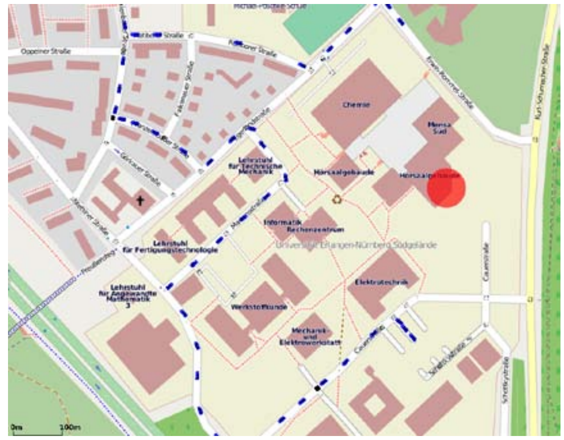
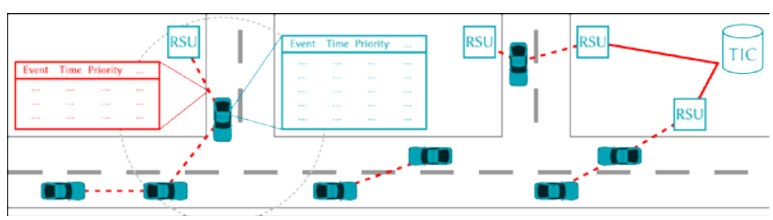
Master's Thesis

# A multi-channel beacon scheduling system for the exchange of traffic information in vehicular networks

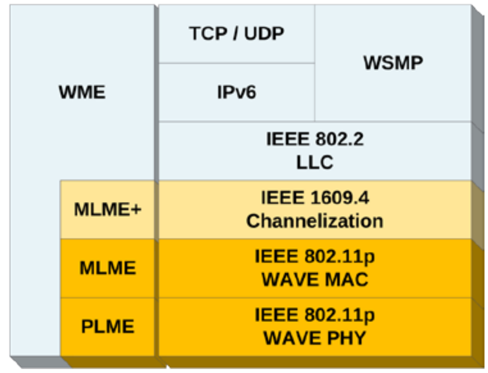


Intelligent Transportation Systems (ITS) are a promising solution to today's problem of ever increasing volumes of road traffic. Early approaches to information exchange between vehicles relied solely on the creation of an ad hoc network on the road, adapting protocols known from the related domain of Mobile Ad Hoc Networks (MANETs) and updating them for highly mobile networks. However, it turned out that this straight-forward approach suffers from scalability problems. More recent approaches in the vehicular communication domain, which are typically termed Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), or Car-to-X communication, have extended this to incorporate the exchange of knowledge via broadcast or using peer-to-peer like systems.

We are mainly interested in broadcast-based approaches, specifically relying on periodic beaconing. Using this approach, vehicles will, at regular intervals, consult a local knowledge base for information which may be of interest to surrounding vehicles. They then broadcast this information and, in turn, incorporate received messages into their knowledge base. ITS rely on accurate and timely information to enable informed decisions for routing and accident prevention. A major challenge that periodic beaconing approaches face is incorporating the needs for both delay-sensitivity and congestion awareness. In other words, a protocol for ITS has to always trade channel load for speed of information dissemination – a tradeoff which should be optimal for any combination of traffic density, penetration rate, and network utilization. It has been discovered that in vehicular networks any such combination of environmental and network parameters can manifest within a single day's time.




Addressing these issues, we have designed the Adaptive Traffic Beacon (ATB) protocol, which is adaptive in two dimensions: network conditions and infrastructural support. ATB uses a variable beacon period, which dynamically adapts the frequency of information exchange to a wide range of parameters such as vehicle density, vehicles' speed, radio communication reliability, and delay. These parameters are the basis for two key metrics to form indicators of channel quality and message priority. To enable flexible use of infrastructure elements, ATB is able to rely on fully decentralized information exchange among participating vehicles. In addition to that, ATB may also automatically make use of available infrastructure, starting with simple Stationary Support Units (SSUs) that serve as stationary members of the network, to intelligent Road-Side Units (RSUs) that participate in the ATB network, as well as using a separate (e.g., wire-bound) backbone, which can in turn be connected to one or more traffic information centers. The buildup and exchange of heterogeneous knowledge bases and, hence, message prioritization, are envisioned as a core features of ATB.




For message transmissions in vehicular networks, the emerging IEEE 1609 Wireless Access in Vehicular Environments (WAVE) standard provides a complete protocol stack covering protocols from the data link layer to the physical layer. The WAVE stack is based on IEEE 802.11p, which is in turn loosely based on WiFi (IEEE 802.11a/b/g), but is specially geared towards vehicular environments, e.g. using 16 QAM on 10 MHz channels with relatively slow data rates. It can thus support high relative speeds and long ranges of operation even in adverse multipath environments. The WAVE employs EDCA functionality based on that of IEEE 802.11e and an OFDM scheme using one control channel and six data channels. This way, both coarse-grade and fine-grade message prioritization can be guaranteed and enforced, respectively.

Currently, our implementation of ATB is using an unmodified WiFi stack for radio communications. Thus, it assumes that all transmissions have to compete for a single channel, handling all prioritization of messages purely at the application layer. In the context of this thesis, the first aim is to study ATB's channel and message priorities and how to take advantage of the enhanced message prioritization mechanisms provided by the WAVE stack. Message sending will therefore have to consider a classic scheduling problem, namely which parts of the local knowledge base to assemble into a single beacon, what priority to assign to the beacon, and when to send it on which of the available channels. After designing the enhanced scheduling algorithms, the objective is to extend the ATB protocol and the corresponding C++ simulation model of ATB. Following this, the design and implementation need to be evaluated in a set of simulation scenarios. Their basic functionality will be asserted in simple, artificial setups and the final implementation compared to that of the single-channel-based approach used in earlier evaluations of ATB.

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