Yoann PIGNÉ
Visiting Researcher at LISER

Research Seminar
January 15th, 2015

Urban Traffic Simulation with Communicating Vehicles

Yoann PIGNÉ
Le Havre University

Luxembourg Institute of Socio-Economic Research
Urban Development and Mobility Department
January 15th, 2015

Yoann PIGNÉ - Curriculum

- **2008**: Ph.D. in Computer Science @ Univ. Le Havre
  - Dynamic graphs & Mobile Ad Hoc Network
- **2009-2011**: Post Doc. @ Uni. Luxembourg
  - Vehicular Ad hoc Networks
- **2011-now**: Assistant Prof. @ Univ. Le Havre
  - Dynamic graphs applied to several problems:
    - Maritime Traffic Analysis (with César Ducruet)
    - Life Cycle Assessment (with Enrico Benetto)
    - Epidemiology coupled with Human Mobility

Institution - Lab - Team

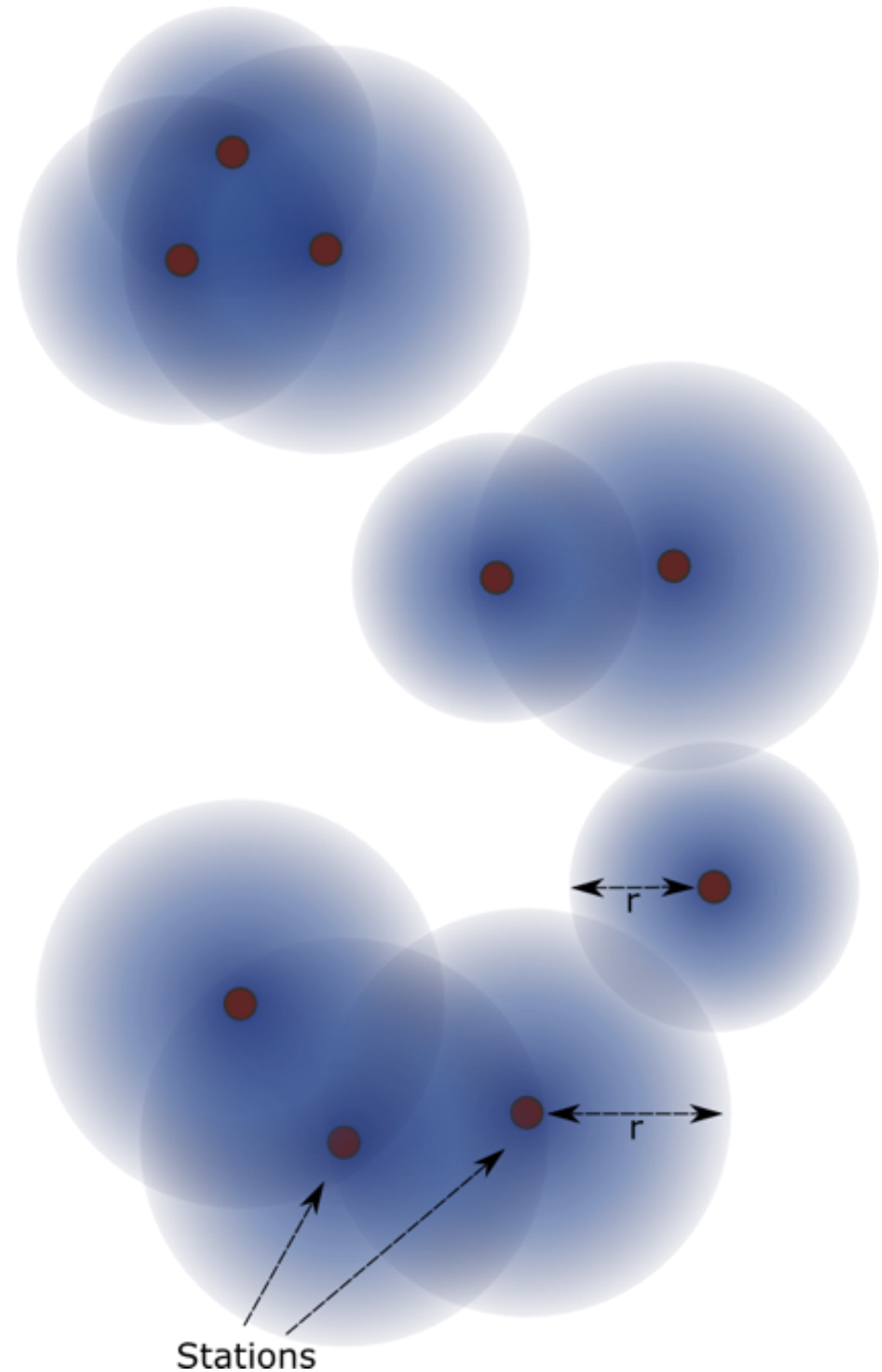
- Le Havre University
  - ~7500 students, 3 faculties, 1 IUT, 1 engineering school, 11 labs
- LITIS Lab « Laboratoire d'informatique de traitement de l'information et des systèmes »
  - Univ. Rouen, INSA Rouen, Univ. Le Havre, 70 lecturers-researchers
  - CNRS Federation with Caen's GREYC Lab
- RIIC Team « Réseaux d'interaction et intelligence collective »
  - 13 lecturer-researcher, ~10 Ph.D. students
  - Methods: Dynamic Graphs, Multi-Agent Systems, Dynamical Systems
  - Applications: Logistics, Population & Crowds Modeling, Industrial Risk Management, Mobile ad hoc Networks

Outline

- An Introduction to Vehicular Ad Hoc Networks
  - Models
  - Applications
- Realistic simulation of Vehicular Traffic Applications
  - Traffic Simulation
  - Wireless Network Simulation
- [Optional] Discuss a bit about « impact of mobility on an epidemiology problem »

Mobile Ad Hoc Networks (MANET)

- Wireless communication networks (WiFi, Bluetooth, Zigbee, …)
- Decentralized networks. No infrastructure (no routers, no access point). Each node is a router.
- Disrupted Networks. Little to no connectivity. Multiple connected components.
- Sending information between two nodes implies:
  - relaying between nodes (multi-hop)
  - waiting for connectivity (mobility)



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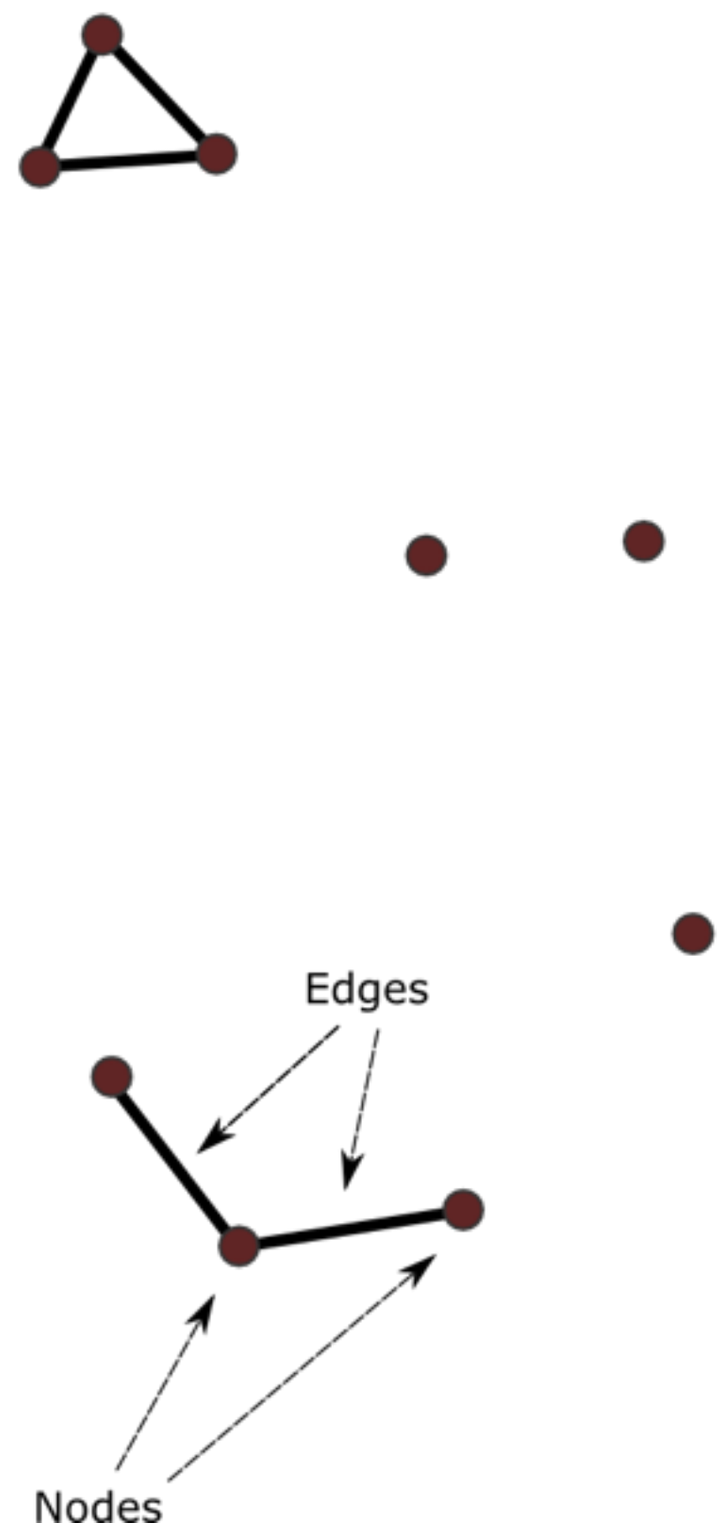
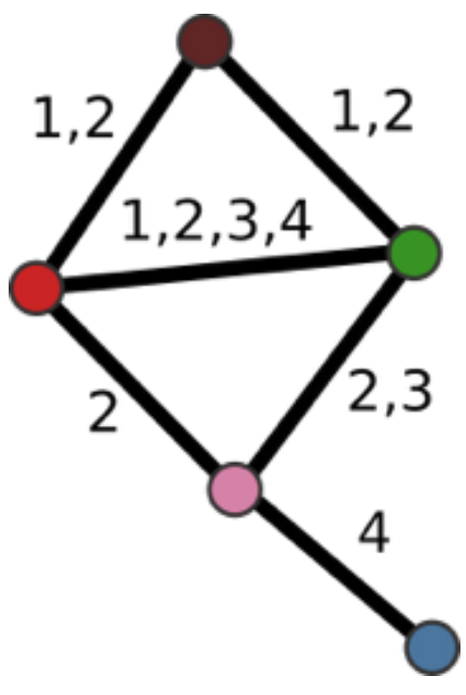
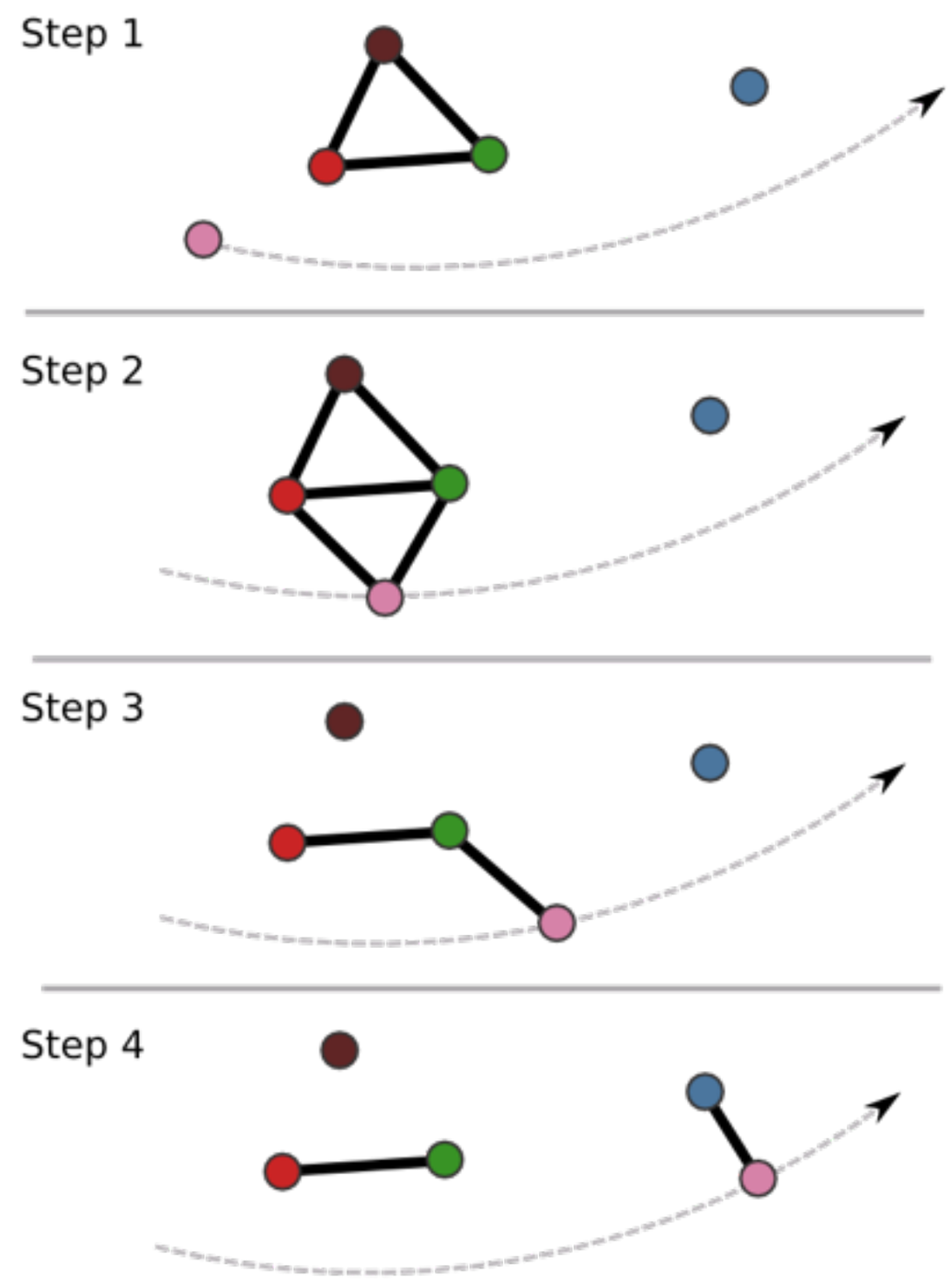


Models for MANET

- Graphs are the traditional model for communication networks.
- Dynamic Graphs (or Temporal Networks) capture the evolution of mobile wireless networks.

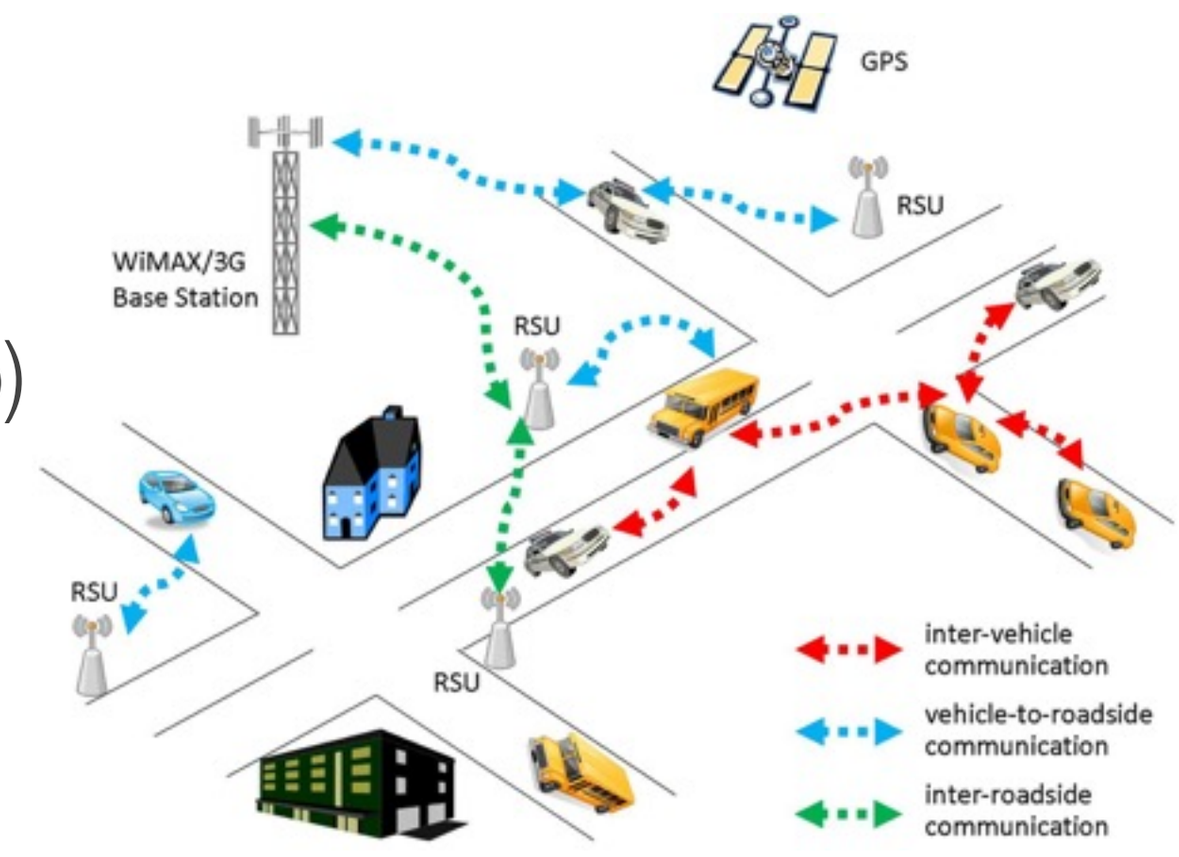




P. Holme and J. Saramäki, “Temporal networks,” Physics Reports, vol. 519, no. 3, pp. 97–125, Oct. 2012.

Vehicular Ad Hoc Networks (VANET)

- Share most of MANET characteristics
- Mobility differs (fast movement but organized)
- Various types of communication
  - Vehicle to Vehicle V2V
  - Vehicle to Infrastructure V2I
- Dedicated protocols (802.11p)



Main VANET Applications: Road Safety

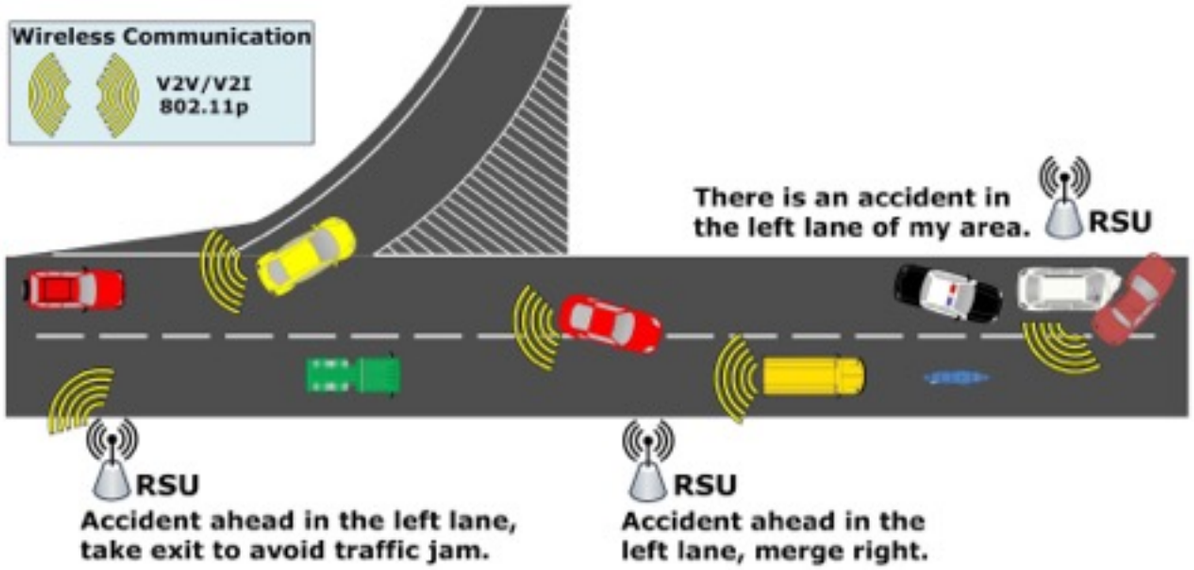
- Various inter-vehicle warning (Collision, sudden brake, lane change, blind spot, ...)
- Numerous research projects with car manufacturers involved.

Main VANET Applications: Traffic Management

- The Centralized Approach (through a service provider)
  - Data gathering through infrastructure (induction loops, cameras, gsm probes, vehicles sending theirs position and speed)
  - Drawbacks: infrastructure bottlenecks, latency (but great for large or recurrent traffic congestion)

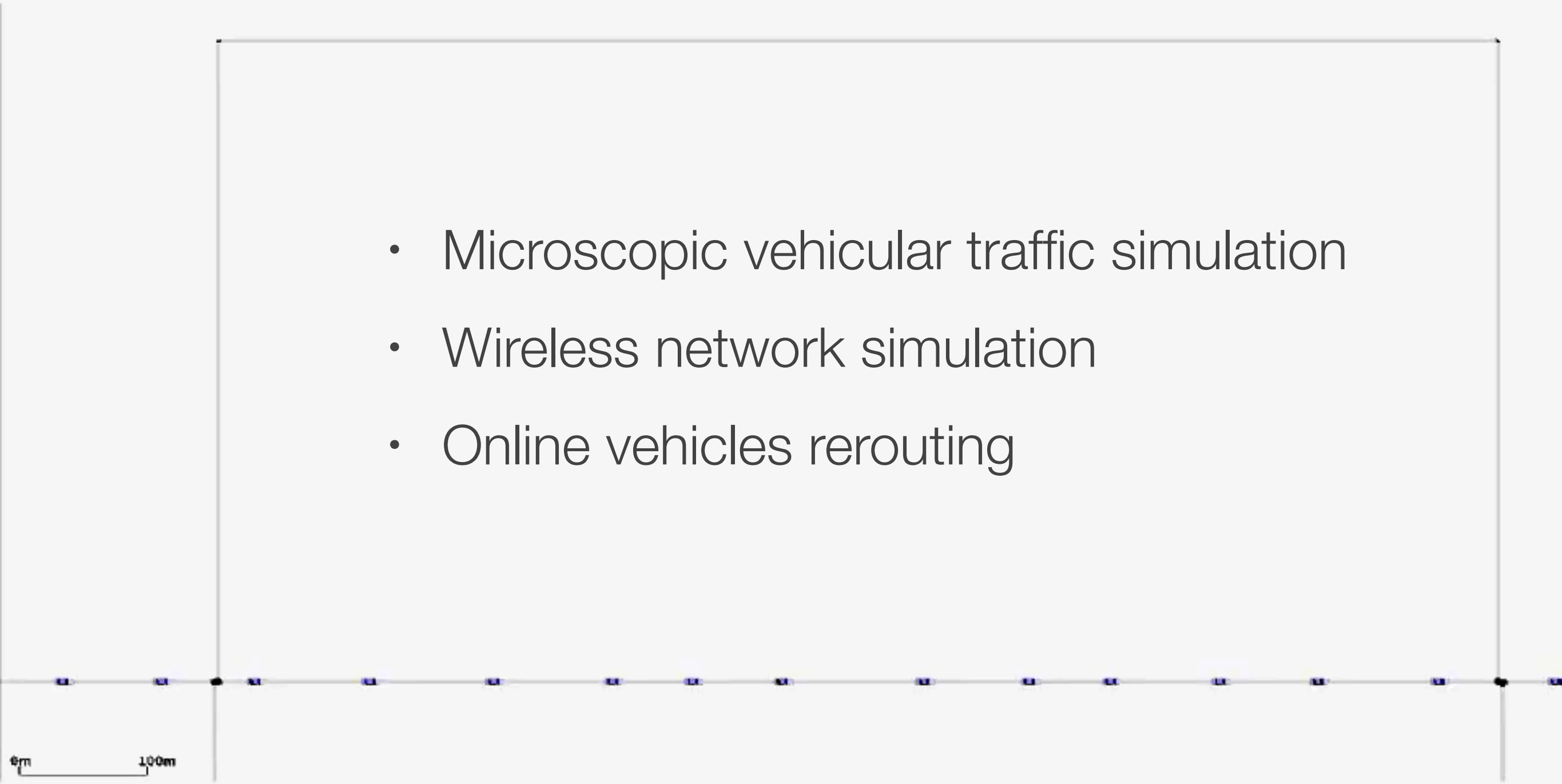
Main VANET Applications: Traffic Management

- The Decentralized approach
  - Vehicles collect local traffic information
  - Exchange with neighbors through the ad hoc network
  - pros: rapid access to local information, rapid detection of isolated events, reduced bottlenecks,
  - problems: trust, validity of information, broadcast storms, routing (packets in the communication network)
  - Collaboration with Tai-Yu MA



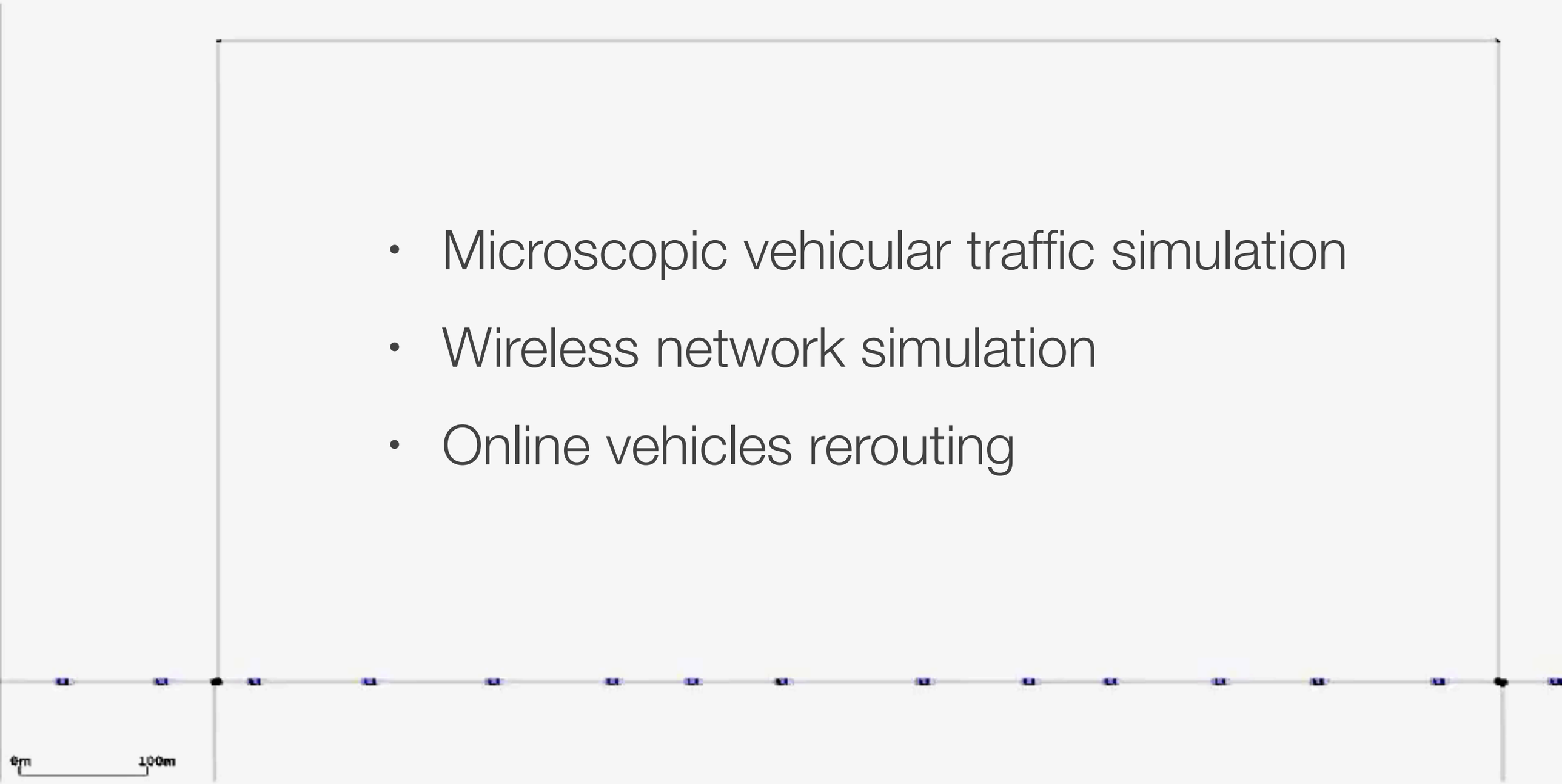
I. Leontiadis, G. Marfia, D. Mack, G. Pau, C. Mascolo, and M. Gerla, “On the Effectiveness of an Opportunistic Traffic Management System for Vehicular Networks,” IEEE Transactions on Intelligent Transportation Systems, vol. 12, no. 4, pp. 1537–1548, Dec. 2011.

Simulation of Decentralized Traffic Management



- Microscopic vehicular traffic simulation
- Wireless network simulation
- Online vehicles rerouting

Simulation of Decentralized Traffic Management



- Microscopic vehicular traffic simulation
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What applications for urban mobility researchers?

- Testing urban transportation planning
- Comparing generated traffic with real date (counting data)
- Integrate Drivers behavior in the traffic model
- Integrate near future communication capabilities in transportation plannings

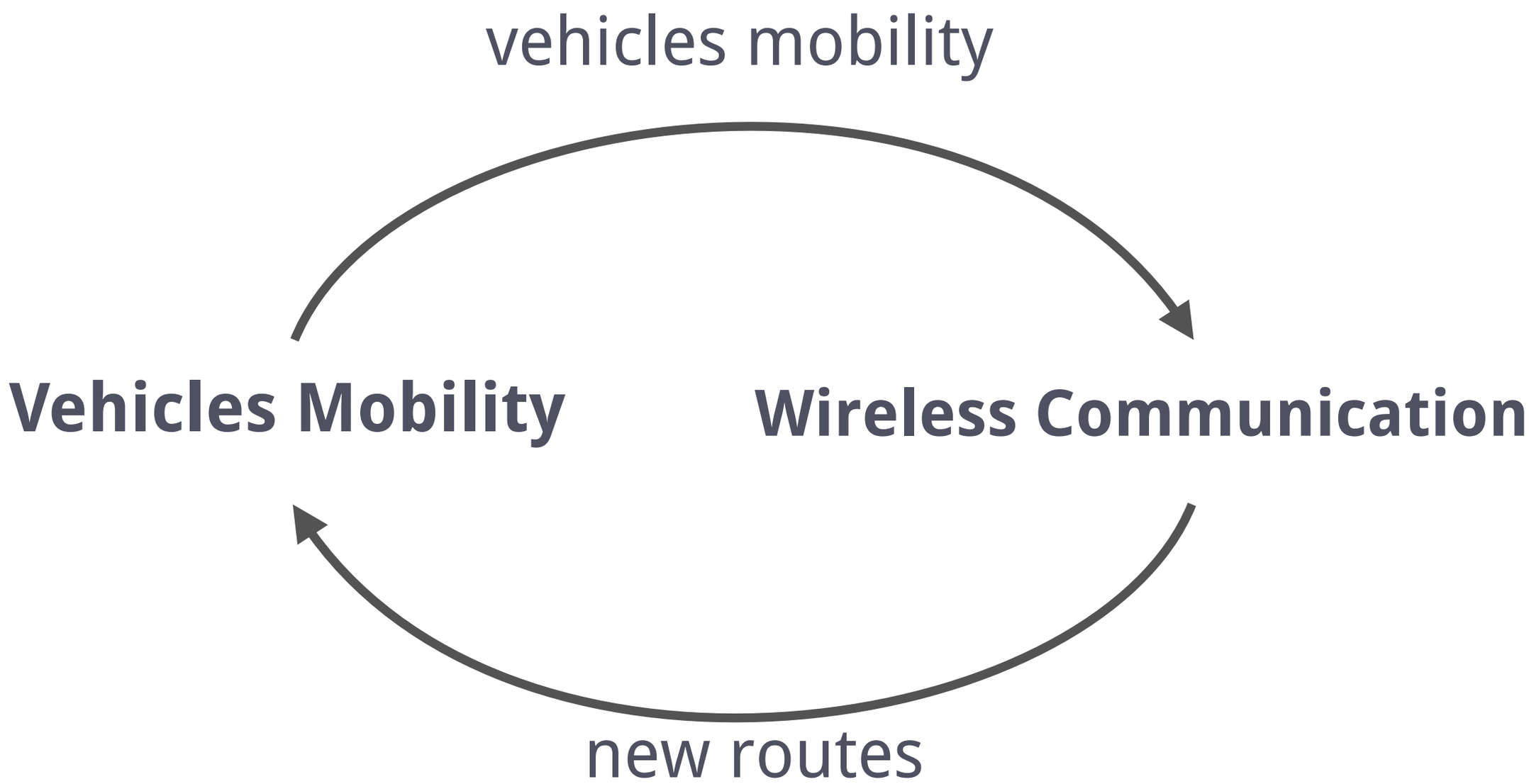
Realistic Simulation of Vehicular Traffic Applications

Realistic simulation of Vehicular Traffic Applications

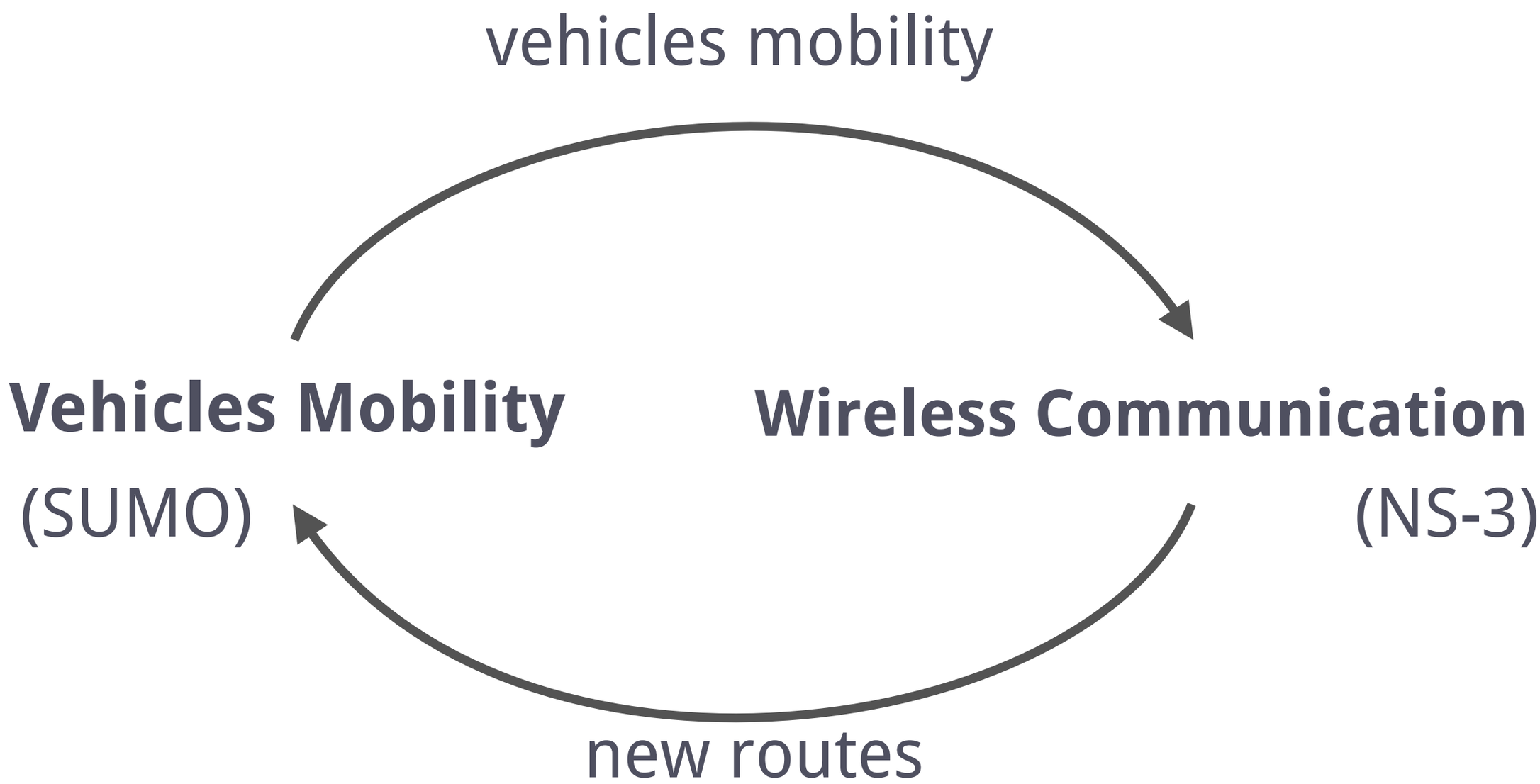
Vehicles Mobility

Wireless Communication

Realistic simulation of Vehicular Traffic Applications



Realistic simulation of Vehicular Traffic Applications

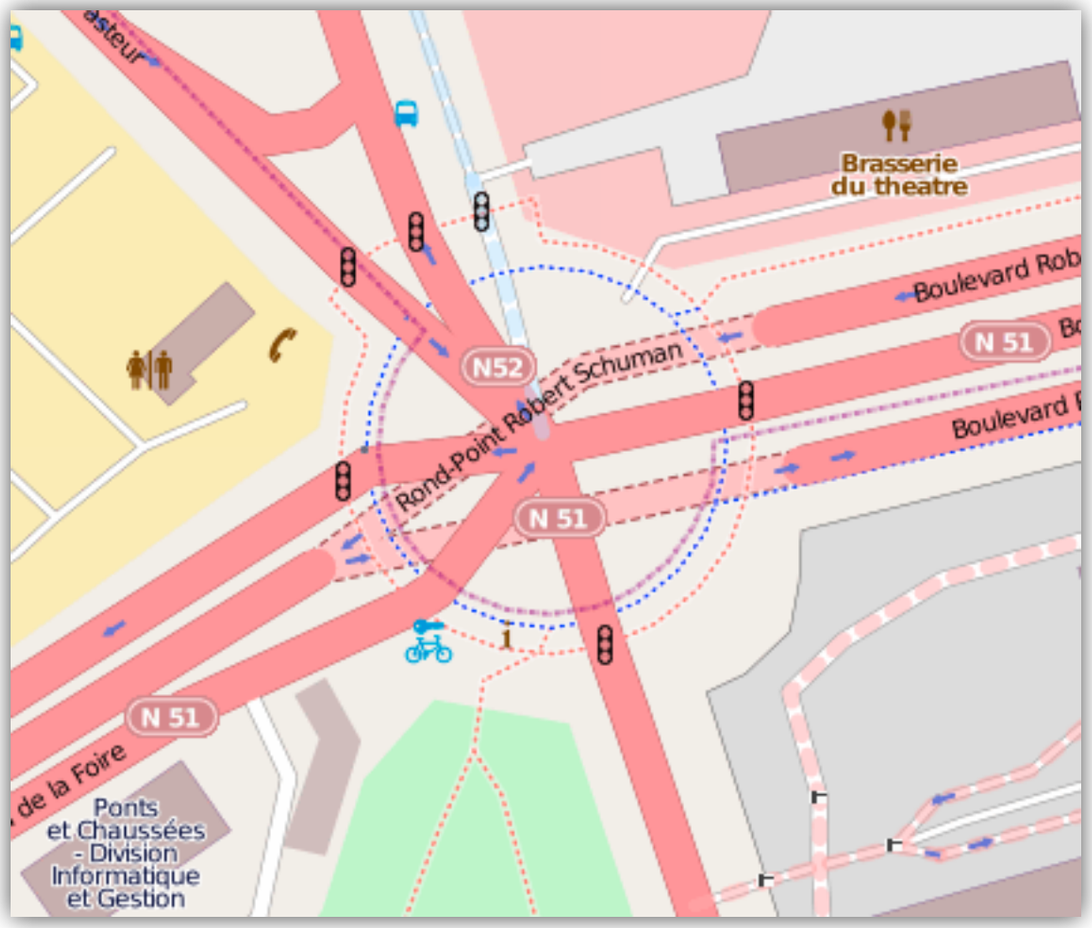


Realistic simulation of Vehicular Traffic Applications

1. Urban transportation planning (trip generation, trip distribution, mode choice, route assignment)
2. Microscopic traffic simulation (with realistic road network)
3. Wireless network simulation (with realistic physical layer and VANET capabilities)

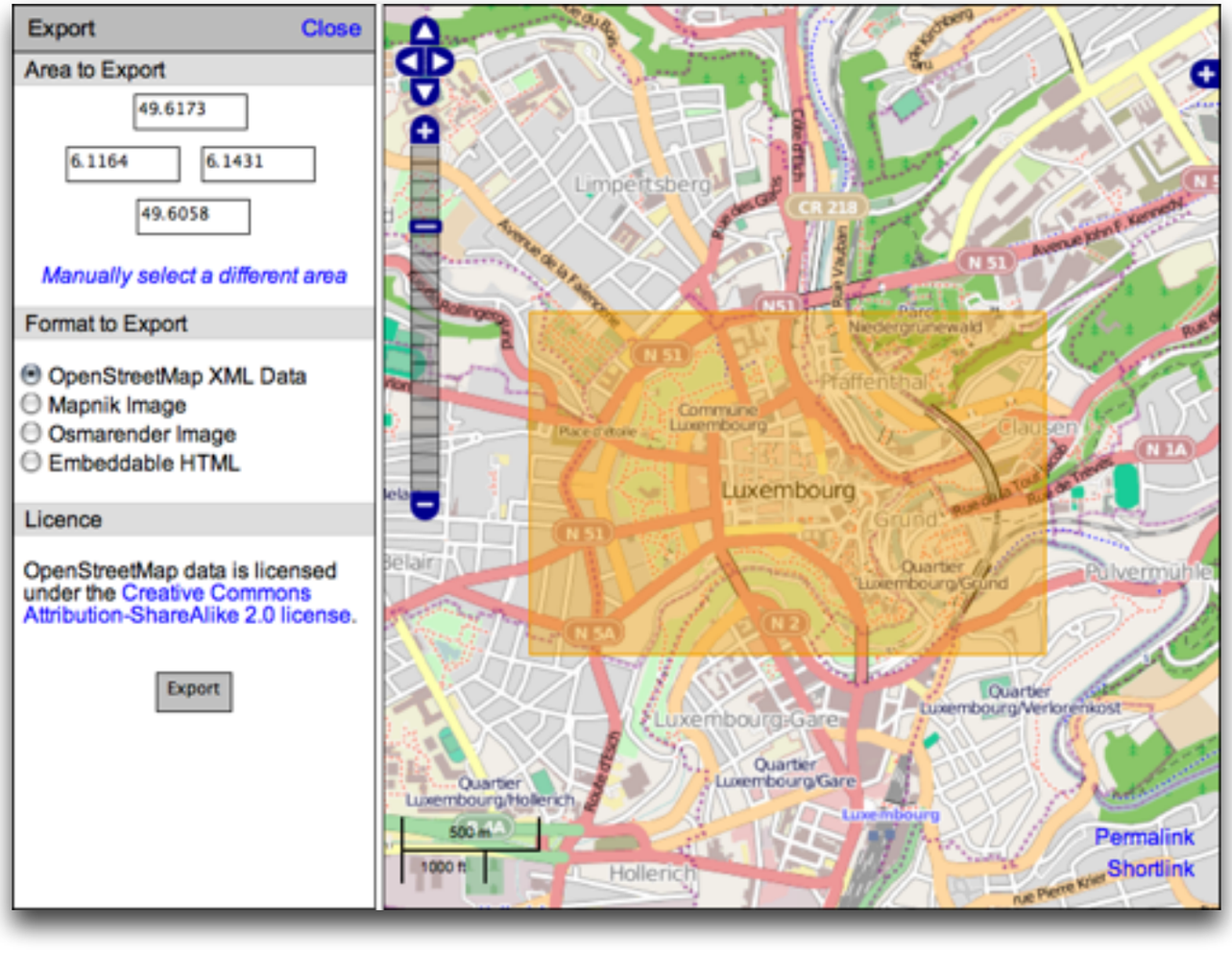
Road Networks with OpenStreetMap

- Road information
  - number of lanes
  - lane type
  - speed limit
  - directions
  - traffic lights (no logic)
- Other information
  - buildings (type, land-use)
  - other networks (train, pedestrian, bicycle)



Road Networks

- Export maps from OpenStreetMap's website
- Manipulate the data in numerical (XML) format



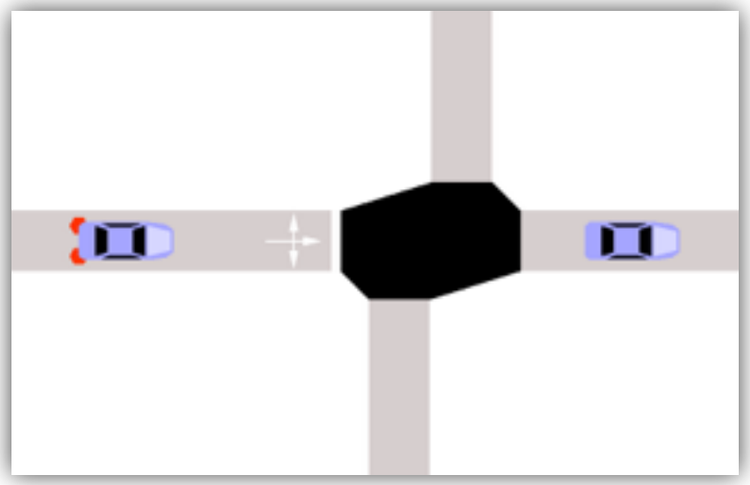
Road Networks

- Export maps from OpenStreetMap's website
- Manipulate the data in numerical (XML) format

```
<way id="50118067" user="Loll78" uid="225442" visible="true" ve
 <nd ref="621218494"/>
 <nd ref="621218497"/>
 <tag k="foot" v="no"/>
 <tag k="highway" v="primary"/>
 <tag k="lanes" v="2"/>
 <tag k="maxspeed" v="70"/>
 <tag k="name" v="avenue John F. Kennedy"/>
 <tag k="oneway" v="yes"/>
 <tag k="ref" v="N 51"/>
</way>
...
<node id="141657" lat="49.6146472" lon="6.1303950" user="Loll78
  <tag k="highway" v="traffic_signals"/>
</node>
...
 <tag k="amenity" v="school"/>
  <tag k="name" v="St. Georg International School Luxembourg"/>
...
```

Microscopic Simulation

- Discrete event-based models
  - Agent-based models
  - Monte Carlo methods
  - Cellular Automata
- Continuous models
  - Differential equations & numerical integrations
  - input / state / output
  - Car-following models
    - Intelligent Driver Model (IDM)
    - Gipps' Model

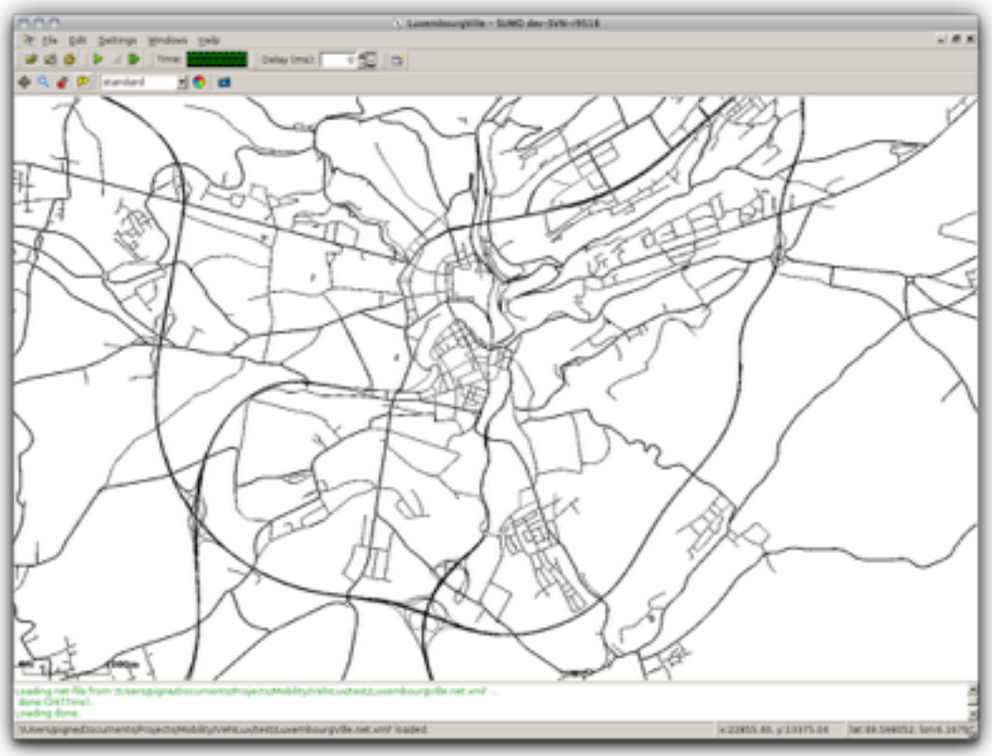


Microscopic Simulation Solutions

- MATSIM http://www.matsim.org/
- Corsim (http://mctrans.ce.ufl.edu/mct/)
- PARAMICS (http://www.sias.com/)
- TransModeler (http://www.caliper.com/)
- SimTraffic (http://www.trafficware.com/)
- …

Simulation of Urban MObility (SUMO)

- Microscopic road traffic simulation
- Handle large road networks
- Open source
- Portable
- Driven by another tool
- [new] Pedestrians with multimodal capabilities
  - road vehicle
  - trains
  - walk



Step-by-Step SUMO Demo

1. Get a map from OSM
   - from the web site (small areas)
   - from the command line if area too large (several downloads)
   - Want the whole world? About 39GB @ http://planet.osm.org/
2. Edit the Map for missing information
   - Several editing tools exist
   - JOSM (https://josm.openstreetmap.de/)

Step-by-Step SUMO Demo

3. Convert OSM map into SUMO map

- Sumo utility programs (netconvert)

```
netconvert [more options] —osm-files centerLuxembourg.osm --output-file
centerLuxembourg.net.xml
```

4. Use SUMO's map edge names to generate route assignment (from our transportation planning)

- Random demand for the demo

```
randomTrips.py -n centerLuxembourg.net.xml -b 0 -e 1000 -L -r random.rou.xml -o
random.trp.xml -p .1
```

Step-by-Step SUMO Demo

5. Gather information/statistics about the simulation

- Basically any information about vehicles junctions and lanes can be logged.
- Basic counting loop on a road (identify flows)

```
<inductionLoop id="pont_blue1" lane="273822773_1" pos="0" freq="900" file="out.xml"/>

<interval begin="0.00" end="900.00" id="pont_blue1" nVehContrib="152" flow="608.00" occupancy="6.52"
speed="13.01" length="5.00" nVehEntered="152"/>
```

- Counting on an area (identify queues)

```
<laneAreaDetector id="Apont_blue1" lane="273822773_1" length="200"  pos="0" freq="900" file=« out2.xml"/>

<interval begin="0.00" end="900.00" id="Apont_blue1" nSamples="2651" meanSpeed="8.55"
meanOccupancy="7.10" maxOccupancy="33.21" meanMaxJamLengthInVehicles="0.69"
meanMaxJamLengthInMeters="5.24" maxJamLengthInVehicles="10" maxJamLengthInMeters="76.39"
jamLengthInVehiclesSum="624" jamLengthInMetersSum="4720.96" meanHaltingDuration="13.54"
maxHaltingDuration="55.00" haltingDurationSum="596.00" meanIntervalHaltingDuration="13.54"
maxIntervalHaltingDuration="55.00" intervalHaltingDurationSum="596.00" startedHalts="52.00"
meanVehicleNumber="2.95" maxVehicleNumber="14" />
```

Simulation of Wireless Communication

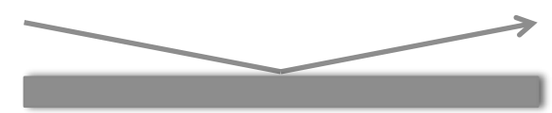
Wireless Communication

- Different simulation approaches
  - Analytical, Based on measurement, Statistical
- Different time scales
  - Bit or Packet level
- Physical models
  - At sending: Carrier Sensing Models
  - At transporting: Propagation Models
  - At receiving: Packet Reception Models

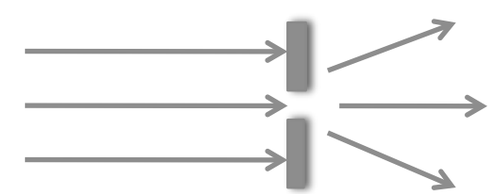
Wireless Communication: signal modeling

- Signal Attenuation

- Reflection



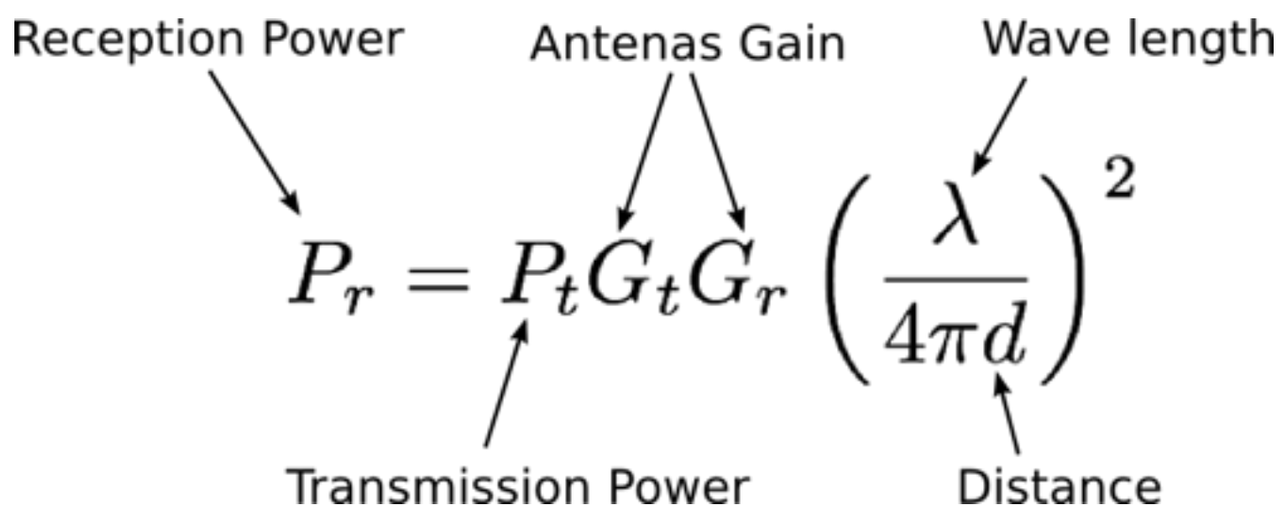
- Diffraction



- Scattering

Wireless Communication: signal modeling

- Modeling The signal
  - Free Space Propagation Model



  - Other long range signal models (Two-Ray Ground Model)

Wireless Communication: signal modeling

- Stochastic approaches for WiFi
  - Attenuation based on measurements and random variables
  - Log-Distance Path-Loss Model

Path Loss

Distance

Random variable

$$PL = P_t - P_r = PL_0 + 10\gamma log_{10}\frac{d}{d_0} + X$$

Reference PL

Path loss exponent

Reference distance

S. Kun, W. Ping, and L. Yingze, “Path loss models for suburban scenario at 2.3GHz, 2.6GHz and 3.5GHz,” in 8th International Symposium on Antennas, Propagation and EM Theory, 2008. ISAPE 2008, 2008, pp. 438–441.

Wireless Communication: signal modeling

- What about VANET?
  - Good Line of Sight signal on straight lines
  - On urban environments, signal on perpendicular roads gets obstructed buy buildings
  - Few field measurements yet

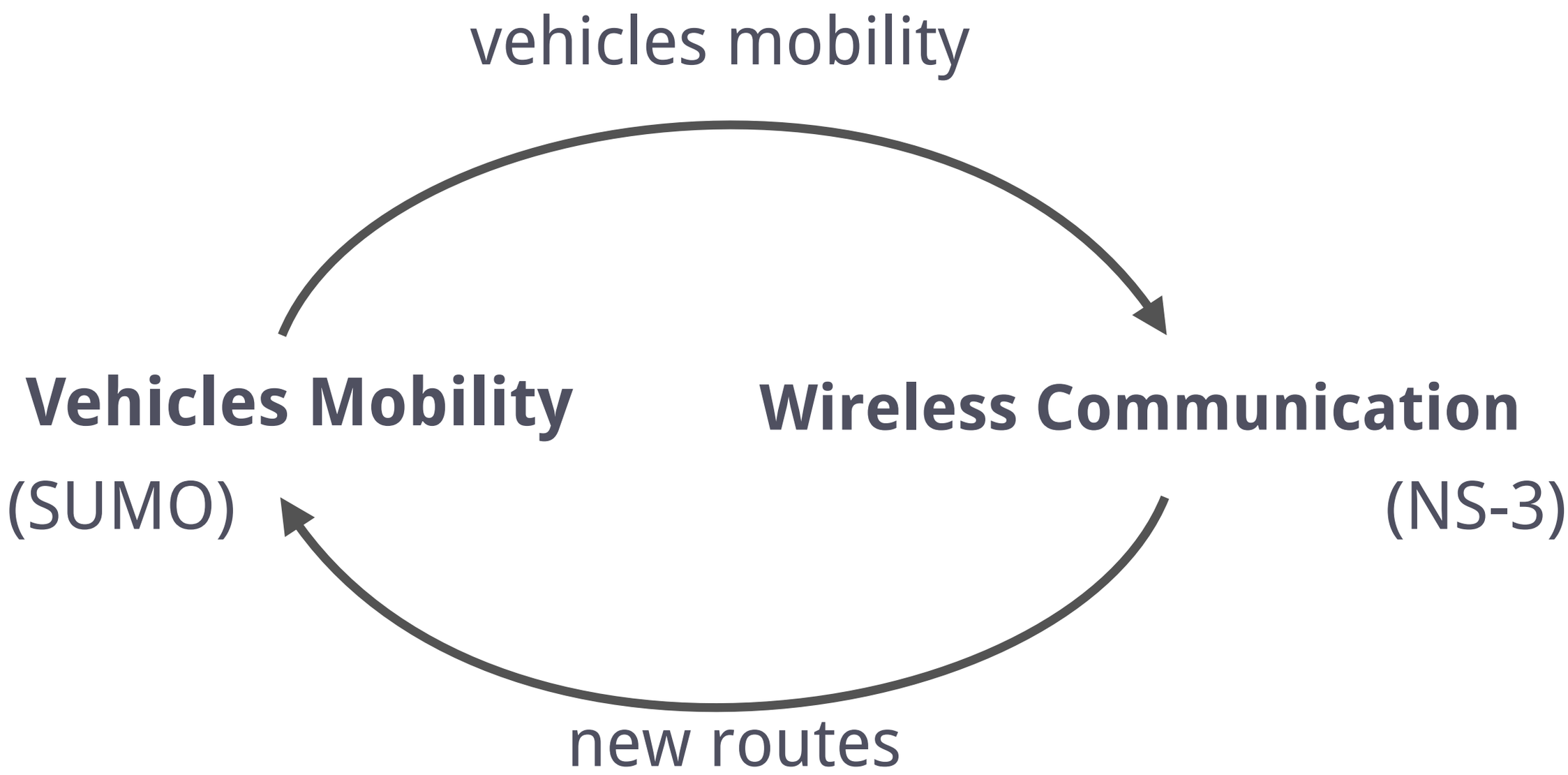
C. Sommer, D. Eckhoff, R. German, and F. Dressler, “A computationally inexpensive empirical model of IEEE 802.11 p radio shadowing in urban environments,” in Wireless On-Demand Network Systems and Services (WONS), 2011 Eighth International Conference on, 2011, pp. 84–90.

E. Giordano, R. Frank, G. Pau, and M. Gerla, “CORNER: A Step Towards Realistic Simulations for VANET,” in Proceedings of the Seventh ACM International Workshop on VehiculAr InterNETworking, New York, NY, USA, 2010, pp. 41–50.

Wireless Communication: What tools?

- Need for a simulation tool that has:
  - Accurate Modeling of the physical layer
  - State of the art communication protocols
  - Possibility to interact with other tools (for the mobility)
- OMNeT++ (http://www.omnetpp.org/)
  - VANET/LTE extension (http://veins.car2x.org/)
  - non-commercial and commercial (Omnest) editions
- ns-3 (successor of ns-2 but not compatible)
  - Strong community
  - Open Source

Online Simulation



Improvement for VANET purposes

- Online addition/deletion of nodes in the network
- Sub-division of the simulation space

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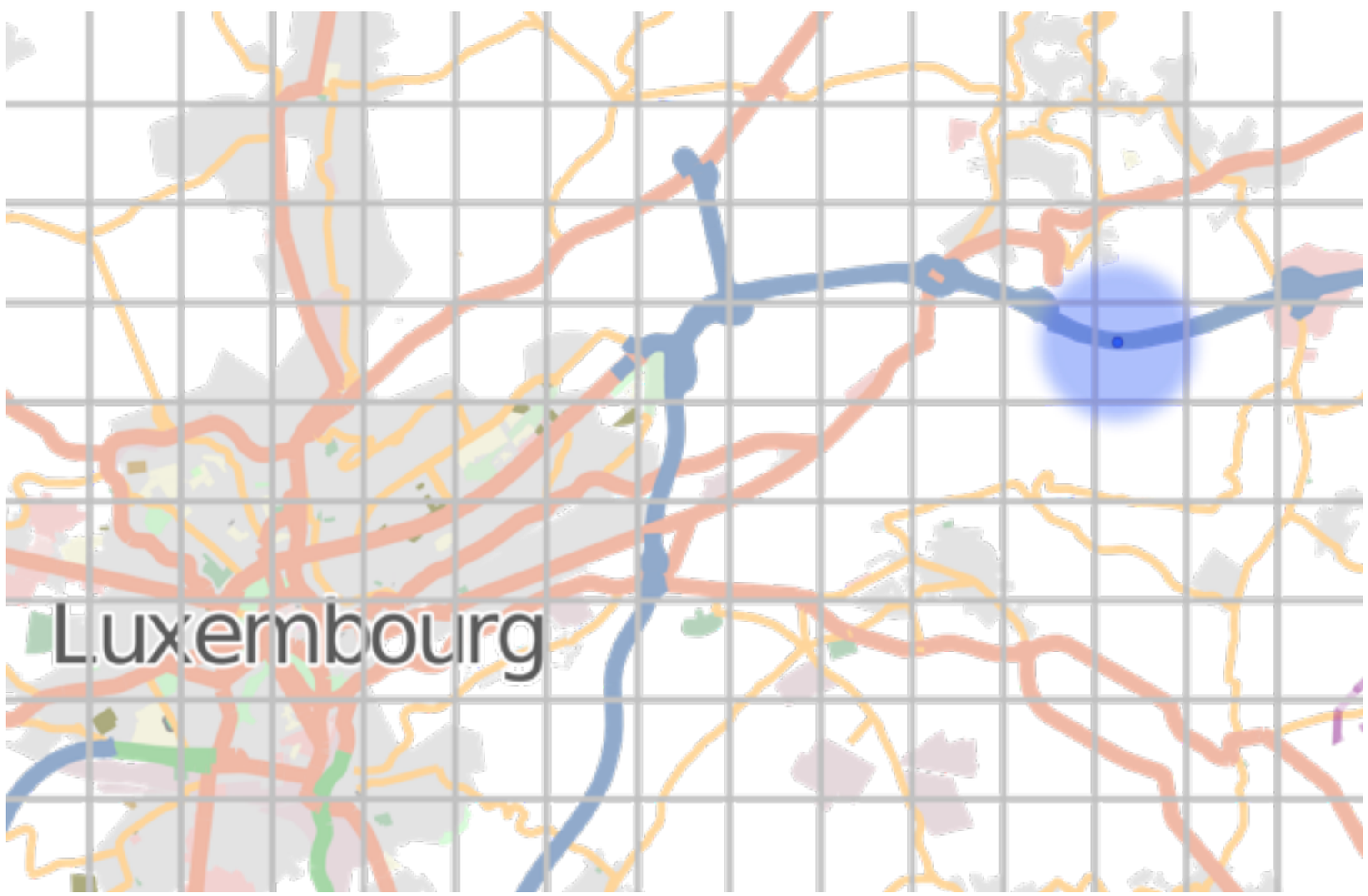

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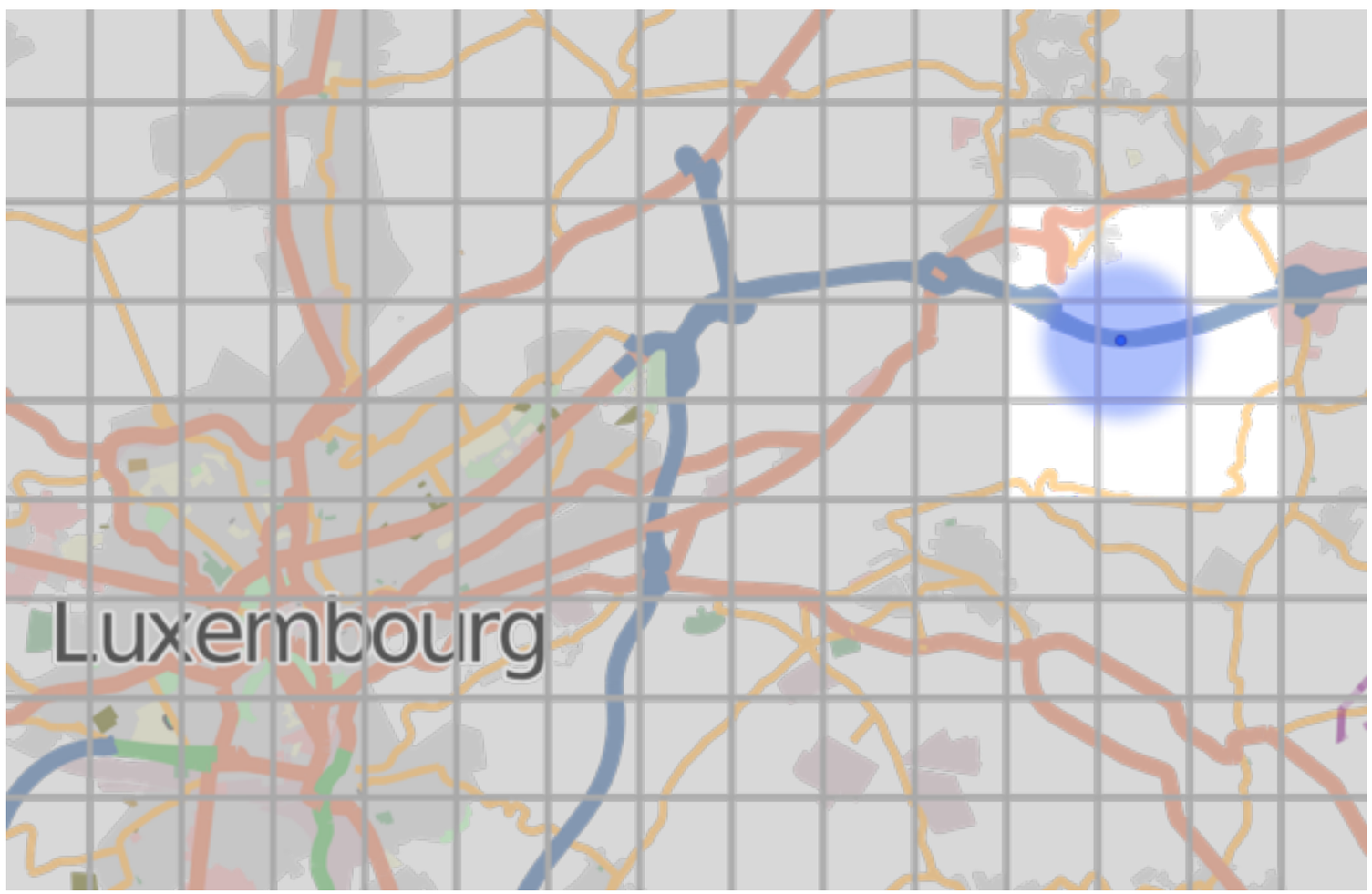

Conclusion

- Realistic simulations tools exist in order to evaluate researchers' urban transportation plannings.
- Near future communication modes are available today in the simulators.
- But will those new communication mode really be useful?
- Will people accept them?
- We can test various scenarios (penetration rate).
- Various modeling tools (stochastic, agent-based, game theory).
- Our purposes for the VESUVE Project (LISER, IFSTAR, LITIS).