Vehicular Communications Definition and Overview for the Task Force on Vehicular Communications (TF on VC)

This document provides an overview of definition, structure, use-cases, and challenges for vehicular communications. Addressing the potential benefits and challenges of vehicular communications requires a comprehensive approach that needs collaboration between industry stakeholders, researchers, and policymakers to protect such communications.

I. Vehicular Communications Definition

Vehicular communications refer to the exchange of information and data between vehicles, as well as between vehicles and their surroundings. This involves the use of various wired and wireless communications technologies. Vehicles share information and data with other vehicles, road users, roadside units, traffic control and management systems, and other road transport infrastructure. Service providers also play a role in this interconnected network.

II. Vehicular Communications Structure

Vehicular communications can be broadly categorised into wired and wireless types.

Current wired communications in vehicles primarily involves information and data exchange through the OBD port and the vehicle charging equipment. While these technologies currently utilise wired connections, they might also incorporate wireless approaches in the future.

Wireless communications technologies in vehicles, listed below in approximate range order, include, but are not limited to:

a. Proximity communications, such as access control technology using RFID and NFC for short-range identification and data exchange.

b. Close-range communications, such as Bluetooth, Ultra-Wide-Band (UWB), and infrared for connecting devices within a few meters.

c. Intermediate-range communications Radio Local Area Networks (RLAN), such as Wireless LAN (802.11) for data transfer over a wider range than close-range communications technologies.

d. Direct trusted short-range communications between vehicles, smart road infrastructure, and vulnerable road users (V2X). This includes vehicle-to-vehicle multi-hop, for example during emergencies when the mobile network is not available.

e. Cellular network communications providing voice, text messages, and mobile internet access.

f. Radio broadcasting,-such as digital audio broadcasting (DAB+).

g. Satellite communications, such as GNSS, satellite radio, and satellite internet.

III. Vehicular Communications Value

Vehicular communications has significant potential to improve road safety, reduce transport costs, enhance transport efficiency, elevate the overall transport experience, and minimise the environmental impact of transportation.

By enabling information exchange between vehicles, other road users, and infrastructure components, vehicular communications facilitate the sharing of critical data. This includes vehicle speed, location, acceleration, braking, signalling, road conditions, and information about other road users. Additionally, vehicles can receive valuable information from road transport infrastructure and service providers.

IV. Vehicular Communications Uses

This section provides general information on common uses of vehicular communications. For clarity for diverse readers, some terms appear in multiple application descriptions below, as common terminology does not always have precise boundaries. Vehicular communications can be used for various applications, including but not limited to:

1. Safety and Emergency

a. *Safety information for vehicle operation*: Vehicular communications enable in-vehicle systems to provide timely notifications and warnings to drivers/vehicle occupants about potential hazards. These notifications can be based on information received from other vehicles, road infrastructure (e.g., electronic signs), and service providers (e.g., weather services). Examples include warnings about wrong-way driving, traffic congestion, and road hazards.

b. *Safety information for infrastructure operators and service providers:* Vehicular communications allow vehicles to transmit real-time data to infrastructure operators and service providers. This data can include detection of wrong-way driving, traffic congestion, and road hazards, which can be used to improve response times and overall traffic management.

c. *Emergency services:* Vehicular communications can enable faster emergency response by providing real-time information about crashes, road hazards, and other incidents. Additionally, Accident Emergency Call Systems can further support improved responses. In the future, vehicular communications could allow emergency services to remotely control vehicles with ADS products active that do not have a fallback user.

d. *Collision warning and avoidance:* Vehicular communications can help vehicles and drivers detect and avoid potential collisions by sharing information about their locations, speeds, and trajectories. This information can be used as an additional input for Advanced Emergency Braking Systems (AEBS), further enhancing collision prevention capabilities. Vehicular communications can also report various types of potential risks, allowing for a more comprehensive risk assessment.

e. *Protecting vulnerable road users (VRU):* Vehicles equipped with VRU detection can share this information with surrounding vehicles and infrastructure to implement VRU protection strategies. Similar to collision avoidance, this information can be used as an additional input for AEBS and other safety functions. Devices, carried by pedestrians, cyclists, and motorcyclists can alert vehicles to their presence and vice versa. Safety is improved when the road transport infrastructure detects VRUs as well as unconnected vehicles and sends the information to surrounding traffic participants in real time.

f. *Emergency alerts:* Vehicular communications can deliver alerts about various emergencies, including tsunamis, typhoons, and fires. This information can be crucial for supporting evacuations, including for vehicles with ADS that do not have a fallback user.

In situations where the primary communications infrastructure is disrupted, vehicle-to-vehicle communications can relay information through a multi-hop approach across the road network, enabling warnings to reach areas with communications outages. Similarly, vehicles with connectivity can use this multi-hop approach to deliver critical information to those in areas with communications outages.

2. Traffic Management

a. Road transport infrastructure management: Vehicular communications can assist road operators to optimise traffic flow, reduce congestion, and improve overall transport efficiency. Vehicles can provide real-time data on their location, movement, and intended manoeuvres (e.g., lane changes, upcoming turns) to support infrastructure improvements. Additionally, vehicles can report local hazards such as road surface issues and areas with frequent braking/electronic stability control activation, enabling targeted maintenance and repair.

b. *Road works:* Vehicular communications can inform drivers about road works, including detours, revised speed limits, and potential delays. Timely warnings can reduce accidents and improve safety for both drivers and road workers.

c. *Optimised Traffic signal Systems:* Traffic signal controllers can transmit their signal phase and timing (SPaT) data, along with intersection topology, to vehicles. This allows vehicles to optimise speed for energy efficiency and achieve green-light-optimal speeds. Additionally, vehicles can provide anonymous traffic data for dynamic signal timing adjustments. In the future, vehicular communications could replace inductive-loop detectors and support red-light violation prevention. Vehicular communications enable emergency and public transport vehicles to request priority at traffic signals, facilitating a swift change to green.

d. *Real-time Traffic Updates:* Drivers can receive information on road network status from infrastructure operators, service providers, and other vehicles.

e. *Event management*: Vehicular communications can provide information about road closures, detours, and other routing changes during special traffic situations such as sporting events, parades, protests, and VIP travel. This can help drivers plan their routes and avoid congested areas.

3. Automated Driving Support

a. *Automated driving support:* Vehicular communications can support, and potentially accelerate, the deployment of automated driving systems (ADS). By utilising data received as an additional input, ADS products might improve their performance within their operational design domain (ODD) and even extend their ODD. This data, explicit and supplementary to the vehicles' own sensor interpretations, allows for earlier and smoother automated actions.

   Road transport infrastructure can provide ADS-equipped vehicles with crucial, real-time updates, including:

   i) Changed road conditions such as special traffic situations, roadworks, and accident locations.

   ii) Information about challenging topological situations such as tunnel entries, highway entries and exits, and complex intersections.

   Emergency vehicles can use vehicular communications to transmit their location, speed, and trajectory, ensuring earlier awareness by ADS products of these emergency vehicles and facilitating safe interaction.

   When approaching their ODD limits, vehicles can announce their status, enabling remote human control and automated guidance from the road infrastructure.

   Additionally, vehicle communications can facilitate valet parking services.

b. *Cooperative automated driving:* Vehicular communications fosters collaboration between vehicles to enhance safety and efficiency. This includes functionalities such as platooning and coordinating intersection entry for ADS-equipped vehicles. Vehicular communications also facilitates challenging manoeuvres such as lane changing and merging. Vehicular communications can provide earlier awareness of emergency and other prioritised vehicles (see Traffic Management).

4. In-vehicle Experience and Convenience

a. *Infotainment and convenience:* Vehicular communications can enhance the in-vehicle experience by delivering multimedia content, internet access, and personalised services. This includes providing real-time information such as location of rest areas for passenger vehicles; availability of overnight parking for lorries; status of facilities for campers; location, availability, and pricing of charge points and petrol stations; and availability of parking spaces. Additionally, reservations can be made for parking, charging, and other services such as dining and lodging.

b. *Remote activations*: Vehicular communications can be used for remote vehicle actions such as locking/unlocking, starting climate control, managing charging, opening the trunk for delivery/pick, and controlling home and destination devices such as appliances and garage doors. Vehicular communications can support vehicle sharing and rental services.

c. *Charging support:* Vehicular communications can provide information from the grid to control charging times and facilitate two-way energy flows, enabling electric vehicles to power the grid or a user's home and devices. Such communications could play a role in supporting energy storage and grid balancing activities.

d. *Payment services*: Vehicular communications can be used for in-vehicle purchases and payments for tolls, road pricing, parking, fuelling, charging, and drive-thru services.

5. Vehicle Management and Maintenance

a. *Geofencing*: Vehicular communications can alert vehicle owners and managers when a vehicle exceeds pre-set geographic limits and speed. Vehicular communications can transmit information relevant to vehicle operations within those limits, such as ADS ODDs and traffic rules.

b. *Vehicle maintenance*: Vehicular communications allows updating vehicle software, firmware, and map data; accessing real-time data on the health and performance of vehicle components; and transmitting maintenance issues detected by vehicle systems to owners and vehicle manufacturers.

c. *ISMR:* Vehicular communications will enable vehicle manufacturers to provide in-service monitoring and reporting (ISMR) to vehicle-regulatory authorities about their vehicles.

6. Other Services

a. *Police authorities*: Vehicular communications can allow police officers to retrieve information from vehicles, including whether an ADS product is active.

b. *Public transport*: Vehicular communications can provide waiting passengers with information about public transport vehicle arrival times and service variations, as well as assist with public service fleet operations and management.

c. *Fleet management*: Fleet operators can use vehicular communications to collect information from their managed vehicles and control operations.

d. *Freight movement*: Vehicular communications can track freight movement, improve freight transport efficiency, and enable lorries to transmit weight and electronic manifests to relevant authorities, such as traffic management centres and customs authorities.

V. Potential Challenges for Vehicular Communications

Although there are many advantages to vehicular communications, it is important to be aware of potential challenges when using vehicular communications. Interpretation of these challenges and the required countermeasures vary across countries and regions.

a. *Cybersecurity Risks*: Communications are sensitive to cybersecurity threats, including hacking attempts and unauthorised access. Malicious actors will attempt to exploit vulnerabilities in the communications protocols and compromise the integrity of data exchanged between vehicles and external systems. The automotive industry has implemented Cybersecurity Management Systems (CSMS) to secure vehicles and data.

b. *Privacy Concerns*: Exchange of information among vehicles and infrastructure can raise privacy concerns, especially with relation to the personally identifiable information (PII) of the vehicle occupants. Concerns have been raised regarding the potential risk of unauthorised tracking and profiling of individuals. Authentication to access the data, including anonymisation and pseudonymization of the data, are mitigations to reduce the risks involved. In general, access and processing of personal data is allowed with the driver´s consent, when necessity to protect the driver´s or another person´s vital interests, and bases on public interest or compliance with legal obligations.

c. *Interference*: Interference, direct or out of band, can disrupt or limit communications between vehicles and between vehicles and infrastructure. International regulations on Radio Spectrum use mitigate the risk of interference.

d. *False Information Propagation*: Malicious entities will attempt to disseminate false information within communications networks. This misinformation might confuse drivers/vehicles and might pose risks to road safety. Verifying the authenticity of data is crucial to prevent the spread of false information. A critical element for some communications technologies, particularly direct communications and cellular networks, is sender verification.

e. *Damage to Infrastructure*: Damage to communications infrastructure caused by physical attacks or environmental effects might cause roadside units and base stations to malfunction and disrupt the communications network.