Vehicular mobility in a large scale urban environment

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Outline

- Motivation
- Tools
- Trace generation
- Resulting trace
- Connectivity analysis
- Conclusions and future work

Motivation

- Networking solutions for vehicular environments require **car mobility information**
  - **Cellular networks**
    - Infrastructure planning
    - Resource allocation
    - Hand-off management
    - Green networking
  - **Autonomous networks** (e.g., DSRC-based)
    - Roadside infrastructure planning (V2I communication)
    - Protocol design and performance evaluation (V2I + V2V)

Motivation

- Trivial solution: collect and use **real-world traffic data**
- Possible sources
  - **Transportation** departments (vehicular mobility only)

Time	Road ID	Coords	In-flow	Out-flow
3:30pm	29834AC	(x,y) (x,y)	26 veh/min	10 veh/min

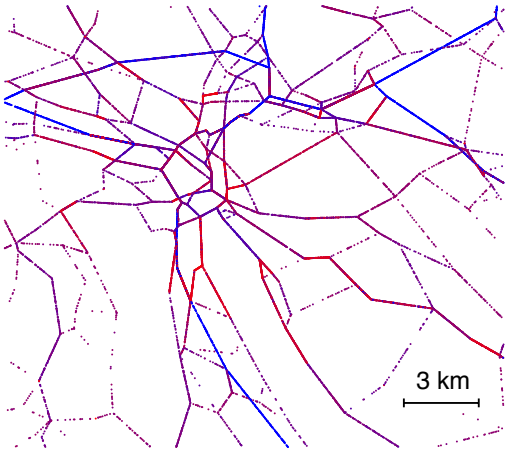
  - **Telecom service** providers (vehicular + pedestrian mobility)

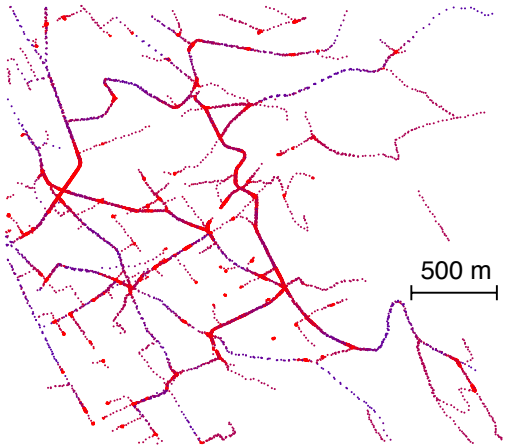
Time	User ID	Cell ID	Previous cell ID	Network
5:50pm	063149***	ladoua_01	villeurbanne_06	3G

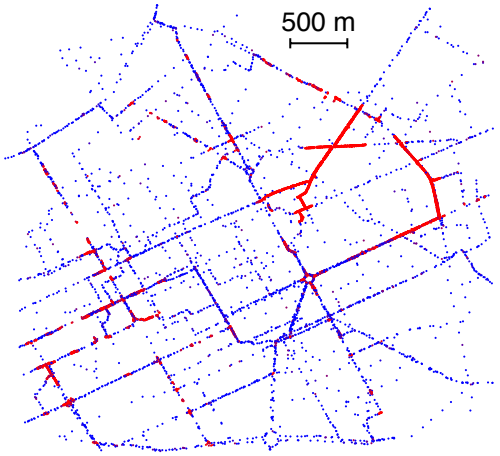
- However, real-world mobility traces are **not publicly available**
  - Public security, privacy, industrial competition, expensive access

Motivation

- Resort to **synthetic traces** of vehicular mobility
- State-of-art mobility traces freely available
  - **Canton of Zurich** (CS Dept., ETH Zurich, Switzerland)
  - **Downtown Zurich** (Telecom Dept., ETH Zurich, Switzerland)
  - **Downtown Turin** (CS Dept., Politecnico di Torino, Italy)







Motivation

- However existing traces have major limitations

Datasets	Canton of Zurich	Downtown Zurich	Downtown Turin	Koln (New)
Area	10000 km^2	12 km^2	20 km^2	400km^2
Road topology	Highways + major roads	Major + minor roads	Major + minor roads	Highways + major + minor roads
Trace length	24 hours	20 minutes	1 hour	24 hours
Microscopic simulation	Low detail (MMTS)	Medium detail (GMSF)	High detail (SUMO)	High detail (SUMO)
O/D matrix	Low detail	Low detail	Observation	Survey

Trace generation tools

- Required components
  - **Realistic road topology**
    - Accurate map of street layout including road properties
  - **Microscopic simulator**
    - Representation of individual driving behavior
  - **Macroscopic model**
    - Identification of trips travelled by drivers
      - Traffic demand: origin-destination (O/D) matrix
      - Traffic assignment: route calculation

Trace generation tools

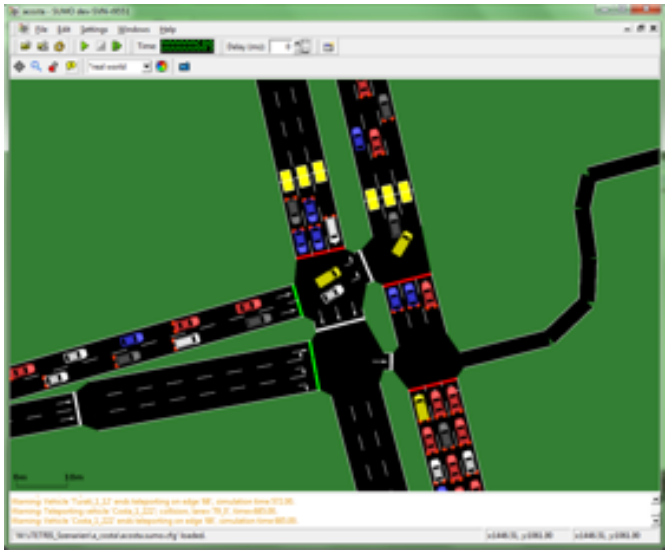
- Required components
  - **Realistic road topology → OpenStreetMap**
    - Accurate map of street layout including road properties
  - **Microscopic simulator → SUMO**
    - Representation of individual driving behavior
  - **Macroscopic model**
    - Identification of trips travelled by drivers
      - Traffic demand: origin-destination (O/D) matrix → **TAPAS**
      - Traffic assignment: route calculation → **Gawron's algorithm**

OpenStreetMap

- World **map database**
  - Open-source
  - **Road topology quality** closely matches that of Google Maps, Mappy
- Includes additional information
  - **Traffic lights**, AOI, buildings
- Dedicated editing tools
  - Osmosis: database information filtering
  - JOSM: road information editing

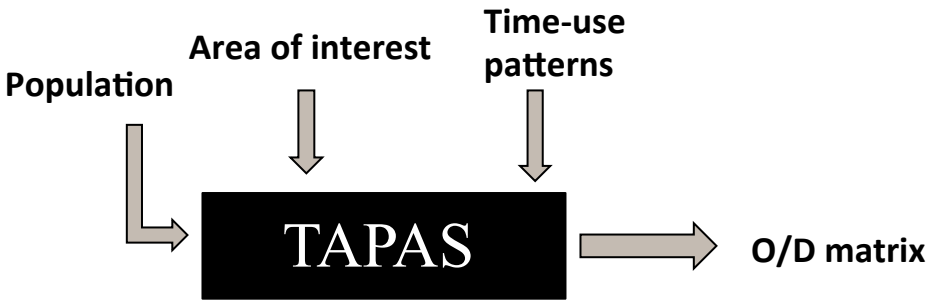
Simulation of Urban Mobility

- Microscopic **vehicular mobility simulator**
  - Open-source
  - Imports different maps formats
    - OSM, GDF, US Census TIGER database
- Featured models
  - Krauss' **car-following model**
    - Controls driver acceleration/deceleration based on car-to-car distance and velocity
  - Krajzewicz's **lane-changing model**
    - Overtaking decisions



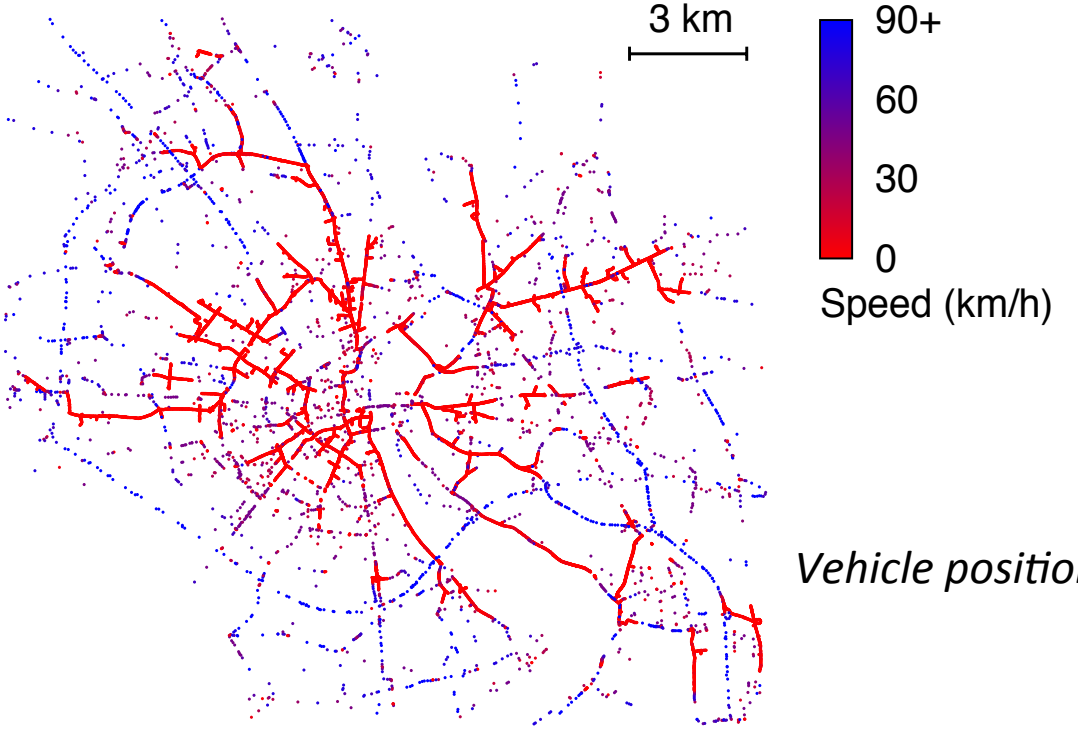
Travel and Activity Pattern Simulation

- Macroscopic **traffic flow** dataset
  - Provided by Institute of Transportation Systems at the German Aerospace center (ITS-DLR)
  - 24-hour O/D matrix of a typical day in Koln, Germany
- Based on **TAPAS methodology**
  - Exploits a survey by German Federal Statistical Office
    - **30,700** daily activity reports
    - **7000** households
    - **1.2 million** trips



Trace generation

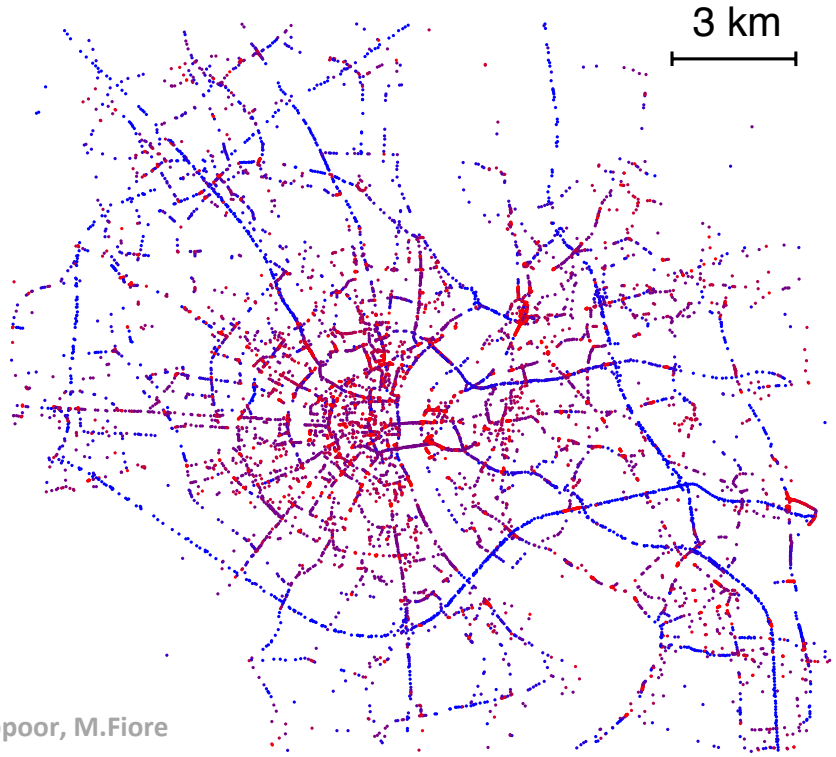
- Integrating the tools as they are leads to a plain **unusable trace**
  - **Pervasive traffic congestion** early in the simulation
  - Impossibility to recover from above condition

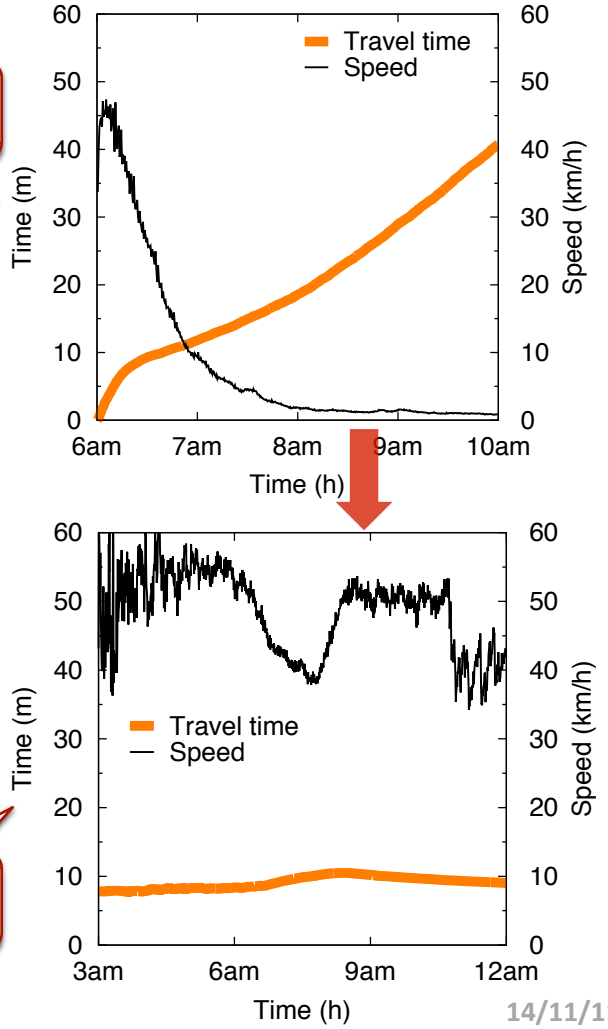


Vehicle position and speed at 7 am

Resulting trace

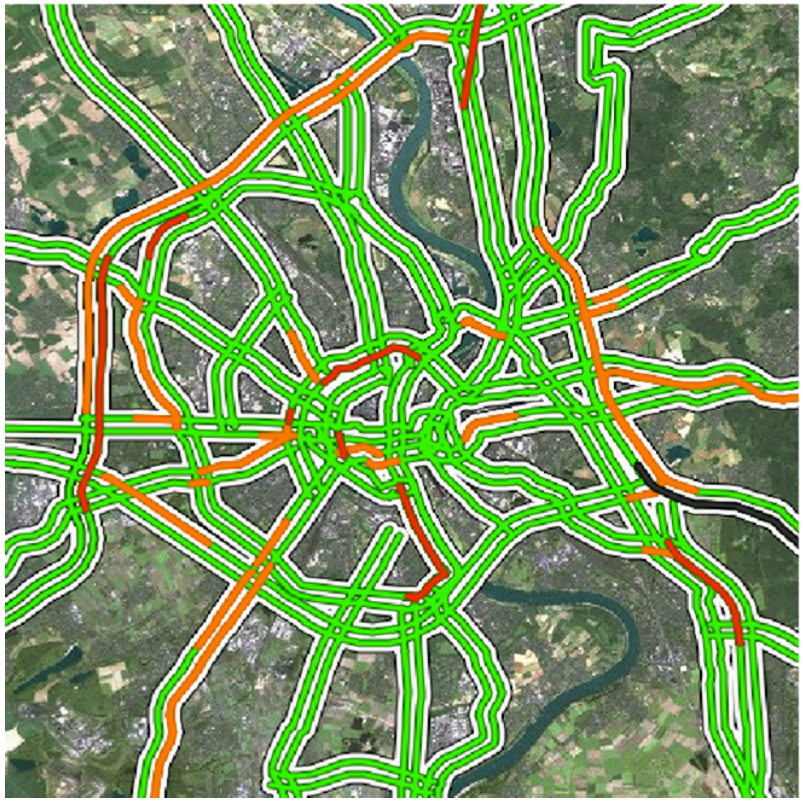
- Repairing all flaws provides **expected road traffic behavior**
  - Realistic **speed** and **travel time**



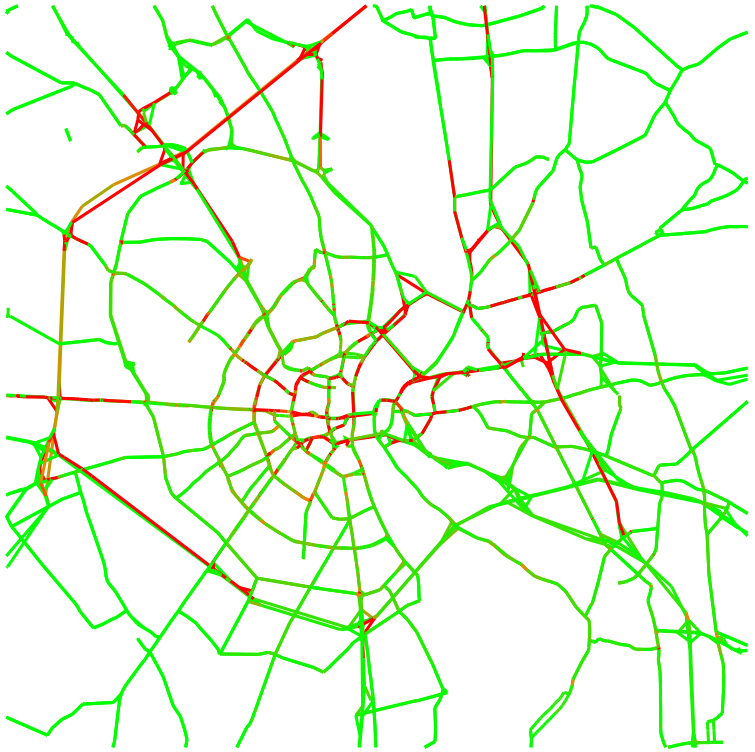


Resulting trace

- **Live traffic** comparison: our trace vs. ViaMichelin



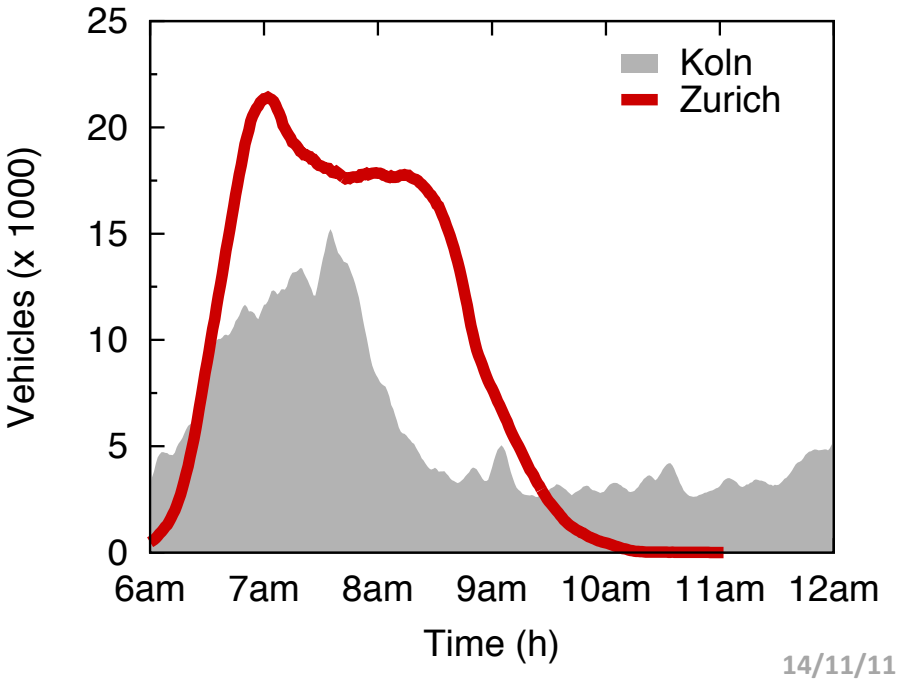
ViaMichelin – 5pm



Koln trace – 5pm

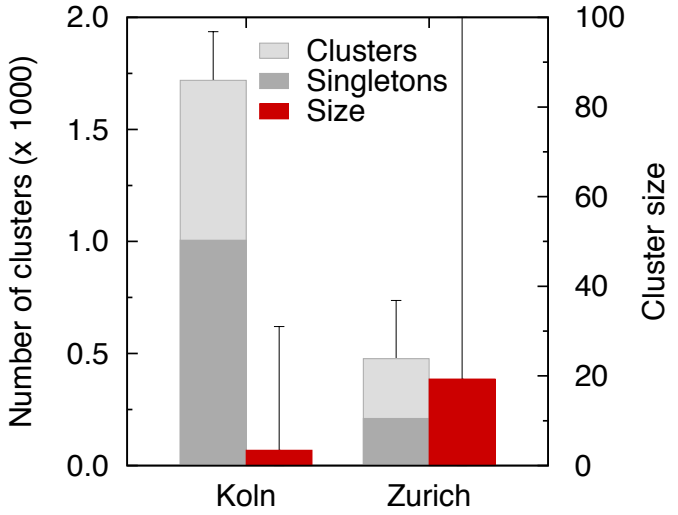
Connectivity analysis

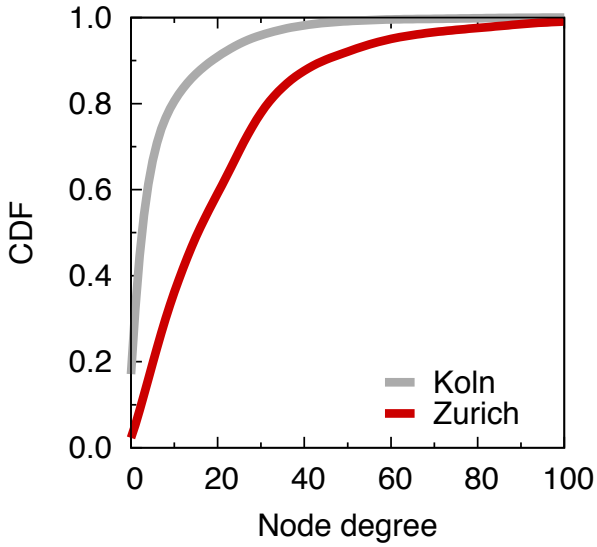
- Impact of car traffic realism on **vehicular network connectivity**
  - Comparison with canton of Zurich trace (only large-scale trace available)
  - Metrics: clustering and degree distribution
- Realism of **Zurich trace**
  - Incomplete road topology
  - Low microscopic detail (queuing approach)
  - Approximate macroscopic model



Connectivity analysis

- Cluster analysis
  - Many **more clusters**
  - Clusters are much **smaller in size**
  - No giant components
- Degree distribution
  - **60%** vehicles have less than **5 neighbors**
- Significantly **reduced connectivity** w.r.t. Zurich trace





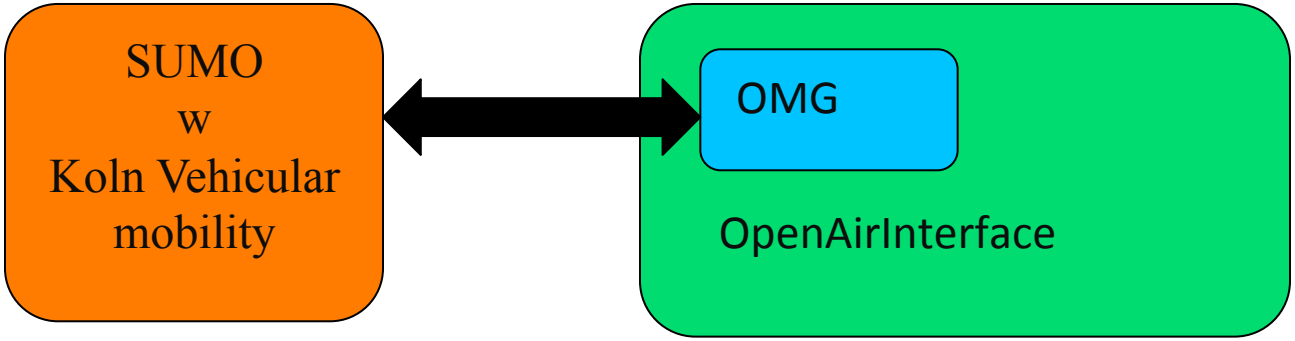
Conclusions

- Large-scale vehicular mobility trace
  - **400 km^2** around the city of Koln, Germany
  - **24 hours** of car traffic, involving **700,000 trips**
  - Generated with **state-of-art tools**
  - Closely matches live traffic
- Comparison with existing traces
  - Simplistic macroscopic and microscopic modeling results in exceedingly good network connectivity
  - **Using current traces may cause over-optimistic protocol performance evaluation**
- Availability : last week of November
  - http://kolntrace.project.citi-lab.fr and http://sumo.sourceforge.net

Recent and Future direction

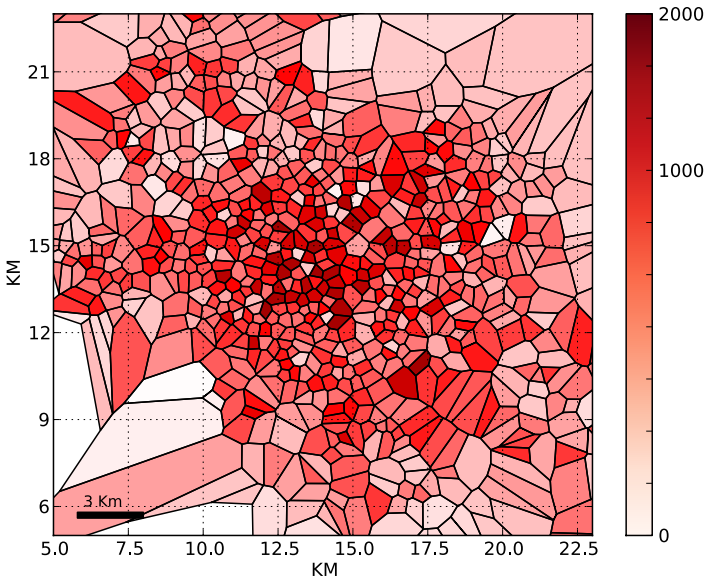
- EURECOM's OpenAirInterface (LTE Emulator) uses Koln vehicular mobility through SUMO.
- Demo in bell labs Open days 2012
- http://www.openairinterface.org

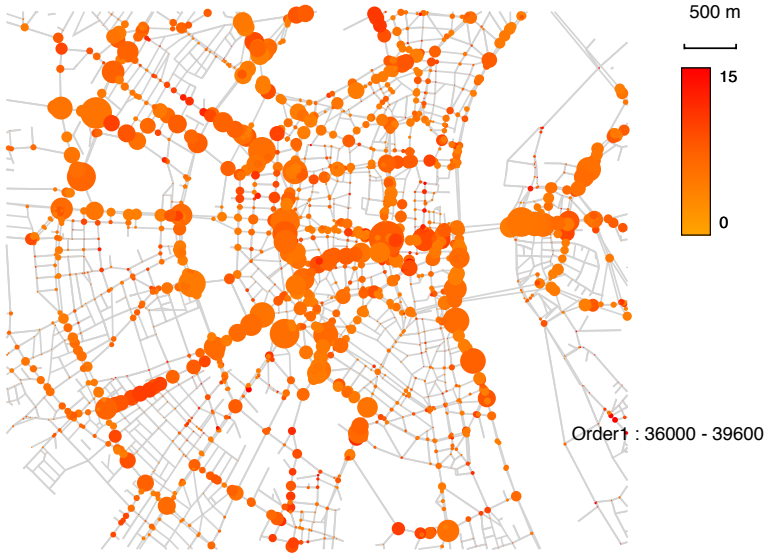
Mobility Simulator **LTE Emulator**



Future direction

- Further mobility analysis using Voronoi tessellations
- Mobility prediction on macroscopic flows
- Exploit the signal propagation in outdoor urban environment using WiPLAN



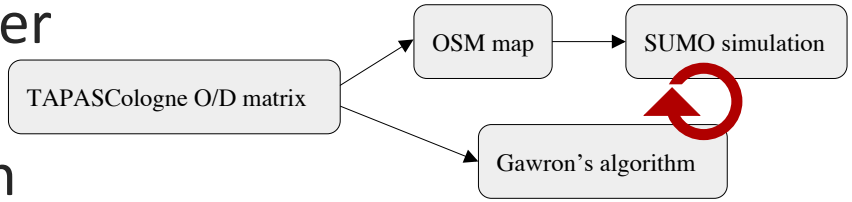


Thank you

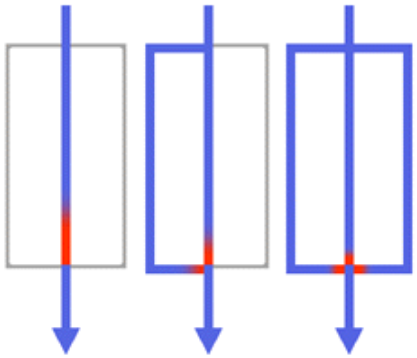
Question ?

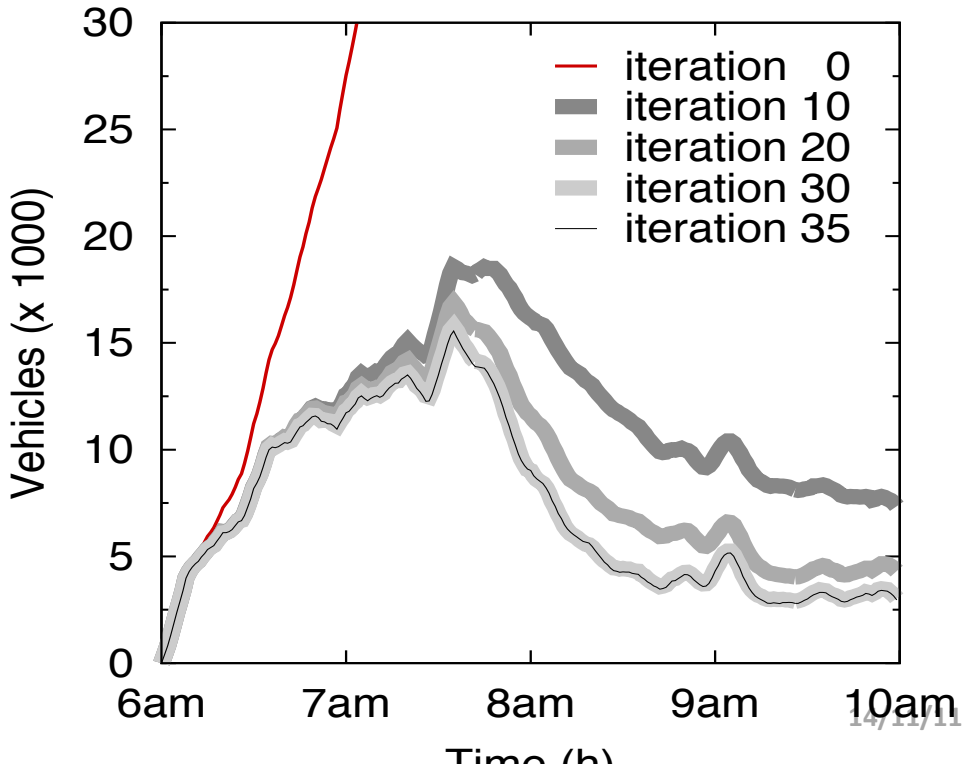
Appendix 1: Gawron's algorithm

- Simple **iterative process** for better route calculation which is more knowledgeable about congestion



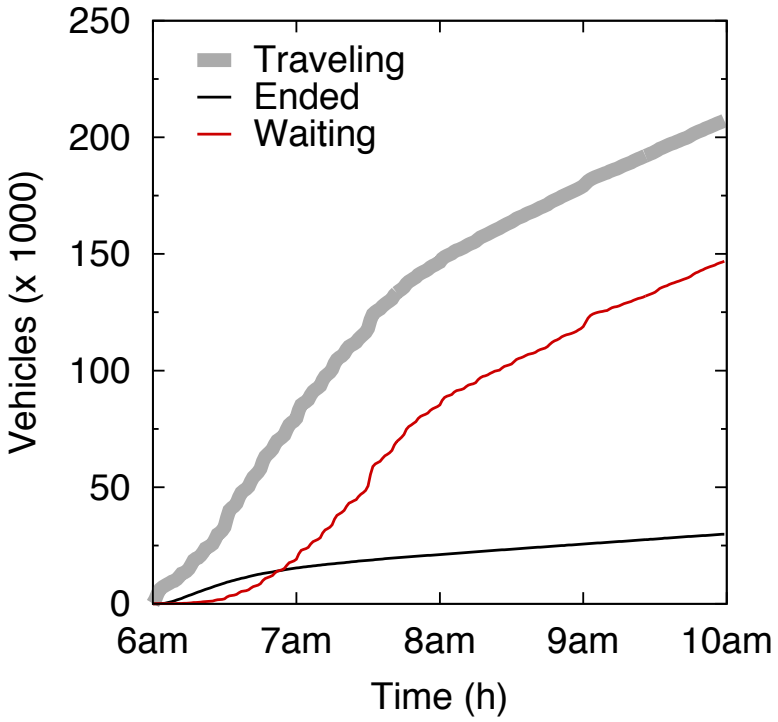
- Traffic Equilibrium requires **repeated simulations**

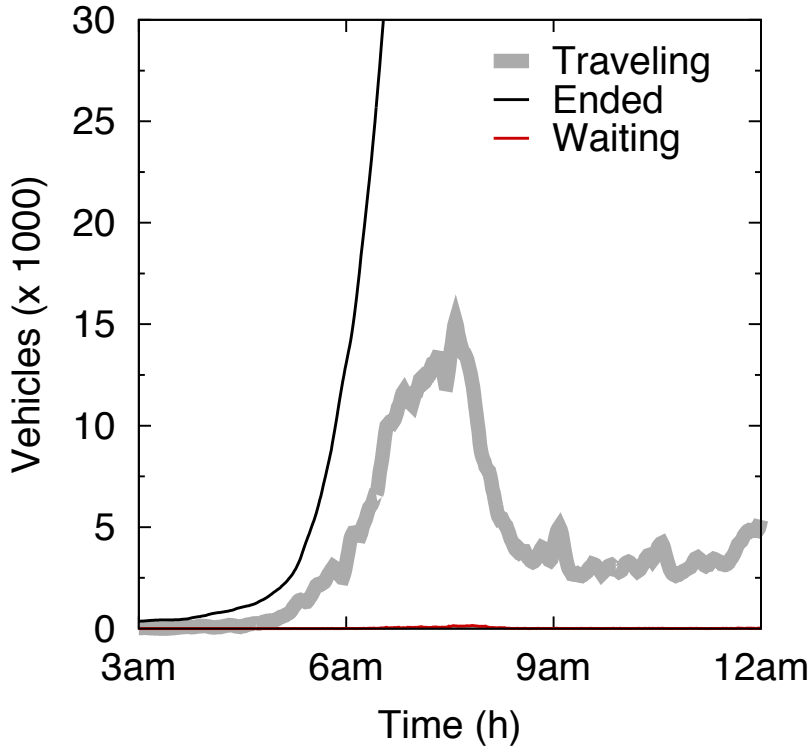




Appendix 2: Few more results

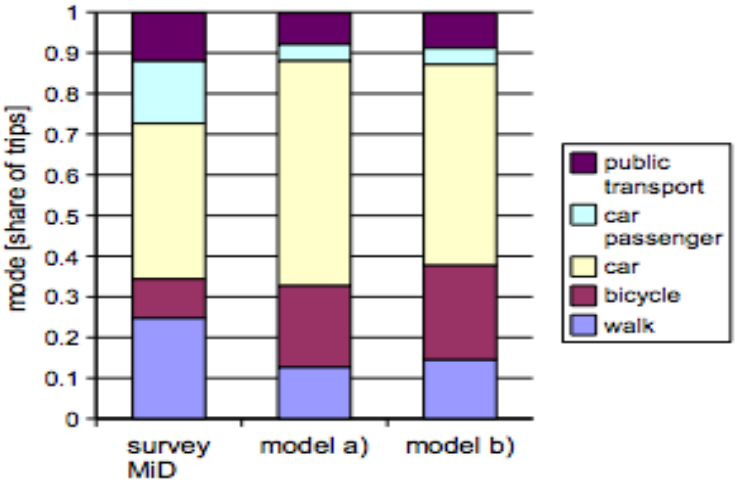
- Vehicles activities during simulation



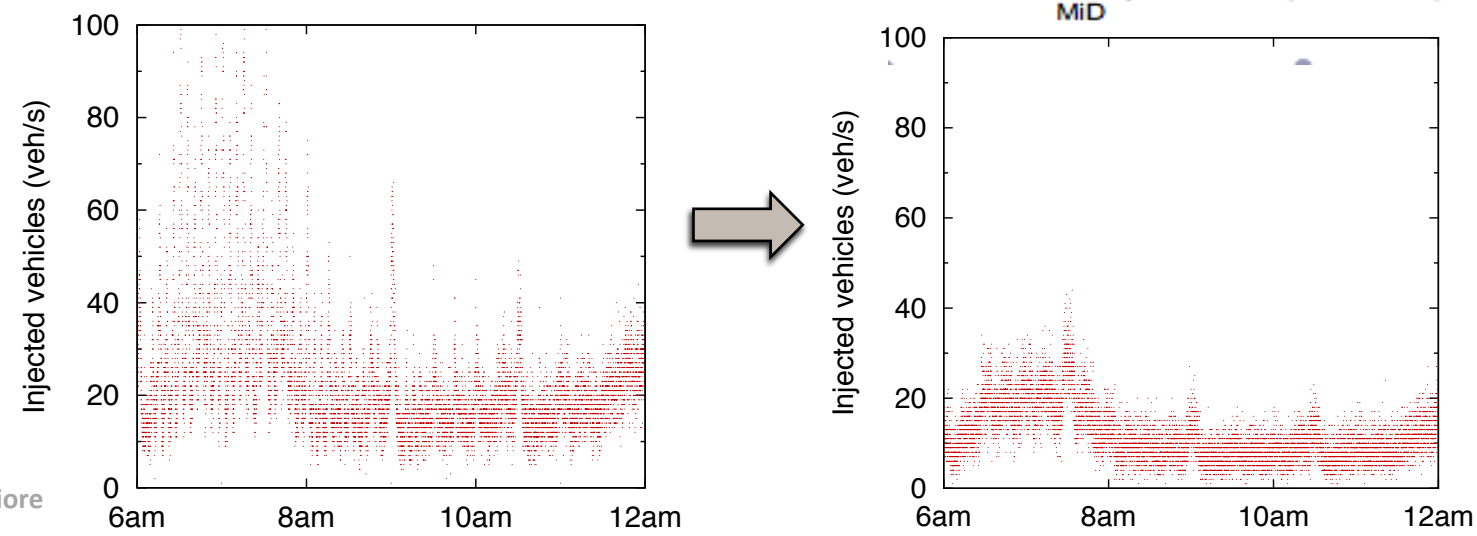


Trace generation

- **Traffic demand**
  - Restricting the dataset to **car traffic**
  - Reduction of bursts of vehicle in-flow to the simulation

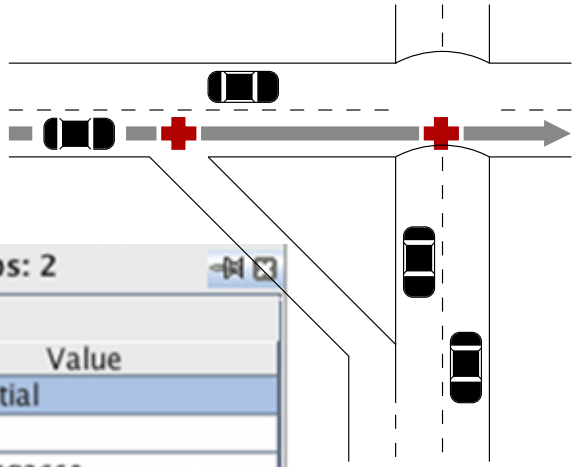


- **Highway traffic** is introduced



Trace generation

- **Wrong restrictions**



Properties: 4 / Memberships: 2

Highways/Streets/Residential

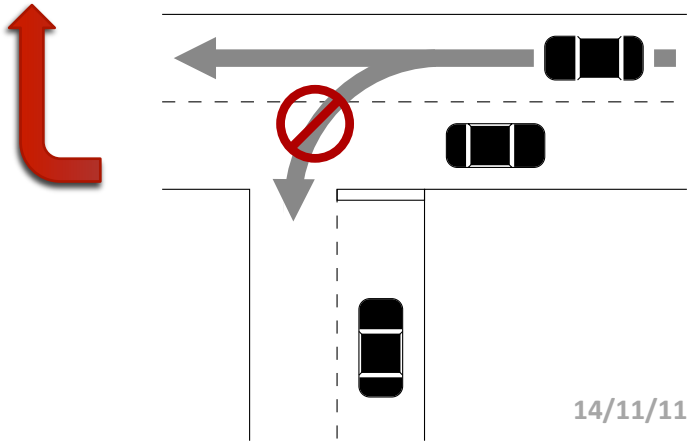
Key	Value
highway	residential
lanes	2
name	Glockengasse
oneway	yes

Member Of	Role	Posit...
restriction ("only_straight_on", 3 me...	from	1
route ("Kölner CityTour", 197 mem...	forward	89

Properties: 9 / Memberships: 3

Key	Value
cycleway	<different>
highway	<different>
lanes	<different>
maxspeed	<different>
name	<different>
oneway	<different>
ref	<different>
source	<different>
surveillance	<different>

Member Of	Role	Posit...
restriction ("no_left_turn", 3 membe...	from	1
restriction ("only_straight_on", 3 me...	<differ...	1-3
route ("B 9", 968 members, incomp...		39-...



Trace generation

- **OSM conversion**
  - Un-built road
  - Complex junctions