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Connected Vehicle : Solution and State of the art and Future Challenge

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ABSTRACT

Self-driving and connected vehicles, communicating with one another and with the road infrastructure are a subject of extensive research nowadays and are expected to revolutionize the automotive industry in the near future. Providing various wireless connectivity for vehicles enables the communication between vehicles and their internal and external environments. Moreover, connected vehicles are also the building blocks of emerging Internet of Vehicles. Extensive research activities and numerous industrial initiatives have paved the way for the coming era of connected vehicles. In this paper, we focus on wireless technologies and potential challenges to provide vehicle-to-x connectivity. In particular, we discuss the challenges and review the state-of-the-art wireless solutions for vehicle to-sensor, vehicle-to-vehicle, vehicle-to-Internet, and vehicle-to road infrastructure connectivity. We also identify future research issues for building connected vehicles.

Keywords : Connected Vehicles, Internet of Vehicles, Intra Vehicle Wireless Sensor Networks, Vehicular Networks, Intelligent Transportation Systems

I. INTRODUCTION

With the development of information and communication technology, connectivity between vehicles and between vehicles and transportation infrastructure was made possible. For instance, information of signal phasing and timing, location and speed of vehicles could be easily transmitted and exploited for any application. During the past decades, many studies have focused on changing traffic signal timings to optimize vehicles delay and fuel levels. Recently, researchers attempted to use connected vehicles and infrastructure technologies to develop eco driving strategies that are more fuel-efficient. Nowadays, people expect more than vehicle quality and reliability. With the rapid development of information and communication technologies, equipping automobiles with wireless communication capabilities is expected to be the next frontier for automotive revolution. The term Internet of Things refers to this internet-based architecture which facilitates the exchange of services, information and data between billions of objects, mostly smart Connected vehicles on the go are proactive, cooperative, well-informed, and coordinated, and will pave the way for supporting various applications for road safety (collision detection, lane change warning, and cooperative merging), smart and green transportation (traffic signal control),location dependent services (point of interest and route optimization), and in-vehicle Internet access. IoT provides the connection between all these objects to facilitate and make people's lives more comfortable and efficient in all situations. Within this approach different aspects of both hardware and software solutions work together to realize the Internet of-Things paradigm. The market of connected vehicles is booming, and according to a recent business report, the global market is expected to reach USD 131.9 billion by 2019. Academia and the automotive industry are responding promptly by exploring reliable and efficient connectivity solutions. There are two immediate driving forces of bringing wireless connectivity to vehicles. The first one is the urgent need to improve efficiency and safety of road transportation systems. Growing urbanization yields an increasing population of vehicles in large cities, which is responsible for traffic congestion and the consequences in terms of huge economic cost and environmental problems. Connected vehicle solutions are very promising to alleviate traffic congestions via intelligent traffic control and management as well as to improve the road safety via on-board advanced warning and driving assistance systems. The second one is the ever-increasing mobile data demand of users on road. In recent years, the demand for high-speed mobile Internet services has increased dramatically. People in their own cars expect to have the same connectivity as they have at home and at work. Connecting vehicles to the Internet can be envisioned not only to meet the mobile data demand but also enrich safety-related applications, such as online diagnosis and intelligent anti-theft and tracking in which the servers can be on the Internet cloud. Internet-integrated vehicles have hit the road, and it is predicted that the percentage of Internet integrated vehicle services will jump from 10% today to 90% by 2020. In addition, government mandate has put the connected vehicle revolution on the fast track. The European Commission proposed to implement a mandatory “eCall” system in cars from 2015, by which cars can automatically establish a telephone link for emergency services in case of a collision. Not surprisingly, the U.S. Department of Transportation’s (DOT) National Highway Traffic Safety Administration (NHTSA) recently announced that it will start taking steps to enable communications between light vehicles. Connected vehicles refer to the wireless connectivity enabled vehicles that can communicate with their internal and external environments, i.e., supporting the interactions of V2S, V2V, V2R, and V2I, as shown below. These interactions, establishing a multiple levels of data pipeline to in-vehicle information systems, enhance the situational awareness of vehicles and provide motorist/passengers with an information-rich travel environment. Further, connected vehicles are considered as the building blocks of the emerging Internet of Vehicles, a dynamic mobile communication system that features gathering, sharing, processing, computing, and secure release of information and enables the evolution to next generation Intelligent Transportation Systems. The development and deployment of fully connected vehicles requires a combination of various off-the-shelf and emerging technologies, and great uncertainty remains as to the feasibility of each technology. In this paper, we focus on the wireless technologies and present an overview of industrial and academic advances for establishing vehicle to-x (V2X) connectivity.

II. METHODS AND MATERIAL

1. Related Work

A. State of the art of solution

Large traffic congestion is an important civilizational and commercial problem, especially in urban, densely inhabited areas. It causes delays in travel time, stress of drivers, noise, problems in organizing public transport and detours, larger air pollution, fuel and energy consumption etc. Drivers in 7 largest polish cities lose yearly approximately 3.6 billion PLN due to traffic jams. The situation is similar in other countries. Drivers in 471 urban areas in U.S. lose yearly 6.9 billion hours (42 hours per auto commuter) and 3.1 billion gallons of fuel (19 gallons per auto commuter), Urban Mobility Scorecard (2015). CEBR (2015) forecasts that the worldwide cost of traffic gridlocks may reach $293.1 billion by 2030 - almost a 50% increase from 2013. Another important problem related to vehicular traffic (not only large traffic congestion) is car accidents and their consequences: deaths of passengers, damages of cars etc. According to KGP (2015), there were 34 970 car accidents and 348 028 collisions in 2014 in Poland. As a consequence, 3 202 people died, 42 545 were wounded. According to WHO (2013), worldwide the total number of road traffic deaths is 1.24 million per year, while the number of injuries caused by crashes is more than 20 million. The economic cost of crashes is estimated to be few times larger than the cost of large congestion. The need for innovative solutions able to decrease traffic congestion as well as number and consequences of crashes arises. According to Google (2015), about 94% of all car accidents in the U.S. involve human error, so eliminating this factor seems to be the best way to reduce the risk of collisions. An innovative solution to do it is introducing autonomous (self-driving) and connected vehicles, capable of driving without any actions of human and communicating with each other (V2V – vehicle-to-vehicle communication) and with the infrastructure (V2I – vehicle-to-infrastructure communication, I2V – infrastructure-to vehicle communication) in order to ensure traffic safety and smoothness. Autonomous and connected vehicles are nowadays the area of extensive research. Many companies from automotive and IT industries try to build their own working models of such automobiles. Simultaneously, research efforts are focused on investigating impact of such vehicles on traffic congestion, safety, the society and global economy. There are premises to suspect that introducing autonomous and connected vehicles may revolutionize the whole transportation area. Thanks to self-driving cars, disabled people, elders or people without valid driver's license, could safely travel to long distances. On the other hand, there may be no more need for a driver's profession or it may look totally different - limited to giving commands and supervising machine. The industry of logistics may change, car go may be delivered cheaper and faster, especially in case of long distance shipments. Public and private transportation may change as well, taxis and buses may be replaced by cars on-demand, shared among many passengers, being in motion almost all the time, instantly picking people up on call (thus, this approach may reduce demand for parking places and improve space utilization in urban areas - the need for parking space in the United States may be reduced by more than 5.7 billion square meters, While the total number of cars in motion may increase in some areas (more people will be able and keen to use a car) having negative impact on traffic density and congestion, reduced demand for parking may reduce number of cars driving in the city center (it is estimated that 30% of traffic congestion in downtown areas in big cities is generated by vehicles cruising for unoccupied parking spot. Passengers will be able to spend their travel time working or relaxing. In addition, thanks to V2V communication cars could potentially exchange information about their positions, speeds, routes, plans for changing speed or lane, turning, stopping. They could let other cars know about their intentions and collaboratively agree on common driving strategies, which would ensure safety and be in some terms optimal for achieving desired goals. It is estimated that self-driving cars could reduce the number of accidents by 90%, saving many lives and yearly about $190 billion in U.S. The self-driving revolution is expected to be the greatest thing to happen to public health in the 21st century. Moreover, V2I communication may totally replace infrastructure-based sensors being in use nowadays, such as inductive loops, radars, video cameras. Cars could just communicate with the infrastructure and send their positions, speeds, routes and intended makeovers to the traffic management center, in which powerful servers equipped with realistic maps may build models of the actual traffic situation in real time and run microscopic traffic simulations, much faster than real time, in order to make very accurate, short-term predictions of traffic conditions.

Bluetooth: Bluetooth is a short-range wireless technology based on the IEEE 802.15.1 standard and operating in the industrial, scientific and medical frequency band (2.4 GHz). It allows the communication between portable devices at a data rate up to 3 Mbps, and is highly commercialized for consumer electronics. The Bluetooth devices are common in current automobiles, such as the Bluetooth headset and rearview mirror. However, the Bluetooth transmission requires a high power level so that it might not be viable for battery driven sensors in vehicles. Moreover, due to the poor scalability, a Bluetooth network can only support eight active devices (seven slave devices and one master device)

ZigBee: One option for enabling the V2S connectivity is through the use of ZigBee technology, which is based on the IEEE 802.15.4 standard and operates on the ISM radio spectrum (868 MHz, 915 MHz, and 2.4 GHz) As the first attempt to evaluate ZigBee performance in an in-vehicle environment, research in the results of packet transmission experiments using ZigBee sensor nodes within a car under various scenarios. This study demonstrates that ZigBee is a viable and promising solution for implementing an intra-vehicle wireless sensor network. ZigBee is low-cost and can provide an acceptable data rate (250 Kbps in 2.4 GHz frequency band). As stated in , however, the challenge of implementing ZigBee sensors is to combat the engine noise and interference from Bluetooth devices. In [30], the performance of ZigBee intra-vehicle sensor networks is thoroughly studied in the presence of Bluetooth interference, based on a realistic channel model. Data latency of in-vehicle sensor applications is an important network design consideration. To meet the hard latency requirements, derives necessary design parameters of medium access control (MAC) protocol based on a star topology. A thorough analysis of transmission latency of using ZigBee is conducted In addition, engineering issues, such as the interactions with the existing CAN backbone.

RFID: The feasibility of using the radio-frequency identification (RFID) technology for building intra-vehicle sensor network. The rationale of the considered passive RFID solution is that each sensor is equipped with an RFID tag and a reader connected to the ECU periodically retrieves the sensed data by sending an energizing pulse to each tag. Extensive experiments have been conducted in these two studies for understanding the capabilities and limitations of RFID technology, including the wireless channel characteristics between the reader and RFID tags at different locations, packet reception rate, and maximum packet delay. The passive RFID solution has obvious advantages: low cost and no power supply to RFID tags. Moreover, the experiments show promising results in terms of the coherence bandwidth and the transmission reliability. These studies also identify two major challenges: connection outage due to large power loss at some locations and difficulty to guarantee the critical data transmission due to collisions among simultaneous transmissions. The suggested solution to address challenge is to use advanced antennas or the active RFID technology and for the second challenge, efficient and reliable MAC protocols should be developed for the RFID sensor network.

Ultra-Wideband: Ultra-wideband (UWB) refers to radio technology that operates in the 3.1–10.6 GHz frequency band and can support short range communications at a data rate up to 480 Mbps and at a very low energy level UWB systems have a number of unique advantages, such as resistance to severe wireless channel fading and shadowing, high time domain resolution suitable for localization and tracking applications, low cost, and low processing complexity UWB has been adopted as a key physical (PHY) layer technology in the ECMA-368 standard specified by the WiMedia Alliance For intra-vehicle scenarios, extensive research has demonstrated the feasibility of UWB technology for satisfying the stringent reliability and energy requirement of on-board sensor networks. The design and implementation of an intra vehicle UWB communication testbed is reported in The testbed is built to transmit automotive speed data from four wheel speed sensors to the ECU. The measurement result shows a high data delivery reliability. Most of the existing works aim at proposing appropriate channel models which can capture the propagation characteristics of in-vehicle environments. These studies focus on different parts of the vehicle, including passenger compartment engine compartment trunk and locations beneath the chassis as the channel statistics are quite different from location to location. Recent measurement study also models small-scale fading within the vehicle which has not been considered before. Given an underlying wireless model, how to define the most suitable transmission techniques at PHY layer is a critical issue for UWB-based intra-vehicle sensor networks.

60 GHz Millimeter Wave: Communications at 60 GHz band, often referred to as millimeter-wave (mmWave) communications, pave another way for building intra-vehicle connectivity. Operating in the frequency band between 57 and 64 GHz, Wave communications can support multi-Gbps wireless connections in a short range for bandwidth-intensive multimedia applications. mmWave-based PHY layer has been specified in the IEEE 802.15.3c and the IEEE 802.11ad. There has been increasing research interest in applying mmWave communication technology to multimedia transmission in the intra-vehicle environment, such as high definition video transmission for seat-monitor in the vehicle. As the propagation loss becomes more serious in 60 GHz frequency band, the first and foremost is to gain a better understanding of propagation characteristics inside the vehicle. Propagation measurement campaigns have been performed to investigate the small-scale parameters the large-scale parameters, and the impact of passenger and antenna location. The results show that mmWave is a promising wireless solution for intra-vehicle multimedia transmissions.

Autonomous and connected cars

Experiments with autonomous and connected cars have been conducted since at least 1925, when a driverless car was driving on streets of Milwaukee. However, the car was not truly autonomous, it was radio operated from a second car (considered as a case of V2V communication). Even these first approaches, designed in the era of computers with lower computational power than nowadays, were based on very advanced tools and concepts, such as transputer (microprocessor designed for parallel processing), neural networks. Some other countries have allowed testing autonomous cars in traffic as well. There are interesting projects aiming to demonstrate autonomous vehicles potential, e.g., CityMobil2 (2015), Beta City Initiative (2015). Partially automated cars are already driving on public roads, but are not as advanced as fully autonomous cars. National Highway Traffic Safety Administration, proposes a formal classification of automation, from Level 0 (No automation) to Level 4 (Full self-driving automation). In our research we focus on models in which no driver's control is required, which is Level 4 of automation, but currently we investigate only standard manoeuvres, so results of our research may be also applied to automation from Level 3 (Limited self-driving). Autonomous cars scan the surrounding area to detect other vehicles and obstacles, but the range of such detection is relatively low and on-board computers have to interpret perceived data fast and correctly.

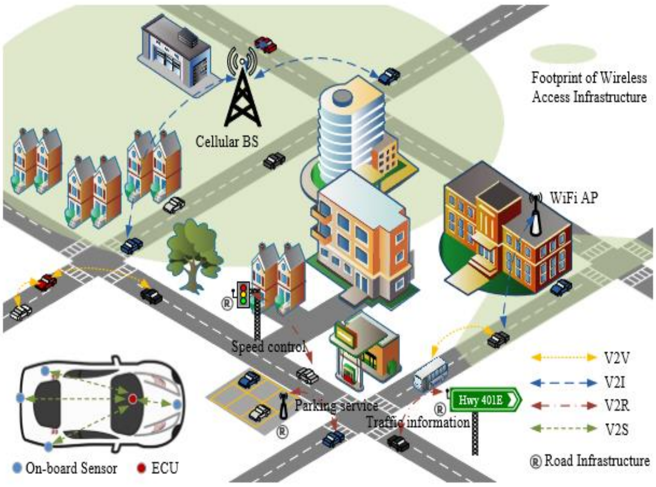

Figure 1: overview of connected car

V2V (vehicle-to-vehicle) – vehicles can “talk” to each other.

V2I (vehicle-to-infrastructure) – vehicles can send information to the infrastructure

I2V (infrastructure-to-vehicle)–vehicles can receive information from the infrastructure

Cars equipped with devices enabling communication with other cars and with the infrastructure are named, in short, connected cars.

TABLE I. Comparision of DSRC and DSA system Parameters

Parameter	**DSRC**	**DSA**
Frequency Band	5.850–5.925 GHz	476-494MHz
Channel Bandwidth	10mHz	1 MHz
Data Rate	3-27Mbps	1Mbps
Modulation	BPSK, QPSK, 16QAM and 64QAM	GMSK
TX Power	33 dBm	16dBm
MAC Protocol	CSMA/CA-based	Simplified CSMA/CA

B. Connecting Vehicles

Intra vehicle connectivity

With increasing intelligence, modern vehicles are equipped with more and more sensors, such as sensors for detecting road conditions and driver’s fatigue, sensors for monitoring tire pressure and water temperature in the cooling system, and advanced sensors for autonomous control. The number of sensors is forecasted to reach as many as 200 per vehicle by 2020. Such a big quantity of sensing elements are required to report event-driven or time-driven messages to the electrical control units (ECU) and receive feedback if necessary. To do so, an intra-vehicle communication network should be carefully designed. Wired solutions such as Controller Area Network (CAN) protocol, FlexRay, and TTEthernet, require cable connections between ECU and sensors. Cables and other accessories nowadays can add significant weight. Moreover, the installation and maintenance of aftermarket sensors (providing add-on functions) are inconvenient by using cable connection. Recent advances in wireless sensor communication and networking technologies have paved the way for an intriguing alternative, where ECU and sensors are composed of an intra-vehicle wireless sensor network, leading to a significant reduction of deployment cost and complexity. There exist multiple candidate wireless technologies to build intra-vehicle wireless sensor networks, and the feasibility of different wireless options to in-vehicle environments has been a research focus.

Characteristics and Challenges

Different from generic wireless sensor networks, intravehicle wireless sensor networks show unique characteristics that provide the space for optimization.

Sensors are stationary so that the network topology does not change over time.

Sensors are typically connected to ECU through one hop, which yields a simple star-topology.

Inter vehicle connectivity

It is widely believed that the advances of inter-vehicle communications will reshape the future of road transportation systems, where inter-connected vehicles are no longer information-isolated islands. By means of inter-vehicle communications or V2V communications, information generated by the vehicle-borne computer, control system, on-board sensors or passengers can be effectively disseminated among vehicles in proximity, or to vehicles multiple hops away in a vehicular ad hoc network (VANET). Without the assistance of any built infrastructure, a variety of active road safety applications (e.g., collision detection, lane changing warning, and cooperative merging) and infotainment applications (e.g., interactive gaming, and file and other valuable information sharing) are enabled by inter-vehicle wireless links.

Characteristics and Challenges

VANETs have attracted extensive research attentions for many years, and how to establish efficient and reliable wireless links between vehicles is a major research focus. The most cumbersome challenge is to combat the harsh communication environment. In urban scenarios, the line-of sight (LOS) path of V2V communication is often blocked by buildings at intersections. While on a highway, the trucks on a communication path may introduce significant signal attenuation and packet loss. is premier to design reliable V2V communication systems. It also provides suggestions for V2V communication systems based on the channel characterization. For example, the adoption of multiple antennas would enhance the communication reliability. From a network perspective, compared to typical low velocity nomadic mobile communication systems, VANETs also present unique characteristics that have a significant impact on inter-vehicle connectivity.

The network topology changes frequently and very fast due to high vehicle mobility and different movement trajectory of each vehicle.

Due to the high dynamics of network topology and limited range of V2V communication, frequent network partitioning can occur, resulting in data flow disconnections.

C. System parameter

Dedicated Short-Range Communications

Dedicated Short-Range Communications (DSRC) is a key enabling wireless technology for both V2V and V2R communications. The U.S. Federal Communication Commission (FCC) has allocated 75 MHz bandwidth at 5.9 GHz spectrum band for DSRC. The dedicated bandwidth is further divided into seven channels to support safety and non-safety services simultaneously. The specifications of DSRC are in the IEEE Standard for Wireless Access in Vehicular Environments (WAVE), including the IEEE 802.11p for PHY and MAC layers and the IEEE 1609 family for upper layers. Many automotive and ICT manufacturers, academia, and governments have responded positively and are actively working in collaboration to bring this promising technology to fruition. There have been extensive research efforts from academia to characterize communication properties of DSRC and to enhance DSRC performance both in the PHY layer and MAC layer.

Dynamic Spectrum Access

In spite of the DSRC spectrum, V2V communications still face the problem of spectrum scarcity due to the following reasons: (i) the ever-increasing infotainment applications, such as high-quality video streaming, require a large amount of spectrum resource, and thereby the QoS is difficult to satisfy merely by the dedicated bandwidth; and (ii) in urban environments, the spectrum scarcity is more severe due to high vehicle density, especially in some places where the vehicle density is much higher than normal. Numerical study has reported the limitation of the dedicated spectrum in supporting the increasing demand of V2V applications.

III. RESULTS AND DISCUSSION

In this we have to use different connectivity such as vehicle to vehicle, vehicle to sensor, vehicle to road and vehicle to road infrastructure.

IV. CONCLUSION

In this paper, we have presented an overview of the state of-the-art wireless solutions to V2S, V2V, V2I, and V2R infrastructure connectivity. We have discussed the potential challenges and identified the space for future improvement. To enable various wireless connectivity, multiple radio interfaces have to be implemented, such as DSRC/WAVE, WiFi, and 3G/4G-LTE interfaces, which may incur a high cost and thereby impede the development of connected vehicles.

A unified solution to provide V2X connectivity with low cost might be required. We focused on the challenges and characteristic of inter vehicle connectivity and intra vehicle connectivity.

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