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Sensory observation message and CAM extensions for VRU safety

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Abstract

In the past, Intelligent Transport Systems (ITS) have been successful primarily through equipment of the vehicle and infrastructure. However, for the safety aspect, the vulnerable road user (VRU) still has a 68% share in traffic fatalities. Therefore, more attention should be given to ITS for VRU safety. In current Cooperative-ITS (C-ITS) systems, warnings can only be sent when there is a direct risk of a collision, in which case it can already be too late to prevent. Sharing of infrastructure sensor information and adding destination information to the CAM can be used for preventive measures. This paper shows scenarios in which a Sensory Observation Message (SOM) and destination information in the CAM may increase safety. It will also analyse user acceptance and willingness to provide destination information. Lastly, it will show SOM message and CAM extension design with a technical analysis to link to other ETSI standardized messages like MAP.

Keywords:

VRU, detection, C-ITS.

Introduction

In the past, Intelligent Transport Systems (ITS) have been successful primarily through equipment of the vehicle and infrastructure. The focus of these ITS has been on clean, safe and efficient mobility for cars and trucks. European, national and international efforts have concentrated on the deployment of these systems. The Vulnerable Road User (VRU) has reaped fewer benefits of the ITS developments. This is a missed opportunity as their combined share in road fatalities is much higher than for other modalities as can be seen in figure1, where a combination of pedestrians, motorcycles, mopeds and bicycles gives a 68% share.

The EU funded projects VRUITS [1] and XCYCLE [2] aim at reducing VRU fatalities by including them in the cooperative technology more actively. A possible method to achieve involvement in C-ITS is to equip them with relevant technology as well, which was previously done in [3]. However equipping VRU’s can turn out to be costly and may introduce problems in the transition phase when not all VRUs are equipped with such technology. Drivers will start relying on the safety systems and are more likely to miss an unequipped VRU.

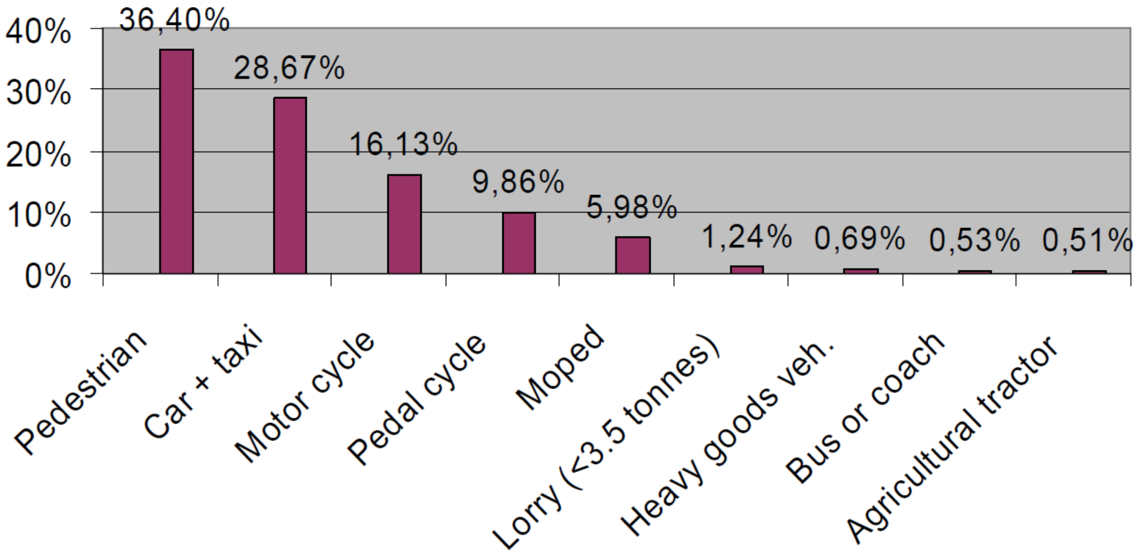

Figure 1: Fatalities by transport mode in EU-27 - inside urban areas (CARE database, 2009).

Standardized messages exist for C-ITS technology, which in Europe are mainly issued by ETSI. Most important for safety are the Decentralized Environmental Notification Message (DENM) [8] and Cooperative Awareness Message (CAM) [9]. The DENM is meant for informing road users about hazards and other information relevant for safety. The CAM message is broadcasted 1-10 times per second and contains the status of the transmitter including speed and position.

Other projects have focused on infrastructure and vehicle sensors, for example SAFESPOT [4], PReVENT [5], SAVECAP[6], INTERSAFE and INTERSAFE-2 [7]. These projects either used no messages or were using the standardized ETSI messages DENM [8] and CAM [9]. While the CAM message lacks path prediction or destination parameters, most vehicle to vehicle collision scenarios can still be implemented using its contents by simply assuming a vehicle continues with the same heading. For unequipped VRUs, however, this is different, the infrastructure can detect the location, but will only send a DENM message once conflicting manoeuvres are detected. In case of conflicts between vehicles and VRUs on intersections it is often too late to prevent a collision. This can best be understood from the well-known intersection safety scenario depicted below, similar to the Braunschweig test site of XCYCLE:

Figure 2: The right turn partial conflict often causes collisions between VRUs and vehicles.

In this scenario the path of the bicycle is very close to that of the car. When the car does not turn right, there is no reason to send the vehicle a warning, only when the car turns this becomes relevant. If the system would always send warnings when a VRU is detected, false alarms will result in low user acceptance. Furthermore, if the warning is send when the driver starts turning the steering wheel it may already be too late to send a warning to the vehicle. This moment may even be too late for automated emergency braking to be able to prevent a collision. eIMPACT [10] carried out an ex-ante safety assessment of the “Pre-Crash Protection of VRUs” (PCV). PCV is a vehicle-based system that employs fully automatic emergency braking when a collision with a VRU is unavoidable. eIMPACT estimated that about 7% of VRU fatalities and about 12% of injuries could be avoided through the full deployment (100% equipment rate) of this system in the EU. Even though it is a significant reduction, prevention of the collision would still be preferred over measures to decrease the severity of the accident.

Therefore, it would be clearly beneficial to share information of the road side sensors before the collision occurs. This would open possibilities to prepare an action in-vehicle, e.g. haptic feedback in the steering wheel as soon as the driver tries to turn the wheel to the path of the VRU. For this the road side unit (RSU) should be able to transmit a new message sharing sensory information with cooperative vehicles in range.

This paper will first explain another scenario where an RSU should send a Sensory Observation Message (SOM). This will be used as an example to further explain the architecture of a system using such a message. The next section discusses the benefits of a CAM extension which includes the destination of the road user in the message as well. This is followed by technical sections that provide details for how the SOM and CAM extensions could be implemented. This focusses on links with the existing MAP message and what data is required for effective use. The information can be seen as a good starting point to define an ASN.1 description of a SOM message and the extension of the CAM message. Finally, conclusions will be drawn.

Bicycle visibility scenario

In the introduction a basic intersection situation was described in which conflicts between vehicles and bicycles often result in serious accidents. To isolate the conflict between a single bicycle and a single vehicle, the scenario of leaving a roundabout as shown in the figure below is introduced.

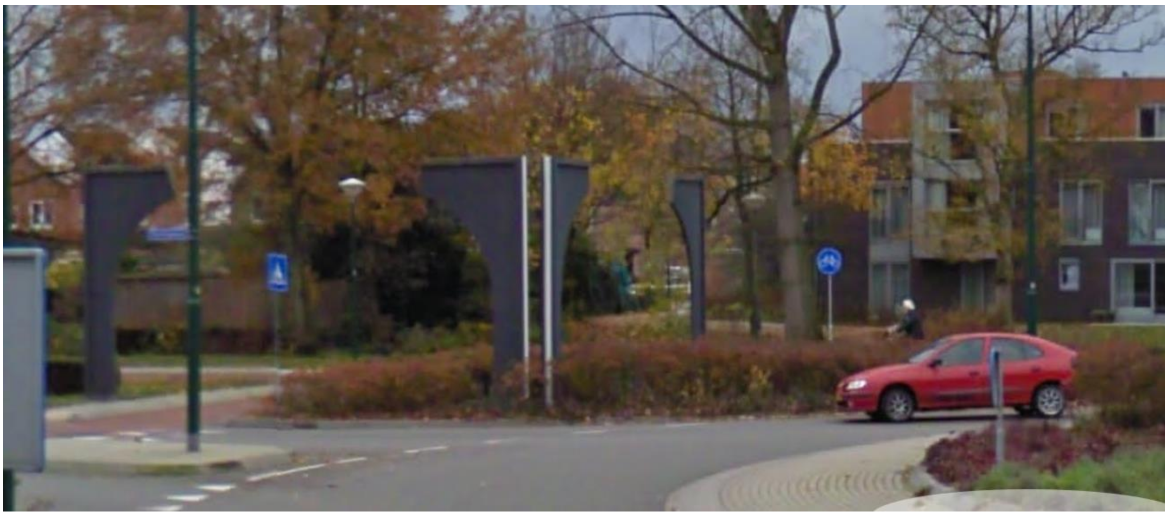

Figure 3: Roundabout with obstructed view for the vehicle.

As can be seen in Figure 3, the view of the bicycle next to the car is obstructed by vegetation in between the bicycle lane and the vehicle lane. Unfortunately, the view for drivers is often obstructed in a similar fashion. Although it is sometimes possible (and easier) to change the infrastructure this is in many cases not possible. In this situation, especially near the first potential conflict point (the roundabout exit ahead of the vehicle) the situation is challenging for the vehicle as art objects with large metal surfaces obstruct not only the view of the driver but also block the range of a vehicle sensor completely. Transmission of a DENM will not be useful as there is no exceptional situation yet. User acceptance of the system will be low when warnings are sent at every intersection and every roundabout exit, independent of the drivers' intended direction. However, once the vehicle decides to exit the roundabout, the conflict point is already very close and a DENM is unlikely to prevent a collision. A SOM message offers a solution, with this the infrastructure can inform the vehicle prior to the decision to turn and the vehicle can give, for example, a haptic feedback as soon as a torque is applied to the steering wheel to initiate a turn movement. This way the turn movement and thus the collision is prevented. Figure 4 shows the situation when no SOM message is sent .Figure 5 shows a scenario when SOM message is sent.

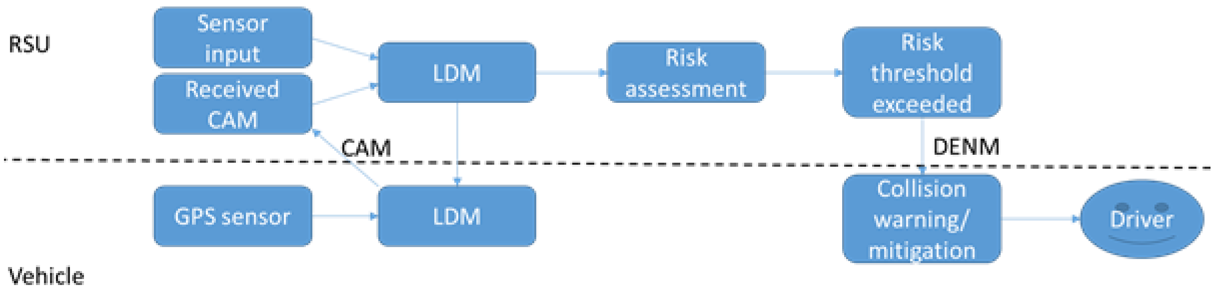

Figure 4: Right turn scenario without SOM message.

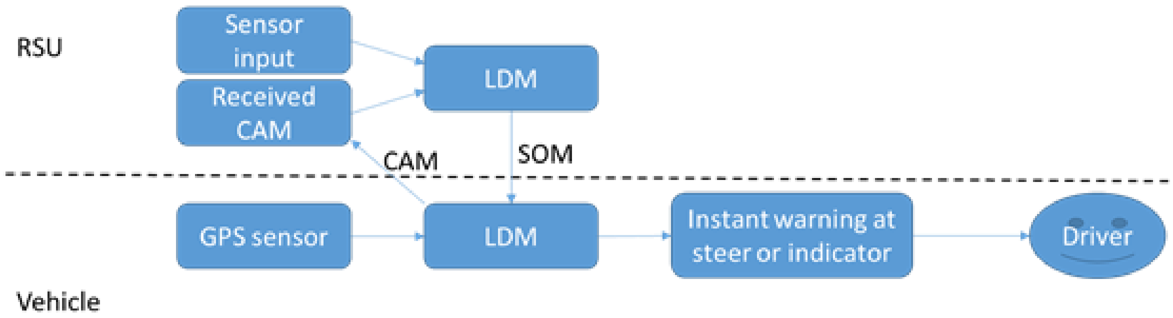

Figure 5: Right turn scenario with SOM message.

As can be seen from the figures, the scenario without a DENM first needs to exceed a risk threshold before a warning is sent. Partly, the architecture of the systems is very similar. The main difference is the SOM message that basically synchronizes the Local Dynamic Map (LDM) of the roadside with the vehicle. With the SOM message the risk assessment and risk threshold evaluation should still run at the roadside, but will not be triggered when the vehicle already prevents the situation. Vehicle architectures to take vehicle sensor observations into account exist already and were used in the projects [4-7]. The adaptation to the algorithms is not needed in order to take infrastructure sensor information into account as well. Since these algorithms read the sensor data from the LDM, the additions made by a SOM message should automatically be taken up.

Bicycle crossing scenarios for CAM extension

The XCycle project will consider two scenarios where bicycles cross the road. The first is at a controlled intersection on which the project will create a green wave for bicyclists. To have as few impact on the other traffic as possible, the presence of bicycles will be monitored by sensors. However, only approaching bicycles planning to turn left or go through will make use of the intersection, as the right turn is often conflict-free and therefore uncontrolled. In this case destination information in the CAM message would be very helpful for the intersection control algorithm.

The second scenario is for bicyclists crossing the road while not on an intersection, which was identified as a major cause for bicycle fatalities by the XCycle project. This happens often since bicyclists often have their origins and destinations at entries and exits alongside the road which are not part of an intersection. Therefore, bicyclists often cross at the locations which may not formally be an intersection. When traffic is dense at the moment of arrival, they often travel the bicycle lane in the opposite direction awaiting a more suitable moment to cross. Similar to knowing when drivers will make a turn, in this case destination information in the CAM message would be helpful to make vehicles aware of potentially crossing bicycles (and not inform them about every bicycle cycling along the road).

Both of these cases basically only require a destination from the bicycle. Other scenarios can benefit from detailed destination information of other modes of traffic. Destination information can be acquired in several ways. Already present in the CAM is the indicator light status. However, not every road user uses the indicator (a bicycle does not even have one) and it may also be used for a lane change and give false information. Most reliable would be the navigation system containing the route and destination of the road user. However, for common trips and for bicycles, navigation systems are rarely used (unless for real time traffic information). An alternative would be to use an app tracking road usage statistics as most trips a user makes are repeated especially when the time of the day is taken into account. The section of psychological factors discusses whether users would be willing to share their trip information in exchange for safety. When considering that different methods of acquiring the destination result in a different reliability, the CAM message should also contain a field with the reliability of the information.

Psychological factors

In both of these scenarios some psychological aspects are relevant. Whether or not a situation will develop into a (potential) conflict situation depends for a large part on the behaviour of the driver or bicyclist. This prediction element together with the reliability should be included in the SOM. Monitoring and predicting this behaviour can be based on several sources. Most importantly, knowing the route that will be taken may improve the accuracy of prediction considerably. This can be done, for example, on the basis of current trajectory data and an interpolation (linear or non-linear) of the trajectory. Knowledge about typical behaviour may help to define constraints to evaluate behaviour and judge whether a conflict situation may arise. Knowing the destination or even better the actual route to reach that destination, may improve prediction of behaviour even more. One of the questions that arises is whether people are willing to be monitored or provide their destination to external systems.

With respect to being monitored, as long as it is a form of monitoring in which the identity of the person is not known, this does not seem to be a problem. Few people have problems, for example, with radar detection systems currently detecting the presence of pedestrians or cyclists at intersections. However, when more detailed information is needed the willingness to share the information might become an issue. With systems tracking traffic participants based on the unique signature of their smartphone or based on a chip (e.g. RFID) that uniquely identifies them, people will be less willing to share the information and governments less willing to allow the monitoring. Knowing the exact route that will be taken, which is in this situation the best option to predict behaviour, might raise even more issues.

The willingness to share information is for a large part determined by trust in the party with whom the information is shared [12]. Their information must not be used in ways they don't want and only available to trusted parties. There is more to the willingness to share than trust however. As Knijnenburg and colleagues described, the willingness to give information or disclosure behaviour is multidimensional [13]. Different people show different disclosure behaviour for different aspects of privacy. People may be willing to share to different degrees information about their destination or planned route depending on what they need to share and what they may gain from it. Benefits are indeed an important factor playing a role in whether people want to share information about their route or destination. Without gain for themselves, there is little motivation to share, especially when sharing takes effort.

The most important benefit, from a design perspective at least, is increased safety for vulnerable road users. By sharing information, the system is able to create a safer environment for them. This effect may however be difficult to see for the driver and even for the bicyclist and therefore hard to appreciate. A more tangible benefit can be provided by especially creating benefits based on the information. For example, by using the traffic participants' location, trajectory, route or destination, traffic lights can be adapted to create a green wave both for cyclist or cars. Such as a tangible benefit might more easily persuade a bicyclist to share their information. Once they have provided their information, it can also be used for safety benefits.

Willingness to use technology

The extension of CAM messages with destination information may entail drivers or cyclists using additional technology through which their destination is known. Parasuraman [14,15] described four, more or less independent, dimensions of technology readiness: optimism, innovativeness, discomfort and insecurity. The first two contribute to technology readiness the latter inhibit it. All four depend partly on the technology and partly on the person. *Optimism* describes whether people have a positive view about technology. Safety systems may in general induce a positive image, which may be helped by creating more immediate benefits by combining with green wave systems as described above. *Innovativeness* is mainly dependent on the person and describes whether someone is likely to adopt new technology, in this case this means that a select group may be very willing to use the technology where others are not. The group that is willing can, for example, be used as ambassadors to promote the system. This is necessary, since a high penetration grade is necessary to have good safety impact. *Discomfort*, determined by the feeling of control over technology, can be reduced by using a simple design and little need for interaction. The most important aspect is probably *insecurity*, describing the distrust of technology. False alarms, unclear messages to the driver or cyclists and especially failing to detect or report (potential) dangerous situations will increase insecurity. This may lead to refusing to try the system or to keep using it. This means it is important to create highly reliable systems and only introduce them after thorough testing, for example with a dedicated sub-group.

SOM Message and CAM extension design

A schematic overview of the SOM message is show in Figure 6.

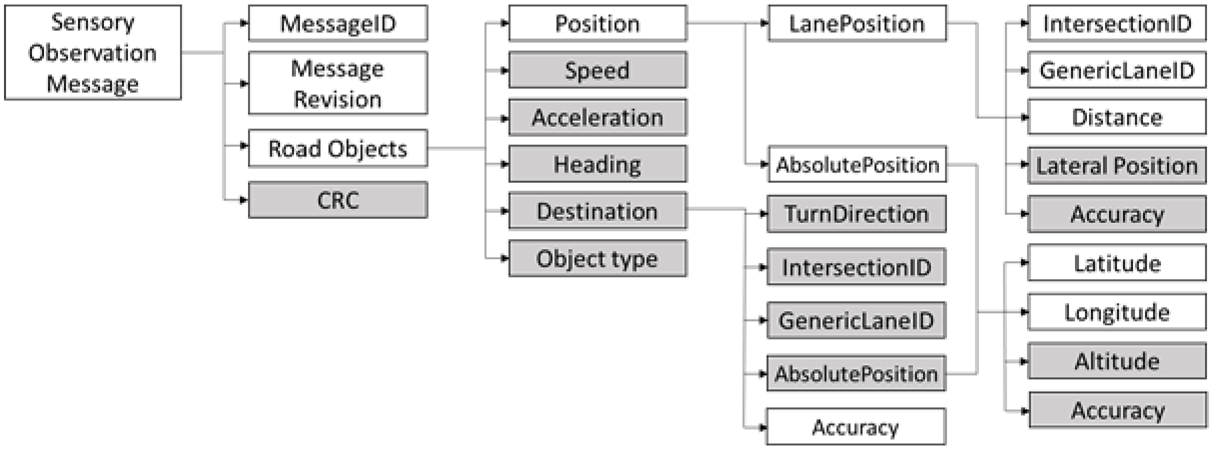

Figure 6: SOM message design, optional elements are grey.

This figure is a schematic representation of a design that could be implemented in ASN.1 [16], which is also used for CAM, DENM and other ETSI standards. The message itself first contains header information: the MessageID and message revision. The first should be in line with other C-ITS messages and have a unique id, the next available is 0x14. The issue revision indicates whether the message received was updated with respect to the last one. Every time the content changes, the revision should be incremented by one. The footer of the message consists of an optional cyclic redundancy check (CRC) to verify data integrity.

Before the footer there is a list of road objects, which in their turn consist of many elements as indicated by the arrows leading to the objects one column to the right. Here, the Position field is mandatory as information of an object without a position cannot be used. For this there are two options, a LanePosition, which can be related to the MAP [17]. In the MAP a list of intersections (usually only one per RSU) is defined with a GenericLane object for each approach and egress that is specified. The objects can be directly referenced in the SOM to indicate a location of an object. The distance from the start of the lane is indicated by the distance field. Optional is to also indicate the lateral position (e.g. is it on the right of left side of a lane?) and the accuracy of the location measurement. Accuracy can vary depending on the technology used, a roadside sensor is generally much more accurate than a GPS system and could be included as a 95% confidence range around the described position. The other alternative for the Position is an AbsolutePosition, which has to contain a latitude and longitude and optionally an altitude and accuracy. Altitude can be interesting when a traffic situation contains a bridge or tunnel, where an object can be at the same position on different levels.

Apart from the Position, the Road Objects contain many optional elements: speed, acceleration, heading, which can be reported as numerical values and destination and object type, which are more complex. All of these optional elements could be known by the sensors or from received CAM messages, but are not necessarily available. The object type can consist of an enumeration of several relevant object types. The destination has four options (indicated as grey/optional, but one has to be chosen): TurnDirection (left, right through), IntersectionID of the next upstream intersection according to the MAP messages, GenericLaneID of next lane the vehicle is going to or an AbsolutePosition. The latter was already described as option to indicate the Road Objects position, but in the same data structure can be used again to indicate a destination position. The last element is mandatory and is the accuracy of the destination information. More research is required to set the confidence levels for a destination based on navigation system or habit data, but it is important for risk assessment to know how accurate the data is.

For the CAM message the destination element of the SOM message can be added to the data. Using the same format increases the compatibility of the messages and makes it easier to integrate CAM data into the SOM message. Since an RSU generally has a better signal reception, because it is mounted at a higher altitude, some CAM messages may be lost to some of the normal traffic due to occlusion, but can still be received by the RSU. In this case inclusion of the data into the SOM is useful.

Conclusion

The paper has demonstrated the need for more VRU safety measures to reduce the share of 68% in current road fatalities of VRU's. To accomplish this, scenarios were defined in which sensory and destination information can increase safety. Key element in these scenarios was that potential conflicts can already be identified and shared between C-ITS stations before actual warnings can be sent. For this the Sensory Observation Message was defined, which can share information of infrastructure and vehicle sensors, but also received CAM messages. With this message vehicles can anticipate on drivers' actions and send warning messages as soon as an action that may lead to a conflict is initiated instead of waiting for risk assessment at the infrastructure to exceed the threshold of sending a warning. Adding destination information in the CAM message also improves identifying potential risks and reduce false positive rates.

Including destination (or route) information will improve prediction of conflict situations. In cases where drivers or cyclists (actively) need to provide this information it is important to make sure there is a benefit for them that they understand. This holds both for the end-users that may need to use additional technology to provide the information as for the authorities that need to approve that information is being shared. The technology itself needs to very be reliable, both from a safety point of view of course, but also to ensure trust by the drivers and cyclists. If the system fails, give false warnings or unclear messages, people will not trust and therefore not use the system.

The SOM and CAM extension design have been related to other standardized messages. This will increase compatibility. The destination information fields in the SOM and CAM use the same definition to ensure mutual compatibility. The scenario's also led to the conclusion that the architecture of the current systems with LDMs can be easily extended to add SOM and CAM destination.

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