Karlsruhe Institute of Technology

Why is Vehicular (still) Challenging?

Unresolved issues and future directions in WiVeC research

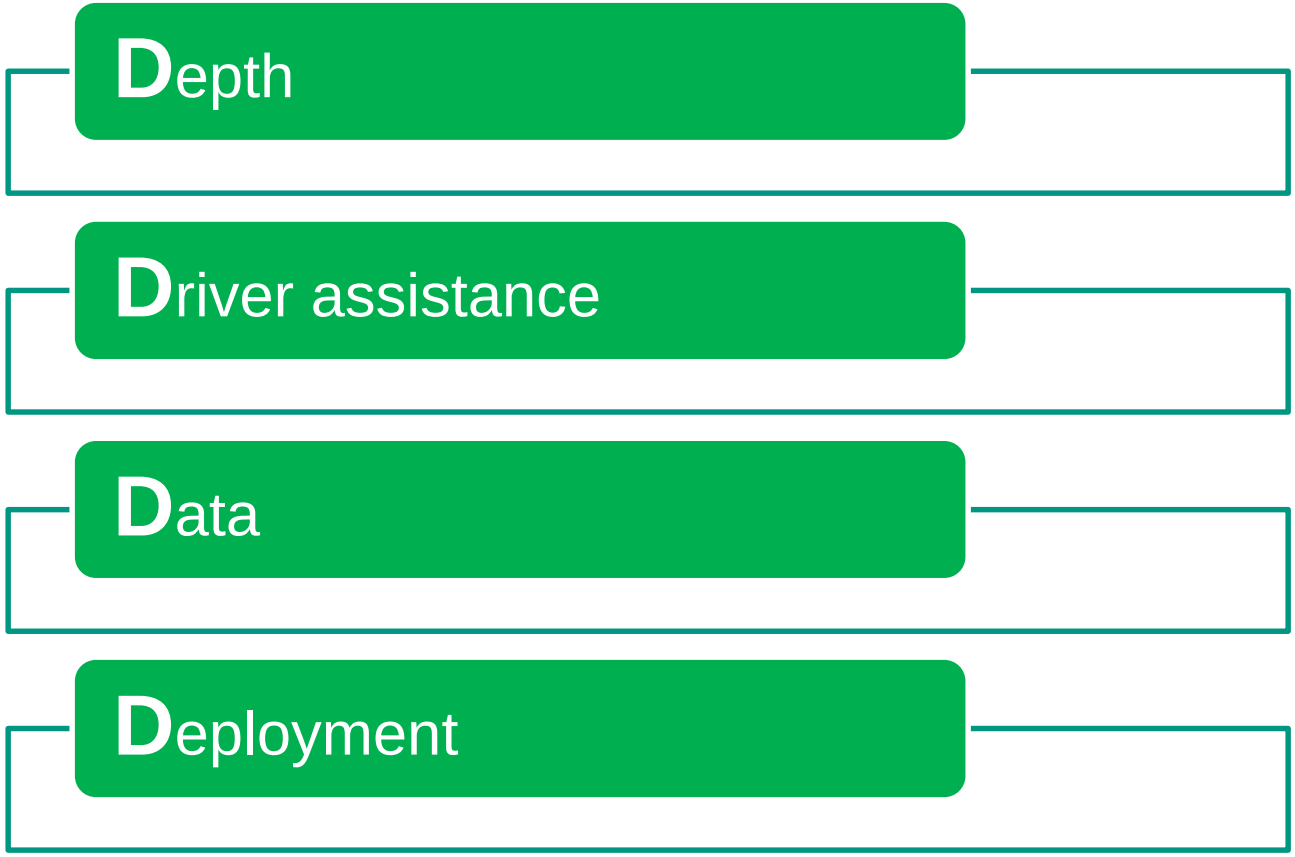
Hannes Hartenstein, Karlsruhe Institute of Technology

IEEE WiVeC, Dresden, June 2nd 2013

Research Group „Decentralized Systems and Network Services“ - DSN



Keynote themes … in Dresden:



Disclaimer, my background, and acknowledgements:

- The talk is really about unresolved issues … work in progress, no „final“ results
- My focus is on vehicle-to-vehicle, most of the time with safety and efficiency in mind, biased towards our own work
- I‘ve done 13 years of research in the field, but my main job is being director of the Steinbuch Centre for Computing
  - Institute with 230 staff, half science, half service
- Thanks to: Natalya An, Tristan Gaugel, Tessa Tielert, Jens Mittag, Daniel Jiang, Erik Ström and many other co-workers
- … and to the EU FP7 IP Consortium DRIVE-C2X

1. Depth

- **Thesis**: In-depth treatment in wireless vehicular communication is still missing, i.e., theorems, proofs of optimality etc.

- **Examples**:
  a) CSMA against the rest of the world
  b) Congestion control

CSMA against the rest of the world

- IEEE 802.11p MAC is pretty simple:
  basically, it is a carrier sense multiple access approach
  (in typical vehicular settings)

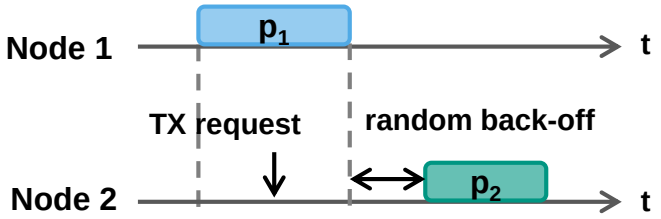
- A statement often heard at conferences:
  „802.11p MAC is not a good choice since under channel load there are many packet collisions. Standardization simply has picked it because it was there.“

- But: it works remarkably well – and there are no results that show that another MAC really works better in vehicular environments …

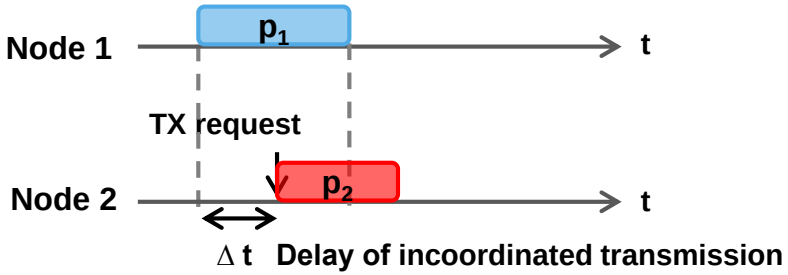
CSMA against the rest of the world

- Our approach to attack the problem: CSMA coordination performance

Case 1: coordination successful!

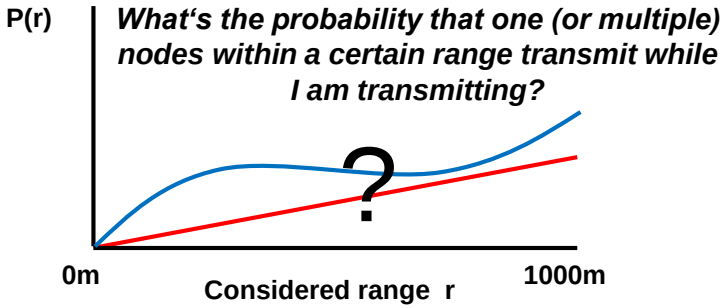


Case 2: coordination failed!

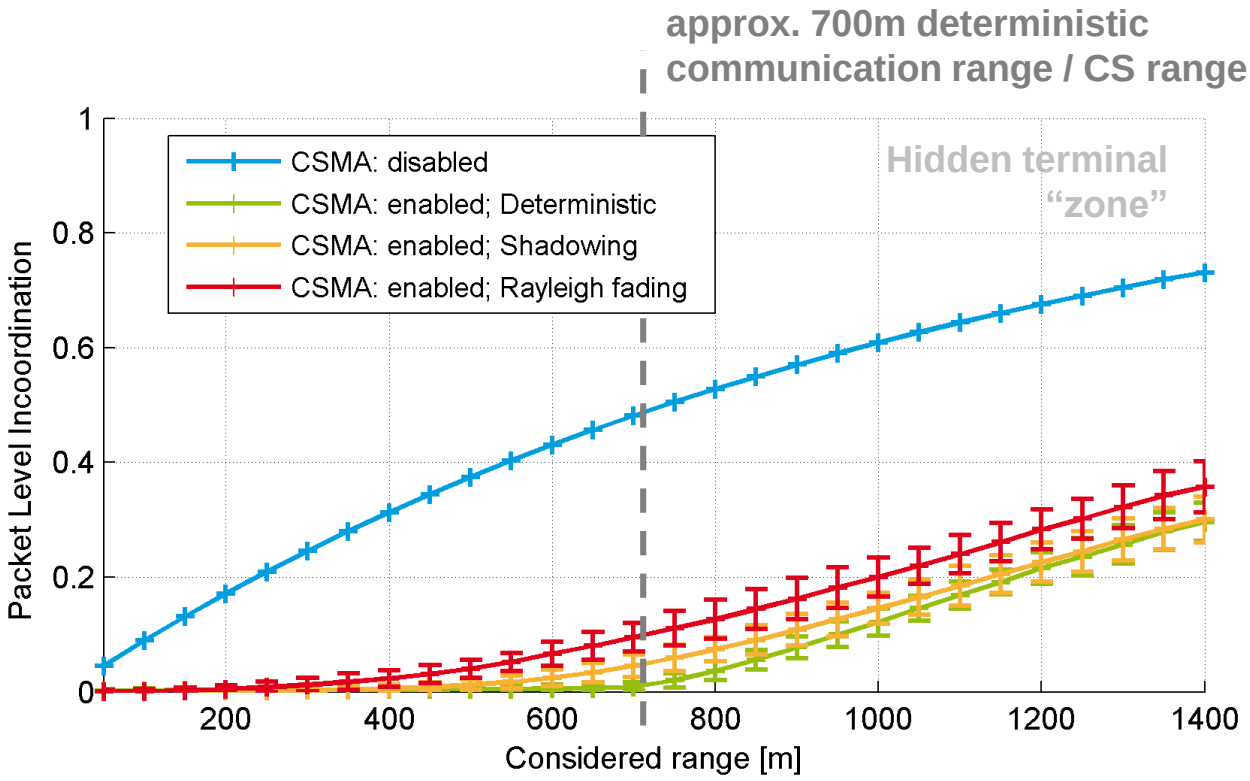


- From the perspective of a single node…

Packet Level Incoordination (PLI)



CSMA Coordination Performance



Packet Level Incoordination (PLI)

Probability that one (or multiple) nodes within a certain range are incoordinated to my own transmission.

Simulation setup

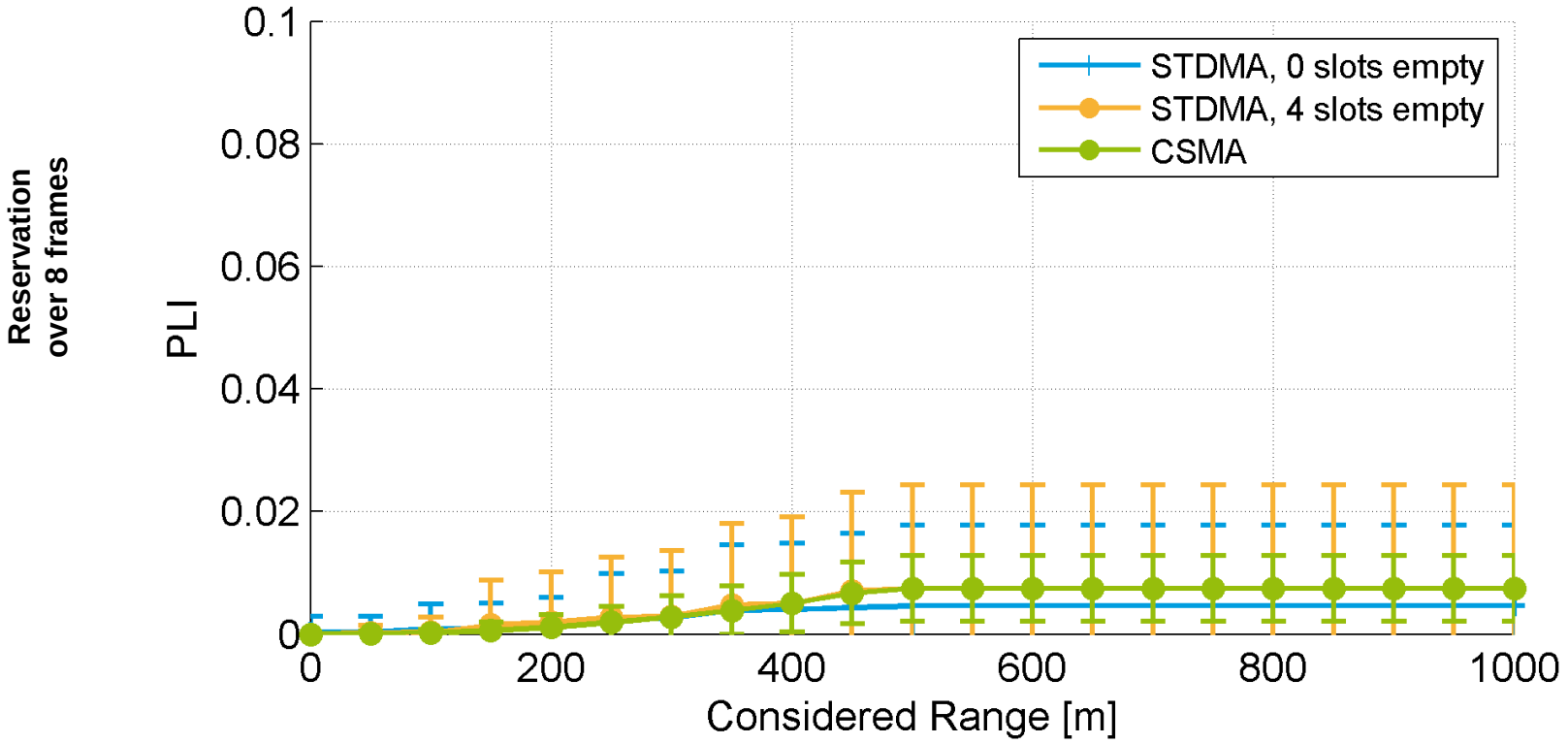
- Highway scenario
- 80 vehicles/km
- 400 byte packets
- 10 Hz packet rate
- ~700m communication range
- ~70% channel saturation

CSMA against the rest of the world

- CSMA: results show pretty good performance of CSMA
- But: what about other MAC approaches?
- Comparison with STDMA: Self-Organizing Time Division Multiple Access
- Joint work in progress with Tristan Gaugel, Jens Mittag, Stelios Papanastasiou, Katrin Sjöberg, and Erik Ström

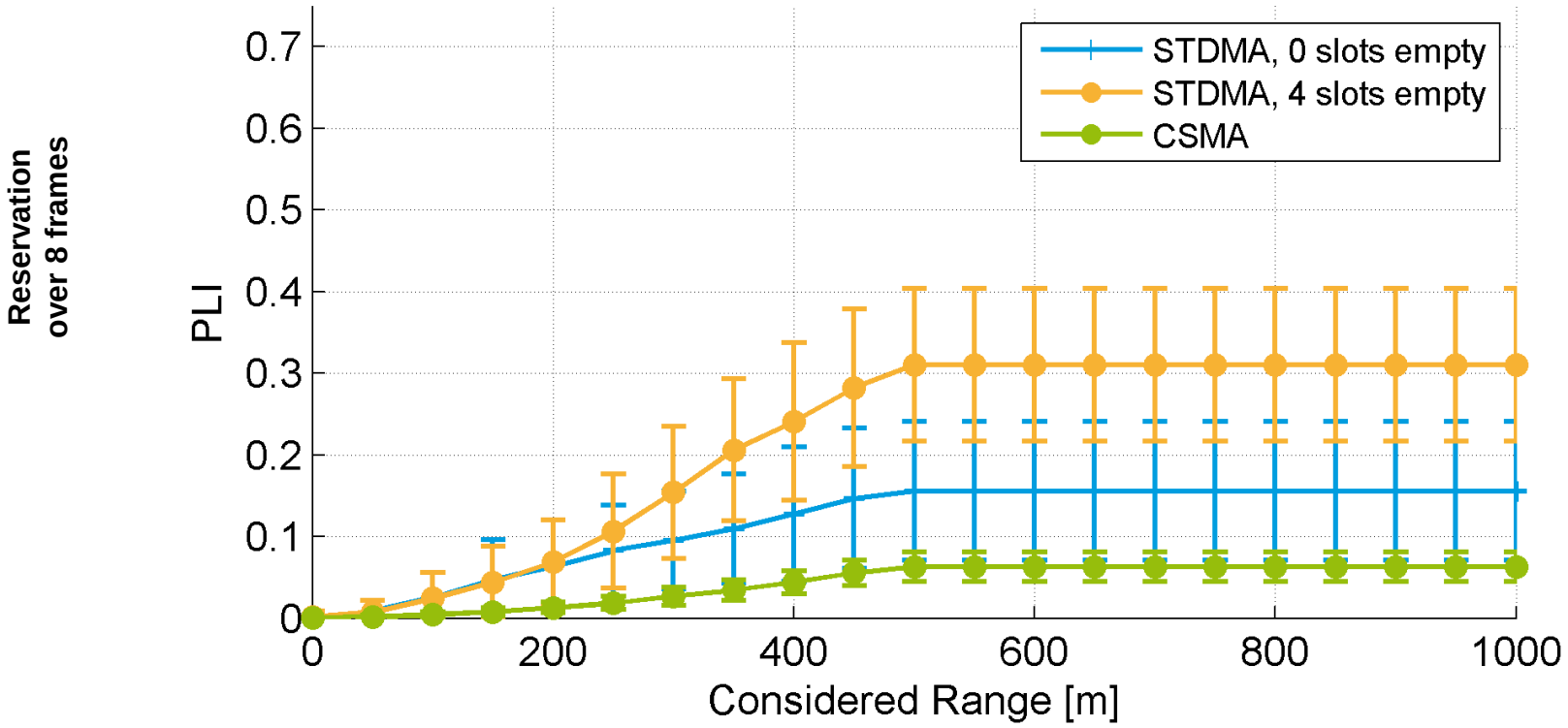
CSMA against the rest of the world

Load on the channel would ideally use 50% of all slots



CSMA against the rest of the world

Load on the channel would ideally use 100% of all slots



CSMA against the rest of the world

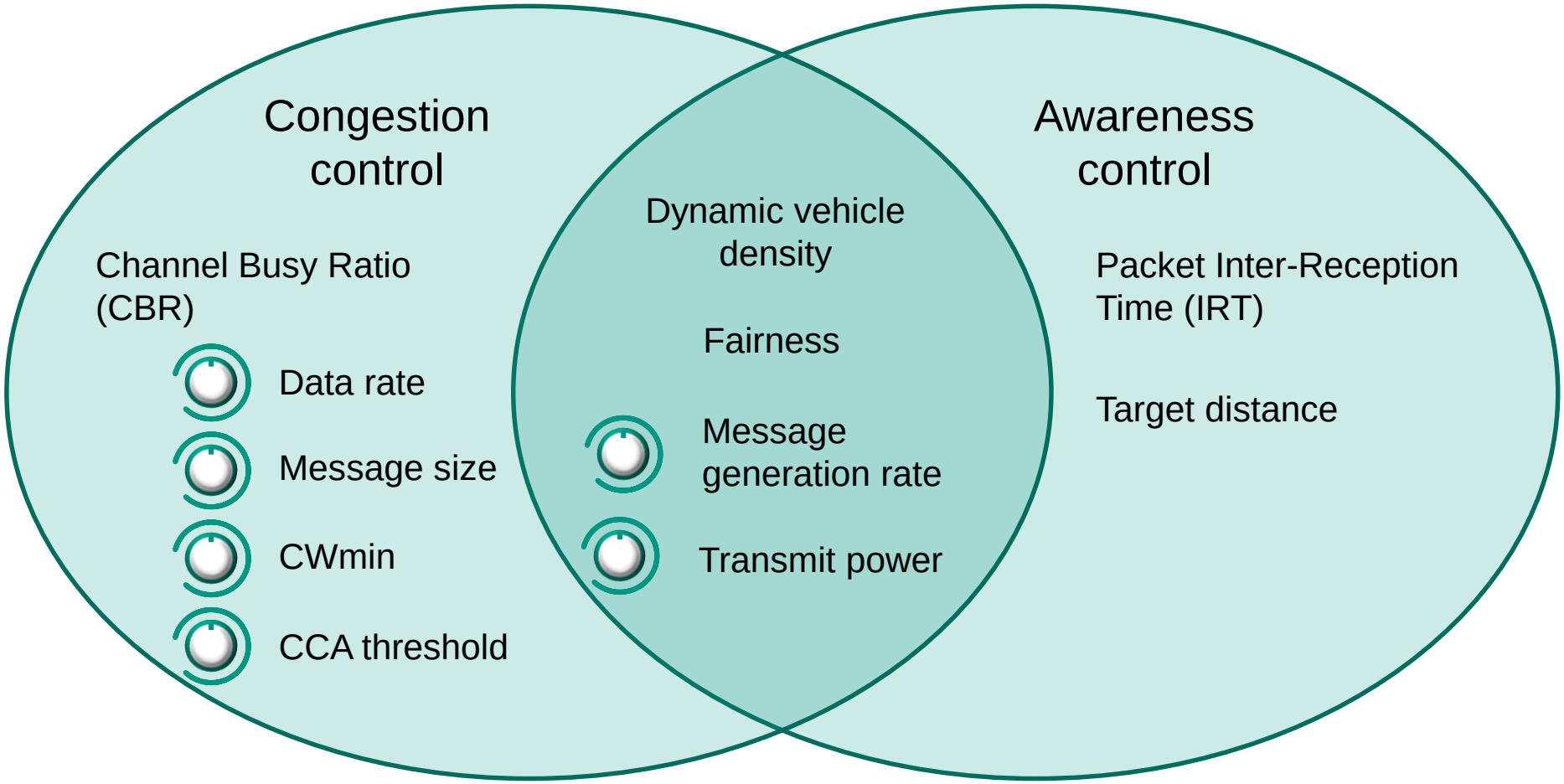
- Still, a lot of unresolved issues …
  - For example, what is the optimal configuration of STDMA?

If interested in the methodology, please check:

- Mittag, J.; Papanastasiou, S.; Hartenstein, H.; Strom, E.G.; , "Enabling Accurate Cross-Layer PHY/MAC/NET Simulation Studies of Vehicular Communication Networks," *Proceedings of the IEEE* , vol.99, no.7, pp.1311-1326, July 2011

- Mittag, J., „Characterization, Avoidance and Repair of Packet Collision in Inter-Vehicle Communication Networks“, Dissertation, KIT, 2012. Available online http://www.ksp.kit.edu/shop/isbn/978-3-86644-880-3

Congestion control with CSMA: Challenge



Many proposals, yet no clear „winning proposal“

Basic questions

What is the optimal outcome?

Minimum
average (or k^{th} percentile of)
Packet Inter-Reception Time (IRT)

Different vehicle densities
Different target distances

Optimal Tx power

Optimal Tx rate

Which control strategy can get us there?

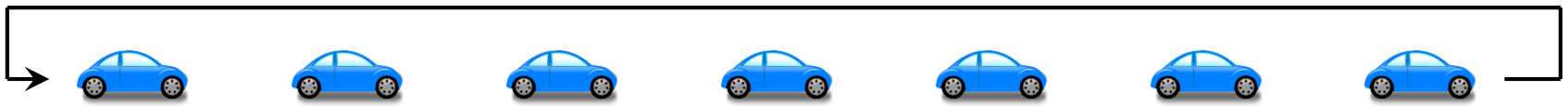
No adaptation

Transmit Power Control (TPC)

Transmit Rate Control (TRC)

Joint Power/Rate Control

Setup for analysis

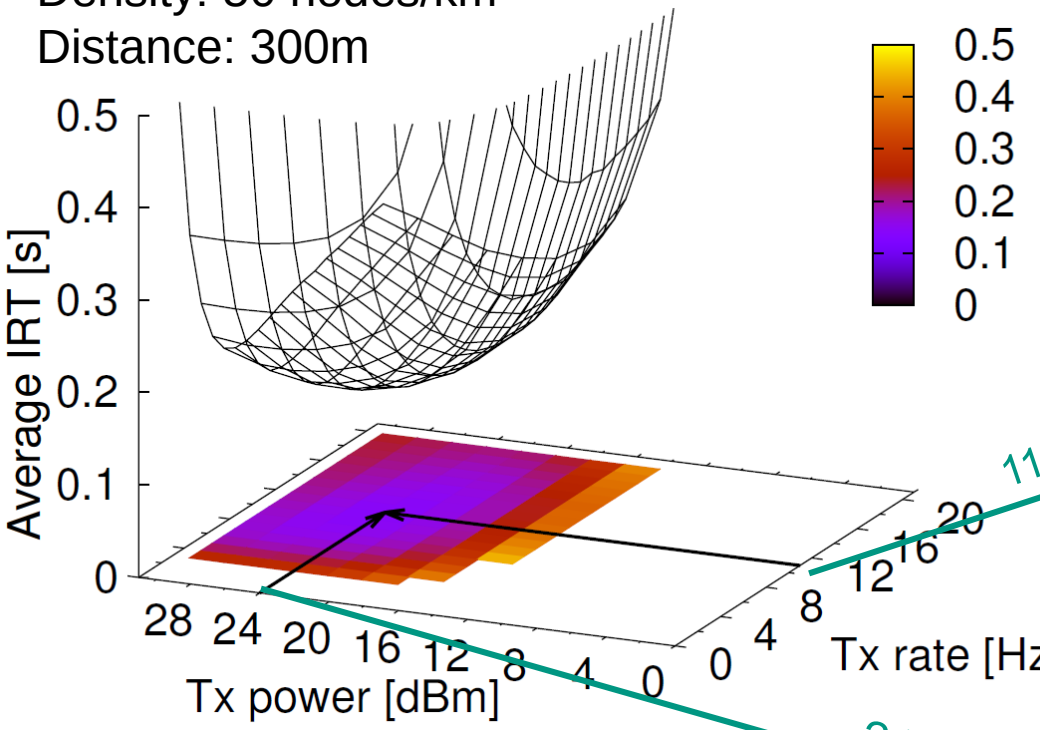


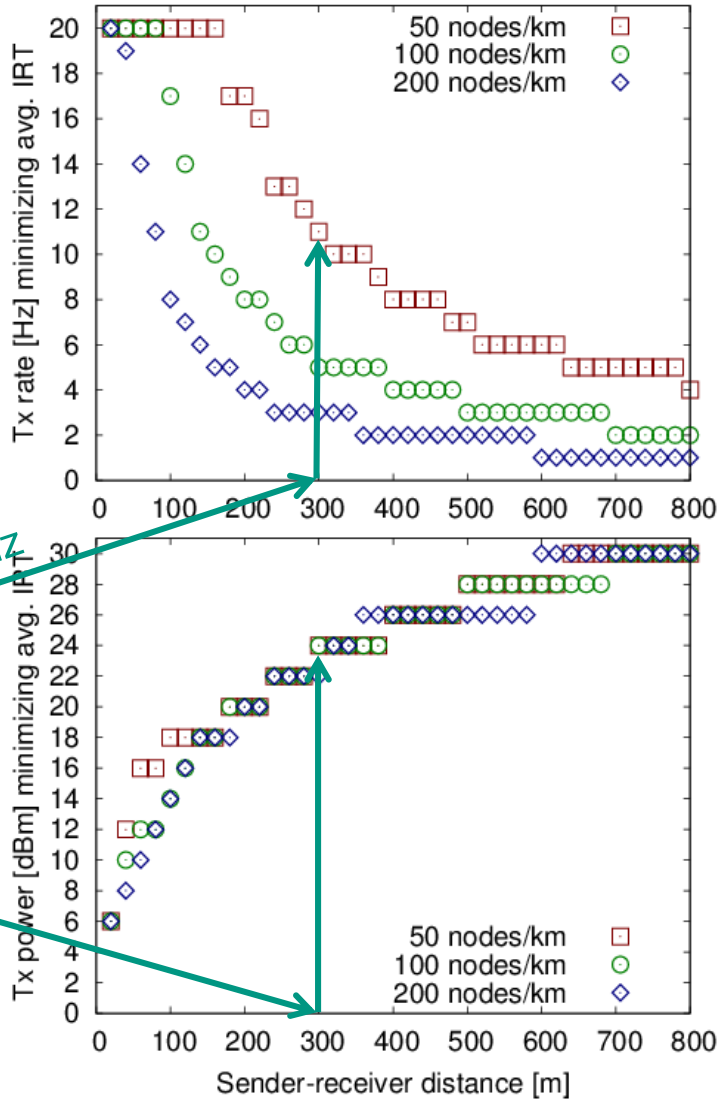
- Very long pseudo-circular road (10-30km)
- Equidistant static vehicles, 3 densities
  - 50, 100, 200 nodes/km
- Homogeneous parameter setup
  - Tx rate 1,2,..20 Hz
  - Tx power 0,2,..30 dBm
- Evaluation metric:
  - Average/ 99th percentile of packet Inter-Reception Time (IRT) per distance

Clipart source: http://clker.com

Tx parameter combinations minimizing avg. IRT

Density: 50 nodes/km
Distance: 300m





11 Hz

24 dBm

Optimal Tx power is <u>independent</u> of vehicle density.

How close can we get to the optimal result?

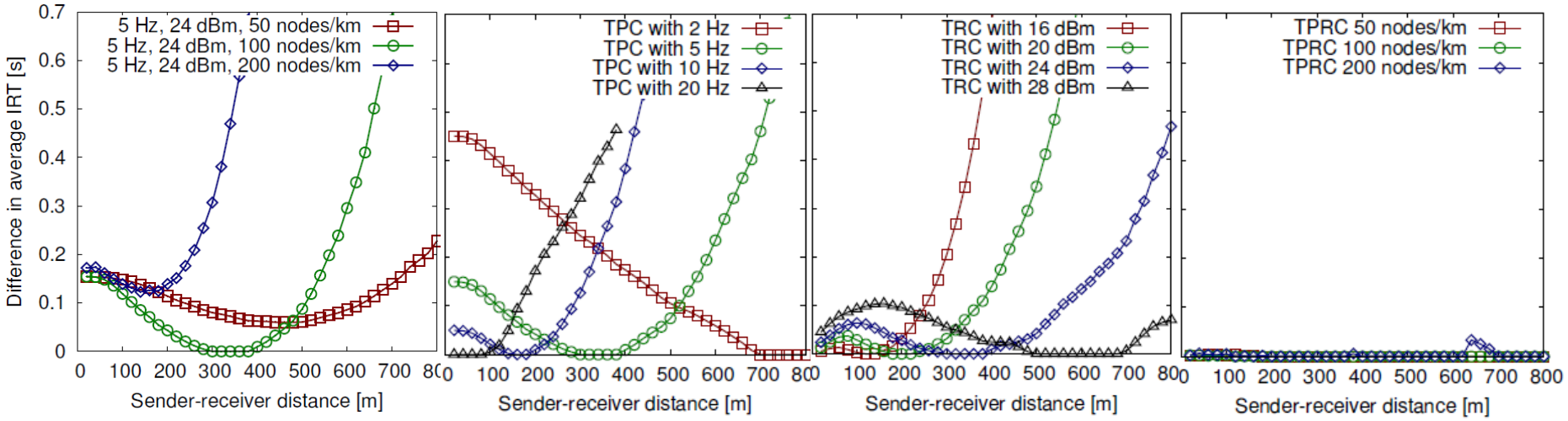
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Without adaptation (example)

Transmit Power Control

Transmit Rate Control

Suggested Joint Power/Rate



Suggested Joint Power/Rate Control strategy

1. Select Tx power based on targeted awareness distance (TPC)
2. Select Tx rate based on channel load (TRC)

Congestion control: our recent work

Karlsruhe Institute of Technology

Mercedes-Benz Research & Development North America, Inc.

- Joint Power/Rate Congestion Control

  Joint Power/Rate Congestion Control Optimizing Packet Reception in Vehicle Safety Communications
  T. Tielert, D. Jiang, H. Hartenstein, L. Delgrossi
  To appear: The Tenth ACM International Workshop on VehiculAr Inter-NETworking, Systems, and Applications (VANET), Taipei, Taiwan, June 25th 2013

- **PULSAR**: Periodically Updated Load Sensitive Adaptive Rate control

  Design Methodology and Evaluation of Rate Adaptation Based Congestion Control for Vehicle Safety Communications
  T. Tielert, D. Jiang, Q. Chen, L. Delgrossi, H. Hartenstein
  3rd IEEE Vehicular Networking Conference (VNC 2011), Amsterdam, Netherlands, November 2011

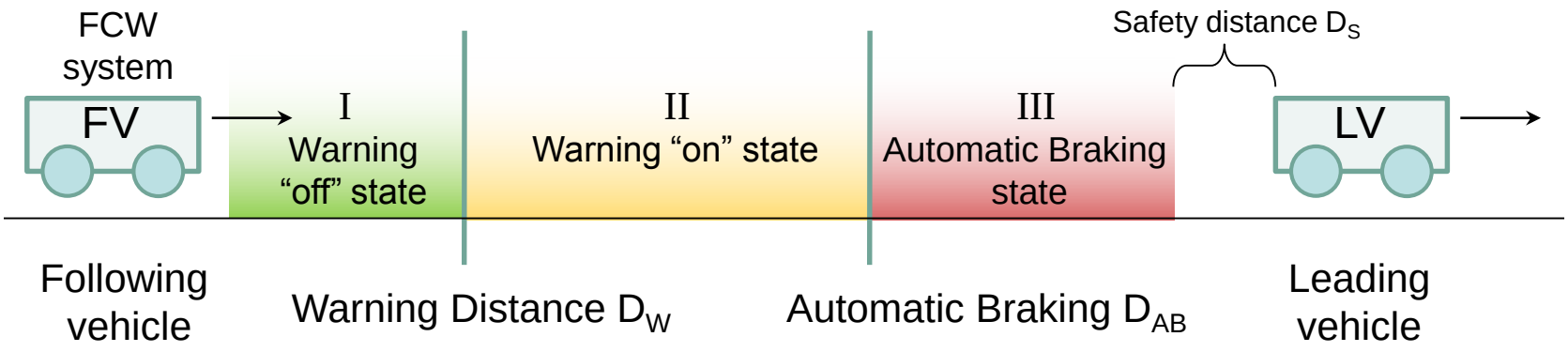
Depth: challenges

- WiVeC represents a modeling challenge
- WiVeC represents an optimization challenge
- WiVeC represents a methodological challenge

2. Driver assistance

- **Thesis**: we have to shift focus to application layer protocols and their specification (like forward collision warning, cross traffic assistance etc.)
- **Examples**: Forward Collision Warning and „Risk Management“

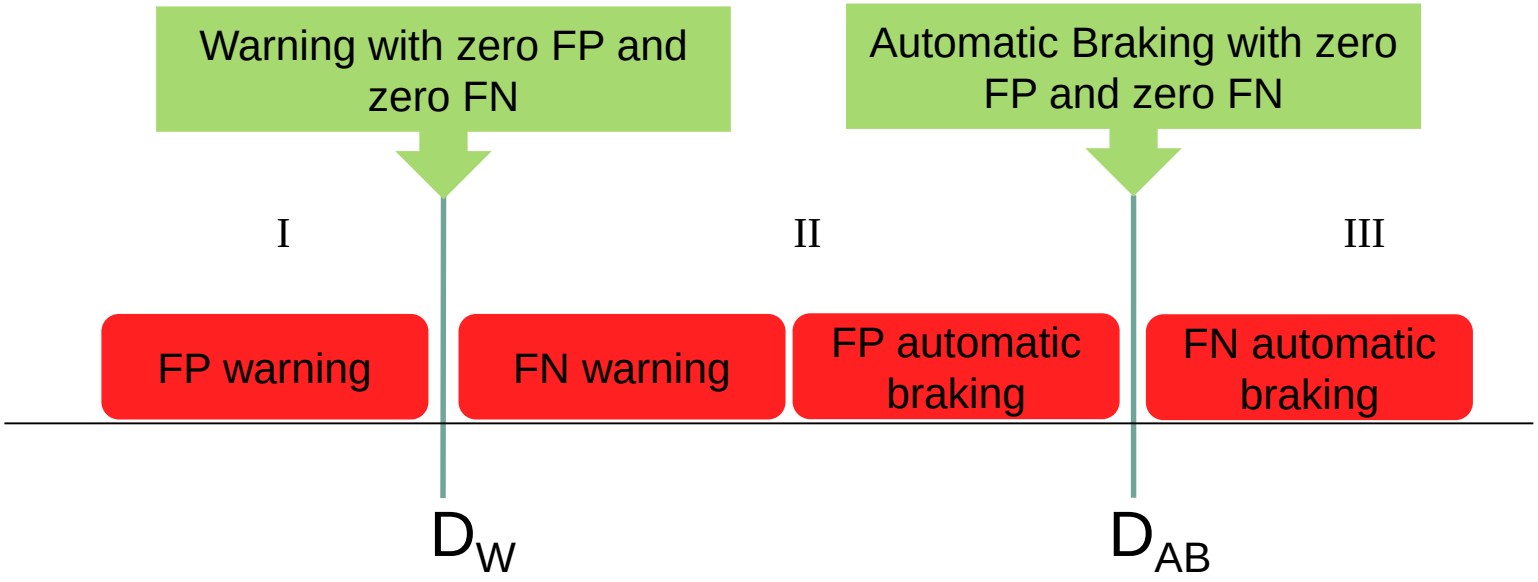
Forward Collision Warning Application



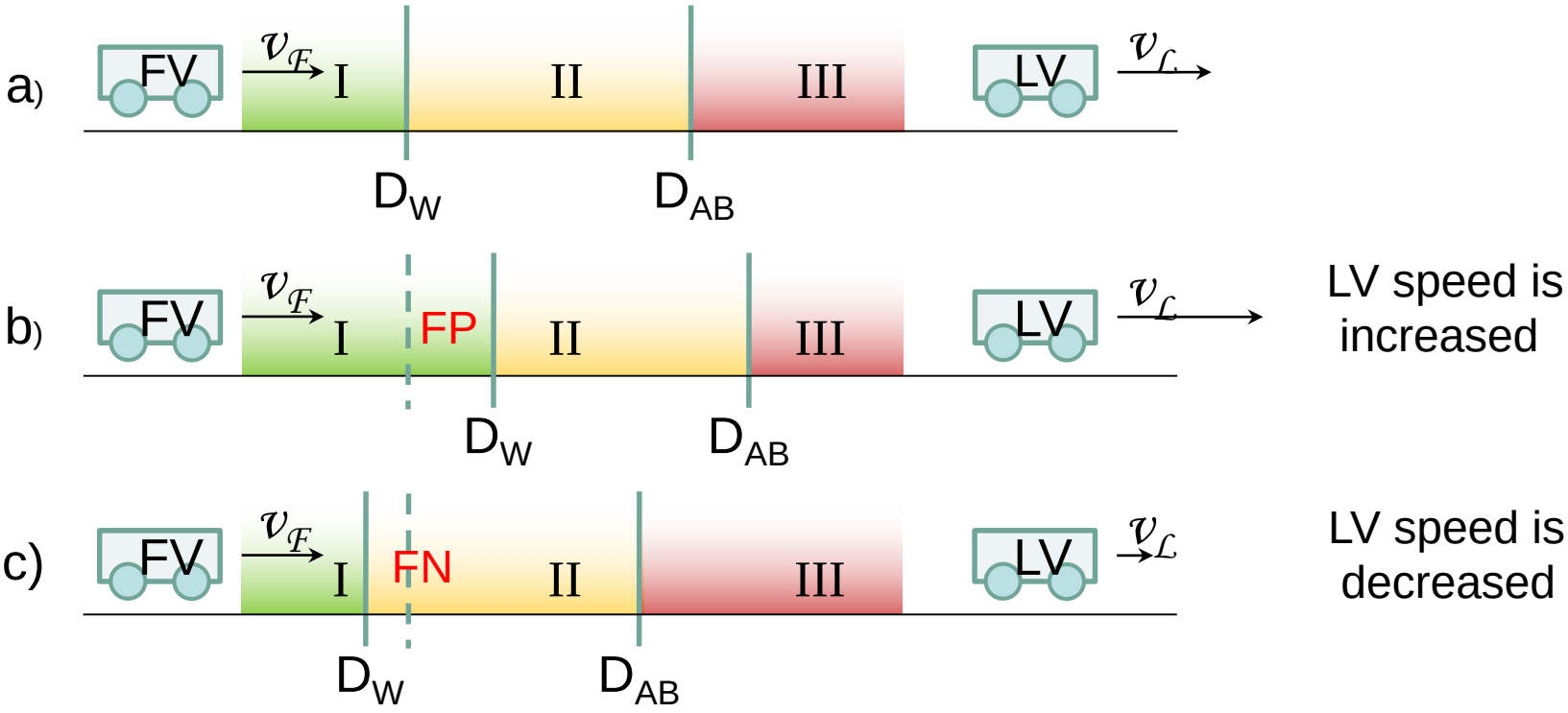
Application Requirement Analysis

- How far and how often do vehicles need to communicate so that the application succeeds?
  - Correct classification of state

False Positive (FP) and False Negative (FN)

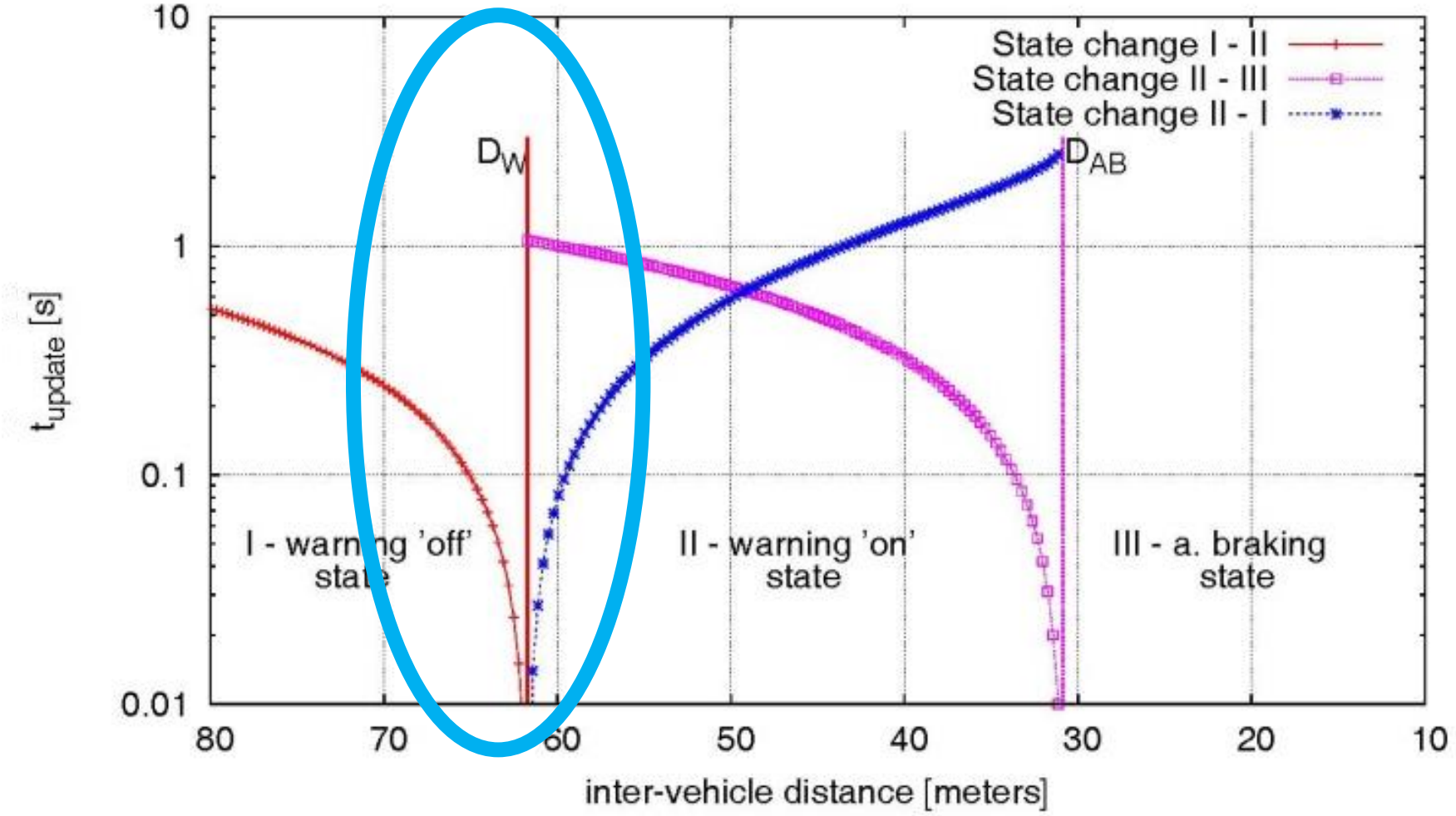


Possible situation change over time



- Need to know when FV can possibly change its state, based on Δv and assumption on possible change rate of v_L (a_L')
  - time (t_{update}) when the next update is needed to correctly identify states

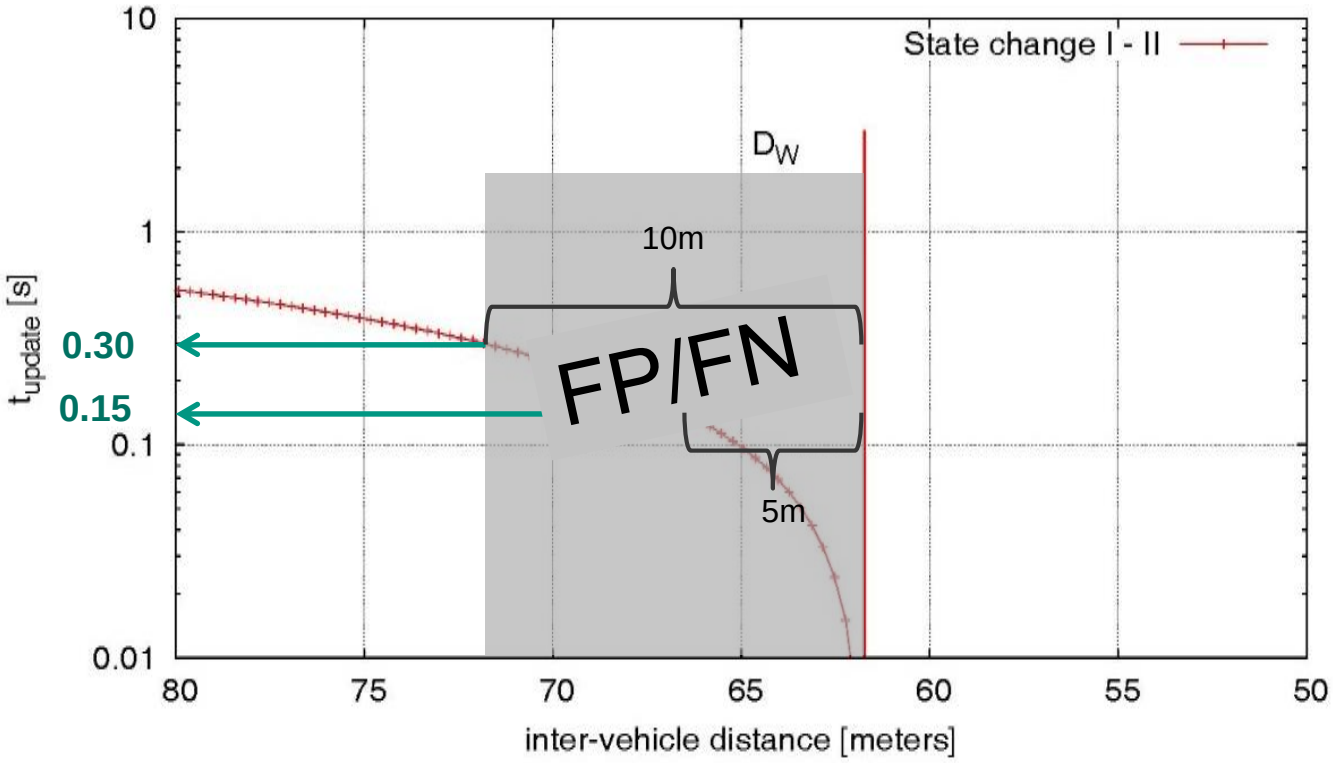
How far and how often do vehicles need to communicate – Idealistic analysis



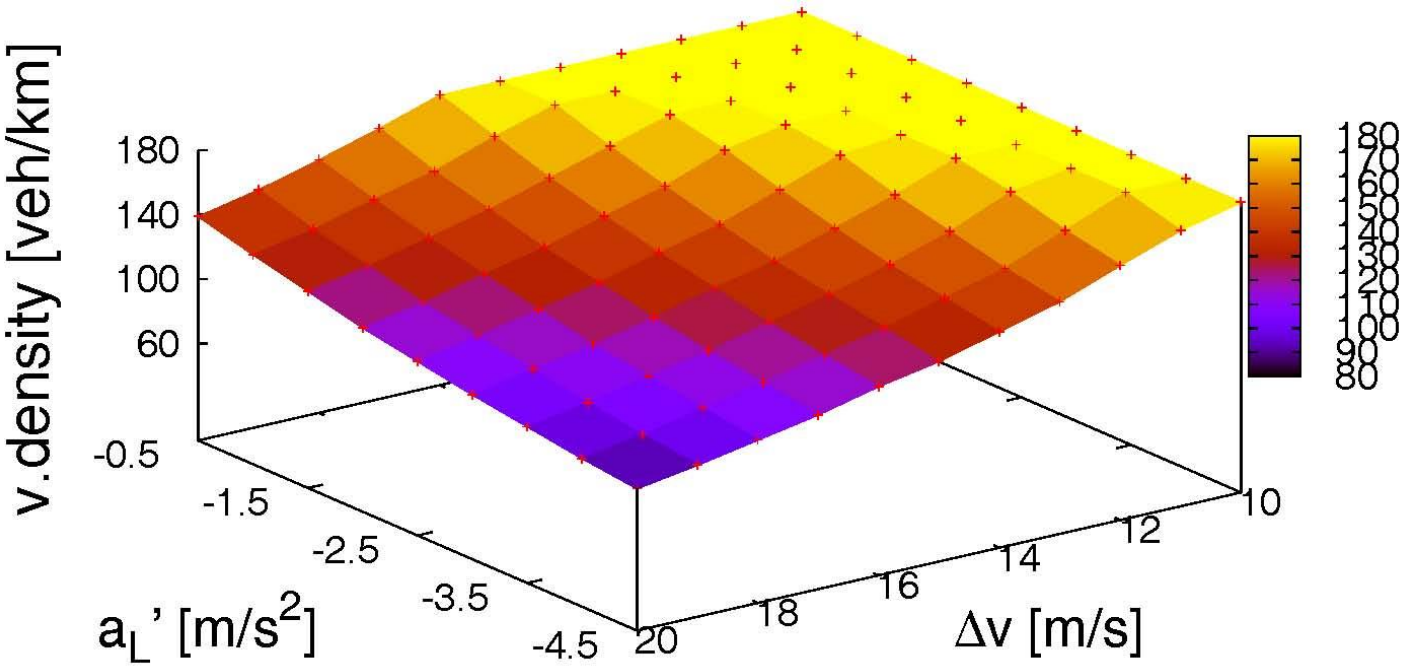
Δv = 22m/s, a_L' = -2m/s^2. for D_W, a_F= -4m/s^2, for D_{AB}, a_F = -8m/s^2, t_R, t_{sys}, D_S=0

Tolerance regions?

- Zero False Negatives and zero False Positives are unrealistic
  - Tolerance region required



Maximum feasible number (worst case)



Tolerance region size 10m

Maximum feasible number (worst case analysis) of communicating vehicles is **88veh/km**

For further information:

- Balancing the Requirements for a Zero False Positive/Negative Forward Collision Warning
  N. An, M. Maile, D. Jiang, J. Mittag, H. Hartenstein
  The 10th Annual Conference on Wireless On-Demand Network Systems and Services (WONS), Banff, Alberta, Canada, March 2013

- See also http://dsn.tm.kit.edu/download/wons2013/

- Feasibility of Virtual Traffic Lights in Non-Line-Of-Sight Environments
  T. Neudecker, N. An, O. Tonguz, T. Gaugel, J. Mittag
  The Ninth ACM International Workshop on VehiculAr Inter-NETworking, Systems, and Applications, Ambleside, United Kingdom, June 2012

Driver assistance: challenges

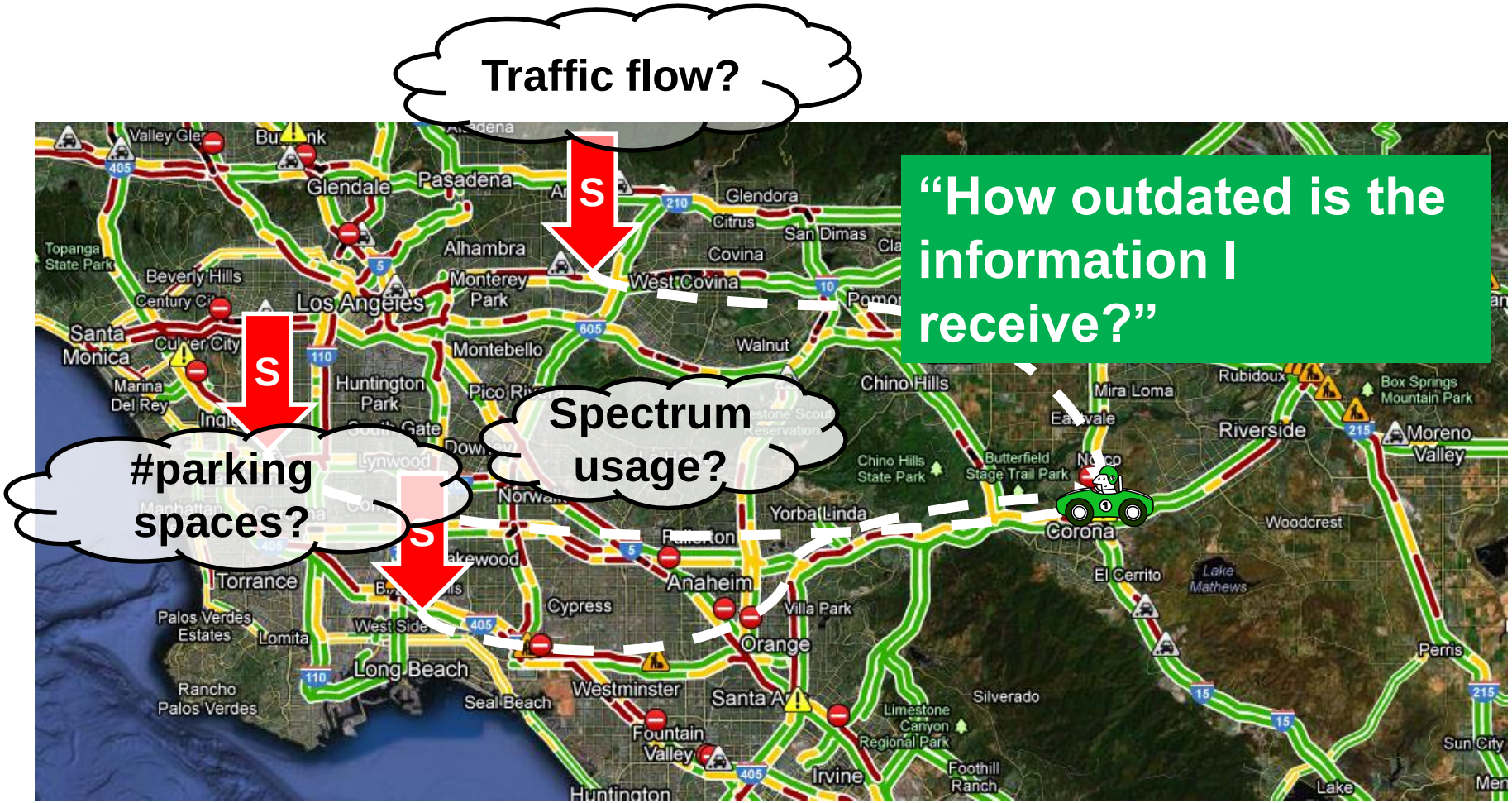
- For which applications is the underlying logic verified?
- Do we know the „tolerance regions“?
- Proprietary knowledge
- Are „dependability experts“ involved in WiVeC issues?
- Risks of „wrong simulations“?

3. Data

- **Thesis**:
- For efficiency/comfort applications and on larger scale, „information“ is more meaningful than „packets“ → information-centric modeling
- „Big data“ is generated – but research moves to the „data owners“ – academic research might not have access
- **Examples**: Collaborative sensing

Data:

Collaborative sensing with vehicles („Sharing“)



- For <u>efficiency and convenience</u>

[Source: Google Maps]

Data:

Collaborative sensing with vehicles

- Probably not with IEEE 802.11p, but with any device
- Could also be a „5th Generation“ device.

- Not clear: role of information dissemination without „cellular“ network infrastructure

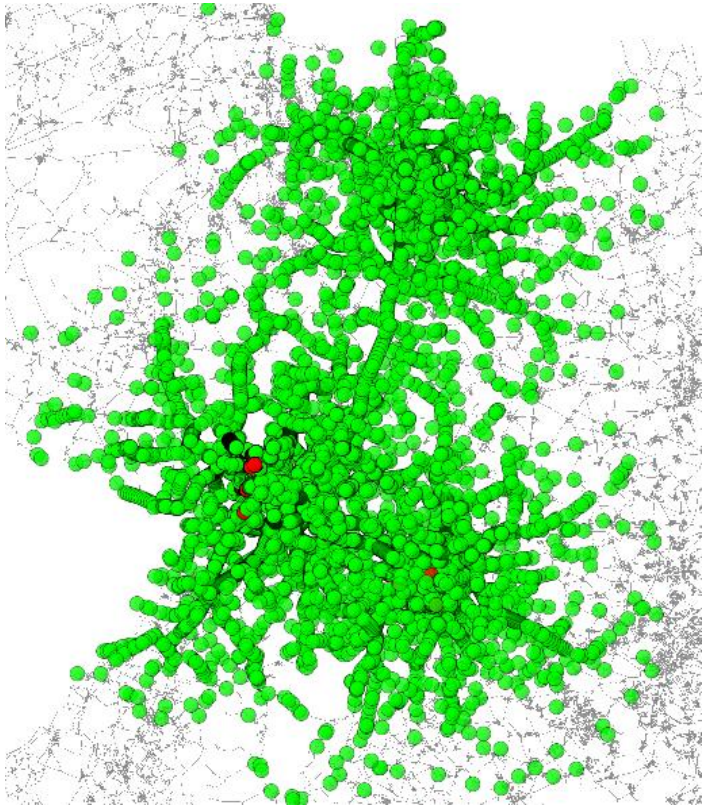
- Let‘s assume that information dissemination via multi-hop vehicle-to-vehicle communication will play a role (for instance, for „spectral efficiency“ reasons)

- → Information-centric view (rather than packet-based) for large scale scenarios

Data:

Collaborative sensing with vehicles

- Move from microscopic traffic simulators to mesoscopic traffic simulators
  - For example, MatSim



Number of vehicles: 200.000
Simulated time: 24 hours
Average distance travelled: 13,9 km
Each vehicle travels two times per day
Number of street segments: > 600.000
Number of junctions: > 200.000

Takes only a few minutes of execution time

But …

Collaborative sensing with vehicles

- … to model the flow of information in large-scale scenarios, we cannot longer check multi-hop packet transmissions.

- We need a statistical model:
  - For given traffic flow (origin-destination matrices, traffic density) ….
  - … how long will the information flow need from position A to position B?

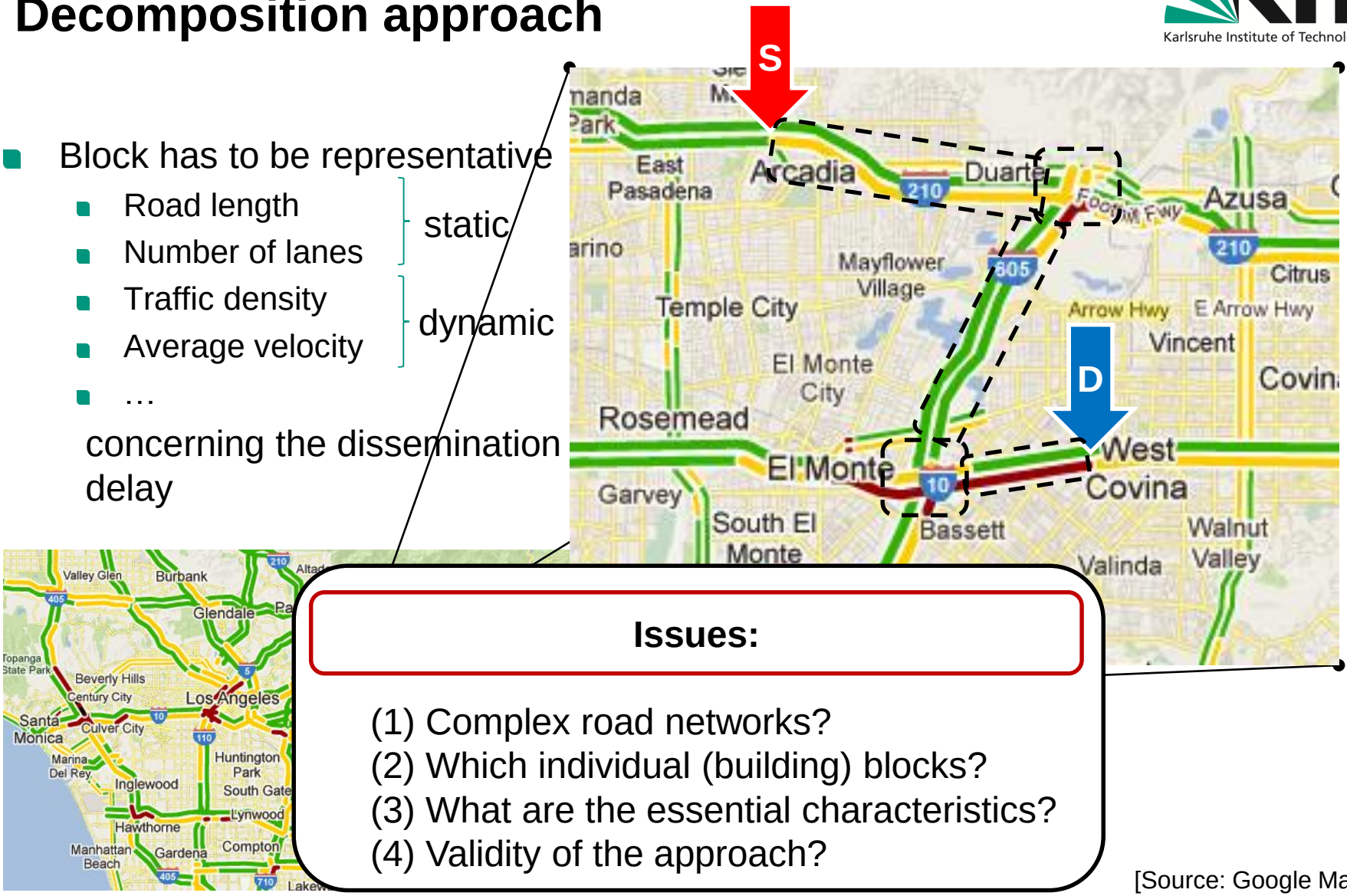
Decomposition approach

- Block has to be representative
  - Road length
  - Number of lanes
  - Traffic density
  - Average velocity
  - …

  static

  dynamic

  concerning the dissemination delay



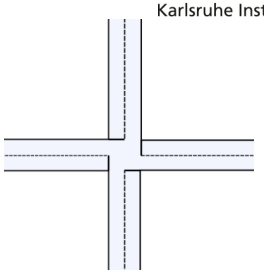
Issues:

(1) Complex road networks?
(2) Which individual (building) blocks?
(3) What are the essential characteristics?
(4) Validity of the approach?

[Source: Google Maps]

Basic blocks and considered parameters





Category	Straight road	Intersection
Layout	■ Single lane / multiple lanes ■ Opposite traffic	■ One / four inflows
Mobility	■ Velocity (fix and varying) ■ Inter-vehicle distance (equidistant, exponential, Gaussian distributed) ■ Overtaking maneuvers	■ Turning probabilities
Comm.	■ Communication Range	■ LOS/NLOS
Protocol	■ Sending Interval	

Our approach and challenge

- We have used state-of-the-art microscopic simulators (packet-level) to build consistent „mesoscopic“ models
  - “Mesoscopic”: information-centric modeling
- Now we would need actual large-scale traffic data for validation
- And here is the challenge: who has enough large-scale traffic data?

For further information:

- Characterization and Modeling of Dissemination Delays in Inter-Vehicle Communication Networks
  T. Gaugel, J. Mittag, H. Hartenstein
  Vehicular Networking Conference, Seoul, Republic of Korea, November 2012

- A Change in Perspective: Information-Centric Modeling of Inter-Vehicle Communication
  T. Gaugel, F. Schmidt-Eisenlohr, J. Mittag, H. Hartenstein
  8th ACM International Workshop on VehiculAr Inter-NETworking (VANET 2011), Las Vegas, NV, USA, September 2011

Data: challenges

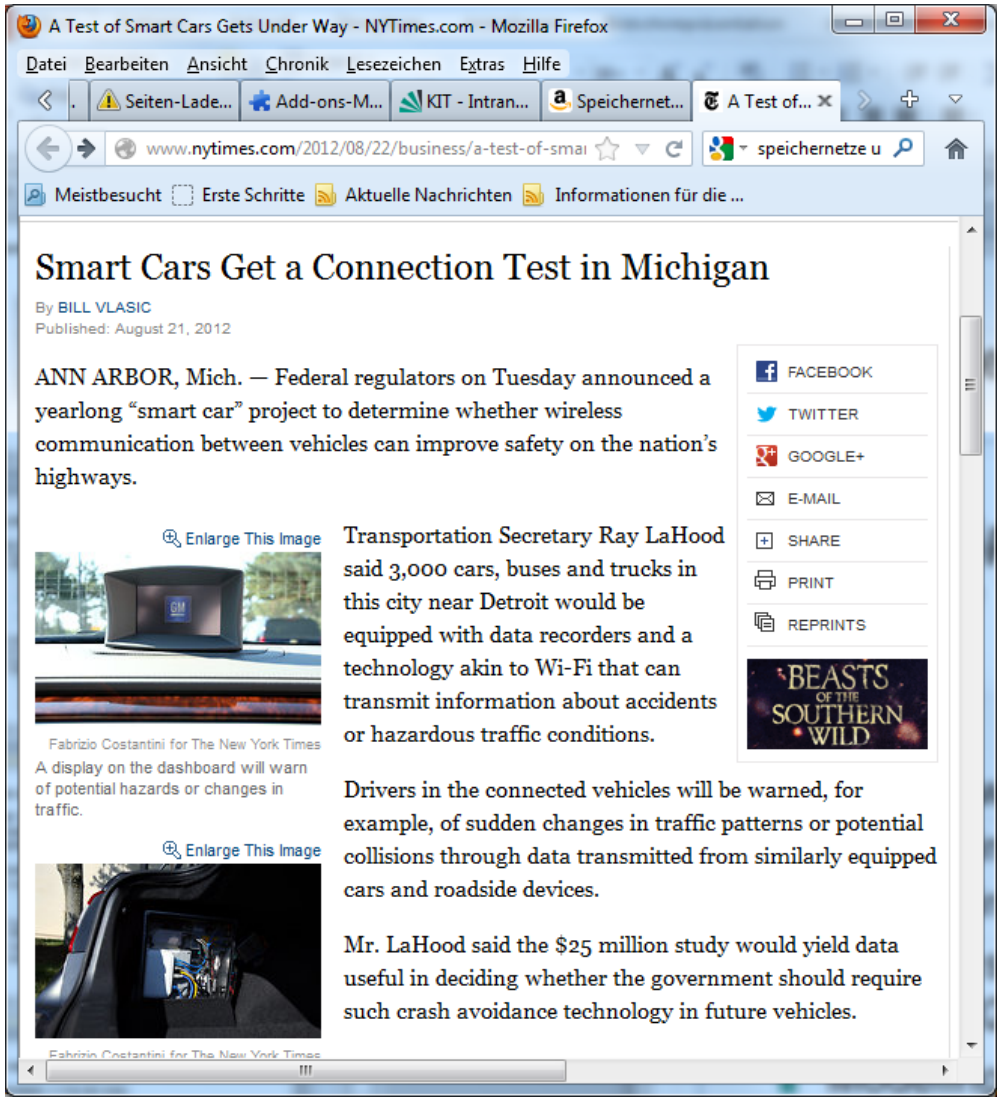
- Availability of data of field tests available („open access“) vs liability issues
- In case data is available: build consistent model hierarchy (microscopic to mesocsopic to macroscopic)

4. Deployment

- **Thesis**: Wireless vehicular communication systems are also a challenge from the IT management point of view

- **Examples**:
  Software distribution, IT security management, cloud integration

The New York Times on August 22, 2012



- "The technology is there, and now we need to deploy it intelligently," said David Cole, a founder of the Center for Automotive Research in Ann Arbor

Software distribution/updates and security

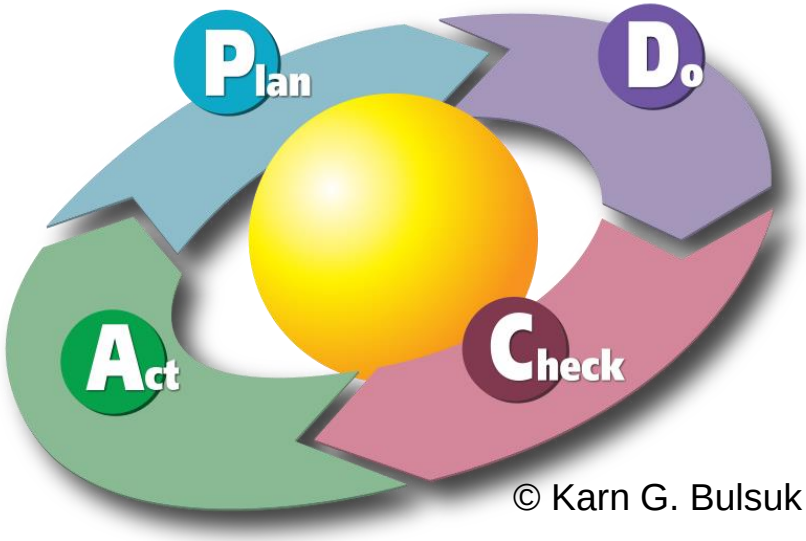
- Computing has its multi- and many-core challenge
- We have a multi- and many **operator** challenge

- How can we build systems that deal with many software versions at the same time?
- Being backward compatible and harnessing up-to-date technology?
- Who is authorized to do changes?
- Why should PKIs now take off?
- Who is certifying what?

… and some other „details“.

IT security management:

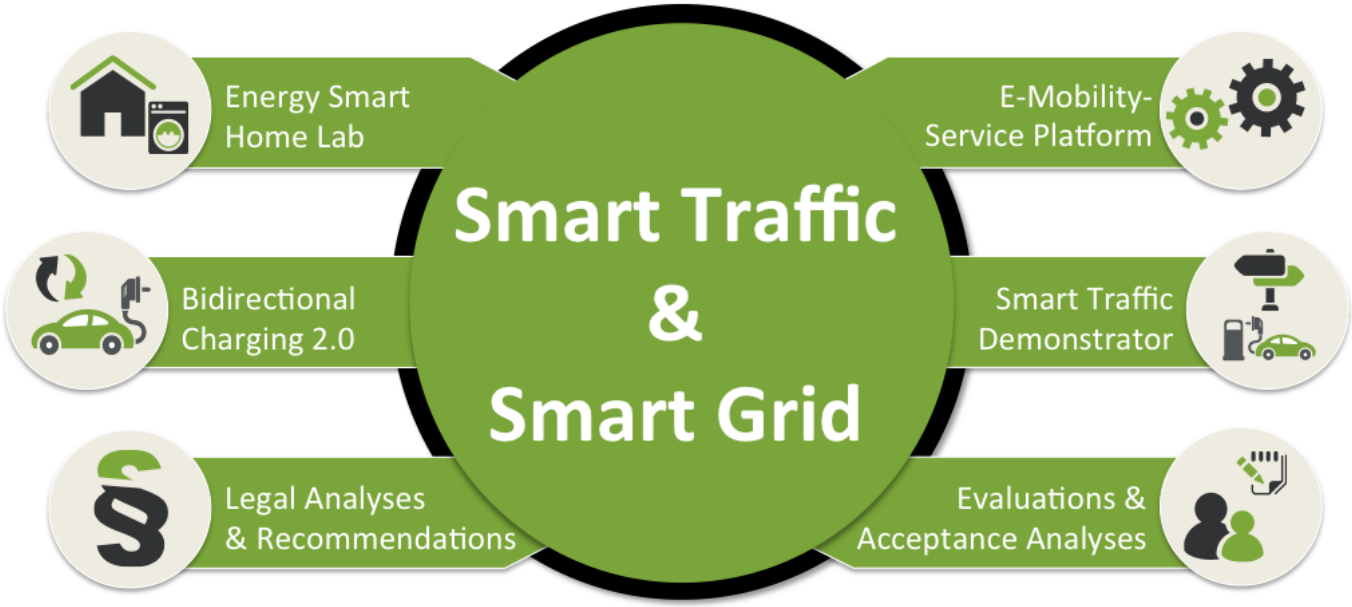
- … how to apply it in our domain?
- ISO 270xx family of standards, e.g. ISO/IEC 27001:2005 – Information technology – Security techniques – Information security management systems – Requirements → focuses on security of *an* organization or an enterprise
- … do we need an ISO 270xx standard for wireless vehicular communications?



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The Cloud issue

Data and service outsourcing in the context of wireless vehicular communication?



ICT FOR ELECTROMOBILITY

Project iZeuS

Data Outsourcing Simplified: Generating Data Connectors from Confidentiality and Access Policies

K. Jünemann, J. Köhler, H. Hartenstein

DPMSS 2012, Proc. of the 12th IEEE/ACM CCGrid 2012, Canada, May 2012

Deployment challenges

- Move WiVeC research also to an „hybrid approach to research“ combining deployment and research
- Bring together „WiVeC science“ and „WiVeC services“
- Look at IT security management and cloud issues

Summary and outlook

Focus on **application layer** protocols and their **dependability**

Open data for research/validation

Driver assistance

Data

Coexistence of deployment and research in wireless vehicular communications

Do **deep theoretical work** in this domain-specific field

Deployment: **IT and security management**

Depth

Deployment

Referenced papers can be found at **http://dsn.tm.kit.edu**