Traffic safety application & scenario requirements

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ABSTRACT
Currently, vehicles use safety systems like airbags or seat belts to increase the traffic safety of passengers during traffic accidents. In the near future, most new vehicles will be equipped with other type of traffic safety applications, which could prevent vehicles from e.g., traffic accident crashing. The purpose of this paper is to provide an overview of these future traffic safety applications and to discuss the requirements that these applications are imposing on the vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication infrastructures.

Keywords
V2V, V2I, road safety, traffic safety, vehicle safety systems, requirements, collision-warning, IEEE 802.11p.

1. INTRODUCTION
Traffic accidents and highway congestion are a serious problem world-wide [1][2] and many people get injured or die due to a traffic accident. Every minute, on average, one person dies in a traffic crash [3]. While different factors contribute to traffic accidents such as vehicle mechanical problems and bad weather, [4] said: “driver behavior is considered to be the leading cause of more than 90 percent of all accidents”.

In present day vehicles, safety systems like airbag or seat belt pretension saves tens of thousands of people a year [5][6]. Also vehicle frames are created which protect the people inside as much as possible when a crash occurs. But better than strong vehicle frames, air bags and seat belt pretension is to prevent vehicles from traffic crashing [5][6].

Techniques which could be used are sensors, radars, cameras and other state-of-the-art technologies that are currently integrated into vehicles to improve safety and convenience [5][6]. Recently, however both academia and vehicle manufacturers are progressively paying more and more attention to vehicular communication systems to improve the traffic safety due to their potential lower manufacturing costs [6]. Future generations of vehicles probably supports additional vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) safety techniques such as pre-crash, collision warning, lane change assistant and brake assistant systems [7][8][9].

V2V is a vehicular networking technology designed to allow vehicles to “talk” to each other. With V2I, road vehicles are directly linked to their physical surroundings, first and foremost in order to improve road safety [7]. A driver will be informed about dangerous situations by other vehicles (V2V) or by the infrastructure (V2I) to improve traffic safety.

Safety benefits from the fact that vehicles can quickly distribute sensor data they have collected of surrounding vehicles and infrastructure allowing the driver to take appropriate action [10]. However, vehicular traffic scenarios pose greater challenges than indoor WLAN applications, due to associated driving speeds, varying vehicular traffic patterns and driving environments [11]. Safety systems must work under varied traffic types under different vehicular mobility and traffic density scenarios [6] which make it more difficult to build a wireless communication system in contrast to an indoor WLAN system.

This paper provides an overview of traffic safety applications described in different research projects, and it discusses the functional requirements imposed by these traffic safety applications on the V2V and V2I communication infrastructures. The paper could help vehicle manufacturers, road operators, telecommunication operators and other type of operators to develop communication infrastructures that could satisfy the several requirements imposed by traffic safety applications.

The main question of this paper is as follows:

Which functionality requirements are imposed by traffic safety applications and scenarios on V2V and V2I?

To answer this research question correctly, sub questions are defined.

1) Which traffic use cases and applications are available?
2) Which application requirements have to be fulfilled by the vehicular infrastructures?
3) What are the communication network requirements from the vehicular infrastructure?
4) What is the impact of these requirements on the functionality supported by V2V and/or V2I communication infrastructures?

There is much literature available describing existing V2V and V2I applications and use cases. This literature can be used to answer question one. The outcomes of question one in combination with a literature study on the imposed application and communication requirements will be used to answer the research questions two and three. The impact of these requirements on the V2V and V2I communication infrastructures will be elaborated by using an example communication infrastructure, i.e., “Car 2 Car Communication Consortium Manifesto (C2C CC)” [12]. This paper is organized as follows. Section 2 describes the traffic safety applications and use cases.
Section 3 describes the application requirements. The communication requirements are discussed in Section 4. Section 5 discusses the impact of these requirements on the functionality supported by the C2C CC communication infrastructure. Finally, the conclusions and the future work activities will be presented in Section 6.

2. APPLICATIONS AND USE CASES

In order to collect a proper set of user needs; requirements, use cases and safety applications are needed to get a clear view of which requirements can improve the traffic safety of those use cases.

There are many road applications available which could be subdivided into vehicle based applications and infrastructure based applications. Such applications can improve traffic efficiency, traffic safety and could be used for entertainment in vehicles [2]. This paper will only focus on traffic safety applications and requirements.

Safety applications monitor the nearby environment, for example the state of other vehicles via message exchanges between vehicles (V2V) and the infrastructure (V2I). The applications are able to assist the driver in handling the potential danger [6]. Some applications inform the driver, while others can even control the vehicle and may automatically take appropriate actions to avoid potential accidents.

In this section some of these applications will be described and in which use cases they can be used. The use cases and applications described below are the ones which are mentioned as the ones which are used in on-going research projects. Based on that, they are most recent and used in this paper.

2.1 Vehicle based applications

Vehicle based applications are applications that are running on vehicles which are communicating with other vehicles without involving any other node in the communication infrastructure [12][13]. Note however, that Road Side Units (RSUs) might be used in some of the vehicle based applications. A RSU is a fixed communicating node located at one of the sides of the road and that uses the same communication wireless technology as the one used by the vehicles. The following applications will be described in this section: Intersection safety; Speed limitation and safety distance; Automatic brake; Adaptive cruise control; Lane change; Overtaking, Frontal collision warning and Road condition and weather condition.

2.1.1 Intersection safety

When a crash happens at an intersection it can result in other dangerous situations because of approaching drivers who aren’t aware of the crash. Intersection safety applications can warn the driver about such an event [13] as shown in Figure 1. Such applications are able to reduce traffic accidents at intersections [14]. In this way drivers will be aware of the specific situations and can adapt their driving style to this situation [6][7]. A vehicle is for example sending information to approaching vehicles after an accident happened [6], for example when an airbag is deployed, the vehicle makes a rollover or when another life-threatening emergency is sensed [13][14]. The vehicle could also see crash relevant situations by using data regarding to position, velocity, heading, yaw rate and acceleration of other vehicles in the vicinity [13][14][15].

![Figure 1: Intersection safety (from [7])](image1)

2.1.2 Speed limitation and safety distance

Velocity is one of the most crucial factors of intersection collisions. With speed limitation and safety distance systems drivers can be informed in term of speed and safety distance regarding to an intersection or to the behavior of the vehicle in front [2][7] as presented in Figure 2.

![Figure 2: Speed limitations and safety distance (from [7])](image2)

2.1.3 Automatic brake

The systems described in section 2.1.2 can be extended with an automatic brake system which will slow down the vehicle when approaching an intersection or another vehicle in front which brakes [6]. When the brake lights are enabled a signal is sent to following vehicles [13] by giving an early warning of the lead vehicle braking hard even when visibility is limited [6][8][14][15]. In [5] such a system is described: Cars are driving behind each other on a safe following distance on the basis of their actual performance characteristics they communicate with each other.

2.1.4 Adaptive cruise control

Adaptive cruise control applications are an improvement of safety distance and speed limitations systems described in section 2.1.2 [2][13]. According to [14] such systems include “stopped vehicle detection, cut in vehicle detection, shorter headway distance following, improved safety, etc.” all to improve the traffic safety and to increase the traffic efficiency.

2.1.5 Lane change

Rear mirrors can help drivers to have a good vision around their vehicle, but the driver can’t see blind spots around his vehicle [6]. For example: When a vehicle changes from lane on a highway, it is relevant to inform the driver about presence of other vehicles around the vehicle so that the driver can also see the blind spots [14] as shown in Figure 3. In [7] and [15] they describe a lane change maneuvers system which can help drivers by informing them of the presence of other vehicles so that the vehicle can change lane without causing dangerous situations [2][12][13].

![Figure 3: Lane change (from [7])](image3)
2.1.6 Overtaking
A system like lane change can also be used when a vehicle wants to overtake another vehicle. Then they are facing the risk of a head on collision due to the approach of a second vehicle in the opposite lane [7][14]. This situation is presented in Figure 4. The situation can be the same for vehicles facing the vehicle which wants to overtake another vehicle. Safe overtaking applications use GPS data to warn the driver about vehicles facing him so that he can wait with his overtaking maneuver until there aren’t facing vehicles anymore.

Figure 4: Overtaking application (from [7])

2.1.7 Frontal collision warning
Another application which can inform drivers about the presence of facing vehicles or obstacles in front is the frontal collision warning application [2][7]. There could, for example, be a slow vehicle in front or an obstacle in a curve which the driver can’t see and that may result in a frontal collision as depicted in Figure 5. This system shares relevant information such as position, speed and heading in order to predict a frontal collision [12] with other vehicles. When the vehicle detects a critical situation, the vehicle warns the driver or even helps the driver by controlling the vehicle [13].

Figure 5: Frontal collision warning (from [7])

2.1.8 Road condition and weather condition
The applications mentioned above are a great benefit in poor visibility and inclement weather situations [14]. They can cooperate with applications which share information about the road, such as the road condition and weather data [2][7]. For instance, when a vehicle detects a critical situation, the vehicle retains information about the location and shares its knowledge with other vehicles in the surrounding area directly (V2V) or via a RSU like presented in Figure 6. Vehicles which receive the information are providing it to the drivers which can adapt their driving behavior to the situation [12].

Figure 6: Road/weather condition warning (from [7])

2.2 Infrastructure based applications
The infrastructure based applications, see [7], can be considered as applications where traffic safety data is processed and decisions are taken by the network infrastructure, i.e., Internet, and the road infrastructure in cooperation with vehicles. The following applications will be described in this section: Navigation; Speed limitation; Vulnerable road user accident avoidance; Curve warning; Hazard and incident warning; Stop sign assistant; Traffic light advisory and Critical zone warning.

2.2.1 Navigation
The most famous example of an infrastructure based applications is the navigation system [12]. Navigation systems can inform the driver about the road he/she is driving, about the driving behavior and about the right speed [1] all to improve the traffic efficiency and safety. Nowadays navigation systems are implemented with speed alert functions which inform the driver when he overrides the maximum speed limit and this makes navigation a traffic safety application.

2.2.2 Speed limitation
Another application that can inform drivers about the legal speed and the recommended speed according to the situation are speed alert applications. A speed alert application can communicate with a RSU which provides the system information [2][7]. But when the speed alert system is built into the navigation system it provides its information from map and position data. The speed system can inform or warn the driver through a human machine interface (HMI) or can even take control of the vehicle [1].

2.2.3 Vulnerable road user accident avoidance
As mentioned earlier in this paper, speed is of great risk for crash involvement and approaching vulnerable road users who want to, e.g. cross an intersection. A vulnerable road user detection and accident avoidance system can inform drivers about vulnerable road users [13] who are crossing or approaching in front of the vehicle [7] like presented in Figure 7. The drivers can be informed in two ways, one is on-board detection by sensors on the vehicle and the other is gathering information from the infrastructure.

Figure 7: Vulnerable road user detection (from [7])

2.2.4 Curve warning
The infrastructure can collect data from different vehicles or infrastructure objects and collect it so that drivers can be informed about dangerous situations [7]. One example is mentioned in section 2.2.3 about vulnerable road users; another example is curve warning [14]. Drivers approaching a sharp curve can be informed about the sharpness and about the best speed to drive the curve [6][8] as presented in Figure 8. This information is collected from other vehicles that have sent the information when they were driving the curve.

Figure 8: Curve warning application (from [7])
2.2.5 Hazard and incident warning
An application which is almost the same as curve warning is hazard and incident warning. Hazard and incident warning systems and road departure warning systems, providing vehicle drivers with a warning of potentially dangerous events or conditions affecting the approaching road [6][7]. These dangerous events can include obstacles, wrong way driving and abnormal road conditions such as low visibility due to, e.g. bad weather.

2.2.6 Stop sign assistant
Stop sign assistant is a system that can contribute to traffic safety by warning the driver about the stop sign at the signalized intersection [6].

2.2.7 Traffic light advisory
As mentioned above a driver could be warned for a stop sign but a traffic light advisory system can do even more. As a vehicle approaches a signalized intersection the vehicle receives information regarding the location of the intersection and the signal timing, which is the time before the signal is changing color [12]. The system calculates an optimal driving speed so that the driver can safely pass the intersection or even determine if a high level of brake is required and taking over control of the vehicle [13].

2.2.8 Critical zone warning
In section 2.1.2 the safety distance system is described as vehicle based application. Such a system is also described as infrastructure based system [8]. E.g.: A vehicle is approaching a zone of risk like the removal of snow on a motorway [13]. The snow remover can’t drive as fast as normal cars or trucks so there is a risk zone around the snow remover. The RSU is communicating with vehicles which are approaching the snow remover and inform the drivers about the specific situation as presented in Figure 9. In [14] they describe another example about an approaching emergency vehicle. The RSU will warn the driver about the speed and in which lane the emergency vehicle is driving so that the driver can adapt his or her driving behavior to that specific situation. Such systems aren’t only infrastructure based but could also be vehicle based.

3. APPLICATION REQUIREMENTS
Is a safety application reliable? What happens if a sensor fails? What happens if GPS data isn’t correct? Or what happens when a driver doesn’t understand the warnings of the system? Such question must be taken into consideration when determining application requirements.

Traffic safety applications can vary from applications providing information, advice and warnings, through applications that assist or even intervene in vehicle control [9]. So it’s important to know whether such systems are used in a warning or control mode or maybe in a combination of these two modes.

The safety aspects that are taken into consideration to determine the application requirements are the functional system and the Human Machine Interface (HMI), see [9].

The functional system focuses mainly on technical reliability of the safety applications. HMI is responsible for the interaction between the driver and the safety application. In appendix 9.1, Table 1, an overview is presented from which requirements must be fulfilled for each application described section 2. These are derived from an analysis of the requirements presented in the references given in Table 1. There is a difference between requirements derived from applications which are informing the driver about non-critical situations and requirements derived from applications that warn the driver about a critical situation or even a take control of the vehicle.

3.1 Functional system requirements
Among the applications mentioned in section 2, different priority on the influence of traffic safety can be defined. For instance, missing a work zone warning is not likely to cause as much harm as missing a collision warning [9].

3.1.1 Reliability
However for both cases described above the reliability of traffic safety application must be as high as possible [16]. E.g. the recognition has to be very reliable and the positioning must be of high accuracy under realistic conditions [3]. A small error in distance measurement will result in a large error in position estimation which can cause a crash.

3.1.2 Trust received information
Vehicles are gathering information from the environment and from other vehicles to determine their positions and the positions of other vehicles. This means that vehicles must trust the information created by other vehicles and RSU’s [12].

3.1.3 Failures
At the same time errors and false data in information has to be restricted [3]. Errors or false data could lead to hazardous situations and could distract the driver from his driving tasks [16].

3.1.4 In-time recognition
In [6] they describe a pre-crash system for vehicles which provides information about a crash relevant situation. The in-time recognition of this accident situation can guarantee the optimum exertion of passive safety systems [6][16]. Nowadays this is a problem for the current systems like airbag or seat belts. First they have to be released at an exactly specified point in
time to achieve the optimum effect. Secondly the decision which systems are activated and with what amount of power, for the most part, depends on the actual accident situation and severity [6].

3.1.5 Exact sensor data
That’s why a pre-crash system has to be as exact as possible [16], about different properties of the environment like: location, distance, speed, brake power, driving direction [12] and relative velocity of the crash-relevant object at a specified time and before the crash actually happens [3].

3.1.6 Performance of vehicle
It’s also very important to know the performance of a vehicle. In [5] they provide the following example of an automatic brake system: Vehicles are driving behind each other on a safe following distance on the basis of their actual performance characteristics. For example: the condition of the brakes of the trailing vehicle. It could be that “you end up having a Porsche or Mercedes limited by the performance of a Fiat,” So it’s very important to know the exact distance before a specific vehicle is standing still from a various speed [16], So the exact distance depends on the state of the least-able vehicle.

3.1.7 Application authority
As described above many applications are designed to automate driving task and may reduce driver’s workload. In [9] they suggested: “automation of part of the driving task may lead to driver under load and hence loss of situation awareness”. This means that low workload can lead to loss of situation awareness and a resulting inability to respond in time to dangerous situations. It also appears that problems occur when drivers must regain control of an automated system [9]. So when designing a system it has to be in consideration how much authority an application must have about the operation of the vehicle [17].

3.2 Human Machine Interface requirements
A human machine interface takes care of the communication between the traffic safety application and the driver. This could be achieved by a display message containing certain information or for example by generating a sound warning if the vehicle comes too close to the dangerous situation.

3.2.1 Driver distraction
However it is necessary to try to limit the total amount of driver information. In [9] it is stated: “The system should be designed in such a way so that the allocation of driver’s attention to the system displays or controls remain compatible with the attentional demands of the driving situation”.

3.2.2 Standards
Visualized information on HMI’s should be so that the driver will not be disturbed driving the vehicle. This can be achieved by usage of standard icons, symbols, words, or abbreviations so that the driver can directly see and understand the information. With the usage of standards, drivers can understand and react to specific warnings or alerts faster.

3.2.3 In-time warnings and information
This information should be in time according to the relevant situation [7]. This means that the information should be provided into save time, earlier than the driver’s own reaction time [3]. The system may not show information or warning which may result in hazardous behavior by the driver.

3.2.4 Liable sound levels
It also should not produce sound levels liable to masks warnings from the environment like emergency vehicles [9]. All these messages and sounds must be designed so that the driver shouldn’t be overloaded or distracted.

3.2.5 Operating mode
In section 3.1.7 we discussed the authority of applications. When this authority is too high and when driver tasks are automated it can occur that drivers may misunderstand the performance of such an application. A driver may not be aware when a system is enabled or disabled or in which mode it is operating. For example: A vehicle with an automated brake system is approaching an intersection and will automatically brake before it. The driver has a monitoring task but may underestimate the situations and may interrupt the braking process [9]. This can lead to dangerous situations for vehicles driving behind the braking vehicle and a collision can occur. So it’s important to show the driver in which mode the system is operating and if the system is enabled or disabled [9].

4. COMMUNICATION REQUIREMENTS
As described in section 2 and 3 vehicles communicate with each other (V2V) or with the infrastructure (V2I). So we can conclude that communication is a core technology for V2V and V2I applications [1]. In appendix 9.2. Table 2, an overview is presented about which communication requirements must be fulfilled for each application described in section 2. These are derived from an analysis of the requirements presented in the references given in Table 2. In particular, Table 2 shows the communication requirements derived from each traffic safety application described in section 2. Also in this table there is a difference between requirements derived from applications which are informing the driver about a non-critical situation and requirements derived from applications which warn the driver about a critical situation or even a take control of the vehicle.

V2V and V2I communication will be possible directly when in range, or, in general, across multiple wireless links, with nodes acting both as end points and routers [18]. Such networks are organized with the goal of facilitating the exchange of short messages between the traffic participants. Messages contain data that is used by safety systems installed in vehicles or RSU’s for determining the risks associated with a traffic situation and informing the driver about it. The associated high velocities and hostile driving environments (high density, low density, different roads, etc.) pose a challenge to the performance of wireless communication [10][11][19].

4.1.1 Data traffic efficiency and accuracy
In [20] they state that when the offered data traffic is large or must bridge a large distance, the reliability, latency, and channel efficiency deteriorate. E.g. a vehicle transmits a package over 100 meters, may not be able to transmit the same package 400 meters. Therefore the offered traffic depends on the message rate, size of the message, range in meters and density of other vehicles producing messages [12]. In [21] and [10] they require a
minimum range of 1000 meters to send safety messages to vehicles and RSU’s and they prefer to make messages as small as possible to unload the data traffic [2][15]. Some applications can be improved with a data aggregation functionality to decrease the message size and accuracy [12].

4.1.2 Functional in multiple environments
Furthermore the system should, as mentioned above, work in environments with low and high density of vehicles [12]. The system should also work in all environmental situations like single lane roads, multi-lane roads, in wooded areas, mountainous areas, on urban roads, sub-urban roads, high-ways, motor-ways, etc.

4.1.3 Fast and reliable signal processing
Beside the data which will be sent and the environment in which it will be sent, the velocity of vehicles could impact the data communication performance and in particular, the packet loss. Vehicles can have velocities up to 400 km/h and higher [10]. Therefore a very fast signal processing is needed that doesn’t need too many observation cycles. The high velocities are also important in the calculation of the message time before a message is received or acknowledged [2][10]. Furthermore when vehicles are driving behind each other it’s necessary to know in-time when another vehicle is braking and what the braking performance of that specific vehicle is [2]. That’s why it’s important to deliver the message fast and reliable [2][4][22] so that the system has enough time to react to the braking vehicle in front.

4.1.4 Low network access time
To send and receive messages a vehicle must first have to access the network [19]. Because of its possible high velocity, it is important to keep the network access time as low as possible to avoid that messages will be lost during this process [10].

4.1.5 Licensed frequency band
In order to find market acceptance perhaps the most important criterion is the usage of a licensed frequency band. Standardization of the vehicular communication is now ongoing in major international projects such as the Car-to-Car Communication Consortium (C2C-CC) [12] and national ITS authorities [14][21][23]. The IEEE develops the Wireless Access in Vehicular Environments (WAVE) [2] and extensions of the 802.11 protocols for ITS applications (IEEE 802.11p [24][25]) as licensed frequency.

4.1.6 Confidentiality and security
Beside the above mentioned requirements it’s important to have a secure and confidential connection. Consider, for example, a node that is transmitting false hazard warnings or other false information, or nodes that are receiving information for another destination. It could also happen that a protocol as mentioned above will hang (i.e., stop operating) due to fault, malicious nodes or errors [26]. Then the system isn’t accessible anymore. These simple examples of exploitation indicate that under all circumstances vehicular communications must be as secure as possible [18][26]. To achieve a secure connection messages must be encrypted or digitally signed when they are sent to a destination to protect them from any alteration [16].

4.1.7 Authentication
Furthermore the receiver must send an acknowledgement to the sender of the message [18], to authenticate the message. This means that the receiver must have evidence of the liveness of the sender, so that it knows if a message contains an error or if the message hasn’t got any latency. The receiver must send the acknowledgement in a specific time, so the sender will know that the receiver has received the message.

4.1.8 Denial of service
Nevertheless applications in the future will require real-time, or near real-time responses as well as hard real-time guarantees. However, attempts to meet real-time demands typically make applications vulnerable to Denial of Service attacks. In the deceleration application, a delay of even seconds can render the message meaningless.

4.1.9 Accessibility
Before a vehicle can send any messages it must first be connected to a network or service [16]. This access to specific services provided by the infrastructure nodes, or other nodes, is determined locally by policies [18]. The content of messages is kept secret from those nodes that aren’t authorized to access it.

4.1.10 Priority
The content of messages must allocate a variable “priority”. With this variable messages could be ordered in importance. The important messages will be shown first to the driver and the other will be stored [16]. Result: messages with a high importance (priority) will be shown first. Vehicles can forward messages to other surrounding vehicles when they receive messages. The messages with the highest priority will be sent first and the other will be stored. They will also be stored when a vehicle can’t forward a message due to e.g. the low density of vehicles [12]. So priority is of great importance to decrease vehicle collisions.

4.1.11 Privacy
Beside these technical issues, it’s important to have customer’s acceptance [16]. An important issue when developing communication systems is that the user’s privacy must be protected [26][27]. This means that vehicular communication systems should not disclose or allow inferences on the personal and private information of their users [18].

5. IMPACT REQUIREMENTS ON VEHICULAR INFRASTRUCTURES
It’s hard to determine if a traffic safety application is safe or not. You can take into consideration that an application is safe when it covers the most important safety requirements. But what are the most important ones and what’s the impact of these requirements on the infrastructure?

In order to analyze the most important requirements and the impact of those on vehicular communication infrastructures, it is important to identify and to at least use an existing vehicular infrastructure as comparison material. In this section the vehicular infrastructure defined in the “Car 2 Car communication Consortium Manifesto (C2C CC) [15]”, is used as example vehicular communication infrastructure. Section 5.1 will describe the C2C architecture and section 5.2 will link the used
requirement to this architecture. In section 5.3 a comparison is made between the requirements derived in this paper and the requirements currently supported by the C2C architecture.

5.1 Car 2 Car (C2C) architecture

The C2C architecture is depicted in Figure 10. This architecture is divided into 3 communication types, i.e., infrastructure domain, Ad-hoc domain and the In-vehicle domain. In this section we will only focus on the In-vehicle and Ad-hoc domain, since these two domains are mainly used for the support of the traffic safety applications. The wireless technology used for the support of the traffic safety applications is IEEE 802.11p.

![Figure 10: Car 2 Car architecture (from [12])](image)

5.1.1 In-vehicle domain

An application unit (AU) is an in-vehicle entity and it could run traffic safety applications like the one’s described in section 2. These applications communicate via the on-board unit (OBU) with other vehicles (via OBU) or with a road side units (RSU) using the IEEE 802.11p wireless technology.

5.1.2 Ad-hoc

The Vehicular Ad hoc Network (VANET) is composed of vehicles equipped with OBU’s and RSU’s that are communicating with each other using the IEEE 802.11p wireless technology.

OBU’s and RSU’s can be seen as ad-hoc network nodes, where OBU’s are mobile nodes and RSU’s are fixed nodes. RSU’s can communicate with each other’s either directly or via a gateway (GW). As presented in Figure 10, OBU’s can be connected with the internet (i.e., Infrastructure domain) using other wireless technology, e.g., Universal Mobile Telecommunication Services (UMTS) or via a hotspot (HS) using the IEEE 802.11a/b/g wireless technology.

5.2 Requirements used in C2C architecture

Firstly the AU will detect a mandatory set of vehicle based data which is as exact and as reliable as possible, like mentioned in section 2 and described in requirement 3.1.1 and 3.1.5. This data is detected in time as discussed in requirement 3.1.4 before a crash actually happens.

The sending vehicle will consolidate the data required by the applications and will package it into an encrypted message as described in requirement 4.1.6 which is as small as possible including performance and security parameters for distribution like: priority, validity and authentication data.

When connected via the IEEE 802.11p network (a licensed frequency band as discussed in requirement 4.1.5), the sender broadcast it to all surrounding vehicles via the OBU. In [12] it is stated: “Data packets are distributed to all nodes within a geographical area efficiently and reliable in an appropriate time". This is covering requirements 4.1.1 and 4.1.3 about efficiency and fast and reliable signal processing.

These messages will be sent using fast forwarding mechanisms over a maximal distance of 500 to 1000 meters with a data rate of 6 Mb/s which is in accordance with requirements 4.1.1 and 4.1.3. OBU’s or RSU’s receive and forward these messages to surrounding vehicles or RSU’s in order of priority or store these messages when the density of vehicles is low and they cannot forward the message like mentioned in requirement 4.1.10. This means that high latency may be acceptable; however it should be reduced if possible. This also means that these applications must work in multiple environments with low and high density of vehicles as described in requirement 4.1.2.

The OBU of the receiver on its turn authenticates (requirement 4.1.7) the message and decodes it into remote vehicle data and checks the validity (authentication, expiry, plausibility and the security parameters) and priority. Then the OBU sends an acknowledgement to the sender when the message is received without latency or faults as discussed in requirements 4.1.6 and 4.1.8.

The AU of the receiving vehicle evaluates the contents of the message and presents the messages in order of priority to the driver or even takes control of the vehicle. These messages will be provided due to standard sound or HMI warnings and information as discussed in requirement 3.2.2. The application is only effective when the information is shown in-time before the response time of the driver is passed as described in requirement 3.2.3.

The goal of all these security mechanisms is to ensure acceptance of the systems’ end user (driver) who must trust information he or she receives due sounds, warnings and information on the HMI as discussed in requirement 3.1.2. Beside all these technical issues it’s important to emphasize also other aspects, e.g., need to address privacy (requirement 4.1.11), law enforcement and liability.

5.3 Requirements Comparison

Many requirements discussed in section 3 and 4 are mentioned in the section above, but still some requirements aren’t specified by [12]. Only the non-used requirements will be discussed in this section.

5.3.1 Application requirements comparison

From the application requirements discussed in section 3.1 Failures, Performance of vehicle and Application authority aren’t specified in the architecture designed by [12]. In [12] they state: “the system must react on to frequent failures”. It is not clear if this requirement is identical to requirement 3.1.3, where it
emphasizes that the system should be designed to avoid failures. This can also be concluded from Table 1, in appendix 9.1, where a low amount of failures is for almost all applications an important requirement.

As described in requirement 3.1.6, AU’s must know the performance of surrounding vehicles. For example the brake process in a safety distance application described in section 2.1.2 and in appendix 9.1. When using such a system it’s very important to know the performance status of the vehicle in front which is e.g. braking. With a signal: “vehicle is braking” the driver can be informed about the driving status of the vehicle in front. But the driver still doesn’t know the power of the braking process (pedal-position) and the power the driver must brake to avoid a collision. So when designing such a system it’s very important to know the performance status of surrounding vehicles to show e.g., the driver brake information which is as exact and reliable as possible.

A system which looks like a safe distance system is the automatic brake system (2.1.3) which is almost the same with the exception that this system can overtake the vehicle control from the driver. As described in requirement 3.1.7: [9] states: “automation of part of the driving task may lead to driver under load and hence loss of situation awareness”. So when designing a system which can overtake the driver maneuvers it’s very important to consider the level and number of authorization rights that could be assigned to an application about the operation of the vehicle [17]. This can also be concluded from the table in appendix 9.1 where only the application which can overtake the vehicle must fulfill this requirement.

5.3.2 HMI requirements comparison
In [12] they barely mentioned HMI requirements as described in section 3.2, except the In-time warnings and information (requirement 3.2.3). But furthermore it’s important to design HMI systems which are not requiring from the driver to take his or her eyes of the road for a too long time. As described in requirement 3.2.2 standards (icons, messages, sounds, words, etc.) can be used to make it easier for drivers to understand the provided traffic safety information [9]. In [7] the authors conclude that there is a reasonable prospect of generating a standardized performance assessment to assure that safety is not harmed by drivers who don’t understand information or warnings of by warnings which aren’t shown in time. It’s also important that the driver will not be distracted (see table in appendix 9.1 and requirement 3.2.1) by sounds or warnings. Therefore liable sounds must be configured and standard warnings could be used as mentioned above.

5.3.3 Communication requirement comparison
Communication requirements like the ones mentioned in section 4 are specified to ensure a safe and reliable connection and data transfer [12]. Almost all communication requirements discussed in this paper are also specified in the C2C architecture except the Low network access time to avoid message lost as described in requirement 4.1.4 and the Accessibility described in requirement 4.1.9. When a vehicle is approaching a network it must connect to it to receive and send safety messages. But it is very important that no messages will be lost during this process and that only the ones which are accessible to the message will receive it (requirement 4.1.9). So the access time must be low, so that the vehicle is as fast as possible in operating mode when switching from network as described in requirement 4.1.4 without affecting the privacy of the consumer. This is most important for applications warning the driver or taking control of vehicles when detecting a critical situation as depicted in the table of appendix 9.2.

To develop vehicular networks so that they are viable and acceptable, we need to establish secure protocols that satisfy the stringent requirements mentioned in section 3. The architecture of such protocols should offer good performances. Complex protocols that lead to latency, overhead and large data packages should be avoided. So a balance must be found between security mechanism and performance, since overhead affect performance of vehicular communication. When keeping this in mind we can develop a high performance network, which works as fast and reliable as possible without affecting the consumer’s privacy.

6. CONCLUSION & FUTURE WORK
This paper focused on one of the most important issues in traffic safety V2V and V2I requirements. In this paper we have tried to give an answer to the main research question: which functionality requirements are imposed by traffic safety applications and scenarios on V2V and V2I? To answer this question several traffic safety applications where studied and the application and communication requirements imposed by such applications have been identified. Furthermore, in order to identify the impact of such requirements on the functionality provided by existing communication infrastructures, a comparison has been made between the derived application requirements and communication requirements and the requirements specified in the architecture of the “Car 2 Car Communication Consortium Manifesto” [12].

We can conclude that many requirements were specified, but as discussed in section 5, future activities are needed. Not all traffic safety applications are yet deployed. Major vehicle manufacturers, government agencies and universities are all expected to work together to make significant progress in this over the next few years [3][15]. Still many systems need considerable improvement in robustness, reliability and cost. This can partly be achieved by discussing which standards must be achieved before it is considered that a system is safe. The approach of standardization of systems needs to be further specified and enhanced. In [9] it is recommended to define common test scenarios and indicators for various categories of warnings and intervening systems to enhance the standardization.

With these innovations in traffic safety systems and the decreasing costs for sensors and actuators, traffic safety will be more and more supported. Maybe it will take decades but in the future vehicle accidents may become almost as rare as plane crashes are now [5]. The role of the driver will change. It is expected that within a decade or so, the drivers of the most advanced vehicles will only have to steer and maybe even that will become superfluous [9].

7. ACKNOWLEDGEMENTS
I would like to thank Georgios Karagiannis for inspiring discussions and valuable comments. I would also like to thank
the reviewers, whose comments and suggestions stimulated new thoughts and helped to improve the paper.

8. REFERENCES


9. APPENDIX

Table 1 and Table 2 show the application requirements and communication requirements, respectively, which are derived from each traffic safety application. The tables are filled in using the following references of described projects: [16][9][7][12][21][13] that has been used to deduce that the particular application derives the particular requirement.

9.1 Application requirements

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<th>Reliability</th>
<th>Trust received</th>
<th>Failures</th>
<th>In-time recognition</th>
<th>Exact sensor data</th>
<th>Performance of vehicle</th>
<th>Authority</th>
<th>Driver distraction</th>
<th>Standards</th>
<th>In-time warnings and information</th>
<th>Liabilities and information</th>
<th>Operating mode</th>
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9.2 Communication requirements

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<th>Low network access time</th>
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