References
Obergfell, P. *et al.*, *"Model-based resource analysis and synthesis of service-oriented automotive software architectures."* in ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (MODELS), 2019.
Cebotari, V. *et al.*, *"Playground for Early Automotive Service Architecture Design and Evaluation."* in IEEE Intelligent Vehicles Symposium (IV), 2020.
Kugele, S *et al.*, "*On service-orientation for automotive software*" in IEEE International Conference on Software Architecture (ICSA), 2017.
Rotermund, R. *et al.*, *"Requirements analysis and performance evaluation of SDN controllers for automotive use cases."* in IEEE Vehicular Networking Conference (VNC), 2020.
Mody, M. *et al.*, *"Understanding vehicle e/e architecture topologies for automated driving: System partitioning and tradeoff parameters."* in Electronic Imaging, 2018.
Kostopoulos, A. *et al.*, *"Use cases and standardisation activities for eMBB and V2X scenarios"*, in IEEE International Conference on Communications Workshops (ICC Workshops), 2020.
R. Grave , "Cloud vs. embedded: where does the function belong?" in Automotive Computing Conference (ACC), 2021.
Cakir, M. *et al.*, (2019, December). *"A QoS aware approach to service-oriented communication in future automotive networks."*, in IEEE Vehicular Networking Conference (VNC), 2019.
Llatser, I. *et al.*, (2019, September). *"Cooperative automated driving use cases for 5G V2X communication"* in 5G World Forum (5GWF), 2019.
Saarinen, M., *"A Literature Review on Connected Vehicle Use Cases."*, 2020.

Benchmark covering objectives
- Have a good representation of the **different dynamicity levels, both from an update and an instanciation point of view**, within the car and car support infrastructures.
- Have a good representation of the **different criticalities** within the applications.
- Have a good representation of the **heterogeneous hardware requirements**.
- Have good representation of the **heterogeneity** with regards to the **communication patterns / actors involved and protocols**.
- Have good representation of the **legacy highly coupled (HW / SW / NW) and the new IT-like stateless / flexible services**
- Show the **possibilities of new techniques** such as virtualisation, shadow mode and delayed start **to enhance the on-board flexibility, adaptability & ressource efficiency**
- Give a **graphic representation of the inter-service dependencies** and the **system real-time dynamicity** possibilities

Definitions	
Update dynamicity	The periodicity with which it will be updated (monthly, weekly, yearly, never...)
Invocation dynamicity	The periodicity with which the function will be instanced (all time, wile parking, while on the highway, once a month...)
Reactivity	Time in which the service will respond a request
Sensor plug-ins / sensors needed	If the service needs to retrieve / be connected to a sensor for operating (because of delay or other contstraints)

Application Profiles Identified

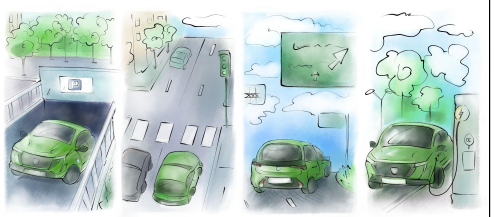
		Communication classification criteria								Hardware classification criteria						Software life-cycle classification criteria			
Profile	Sub-profile	Deadline	Reactivity	Data complexity	Data size	Communication pattern	Reliability	Protocol	Actors	Hardware coupling	CPU needs	RAM needs	ROM needs	Sensor plug-ins	Software complexity and size	Quantity	Dynamicity	Launch time	Delayed launching
Static Driving Real Time Services	Low complexity services (i.e., sensors, actuators...)	Hard	Few μs to *ms*	Low (simple values)	Low	Periodic	Exactly once	Signal based	Inter-vehicle	High	Low	Low	Low / None	Yes	Low	Several	Static	< 100ms	No
	High complexity services (i.e., ADAS, control services, image recon...)			Medium / High	Low / Medium / High			IP based	Inter-vehicle (might use cloud support)	Medium / High	High	High	Low (cache)	Possible	High	A Score (~ 20)	OTA-Dynamic		
Collaborative Services (V2X / V2V / V2L / V2G)	Real time dynamic collaborative services (i.e. shared driving)	Hard	1-10ms	Low / Medium	Low	Periodic (changes dynamically)	At least once	IP based	Intra-vehicles and infrastructure	Low	Low / Medium	Low/Medium	Low	Possible	Low	Many	Highly dynamic	< 20 - 100 ms	No
	Not time constrained services (i. e., logging, GNSS optimization...)		10-250ms	Low / High	Medium / High	Event-driven								No		Few	Dynamic	< 500 ms	Possible
HMI / Infotainment / Logging services	In vehicle comfort services	Soft / Medium	100-250ms	Low	Low	Sporadic	At most once for streaming / Exactly once others	Signal-based	Inter-vehicle	High	Low	Low	Low	Yes	Low	Many	Static	< 300 ms	Possible
	Infotainment / Navigation services / Business services			High	High	Periodic / Bursts		IP-based	Vehicle and cloud	Medium (sceen needed)	High (unless GPU)	High (unless GPU)	High	Rare	High	A Score (~ 20)	OTA-Dynamic		
	Logging services			Medium / High	Medium / High	Periodic				Low	Medium	Medium	High	No	Medium	Few	Static		No
Remote services (V2C)	Cloud offloaded services (i.e., inter-software dependency calculation...)	Soft	Many seconds	Medium	Medium / High	Sporadic	At least once / Exactly once	IP-based	Vehicle to cloud	Low	Medium	Low	Low	No	Low	Few	Dynamic	< 300 ms	Possible
	Cloud Triggered services (i.e., telediagnosis)								Cloud to vehicle		Medium / High	Medium	Low / Medium / High	Possible			OTA-Dynamic	< 200 ms	

Applications selected for the benchmark (comming from litterature) classified by *"business domain"*

						Use case scenario			
Category	Definition	Service name	Service task description	Profile	Sub-profile	A	B	C	D
Actuators	Control the on-board actionable peripherals.	Motor Air system controller service	Service in charge of managign the motor air actuator.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Fuel system controller service	Service in charge of managing the fuel actuator	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Ignition system controller service	Service in charge of managing the ignition actuator	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Interior light actuator service	Service in charge of the cockpit lights actuator.	Static Driving Real Time Services	Low complexity services	Yes	No	No	No
		Mirror joystick actuator service	Service in charge of the mirror joystick actuators.	Static Driving Real Time Services	Low complexity services	Yes	No	No	No
		Brake controller (front left, front right...) service	Service in charge of the brake actuator.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
Sensor data gathering service	Product the vehicle data	Brightness provider collection service	Service in charge of measuring the env brigtness.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Camera (rear, front, sides, down...) collection services	Service in charge of retrieving / pre-treating the camera output	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Lidar collection service	Service in charge of treating lidar output.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Motor status smartsensor (air, fuel, ignition, temperature/rpm...) service	Service in charge of retrieving the different motor sensor data.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Hands on the steering wheel sensor collection service	Service in charge of detecting if the driver has or not the hands on the steering wheel.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Seat passenger sensor service	Service in charge of detecting if a seat is occupied or not	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Seat belt sensor	Service in charge of detecting if the seat belts are plugged.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Radar	Service in charge of retrieving the radar output.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Tire pressure monitoring	Service in charge of monitoring if the tire pressure is within acceptable ranges.	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	No
		Data fusion service	Service in charge of putting together multiple sensor data to ease their posterior use.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Door (side and rear) status sensors	Service in charge of monitoring if the door is correctly closed	Static Driving Real Time Services	Low complexity services	Yes	Yes	Yes	Yes
		Blind spot monitoring service	Involves cameras that monitor the driver's blind spots and notify the driver if any obstacles come close to the vehicle.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
Basic ADAS	Help but do not substitue the driver	Driver drowsiness detection	Aims to prevent collisions due to driver fatigue	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Driver monitoring system	Monitores the alertness of the driver.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Forward collision warning	Monitores the speed of the vehicle and the vehicle in front of it, and the open distance around the vehicle.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Intelligent speed adaptation	Assists drivers with compliance to the speed limit.	Static Driving Real Time Services	High complexity services	No	Yes	Yes	No
		Intersection assistants	Uses two radar sensors in the front bumper and sides of the car to monitor if there are any oncoming cars at intersections, highway exits, or car parks.	Static Driving Real Time Services	High complexity services	No	Yes	No	No
		Lane departure warning system (LDW)	Alerts the driver when they partially merge into a lane without using their turn signals	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Parking sensors	Scan the vehicle's surroundings for objects when the driver initiates parking.	Static Driving Real Time Services	High complexity services	Yes	No	No	No
		Pedestrian protection systems	Minimize the number of crashes or injuries that occur between a vehicle and a pedestrian.	Static Driving Real Time Services	High complexity services	Yes	Yes	No	No
		Lane change assistance	Helps the driver through a safe completion of a lane change by using sensors to scan the vehicle's surroundings and monitor the driver's blind spots.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Automotive head-up display (auto-HUD)	Safely displays essential system information to a driver at a vantage point that does not require the driver to look down or away from the road.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Automotive night vision systems	Enable the vehicle to detect obstacles, including pedestrians, in a nighttime setting or heavy weather situation when the driver has low visibility.	Static Driving Real Time Services	High complexity services	Yes	No	No	No

Useful links	
Limit CPU usage in LXC	https://www.jamescoyle.net/how-to/2532-setting-cpu-resource-limits-with-lxc
Limit Memory usage in LXC	https://bobcares.com/blog/lxc-container-memory-usage/
Dependency graph	https://drive.google.com/file/d/1ACSoQmoHvGjQ8hF7benjvOE_xLkcgr8/view?usp=sharing

Use-case scenario (A-B-C-D)



A	Vehicle (issued from a renting website) going out from parking lot
B	Vehicle getting into an intersection
C	Vehicle integrating the beltway
D	Vehicle (electric) parked and recharging his battery

		Omniview technology	Improves a driver's visibility by offering a 360-degree viewing system.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Cruise control	Maintain a specific speed pre-determined by the driver.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Traffic sign recognition (TSR)	Systems can recognize common traffic signs, such as a "stop" sign or a "turn ahead" sign, through image processing techniques.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Object collision detection	Detects when another car / pedestrian / object is goingto collide with the car, warning the passengers.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		GPS / GNSS	Service in charge of assisting the drivier with maps and itinerary calculation tools.	HMI / Infotainment / Logging services	Infotainment / Navigation services / Business services	No	Yes	Yes	No
		Trajectory calculation service	Calculates the trajectory of the vehicle and warns if the trajectory might be a danger for the passengers.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Wrong-way driving warning	Issues alerts to drivers when it is detected that they are on the wrong side of the road.	Static Driving Real Time Services	High complexity services	No	Yes	Yes	No
Enhanced ADAS	Partially or fully substitute the driver	Adaptive cruise control (ACC)	Maintain a chosen velocity and distance between a vehicle and the vehicle ahead.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Anti-lock braking system (ABS)	Restore traction to a car's tires by regulating the brake pressure when the vehicle begins to skid.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Automatic parking fully	Takes over control of parking functions, including steering, braking, and acceleration, to assist drivers in parking.	Static Driving Real Time Services	High complexity services	Yes	No	No	No
		Collision avoidance system (pre-crash system)	Uses small radar detectors, typically placed near the front of the car, to determine the car's vicinity to nearby obstacles and notify the driver of potential car crash situations.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Crosswind stabilization	Helps prevent a vehicle from overturning when strong winds hit its side by analyzing the vehicle's yaw rate, steering angle, lateral acceleration, and velocity sensors.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Electronic stability control (ESC)	Lessen the speed of the car and activate individual brakes to prevent understeer and oversteer.	Static Driving Real Time Services	High complexity services	No	Yes	Yes	No
		Emergency driver assistant	Facilitates emergency counteract measures if the driver falls asleep or does not perform any driving action after a defined length of time.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Hill descent control	Helps drivers maintain a safe speed when driving down a hill or other decline.	Static Driving Real Time Services	High complexity services	No	Yes	Yes	No
		Hill-start assist	Helps prevent a vehicle from rolling backward down a hill when starting again from a stopped position.	Static Driving Real Time Services	High complexity services	Yes	No	No	No
		Lane centering	Assists the driver in keeping the vehicle centered in a lane.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Traction control system (TCS)	Helps prevent traction loss in vehicles and prevent vehicle turnover on sharp curves and turns.	Static Driving Real Time Services	High complexity services	No	No	Yes	No
		Full autonomous driving service	Fully pilots the vehicle without driver interaction.	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	No
		Rain sensors	Detect water and automatically trigger electrical actions, such as the raising of open windows and the closing of open convertible tops.	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	Yes	Yes	Yes
V2V / V2X / Collaborative driving	Services used to coordinate a vehicle with the other vehicles and/or the infrastructure	Indoor Positioning	Service that collaboratively offers navigating within building premises.	Collaborative Services (V2X / V2V / V2L / V2G)	Real time dynamic collaborative services	Yes	No	No	No
		Green Light Optimal Speed Advisory	Informs drivers about the speed that needs to be sustained to reach an upcoming traffic light in green status to prevent speed limits violations, improve fuel efficiency and reduce pollution.	Collaborative Services (V2X / V2V / V2L / V2G)	Real time dynamic collaborative services	No	Yes	No	No
		Collective Perception Service / Collective awareness	Allows cars to infrom nearby vehicles of objects measured by their own on-board sensors.	Collaborative Services (V2X / V2V / V2L / V2G)	Real time dynamic collaborative services	Yes	Yes	Yes	No
		Coopertive maneuver coordination service	Cooperation with nearby vehicles to coordinate who passes first, their speed, trayectory...	Collaborative Services (V2X / V2V / V2L / V2G)	Real time dynamic collaborative services	No	Yes	Yes	No
		Collaborative logging forwarding	Forwards logs to the nearest edge computing station car by car	Collaborative Services (V2X / V2V / V2L / V2G)	Not time constrained services	No	No	Yes	No
		Connected Lane Merge	Coordination withing vehicles when merging 2 or more lanes	Collaborative Services (V2X / V2V / V2L / V2G)	Real time dynamic collaborative services	No	No	Yes	No
V2C / Remote services	Services involving distant / cloud interactions	Tele-diagnosis	Operates test & analyzes data remotely to prevent major component errors	Remote services (V2C)	Cloud Triggered services	No	No	No	Yes
		Remote updating of vehicle	Remotely updates the in-vehicle software blocks	Remote services (V2C)	Cloud Triggered services	No	No	No	Yes
		Data collection	Big-data / data collection / distant log collection / log cons. energetique / logs reglementaires	Remote services (V2C)	Cloud Triggered services	Yes	Yes	Yes	Yes
		Collision monitoring and alerting	Alerts the security services in case of collision	Remote services (V2C)	Cloud offloaded services	No	No	Yes	No
		Driving assist system with digital twin	Driving assisting based on augmented reality support.	Remote services (V2C)	Cloud offloaded services	Yes	Yes	Yes	No
		Remote controlling of a vehicle	Remote control of a vehicle from the cloud (fleet control, taxis...)	Remote services (V2C)	Cloud offloaded services	No	Yes (vehicles around)	Yes (vehicles around)	No
		Battery usage optimization	Software to optimise the battery usage by changing the configuration of the vehicle.	Remote services (V2C)	Cloud offloaded services	No	No	No	Yes
Multimedia	Video / audio related services	Cloud-Assisted AR/VR	Cloud-assisted Augmented Reality enables users to stream video games or virtual contents from cloud servers like other streaming media.	Remote services (V2C)	Cloud offloaded services	No	No	No	Yes
		Video streaming enetertainment (netflix...)	Stream media	Remote services (V2C)	Cloud offloaded services	No	No	No	Yes
		Audio streaming entertainment (spotify...)	Stream media	Remote services (V2C)	Cloud offloaded services	Yes	Yes	Yes	Yes
		UI personalisation	Full personalisation of the central screen, the driving HUD or even the exterior in the future.	HMI / Infotainment / Logging services	Infotainment / Navigation services / Business services	Yes	Yes	Yes	Yes
On-board control services	System control services	Central state management	Manages the state of the vehicle (drivig, parked...)	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Central vehicle storage	Handles the storage of global variables	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Global scheduling service	Handles the orchestration of services & load balance	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		In-vehicle Network management service	Handles the network configuration	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Communication abstraction service	Handles the abstraction service - component to enhance the system reusability	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Service registry	Handles the service discovery mechanism	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Installation service	Handles the service installation	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Global in-vehicle log collection service	Handles the log collection	HMI / Infotainment / Logging services	Logging services	Yes	Yes	Yes	Yes
		Service health monitoring / self-repair service	Handles the monitoring and repairing of the services deployed	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Access manager (IAM) service	Handles the access of the different VMs	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Centralised Sécurity Management service	Handles the security of both network and software	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Global time synchronization service	Handles the single time sync within the different vehicle components	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
		Global car configuration service	Handles other configurations needed to be spread among a set of services	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes
Passenger Comfort	Cockpit confort services	Air conditioner service	Handles air conditioner	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	Yes	Yes	No
		Cabin heating service	Handles heater	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	Yes	Yes	No
		Car-seat heating service	Handles car-seat heater	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	Yes	Yes	No
		Mirror position service	Handles mirrors	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	No	No	Yes
		Steering wheel position service	Handles the steering wheel position	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	No	No	Yes
		Interior light handler	Handles interior lights	HMI / Infotainment / Logging services	In vehicle comfort services	Yes	No	No	No
High level business products / services	Services that companies can sell afterwards	Vehicle leasing	Handles vehicle leasing / profiles	HMI / Infotainment / Logging services	Infotainment / Navigation services / Business services	Yes	No	No	Yes
		Insurance tracking	Handles insurance tracking for a determined passenger	HMI / Infotainment / Logging services	Infotainment / Navigation services / Business services	Yes	Yes	Yes	Yes
		Eye Gaze HMI Control	Handles how to interact with the HMI with the movement of the eyes	HMI / Infotainment / Logging services	Infotainment / Navigation services / Business services	Yes	Yes	Yes	No
		Driverless-taxi controller / fleet management service	Handles the fleet management and organisation of a driverless taxi fleet	Static Driving Real Time Services	High complexity services	No	Yes (vehicles around)	Yes (vehicles around)	No

			Multi-driver recognition / adaptation service	Handles the adaption of the vehicle configuration to a previously defined driver configuration after reconigsing him	HMI / Infotainment / Logging services	Infotainment / Navigation services / Business services	Yes	No	No	No													
	Telematics	External communication services	Surrounding network detection	Detects the networks active around	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes													
			Intelligent network technology switch	Detects which technology to use to talk to a certain device by considering the channel noise, energy efficiency, the vehicle preferences, the service needs...	Static Driving Real Time Services	High complexity services	Yes	Yes	Yes	Yes													