Replication of Local Road Networks for Regional Information Dissemination in VANETS

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Abstract - Conceivable applications that are based on inter-vehicle communication include the distribution of warning messages, traffic flow information, or communication with road signs and traffic lights. An outstanding characteristic of these applications is the regional relevance of the information that is distributed by the nodes. In this paper a novel addressing technique is presented that is based on a reproduction of the relevant area using interpolation points. The approach is not restricted to specify the region but additional parameters like the affected moving direction can be determined. The applicability of this concept is demonstrated by means of an intersection assistant that has been implemented.

1 Introduction

Within the last years, wireless car-to-car- and car-to-infrastructure-communications (C2X-communications) has drawn high attention from the Intelligent Transportation Systems (ITS) community. This trend is reasoned by the great expectations on C2X-based active safety applications in terms of reducing the number of road accidents or their severity.

Future C2X-networks constitute so-called *vehicular ad hoc networks* (VANETS) that operate in a decentralized manner and do not rely on existing infrastructure. Since the C2X-nodes are in general mobile, there is a continuous change of the network topology. Furthermore due to the limited communication range of each unit the overall network consists of a varying number of ad hoc network partitions.

Since the regional relevance of information is an essential characteristic of multiple C2X-applications it is important to provide means for an appropriate description of the addressed region. For instance in case of traffic jam warnings, messages are primarily intended for vehicles that will directly be affected by this situation, i.e. approaching vehicles on the same lane. Other fundamental scenarios include the communication between traffic infrastructure and vehicles. Imagine for example a traffic light that is enabled to disseminate information about its current state to approaching vehicles. In this case it is also necessary to specify the affected road and driving direction. However, this task can be difficult in realistic traffic scenarios, since the mobile nodes may be hundreds of meters away when they receive the information and the roads are in general no straight lines. Consequently it is a challenging issue for vehicles to evaluate the relevance of the received information. The concept presented in this document intends to cope with these problems as it allows to reshape the affected road and thus enables vehicles to determine the relevance of the received information

This paper is organized as follows: After this introduction, a short overview of ongoing research activities and approaches in the field of C2X-communications is given in the second paragraph. Afterwards, the new addressing scheme is presented and described in detail. Subsequently the practicability of this concept is verified by a real driver assistant application. The demonstrator application, the scenario as well as the implementation are specified and discussed in the third paragraph. Eventually the last section comprises a conclusion and outlook on further extensions of the proposed approach.

2 Related Work

Research projects in the US and Europe determined the wireless LAN amendment IEEE 802.11p [3] as basis for realizing short to medium range communication services in vehicular environments. US efforts originally addressed single-hop communication between infrastructure points and moving vehicles.

Contrary to this approach and widespread centralized infrastructure-based wireless solutions like cellular networks, European research from the outset focused on self-organizing, decentralized multi-hop ad hoc networks. These networks operate without any central instance that coordinates resource allocation and medium access or which is permanently aware of communication links between the network nodes. But rather each station simultaneously acts as a sender, receiver and relay node and is in charge of maintaining the required information on the network.

As yet recent European projects like FleetNet [1] or CarTalk2000 [7] concentrated on the evaluation and development of algorithms for position-based routing and forwarding [6] [5]. The protocols imply a position-awareness of the nodes and were intended enable networking over multiple hops to a destination node or a target area, even in environments with high node mobility. Each C2X-node regularly broadcasts so-called *beacon* messages that include position information to inform neighboring nodes about their presence and location. Additionally the position information is included in each data packet that is transmitted.

Communication that uses position information to address nodes based a region or area is called *geocast*. By now the concepts propose to use basic shapes like circles or rectangles for determining the affected region.

3 Concept for Replication of the Local Road Network

In realistic traffic settings the approach of describing the addressed region using basic shapes is often impractical since it ignores the specific characteristics of the vehicular environment. The affected region might have a sophisticated run and furthermore not all nodes in this area are concerned. The relevance is rather a matter of the actual moving direction. The concept proposed in this section faces these challenges using a basic mechanism of position caching in order to reshape the relevant street section. It is implied that each C2X-enabled vehicle is equipped with a wireless communication unit as well as a positioning system like GPS. However, there is no need for a navigation system in each car.

The approach is to locally store the sequence of the own current and recent position information for a defined period of time. Thus each vehicle has a good extract of its last driving path. This can be either a straight line (e.g. on motor-ways) a curve (e.g. on a motor-way exit or on a country road). If a situation occurs that necessitates to transfer a message to preceding vehicles like a slippery road warning, the addressing region for this message can be specified with the stored position information. The interpolation points might exemplarily have a distance of $100\,m$. The whole set can be interpreted as a strongly reduced digital map extract of the local road network of the sending vehicle's traveled route.

The decision which position information is actually stored and used for mapping is a non-trivial problem, since the number of points highly depends on the current situation. Significant properties include:

- **Shape of the road** – Different shapes of the roads require different numbers of supporting points. If the road has many curves it is necessary to save more position information for reconstruction. In contrast if the road is a straight line it might be sufficient to employ only two points.

- **Speed of the vehicle** – Vehicles that drive with a higher speed in general have to save the information in a shorter time interval as the variation of the position is higher.

Along with the interpolation points the width of the addressing region (corridor) is needed. This width can be equal for the whole set of supporting points in order to reduce the amount of data. However, it might also be necessary to specify different width parameters in case of a complicated road shape. Figure 1 shows the supporting points $X_1/Y_1, \ldots X_n/Y_n$ for an

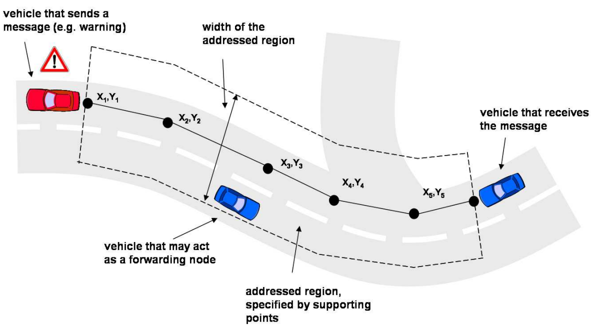

Figure 1: Visualization for the proposed addressing approach

example road. It can be seen that the distance between two points is not the same for the whole addressing region. A collection of such interpolation points together with additional information, i.e. driving directions for which the information is intended, form the addressing area that is linked to a dedicated road section. This new approach inheres several advantages that are summarized below:

- **Low Basic Hardware Requirements** – All necessary information like current position, driving direction and time can be obtained from a basic positioning system. Additionally, the memory demand can be restricted by limitation of the maximum number of cached position data.

- **Simple Relevance Estimation** – Using the received information vehicles are enabled to make a first estimation of the relevance of the information even if they are not equipped with a navigation system. The specification of the addressed region along with the moving direction has the advantage that vehicles with distinct headings may still act as forwarders for the received information.

- **Extendable** – There are several ways for potential improvements. For instance if a vehicle is equipped with a navigation system it may also address streets that were not on its recent route but that might also be affected.
- **Flexible** – The approach can be applied either to mobile as well as fix nodes. If an immobile station like a traffic sign is the sender, the position information may alternatively be hard-coded in the device.

As indicated above, the addressing approach is not restricted to the car-to-car scenario that has been used to describe the technique. It can be further applied in different C2X-applications like the communication between a car and a traffic signal system. This example will be illustrated in the following section.

4 Demonstrator Implementation – Traffic Light Assistance

From accident analysis it can be deduced that intersections are a serious focal point for accidents in urban traffic scenarios [4]. Common causes are violation of traffic lights/signs and disregarding others right of way either by fault or lack of information. Especially the violation of traffic lights or stop/yield signs leads to the most severe injuries out of these intersection accidents. For such a traffic light assistance exact information of the traffic light position along with its signal phases is important to judge the risk of a potential red light violation. Therefore a car-to-infrastructure module transfers the needed data by means of a conventional IEEE 802.11b unit to approaching cars. Figure 2 shows the modules we set up for this communication system.

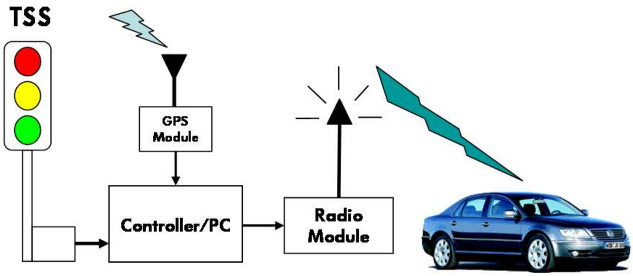

Figure 2: Communication with the Traffic Signal System

Communication Functions

In general, communication with the traffic signal system offers valuable functions for intersection safety systems:

1. Compared to intersection safety approaches that just use image processing techniques to get the status of a traffic light [2], communication with the traffic signal system provides information to the on-board application for an estimation of the remaining time before light signal changes. An appropriate warning or intervention strategy can be derived in order to assist the driver.

2. Instead of only warning the driver in case of a possible traffic light violation, a more convenient system is able to give speed recommendations to the driver when he is approaching this intersection. Such a recommendation for reaching the green light phases enables better traffic flow and shorter stopping times at intersections. It can be very useful to prevent dangerous situations already in an early stage.

Both functions are realized by using just unidirectional communication from the traffic light to the cars. The traffic signal system broadcasts its information periodically to all cars in the range of communication.

In order to realize the mentioned function it is necessary to determine exactly for which vehicle in the communication range of the traffic signal system the according data (e.g. signal times of traffic light) is intended.

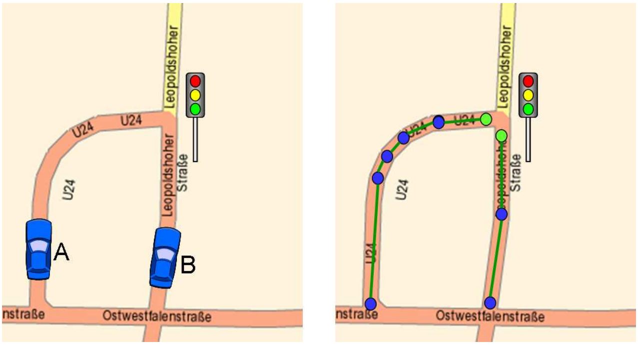

Figure 3: Travel Scenario and Geo-Based Addressing

Consider for instance a travel scenario as shown on the left hand side in Figure 3. A simple addressing scheme based on the points of the compass or on rectangular/ellipsoid shapes would not be appropriate because of the design and layout of a road. In order to overcome such drawbacks the proposed geo-based addressing technique is used as denoted in the right picture of Figure 3. Although it has no on-board digital map but a GPS positioning system, vehicle A can compute the addressing area it belongs to and further the corresponding signal times of the traffic light that is approached. It was mentioned before that this scheme is not restricted to specify the addressing region for the vehicle but is suitable for further information retrieval. For the above-quoted intersection application it is necessary for the system to compute its current distance to the intersection in order to compute the own arrival time and compare it to the signal times of the traffic light. Only with this information it is possible to give a recommendation about the driving speed in order to reach the green-light or to stop in front of the red-light. Our proposed replication of the local road network around the intersection enables the system to compute its position in this local map extract and therefore to get the desired distance to the relevant traffic light. Figure 4 shows the traffic light information and speed recommendation that is displayed in the car.

5 Conclusion and Outlook

A novel addressing approach for wireless C2X-applications by a replication of local road networks is proposed. This approach allows addressing of regions where other techniques like rectangular

Figure 4: Information about traffic signal states and speed recommendation in the car

or ellipsoid shapes are not suitable. With an intersection assistance system that gives information about the signal status times of the traffic lights the suitability of this approach was shown. The demonstrator vehicle was able to extract the relevant information out of the whole data stream and to localize itself within the addressing region to compute the distance to the intersection. With this information a speed recommendation is given to the driver in order to warn him of a potential red light violation.

A further extension to such a system could be the addressing of conflict areas for an advanced intersection safety system that deals with the warning of potential collisions within the intersection. If the conflicting area is addressed in the same way and all vehicles locally exchange their current positions in the intersection area one could generate warnings if a specific driver is going to disregard others right of way.

Other investigations may focus on the development of adaptive algorithms that determine reasonable intervals for caching the volatile position information of mobile nodes.

References

[1] Franz, Walter, Wagner, Christian, Maihöfer, Christian, and Hartenstein, Hannes. Fleet-Net: Platform for Inter-Vehicle Communications. 1st International Workshop on Intelligent Transportation (WIT), March 2004.

[2] Gehrig, S., Wagner, S., and Franke, U. System Architecture for an Intersection Assistant Fusing Image, Map and GPS Information. Intelligent Vehicles Symposium 2003, Columbus, USA, 2003.

[3] IEEE standard 802.11p draft amendment. *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. Wireless Access in Vehicular Environments (WAVE)*, 2005.

[4] Intersafe Consortium. Requirements for Intersection Safety Applications. http://www.prevent-ip.org/en/public_documents/deliverables, 2005.

[5] Christian Maihöfer. A Survey on Geocast Routing Protocols. *IEEE Communications Surveys and Tutorials*, 6(2):32–42, 2004.

[6] Mauve, Martin, Widmer, Jörg, and Hartenstein, Hannes. A Survey on Position-Based Routing in Mobile Ad-Hoc Networks. *IEEE Network Magazine*, 15(6):30–39, November 2001.

[7] Cartalk2000 Project. http://www.cartalk2000.net.