



# Evaluating Car-to-X Communication in Heterogeneous Environments with Veins

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# Outline

- Introduction
- Veins Simulation Framework
- Operation
- Metrics
- Outlook

# Who we are

## University of Erlangen

- School of Engineering
  - Dept. of Computer Science
    - Computer Networks and Communication Systems
    - Autonomic Networking Group

## Group members

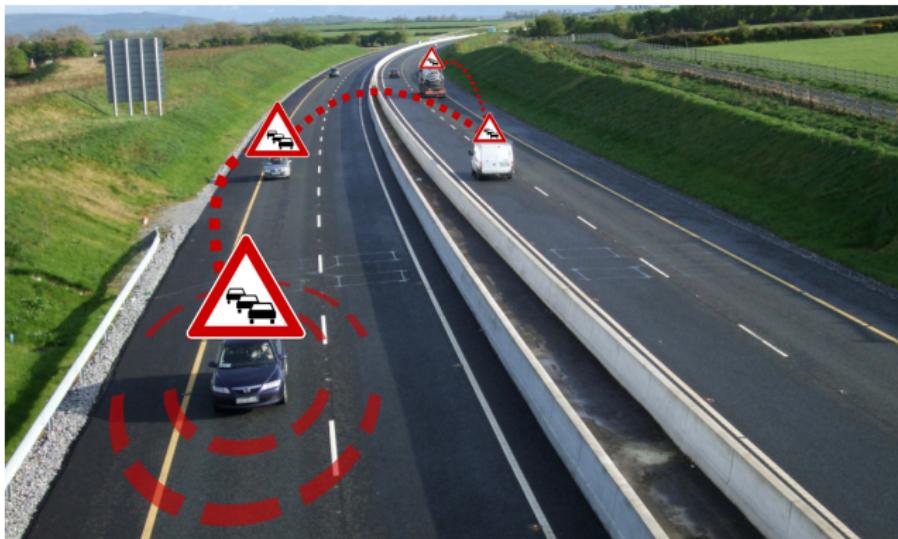
- Falko Dressler (coordination)
- Abdalkarim Awad
- Feng Chen
- Isabel Dietrich
- David Eckhoff
- Jürgen Eckert
- Tobias Limmer
- Noorsalwati Nordin
- Christoph Sommer



# Car-to-X

## Focus

- ▶ Traffic Information Systems (TISs)  
based on Car-to-X communication



# Heterogeneity

## Heterogeneous Environments

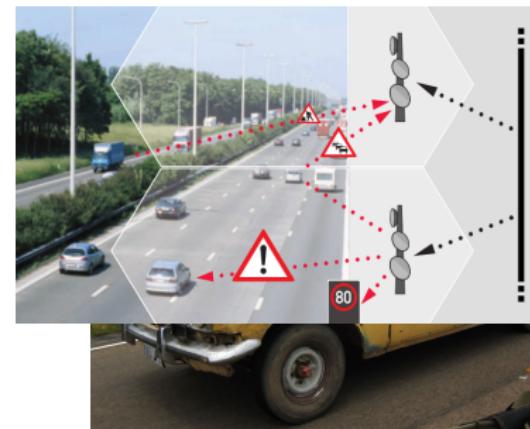


Images: AUDI AG

# Heterogeneity

## Heterogeneous Environments

- ▶ Ad Hoc vs. Infrastructure support



# Heterogeneity

## Heterogeneous Environments

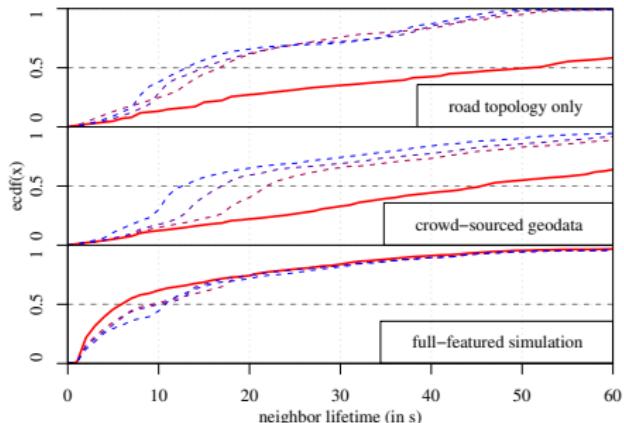
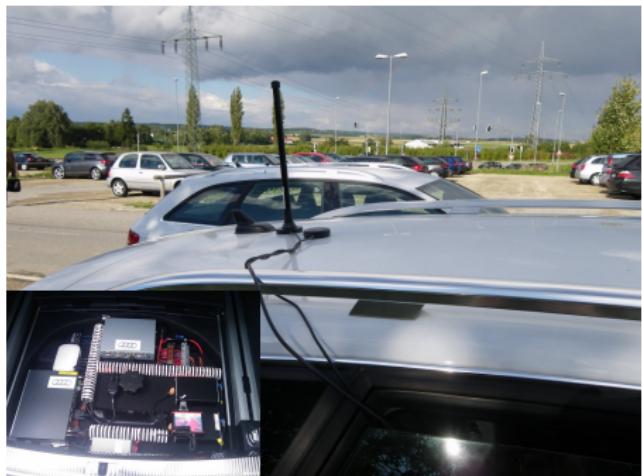
- ▶ Ad Hoc vs. Infrastructure support
- ▶ Freeway vs. Urban deployment



# Impact of Network Traffic Simulation

## Effects to be considered

- ▶ segmentation and reassembly, channel contention
- ▶ packet collision, signal interference and shadowing
- ▶ profound impact on network performance

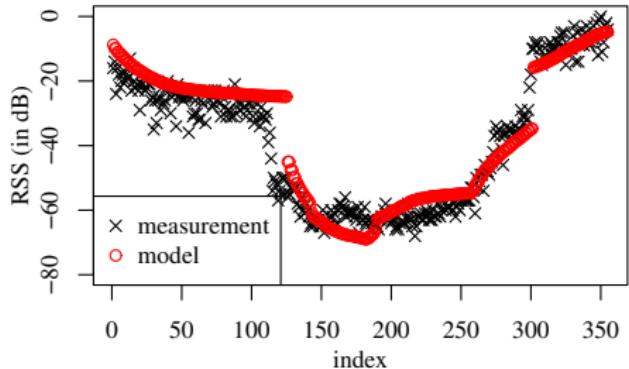
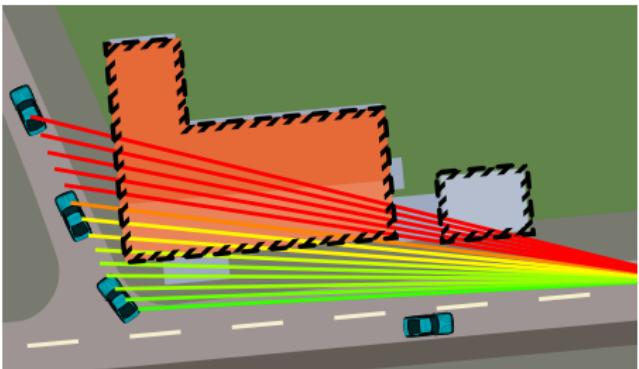


# ex. Channel Modeling

## Modeling IEEE 802.11p radio shadowing in cities

$$Pr[dBm] = P_t[dBm] + 10 \lg \left( \frac{G_t G_r \lambda^2}{16\pi^2 d^\alpha} \right) - \beta n - \gamma d_m$$

$$\beta \approx 9 \text{ dB}, \gamma \approx 0.4 \text{ dB/m}$$



# OMNeT++ Kernel

## Network traffic simulation

- ▶ open source C++ kernel with Eclipse GUI, text-based simulator config files

## Addl. MiXiM module framework

- ▶ physical layer
- ▶ link layer
- ▶ interfaces to INET Framework

## Addl. INET Framework modules

- ▶ typical Internet protocols
- ▶ wireless communication
- ▶ basic mobility models (unused)

**OMNeT++**

THE OPEN SIMULATOR

# OMNeT++ GUI

OMNeT++ IDE File Edit View Source Navigate Search Project Run SUMO Window Help (Charged) Sun 13:01 sommer Debug Simulation

Simulation - INET/examples/traci/Car.ned - OMNeT++ IDE - /Users/sommer/src/workspace.omnet4

**Project Explorer**

- rtp
- sctp
- traci
- bitmaps
- results
  - config1-0.vci
  - config1-0.vec
  - Car.ned
  - config1.anf
  - Highway.ned
  - net.net.xml
  - omnetpp.ini
  - README
  - routes.routes.xml
  - run
  - run.cmd

**Properties**

INET/examples/traci/Car.ned

Property	Value
Info	derived: false editable: true last modified: March 27, 2009 linked: false location: /Users/sommer/src/workspace.omnet4/INET/examples/traci/Car.ned name: Car.ned path: /INET/examples/traci/Car.ned size: 2,570 bytes

**Car.ned**

**Palette**

- Selector
- Connection
- Types
  - Simple Module
  - Compound Module
  - Network
  - Channel
  - Module Interface
  - Channel Interface
- Submodules
  - TraCI mobility (inet.mobility.traci)
  - TraCIScenarioManager (inet.world.traci)
  - TraCIScenarioManagerLaunch (inet.world.traci)
  - TurtleMobility (inet.mobility.turtle)
  - TwoNetsArea (inet.examples.twonetsarea)
  - UDP (inet.transport.udp)
  - UDPApp (inet.applications.udapp)
  - UDPBasicApp (inet.applications.udapp)
  - UDPEchoApp (inet.applications.udapp)

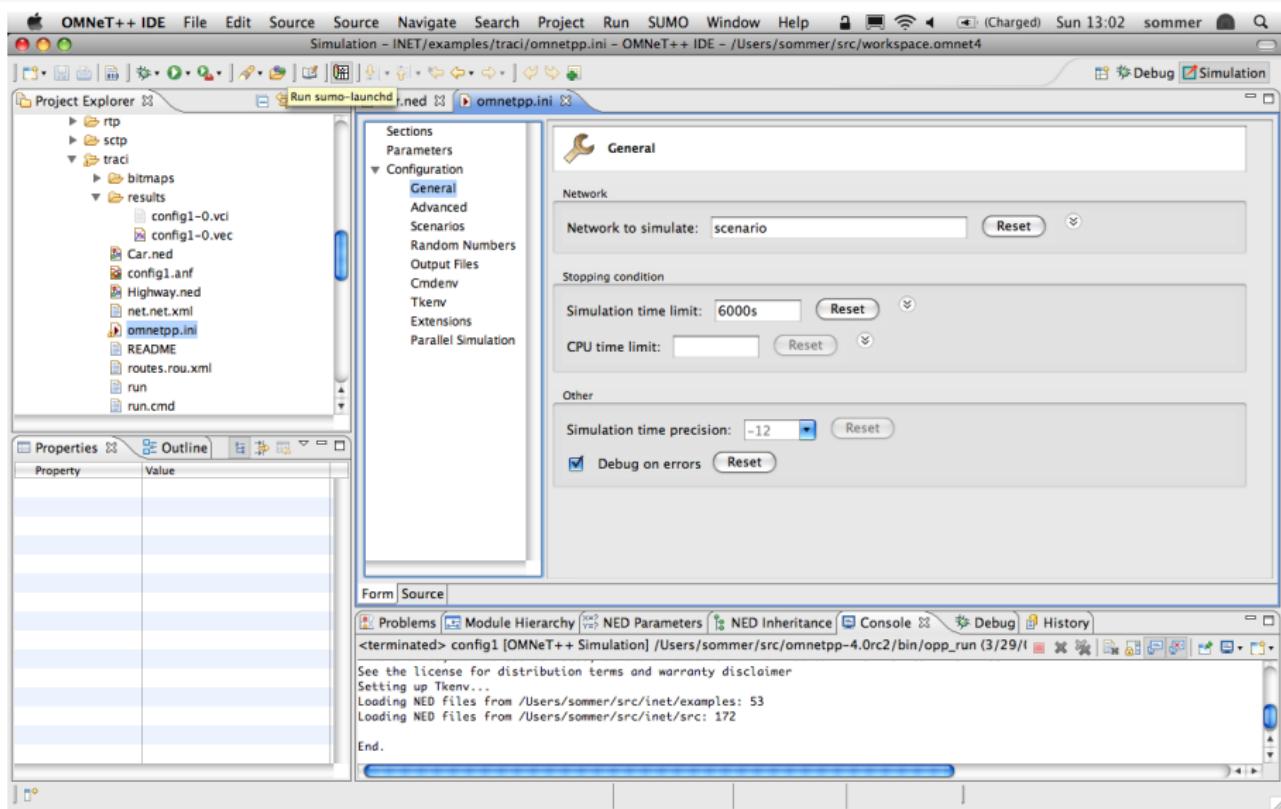
**Design**

**NED Parameters**

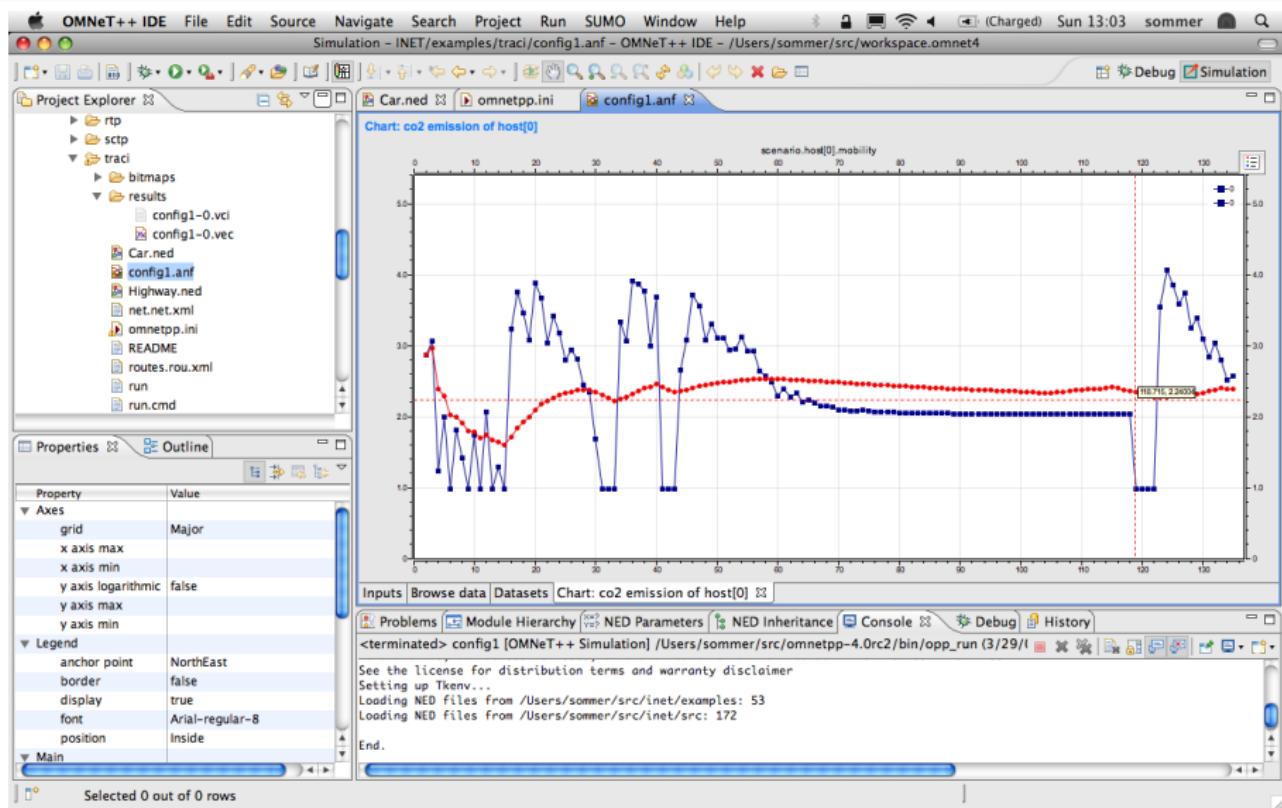
Parameter	Value	Remark
networkLayer.proxyARP	false	NED
networkLayer.ip.procDelay	0s	NED default applied implicitly
networkLayer.ip.timeToLive	32	NED
networkLayer.ip.multicastTimeToLive	32	NED
networkLayer.ip.protocolMapping	'6:0,17:1;1:2:2'	NED
networkLayer.ip.fragmentTimeout	60s	NED

INET/examples/traci/Car.ned

# OMNeT++ GUI



# OMNeT++ GUI



# Veins (Vehicles in Network Simulation)

## Components

- ▶ OMNeT++ for network traffic simulation
- ▶ SUMO for road traffic simulation, coupled via TraCI

## History of Veins

- ▶ SUMO 0.8.3+ — proprietary, subscription based (2005)
- ▶ SUMO 0.9.8+ — merged into common interface
- ▶ SUMO 0.11.1+ — new-style subscription based API
- ▶ SUMO 0.12.1 — current

## Bidirectional coupling

- ▶ Network traffic can influence road traffic (and vice versa)



# Veins

## Diverse user base



## Diverse deployment

- ▶ OMNeT++ 3 and 4 / OMNEST
- ▶ INET Framework / MiXiM
- ▶ interactive Demos
- ▶ driving simulators
- ▶ our JiST/SWANS port
- ▶ ...



# TraCI Client

## Mode of operation

- ▶ get API version, road network boundaries
- ▶ subscribe to list of vehicle IDs
  - subscribe to list of arrived/departed vehicles
- ▶ advance network simulation, passing commands
  - advance SUMO, handling subscription responses

## API

```
queryTraCI(  
    CMD_DISTANCEREQUEST, TraCIBuffer()  
    << POSITION_2D << p1.x << p1.y  
    << POSITION_2D << p2.x << p2.y  
    << REQUEST_DRIVINGDIST  
) » cmdLength » commandId » flag » distance;  
return distance;
```

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# sumo-launchd

## Problem

- ▶ need to manually start one SUMO process per replication
- ▶ (massively) multiple replications in parallel: MRIP needs managed instances of SUMO

## Solution

- ▶ network simulator connects to proxy (sumo-launchd)
- ▶ proxy takes care of setting up and running SUMO

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OMNeT++

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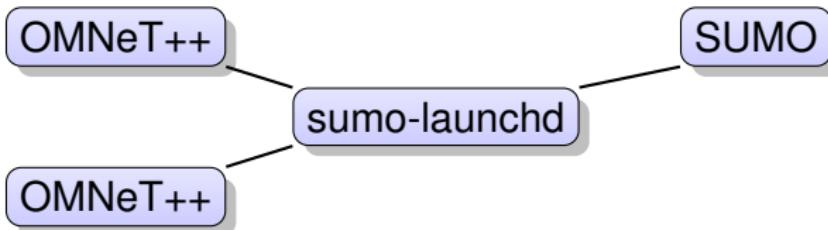
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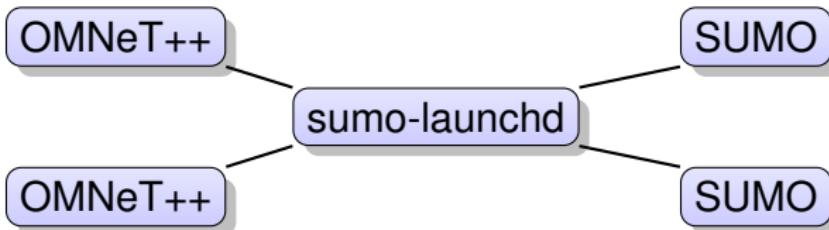
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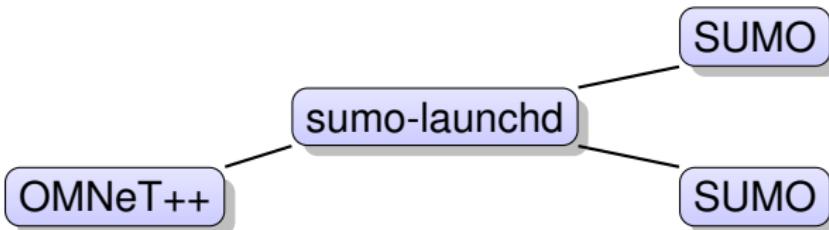
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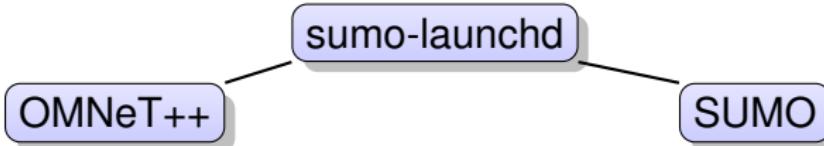
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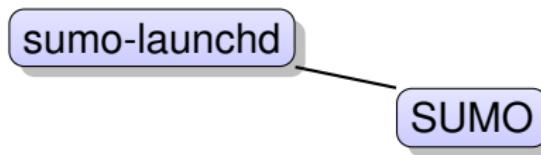
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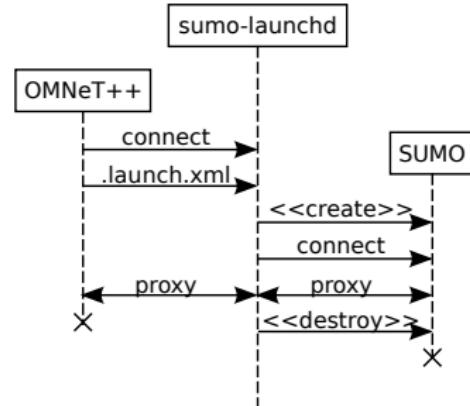
# sumo-launchd

## Based on TraCI

- ▶ first command CMD\_FILE\_SEND (0x75) (new command)
- ▶ file name sumo-launchd.launchd.xml

## File contents

```
<?xml version="1.0"?>
<launch>
<basedir path="/net/veins/s1/" />
<seed value="1234" />
<copy file="s1.net.xml" />
<copy file="s1.rou.xml" />
<copy file="s1.sumo.cfg" type="config" />
</launch>
```



# Development

## Development model

- ▶ free and open source software
- ▶ public Git repository/-ies
- ▶ feature branches, ready for merging

## Try it out!

- ▶ install python 2.6, SUMO 0.12.1, OMNeT++ 4.1  
`git clone git://github.com/sommer/inet-sommer.git  
git merge origin/traci  
git merge origin/tracidemo  
git merge origin/obstacles  
make makefiles all`
- ▶ screencast, tutorial on [www7.cs.fau.de/veins/](http://www7.cs.fau.de/veins/)

# EMIT Emission Model

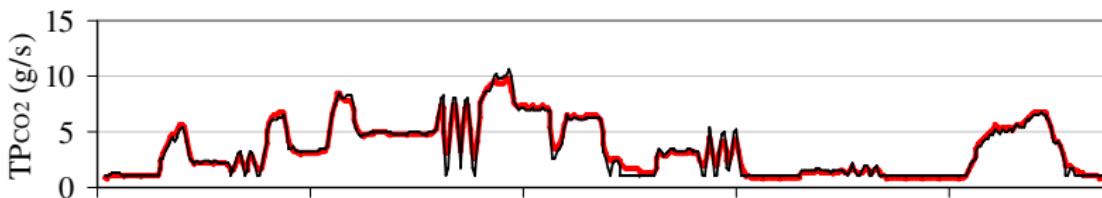
## Approach

- ▶ Cappiello et al., “A Statistical Model of Vehicle Emissions and Fuel Consumption”, IEEE ITSC 2002
- ▶ model fitting of polynomial to measurements

## Example: Tailpipe emission of CO<sub>2</sub>

$$P_{tract} = Av + Bv^2 + Cv^3 + Mav + Mg v \sin \vartheta$$

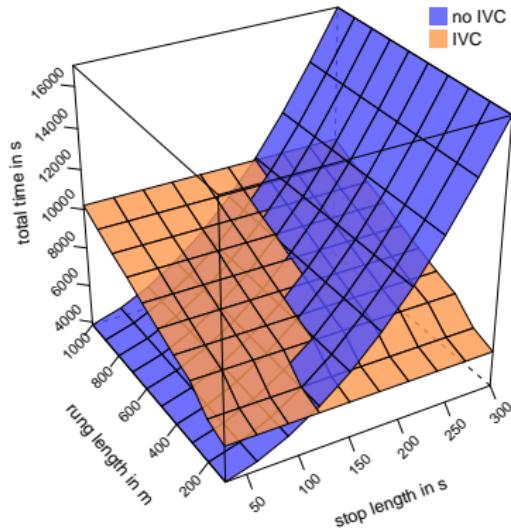
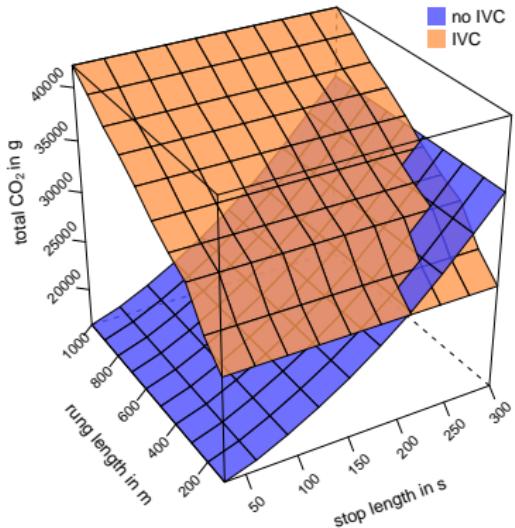
$$TP_{CO_2} = \begin{cases} \alpha + \beta v + \delta v^3 + \zeta av & \text{if } P_{tract} > 0 \\ \alpha' & \text{else} \end{cases}$$



# Routing Decisions

## Traffic Information System (TIS) re-routing traffic

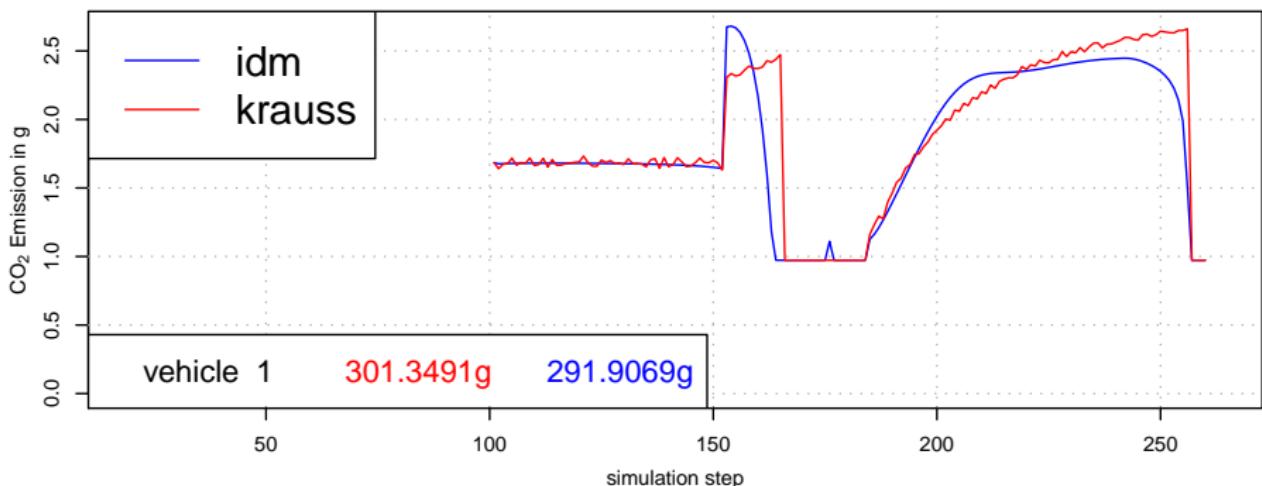
- ▶ base decisions on CO<sub>2</sub> emissions or travel time?
- ▶ break-even points differ according to metric



# Dependence on Mobility Model

## IDM vs. Krauss model

- ▶ IDM model exhibits smoother accel/decel
- ▶ experiments measure emissions at tail-end of jam
- ▶ emission metric differs (300 g vs. 290 g)



# Past and Ongoing Work

## Publications

- Christoph Sommer, Ozan K. Tonguz and Falko Dressler,  
**"Adaptive Beaconing for Delay-Sensitive and Congestion-Aware Traffic Information Systems,"**  
Proceedings of 2nd IEEE Vehicular Networking Conference (VNC 2010), Jersey City, NJ, December 2010.
- David Eckhoff, Christoph Sommer, Tobias Gansen, Reinhard German and Falko Dressler, **"Strong and Affordable Location Privacy in VANETs: Identity Diffusion Using Time-Slots and Swapping,"**  
Proceedings of 2nd IEEE Vehicular Networking Conference (VNC 2010), Jersey City, NJ, December 2010.
- Christoph Sommer, David Eckhoff and Falko Dressler,  
**"Improving the Accuracy of IVC Simulation using Crowd-sourced Geodata,"**  
Praxis der Informationsverarbeitung und Kommunikation (PIK), vol. 33 (4), December 2010.
- Falko Dressler and Christoph Sommer,  
**"On the Impact of Human Driver Behavior on Intelligent Transportation Systems,"**  
Proceedings of 71st IEEE Vehicular Technology Conference (VTC2010-Spring), Taipei, Taiwan, May 2010.
- Christoph Sommer, Robert Krul, Reinhard German and Falko Dressler,  
**"Emissions vs. Travel Time: Simulative Evaluation of the Environmental Impact of ITS,"**  
Proceedings of 71st IEEE Vehicular Technology Conference (VTC2010-Spring), Taipei, Taiwan, May 2010.
- Christoph Sommer, Armin Schmidt, Yi Chen, Reinhard German, Wolfgang Koch and Falko Dressler,  
**"On the Feasibility of UMTS-based Traffic Information Systems,"**  
Elsevier Ad Hoc Networks, Special Issue on Vehicular Networks, vol. 8 (5), pp. 506-517, July 2010.
- Christoph Sommer, Isabel Dietrich and Falko Dressler, **"Simulation of Ad Hoc Routing Protocols using OMNeT++: A Case Study for the DYMO Protocol,"** ACM/Springer Mobile Networks and Applications (MONET), Special Issue on Simulation Techniques & Tools for Mobile Networking, 2009.
- Christoph Sommer and Falko Dressler, **"Progressing Towards Realistic Mobility Models in VANET Simulations,"** IEEE Communications Magazine, vol. 46 (11), pp. 132-137, November 2008.



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Thanks!

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