Top Level Newsletter: Connected Vehicle

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This month's newsletter departs from the usual style. It is a top level synopsis of the 74 recent entries from the twelve previous volumes (17 to 6) since March 2020. Entries are even more condensed compared to the compressed entries in the previous newsletters. It is hoped this would enable the reader to get a fast top level understanding and overview of the different topics and "join the dots", if and where possible, to advance the state of the art. To access the complete article, the reader is, as before, encouraged to access the related newsletter where the Digital Object Identifier (DOI) and detail including authorship are available in individual newsletters Vol 17.1 to Vol 6.0.

Vol 17.1

(from IEEE Intelligent Transportation Systems Magazine , Spring 2021)

1. Mapping for Autonomous Driving: Opportunities and Challenges : (The art and science of creating suitable maps for autonomous driving). This article provides a review of the production and uses of maps for autonomous driving and a synthesis of the opportunities and challenges. For many years, maps have helped human drivers make better decisions, and in the future, maps will continue to play a critical role in enabling safe and successful autonomous driving. There are, however, many technical, societal, economic, and political challenges to mapping that remain unresolved**.**

(from IEEE Communications Magazine, Febuary 2021)

2. The challenges of validation of complex systems such as 5G automotive systems: (Digital Twin for 5G and Beyond): Validation is a challenge to all new systems, not least the connected vehicle, IoT and 5G developments. This article introduces the concept of a Digital Twin, DT. Despite promises, customers and investors remain skeptical of the technology maturity. There are prohibitive complexities with hybrid network deployment challenges, multi-vendor scenarios and security risks. The advantages of 5G DT integration within the automotive industry include efficient use of road capacity in real time, reduced carbon emissions, and reduction of road accidents to name a few.

Vol 16.0

(from IEEE Vehicular Technology Magazine, March 2021)

- Artificial intelligence (AI) applied to mobile networks, aerial vehicular networks and satellite communications, and automotive electronics:

1. Effective Cache-Enabled Wireless Networks: An Artificial Intelligence and Recommendation-Oriented Framework. Discussion on the potential of using AI for caching at the network edge as a way to reduce network latency and facilitate the deployment of innovative latency-sensitive applications. The authors analyze how AI can be leveraged to improve the effectiveness of caching policies and also present a hierarchical, cache-enabled wireless network architecture that can exploit AI techniques and recommendations.

2. Green Deep Reinforcement Learning for Radio Resource Management: Architecture, Algorithm Compression, and Challenges. The authors leverage AI as a means of addressing radio resource management (RRM) challenges in 5G and beyond networks. They highlight the potential of deep reinforcement learning (DRL) for optimizing high-dimensional RRM problems in dynamic environments but also point out that DRL can consume a high amount of energy over time and so risk compromising the deployment of future green wireless networks.

3. Online Velocity Control and Data Capture of Drones for the Internet of Things: An Onboard Deep Re - inforcement Learning Approach. The authors address the use of unmanned aerial vehicles (UAVs) for data collection as a way to extend Internet of Things (IoT) networks into remote areas. In particular, the authors propose and evaluate the design of onboard, AI-based deep Q-networks to deliver UAVs' online velocity control and facilitate data capture decisions in UAV- enabled IoT networks. Online velocity control and communication decision making are challenging in UAV-enabled IoT networks, due to a UAV's lack of up-to-date knowledge about the state of the nodes, e.g., the battery energy, buffer length, and channel conditions.

4. Interference Geolocation in Satellite Communications Systems: An Overview. The authors tackle the problem of radio interference in satellite communications. Traditionally, interference geolocation has relied on approaches based on time- difference-of-arrival and frequency-difference-of-arrival measurements. However, new interference geolocation approaches have emerged to address the challenges associated with modern satellite communications.

5. Toward Smart Vehicle-to- Everything (V2X)-Connected Powertrains: Driving Real Component Test Benches in a Fully Interactive Virtual Smart City. The authors present an X- in-the-loop validation platform for testing powertrains, considering the complex interactions among traffic flow control, powertrain control, component design, and intervehicle communication. These domains have usually been addressed separately, but a more holistic approach is necessary in the context of increasing electrification, automation, and connectivity for future mobility.

6. Prospective Immersive Human–Machine Interface for Future Vehicles: Multiple Zones Turn the Full Windscreen into a Head-Up Display. The authors address the design and usage of head-up displays (HUDs) in vehicles. They present an immersive augmented reality HUD concept to support future vehicle design following a human-centric design approach. They propose overcoming the limited field of view of contemporary optical solutions by using multiple display elements tiled to utilize images over the entire windscreen for an immersive experience. The physical interface generates the images via multiple optical apertures/image sources, and images are displayed according to human visual system requirements. The proposed concept is tested in a laboratory environment with a replica of a real car interior and a prototype vehicle with multiple distributed HUD units installed**.**

<u>(from IEEE Communications Magazine , January 2021)</u>

1. Editorial: This first issue in 2021 covers the main technological domains related to mobility systems (mobile radio, automotive electronics, connected and automated vehicles, and transportation systems). It includes eight open call papers, six of which are cited in this newsletter. Topics range from artificial intelligence (AI) applied to mobile networks, aerial vehicular networks and satellite communications, and automotive electronics.

2. Guest Editorial: Communication Technologies for Robotics and Autonomous Systems: The increased deployment of robots to automate repetitive, high precision, and difficult tasks is a key enabler for the Industry 4.0 paradigm. Robots and autonomous systems (RAS) provide significant productivity gains by allowing flexible production lines that can be dynamically reconfigured to manufacture highly customized products. Such intelligence can be acquired by exploiting recent advancements in Machine Learning (ML). It enables the implementation of cognition as a learning process based on experience about a certain task with an associated performance measure. (Newsletter Editor: This entry takes a broader view of technologies for connected and automated systems such as connected vehicles)

3. Position Location for Futuristic Cellular Communications: 5G and Beyond: With vast mmWave spectrum and narrow beam antenna technology, precise position location is now possible in 5G and future mobile communication systems. In this article, we describe how centimeter-level localization accuracy can be achieved, particularly through the use of map-based techniques. We show how data fusion of parallel information streams, machine learning, and cooperative localization techniques further improve positioning accuracy.

(from IEEE Signal Processing Magazine , January 2021)

4. 3D Point Cloud Processing and Learning for Autonomous Driving: Impacting Map Creation, Localization, and Perception: Autonomous system: An autonomous system typically includes the sensing, map-creation, localization, perception, prediction, routing, planning, and control modules. A high-definition (HD) map is created offline. At runtime, the online system is given a destination. The system then senses its environment, localizes itself to the map, perceives the world around it, and makes corresponding predictions of future motion for these objects. The motion planner uses these predictions to plan a safe trajectory for an AV to follow the route to the destination executed by the controller.

Sensing: To ensure reliability, autonomous driving usually requires multiple types of sensors. Cameras, radar, lidar, and ultrasonic sensors are most commonly used. Among those sensors, lidar is particularly interesting because it directly provides a precise 3D representation of a scene. Although the techniques for 3D reconstruction and depth estimation based on 2D images have been significantly improved with the development of deep learning-based computer vision algorithms, the resulting estimations are still not always precise or reliable.

V15.0

(from Proceedings of the IEEE Magazine, Feb. 2021)

1. Concept: Lane-Free Artificial-Fluid Concept for Vehicular Traffic: A novel paradigm for vehicular traffic in the era of connected and automated vehicles (CAVs) is proposed, which includes two combined principles: lane-free traffic and vehicle nudging; the latter implying that vehicles may be "pushing" (from a distance, using communication or sensors) other vehicles in front of them. This traffic paradigm features several advantages, including smoother and safer driving; increase of roadway capacity; and no need for the anisotropy restriction. Anisotropy is the property of a material which allows it to change or assume different properties in different directions as opposed to isotropy. It can be defined as a difference, when measured along different axes, in a material's physical or mechanical properties. The proposed concept provides the possibility to actively design (rather than model or describe) the traffic flow characteristics in an optimal way.

(from IEEE Signal Processing Magazine, January 2021)

2. Simulating the Autonomous Future: How to Validate Simulation Using Public Data Sets: The rapid evolution of autonomous vehicles (AVs) has exposed the need for fast-paced development and testing processes of a variety of perception, planning, and control algorithms. To expedite development, the AV industry and researchers leverage virtual vehicle environments to simulate a range of test scenarios that may otherwise be costly or difficult to conduct on a real test track. However, the various virtual environments may have different results depending on the fidelity of various simulation features, such as vehicle dynamics, sensor simulation, and environment recreation. This tutorial article examines a proposed framework for constructing, parameterizing, and validating a virtual vehicle environment using an existing AV data set.

3. Object Detection Under Rainy Conditions for Autonomous Vehicles: Emerging autonomous vehicles are employing cameras and deep learning- based methods for object detection and classification. These methods predict bounding boxes that surround detected objects and classify probabilities associated with each bounding box. In particular, convolutional neural network (CNN)-based approaches have shown very promising results in the detection of pedestrians, vehicles, and other objects. These neural networks are usually trained using a large amount of visual data captured in favorable clear conditions. However, the performance of such systems in challenging weather, such as rainy conditions, has not been thoroughly surveyed or studied. There is a need for novel deep learning architectures and solutions that have capacity for handling object detection under diverse conditions.

Vol 14.0:

(from IEEE Vehicular Technology Magazine, March 2020)

1. Propagation Channels of 5G Millimeter-Wave Vehicle-to-Vehicle Communications: Recent Advances and Future Challenges: 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 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 in the mm-wave band.

2. Mobile Edge Computing: Edge-Based Collision Avoidance for Vehicles and Vulnerable Users:
According to the WHO, half of traffic fatalities concern vulnerable users, such as pedestrians and bicyclists. These users 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.

3. Next-Generation mm-Wave Small-Cell Networks: Multiple Access, Caching, and Resource Management: 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. Several promising future research directions for these networks are identified.

4. Software Verification and Validation: 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.

(from Proceedings of the IEEE magazine, Dec. 2019)

5. Unmanned Aerial Vehicles: Accessing from the Sky: A Tutorial on UAV Communications for 5G and Beyond: Unmanned aerial vehicles (UAVs) have found numerous applications and are expected to bring fertile business opportunities in the next decade. This is a tutorial overview of the recent advances in UAV communications with an emphasis on how to integrate UAVs into the forthcoming 5G and future cellular networks. 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. We point out promising directions for future research. The reader is invited to ponder on applicability and relevance to Connected Vehicle technology.

(from IEEE Communications Magazine April 2020)

6. Network Slicing: End-to-End Network Slicing for Flash Crowds: 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.

Vol 13.0:

(from IEEE Communications Magazine, October 2020)

- Data Science/ AI/ Deep Learning/ 5G:

1. Editorial: The trend toward learning-based, data-driven approaches has been mainly motivated by two things: the amount of available data retrieved from devices and network equipment, and the need to tune large numbers of network operational parameters in order to meet the frequently changing needs of the services. Indeed, 5G and the rise of new services – the Internet of Things (IoT), connected vehicles, augmented and virtual reality (AR/VR), and so on – are expected to make traffic much more dynamic, thus requiring frequent network reconfiguration.

2. Deep Learning at the Physical Layer: System Challenges and Applications to 5G and Beyond: The unprecedented requirements of IoT have made fine-grained optimization of spectrum resources an urgent necessity. Thus, designing techniques able to extract knowledge from the spectrum in real time and selecting the optimal spectrum access strategy accordingly has become more important than ever. Moreover, 5G networks will require complex management schemes to deal with problems such as adaptive beam management and rate selection.

(from IEEE Intelligent Transportation Systems Magazine, Fall 2020)

3. An Experimental Evaluation of GNSS System-Verification Strategies for Vehicular Applications: An effective way to detect the presence of a spoofing attack is to verify Global Navigation Satellite System (GNSS) data with measurements from other sensors, such as inertial navigation systems (INSs). In this article, uncoupled GNSS/INS-verification approaches are experimentally evaluated in an automotive context. The analysis shows the need for integrated approaches that implement zero-velocity detection, outlier removal, and adoption of an adaptive behavior dependent on vehicle dynamics.

4. Object-Detection-Aided GNSS and Its Integration with Lidar in Highly Urbanized Areas: Positioning is a key function for autonomous vehicles that requires globally referenced localization information. Lidar-based mapping, which refers to simultaneous localization and mapping (SLAM), provides continuous positioning in diverse scenarios. However, SLAM error can accumulate with time. Besides, only relative positioning is provided by SLAM. The GNSS receiver is one of the significant sensors for providing globally referenced localization, and it is usually integrated with lidar in autonomous driving. However, the performance of the GNSS is severely challenged due to the reflection and blockage caused by buildings in super-urbanized cities. This article innovatively employs lidar to identify non line of sight (NLOS) measurement of the GNSS receiver using point-cloud-based object detection.

(from IEEE Communications Magazine, October 2018)

5. Key Technologies, Modeling Approaches, and Challenges for Millimeter-Wave Vehicular Communications: Millimeter-wave communications have been recently proposed as a promising candidate to fulfill the connectivity requisites imposed over autonomous driving. The need for transmission capabilities of multiple gigabits per second for autonomous vehicles is the main driving factor for millimeter-wave technology. However, there are other requirements, such as latency, reliability, security, and support for unicast and broadcast communications, which must be addressed. We envision that a combination of analog/ hybrid beamforming with a location-based beam search protocol, using full duplex radio and physical layer key generation, has the potential of fulfilling the requirements of autonomous driving technology.

(from IEEE Intelligent Transportation Systems Magazine, Fall 2020)

6, **Deep-Urban Unaided Precise Global Navigation Satellite System Vehicle Positioning**: Future vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connectivity will permit vehicles to relay their positions and velocities to each other with millisecond latency, enabling tight, coordinated platooning and efficient intersection management. More ambitiously, broadband V2V and V2I enabled by 5G wireless networks will permit vehicles to share unprocessed or lightly processed sensor data. Ad hoc networks of vehicles and infrastructure will then function as a single sensing organism. The risk of collisions, especially with pedestrians and cyclists—notoriously unpredictable and much harder to sense reliably than vehicles—will be significantly reduced as vehicles and infrastructure contribute sensor data from multiple vantage points to build a blind spot-free model of their surroundings.

Vol 12.0:

(from IEEE Transactions on Intelligent Transportation Systems Magazine, May 2020)

1. An Efficient and Scalable Simulation Model for Autonomous Vehicles: Autonomous vehicles rely on sophisticated hardware and software technologies for acquiring holistic awareness of their immediate surroundings. Deep learning methods have effectively equipped modern self-driving cars with high levels of such awareness. It becomes inherently challenging to achieve high performance while at the same time maintaining adequate computational complexity. In this paper, a monocular vision and scalar sensor-based model car is designed and implemented to accomplish autonomous driving on a specified track by employing a lightweight deep learning model.

(from Proceedings of the IEEE magazine, Feb 2020)

2. The Security of Autonomous Driving: Threats, Defenses, and Future Directions: Autonomous vehicles (AVs) have promised to drastically improve the convenience of driving by releasing the burden of drivers and reducing traffic accidents with precise control. With the fast development of artificial intelligence and significant advancements of the Internet of Things technologies, we have witnessed the steady progress of autonomous driving over the recent years. As promising as it is, the march of autonomous driving technologies also faces new challenges, among which security is the top concern. In this article, we give a systematic study on the security threats surrounding autonomous driving, from the angles of perception, navigation, and control. We discuss future research directions of new security threats, especially those related to deep-learning-based self-driving vehicles.

(from IEEE Transactions on Intelligent Transportation Systems, March 2020)

3. Autonomous Vehicles That Interact with Pedestrians: A Survey of Theory and Practice: One of the major challenges that autonomous cars are facing today is driving in urban environments. To make it a reality, autonomous vehicles require the ability to communicate with other road users and understand their intentions. Such interactions are essential between vehicles and pedestrians. Understanding pedestrian behavior, however, is not intuitive and depends on various factors, such as demographics of the pedestrians, traffic dynamics, environmental conditions, and so on. In this paper, we identify these factors.

(from IEEE Signal Processing Magazine, July 2020)

4. Toward Robust Sensing for Autonomous Vehicles (An adversarial perspective) : Autonomous vehiclesrely on accurate and robust sensor observations for safety-critical decision making in a variety of conditions. The fundamental building blocks of such systems are sensors and classifiers that process ultrasound, radar, GPS, lidar, and camera signals. It is of primary importance that the resulting decisions are robust to perturbations, which can take the form of different types of nuisances and data transformations and can even be adversarial. These could be purposefully crafted alterations of the environment or of the sensory measurements, with the objective of attacking and defeating the autonomous systems. We survey the emerging field of sensing in adversarial settings: and discuss countermeasures and present future research directions.

5. Automated Vehicular Safety Systems (Robust function and sensor design): Automated vehicular safety functions that intervene in dangerous driving situations, e.g.,emergency braking, use sensor measurements for the interpretation of the driving situation. Consequently, they are vulnerable to sensor imperfections, and unavoidable measurement errors have a negative impact on both the safety and the satisfaction of the customer, which has to be taken into account when designing automated vehicular safety systems, such as an automatic emergency braking (AEB) system. Article reviews a well-established worst-case design approach for integrated circuits and explains how ideas from integrated circuit design can be transferred to the design of automated vehicular safety systems.

6. Event-Based Neuromorphic Vision for Autonomous Driving (A paradigm shift): As a bio-inspired and emerging sensor, an event-based *neuromorphic vision sensor* has a different working principle compared to the standard frame-based camera. This leads to promising properties of low energy consumption, low latency, high dynamic range, and high temporal resolution. It poses a paradigm shift to sense and perceive the environment by capturing local pixel-level light intensity changes and producing asynchronous event streams. Advanced technologies for the visual sensing system of autonomous vehicles from standard computer vision to event-based neuromorphic vision have been developed. In this tutorial-like article, a comprehensive review of the emerging technology is given.

7. Lidar for Autonomous Driving (principles, challenges): Autonomous vehicles rely on their perception systems to acquire information about their immediate surroundings. It is necessary to detect the presence of other vehicles, pedestrians, and other relevant entities. Safety concerns and the need for accurate estimations have led to the introduction of lidar systems to complement camera- or radar-based perception systems. This article presents a review of state-of-the-art automotive lidar technologies and the perception algorithms used with those technologies. The specific perception pipeline for lidar data processing is detailed from an autonomous vehicle perspective.

(from IEEE Communications Magazine, April 2020)

8. 5G Radio Access Network Slicing: The article deals with Radio Access Network (RAN) slicing in 5G networks. The authors argue that existing cloud-related slicing technologies cannot be applied to RAN slicing because of mobility, variable interference, and the dynamic nature of wireless link capacity that do not allow over-provisioning. They propose a unified framework for operator-to-waveform 5G RAN slicing, which allows mobile network operators to control the selection of base stations and the maximum number of users, down to the scheduling of resource blocks at the waveform level. The framework enables coordination-based 5G communications and reduces inter-slice interference, which eventually results in improved isolation between slices. Simulation results show that the proposed framework generates RAN slices where 95 percent of allocated resources can be used to perform coordination- based 5G transmission technologies and facilitates the coexistence of multiple RAN slices.

Vol 11.0:

(from IEEE Spectrum Magazine, March 2020)

1. **Autonomous Vehicles Should Start Small, Go Slow: Case Study of a Start-up With an Alternative Approach:** Many young urbanites today don't want to own a car, and unlike earlier generations, they don't have to rely on mass transit. Instead they treat mobility as a service: When they need to travel significant distances, say, more than 5 miles (8 kilometers), they use their phones to summon an Uber (or a similar ride-sharing company). If they have less than a mile or so to go, they either walk or use various "micromobility" services, such as the increasingly ubiquitous Lime and Bird scooters or, in some cities, bike sharing.

The problem is that today's mobility-as-a-service ecosystem often doesn't do a good job covering intermediate distances, say a few miles. ***PerceptIn*** has shown that it's possible to build small, low-speed autonomous vehicles for much less than it costs to make a highway-capable autonomous car. The main tactic used to reduce costs is to do away with lidar entirely and instead use more affordable sensors: cameras, inertial measurement units, satellite positioning receivers, wheel encoders, radars, and sonars.

(from IEEE Vehicular Technology Magazine, Dec 2019)

2. 5G Radio Access Network Slicing: System-Level Evaluation and Management: Currently, tremendous resources are allocated for conceptualizing and realizing 5G wireless/mobile communications. This push toward 5G is motivated by a combination of business requirements and technology trends that can efficiently boost the performance of various parts of the infrastructure. Services are associated with numerous vertical sectors (e.g., energy, health, media provision, and water/environment management). Due to their heterogeneous QoS requirements, services are categorized with respect to aspects such as whether they involve enhanced Mobile Broadband (eMBB) traffic or require ultrareliable low latency communications (URLLC). To effectively handle such different types with diverse requirements, operators are working on network slicing concepts for dedicating resources to these services. This article outlines means to design, develop, and validate mechanisms for creating and deciding on the dynamic resource allocation of network slices.

(from IEEE Signal Processing Magazine, July 2020

3. Autonomous Driving (part 1): "Sensing and Perception: Signal processing is a critical component of automated driving. Some of the needed enabling technologies include affordable sensing platforms that can acquire useful data under varying environmental conditions; reliable simultaneous localization and mapping; machine learning that can effectively handle varying real-world conditions and unforeseen events; "machine learning-friendly" signal processing to enable more effective classification and decision making; hardware and software co-design for efficient real-time performance; resilient and robust platforms that can withstand adversarial attacks and failures; and end-to-end system integration of sensing, signal processing, machine learning, and controls. The goal of Part 1 is to provide the reader with tutorial-style articles covering the state of the art as well as emerging trends in development and deployment of sensing and perception technologies. Such technologies include camera, ultrasound, Global Navigation Satellite System, lidar and radar-based platforms. Seven articles are focused in this magazine.

Vol 10.0:

(from Intelligent Transport Systems magazine, Fall 2020. (GNSS Special Issue)

1. Editor's Column: there have been significant enhancements in the development of roadside technologies (smart road infrastructure and human participation). The state of the art in fusing global navigation satellite systems (GNSSs), with complementary positioning technologies, such as inertial navigation systems, optical sensing technologies, digital maps, and cellular signals to compensate localization errors. The articles include the testing of a self-driving vehicle under heavy snow conditions.

2. Guest Editorial: The special issue includes 11 articles that span from applications to terrestrial navigation, inland waterways, and aeronautical topics, and they target some of the most relevant challenges currently open to exploit the benefits of GNSS for navigation in ITS applications. Also, the modernization of GPS and Russia's GLONASS system and the development of Galileo and Bei- Dou are proceeding at a fast pace, introducing improved potential capabilities and higher performance levels for satellite-based positioning,

The next article below presents an Experimental Evaluation of GNSS/Inertial Navigation System Verification Strategies for Vehicular Applications. A modified strategy that requires leveling was developed, and an approach based on the horizontal angular velocity was proposed.

3. An Experimental Evaluation of Global Navigation Satellite System/Inertial Navigation System Verification Strategies for Vehicular Applications: An effective way to detect the presence of a spoofing attack is to verify GNSS data with measurements from other independent sensors such as inertial measurement units (IMU),inertial navigation systems (INS). In this article, uncoupled GNSS/INS-verification approaches are experimentally evaluated in an automotive context. From the analysis, it emerged that IMU measurements can be used to verify GNSS information even when data from smartphones are used. The smartphones, however, have to be of sufficient quality to provide reliable angular velocity information.

Vol 9.1:

(from IEEE Communications magazine, May 2019)

Data Science and AI for Communications Issue 1: The innovation in AI, machine learning (ML), and network data analytics provides a huge opportunity to revolutionize the world's communications systems and user experience. Through processing the vast amounts of information in an intelligent manner, systems can be optimized in a way that was not previously possible. The connected vehicle is a major application.

1. Toward the Realization of Encoder and Decoder Using Deep Neural Networks: Presents the design and implementation of a low-complexity deep neural network (DNN)-based encoder and decoder for real-time operation.

2. Computation Offloading in Multi-Access Edge Computing: Mobile edge computing (MEC) is positioned to deliver cloud computing capabilities at the edge of the cellular network, to store and process content closer to the user for faster response times. The article examines the challenging problem of computation offloading in MEC.

3. Reinforcement Learning for Satellite Communications: (LEO to Deep Space). Future space-based communications systems could operate close to optimum performance by autonomously allocating radio resources and handling conflicting goals. Highly time-varying challenges due to spacecraft orbital dynamics and radio propagation characteristics make this a complex task. A novel algorithm is presented.

4. An Overview: Deep Learning for Encrypted Traffic Classification: New approaches are needed to capture the more complex patterns and characteristics of traffic today.

5. Machine Learning in Adversarial RF Environments: survey of different kinds of ML approaches that can be applied to RF parameter learning. In reviewing the various learning strategies, the authors observe some of their inherent vulnerabilities to attackers and situations where the trained data might be compromised.

(from IEEE Comms magazine, November 2019)

Data Science and AI for Communications Issue 2 (abstract/ editorial are similar to issue 1)

1. Emotion Sensing for Mobile Computing: Emotion is a complex human mental state that guides our thoughts and behaviors. The article introduces an emotion sensing framework that consists of sensing, inferring, and responding steps, how various sensing modalities enabled by mobile and wearable devices can be used, and describes the widely used inferring procedures and methods.

2. An Intelligent Robust Networking Mechanism for the Internet of Things: An important application of IoT is in smart cities, where many low-powered devices are widely deployed, and networked. It is important for these devices and their interconnections to be resilient to all attacks, especially malicious ones that can cause nodes to fail. Existing optimization algorithms have a prohibitively high computational cost. This problem is addressed here.

3. Heuristic-Learning-Based Network Architecture for Device-to-Device User Access Control: Device-to-device (D2D) communications are used in various wireless communications. However, with limited wireless resource, data transmission requirements may not be guaranteed for all. Some users need to temporarily disconnect from the network. The user access control strategy depends on the authenticity of channel state information (CSI) estimation. Users with higher CSI values may be allocated more wireless resource and allowed to stay longer. The authors propose a heuristic learning method in which each user's CSI is verified. A dramatic increase in network performance can be achieved.

4. Service Function Chain Embedding for Network Function Virtualization-Enabled IoT Based on Deep Reinforcement Learning: Network Function Virtualization (NFV) is now being used in many communications networks, including IoT, due to its prospect of achieving efficient resource management. In an NFV-enabled IoT infrastructure, a Service Function Chain (SFC) consists of an ordered set of Virtualized Network Functions (VNFs) that are connected based on the business logic of service providers. However, due to the dynamic nature of IoT networks, and the large number of IoT devices, the SFC embedding process for IoT networks can become inefficient. This article introduces a solution to this problem.

5. Machine-Learning-Based Data Processing Techniques for Vehicle-to-Vehicle Channel Modeling
V2V communications have become a major research topic in the last decade because of their many potential applications and opportunities, such as the intelligent transportation system. However, the performance of V2V communications fundamentally depends on the propagation channels in which they are operating. The development and analysis of V2V systems thus requires suitable channel models. This article deals with channel modeling for V2V communications, and in particular machine-learning based techniques.

6. Data Security Issues in Deep Learning: Attacks, Countermeasures, and Opportunities: This article addresses data security issues in deep learning, and investigates potential threats. It then presents the latest countermeasures based on various underlying technologies. Then they propose the SecureNet protocol, which is presented as the first verifiable and privacy-preserving prediction protocol to protect model integrity and user privacy in deep neural networks.

(from IEEE Comms magazine, January 2020)

The six papers in this special section address the application of artificial intelligence, machine learning, and data analytics at different layers and different applications of different types of communications networks.

1. Spectrum Intelligent Radio: Technology, Development, and Future Trends: The article deals with machine learning applications at the physical layer in wireless networks. It addresses the significant spectrum strains imposed by information collection and decision making. The focus is on machine-learning-based intelligent radios as a viable solution and proposes a new radio architecture consisting of three hierarchical forms: perception, understanding, and reasoning.

2. Toward an Intelligent Edge: Wireless Communication Meets Machine Learning: This deals with wireless networks in an environment with massive numbers of edge devices for data collection and upload to edge servers that learn from the data. Examples: sensors in IoT networks, auto-driving cars,

3. Programmable Multilayer In-band Network Telemetry: Enabler for AI-assisted Network Automation: The article addresses traffic monitoring over optical networks. Advances in optical networks have increased the complexity of traffic monitoring. It proposes a programmable multilayer in-band network telemetry system, which can visualize a packet-over-optical network in real time.

4. Evolving Switch Architecture with In-Network Intelligence: Proposal for the replacement of traditional switches, which only implement the forwarding function, with intelligent switches. Switches are augmented with an intelligence plane which, together with the data and control planes, implements a sensing-cognizing-acting closed loop to understand and react to network events and dynamics.

5. Machine Fault Detection for Intelligent Self-Driving Networks: The article deals with self-driving networks which are autonomous networks that are capable of making predictive and adaptive responses to their environment.

6. Securing Collaborative Learning Systems via Trusted Bulletin Boards: Collecting training data is difficult, especially if the amount of needed data is massive and data is diverse, such as applications that include facial recognition, natural language processing, and medical image processing. Collaborative learning addresses this issue by allowing participants to train a global model by uploading subsets of parameter changes to a centralized server instead of centralized data collection

(from IEEE Comms magazine, March 2020)

The articles in this special section present new technical advancements in applying AI and data science for communications.

1. On Leveraging Machine and Deep Learning for Throughput Prediction in Cellular Networks: Design, Performance, and Challenges: An immediate application of machine learning to networks is to predictively comprehend the throughput in a cellular network and thus better network design and performance. It is difficult due to highly dynamic wireless communication environments and complex traffic services. The article proposes throughput prediction and cellular resource scheduling. HTTP adaptive video streaming is selected as the use case of interest.

2. Big Data-Driven and AI-based Framework to Enable Personalization in Wireless Networks: Among the broad user services in state-of-the-art communication networks, technology to tailor services for each person while keeping privacy is a challenge for the operators. Utilizing AI, big data analytics, and real-time non-intrusive user feedback we can develop frameworks for personalization.

3. A Flexible Machine Learning-Aware Architecture for Future WLANs: In addition to applying ML to communication networks, appropriate network architecture emerges as a critical technological stage. A focus group on Machine Learning has been established in the International Telecommunication Union - Telecommunication (ITU-T) during 2017–2020.

(from IEEE Comms magazine, June 2020)

The articles in this special section are dedicated to the application of artificial intelligence (AI), machine learning (ML), and data analytics to address different problems of communication systems.

1. When Machine Learning Meets Wireless Cellular Networks: Challenges, and Applications: The article provides an overview of the main requirements identified for efficiently deploying and integrating AI functionalities in 5G and beyond. The authors discuss the distribution of network intelligence, introducing three main types. Also the challenges posed by a ML-based air interface supporting efficient data transmission, reducing energy consumption, while satisfying latency requirements.

2. A Machine Learning-based Framework for Optimizing the Operation of Future Networks: The article proposes a general machine learning-based framework that leverages AI and ML tools to efficiently manage and optimize the performance of highly dynamic wireless networks. The proposed framework is modular and can instantiate and orchestrate multiple ML pipelines across different network segments for achieving different objectives.

3. Assisting Intelligent Wireless Networks with Traffic Prediction: Similar line of work above, the article endeavors to improve traffic prediction accuracy by exploiting predictable causality which arises between occurrences of special events and triggered traffic variations.

4. Network Slicing Meets Artificial Intelligence: An AI-based Framework for Slice Management: The article highlights network slicing as an emerging paradigm in mobile networks in order to meet the highly stringent and diverse user requirements for service provisioning. Network slicing leverages Network Function Virtualization (NFV) to enable the instantiation of multiple virtual networks, i.e. slices, over the same physical network infrastructure in real time. A general framework for AI-based network slice management is outlined, into three key system functions: admission control of new slices, radio resource scheduling of slice traffic, and resource allocation to slices in the network core. Conclusion: AI has great potential to optimize next generation mobile network performance,

5. Explainable Artificial Intelligence for 6G: Improving Trust between Human and Machine: This article highlights important open challenges to be addressed in AI/ML based architectures: building and quantifying trust between human end-users and enabling AI algorithms. Specifically, the author proposes adoption of Explainable AI that can quantify uncertainty in wireless networks.

6. Federated Learning for Wireless Communications: Motivation, Opportunities and Challenges: This article highlights privacy preservation and communication limitations as another great challenge that needs to be adequately addressed by AI empowered wireless network architectures. The adoption of federated machine learning in the context of 5G networks and beyond is proposed, satisfying decentralization, privacy preservation, scalability, and efficiency requirements.

7. Machine Learning for End-to-end Congestion Control: As future networks become more complex, conventional rule-based congestion control approaches become inefficient. Therefore, ML techniques are embraced to design effective congestion control algorithms.

8. When Artificial Intelligence Meets Active Defense for Online Service: This article falls within the realm of security, exploiting AI to improve endogenous security and the defense mechanisms of the active defense systems themselves.

Vol 8.0

(ABI Research publication)

The Critical Importance, Key Benefits, and Market Opportunities of Cloud-Based AI: The demand for cloud-based services has never been greater. While nearly half of the world's population is in partial or full lockdown, people are continuing their daily activities online. This has increased Internet traffic, with many communication service providers reporting a 30% to 40% spike in average traffic, but it has also led to a shift from many offline activities and transactions to online platforms. The COVID-19 outbreak has caused global new vehicle sales to contract by 19% in the first quarter of 2020 due to supply chain disruption, factory shutdowns etc. As the dust settles and the post-COVID-19 landscape takes shape, cloud AI adoption is set to accelerate key industries and domains across the globe. There is strong demand for cloud AI chipsets.

Vol 7.0:

(ABI Research publication)

COVID -19 and Connected Vehicle: Key benefits and market opportunities of cloud-based artificial intelligence: the demand for cloud-based services has never been greater. While nearly half of the world's population is in partial or full lockdown, people are continuing their daily activities online. This has increased Internet traffic, with many communication service providers reporting a 30% to 40% spike in average traffic, but has also led to a shift from many offline activities and transactions to online platforms. As business continuity has become a vital challenge during COVID-19, fully scalable and flexible, yet secure cloud resources have become more important than ever. Despite some already having remote working arrangements and cloud processing capabilities in place, many organizations have yet to fully leverage the capabilities of cloud-based AI. As the dust settles and the post-COVID-19 landscape takes shape, cloud AI adoption will accelerate key industries and domains across the globe.

Vol 6.0:

(from Proceedings of the IEEE magazine, Feb 2020, Special Issue on Internet of Vehicles)

1. Editorial. Conventional vehicular ad hoc networks (VANETs) are often operated in the ad hoc mode and focus on road safety applications based on the connection between vehicles and roadside units (RSUs). To support vehicular communications, dedicated shortrange communication (DSRC) and car-to-car communication consortium (C2C-CC) have been initiated in the US and Europe, respectively. With the new era of the Internet of Things (IoT), VANETs have evolved to the Internet of Vehicles (IoV). In IoV, each vehicle is envisioned as an intelligent object, equipped with sensing platforms, computing facilities, control units, and storage and is connected to other vehicles, RSUs, charging/gas stations, the cloud, and so on via vehicle-to-everything (V2X) communications. Intelligent vehicles can take different roles, i.e., being both a client and a server, taking and providing big data services, leading to numerous new IoV applications like platooning, secure information sharing etc. Two articles have been selected:

2. Mobile Edge Intelligence and Computing for the Internet of Vehicles: The capability and intelligence of vehicles are being rapidly enhanced, and this will have the potential of supporting a plethora of new exciting applications that will integrate fully autonomous vehicles, the Internet of Things (IoT), and the environment. To store and process the massive amount of data generated by intelligent IoV, onboard processing and cloud computing will not be sufficient due to resource/power constraints and latency. By deploying storage and computing resources at the wireless network edge, e.g., radio access points, the edge information system (EIS), including edge caching, edge computing, and edge AI, will play a key role. EIS will provide not only low-latency content delivery and computation services but also localized data acquisition, aggregation, and processing.

3. Evolutionary V2X Technologies Toward the Internet of Vehicles: Challenges and Opportunities: To enable large-scale and ubiquitous automotive network access, traditional vehicle-to-everything (V2X) technologies are evolving to the Internet of Vehicles (IoV) for increasing demands on emerging advanced vehicular applications, such as intelligent transportation systems (ITS) and autonomous vehicles. In recent years, IoV technologies have been developed and achieved significant progress. However, it is still unclear what is the evolution path and what are the challenges and opportunities brought by IoV. For the aforementioned considerations, this article provides a thorough survey on the historical process and status quo of V2X technologies, as well as demonstration of emerging technology developing directions toward IoV.