Connected Vehicles:

Can V2V Communication and

Internet Connectivity Improve Safety?

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Tiivistelmä – Abstract

This study explores the possibilities of V2V communication on vehicles. Starting with a broad overview of the history of vehicle safety, leading up to current safety technologies and then adding digitalization. Many parts of the everyday life became digital in recent years and the most used transportation device–the car–is to some extend already part of it. The latest studies on the subject will be examined and how the car manufacturers picture the near future of cars that are connected. The possibilities are nearly endless; a car could be aware of an upcoming obstacle, also infrastructure such as traffic lights could send information to approaching cars. In addition, the regular Internet connectivity opens new opportunities for entertainment features as well as enabling vehicles to become part to the grid of the Internet of Things. Furthermore, the question of reliability as well as security and privacy issues regarding a connected vehicle will be discussed.

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Tiivistelmä – Abstract

Tämä tutkielma tarkastelee ajoneuvojen välisen V2V-kommunikaatiotekniikan (vehicle to vehicle) mahdollisuuksia ajoneuvoissa. Tutkielma alkaa laajalla katsauksella ajoneuvoturvallisuuden historiaan ja etenee nykypäivän turvallisuusteknologian sekä digitalisaation käsittelyyn. Monet arkielämän osa-alueet ovat muuttuneet digitaalisiksi viime vuosien aikana ja käytetyin kulkuneuvo - auto - on jo jossain määrin osa tätä kehityskulkua. Tutkielmassa käydään läpi viimeisimmät aihetta koskevat tutkimukset sekä kuinka autonvalmistajat kuvaavat yhdistettyjen autojen lähitulevaisuutta. V2V-kommunikaatiotekniikan mahdollisuudet ovat lähes loputtomat; auto voi havaita vastaantulevan esteen ja liikennevalojen kaltainen infrastruktuuri voi lähettää informaatiota lähestyville autoille. Säännöllinen yhdistettävyys Internetiin mahdollistaa erilaiset viihdeominaisuudet sekä ajoneuvojen liittämisen osaksi esineiden Internetin verkostoa. Lisäksi tutkielmassa tarkastellaan yhdistettyjen autojen luotettavuuteen, turvallisuuteen sekä yksityisyyteen liittyviä kysymyksiä.

Asiasanat – Keywords V2V, verkotetut autot, liikenneturvallisuus

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1 Introduction

The connected vehicle is a term which is used to describe the new possibilities that the digitalization opened up for road transportation. The term covers all kind of connectivity around the vehicle. However, two main areas can be identified. One is the regular Internet connectivity, and the other one is vehicular ad hoc networks (VANETs).

Services that use regular Internet connectivity are usually digital services implemented into the infotainment systems of the vehicles. An example would be Spotify–the most popular music streaming service–or similar services. Other examples would be apps that provide additional en route information such as gas stations, and other places of interest. Also satellite navigation system can benefit from an Internet connection; the map data can be updated and real time traffic information can be displayed inside the vehicle. This area of providing smartphone-like information and apps are already implemented for the most part, even though the technology is an optional extra for most of the cars.

Many of these services are based on cloud computing, therefore an internet connection needs to be available. Many cars have a build in SIM card to provide the needed Internet connectivity. It can be said that the vehicle becomes part of the *Internet of Things*. Thus, this topic will be discussed in the chapters 4.8 to 4.10.

The next area is the topic of big data around the vehicle. The mobility provider can collect data about the user's driving behavior, the state of the car and then use the data to develop predictions and profiling. Based on the profile, the services can be tailored and customized to driver's and passenger's individual needs. In addition, the functionality of vehicles can be optimized and developed with the collected information. Car insurances is an area where the data of individual driving behavior is already in use and will briefly described in chapter 4.5.

The existing Internet connectivity can be used as an access point for other devices such as mobile phones or smartwatches–basically every customer device that can be potentially used in a vehicle.

Last but not least there is the direct communication between vehicles that run under the term of connected vehicles, which this study is focused on. Potential examples for the use of connected vehicles will be outlined in the chapter 4.3. The main goal of direct communication between vehicles is to optimize vehicle and traffic safety. In order to understand where vehicle safety stands it is necessary to have a brief overview of the history (chapter 3.1) and the main achievements in the recent years (chapter 3.2)

Today the transportation possibilities (either for goods or passengers) are numerous, but the car remains the number one personal transportation device. According to a statistic by the British government, 64% off all trips were made in a car or van in the U.K. in 2012 (Department of Transportation, 2013).

Vehicle safety plays a major role in personal transport due to a large number of traffic accidents and fatalities around the world. Global fatale road injuries reached a number of 1.25 million in 2007 and remained at that level until 2013 (WHO, 2015). Every 7 minutes, a pedestrian is injured on American roads (NHTSA, 2012). According to the report by the World Health Organization in 2004, road injuries were the leading causes of injury-related death by 25%. Almost two-thirds of all fatalities are pedestrians. These numbers show how important vehicle safety is. It seems that the increasing number of safety features cannot stop the increase of fatalities. Globally seen, the number of driven distances is increasing; therefore, it is evident that the number of deaths is also increasing. However, the NHTSA–National Highway Traffic Safety Administration–released a report that the number of death on U.S. roads increased by 3.3% in 2012 compared to 2011 even though the travel distance remained almost the same. However, in the following years the number slowly decreased (-0.7% in 2014 compared to 2013) (NHTSA, 2016).

In general, vehicle safety is divided into two main sections: *passive safety* and *active safety.* The passive safety covers all aspects that reduces the effects of a crash. Focusing not only on the driver and passengers well-being but also on minimizing the injuries of pedestrians. For example, a padded dashboard, a protected steering wheel, seatbelts or airbags are elements of passive safety.

However, active safety aims at the prevention of crashes. Active safety can split up into two or three parts. The first part is hazard detection: e.g. adaptive cruise control, blind spot detection and lane departure warning systems. Second part: hazard avoidance. Systems that interfere when the vehicle is already in a dangerous state. E.g. anti-brake systems and electronic stability control. Third part: safety–hazard mitigation. This come into play when the crash is predictable and it reacts (e.g. emergency braking system) to avoid it. A study by the Insurance Institute for Highway Safety comes to the conclusion that crash warning system plus autonomous braking is an efficient feature to reduce crashes (IIHS, 2012).

Road traffic safety is an even broader term that includes road condition and roadway design, which will be not discussed in this study because this study is focused on in-vehicle technology.

Another factor towards a safe journey is the *education of the driver*. How to behave in traffic, an appropriate and responsible driving style and how to act in certain situations is usually covered by the drive training that leads to the driving license. What effects the driving education has on the traffic safety will not be considered in this study.

The latest development in vehicle safety is *vehicle-to-x communication*. The x stands for a variety of possible receivers and senders. Vehicle-to-vehicle communication is one of the possibilities–it is also known as car2car communication in Europe. Most information and facts in this study are based from U.S. sources, the term *vehicle2vehicle* (or shortened *V2V*) *communication* is used. Gathering the information about V2V communication revealed that the United States are much more active bringing this new technology on the road than European countries. It must be also taken into account that the major European car manufacturers may not want to reveal their technology in order to have an advantage over competitors. Therefore, information about their activities are rare. Nevertheless, V2V communication is one of the next steps of the development of vehicle safety technology and will most likely open up the world for a self-driving car. Until then it is a difficult way; the driver will have to adapt to a new style of driving, allowing the system to interact. In order for this to happen, the information, warnings etc., need to be accurate and relevant to be accepted. the society needs to adapt to a new way of how to interact with vehicles. The traffic in the future will be much more transparent than it is already today. The people have to start to live with the idea that their road activities are under control of a computer system, and that other cars are able to process this information.

In addition, the governments have to talk about insurance issues and in the end open up the world for a legal use of connected vehicles. Later, communicating infrastructure will probably also be added to the connected world of communicating vehicles. This technology runs under the name of *vehicle-to-infrastructure*, or in short *V2I communication*. In a world where everything becomes connected, it is most likely that the infrastructure around the connected vehicle will become smart as well. Traffic lights that recognize an approaching car, a road that detects how many cars are on it and how fast they are moving are just some examples of V2I communication. These infrastructure elements need to be standardized, paid, maintained and in the end effectively installed on public roads. This system needs to be as relevant, important and beneficial to the people, that they see the need for it and would support extra costs.

2 Research Questions, Methodology and Materials

This study is giving an overview on the status quo of the development of vehicle safety and eventually investigates future scenarios when V2V and V2I come into play. Therefore, the research question of this literature investigating paper is:

RQ: What are the main digital car-safety technologies that run under the term V2V communication adapted recently or under development, and what is their expected significance?

Since the topic is relatively new and in development, most of the research and information are based on hypothesis, theories, simulations and tests. Many people around the world are working on V2V communication, therefore one can find a lot of discussions and examples how the future most likely will look like. In this thesis the topic will be approached from different levels and from different point of views. First, the study explores the history of vehicle safety and what research has been done in the past. Then, the up-to-date technologies will be discussed and finally the offered V2V solutions will be analyzed. To get a better understanding how the V2V communication will fit in the big picture of digitalization, the study will briefly illustrate what major developments technology has done so far over the last decades. The Internet of Things plays an important role when it comes to connecting different types of machines and applications.

The study uses mainly journal publications supported by facts from books and patents. Each aspect of this thesis has been undergone a search of relevant publications. When it comes to future scenarios how V2V communication can be used scientific organizations offer a variety of illustrational videos to demonstrate the potential of the technology. To provide accurate information on the development on vehicle safety, patents has been used. Companies from different fields show their technological achievements on events such as motor shows, which can be viewed by the public in polished videos on YouTube.

3 Developments in Vehicle Safety

Research on safety issues around moving vehicle is as old as the vehicles. Without going into too much detail, the gasoline car was invented around 1886, (DE Patentnr. 37435, 1886) and as soon as it got more popular, people realized that certain regulations are necessary to keep the numbers of injuries and death on roads low. One of the first academic studies on vehicle safety was published 1950 in Popular Science under the title “Making the Death Seat Safer”. Using a human shaped silhouette, the advantages of seat belts and padded dashboards were illustrated (Waltz, 1950).

3.1 History of Vehicle Safety

The following chapter is focused on major technical breakthroughs in the development of vehicle safety. It has been tried to give a general overview, even though the developments in car safety and safety regulations were slightly different from country to country. It has to be mentioned that vehicle safety is not only based on technical developments, also traffic education and other factors are playing a role in a decreasing number of crashes and fatalities over the years.

3.1.1 Windscreen Wipers

It might seem banal but wipers are an essential part of vehicle safety. In the year 1903, the American woman Mary Anderson developed the first mechanical wipers (US Patentnr. 743801, 1903). The device removes rain (or other things that may end up on the windscreen) with a rubber blade at the end of an arm, which moves typically in a circular manner. Most cars are equipped with two wipers for the windscreen and one for the rear window. A better view on the road when it was raining or snowing increased the safety. The German company Bosch picked up the idea and engineered the electric wipers during the early 1920s and filed the system in 1926 as a patent (Bähr & Erker, 2015).

In 1963 Robert Kearns invented the *intermitted wipers*. The human eye, which blinks in a millisecond, was the inspiration to build a wiper that only works in a certain interval (US Patentnr. 3351836, 1967). He showed his idea to the Ford company and they build their own intermitted wipers, which led to long court dispute between Kearns and Ford and other carmakers who used his system (Fuglsang, 2008).

The development did not end with the intermitted wipers. Sensors that detected the rain on the windscreen opened new possibilities. The wipers would start working automatically the moment it starts raining. The Citroën SM, produced between 1970 and 1975, was the first car equipped with a rain sensor. According to the amount of rain, the system adjusted the speed of the wipers (Cooley, 2014). Today, many vehicles are coming with standard equipped rain sensors.

3.1.2 Pneumatic Tires

The next major impact on vehicle safety was the invention of pneumatic tires. The chemic Charles Goodyear got the patent on vulcanization of rubber in 1844, which was the foundation for the development of tires (US Patentnr. 3633, 1844).

At the beginning, tires have been solid rubber tires. Dunlop invented the pneumatic tire in 1890 (US Patentnr. 435995, 1890), and since 1904 the tire became a tread pattern, which gave the vehicle more stability (Continental, 2008).

Michelin picked up an idea in the late 1940s by Arthur W. Savage who filed a patent in 1915 to construct tires in a different way. The cord plies are positioned 90 degrees to the direction of travel. These radial tires had a significant advantage over the common bias tires (US

Patentnr. 1203910, 1915). Michelin brought the system to life 1946, and because Michelin owned the French biggest carmaker Citroen, introduced the new tire to 12 models in 1950. The new tier provided more stability for the vehicle and the durability increased as well (Lottman, 2003). Due to the success, the new technology spread quickly in Asia and Europe. However, North American tire manufacturers tried to stick to the cheaper bias tire as long as they could. After decades of fighting over market share, the radial tire eventually won and in 1983, 100% of all new cars in the U. S. where equipped with radial tires (Tedlow, 2010).

Today the condition and type of the tires are often under certain regulations. Countries with snowy winters require winter tires with a thicker tread to remain stability; otherwise they can be sued for not using the correct tires in case of an accident.

3.1.3 Unitary Construction

The Lancia Lambda in 1922 was the first car with unitary construction design (unibody) (Jain & Asthana, 2002) (See also Figure 1 on page 16). Unlike other cars it was not build in different parts like the chassis at the bottom and the coach (passenger cabin) on top. The unibody method combined those two parts into one. The method was not only cheaper and lighter; it was also an improvement of safety. In case of a crash, the energy could spread to the whole body of the car and therefore the impact of the crash could be better absorbed. In 1934, the Citroën Traction Avant became one of the first mass-produced unibody cars of which over 760.000 unites where sold (Wood, 2008). Despite a few small manufacturers, like Lotus, every passenger car today is built in a unibody design. Trucks, however, are still built in the old style.

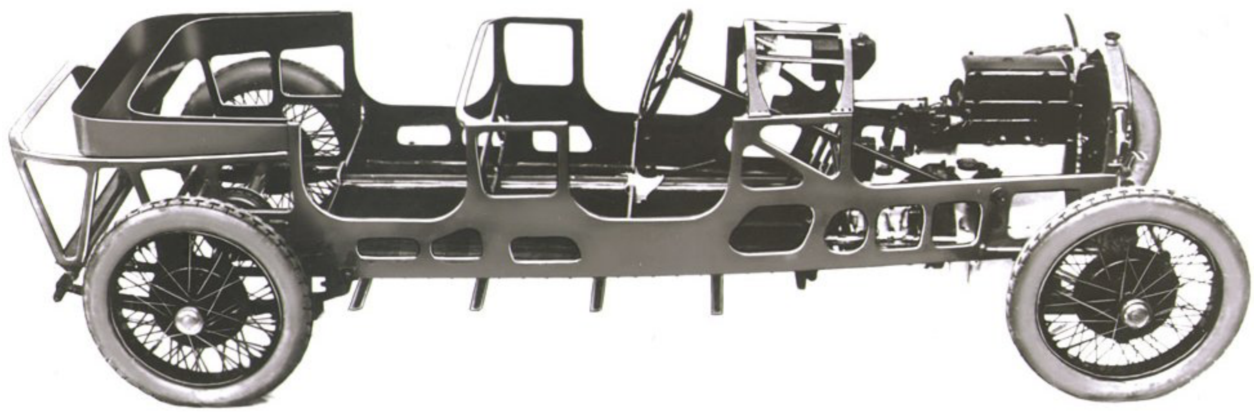

Figure 1: Unitary Construction of a Lanica Lambda 1922 (Harding, et al., 1969)

3.1.4 Three-Point Safety Belt

Coming from airplanes, the normal lap seat belt was already patented in 1885 (US Patentnr. 312085, 1885). Also in other areas seat belts has been in use already. The three-point safety belt, which is commonly used today, was an invention by the swede Nils Ivar Bohlin, which got the patent in 1962 (US Patentnr. 3043625, 1962). Volvo fitted every car already since 1959 with those safety belts. Volvo's core brand values is to provide safe passenger cars and is always working on increasing the benchmark for even safer cars. Volvo foresaw the great benefit of three-point safety belts, consequently they opened the patent for everybody for free.

1967, Volvo conducted a study among 28,000 crashes, which showed impressively the positive advantages of the three-point safety belt (Bohlin, 1967).

The state Victoria in Australia became the first to make three-point safety belt mandatory in the year 1970 (Milne, 1985).

3.1.5 The Airbag

Walter Linderer invented a system for the protection of passengers in 1951. The system was blowing compressed air into a plastic bag (DE Patentnr. 896312, 1953). The idea was to have a soft cover between the driver and the car's hard dashboard and steering wheel. Unfortunately, Linderer's idea was to slow to pump enough air into the plastic bag to really have a positive effect. So it took years before the air bag arrived in everyone's cars. Mercedes-Benz for example started in the mid 1960s to work on the airbag. The first German production car equipped with an airbag was the Mercedes-Benz W 126 in 1981 and in 1986 every new Mercedes-Benz model was equipped with an airbag as a standard. General Motors was quicker; they offered the airbag from 1975 as an optional extra (Schubert, 2007). However, the airbag finally became popular in the mid 1990s, and in 1997 the U.S. released a law that every new car needs to be fitted with front airbags for the driver and co-driver. An Australian study on the effectiveness of airbags found that airbag successfully prevents injuries in frontal crashes (Morris, Barnes, & Fildes, 2001). In the last decade the field of use for airbags extended. Head, knee, side or even airbags for motorcycles were invented, practically there are no limits. The U.S. introduced the law for safety belts in 1980. But today, there is still one State, New Hampshire, where safety belts are not compulsory. These circumstances made it necessary that the airbags in U.S. cars needs to work without safety belts as well, what makes them around double the size of European's airbags. Along with the size, the price is roughly as double as well.

A study by Klanner, Ambos, & Paulus shows that the airbag is not the main lifesaver; it is more an addition to other systems. The main lifesaver is still the safety belt (read 4.1.4) (Klanner, Ambos, & Paulus, 2004).

3.1.6 The Crumple Zone

A person called Béla Barényi was working for Daimler-Benz, when he invented the crumple zone in 1952. The idea was to have a very strong protective passenger cell in the middle of the car. The front and the back of the car was built in a less stable way in order to absorb the kinetic energy in case of a crash (DE Patentnr. 854157, 1952). This invention revolutionized the whole automobile industry. Before the crumple zone the engineers tried to build the cars as stiff and solid as possible. This radical change of thinking took years to spread, but in the end it came to every new-built car.

A study by Moon et al explores the possibilities of a crumple zone for pedestrians. As a basis for their study they used the Euro NCAP test for pedestrians. Based on their test results they developed a model that reduces impact load and the bending moment by 27% and 36% (Moon, Jeon, Kim, Kim, & Kim, 2012).

3.1.7 Lighting

The lighting system of a vehicle has several functionalities. First there is the illumination of the environment when it is dark. The driver can see where she or he is going and will less likely have a crash. The second function is to make the vehicle visible and furthermore to inform other road users of upcoming changes.

At the beginning of the mass production of cars, the vehicles where not equipped with electricity, therefore, the lights where powered by gas or oil. The Ford Model T was already in production for several years after the company started to equip the car with electric lighting (Collins, 2007). Dynamos produced the needed electricity around 1908 for the first time. Taillights and brake lights were added in 1915. Electric lighting became a standard in the 1920s (Wördenweber, Wallaschek, Boyce, & Hoffman, 2007).

During the industrialization people were moving to bigger cities and cars became more popular. Soon the roads were very busy and it became necessary to show other people on the road in which direction a driver is intended to go. The first electric indicators date back to 1907 (US

Patentnr. 912831, 1909). However, the indicators that are common today are based on a patent from 1938 (US Patentnr. 2122508, 1938).

In European countries the turn signal lamps are amber. However, in the United States, red color is also allowed. A study by Allen examined whether or not the color makes a different on reducing rear impacts. The result was that amber turn signals effectiveness is 5.3% over red colored turn signals (Allen, 2009).

Today there are several standardized lamps, which even have their normed ISO-symbols to be shown in the dashboard. The forward illumination consists out of two main lamps. First there is the *dipped beam* or *low beam*. It is designed in a way to be used when other road users are ahead and build in a way that the oncoming vehicle is not glared.

The *main beam* or *high beam* is a lamp that provides an intense light with a less controlled beam direction. It is made for the use when no other vehicle is ahead.

In addition, other lamps might support the forward illumination. Rally cars or in the Nordic countries, cars are equipped with *auxiliary high beam lamps* or *driving lamps.* They provide an even brighter light beam than the normal high beam. Long nights during the wintertime and unlit roads can be used more safely with those lamps.

Front fog lamps are usually mounted very low and provide a wide spread light in order to lighten up road directly around the vehicle in rough weather conditions such as fog, snow, rain or dust.

Cornering lamps are used to illuminate the road when the driver is going to have a lane change or is intending to turn. The lamps are often connected to the turn signal system and are switched on only as long as the turn signals are used or the wheels are turned.

Over the years, different types of light systems have been invented. Halogen lamps where already developed in the 1960s, Xenon lights entered the market in 1991 and LED lamps where introduced in the 2000s. The latest development is the laser light by BMW. They use laser beams as the light source. The system has less weight and uses less volume than previous light system. But the main advantage is that it offers 600m of lighting, when an LED light is only offering 300m (see Figure 2 on page 20). Also the laser light is able to turn of parts of the beam. Sensors detect an upcoming car and the laser light system turns the part of the beam off that would hit the other car. Therefore, the driver of the BMW i8–the first production car with optional laser light–has the maximum light there is available, without glaring the oncoming driver at any given moment (BMW, 2013).

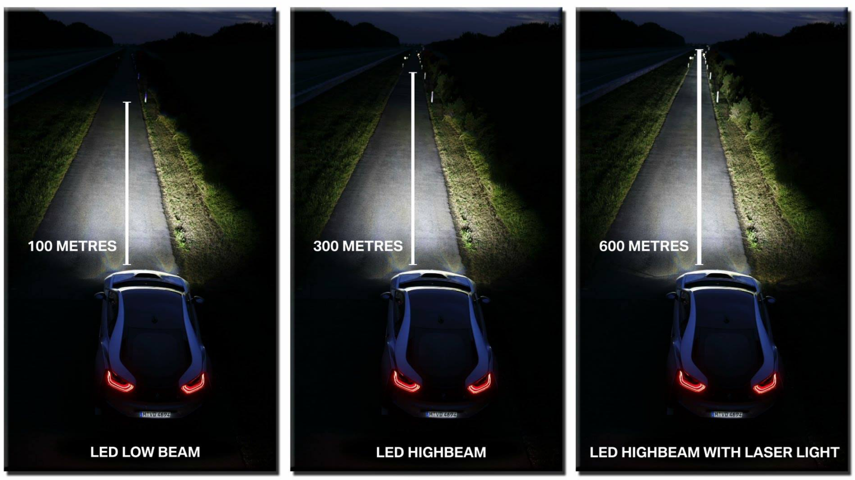

Figure 2: BMW Laser Light Technology (BMW, 2013)

Daytime running lamps (DLRs) are lamps in the front, which are switched on at all time as soon as the engine is running. In many countries they became a law, especially the Nordic countries have a long history of lamps that needed to be switched on during daytime. The goal is to increase the visibility of approaching vehicles. Especially roads with many trees and direct sunlight producing long shadows often make it hard to spot an approaching car. A study Krajicek and Schears found that the crash rate is higher for cars that have no DRLs than cars that have standard DLRs (Krajicek & Schears, 2010).

The European Union Directive 2008/89/EC decided to make DLRs mandatory from the 7^{th} of February 2011. (European Commission, 2011)

Nowadays DLRs are also used as a design element and have become a major characteristic to identify a certain brand.

Rear position lamps or *Tail lamps,* are red lamps which provide a contour of the car seen from the rear. The lamp is often combined with the *stop lamps* or *brake lights* and they are positioned symmetrically at the rear on the right and left edges of the car. To prevent misinterpretation, the stop lamps are significantly more intense than the rear position lamps. In many newer models, the rear position lamps are replaced by LED lighting.

In 1986 in the U.S. and Canada a third stop lamp became a law. The so-called *center high mount stop lamp (CHMSL)* gives an extra of safety because an already glowing stop lamp is indistinguishable to the normal rear position lamps. Also other cars can block the normal stop lamps. The third stop lamp makes it distinctive for other road users whether a vehicle is braking or not. A study by Kahane and Hertz investigated crashes between 1986 and 1995. The study comes to the conclusion that CHMSL reduces rear-impacted crashes by 4.3% in the United States. Considering the low cost of the implementation, it is a very effective way of reducing the amount of crashes (Kahane & Hertz, 1998).

The development went further and certain car manufacturers are equipping their cars with an *Emergency stop signal (ESS).* When the brakes are hit hard the CHMSL starts to flash to give the signal of a vast decrease of speed. The UN Regulation 48 regulates the ESS; the lamp should flash at 4 Hz and only when the car is decelerating more than 6 m/s^2 (buses and trucks 4 m/s^2). However, it is not proven yet if a flashing braking light has a significant impact on automobile safety.

Rear fog lamps can come in a single or double setup and must be switched on in poor visibility conditions. Even though rear fog lamps are not required in the U.S., most of European car companies have functioning rear fog lamps in their U.S. models.

Reversing lamps are only switched on automatically when the vehicle is in reverse gear. The lamp warns other road users of a backing up vehicle. This lamp is white, even though it is mounted to rear and it also can come in a twin setup.

In addition to the mentioned lamps, in special cases such as emergency vehicles there are even more lamps for different purposes. Those lightings are not discussed here because those are only used in special cases and do not have much relevance for this study.

3.1.8 Mirrors

A car is usually equipped with three mirrors. One *rear-view mirror* which is mounted in the middle of the vehicle and is built in a way that it is easily adjustable for any person. The mirror allows the driver to see through the back windshield. In 1911 the famous racer Ray Harroun experimented with mirrors, but he was not convinced of his idea due to the high vibration of the vehicle that made it impossible to use the mirror. Nonetheless he won the race, and since then mirrors became more popular (Pendergrast, 2003). Elmer Berger was the first one who patented the rear-view mirror in 1921. He named his invention “Cop-spotter” (Longman, 2001).

Because the lighting of other vehicles would glare the driver, a tilt functionality was invented in the 1930s. The front and rear surface are not parallel which leads to the result that the light is not mirrored and therefore the driver is not blinded. Since the 1970s this system became a standard. In the 1950s Jacob Rabinow experimented with an automatic system and Chrysler started to sell production cars from 1959 with this extra option. However, it did not reach popularity until the late 1980s.

Today the automakers use photo sensors to control the rear-view mirrors.

The latest development in the field of rear-view mirrors is to either support or even replace them with a back facing video camera. Especially big cars like SUVs are easier to drive in small areas such as parking garages with video camera support. Each year the NHTSA counts 210 fatalities caused by vehicles that are moving in reverse gear. In fact, the US requires all vehicles to be equipped with rear facing cameras from May 1, 2018 on (NHTSA, 2014).

Wing mirrors or *side-view mirrors* are mounted on the outside of the vehicle on the right and left side. Even though the mirrors are usually mounted at the A-pillar, they are often still called wing mirrors.

At the beginning, the wing mirror was only mounted on the driver side of the vehicle. The roads had only two lanes, one in each direction, so there was no need for a mirror on the passenger side. To broaden the view, the auto manufacturers started make the mirror convex. This led to the fact that the things in the mirror appeared smaller than they are. The U.S. Federal Motor Vehicle Safety Standard 111 regulates by law that in the mirror itself needs to be a warning that the things in the mirror are bigger than they appear. Other countries have similar regulations, in the EU, however, such a warning is not obligatory.

The wing mirrors are adjustable, either mechanically or electronically to be put in the right position for any kind of driver. To provide more safety during winter time, some carmakers are fitting their side mirrors with a heating system to prevent the surface to be covered with ice.

Some automakers already experimenting with the replacement of side-view mirrors with cameras. The main advantage is to make the vehicles even more fuel efficient by optimizing the aerodynamics. A concept by BMW premiered on the CES (Consumer Electronic Show) merged the videos from four cameras into one picture to create an overview look of the vehicle (LinusTechTips, 2016).

3.1.9 Anti-lock Braking System (ABS)

Dunlop was the first company which developed an anti-lock braking system (ABS) and was built for aircrafts. The system prevents the tires from locking when the brakes are used. The result was that the car remained under the control of the driver and the system improved the stopping distance by 30% (Flight, 1953). A company called Ferguson Formula was the first to implement ABS into a production car in 1966, the Jensen FF (Hillier & Coombes, 2004). Bosch held the patent on the system and started to sell the system to several car manufactures. The Mercedes-Benz s-class and the BMW 7-series where the first vehicles that had the system as an optional extra (Denton, 2004). A study found that vehicle-to-vehicle crashes are 18% reduced with a car that is equipped with ABS (Burton, Delaney, Newstead, Logan, & Fildes, 2004). European car companies announced on 1st of July 2004, that every new car would be equipped with ABS from that date on.

3.2 Latest Developments of Vehicle Safety: Electronic Driving Assistants

The development of new safety systems did not stand still in recent years. New safety systems include for example a warning system when the safety belt is not used or when the tire pressure is not correct. The use of a hands-free car kit to safely use a mobile phone could be also counted as a safety system. Studies found that using a hands free kit while driving does not significantly improve the focus of the driver compared to handheld phone (Ishigami & Klein, 2009) However, that system is not an in-vehicle technology that is built-in and therefore not in the focus area of this paper. Many different safety systems were invented. On the contrary to the systems discussed in 3.1, it cannot be said for sure that newer systems actually improve the safety. It also needs to be taken into account that manufacturers decisions and objectives are not mainly the safety and well-being of the customers, but are business based with the goal to increase revenues for the company. Therefore, it might be possible that some of the alleged new safety features are in fact just one more reason to try to convince the people to buy more cars.

In 1997 the European New Car Assessment Program (Euro NCAP) was founded. The organization tests new cars towards safety issues. The standardized crash tests and a five-star rating offers the consumer to compare certain models to each other. The three main test are: frontal crash, performed at 64 km/h (40 mph), the side impact test, performed at 50 km/h (31 mph) and side pole impact test is performed at 29 km/h (18 mph). Often the manufactures highlight the crash test results to their advertisements in favor to build trust for their product, with test results coming from an independent source. Some people suspect that car manufacturers have customized or adjusted the ways the cars are built to pass these tests. However, a study in 2000 by Lie and Tingvall suggests that the cars are often even safer than the test score results are stating (Lie & Tingvall, 2002).

3.2.1 Electronic Stability Control–ESC

ESC stands for *electronic stability control* and is used as an overall term for this technology. The system was first developed by Mercedes-Benz under the acronym ESP. ESP stands for *electronic stability program* and first introduced in 1995 in their upper class S-Class model (DE Patentnr. 2912578, 1995). The program is constantly analyzing a set of sensors. Steering angle, wheel spin, lateral acceleration, acceleration and traction are put together and the computer helps to control the car by braking individual wheels in borderline situations. Every major car company developed a similar system in the following years. The only thing is that they have different names because ESP is held by Mercedes-Benz. Since 2011 it became a regulation in the US and Germany that every new car has to have ESC. A study by Blower in 2014 investigated the effectiveness of ESC by analyzing several studies by Farmer (Farmer, 2004)

(Farmer, 2010), (Green & Woodrooffe, 2006), (Dang, 2007), (Sivinski, 2011) and (Aga & Okada, 2003). The result was very similar to a study by Hoye (Hoye, 2011). Blower found that ESC reduces crashes overall 7% to 9%. Single-vehicle crashes that could have been addressed by ESC reduced the crash rates by 35% to 41% (Blower, 2014).

Therefore, it can be said that ESC is a safety improvement over the vehicles that not have ESC equipped.

3.2.2 Forward Collisions Avoidance Technologies

The *forward collision avoidance technologies* (FCAT) work with a radar or laser cameras to analyze the area in front of the vehicle and are split up into three parts. The first part is recognizing a potential collision and giving the driver a visual or audible warning. The safety belt might me tightened.

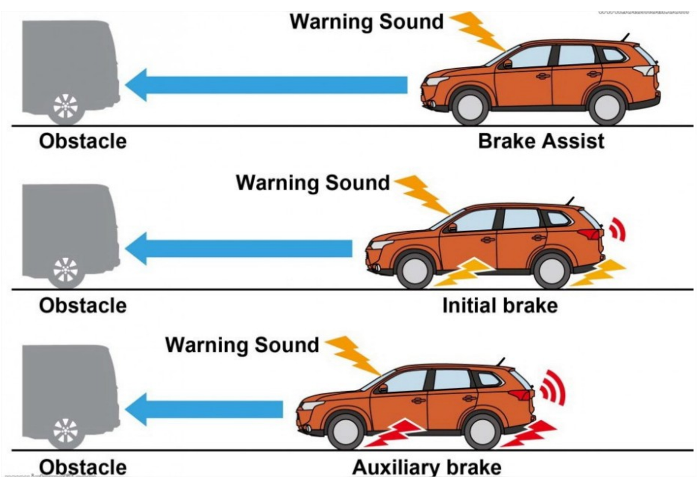

Figure 3: Forward Collisions Avoidance Technology (Sayers, 2014)

The second part is the *emergency brake assistant* (EBA). This system is aware of the situation the vehicle is in and supports the braking process. In a dangerous situation the brake assistant prepares the brakes to be used any moment. In addition the intensity of braking will be increased if needed (see Figure 3 on page 26). Many crashes could have been prevented when the brakes would have been used to its maximum. The brake assistant fills this lack of driving skill. A French study suggests that an EBA lowers the crash probability (Page, Foret-Bruno, & Cuny, 2005).

The third part of forward collisions avoidance technologies is the *automatic emergency braking* (AEB). This system takes control over the braking when a collision is inevitable. Therefore, the driver can be badly distracted, and the vehicle would not crash thanks to the AEB.

All three systems are often working together and are set up in a three level intervening system. Usually the system is designed to work when the opponent vehicle is traveling in the same lane in the same direction. More advanced systems are also able to detect potential crashes in more complex situations such as forward collisions or intersections. Newer systems also recognize smaller road users such as bicyclists and pedestrians.

Unfortunately, public crash data does not provide the information whether the vehicle is equipped with FCAT or not. However, a few simulations studies have been done how effective FCAT is (Najm, Stearns, Howarth, Koopmann, & Hitz, 2006), (Kusano & Gabler, 2012) (Van Auken, et al., 2011), (Coelingh, Eidehall, & Bengtsson, 2010), (Coelingh, Jakobsson, Lind, & Lindman, 2007), (Isaksson-Hellman & Lindman, 2012), (Georgi, et al., 2009), (Rosén, et al., 2009), (Rosén, et al., 2010), (Itoh, Horikome, & Inagaki, 2013), (Anderson, et al., 2012).

Blower (2014) examined the mentioned studies above and summarizes that FCAT is highly effective;

> The combination of FCW, BA, and AEB was estimated to reduce the number of severe injuries by 27% to 50%; reduce the number of rear-end crashes by 9.3% to 72%; and reduce the number of fatalities by 30% to 40% (p. 24) (Blower, 2014).

The results are very diverse due to the fact that the studies based on different approaches and different simulations. However, they all show a positive impact on vehicle safety.

The European Commission made FCAT mandatory to the 1th November 2013 for new vehicle types and on 1th November 2015 for all vehicles. The impact assessment states that 5,000 fatalities and 50,000 serious injuries per year can be prevented by equipping vehicles with FCAT (Commission Of The European Communities, 2008).

3.2.3 Lane departure warning system (LDW)

Combined with the radar and laser sensors, many vehicles offer a *lane maintaining* or *lane departure warning system*. The system warns the driver when the vehicle seems to leave the lane unintentionally. In the case of a lane changing process initiated by the driver, the system is not giving any warning. The indicator is switched on in the direction of traveling and that is a clear information for the computer of the vehicle of what is going to happen. LDW is addressing the main source of accidents; the inattention of the driver. The warning can be visual, audible or through vibration.

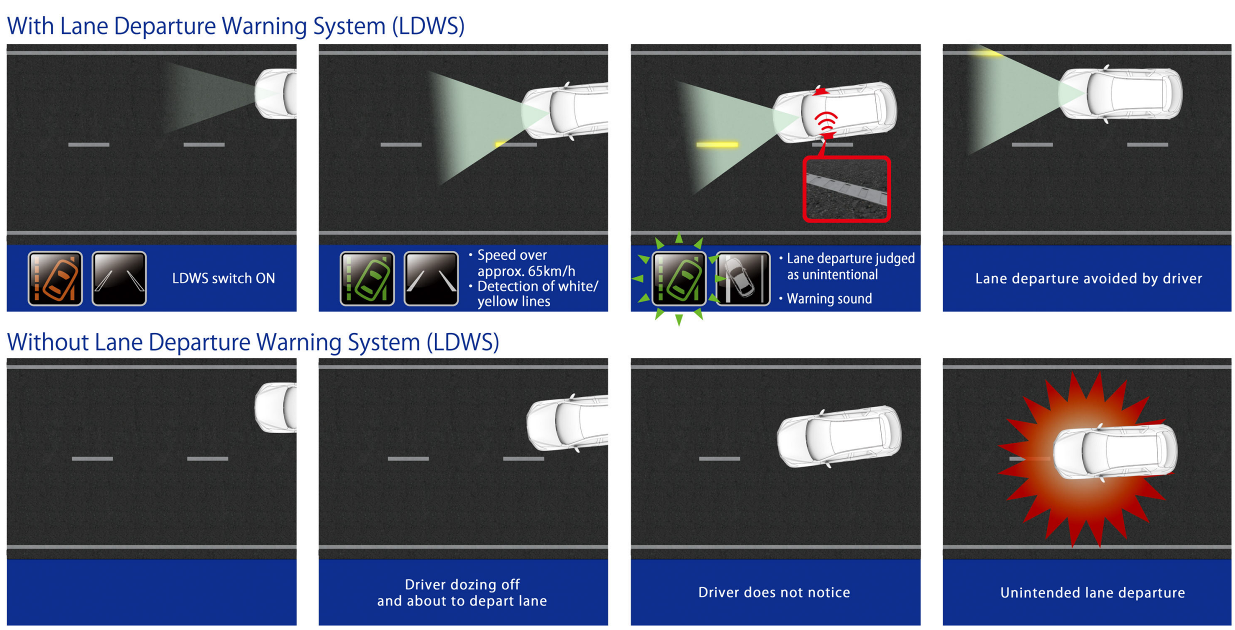

Figure 4: Lane departure warning system (Luft, 2016)

The extension of the system is the lane keeping system, which is not only giving a warning to the driver; moreover, it intervenes in order to keep the vehicle in the lane. The first system was built into the Mercedes Actros truck in 2000 (Walter, Fechner, Hellmann, & Thiel, 2012). Today, the system is available for almost every truck sold in Europe.

Just one year later, Nissan introduced the system for its Cima model, sold in Japan in 2001. In the following years, almost every major manufacturer developed their own version on a lane departure warning system or lane keeping system.

In combination with other sensors that detect other road users, the system is able to steer the vehicle back into the lane if needed. Normally, the system is only warning the driver by vibrating the steering wheel if the vehicle is coming closer to the broken line. However, this other lane can be blocked, ether by a vehicle traveling in the same or opposite direction. In this case the lane keeping system is not only giving a warning, it also steers the vehicle back into the lane to avoid a collision.

In October 2014, Tesla announced new features for their Model S. All new build models will be fitted with a front facing radar along with other sensors and cameras. Described as an autopilot–that can be used under clear conditions–the car is able to for example stay in the lane or change the lane by itself just by activating the turn signal (Tesla, 2014).

To evaluate the effectiveness of lane departure warning systems cannot be finalized yet, the system is too new to rely on existing crash data. Although, a few studies have been conducted based on simulation methods.

Bower examined several studies (LeBlanc, et al., 2006), (Wilson, Stearns, Koopmann, & Yang, 2007), (Sayer, et al., 2011), (Nodine, Lam, Najm, & Ference, 2011), (Gordon, et al., 2010), (Kusano & Gabler, 2012), (Tijerina, et al., 2010), (Tanaka, Mochida, Aga, & Tajima, 2012), (Robinson, et al., 2011), (Anderson, et al., 2012).

Bower (2014) writes:

> Estimates of the effectiveness of lane/road departure technologies are reasonably consistent. Results from a small early FOT estimated that the road-departure system would reduce road departure crashes by 7% to 57%. Later crash-reduction estimates were derived from different types of simulations. Estimates from four different simulations put the reduction of lane/road departure crashes at 6% to 34%. Another study estimated a 7% to 29% reduction in fatal injuries; 13% to 34% reduction in serious injuries; and 19% to 35% reduction in minor injuries (p. 31) (Blower, 2014).

Although the study results are based on simulations, it can be assumed that lane departure systems have a positive effect on decreasing the number of crashes.

3.2.4 Blind Spot Monitoring

The blind spot monitoring technology addresses the danger that comes from the blind spot, the area that cannot be seen in a side-view mirror. Whether it is another vehicle or other obstacles blocking the road, the blind spot monitoring system warns the driver by showing a little warning triangle in the side mirror (see Figure 5 on page 31). It also works at slow speeds, which is often the case in city areas. It is not only able to recognize other vehicles but also other road users such as bikes.

Figure 5: Blind Spot Monitoring on a Mercedes-Benz (Daimler AG, kein Datum)

As with all other safety technologies, blind spot monitoring can differ in functionality from manufacturer to manufacturer. The Volvo S80 was the first car in 2007 with standard equipped blind spot monitoring technology.

The blind spot detection system often works hand in hand with the lane departure warning system.

3.2.5 Driver Drowsiness Detection

The driver drowsiness detection system monitors the driver's behavior and warns the driver in case it detects inattention. Volvo was the first manufacturer to introduce such a system in 2007 (Čolić, Marques, & Furht, 2014). The system constantly analyzes the style of driving by measuring the distances to the road markings. If the car detects the driver does not drive adequate, it warns the driver by an audible signal as well as a text with a coffee cup symbol (see Figure 6 on page 32).

Figure 6: Driver Drowsiness Detection on a Volvo (Duemotori.com, 2007)

As well as other new safety technologies, it is hard to say whether such a system is effective or not. In fact, existing crash data does not include whether driver fatigue was involved or not. However, Horne & Reyner found already in 1999 that presumably 20% of road accidents in the UK are caused by drowsiness of the driver (Horne & Reyner, 1999). Therefore, the system promises great potential to reduce accidents.

3.2.6 Autonomous Cruise Control System (AAC)

Even though ACC systems are not directly related to safety systems, it does play a role in the latest development of assistant driving.

In addition to the regular cruise control–where the driver sets a certain speed and the vehicle maintains the speed–autonomous cruise control systems are able to follow another car accelerating and slowing down on its own. The technology works independently and is not connected to other cars. Therefore, it relies on sensors build into the car. The sensors are either laser or radar sensors. Both systems differ from their capabilities and price. When the laser system needs to be exposed, it is not able to work in bad weather conditions, nor is it able to recognize an extremely dirty–not reflective–vehicle.

In addition to follow other vehicles, a camera is able to read the street signs, which are not only displayed on the screen, the vehicle is also slowing down when the vehicle is recognizing a speed sign that is lower than the speed that is currently engaged. Other street signs do not have an impact on the driving, for example a “no overtaking” sign, however these signs are displayed for the driver. More complex situations such as a pedestrian crossing are as well recognized and show a warning message in the dashboard.

The system has many different names depending on the manufacturer. Also the capabilities differ from vehicle to vehicle. Nevertheless, Mitsubishi was the first to introduce AAC in 1995 (Bhatia, 2003).

In combination with lane keeping systems, both system combined are able to drive the vehicle by its own in slow stop-and-go traffic situations. Higher speeds are still in development.

3.2.7 Pedestrian Recognition System

Some vehicles are equipped with a pedestrian recognition system. The technology uses lasers or cameras to detect humans. In case of a dangerous situation, the vehicle will show a warning message combined with a warning sound. In case the driver is not reacting the system applies the brakes to avoid a crash.

Another common situation is that the driver tries to avoid a collision by trying to steer the vehicle around the obstacle. The result is often a crash with another object such as a tree or crash barriers. Combined with a lane keeping system, the vehicle will support the driver during a crash avoiding maneuver by steering in the right direction to avoid the collision with the pedestrian and other obstacles.

3.2.8 Head Up Displays

The idea behind head-up displays is simple: the driver can keep the eyes on the road while the head up display is showing additional information. The technology was invented and used for military purposes long before it came to civil vehicles. The first was the Ford Oldsmobile Cutlass Supreme in 1988 (Jurgen, 1999). The system projects information e.g. the current speed onto the windscreen. A study by Liu comes to the conclusion that head up displays help to improve the drive's ability to react fast to changing conditions (Liu, 2003). Many manufacturers offer head up displays for their models offering a variety of information from speed limit detection to turn by turn navigation.

The BMW Group brought the idea a step further with Augmented Vision project. They created glasses for their MINI brand which offered additional information through augmented reality glasses (BMW Group, 2015; BMW Group, 2015). Even though the *Google Glass* project–glasses that offer additional information through an augmented-like display–was not a commercial success, augmented reality–connecting the real world with the digital world–offers great potential. Using the smartphone as a device for augmented reality–a device that is in the hands of millions of people–*Pokémon Go* celebrates a huge commercial success in the middle of 2016. The game picks up the idea of catching Pokémon–which are fictional creatures–in a virtual world and bringing it to the real world. It used to be a *Gameboy* game, now people walking around with their smartphones and catching Pokémon in the real world. Pokémon Go shows that the people becoming more open towards technology that are linking the two worlds using augmented reality.

3.3 Conclusion Regarding Vehicle Safety

Vehicle safety has a long history. Over the years many systems have been developed and over all, it can be said that vehicles have become much safer compared to the beginning of the history of the car. Many technologies like the three-point safety belt have proved over the years that they really have a positive impact on vehicle safety. Newer technologies like ESC brought vehicle technologies even further. However, as mentioned in the introduction of this paper, many people still lose their life or get injured on the roads every year. V2V communication is great chance to increase the reliability of on board safety systems even more. Combined with V2I technology, scholars predicting a massive 80% potential reduction of all fatal crashes for light vehicles a study shows (Najm, Koopmann, Smith, & Brewer, 2010). V2V communication is trying to eliminate human error.

4 Vehicle to Vehicle Communication: Possibilities and Challenges

In the beginning of Connected Vehicles it was all about making the driver smarter. The idea was to give the driver as much information as possible to make driving a car safer and more efficient. In many countries roads with high traffic peaks are equipped with *ITS – Intelligent Transportation Systems*. They provide additional information such as road conditions for example that the road is icy. The information is displayed along the road using electronic street signs. In case of accidents or road constructions the system is able to direct the traffic flow to use just one lane for example because the others are blocked. At traffic peaks the systems often adjust the speed limit to keep the traffic flowing. These outside-of-the-vehicle systems can be considered as one of the first systems that connect individual vehicles in a sense that the system is detecting the amount of vehicles that use the roads or reacting to other factors such as weather conditions and then influencing the traffic by showing relevant information.

Then there is *GPS–Global Position System.* It is owned by the US and was originally developed for military purposes. In the year 2000 the use of *GPS* was made available for the general public. Prior to that the government kept the system intentionally inaccurate (by 100m) for the public. Satellite navigation systems emerged and soon they became affordable for everyone (Carrier, 2015). GPS locates the driver's position and combines it with digital map data. This way it can provide accurate, individual information on the driver's whereabouts which makes it the perfect tool to navigate through unknown areas.

Nowadays, for the best driving experience, the driver has two main technology sources to rely on: the ITS and the in-car information technology such as GPS.

The ITS is capable to detect and analyze traffic, road and weather conditions and can react with traffic regulations, displayed on signs "along the road." However, the driver still needs to combine some of this information herself– the car itself is not really connected yet.

Next to the ITS and GPS, technology that is not an in-car feature or rely on technology that is somewhere else (e.g. satellites), the car itself got equipped with a variety of in-vehicle technology over the years. These technologies are divided into *safety systems* and *information technology*. In-car information technology includes mainly the entertainment features for instance radio or car telephones. The safety systems have been already described in the previous chapter 3.

Putting all those developments together it seems as a logical step to combine the technologies to create the connected vehicle. A smart link between the vehicles and the infrastructure opens new possibilities in terms of vehicles safety and other areas e.g. traffic flow optimization.

4.1 The Basic Concept of V2V Communication

It needs to be pointed out that the connected vehicle as it is described in this paper has two elements. The first element is that it is part of the global network, part of the Internet of Things. The second element is a very fast independent ad-hoc connection between a certain amount of vehicles. This technology has been developed under the term V2V communication.

The next step in the development of connected vehicles is that the vehicles are actually starting to actively sending, receiving, and processing information. The vision is that everything that moves is connected to each other in order to generate more safety. In addition, V2X communication is able to e.g. optimize traffic flow and fuel economy. The system consists out of a device that is built into the vehicle, which collects the existing data from the vehicle. That data includes velocity, tire pressure, steering, temperature and a lot of other parameters. V2V communication focuses on a few of them and send it as the so-called “Here I am” message to other vehicles. The message is transporting speed, location and the direction of movement. The data that a group of connected cars generate will be combined and translated into relevant warnings and advices for each individual driver.

As an example: 1km ahead there is a row of cars, the first one brakes abruptly–leading to a chain reaction of cars braking. This information will be send from vehicle to vehicle allowing the following to adjust to the situation. The system transforms the information into a warning and perhaps a recommended speed. As a result, possible crashes or traffic jams can be avoided.

Taking this system one step further, the car could already prepare the onboard safety systems and apply the brakes automatically in case the driver is not reacting and the obstacle is coming closer. Ideally, the vehicles would prevent situations that require emergency braking before they happen.

Between August 2012 and August 2013, the UMTRI–University of Michigan Transportation Research Institute–conducted a pilot project in Ann Arbor, Michigan, USA. It involved 3000 cars, which has been fitted with V2V technology (Funkhouser, 2012). The results of the ongoing research have not been published yet. The project is a collaboration between UMTRI and USDOT, the U.S. Department of Transportation. Another organization, which is interested in the results, is the NHTSA. They are focused on determining standards for all car manufactures. Their plan was to make those guidelines public in 2013 for cars, in 2014 for heavy trucks, and 2015 for infrastructure. Unfortunately the Ann Arbor Safety Pilot project has not been analyzed in every detail, therefore the standards has not been determined although they released a press statement regarding the Ann Arbor in February 2014 that they are continue to work on V2V communication (NHTSA, 2014).

4.2 Standardization of V2V Communication Technologies

A crucial step that needs to take place in order to make connected vehicles possible, is to provide a radio connection that fits the requirements. Other wireless connections that we use today–for instance a laptop computer that is connected to the internet using Wi-Fi–have different specifications and this technology would not be sufficient for V2V communication. Since it is too slow, and not made for a wide range. However, both technologies (the use at home or at a workplace and the use-case in a vehicle) are based on the same IEEE 802.11 standard. The IEEE, Institute of Electrical and Electronics Engineers, is an international organization for defining electronic standards. In 2010 the IEEE published the 802.11p standard or WAVE, Wireless Access in Vehicular Environments (IEEE, 2010). However, the standard is still in development and the IEEE is publishing newer versions regularly. 802.11p enables a fast connection between vehicles because it does not use a basic service set (BSS), which means the devices do not authenticate each other before they exchange information. The receiver is getting information from the sender as long as it is in range.

However, other organizations and companies are working on V2V communication as well. Different countries require different approaches because of local requirements. Vehicles are not everywhere exactly the same e.g. left handed drive in some countries, that has an effect on e.g. the lighting systems. These differences are already observable in the area of V2V communication even though it is still under development. The European Union for example is also working on developing a wireless connection standard but with slightly different specifications compared to the U.S. However, during the development the different parties took care to make the technologies compatible to one another. Both sides are using nearly the same spectrum of radio frequencies making sure that they partly overlap. This way a European vehicle is also able to communicate in the U.S.

The U.S. approach of V2V, is that the vehicle permanently sends information and every driver in range receives it. This transmitted data is called the basic safety message (BSM). The standard was developed by the SAE and they constantly working on newer versions (SAE International, 2016). The BSM contains speed, location and direction. Therefore, other vehicles behind may get the information that the speed is zero, but no information is provided why the vehicle in front is not moving. This method is called *awareness based communication*. The Europeans, however, are working on another approach called *event based communication*. The message is called DENM–decentralized environmental notification message and is standardized by ETSI–European Telecommunications Standards Institute (ETSI, 2014). That means that the vehicle which is not moving is also sending the information *why* it is not moving. This may influence the driver's decision how to deal with the situation. In case of a traffic jam, the driver may choose to take another route. In case of an accident the driver might choose to slow down and check if the other person in the stopped vehicle needs help.

At first glance the European awareness based communication seems to have an advantage: the driver gets more information and is able to make a better decision. But this approach has a major drawback: It is only able to deal with known situations and cannot react to unforeseen conditions. The U.S. event based communication leaves the driver with less information, so she needs to interpret the data herself and cannot react in her favorable way.

The Europeans and the U.S. are in constant exchange of information, so the Europeans also developed their equivalent to BSM, called the corporate awareness message–CAM. On the other hand, the Americans added event flags (e.g. hard breaking) to their BSM system, therefore the BSM approach becomes also an event based system. Merging the two approaches together offer the benefits of both worlds, combining them to something more powerful.

The biggest market of V2V communication seems to be the United States. The advantage is that if such a big country sets standards, it can influence the global market. On the other side, the European Union is much more cut into pieces because every country has their own regulations and standards. With the NHTSA and the USDOT, the US has two big organizations that are supporting the idea of V2V communication. However, the International Organization for Standardization Technical Committee 204 (ISO TC204) is trying to bring all working organizations and companies around the world together in order to adjust the V2V standards (Paier, Güner, & Brückler, 2013). In 2009 the U.S. and Europe have already agreed to use global standards when possible (RITA 2009) (Hong, et al., 2016). The development on the communication technology has not ended yet and Hong et al. concludes that at this time there is not a single vehicle that works around the globe in any network (Hong, et al., 2016). However, every asked stakeholder does believe that a global standardization does help to accelerate the implementation of a V2X network (Hong, et al., 2016).

4.3 Examples for V2V communication

In general, the logical prediction of V2V is that it will be added to more and more existing features. As in 3.2 described vehicles are already fitted with a number of electronic safety features. V2V communication should be understood as an addition, not the primary safety system on the vehicle. It rather complements the basic safety features in context of relevant influencing variables from outside factors such as e.g. traffic and weather. On the following pages, the potential use of V2V communication will be explained.

4.3.1 Braking Because of Obstacles

If a car ahead is braking because of an emerging obstacle, the V2V device sends this information to other vehicles where the information is relevant, usually the other cars driving behind (See Figure 7 on page 42). The information of the braking car will be transmitted into a warning message. This warning message reacts to the relevant cars in the influence zone individually. Depending on the driving behavior and calculated risk of the situation, the warning message can be intensified. E.g.: for the cars that are following at a higher speed than others, the alert of the warning message will be higher. It is possible that the system works together with FCAT discussed under 3.2.2 and reacts on its own by braking and steering, if the driver is ignoring the warning message or failing to react to avoid a probable collision. On the contrary to an independent onboard system, the V2V communication supported by FCAT can be, theoretically, 100% sure that the cars ahead are slowing down, even when they are too far away and cannot be detected by the onboard sensors.

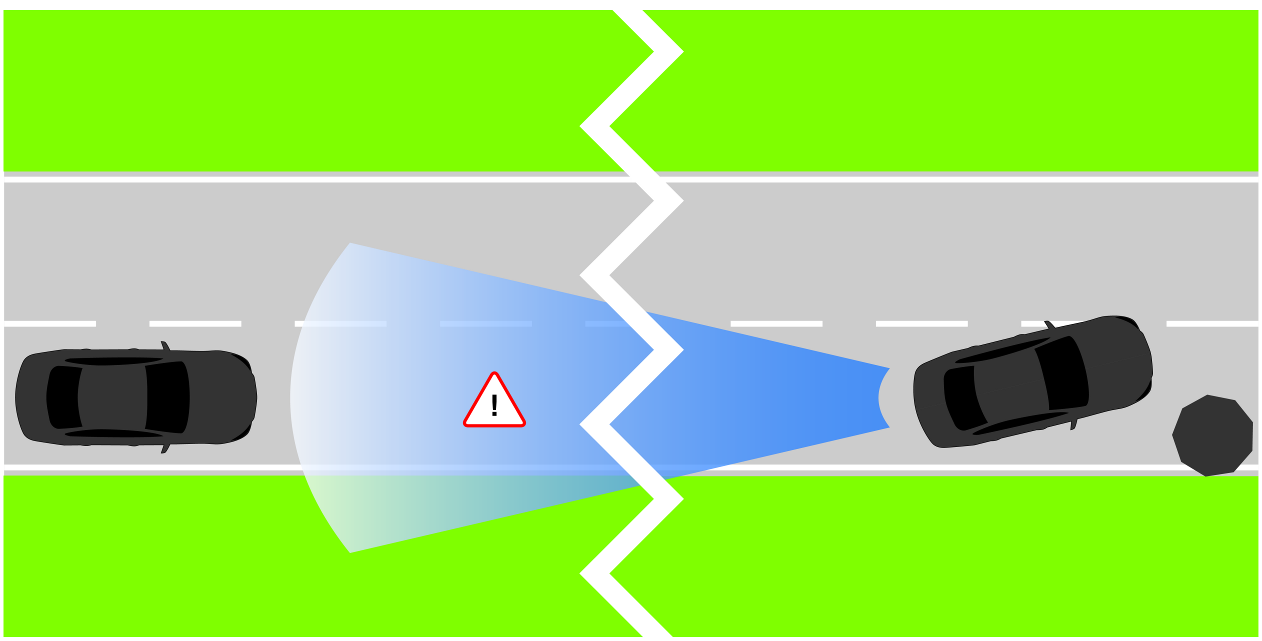

Figure 7: V2V Communication (von Hofe, 2016)

4.3.2 Road Conditions

Road conditions can be unpredictable and tricky. Especially in the countries, where ice and snow plays a major role during the winter month. Also rain can be a cause for difficult driving conditions. While view and sight is limited, also the traction to the road has an affect: aquaplaning is a very serious issue, drivers frequently have to deal with. 24% of all crashes in the U.S. are weather related (Pisano, Goodwin, & Rossetti, 2008). Potholes or gravel can be also dangerous problems. Basically everywhere where the road is not in its original state, is a potential hazard zone. A modern car is usually able to detect those conditions using ESC and can monitor those differences. By collecting the information from a network of numerous vehicles, V2V communication is able to identify an issue that has repeatedly been detected at the same location. This information will be mapped and combined with GPS coordinates. This data will be translated into a warning message and send to other road users. This scenario would benefit of an integration of a V2I device. V2V communication works in a certain density of traffic, only the vehicles in range receive the relevant information. Cars that are further distance apart will not be able to connect with each other. More remote areas, where traffic flow is not dense and frequent, would benefit from a V2I integration, since relevant information can be stored and send out to the vehicles once they are in range. In this case the data is not dependent on the distance between vehicles. A V2I device, or many of them installed along the road, can store the data and are able to make the information available for the next vehicle that uses the road (Land Rover, 2015). Another advantage is that this message could not only warn other drivers, it could also be useful and add value to the road maintain services to get a more accurate insight on the road conditions e.g.: where a pothole is that needs to be fixed, or in which areas the snowplow should drop a little more salt to keep the street clean. The V2I device must be connected to the Internet to transfer the information to the road services. The vehicles have two channels to transmit the data: Internet connectivity or V2V connectivity.

4.3.3 Overtaking/Lane Changing

Overtaking or lane changing requires the driver to be fully aware of the situation around the vehicle. The blind sport, as the name indicates, is an area that is not covered by the rear or side mirrors. It is literally blind in the driver's field of vision. In order to make sure that this area is clear, the driver has to turn around and look over his shoulder. Which means, that the driver cannot pay attention to the road in front in that moment. In curves the area of the blind spot is even larger, increasing the risk factor in traffic. In recent years the automobile industry has developed sensors, that are able to detect if the blind spot is not clear and bring up a warning triangle in sight for the driver (read also 3.2.4.). V2V communication brings this technology to a new level. It can warn the driver even when an approaching car is not in sight. With V2V communication the warning triangle constantly shows the driver whether or not the vehicle can switch to the other lane. This message is more reliable than an onboard LDW system, since the sending vehicle "knows" in which lane it is at the moment and if it is going to change the lane or not (based on the information whether the indicator is switched on or not. Therefore, the receiving vehicle is not only "guessing" through the onboard sensors where the other car is and where it intends to go.

When it comes to traditional overtaking on roads with one lane in each direction, the V2V system could display whether the oncoming lane is free or not, even in curvy roads. This system would only work if every road user is connected to a V2V network, or if the infrastructure–the road itself–is giving the signal using V2I devices: "yes I am free".

In the case of driving behind a slow vehicle, for example a tractor, the tractor, as well as the vehicle trailing it could send a warning message to faster vehicles that will follow, regardless if it will try to overtake the tractor or not. Often, this situation can lead to dangerous situations when the driver in first car behind the slow vehicle is concentrated on the things that happen in front of it, and not paying attention to other vehicles that are overtaking as well and approaching from behind at higher speeds.

4.3.4 Traffic Congestion

Traffic jams can be dangerous especially if the end of traffic congestion is not visible e.g. hidden behind a corner, or a hill. The data of a few not moving, or very slow moving cars can instantly create a traffic warning, that is sent through V2V communication to the following vehicles. Within seconds, the system calculates the best speed and possible alternative routes. Traffic jams can be reduced and help the driver to have more pleasant and efficient journeys. Studies have also shown that accelerating fast, as well as sudden and hard braking can be a cause of traffic congestions. An optimized and coordinated driving speed would reduce the potential for traffic congestion. A smart system using the real time data from the current situation on the road could generate individual recommended speeds for each vehicle. A study in 2015 suggests that the average trip time could be reduced by up to 47% in urban centers by using an Intelligent Traffic Information System (Souza, Yokoyama, Maia, Loureiro, & Villas, 2015).

This would mean that a controlled traffic flow would lead to a more efficient use of vehicles–ecologically and in terms of saving time.

4.3.5 Intersections

The main problem at intersections is the complexity of the situation. With at least two roads crossing it creates multiple possibilities for problematic traffic situations. E.g.: the view might be blocked, confusing signage, a driver misjudges the situation or a speeding motorcycle is approaching. With so many different and unpredictable influence factors, an intersection can be a serious source for danger. 36% of all crashes happened at intersections (Choi, 2010).

Consequently, V2V communication can warn the driver if the intended direction is blocked or not. As mentioned before, in combination with an active brake assistant, the moving car could also brake on its own if it is necessary to prevent a collision.

Some intersections are equipped with traffic lights and some without. The ones without would benefit the most from V2V communication, since in this situation the road users do not have the traffic lights as regulating force, therefore they are more dependent on communicating with one another. Based on the data of speed, location and direction, the system can direct and coordinate, which car goes first, and which one has to stop or slow down. This helps especially in unclear situations where it is hard to get a clear overview of the circumstances and surroundings that influence the situation.

Intersections with traffic lights have already been regulated for the longest time and have shown that it helps to optimize the traffic flow. Even with traffic lights regulating traffic, there is still the factor of human error, that influences the traffic safety. E.g. a red light can be ignored or not seen by the driver. In both scenarios, V2V communication combined with an active brake assistance could prevent accidents. The car would brake on its own if a collision is inevitable.

Some of the newer traffic lights are already equipped with sensors that detect an approaching vehicle. In this case the traffic light would automatically switch to green light, if the road is clear. In the best case scenario, the approaching vehicle does not have to stop. This optimization would save fuel and time. V2I communication could bring this technology to the next level by calculating and coordinating the speed of all the vehicles heading towards the junction from different directions. Ideally it could even time and orchestrate a flowing passing through the intersection where the vehicles cross in between the gaps in traffic. In this vision it is a perfectly choreographed intersection in constant flow, without the need to stop.

4.3.6 Recognizing, Categorizing & Prioritizing Vehicles in Traffic

Studies have shown that many deaths can be prevented if the emergency vehicle would reach the location of the accident sooner (Sánchez-Mangas, García-Ferrrer, Juan, & Arroyo, 2010).

Recently drivers have been taught to always steer their vehicle to the outside of a two-lane road in traffic congestions. Unfortunately, this system does not always work properly, since not every single driver, the way they behave in traffic, their judgement or their reactions can be controlled or goes as planned. A V2V communication system could overcome this problem. The emergency vehicle automatically informs the cars in in their way early enough to clear the road for them. In addition, V2I devices could also support this process by controlling traffic lights in favor of the emergency vehicle.

The angle of V2V and V2I recognizing the different categories of vehicles participating in traffic, such as emergency vehicles (police, firetruck, ambulance) or public transportation. The system could also be used to give priority to public transport such as buses. They would not need extra lanes anymore, the V2V system would simply tell the other road participants to clear the road when a bus is coming through.

4.3.7 Train Driving

An area where V2V could also be of use is the idea of *train driving.* The cars are following a leading vehicle in a certain distance. Adding more cars creates a train-like picture of autonomous driving cars. This system saves fuel and gives the driver the freedom to do other tasks such as talking to other people, reading or eating (Volvo, 2012).

4.4 Opinion Towards V2V Communication in the English-speaking World

A study by Schoettle & Sivak investigated the public opinion about connected vehicles in the English-speaking countries United States, United Kingdom and Australia. The survey was given to people with no or less knowledge about connected vehicles. In numbers 78,1% had never heard about connected vehicles but the majority had a positive impression of the technology. The participants marked every given benefit as “likely to occur”. The benefits listed were: fewer crashes, reduced severity of crashes, improved emergency response to crashes, less traffic congestion, shorter travel time, lower vehicle emissions, better fuel economy, lower insurance rates and fewer distractions for drivers.

Furthermore, the surveyed where asked to express their opinions or concerns about the use of connected vehicles. All apprehensions were rated around “moderately concerned”, except the U.S. participants, who were “very concerned” about the following three aspects:

- System security (cyber threat attacks) and vehicle security (cyber threat attacks)
- Data protection / Information privacy (location and speed tracking)
- Drivers relying too much on the technology (p 9.) (Schoettle & Sivak, 2014)

The question which area is the most important, that connected vehicles should address, the participants answered: 83.8% said that safety is the most important thing, followed by mobility (10.4%) and third, environment by 5.9%.

More than 50% of the participants rate the integration of personal communication devices as “very” or “moderately important”. A somewhat similar ranking was given to the question how important Internet connectivity is.

Ultimately, 62.4% of the participants are “very” or “moderately” interested in owning and paying for a connected vehicle. However, 44.4% of all respondents stated that they are not willing to pay extra for connected vehicle features (Schoettle & Sivak, 2014).

The survey also concluded that individuals, that have been introduced or exposed to the topic of connected vehicles beforehand and therefor where able to gain a deeper knowledge, had a more positive opinion towards this technology.

4.5 Secure Connection between V2V Vehicles and the Question of Privacy

A smart car, or a connected car brings up the question of privacy. A vehicle that is connected to the Internet can possibly be a vulnerable target to cyber-attacks. As stated in 4.4 one of the major concerns that people have about connected vehicles is that the vehicles data is not secure and could get hacked. In July 2015, the Wired magazine showed with the support of two hackers that it was possible to hack into a Jeep wirelessly. Disabling the brakes or shutting down the engine while the vehicle was moving on the highway were the most dangerous commands (Greenberg, 2015). Therefore, it is essential to develop safety standards that allow secure connections between vehicles. However, a network device always has its exact identification, to enable communication, otherwise the data packages cannot be transferred from the sender to the receiver without an address. To provide better privacy standards, the *European car2car Communication Consortium* developed an approach that generates pseudonyms for each individual vehicle. The idea is that every vehicle will have 20 pseudonyms at the same time with an expiration date of a week. This will make it more difficult to track the activities of an individual vehicle. However, even if the vehicles identity changes each time it is turned on again, a receiver could manage to put the data together from different identities. The reason this is possible is: the position of the vehicle is part of the transmitted and stored information. Each time the vehicle is turned off, the transmission of the V2V messages ends and the location from the vehicle are stored. Once the board computer has regained its activity, the V2V device continues to send messages, this time with a new identity. The two identities can be put together and assigned and tracked to that one vehicle. It is very likely that the vehicle has not moved without the engine (and the V2V device) running.

The researchers and engineers are still working on a solution to keep the movement of a vehicle private.

On the other hand, road maintenance services or traffic flow systems could not work without a broader connection with many vehicles. It is most likely that in the future every movement on a public road will be monitored somewhere. Speeding or other inappropriate behavior could be an issue of the past, since the system will detect it and could be able to report it to the police automatically.

Today, the cars telematics are already used to monitor the behavior of the driver for various applications. In 2013 38% of all new cars in the U.S. had already a telematics device installed (Buettner, 2013). Telematics can be used for an automated emergency call, diagnostics of the vehicle can be transmitted to the workshop or it can help to track cars when they get stolen (Karapiperis, et al., 2015). In the past, car insurance companies calculated the insurance fee based on factors like the age of the driver, which gives the insurer an indication how safe the driving style would be. In recent years, many U.S. insurance companies started offer usage based policies using the telematics of the car using either the in-vehicle technology, small devices provided by the insurer or even smartphones apps of the car owner (Karapiperis, et al., 2015). The speed, mileage and also the type of roads the customer is using can be tracked and analyzed. This information is then used as the basis to calculate the insurance fee. When the driver is on vacation and the car stayed at home, he will not be billed for that particular period of time. On the other hand, if the driver is often faster than the speed limit, the driver needs to pay more for having a riskier driving style. In addition, certain roads that are known for being dangerous could increase the monthly fee to the insurance company (Lieber, 2014). The people who have chosen a usage-based policy nearly doubled between February 2013 and July 2014. At the same time privacy concerns decreased from 41,6 % to 25.2% (Towers Watson, 2014).

Google Analytics is a tool to track the public behavior of using a website. The system is collecting a lot of information. For example, what browser the person was using and on what system. Where and when, and how long they have been using the website. In the end the owner of the website has a clear picture of the user’s activity on the website. This information is then used to increase the usability of the website and therefore provide a better experience for the user. This could also be the future for vehicles. The vehicles of today are already monitoring all sorts of things. In the event that something does not work properly, a warning signal is shown and the workshop can find the information, what is wrong with the vehicle this way. In the future those statuses will be probably uploaded and synced to the manufacturers system. Software updates can be downloaded over night when the vehicle is in the garage of the owner. BMW offers a system called *BMW TeleServices*. The system in the vehicle is able to inform the closest garage, or the configured workshop when the vehicle needs new brakes for example. The employees in the workshop will then notify the owner of the vehicle to arrange an appointment to change the brakes (BMW, 2013). A key of a modern car also saves a lot of data. Only be reading the information on the car key, there is access to a huge amount of the vehicles data. Including for example the fuel level in the tank. Considering all these factors, the vehicle status is already pretty transparent to the manufacturer and those who have access to the data.

4.6 Failure of V2V Communication

All possible scenarios for V2V communication, as discussed under 4.3, are not providing any safety or other convenient advantages if the system is not working a 100%. Most concerning: the possibility that someone could hack a V2V communication device and could send out false messages. Or the system itself is not working properly and sends out false messages. Thus, the V2V communication system cannot be a taken for a source that produces 100% correct information. It should be used and understood as a tool to add information, like e.g. another sensor, and help the driver make decisions as well as having a better and more efficient driving experience. It is not intended to take over driving and make decisions for the driver. Therefore, the car and the driver does not rely on just one source of information, but multiple sources. If all the other on-board sensors are signaling a free road ahead of the vehicle there is no need for an emergency brake maneuver even if the V2V system tells otherwise.

The system cannot properly be working either if the V2V technology is not implemented in the vehicles on the road. To get all the possible benefits out of V2V communication it must be installed in every vehicle on the road. The USDOT estimates that the technology for each vehicle will cost between \$341 to \$350 in 2020 (Harding, et al., 2014)

Another unsolved question is where the position of the vehicle is defined. Is it the front bumper? The center of the car? Or is it the rear end? In any case, the measurements of the vehicle play a role as well. When it comes to EAB (3.2.2) a meter less or more of stopping distance can make the difference. The size of a vehicle really has to be taken into account when it comes to trucks which can be quite big. Another important question is where the data of the measurements are stored. Will it be part of each message? Or does every car have a library with all the vehicles?

4.7 The Vehicle as a Part of the Global Network?

The digitalization of things increases on many levels and it does not stop at automobiles. Even though many new cars are already equipped with SIM cards, the Internet has not really arrived yet as a general standard in vehicles. This might have something to do with the average age of people who buy a new car. In the U.S. the average age in 2014 was 52 years (Frohlich, 2014). However, this fact is not stopping the manufacturers to develop more and more safety features as well as other digital technologies for their vehicles. In 2011, BMW integrated Facebook and Twitter in their ConnectedDrive package. Since 2013, the ConnectedDrive feature enables the user to setup apps through the Internet on their BMW. They adapted the system of modern smartphones on their automobiles (BMW, 2013) Due to this development it is not a big step to claim that the car of the future will become part of our (personal) network. Like our phone, our TV, our console, and maybe the refrigerator, the car will be part of this network.

In order to get a better understanding of the processes of digitalization and what impact the Internet had so far on the society and other businesses, the following chapter is taking a look back what happened so far and what that could mean for the car industry.

4.8 The Digitalization of the Everyday Life

When the first data was transmitted via the Internet between UCLA and the Stanford University in 1969, also known as the ARPANET, nobody knew what impact the Internet will have on society. Based on the military need to build a network without a central unit, the Internet today consists out of an uncountable number of independent nodes, that makes the world the so called Global Village (Gere, 2008). In 1995 the remaining (military) restrictions where banned and the Internet was completely open for the public use. Since then, the Internet celebrated an unbelievable success. No technology ever before has spread so quickly as the Internet did. In

2006 43% of all Europeans never used the Internet, in 2014, only 18% never used the Internet (Seybert & Reinecke, 2014).

Over the years, many different businesses experienced major changes. In the field of music consumerism, the Internet lead to inventions like Napster, the first peer-to-peer network, which started the new area of music. At its peak–Napster counted 32 million users–it got closed down by music industry, which was afraid of the impact of the invention (Giesler, 2006). The iPod eventually picked up the zeitgeist and brought up a whole new experience how people purchase and listened to music (Cosentino, 2006).

Photography transformed from film cameras to digital cameras. Giants like Kodak and the famous Polaroid cameras disappeared. Amazon revolutionized how we shop things and the old retail stores started to struggle. Online newspapers, reading devices such as tablets and the iPad replacing more and more printed publications such as newspapers, magazines and books.

In 2007, Apple introduced the iPhone, which revolutionized the phone business. Nokia phones–market leader back in the days–officially became history in 2014, when Microsoft no longer uses the brand Nokia on the current Lumia lineup. The iPhone came at the right time. The ecosystem was already built with the iPod, and with the introduction of the AppStore in 2008 Apple opened the door for developers to create their own apps. Overnight, the iPhone became endless capabilities and the smartphone was born. Since then, Google founded their own mobile operating system, what they called Android and became Apples biggest rival. In contrast to a closed ecosystem between hard- and software (Apple), Google decided to open their system to everyone. Therefore, many hardware manufacturers now rely on Android.

During the same time, Facebook was founded in 2004. The so-called web 2.0 area began, where the Internet not only provided information, it became a participatory web. People got in touch with the new technology in masses and Facebook became the biggest social network on the planet. In October 2012, the network reached 1 billion users (Fowler, 2012)

Another network called Skype enabled the user to make phone- (and video-) calls over the Internet. Voice over IP–making phone-calls using the Internet–was born and became a serious opponent of traditional telephone companies.

The smartphone however made the Internet mobile. Firstly, only used by enthusiasts, the smartphone quickly replaced many of the older mobile phones that did not have the ability to access the Internet. For those who purchased a smartphone, the use of the Internet changed dramatically. Emails were answered immediately, services like Whatsapp made it easy and cheap to communicate; “to go online” became “always on”. A survey stated that 73% of all Americans go online at least once per day. 21% said that they are almost constantly online (Perrin, 2015).

The social networks made the Internet more personal and the smartphone brought the Internet closer to the user. The smartphone is a tool between the world we can feel and see and the digital world. Google enables the user to access information, no matter where the user is. Digital maps help to navigate and to find new interesting places in unknown territories. The smartphone camera became the most used camera on the planet. 42% of all uploaded pictures to Flickr are pictures taken with a phone (Tirosh, 2015). Apps enable the camera to scan the content and provide additional information.

In general, the smartphone became the central tool to communicate with other people and interact with the Internet.

Slowly but surely the Internet is conquering everyone’s everyday life and making it essential to work and to live. Digitalization is enabling us to analyze, measure and find things more easily. E.g. maintaining an overview over a library suddenly became much simpler when a computer could store all the titles of the books, and which ones are currently borrowed by people. Searching for a book and and to check its availability became fast and easy. The library is just one example of many uses of computer technology to achieve and organize things. This also applies for our private life. Music, documents, videos and so on became much easier to categorize, sort out and handle. However, connecting the things in our everyday life with the digital world just had begun. In the area of fitness, where the athletes for years already measuring and counting their improvements; digitalization gives them a much handier tool. In addition to the smartphone, which are the most used, companies like Nike and Jawbone offering for a few years now fitness wristbands to measure the daily activities. Jawbone also includes monitoring the activities during sleeping. These devices are just the forerunners of a new generation of connectedness. Apple launched the AppleWatch, which is also able to monitor the heart rate of the wearer. With iOS8, Apple introduced *Healthkit* in 2014. A tool for developers and a bay for health related data. In combination with other hardware devices the smartphone becomes a powerful hub for all health matters and can be even connected to medical center.

Another tool is *Homekit*, which is a tool for developers to address and organize things around one's home. This can be for example the on and off switch for lights, or regulating the temperature, all using the smartphone as a tool. Google bought a company called *Nest* in 2014, specialized in smart home devices. However, smart homes require many different sensors and other hardware which makes it expensive to set up a smart home. In addition, security issues and the lack of standards did not help to bring smart home devices to the masses. Nevertheless, the big companies are slowly building the infrastructure and pave the way to the Internet of Things.

4.9 The Internet of Things

The Internet built its success mainly on the users who created content, which could be consumed and used by other users all around the world. Companies and businesses needed to learn how to use the Internet to their advantages. Many services were introduced as free services such as news websites, which is still a problem today because the users got used to access content for free. However, the Internet is deeply embedded into people’s lives. The next step of how to use the Internet is that machines instead of humans will use the Internet. This means that machines start to communicate to each other to exchange information. This communication is called machine-to-machine communication, shortened M2M communication. An example for M2M communication is a system that detects a level of something e.g. the amount of water that has been used in an apartment. When the sensor is measuring a certain level, it will transmit the data through a network to a software that interpreters the measured level and gives it a meaning by giving further instructions. In the described example, the water supplier could send out monthly or annually invoices to their customers automatically. Another example would be that a person is loading a washing machine and instead of starting it or programming it to start at a certain time, the washing machine starts the process of washing itself. The impulse for the start would be managed by a smart grid. The initial parameter could be e.g. the lowest price for electricity or when the wind is blowing to produce clean energy from the nearby wind turbine.

The main idea of Internet of Things is that the physical world will be connected to the digital world. Many pieces of the people’s everyday life will most likely become digitalized or at least recognizable meaning that they get a readable code for other machines. Also production industries will benefit to a large extend. The machines will organize themselves and order supplies if they need certain things. In order to do that it is necessary to assign to every object an individual identity. This became possible with the introduction of IPv6. IPv4 was able to provide addresses for 2^{32} ($\approx$ 4.3 billion = $4{,}3 \cdot 10^{9}$) devices. IPv6, however now offers 2^{128}($\approx$ 340 sextillion = $3{,}4 \cdot 10^{38}$). A thing of the Internet of Things needs the ability to communicate–connectivity, and it needs sensors to gather information.

A device that already today connects the digital world with the physical world is the smartphone. Apps allow the user to scan things using the camera. A product in the supermarket can be easily identified through the barcode, additional information such as ingredients can be displayed. Furthermore, the software could also tell the user if there are allergies or where the food was grown.

Searching things, even physically, will become much easier as well. A key that is digitally connected and provide the location can be effortlessly found. In a world where everything becomes connected it is simpler to manage things. Increasing traffic in growing cities are manageable through a grid of intelligent devices. Vehicles are becoming therefore part of the Internet of Things. In this connectedness lays a chance to significantly improve the living.

The personal car already reached a status in the connected world. As in 4.5 mentioned some cars already take actions in certain situations and contacting the local workshop. In-car entertainment features use the Internet connection to provide a smartphone-like experience. Furthermore, in a world where V2X communication has been fully deployed the vehicle is part of an intelligent grid that organizes traffic flow helps to make the roads safer and traveling more economical. Furthermore, a fully working grid of V2X communication opens the world for self-driving vehicles. Companies show their technological achievements already today; vehicles are able to operate in unknown areas without having the support of V2X communication. An environment full of information where potential hazards are and where the road is free a self-driving car could be used more safely. A self-driving vehicle would be able to optimize traveling economically in a nature friendly way and timewise. The focus of traveling would shift from active driving to passive moving. It could be possible that the in-vehicle entertainment features become the main focus of the passengers. The passenger cell might also be used as a room that is a moving office. Emails could be read and replied, video calls could be made.

However, the emerge of virtual reality and 3D printing could reduce the need of actual traveling. Instead, e.g. a business meeting can be arranged in virtual worlds using head-mounted displays such as the Oculus Rift. Therefore, the need for a transportation device to meet in person is not needed. It is imaginable that the personal vehicle becomes less of a status symbol, it just offers personal transportation. Car-sharing becomes more and more popular, the vehicle can be personalized every time a user enters a vehicle.

On the other hand, traditional driving, and the pleasure that comes with it for some people, may become a thing of the past. Fossil fuels maybe banned at some point and vehicles that are not connected are not able to use modern roads anymore. Therefore, people that are into driving or even racing might meet up to follow their hobby and use their vehicles on closed roads.

5 Conclusion

The main conclusion of this study is that V2X communication is not ready yet to be part of the connected world today. Many parties are involved to develop standards that work around the globe. The biggest issue is the question of privacy and network security. Thus, this is the major concern that people have towards V2V communication (4.4). However, the people do understand the advantages of V2V communication. While predictions promise great potential to improve vehicle safety, the question of privacy concerns is decreasing. It might be possible that V2V communication comes with the price that the people partly have to pay with their privacy and the willingness to give up this privacy seems to grow over the years. The utopia of a society that is constantly watched by a system may become true when it comes to vehicles and their movement on public roads.

However, the car as a personal device that is connected to the Internet as described in 7 slowly but surely becoming a reality. Future generations might take the availability of Internet connectivity in vehicles for granted and as mentioned parts are already in use.

Nevertheless, the people and the press are following very closely the development of the autonomous car. Big tech companies like Google are investing in self-driving cars. Rumors say that Apple is working on a car as well. Tesla, which announced the Model 3 in March 2016 coming in 2017, celebrating the huge demand of their vehicles (Tesla, 2016). They are pushing the borders of the possibilities for new technologies on the road and introduced a system called autopilot. The system is basically a lane keeping system combined with ACC (Tesla, 2015).

Taking the people's enthusiasm for autonomous driving features, V2V communication might have a chance to be accepted by the people. It certainly will bring a lot of safety to the roads because it reduces the possibility of human misjudgment and error.

Due to the fact the field of study around connected vehicles is relatively new, not that much research has been done actual V2X communication that is in use. In general, most research relies on simulation, which does not portray the reality 100%. Projects such as “project in Ann Arbor” are still under examination. On the other hand, the manufacturers whose intentions are not to make the roads safer, but rather focus on the amount of vehicles produces, are developing their newest features in secret and are not willing to make their latest technology breakthroughs public. Therefore, the technologies they share with the public are either to show their willingness to innovate or to show another reason to the customer to buy their car.

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