Top Level Newsletter: Connected Vehicle

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Editor-in-Chief: Kay Das, IEEE Life Member,
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Vol 24 comprises the following topics:

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We wish our readers a Merry Christmas and a Connected New Year!

General Notes

This series of newsletters is intended to provide the IEEE member with a top level briefing of the many different subjects relevant to the research, development and innovation of the connected vehicle.

A note on the Connected Vehicle Newsletter development: Volume 18 was a top-level synopsis of the 74 most recent entries from the twelve previous volumes (vol 17 to vol 6) since March 2020. Volumes 19 to 22 returned to the usual format. Volume 23 departed from the norm and included a single complete article. We return to the usual format of multiple article summaries here.

The objective is to provide a platform for fast learning and quick overview so that the reader may be guided to the next levels of detail and gain insight into correlations between the entries to enable growth of the technology. Intended audiences are those that desire a quick introduction to the subject and who may wish to take it further and deepen their knowledge. This includes those in industry, academia or government and the public at large. Descriptions will include a range of flavors from technical detail to broad industry and administrative issues. A (soft) limit of 300 to 600 words is usually set for each entry, but not rigorously exercised.

As descriptions are not exhaustive, hyperlinks are occasionally provided to give the reader a first means of delving into the next level of detail. The reader is encouraged to develop a first level understanding of the topic in view. The emphasis is on brief, clear and contained text. There will be no diagrams in order to keep the publication concise and podcast-friendly. Related topics in the case of Connected Vehicle technology, such as 5G cellular and the Internet of Things will be included. The terms Connected Vehicle and Automated Driving will be used inter-changeably. Articles from other published sources than IEEE that add to the information value will occasionally be included.

This newsletter forms part of the regional Advanced Technology Initiative (ATI) of which connected vehicles form a constituent part. Technical articles solely from IEEE journals/magazines are referred to by their Digital Object Identifier (DOI) or corresponding https link. The link for each article is provided. Those readers who wish to delve further to the complete paper and have access to IEEE Explore (www.ieeexplore.ieee.org) may download complete articles of interest. Those who subscribe to the relevant IEEE society and receive the journal may already have physical or electronic copies. In case of difficulty please contact the editor at kaydas@mac.com. The objective is to provide *top level guidance* on the subject of interest. As this is a collection of summaries of already published articles and serves to further widen audiences for the benefit of each publication, no copyright issues are foreseen.

Readers are encouraged to develop their own onward sources of information, discover and draw inferences, join the dots, and further develop the technology. Entries in the newsletter are normally either editorials or summaries or abstracts of articles. Where a deepening of knowledge is desired, reading the full article is recommended.

1. Overview of Embedded Systems to Build Reliable and Safe ADAS and AD Systems, by Francisco Belmonte et al

Published: IEEE Intelligent Transport Systems Magazine (Winter 2021, pp 239 - 250)

The automotive industry is a key sector in developed countries, taking advantage from Electronic and Semiconductor industries, for which this work is focused on, including an overview of embedded systems and related technologies for Advanced Driver Assistance Systems (ADAS) development, end user applications and their implementation (SoCs, Application Processors-APs, MCUs, software and boards), manufacturers solutions, architectures, trends and other aspects (like methodologies) to improve functional safety, reliability and performances. The current status to permit the transition from ADAS to Autonomous Driving (AD) systems and Self-Driving Cars (SDC) is also explored.

Throughout the last decades previous innovations have already contributed to this objective, like the multiple airbags, anti-lock braking systems (ABS) and electronic stability programs (ESP).

Few years ago, new features like radar, LiDAR (light detection and ranging), camera-based systems, advanced computation and other digital and image-processing devices were introduced to make driving more comfortable, reliable and safer. Many of these ADAS applications, like adaptive cruise control, lane departure warning, traffic sign recognition and others, have been until now mainly complementary features, with a minimal influence on the vehicle and its direct driving behavior.

All these new technologies are taking now a more active role in the control of the car and the driving itself, with applications like Lane Keep Assist (LKA), automatic emergency braking (AEB), Adaptive Cruise Control (ACC), collision avoidance, parking assistance, lateral and longitudinal control, to achieve the intended goals, without creating an increased risk to the driver and occupants of the vehicles.

Different international standards organizations (SAE, ISO, NHTSA, etc.) are helping to define a set of autonomous driving levels, functional safety levels and other requirements and characteristics for ADAS and Autonomous Driving systems, also providing a common terminology.

The present work will introduce some of those definitions, applications and technologies, exploring a bunch of current and future alternatives offered by different manufacturers with an important role in the electronic industry. With respect to safety, one of the main objectives introduced has been the so-called "vision zero," which refers to the goal of eliminating traffic fatalities and injuries by 2050.

As the complexity of ADAS and AD is rising the automotive industry and standards organizations have increased efforts to provide safety-compliant systems. For instance, if current automobiles want to use by-wire systems such as throttle-by-wire (i.e. when the driver pushes on the accelerator and a sensor in the pedal sends a signal to an electronic control unit, with a control unit analyzing several factors such as engine speed, vehicle speed, and pedal position and relaying a command to the throttle body) it is a challenge of the automotive industry to address it at system level, test and validate it.

A main goal of ISO 26262 and similar international and national standards is to provide unified safety standards for all automotive E/E systems. Implementing ISO 26262 and derived normative and rules, allow leveraging a common standard to measure how safe (and probably, also reliable) a system will be in service. It also provides the ability to reference specific parts of the system as a common vocabulary is provided by the standard. ISO 26262 uses a system of steps to manage functional safety and regulate product development on a system, hardware, and software level. It provides regulations and recommendations throughout the product development process, from conceptual development through decommissioning. It details how to assign an acceptable risk level to a system or component and document the overall testing process, through the definition of a safety lifecycle and risk classes (Automotive Safety Integrity Levels, ASILs).

The ASIC (Application Specific Integrated Circuit) and FPGAs (Field Programmable Gate Arrays) can be considered as one of the more flexible devices to implement and support new ADAS and AD applications, probably with specific AI features, considering compliance with functional, safety and dependability (availability, reliability and maintainability) requirements, at short-term development schedules.

An optimal compute architecture will depend on different use-cases (processing speed, HW interfaces, processing per watt, backward compatibility, flexibility, form factor, required technical capabilities, etc.), which are very important for ASICs, FPGAs and GPUs used in Autonomous Driving.

Conclusions: The transition from ADAS to AD systems has already started, different manufacturers are offering their products and solutions or developing new ones, the standards organizations are defining rules, authorities (America, Europe, Asia, and Australia) have prepared studies and reports to anticipate potential issues and to improve the current and coming AD systems.

The present work has introduced some of the standards, design trends, features and examples required to build safe, reliable and secure traditional, semi-autonomous and self-driving or fully Autonomous Driving cars, with different levels of automation and human driver participation, exploring available ADAS and AD systems technologies, applications and product families from key actors in the Electronics and Semiconductor industries, already being used or to be integrated in next generation vehicles.

Current and future market needs will be satisfied through these technologies or new ones derived from them. We need to keep in mind respect to the environment, energy efficiency, compliance with performance, reliability and functional safety requirements. Other critical aspects like maintaining security and integrity of the exchanged data between autonomous driving systems and services or information available in roads and cities in a cooperative manner must be heeded. (867 words)

DOI: https://doi.org/10.1109/MITS.2019.2953543

2. Toward Reliable and Scalable Internet of Vehicles: Performance Analysis and Resource Management, by Yuanzhi Ni et al

Published: Proceedings of the IEEE (February 2020 Volume 8, Issue 2, pp 324-340)

Reliable and scalable wireless transmissions for Internet of Vehicles (IoV) are technically challenging. Each vehicle, from driver-assisted to automated, will generate a flood of information, up to thousands of times of that by a person. Vehicle density may change drastically over time and location. Emergency messages and real-time cooperative control messages have stringent delay constraints while infotainment applications may tolerate a certain degree of latency. On a congested road, thousands of vehicles need to exchange information badly, only to find that service is limited due to the scarcity of wireless spectrum. Considering the service requirements of heterogeneous IoV applications, service guarantee relies on an in-depth understanding of network performance and innovations in wireless resource management leveraging the mobility of vehicles, which are addressed in this article. For single-hop transmissions, we study and compare the performance of vehicle-to-vehicle (V2V) beacon broadcasting using random access-based (IEEE 802.11p) and resource allocation-based (cellular vehicle-to-everything) protocols, and the enhancement strategies using distributed congestion control. For messages propagated in IoV using multihop V2V relay transmissions, the fundamental network connectivity property of 1-D and 2-D roads is given. To have a message delivered farther away in a sparse, disconnected V2V network, vehicles can carry and forward the message, with the help of

infrastructure if possible. The optimal locations to deploy different types of roadside infrastructures, including storage-only devices and roadside units with Internet connections, are analyzed. (229 words)
DOI: https://doi.org/10.1109/JPROC.2019.2950349

3. Future Intelligent and Secure Vehicular Network Toward 6G: Machine-Learning Approaches, by Fengxiao Tang et al

Published: Proceedings of the IEEE (February 2020 Volume 8, Issue 2, pp 292 - 307)

After the fifth-generation (5G) network is competitively deployed around the world, the artificial intelligence (AI)-enabled next-generation (6G) network will be proposed for future evolution of network intelligentization . Recently, the new generation vehicle-related works, such as autonomous driving, cooperative vehicular networks, Internet of Vehicles (IoV) , vehicular *ad hoc* networks (VANETs), air-to-ground (A2G) networks, and space–air–ground integrated networks (SAGINs), have attracted considerable attention from researchers in both academia and industry. The AI-enabled future vehicular network that benefited from those vehicle-related works paves the way for future intelligent transport system (ITS) and intelligent vehicle-to-everything (V2X) communications in 6G.

The 6G vehicular network aims to develop a highly dynamic and intelligent system, which enables the networks to change the environment to satisfy various application requirements and service types, such as enhanced mobile broadband (eMBB), ultrareliable and low-latency communications (uRLLCs), and massive machine-type communications (mMTC) adaptively. There are various evolutions that should be addressed. Different from conventional vehicular networks that mainly focus on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, the 6G vehicular network has been constructed with better heterogeneous structure with space–air–ground even underwater vehicles. Furthermore, the 6G AI-enabled vehicular networks can have a positive impact not only on transportation but also on the interaction between humans and the world, such as smart grid, smart living, and human socialization. The dynamic adaptivity-enabling self-optimization, the secure communication, as well as the rapid response capability improving transmission quality of service (QoS) and reducing end-to-end delay are essential to such large-scaled 6G vehicular networks. To achieve the goal, some advanced techniques, such as network function virtualization (NFV), cognitive radio (CR), and reactive vehicular network control, are proposed in 5G. However, the new key performance indicators (KPIs) of the 6G network require further evolution to network intelligentization, intelligent radio (IR), and self-learning with proactive exploration.

Machine learning (ML) is the promising AI technology, which brings intelligence to various widely used systems and has been proven to be efficient in various areas, such as pattern recognition natural language processing, and autonomous driving and game AI [8]. The current ML technologies develop efficient approaches to data recognition and fast correlation recovering and can be potential tools to satisfy the high requirements of dynamic adaptation, secure communication, and rapid response toward the 6G intelligent vehicular network. (381 words)

DOI: https://doi.org/10.1109/JPROC.2019.2954595

4. Radar Interference Mitigation for Automated Driving: Exploring Proactive Strategies, by Canan Aydogdu et al

Published: IEEE Signal Processing Magazine (July 2020, Volume 37 Issue 4,pp 72-84)

Abstract: Autonomous driving relies on a variety of sensors, especially radars, which have unique robustness under heavy rain/fog/snow and poor light conditions. With the rapid increase of the amount of radars used on modern vehicles, where most radars operate in the same frequency band, the risk of radar interference becomes a compelling issue. This article analyzes automotive radar interference and proposes several new approaches that combine industrial and academic expertise toward the goal of achieving interference-free autonomous driving (AD).

Excerpts: Radar is becoming standard equipment in all modern cars, supporting, e.g., cruise control and collision avoidance in most weather conditions while providing high-resolution detections on the order of centimeters in the millimeter-wave (mm-wave) band. The next generation of advanced driver assistance (ADAS) and AD vehicles will have a multitude of radars covering numerous safety and comfort applications such as crash avoidance, self-parking, in-cabin monitoring, cooperative driving, collective situational awareness, and so on. Because automotive radar transmissions are uncoordinated, there is a nonnegligible probability of interference among vehicles.

However, the mutual interference problem is expected to become more challenging if not properly handled, as more vehicles are equipped with a greater number of radars providing 360° situational awareness at various distances that enable more advanced future ADAS and AD functionalities. This is evidenced by multiple international studies, such as the MOSARIM project [1] and the more recent IMIKO radar project. All of the major players in the automotive sensor market, such as Volvo and Veoneer, are studying the next generation of "interference-free radars." This includes, for example, enhancing models to determine the impact of a larger density of radars, simulating new interference scenarios, and investigating different medium access control (MAC) models and methods to coordinate radar transceivers, both decentralized and centralized.

At this point, the automotive industry is ready to consider novel designs and approaches, which may impact standardization bodies before a new frequency spectrum is made available in the higher radio-frequency (RF) bands. Signal processing can provide ways to reduce or mitigate interference, both at the raw signal level as well as at the postdetection/ target-tracking level. The particular properties and requirements of automotive radar impose significant challenges in terms of signal processing. This includes the combination of radar and communication waveforms, which brings up further possibilities regarding ultrareliable low-latency communications in vehicular ad hoc networks (VANETs). It is therefore important and timely to review what has been done and what the future holds.

The focus of this article is on frequency-modulated continuous wave (FMCW) radar because it is the most common and robust automotive radar. We provide an analysis of the impact of interference in FMCW both quantitatively and qualitatively, in terms of their probability, severity, and effects. Then, we cover different ways to mitigate interference, ranging from changing FMCW parameters to new signal structures and the explicit coordination between vehicles. We also study new techniques that are potentially more robust toward interference, including stepped-frequency orthogonal frequency-division multiplexing (OFDM). Finally, we describe what we believe will be the long-term evolution of automotive radar and its relation to mobile communication.

We consider the primary research and development challenges for the coming years. For communication-based interference mitigation strategies, the coexistence between radar and communication signals is an important challenge. For joint radar and communication signals, there is the potential of a revolution of cellular-type signals (e.g., 5G New Radio) to be reused for radar purposes, opening new synergies and avoiding the need for dedicated RF hardware all together. The extended frequency bands made available for 5G are interesting by themselves due to the possible improvement in radar resolution, which, together with the already standardized orthogonal signaling, establishes an exciting area for automotive sensing. The main challenge is to find solutions with low information latency. These solutions should include techniques for a fair distribution of the available time and frequency space for all users. It must also secure a low data loss for both radar and communication, which, of course, is the aim of minimizing the possibility of interference.

For the generation and detection of slow chirps, new hardware architectures will be necessary; this will push a migration from analog toward digital electronics and signal processing, which will pave the way for technologies such as imaging radar. The other modulation waveforms proposed in this article will also require hardware that differs from the current radar designs. Analog-to-digital (and vice versa) conversion will be close to the RF front end, making more complex digitally generated and filtered waveforms possible.

Further development would include the integration of critical electronic components in CMOS technology. Advanced CMOS technologies can also facilitate the implementation of alternative waveforms on automotive radars, such as phase-modulated continuous wave (PMCW). Compared to the widely used FMCW radar, the PMCW waveform has the major disadvantage of requiring very high-rate ADCs to sample wideband code sequences. Conversely, it possesses several advantages that make it attractive for future deployments, including improved robustness to interference via proper code design, not requiring a highly linear frequency ramp synthesizer, and the inherent applicability to multiple-input, multiple-output (MIMO) radar configurations through code orthogonality across multiple antennas. From the perspective of radar interference mitigation and radar communications convergence, we expect that the main focus of the automotive industry in the coming years will be on the cost and integration of both analog and digital functions on the same silicon chip to reduce the likelihood of hardware failure.

Vehicle radars can also be expected to operate in higher frequency bands such as 100–300 GHz to enable more bandwidth, reduce costs, and miniaturize hardware. It is possible to influence regulators to include some level of standardization in automotive radars, which is needed for mitigating interference among different automobile brands, before new spectrum is made available in the higher RF bands. It is therefore timely to conduct research and discuss the developmental challenges of automotive radar interference before it becomes a problem. (983 words)

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5. High-Density Platooning in Cellular Vehicle-To-Everything Systems: On the Importance of Communication-Aware Networked Control Design, by Sudeep Hegde et al

Published: IEEE Vehicular Technology Magazine (September 2021, Volume 16 Issue 3 ,pp 66-74)

Abstract: Fifth-generation (5G) cellular networks enable many vehicular communication applications by providing wireless interfaces for the exchange of messages among vehicles [vehicle to vehicle (V2V)] and among vehicles and pedestrians, infrastructure components, and application servers [vehicle to everything (V2X)]. Platoon networked control systems to maintain intervehicle distance (IVD) represent one of the most demanding use cases in V2X. Closed-loop feedback controllers introduced decades ago have been demonstrated to work with string stability and IVDs of only a few meters at highway speeds. However, the effects of temporally and spatially correlated packet losses, as experienced at the cell edge and during handovers, have not been sufficiently analyzed.

Conclusions: The findings reveal that, for the more accurate spatial correlation of burst losses during cellular handover, string-stable and safe platooning cannot be provided at the cell edge. With the use of static control coefficients, large distance errors are caused and take tens of seconds to be corrected. The findings thus provide motivation for solutions considering the joint design of platoon communication and the control mechanisms governing platoon member maneuvers. Since a simplified cell layout and physical layer modeling are considered in this study for the ease of analysis, we will implement realistic system-level models in our future work. We will also extend the framework to the simultaneous loss of leader and front PM messages in longer platoons. (224 words)

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