Modelling Bluetooth Inquiry for SUMO

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- Motivation
- Bluetooth Traffic Monitoring
- The Inquiry Process
- Modelling and Simulation
- Results
- Conclusions and Future Prospects

Motivation

Effective traffic and mobility management…
- requires reliable (i.e. up-to-date, spatio-temporal and area-wide) traffic information
- And thus needs appropriate sensor systems

New systems such as Bluetooth traffic monitoring uses wireless radio-based technologies to detect traffic objects.

Research Question:
How likely is it to monitor a detectable traffic object within the detection range?

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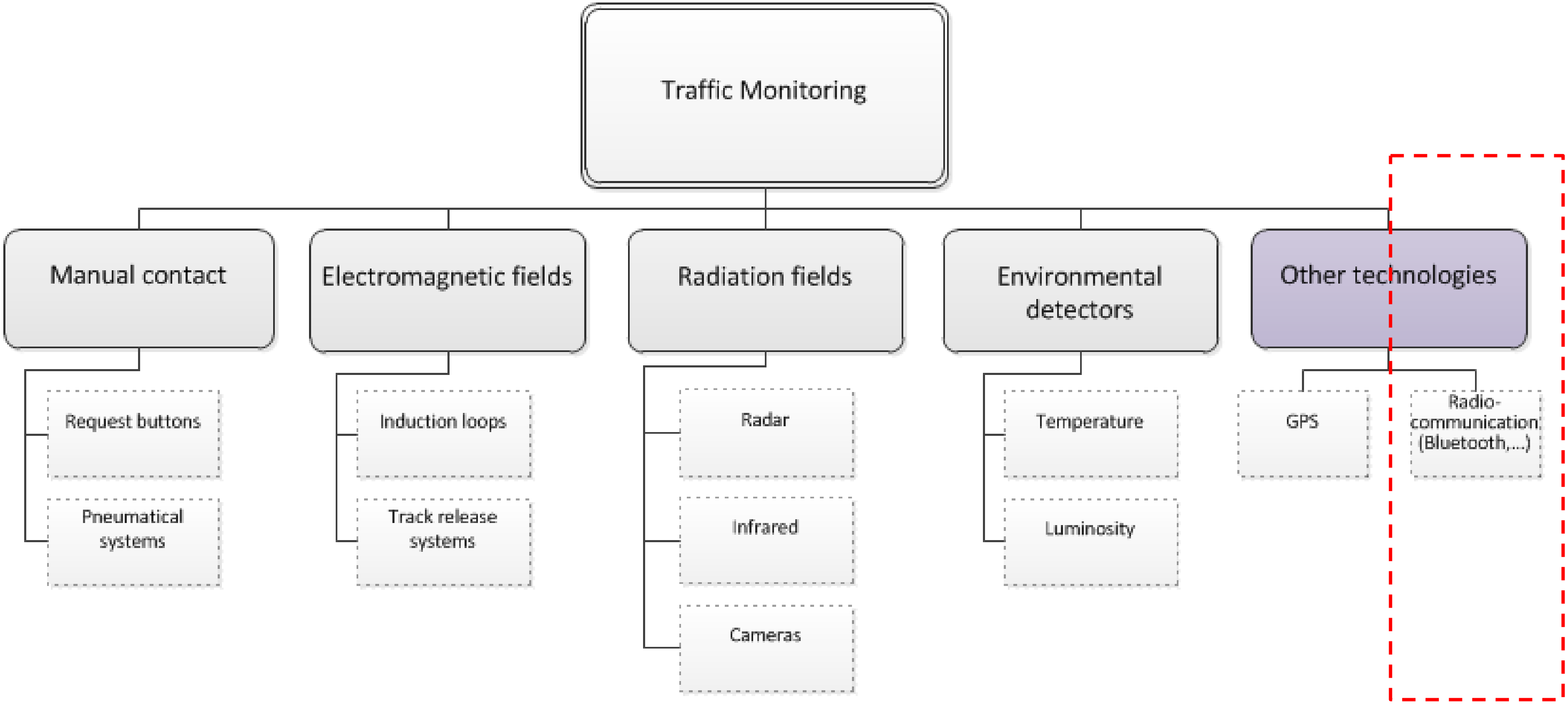
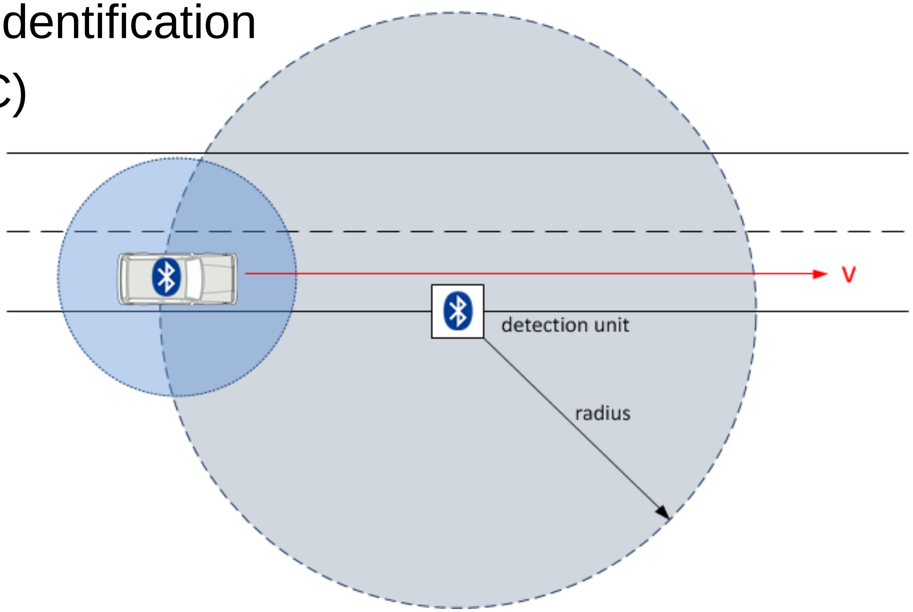
Bluetooth Traffic Monitoring



Bluetooth Traffic Monitoring
Principle

- Based on wireless radio-based communication between electronical devices (e.g. smartphones and headsets)
- Using communication standards like Bluetooth, Wi-Fi, ZigBee, …
- Traffic object detection via mobile or stationary electronical on-board devices equipped with Bluetooth (identification token: device address, called MAC)
- advantages: unique identifiability and therefore chance for redetection (origin-destination information!)



Bluetooth Traffic Monitoring
Applications

- Derivation of spatio-temporal traffic information (travel times, velocity, …)
- Special feature: area-wide origin-destination / route information due to redetection chance
- Additional traffic objects (e.g. cyclists, pedestrians, public transport systems) can be monitored as well

Use cases:

- Queue time measurement at the airport
- Visitor flow measurements e.g. at trade fairs
- Temporary traffic measurements e.g. in case of road works and rerouting
- Long-term traffic measurements on highways
- Pedestrian stay time measurements for advertising spaces

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Inquiry Process

Scanning frequencies in two different trains

Detecting several devices which appear only for a short time period

Neglecting several properties

- Backoff time
- Length of the appearance interval

http://www.mcl.hu/~fazek/oktatasi_segedanyagok/IEEE80211,%20Wimax,%20Bluetooth/200206BluetoothNetworks.pdf

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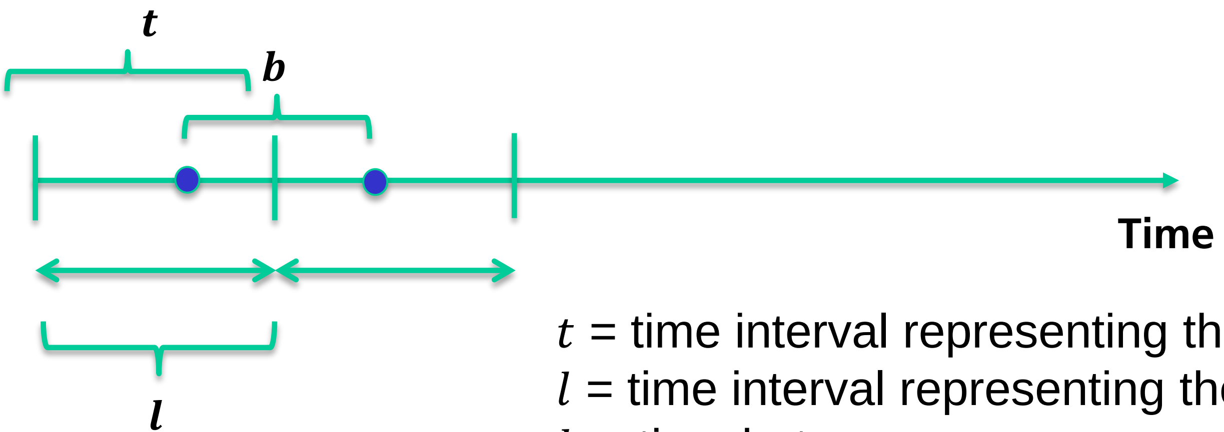
Analytical Model

Traffic monitoring using Bluetooth depends not only on penetration rates, detection range or velocity but also on the Bluetooth inquiry process itself.

Modelling approach:

We calculate the probability that the overlapping time intervall t contains the target frequency which has to be scanned for being detected.



t = time interval representing the travel time

l = time interval representing the scanning interval

b = time between occurences of the device

Analytical Model

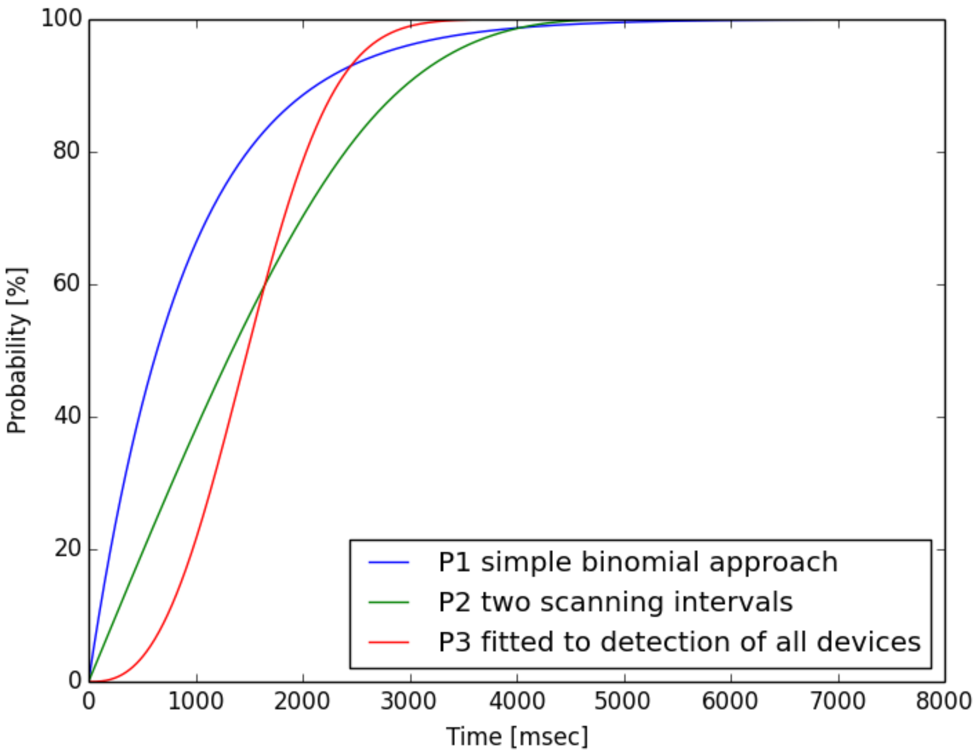
$$P_1(t, p_d, b) = 1 - (1 - p_d)^{\frac{t}{b}}$$

Two additional approaches:

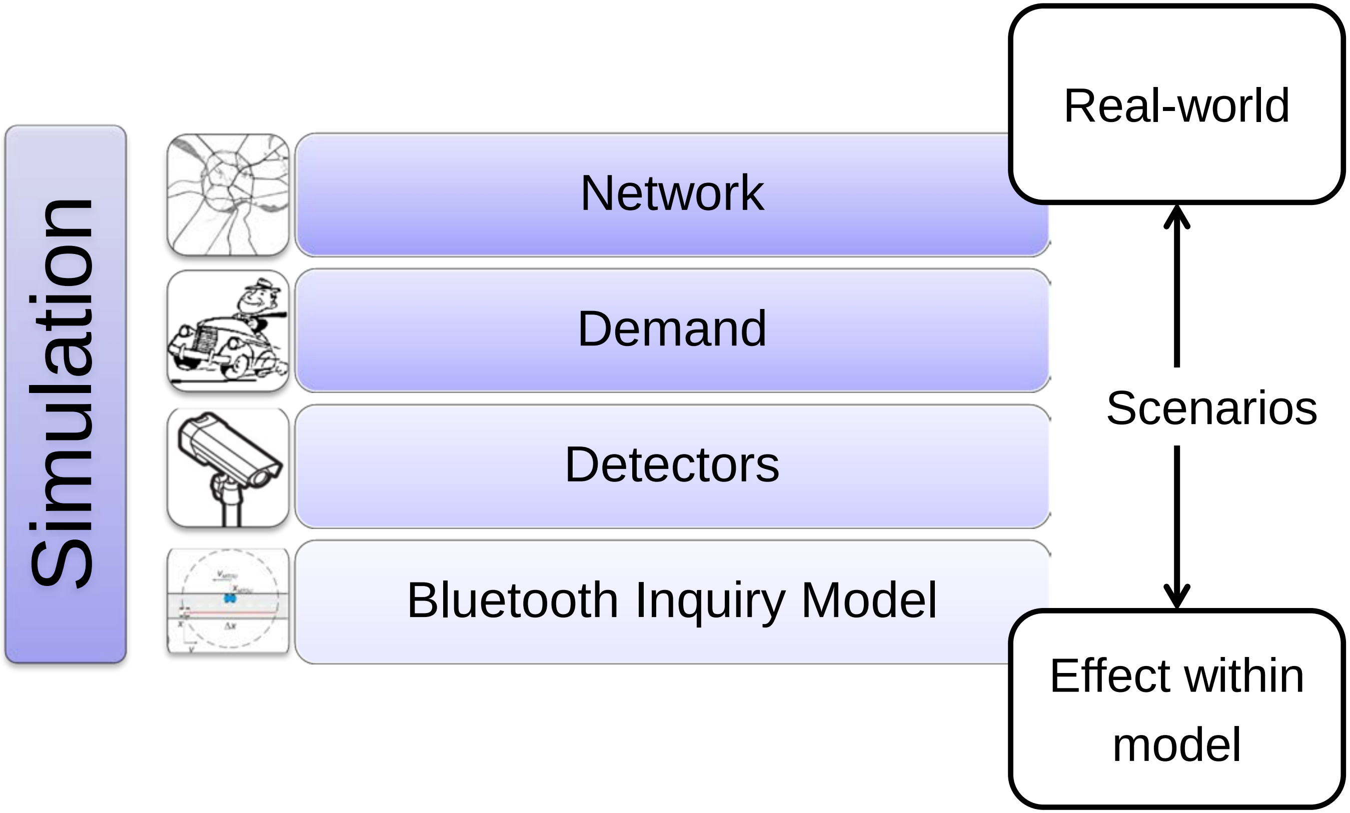
$$P_2(t, l) = \frac{\int_0^l p(t, l, x)dx}{l}$$

1. $t < l$: $P_2(t, l) = \frac{t}{l} - \frac{t^3}{6l^3}$
2. $l \leq t < 2l$: $P_2(t, l) = 1 - \frac{(2l-t)^3}{6l^3}$
3. $t \geq 2l$: $P_2(t, l) = 1$

$$P_3(t) = 1 - e^{-.24 * t^{2.68}}$$



Simulation

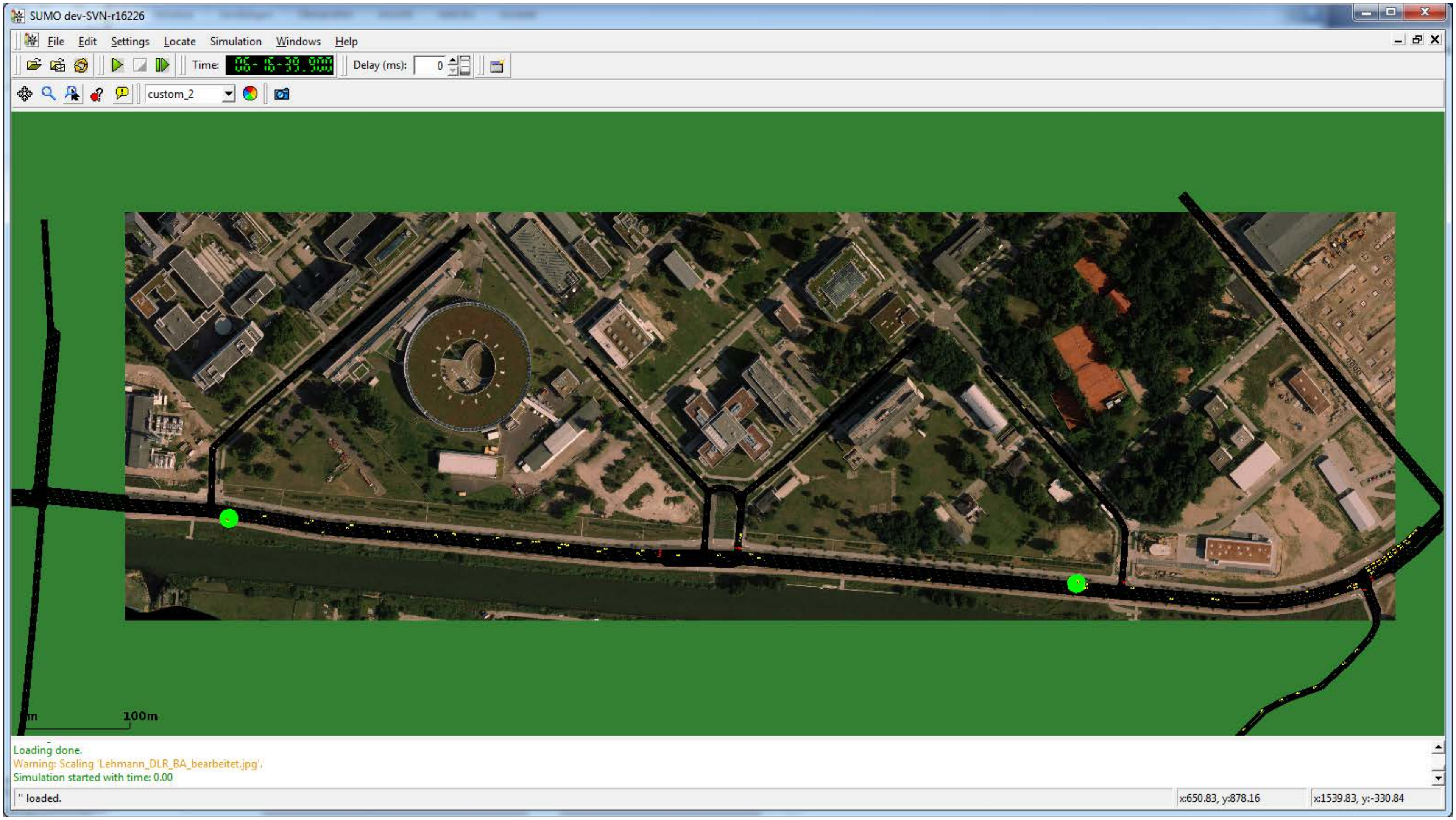

Simulation
Network
Demand
Detectors
Bluetooth Inquiry Model
Real-world
Scenarios
Effect within model

Simulation

- Adaptations in SUMO
  - ✓ Bluetooth inquiry model implemented
  - ✓ Equipment rates:
    - BTreceiver rate (--device.btreceiver.probability)
    - BTsender rate (--device.btsender.probability)
  - ✓ Detection range (--device.btreceiver.range)

- Simulation scenario
  - representing DLR test track (Ernst-Ruska-Ufer)
  - 2 fixed BTreceiver (east and west)
  - fixed BTsender equipment rate of 30%
  - detection range 100m

Simulation


SUMO dev-SVN-r16226
File Edit Settings Locate Simulation Windows Help
Time:
Delay (ms): 0
custom_2
100m
Loading done.
Warning: Scaling 'Lehmann_DLR_BA_bearbeitet.jpg'.
Simulation started with time: 0.00
'' loaded.
x:650.83, y:878.16
x:1539.83, y:-330.84

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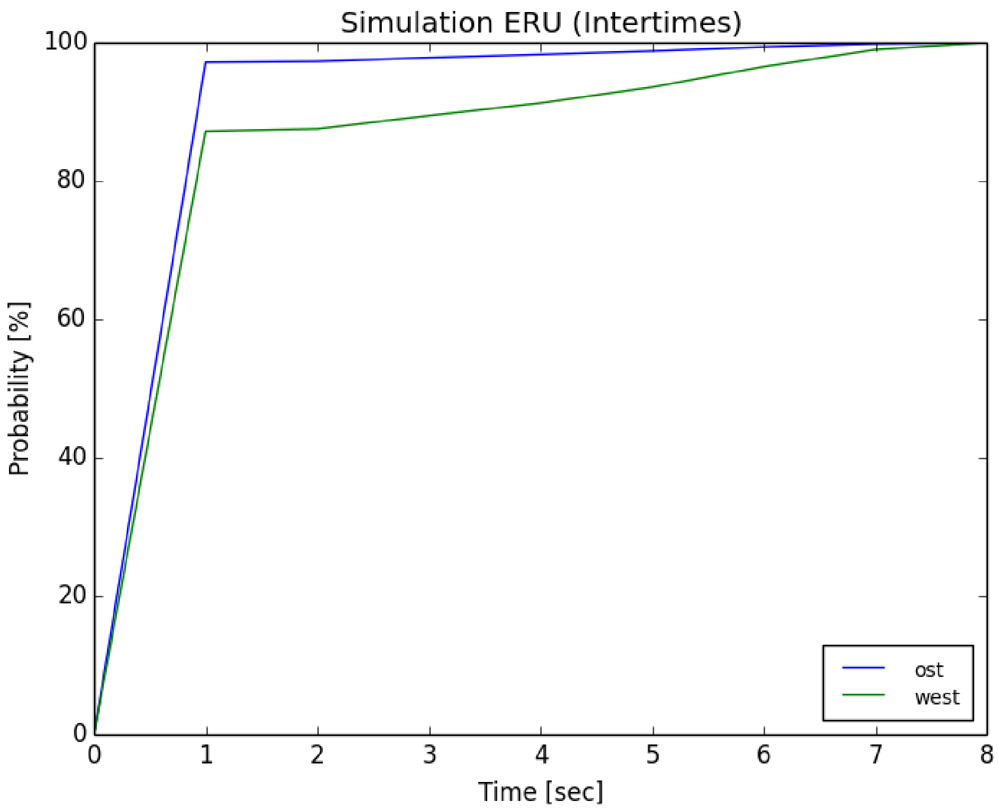
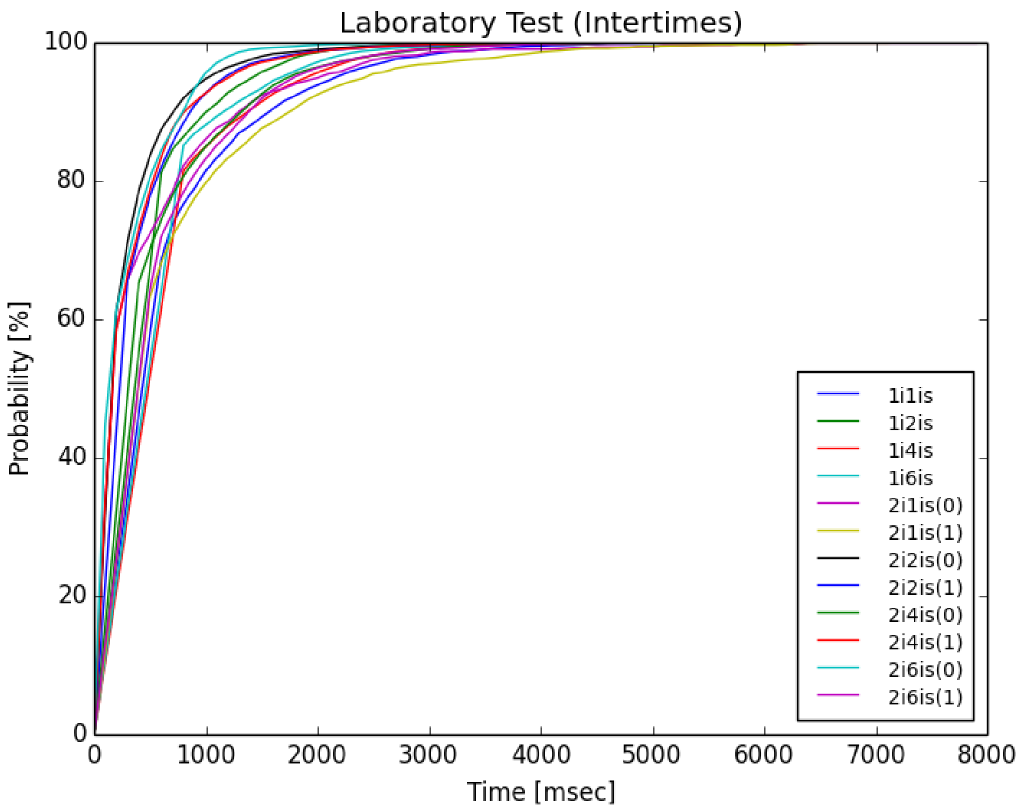
Simulation Results



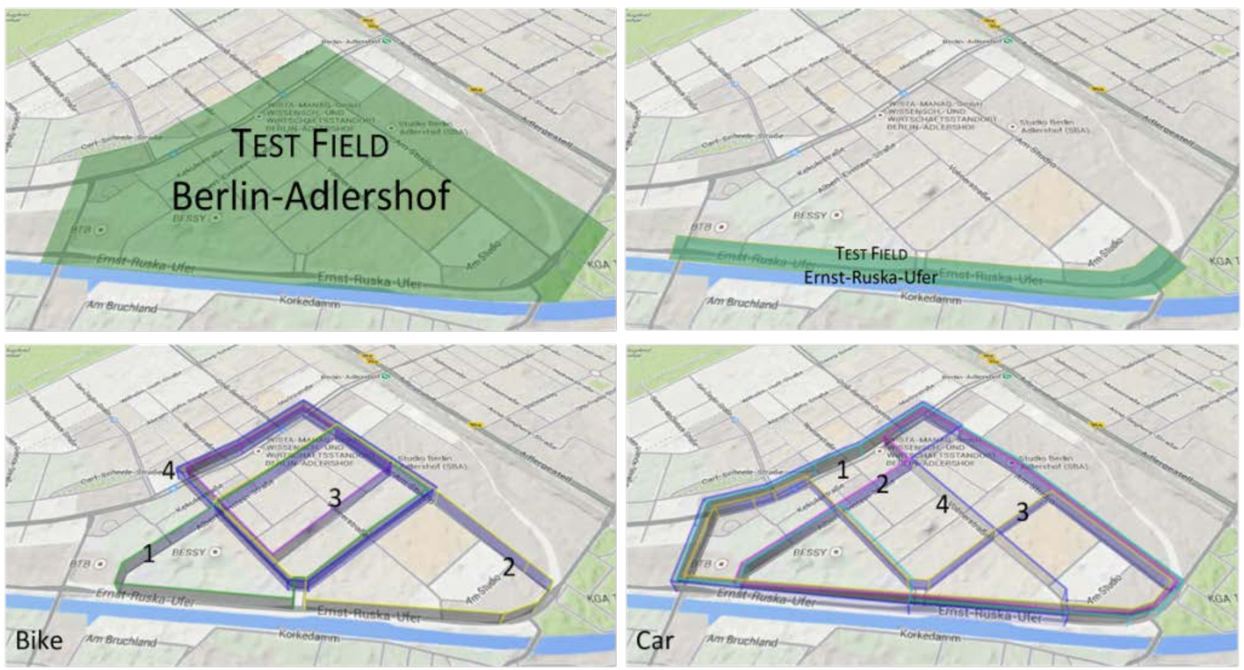
Intertimes represent the inquiry time process

Real World Measurements
Laboratory Test



Real World Measurements
Field Test

- Test run (2013-08-20, 1h) at the DLR test track using
  - 2 stationary Bluetooth detectors
  - 8 moving Bluetooth observer objects (cars and bikes, 4 of each)



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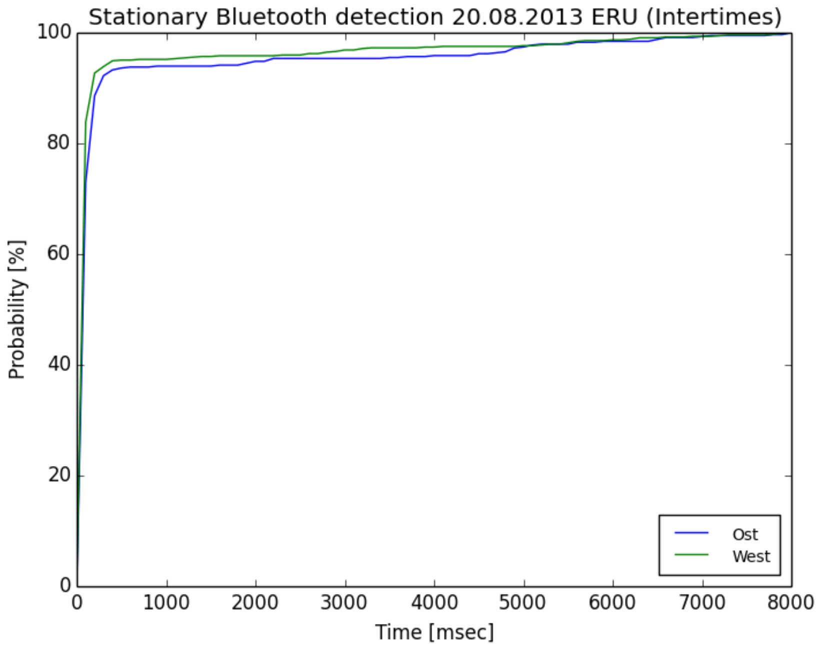
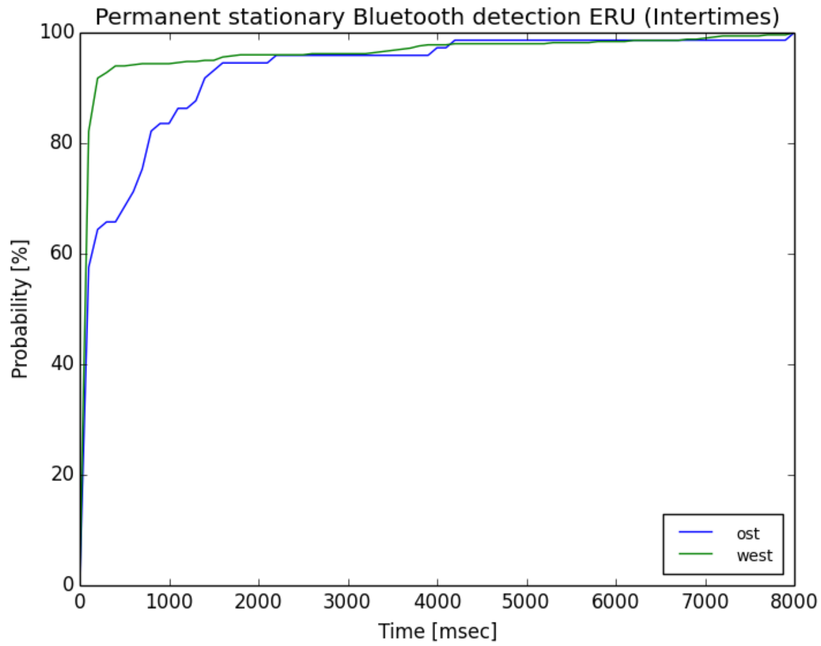
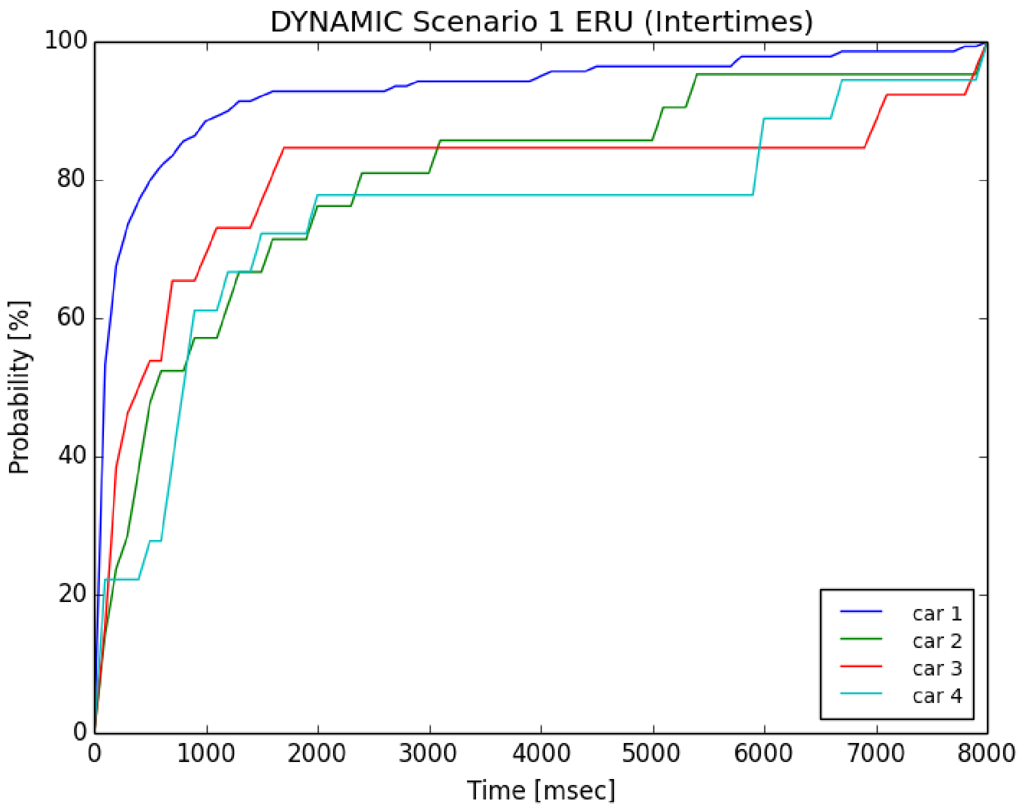
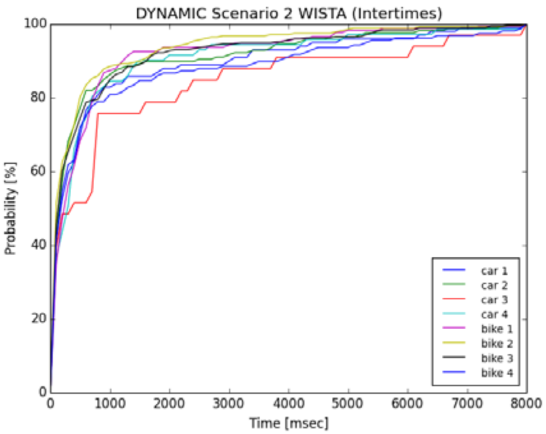
Real World Measurements
Results from Stationary Bluetooth Detection

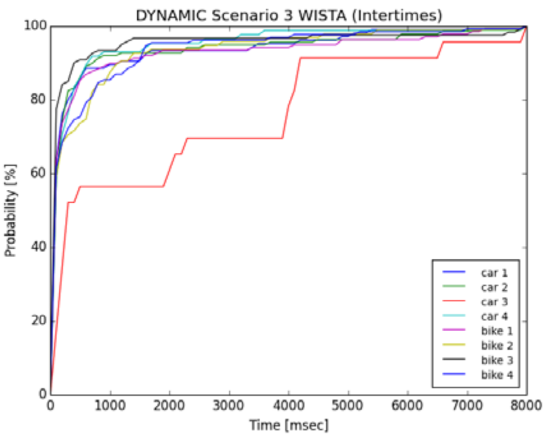




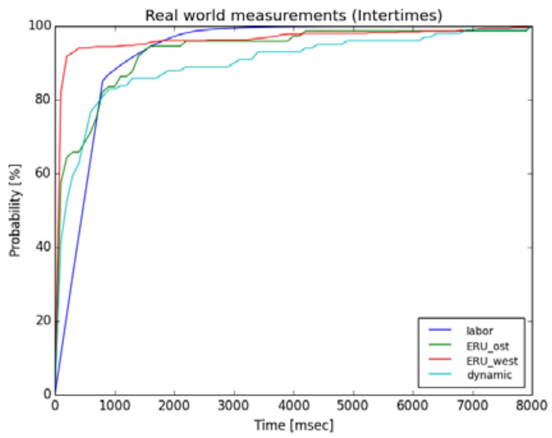
Real World Measurements
Results from Moving Bluetooth Detection

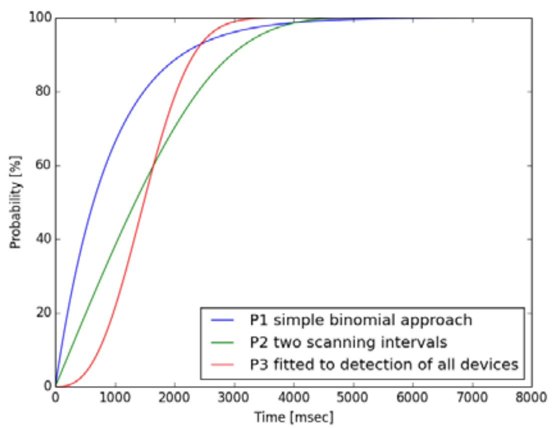


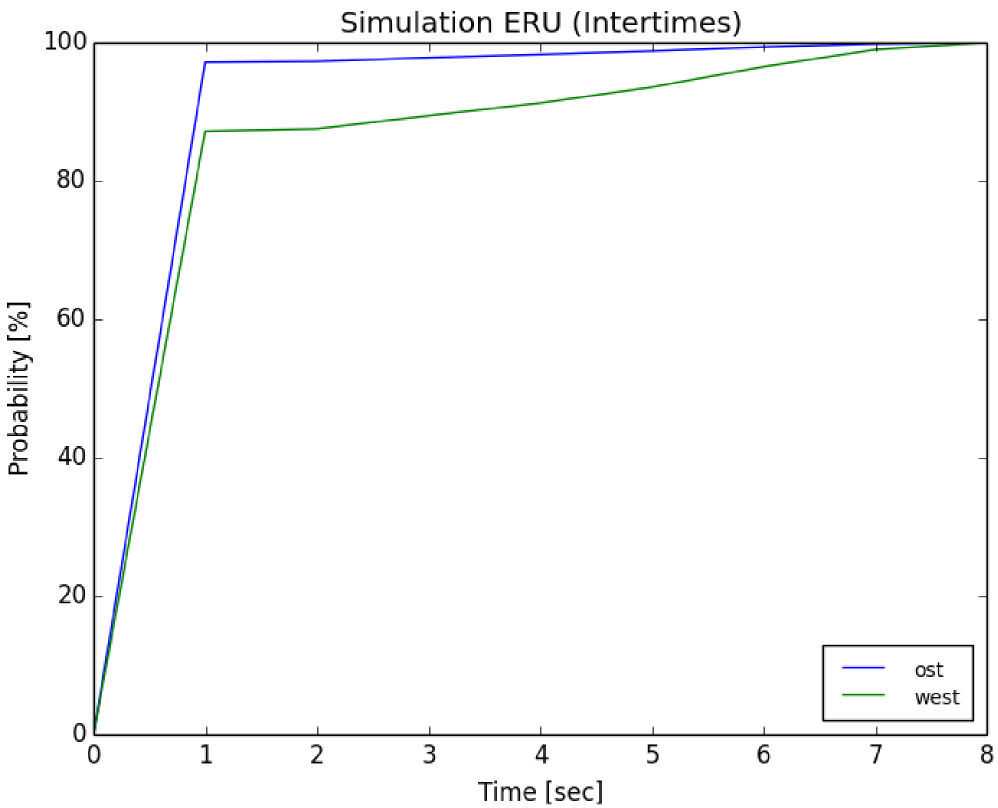




Results
Comparison







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Conclusions

- Bluetooth inquiry process was modelled and implemented in SUMO.
- A specific scenario was simulated and the results were compared to laboratory and real world measurements.
- We could see that:
  - Probability density seems to be best fitted by exponential function
  - Simulation results fit the real world stationary Bluetooth monitoring results quite well
  - Unusual „plateau behaviour“ between 2 and 7 seconds in case moving Bluetooth observers

Thank you for your attention!

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