parkITsmart@TUD 18.11.15

Minimization of Cruising for Parking

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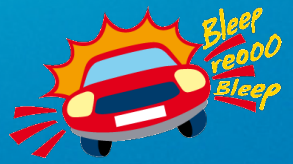
Outline

- Introduction
- parkITsmart in a glimpse
- Benefits for drivers and cities
- Evaluation
- Challenges
- Future work

Introduction

- Cruising: Driving while looking for parking space after arriving to the desired destination
  - Adds up to 30% unnecessary congestion on streets
    - Vehicle's emission
    - Noise
  - Unoccupied free spaces
    - Revenue losses for the city



Impact of Cruising in Traffic

- Consider **6** minutes cruising for a parking space
- Parking space turnover: **5** vehicles per day
- Each parking space generates **30** minutes of cruising time per day
- If the average cruising speed is approximately **15** Km/h
- Each parking space generates approximately **8** Vehicle Km Traveled (VKT) per day
- In a year this is **2937** VKT per parking space

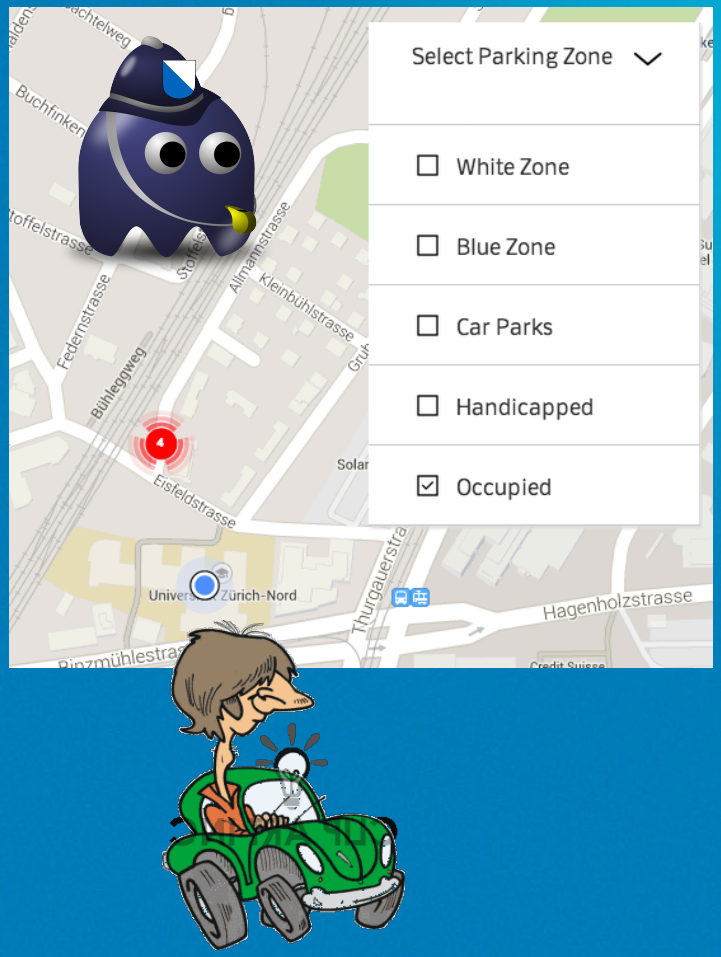
Environmental Impact of Cruising

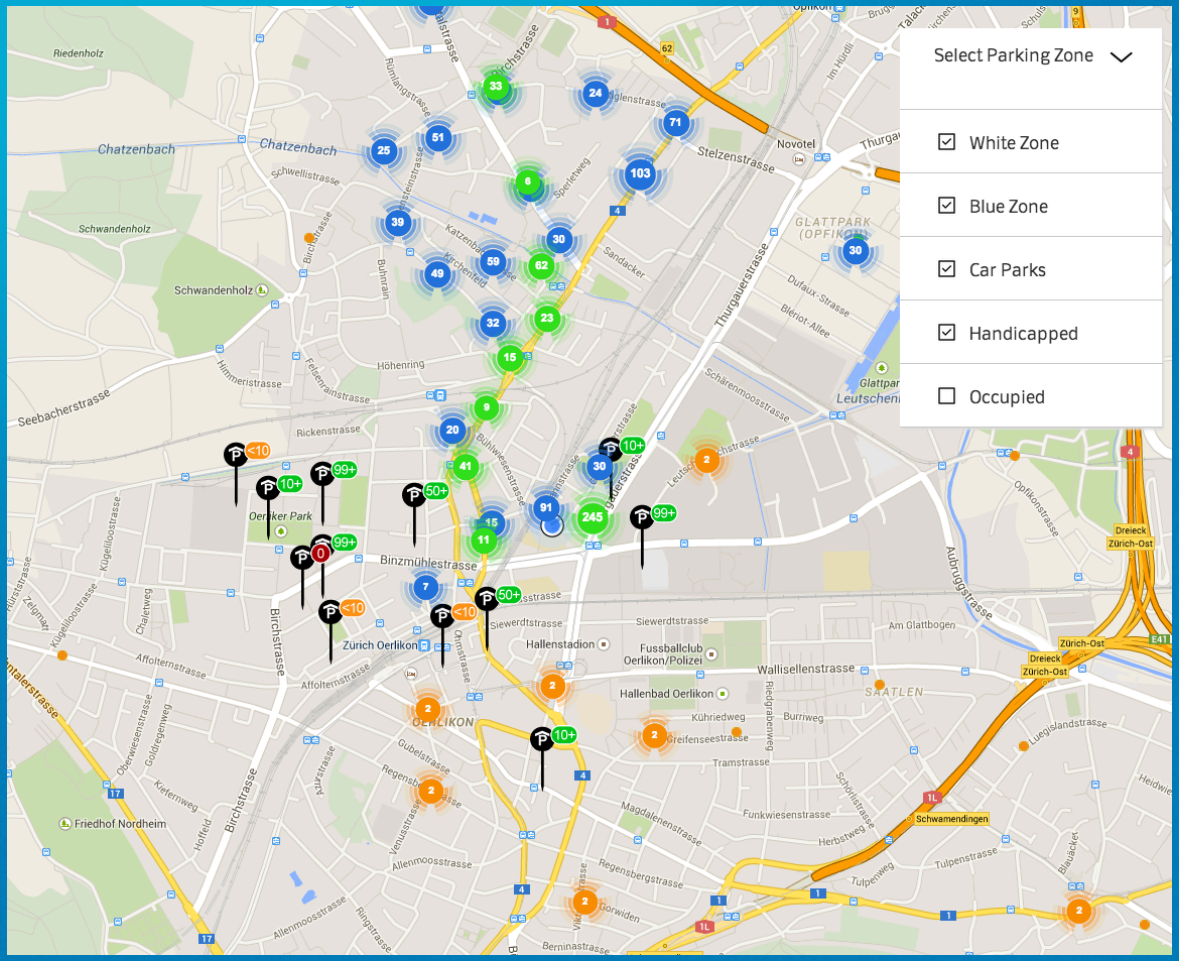
- EU regulations are being introduced to reduce the average emissions of vehicles sold beginning in 2012, to 130 g/km of CO_2
- Even if all vehicles comply with this rule the environment is encumbered with 381 Kg CO_2 per parking space, per year, because of cruising!

Economic Impact of Cruising

- Waste of time for everybody
- Waste of fuel
- Waste of revenue of the unused parking spaces

parkITsmart High-Level Overview





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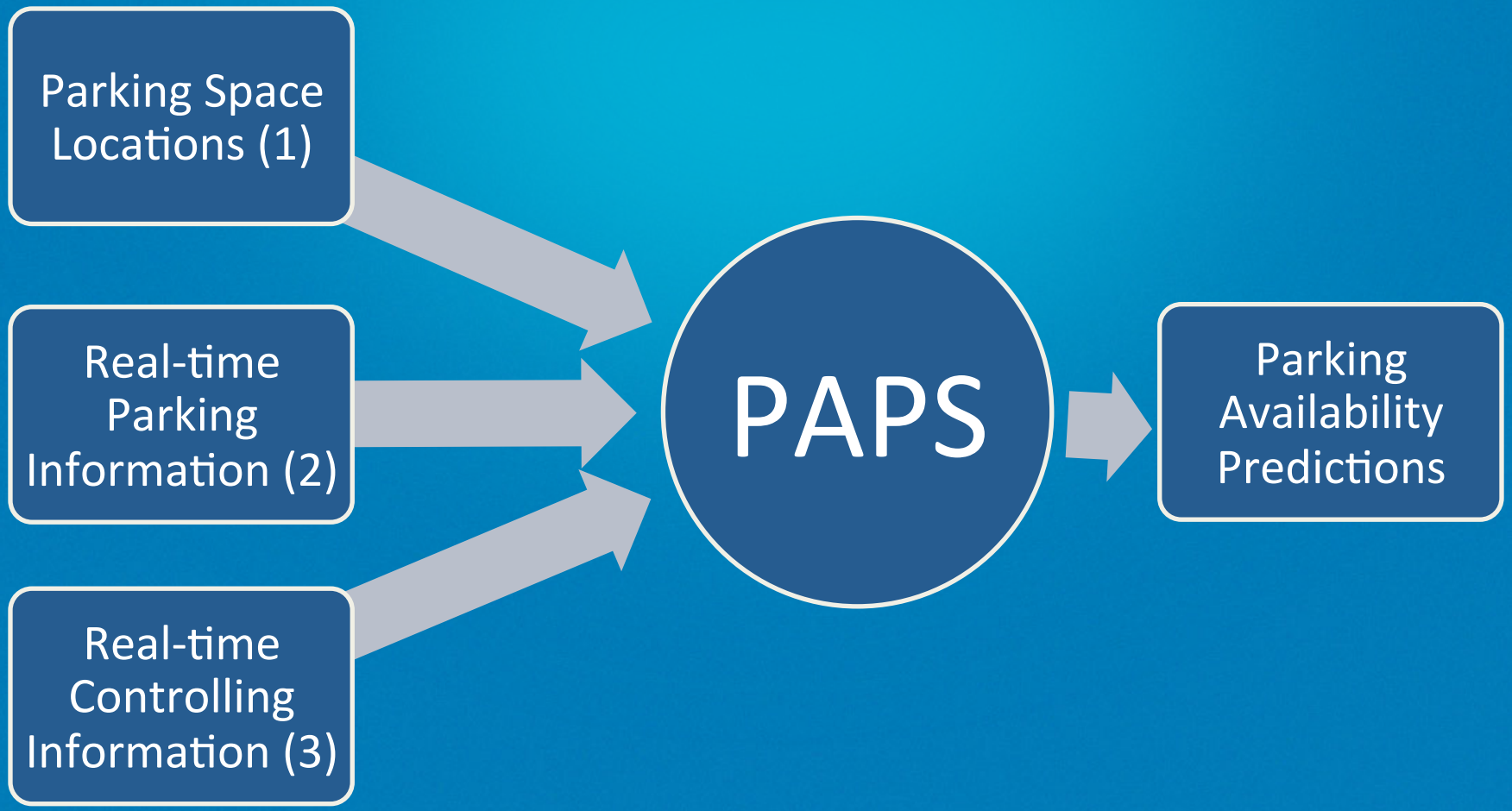
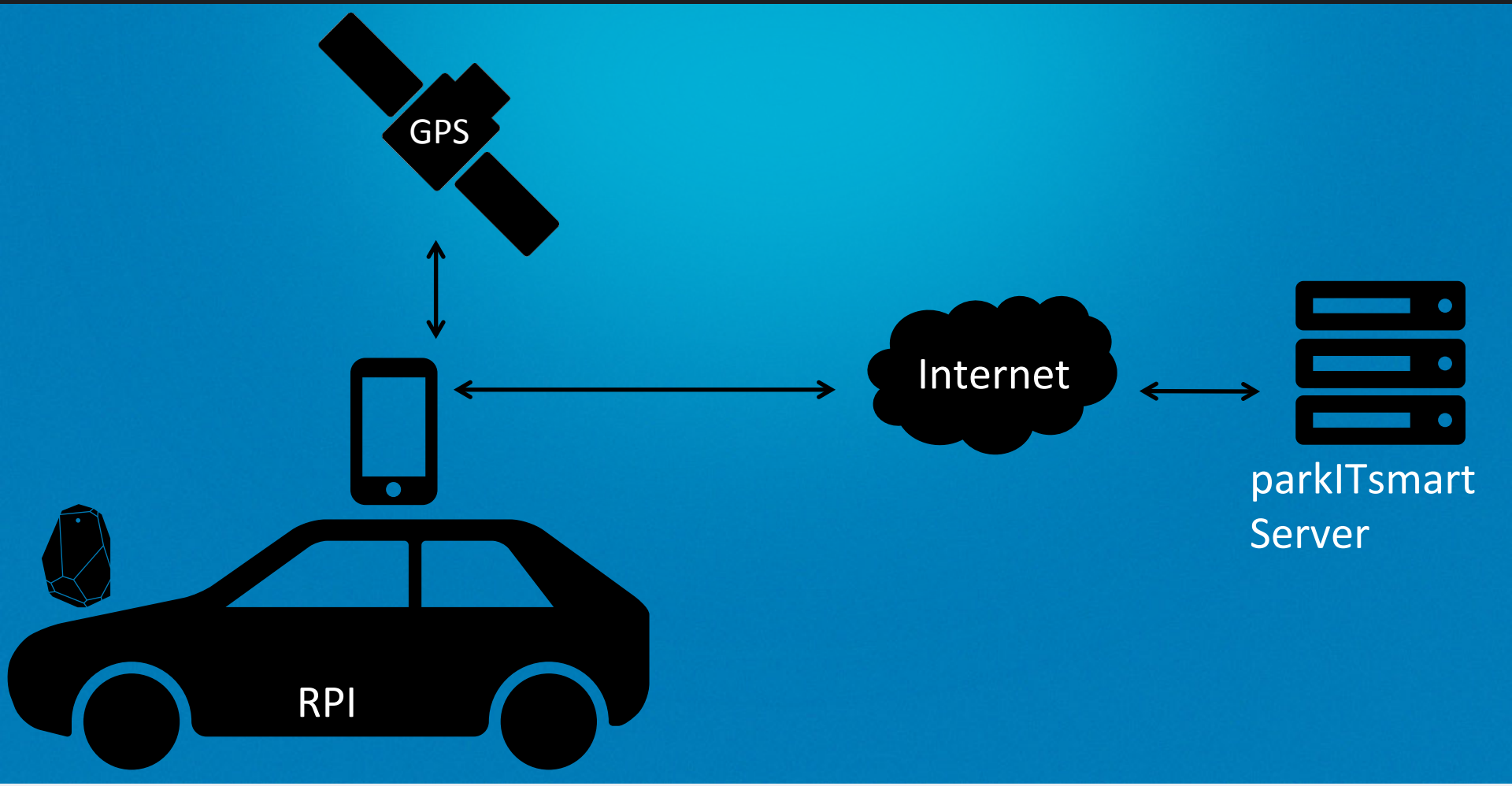
Parking Availability Prediction System (PAPS) Overview



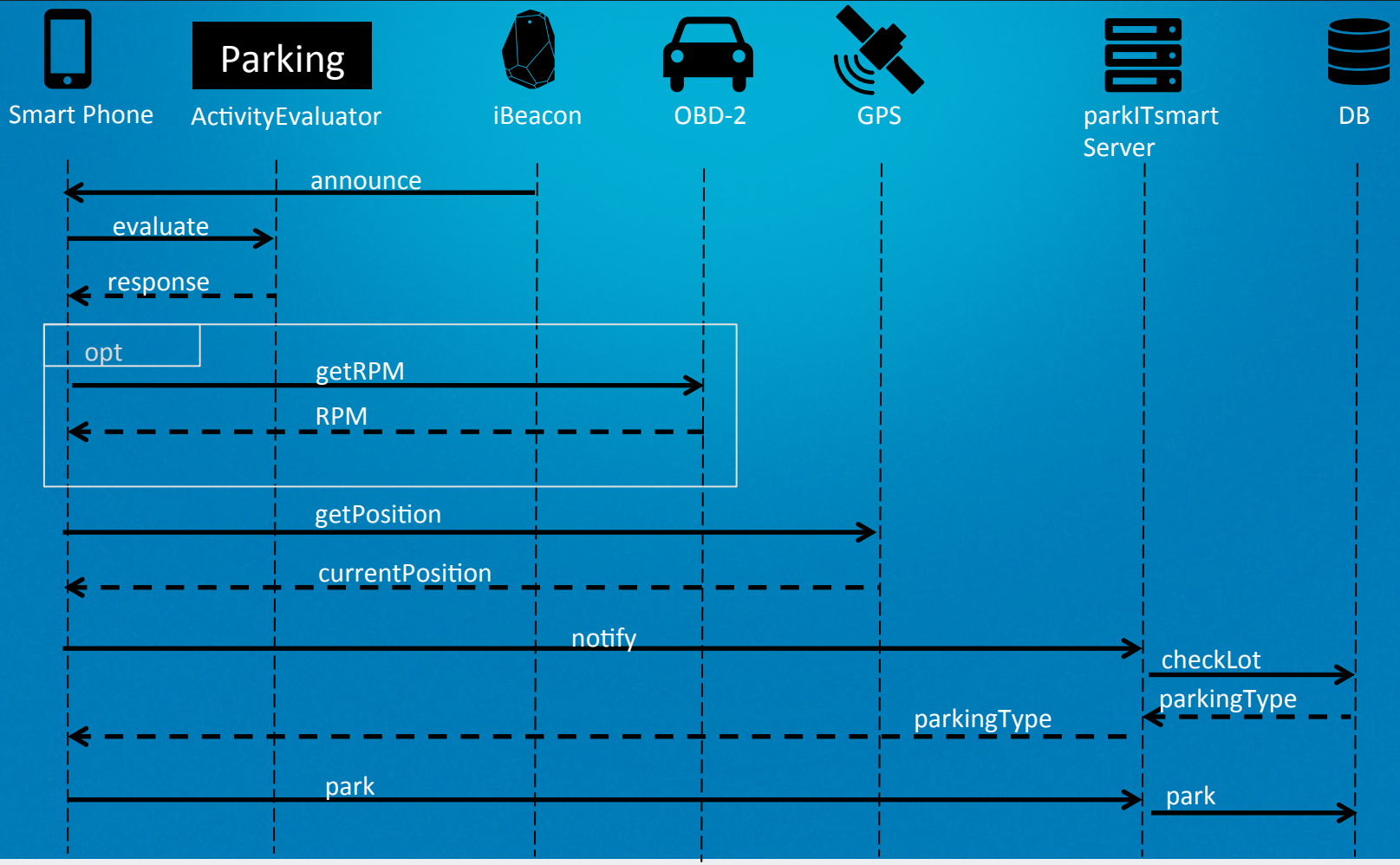
Parking Space Locations (1)

Real-time Parking Information (2): I



Satellite by Guillermo Vera from the Noun Project
Phone by Joris Hoogendoorn from the Noun Project
Server by Konstantin Velichko from the Noun Project

Real-time Parking Information (2): II



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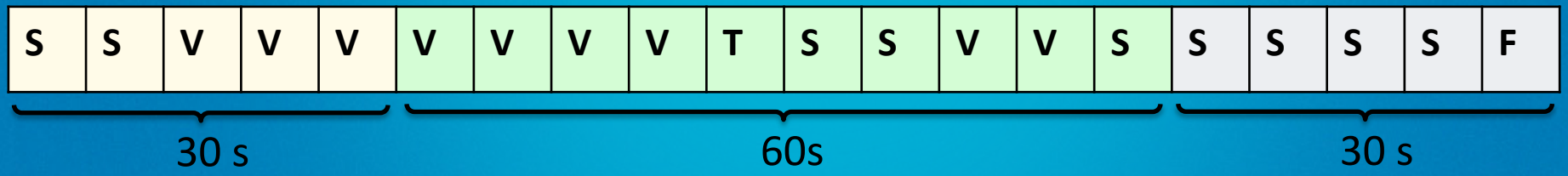
Server by Konstantin Velichko from the Noun Project
Database by Mister Pixel from the Noun Project

Parking Activity Evaluation

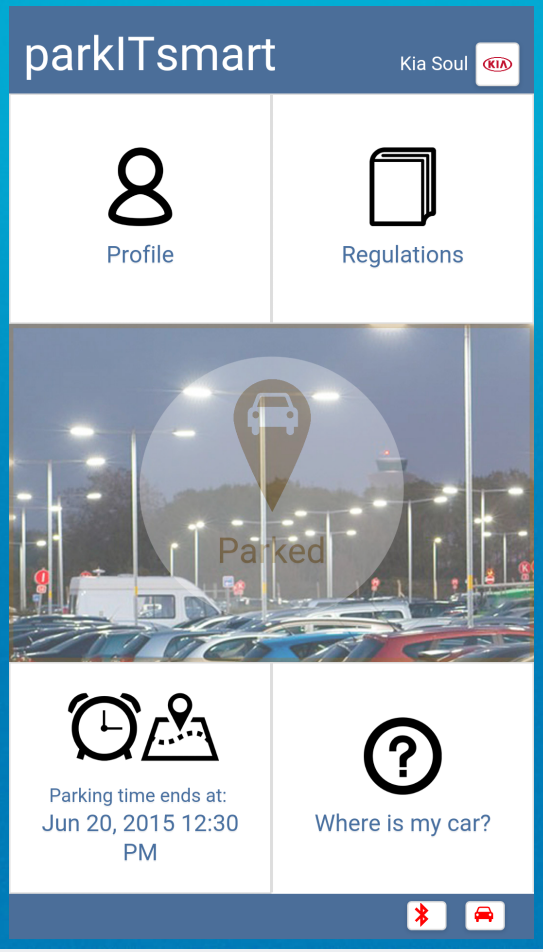


Case	Head	Middle	Tail	Activity
1	1	1	1	1
2	1	1	0	0
3	1	0	1	Postpone Decision
4	1	0	0	0
5	0	1	1	1
6	0	1	0	0
7	0	0	1	Postpone Decision
8	0	0	0	0

S: Still
V: In Vehicle
T: Tilting
F: On Foot

1: Parked
0: Driving

parkITsmart: End-user App



Current Activity

Parking Information

Parking Location

iBeacon Connection Status

Real-time Controlling Information Importance (3)

- Easier and more efficient vehicle controlling
  - QR-code and NFC-tag scanning
- Directly send fines
  - No manual processing needed
  - Integration in existing fine management possible
- Prevent parking fraud
- Efficient parking distribution
- Driver's parking pattern recognition

Evaluation: Controller Time Efficiency (I)

- Scenario
  - 20 parking spaces
  - 1.5 minutes to walk
  - 2 vehicles are parked illegally
  - Controlling : 3 s with application (NFC or QR code)
    5 s without application
  - Fine: 30 s with application
    120 s without application

Evaluation: Controller Time Efficiency (II)

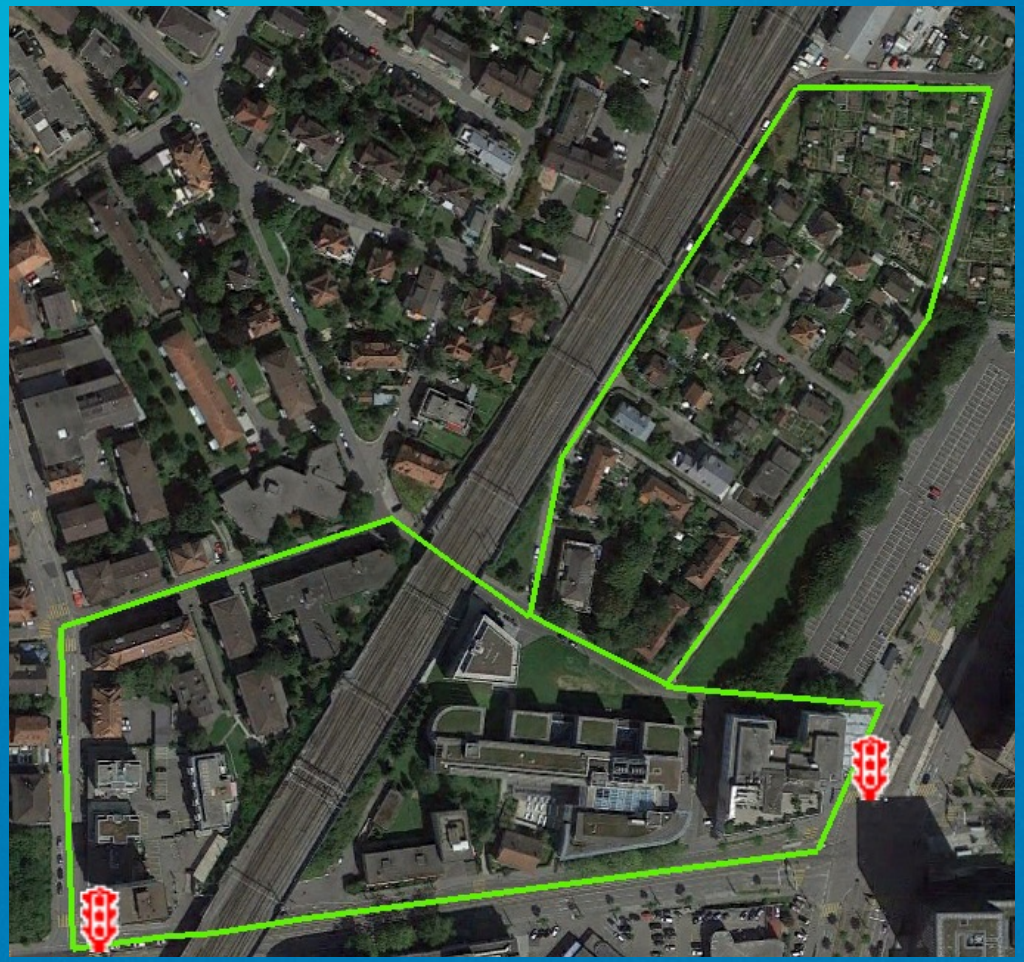
- Formula
  - $T_{total} = t_w + (t_c \times \sigma_s) + (t_f \times \sigma_p)$
- Result
  - $T_{iBeacon} = 90s + (2s \times 20) + (30s \times 2) = 190$ seconds
  - $T_{QR/NFC} = 210$ seconds
  - $T_{manual} = 430$ seconds

-55%

Symbol	Unit	Explanation
T_{total}	sec	Total time
t_w	sec	Time to walk 100 meter
t_c	sec	Time to control a parked vehicle
t_f	sec	Time to report a fine
σ_s	#	Number of spots to control
σ_p	#	Number of illegally parked vehicles

Real-time Parking Information Evaluation (I)

- Goal
  - Power Consumption
  - Location Accuracy
  - False Parking Reports
- Experiments
  - Experiment 1
    - Around UZH
    - 40 mins
    - Display on
  - Experiment 2
    - Display partially on
  - Experiment 3
    - Display off



Real-time Parking Information Evaluation (II)

$$False_{Positives} = \frac{\#WrongDetectedEvents}{\#ActualEvents} = \frac{1}{18} = 0.06$$

$$False_{Negatives} = \frac{\#NotDetectedEvents}{\#ActualEvents} = 0$$

Real-time Parking Information – Power Consumption

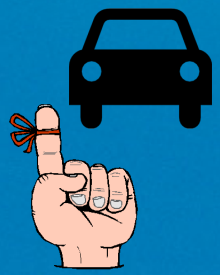
$$E(J) = 12.16Wh * 3600s = 43776J$$

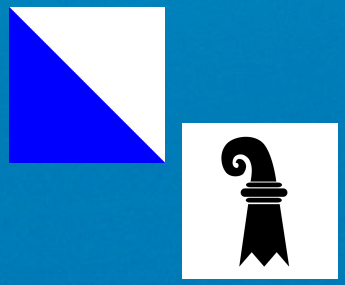
$$P_{DisplayOff} = \frac{E(J) * battery_{used}}{t_{experiment}(s)} = \frac{43776 * 0.27}{557 * 60s} = 0.354W$$

Consumption	Time [h]	Power [W]
parkITsmart (Display on)	-	**1.277**
Internet Usage 3G	11	1.105
Talking WCDMA	21	0.579
parkITsmart (Display off)	-	**0.354**
Stand-by	380	0.032

Why is parkITsmart good for drivers?

- Locate unoccupied parking spaces
- Remember where I parked my vehicle, precisely
- Look up city's parking regulations
- Supporting 15 languages!





Cruising for Parking Minimization (I)

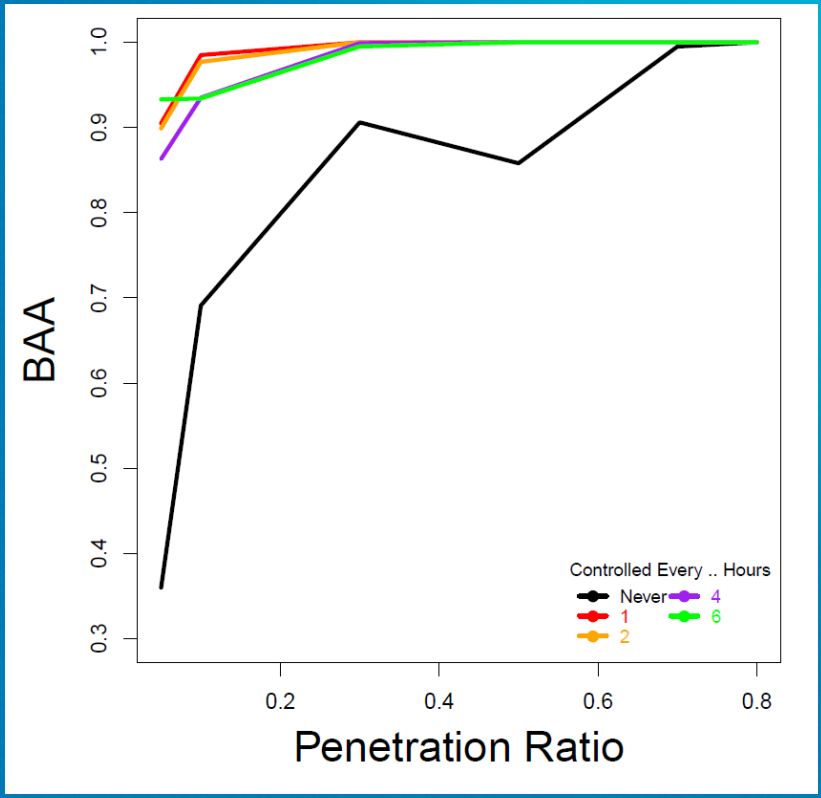
- Drivers that search for a space randomly have to cruise longer than drivers with parking space availability information.

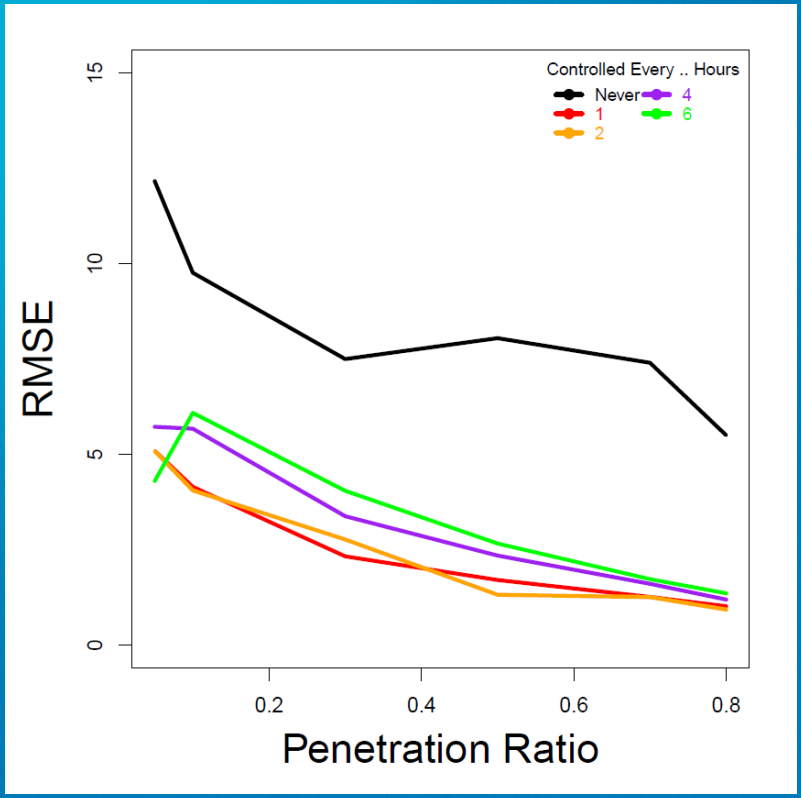
Parameters	City center 12:00	City suburb 10:00
Drivers	10	5
Free parking spaces	20	70
Vehicle speed	30 Km/h	50 Km/h

Cruising for Parking Minimization (II)

Minutes of cruising for parking	City center	City suburb
Cruising time without availability notifications	11.1 min	9.9 min
Cruising time with availability notifications	3.2 min	1.3 min
Improvement	71%	87%

Impact of the Controlling Availability Feedback (CAF)





BAA and RMSE of the SFM with Varying Penetration Ratios and CAFs

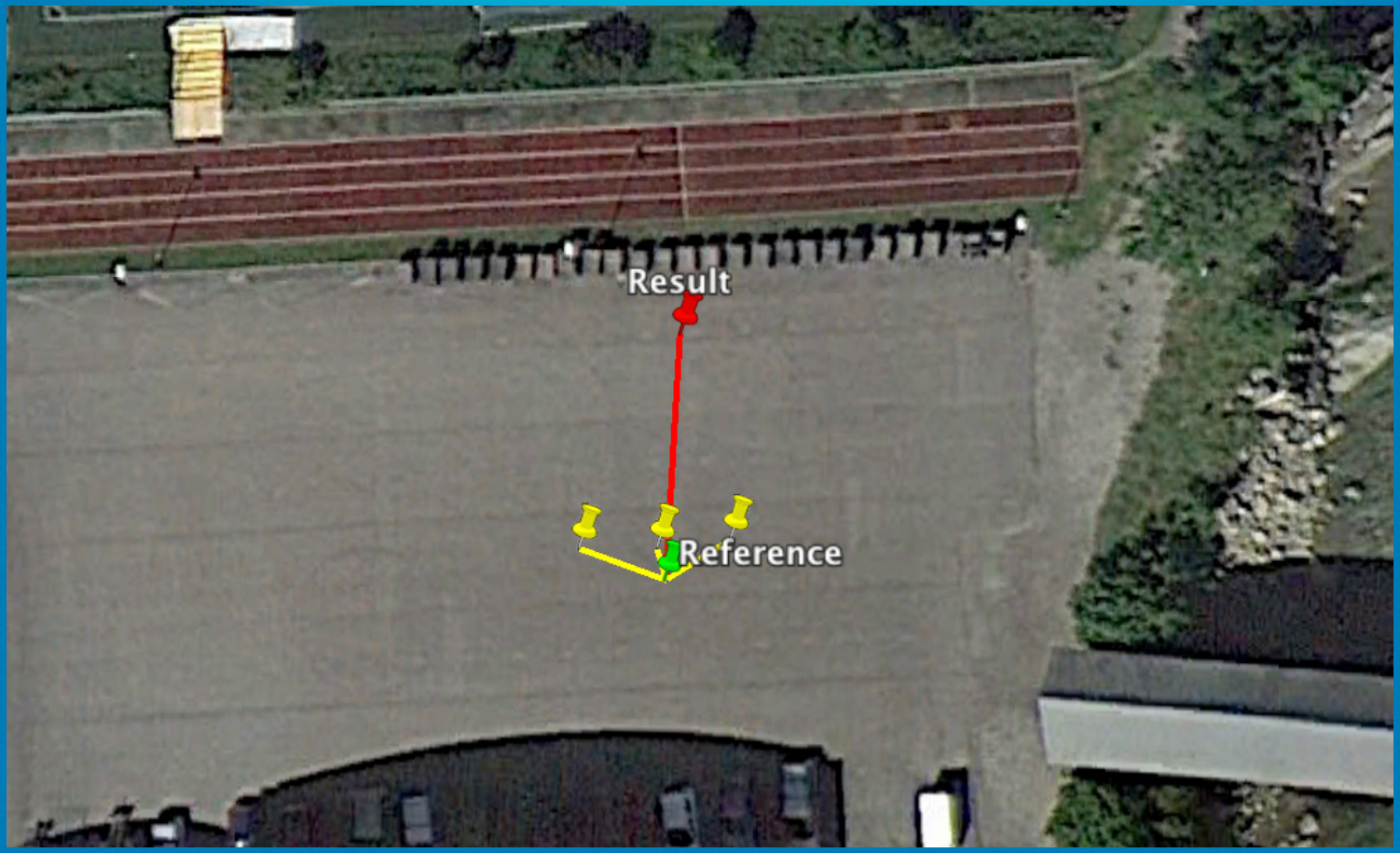
Other Approaches – Cost Evaluation

Functionality \ Solution	Raspberry Pi	Arduino	Freematics	iBeacon & Smartphone
Retrieve Position	x	x	x	x
Internet Connectivity	x	x		x
Bluetooth Low Energy	(x)	(x)	x	x
Evaluate Movement	x	x	x	x
Access Engine Control Unit			x	x
Store Data	x	x	x	x
Process Data	x	x	x	x
Costs [CHF]	**236**	**183**	**69**	**43**
Power Consumption [W]	**>1.41**	**N.A**	**N.A**	**0.354**

Challenges

- Pre-conditions
  - Running parkITsmart (Android)
  - Enabled mobile network / bluetooth / location service
  - iBeacon
- False parking reports
  - Traffic Lights (Waiting Time > 120s)
  - Traffic Jam / Accident (Blocked Road)
  - Stop to let passenger out
- Beacon IDs not globally unique

Challenges: Trilateration Evaluation

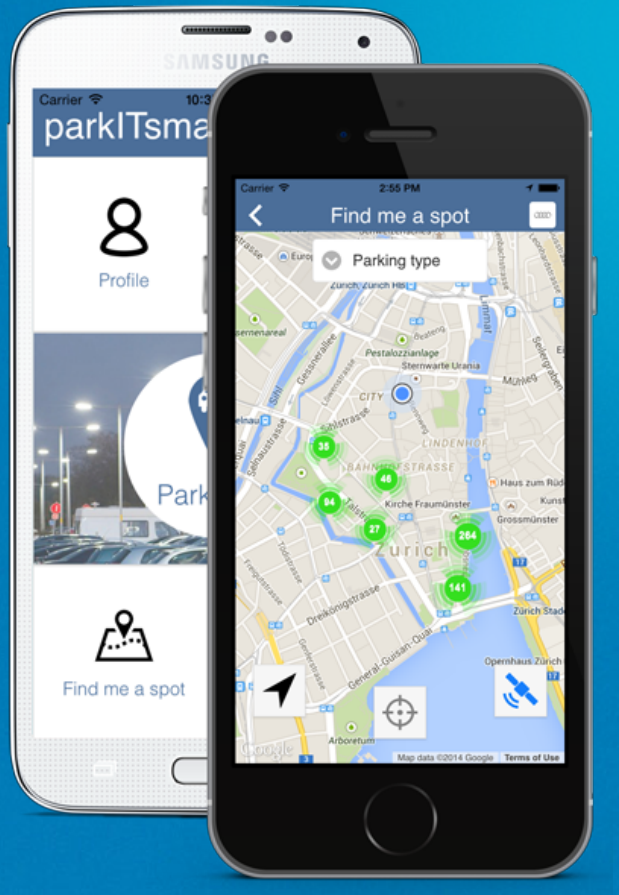


Technologies

Future Work

- Long-term / Large-scale study
  - Verifying scalability
  - Evaluation of Movement Patterns
- Low power location retrieval with high accuracy
- Security feature for iBeacons (*e.g.*, Rotating UUIDs)
- Real-time Parking Information for other platforms
  - Extend user-base

www.parkITsmart.com



Thank you!