Transformation of Vehicle 2 Everything (V2X) communication to the railway sector

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Abstract. Currently, there are few technical tools or even newer communication tech-nology that allows us to communicate between rail vehicles and road-bound ve-hicles. This communication is very important as the automation of vehicles is advancing here as well. We will now show how vehicle-to-everything communi-cation can also be used for the railroad sector. This so-called Rail2X is realized by communication between road users and level crossings using modified vehi-cle-to-infrastructure communication (V2X). We will now show how Vehicle to Everything communication can also be used for the railroad sector. Applications in a previous research project have shown that use of V2X communication can make level crossings, as well as stopping a train at a request stop, more conven-ient and efficient for everyone. Equipping level crossings with a digital St. An-drew's Cross can increase the comfort of road users, as for the first time directly transmitted real-time in-formation about the status of level crossings are availa-ble. In this application the level crossing broadcasts position of a train and open-ing status of a level crossing via V2X. Out of this information the road user re-ceives information, like the remaining time the level crossing is still closed. Ac-cidents at level crossings are mainly caused by road users. The number of acci-dents has remained constant in recent years and has not yet been reduced. There-fore, there is a need of action to sustainably increase traffic safety at level cross-ings and reduce the number of accidents there. The use of the digital St. Andrew's Cross creates opportunities for optimizing traffic flow near railroad crossings by significantly improving the information for road users in the vicinity.

Keywords. V2X, V2X, Vehicle2Everythingh, level crossing, Rail2X, Realabor Ham-burg, Digital St. Andrew's Cross, Digitales Andreaskreuz

1. Introduction

The IEEE 802.11p[5] communication standard has been defined together with a special purely software-defined protocol for information exchange between roads vehicles. Therefore, it is called Vehicle2Vehicle (V2V). It can be used to communicate with infrastructure as well and then result to Vehicle2X (V2X) communication or Car2X (C2X). Wider use in the automotive environment will lead to high market penetration and availability as well as extremely low cost for the technology[2].
For railroad traffic, broader distribution of information and more intensive ex-change with other railroad traffic users is an increasing demand in the next years to be expected. One possible idea to solve this demand could be the use of standard technologies as well as V2X communication. This can be used to distribute additional information within the railroad system as well as to other interested users. Nevertheless, the railroad automation and protection systems must ensure the safety and conduct the operation. Therefore, they remain unchanged and the Rail2X systems either give additional information without safety requirements or act as an overlay. In such cases, an Intelligent Transportation System (ITS) has a Road Side Unit (RSU) installed as a fixed base station. In a moving vehicle, whether a car or a train, an On-Board Unit (OBU) is installed[1].

1.1. Motivation

According to Section 11 of the Railway Construction and Operating Ordinance (EBO)[3], a level crossing refers to a level crossing on a railway line that can only be used by streets, paths and squares.
In Germany (as of 2017) there are 17,000 level crossings. 2012 only inn Germany, there were 193 traffic accidents at level crossings, in which 44 people died[4]. These numbers have remained relatively stable over the years and only new measures and technology can be used to reduce these numbers.

1.2. Vehicle infrastructure communication V2X

V2X is a WLAN-similar standard that is used in the automotive sector to ex-change information between vehicles and / or infrastructure. For example, this messaging standard is used in road traffic to immediately warn and support drivers in emergency situations. That is why V2X components have been developed and tested for several years. However, this communication standard is not limited to the automotive industry, but should also have nothing to do with the means of transport. The use of V2X communication in the railway sector has been evaluated in a number of projects. The aim of these projects is to investigate V2X as Rail2X and to extend it to rail traffic in order to improve the comfort, effective-ness and economy of regional rail traffic. In principle, it is possible to exchange information across modes and modes.
For the testing and evaluation, three relevant use cases in the railroad sector were defined and designed, which enable an economic operation through the V2X application. By means of these use cases it could be shown that on one hand the use of V2X standard is possible and on the other hand the application of low-cost standard components from the automotive sector is also target-oriented in the railroad sector.
In order to enable communication between vehicles and infrastructure, which is relevant e.g. for intelligent assistance systems in vehicles, standards for vehicle/infrastructure

communication (V2X) have been developed. The European Telecommunications Standards Institute (ETSI) has produced a set of standards for this purpose.
V2X messages are exchanged between receivers via the extended WLAN standard IEEE 802.11p in the 5 GHz frequency range. Research is also being conducted on V2X communications over cellular networks. Studies show that although LTE achieves higher latency than communication over 802.11p, it has better scalability and enables long-distance (or global) communication.
For data exchange in the IEEE 802.11p WLAN standard, the ETSI ITS G5 standards specify the necessary network architecture. The ETSI ITS G5 was developed to describe architecture and network mechanisms for V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure, such as roadside units) communication.

1.3. Range measurement V2X

Since we don’t have any information about the local conditions at the various test environments, first thing we have to do is measurement how far the V2X messages can be sent and received. This is done by using a range measurement, which has been tested many times and is therefore accurate enough to give us a first estimate of how far V2X messages are transported correctly.
The range measurement test was performed with a Cohda Wireless[8] MK5 RSU – as Basestation, as well as with a Cohda MK5 OBU in the vehicle - with the last available firmware version. The used antennas are original supplied by Cohda Wireless. Recording was done with the help of Cohda's own fieldmesstool, which is standard on every Cohda[9]. The evaluation of the generated files was done by a DLR Tool created specifically for reach measurement. The used modulation was a 12QPSK, which calculated the range using different packet lengths of 100,400,800,1500 bytes.
At the first use case, a portable mast was erected to determine the optimum transmitter range of 3 m, and the antennas of the RSU were mounted on this mast in an elevated position. The following Figure 1 shows the PER (Package Error Rate) as a graph. On the east-west axis, speed limits of 50 km/h are mandatory. On the northern road, a maximum speed limit of 30 km/h is allowed. In the center of the circle is a level crossing with RSU at a height of 3m.

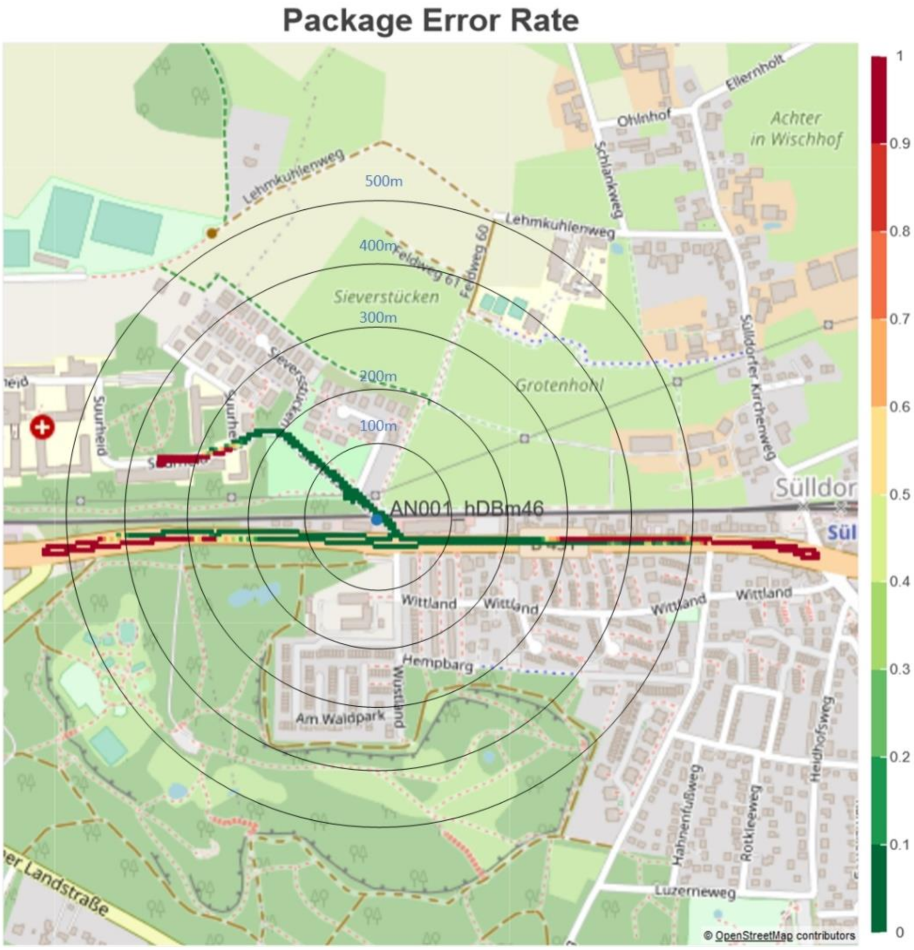

Fig. 1. V2X Range measurement in the near of Hamburg (53°34'51.5"N; 009°47'08.6"E)

The evaluation is based on the packet error rate (PER). This error rate refers to the data packets that were not received. Unreceived data packets can be detected using the message ID. In the evaluation, several messages in each case are combined in a previously defined measurement section to form a measurement point. The PER of these measurement points are averaged and designated as PER. Three categories were defined to subdivide the PER at the measurement points.

A PER smaller than 40% is considered the best possible result and is marked with a green dot in the overview map. A PER between 40% and 60 % is considered a still acceptable result, since increasing packet loss may already be expected here. The reception of messages can no longer be accepted even with multiple transmissions. In the overview map, these measurement points are marked with a yellow dot. The last category is a PER of greater than 60%. Here, the reception of a message can almost no longer be assumed. Reception may still be possible in isolated cases, but the message may be so error-ridden that it can no longer be used. These measurement points are marked with a red dot on the overview map.The subsequent evaluation of the results shows that in urban areas, due to coverage by buildings, a range of about 300m is achieved. This result represents a communication range of 21.6 seconds at 50 km/h. On smaller access roads, speeds of only 30 km/h are often permitted, resulting in a time span of 36 seconds, which can beused for communication.

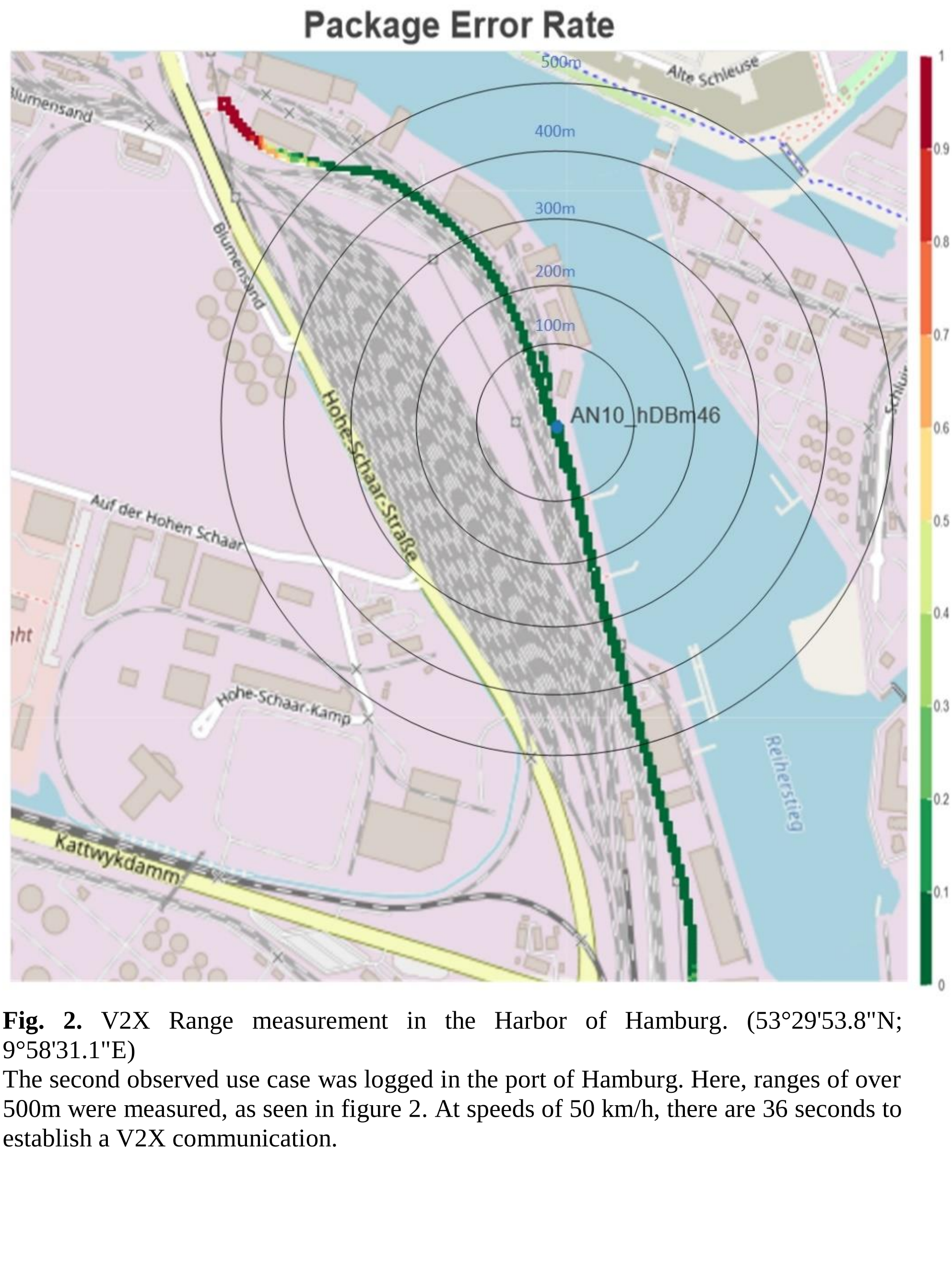

Fig. 2. V2X Range measurement in the Harbor of Hamburg. (53°29'53.8"N; 9°58'31.1"E)

The second observed use case was logged in the port of Hamburg. Here, ranges of over 500m were measured, as seen in figure 2. At speeds of 50 km/h, there are 36 seconds to establish a V2X communication.

2. System structure in the test field

2.1. Stop on Demand Use Case

There are currently various forms of request stops in the German rail network. In the simple case, there is no technical support. This means that both the passenger and the driver can implement a possible request for a stop by carefully observing the line or stop. In modern cases, there are solutions with operating devices on the platform that trigger a signal a few hundred meters before the requested stop, depending on the direction. Depending on the design, this signal can light up or flash. If this is the case, the driver can prepare for a stop in good time.

The establishment of request stops in the railroad area strongly dependent on the respective traffic demand of the passengers at the respective station. Demand stops can be established when an extremely low number of boarding and alighting passengers is expected, e.g., during operating times with lower passenger frequency. Demand stops are often located near manufacturing industries with shift operations. The majority of demand here occurs at the beginning or end of shift hours. Otherwise, low demand can be expected. The request stop is therefore an option for connecting new residential areas with low passenger volumes to the rail network. At the same time, a high degree of operational flexibility can be achieved, since it is possible to react very quickly to changing passenger numbers. It is thus possible to determine between regular stops and request stops depending on the season, which is advantageous, for example, for stops that are important for tourism.

A request stop in passenger rail transport offers several advantages from the customer's point of view. On one hand, the request stop contributes to shorter travel times, since unnecessary stops on the trip as well as braking and acceleration phases can be eliminated. Provided that there is no need to change passengers. On the other hand, a request stop offers the possibility of providing more stopping options per route. The train can, so to speak, move closer to the customer and the residential areas. Request stops make a rail connection even for smaller settlements for which a permanent stop is not worthwhile possible to provide. From the resident’s point of view, a request stop leads to fewer noise emissions because noise emissions are reduced by avoided braking and acceleration processes when the train slowly passes through the stop.

In addition to the numerous advantages, the current disadvantages of request stops should also be highlighted. From the position of the driver, a request for a stop is not always clearly recognizable if there is no signaling solution. Furthermore, the passenger must make an active effort to ensure that the train stops at the request stop, e.g. by waving and approaching the platform edge. Even from the passenger's perspective, it is therefore not always clear whether the driver has actually recognized the request or not. Both can easily lead to stress and uncertainty for both the passenger and the driver.

Depending on the routing and visibility of the request stop, Rail2X technology offers the potential to significantly improve communication between passenger and driver, enabling clear signaling of the demand stop and reducing stress for both sides. The use case "request train stop" envisages transmitting the information "stop request" from the passenger directly to the driver's cab using Rail2X. In this way, the driver knows much earlier compared to locally signaled variant whether there is a request to stop or not. Ideally, the driver sends confirmation to the platform, so that it is signaled to the passenger on site that the stop request has been successfully registered.

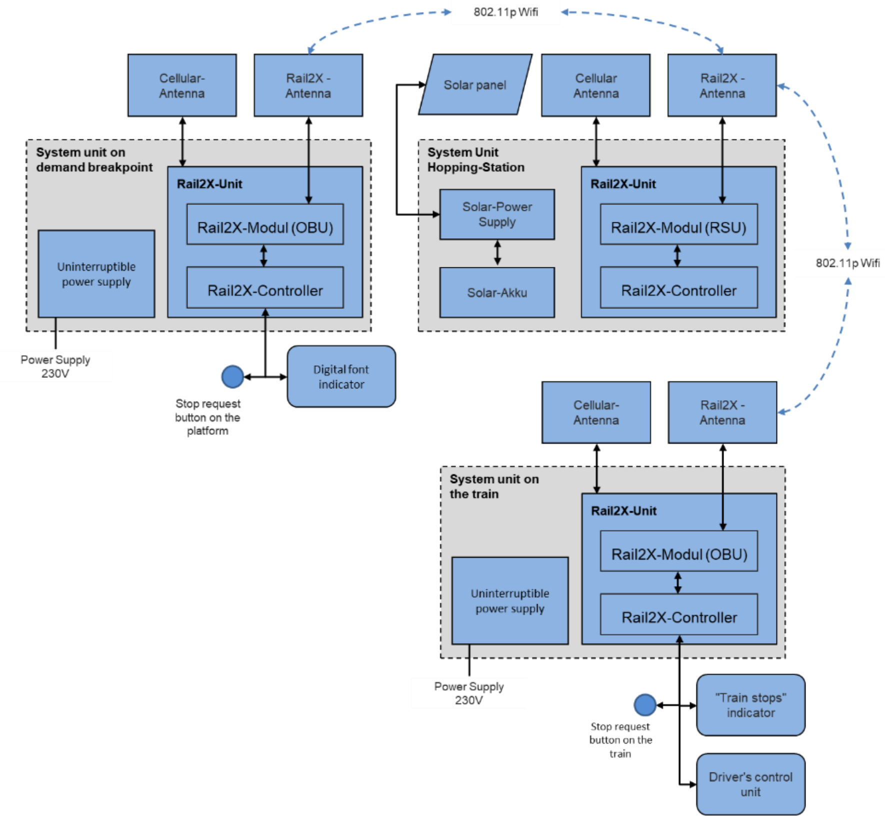

Fig. 3. System diagram for the Request Train Stop System

In addition, the radio-based Rail2X solution significantly reduces the amount of cabling required, and costs can also be saved by avoiding cabling at the request stop. As in the previous two use cases, this benefit of avoided costs is advantageous in rural areas, where the request stop is also most likely to be used. Another advantage is the elimination of higher-level communication networks such as cellular networks, which has a direct impact in terms of availability and cost.

The Rail2X request stop is thus a further building block for strengthening rail transport in rural areas from an economic and structural point of view. The schematic system overview of the demand stops use case is shown in Figure 3 below. It consists of the three building blocks of the demand stop module at the stopping point, the hopping station and the equipment in the traction unit, which interact with each other via the air interface. The hopping station, which is located in the middle between the train and the station, forwards all incoming V2X messages without changing them. In the simplest sense, this only enables forwarding to increase the range of the train.

2.2. Digital St. Andrew's cross (DiAK10)

The first use case consideres a technical secured level crossing with classicprotection. A central unit controls the technical components such as light signals and barrier beams, which is shown in Figure 4. When a train approaches the level crossing is secured by barriers. When the train has completely passed the level crossing it is reopened to road traffic. The information about the opening status of the level crossing (open/closed) is already available in the internal logic of the safety technology and can be retrieved non-intrusive via a physical diagnostic interface.

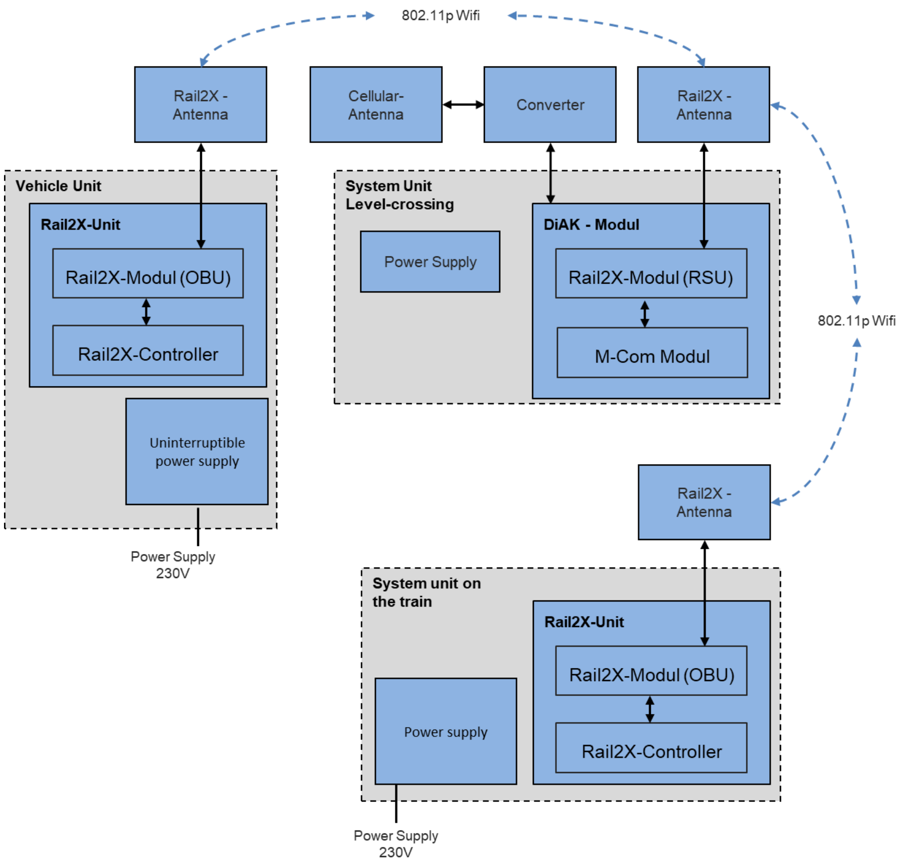

Fig. 4. System diagram for the digital St. Andrew's cross

In a second use case, a technically unsecured level crossing is considered. This means that the level crossing is only announced by a St. Andrew's cross. The road user is responsible for safe passage - he or she must actively look out for approaching rail vehicles before passing the level crossing. In this case there is no system initially knowing the opening state of the level crossing. A central module (Road Side Unit = RSU) at the level crossing broadcasts data, including status information of the opening status of the level crossing via V2X to the environment, which is used or further distributed as explained in the first use case. However, this central module is supplemented by functionality that determines the opening status of the level crossing from information broadcasted by approaching rail vehicles via V2X messages. Based on the requirements collected, an initial rough model was created showing the various system components planned for the technical realization of the two use cases. This system architecture shows the functional and technical subcomponents of the overall system, as well as a delineation of the system and the communication interfaces to be used for data exchange between the subcomponents.

3. Forecast

In the course of Rail2X project, it was shown that V2X communication does not have to be limited exclusively to the automotive sector, and that there are sufficient fields of action for the railroad sector as well. During the project the focus was on the exchange of information between the train and the infrastructure system on the rail side, in the form of a switch in one use case. Other use cases focused on communication between train and request stop, and on the interaction between a motor vehicle and a barrier system for crossing the rail infrastructure on the road side.

The Rail2X communication solution presented here is also subject to a security-critical aspect in terms of availability, integrity and confidentiality. For security reason t possibilities for the use of public key infrastructures were discussed and proposed. In particular, the need of system-specific parameters, i.e., road- and rail-specific, were identified. The main issues discussed were system-specific options, i.e., separate road and rail-specific options. The introduction of sub-solutions, and a proposed procedure for distributing the authorizations for the messages sent were prepared. The V2X communication protocols already defined by ETSI are currently based on the communication of road vehicles among each other and between road vehicles and infrastructure. Within the project Rail2X[6] duration, a standardization process was initiated at ETSI, which in the future will consider the railway-specific content from the project in the existing message types.

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