



Tele-operated Driving Use Cases

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5GAA ToD Work Item

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Driving Connected Mobility Forward

5GAA bridges the automotive and telecommunication industries in order to address society's connected mobility and road safety needs with applications such as automated driving, ubiquitous access to services, integration into intelligent transportation and traffic management



AUTOMOTIVE INDUSTRY

Vehicle Platform, Hardware
and Software Solutions



TELECOMMUNICATIONS

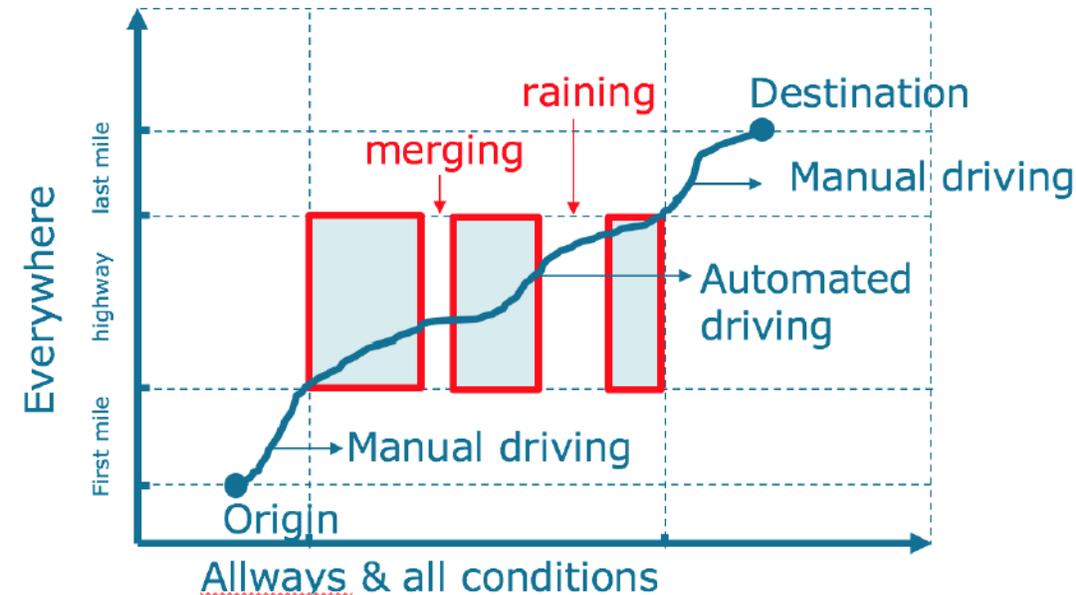
Connectivity and Networking
Systems, Devices and Technologies

5GAA unites today 133 members from around the world working together on all aspects of C-V2X including technology, standards, spectrum, policy, regulations, testing, security, business models and go-to-market

Tele-operated Driving (ToD) Service for Automated Vehicles

- **Tele-operated Driving:** Part or all of the dynamic driving task are performed by a remote driver on a sustained basis.

- **Operational Design Domain (ODD)*:** Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.



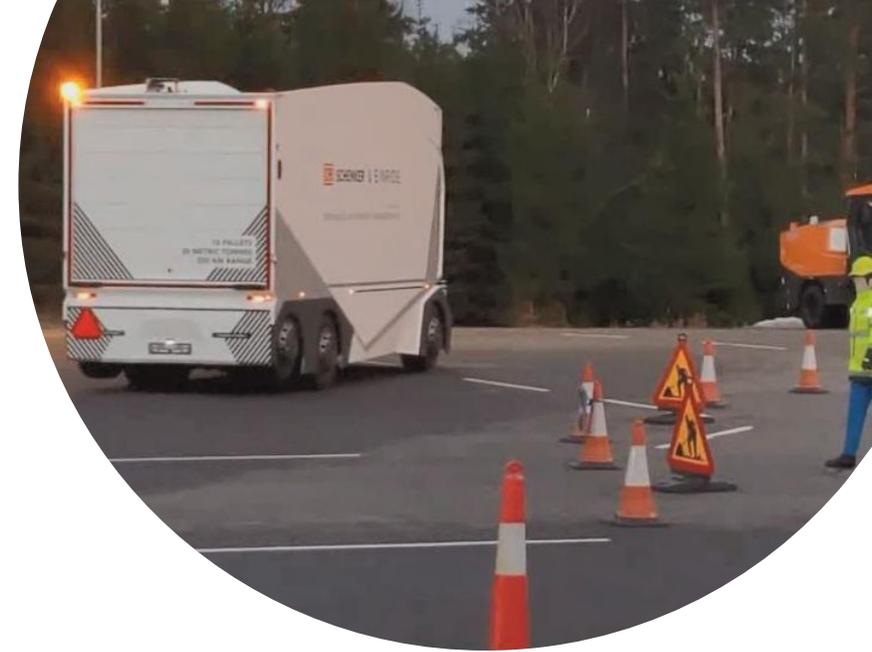
* Defined in SAE J3016, Jun 2018

Tom Alkim, Rijkswaterstaat, 2017

Tele-operated Driving (ToD) Service for Automated Vehicles

Why ToD?

- **Functional consideration:** one way to provide fallback for automated driving system (ADS) failure* or operational design domain (ODD) exit* of Autonomous Vehicles (AVs)
- **Economic consideration:** allocate one driver to more than one vehicles; decouple physical presence of driver and vehicle;
- **Legal consideration:** part of the legal framework for testing and deploying AVs on public roads in some regions, e.g. U.S. CA, DMV, [13 CCR § 228.06](#)
- **And more ...** e.g. logistics at sea-ports, saving parking space, road traffic efficiency



5GCroCO 5GMOBIX 5GConnectedMobility Phantom Auto Starsky Robotics Designated Driver

Photos source: Ericsson, Einride, Telia, DB Schenker
<https://www.youtube.com/watch?v=mWu53vAdtYE>

* Defined in SAE J3016, Jun 2018

Types of Tele-Operated Driving

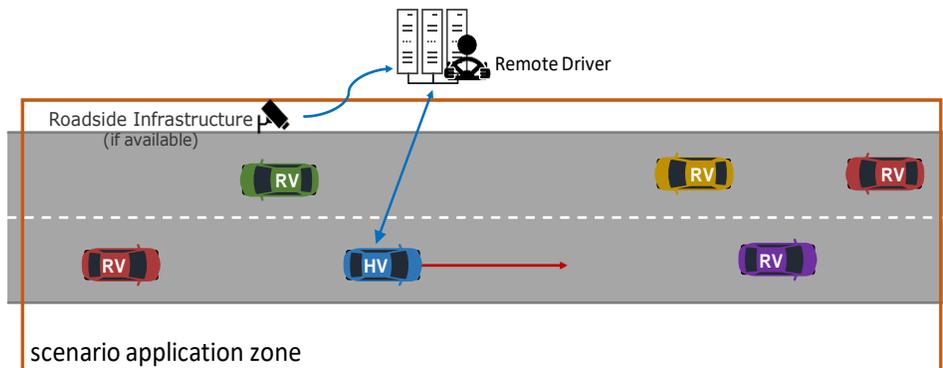
Based on the role of the remote operator when engaging in the act of driving:

- **ToD Type 0:** role of Monitoring, i.e. no role in the act of driving.
- **ToD Type 1:** role of Dispatcher, strategic level operations of driving.
- **ToD Type 2:** role of Indirect Controller, strategic and tactical levels.
- **ToD Type 3:** role of Direct Controller, strategic, tactical and operational levels. (In this case, the in-vehicle user or system is not engaged in the act of driving.)

ToD Type (Role of ToD operator when engaging in the act of driving)	Act of Driving		
	Strategic Operation (Travel planning, route and itinerary selection)	Dynamic Driving Task (DDT)	
		Tactical Operation (Object and Event Detection and Response OEDR)	Operational Operation (Sustained lateral and longitudinal vehicle motion control)
0 (No Role)	In-vehicle user or system	In-vehicle user or system	In-vehicle user or system
1 (Dispatcher)	ToD operator	In-vehicle user or system	In-vehicle user or system
2 (Indirect Controller)	ToD operator	ToD operator	In-vehicle user or system
3 (Direct Controller)	ToD operator	ToD operator	ToD operator

Example ToD Use Case: Tele-operated Driving Support

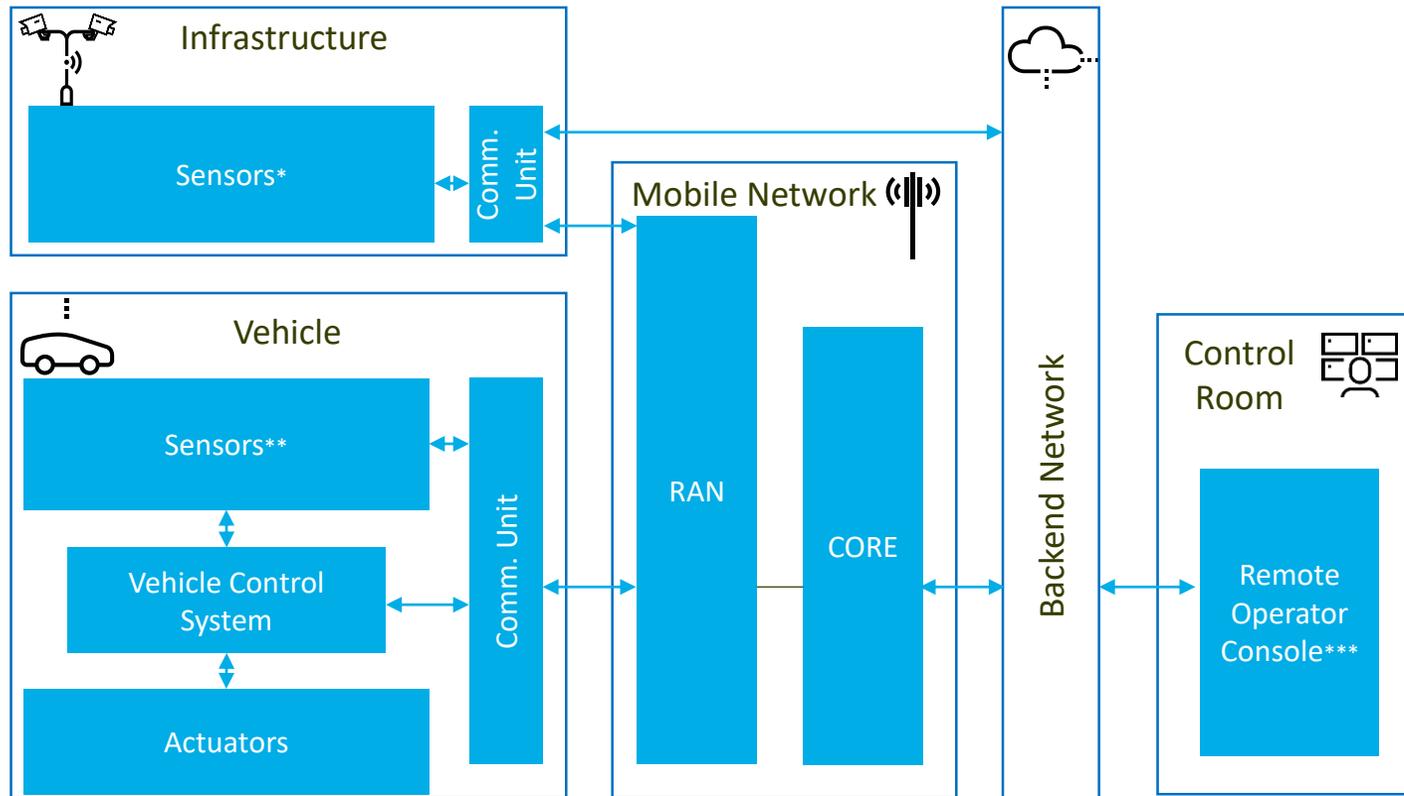
- ToD service for a short period of time when the automated vehicle faces a situation where uncertainty is high for the decision making



- Two user stories
 - I: ToD Type 2 (Indirect Control): trajectory or instructions for driving
 - II: ToD Type 3 (Direct Control): remote steering
- Typical scenarios
 - Confined areas
 - Predetermined routes



Architecture and event flow



*Infrastructure sensors: Video, audio, etc.

**Vehicle sensors: Video camera, Radar, Lidar, ultrasonic, audio, positioning, etc.

***Remote Operator Console incl. at least HMI, remote control rig, remote driver

DL: downlink, i.e. remote operator to vehicle

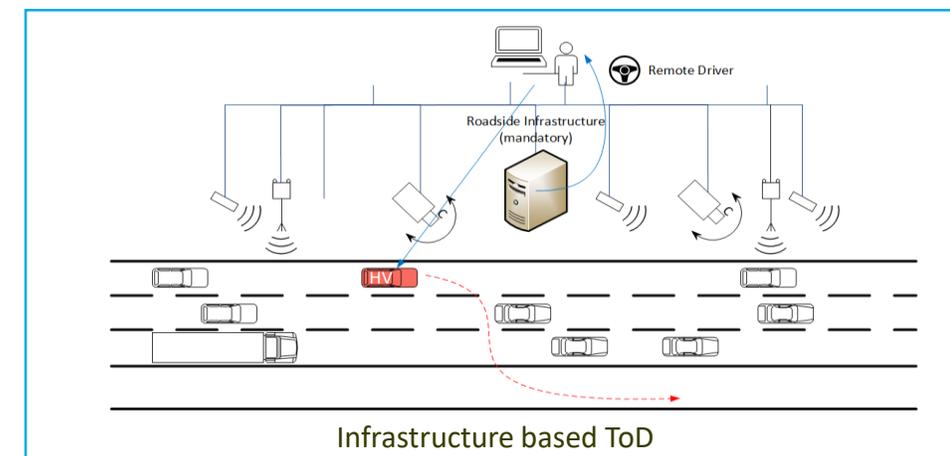
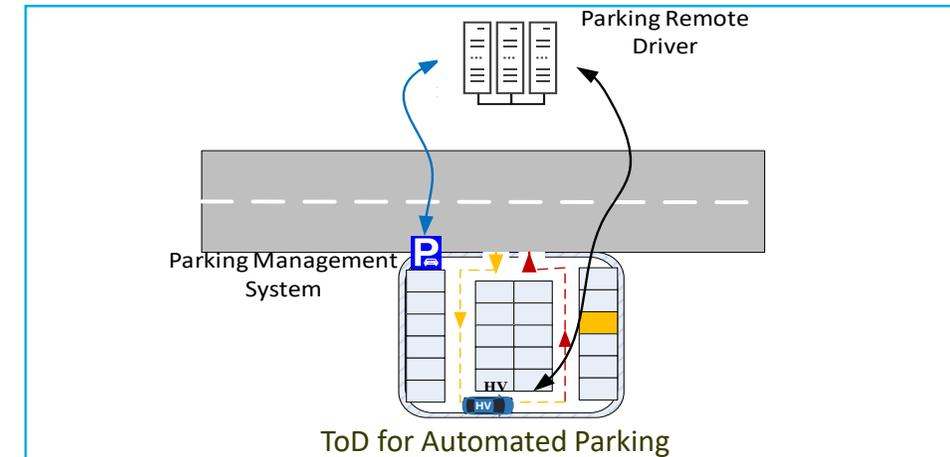
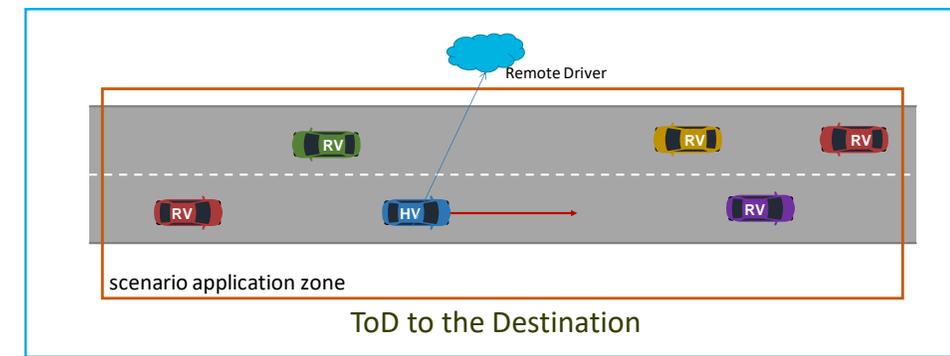
UL: uplink, i.e. vehicle to remote operator

† 5GAA White Paper, C-V2X Use Cases Volume II: Examples and Service Level Requirements, Oct. 2020 ([URL](#))

- Event Flow (after establishing an authenticated and secure communication channel between the vehicle and the remote operator)
 - The vehicle provides high-quality video streams and its status information (e.g. speed, location, destination)
 - If available, secondary information from road infrastructure is accessed to obtain a more holistic view of the situation
 - The remote driver analyses the situation and selects the appropriate trajectory and/or the manoeuvre instructions that will help the HV to resolve the corresponding situation where the uncertainty is high
 - The remote driver sends to the vehicle trajectory and/or manoeuvre instructions, which are executed according to the vehicle's on-board security checks
- Typical comm. performance requirements (vehicle speed < 50 km/h)[†]
 - Service level latency:
 - Type 3: 100 ms UL + 20 ms DL
 - Type 2: 100 ms UL + 200 ms DL
 - Data rate UL: 36 Mb/s (Video + Objects)
 - Data rate DL:
 - Type 3: 400 kb/s
 - Type 2: 25 kb/s
 - Reliability
 - UL: 99%, DL: 99.999%

Other ToD Use Cases

- Tele-operated Driving to the Destination
 - A remote driver takes control of the vehicle and drives it in an efficient and safe manner, from the current location to the destination, when for example the local driver has a temporary health issue.
- Tele-operated Driving for Automated Parking
 - Enables vehicle parking using remote driving without the presence of the passengers.
- Infrastructure based Tele-Operated Driving
 - Enables the remote driver to support the vehicle remotely in the absence of sensor data from the vehicle itself, by relying on sensors at the infrastructure.



Tele-operated Driving Services and Video Quality

- Video quality and latency are critical for ToD with a human remote operator.
- A common understanding on the relation between video quality (quality of experience) and ToD performance seems missing.
- Different types of ToD services may have different requirements on video quality.
- Environments and speed of vehicles also influence the requirements.
- Network conditions need to be considered.





Thank you!