



## Why we are now equipping our vehicles with the new 5G mobile communications standard

- 5G and C-V2X for entertainment and greater road safety
- Technical basis for many future applications
- Global research on connected driving

Ingolstadt, August 26, 2021 – Audi is adding 5G mobile communications to production models for the first time. What does the technology offer in combination with the C-V2X wireless standard? What applications can be implemented with the technologies now and in the future? And how is Audi working around the world to continuously improve road safety? This TechFocus provides the answers.

### When and where will Audi deploy 5G and C-V2X?

Audi will soon ship the A7 L and A6 L, and subsequently many other models for the Chinese market, with a new wireless module that supports both 5G mobile communications and C-V2X technology. Other markets are expected to follow in 2023.

### How do vehicles communicate via C-V2X?

[C-V2X](#) stands for "[cellular vehicle-to-everything](#)" and refers to a technology that allows vehicles to communicate with the environment around them. This includes other road users, but also connected infrastructure such as traffic lights, traffic and construction signs, connected parking spaces, and traffic guidance systems.

C-V2X communication is based on cellular technology and offers two complementary transmission modes.

C-V2X direct communications refers to directly connecting the vehicle with its immediate surroundings. Data is transmitted in the globally harmonized 5.9 GHz ITS frequency band and does not rely on the cellular network.

In contrast, C-V2X network communications uses the cellular network to extend the transmission radius for telematics or infotainment, for example. The Audi A7 L and A6 L models utilize both C-V2X transmission modes. For the first time, the module in China now also sends and receives data via a 5G network.

### What advantages does 5G offer over the previous mobile communications standards?

The 5G standard was specified by the [3<sup>rd</sup> Generation Partnership Project \(3GPP\)](#) in late 2018. As an enhancement of the 4G/LTE cellular standard, [5G, the fifth generation of mobile communications](#), is primarily designed for robust communications in mission-critical industrial applications. The [International Telecommunication Union \(ITU\)](#) has defined three application



profiles for 5G:

**Ultra-Reliable and Low-Latency Communications (uRLLC)** requires both high reliability and low latency with response times of a few milliseconds for particularly time-critical applications such as safety-related alerts and automated driving (in comparison, 4G: >20 ms).

**Massive Machine-Type Communications (mMTC)** guarantees a reliable connection between up to one million devices per square kilometer, which is important, for example, for the secure communication between road users and the infrastructure in urban areas (4G: 100,000/km<sup>2</sup>).

**Enhanced Mobile Broadband (eMBB)** delivers extremely high data rates under ideal conditions with download speeds of up to 20 Gbit/s or upload speeds of 10 Gbit/s for data-hungry applications such as infotainment or streaming (4G: 1 Gbit/s download and 500 Mbit/s upload).

### **How will drivers benefit from 5G?**

As the successor to 4G/LTE, 5G optimizes three areas of application at once.

**Increased road safety:** Thanks to uRLLC, 5G can be used to implement extremely time-critical applications, such providing warnings in hazardous situations like accidents and emergency braking situations.

**Expanded connectivity:** Cars and motorcycles, traffic lights and road signs, bicycles and smartphones – thanks to mMTC, 5G enhances the simultaneous connection between a large number of devices and components and the cellular network, and does so with guaranteed quality and availability.

**Enhanced entertainment:** Whether multi-channel audio when listening to music or streaming live video in 4K quality – 5G is the basis for immersive entertainment experiences in the car. Smooth video conferencing that allows passengers to work from the vehicle during their ride will equally benefit from 5G as will [extended reality gaming or virtual tours of cities using VR headsets](#) – where passengers are completely immersed in virtual worlds that react in sync with the car's movements. The 5G feature eMBB guarantees the high data rates required for these bandwidth-intensive applications.

### **In which situations can 5G and C-V2X help?**

**Local hazard information:** Many services already use cellular networks for data communications. 5G will further improve [Audi's "Local Hazard Information" service](#). Thanks to its latency and bandwidth advantages, 5G will be able to increase the speed of communication between vehicles and the cloud and send alerts even earlier and more accurately. The service, which currently runs on the 4G network, allows Audi vehicles to warn each other of accidents, broken-down vehicles, traffic jams, icy roads, or limited visibility. The service has been able to draw on



[swarm intelligence](#) since 2019. In 2021, more than 1.7 million vehicles from the Volkswagen Group will provide up-to-date data that will be processed in the cloud and displayed to Audi drivers in Europe on their dashboard or optional head-up display. A novel method to estimate the coefficient of friction based on wheel slip can detect the smallest changes in road grip, upload the data to the cloud for processing, and warn drivers behind the vehicle of slippery roads, for example.

**Broken down vehicle warnings and emergency braking:** If a vehicle breaks down on the road, the system immediately sends a warning to all road users within range via C-V2X technology. If the hazardous situation is located out of view around a bend or after the crest of a road, direct communication between vehicles may not be sufficient. In this case, the warning message is transmitted via the 5G cellular network to the nearest cell tower, which acts as a relay station and sends it to other vehicles out of range. This helps them react sooner and thus significantly increases safety for all road users. In the event that a vehicle has to stop suddenly, a targeted warning is also sent automatically via C-V2X to all those driving behind the braking vehicle – even if it isn't directly visible. In China, the system also makes it possible to warn drivers of approaching emergency vehicles.

**Traffic light information:** [Connecting vehicles to traffic light systems](#) makes driving in the city more efficient and relaxed. The “Green Light Optimized Speed Advisory” (GLOSA) service calculates and displays the ideal speed in order to catch a “green wave.” For example, GLOSA may suggest gradually reducing speed about 250 meters before the traffic light to arrive at the intersection just in time for the light to turn green. This reduces inefficient stop-and-go traffic. If a stop at a red light cannot be avoided, a countdown timer counts down the seconds until the next green phase. Thanks to this “time-to-green” feature, drivers can relax and coast to the light, saving fuel, but also wait for the green phase at the red light in a more relaxed manner.

### **Which applications will be possible in the future with C-V2X and 5G?**

**Cooperative driving:** The aim of cooperative driving is to prevent accidents and traffic jams in the future and make driving safer overall. In this context, 5G and C-V2X enable direct, intelligently coordinated and responsive communication between vehicles. This connectivity is intended to help defuse critical situations such as turning, passing on rural roads, or merging into acceleration lanes. C-V2X and 5G also offer the low latency and reliability needed for platooning, i.e., efficient driving in a group. If all of the vehicles stopped at a light accelerate at the same time, then more cars will make it through the intersection when the light is green.

**Autonomous driving:** Near real-time communication between a vehicle and its environment is a key requirement for the various stages from highly automated to autonomous driving. Reaching these stages will only be possible with 5G and C-V2X, especially when the vehicle is traveling on a highway or in dense urban traffic and hazardous situations are not directly visible. In addition, 5G offers both the availability and guaranteed quality of service (QoS) necessary for autonomous driving. Among other requirements, 5G's high data rates are needed to transmit highly accurate



navigation maps to autonomous cars.

## Through which projects is Audi supporting 5G research?

Christoph Voigt, Head of R&D Connectivity, Smart Antennas & Vehicle2X Technologies at Audi, is also the chair of the [5GAA](#) (see below) and is actively involved in joint research projects. At a showcase in Turin in 2019, [Audi, Ericsson, Pirelli, and Qualcomm](#) demonstrated the combination of 5G, C-V2X, augmented reality, and eye-tracking technology. In the demo, a vehicle whose smart tires registered aquaplaning sent its sensor data to the cloud in real time via 5G. Another connected vehicle behind it then enriched the images from its front camera with data from the cloud and used augmented reality to mark the dangerous area of the road on the display.

Another scenario demonstrated direct communication between pedestrians and cars – with the aim of warning both road users in a timely manner if, for example, they cannot see each other and there is a risk of a collision.

Within the scope of the [ConVex project, Audi tested C-V2X technology together with motorcycle manufacturer Ducati](#) in three situations that are as common for motorcycle drivers as they are hazardous – entering an intersection, turning left, and sudden braking by the vehicle ahead of them. The motorcycle autonomously transmits its position, speed, and direction to other road users. If, for example, a motorcycle up ahead has to brake, a warning symbol is immediately displayed on the dashboard of any vehicles behind it. In the event of an oncoming motorcycle, the system warns drivers above a certain speed of a possible collision if they are planning to turn left. In the future, the system designed to work across all vehicle classes will also be expanded to include bicycles and smartphones.

At CES 2019, Audi joined [Ducati, Ford, and Qualcomm](#) in a cross-brand showcase to demonstrate how C-V2X can be used to resolve the situation at a four-way stop – an intersection of two roads at which all vehicles must stop – which is widespread in the United States. Whoever arrives at the intersection first also gets to go first. If two or three vehicles arrive at the same time, they must communicate with each other in order to safely enter the intersection. In this complicated situation, C-V2X helps drivers decide who goes first by having the vehicles deal with the situation themselves. They determine the correct sequence on the basis of the movement data from all the vehicles involved and confirm the results with each other. The drivers then receive information on their instrument panel that lets them know when they are allowed to proceed through the intersection.

[In the USA](#), Audi used C-V2X in a pilot project to warn drivers of road works and people on the road. In this case, the dashboard predictively displays information from C-V2X-equipped road signs, i.e., both the current speed limit and a graphic showing which lane is closed. In addition, drivers are warned of construction site personnel on the roadway wearing a C-V2X vest.

Audi is currently researching risk situations involving schoolchildren, a particularly vulnerable



group, [with private and public partners in the United States](#). For example, vehicles entering a school zone with a reduced speed limit will automatically receive a warning message on their dashboard via C-V2X. In addition, there are plans to display a warning on the dashboard as soon as a school bus stops at a bus stop to let children off.

These examples demonstrate the potential benefits of connecting vehicles via 5G and C-V2X – it increases drivers' awareness of dangerous situations and, as a result, makes driving much safer.

### Who are the members of the 5GAA?

The [5G Automotive Association \(5GAA\)](#) is a global, cross-industry organization composed of companies from the automotive, technology, and telecommunications industries that are working together to develop solutions for future mobility and transportation services. Founded in September 2016 by eight companies, including AUDI AG, the 5GAA now brings together more than 130 automotive manufacturers, suppliers, and mobile network operators, as well as providers of chipsets, communications systems, and telecom infrastructure.

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The Audi Group, with its brands Audi, Ducati and Lamborghini, is one of the most successful manufacturers of automobiles and motorcycles in the premium segment. It is present in more than 100 markets worldwide and produces at 19 locations in 12 countries. 100 percent subsidiaries of AUDI AG include Audi Sport GmbH (Neckarsulm, Germany), Automobili Lamborghini S.p.A. (Sant'Agata Bolognese, Italy), and Ducati Motor Holding S.p.A. (Bologna/Italy).

In 2020, the Audi Group delivered to customers about 1.693 million automobiles of the Audi brand, 7,430 sports cars of the Lamborghini brand and 48,042 motorcycles of the Ducati brand. In the 2020 fiscal year, AUDI AG achieved total revenue of €50.0 billion and an operating profit before special items of €2.7 billion. At present, 87,000 people work for the company all over the world, 60,000 of them in Germany. With new models, innovative mobility offerings and other attractive services, Audi is becoming a provider of sustainable, individual premium mobility.

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