

# **Analysis and Design of Effective and Low-Overhead Transmission Power Control for VANETs**

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# I. Motivation

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## » What are the key factors for stressed channel conditions?

- communication pattern of vehicles
- number of vehicles participating in the network



### Periodic Status Messages

- » One-Hop broadcast
- » Resulting network load depends on
  - transmission rate
  - transmission power



### Event-driven Safety Messages

- » Multi-Hop broadcast
- » Efficient dissemination techniques

# I. Motivation

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## » Capacity of multilane highways with speed limit 100 km/h

Level Of Service	Density (vehicles/km/lane)	Average Speed (km/h)	
<b>A</b>	<b>0 – 7</b>	<b>100.0</b>	<b>free flow conditions</b>
<b>B</b>	<b>7 – 11</b>	<b>100.0</b>	<b>reasonable free flow</b>
<b>C</b>	<b>11 – 16</b>	<b>98.4</b>	<b>reasonable free flow</b>
<b>D</b>	<b>16 – 22</b>	<b>91.5</b>	<b>stable traffic operation</b>
<b>E</b>	<b>22 – 25</b>	<b>88.0</b>	<b>unstable traffic</b>

Highway Capacity Manual 2000, Transportation Research Board

## » Without or at higher speed limits the average speed even increases

# I. Motivation

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## » Expected network load, assuming

- avg. periodic message size: 400 bytes
- 6 lane highway
- transmission rate: 10 messages/sec

Density (vehicles/km/lane)	Transmission Power			
	20 dBm	15 dBm	10 dBm	5 dBm
25	10.18 Mbps	7.64 Mbps	5.73 Mbps	3.46 Mbps
22	8.95 Mbps	6.72 Mbps	5.04 Mbps	3.04 Mbps
16	6.51 Mbps	4.89 Mbps	3.67 Mbps	2.21 Mbps
11	4.48 Mbps	3.36 Mbps	2.52 Mbps	1.52 Mbps
7	2.85 Mbps	2.14 Mbps	1.60 Mbps	0.97 Mbps

↑  
default power

# I. Motivation

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## » On the one hand

- using default power of 20 dBm in medium and high densed traffic situations exceeds available bandwidth of 3 Mbps or 6 Mbps
- if DSRC channel synchronization and coordination is applied, the available bandwidth for safety might be further reduced

## » On the other hand

- in low densed traffic situations the available bandwidth is not exceeded when using default power of 20 dBm

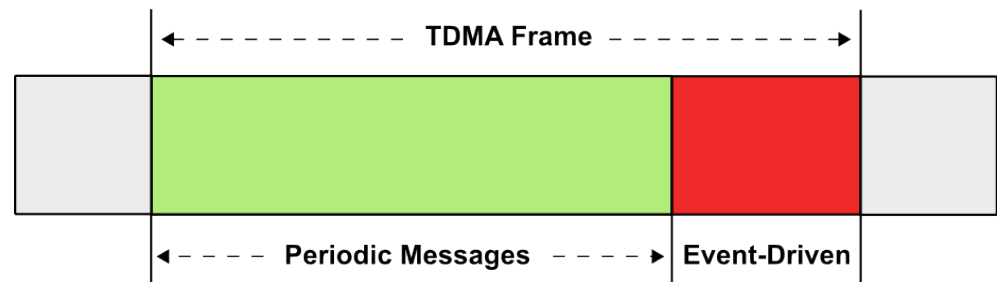
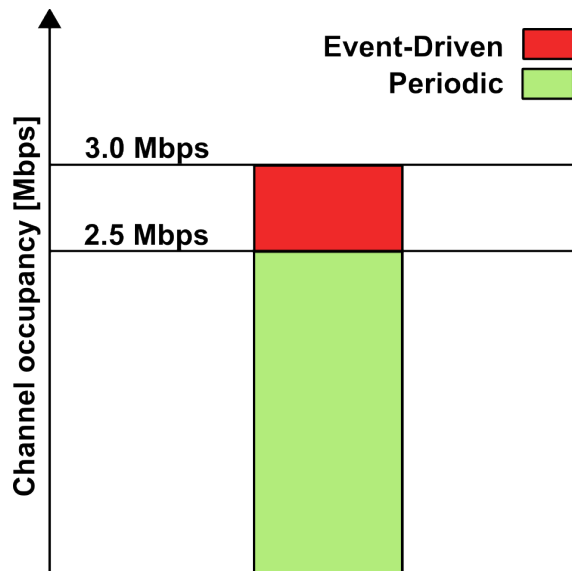
» **We need to adjust the transmission power dynamically in order to adapt to different traffic situations**

» **By adjusting the transmission power, we are able to exhaust the available bandwidth in every traffic situations**

# I. Motivation

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- » Traffic of periodic status messages should be upper bounded to “reserve” bandwidth for high priority event-driven messages
  - explicit differentiation between periodic and event-driven messages
- » In 802.11 with CSMA , no trivial strict separation, e.g. as in TDMA, possible



# I. Structure of this talk

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» Basics

» Fundamental Limitations

» Sensitivity Analysis: Accuracy vs. Overhead

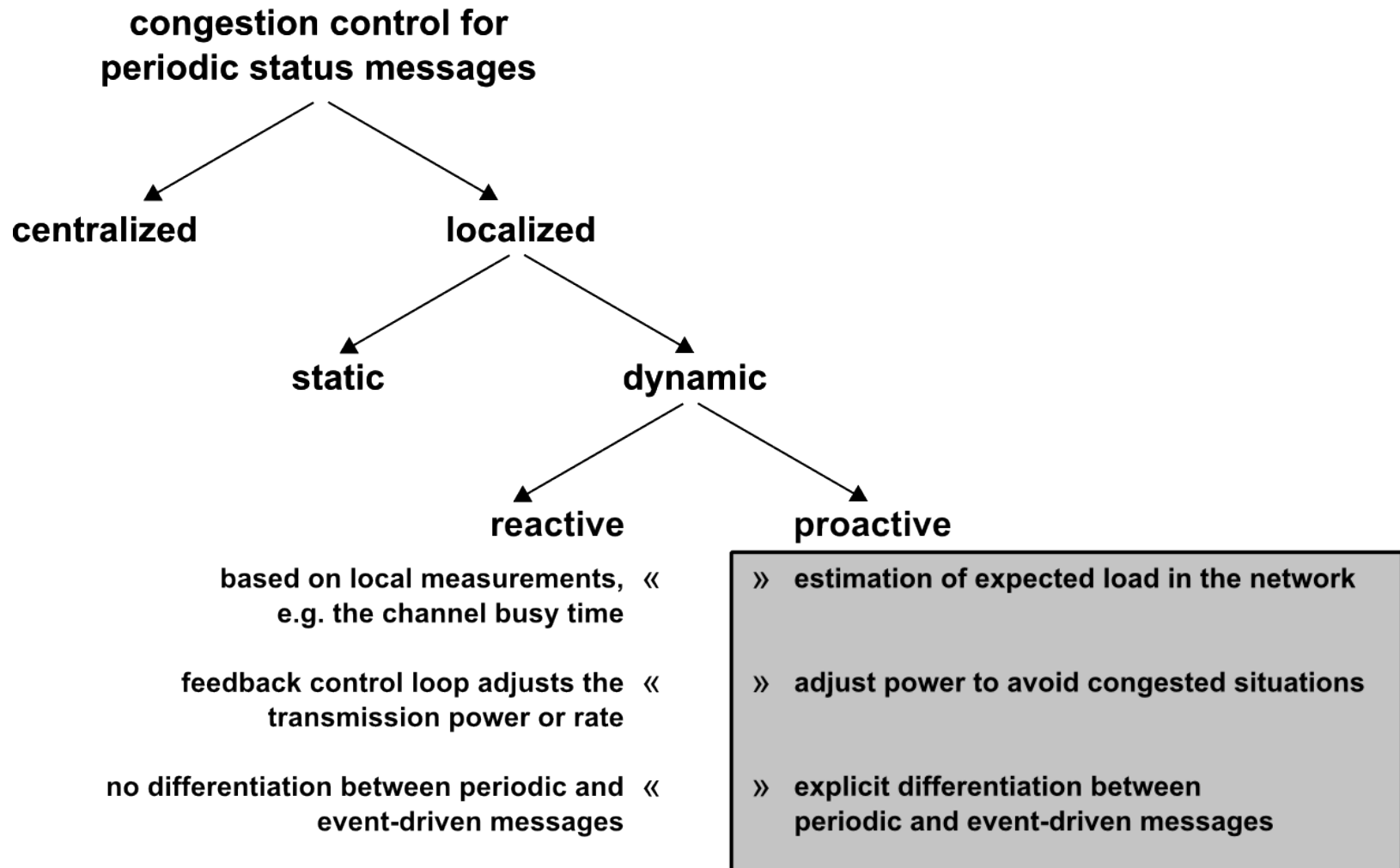
» Effective & Low-Overhead Congestion Control

» Results

» Conclusions

## II. Basics – Taxonomy

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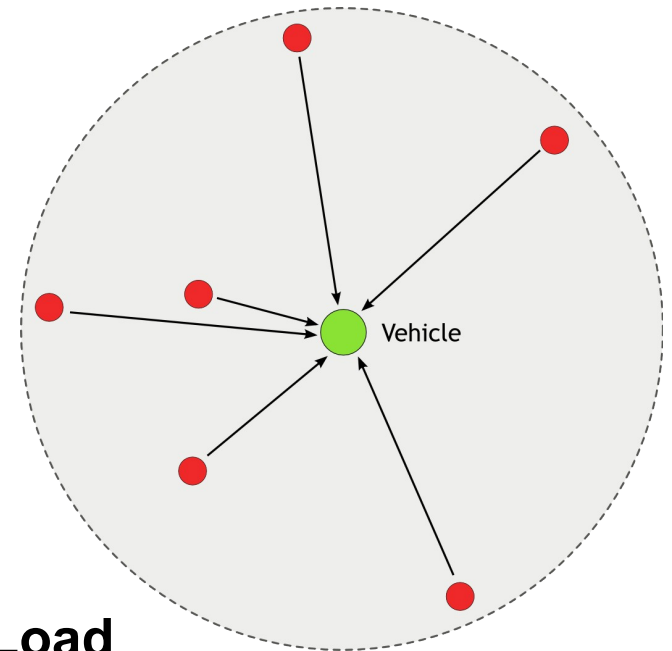
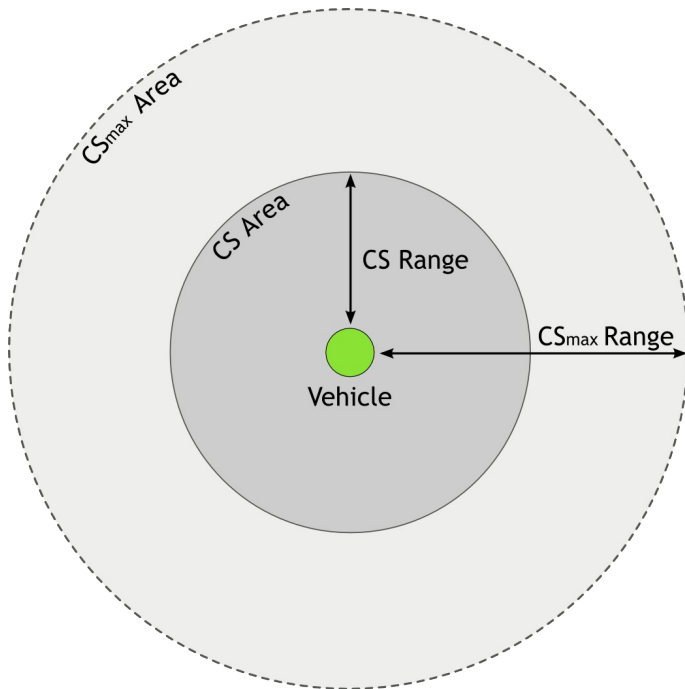


## II. Basics – Terms & Concepts

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### » Carrier Sense Range (CSR) and Carrier Sense Area (CSA)

- at maximum transmission power
- with adjusted power



### » **Beaconing Load**

- sum of all periodic status messages (in Mbps) sensed by a vehicle during a time interval  $t$ , e.g. 1 second

### » **Overhead**

- additional communication which is performed to enable the congestion control

## II. Basics – Objectives

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- » **Limit the beaconing to a network-wide Maximum Beaconing Load (MBL)**
  - Reserve a portion of the available bandwidth for high-priority event-driven messages
- » **Share the bandwidth for beacons under fairness constraints among vehicles**
- » **Maximize the beacon transmission power without violating the MBL and fairness constraints**

**The only existing protocol which has been proven to achieve these objectives is called D-FPAV**

## II. Basics – Problem Statement

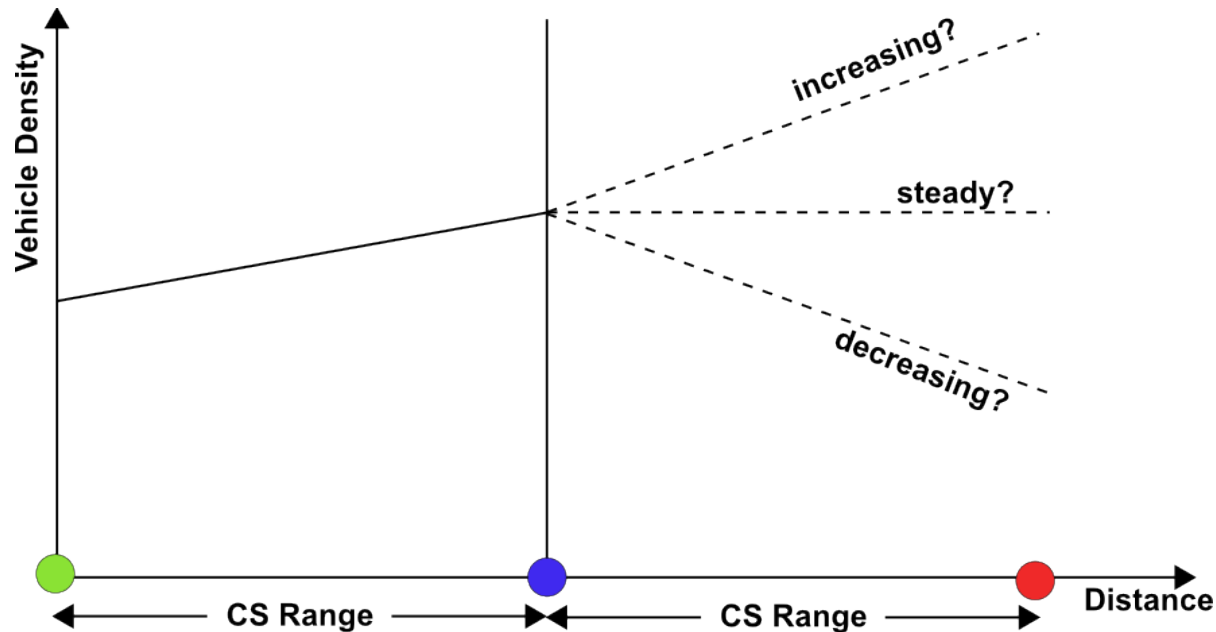
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- » **D-FPAV explained: every vehicle determines its transmission power by**
  - 'virtually' increasing the power level of each surrounding vehicle step by step
  - estimating the resulting beaconing load in the network after each step
  - as long as the MBL constraint is not violated at any vehicle
  
- » **Core: load estimation process**
  - The better D-FPAV estimates the load, the better its effectiveness
  
- » **D-FPAV is a proactive protocol, however, it suffers from a huge overhead**

**Is it possible to design an effective power control mechanism with less overhead?**

### III. Fundamental Limitations

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» In order to estimate the load at the **blue vehicle** correctly, the **green vehicle** has to know

- Who else is interfering at the blue vehicle, e.g. the **red vehicle**
- By which extent those vehicles interfere, e.g. how many bytes/sec

» To provide this knowledge every vehicle has to periodically broadcast a list of known neighbors

## IV. Sensitivity Analysis: Accuracy vs. Overhead

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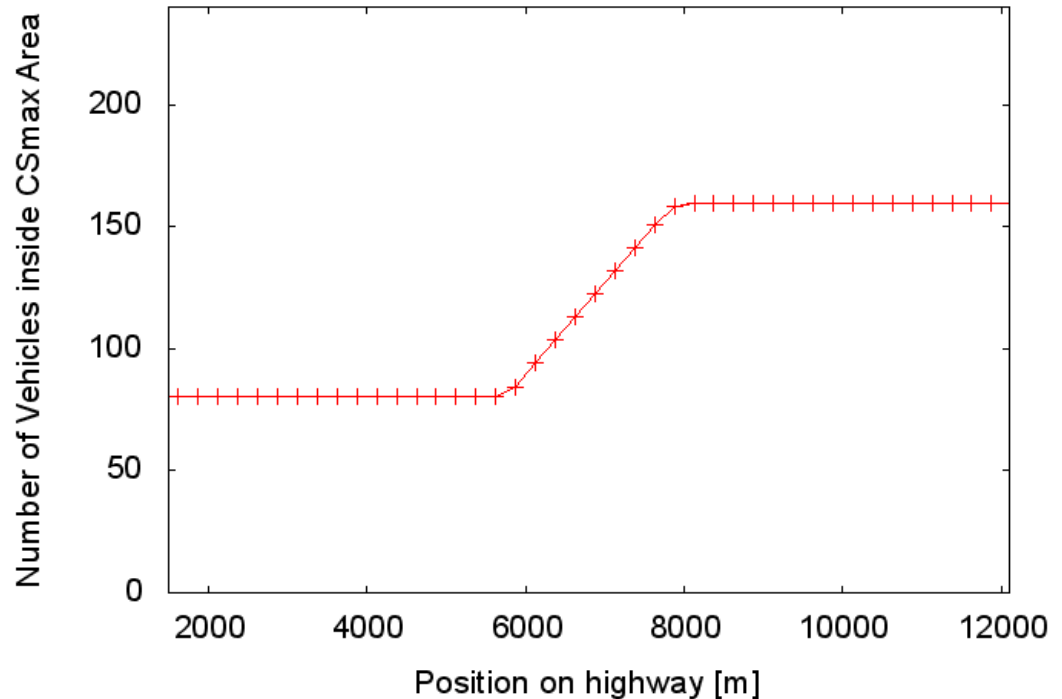
- » In theory, a worst-case knowledge of up to 3 maximum CSR is necessary for proper load estimation
- » How sensitive is the estimation accuracy w.r.t available or used knowledge
- » We looked at the following aspects
  - Impact of different communication overheads
  - Impact of different amounts of used knowledge
  - Impact of inhomogeneous traffic density areas
  - Impact of realistic propagation models (TRG vs. Nakagami)
- » Due to time restrictions: we will look at the first 3 impacts now

# IV. Sensitivity Analysis: Accuracy vs. Overhead

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## » Framework

- ns-2.31
- overhauled Mac/Phy
- 802.11p with 3 Mbps
- MBL: 2.5 Mbps
- 32 power steps

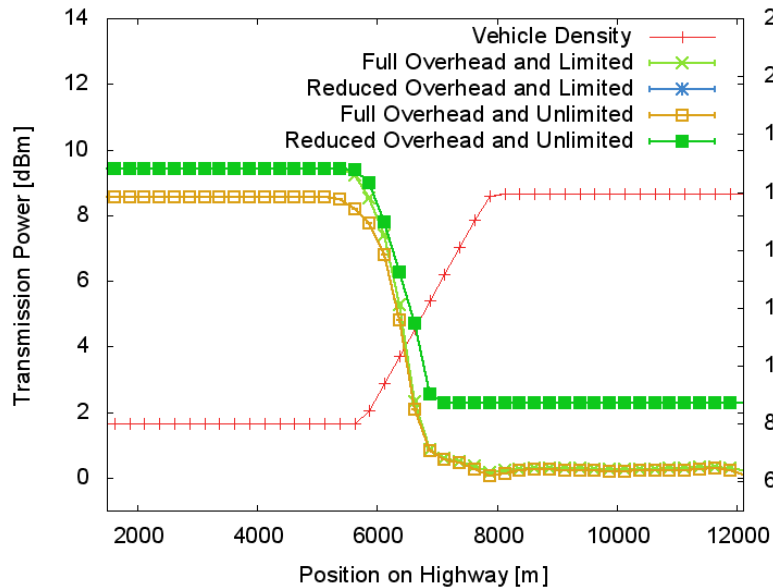


## » Simulation Scenario

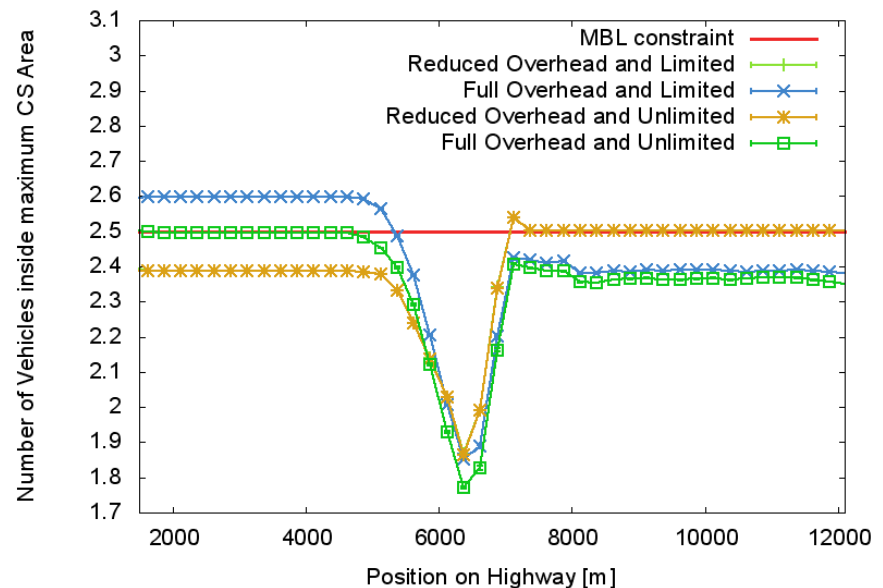
- Homogeneous area with 80 vehicles inside maximum CSA
- Homogeneous area with 160 vehicles inside maximum CSA
- Transitional area with increasing number of vehicles inside maximum CSA

# IV. Sensitivity Analysis: Accuracy vs. Overhead

## » Transmission Powers and Beconing Load when assuming Two-Ray Ground radio propagation



TxPowers w.r.t Highway Position



Beacon Load w.r.t Highway Position

## » More realistic radio propagation models did not break the effectiveness (see our paper)

# IV. Sensitivity Analysis: Conclusions

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## » Conclusions of the Sensitivity Analysis

- It is possible to reduce the overhead
- However, slight MBL violations can not be avoided
- Still, amount of overhead is not negligible (around 15%- 20%)

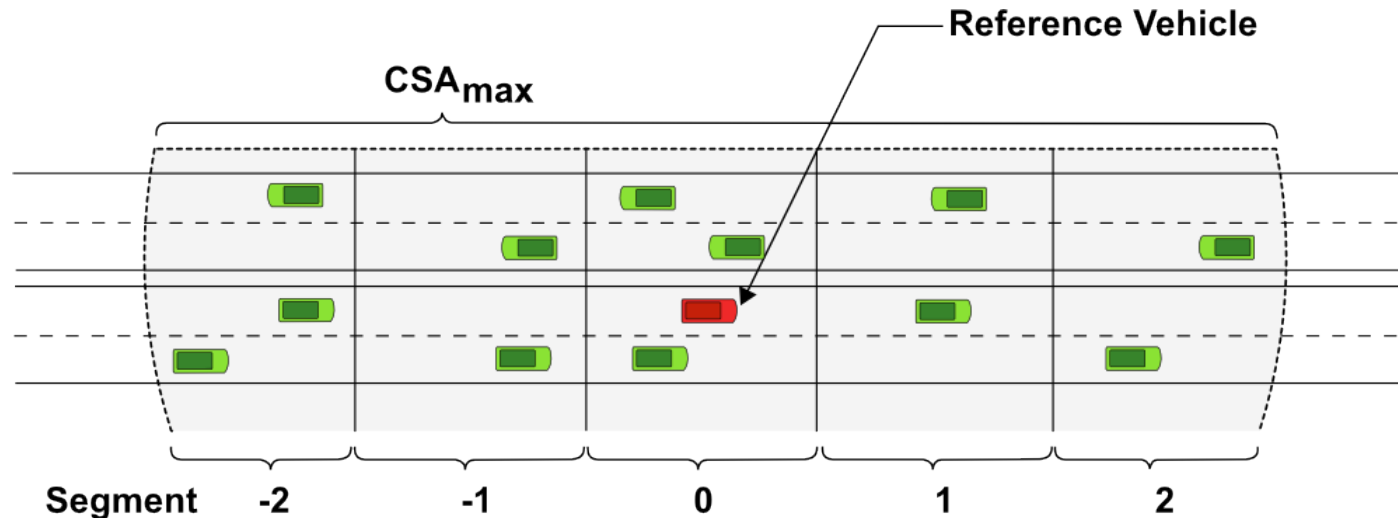
» **Idea: further reduction of overhead might be possible by using macroscopic knowledge to estimate the load**

» **Proposal:**

**Distributed Vehicle Density Estimation  
+  
Segment Based Power Ajustment in VANETs**

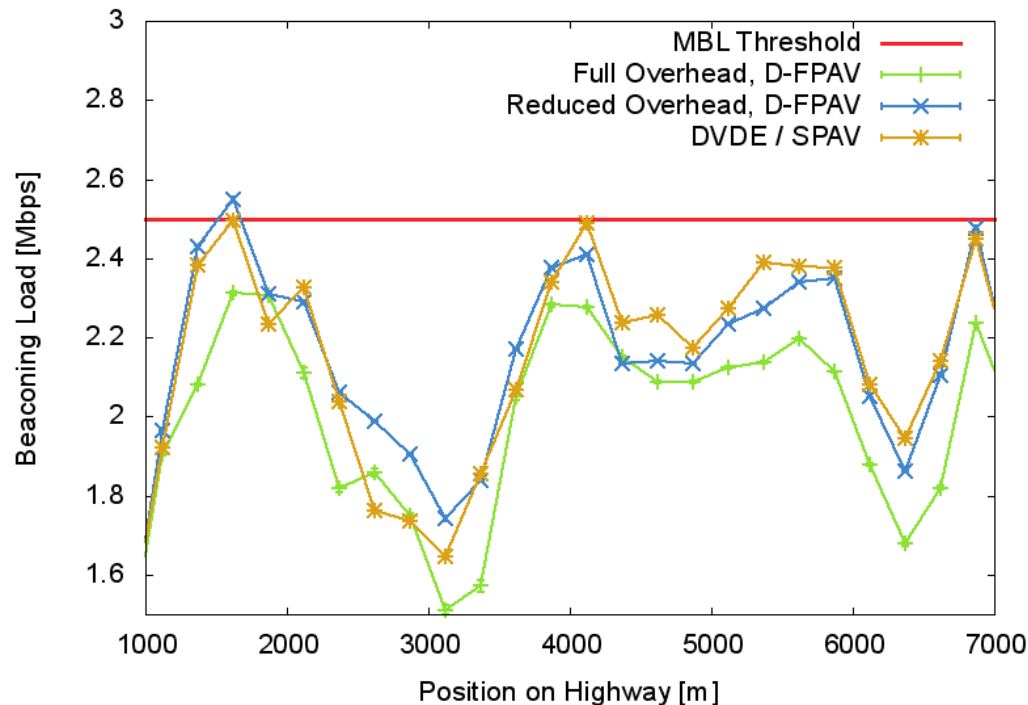
# V. Effective & Low-Overhead Congestion Control

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- » Every vehicle periodically derives a local view of surrounding traffic densities and piggybacks it in a status message
- » By merging local and all received views, each vehicle obtains a distributed estimation of surrounding vehicle densities
- » Use distributed vehicle density estimation for the load estimation process

# VI. Results

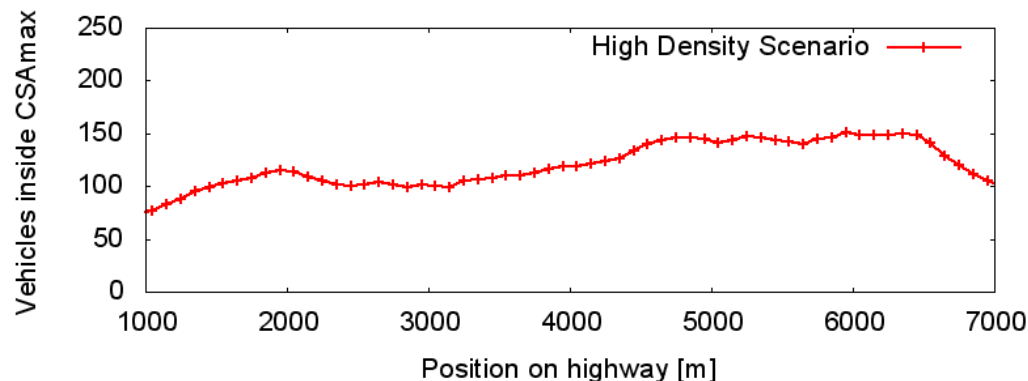


## » We compared

- D-FPAV with full and reduced overhead
- DVDE/SPAV with 21 segments per view

## » Scenario

- German highway
- 3 lanes per direction
- avg. speed: 121 km / h
- 10 messages / sec
- 500 byte / message



## » Overhead

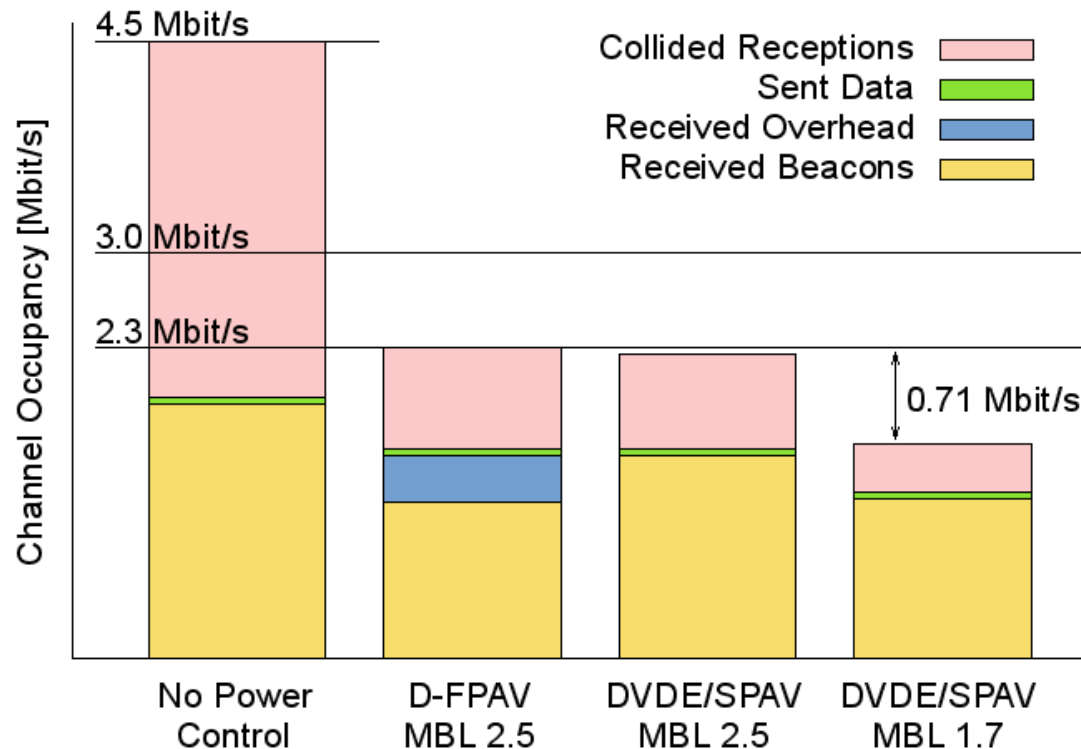
- D-FPAV: 18 - 41 %
- DVDE: less than 1 %

# VI. Results

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## » What is the benefit of this significant reduction?

- Use higher transmission powers to increase mutual awareness between vehicles while staying below the same MBL
- Reserve a larger portion of the bandwidth for event-driven messages



# VII. Conclusions

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## » Conceptual Aspect

- To guarantee a network wide MBL, precise positional information beyond the communication range is needed
- The required overhead to provide this information might not scale in VANETs
- We see D-FPAV as a conceptual reference mechanism

## » Engineering Aspects

- By making a tradeoff between accuracy and overhead, it is possible to limit the overhead
- However, slight MBL violations have to be accepted

## » Benefit

- We can use higher transmission powers
- Reserve more bandwidth for event-driven messages or other applications