

Top Level Newsletter: Connected Vehicle
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Vol 19 comprises:

- (1) a general article on how far down the road is the connected/autonomous vehicle,
- (2) issues pertaining to system validation, specifically Digital Twin technology for 5G and beyond,
- (3) automatic vehicle detection with roadside LIDAR under adverse weather conditions, and
- (4) the application of millimetric wave technology to the connected vehicle arena.

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.

Volume 19 returns to the usual format. 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. An addition to the newsletter this time is the inclusion of contents of an earlier newsletter (vol5.1, February 2020) with updates listing and describing some fundamental concepts applicable to the science of the connected vehicle. This is aimed as a refresher for the experienced or as a starting platform for newcomers.

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. On occasion, the full article will be presented. 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. How Far Down the Road is the Autonomous Vehicle? By Greg Smolka

Excerpt of article from May 2021 edition of Photonics magazine by the VP of business development at Insight LiDAR. For complete article, go to:

https://www.photonics.com/Articles/How_Far_Down_the_Road_Is_the_Autonomous_Vehicle/p5/vo202/i1277/a66856

AV technology is truly in the “last mile” of development, but like for many design projects, that mile can take the majority of the development time. In the case of autonomous vehicles, the last mile involves the challenges of capturing sufficient quality data, enabling the AV system to make good decisions, and resolving the corner cases — the problems or situations that occur outside of normal operating parameters. Thus, while consumers remain enthusiastic about the prospects of greater safety on the road, mass deployment of autonomous vehicles remains elusive. Despite the progress that has been made in artificial intelligence (AI) and the underlying perception algorithms, fully autonomous personal vehicles are still predicted to be a good 10 years out. According to a recent *New York Times* article, both carmakers and technology companies have concluded that making autonomous vehicles is going to be harder, slower, and more costly than originally thought.

This doesn't mean that companies have given up on the dream. Several small-scale deployments and test cases are on the road today. For example:

- Waymo is offering rides without human safety drivers in Phoenix.
- Cruise is testing AVs without human safety drivers in San Francisco.

- An autonomous truck from Kodiak Robotics recently covered 800 miles without a single disengagement — that is, the safety driver did not once have to take control of the truck's AV system.
- Nuro announced a pilot with pharmacy/retailer CVS to autonomously deliver prescriptions in Houston.

2. Digital Twin for 5G and Beyond, Huan X. Nguyen et al (IEEE Communications Magazine, Vol 59 Issue 2, February 2021), pp 10-15

Editor's Note: This article is a repeat from Vol 17 of the Newsletter, emphasizing the need for validation. Validation remains a big challenge to all new systems, not least the connected vehicle, IoT and 5G developments. Here is an article that introduces the concept of a Digital Twin, DT

Introduction: Thanks to recent and notable improvements in technologies such as the Industrial Internet of Things (IIoT), wireless sensor networks, deep learning algorithms, cloud-based platforms, and high-performance computing, a new data-driven paradigm, digital twin (DT), has emerged and is currently receiving increasing attention. *The DT represents a high-fidelity digital mirror of the physical entity where the former evolves synchronously with the latter throughout their entire life cycle.* Operators rely on DT data and a virtual prototype to enhance preventive maintenance programs, pioneer next generation business models, rapidly improve product development, and maximize a product's sustainability and efficiency in the field. DT helps create comprehensive digital models of physical environments with full support for two-way communication between the digital model and the physical object to enable real-time engineering decisions.

One can build one-way data-driven/analytics-based DTs by connecting assets to an Internet of Things (IoT) platform on the cloud. However, these simulation-based DTs are often not as accurate as we want in real life. Thus, one should use physics-based DTs to get an emulated model of the asset as it goes through environmental impact, thereby producing a much more accurate prediction. The very initial concept of DT dates back to when NASA used basic twinning ideas during the 1960s for their space programs (e.g., Apollo 13). However, only around 40 years later did the concept start being developed through different names such as virtual space, digital mirror, digital copy, and then finally the term “digital twin.” Only as recently as 2017 has the DT become one of the top strategic technology trends, widely investigated in many industries, including manufacturing, energy, industrial assets, and structures, such as a dual fault diagnosis method based on DT for high diagnosis accuracy in predicting the trend of production throughput, and a DT-based real-time monitoring system in for mechanical structures to improve the safety of the work environment using IoT and augmented reality.

With the support of artificial intelligence, development of digital transformation through the notion of a digital twin has been taking off in many industries such as smart manufacturing, oil and gas, construction, bio-engineering, and automotive. However, digital twins remain relatively new for 5G/6G networks, despite the obvious potential in helping develop and deploy the complex 5G environment.

General Electric developed their Predix IoT platform denoted as a DT that has the capability of ingesting large volumes of sensory data, running analytic models, and performing business rules at the same time, allowing detection of abnormal phenomena and improving plant reliability. Siemens integrates its DT solutions into smart operations at key stages throughout the product life cycle, from product design and production to operation. Microsoft also enables DT support through its ubiquitous IoT platform that models the interaction between people, spaces, and devices. The adoption of DT technology by tech leaders opens up new opportunities of DT integration for more advanced engineering applications.

It is expected that 5G will enable \$12.3 trillion global economic output and support 22 million jobs by 2035. Manufacturing is expected to see the largest share of 5G-enabled economic activity (3.4trillion out of 12.3 trillion, i.e., 28 percent), while information, communications, and technology (ICT) is second with \$1.4 trillion. The potential advantages from 5G are significant, but realizing them remains a challenging task. Despite all the promises, customers and investors remain skeptical of the technology maturity. There are prohibitive complexities with hybrid network deployment challenges, with multi-vendor scenarios and with security risks. Minimizing the risk for life-critical manufacturing and robotic doctor applications is essential, especially with the evolving security risks. Some market challenges with open questions exist:

1. How do we speed up the deployment of new (but complex) 5G technologies?
2. How do we provide flexible testbed facilities with high availability?
3. Who is willing to invest in the expensive 5G deployment with uncertain returns?

Thus, there is demand for a virtual solution that could create a digital model to replicate as accurately as possible the 5G ecosystem and help tackle all the above obstacles to satisfy the 5G needs. Using DT for 5G networks has recently gained significant interest, including from the leading telcos (e.g., Ericsson and Huawei), being a new topic where sensor/network data, traffic data, data mining, data visualization, and data interpretation are integrated into one system to facilitate the live replica of a process or whole 5G network. The DT has the potential to assess the performance, predict the impact of the environment change, and optimize the 5G network processes and decision making accordingly. Consequently, this study presents a concept of cloud DT for 5G networks aiming to perform continuous assessment, monitoring, and proactive maintenance through the closed-loop data from physical entities to the virtual counterparts and vice versa. Within the 5G DT, the digital 5G model will run alongside the physical 5G

network to perform operational predictions and enforce optimized decisions into the living network and associated services.

5G Automotive Specifics: The latest developments in both the automotive and communications industries, especially related to the rollout of 5G networks, the Internet of Vehicles, and adoption of cellular vehicle-to-every-thing (C-V2X) connectivity, are fueling significant transformations on the roads in terms of autonomous driving where 5G connected vehicles will negotiate traffic, motorways, roundabouts, and so on, without human intervention behind the steering wheel. Thus, 3rd Generation Partnership Project (3GPP) Release 16 targets Industry 4.0 and C-V2X services.

The deployment of 5G aims to enable effective connected cars communication as well as fully automated driving that could increase road safety and improve traffic management. The provisioning of ultra-reliable low-latency communication (URLLC) through 5G will enable the support for these connected cars services as well as a new set of related applications (traffic prediction, intelligent navigation systems, cooperative collision avoidance systems, etc.). The highly dynamic nature of vehicular networks along with the heterogeneity of wireless infrastructures for connected cars and the variety of vehicular applications (e.g., safety, traffic management, infotainment, etc.) make the resource management and low-latency communication requirements a significant challenge. It is expected that thousands of millions of miles of expensive driving setup is required for testing and validating the connected autonomous vehicles. Consequently, one promising solution in the automotive sector is the use of DTs to create the virtual model of a 5G connected vehicle. The DT could analyze the overall performance of the 5G connected vehicle and enable the delivery of personalized services. AI is used to predict the vehicle's performance under various dynamic conditions, identify problems, and apply solutions, making the driving experience safer for the user. However, before taking the solution out on the public roads, it has to be tested thoroughly through emulations. The Spirent 5G DT aims to emulate the 5G network for testing the behavior and performance of the connected vehicles within a controlled realistic environment using a 3xD drive-in simulator.

The 5G emulator would enable the car manufacturer understand how the vehicle behaves under different road specific scenarios (e.g., parking, pedestrians, road traffic, weather conditions) as well as under various 5G connectivity specific scenarios (handover, network traffic load, radio propagation, etc.). As the automotive industry relies on 5G to power core functionalities, this level of testing could speed up the adoption and integration of autonomous vehicles in a safe, reliable, and secure manner. The advantages of 5G DT integration within the automotive industry include efficient use of road capacity in real time, reduction of carbon emissions, reduction of road accidents, as well as limiting the need for emergency services in case of accidents. However, some significant questions still remain open, such as: In a critical scenario, should the autonomous car value the life of its passenger over a pedestrian's? (1269 words)

3. Automatic Vehicle Detection with Roadside LiDAR Data Under Rainy and Snowy Conditions, Jianqing Wu et al.

(IEEE Intelligent Transportation Systems Magazine, Vol 13, Issue: Spring 2021), pp 197-209

Abstract: Previous studies showed that rainy and snowy weather can reduce the quality of LiDAR (Light Detection and Ranging) data. In rainy and snowy weather, laser beams of LiDAR were often blocked by raindrops or snowflakes, which was called weather occlusion. The vehicle detection with weather occlusion is a challenge. When the traditional density-based spatial clustering of applications with noise (DBSCAN) was used for vehicle clustering, the data processing showed that the false detection rate of the conventional DBSCAN under the snowy weather was high. This paper aims to present the characteristics of roadside LiDAR data in snowy and rainy days and improve the accuracy of vehicle detection during challenging weather conditions. A revised DBSCAN method named 3D-SDBSCAN is raised up to distinguish vehicle points and snowflakes in the LiDAR data. Adaptive parameters were applied in the revised DBSCAN method to detect vehicles with different distances from the roadside LiDAR sensor. The performance of the proposed method and the conventional DBSCAN algorithm were compared using the data collected under rainy and snowy conditions. The results showed that the 3D-SDBSCAN algorithm could overcome weather occlusion issue better than the conventional one.

Introduction: LiDAR is a surveying method that measures the distance to a target with laser light. LiDAR sensors have been widely used in intelligent transportation systems (ITS), including autonomous vehicles and connected vehicles. The new 360° LiDAR sensors can detect the 360-degree surrounding objects with high accuracy and high frequency. During each scan, a LiDAR sensor collects a cloud of points with x, y and z coordinates of surrounding objects. LiDAR sensors can work in days and nights without the influence of light condition. One important factor that may influence the performance of LiDAR is the weather. Weather conditions have been an important crash-contributing factor. It was estimated that about 22% of crashes were related to weather. Fog, snow, and rain may result in a sudden reduction in visibility and slippery roadway pavement surfaces, which may lead to an increased risk of crash occurrence. Drivers' reaction ability to the emergency is greatly impacted by the worse visibility and road surface conditions during severe weather, such as rain or snow when ITS (autonomous vehicles and connected vehicles) is most needed. The performance of the existing data processing algorithms for LiDAR sensors under different weather conditions is unknown. The water drops and snowflakes may refract or reflect the laser beam. Vehicles scanned by the LiDAR sensor may be partly occluded by the water drops and snowflakes. Therefore, the number of points of the vehicles may be reduced, and the shape of the vehicles may be bizarre compared to that under normal weather. Both rain and snow can cause the same issue of occlusion, which is called weather occlusion in this paper. (459 words)

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4. Millimeter-Wave Downlink Coverage Extension Strategies, Jeffrey Baenke et al (IEEE Communications Magazine, vol 58 Issue 9, September 2020, p 74- 78)

Abstract: Traditionally, the uplink and downlink in a cellular network are associated with the same base station and the same frequency band since it promotes simpler network design, maintenance, and operation because of reduced complexity. However, when deploying millimeter-wave (mmWave) spectrum, network coverage has limitations hinging on the nature of the mmWave propagation characteristics relative to the traditional sub 6 GHz frequency bands. In this article, we present a method for an extension of the mmWave downlink coverage by demonstrating the benefits of decoupling the reverse and forward link frequencies and by leveraging macro-type radio deployment heights to maximize the line-of-sight coverage. The accompanying link budget analysis and coverage simulations quantify the benefit of the coverage extension methodology to be as much as 6.8 dB while extending possible coverage range distance to greater than 2 km.

Introduction: In wireless networks, network coverage is largely dependent on the propagation characteristics of the transmission frequency. Low frequencies below 6 GHz can exhibit strong propagation characteristics, in-building penetration, and coverage distances spanning several kilometers. One of the drawbacks of 5G New Radio (NR) deployments using spectrum below 6 GHz is that these frequency bands mostly have limited bandwidth availability, resulting in lower throughput performance. In comparison, higher frequencies bands such as millimeter-wave (mmWave) typically provide smaller coverage areas on the order of several hundred meters and can be prone to outages due to foliage and other obstructions. mmWave frequencies can, however, provide very attractive throughput performance due to the availability of large bandwidths. We analyze and propose a concept to substantially improve downlink (DL) mmWave coverage via the application of uplink (UL) decoupling techniques such as dual connectivity and carrier aggregation, using Frequency Range 1 (FR1) and Frequency Range 2 (FR2) frequencies, with a reallocation of the UL transmissions to FR1 frequencies. When decoupling is implemented, FR2 DL coverage is maximized as it is no longer limited by the FR2 UL coverage capability. When applied for rural network deployments of mmWave transmission radios at heights of 30 m or more, a significant coverage extension can be realized as the radio height in this type of deployment will greatly exceed the height of the surrounding environmental and building obstructions, therefore increasing the likelihood of line-of-sight (LoS) coverage. (373 words)

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5. Toward Standardization of Millimeter-Wave V2V Networks, Tommaso Zugno et al (IEEE Communications Magazine, vol 58 Issue 9, September 2020, p 79- 85)

Abstract: IEEE 802.11bd and 3GPP NR V2X represent the new specifications for next generation vehicular networks, exploiting new communication technologies and new spectrum, such as the millimeter-wave (mmWave) band, to improve throughput and reduce latency. In this article, we specifically focus on the challenges that mmWaves introduce for vehicle-to-vehicle (V2V) networking, by reviewing the latest standard developments and the issues that 802.11bd and NR V2X will have to address for V2V operations at mmWaves. To the best of our knowledge, our work is the first that considers a full-stack, end-to-end approach for the design of mmWave V2V networks, discussing open issues that span from the physical to the higher layers, and reporting the results of an end-to-end performance evaluation that highlight the potential of mmWaves for V2V communications.

Introduction: Recent advances in the automotive industry have paved the way toward connected and autonomous vehicles (CAVs) to promote road safety and traffic efficiency. The potential of CAVs will be fully unleashed through vehicle-to-everything (V2X) wireless communications, providing connectivity to and from cellular base stations (vehicle-to-infrastructure, V2I) and among vehicles (vehicle-to-vehicle, V2V). Today, the two key access technologies that enable V2X communications are IEEE 802.11p and 3rd Generation Partnership Project (3GPP) Cellular-V2X (C-V2X), which, however, fall short of fulfilling the foreseen extreme traffic demands (e.g., in terms of very high throughput, ultra low latency, and ultra high reliability) of future vehicular services.

The authors focus on the challenges that mmWaves introduce for vehicle-to-vehicle (V2V) networking, by reviewing the latest standard developments and the issues that 802.11bd and NR V2X will have to address for V2V operations at mmWaves.

In this regard, different standardization activities are currently being promoted by the IEEE and the 3GPP, with the 802.11bd and NR V2X specifications, respectively, to overcome the limitations of current technology. Both standards aim at boosting the wireless capacity by encompassing the possibility of using, besides traditional sub-6 GHz frequencies (that may support only basic safety services), the lower part of the millimeter-wave (mmWave) spectrum, which features the availability of large chunks of untapped bandwidth. This would enable data rates on the order of hundreds of megabits per second to support more advanced use cases (from semi-or fully automated driving to cooperative perception), and improve over 3GPP C-V2X and IEEE 802.11p, which can reach — at most — a few tens of megabits per second. Additionally, the unique characteristics of the mmWave signal, including the channel sparsity and the high temporal and angular resolution, may be used for very accurate positioning of vehicles, a critical requirement for most future vehicular services. However, communication at mmWaves introduces serious challenges for the whole protocol stack and requires the maintenance of directional transmissions, due to severe path and penetration losses: even though IEEE and 3GPP research activities are in their initial

stages, adequate discussion on whether (and how) standardization proposals will be able to overcome such limitations is still missing.

Therefore, in this article, we discuss how mmWave operations can be efficiently integrated in IEEE 802.11bd and 3GPP NR V2X systems. Specifically, we focus on the V2V component of these specifications, and, unlike existing literature reviewing vehicular standard developments e.g., we shed light on potential shortcomings that future releases need to overcome to fully enable V2V operations at mmWaves. We focus on physical (PHY), medium access control (MAC), and higher-layer design challenges, including the issues related to channel estimation, synchronization, mobility management, resource allocation, and congestion and flow control. (570 words)

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