SAFETY 2.0 – POTENTIALS OF COOPERATIVE SAFETY BY VEHICLE-TO-X COMMUNICATION

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ABSTRACT

Safety Technology has evolved significantly over the last decades. The technological progress, based on the continuous advances in vehicle crash worthiness, restraint systems and active safety functions have made traffic safer than ever before. Latest development has led to a sharp increase in the equipment rates for advanced surrounding sensors, so that on-board surrounding sensors such as camera, radar and lidar sensors have become standard equipment in modern vehicles. Surrounding sensors can provide safety critical information to a vehicle and are thus a pre-requisite for new integrated safety functions such as Forward Collision Warning (FCW) or Emergency Brake Assist (EBA). What if vehicles could communicate with each other and create a network for safety critical information in traffic? What if my vehicle gets real-time information on sudden braking maneuvers 500 meters ahead? What if a vehicle camera detects a cyclist approaching at an urban intersection and shares the cyclist position information with other vehicles? What if vehicles share their mass, velocity and position before a crash to optimize the strategy of airbag deployment? Wouldn`t all this open a new dimension of safety in future traffic – Safety 2.0?
This paper promotes cooperative safety as a new approach based on the exchange of safety critical information in traffic. The underlying thesis is that cooperative safety would dramatically increase the safety for a large number of traffic participants, including vehicles without on-board surrounding sensors and vulnerable road users (VRUs) like children, pedestrians and cyclists.

INTRODUCTION

Traditionally, vehicle users rely on the seat belt and airbag to protect them from harm during an accident, just like a safety net would protect the fall of an acrobat in a circus. Today's approach goes far beyond this safety net. Advanced Driver Assistance Systems (ADAS), tailored to specific driving situations, help to avoid accidents, should the driver fail to take proper action. ADAS are doing an excellent job of this because they have traits that make them perfect co-pilots: They do not get distracted, they don't suffer from mood swings, they don't drink, and they never become tired. The EU commission has in its Vision Zero set the ambitious goal for halving road casualties down to 15,750 by 2020 and moving close to zero fatalities in road transport by 2050 [1]. An increasing number of ADAS is a significant move towards more driving safety, fewer accidents, and fewer fatalities – towards the EU target of Vision Zero.

So, are we nearly there yet? No, we are not. After all, on-board surrounding sensors are subject to similar limitations as they apply to the human senses. Due to many reasons the practical range of an automotive sensor can be limited just as much as human eyesight, for instance. Ultimately, the human eyesight needs a "line of sight" to detect objects, traffic signs or road markings. At low visibility e.g. due to bad weather or fog, with the support of different surrounding sensor technology, ADAS can help to recognize vehicles and obstacles more accurately than the human eye could do. However, hidden objects, like approaching vehicles hidden by trucks, or vehicles behind buildings in an inner-city crossing situation, cannot be recognized. Even the most advanced surrounding sensors have a line of sight. If there is no such line of sight, ADAS cannot help.

This is a non-satisfying situation, considering the enormous benefit that could be reaped, if the "line-of-sight" problem was finally overcome. According to a study of the U.S. Department of Transportation (DOT), Federal Highway Administration [2], in 2007, approximately 2.4 million intersection-related crashes occurred in the U.S.A., representing 40% of all crashes and 21.5 % of traffic fatalities. Therefore, the ultimate integrated approach to driving safety needs to address just that – integrating new technologies to close the gaps of visibility and enable powerful and effective safety functions.

The answer lies in an exchange of safety critical data between vehicles (V2V) and between vehicles and infrastructure (V2I). Such V2X communication is based on IEEE 1609 Standard (in EU: ITS-G5) [3], also known as automotive WLAN technology. In V2X communication vehicles become cooperative by exchanging relevant information with each other and with the infrastructure (like traffic lights, construction sites, etc.). Based on cooperative safety, imminent collisions can be recognized and prevented, even when collision objects are hidden and even at higher speeds over a broader range than vision and radar based systems can do.

SHORT RANGE AND LONG RANGE COMMUNICATION

With the use of V2X communication a wider scope of cooperative safety functions can be evaluated and initiated, ideally before a situation even gets critical. This data flow can take driving safety to a whole new dimension that can be called "Safety 2.0".

As the timeline for this type of V2X communication can be very short, and initiating a safety function may have to be done in split seconds, it is unlikely that drivers will want to rely on the instantaneously available bandwidth for internet access and a communication flow via a backend. True, this long-range networking of vehicles will be of immense importance during normal driving. Actually, vehicle drivers and passengers will probably consider being "always on" to be the most useful part of wireless communication. However, when there is immediate danger to life and health, short range V2X is essential. Long and short range communication complement each other because they have different strengths to offer during different driving scenarios (see figure 1).

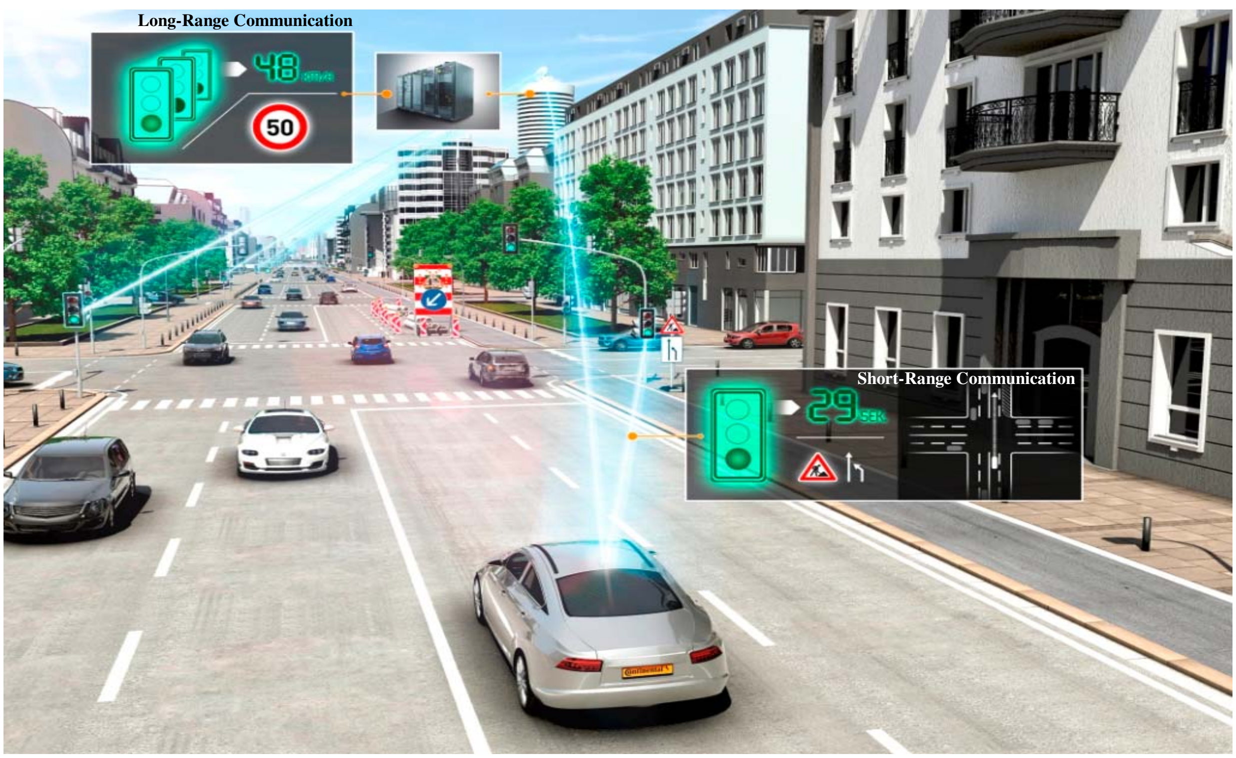


Figure1. Short range V2X communication and long range communication via backend complement each other

VEHICLE-TO-X HAS PASSED THE TEST

Short range V2X is no longer a vision. Since the successful conclusion of the Safety Pilot field trial in the US and the large sim^{TD} (Safe Intelligent Mobility – Field Test Germany) pilot project on V2V communication in Germany [4], it is clear that the underlying technology works. A V2X unit has been developed during the sim^{TD} project and is close to serial production at Continental. With this unit safety critical data such as vehicle speed, location, precise time (time stamp), or brake status, can be communicated within a spontaneous "ad-hoc" network of vehicles (compare ETSI specification [5]). As a further enhancement, objects or traffic situations (e.g. broken vehicles, accidents or slippery road conditions) detected by the sensors of another vehicle, can also be communicated to the ego vehicle before the situation becomes visible to that vehicle. By receiving and processing data from other vehicles, V2X communication turns into a new cooperative "sensor" that complements the existing on-board surrounding sensors.

Imagine a scenario, where a truck and a sports utility vehicle are at risk of colliding because the drivers are unable to see one another approaching the intersection (the stop sign is disabled). With V2X, both drivers would receive warnings of a potential collision, allowing them to take actions to avoid it. The Intersection Movement Assist (IMA) warns the driver of a vehicle when it is not safe to enter an intersection due to a high probability of colliding with one or more vehicles at intersections both where a signal is present (a "controlled" intersection) (see figure 2) and at those where only a stop or yield-sign is present (an "uncontrolled" intersection).

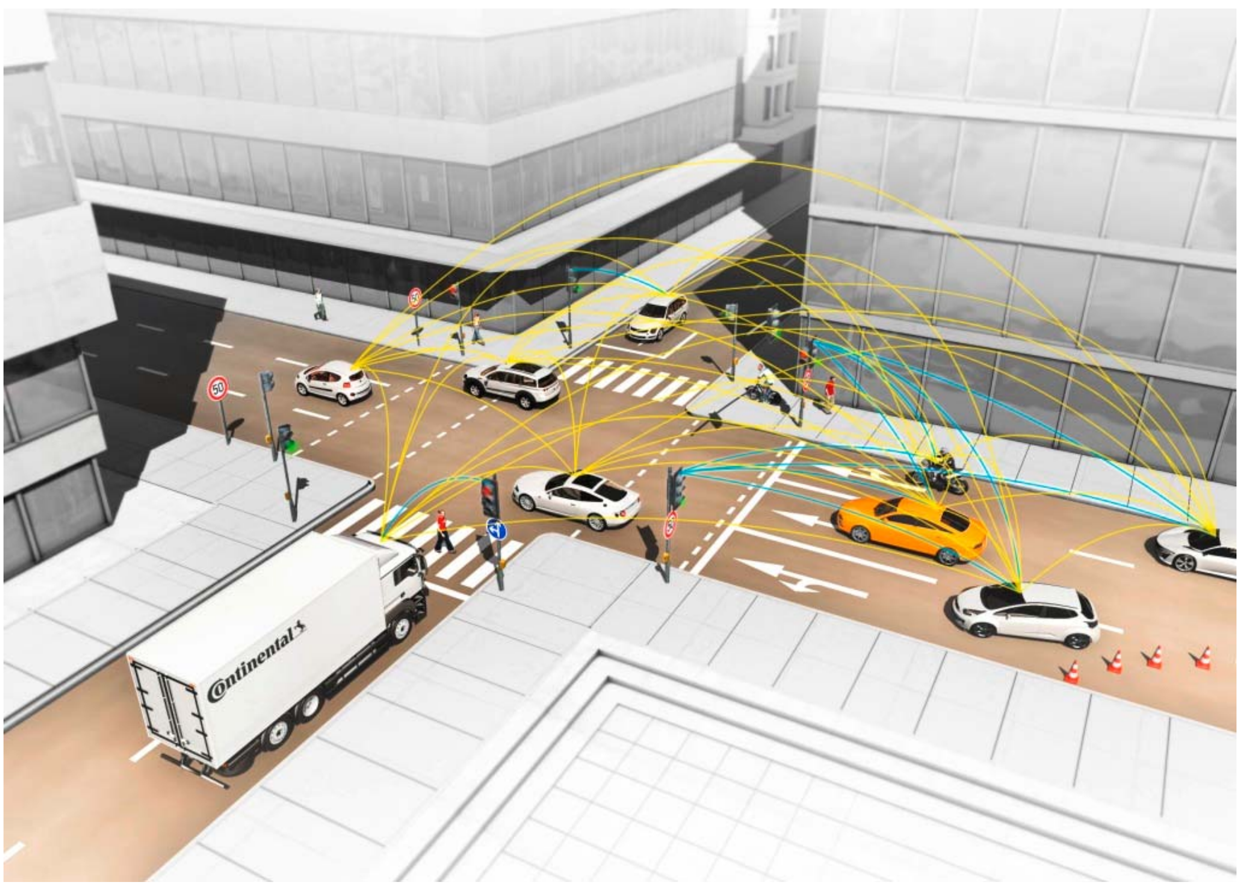


Figure2. Example of V2V Intersection Movement Assist warning scenario

Also scenarios with oncoming traffic in the opposite direction can be addressed: A Left Turn Assist (LTA) can warn the driver of a vehicle, when they are entering an intersection, not to turn left in front of another vehicles traveling in the opposite direction. Even in overtaking scenarios hidden "blind spot" vehicles driving in the opposite direction can be detected and signalized with a warning. A cooperative V2X communication can even detect a vehicle traveling towards you when it is hidden behind a curve (see figure 3).

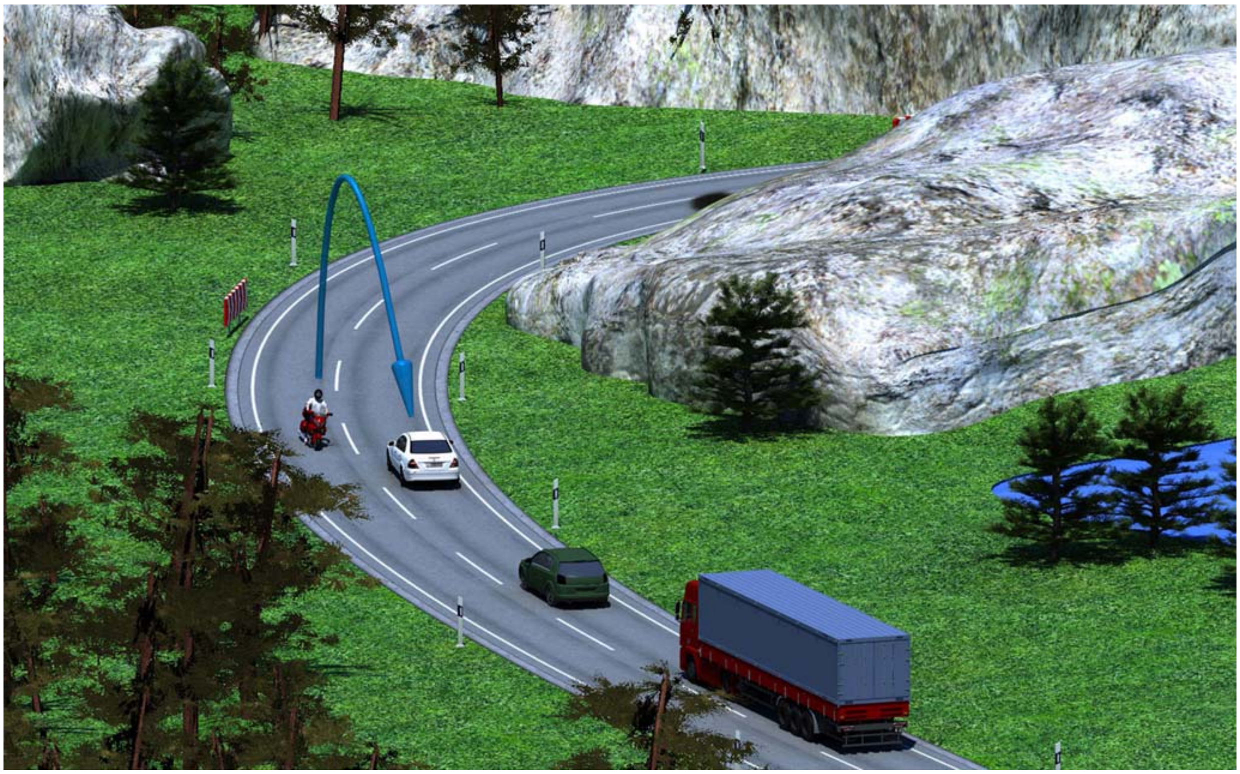


Figure3. Avoiding an accident at a hazardous location through short range V2X (image courtesy of Car2Car Communication Consortium)

Imagine a motorway where traffic going in the opposite direction will have passed an accident on the ego vehicle's side of the motorway long before the ego vehicle gets to the accident (see figure 4). As soon as this information is available, the driver can be warned and the lateral and longitudinal dynamics of the ego vehicle can be adjusted to the situation. Other use cases include crossroads where another vehicle may have a good field of vision while the ego vehicle next to it has not. The other vehicle will therefore be able to detect the approaching truck and will share this bit of information with the vehicles around. During this mutual information sending and retrieval process one vehicle tells the other what it "sees".

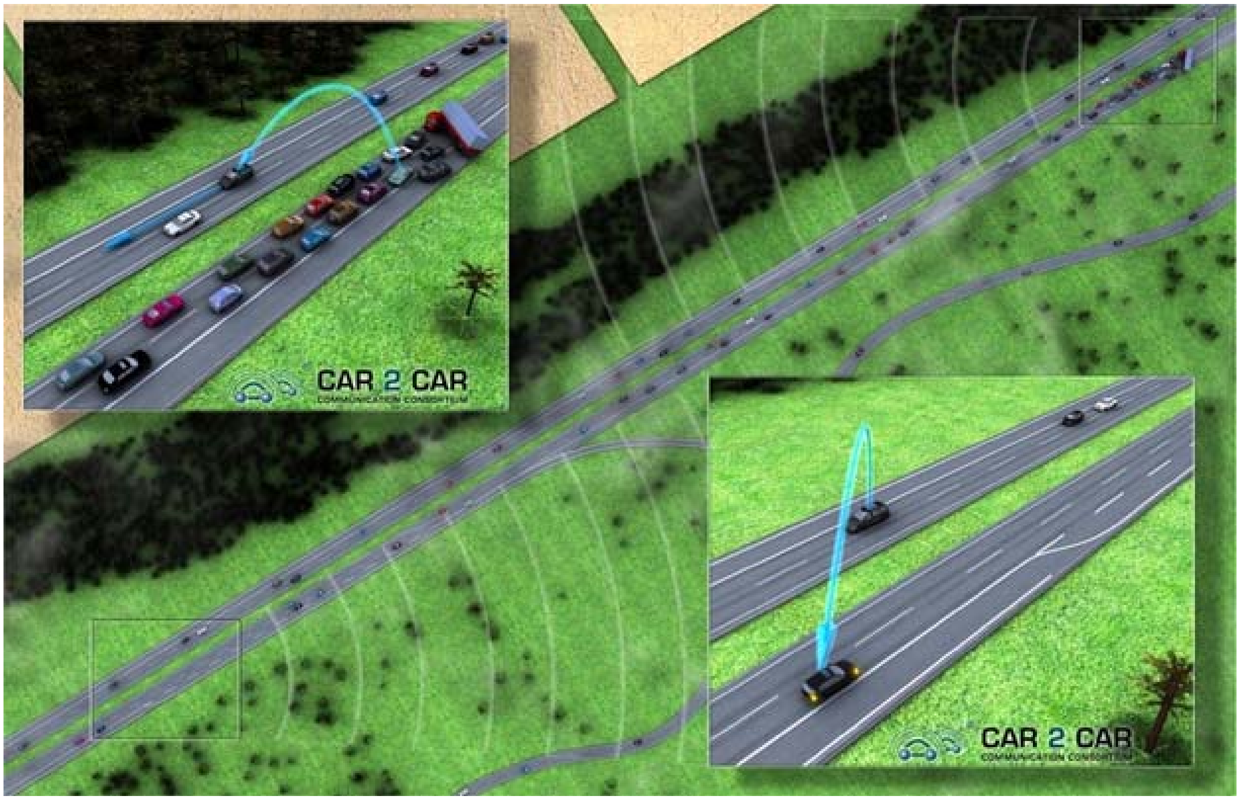
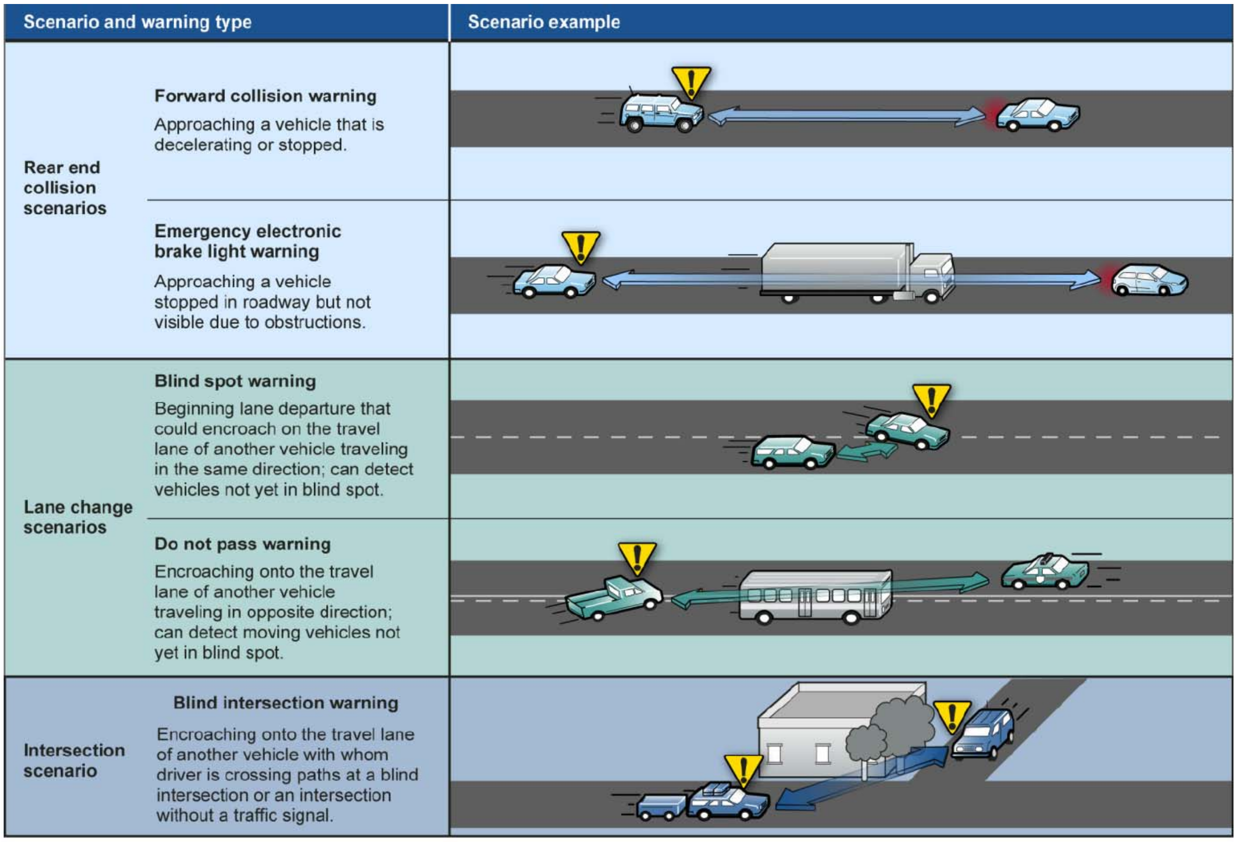


Figure4. Avoiding a traffic jam through short range V2X (image courtesy of Car2Car Communication Consortium)

NHTSA STUDY ON EFFECTIVENESS OF V2V COMMUNICATION

According to a new report on the readiness of V2V technology, initiated by DOT's National Highway Traffic Safety Administration (NHTSA) [2], V2V safety technology can help drivers avoid or reduce the severity of four out of five unimpaired vehicle crashes.

In order to measure the potential impact of V2V technology, the NHTSA report looks at rear end collision scenarios, lane change scenarios and intersection scenarios (see figure 5). In the scenarios new safety functions based on V2V communication help to avoid accidents. These functions include Forward Collision Warning (FCW), Intersection Movement Assist (IMA) and Left Turn Assist (LTA). In terms of safety impacts, the report estimates that Intersection Movement Assist and Left Turn Assist would per year prevent up to 592,000 crashes and save up to 1,083 lives. And in addition the severity of accidents would be reduced significantly [2].



Source: GAO analysis of Crash Avoidance Metrics Partnership information.

Figure5. Examples of crash scenarios and Vehicle-to-Vehicle applications (image courtesy of [2])

PROTECTION FOR VULNERABLE ROAD USERS (VRU)

Let's turn to another important group of road users besides vehicles and their drivers and passengers: vulnerable road users (VRUs) such as children, pedestrians and cyclists, suddenly appearing from behind an object, are one of the major concerns to developers. In comparison to vehicles, they have no or almost no protection systems, but they operate in more complex traffic scenarios: between two parking vehicles, behind an obstacle, in a crowd, at crossings, etc.

Vision or radar based sensors can detect VRUs as long as the "line of sight" (compare above) is given. Is the VRU hidden by other objects, V2X communication can help to identify VRUs and to trigger the right warning or vehicle function. At Continental several technological approaches are under research. Within the German Ko-FAS research project Continental has developed and tested new hardware and software which facilitates an innovative approach to cooperative driving safety. In addition to conventional radar the research vehicles were equipped with a secondary radar system. In principle this is aircraft technology that has been modified for automotive requirements. A transponder (receiver and transmitter), called Ko-TAG 2.0, installed in each vehicle sends out an interrogating signal and receives active replies from other road users [6]. During the project pedestrians were equipped with an early version of a Safe-TAG 1.0 transponder so that they too could be identified and located. During extensive testing, which included equipping a complex crossroads in the town of Aschaffenburg (Germany) with stationary transponders, this type of tagging and short range V2X communication demonstrated enormous accident avoidance potential. Alternative technologies to the transponder developed in Ko-TAG could be promising for an ad-hoc communication between the vehicle and the VRU [7].

BUILDING SAFETY 2.0

The vehicle architecture required for Safety 2.0 adds new sensors and controllers to the vehicle. As described by the above mentioned NHTSA report [2], a typical setup of a V2X system would consist of DSRC (Dedicated Short Range Communication) radios and a GNSS receiver (see figure 6). Furthermore a V2X Control Unit is needed to process and interpret all sensor data and to trigger required safety functions.

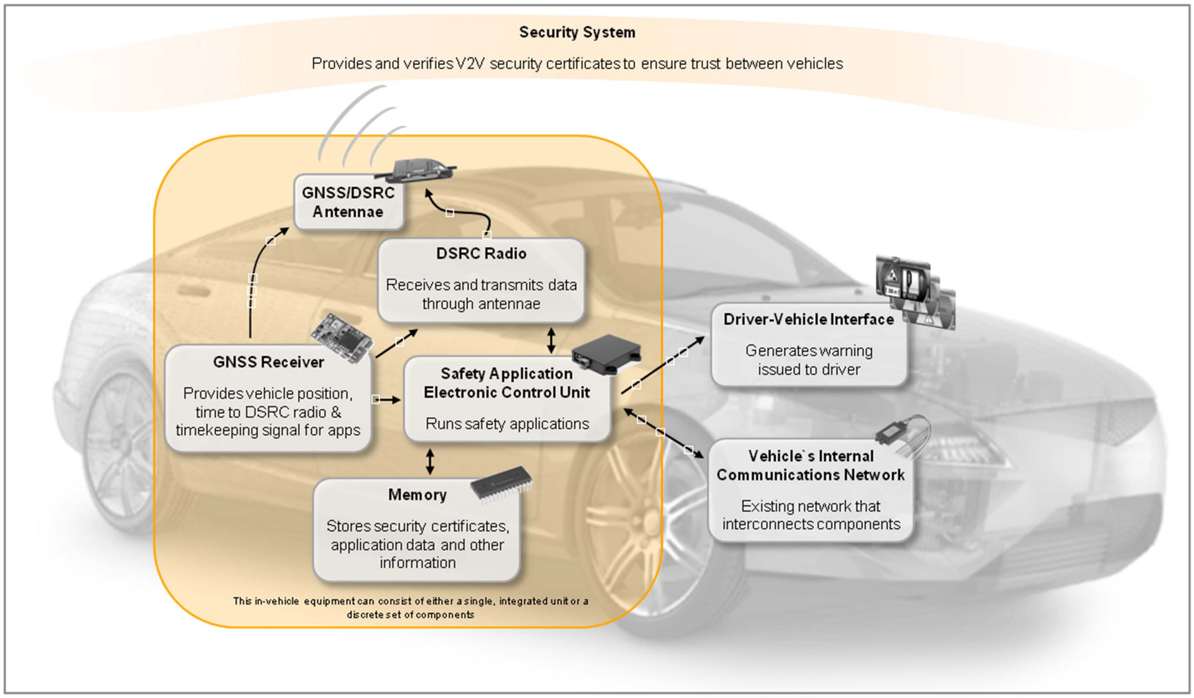


Figure6. In-Vehicle components of a generic V2V System (based on [2])

ACCURATE POSITION IDENTIFICATION IS BECOMING AVAILABLE

In Safety 2.0 knowing the exact position of vehicles will become essential to any cooperative safety function. Up to now, the guidance of the vehicle was realized by the identification of landmarks and traffic – by the driver. Two main challenges can be distinguished: to reach the desired target by choosing the best routes (macro navigation) and to guide the vehicle in order to follow the route, which means longitudinal and lateral guidance while keeping the traffic regulations, avoid collisions etc. (micro navigation).

Safety 2.0 is addressing cooperative safety at the level of micro navigation. To achieve this, the position of all vehicles involved in the V2X communication network needs to be known at all times. Continental has developed the sensor "M2XPro®" (Motion Information to X Provider), which is designed to fulfill positioning requirements of V2X functions and of future systems for automated driving.

In order to achieve an effective and affordable solution, the concept of the M2XPro® positioning algorithm builds on existing standard sensors in the vehicle. By fusion of the vehicle-typical sensors Inertial Measurement Unit (IMU), Wheel Speed Sensors, Steering Angle Sensors (Odometry) and GNSS sensor, the existing redundancy of these sensors can be utilized to determine the accurate position of a vehicle.

Sensors can be disturbed due to their measuring principles, depending on the surrounding conditions. Using a fusion approach, those disturbances can be compensated by the strengths of the other sensors. For example wheel-slip or a reduced number of visible satellites of the GNSS sensor can be weighted lower based on their increased noise or the given sensor information can be canceled out of the motion calculation by means of plausibilization.

This M2XPro® sensor can either be used as a stand-alone unit, or it can be integrated into a specific V2X unit – whichever suits the architecture best (compare [8]). The data provided by M2XPro® is completed by an integrity measure, which indicates what sensor data is actually available and how consistent the sensors are to each other and to the values the algorithm has calculated. The integrity measure is of high value for any safety function. At a high integrity measure a safety function can produce a precise warning or can trigger the correct reaction of the vehicle. However, at a low integrity measure a safety function might decide to stop any further execution due to uncertainty.

Overall the concept of M2XPro® leads to a significant improvement for information on the position and motion of a vehicle. Compared to a GNSS-only position information M2XPro® is improving availability, accuracy and reliability. Thereby M2XPro® is a requirement to any safety function in Safety 2.0.

OUTLOOK

As safety technology has evolved and modern ADAS contribute to a safe driving in most traffic scenarios, V2X communication can close a missing gap: by the cooperative exchange of safety critical data, other vehicles or Vulnerable Road Users (VRU) become visible, even when they are out of the "line of sight" for the on-board surrounding sensors. Closing this gap carries the potential of developing a new level of cooperative safety functions - Safety 2.0. Eventually this new level of functions will bring us a big step further towards the vision of zero accidents.
V2X technology is ready to be applied and with the underlying potential of this technology it will be exciting to develop new safety functions. To speak with the words of David Strickland, NHTSA Administrator: "[…] Vehicle-to-vehicle communication has the potential to be the ultimate game-changer in roadway safety" [9].

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