Report Dagstuhl Seminar 10402
Working Group on Fundamental Limits and Opportunities

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Abstract

This working group investigated first steps towards finding a theoretical foundation for inter-vehicle communication. The main outcome is a sketch of a roadmap for future work in this direction.

1 Introduction and Motivation

There has been a lot of work on inter-vehicle communication during the past decade. Both academia and industry have spent significant resources to explore suitable technologies, protocols, and applications. Currently, large-scale field operational tests are under way and standardization bodies are reasonably close to finalizing a first set of standards. However, surprisingly little is known about the fundamental limitations and opportunities of inter-vehicle communication from a more theoretical perspective. We do not have a good understanding of how many accidents are theoretically preventable or to which extent resources (like fuel or travel time) could be saved by optimal communication between vehicles. We do not even have definite knowledge about whether there exist any situations at all that require communication in order to, for example, avoid an accident—or whether just relying on input from local sensors in the individual cars is, in the end, more effective and/or more efficient. It was the goal of this working group to explore first steps towards a theoretical foundation of inter-vehicle communication.

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2 Results

We started our discussion with stating the key objectives of inter-vehicle communication. We believe that they are twofold: avoiding accidents and minimizing resource usage. We therefore decided to use loss of efficiency and the probability of having an accident as the axes of our solution space. This is depicted in Figure 1, which was produced during our discussion. Please note that the origin of the solution space is the spot where one "wants to be": no accidents and minimum resource usage.

After a brief discussion we realized that for any given technology those two objectives are not independent from each other. For example, one could prevent all car accidents by simply not traveling by car at all. However, this would not be very efficient in terms of travel time. Any technology would therefore be a curve in this solution space, describing the achievable tradeoff between efficiency and safety.

We then proceeded to identify curves in that solution space that might be of interest. First, we pictured a perfect world where every vehicle is omniscient—that is, it has all information on everything that is relevant to it instantaneously available. There might still be inevitable accidents, but the resulting curve would be optimal in the design space: any practical technology will have less accurate knowledge and thus cannot achieve better results. This curve is interesting since it is a good benchmark: if we can get close to it, then we do have a good solution for inter-vehicle communication.

The second curve that is of interest is the information-theoretical optimum, given a certain communication channel. Points on that curve can be realized even though information exchange between cars is constrained by a limited channel, if it is assumed that this channel is used optimally. This curve will certainly be above the first one, because there is no perfect knowledge about the environment readily available at any point in time, but instead only the information that can possibly be provided if optimal use is made of the given channel. Nevertheless, this is still a (potentially unreachable) optimum for all practical systems.

We then took a step back and thought about the best possible curve without using any communication between vehicles at all. The available information would be local only, measured by the sensors in each car.

In order to show that inter-vehicle communication makes sense, one would have to prove that the curve indicating real-world inter-vehicle communication is below the curve where no communication is required. This is a challenge! We also discussed that if wrong (intentionally or not) information is transmitted via inter-vehicle communication, the situation might become arbitrarily bad. In particular, it might become worse than it is today without any communication and without an optimal local sensor-only solution.

We are very much aware that this is essentially just a very high-level structuring of what needs to be done. We consider the next steps to be very challenging. They will mainly consist of stating how the curves mentioned above look like for some real applications and scenarios. We strongly believe that this effort is indeed worthwhile, since it would allow us to understand what we may actually gain from inter-vehicle communication.

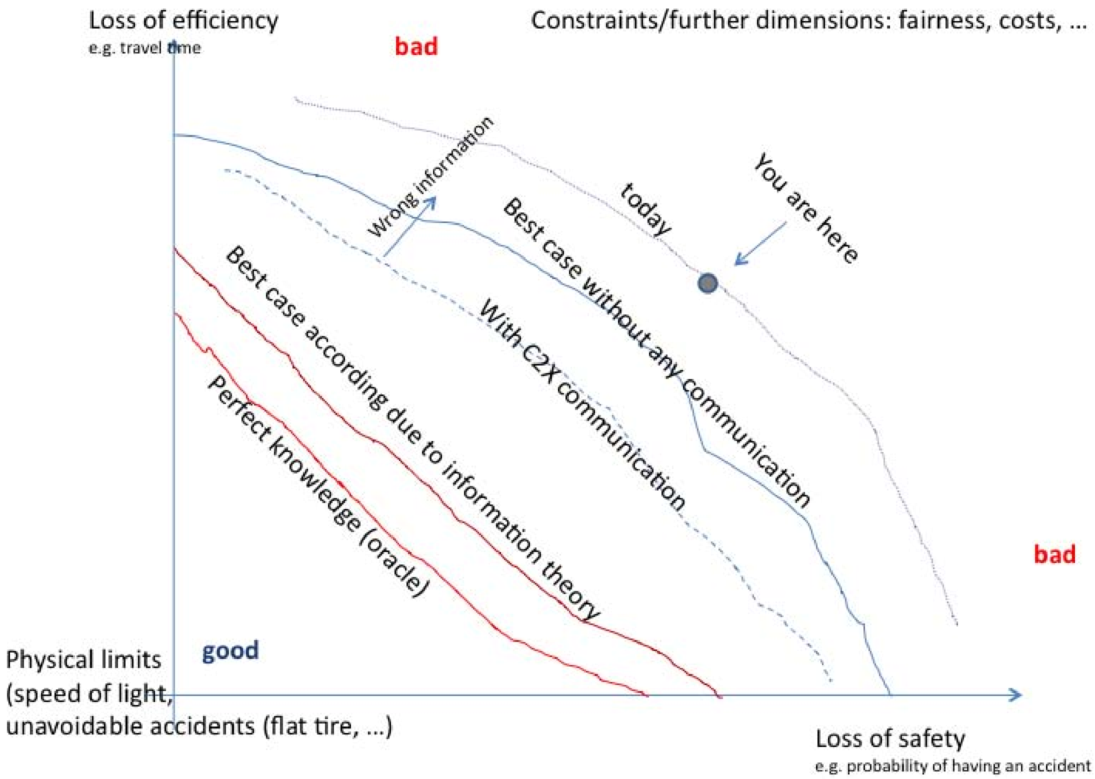

Figure 1: The design space of inter-vehicle communication.