**Top Level Newsletter:** **Connected Vehicle**

**(Published by IEEE Orange County Section)**

**August 2019**

**Vol 1.0**

Editor-in-Chief: Kay Das, IEEE Life Member,

Systems Research Development and Innovation

This publication is intended to provide the reader with a top level briefing of the subject under review. There are two sections:

- ***Concepts:*** Background information for a first level comprehension of new concepts

- ***Publications:*** Summary of material of deeper interest in selected dated publications

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 limit of 200 to 300 words is set for each topic in the two sections. 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 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. Publications from 2017 onwards will only be included. The publication will be updated periodically.

This newsletter forms part of the Advanced Technology Initiative (ATI) in the region. Technical articles solely from IEEE journals/magazines are referred to by their Digital Object Identifier (DOI). Those readers who wish to delve further and have access to IEEE Explore may download a complete article of interest directly by inserting the DOI. Those who subscribe to the relevant IEEE society and receive the journal may already have physical or electronic copies in their possession. 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. A small quiz is included at the end of this publication.

Table of Contents

[Artificial Intelligence (AI) 3](#_Toc16177374)

[Building Blocks of Connected Vehicle Technology 3](#_Toc16177375)

[Caching: 3](#_Toc16177376)

[Cloud Computing 4](#_Toc16177377)

[Computer Vision 4](#_Toc16177378)

[Connected Vehicle 4](#_Toc16177379)

[Co-ordinated Multipoint (CoMP) 4](#_Toc16177380)

[Dedicated Short Range Communications 4](#_Toc16177381)

[Deep Learning 4](#_Toc16177382)

[Device-to-Device (D2D) 5](#_Toc16177383)

[Fog Computing 5](#_Toc16177384)

[Fronthaul and Backhaul 5](#_Toc16177385)

[Internet of Things (IoT) 5](#_Toc16177386)

[Machine Learning 5](#_Toc16177387)

[Near Far Effect 6](#_Toc16177388)

[Network Slicing: 6](#_Toc16177389)

[Non-Orthogonal Multiple Access (NOMA) 6](#_Toc16177390)

[5G Worldwide Developments/ Gozalvez 6](#_Toc16177391)

[Initial Steps Toward a Cellular Vehicle to Everything Standard/ Uhlemann 7](#_Toc16177392)

[New Eye on the Road/(Amnon Shashua, Mobileye) 7](#_Toc16177393)

[Eliminating Driving Distractions/ Chen et al 7](#_Toc16177394)

[Better Platooning Control Towards Autonomous Driving/ Campolo et al 7](#_Toc16177395)

[Using Technology to Make Roads Safer/ Al Dweik et al 7](#_Toc16177396)

[Motivating Network Development/Tom McGiffen, A Paulraj et al 8](#_Toc16177397)

[Reinventing Wheels 8](#_Toc16177398)

[Channel Coding in 5G New Radio/Hui et al 8](#_Toc16177399)

[A Wireless Localisation Algorithm..for Connected Vehicle/ Lei Chen et al 9](#_Toc16177400)

[Caching in Heterogeneous Ultradense 5G Networks/ Peng Lin, Jamalipur et al 9](#_Toc16177401)

[Silicon Evolution for the Automotive Revolution/2019/Andrew Hopkins 9](#_Toc16177402)

[AQUARIUS: A Proposal for Validation of Connected Vehicle Systems/ Kay Das 9](#_Toc16177403)

[QUIZ 10](#_Toc16177404)

**Concepts (in alphabetical order)**

Artificial Intelligence (AI) is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience. Since the development of the digital computer in the 1940s, it has been demonstrated that computers can be programmed to carry out very complex tasks—as, for example, discovering proofs for mathematical theorems or playing chess—with great proficiency.

Big data has spawned the current interest and increased investment in artificial intelligence. The availability of large volumes of data—plus new algorithms and more computing power—are behind the recent success of deep learning, finally pulling AI out of its long “winter.” More broadly, the enthusiasm around big data (and the success of data-driven digital natives such as Google and Facebook), has led many enterprises to invest heavily in the collection, storage, and organization of data. (170)

Building Blocks of Connected Vehicle Technology**:** Mimicking themany things humans do while driving requires a complex blend of technologies. Several sensors are required to analyse inputs and make decisions about steering, braking, speed…and routing. OEMs, Tier1s, start-ups etc are all involved in this disruption. Key areas are (47):

- Processing Power*:* a range of technologies from NXP. Infineon, Renesas, STMicroelectronics, Intel etc. Joined by (1) Nvidia with its GPUs which excel at performing multiple tasks simultaneously, like analyzing the many pixels streaming in from cameras. Nvidia’s recent platform for SAE level 3 to 5 is the size of a car license plate delivering 320Moperations per sec. (2) Mobileye/Intel with its dedicated video processor EyeQ3. Conventional CPUs will not disappear as the need to make sequential decisions remains.

Specialised parallel devices can be made from FPGAs from Xylinx, Altera/Intel, Lattice and Microsemi. The fusion of sensors and localized processors will continue. The likely progression will be that a major control unit will collect all relevant data and make decisions. That will push the demand for more cores, lower latency/higher clock rates, and lower power consumption. Another development is driver alertness monitoring for SAE 2 upwards. The driver’s face angle is perceived to determine drowsiness. (155)

- Sensors*:* Radar, Video, Lidar: Humans need two eyes and some mirrors to drive well but vehicles will need upto 30 sensors to match. The radar component is dominated by NXP, STMicroelectronics, Analog Devices and Renesas who are pairing controllers and radar. Start-ups/others include Oculii, Omniradar, Artsys360, Bosch, Delphi. Cameras and radar currently work together and overlap to identify objects and it is likely that lidar will be added when solid state devices meet automotive requirements. The shift to 77 GHz radar from 24 GHz permits more bandwidth. Advanced techniques for sending and receiving signals are helping radar identify objects instead of simply providing range information. In video, 8-10 Mpixels will supersede today’s 2-4 Mpixel cameras. Increased data will require innovative latency management.

Various smaller companies now make electro-mechanical lidar systems but all are developing solid state versions. Some lidar systems are ready but only for short distance usage like lane departure. High resolution at distances of 200 to 300 ft is required. (162)

- Architecture and SW/HW interfaces*:* The architecture is of prime importance in achieving quality of performance. Amongst many responsibilities, it determines how sensor data is collected and fused to create a single and dynamic view of the surroundings, how data is shared throughout the vehicle, how decisions are made, and how efficiently data is cross-checked. Software will play a key role as electronic controls determine actions in reponse to what is happening around the vehicle. Hardware must be powerful enough to make computations in time to avoid danger. Today software and hardware are often made by the same supplier, though the Automotive Open System Architecture (AUTOSAR) has enabled some separation. However, a continued necessity for abstraction between the two prevails in order to bring in third party software. One critical aspect is whether the processing power needs to be centralized or distributed (ADAS favours the latter). There is evenly divided opinion on this. Some OEMs opt for a mix of the two approaches. It is difficult to create software that will respond correctly to all the possibilities that autonomous vehicles will see while in operation. This is sparking a huge investment in creating AI programs that ‘learn’ as vehicles are in operation. (202)

- Communications*:* If vehicles can communicate, they can get information their onboard sensors cannot get, such as emergency braking, blind spot activity etc. V2I communications to roadside beacons can also aid in safety and in traffic flow. The NHSTA is advocating the use of Dedicated Short Range Communication (DSRC), though the uptake has been slow in some sectors of the industry. DSRC promises low latency. There are some spectrum issues to be resolved. Cadillac has been the first to adopt V2V. On highway tests have already proven DSRC’s performance. While some 5G proponents feel that cellular, already embedded in the industry, can displace DSRC, many feel that both systems can share roles and co-exist. It will take time for V2X vehicles to displace older cars. Aftermarket systems cannot offer many safety features since it is difficult to verify that messages are coming from a verified source and not a hacker! (151)

Caching:  a hardware or software component that stores data so that future requests for that data can be served faster; the data stored in a cache might be the result of an earlier computation or a copy of data stored elsewhere. A *cache hit* occurs when the requested data can be found in a cache, while a *cache miss* occurs when it cannot. Cache hits are served by reading data from the cache, which is faster than recomputing a result or reading from a slower data store; thus, the more requests that can be served from the cache, the faster the system performs.

To be cost-effective and to enable efficient use of data, caches must be relatively small. Nevertheless, caches have proven themselves in many areas of computing, because typical computer applications access data with a high degree of locality of reference. Such access patterns exhibit temporal locality, where data is requested that has been recently requested already, and spatial locality, where data is requested that is stored physically close to data that has already been requested. (177)

Cloud Computing is the on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user. The term is generally used to describe data centers available to many users over the Internet. Large clouds, predominant today, often have functions distributed over multiple locations from central servers. If the connection to the user is relatively close, it may be designated an edge server. Clouds may be limited to a single organization (enterprise clouds) or be available to many organizations (public cloud,) or a combination of both. (92)

Computer Vision is an interdisciplinary field that deals with how computers can be made to gain high-level understanding from digital images or videos. Computer vision is concerned with modeling and replicating human vision using computer software and hardware. It is a discipline that studies how to reconstruct, interrupt and understand a 3D scene from its 2D images in terms of the properties of the structure present in scene.

From the perspective of engineering, it seeks to automate tasks that the human visual system can do. Computer vision is concerned with the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images. It involves the development of a theoretical and algorithmic basis to achieve automatic visual understanding. As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. (164)

Connected Vehicle: Although many terms are in use such as Autonomous Vehicle, Connected Car, and others, we choose this nomenclature to include partially and fully autonomous vehicles of all descriptions, for example, including two-wheel machines.

Co-ordinated Multipoint (CoMP) When a UE is in the cell-edge region, it may be able to receive DL signals from multiple cell sites and the UE’s UL transmission may be received at multiple cell sites regardless of the system load. Given that, if the signaling transmitted from the multiple cell sites is coordinated, the DL performance can be increased significantly. This coordination can be simple as in the techniques that focus on interference avoidance or more complex as in the case where the same data is transmitted from multiple cell sites. For the UL, since the signal can be received by multiple eNBs, if the scheduling is coordinated from the different cell sites, the system can take advantage of multiple reception to significantly improve the link performance. A UE at the edge of a cell is able to be served by two or more eNBs to improve reception / transmission and increase throughput particularly under cell edge conditions.

An advantage of intra-site CoMP is that significant amount of exchange of information is possible since this communication is within a site and does not involve the backhaul (connection between base stations). Inter-site CoMP involves the coordination of multiple sites for CoMP transmission. Consequently, the exchange of information will involve backhaul transport. This type of CoMP may put additional burden and requirement upon the backhaul design. (221)

Dedicated Short Range Communications [DSRC](https://whatis.techtarget.com/definition/dedicated-short-range-communication-DSRC) allows high-speed communications between vehicles and the roadside, or between vehicles. It has a range of up to 1,000 meters. DSRC applications for public safety and traffic management include intersection collision avoidance and many others. DSRC applications now in use include electronic toll collection, and electronic credentialing and monitoring of commercial vehicle operations. Current applications operate at 915 MHz utilizing a bandwidth of 12 MHz and primarily use proprietary technology,although some standards- compliant devices have been developed. The new 5.9 GHz frequency permits much higher data-transmission rates than the lower-frequency 915 MHz bandand provides 75 megahertz of spectrum for DSRC applications. In the case of 5.9 GHz, other users in the band include military radars and satellite communications systems.

DSRC has low [latency](https://whatis.techtarget.com/definition/latency) and high [reliability](https://whatis.techtarget.com/definition/reliability), is secure, and supports [interoperability](https://searchmicroservices.techtarget.com/definition/interoperability). It receives very little interference, even in extreme weather conditions, because of the short range that it spans. This makes it ideal for communication to and from fast-moving vehicles.

DSRC technology can be used in either a vehicle-to-vehicle ([V2V](https://internetofthingsagenda.techtarget.com/definition/vehicle-to-vehicle-communication-V2V-communication)) or vehicle-to-infrastructure ([V2I](https://whatis.techtarget.com/definition/vehicle-to-infrastructure-V2I-or-V2X)) format, and communicates using transponders known as on-board units (OBUs) or roadside units (RSUs). (192)

Deep Learning: This is a class of [machine learning](http://en.wikipedia.org/wiki/Machine_learning)algorithms that use multiple layers to progressively extract higher level features from raw input. For example, in image processing, lower layers may identify edges, while higher layers may identify human-meaningful items such as digits/letters or faces. In deep learning, each level learns to transform its input data into a slightly more abstract and composite representation. In an image recognition application, the raw input may be a matrix of pixels; the first representational layer may abstract the pixels and encode edges; the second layer may compose and encode arrangements of edges; the third layer may encode a nose and eyes; and the fourth layer may recognize that the image contains a face. Importantly, a deep learning process can learn which features to optimally place in which level *on its own*.

It is predicted that by 2020, deep learning will have reached a fundamentally different stage of maturity. Deployment and adoption will no longer be confined to experimentation, becoming a core part of day-to-day business operations across most fields of research and industries. This is because advancements in the speed and accuracy of the hardware and software will have made it both viable and cost-effective. Much of this added value will be generated by deep learning inference - that is, using a model to infer something about data it has never seen before. Models can be deployed in the cloud or data center, but more and more we will see them on end devices like cameras and phones. (254)

Device-to-Device (D2D) This mode of communication is expected to play a significant role in upcoming cellular networks as it promises ultra-low latency for communication among users. This new mode may operate in the licensed or unlicensed spectrum bands. It allows UEs in close proximity to communicate using a direct link rather than having their radio signal travel all the way through the base station or the core network. One of its main benefits is ultra-low latency in communication due to a shorter signal traversal path. Various short-range wireless technologies like Bluetooth, WiFi Direct and LTE Direct can be used to enable D2D communication.

In a typical cellular network, UEs achieve time and frequency synchronization using periodic broadcasts from the BS. Devices in D2D communication can also synchronize with the same broadcasts so long as they belong to the same BS. The situation gets complicated in the following cases: (1) UEs belong to different BSs that may not be themselves synchronized, or (2) some of the UEs are in the coverage of the network and some outside the coverage, and (3) all UEs lie outside network coverage [9]. Synchronization among UEs is beneficial for D2D communication because it helps a UE use the right time slot and frequency for discovering and communicating with its peer and thus engage in more energy-efficient communication. Note that *global* synchronization among all UEs in a network may not be required for D2D communication; rather *local* synchronization among neighboring devices is sufficient. (243)

Fog Computing **:** An architecture that uses edge devices, which provide entry points into enterprise or service provider core networks, to carry out a substantial amount of computation, storage, with local communication and routed over the internet backbone. It can be perceived both in large cloud systems and big data structures, making reference to the growing difficulties in accessing information objectively, resulting in a lack of quality of the obtained content. Fog networking consists of a control plane and a data plane. On the data plane, fog computing enables computing services to reside at the edge of the network as opposed to servers in a data-center. Fog computing emphasizes proximity to end-users and client objectives, dense geographical distribution and local resource pooling, latency reduction, and backbone bandwidth savings. Fog networking supports the Internet of Things (IoT) concept, in which most of the devices used by humans on a daily basis will be connected to each other. (156).

Fronthaul and Backhaul are an essential component of the 5G radio access infrastructure. They provide connectivity and data transport in the 5G radio access network. The fronthaul connects 5G antennas with base stations and the backhaul connects base stations with the operator's core network. The term Xhaul refers to the integrated combination of fronthaul and backhaul. (56)

Internet of Things (IoT)is the extension of Internet connectivity into physical devices and everyday objects. Embedded with electronics and other forms of hardware (such as sensors), these devices can communicate and interact with others over the Internet, and they can be remotely monitored and controlled. The definition of the IoT has evolved due to convergence of multiple technologies such as real-time analytics, machine learning, commodity sensors, and embedded systems. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices such as smartphones and smart speakers like Alexa from Amazon.(130)

Machine Learning is the scientific study of algorithms and statistical models that computer systems use in order to perform a specific task effectively without using explicit instructions, relying on patterns and inference instead. It is seen as a subset of artificial intelligence. Machine learning algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task. Machine learning algorithms are used in a wide variety of applications, such as computer vision, where it is infeasible to develop an algorithm of specific instructions for performing the task. (102)

Near Far Effect : Consider a receiver and two transmitters, one close to the receiver, the other far away. If both transmitters transmit simultaneously and at equal powers, then due to the inverse square law the receiver will receive more power from the nearer transmitter. Since one transmission's signal is the other's noise, the SNR for the further transmitter is much lower. This makes the farther transmitter more difficult to understand. Possible solutions to the near–far problem:

1. Increased receiver dynamic range - Use a higher resolution ADC. This can increase the dynamic range of receiver stages that are saturating.
2. Dynamic output power control – Nearby transmitters decrease their output power so that all signals arrive at the receiver with similar signal strengths.
3. TDMA – Transmitters use a time division scheme to avoid transmitting at the same time.

(138)

Network Slicing: Use cases such as mobile broadband (MBB), the Internet of Things (IoT), and enterprise—put very different requirements on the network, but you do not want to build separate physical networks for the different services. Network slicing enables you to build multiple logical networks—network slices—on top of a common shared physical infrastructure. These network slices, one for each kind of service, are separate and independent to the extent that if something goes wrong in one slice it will not affect the other slices. This separation and independence also enable you to add new slices without impacting the rest of the network.

You can use network slicing for any access technology, and the building blocks for both building and managing a sliced network are available. Network slicing in 5G is expected to open lucrative new business opportunities for mobile operators and other newer entrants. For example, a mobile operator will be able to split its physical network resources into multiple logical slices and lease these slices out to multiple parties. Network slicing is expected to be a key component of 5G networks.

In November 2016, a [white paper](http://www.5gamericas.org/files/3214/7975/0104/5G_Americas_Network_Slicing_11.21_Final.pdf) that explores an end-to-end 5G systems framework for the creation of customised network slices was released. It also considers the application of network slicing to air-interface technologies and the long-term technology roadmap. (221)

Non-Orthogonal Multiple Access (NOMA) is a new multiple access scheme proposed. It is one of the many technologies that promise greater capacity gain and spectral efficiency than the present state of the art, and as such, is a candidate technology for 5G. Each generation of cellular technology is usually characterized by a specific multiple access scheme (FDMA/ TDMA/ WCDMA/ OFDMA). NOMA is a likely candidate in the line of succession for these technologies. NOMA goes against the present trend of transmitting information in orthogonal carriers or subcarriers. Here, the multiple users are multiplexed in the power domain, either in downlink or uplink.

In the downlink version, the Base Station (BS) transmits two signals with different powers in the same frequency band simultaneously. One message will be for a User Equipment (UE) located near the BS, while the other will be intended for a UE located a fair distance away. The UE near the base station will be allotted less power, while the far UE will be allotted more power. The UE located at the high Signal to Noise Ratio (SNR) region first decodes the message intended for the far receiver. This message is then subtracted from the received signal, and we are left with the interference-free signal that the near UE is supposed to decode. This approach requires a Successive Interference Cancellation (SIC) receiver. The non-orthogonally improves resource utilization and is found to increase the user throughput by about 38%. The tradeoff is receiver complexity.

NOMA can be extended by usage in conjunction with Massive MIMO systems. The power allocation to the antennae is based on distance and direction of the user. As a result, beams with possible slight overlaps can be directed towards different users. (A. Mohan, NOMA seminar, Govt Engg College, Trichur). (289)

**Publications 2017**

# 5G Worldwide Developments/ Gozalvez

**IEEE Vehicular Technology/March2017/p4**

* Huawei and NTT Docomo: world’s first 5G large scale field trial in 4.5GHz band in Yokohama
* NTT DoCoMo and Samsung: achieve data rate of 2.5Gbps in 5G trial, 150 kmph at 28 GHz
* Telia and Ericsson: first European 5G trial, Sweden: 15 GHz band, 800 MHz, 15 Gbps peak, 3mS latency
* NTT DoCoMo and Ericsson: first proof of concept dynamic network slicing, different types of services
* Ericsson: commercializing world’s first 5G NR (new radio) for massive MIMO
* Qualcomm: Snapdragon 5G modem chipset, MIMO with adaptive beamforming, commercial 2018
* European Commision: action plan for 5G commercial launch 2020
* Ericsson: 550m 5G subscribers 2022. N.America 25%, Asia Pacific 10%. Majority mobile broadband
* SK Telecom and Nokia: world’s first cloud-based software defined RAN
* NEC: development of a real time radio sensing system which measures usage of radio spectrum
* NEC: new geo-magnetic /deep learning technology gets locations indoors where no GPS. Geo-magnetic characteristics for each floor of building learnt. (165)

DOI: 10.1109/MVT2016.2641138

# Initial Steps Toward a Cellular Vehicle to Everything Standard/ Uhlemann

**IEEE Vehicular Technology/March2017/p14**

The V2V work item on 3GPP builds on earlier work on D2D communications and introduces a new D2D interface PC5 which is also known as the sidelink at the physical layer addressing communications at vehicular speeds. Four additional pilot signals have been added to the demodulation reference signal to improve tracking at relative speeds of upto 500 km/h and at high frequency (target is 5.9 GHz). Resource allocation based on geographical information is introduced to counter the “near-far” effect due to in-band emissions. See “near far effect”.(85).

DOI: 10.1109/MVT.2016.2641139

# New Eye on the Road/(Amnon Shashua, Mobileye)

**Automotive Engineering/March 2017/p16**

Contends that a relatively simple and cheap monocular camera and an image processing system on chip could reliably accomplish the sensing task for ADAS equipped vehicles, without need for radio ranging and for stereo cameras that find depth using visual parallax. See also “Building Blocks of Autonomous Technology”. (48)

# Eliminating Driving Distractions/ Chen et al

**IEEE Vehicular Technology/March2017/p20**

An in-vehicle interactive and intuitive user interface is described and comparison of effectiveness made for smart and traditional vehicles. A transparent windshield display is employed and gesture and voice control methods are explored. A statistical study was made to quantitatively assess each of the features.

The platform includes microphone and gesture sensing inputs. Eye-tracking and electroencephalograph (EEG) sensing are available on the platform for further research. (66)

DOI: 10.1109/MVT.2016.2625331

# Better Platooning Control Towards Autonomous Driving/ Campolo et al

**IEEE Vehicular Technology/March2017/p30**

Platooning is a pervasive use case in 5G/autonomous driving. Regulation of spacing and speed relies on up to date vehicles’ kinetic data. The potential of LTE and D2D communications for data dissemination is explored. Exploiting pooled resources and co-ordination by the in-front vehicle of the platoon is shown to fulfill the low latency requirements. Providing spatial re-use of LTE resources in the platoon membership is shown to drastically reduce the capacity demand. Each vehicle’s control system is triggered at a frequency higher than 10 Hz. Handover management and tolerating packet losses need to be further explored. A non-technical issue that requires further work is the definition of business models by mobile network operators to provide such services. (117)

DOI: 10.1109/MVT.2632418

# Using Technology to Make Roads Safer/ Al Dweik et al

**IEEE Vehicular Technology/March2017/p39**

Adaptive speed limits to make roads safer, and reduce social costs such as accidents, pollution, congestion, noise, and greenhouse gas emissions. System design framework of an ITS that comprises an interactive in-vehicle display and supporting communication units. Realizations based on cellular networks, vehicular ad hoc networks (VANETs) and a hybrid of the two are discussed. Uses standard components in the Roadside Service Unit (RSU). On board unit for receiving the transmitted speed values, observing driver behavior based on STM32 microcontroller. Extensive measurements still needed to evaluate system performance under more weather and traffic conditions. Another issue is the difficulty in dealing with closely spaced regions with different speed limits, such as car pool lanes, multi-level bridges and highways. (118)

DOI: 10.1109/MVT.2016.2634462

# Motivating Network Development/Tom McGiffen, A Paulraj et al

**IEEE Vehicular Technology/September2017/p22**

Many new and promising [vehicular communications applications](https://doi.org/10.1109/MVT.2017.2699699) are currently being developed. However, sufficient network resources to support these applications, in terms of equipped vehicles, base stations, and other infrastructure, are simply not yet available and are progressing slowly. We examine the strengths and weaknesses and uses of dedicated short-range communications (DSRC) and cellular vehicular networks. Applications are V2V, V2I, sensors on wheels, telematics, and other general applications. Telematic services are OnStar (GM), Car-Net (VW), Safety Connect (Toyota) etc.

V2V applications are control loss warning (warns surrounding vehicles of a control loss event), emergency vehicle alert, situational awareness (determines if road conditions, as measured by other vehicles, are potentially unsafe). Others are emergency electronic brake light (warns driver of a hard-braking vehicle ahead), left turn assistance (warns driver beginning to turn left of an imminent crash with a vehicle from the opposite direction) etc. We then explore strategies beyond government mandates and subsidies, the encouragement of vehicular network deployment and DSRC growth, cellular growth for vehicles, and sensors on wheels.

Vehicular communications applications, strengths of the DSRC and cellular networks, DSRC deployment in the US, comparison with Europe and Japan are explored. DSRC strengths: dedication, low latency, high security, free airtime. DSRC weaknesses: access limitations, financing, limited infrastructure, limited range, no Internet Protocol (a vehicle moving to a new base station receives a new IP address).

A weakness of cellular: higher data demand over a given area tends to occur with high-density vehicle traffic, which tends to coincide with slower vehicle motion. At many intersections governed by a traffic light, roughly half the vehicle traffic is either stopped or stopping. Cellular systems are not currently designed for high demand along busy vehicle corridors and intersections. With small cells, scenarios such as these can potentially be accommodated. (295)

DOI: 10.1109/MVT.2017.2699699

**Publications 2018**

# Reinventing Wheels

**The Economist: Special Report on Autonomous Vehicles/ 3 March 2018**

A new kind of vehicle is taking to the roads, and people are not sure what to make of it. How will it get along with other road users? Will it really shake up the way we travel? Exactly the same questions were posed when the first motor cars rumbled on to the roads. By granting drivers unprecedented freedom, automobiles changed the world. They also led to unforeseen consequences, from strip malls and urban sprawl to road rage and climate change. Now autonomous vehicles (AVs) are poised to re-write the rules of transport again. AVs are on the threshold of being able to drive without human supervision, within limited and carefully mapped areas. Waymo, the self driving car unit of Google’s parent company, hopes to launch an AV robo-taxi service in the suburbs of Phoenix AZ. GM has similar plans. There will be trade-offs in personal freedom, between goods and services, and politics will swim alongside technology. UBS, a bank, reckons that urban car ownership will fall by 70% by 2050. Today’s cars sit unused 95% of the time, so a widespread switch to robo-taxis would let urban land wasted on car parking to be re-allocated.

A century ago cars were seized upon as a solution to the drawback of horses which were clogging up the streets with manure. AVs have the potential to transform physical transport as radically as packet switching transformed the delivery of data. But as with the Internet, realizing their benefits is a matter of politics as well as technology. Lessons learnt with the horseless carriage in the 20th century applied to the driverless car of the 21st century. (273). (Some edits by author.)

# Channel Coding in 5G New Radio/Hui et al

**IEEE Vehicular Technology/Dec2018/p60**

Channel coding techniques are used in digital communications to ensure a  transmission is received with minimal errors. It is achieved by interweaving additional binary digits into the transmission. When decoded on the receiving end, the transmission can be checked for errors and repaired. Compared to 4G/LTE new error-correcting codes have been introduced. LDPC (low density parity check) replaces turbo-codes for data and polar replaces convolutional codes for control channels. LDPC gives better throughput (Gb/sec/mm2) at lower latency and reduced decoder complexity. The main idea of polar coding is to transform a pair of identical input channels into two distinct channels of different qualities: one better and one worse and thus introduce diversity in transmission. Clever bit manipulations and mappings to the channels occur at the encoder. However, complexity and dealing with re-transmissions are future research issues. Better suited to control channels. (141).

 DOI: 10.1109/MVT.2018.2867640

**Publications 2019**

# A Wireless Localisation Algorithm..for Connected Vehicle/ Lei Chen et al

**IEEE Intelligent Transport Systems/summer2019/p96**

As one of the key technologies of connected vehicle applications, wireless localization can provide accurate and reliable location for high occupancy tolling and for collision avoidance. GPS and RSSI (Received Signal Strength Indicator) are less reliable in highly dense urban areas. Several AI methods have been employed to optimize the accuracy of path loss modelling algorithms. However, due to the stochasticity of initial weights it is difficult to reach convergence. In this study a novel double layer architecture is proposed based on optimization of the initial weights and thresholds. Also, location accuracy shows improvement with increasing the number of base stations connected to the moving vehicle. Error of less than 10 m, claimed to be sufficiently good, when connected to 7 base stations. (119)

DOI: 10.1109/MITS.2019.2903433

# Caching in Heterogeneous Ultradense 5G Networks/ Peng Lin, Jamalipur et al

**IEEE Vehicular Technology/June2019/p22**

Cache-enabled network densification is expected to be an effective approach to satisfy the explosive growth of mobile data traffic. The improvement is based on the fact that some very popular contents are transmitted from a remote server repeatedly. Equipping cache-enabled access points with prediction capabilities, context awareness, and even social networking can substantially reduce redundant traffic by proactively serving predictable user demands. Stimulated by network densification, co-ordinated multipoint (CoMP) joint transmission techniques are expected to have a significant role in 5G networks. Three co-operative cacheing schemes in cellular networks, D2D networks, and cross tier networks are examined. Cross tier networks are a feature of 5G wherein the network comprises two network hierarchies for efficient utilization and distribution of channel resources: MBSs for large macrocells (radius 1 to 16 km, transmit power 40W) and FBSs for femto-cells (radius 10 to 50m, transmit power 200mW). (143)

DOI: 10.1109/MVT.2019.2904748

# Silicon Evolution for the Automotive Revolution/2019/Andrew Hopkins

**White Paper (ARM)**

The high growth of the automotive market is attractive to semi-conductor vendors. An accompanying challenge is how to develop systems suitably, where safety is of paramount concern. One standard guiding functional safety engineering is ISO26262. It defines functional safety as ” the absence of unreasonable risk due to hazards caused by malfunctioning electrical/electronics systems”. Failures can occur in the design or implementation of a hardware component or software module, the way the pieces and sub-systems are integrated, or the conception of the overall system architecture

This means that systems must function correctly, with potentially unsafe faults detected and controlled to prevent a hazard. Predictability of failure modes is expected to enable a thorough analysis. Among the main concepts for functional safety are: determining the level of design robustness, verification and validation, performing independent assessments, and managing change and modifications. Developing and verifying software for the higher levels of integrity (ASIL D) is challenging. Practical methods include the development and execution of two different software programs to perform the same or similar system function to thus reduce the likelihood of a common cause failure. Strategies include continuous detection, run-time diagnostics. (190)

# AQUARIUS: A Proposal for Validation of Connected Vehicle Systems/ Kay Das

**IEEE VTC2019/ Connected and Autonomous Vehicles paper submission/ September 2019**

There is currently much on-going activity in the research and design of systems to enhance the safety of vehicular traffic on roads and highways. Systems will comprise a dynamically changing mix of existing and new technologies and disciplines. A range of products and systems will compete for market entry from diverse sources and nations. A significant challenge exists in validating prototypes and final systems productized for market entry.

Validation is the process of ensuring that a product, service, or system meets the operational and safety requirements of the user.The need for continued validation in the connected vehicle developments is paramount. There are two current approaches. The first involves real life-sized test beds with real vehicles. The second relies on computer modeling and simulations of use cases. While the first approach is the most accurate possible, demands on cost, real estate, and logistics are very high. The second approach is highly configurable and less expensive to develop but validation of the models themselves, with constant updating as newer systems are developed, will be a major challenge. Observing the totality of an event can also be severely limited by dependence on two-dimensional displays, even if more than one is employed. There can be no “touch and feel”. There is justification for a third approach which we shall code-name AQUARIUS. In this, a real-world test bed would be built based on actual geography, geometry and highway and town planning, but on a reduced scale. (243).

# QUIZ

1. What are the limits (in metres) to wireless localization accuracy of moving vehicles and how can these be improved?
2. What are some of the new techniques for channel coding in 5G compared to 4G/LTE?
3. A century ago what was the big problem with horses on the roads?
4. What is the name of Google’s self-driving car unit?
5. What are some of the techniques that can be utilized to minimize latencies of information flow in connected vehicles?
6. How many electronic system sensors does it take to match human performance?
7. How does platooning of connected vehicles make for reduction in system capacity demand?
8. How will network slicing help improve reliability and performance in 5G networks?
9. What is the forecast percentage in fall of urban car ownership by 2050?
10. How does the ISO 26262 standard help in the design of reliable connected vehicle systems?

