A Framework for Network Utility Maximization in VANETs

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Motivation

- Increase traffic safety by direct message exchange between vehicles ("active safety applications")
- In addition: applications for added driving comfort, entertainment and information ("deployment applications")

Challenges

- Different application requirements concerning e.g. latency and dissemination area in respect to supporting different aspects of the driving task:

Driving task		**Latency**	**Dissemination area**
Navigation	Selecting a route	easy	large
Guidance	Keeping a vehicle within the street course, obeying traffic signs and laws	medium	medium
Stability	Operating pedals, steering wheel	hard	small

Table 1: *Subtasks of the driving task with opposing requirements*

- Precedence of active safety applications over deployment applications
- Different scenarios: dense and sparse networks
- Network bandwidth is scarce

Solution approach

- Estimate the utility of an information
- Prioritize information based on its relevance
- Apply *Network Utility Maximization* [1] techniques

System concept

New paradigms

- Altruism:
  Utility gain at the receiver-side is basis for the optimization
- Joint Fairness:
  Only information with the lowest utility is most likely to starve
- Application-oriented information differentiation:
  Utility estimation is performed on a per-application basis
- Utility estimation based on different context parameters and utility estimation functions

$$\hat{U} = \frac{\sum_{i=1}^{I} c_i \cdot f_i}{\sum_{i=1}^{I} c_i}$$

where f_i are application-specific functions based on context parameters and c_i are weighting factors.

Context	**Description**
Expectation	Probability that the event exists as described
Distance	The current distance to the detected event
Prev. knowledge	Probability that neighboring vehicles have already knowledge about a specific information
Concern	Concern of other vehicles in this information
Impact	Pot. impact of the described event on the driver
Message age	Time passed since the message was created
Last broadcast	Time passed since the message was broadcasted
Last reception	Time passed since the message was received
Forwarder distance	Distance to the last forwarder of the message
Road position	Special road position
Heading	Heading for determination of opposite lanes
Connectivity	Current connectivity of the VANET
Coverage	Area that a broadcast by the vehicle would cover

Table 2: *Possible context parameters*

- Scheduling

1. Internal contention process within a vehicle ("*Intra-vehicle scheduling*")
2. Continuous packet reorganisation
3. Utility-based medium access ("*Inter-vehicle scheduling*")

Architecture

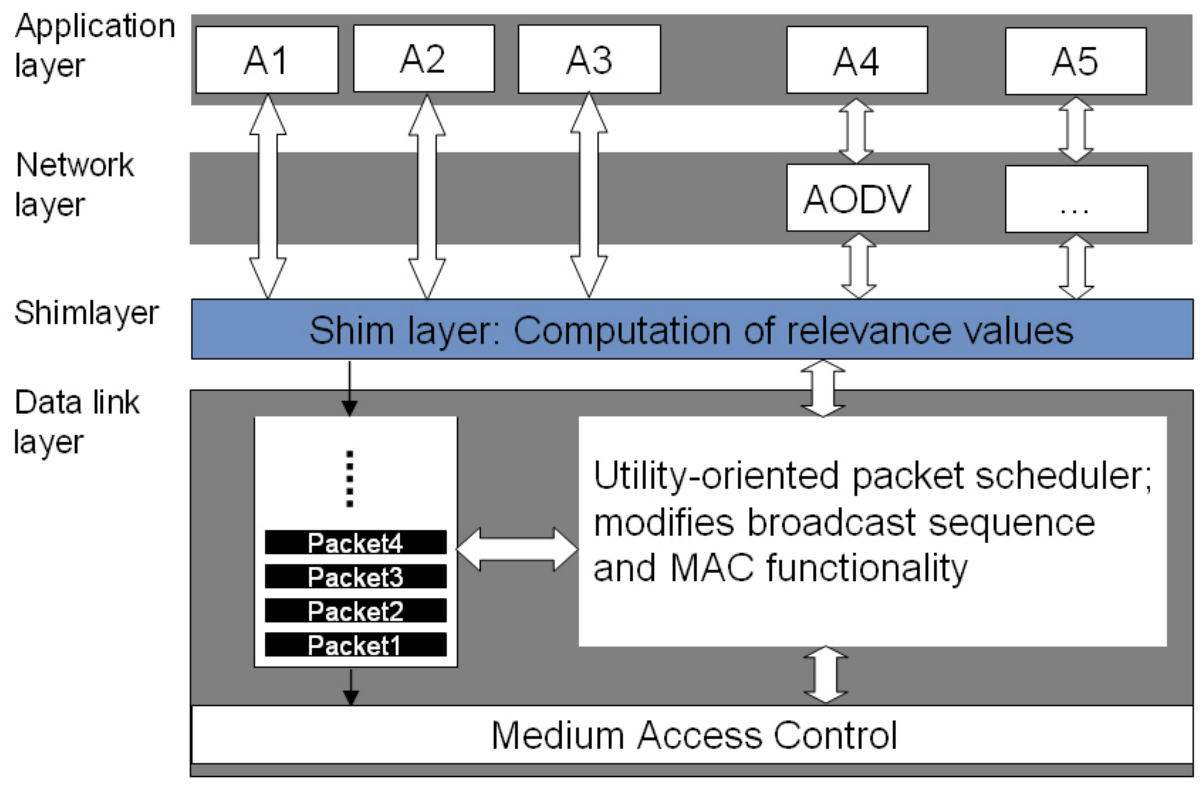
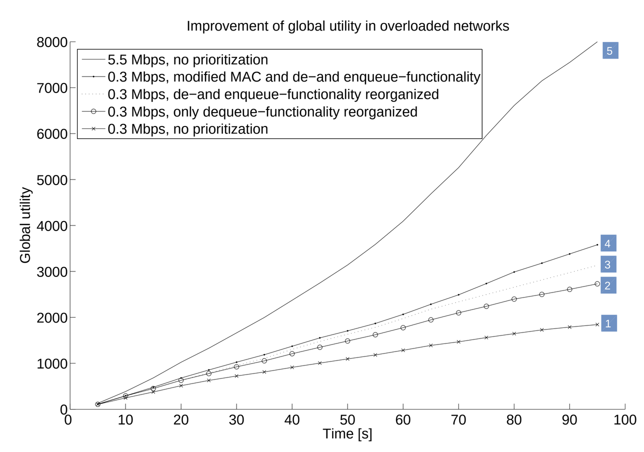


Figure 1: *Cross-layer architecture*

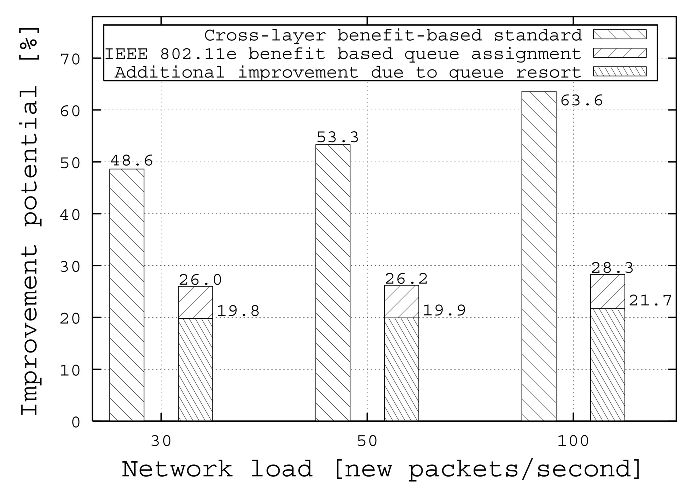
- Cross-layer-design
- Shim layer continuously calculates utlity values
- Possibility of mapping other solutions like CBF or other routing protocols like AODV to a utility function, thus integrating other solutions
- Adapted MAC layer taking into account utility estimations
- Possible alternative: 802.11e architecture?

Simulation Results

- NS2
- Area: 8km^2
- 300 vehicles
- Communication range: 400m



(a) Optimization potential



(b) Comparison with 802.11e

Figure 2: *Improvements towards the theoretical optimum*

Disadvantages of the 802.11e architecture

- No internal queue reorganization
- No utility re-evaluation according to actual application-level data
- Only rough priority gradation of packets
- 802.11e fairness rules avoid packet starvation, which may not be optimal with regard to VANET objectives

Conclusion

- Introduction of an utility-oriented, altruistic approach
- Comprehensive, integrating framework for efficient use of network resources
- Application-oriented data differentiation
- Applicable in both early and mature states of VANET deployments

References

[1] F. P. Kelly, A. Maulloo, and D. Tan. Rate control for communication networks: shadow prices, proportional fairness and stability. In *Journal of Operations Research Society, vol.49, no.3*, pages 237–252, 1998.

[2] C. Schroth, M. Strassberger, R. Eigner, and S. Eichler. A framework for network utility maximization in vanets. Technical Report LKN-TR-1, Institute of Communication Networks, Technische Universität München, August 2006.

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