Top Level Newsletter: Connected Vehicle

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Vol 28: This issue identifies some of the challenges related to the development of intelligent control related to automated/ autonomous vehicle technology development and network softwarization. These are:

(1) Gaps in the Control of Automated Vehicles on Roads

(2) Intelligent Traffic-Lights Management by Exploiting Smart Antenna Technology

(3) Softwarization, Virtualization, and Machine Learning for Intelligent and Effective 5G Vehicle-to-Everything (V2X) Communications

(4) Challenges and Solutions for Antennas in Vehicle-to-Everything (V2X) Services

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.

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. Gaps in the Control of Automated Vehicles on Roads, Simeon Calvert et al

Published: IEEE Intelligent Transportation Systems (Vol 13, Issue 4, Winter 2021, pp146 - 153)

On-road testing and increased automated functionality in production road vehicles has increased steeply in recent years. It is estimated that many hundreds of million miles have now been driven in vehicles that have SAE level 2 capability or higher (both longitudinal and lateral automation, but with the driver monitoring). However, accidents involving automated vehicles (AV's) have also been occurring and have attracted increased media attention. It is not surprising that accidents occur. However, the causes behind the accidents do give insight into the performance of the current crop of AV's on roads and there may be cause for concern. While responsibility is quickly attributed by various parties, there may to be a deeper underlying problem in regard to AV-control. In this article, we aim to address the aspect of control over an automated vehicle and show that current driver-vehicle setups may contain critical gaps in their control chain.

Quotations of the number of accidents involving AV's vary extensively depending on the source, but can be found to lie in the region of one accident per 42017 miles, while it remains inconclusive if AV's are safer than conventional vehicles due to low and non-representative conditions. The vast majority of the accidents are at very low speeds (<10 mph) with minimal to no structural damage, never mind human injury or death. The first reported deaths involving an AV on public roads have also occurred. Three well publicized incidents have been the Tesla-trailer collision in May 2016 in Florida, the Uber Volvo collision with a pedestrian in March 2018 in Arizona and the Tesla collision with a parked police car in May 2018 in California. Characteristics of the first two incidents are given in a table in the article. The official investigation report for the third accident is pending. For this reason, use is made of official police statements gathered by media. In each of these incidents, a similar explanation emerged: the vehicle was not able to fulfil a designated task and the driver did or could not react to mitigate the impending incident. Without further analysis, we can already clearly state that a discord existed between the driver and the Automated Driving Control System (ADCS). The three accidents are analyzed later in the article and are used for a proxy of current AV systems in practice.

Conclusions: We demonstrate that a potential gap in vehicle-driver control exists in current partially automated vehicles that are applied in practice. This was shown by analyzing three recent and serious accidents involving partially automated AV's that serves as a proxy for many current on-road AV's, in which the driver remains in the loop. This gap in control has become evident through accidents involving automated vehicles and exists in part due to an inability of drivers to perform tasks and given responsibility. Using the concept of Meaningful Human Control (MHC), we demonstrate that although operational control might exist, control through MHC does not always exist in emergency circumstances as various circumstances fall outside of the operational design domain of many partially automated vehicles, while control cannot always be undertaken by a driver, even if the expectation of the vehicle manufacturer and the law demand it. A recommendation is made to consider automated vehicle control from the perspective of MHC to aid a closed control system that is reasonable and humanly acceptable and achievable. This responsibility to consider vehicle control in such a way may lie with the vehicle developers and manufactures, and with policymakers, including vehicle approval authorities. (583 words)

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2. Intelligent Traffic-Lights Management by Exploiting Smart Antenna Technology (ITSAT),

(Ambreen Joyo et al)

Published: IEEE Intelligent Transport Systems ((Vol 13, Issue 4, Winter 2021, pp155 - 163)

Abstract: The objective of this paper is to add functionality to the traffic lights, which can send a signal to a receiver in the vehicle, when the light changes from Red to Green. Existing traffic lights' timings and switching patterns do not operate with real-time traffic conditions. This results in wastage of time, fuel, and higher emission of CO_2. This paper proposes an intelligent traffic-lights management system by exploiting Smart Antenna Technology (already installed on cellular Base Stations). With the proposed approach, the traffic lights' duration adapts to the real-time traffic flow. Our proposed approach does not delve into improvements of Smart Antenna Technology but suggests to extract cell-phones' location information, which translates it into traffic density and use the information to control traffic lights' timings. The work is based on the assumption that the cell-phones density corresponds to the vehicles' density on the roadways. We also propose a Notifier integrated into the Traffic-light Duration Controller (TDC). It alerts the driver about the signal transition from red to green, and thus helps drivers use their cell phones serenely for the transitory duration the light stays the red. The analysis shows that the proposed approach

not only improves the Average Waiting Time (AWT) by 59.3% but also saves 3.42 gallons of fuel, and reduces CO_2 emission by 67 pounds per year for each commuter.

We previously proposed a technique that exploits Smart Antenna Technology for traffic light signaling optimization. The Smart Antenna System is capable of automatically changing the direction of its radiation patterns in a spatially sensitive manner in response to its signal environment. It consists of a set of radiating elements arranged in the form of an array (thus named adaptive array antennas), and Smart signal processing algorithms to identify the Direction of Arrival (DOA) of the signal. The system uses this, and some additional information, to calculate beamforming vectors to track and locate the antenna beam on the cell-phone units. Since continuous steering of the beam is required as the cell-phone moves, a high interaction between the cell-phone unit and Base Station is required.

However, as a first approach, it had an unrealistic assumption that the pedestrians on the walkways carrying cell-phones do not add any potential error, and the preliminary study was restricted to qualitative analysis. Later, we proposed a technique for realizing adaptive traffic light timings and modified the algorithm to perform more in-depth analysis.

Challenges: Some of the challenges of Smart Antenna Technology are that Smart Antennas are complex, more expensive, and are of larger size. However, mobile operators are inclined to deploy the Smart Antenna Technology, as it offers several positive factors, such as increased number of users, increased range, security, reduced interference, and increased bandwidth. Considering these positive factors, the demand for Smart Antenna is set to rise during the forecast period from 2015 – 2023.
Another potential challenge is an aggregation of the traffic statistics from diverse mobile service providers, as different mobile operators have their own Base Stations. The authors, from extensive experience in the mobile industry, believe that due to the economy of scale motive of telecommunication industry, sharing of telecom infrastructure among telecom service providers is becoming the requirement and process of business in the telecom industry where competitors are becoming partners to lower their increasing investments. (550 words)

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3. Softwarization, Virtualization, and Machine Learning for Intelligent and Effective Vehicle-to-Everything (V2X) Communications, (Abdellah Moubayed et al)

Published: IEEE Intelligent Transport Systems ((Vol 14, Issue 2, March/April 2022, pp156 - 173)

Abstract: The concept of the 5G mobile network system has emerged in recent years as telecommunication operators and service providers look to upgrade their infrastructure and delivery modes to meet the growing demand. Concepts such as softwarization, virtualization, and machine learning will be key components as innovative and flexible enablers of such networks. In particular,

paradigms such as software-defined networks, software-defined perimeters, cloud and edge computing, and network function virtualization will play a major role in addressing several of the challenges of 5G networks, especially in terms of flexibility, programmability, scalability, and security. In this article, the role and potential of these paradigms in the context of vehicle-to-everything (V2X) communication is discussed. This article provides an overview and background of V2X communications and then a detailed discussion of the various challenges facing V2X communications and some of the previous studies done to tackle them. Finally, the article describes how softwarization, virtualization, and machine learning can be adapted to tackle the challenges of such networks.

Introduction: The explosion, evolution, and penetration of technology in our daily lives has resulted in increased dependency on connected devices and the emergence of the Internet-of-Things (IoT) concept. This includes the way we communicate, how we learn, and how we travel from one place to another.

Telecommunication operators and service providers have been pushed to upgrade their infrastructure and delivery models to address this demand. This has led to the emergence of the 5G mobile network system, which aims to build on the success of the previous generation (4G) by introducing new network and service capabilities. However, 5G is also expected to consider various business demands that often have conflicting requirements, which is a divergence from the "one-size-fits-all" model offered by the 4G architecture. This will lead to increased innovation and flexibility in terms of the services and programmability of such networks. Hence, 5G networks aim to support various use cases that tackle new market segments and business opportunities.

To that end, different paradigms have been advanced. For example, softwarization paradigms, such as software-defined networking (SDN) have been suggested as a potential solution for flexible network management. Similarly, software-defined perimeters (SDPs) promise to be a core component to secure such networks. Moreover, virtualization paradigms, such as network function virtualization (NFV) and cloud/edge computing can help tackle various challenges facing 5G networks, including scalability and cost.

Machine learning (ML) also has a major role in detecting patterns that can help improve the performance and security of modern networks. In particular, ML can scale well with increasing network size and complexity as the generated data will provide the necessary foundation for the extraction of updated system characteristics and behavior. This is further emphasized by recent studies showing that the use of ML has grown substantially, with ML patents filed in the United States growing at a compound annual growth rate of 34% between 2013 and 2017.

One such use case is vehicle-to-everything (V2X) communication. V2X communication has garnered significant interest from various stakeholders as part of the development and deployment efforts of intelligent transportation systems (ITSs). This is due to the many projected benefits it offers, including a reduction in traffic-related accidents, introduction of new business models, and a decrease in operational expenditures of vehicular fleets. V2X communication is required to offer a variety of services ranging from autonomous vehicle operation to traffic flow optimization and in-car infotainment.

However, efficient and effective adoption of V2X communication introduces a new set of challenges that is dependent on the service offered and the communication mode adopted. This includes access technology, quality-of-service (QoS) performance, capacity and coverage, security and privacy, scalability and cost, and standardization. By combining multiple paradigms and technologies, the 5G concept can improve ITS systems by supporting higher network throughputs and lower delays in supporting basic ITS system services. Moreover, 5G networks promise to provide the needed architectures to efficiently manage the different technologies and business models through paradigms such as softwarization, virtualization, and ML.

To that end, this study aims to contextualize the challenges facing V2X communication networks and to elaborate on the potential methodologies that can address them. Accordingly, this article

- discusses in detail the various challenges facing V2X communications and some of the previous studies conducted to address them
- describes the role of softwarization, virtualization, and ML paradigms and techniques in tackling these challenges and proposes the architecture to implement them. (726 words)

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4. Challenges and Solutions for Antennas in Vehicle to Everything (V2X) Services (Kranti Kumar Katare et al)

Published: IEEE Communications Magazine (Vol 60, Issue 1, January 2022, pp 52 - 58)

Abstract: The autonomous vehicle is being developed for widespread deployment. Its reliability and safety are critically dependent on advanced wireless technologies, e.g., vehicle-to-everything (V2X) communication. The frontend of a V2X system needs an antenna module that enables the vehicle to reliably connect to all other networks. Designing V2X antenna is challenging due to the complex in-vehicle environment, trend for hidden antenna solution, long simulation time and need for omnidirectional coverage. In this article, we survey these challenges as well as existing V2X antenna solutions. In view of the drawbacks in the existing solutions, we propose an efficient design methodology for V2X antennas to provide the desired coverage. The method utilizes a simple geometrical model of the vehicle that

captures the shadowing effects of the vehicle body to obtain candidate antenna locations that offer the best coverage via multi-antenna diversity. Hence, complex full-wave simulation can be avoided. The approach is validated through comprehensive full-wave simulations and pattern measurements on two car models. The results confirm that, at 5.9GHz, line-of-sight shadowing has more dominant effect on the received power than multipath propagation due to the car body. In cases of strong diffraction and surface waves, a simple rule-of-thumb can be devised to improve the accuracy of the method.

Introduction: Autonomous vehicles excel in safety, traffic efficiency and infrastructure utilization. As a basic requirement, several sensors are currently used to control the vehicle's movement in both longitudinal and lateral directions. However, due to range limitations, these sensors only detect nearby objects. Moreover, these sensors' data are not exchanged with other infrastructures (fixed networks, vehicles) to assure safety, reliability, and coordination.

The authors propose an efficient design methodology for V2X antennas to provide the desired coverage, The method utilizes a simple geometrical model of the vehicle that captures the shadowing effects of the vehicle body to obtain candidate antenna locations that offer the best coverage via multi-antenna diversity, Hence, complex full-wave simulation can be avoided, The approach is validated through comprehensive full-wave simulations and pattern measurements on two car models.

As an emerging vehicular wireless technology, vehicle-to-everything (V2X) communication is attracting tremendous interest. V2X offers ubiquitous applications, particularly as vehicle-to-vehicle (V2V), vehicle-to-pedestrian (V2P), vehicle-to-network (V2N), vehicle-to-roadside units (V2R), and vehicle-to-infrastructure (V2I) communication.

The front end of a V2X communication system requires an antenna module to communicate with all other networks. This article overviews various key parameters, challenges and possible solutions of V2X antennas. A simple geometrical model-based multi-antenna diversity scheme is then proposed as a computationally efficient approach to solve the challenging problem of vehicle-body shadowing degrading the antenna coverage. This is achieved by identifying candidate locations for multi-antenna using a geometrical model, without having to resort to time-consuming full-wave simulations over the entire search space of possible antenna locations. The proposed scheme was verified using antenna patterns from both full-wave simulations and measurements for real car models (Volvo S60 and XC90).

To our knowledge, this is the first complete study of antenna diversity scheme in V2X communication, which leverages a geometrical study of line-of-sight (LOS) propagation in a vehicular environment to achieve tremendous saving in computational efforts. In particular, due to the (electrically) large size of vehicles (typically 4m-6m) relative to the wavelength of 51 mm at the allocate V2X band at 5.9 GHz, many millions of mesh cells are needed in the simulations to solve for the antenna properties accurately, as we have confirmed in measurements. For just one antenna location, the simulation can take many days to complete, even with multiple GPUs or simulation clusters. Therefore, it is prohibitively expensive in time/effort to adopt a brute force approach to locate suitable antenna locations for various vehicle models with different design constraints. Moreover, the proposed scheme may be even more useful for V2X systems operating at millimeter-wave (mmWave) frequencies (e.g., 28 GHz), since shadowing is more severe due to narrow beamwidth and poor scattering contributing to the lack of multipath propagation. Moreover, simulation complexity will increase by over 100-fold compared to sub-6G Hz frequencies, making it impossible to run conventional full-wave simulations even with advanced computers. However, to ensure sufficient link budget as well as coverage at mmWave frequencies, phased arrays with beam-scanning capability may be needed. (695 words)

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