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OMNeT++ Community Summit 2017

LIMoSim: A Lightweight and Integrated Approach for Simulating Vehicular Mobility with OMNeT++

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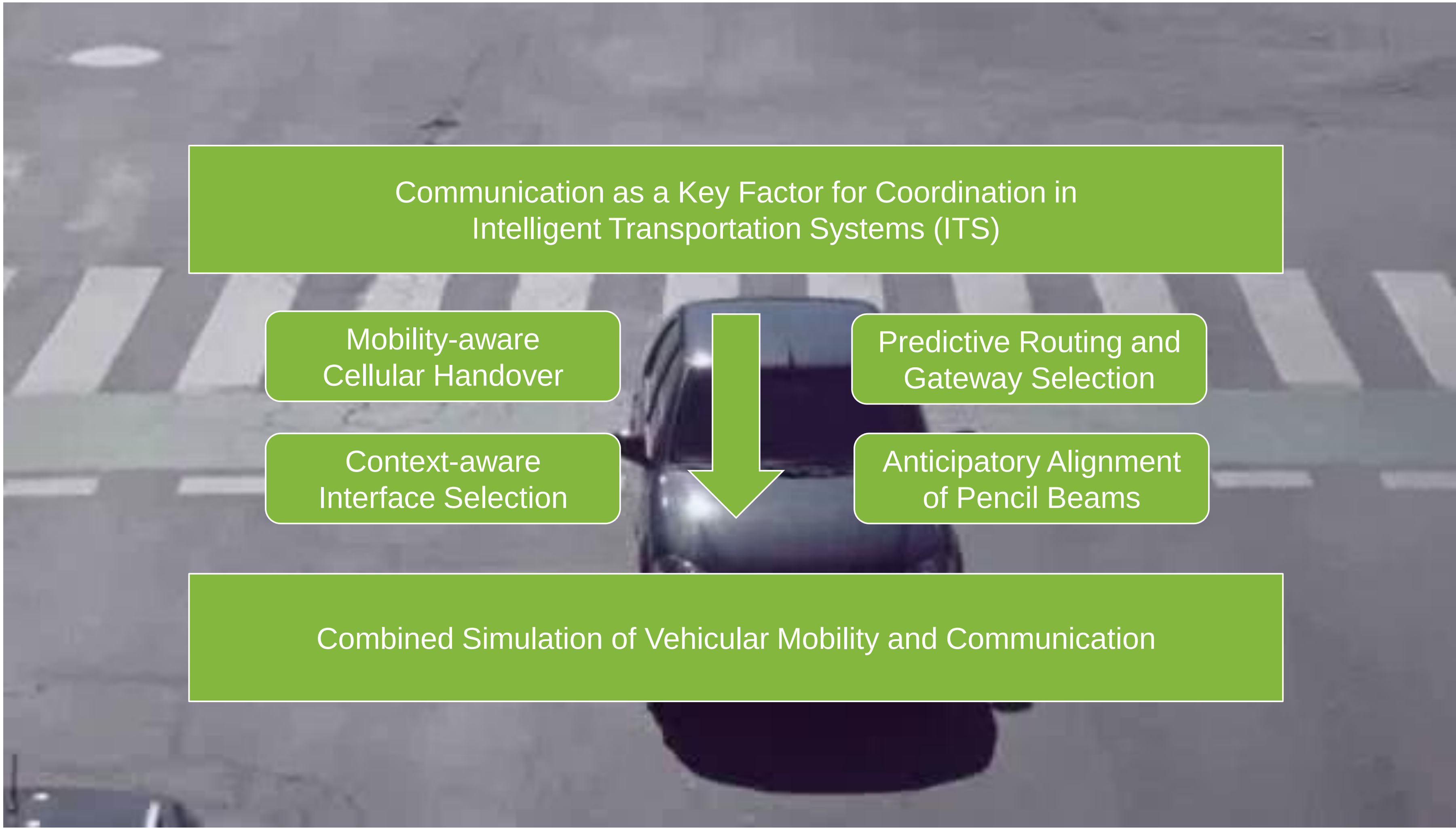
Outline

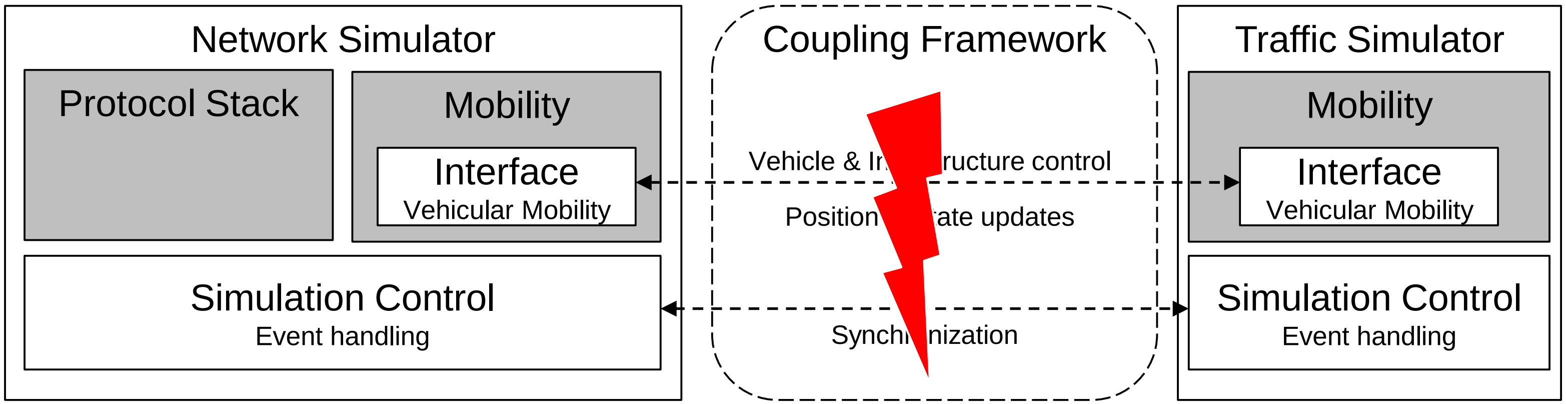
- Motivation: Convergence of Vehicular Mobility and Communication
- State-of-the-art: Coupling based on Interprocess Communication
- Proposal: Lightweight ICT-centric Mobility Simulation (LIMoSim)
- Integration of LIMoSim into OMNeT++
- Proof-of-concept Evaluation in an LTE Context
- Conclusion and Future Work

Convergence of Vehicular Mobility and Communication



Source: Yunfei Hou, Autonomous Intersection in Action, https://youtu.be/4SmJP8TdWTU

Coupling based on Interprocess Communication



- Coupling as a side feature of a framework for a specific communication technology (e.g. IEEE 802.11p)
  - Violation of the modular paradigm
  - Portability effort: LTE, MANET, IEEE 802.15.4
- Limited interaction possibilities – bound to protocol specification
- Complex setup – simultaneous execution of multiple processes
- Risk of compatibility drifts

Demand for IPC-free alternatives for mobility simulation with network simulators

Simulation of Vehicular Traffic with SUMO

High Level of Complexity

- Rather a package of different tools than a standalone simulator
- Map data import: *"Congratulations! When you performed **all the steps** so far, you have a map suitable for traffic simulation with SUMO"*
  (Source: http://sumo.dlr.de/wiki/Tutorials/Import_from_OpenStreetMap)
- Wide range of different mobility models
- External control through TCP-based TraCI

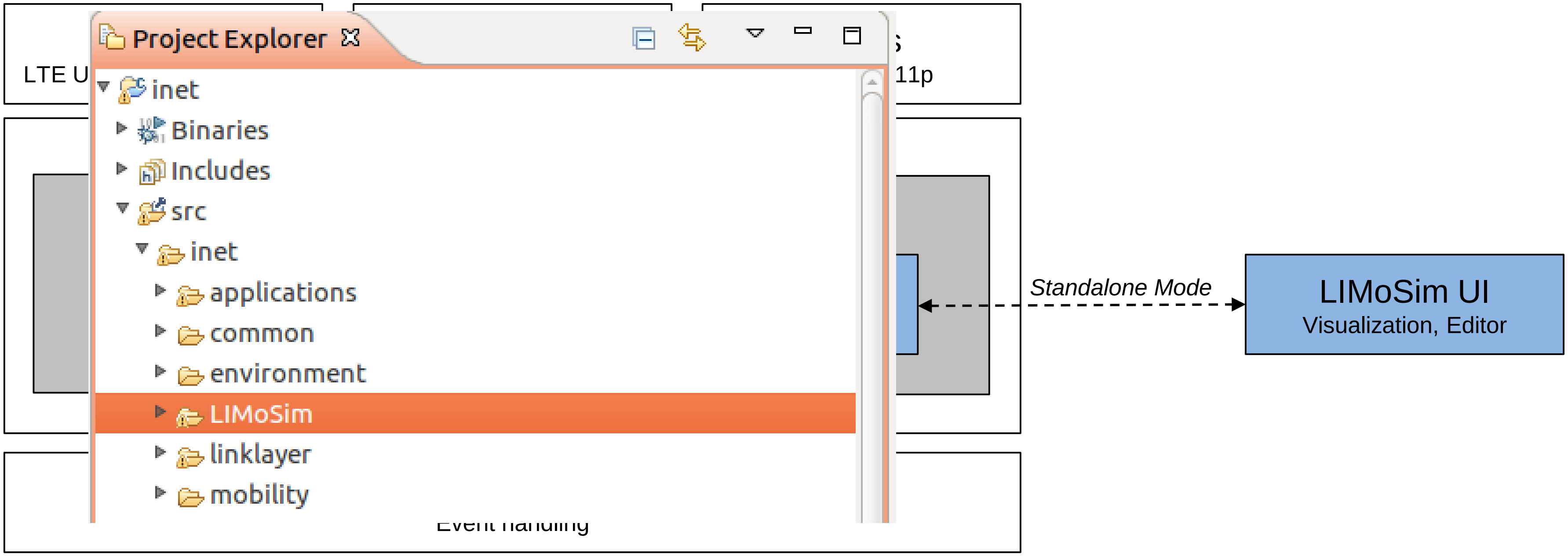
Static Approach

- Routes are usually precomputed using external tools
- Dynamic routing is possible with TraCI, but complicated

Demand for lightweight alternatives to SUMO with focus on communication

TraCI – Traffic Control Interface

Lightweight ICT-centric Mobility Simulation – LIMoSim



Focus: Seamless Integration

- Interaction-level: **Shared codebase**

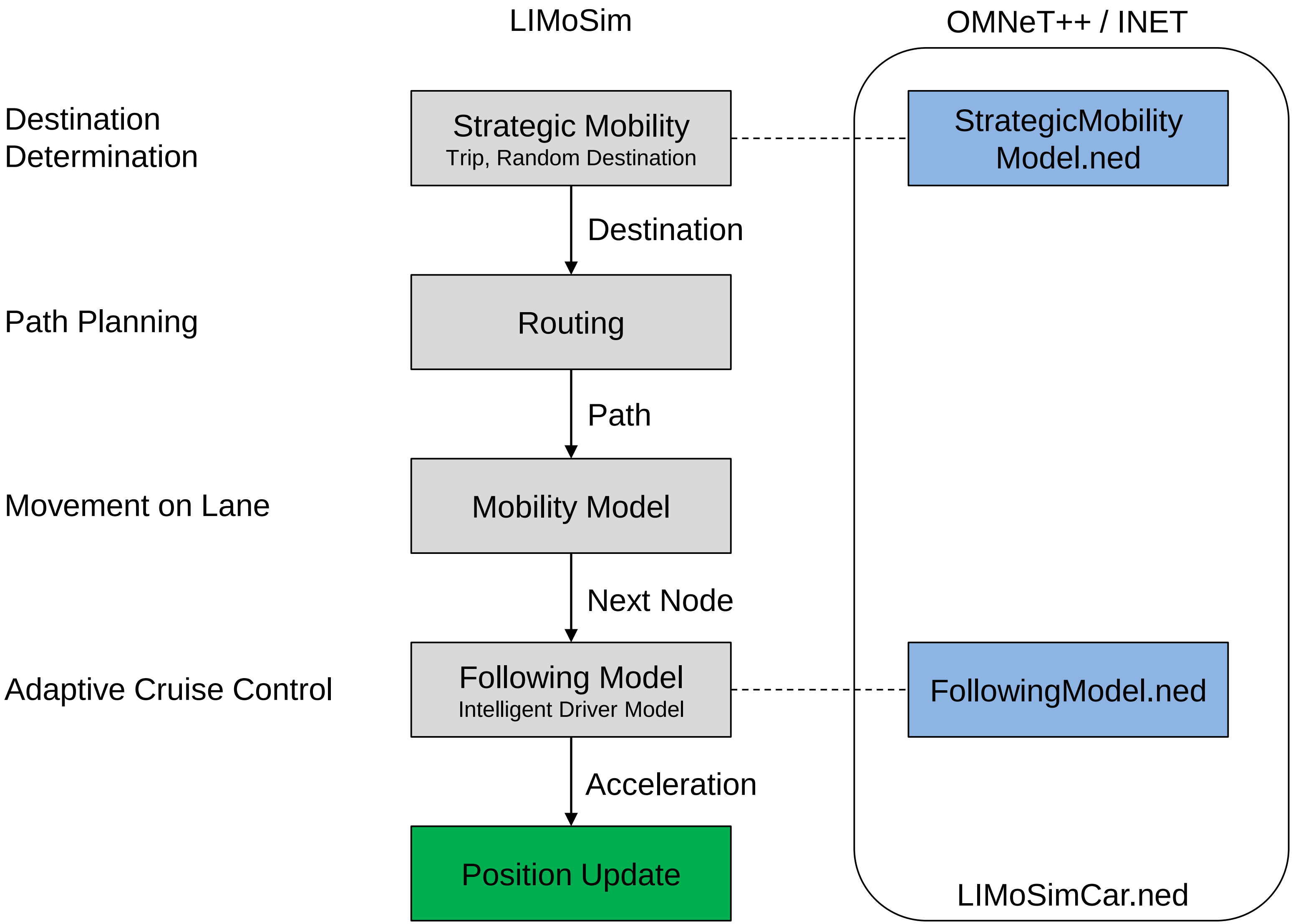
→ Exploiting synergies

- Independence from the communication technology

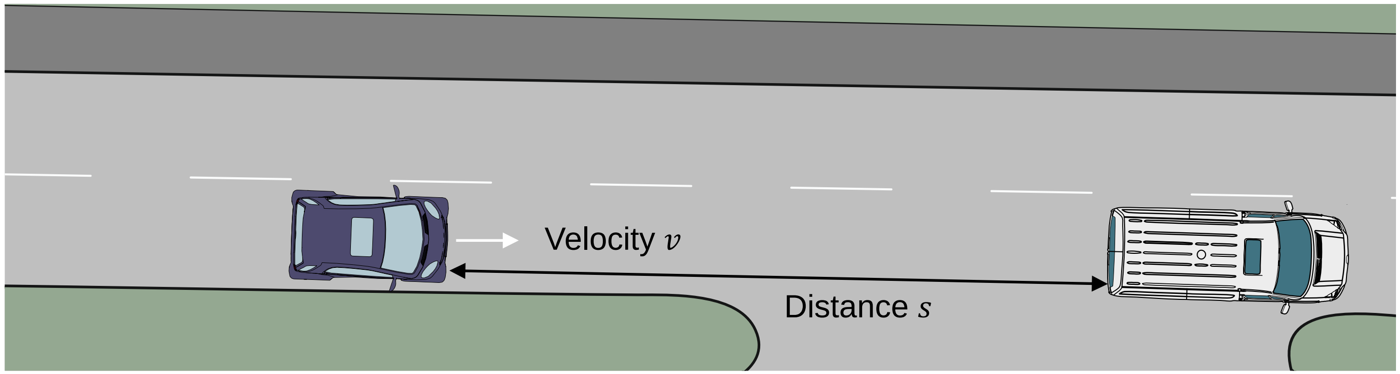
Focus: Lightweight Approach

- Relies on selected well-known mobility models
- Native support for OSM map data
- Dynamic decision processes

Hierarchical Mobility Model



Car Following Behavior with the Intelligent Driver Model



$$\dot{v} = a \left[\underbrace{1 - \left(\frac{v}{v_0} \right)^{\delta}}_{\text{Free Flow}} - \underbrace{\left(\frac{s^*(v, \Delta v)}{s} \right)^{2}}_{\text{Following Behavior}} \right]$$

$$\underbrace{s^*(v, \Delta v)}_{\text{Desired Distance}} = s_0 + max \left(0, vT + \underbrace{\frac{v \Delta v}{2\sqrt{ab}}}_{\text{Intelligent Braking Strategy}} \right)$$

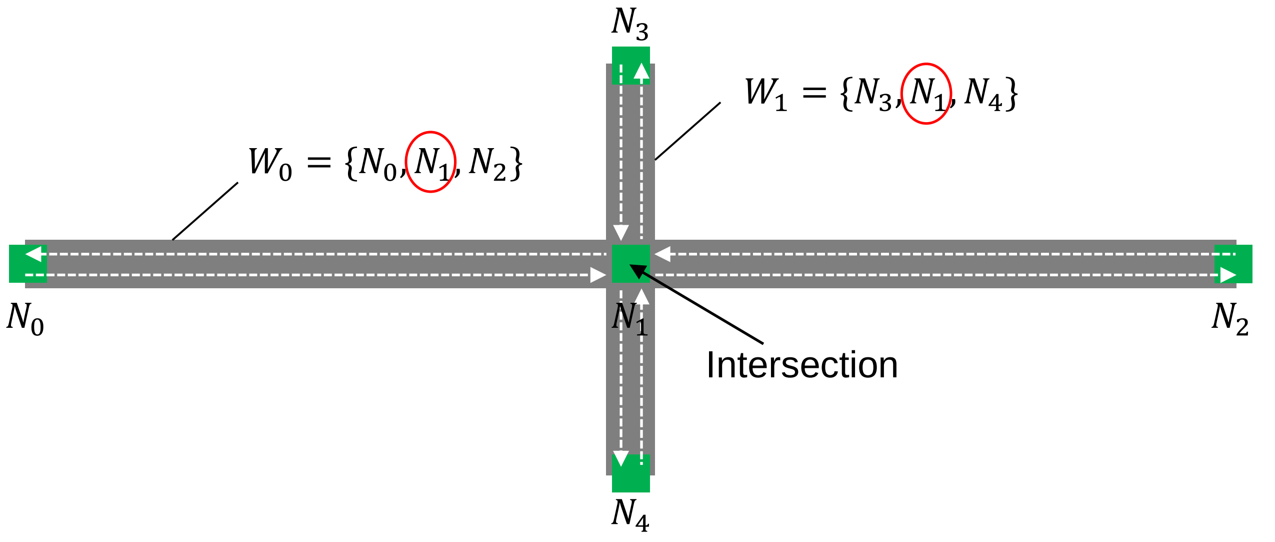
Safety Distance (s_0 and vT)

v_0	Desired speed	a	Maximum acceleration
T	Time gap	b	Comfortable deceleration
s_0	Minimum distance	δ	Acceleration exponent

- **Goal**: determine the acceleration with respect to other traffic participants
- LIMoSim: Traffic Signals are treated as “static vehicles” if the state is yellow or red

Treiber, M. & Kesting, A., **Traffic Flow Dynamics: Data, Models and Simulation**, *Springer-Verlag Berlin Heidelberg,* 2013

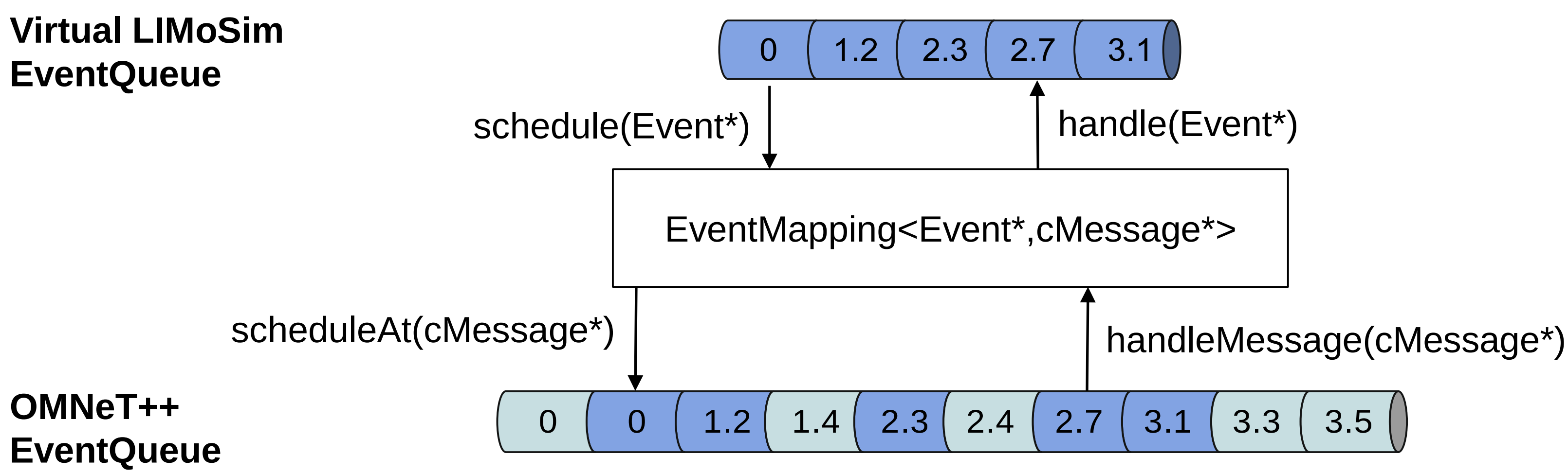
Representation of Map Data with the OpenSteetMap Data Model



- *Nodes* as basic entities with identifier and location information
- *Ways* describe street segments with the same properties
- *Lanes* provide alignment references for vehicles
- Automatic detection of intersection nodes

Integration of LIMoSim Events into OMNeT++

- LIMoSim objects are not aware of their OMNeT++ Environment
  → Cannot be derived from *cModule / cSimpleModule*
  → How to integrate event-based behavior?



Transparent embedding of events without requiring actual OMNeT++ modules

Setup of a Vehicular LTE Scenario with LIMoSim and SimuLTE

```xml
<node id="677230875" x="272.392" y="368.178"/>
<node id="275672221" x="1141.36" y="499.156"/>
<node id="3569208993" x="1060.36" y="897.189"/>
<node id="477807" x="254.202" y="767.967"/>
<way id="337055293">
    <nd ref="677231620"/>
    <nd ref="677231627"/>
    <nd ref="627846556"/>
    <nd ref="677231621"/>
    <nd ref="52919181"/>
    <nd ref="477807"/>
    <nd ref="3441521491"/>
    <tag k="lanes" v="2"/>
</way>
```

map.osm.limo

```ini
*.ue.mobilityType = "LIMoSimCar"
*.ue.mobility.map = "map.osm"
*.ue.mobility.strategicModel = "Trip"
*.ue.mobility.strategicModel.trip = "677230875,
275672221,3569208993,477807"
*.ue.mobility.way = "337055293"
*.ue.mobility.segment = 4
*.ue.mobility.lane = 0
*.ue.mobility.offset = 1m

# interference traffic
*.car[].mobilityType = "LIMoSimCar"
*.car[].mobility.map = "map.osm"
*.car[].mobility.strategicModel = "RandomDestination"
```

Random position if undefined

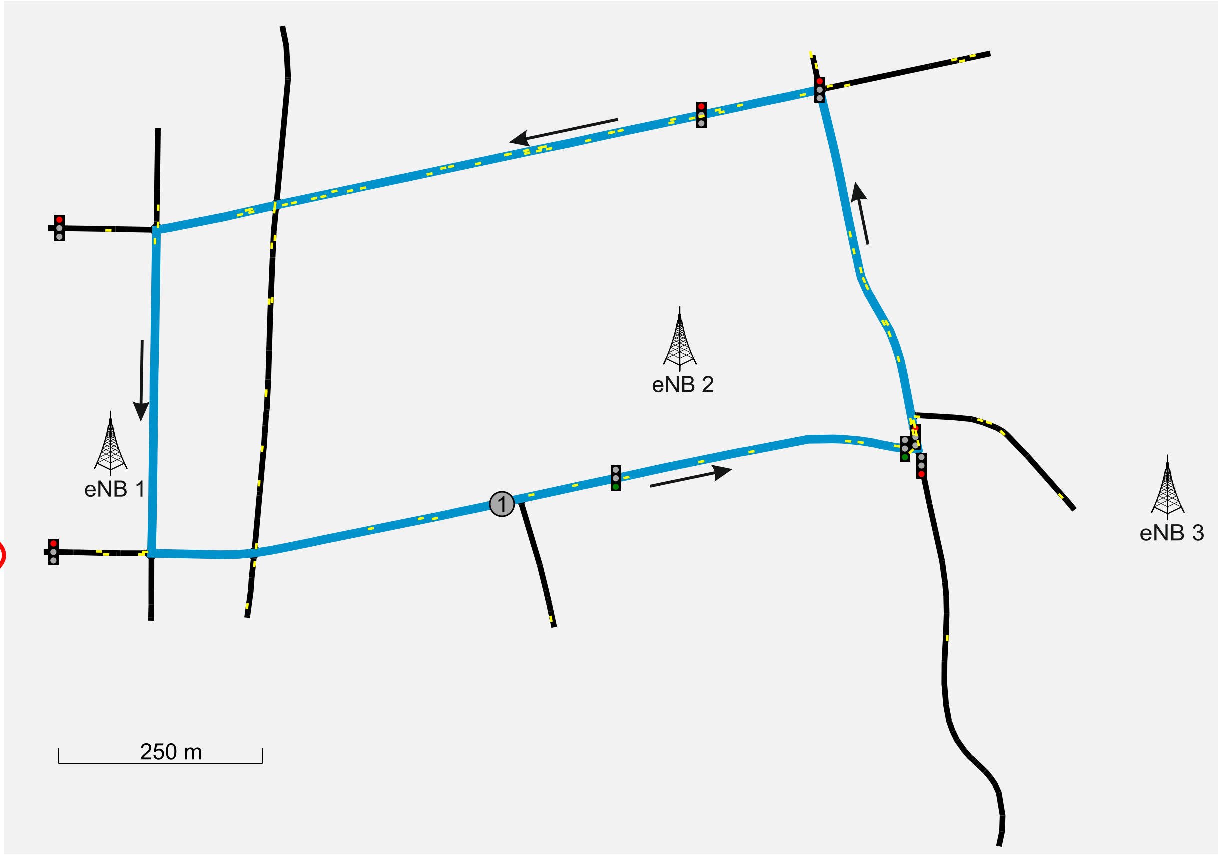
omnetpp.ini

- Optimized map file *.limo is generated automatically
- Node IDs can be obtained from the LIMoSim UI
- Optional configuration via XML

XML – Signal-to-noise ratio

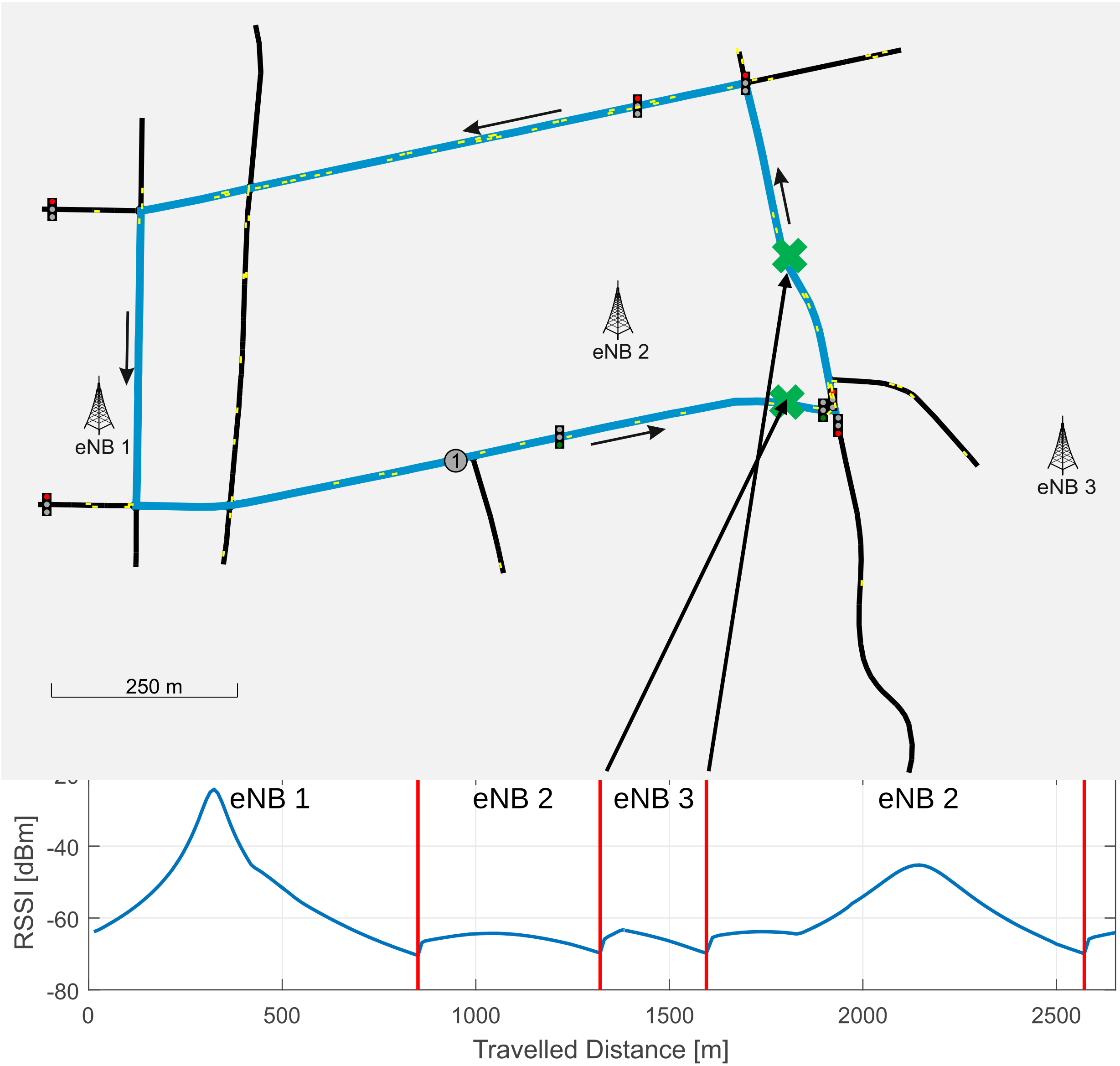
Reference Scenario: University Campus of the TU Dortmund

Simulation Parameter	Value
Strategic mobility model (UE)	Trip
Strategic mobility model (interference traffic)	Random Direction
Number of interference cars	100
Following model	IDM
Speed factor (driver behavior)	1±[0…0.2]
Carrier frequency	1800 [MHz]
eNode B transmission power	46 [dBm]
eNode B antenna	Omnidirectional



- Sensing of the LTE signal strength using an LTE-enabled car

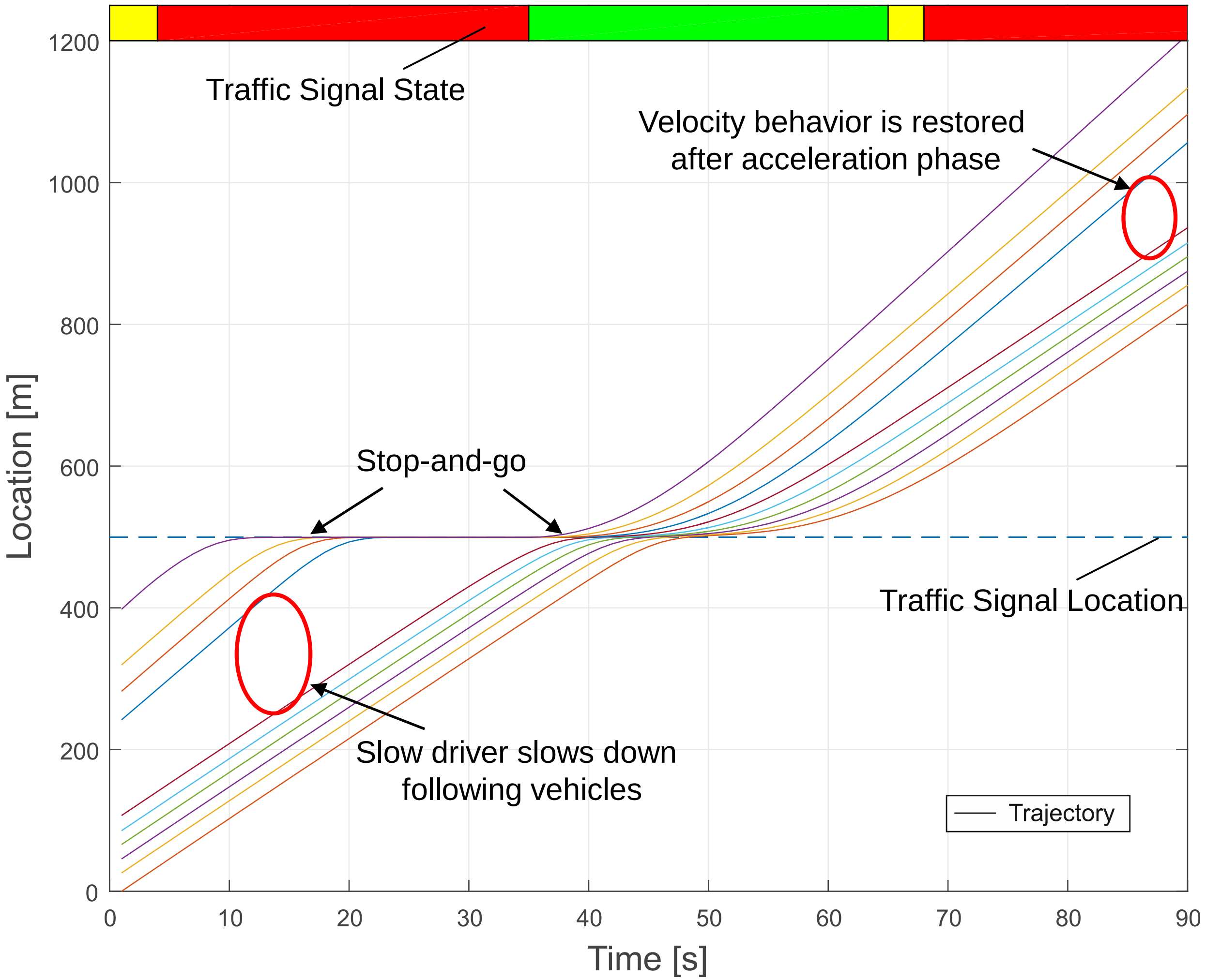
Behavior



- Inner city characteristics for velocity and acceleration
  - → Interference Traffic
  - → Traffic Signals
- Mobility behavior causes varying LTE signal strength and triggers handovers
- Motivation for developing mobility-aware handover schemes

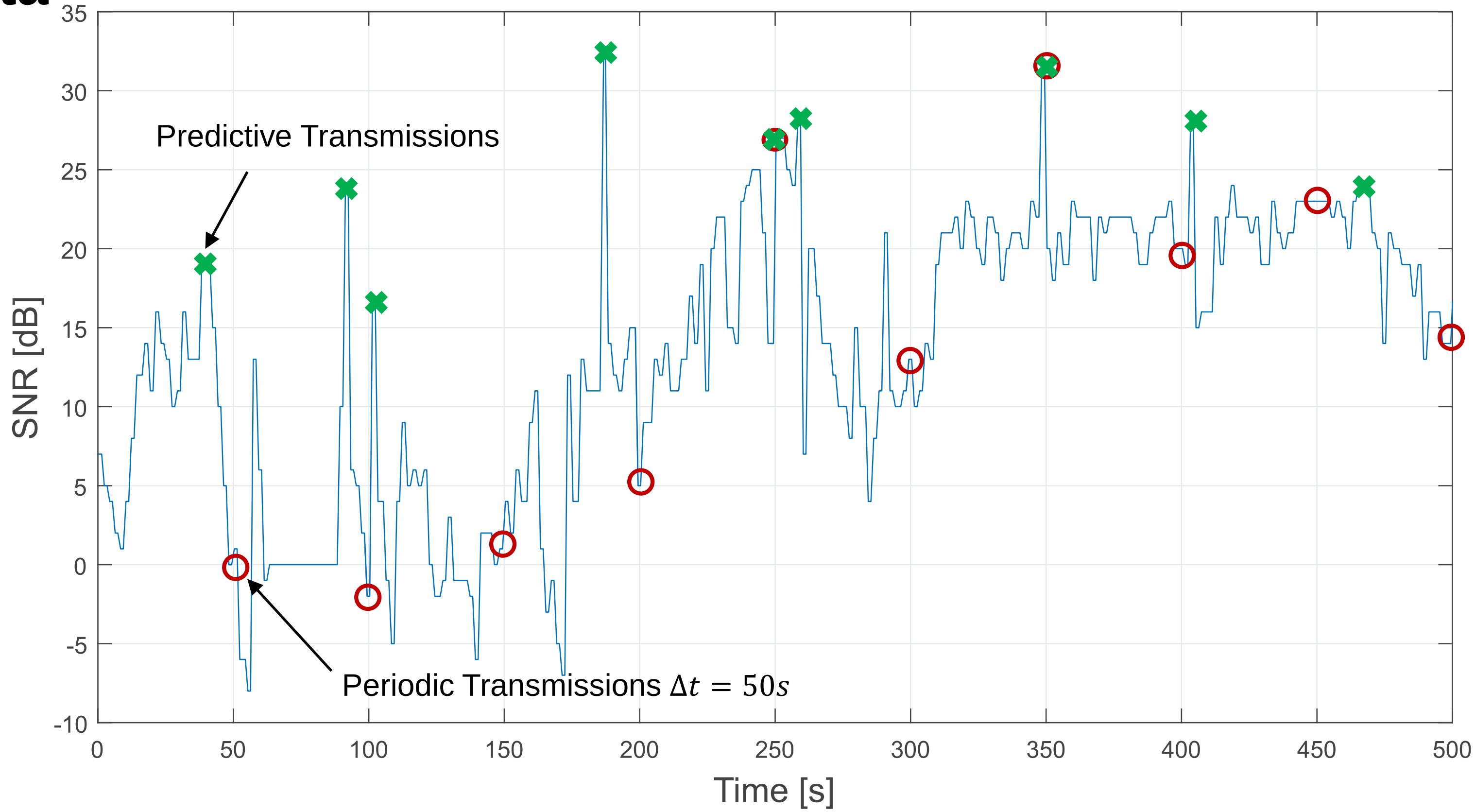
eNB – Evolved Node B

Inner City Traffic Dynamics with the Intelligent Driver Model



- Impact of different driver types on the following vehicles
- IDM is suitable for modelling intersection approaching

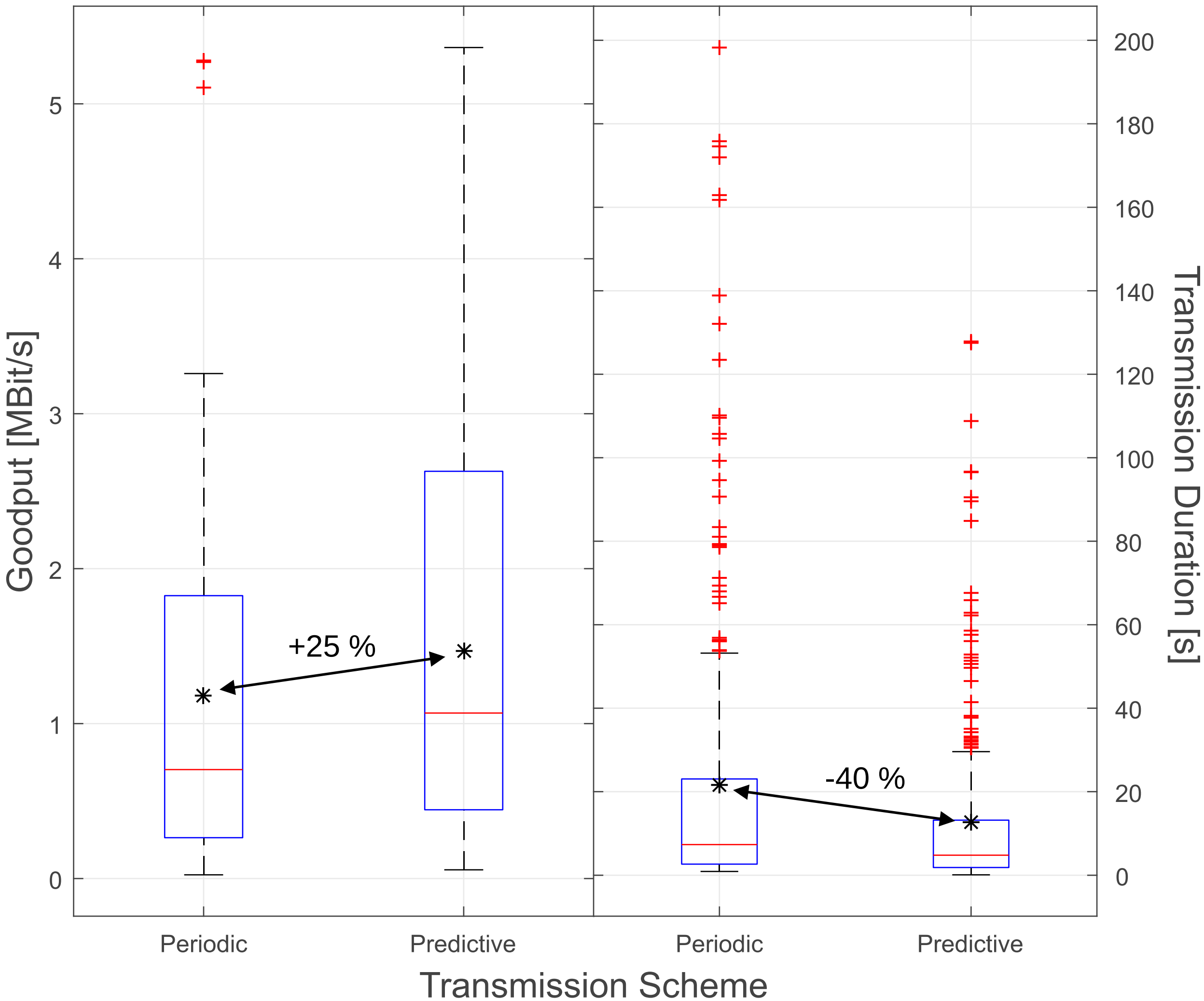
Example Application: Mobility-aware Transmission of Sensor Data



- **Idea:** Leverage connectivity hotspots and avoid resource intensive transmissions
- Early / Delayed transmission depending on the predicted channel quality
- Crowdsensing-based connectivity map

SNR – Signal-to-noise ratio

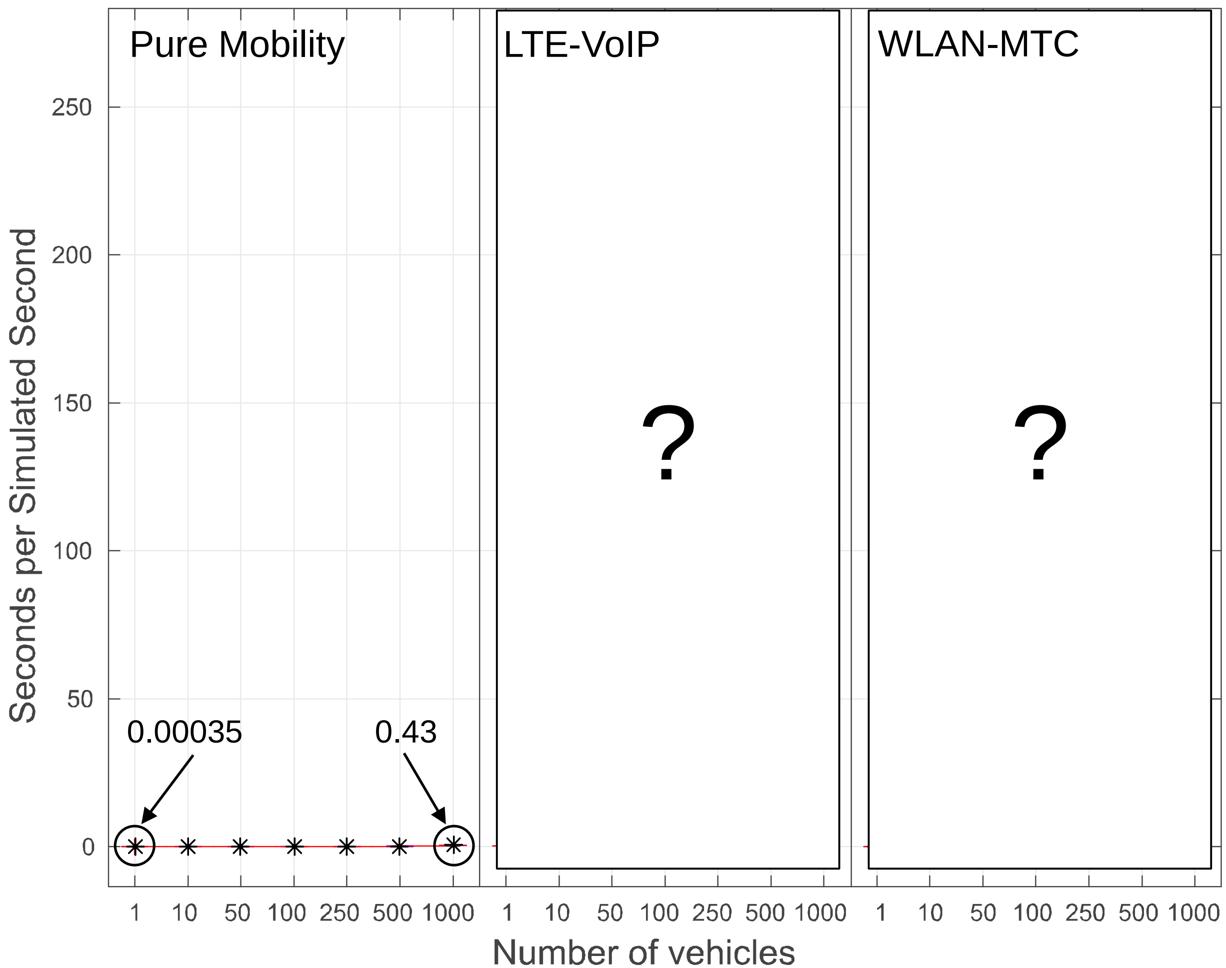
Example Application: Mobility-aware Transmission of Sensor Data



- Increased mean goodput
- Significant reduction of the mean transmission duration

→ Reduced interference with other cell users

Impact of the Mobility Simulation on the Overall Performance



- Simulating the communication has the main impact on the simulation duration
- Mobility has negligible impact on the overall simulation time in ITS scenarios

→ Precomputed routes do not reduce the simulation time

VoIP – Voice over IP
MTC – Machine-Type-Communication

Conclusion and Future Work

Lighweight ICT-centric Mobility Simulation - LIMoSim

- Seamless integration into OMNeT++ / INET
  - → Interaction level between mobility and communication: shared codebase
  - → Easy integration with INET-based extension frameworks
- Dynamic decision processes for modern ITS-applications

Extensions for the Simulator

- Transition from QML to OpenGL
- LIMoSim as an alternative to SUMO for Veins and Artery
- Flow-based traffic models
- Integration of buildings → Generation of INET obstacles

Applications

- Behavior-based strategic models (e.g. SWIM)
- Mobile robotic networks in wireless warehouses

LIMoSim

QML – Qt Meta-object Language
SWIM – Small Worlds In Motion

Thank you for your attention!

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