Note by the secretariat

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Vehicular Communications Definition, Overview, and ~~Challenges~~Considerations
Prepared for the Task Force on Vehicular Communications (TF on VC)

This document provides an overview of the definition, structure, value, uses, and ~~challenges~~considerations for vehicular communications. Achieving the potential benefits ~~and challenges~~ of vehicular communications requires a comprehensive approach ~~that needs~~involving collaboration between industry stakeholders, researchers, and policymakers to deploy and protect such communications capabilities.

I. Vehicular Communications Definition

Vehicular communications is the exchange of information between vehicles, as well as between vehicles and their surroundings. In this document, the word 'information' includes data.

This information exchange involves the use of various wired and wireless communications technologies. Vehicles ~~share~~exchange information with other vehicles, road users, and road transport infrastructure components (roadside units, electronic signs, 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.
- One to one and one to many (broadcast).
- ~~One way~~Unidirectional and ~~both ways~~bidirectional.

Current wired communications in vehicles primarily involves information exchange through the OBD port, USB ports, and the vehicle battery charging equipment. While these technologies currently utilise wired connections, they might also incorporate wireless communications 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 radio-frequency identification (RFID) and near-field communication (NFC) for short-range identification exchange.

b. Close-range communications, such as Bluetooth, ultra-wide-band (UWB), and infrared for connecting equipment within a few met~~er~~res.

c. Intermediate-range communications radio local area networks (RLAN), such as Wireless LAN (802.11) for information transfer over a wider range than close-range communications technologies.

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

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

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

g. Satellite ultra-wide-range communications, such as GNSS, satellite radio, and satellite internet.

III. Vehicular Communications Value

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

By enabling information exchange between vehicles, other road users, and road transport infrastructure components, vehicular communications facilitates sharing critical information. This includes driver's health condition, whether the driver is paying attention, driver's use of ADS, vehicle speed, vehicle location, vehicle acceleration~~,~~ and braking, vehicle signalling, road conditions, and information about other road users. ~~Additionally~~In addition, vehicles and ~~drivers~~their occupants can receive valuable information from the 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~~elements appear in multiple ~~application~~use-case descriptions below, as common terminology does not always have precise boundaries. Vehicular communications can be used for various ~~applications~~use cases, including but not limited to:

1. Safety and Emergency

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

b. *Safety information for other road~~-~~ transport ~~infrastructure operators and service providers~~operations*: Vehicular communications ~~allows~~enables vehicles to transmit real-time information to road transport infrastructure operators and service providers. This real-time information can include detection of wrong-way driving, traffic congestion, and road hazards, which can be used to improve drivers' response times, service operators' information, 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. In the future, vehicular communications could ~~allow~~enable emergency ~~ser~~vehicles to remotely control automated driving systems (ADS)-equipped vehicles that do not have a fallback user.

d. *Automated ~~Emergency Call~~emergency call*: In-vehicle eCall can support improved emergency response~~s~~.

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

f. *~~Protecting vulnerable road users (~~VRU~~):~~ protection:* Vehicular communications ~~allows~~enables vehicles equipped with VRU detection capabilities to share the information that they identify with surrounding vehicles and ~~the~~ road transport infrastructure components to implement VRU protection strategies. Communications equipment~~, carried by~~ in the possession of pedestrians, cyclists, and motorcyclists can alert drivers and vehicles ~~to~~system about their presence.

Similar to the collision warning and avoidance ~~application~~use case, this information – if reliable, relevantly accurate, and real-time – can be used as an additional input for AEBS and other safety ~~features~~systems. Safety is improved when ~~the~~ road transport infrastructure ~~detects~~components detect VRUs as well as unconnected vehicles and send~~s~~ the information to surrounding traffic participants in real time and with high accuracy.

g. *Emergency alerts:* Vehicular communications can deliver alerts about various emergencies, including tsunamis, typhoons, and wild fires. This information can be crucial ~~for~~in supporting evacuations, including ~~for~~by ADS-equipped vehicles 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 using a multi-hop approach, enabling comprehensive warnings to reach vehicle occupants in areas ~~with~~where there are communications infrastructure outages. Similarly, vehicles in areas ~~with~~where there are communications infrastructure outages can use ~~this~~such a multi-hop approach to deliver critical information to road transport operators.

h. In-*vehicle alerts*: Vehicular communications can ~~allow~~enable road transport infrastructure components and other vehicles to send alerts to vehicles for their drivers and ADS-equipped vehicles to be informed ~~about~~of special situations.

2. Traffic Management

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

b. Road *works:* Vehicular communications can inform drivers and ADS-equipped vehicles about road works, including detours, lane changes, revised speed limits, and potential delays. Timely warnings can reduce accidents and improve safety for both ~~drivers~~vehicle occupants and road workers.

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

d. Real-*time ~~Traffic Updates~~traffic updates:* Vehicular communications ~~allows~~enables drivers to receive information on road network status from road transport infrastructure operators, service providers, and other vehicles.

e. Event *management*: Vehicular communications can provide information about road closures, detours, and other rout~~inge~~ changes during special traffic situations such as sporting events, parades, protests, and VIP travel. This can help drivers and ADS-equipped vehicles 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 information received as an additional input, ADS ~~features~~products might improve their performance within their operational design domain (ODD) and even extend their ODD. This information, explicit and supplementary to the vehicles' own sensor interpretations, allows for earlier and smoother automated actions.

Road transport infrastructure components 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 ~~features~~products of these emergency vehicles and facilitating safe interaction with them.

When approaching their ODD limits, ADS-equipped vehicles can announce their status, enabling remote human control and automated guidance from ~~the~~ road transport infrastructure components.

Additionally, vehicular communications can facilitate valet (remote) parking ~~services~~systems.

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

4. In-~~v~~Vehicle Experience and Convenience

a. *Infotainment and convenience:* Vehicular communications can enhance ~~driver and occupants~~vehicle occupants' 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 battery charge points and petrol stations; and availability of parking spaces. Additionally, reservations can be made for parking, battery charging, and other services such as dining and lodging.

b. *Remote activations*: Vehicular communications can be used for remote ~~control~~initiation of vehicle actions such as door locking and unlocking, activating the climate-control~~ settings~~, managing battery charging, opening the trunk for delivery and pick up, and controlling home and destination devices such as home appliances and garage doors. Vehicular communications can support vehicle sharing and vehicle rental services.

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

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

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~~enables updating vehicle software, firmware, and map data; accessing real-time information on the health and performance of vehicle components; and transmitting the maintenance status of vehicle components to vehicle 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~~enable police officers to retrieve information from vehicles, including whether an ADS ~~feature~~product is active.

b. Remote authority vehicle control: Vehicular communications can remotely slow, stop, and disable a vehicle with appropriate legal authorisation~~ of police authorities~~.

c. Stolen vehicle tracking: Vehicular communications can ~~allow~~enable police authorities to track a stolen vehicle.

d. Public transport: Vehicular communications can provide waiting passengers with information about public transport ~~vehicle~~ arrival times and service variations. Vehicular communications can assist public transport fleet operations and management~~.~~ (e.g., prioritisation of public vehicles at traffic signals).

e. Fleet management: Vehicular communications can ~~allow~~enable fleet operators to collect information from their managed vehicles and control their ~~managed vehicles'~~ operations.

f. 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.

g. Vehicle emissions information: The actual vehicle emissions can be reported to authorities to determine the real-world emissions performance of vehicles.

V. Vehicular Communications ~~Challenges~~Considerations

Although there are many ~~advantages to~~benefits from vehicular communications, it is important to be aware of potential ~~challenges with~~considerations of using vehicular communications. These ~~challenges~~considerations and the required countermeasures vary across uses, countries, and regions. The considerations include, but are not limited to

a. Cybersecurity: 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 information exchanged between vehicles and external systems. There is a risk of a terrorist group ~~taking~~could take remote control of connected vehicles including ADS-equipped vehicles. Vehicle manufacturers have implemented Cybersecurity Management Systems (CSMS) to secure vehicles and the vehicle's data. Similarly, road transport infrastructure operators have implemented Information Security Management Systems (ISMS) to secure their components and data.

b. Privacy: Exchange of information among vehicles and road transport infrastructure components can raise privacy issues, especially with ~~relation~~regard to the personally identifiable information (PII) of vehicle occupants. Concerns have been raised regarding the potential risk of unauthorised tracking and profiling of individuals. Authentication to access vehicle information, including anonymisation and pseudonymisation of the information, are mitigations to reduce the risks involved. In general, access and processing of personal information is allowed (1) with the driver´s consent, (2) when necess~~it~~ary to protect vital interests of the driver~~´s~~ or another person~~´s vital interests~~, and (3) based on public interest or compliance with legal obligations.

c. *Communications interference*: Communications interference, ~~direct or~~in-band and out-of-band, can disrupt or limit information transfer between vehicles~~ and between vehicles~~, road transport infrastructure components, and the communications infrastructure. International (ITU-R) regulations on radio spectrum use mitigate the risk of communications interference.

d. *False ~~Information Propagation~~information propagation*: Malicious entities will attempt to disseminate false information. This misinformation might confuse drivers and ~~vehicles~~vehicle systems and might pose ~~risks~~a risk to road safety. Verifying the authenticity of information 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. *Vehicle ~~life~~service lifetimes*: In many countries, vehicle service ~~life is more than~~lifetimes exceed 20 years. ~~Vehicular~~In some countries, the average age of vehicles routinely operating on its roads is up to 15 years. Development of vehicular-communications ~~life and in-vehicle communications~~ equipment ~~life must be made to match vehicle service life so that vehicular communications is not lost as older vehicles move~~has to ~~less-advantaged owners~~take into account the long service lifetimes of vehicles.

f. *Damage to ~~Communications Infrastructure~~communications infrastructure*: Physical attacks or environmental effects might cause roadside units and base stations to malfunction and disrupt ~~the~~ communications~~ infrastructure. ~~. See the cybersecurity consideration.

g. *Damage to in-vehicle communications equipment*: Physical ~~or remote~~ damage to in-vehicle communications equipment might cause ~~safety issue. In addition, compromised in-vehicle communications equipment might cause erroneous transmissions that impact the communications infrastructure~~issues.

h. *Delays~~:~~ (latency)*: All communications ~~is~~are subject to delays ~~from~~due to equipment processing time, protocol set-up time, radio-spectrum bandwidth for information, etc. Additional delays can come from the communications infrastructure. Vehicular communications applications ~~must ensure~~should be designed so that the delays for the selected communications ~~method~~technology match the acceptable data-transmission delays for the application, taking into account elements such as the maximum ~~driving~~ number of communications participants at any time, coverage of communications networks used, the vehicle speed that is supported~~.~~, etc.

i. *Timeliness*: Safety-related vehicular communications should ~~have~~be given priority in the radio spectrum used and for transmissions across communications infrastructure.

j. *Coverage*: Communications infrastructure can have areas of no coverage (dead spots). ~~Vehicular communications needs to avoid coverage limitations.~~

k. *~~A~~Unavailability*: Communications infrastructure can have service outages. Vehicular communications needs to avoid interruptions by communications infrastructure outages, both local and wide area.

~~l. *Backup*: Vehicles must be built to properly handle all possible communications issues.~~

l. *Costs*: Communications infrastructure, road transport infrastructure components, and in-vehicle communications equipment as well as licenses for communications technologies might be expensive. ~~Cost for vehicular communications must be controlled. Safety-related~~How costs are handled can be policy issues.

m. *Radio spectrum misuse*: Some radio spectrum has been allocated, and will be allocated, for safety-of-life vehicular communications~~ should not incur usage costs to vehicle owners, vehicle occupants, and road users~~. It is tempting for developers and operators of vehicular communications systems that are not safety of life to use safety-of-life radio spectrum because it is ‘free’.

n. *Penetration.* SomePenetration. Many vehicular communications applications only work well if there isonly when a significantsubstantial number of vehicles with the vehicular communications equipment.devices are deployed. Ways mustshould be found to createachieve substantial, fast rollouts and rapid deployment of in-vehicle communications capabilitiesdevices in the road transport infrastructure or vehicles.

o. *VRU awareness:* VRUs can be detected, by (1) roadside sensors (and possibly forwarded by a collective perception service), 2) vehicle sensors (and possibly forwarded by a collective perception service), and (3) VRU communications. The devices.

Thereafter, awareness about VRUs can be communicated to all traffic participants. The detection and integration components of systems protecting VRUs should take into account the position accuracy, reliability, availability of data (independent of whether a mobile device is charged or switched on), etc. The information received from communications capabilities of VRUs are not controlled by vehicleshould supplement the vehicle´s safety systems for protecting VRUs.

p. *Interoperability:* Vehicles and road transport infrastructure components should be able to successful exchange data and share information and knowledge for common services.

q. *Backward compatibility:* As services and communications equipment manufacturers. Ways must be found to equip VRUs with equipment capable of reliably communicating to equippedtechnologies evolve, they should remain compatible with previously deployed vehicles and road transport infrastructure components using the same service.

r. *Harmonised services*: Triggering conditions and minimum key performance indicators (KPI) for senders and receivers of vehicular communications should be harmonised to provide effective communications-based services.

o.s. *Compliance assessment:* The minimum performance of communications systems and communicated information should be validated so that the required quality and timeliness of transmitted data is achieved for the communications services offered.