Mobile Crowdsensing

Marcelo Armentano

About me

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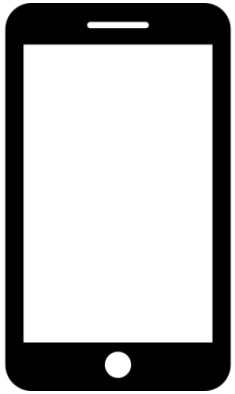
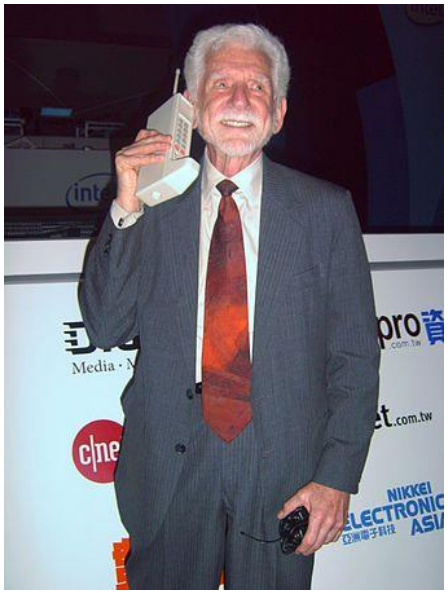
These are us...

Smartphones



Smartphones

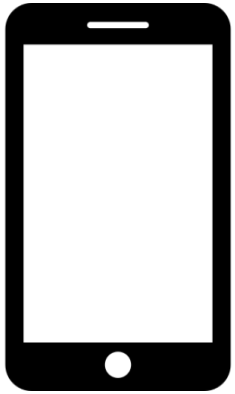


Martin Cooper prototype of DynaTAC model on 3 April 1973

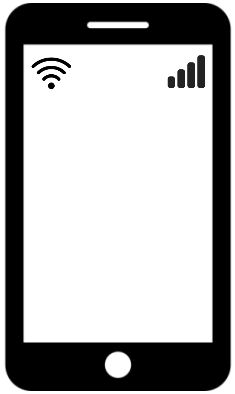
The Motorola DynaTAC 8000X. First commercially available handheld cellular mobile phone, 1984

- 30 minutes of talk-time
- 6 hours standby
- 10 hours to re-charge
- could store 30 phone numbers
- 2 kilograms
- 23 by 13 by 4.5 cm
- Analog
- 1G
- £2639 ($3995)

Smartphones

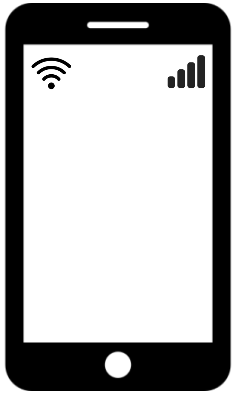


Smartphones



Internet connection → Smartphones!

Smartphones



Nokia 9000 Communicator

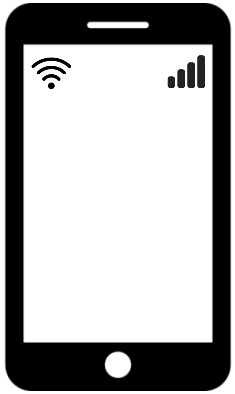
- first mobile phone with Internet connectivity
- launched in Finland back in 1996
- Very high prices by the operators.

Internet connection → Smartphones!

Smartphones

NTT DoCoMo Inc.

- In 1999, launched i-Mode in Japan, which is considered the birth of mobile phone Internet services.
- Helped to establish the W-CDMA standard for mobile communications and then kick off the first 3G service based on this standard in 2001

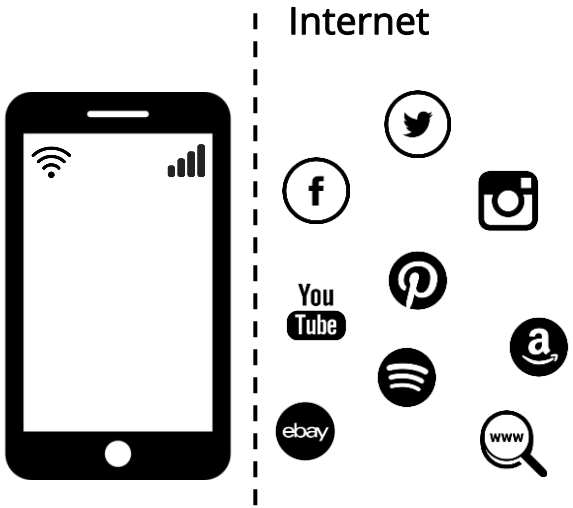


"***do co**mmunications over the **mo**bile network*"

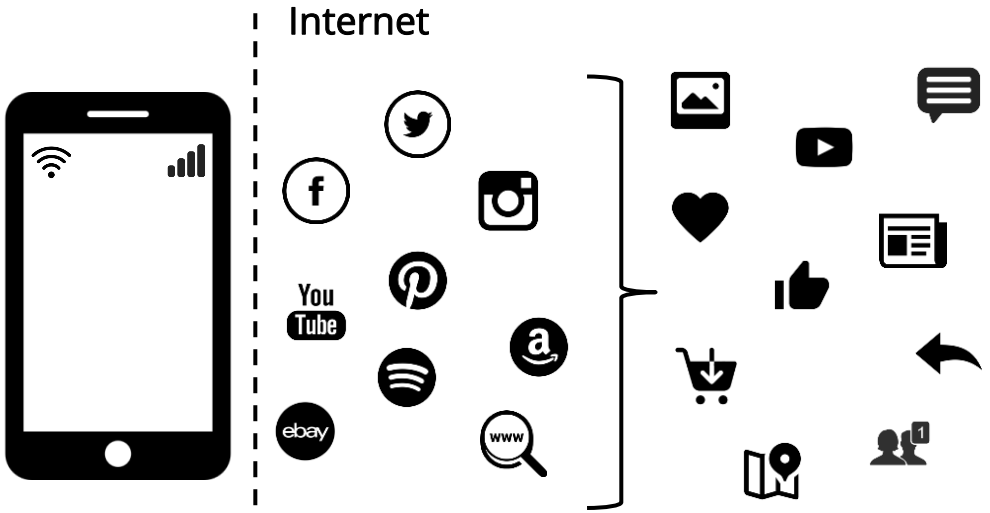
Also from a compound word ***dokomo***, meaning "everywhere" in Japanese.

Internet connection → Smartphones!

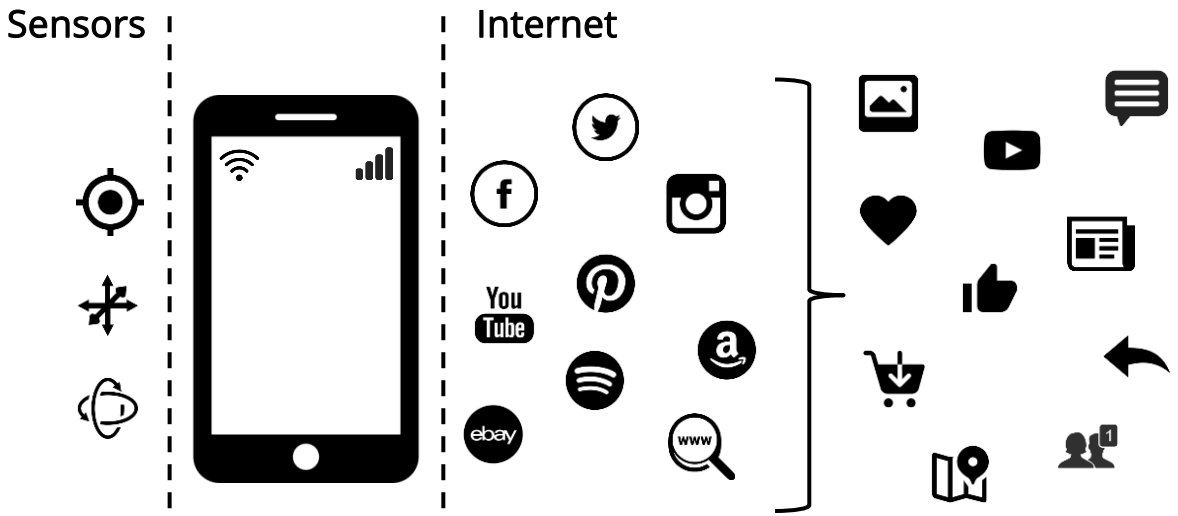
Smartphones



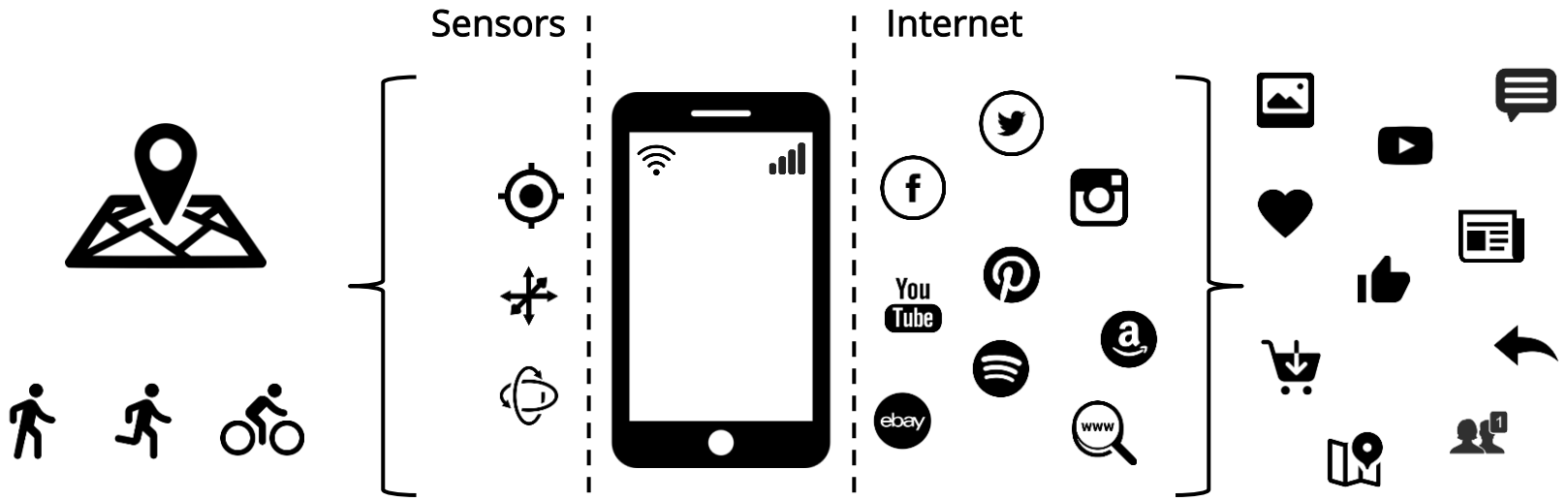
Smartphones



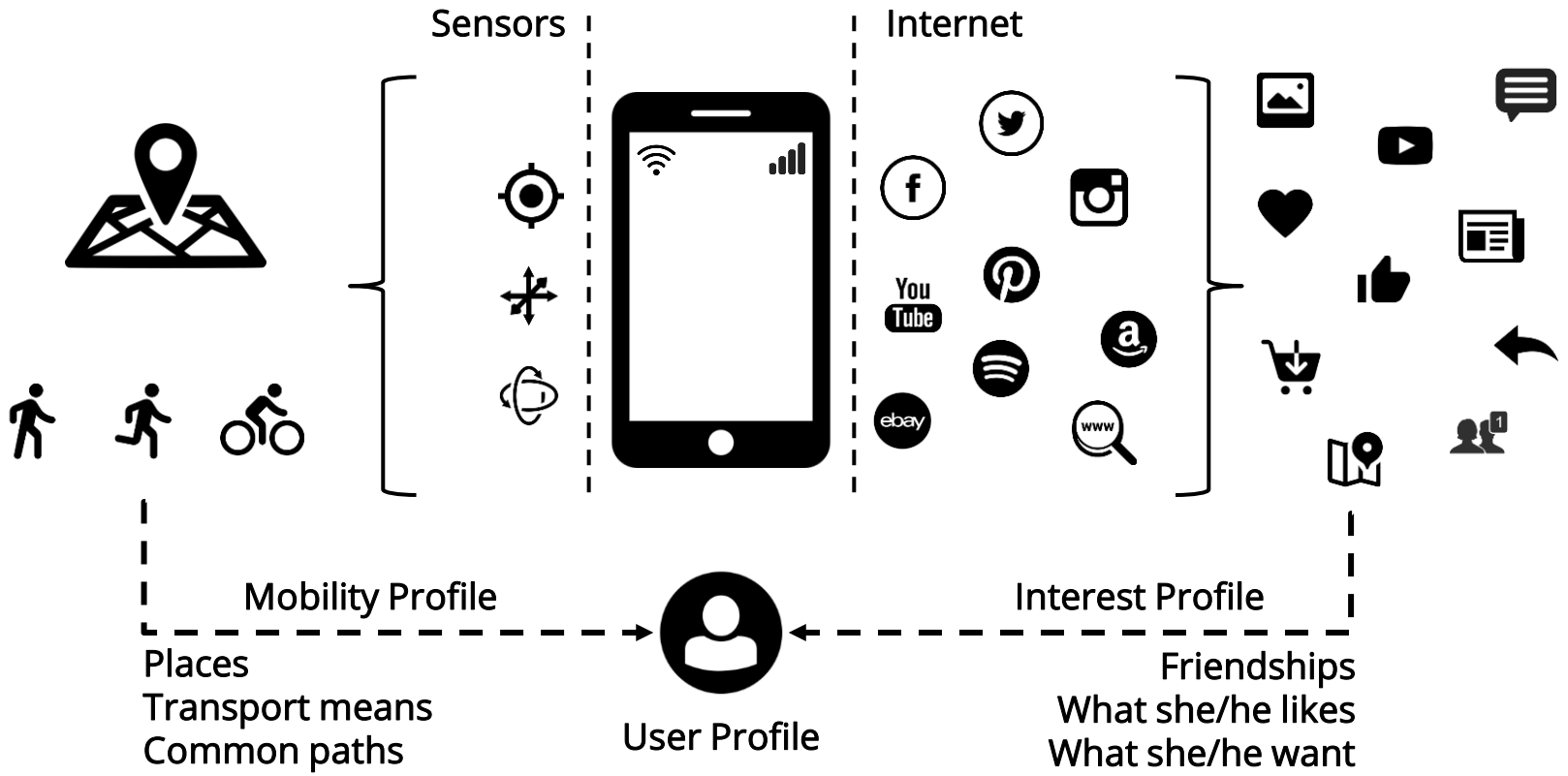
Smartphones



Smartphones



Smartphones



Mobile sensing

Smartphone sensors

Mobile apps

Software APIs

Personal Sensing

Personal monitoring

Public Sensing

Central server / Cloud

Evolution of mobile phones

1999-2002 | 2003-2006 | 2007-2010 | 2011-2012 | 2013-...

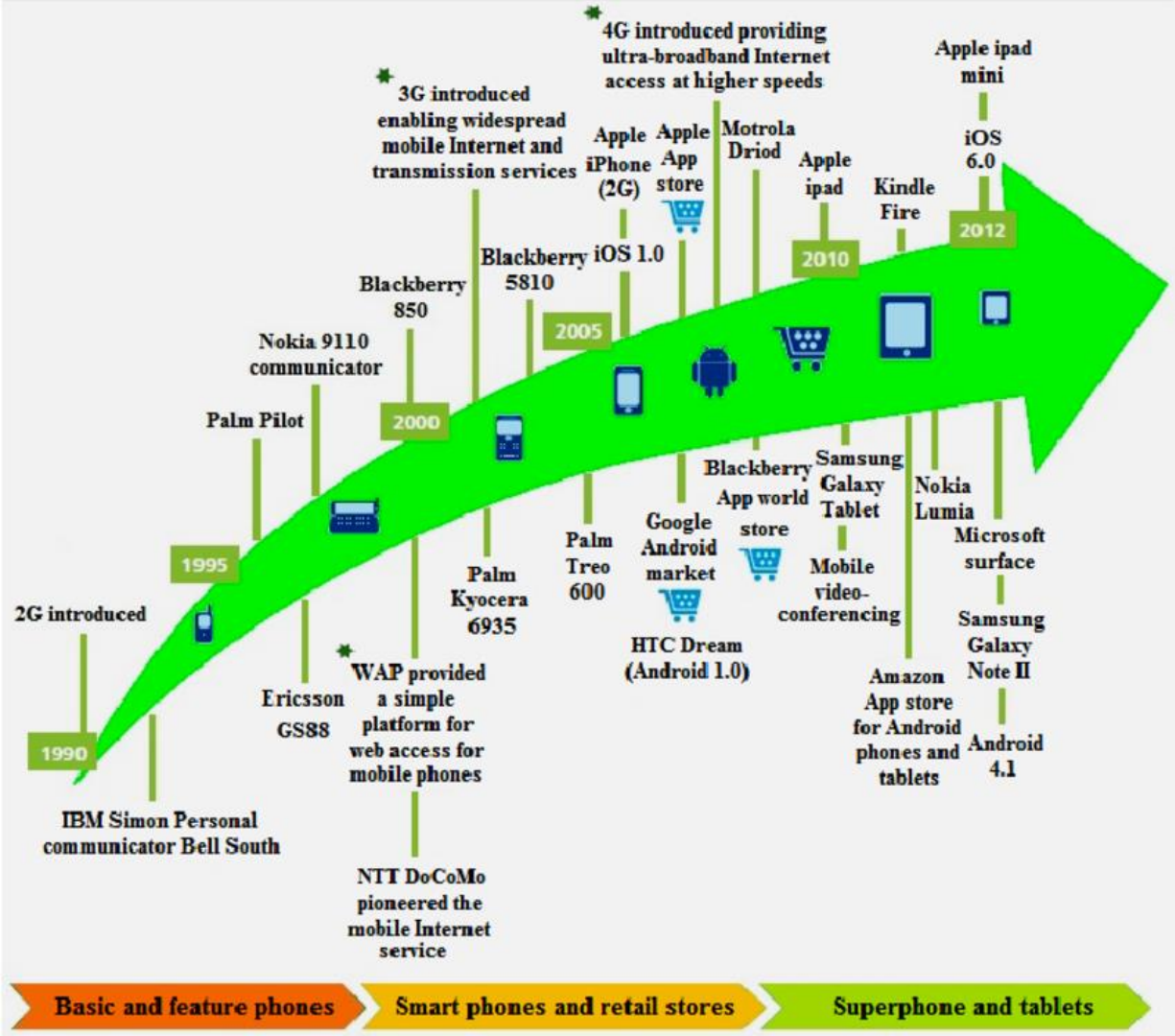
Alcatel One Touch Easy

Nokia 3310

Nokia 6500 Slide

Samsung focus

Google Nexus 4


4G introduced providing ultra-broadband Internet access at higher speeds
Apple ipad mini
3G introduced enabling widespread mobile Internet and transmission services
Apple iPhone (2G)
Apple App store
Motrola Driod
Apple ipad
Kindle Fire
iOS 6.0
2012
2010
Blackberry 5810
iOS 1.0
Blackberry 850
2005
Nokia 9110 communicator
Palm Pilot
2000
1995
2G introduced
1990
Ericsson GS88
WAP provided a simple platform for web access for mobile phones
Palm Kyocera 6935
Palm Treo 600
Google Android market
HTC Dream (Android 1.0)
Blackberry App world store
Samsung Galaxy Tablet
Mobile video-conferencing
Nokia Lumia
Microsoft surface
Samsung Galaxy Note II
Android 4.1
Amazon App store for Android phones and tablets
IBM Simon Personal communicator Bell South
NTT DoCoMo pioneered the mobile Internet service
Basic and feature phones
Smart phones and retail stores
Superphone and tablets

Components that enable mobile sensing

1- Apps

- Personal sensing apps (personal monitoring, healthcare,...)
- Home sensing apps (HVAC, surveillance,...)
- City-wide sensing apps (vehicular traffic and infrastructure monitoring)
- Vehicle sensing apps (phone-to-car and car-to-phone communication)
- Games (sensing for augmented reality games)

Components that enable mobile sensing

1- Apps

Apps stores (Google play, Apple app store, Blackberry world, Galaxy Store...)

Components that enable mobile sensing

2 - Sensors

- Motion / Position sensors
- Environmental sensors
- Radios
- Other hardware

Hardware

- Software-based sensors
  - Combine hardware sensors' readings
  - Social Sensors

Components that enable mobile sensing

2.1 - Motion / Position sensors

Accelerometer

Magnetometer

Gyroscope

Proximity

Pedometer

Components that enable mobile sensing

2.2 - Environmental sensors

Ambient Light

Barometer

Temperature

Humidity

Radiation

Components that enable mobile sensing

2.3 - Radios

GPS

Cellular radios

WiFi

Bluetooth

Components that enable mobile sensing

2.4 - Other sensors

Microphone

Camera

Flash light

Touch screen

Fingerprint

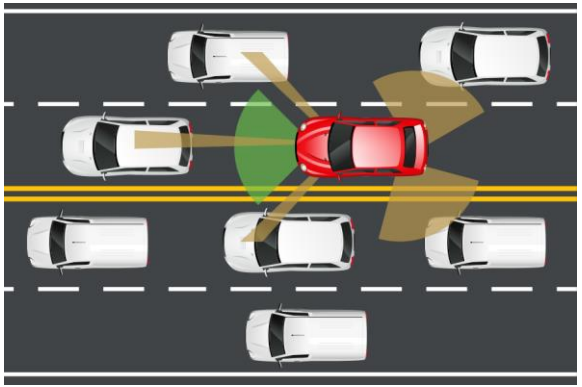
Components that enable mobile sensing

2.5 - External sensors

Body-wearable sensors

Sensors on bicycles

Sensors in cars



Components that enable mobile sensing

3- Software APIs

- Access to raw sensor data
- Access to higher-level sensor data

- Some challenges:
  - Energy consumption, for example
  - Portability

GPS

vs

Cellular radios

Mobile sensings hurdles

- Battery consumption
- Data reliability
- Incentives
- Privacy

Working groups

Introduction > Smartphones > Mobile sensing > Activity

Think of services that can be offered if we are aware of the geographical location of the user, the semantic place where she/he is (at home, in a cafe, etc.), her/his daily routine (where will he/she go next, what route will be taken and the transportation means)

How can be the service be improved if we know information about the location of our friends and what are they doing?

Mobile Crowdsensing

Mobile Crowdsensing > Definition

"a new sensing paradigm that empowers ordinary citizens to contribute data sensed or generated from their mobile devices"

Bin Guo, Zhiwen Yu, Xingshe Zhou, and Daquing Zhang. From participatory sensing to mobile crowdsensing. PERCOM Workshops. IEEE, 2014

Data is then aggregated and fused in the cloud for crowd intelligence extraction and people-centric service delivery.
It allows smartphone users to collectively sense the data, which helps in the monitoring of large-scale phenomena that cannot be easily measured by a single individual.

Application areas

Environmental

- **Common Sense**[1]: pollution monitoring
- **CreekWatch**[2]: monitors water levels and quality in creeks
- **MobGeoSen**[3]: local environment pollution
- **NoiseTube**[4]: Noise pollution

[1] https://www.communitysensing.org/.
[2] https://www.waterboards.ca.gov/videos/video_pages/creekwatch.shtml
[3] E. Kanjo, S. Benford, M. Paxton, A. Chamberlain, D. Stanton Fraser, D. Woodgate, D. Crellin, and A. Woolard. Mobgeosen: facilitating personal geosensor data collection and visualization using mobile phones. Personal and Ubiquitous Computing, 12(8):599-607, 2008.
[4] http://www.noisetube.net

Application areas

Infraestructure

- **MIT's CarTel**[1] and **Microsoft Nericell**[2]: traffic congestion
- **ParkNet**[3]: street parking availability
- **TrafficSense**[4]: potholes, road bumps, traffic jams and emergency situations
- **PetrolWatch**[5]: petrol price monitoring
- **Mobile Millenium**[6]: traffic estimation

[1] http://news.mit.edu/2010/cars-sensors-0924
[2] https://www.microsoft.com/en-us/research/project/nericell/
[3] https://www.dunavnet.eu/parknet
[4]https://www.microsoft.com/en-us/research/publication/trafficsense-rich-monitoring-of-road-and-traffic-conditions-using-mobile-smartphones/
[5] Yi Fei Dong, Salil Kanhere, Chun Tung Chou, and Ren Ping Liu. Automatic image capturing and processing for PetrolWatch. In 17th IEEE International Conference on Networks (ICON), pages 236-240. IEEE, 2011
[6] https://traffic.berkeley.edu/

Application areas

Social

- **BikeNet**[1]: Biking routes
- **DietSense**[2]: sharing lunch pictures to compare eating habits
- **Party Thermometer**[3]: measures how hot is a party
- **LiveCompare**[4]: grocery price comparison

[1] https://www.bikemap.net/

[2] S. Reddy, A. Parker, J. Hyman, J. Burke, D. Estrin, and M. Hansen. Image browsing, processing, and clustering for participatory DietSense prototype. In Proceedings of the 4th workshop on Embedded networked sensors, pages 13-17. ACM, 2007.

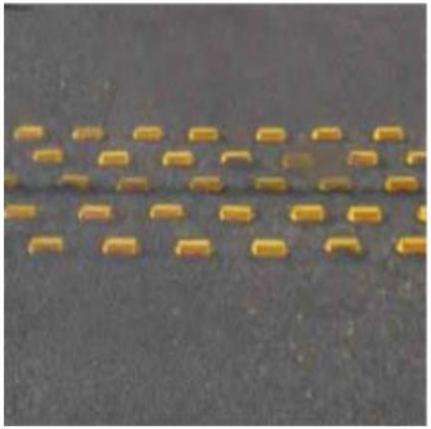
[3] T. Das, P. Mohan, V. Padmanabhan, R. Ramjee, and A. Sharma. PRISM: platform for remote sensing using smartphones. In Proceedings of the 8th international conference on Mobile systems, applications, and services, pages 63-76. ACM, 2010.

[4] L. Deng and L. P. Cox. LiveCompare: grocery bargain hunting through participatory sensing. In Proc. of the 10th workshop on Mobile Computing Systems and Applications, page 4. ACM, 2009.

Application domains

Road Transportation

- large-scale data about traffic patterns using location and speed data
- personalized traffic re-routing guidance for congestion avoidance
- direct drivers toward free parking spots
- quality of roads
- picture analysis



Application domains

Mobile Crowdsensing > Application domains > Transportation > Roads

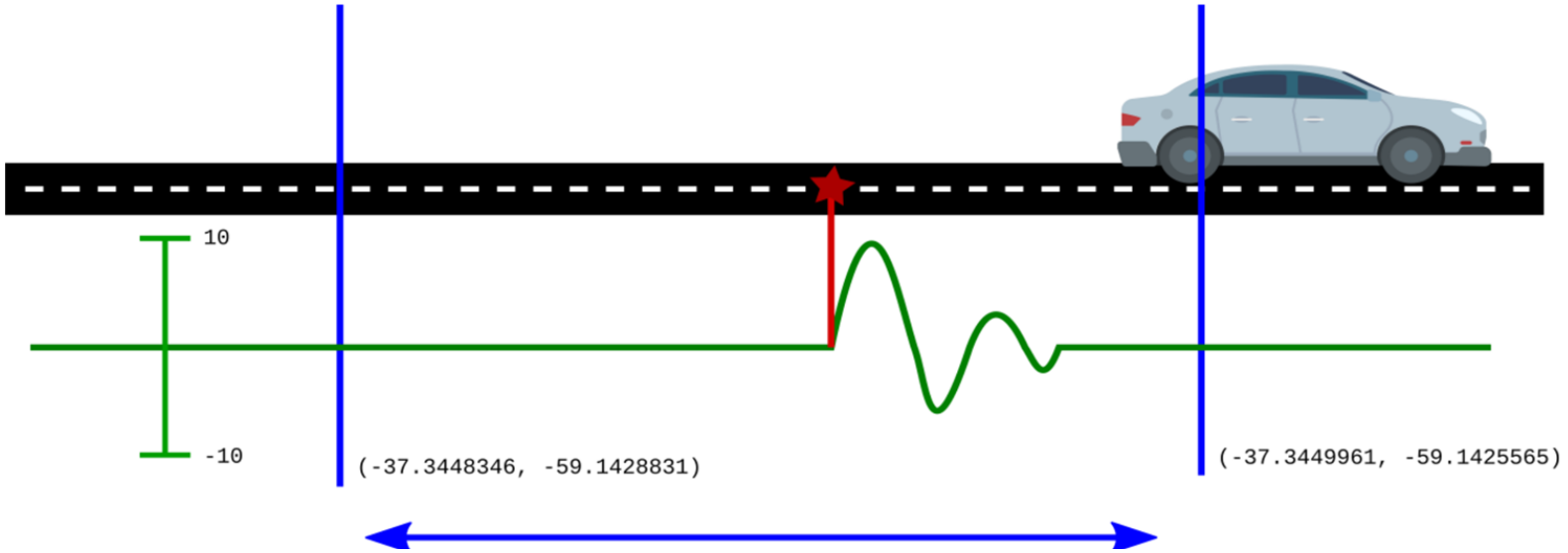
Data collection and detection of road quality

Data aggregation

Visualization of nearby road conditions

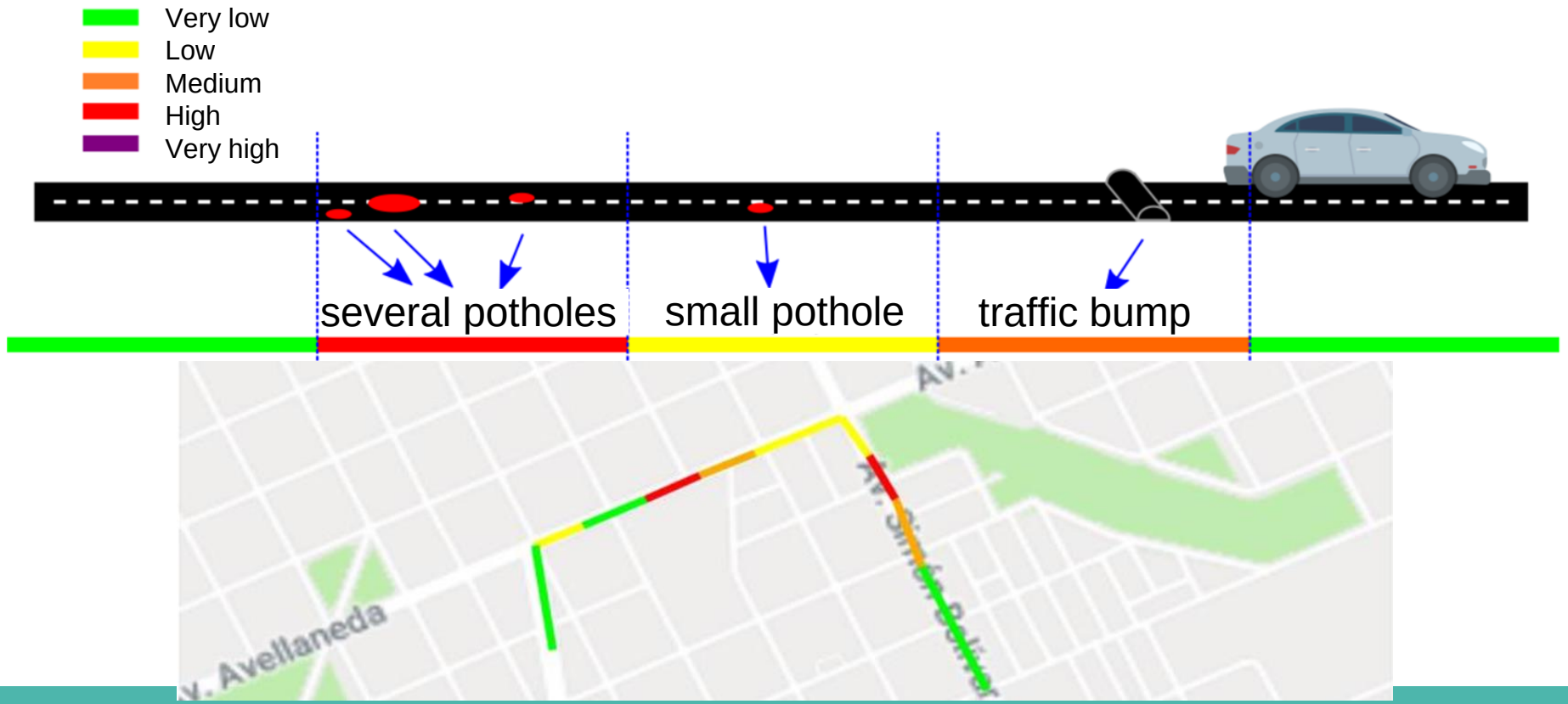
Application domains

Mobile Crowdsensing > Application domains > Transportation > Roads



Application domains

Mobile Crowdsensing > Application domains > Transportation > Roads



Application domains

Health and wellbeing

- Large scale health studies from individual health monitors (heart rate, blood pressure, etc)
- Level of physical exercise
- Social interaction
- Spreading of epidemic diseases

Application domains

- Example: Sedentary behaviour prediction

Any waking behaviour characterized by an energy expenditure ≤1.5 METs (Metabolic Equivalent of Tasks) while in a sitting or reclining posture (Tremblay 2012).

- MET measures the intensity of an activity in multiples of resting energy expenditure. For example:
  - watching television (1.0 MET),
  - eating while sitting (1.5 MET)
  - playing video games (1.0 MET)
  - driving (1.3 MET)

https://www.sedentarybehaviour.org/

Application domains

Mobile Crowdsensing > Application domains > Health and wellbeing

- **Example: Sedentary behaviour prediction**

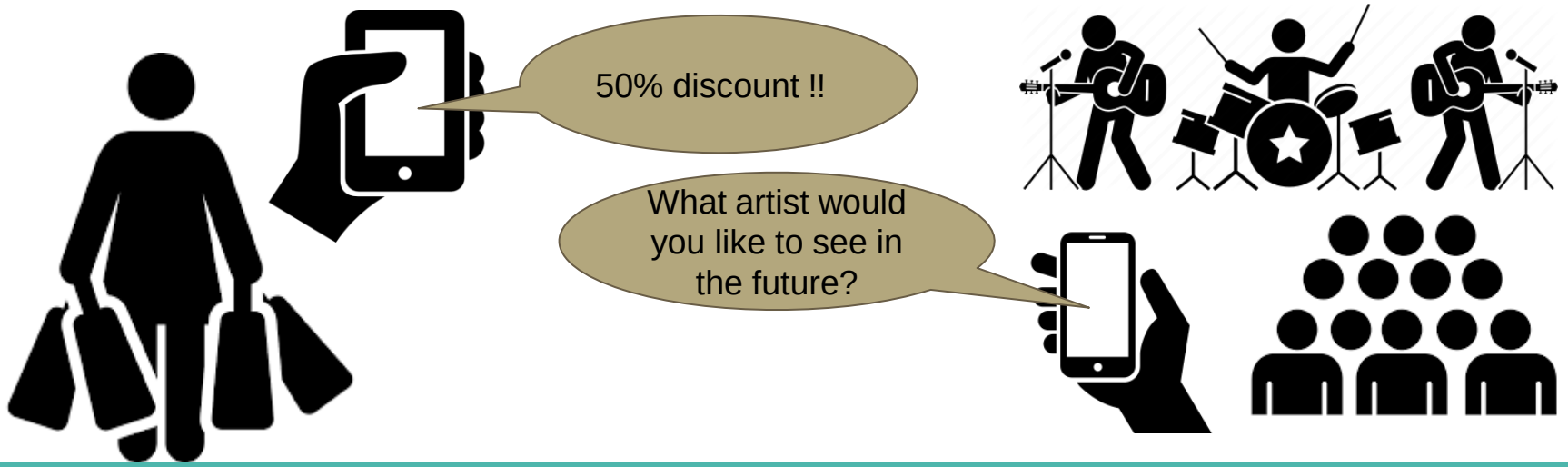
- StudentLife Dataset (Wang et al. 2014)
  - 30 undergrad and 18 graduate students
  - 10-week term
  - Activity data, including activity duration (total time that the user moves per day), indoor mobility and the total travelled distance (i.e., outdoor mobility) per day;
  - Conversation data, including conversation duration and frequency per day;
  - Sleep data, including sleep duration, sleep onset and waking time;
  - Location data, including GPS, inferred buildings when the participant is indoors, and the number of co-located Bluetooth devices.

Application domains

Marketing/Advertising

- Vendors/Advertisers can target certain categories of people

- Run context-aware surveys (as a function of location, time, etc)



Classification of sensing types

Crowdsensing can be broadly classified into:

- **Participatory** manual sensing
  - Participants manual interaction is needed
  - Major control of when, where and what to sense
- **Opportunistic** automatic sensing
  - Sensing is performed on the smartphones in the background
  - The sensing system determines when, where and on which participant's smartphones to perform automatic sensing
  - The system considers social aspects of the participants (people-centric sensing)

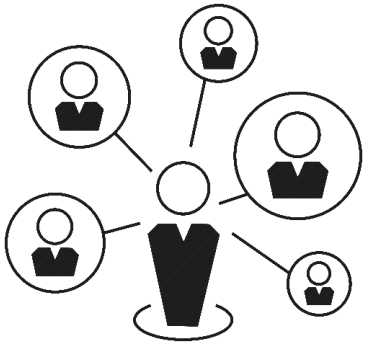
Participatory Manual Sensing

Mobile Crowdsensing > Classification > Participatory Sensing

- Road transportation sensing

- Photo and video journalism

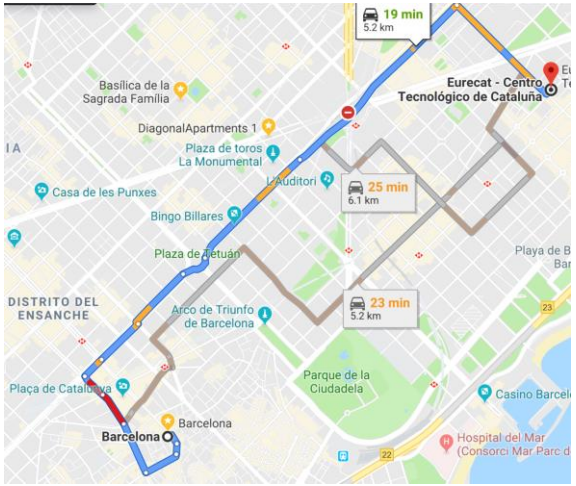
- Data sharing in social networks



Opportunistic automatic sensing

Mobile Crowdsensing > Classification of sensing types > Opportunistic

- Road transportation sensing
  - Parking
  - Road state
  - Traffic jams



- Indoor Localization
  - Targeted advertisements
  - Emergency notifications

Incentive Mechanisms for Participants

- Social Incentives
- Monetary Incentives
- Mobile Games Incentives

Social Incentives

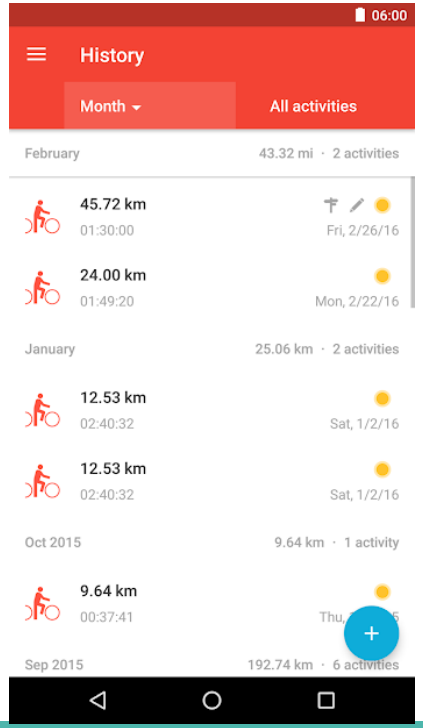
- **Biketastic[1] / Runtastic**
  - Basic route information (spatial and temporal extent, length and speed) → **GPS**
  - Physical dynamics of the route (road roughness and general noise) → **accelerometer** and **microphone**
  - Experience of a route (interesting, troublesome and beneficial assets) → **camera**
  - Route data are uploaded to a backend platform that contains a map-based system that makes visualizing and sharing the rout information easy and convenient

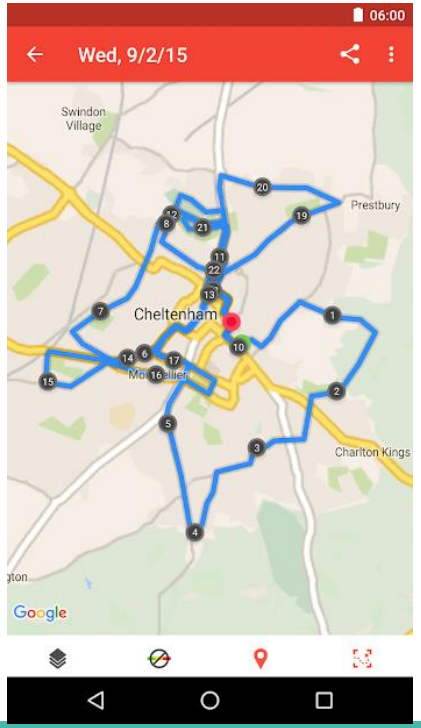
[1] S. Reddy, K. Shilton, G. Denisov, C. Cenizal, D. Estrin, and M. Srivastava. Biketastic: sensing and mapping for better biking. In Proc. of the SIGCHI Conf. on Human Factors in Computing Systems, pages 1817-1820. ACM, 2010.

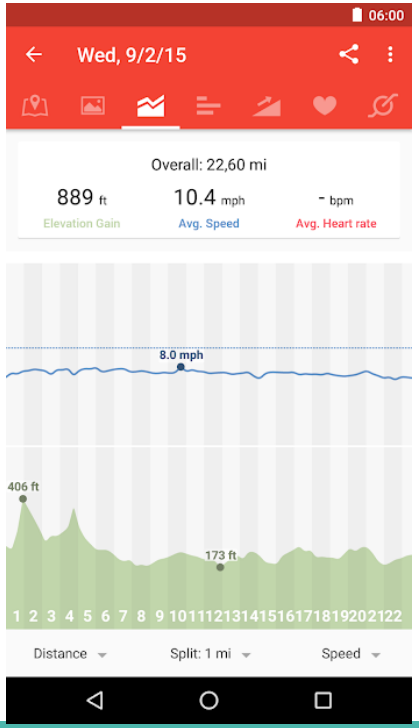
Social Incentives

Mobile Crowdsensing > Incentives > Social > Examples

- Biketastic / Runtastic







Social Incentives

- LiveCompare[1]
  - Participants use their cameras to snap a photograph of the price tag on their product of interest
  - The product is uniquely identified via a barcode included on the price tag
  - The photo is uploaded to a central repository for satisfying future queries
  - In exchange for submitting this price data point, the user receives pricing information for the scanned product at other nearby grocery stores
  - Users interpret the prices, the machine only interprets the barcode
  - Users can flag irrelevant retrieved images → faulty or malicious data

[1] L. Deng and L. P. Cox. LiveCompare: grocery bargain hunting through participatory sensing. In Proc. of the 10th workshop on Mobile Computing Systems and Applications, page 4. ACM, 2009.

Social Incentives

Mobile Crowdsensing > Incentives > Social > Examples

- LiveCompare

Social Incentives

- LiveCompare

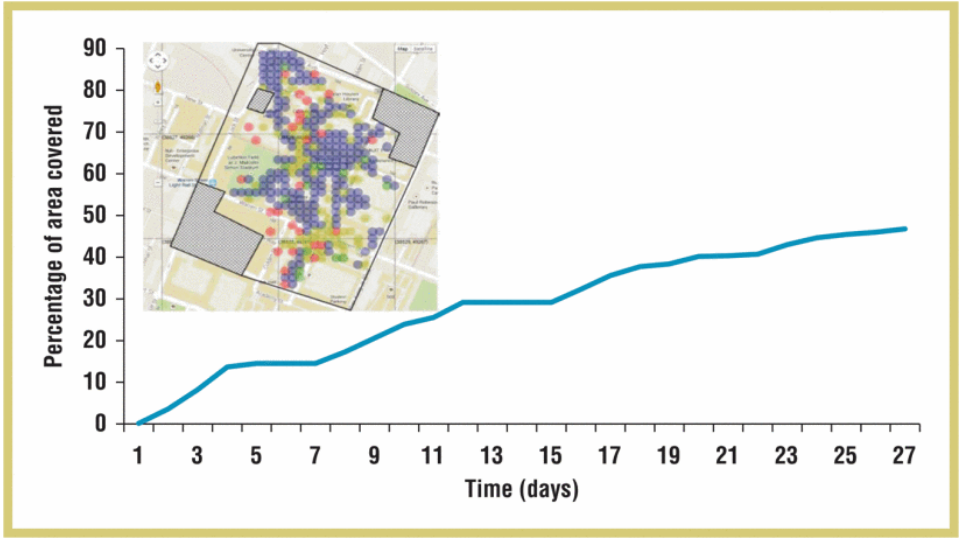
Monetary Incentives

- McSense[1]
  - micro-payment-based system for different tasks
    - collecting GPS and accelerometer readings
    - taking photos at events on campus
    - collecting application and network usage
  - Users must balance the value of micro-payments against their effort, potential loss in privacy and resource consumption on the phone

[1] G. Cardone, L. Foschini, C. Borcea, P. Bellavista, A. Corradi, M. Talasila, and R. Curtmola. Fostering ParticipAction in Smart Cities: a Geo-Social CrowdSensing Platform. IEEE Communications Magazine, 51(6), 2013

Monetary Incentives

- Talasila et al[1] studied the impact on area coverage based on the collected WiFi data while using micro-payments



[1] Manoop Talasila, Reza Curtmola, and Cristian Borcea. Crowdsensing in the Wild with Aliens and Micro-payments. IEEE Pervasive Computing Magazine, 2016.

Mobile Games Incentives

- Aliens vs Mobile User
  - Hunt aliens across the campus map of a University
  - Goal: collect WiFi signal data to reconstruct the WiFi coverage map of the targeted area
  - The game provide in-game incentives to convince users to visit unpopular regions

https://web.njit.edu/~mt57/avmgame/

Mobile Games Incentives

- Aliens vs Mobile User - Game Story
  - Aliens are hiding at different locations across the targeted area.
  - Players can see the aliens on their screens only when they are close to the alien positions → encourage the players to walk around to discover aliens.
  - In the process, the game collects sensing data.
  - When users find aliens, start shooting at them.
  - When an alien gets hit:
    - If it is the first or second time it gets hit, it moves to another area to hide from the user, but leaves a hint of its new location
    - If it is the third time, it is destroyed
  - Users earn points for shooting aliens

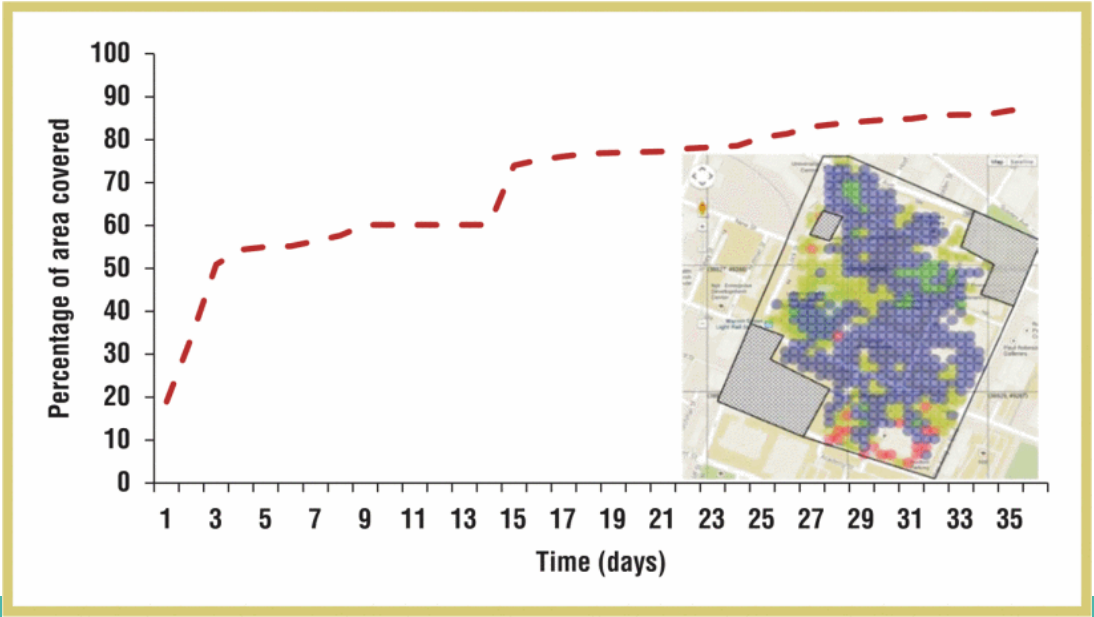
Mobile Games Incentives

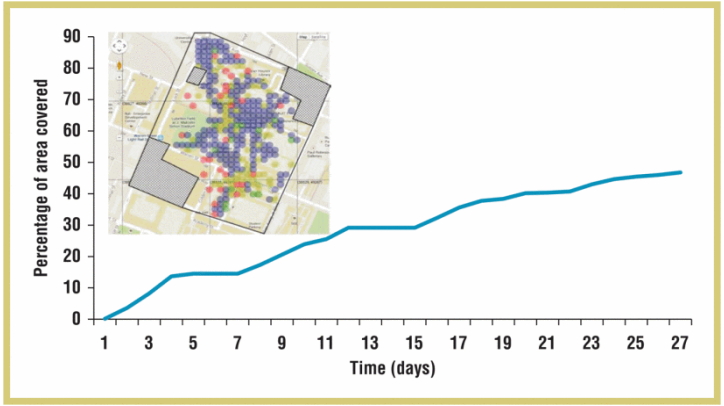
- Aliens vs Mobile User - Sensing
  - Data is collected periodically when the game is on
  - The placement of aliens on the map seeks to ensure uniform sensing coverage of the area
  - How to ensure fast coverage while at the same time maintaining high interest in the game?
    - More points for shooting the alien for a second time (and even more for the third time)
    - Players have to kill a minimum number of aliens to unlock specific achievements and to enter the next levels of the game.

Mobile Games Incentives

Mobile Crowdsensing > Incentives > Mobile Games> Examples

- Aliens vs Mobile User - User Study
  - 35 days, 53 players





Micropayments

Mobile game

Comparison of incentives

- Sensing task duration
  - Challenge: keep users engaged

Comparison of incentives

- Sensing task duration
  - Challenge: keep users engaged
- Sensing task type
  - There is no “one-size fits all” solution

Comparison of incentives

- Sensing task duration
  - Challenge: keep users engaged
- Sensing task type
  - There is no “one-size fits all” solution
- Incentive quality or value
  - What made you to continue playing the Aliens Vs. Mobile User game?
    i. curiosity about the game story
    ii. moving into the next level and being on top of the leaderboard
    iii. competing with friends
    iv. winning game achievements
  - Micro-payments average price was $1.18
    i. Higher prices increased 15% task completion
    ii. Better data quality for high-priced photo tasks


gracias
go raibh maith agat
merci
obrigado
teşekkür ederim
thank you
danke
bedankt
謝謝
dziękuję
mochchakkeram
мерси
ngiyabonga
sukriya
sagolun
arigatô
tapadh leat
kop khun krap
dakujem
takk
terima kasih
спасибо
dank je
grazie
hvala
mauruuru
koszonom
malondo
asante
dhanyavad
rahmet
najis tuke
barka
kia ora
mamnun
sobodi
bayarlalaa
chokrane
rahmat
vinaka
gratias ago
dankie
kam sah hamnida
blagodaram
gracies
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taiku
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djiere dieuf
akun
mahalo
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merce
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spas
dankon
tenki
xiexie
misaotra
kiitos
welalin
nanni
ありがとう
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dhanyavadagalu