Proactive Adaptation of Heterogeneous V2X Communication for Safety-relevant Applications

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***Abstract*—Future safety-relevant V2X applications will require a highly reliable and low-latency communication. Current V2X radio interfaces cannot fulfill the increasing communication requirements. The individual performance of different radio interfaces is sensitive to the propagation environment, message generation rate and dissemination strategy, where the upper communication stack controls the latter ones. In a heterogeneous communication approach, different radio interfaces can be coupled to leverage their individual advantages. While current reactive heterogeneous communication approaches switch the radio interfaces to counteract a degrading communication performance, proactive approaches can adapt the message dissemination strategy to the respective application and environmental context to prevent any performance degradation upfront. Therefore, proactive interface selection schemes can further improve the communication performance for a variety of different safety-relevant V2X applications in a rapidly changing environment.**

***Index Terms*—proactive adaptation, heterogeneous V2X communication, safety-relevant applications**

I. Introduction

Communication among vehicles increases safety and efficiency on the road. Relying on wireless information exchange for safety-relevant V2X applications requires the provision of highly reliable and low-latency communication. Possible radio interfaces to meet the current requirements are 802.11p for ad hoc and LTE for cellular communication.

802.11p can provide low-latency communication, as the respective message is transmitted to all vehicles in the proximity. Main drawbacks of this radio interface are the limited transmission range, low channel utilization, and low reliability. That is, 802.11p has no central resource scheduler and the radio transmission is prone to shadowing and fast fading [7]. In contrast, LTE leverages its central topology, which enables an almost unlimited transmission range, high channel utilization, and high reliability, as the base station antenna is stationary and usually located at a higher position. One of the disadvantage of LTE is increased latency, as messages have to be processed and forwarded in the backend [1]. Another disadvantage is, that IP-based message transmission requires frequent location updates by all V2X enabled vehicles.

Thus, a combination of the aforementioned radio interfaces has been proposed to leverage the advantages of both interfaces. This combination is often referred to as *heterogeneous communication* [13]. Existing approaches range from channel offloading [2] over relay [11] and cluster [10] to single or multiple metric optimization approaches [6]. All of these approaches can improve the communication performance by reducing the local channel load (cluster), enabling reliable long range transmission (relay), or switching to the most promising radio interface according to the metrics observed (single/multiple metric optimization). For example, the single metric optimization approach switches to the radio interface with the lowest channel load (channel offloading).

Even though these approaches can improve their predefined communication optimization problem, they are not adaptive to the upper communication stack. That is, their input data is only retrieved from the physical radio propagation channel. Therefore, these approaches can only counteract a degrading communication performance. By also taking the environmental context into account, the communication strategy can be adjusted upfront. For example at intersections, the channel load is expected to be higher, as the vehicle density in the intersection is generally higher. Thus, the information that the vehicle is approaching an intersection can be retrieved from the respective V2X application and data can be offloaded upfront.

In our research, we aim at proposing a *heterogeneous V2X communication approach*, which improves the communication performance *proactively* by considering the respective V2X application behavior. Thus, the choice of the message dissemination strategy and selection of the radio interface is not only based on the current radio propagation channel performance, but also adapts to the current state of the V2X applications. Therefore, the message dissemination strategy will be adapted to the current environmental context and the respective safety-relevant V2X application behavior as motivated before.

Thus, the following research questions are to be answered:

- Which information quantity and quality depending on the location of the receiver is required to improve the communication efficiency for safety-relevant V2X applications?
- How to describe and quantify the impact of message dissemination on communication performance for safety-relevant applications?
- How to measure, adapt and realize an efficient dissemination of information for safety-relevant V2X communication in heterogeneous networks?

II. Contribution and Research Impact

In this paper, we briefly outline the planned contributions and summarize already existing work in the respective area.

A. Location-based information relevance

As of now, the message dissemination strategy is controlled by the upper communication stack, where the destination address of the message and the message generation rules are set. In [4], the message generation rule depends on the current transmitter's dynamic state (like speed, heading and position) and does not depend on the receiver's interest in this message. Independent of the radio interface, the available bandwidth for message dissemination is always a limited resource. In [12], the LTE interface is used to control the beacon rate to decrease the channel load. The controller uses current vehicle traffic information and the priority of the respective message.

The relevance of a message regarding quantity and quality depends on the location between transmitter and receiver and the environmental context [9]. We aim at extending the approaches in [12] and [9] to further improve the message dissemination strategy. Depending on the relevance of messages for different receivers, the routing protocols and generation rate are adapted to preserve resources and thereby also improving the respective application performance for transmitter and receiver.

B. Relation between V2X application and communication performance

Heterogeneous V2X communication approaches, which aim at optimizing the communication performance, usually use the radio propagation channel state as input data [6]. The individual need of the respective application on the communication performance, like latency and packet-error-ratio (PER), is neglected or expected to be static, e.g., 100 ms latency and PER below 0.0001 for V2X safety applications [5]. We think that the desired Quality of Service (QoS) for safety-relevant applications is not static, but varies with the environmental context. Furthermore, with the help of a central communication entity, e.g., a backend, the channel state in local areas can be predicted. In [8], the extended knowledge of the backend is used to control the transmission power of vehicles reactively. We aim at extending this by also predicting the future channel state with the help of environmental information. This enables the optimization of the communication before its degradation.

C. QoS for heterogeneous V2X communication

Heterogeneous communication allows to significantly improve the communication quality by leveraging the individual advantages of different radio interfaces. In [3], a context indicator and estimator is implemented to track the QoS for different radio interfaces. For 802.11p, the level of the current QoS is unknown and can only be estimated based on received messages. To further improve the message dissemination strategy and choose the best radio interface, we plan to extend the approach in [3] with a resource efficient feedback message. This feedback message tracks the QoS for the communication in safety-relevant V2X applications.

III. Conclusion

In this paper, we have formulated research questions for *proactive adaptations for heterogeneous communication* approaches to support future safety-relevant V2X applications. Instead of counteracting a channel performance degradation, we aim at preventing it with the help of diverse radio interfaces and extended environmental knowledge.

Therefore, we focus on investigating the *location-based information relevance*, the *relation between V2X application and communication performance* and the *QoS for heterogeneous V2X communication*. For our future evaluations, we build a simulator for heterogeneous V2X communication with a realistic representation of radio propagation effects for realistic large-scale simulations. We also plan to evaluate our system in a small-scale real-world environment and compare it with our simulation results.

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