Context-Aware and Class-Based Broadcasting in VANETs

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Abstract—**Dedicated Short Range Communication (DSRC), i.e., the use of wireless communication for message dissemination, is a major building block in Inter-Vehicle Communication (IVC). We investigate broadcasting as the main communication primitive to share information among vehicles, or between vehicles and infrastructure. In recent years dozens of broadcast protocols have been proposed, including protocols for one-hop broadcasting (beaconing) of status information and protocols for geo-casting. The main commonalities of all these solutions are that they are designed only for one specific application and cannot co-exist, nor a single broadcast solution can meet the demands of all applications. This PhD thesis focuses on a holistic Network layer to support broadcast based applications.**

I. Introduction

After many years of vehicular networking research [1], [2], still no generalized networking architecture is available [3].

We find broadcasting as the most important communication primitive in vehicular networking for two main reasons: First, almost all Vehicular Ad Hoc Network (VANET) applications need to share the same piece of information with all the vehicles in some area, e.g., information about traffic jams. Second, even in those cases, where some information is destined for a specific vehicle, e.g., intersection collision avoidance, it is easier and faster to reach this vehicle using broadcast.

Current approaches of broadcast protocols follow the "one-fits-all" approach: they employ a single, beaconing-based, broadcast protocol to support all envisioned VANET applications. When we study the properties of such applications, we soon see that they can be optimally supported using a *specialized Network layer* that employs several different broadcast protocols. In recent years we have witnessed many VANET broadcast protocols, each designed with a specific application in mind, e.g., platooning, intersection safety, cooperative awareness and traffic information [4]–[7]. All these protocols were not intended to cooperate or even to co-exist on the same Network layer.

We identified that not all VANET broadcasts are the same by carefully investigating the differences and commonalities of VANET broadcast protocols. Moreover, we are able to distinguish a set of four classes of broadcast protocols that we believe would suit all envisioned VANET applications, ranging from low latency safety to generic geo-casting solutions. The protocols' basic properties in each class depend on the application requirements, thus they have to be context-aware. These properties differ greatly in the numbers of vehicles that are likely to invoke each broadcast protocol, in the coverage and retransmission strategy of each protocol and in the channel priority of the messages created by each protocol.

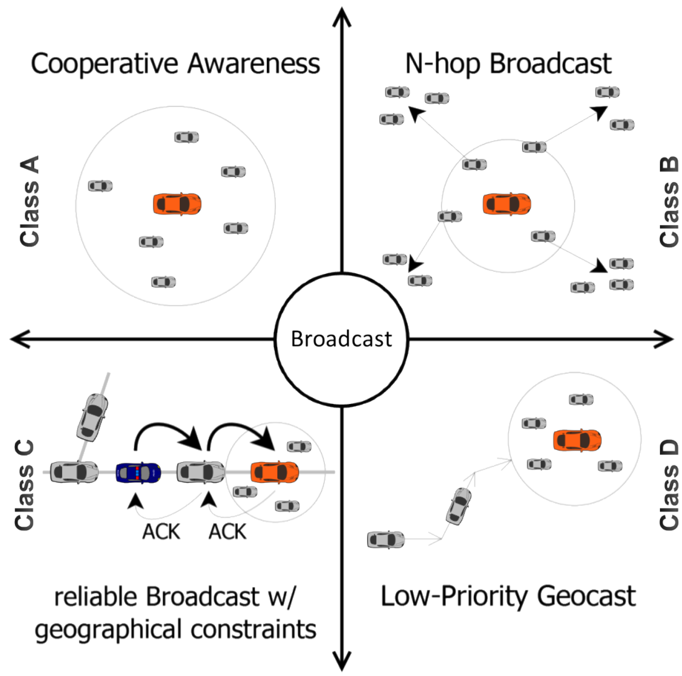

Fig. 1. Our vision of VANET broadcast classes: Class-A for medium priority Cooperative Awareness Messages (CAMs); Class-B to forward highest priority events within N-hops; Class-C for high priority reliable broadcasting with geographical constraints; and Class-D for low priority geo-casting.

In Figure 1 we depict our view on the set of four different VANET broadcast categories:

Class-A consists of beaconing protocols, which broadcast periodic CAM or HELLO messages to 1-hop neighbors.

Class-B are protocols that broadcast information about an emergency event within N-hops.

Class-C protocols disseminate information about important (but not very urgent) events using reliable broadcasts and having geographical constraints.

Class-D category protocols broadcast information about non-urgent events whose expiration time is much longer than those of class-C events by using classical geo-casting.

Our goal is to provide accurate networking protocols for each of the classes and answer interesting research questions which are described in detail as potential contributions in Section III.

II. State of the Art

Protocol stacks for Inter-Vehicle Communication (IVC) usually focus on a single application domain, *cooperative awareness*, but make the underlying broadcast protocol also available for other applications [8]. Cooperative Awareness Messages (CAMs) broadcast at fixed intervals, a procedure also known as *beaconing*. The main challenge, which holds for all classes of broadcast based protocols, is that the frequency of possible broadcasts strongly depends on the available capacity of the wireless channel. The problem of over-utilizing the wireless channel by the use of beacons with static intervals lead to the idea of adaptive beaconing which has also been incorporated into the ongoing ETSI standardization. The new Decentralized Congestion Control (DCC) approach [9], developed by the ETSI ITS-G5 working group, integrates mechanisms to prevent overloading the wireless channel, including Transmit Rate Control (TRC) and Transmit Power Control (TPC). Most recently, a new protocol for dynamic beaconing [10] shows that a more aggressive approach is especially beneficial for abrupt topology changes and to better support low latency applications. In this paper an upper-bound limit for channel utilization is provided to allow reliable communication in VANETs.

Geo-casting combines N-hop broadcasting with geographical knowledge, and fulfills many additional application requirements [11]. However, this one-fits-all concept is very limited in its suitability for all possible IVC applications.

Application-specific protocols have been investigated in a whole spectrum of potential applications [2], and are not intended to be compatible to each other [5]–[7].

III. Contributions

To provide a holistic network stack for IVC, we will focus on classification criteria for all broadcast related communication. First we distinguish between routine events, such as broadcasting awareness beacons periodically in order to detect neighboring vehicles, and extraordinary events, such as obstacles on the road and other emergency cases. Furthermore, the numbers of vehicles which are likely to detect an event play a role in the classification of the event. Another criterion is the target of the broadcast message, i.e., to which vehicles the message should be propagated.

In the following, we outline interesting research questions to be answered in the scope of this PhD thesis:

- **Context Awareness:** The information forwarding scheme depends on the event-detection rate of vehicles, thus it is necessary to adapt the broadcast scheme of events individually according to their classification criteria. This context awareness should be completely abstracted from the lower layer forwarding protocols, such that we can provide a dedicated layer of information management which uses information reported by class-A beacon protocols. We want to study how such a layer should work and define criteria to categorize events into one of our four proposed class based broadcast schemes.
- **Evaluation of *Class-A* beaconing protocols:** Most geo-casting protocols rely on accurate neighbor information for optimal relay node selection. Therefore it is crucial to have an accurate view of the neighboring vehicles. Here we want to answer the question, whether specific beaconing protocols are more suitable for specific scenarios and what information should be included in a single CAM to provide accurate neighbor information, e.g., position, moving direction and speed.
- **Detailed protocol specifications for *Class*-$\{$*B,C,D*$\}$:** We are interested in protocols which take the advantages of the road topology into account, e.g., freeway, Manhattan grid or suburban scenarios. Thus we want to create networking protocols which are special designed to work in a certain environment, and can be switched without interruption, while being fully compatible to each other.
- **Multi-Channel / Multi-Radio:** Wireless channel capacity is a valuable asset; therefore we are interested to study multi-channel and multi-radio systems for information dissemination in vehicular networks. In our previous work in [12] we have studied single-radio multi-channel beaconing, thus we are interested how our context aware broadcast scheme can benefit from multi-channel and multi-radio approaches.

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