

C-V2X Drives Intelligent Transportation

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This white paper describes the benefits that cellular vehicle-to-everything (C-V2X) technology will provide by enabling vehicles to communicate directly with each other (V2V), transportation infrastructure (V2I), and network-connected service providers (V2N). The Linley Group prepared this paper, which Qualcomm sponsored, but the opinions and analysis are those of the author.

Introduction

For more than 50 years, automotive-industry visionaries have dreamed of building intelligent transportation systems (ITSs), with the goal of increasing safety and traffic-management efficiency by connecting vehicles to transportation infrastructure through a network of two-way radio links. Now, thanks to Cellular Vehicle-to-Everything (C-V2X) technology, that dream is finally becoming a reality. But C-V2X offers even more benefits than vehicle-to-infrastructure (V2I) communications. It also enables vehicles to communicate with each other (V2V), allowing real-time information sharing to prevent accidents, avoid obstacles, and broadcast road-condition updates.

Furthermore, by taking advantage of cellular technology, vehicle-to-network (V2N) communications will enable transportation authorities to broadcast road-construction alerts to travelers in the affected areas, clear a path for emergency responders, and manage traffic on a broader scale. High-bandwidth low-latency connections to the cloud will also allow remote fleet management, a key to deployment of autonomous robotaxis.

The C-V2X specifications, initially defined by 3GPP in its Release 14 standard, overcome deficiencies that stalled previous attempts to develop an ITS. In 1999, the FCC allocated wireless spectrum for ITS using Wi-Fi-based digital short-range communications (DSRC), but as its name indicates, that system lacks a mechanism for long-range communications. After some initial interest by carmakers, DSRC has failed to gain much traction.

In the past few years, however, key transportation-ecosystem players in China, Europe, Japan, and the US have aligned to support the C-V2X standard. Numerous field trials have proven that the technology is ready for deployment, and many pilot programs are now underway. Companies such as Qualcomm Technologies have chipsets in production, and carmakers have committed to installing the technology in vehicles that will be available starting in 2021 in China and reaching other regions in 2022.

Unlike earlier attempts to develop an ITS, C-V2X is ready to roll out now, and it offers a roadmap to continue development in the coming years. Initial C-V2X systems are based on the widely deployed LTE cellular standard. Future models can take advantage of newer 5G technology to add features and to improve data rates and latency.

C-V2X Gains Global Momentum

Because China never deployed the legacy DSRC technology, it's able to move ahead more quickly with C-V2X. The technology is critical to its Strategy for Innovative Development of Intelligent Vehicles, which includes constructing a national traffic-control network of smart roads connected by 5G cellular technology. China's Ministry of Industry and Information Technology (MIIT) designated 20MHz of spectrum in the 5.9GHz band for C-V2X, and the National Development and Reform Commission (NDRC) set a goal of 90% network coverage in 2020. Last October in Shanghai, more than 30 automotive companies participated in an interoperability and performance test, including nine Chinese carmakers and the country's largest cellular-network operator, China Mobile.

The path for C-V2X deployment has become clear in the EU, where work is underway to develop a Cooperative Intelligent Transport System (C-ITS). In March 2020, Qualcomm announced that several products based on its 9150 C-V2X chipset successfully completed certification in accordance with the Radio Equipment Directive (RED) of the European Telecommunications Standards Institute (ETSI). Following the tests, ETSI modified the ITS Release 1 specifications to include C-V2X as an access-layer technology. The organization also updated higher protocol-layer specifications to support C-V2X. In May 2020, ETSI announced plans for a second round of interoperability tests, which will focus on ITS security features, enabling C-V2X device suppliers and Public Key Infrastructure (PKI) vendors to demonstrate support for the C-ITS security framework.

In the US, C-V2X FCC Chairman Ajit Pai accepted a 5G Automotive Association (5GAA) petition to allow deployment of the 3GPP technology. The 5GAA launched in 3Q16, formed by founding members Audi, BMW, Daimler, Ericsson, Huawei, Intel, Nokia, and Qualcomm. It now includes more than 130 member companies, spanning automotive Tier Ones, OEMs, mobile-network operators and suppliers, semiconductor companies, and testing-equipment manufacturers.

The FCC proposes to reallocate most of the 5.9GHz spectrum it reserved for DSRC more than 20 years ago. Like the MIIT plan, it dedicates the upper 20MHz in the 5.9GHz band for C-V2X. The proposal left open for discussion, however, whether to give C-V2X an additional 10MHz or allow DSRC to use those frequencies. The next step for the FCC is to issue a Report and Order (R&O) describing the new rules it will enact. The commission hasn't announced when it will publish an R&O for the 5.9GHz reallocation. Ford has already announced it will equip all its new vehicles with C-V2X, beginning with models entering production in 2022.

Technology Overview

The 3GPP's C-V2X standards define two complementary communications methods: a cellular-radio link (Uu) for long-range broadcasts, and a sidelink—called the PC5 interface—for short-range messages. Because roundtrip communications through LTE cellular networks could add unacceptable delay to time-critical safety messages, C-V2X uses the sidelink for short-range V2V and V2I communications (less than about 1km), as Figure 1 shows. The sidelink broadcasts on 5.9MHz spectrum, employing an updated

version of the LTE direct device-to-device (D2D) link. Besides reducing latency, the sidelink eliminates the risk of failure due to a lack of cellular coverage.

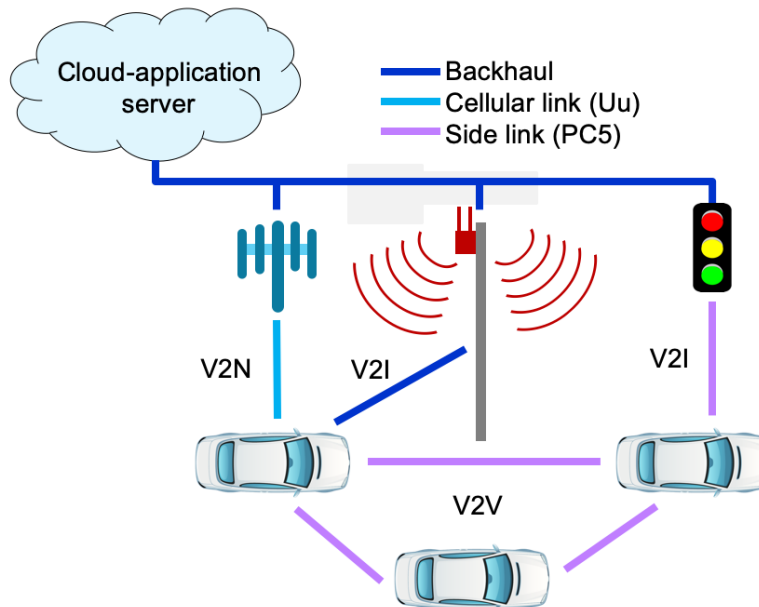


Figure 1. C-V2X communications network. Time-critical V2V and V2I messages use a dedicated 5.9GHz sidelink, avoiding the roundtrip delay through the cellular network. Less critical messages, such as information about road construction, use the V2N connection on conventional cellular channels.

In C-V2X, the cellular V2N link supports less time-critical long-range communications, such as broadcasting alerts of an accident up ahead that's beyond the reach of sidelinks. The link broadcasts using the same licensed spectrum as traditional cellular communications, connecting vehicles to metro base stations or small cells. Because V2N uses a standard cellular modem, which ships in about half of all new 2020-model cars, OEMs can also use it to offer other cloud-based services, such as diagnostics and preventative maintenance, navigation, streaming-music subscriptions, and roadside assistance.

Deployments of 5G new radio (NR) technology offer several enhancements to LTE-based C-V2X. The technology delivers increased capacity to handle dense traffic, reduced latency for time-critical maneuvers, and higher bandwidth that allows for greater capacity for sharing high-volume sensor data, including video.

Use Cases

Enabling vehicles to communicate directly with each other and to transportation infrastructure addresses the most safety-critical components of an ITS. By employing C-V2X, a vehicle can broadcast messages from onboard computers and sensors, sharing information such as its accelerating/braking/turning status, heading, position, and speed. Vehicles can also report weather conditions, using sensors that detect fog, precipitation, sunlight, temperature, and windshield-wiper rate.

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Antilock-braking system (ABS) sensors that detect skids are standard features in all new passenger vehicles. By transmitting the ABS status through a C-V2X radio, a vehicle can broadcast warnings of icy road conditions. Roadside units (RSUs) installed on transportation infrastructure equipment can alert vehicles of a red-light runner, railroad crossings, and other hazards. The C-V2X localization feature enables authorities to broadcast notices of approaching emergency vehicles, provide early warnings of hazardous locations, road construction, and other infrastructure-related messages.

C-V2X complements the advanced driver assistance system (ADAS) features available in many new passenger vehicles, such as automatic emergency braking (AEB), blind-spot detection (BSD), and lane keeping assist (LKA). Although those systems prevent accidents, they rely on camera and radar sensors that can fail in bad weather and other situations. Furthermore, these sensors can't see around corners, particularly at intersections, and can be blocked by other vehicles.

On the other hand, radio signals used by C-V2X aren't affected by weather. As Figure 2 shows, information from other vehicles can provide visibility around corners and through obstacles, enabling a 360-degree view of the surroundings. The emergency electronic brake-light example illustrates a situation that often occurs in bumper-to-bumper traffic. Although AEB will activate when a vehicle comes too close to the one ahead, C-V2X provides earlier warnings of sudden stops, and the broadcast message enables all the following vehicles to maintain a safe distance.

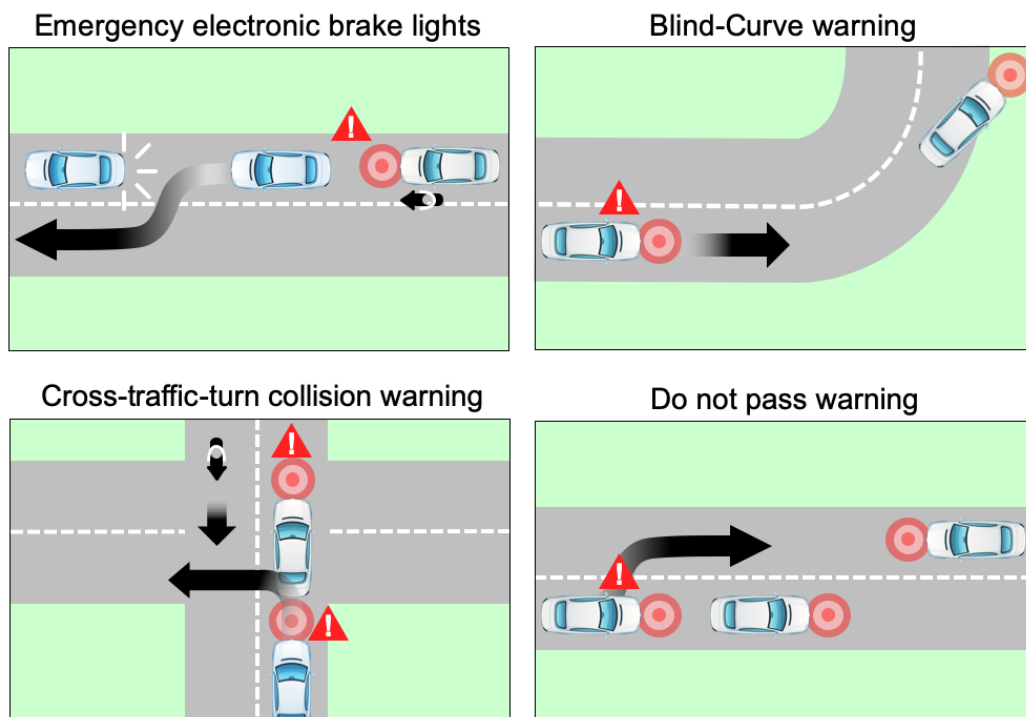


Figure 2. V2V warning messages. These applications use C-V2X's 5.9GHz sidelink to broadcast safety alerts and status messages to other vehicles. These applications don't require a cellular-network connection, but a separate LTE or 5G radio can broadcast traffic information and other non-safety-related services.

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Using V2V communications, disabled vehicles can broadcast their status to oncoming vehicles, enabling them to avoid collisions around a blind corner. By detecting obscured vehicles traveling in the opposite direction, C-V2X can also prevent head-on collisions that occur when attempting a left turn or a passing maneuver with a partially obstructed view.

Upgrading C-V2X with 5G technology will eventually enable new applications. Release 16 adds the Ultra-Reliable Low-Latency Communication (URLLC) capability to 5G networks, augmenting the 5.9GHz sidelink. This capability will enable remote control of driverless vehicles, a capability that will enable managing autonomous trucks and robotaxi fleets. The lower latency will also enable vehicles to respond more quickly to C-V2X events and potentially coordinate their maneuvers with other vehicles.

Whereas human drivers coordinate their movements through gestures and turn signals, AVs will use C-V2X to support coordinated driving. Vehicles linked through their C-V2X radios can safely execute maneuvers that might be risky for human drivers, allowing for increased traffic-flow efficiency. The increased bandwidth that 5G provides enables broadcasting high-resolution real-time maps that will aid AV path planning.

Qualcomm Solutions

Qualcomm is the leading supplier of C-V2X chipsets, and its participation in 3GPP task groups, the 5GAA, and other industry collaborations is catalyzing ecosystem development. In 2018, Qualcomm was first to produce a C-V2X product, the Qualcomm 9150 C-V2X platform. In 2019, the company introduced its newest additions to the automotive wireless portfolio, the Snapdragon Automotive 4G and 5G Platforms with integrated C-V2X technology, both of which support a 5.9GHz sidelink. A GNSS baseband provides the vehicle's location at 10Hz, along with precise time for system synchronization. It works with the company's dead-reckoning technology, which employs multi-constellation GNSS and other sensor data to increase location accuracy. The sensor fusion improves reliability for locations where a GNSS is unavailable, such as in urban canyons.

At the 2020 Consumer Electronics Show, Qualcomm rolled out its third-generation C-V2X platform, which supports 5G WAN features introduced in 3GPP Release 15. The 5G platform works in on-board units (OBUs) as well as RSUs. Seven module manufacturers have publicly announced shipping C-V2X products based on the company's chipsets, and more than a dozen OBU and RSU manufacturers are shipping products based on Qualcomm chipsets.

Conclusion

C-V2X technology is the key that will finally unlock the promise of intelligent transportation systems. Pilot programs are underway in nations around the globe, and in 2021, the first production vehicles integrating 5G C-V2X will begin production in China, many using Qualcomm's 9150 C-V2X platform. China will see the most rapid C-V2X rollout: by mid-2019, it had 20 trials in 10 provinces. In Europe, Audi, BMW, Bosch, Ducati, Ericsson, Groupe PSA and Vodafone all support C-V2X for trials, but a few

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DSRC proponents still support the legacy technology (known as ITS-G5 in Europe). The EU allows coexistence with C-V2X, but we believe that cellular technology will prove to be superior.

In the US, Colorado's DoT worked with Ford and Qualcomm on its C-V2X trial, installing 100 RSUs on 90 miles of I-70. In 3Q20, Audi, Qualcomm, and the Virginia DOT will launch a C-V2X pilot connecting Q8 SUVs to traffic lights and RSUs. The project aims to fine-tune signal timing and to prevent accidents around work zones. Qualcomm also supports a pilot program to install RSUs along a three-mile corridor in the San Diego area and a second pilot to upgrade 34 traffic signals in Honolulu. As this infrastructure becomes more widely deployed, Ford will in 2022 begin the process of adding C-V2X to all of its new vehicles.

Initial C-V2X pilots use LTE technology, but 5G deployments are increasing rapidly. The 3GPP roadmap includes enhancements in the next two releases, which will add new capabilities to the NR sidelink. The 5.9GHz sidelink supports short-range V2I and V2V communications, but supplementing that with standard 5G networks will enable additional use cases. One of the features that 5G offers is its ability to handle a greater number of connections per cell site than LTE, providing the capacity needed for a large number of vehicles on congested roads, and allowing more vehicles to share their data.

Because of organizations such as the 5GAA, C-V2X has a well-established ecosystem. Chipsets, modules, OBUs and RSUs are already in production. Qualcomm offers platforms that support LTE as well as 5G, and it has successfully demonstrated its products in numerous field trials and pilots. There are still a few regulatory issues to sort out in some regions, but C-V2X technology is ready to realize the 50-year-old vision of intelligent transportation systems.

Mike Demler is a senior analyst at The Linley Group and a senior editor of Microprocessor Report. The Linley Group offers the most-comprehensive analysis of microprocessors and SoC design. We analyze not only the business strategy but also the internal technology. Our in-depth articles cover topics including autonomous-vehicle technology, embedded processors, mobile processors, server processors, AI accelerators, IoT processors, processor-IP cores, and Ethernet chips. For more information, see our web site at www.linleygroup.com.