How 5G Will Influence Autonomous Driving Systems

## ADAS and Autonomous Driving Improve Safety and Save Lives

Some 1.2 million people are killed by car accidents every year and human errors (e.g. drunk-driving, speeding, ignoring traffic signals, texting while driving, etc.) are responsible for more than 90 percent of these fatal accidents. This loss of 1.2 million lives per year is equivalent to seven 500-passenger aircrafts crashing every day.

To reduce the number of car accidents as close to zero as possible, carmakers, automotive suppliers, governments, academics, and even non-automotive technology providers are jointly developing Advanced Driver Assistance Systems (ADAS) and ultimately autonomous driving systems.

In this paper, understand the benefits and limitations of vehicle-to-X technologies:

- 802.11p DSRC
- LTE-based V2X
- 5G New Radio

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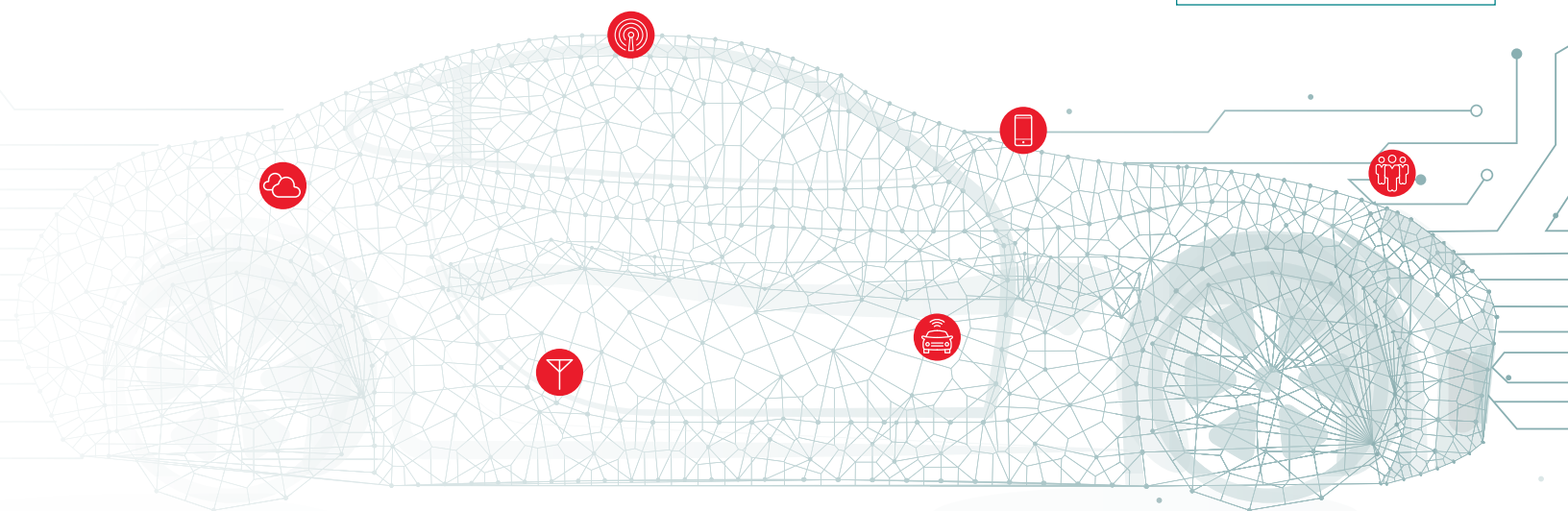
This new automotive ecosystem is combining a wide variety of advanced technologies such as:

- Sensor fusions with Radio Detection and Ranging (RADAR), Light Detection and Ranging (LIDAR), and optical sensors (cameras)
- High-speed information systems integrating automotive Ethernet networking, powerful signal processing, high definition (HD) mapping with high precision navigation, and artificial intelligence (AI)
- Communications for vehicle to vehicle (V2V), vehicle to network (V2N), vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), vehicle to utility (V2U), and eventually vehicle to everything (V2X)

Sensing technologies and artificial intelligence are delivering state-of-the-art 360-degree vision for safe, reliable autonomous driving systems. Similarly, wireless communications will play a critical role in keeping the entire ecosystem of vehicles, infrastructure, and pedestrians in sync. These technologies reduce risk by sharing and receiving critical safety information, movements of other vehicles and pedestrians, traffic information, and road conditions. This data also helps autonomous vehicles and ADAS systems perform optimally.

Two existing wireless communications technologies, Dedicated Short Range Communications (DSRC) and 4G-cellular LTE, are used in current and near-future automotive wireless communications. However, limitations in these technologies affect their suitability for mission-critical requirements for autonomous driving and advanced ADAS systems. Neither provide gigabit/s data rate, high-speed mobility support, massive machine communication, or ultra-reliable low latency. In this paper, you will learn how emerging 5G cellular communications solutions address the limitations of DSRC and 4G-cellular LTE to truly deliver on the promise of a safer and enhanced transportation experience.
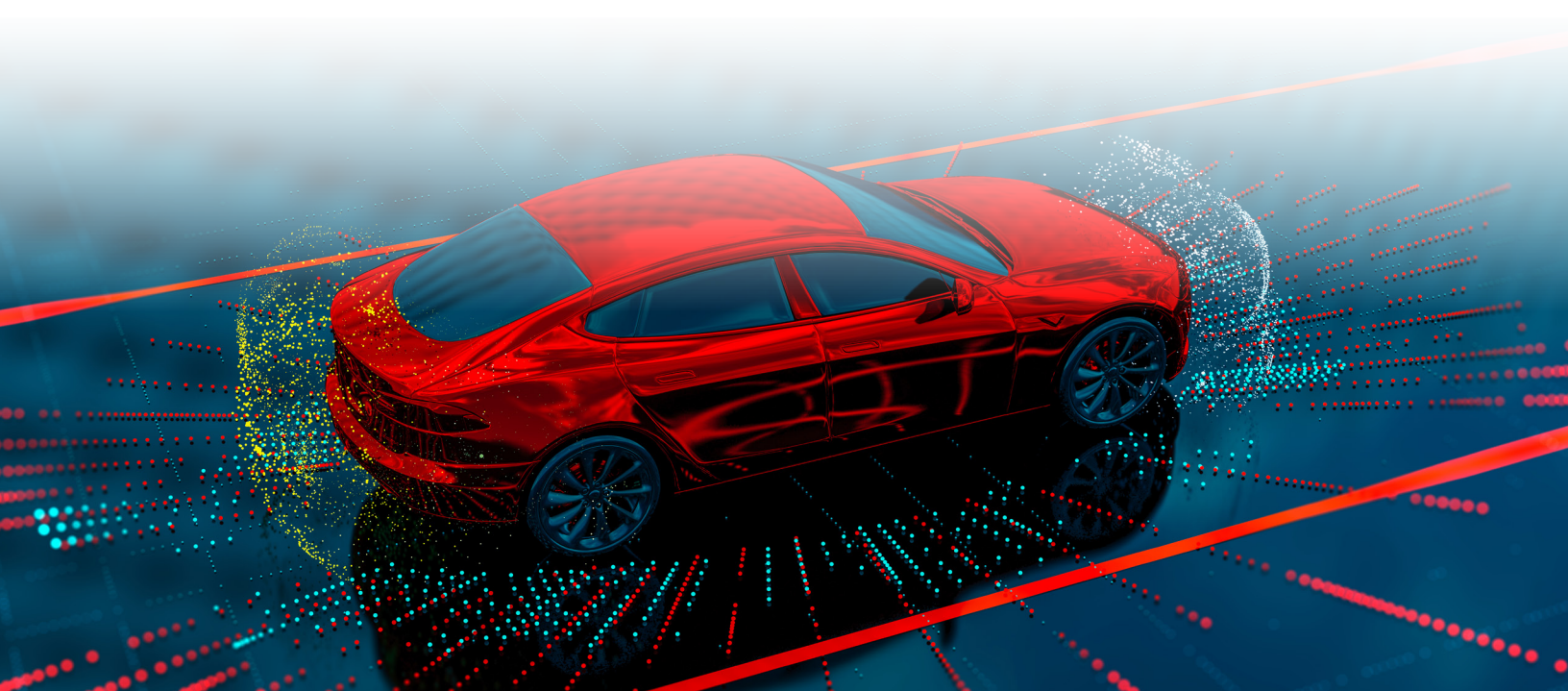
How wireless communications contribute to autonomous driving

Wireless communication technologies offer three major benefits: safer roads, a more efficient traffic routing, and more in-vehicle convenience. A wireless-enabled vehicle can share road information and traffic conditions with other cars and/or roadside infrastructure, and better anticipate potential risk or delay on the route.

To deliver these benefits, wireless communication technologies use multiple communication methods such as vehicle to vehicle (V2V), vehicle to network (V2N), vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), vehicle to grid (V2G), and ultimately, vehicle to everything (V2X).

Vehicle to Vehicle (V2V)

Vehicles directly communicate with each other to share pre- and post-collision warnings, near real-time road conditions, blind spot warning, and visibility enhancement. V2V also enables connecting two or more vehicles in a convoy, also called platooning.

Here is an example of applied V2V: a leading car passes an icy patch on the road and its Anti-lock Braking System (ABS) and/or Electronic Stability Control (ESC) system engages. Immediately wireless communications send out warning signals to the following cars so they can slow down or make a detour to avoid this icy road. Another case can be when a leading car is involved in an accident and its airbag system is activated. Immediately wireless signals are sent to following vehicles to reduce their speed or get ready to stop to avoid chain collisions. To properly perform this vital V2V mission, wireless communications need to exhibit very low latency.

Vehicle to Network (V2N)

Vehicles communicate with a wireless network infrastructure made of base stations and remote radio head (RRH) to share real-time traffic information (e.g. work zone warning). V2N is also used for calling SOS services (e.g. eCall and ERA-GLONASS) and for making remote diagnostic and repair. Unlike V2V, very low latency is not as important, however, reliability is critical. If an eCall or ERA-GLONASS call using V2N fails to connect to emergency services (e.g. 911 in the U.S., 112 in Europe, and 119 in South Korea), consequences to persons in need of assistance can be catastrophic.

Vehicle to Infrastructure (V2I)

Vehicles communicate with roadside infrastructure elements such as traffic signals, road signs, intersections, and street lights to share traffic signal change notice, road condition warning, intersection collision warning, and pedestrian crossing information. To make such V2I communication seamless, a considerable number of access points must be deployed in the roadside infrastructure, at considerable expense. One of the European car makers launched the first V2I communication pilot program in Las Vegas, USA, in 2016, but more mainstream V2I deployments may take time.

Vehicle to Pedestrian (V2P)

Vehicles communicate with pedestrians to be warned of a pedestrian crossing or proximity to protect them even under low visibility conditions such as a dark night, fog, or heavy rain. Mobile devices or wearable devices on pedestrians can be used for V2P communication.

Vehicle to Grid (V2G)

Vehicles communicate with the power grid to help electric or hybrid vehicles charge during off-peak hours when it is most cost-effective, or to resell stored electricity to the power company by discharging into the grid.

Advantages and limitations of current V2X technologies: DSRC vs. 4G cellular

Before discussing advantages of 5G wireless communications in automotive connectivity, it is worth reviewing the wireless communication technologies currently used in the automotive industry, 802.11p DSRC, and LTE-based Cellular V2X. Both enable V2X communications but each technology has pros and cons and neither of them can currently enable a full V2X experience. The table below contrasts the advantages and limitations of each technology.

Criteria	802.11p DSRC	Cellular V2X	
Readiness	IEEE 802.11p approved in 2010	4G (LTE) with evolution to 5G	
Cost Effectiveness	Requires deployment of access points and gateways	Leverages the existing cellular network infrastructure	
Scalability & Evolution	No current path	4G to 5G to next gen	
Latency	Less than 5 ms	4G at 50 ms	5G at 1 ms
Positioning	Only V2V / V2I	V2V / V2N / V2I / V2P / V2G	

DSRC is built on the IEEE 802.11p physical layer standard, the 1609 Wireless Access in Vehicular Environment (WAVE) protocol in the U.S., and the European Telecommunications Standards Institute (ETSI) TC-ITS European standards. The two key benefits of 802.11p DSRC are immediate readiness for the automotive industry and very low latency around 5 milliseconds (ms). Based on proven Wi-Fi 802.11a technology, the IEEE approved the 802.11p specification in 2010. Many car makers who want to deploy their V2X (especially, V2V and V2I) communications right now prefer 802.11p for its availability. DSRC is ad-hoc based communication and doesn't depend on network infrastructure services.

However, 802.11p requires the installation of many new access points (APs) and gateways, increasing time and cost of full deployment. Since it is based on free Wi-Fi technology, it is difficult to find an operator willing to pay the cost of deploying the APs with no clear business model in sight. There is no clear path for technology evolution either.

Cellular V2X (C-V2X) is more recent to the automotive industry. Recent 3GPP Release 14 defined some C-V2X specifications based on LTE technology (also called LTE-V for vehicles). LTE-V supports automotive wireless communications with networks for V2N as well as Device-to-Device (D2D) communications for V2V and V2P. A big advantage for C-V2X is that it uses the existing cellular network infrastructures, providing better security, longer communication range, and technology evolution path from 4G to 5G and beyond. However, current LTE-V on 4G LTE networks doesn't provide the low latency needed to enable critical V2V communications as it varies between 30 ms and 100 ms. If a leading car sends an emergency signal but V2V communications fail to notify following cars in time, a critical situation could develop very rapidly.

How 5G Will Improve V2X and Autonomous Driving Systems

5G is taking cellular from a consumer technology to high-stakes automotive applications

The radiocommunication sector of the International Telecommunication Union (ITU-R) – the specialized agency of the United Nations responsible information and communication technologies – has identified three main usage scenarios for 5G: enhanced mobile multi-gigabit broadband, massive density of machine-type connections, and low-latency ultra-reliable (99.999%) communications.

The specifications in these scenarios bring tremendous benefits to transform the driving experience by delivering peak data rate, latency, spectrum efficiency, and connection density that autonomous driving systems demand.[1]

- Ultra-low latency of 1 ms at up to 500 km/h (310 mph) speed
- High peak data rate of 20 Gbps at up to 500 km/h (310 mph) speed
- Extreme density up to 1,000,000 connected cars and devices

1   ITU-R IMT-2020 Vision: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I%21%21PDF-E.pdf

Conclusion

5G will deliver life-saving low latency to autonomous driving systems

5G's ultra-low latency will play a critical role in automotive connectivity. As an example, in a sudden jam-brake scenario, the safety features of autonomous driving systems and ADAS should immediately send out a warning in real time to the following vehicles to prevent a chain collision. This can only be achieved if the message from the lead car can reach the following cars in time for the following cars to take evasive action. In addition, low latency 5G enables better accident-prevention capabilities; particularly in non-line of sight (NLOS) situations, as most current sensor fusion technologies based on cameras, LIDAR, or RADAR can only detect objects that are in the line of sight (LOS). Research demonstrates that most drivers take 700 ms to react to a dangerous situation by either taking evasive or preventive actions. With its 1 ms low latency, 5G-based autonomous cars and ADAS will lower risks and save lives by reducing the number of accidents.

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5G will also deliver data at very fast rates to autonomous driving navigation systems

With up to 20 Gbps peak data rates, 5G will enable real-time video and audio entertainment in autonomous cars. But more importantly, 5G's fast and reliable data connection will allow downloading a sophisticated 3D map in near real time. Beyond sensor fusion technologies, autonomous vehicles heavily rely on accurate and highly detailed 3D mapping for navigation. However, storing huge map data sets at a state or country level in the vehicle itself will be a challenge. A natural solution is to use the 5G data connection to download up-to-date 3D maps in near proximity. 5G is also expected to operate reliably in both very crowded urban or sparse rural areas, addressing the need for always-on connectivity regardless of location. Whether your autonomous driving car is idling at a parking lot or driving on the Autobahn in Germany, 5G makes sure all mission-critical wireless services seamlessly work up to 500 km/h (310 mph).

5G will be available soon for automotive applications

Pilots of 5G for automotive applications have been demonstrated in the last two years. In particular, the 2018 Winter Olympics in Pyeongchang, South Korea demonstrated the high data rate and low latency attributes of 5G, where a top domestic automaker let visitors test out its autonomous driving SUV. The 5G-enabled autonomous vehicle successfully carried out a test drive of several hours from Seoul to Pyeongchang without any human intervention. Visitors also enjoyed a premier infotainment system of 'Immersive broadcasting' using 5G-powered gadgets like cameras, communication equipment and sensors attached to olympic athletes, sports gear, and arenas, so that viewers could experience the game on their mobile apps with 5G test phones.

Leading wireless service providers around the world have already announced their plans to deploy 5G as early as the end of 2018. Japan plans to launch 3GPP-based 5G at the Summer Olympics in 2020. With a mission to protect lives with critically reliable technologies, the automotive industry will fully adopt 5G communications once the wireless industry has proven its performance and dependability. In the meantime, leading car makers and automotive suppliers are already working closely with major wireless technology companies to develop 5G wireless communications for their automotive markets.

Keysight is an active contributing member of the 5G Automotive Association (5GAA)

To advance the adoption of 5G wireless communication technology in the automotive industry, leading wireless and automotive companies have formed the 5GAA with "the mission to have vehicles share information to make transportation safer, greener, and more enjoyable are at our doorstep" and to "develop, test and promote communications solutions, initiate their standardization and accelerate their commercial availability and global market penetration to address society's connected mobility and road safety needs with applications such as autonomous driving, ubiquitous access to services and integration into smart city and intelligent transportation." The 5GAA has set up five working groups (WGs) and has adopted 3GPP procedures to deliver on its mission.

- **WG1** - Determines use cases & technical requirements. One key area of focus is addressing latency issues in cellular V2X communication.
- **WG2** – Once WG1 outlines the use cases and technical requirements, this group will define the system architecture and solutions, such as what network architecture is required to achieve 1 ms end-to-end latency for cellular V2X.
- **WG3** – Next comes evaluation, testbeds, and pilots, and the challenge of figuring out how to test these architectures or devices, to make sure the device performance meets requirements.
- **WG4** – Members in this workgroup focus on defining the standards and spectra associated with the connected car ecosystem, and interoperability with other platforms such as 3GPP.
- **WG5** – Technology is only as viable as its adoption and therefore WG5 focuses on business models, go-to-market, and how to maximize the benefits of cellular V2X (V2V, V2C, V2I, V2N) to promote safety and offer an enhanced driving experience.

Keysight is an active contributing member of 5GAA working with 74 other industry participants, and collaborates with leaders of the wireless communication and automotive industries to bring 5G rapidly and safely to market by providing the industry's best 5G design and test solutions.
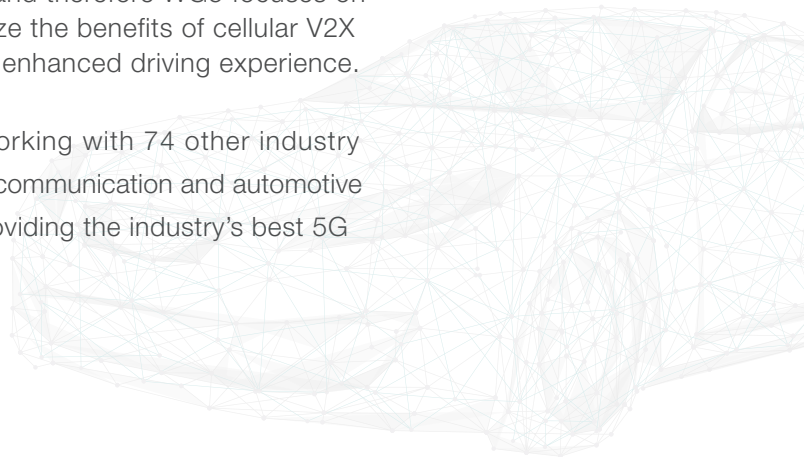
5G Will Dramatically Strengthen Autonomous Driving Systems

Wireless communication technologies promise to enable safer driving and more in-car conveniences for autonomous vehicles. Although 802.11p DSRC is ready to be deployed now, it requires huge investments to install numerous access points along miles of roads. On the other hand, major wireless companies are diligently working to bring LTE technologies into V2X communications, but it will take time for C-V2X to go mainstream. The current latency of 4G-based LTE-V doesn't meet the mission-critical V2V requirements, but can be a stepping stone for lower-level ADAS functionality.

Both DSRC and 4G C-V2X (LTE-V) compete with and complement each other, though neither of them meet the stringent requirements of mission-critical autonomous driving and ADAS systems. Ultimately, 5G will deliver the concrete benefits of 20 Gbps connections, and ultra-reliability required by autonomous driving cars and ADAS.

Keysight is partnering throughout the 5G and automotive ecosystems to deliver the technology and standards necessary to realize the vision of V2X and the full potential of ADAS via self-driving vehicles. Our test and measurement solutions are helping accelerate design and manufacturing of technologies critical to implementing autonomous vehicles with advanced 5G technology.

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

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