Top Level Newsletter: Connected Vehicle

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Vol 14.0 (this issue): 5G mmWave communications, Mobile Edge Computing, mmWave small cell networks, Software Verification and Validation, Unmanned Aerial Vehicles, and Network Slicing.

Vol 13.0
- Data Science/ AI/ Deep Learning/ 5G
- Global Navigation Satellite System (GNSS)
- mmWave Vehicular Communications

Vol 12.1:
- 7 topics on Autonomous Vehicles Technology
- 1 topic on 5G Radio Access Network Slicing

Vol 11.0:
- Autonomous Vehicles Should Start Small, Go Slow
- 5G Radio Access Network Slicing
- Autonomous Driving – Sensing and Perception

Vol 10.0: GNSS Special Issue, Intelligent Transport Systems magazine, Fall 2020.
Vol 9.1: Data Science and AI for Communications
Vol 8.0: Cloud-Based AI (ABI Research publication)
Vol 7.0: COVID-19 and Connected Vehicle
Vol 6.0: Proceedings of the IEEE, Internet of Vehicles,
Vol 5.1: Co-operative Automated Driving
Vol 4.0: Current Sensor Technology

This newsletter is intended to provide the IEEE member with a top level briefing of the subject under review. Instead of a cumulative approach, as adopted previously, it will now only feature new content. For older content, please access previous volumes.

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 200 to 300 words is usually set for each topic, 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. However, it is not the intent to make this a forest of hyperlinks. The reader is encouraged to develop a first level understanding of the topic in view. The emphasis is on podcast-friendly, brief, clear and contained text. There will be no diagrams in order to keep the publication concise. 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. The publication will be updated periodically. 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. Propagation Channels of 5G Millimeter-Wave Vehicle-to-Vehicle Communications: Recent Advances and Future Challenges , Ruisi He et al

IEEE Vehicular Technology Magazine Volume: 15, Issue: 1 March 2020 (pp16-26)

In this article, we review the state of the art in mm-wave V2V channel measurements and modeling, describe recent directional V2V channel measurements performed in the 60-GHz band, and discuss future challenges to be addressed in mm-wave V2V channel measurements and modeling. Based on the allocation of the ITS spectrum in the European Union and United States, V2V channels are measured mainly in the 5.9-GHz band, with the 2.4-GHz (IEEE 802.11 b/g) and 5-GHz (IEEE 802.11a) bands also receiving attention. Beyond the allocated ITS bands, the scarcity of spectrum below 6 GHz has resulted in interest for enabling 5G vehicular communications at frequencies in the mm-wave band. Here, we summarize the potential mm-wave frequency bands for V2V communications based on both industry reports and academic papers.

Wireless communication and sensing technologies for vehicles are expected to support a wide variety of safety-related applications in vehicular networks. In future ITSs, intelligent vehicular sensing supported by wireless communications will go beyond current capabilities—such as road condition perception and emergency handling of traditional GPS, radar, and video monitoring systems—that are applicable only in line-of-sight (LOS) conditions. In non-LOS (NLOS) conditions, wireless communication can provide increased situational awareness as well as coverage and connectivity.

To achieve accurate intelligent sensing of the environment and increase vehicle automation, a large amount of sensing data needs to be exchanged among vehicles, and the number of vehicular sensors is rapidly increasing. With this greater number of vehicular sensors and the higher complexity of sensing systems, it is more difficult for vehicles to transmit and process the massive amounts of data (on the order of terabytes) from the sensors in real time. Such transmission and processing are generally not supported by current V2V communication systems, such as dedicated short-range communication (DSRC). To support signal transmission of so-called big data, mm-wave communication technology allows gigabit-per-second-transmission rates.

Compared with the 5.9-GHz band, mm-wave channels have higher propagation loss, and obstructions (caused by large vehicles and so on) lead to higher attenuation. Moreover, the multipath components (MPCs) of mm-wave channels are sparse, and the fading distribution of MPCs is also different compared with the 5.9-GHz band. Therefore, to design the mm-wave V2V communication system, propagation channels must be accurately modeled. Currently, deep investigations of mm-wave V2V propagation channels are not available in the literature. This article aims to fill the gap by providing a systematic account of key challenges in mm-wave V2V channel measurements and modeling. (406 words)

DOI: https://doi.org/10.1109/MVT.2019.2928898

2. Edge-Based Collision Avoidance for Vehicles and Vulnerable Users: An Architecture Based on Mobile Edge Computing, Marco Malinverno et al

IEEE Vehicular Technology Magazine Volume: 15, Issue: 1 March 2020 (pp27-35)
Collision avoidance, one of the most promising applications for vehicular networks, dramatically improves the safety of vehicles that support it. In this article, we investigate how it can be extended to benefit vulnerable users, such as pedestrians and bicyclists, equipped with a smartphone. Owing to the reduced capabilities of smartphones compared to vehicular onboard units (OBUs), traditional distributed approaches are not viable, and multi-access edge computing (MEC) support is needed. Thus, we propose an MEC based collision-avoidance system, discuss its architecture, and evaluate its performance. We find that, thanks to MEC, we are able to extend to vulnerable users the collision avoidance protection traditionally applied to vehicles, without impacting its effectiveness or latency.

The U.S. National Highway Traffic Safety Administration reported more than 37,000 traffic fatalities in 2017, and, today, the World Health Organization (WHO) estimates 3,400 daily traffic-related deaths, 50% of which could be avoided with appropriate action.Because of these statistics, safety has emerged as a prominent application of vehicular networks. Among safety applications, the most popular—and, arguably, the most effective—is collision avoidance. The idea of collision avoidance is fairly simple: vehicles are equipped with an OBU that periodically (and anonymously) broadcasts a basic safety message (BSM) containing the vehicle's position, direction, acceleration, and speed. [Equivalently, the cooperative-awareness messages standardized by the European Telecommunications Standards Institute (ETSI) could be considered.] The OBU uses the BSMs sent by other vehicles to assess whether they are set on a collision course; if this is the case, the vehicle can alert its driver and/or take immediate action, such as emergency braking.

Collision-avoidance systems are especially important in the presence of obstacles, such as buildings, that prevent drivers/vehicles from realizing the danger in a timely manner. Their importance and relevance have been acknowledged by transportation regulators: in December 2016, the U.S. Department of Transportation published a notice of proposed rulemaking for vehicular communications. The document proposes establishing a new Federal

Motor Vehicle Safety Standard, number 150, to make vehicular networking technology compulsory: 50% of newly manufactured vehicles would have to be equipped with such capabilities in 2021, 75% in 2022, and 100% in 2023. However, an important part of the picture is missing. According to the WHO, half of traffic fatalities concern vulnerable users, such as pedestrians and bicyclists. Obviously, users like these cannot carry an OBU, which puts them beyond the scope of traditional collision-avoidance systems. On the positive side, vulnerable users do often carry smartphones, equipped with all of the sensors—most notably, a global navigation satellite system and an accelerometer—needed for collision avoidance. Our suggestion, therefore, is to leverage smartphones to integrate vulnerable users into collision-avoidance systems, thereby extending to them the associated safety benefits. Smartphones differ from OBUs in two key aspects. The first is their lack of support for network technologies, such as IEEE 802.11p wireless access in vehicular environments, that are popular in vehicular networks. The second is represented by their computational power and energy limitations: constantly processing an endless flow of incoming BSMs would impose too great a strain on the CPU and battery of a smartphone. Both of these concerns can be addressed with the help of the MEC paradigm, where computation happens within the mobile network. (535 words)
DOI: https://doi.org/10.1109/MVT.2019.2953770

3. Next-Generation mm-Wave Small-Cell Networks: Multiple Access, Caching, and Resource Management, Jingjing Cui et al

IEEE Vehicular Technology Magazine Volume: 15, Issue: 1 March 2020 (pp46-53)

Millimeter-wave (mm-wave) small cells have been considered an effective technique for significantly improving the data rates of future networks. More particularly, this article investigates the potential benefits of mm-wave small-cell networks from the perspective of nonorthogonal multiple access (NOMA) and wireless caching. We highlight a range of innovative resource management solutions conceived for mm-wave small-cell networks by invoking adaptive learning. Finally, several promising future research directions for these networks are identified.

To meet the explosive increase in the volume of mobile traffic over the coming decade, new solutions have to be conceived for addressing future challenges. Given the availability of large bandwidths, mm-wave solutions may find their way into next-generation networks. To support the ever-growing mobile traffic demand and massive connectivity required, the combination of mm-wave techniques and network densification is considered a potential future candidate.

Owing to their advanced radio technologies, mm-wave small-cell networks are generally different from systems used at lower frequencies. One reason is that the short millimeter wavelength allows large numbers of antennas to be packed into compact form factors which supports the highly directional transmission required to compensate for the high path loss. Moreover, the unique propagation conditions at mm-wave frequencies impose fundamental challenges on mm-wave small-cell systems. As a result, new system concepts and architectures are required for efficiently exploiting these characteristics.

In contrast to the propagation encountered with traditional wireless communication in the sub-6-GHz band, propagation in the mm-wave band takes place between 30 and 300 GHz. As a consequence, mm-wave solutions are expected to have the following: 1) highly directional transmission to compensate for the path loss, which has the benefit of increasing the number of users served in small cells; 2) low wall-penetration and consequently high signal attenuation, hence reducing intercell interference; and 3) high bandwidth, resulting in a high data rate for users.

Motivated by the exploration of emerging technologies for improving spectral efficiency, the goal of this article is to provide a comprehensive overview of mm-wave small-cell networks in terms of their options for multiple access, resource management, and caching. For instance, Non-Orthogonal Multiple Access) NOMA-aided mm-wave small-cell networks are capable of providing multiplexing gains by encouraging multiple users to share the same resource block. Another application of cache-enabled mm-wave small-cell networks is to exploit the benefits of memory for reducing the network's tele-traffic. Moreover, advanced resource management techniques enhance network capacity and fairness using efficient algorithmic designs. By jointly designing resource allocation methods in terms of subchannel assignments, user scheduling, and power allocation with the aid of machine learning tools, near-optimal resource management can be achieved. The application of mm-wave small cells brings significant potential benefits, but substantial research challenges still exist. (444 words).
DOI: https://doi.org/10.1109/MVT.2019.2922110

4. Virtualized In Situ Software Update Verification: Verification of Over-the-Air Automotive Software Updates, David Coe et al

(IEEE Vehicular Technology Magazine, Vol 15 Issue 1, March 2020, pp84-90)

The integration of driver assistance and autonomous driving capabilities has increased the complexity of automotive software, making the verification of software updates more challenging. The utility of simulators in software verification is limited in terms of their level of fidelity to real-world hardware and driving conditions. The use of physical test vehicles on a test track is both costly and not representative of real-world conditions and vehicle configurations.

This article proposes architectures that leverage multicore virtualization technologies to safely perform in situ verification of a software update by executing the update in parallel with the software currently controlling the vehicle. This approach allows for a side-by-side, on-target comparison of code execution to detect anticipated and unanticipated discrepancies in behavior. When an unanticipated discrepancy is detected, a discrepancy report may be forwarded to the automaker for further analysis.

Over-the-Air Updates

The advent of mobile broadband, cloud computing, low-cost computation hardware, and precision geolocation has spurred a renaissance in automotive design. Advanced driver-assistance technologies, such as lane keeping, braking assistance, and autonomous parking, are already being integrated into today's vehicles. Future generations of automobiles are projected to include vehicle-to-vehicle and vehicle-to-infrastructure communications, as well as fully autonomous driving capabilities. Modern premium cars already include over 100 million lines of code, and the size of the code base will continue to increase as new capabilities are integrated. With the increasing volume and complexity of software, manufacturers must be concerned with the risk of unintended security and safety consequences as this software is deployed and maintained.

Onboard embedded software requires regular updates to correct defects and integrate new features]. Over-the-air (OTA) updates are critical from both a safety and a security perspective because, whenever a software-related safety defect or security vulnerability is discovered in a car's onboard software, it can be patched quickly. This ability to deliver OTA updates is also convenient for consumers because they no longer have to visit a dealership to receive the updated software.

The proposed verification architectures will enable automakers to safely turn every vehicle capable of receiving an OTA update into a hardware-in-the-loop (HIL) testbed that allows for a side-by-side comparison of the old and new software to determine the suitability of the update for that specific vehicle. Safety is assured by 1) keeping the older baseline software in control of each vehicle until the stability and correctness of the candidate software update can be established and 2) through the use of virtualization techniques that isolate the execution of the new, unproven software update, even those supplied by third-party vendors. The choice to release the software update for a particular vehicle is a business decision. Our approach augments verification techniques as recommended in ISO Standard 26262:2018 *Road Vehicles—Functional Safety* by providing virtual in situ verification of the updates, subjecting the software to a wider range of driving scenarios, environmental conditions, vehicle conditions, and vehicle configurations than can be recreated using a handful of test vehicles owned by the automaker. On-target analysis, filtering, and compression manages the flow of data back to the manufacturer for comprehensive analysis. (510 words)

DOI: https://doi.org/10.1109/MVT.2019.2954302

5. Accessing from the Sky: A Tutorial on UAV Communications for 5G and Beyond, Yongs Zeng et al

Proceedings of the IEEE (Volume: 107, Issue 12,, Dec. 2019, pp 2327-2375)

Abstract:
Unmanned aerial vehicles (UAVs) have found numerous applications and are expected to bring fertile business opportunities in the next decade. Among various enabling technologies for UAVs, wireless communication is essential and has drawn significantly growing attention in recent years. Compared to the conventional terrestrial communications, UAVs' communications face new challenges due to their high altitude above the ground and great flexibility of movement in the 3-D space. Several critical issues arise, including the line-of-sight (LoS) dominant UAV-ground channels and induced strong aerial-terrestrial network interference, the distinct communication quality-of-service (QoS) requirements for UAV control messages versus payload data, the stringent constraints imposed by the size, weight, and power (SWAP) limitations of UAVs, as well as the exploitation of the new design degree of freedom (DoF) brought by the highly controllable 3-D UAV mobility.

In this article, we give a tutorial overview of the recent advances in UAV communications to address the above issues, with an emphasis on how to integrate UAVs into the forthcoming fifth-generation (5G) and future cellular networks. In particular, we partition our discussion into two promising research and application frameworks of UAV communications, namely UAV-assisted wireless communications and cellular-connected UAVs, where UAVs are integrated into the network as new aerial communication platforms and users, respectively. Furthermore, we point out promising directions for future research.

The reader is invited to ponder on applicability and relevance to Connected Vehicle technology.

Outline:

Section I: Wireless Communication with UAVs: Basic Requirements/ Wireless Technologies for UAV Communication: Direct Link, Satellite, Ad Hoc Network, Cellular Network / New Paradigm: Integrating UAVs into Cellulat Network/

Section II: UAV Communication Basics: Channel Model, Antenna Model, UAV Energy Consumption Model, UAV Communication Performance Metric

Section III: UAV-Assisted Wireless Communications: Section Overview, Performance Analysis, UAV Placement, Trajectory and Communication Co-Design, UAV-Assisted Communication via Intelligent Learning

Section IV: Cellular-Connected UAV

Section V: Extensions

Section VI: Conclusion

(307 words)

DOI: https://doi.org/10.1109/JPROC.2019.2952892

6. End-to-End Network Slicing for Flash Crowds, Simona Marinova et al

(IEEE Communications Magazine April 2020 | Volume: 58, Issue: 4, pp31- 37)

Abstract:

End-to-end network slicing is a novel concept based on virtualization and softwarization technology that can efficiently address the problems of legacy networks. It can leverage agile physical and network layer adaptability, and foster optimal user and system performance. These features make end-to-end network slicing suitable for scenarios such as flash crowds and emergency situations. This article presents an end-to-end network slicing framework capable of addressing the demands of flash crowd and emergency scenarios. The article provides details about these scenarios, and it introduces an end-to-end agile, flexible, and scalable wireless system architecture consisting of softwarized components that can be orchestrated to fulfill the underlying system requirements. By addressing important key performance indicators with experimental measurements, the article demonstrates the applicability of our slicing framework for flash crowd scenarios.

Introduction (part of):

Conventional networks are characterized by static deployment and configuration, which make them unable to handle temporal and geographical variations in user capacity demand. This rigidity presents an insurmountable obstacle when attempting to satisfy service demands in flash crowd scenarios, especially in emergency situations involving terrorist attacks or natural disasters. The overarching goal in these scenarios is to reliably and promptly provide communications between first responders and victims.

The strict requirements imposed by the flash crowd scenarios can be met with the emerging architectural changes in mobile systems. Flash crowd scenarios impose service requirements that traditional networks cannot provide on the fly in a manner that operators are willing to support (i.e., with low cost and efficient real-time service demand fulfillment).

End-to-end (E2E) network slicing is an inherent characteristic of emerging 5G systems which allows creation of flexible, scalable, and demand-oriented systems that are able to meet the diverse requirements of heterogeneous traffic. A network slice is composed of suitably configured network functions together with underlying infrastructure (physical or virtual) resources to meet the quality of service (QoS) requirements of the needed services. The network slicing concept deviates from the traditional one-size-fits-all model by providing logically isolated and custom-tailored network slices capable of providing a set of specific, possibly mission-critical, services.

Network virtualization and softwarization are the key enablers of network slicing. They enable flexible, scalable, and agile networks that can address the demands of flash crowds and emergency situations. Network virtualization allows isolated coexistence of multiple virtual networks on the same physical infrastructure and supports the ability to dynamically create heterogeneous virtual networks. Network softwarization, through software defined networking (SDN) and network function virtualization (NFV), enables network programmability at the control plane. SDN decouples the data and control planes, and NFV enables network functions to replace purpose-built hardware with software running on virtualized computing.

The reader is invited to ponder on applicability and relevance to Connected Vehicle technology.

(435 words)

Outline: Introduction/ Specific Scenario and Requirements/ Softwarized Wireless Systems/ End-to-End Network Slicing Framework/ Performance Evaluation/ Conclusion

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