DSRC 802.11p Is Ready for Advanced Driver Assistance Systems (ADAS)

Although the word *autonomous* in autonomous vehicles evokes an image of a completely independent platform, in reality, it is the communication capabilities of the vehicle that significantly enhance its ability to receive and share information to help others.

Wireless communications are playing a critical role in keeping the entire ecosystem of vehicles, infrastructure, and pedestrians in sync, even as sensing technologies and artificial intelligence expand the possibilities for safe, reliable autonomous driving. Such a wide array of communications aims to reduce risk by sharing and receiving critical safety information, movements of other vehicles and pedestrians, traffic information, and road conditions.

The Society of Automotive Engineers and the National Highway Traffic Safety Administration define six levels of autonomous driving (see Figure 1), ranging from Level 0, where the human driver controls everything, to Level 5, where the vehicle’s capabilities are equal to or even better than a human driver. A Level 5 autonomous vehicle requires no human intervention or even interaction in any scenario.

Two existing wireless communications technologies, Dedicated Short Range Communications (DSRC) and LTE-based cellular, are competing for current and near-future automotive wireless communications.

In this paper, we explore how DSRC can be used today to help implement ADAS, and deliver on the promise of the safer and enhanced transportation experience.
Wireless Communications Are Key to Autonomous Driving

Wireless communication technologies help make roads safer by enabling vehicles to seamlessly share and receive road information and traffic conditions, delivering critical information to help anticipate potential risk and optimize the driving route.

Wireless communication technologies enable several types of communications frameworks such as vehicle-to-vehicle (V2V), vehicle-to-network (V2N), vehicle-to-infrastructure (V2I), vehicle-to-roadside (V2R), vehicle-to-pedestrian (V2P), vehicle-to-grid (V2G), and 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.

**Vehicle-to-Network (V2N)**

Vehicles communicate with a wireless network infrastructure made up of base stations and remote radio head (RRH) to share real-time traffic information; for example, a work zone warning. V2N is for calling SOS services; eCall and ERA-GLONASS, and remote diagnostic and repair. Unlike V2V, very low latency is not as important; however, reliability is critical for access to emergency services such as 911 in the U.S., 112 in Europe, and 119 in South Korea.

**Vehicle-to-Infrastructure (V2I)**

Vehicles communicate with infrastructure elements such as traffic displays, emergency terminals, and street lights to share traffic information.

**Vehicle-to-Roadside (V2R)**

Vehicles communicate with roadside elements such as road signs, intersection monitors, and construction warning displays to share road conditions, intersection collision warnings, and pedestrian crossing information. To make such communication seamless,
it is necessary to deploy a considerable number of access points in the roadside elements, requiring considerable time and budget. One of the European car makers launched the first V2R communication pilot program in Las Vegas, USA, in 2016, but more mainstream V2R deployments may take time.

**Vehicle-to-Pedestrian (V2P)**

Vehicles communicate with pedestrians to warn of a pedestrian crossing or proximity to protect them even under low visibility conditions such as night, fog, or heavy rain. Mobile devices or wearable devices on pedestrians are available 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.

**Introducing Dedicated Short Range Communications (DSRC)**

DSRC is a variation of the IEEE 802.11 Wireless LAN (WLAN) framework, specifically modified to work in an automotive environment with robust performance for short packets. The IEEE 802.11p standard is an amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE). It is a critical element of DSRC along with IEEE 1609, a family of WAVE standards (P1609.0, P1609.1, P1609.2, P1609.3, and P1609.4) which supplement 802.11p with high-layer messaging.

The Society of Automotive Engineers (SAE), a U.S. based professional association and standards development organization for engineering professionals defined the J2735 and J2945 standardized systems of message sets for carrying information between vehicles (see Figure 2). Devices based on the 802.11p standard work well in environments where very short-duration communication exchanges are required. While the implementation of intelligent transportation systems varies based on regional norms (see Figure 3), these systems all use 802.11p for the PHY and MAC layers.

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**Figure 2: DSRC structure from physical to application layers**

[Diagram showing the DSRC structure from physical to application layers including layers such as PHY, MAC, LLC, Message, Network and Transport, Application, and Safety and Non-Safety Applications with references to standards like IEEE 802.11p, IEEE 1609.3, IEEE 1609.4, and others.]
A quick comparison of PHY layer specifications of the 802.11a and 802.11p standards, reveals the modifications made to the PHY and MAC for 802.11p to achieve a robust connection and a fast setup for a moving vehicle environment (see Table 1).

Changes from 802.11a make 802.11p a more resilient standard

<table>
<thead>
<tr>
<th>Parameters</th>
<th>802.11a</th>
<th>802.11p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bandwidth</td>
<td>20 MHz</td>
<td>5, 10, 20 MHz</td>
</tr>
<tr>
<td>Bit rate (Mbps)</td>
<td>6, 9, 12, 18, 24, 36, 48, 54</td>
<td>1.5, 2.25, 3, 4.5, 6, 9, 12, 13.5, 18, 24, 27, 36, 48, 54</td>
</tr>
<tr>
<td>Modulation type</td>
<td>BPSK, QPSK, 16 QAM, 64 QAM</td>
<td>BPSK, QPSK, 16 QAM, 64 QAM</td>
</tr>
<tr>
<td>Code rate</td>
<td>1/2, 2/3, 3/4</td>
<td>1/2, 2/3, 3/4</td>
</tr>
<tr>
<td>Number of subcarriers</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Symbol duration</td>
<td>4 μs</td>
<td>16, 8, 4 us</td>
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<tr>
<td>Guard time</td>
<td>0.8 μs</td>
<td>3.2, 1.6, 0.8 μs</td>
</tr>
<tr>
<td>Preamble duration</td>
<td>16 μs</td>
<td>64, 32, 16 μs</td>
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<tr>
<td>Subcarrier spacing</td>
<td>312.5 kHz</td>
<td>78.125, 156.25, 312.5 kHz</td>
</tr>
<tr>
<td>SEM</td>
<td>Fixed</td>
<td>IEEE and regional FCC, ETSI</td>
</tr>
</tbody>
</table>

Table 1. 802.11p and 802.11a physical layer specification comparison

DSRC 802.11p uses the 5.9 GHz band with different channel structures in the regions; 5.850 GHz to 5.925 GHz in the United States, and 5.855 GHz to 5.925 GHz in Europe.

Figure 3. 802.11p channels at 5.9 GHz in the United States
Advantages of DSRC Over Cellular

Two competing approaches to wireless communications are currently in use in the automotive industry: 802.11p DSRC, and LTE-based cellular V2X. Both enable V2X communications. Both deliver first-generation V2X capabilities, but neither DSRC nor Cellular V2X can currently enable a full V2X experience. Table 2 summarizes the advantages and limitations of each technology.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>802.11p DSRC</th>
<th>Cellular V2X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readiness</td>
<td>IEEE 802.11p approved in 2010</td>
<td>4G (LTE) with evolution to 5G</td>
</tr>
<tr>
<td>Cost effectiveness</td>
<td>Requires deployment of access points and gateways</td>
<td>Leverages the existing cellular network infrastructure</td>
</tr>
<tr>
<td>Scalability &amp; evolution</td>
<td>No current path</td>
<td>4G to 5G</td>
</tr>
<tr>
<td>Latency</td>
<td>Less than 5 ms</td>
<td>4G at 50 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5G at 1 ms</td>
</tr>
<tr>
<td>Positioning</td>
<td>V2V / V2I</td>
<td>V2V / V2N / V2I / V2P / V2G</td>
</tr>
</tbody>
</table>

Table 2. Comparison of DSRC and LTE-based cellular-V2X

Cellular V2X (C-V2X) benefits from existing 3G and 4G network infrastructure, providing a rapid route to market for non-latency-sensitive services. Release 15 of the 5G 3GPP standard paves the way for lower latency C-V2X implementations, but many specifics for ultra-low-latency won’t be fully developed until Release 16, and won’t be commercialized until 2020 or beyond. Thus, manufacturers cannot depend on C-V2X for low-latency implementations in current designs.

DSRC offers two compelling advantages over the current 3/4G based C-V2X: immediate readiness and low latency for safety and mission-critical V2V and V2R communications.

DSRC is Ready Today

IEEE 802.11p was designed for V2X applications a decade ago. The U.S. Federal Communications Commission (FCC) set the V2X spectrum for intelligent transportation systems (ITS) at the 5.9 GHz band with 75 MHz bandwidth in 1999.

DSRC testing went through many trials and interoperability tests at the various plug-fests since IEEE set its specifications in 2010. The DSRC chipsets, devices and modules are commercially produced today. The standard is supported by many car makers as well as governments in Europe, United States, Japan, and Korea. Some commercial passenger cars already deployed 802.11p DSRC V2X communication features. Compared to Cellular V2X, which just had its standards ratified by 3GPP in 2017, DSRC is ready to deploy today based on technology and ecosystem readiness.
Latency

V2X communications operate in a very dynamic and high-velocity environment to support mission-critical safety messages. In addition to the robust communications, V2X must support extremely low latency, especially in V2V communications. Too much latency of V2V communications from a leading car involved in an accident may not give sufficient time to following cars to reduce their speed fast enough to avoid chain collisions. To correctly perform this mission-critical V2V communication, DSRC provides much shorter latency than current 4G based C-V2X. V2V communications also need to tolerate the high load generated by the periodic transmission of multiple messages by multiple actors, and the high-vehicle density typical of congested traffic scenarios.

DSRC 802.11p Rigorous Test Requirements

Given the criticality of DSRC’s applications, a very stringent regimen of tests are administered to validate the primary functions of the communication framework: transmitter tests, static receiver tests, and receiver tests under fading conditions. Your design must meet these requirements, and must be validated in an approved third party lab. Understanding the requirements and designing to them is critical to achieving certification.

802.11p Transmitter and Receiver Tests

802.11p transmitter measurements are necessary to analyze the physical specifications of the 802.11p signal generated from a device-under-test (DUT) to verify its transmit characteristics and compliance with the standards including channel power, occupied bandwidth, spectrum emission mask (SEM), center frequency, symbol clock tolerance, and modulation accuracy.

Some test requirements are identical for both the traditional 802.11a standard and the automotive 802.11p standard; spectral flatness and constellation error, but others are defined explicitly for 802.11p. Beyond the 802.11p test requirements specified in 802.11, specific regional test requirements by the Federal Communications Commission (FCC) in the United States and the European Telecommunications Standards Institute (ETSI) in Europe are required.

The 802.11-2012 Annex D.2.2 specification defines four different power classes: A, B, C, and D. Annex D.2.3 defines the SEM for operations in the United States. The FCC and ETSI also determine SEMs for local test requirements. The SEM test requirements for 802.11p power classes C and D are much stricter than for 802.11a (IEEE normal) to mitigate interference issues and ensure reliable communications.

The 802.11p standard also defines more stringent receiver test requirements for adjacent (12 dB stricter) and nonadjacent (10 dB stricter) channel rejection.
Testing 802.11p Receivers Under Fading Conditions

Testing receivers under fading conditions is essential to validating the performance under moving conditions. The 802.11-14/0259r0 document, an amendment to the 802.11 standard, specifies 802.11 V2V radio channel models for fading conditions that can be used during simulation. It defines five scenarios:

- **Rural line-of-sight:** Intended primarily as a reference result, this channel applies in very open environments where other vehicles, buildings, and large fences are absent.
- **Urban approaching line-of-sight:** This scenario comprises two vehicles approaching each other in an urban setting with buildings nearby.
- **Street crossing non-line-of-sight:** This scenario defines two vehicles approaching an urban blind intersection with other traffic present. Buildings/fences are also present on all corners.
- **Highway line-of-sight:** In this scenario, two cars are following each other on a multi-lane inter-region roadway. Signs, overpasses, hill-sides and other traffic are also present.
- **Highway non-line-of-sight:** This scenario mimics the highway line-of-sight, but with obstructing trucks present between the vehicles.

In a vehicular environment where both the transmitter and receiver are moving, the Doppler spectrum becomes asymmetric because the multipath signals are absorbed by obstacles. To describe the channel conditions more accurately, the 802.11p standard defines a new half bathtub (HalfBT) Doppler spectrum profile. HalfBT spectra induce a significant bias to the instantaneous Doppler that is consistent with the constant macro dynamics of the scenario.

Certification & Validation

The United States Department Of Transportation (USDOT) competitively selected three certification service providers (7Layers, Danlaw, and Southwest Research Institute (OmniAir)) who work together through the Certification Operating Council (COC) to support certification testing for connected vehicles pilots. Their mission is to help the industry to organize and run a self-sustaining certification program supporting the deployment of DSRC-based services.
Solutions for the Entire DSRC Lifecycle

As you develop DSRC 802.11p offerings, look for a testing partner who can provide solutions for the entire lifecycle of DSRC; from design simulation through R&D, manufacturing, to certification and validation.

Design Simulation

For the early research and development stage of the design process, seek powerful tools with accurate measurements and the ability to handle the complexity of the 802.11p standard while flexible enough to adapt to its changing requirements quickly. The appropriate modeling and simulation solutions can help designers rapidly verify various options and make reliable trade-offs.

Research and Development

Choose a testing solution spanning the traditional IEEE standards as well as automotive specific DSRC tests, including fading spectrum emission mask (SEM), EVM, channel power, sensitivity, adjacent channel rejection, and fading.

Manufacturing

Select wireless test equipment offering speed, accuracy and multiport density in a single test platform to ramp up rapidly and optimize full-volume manufacturing.
Summary

V2X communications are bringing great benefits today as the automotive industry is developing autonomous driving systems. 3G and 4G-based C-V2X can help you gain valuable experience while leveraging the existing cellular networks and infrastructures. While the first commercial 5G networks will start appearing at the end of 2018, it will be 2020 or beyond before the new, lower latency cellular infrastructure will be widely available to take the next steps in C-V2X. DSRC offers an immediate path to C-V2X for current automotive designs.

DSRC 802.11p offers low latency, and its proven technology allows immediate and reliable deployments for safer and more convenient driving today. Developers and engineers can count on Keysight solutions to help validate mission critical DSRC V2X communications, and verify that their products meet both standards and expectations for design and test.

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