADOR mobile application
- 40 tasks distributed over the path
  - Task radius from 250 to 500 meters

Trip duration	4h 20 mins
# of samples	252
# of GPS samples	103
# of Network samples	149
Average Network accuracy	2159 m
Average GPS accuracy	5 m
Detection Rate	76%