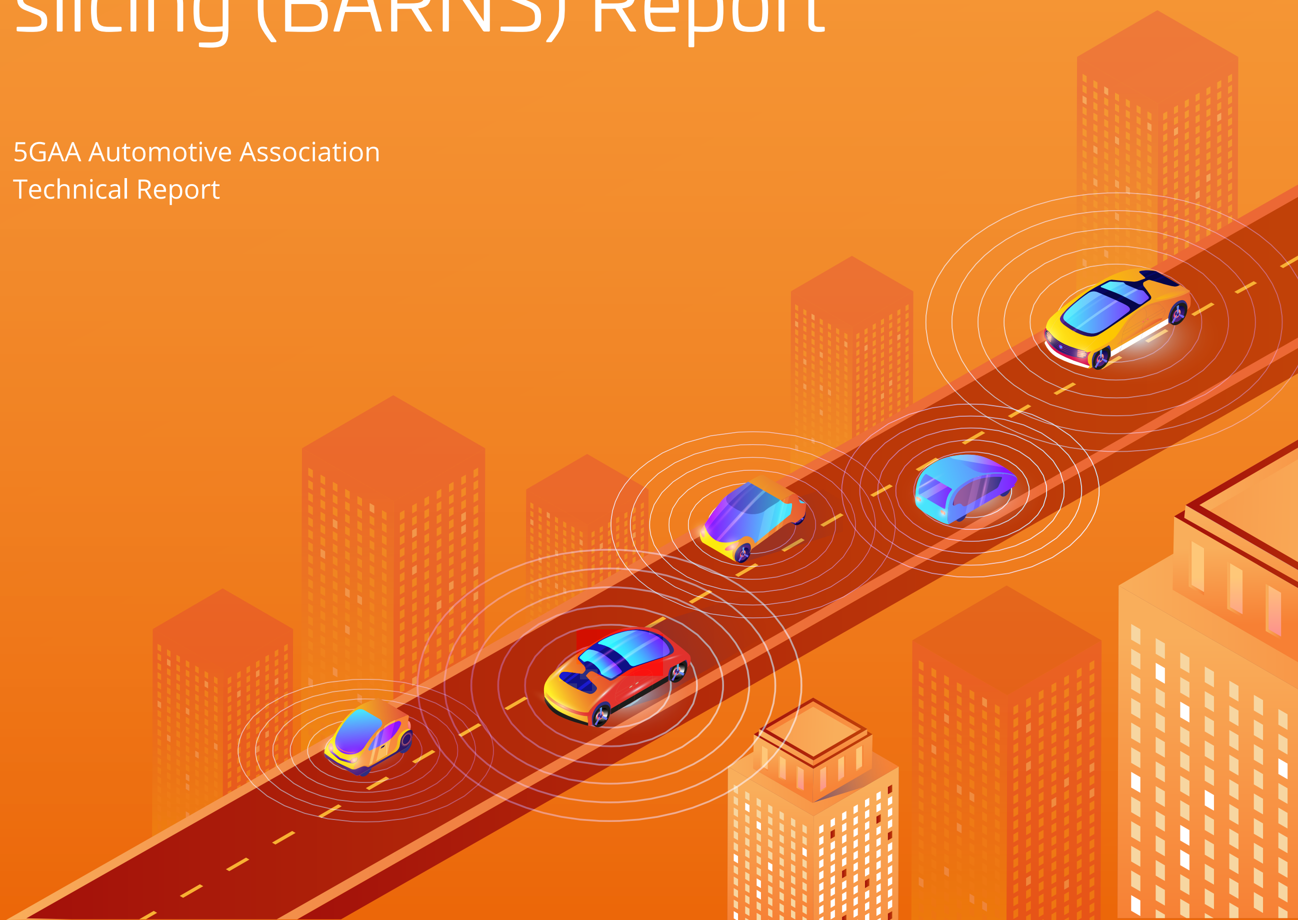
Business Aspects and Requirements of 5G Network slicing (BARNS) Report

5GAA Automotive Association
Technical Report



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Introduction

5G will help vertical industries to achieve the ‘internet of everything’ vision of ubiquitously connected, highly reliable, ultra-low latency services for a massive number of terminals. Network slicing is considered as one of the key features for 5G allowing in particular to support the different needs of various vertical industries, including the automotive industry. Network slicing is a concept for running multiple logical networks (which could be customised and provided with guaranteed Service Level Agreements, SLAs) as virtually independent business operations on common physical infrastructure.

The requirements for network slicing have been described by the 3GPP[1] and NGMN[2], while the corresponding technical specification to enable network slicing in 5G architecture design has been driven by the 3GPP[34]. Network slicing is a neat concept to achieve the above-mentioned vision. The fundamental 5G system architecture and associated key technology components to enable network slicing are maturing. In order to apply such system support to automotive industry services, it is not only essential to understand what are the specific features and requirements desired by the automotive sector, but also to understand what is the business logic behind these in order to guarantee future success.

In general, network slicing could be used to satisfy three types of requirements from the automotive industry customers (which are also called ‘network slicing tenants’):

- Performance requirements: one of the fundamental features of the mobile network is to provide Quality of Service (QoS) for network service differentiation purposes, which can be considered as the fulfilment of a set of pre-defined Key Performance Indicators (KPIs), such as network coverage, data throughput, and latency.
- Functional requirements: this refers to network service provisioning customisation.
- Operational requirements: this implies requirements like self-management of resources, policies, etc.

To limit the scope of this work, it will initially focus on the very basic functions of a mobile network, which are to provide coverage, throughput and latency for data transmission between the vehicle (UE) and a backend infrastructure (i.e. mobile networks) using the network slicing approach. In further steps, the scope of this work shall be extended from how to use network slicing to tackle the additional functional and operational requirements from automotive industry and their business implications.

1 Scope

The scope of this 5GAA work item is to:

- Jointly define and analyse the automotive use case requirements in terms of QoS that is provided using network slicing.
- Analyse the business value for the automotive industry of using network slicing.
- Adopt existing definition of network slicing (i.e. from 3GPP), and identify the specific features that are required to support the automotive use cases that cover the Internet of Things (IoT), mobile broadband services, etc. Such slices will tackle the performance requirements associated to the automotive use cases.
- Define all the potential business roles that may exist or emerge in 5G era due to the cooperation among the telecommunication, third-party service provider, and automotive industries.
- Define the business models, pricing schemes (CAPEX and OPEX), and value proposition for the performance and functional features associated with the automotive use cases.
- Map business requirements and models with relevant technical solutions.
- Provide input to relevant Standards Developing Organisations (SDOs) for KPI definition, measurement methods, etc., as well as the method explaining how to specify, achieve and ensure QoS in mobile networks:
    - Notify actual achievable KPIs via an API
    - Notify of actual achievable KPIs and their prediction via an API
    - Active control of network behaviour to guarantee a UE a requested KPI (with probabilities), which is requested via an API, etc.
- Define the next steps for additional topics such as functional requirements and operational requirements.

2 Network Slicing

2.1 Networking Slicing Concept

5G end to end network slicing is a concept for running multiple logical networks (which could be customised with a guaranteed SLA) as virtually independent business operations on a common physical network infrastructure. The technology enabling network slicing is transparent to business customers for whom 5G networks, in combination with network slicing, allow connectivity and data processing tailored to the specific business requirements.

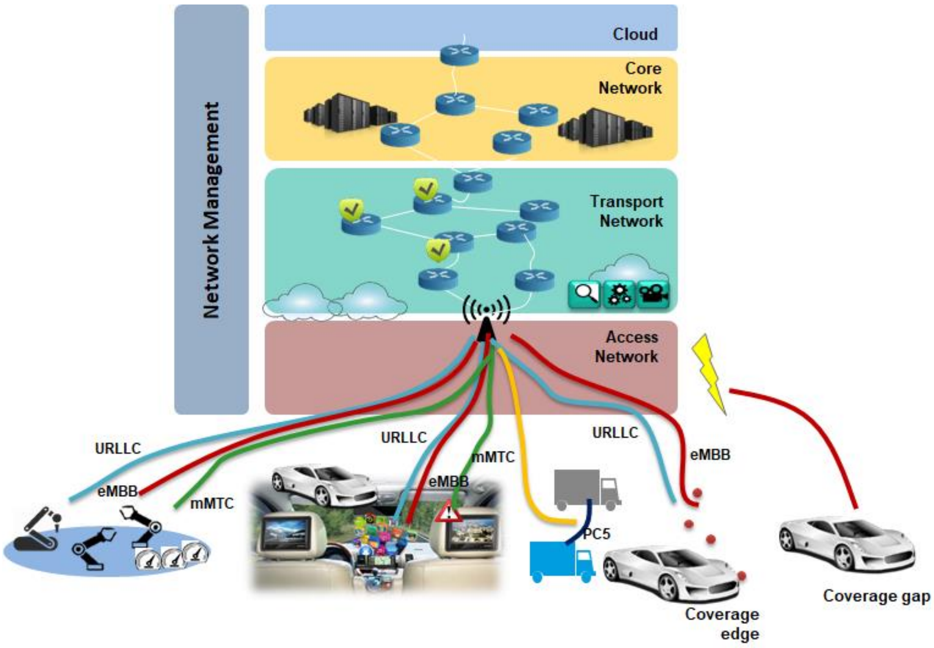


Figure 1 Logical Diagram of Network Slices

The **customisable network capabilities** include data speed, quality, latency, reliability, security, and services. These capabilities are always provided according to a Service Level Agreement between the mobile operator and the business customer. Guaranteed performance will support various automotive use cases: platooning, see-through, etc. Moreover, the ‘global slicing’ feature will address cross-operator/country business.

Being different from the dedicated network solution that uses physically isolated and static networks to support tenants, network slicing promotes the use of a common infrastructure among industrial customers from the same operator. Such design is beneficial for long-term technology evolution as well as for shaping a healthy industry ecosystem with high resource usage efficiency. The overall architecture supports the isolation of network slices, including resource isolation, observations and measurements (O&M) isolation, and security isolation. Network slices can be either physically or logically isolated at different levels[5].

2.2 Network Slicing Regulation Aspect

In the future, one single physical infrastructure will be able to perform different tasks based on various network slices on top of the ‘public internet access slice’. It is our understanding that net neutrality rules shall naturally apply to the ‘public internet access slice’ while for the dedicated purpose-built network slices, special rules apply based on commercial agreements.

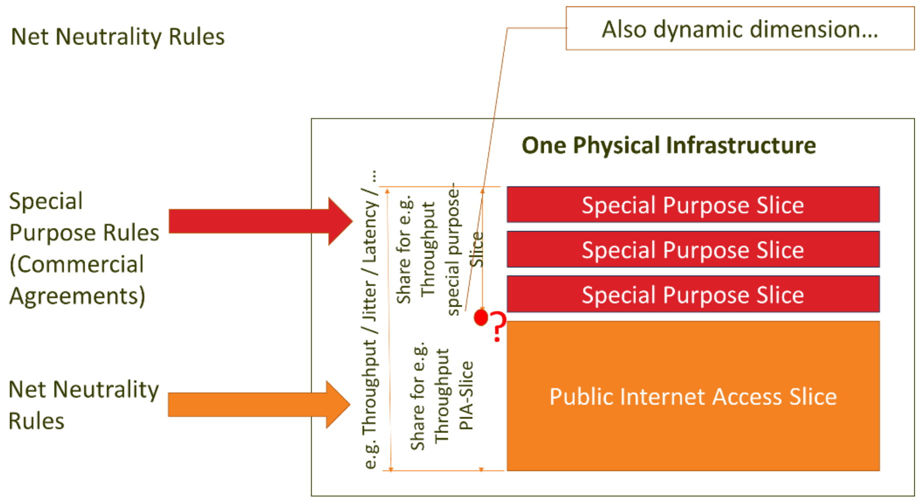


Figure 2 Net Neutrality Rules and Special Purpose Rules

At present, there does not seem to be new regulatory challenges as a result of network slicing. However, the challenge(s) may be on how best to meet existing regulatory obligations as a result of network slicing. Essentially, the Public Internet Access Slice shown in the diagram (in orange) should not reduce due to special purpose slices.

As the net neutrality debate has evolved, policy makers and industry bodies have come to accept that network management plays an important role in service quality.

For example, the GSMA Industry position on network slicing outlines that[6]:

• To meet the varying needs of consumers, mobile network operators need the ability to actively manage network traffic and the flexibility to differentiate between different types of traffic.

• Regulation that affects network operators' handling of mobile traffic is not required. Any regulation that limits their flexibility to manage network, service quality and provide consumers with a satisfactory experience is inherently counterproductive.

3 Automotive Use Case Analysis

3.1 Use Case Prioritisation

The existing definition of network slicing (i.e. from 3GPP) was adopted, and 5GAA work instructions identified the specific features required to support the automotive use cases covering IoT, mobile broadband services, etc. Such slices will tackle the performance requirements associated with the automotive use cases.

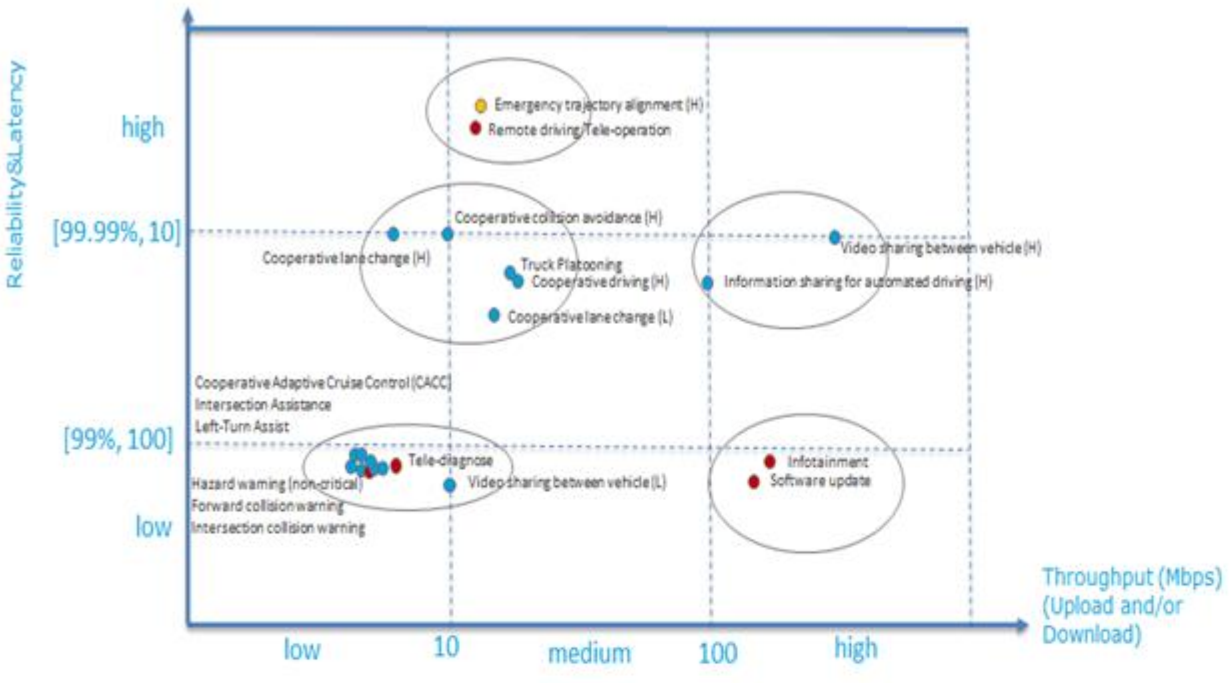


Figure 3 Use Case Assessment Matrix

Figure 3 shows the use case landscape mapping as Throughput vs Reliability/Latency.

Within the WG5 members' discussion on use case, prioritisation occurred within the TEC TF work instruction.

Four priority use cases were selected from by WG5 members for the BARNS assessment, namely:

1. Real-time situational awareness and HD map (RTSA & HD)
2. Software over the air updates (SOTA)
3. Tele-operated driving (TOD)
4. Platooning

The initial assessment matrix of Throughput vs Reliability/Latency moved to a more detailed assessment of seven KPIs per use case, to match the user stories described in the next section.

3.2 Use Case Analysis Methodology

5GAA Working Group 1 and Working Group 5 jointly worked on harmonising the requirements for each use case.

This required a methodology for aligning the WG1 Service Level Requirement (SLR) and WG5 network slicing KPI which includes user story alignment and justification for KPIs based on SLR input.

In order to reach a better understanding of the use cases in terms of performance requirements for network slicing, a spider graph with seven KPIs has been defined in this study. The parameters are defined as following:

- **E2E latency**: this parameter characterises the **network-level latency requirement** between the terminal and its communication end point. E2E latency parameter range from 1 millisecond (ms) to 10 seconds (s). If a service does not have any requirements in terms of latency, or could even tolerant a delay (e.g. a software update that could be completed within one week, for example), it is then specified as being delay tolerant (DT).
- **Reliability**: this parameter specifies the network-level reliability requirements between the terminal and its communication end point, which could be measured as the packet data transmission success rate between the terminal and its communication end point in a given time frame. It ranges between best effort and 99.999%.
- **Downlink/uplink speed**: these parameters specify the data rate for downlink and uplink correspondingly. It ranges from few kbps to 1 Gbps or higher.
- **Data volume:** this parameter represents the total amount of data traffic needed to provide a given service. It ranges from few KB to several GB. For example, if a vehicle is benefiting from a tele-operated driving service, the data volume will be the total amount of traffic generated by the uplink video streaming from the local vehicle, the sensor data traffic and the downlink vehicle control data traffic.
- **Use case frequency**: this parameter specifies how frequently a use case could be performed and may vary a lot from user to user due to different driving preferences, habits, etc. It ranges from 'once per second' to 'once per month'. Many services are event driven and identifying clearly the frequency of a specific event such as the detection of a pothole is very challenging. When we cannot get precise statistics about the frequency an event occurs, we kept 'event driven' as the reference value.
- **Local context**: when a service is provided to the end user, it may wish to know the local information/context about the vehicle. For instance, a car maintenance software update may be relevant at a country/region level (e.g. due to regional regulation specificities); a navigation service should be provided with a local context in the range of 20 km; finally, a tele-operated driving service would need to know the direct vicinity of a car, meaning a local context of 10 m.

For each parameter, seven levels are defined. **Error! Reference source not found.** gives an overview of the different values' ranges for each KPI parameter.

Figure 4 KPI Parameter and Corresponding Scales Used in the Use Case Analysis

Scale	E2E Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
0	Delay tolerant (DT)	Best effort (BE)	0	0	1kB	Event driven (several times per year)	Free of localisation (FL)
1	10s	90%	0.001	0.001	10kB	Once per month	Market region (MR)
2	1s	95%	1	1	1MB	Once per week	Country region (CR)
3	200ms	99%	10	10	10 MB	Once per day	Regional (20km)
4	100ms	99.9%	25	25	100 MB	Once per hour	Vicinity (10-400m)
5	10ms	99.99%	50	50	1 GB	Once per min	Position match (10m)
6	1ms	99.999%	50+	50+	10 GB+	Once per sec	Position match (<1m)

3.3 Selected Use Cases and SLR/KPI Alignment

The detailed uses case descriptions and use case families with BARNS scope are shown in Figure 5. The WG1 technical documents (T-docs) and WG5 business documents (B-docs) are also referenced.

Figure 5 WG1 and WG5 Document Alignment

BARNS Use Case Families	User Stories / sub-UC	WG1 T-Doc	WG5 B-Doc
Real Time Situation Awareness and High Definition Map	1.1 Hazard Warning Indication – Critical (Human, Machine)	T-180170	B-190079
	1.2.1 Hazard Warning Indication – Non Critical (Human, Machine)		
	1.2.2 Hazard Warning Indication - Traffic Jam Indication		
	1.3 HD Map update for CAD	T-180250	
SW Update	2.1 SW Update – Urgent	T- 180153	B-190027
	2.2 SW Update – Not Urgent		
Tele-Operated Driving	3.1 Tele-Operated Driving (ToD)	T-180205	B-180107
	3.2 Tele-Operated Support (ToS)	T-180206	
	3.3 Remote Driving for Automated Parking	T-180207	
High-Density Platooning	4. High-density Platooning – Steady State	T-190033	B-180068
WG1 / WG5	KPI / SLR Harmonisation document	B-190061	

3.3.1 Real-Time Situation Awareness and High-Definition Map

3.3.1.1 Hazard Warning – Critical

User story

5GAA WG1 reference technical document T-180170 – Real-Time Situational Awareness and High-Definition Maps 'HV only supported by RVs' user story

- This use case mainly refers to a real-time HD map update service. The HV is receiving information that is relevant for the road/route ahead from a backend, containing information that might allow the HV to adjust its route accordingly. The traffic management mentioned in 'Other Actors' roles could play a role here.

BARNS user story

- The host vehicle is warned of a fast approaching hazardous location.
- The 'Hazard Warning – Critical' use case family includes event-driven safety applications where the vehicle is approaching a hazardous location that is very close to the vehicle.
- There is a distinction in terms of latency depending on whether it involves an automated driving case or human-machine interaction. As in WG1, WG5 BARNS estimated that a latency of 100ms is acceptable in the case of human-machine interaction, while the latency is around 10ms in the case of automated driving. This chapter will analyse selected use cases human-machine interface and associated network slices.

Justifications of BARNS 'Hazard Warning – Critical' user story KPIs

- E2E latency = 100ms (network-level latency)
  - Driving at 120km/h, 300m (minimum communication range) will take just short of 10 s, so WG1 considered that 10 ms for the car to react should be enough.
  - There is a distinction in terms of latency depending on whether it is an automated driving case or human-machine interaction. As in WG1, WG5 BARNS estimated that a latency of 100ms is acceptable in the case of a human-machine interaction while the latency is around 10ms in the case

of automated driving. WG1 describes that information may need to be aggregated from multiple RVs before a situation is identified. Service level latency of 1-2s for safety-related information concerning the vicinity of the HV

- Reliability = 99% (WG1) [or 99.99% as proposed in BARNS]
  - WG1 Reliability = 99%. For safety-related information, timely and reliable communication is decisive. In the backend, data from several vehicles is aggregated, so the single vehicle's data has to be moderately reliable. For rerouting information, this should be enough.
- DL/UL speeds = DL speed of 2kbps
  - Assuming a 300bytes message has to be transmitted in 100ms, the DL speed can be calculated as 300bytesx8 bits / 0.1 s = 24,000 bps = 24kbps.
- Data volume = 300 bytes
  - WG1 considers that the normal size of CAM/BSM (300bytes) should be enough, maybe containing fields indicating common types of critical situations that lie ahead. Transmission of detailed object information is not needed. Standard transmission rate of 10Hz should be enough.
- Use case frequency = event driven
  - Hazard warning – Critical use case family includes event-driven safety applications where the vehicle is approaching a hazardous location that is very close to the vehicle.
- Local context
  - Hazard warning – Critical use case family includes event-driven safety applications where the vehicle is approaching a hazardous location. The local context for a human driver location assumes a relatively high position match. A position match (10m) of the vehicle in KPI table is proposed.
  - Note: Autonomous driving will require the highest position match.

Figure 6 KPI Parameters – 'Hazard Warning – Critical Human'

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Human-machine	100ms	99%	22 bps	-	300bytes	Event driven	<10ms
Spider value	*4*	*3*	*2*	*0*	*0*	*0*	*5*

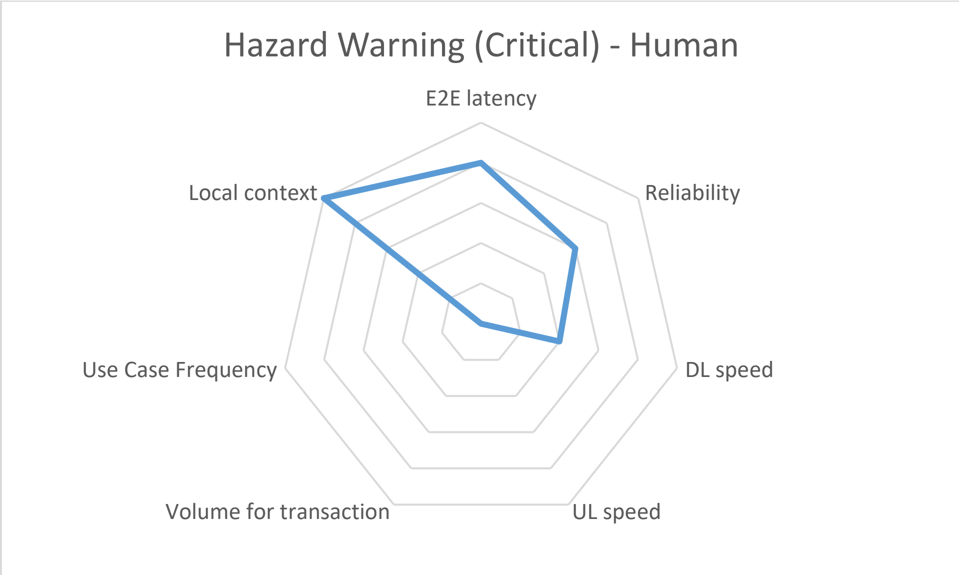


Figure 7 Hazard Warning Critical – Human

3.3.1.2 Hazard Warning Indication – Non Critical

User story

5GAA WG1 reference technical document T-180170 – Real-Time Situational Awareness and High-Definition Maps 'HV receives information from a backend/cloud' user story

- This use case mainly refers to a real-time HD map update service. The HV is receiving information that is relevant for the road/route ahead from a backend, containing information that might allow the HV to adjust its route accordingly. The traffic management mentioned in 'Other Actors' roles could play a role here.

BARNS user story

- A vehicle or infrastructure detects a hazardous location and sends a warning so that several applications (incl. navigation system) in vehicles located at a certain distance can be updated and allowed to take relevant action (e.g. indicate to slow down or define a new route in the case of a traffic jam).
- The use case is not safety related, it could be for general information about route obstructions or the like further ahead, in order to make timely re-routing possible. The type of information detected/ transferred also impacts the time during which the information remains valid. It could be for a couple of seconds, for a couple of minutes or for a couple of months/years, etc. For instance, construction works can remain in place for hours/days/weeks/months/years. Potholes could be another example.
- The use case is event driven.
- There is a distinction in terms of latency depending on whether it is an automated driving case or a human-machine interaction.

Justifications of BARNS 'Hazard Warning Indication – Non-Critical' user story KPIs

- E2E latency = 10s (lowest value proposed by WG1 for non-safety user stories)
  - WG1 considers that the E2E latency is somewhere between 10s and 200s for general information about route obstructions or the like further ahead, in order to make timely rerouting possible.
  - WG5 BARNS came up with an estimation of a network latency of 200ms, but this seems very low compared to the WG1 estimate and based on the specified user story.
- Reliability = 99%
  - According to WG1 T-180170 technical document.

        - For safety-related information, timely and reliable communication is decisive and a reliability of 99% seems reasonable.
        - In the backend, data of several vehicles is aggregated, so the single vehicle's data has to be moderately reliable. For rerouting information, even a poorer level of reliability should be enough.
    - BARNS estimated that a reliability of 99% is acceptable.

- DL/UL speeds = <1kbps
    - Assuming a 1000bytes message has to be transmitted in 10s, the DL speed can be calculated as 1000bytesx8bits/10s = 800bps = 0.8kbps
- Data volume = 1KB
    - According to the WG1 T-180170 technical document, from the backend, the HV will receive information (events, or vector data), not raw data. Some details are needed, but still no need for detailed object descriptions or the like. Hence a volume of 300-1000bytes shall be enough. This is in line with the estimation made by BARNS.
- Use case frequency
    - The use case is event driven.
- Local context
    - Estimate of city block = 400m.

Figure 8 KPI Parameters – 'Hazard Warning Indication – Non-Critical' human

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Human-machine	10s	99%	<1kbps	-	1KB	Event driven	400m
Spider value	*1*	*3*	*1*	*0*	*0*	*0*	*4*

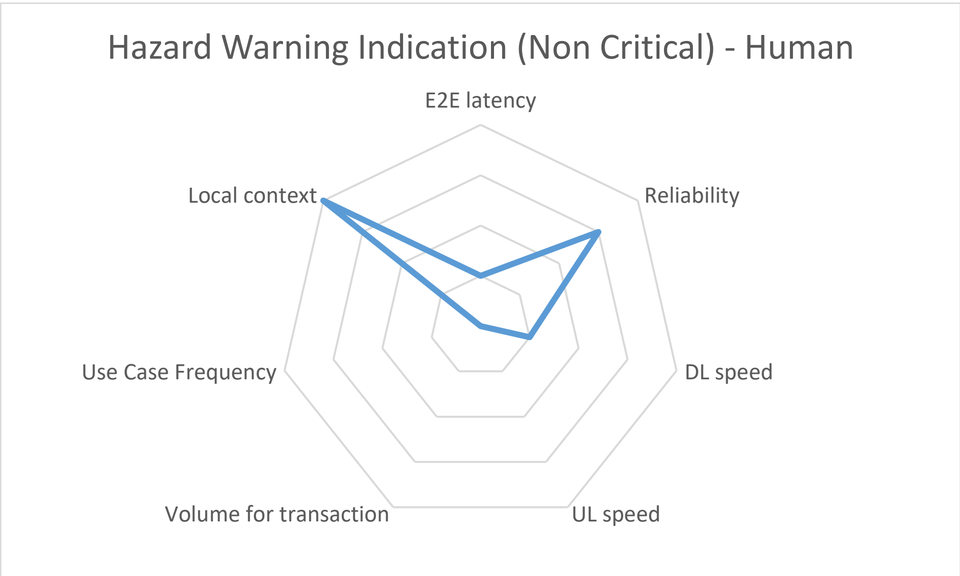


Figure 9 Spider Diagram Hazard Warning Indication – Non-Critical – Human

3.3.1.3 Hazard Warning Indication – Non-Critical – Case of 'Traffic Jam Warning'

User story

5GAA WG1 reference technical document T-180241 proposes six user stories for the use case 'Traffic Jam Warning'

- We will focus on the 'User Story #3 Highway Scenario on Route Information'.
- This is the closest scenario to the BARNS user story described hereafter.

BARNS user story

- One specific user story of a 'Hazard Warning Indication – Non Critical' use case that could be monetised might be a 'Traffic Jam Warning' service to let the car owner have a chance to optimise his/her way to work, for instance. This service is not safety related, but is a comfort/value-added service.
- Based on information from INRIX, if the driver leaves in London and has to use the M25 on his/her way to work, he/she is very likely to experience traffic jams. On the M25, between the junctions 5-7, there are 343 traffic jams per month. The use case is considered to be while driving on a highway.

Justifications of BARNS 'Traffic Jam Warning' user story KPIs

- E2E latency = delay tolerant
  - WG1 assessment is 2000ms (2s) traffic jams not normally happening within a short time. 2s gives 80m at 150km/h. Urban environment 2 s means 26m at 50km/h.
- Reliability = best effort
  - Normally traffic jams contain several cars. Assuming a penetration rate of 20% and an average of 10 cars per jam means there are at least 2 cars sending the message in parallel.
- DL/UL speeds of around 300bytes in 100ms (highest rate)
- Data volume = 300bytes
  - Traffic jam information comes from BSM or DENM, or from other (backend) services. The size is usually around 300bytes.
- Use Case Frequency = 2-3 times a day
  - We assumed that a driver may receive traffic jam warning indications 2-3 times a day.
- Local context = regional (20 km)
  - Driving on highway, it would be beneficial to receive warnings about traffic jams and re-routing proposals enough in advance to be able to take a motorway exit, for example. In that case, the local context KPI value of 'regional (20km)' seems relevant.
  - WG1 T-180241 document mentions 30 km for the Range SLR for the 'User Story #3 Highway Scenario on Route Information'.

Figure 10 KPI Table – 'Traffic Jam Warning'

	E2E Network latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Traffic jam warning	Delay tolerant	Best effort	1kbps	-	300bytes	2-3 times a day	Regional (20 km)
Spider value	*0*	*0*	*1*	*0*	*0*	*4*	*3*

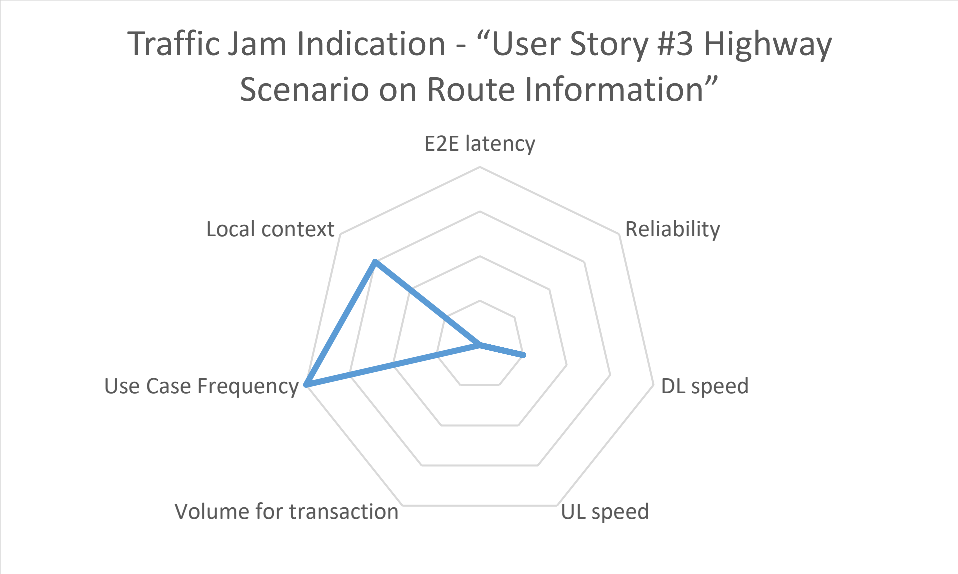


Figure 11 Spider Diagram Traffic Jam Indication

3.3.1.4 HD Map UPDATE for CAD

User story

5GAA WG1 reference technical document T-180250 – HD map collecting and sharing

- The use case is for vehicles to receive a HD map which is updated in real-time and thus more accurate.

BARNS user story

- The use case is for vehicles to receive a HD map which is updated in real-time and thus more accurate.
- While in urban environment, an autonomous car needs to update its HD map.

Justifications of BARNS ‘HD Map Update’ user story KPIs

- E2E latency = 100ms
  - According to WG1 T-180250 document, a latency of 100ms is needed for HD map’s end-to-end real-time performance.
- Reliability = 99%
  - According to WG1 T-180250 document, for safety-related information, timely and reliable communication is needed and a reliability of 99% is required. In addition, the HD map data from the HV or HD map provider is not the only way for RVs to receive surrounding information.
- DL speed of 30-50Mbps/UL speed of 50 Mbps
  - WG1 T-180250 document provides the following information for UL speed:
    - Case 1: Unprocessed sensor data are provided from the HV to the HD map provider. 50Mbps is derived from: H.265/HEVC HD camera ~10Mbps + LIDAR ~35Mbps + other sensor data. (From 3GPP 22.886).
    - Case 2: Processed sensor data (interpreted objects) are provided from the HV to the HD map provider. We can assume 1 KB/Object/100ms. So for 50 objects it ends up with 4Mbps.

- WG1 T-180250 document provides the following information for DL Speed = HD maps of 500m*500m in the city or 1000m*1000m on the highways at about 2MB. Assumes RVs download the HD map within 1s, so it requires about 15Mbps.

- A market example from Navinfo details a tile-based map loading strategy. The size of each tile is 2.5km*2.5km at the Level 13 (Navigation Zoom scales ranging 25m ~ 500m) in terms of database and navigation usage.

- Each tile size is around 640 KB based on the content (only vectorised HD map data – excluding satellite image data), the system will download load 25 tiles (the main tile on which the car locates plus the 24 neighbour tiles) as per the illustration below:

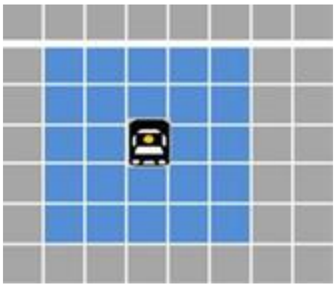


Figure 12 Navinfo Example of Map Tile

- We assume that these tiles need to be downloaded within a 1 s time limit, so the downlink volume in 'Light info-simple junction' is around 640 Kb*25/1024/s = 15.625Mb/s.

- The downlink volume in 'Heavy info-complex junction' is around 1.25Mb*25/s = 31.25Mb/s

  Therefor both downlink and uplink KPI will score 5 on scale (max. 50MB/s)

- Data volume – 30MB for complex junction

  - WG1 T-180250 document mentions that HD maps of 500m*500m in the city or 1000m*1000 m on the highways are about 2MB data volume, although market information implies that multiple tiles are downloaded at each iteration.

  - The market example from Navinfo shows that 25 of tiles of 2MB will be downloaded for a complex junction – 1.25Mb*25/s = 31.25Mb/s.

- Use case frequency

  - Static features of the HD map can be refreshed daily or weekly based on different regions (and also depending on the requirements from OEMs), and the dynamic features like **traffic events** can be refreshed every few minutes. These static and dynamic layers of data is explained in a later section.

- Local context = 500m (city)/1km (highway)

  - WG1 T-180250 document provides the following information for the Range SLR that could be relevant for BARNS Local Context KPI.

    - In the city, a 500m range is about two blocks around the vehicle. The AV can receive at least two blocks on dynamic HD map used for trajectory planning and collision/congestion avoidance.

    - While on the highway, because of higher speed and less surrounding road information than in the city, 1000m will be a suitable range.

Figure 13 KPI Table – 'HD Map Update in City'

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
HD map update in city	100ms	99%	50Mbps	50Mbps	30MB	Every few minutes	500m
Spider value	*4*	*3*	*5*	*5*	*4*	*5*	*4*

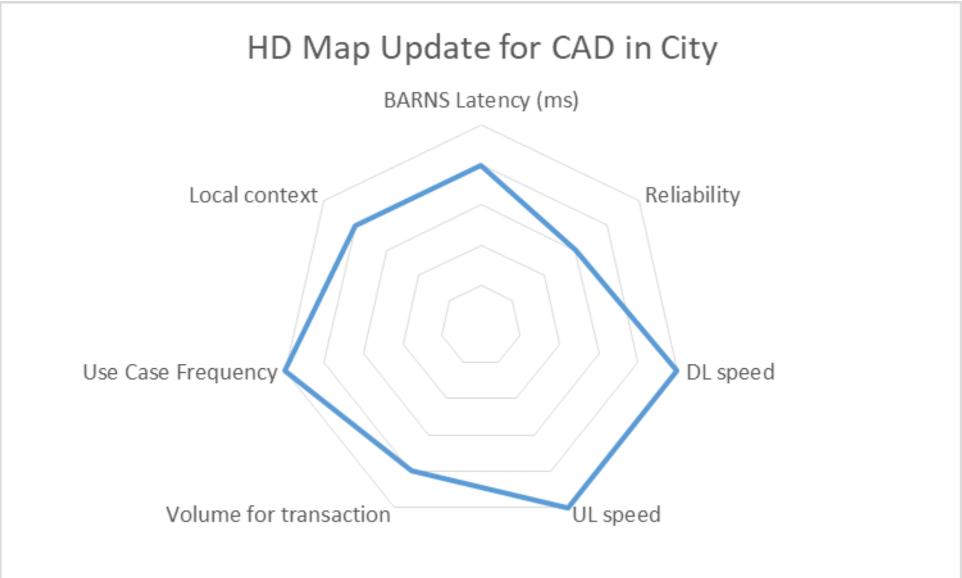


Figure 14 Spider Diagram HD map Update for CAD in City

3.3.2 Software Update

3.3.2.1 Software Update – Not Urgent

User story

5GAA WG1 reference technical document T-180153 – SW Update Routine

- Software Update (Conventional-Routine): Non-urgent delivery of a software update to a conventional (human-driven) vehicle, installed when convenient with the permission of the authorised driver or owner where required.
- Software Update (Autonomous-Routine): Non-urgent delivery of a software update to an autonomous (self-driving) vehicle; a routine delivery of new software that can be installed when convenient (such as when refuelling or charging).

BARNS user story

- A vehicle manufacturer updates the electronic control module software for targeted autonomous vehicles in a specific market area for maintenance purpose.

Justifications of BARNS 'Software Update – Not Urgent – Autonomous Car' user story KPIs

- E2E latency = delay tolerant
  - Software updates themselves are not latency-sensitive.
- Reliability = 99%

        - Software updates should successfully transfer reliably but this can occur over an extended period of time. It can take several days.
    - DL/UL speeds = DL speed of 277kbps; UL speed of <1 kbps
        - Based on WG1 T-180153 document, for an autonomous car it is assumed a routine software update of 3GB within 24 hours, which was characterised as a conservative estimate of a current self-driving stack based on publicly-available information. We derived the DL speed as following:
            - DL speed = 3GB/24h = 3000MB*8/(24x60x60) = 24,000Mb/86,400s = 277kbps
    - Data volume = 3GB
        - Based on WG1 T-180153 document, for an autonomous car the size of a routine software update can be estimated at 3GB.
    - Use case frequency = once per month
        - We assume that a routine software update may occur once per month, but did not distinguish the cases of a conventional car versus an autonomous car.
        - Routine software updates may occur more often for an autonomous car than for a conventional car.
    - Local context = market region
        - We assume that a car maintenance software update may be relevant at a country/region level (e.g. due to regional regulation specificities).

Figure 15 KPI Parameters – 'Software Update – Not Urgent – Autonomous Car'

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Software update – not urgent – autonomous car	Delay tolerant	99%	277kbps	<1kbps	3GB	once per month	Market region
Spider value	*0*	*3*	*2*	*0*	*5*	*1*	*1*

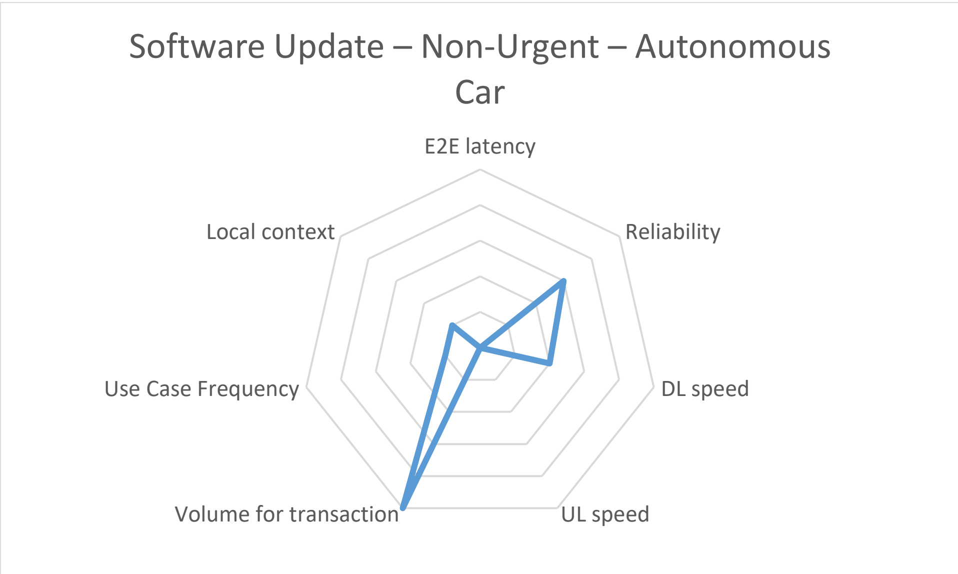


Figure 16 Spider Diagram – 'Software Update – Not Urgent – Autonomous Car'

Figure 17 KPI Parameters – 'Software Update – Not Urgent'

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Software update – not urgent	Delay tolerant	99%	<1kbps	<1kbps	1MB-10MB	once per month	Market region
Spider value	*0*	*3*	*0*	*0*	*3*	*1*	*1*

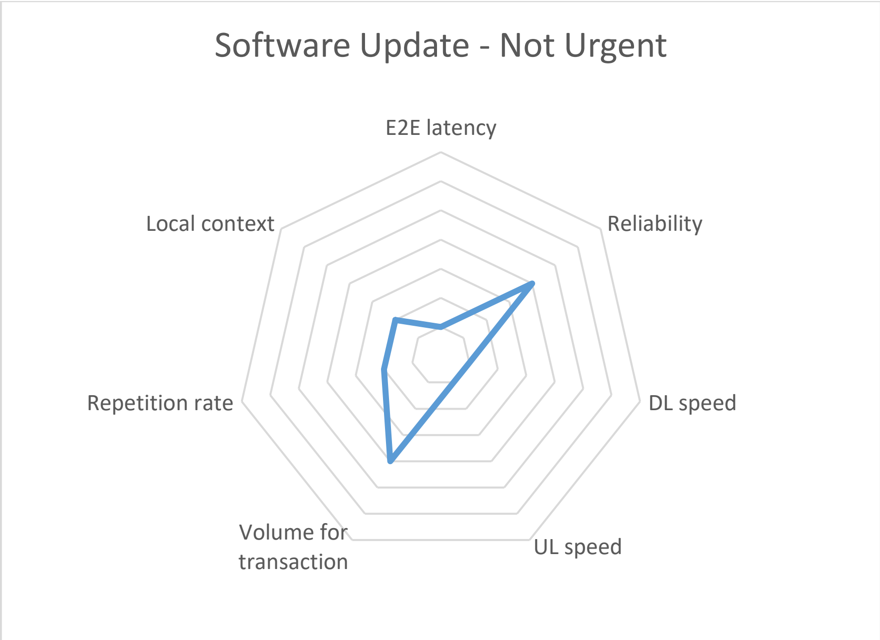


Figure 18 Spider Diagram – 'Software Update – Not Urgent'

3.3.2.2 Software Update – Urgent

User story

5GAA WG1 reference technical document T-180153 – SW Update Urgent – two user stories

- Software update (conventional-urgent): Software update is critical enough to require a message to the human driver that an update is needed as soon as possible and should be installed (with driver permission where required) as soon as practical.
- Software update (autonomous-urgent): Software update is critical enough to order a self-driving vehicle to exit the roadway and secure itself until the update can be installed to the relevant systems. We should anticipate future legal or regulatory requirements for these capabilities.

BARNS user story

- A vehicle needs some of its safety-related software to be updated urgently.
- Car OEMs would need to be able to push such requests on-demand and have the updates performed in a relatively short period of time.
- Car OEMs would also need to measure the completeness of the task to ensure all relevant vehicles have been updated.

Justifications of BARNS 'Software Update – Urgent – Autonomous Car' user story KPIs

- E2E latency = delay tolerant
  - According to WG1 T-180153, the most stringent requirement is to deliver the 'critical update required' message within 10 minutes in the case of an urgent software update for autonomous cars. This corresponds to BARNS' delay tolerant KPI.
- Reliability = 99.9% (need to check with WG1)
  - Urgent software updates should be reliably transferred and BARNS considers that a network reliability of 99.9% is required.
  - WG1 E2E reliability SLR is 99%.
- DL/UL speeds = DL speed of 3.3Mbps; UL speed of <1 kbps
  - Based on WG1 T-180153 document, for an autonomous car it is assumed that an urgent software update of 3GB is downloaded within 2 hours, which was characterised as a conservative estimate of a current self-driving stack based on publicly-available information. We derived the DL speed as following:
    - DL speed = 3GB/2h = 3000MB*8/(2x60x60) = 24000Mb/7200s = 3.3Mbps
- Data volume = 3GB
  - Based on WG1 T-180153 document, for an autonomous car the size of an urgent ECU software update can be estimated at 3GB.
- Use case frequency = 1-5 per year --- Need to check in WG5
  - We assume that an urgent software update may occur 1-5 times per year, but we do not distinguish between a conventional car versus an autonomous car.
  - Urgent software updates may occur more often for an autonomous car than for a conventional car.
- Local context = market region
  - We assumed that a car maintenance software update may be relevant at a country/region level (e.g. due to regional regulation specificities).

Figure 19 KPI Parameters – 'Software Update – Urgent – Autonomous Car'

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Software update – urgent – autonomous car	Delay tolerant	99.9%	3.3Mbps	<1kbps	3GB	1-5 per year	Market region
Spider value	*0*	*4*	*3*	*0*	*5*	*1*	*1*

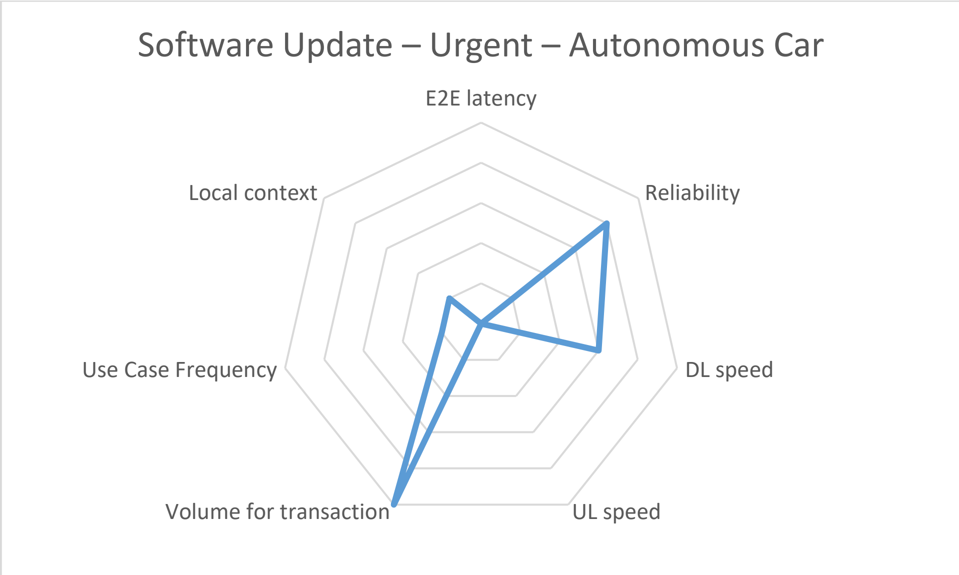


Figure 20 Spider Diagram – 'Software Update – Urgent – Autonomous Car'

3.3.3 Tele-Operated Driving

3.3.3.1 Tele-Operated Driving

User story

5GAA WG1 reference technical document T-180205

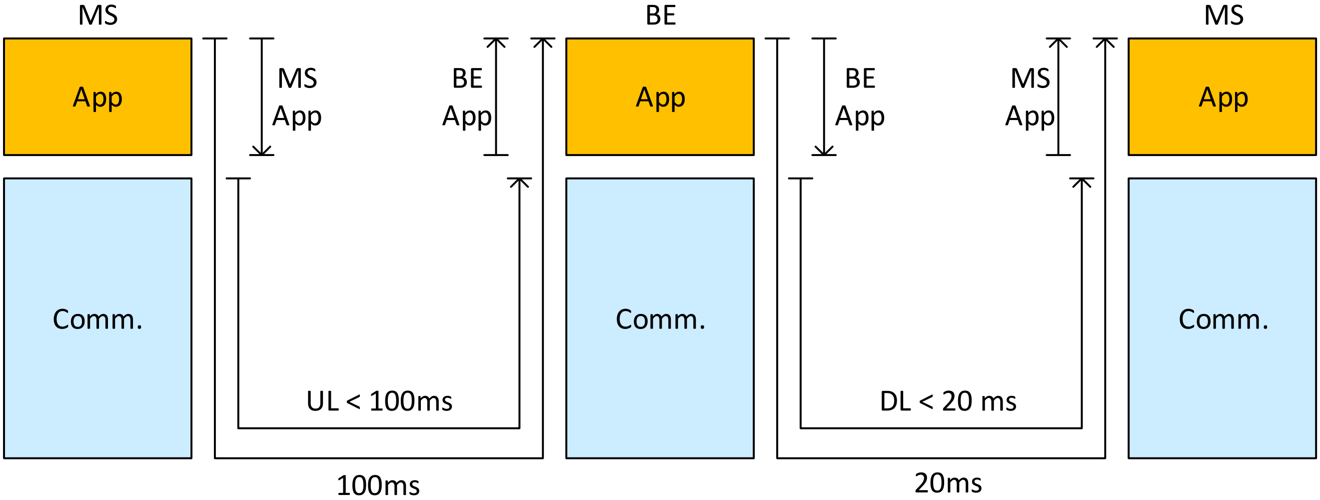
- A temporary health issue (e.g. illness, headache) of a driver impairs his/her concentration, reactions and judgement and consequently affects his/her ability to drive safely. The driver of the vehicle (with some autonomous capabilities) asks a remote driver to take control of the vehicle and drive it in an efficient and safe manner from the current location to the destination.

BARNS User Story

- A temporary health issue (e.g. illness, headache) of a driver impairs his/her concentration, reactions and judgement and consequently affects his/her ability to drive safely. The driver of the vehicle (with some autonomous capabilities) asks a remote driver to take control of the vehicle and drive it in an efficient and safe manner from the current location to the destination.
- We assume that, in the case of a driver not being able to drive temporarily, a remote driver drives the car to a safe place within 5 minutes maximum. During this period of time, both DL and UL transmissions are permanently running.

Justifications of BARNS 'Tele-Operated Driving' User Story KPIs

- E2E latency = 10ms



  - WG1 E2E Latency = from HV to remote driver: 100ms/from remote driver to HV: 20ms. From remote driver to HV, latency time depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For instance, at a speed of 50 km/h, the HV will move 0.27m within 20ms.
  - Based on external papers from 3GPP and 5GAA, BARNS assumed a network latency of 10ms which is below the most stringent WG1 E2E Latency value of 20ms.
- Reliability = 99.999%
  - WG1 E2E Reliability = from HV to remote driver: 99% from remote driver to HV: 99.999% (very high).
  - From remote driver to HV: The transmission of commands from the remote driver requires a very high level of reliability, since this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should also be sent with high reliability to ensure that the remote driver has the correct (current) view of the surroundings.

        - BARNS adopted the most stringent WG1 E2E Reliability value of 99.999%.
    - DL speed = 400kbps/UL Speed = 64Mbps
        - WG1 T-180205 assumed the following speeds for UL.
            - From HV to remote driver: 60Mbps (video streaming) or from HV to remote driver: 64Mbps (if video streaming and object information is sent)
                - From HV to Remote Driver: 15-29Mbps are needed for a progressive high definition video/camera. Four cameras are needed (one for each side): 4*15=60Mbps.
                - From HV to remote driver (optional): Sensor data (interpreted objects) are also provided from the HV to the parking remote driver. We can assume 1kB/Object/100ms. So if we have 50 objects, we end up with 4Mbps.
            - From remote driver to HV: Up to 1000bytes per message (up to 400kbps) (commands from remote driver)
                - From remote driver to HV: The size of command messages, e.g. a) turn steering wheel, direction, angle, etc. b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20ms (maximum 50 messages per second).
        - BARNS adopts the most stringent DL/UL Speeds based on WG1 SLRs.
    - Data volume = 2.4GB
        - We assume that in the case of a driver temporarily not being able to drive, a remote driver takes drives the car to a safe place within 5 minutes maximum. During this period of time, both DL and UL transmissions are permanently running.
        - Data Volume = 5minsx(64Mbps+400kbps) = 5x60x(8MBps+0.05MBps) = 2415MB ~ 2.4GB
    - Use case frequency = once a month
        - Estimated occurrence.
    - Local context = 5-10cm
        - High accuracy

Figure 21 KPI Parameters – ‘Tele-Operated Driving’

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Tele-operated driving	10ms	99.999%	400kbps	64Mbps	2.4GB	Once per month	5-10cm
Spider value	*5*	*6*	*2*	*6*	*5*	*1*	*6*

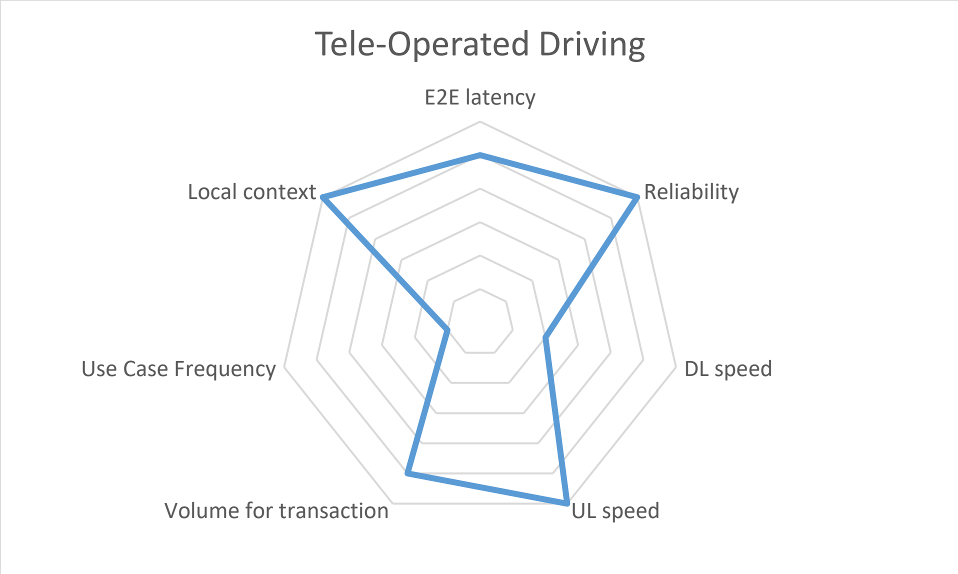


Figure 22 Spider Diagram –"Tele-Operated Driving"

3.3.3.2 Tele-Operated Driving via Remote Control

User story

5GAA WG1 reference technical document T-180206 document – Tele-Operated Support: 'Remote Steering' user story

- An autonomous vehicle (e.g. passenger cars, or even a vehicle that performs dedicated tasks in very complex environments such as snow ploughing, cleaning, loading and unloading) may detect a situation which is highly uncertain and cannot make the appropriate decision for a safe and efficient manoeuvre. In this case the autonomous vehicle can ask for the support of a remote driver in order to resolve the difficult situation and then switch back to the normal autonomous driving mode without the remote driving support.

BARNS user story

- Tele-Operated Support (TeSo) enables a single human operator to remotely control autonomous vehicles for a short period of time. Examples include when a service vehicle is performing an action (e.g. snow ploughing, cleaning, loading and unloading) and asks for help if it cannot resolve a situation by itself. This requires the sharing of video and data from RADAR and LIDAR sensors, enabling reliable environment perception.

Justifications of BARNS 'Tele-Operated Support via Remote Control' user story KPIs

- E2E latency = 10ms
  - WG1 E2E Latency = from HV to remote driver: 100ms from remote driver to HV: 20ms. From remote driver to HV, latency time depends on the reaction time needed which is directly related to the maximum driving speed allowed. For instance, at a speed of 50km/h, the HV will move 0.27m within 20ms.
  - Based on external papers from 3GPP and 5GAA, BARNS assumes a network latency of 10ms which is below the most stringent WG1 E2E Latency value of 20ms.
- Reliability = 99.999%
  - WG1 E2E Reliability = From HV to Remote Driver: 99% .From Remote Driver to HV: 99.999% (Very high). From Remote Driver to HV: The transmission of commands from the remote driver require very high level of reliability, since this affects the safe and efficient operation of the AV.

In addition the video streams and/or sensor information that should be also sent with high reliability to make sure that the Remote Driver has the correct (current) view of the surroundings.

  - BARNS adopted the most stringent WG1 E2E Reliability value of 99.999%.

- DL speed = 400kbps/UL speed = 64Mbps

  - WG1 T-180206 assumes the following speeds for UL.

    - From HV to remote Driver: 60Mbps (video Streaming) or from HV to remote driver: 64Mbps (if video streaming and object information is sent).

      - From HV to remote driver: 15-29Mbps are needed for a progressive high definition video/camera. Four cameras are needed (one for each side): 4*15=60Mbps.

      - From HV to remote driver (optional): Sensor data (interpreted objects) are also provided from the HV to the parking remote driver. We can assume 1kB/Object/100ms. So if we have 50 objects, we end up with 4Mbps.

    - From remote driver to HV: Up to 1000bytes per message (up to 400kbps) (commands from remote driver).

      - From remote driver to HV: The size of command messages, e.g. a) turn steering wheel, direction, angle, etc. b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20ms (maximum 50 messages per second).

  BARNS adopted most stringent DL/UL Speeds based on WG1 SLRs.

- Data volume = 161MB

  - BARNS assumes that if an autonomous vehicle asks for the support of a remote driver in order to resolve a difficult situation and then switch back to the normal autonomous driving mode, a remote driver may have to drive the car for a very limited amount of time. We assume 20s may be enough. During this period of time, both DL and UL transmissions are permanently running.

  - Data Volume = 20sx(64Mbps+400kbps) = 20x(8MBps+0.05MBps) = 161MB.

- Use case frequency = once a month

  - Estimated use case frequency.

- Local context = 5-10cm

  - High accuracy.

Figure 23 KPI Parameters – ‘Tele-Operated Support via Remote Control’

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Tele-operated support via remote control	10ms	99.999%	400kbps	64Mbps	161MB	Once per month	Position match (10cm)
Spider value	*5*	*6*	*2*	*6*	*4*	*1*	*6*

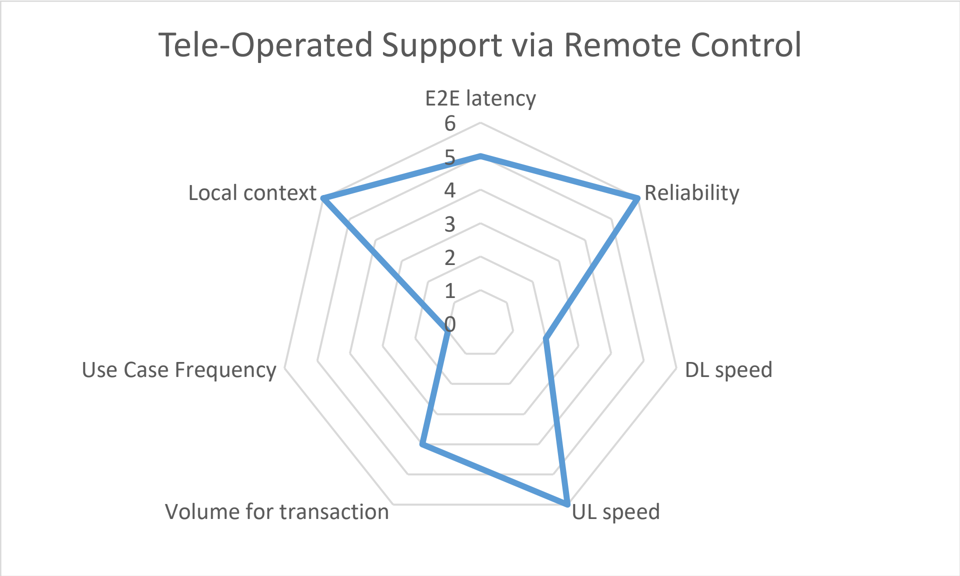


Figure 24 Spider Diagram –"Tele-Operated Support via Remote Control"

3.3.3.3 Autonomous Vehicles Parking by Remote Driving

User story

5GAA WG1 reference technical document T-180207 – 'Autonomous Vehicles Parking by Remote Driving: Remote Steering' user story

- A remote driving centre (human or machine) undertakes to park the vehicle, supported by real-time video streaming that is sent from the remotely-driven vehicle and sensor information.

BARNS user story

- When a vehicle arrives at its destination parking area, the vehicle is parked by parking remote driver.
- This use case is a low-speed variant of ToD. It can apply when the vehicle does not have any information about the car park area or cannot perform automated parking. In that case, a remote operator can slowly drive the vehicle into a parking space. Maximum speed of 15km/h is assumed in the car park. The use case may require a more precise location context than for normal ToD in order to perform the parking manoeuvre without incidents. The time taken to park a car is estimated to be around 2-3 minutes.
- Finally, we assume that a given parking slot is occupied by a different car 10 times per day.

Justifications of BARNS 'Autonomous Vehicles Parking by Remote Driving' user story KPIs

- E2E latency = 10ms
  - WG1 E2E latency = from HV to remote driver: 100ms;from remote driver to HV: 20ms. From remote driver to HV, latency time depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For instance, at a speed of 50km/h, the HV will move 0.27m within 20ms.
  - Based on external papers from 3GPP and 5GAA, BARNS assumes a network latency of 10ms which is below the most stringent WG1 E2E latency value of 20ms.
- Reliability = 99.999%

- WG1 E2E Reliability = from HV to remote driver: 99% ; from remote driver to HV: 99.999% (very high). From remote driver to HV: The transmission of commands from the remote driver requires a very high level of reliability, since this affects the safe and efficient operation of the AV. In addition the video streams and/or sensor information that should also be sent with high reliability ensure that the remote driver has the correct (current) view of the surroundings.
- BARNS adopts the most stringent WG1 E2E Reliability value of 99.999%.

- DL speed of 400kbps and UL speed of 64Mbps
  - WG1 T-180207 assumed the following speeds for UL
    - From HV to remote driver: 60Mbps (video streaming) or from HV to remote driver: 64Mbps (if video streaming and object information is sent)
      - From HV to remote driver: 15-29Mbps are needed for a progressive high definition video/camera. Four cameras are needed (one for each side): 4*15=60Mbps.
      - From HV to remote driver (optional): Sensor data (interpreted objects) are also provided from the HV to the parking remote driver. We can assume 1kB/Object/100ms. So if we assume 50 Objects, we end up with 4Mbps.
    - From Remote Driver to HV: Up to 1000 bytes per message (up to 400kbps) (commands from remote driver)
      - From remote driver to HV: The size of command messages, e.g. a) turn steering wheel, direction, angle,… b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20ms (maximum 50 messages per second).
  - BARNS adopted most stringent DL/UL speeds based on WG1 SLRs
- Data volume = 966MB
  - In the case of an autonomous vehicle being parked by a remote driver, we assumed that 2 minutes might be enough to park the car in a specific car park (closed environment). During this maximum period of time, both DL and UL transmissions are permanently running.
  - Data Volume = 2minsx(64Mbps+400kbps) = 2x60sx(8MBps+0.05MBps) = 966MB
- Use case frequency = 10 times per day
  - Based on INRIX parking reports, we assume that a given parking slot is occupied by a different car 10 times per day.
- Local context = 5-10cm0
  - High accuracy.

Figure 25 KPI Parameters – 'Autonomous Vehicles Parking by Remote Driving'

	E2E Network Latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data Volume	Use Case Frequency	Local Context
Autonomous vehicles parking by remote driving	10ms	99.999%	400kbps	64Mbps	966MB	10 times [er day	Position match (cm)
Spider value	*5*	*6*	*2*	*6*	*4*	*4*	*6*

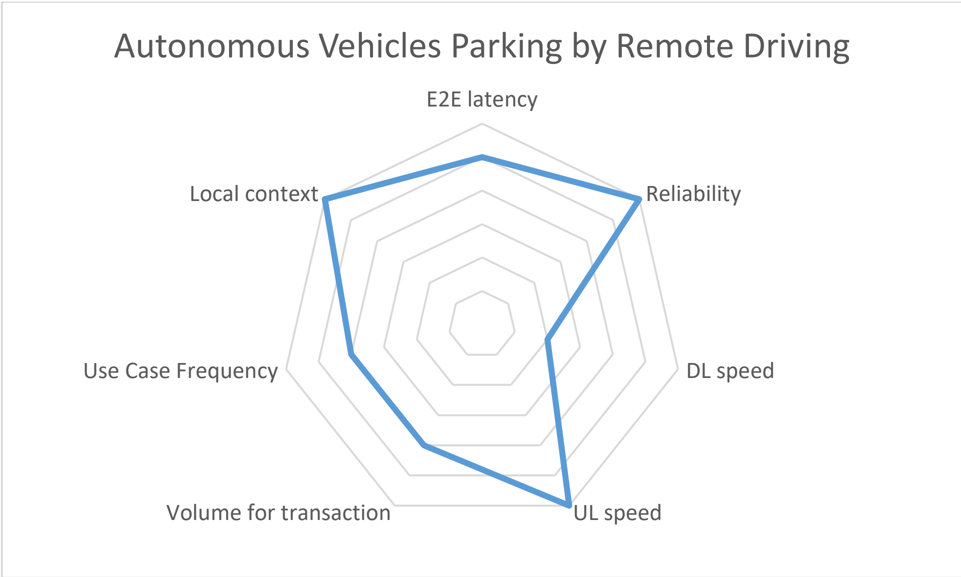


Figure 26 Spider Diagram – ‘Autonomous Vehicles Parking by Remote Driving’

3.3.4 High-Density Platooning

User story

5GAA WG1 reference technical document T-190033 – 'Vehicles Platooning in Steady State'

- A group of vehicles (e.g. trucks that travel from warehouse facilities to a transportation area such as rail, shipping) drive closely, in a coordinated manner, to decrease fuel consumption, increase efficiency and reduce traffic congestion. There are also potential driver and logistics efficiencies possible.

BARNS user story

- A group of vehicles (e.g. trucks that travel from warehouse facilities to a transportation area such as rail, shipping) drive closely, in a coordinated manner. In its user story, BARNS considers the use case of the coordination between the head of a platoon (HV) and the cloud assistance (CA).
- 5GAA WG1 considers that the distance between the members of a platoon may be between 5-15m. We assume a 5m distance to describe a high-density platoon.

Justifications of BARNS 'High-Density Platooning' user story KPIs

- E2E latency = 1s
    - WG1 E2E latency = MV – MV: <100ms; HV – MV: 100ms; HV – CA: >1 sec
        - Member of a platoon (MV) to member of a platoon (MV): For a short inter-vehicle gap a latency of 100ms or less is needed.
        - Head of a platoon (HV) to member of a platoon (MV): 100ms may be needed for notification of important/critical changes of the status of MVs or the configuration of the platoon by the HV (e.g. trajectory change). Other messages are not that critical.
        - Head of a platoon (HV) to coordination with cloud assistance (CA) (optional): This is not time-critical interaction.
    - In its user story, BARNS considers the use case of the coordination between the HV and CA, and consequently adopts a latency of 1s.
- Reliability = 99%
    - WG1 E2E Reliability = MV – MV: 99.9%; HV – MV: 99.9%; HV – CA: 99%
        - Member of a platoon (MV) to member of a platoon (MV): Reliability of 99.9% should be enough to allow the MV to keep a low inter-vehicle distance in a safe and efficient manner and thus allow a high-density platoon to be maintained.
        - Head of a platoon (HV) to member of a platoon (MV): Reliability of 99.9% will be needed for important/critical changes of the status of MVs, or the configuration of the platoon by the HV that should be notified.
        - Head of a platoon (HV) - coordination with cloud assistance (CA) (optional): This is not time-critical interaction.
    - In its user story, BARNS considers the use case of the coordination between the HV and CA, and consequently adopted a reliability of 99%.
- DL/UL speeds = 65Mbit/s
    - According to WG1, different messages are sent, but no DL/UL requirements are described in T-190033.
    - In its user story, BARNS considers truck platoons must be managed continuously by a cloud-based NOC that connects to them through cellular communication. Real-time supervision enables dynamic adjustment to conditions, and can enforce limits to the operation of platoons to specified

roads under safe driving conditions (where, when and how it is safe). Enhanced sensor sharing is required when the platoon leader is not able to oversee the situation of the platoon with its own sensors. In this case the main requirement is for throughput of around 50Mbit/s.

- Data volume
  - According to WG1, different messages are sent according to the different interactions among involved entities in this use case:
    - Member of a platoon (MV) to member of a platoon (MV): Maximum 100Bytes, since the MVs exchange speed, position and intentions such as braking, acceleration, etc. The messages are periodic, while their periodicity depends on the inter-vehicle gap taking into account that the MVs have similar relevant speed, 10Hz periodicity is considered as adequate.
    - Head of a platoon (HV) to member of a platoon (MV): Reports are provided from the MV to the HV (e.g. speed, location information), while the HV provides configuration information (e.g. trajectory, speed and acceleration intention of the HV). The maximum length of a HV to MV message that includes path/trajectory information is 300Bytes. The messages from HV to MV are not periodic, but event-based.
    - Head of a platoon (HV) – coordination with cloud assistance (CA) (optional): 1000Bytes of information about the road and weather conditions, if available, as well as traffic conditions according to the route that the platoon follows. This message is not periodic. It is sent during the initial establishment and when there is any update on any of the above parameters.
- In its user story, BARNS considers the use case of the coordination between the HV and CA. The key assumptions will consequently be:
  - How often a message is sent by HV to CA during a platoon.
  - How long the average platoon lasts to understand overall volume with a user story.
  - Estimate >1000 Bytes based on WG1 input; road conditions and weather conditions, message sent during initial establishment.
- Use case frequency = event driven
- Local context = 5-15m location spacing per truck

Figure 27 KPI Parameters – 'High-Density Platooning Host Vehicle to Cloud Use Case HV-CA'

	E2E latency (ms)	Reliability	DL (Mbps)	UL (Mbps)	Data volume	Use Case Frequency	Local context
High-Density Platooning	1000 ms	99%	50	50	>1GB	Event driven	10m
Spider value	*3*	*4*	*6*	*6*	*6*	*1*	*6*

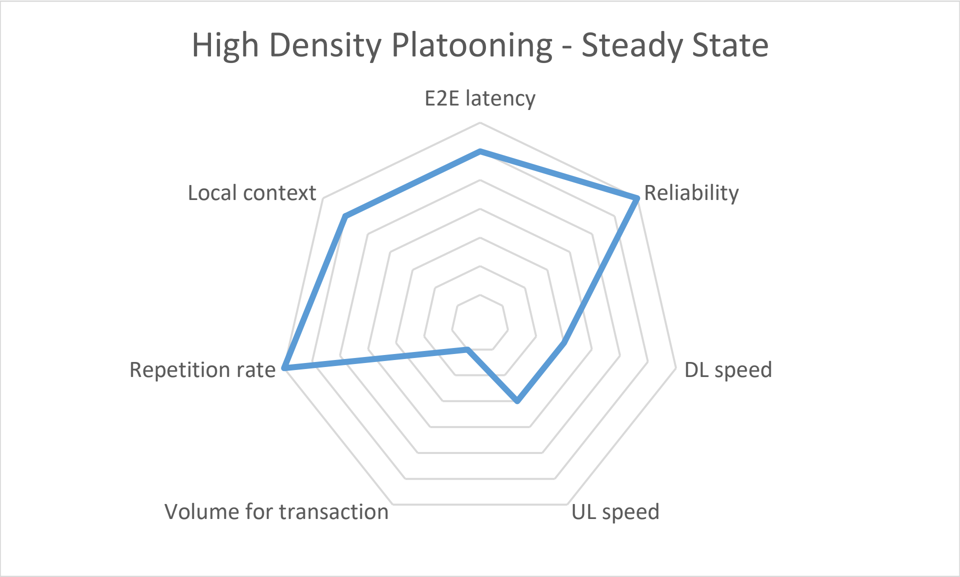


Figure 28 Spider Diagram – 'High-Density Platooning Host Vehicle to Cloud Use case HV-CA'

3.4 Use Case Analysis and Network Slice Grouping per KPI Sets

Network slicing is a tool for mobile network operators to provide customised networks to satisfy diverse sets of use cases and requirements fulfilling the diverse requirements in a cost-efficient way.

In October 2018, GSMA sent a Liaison Statement (LS) to 5GAA, asking 5GAA to

1. Review the Generic Slice Template (GST) from the automotive industry's perspective, and
2. Fill in values for the Generic Slice Template attributes, thereby creating a NEtwork Slice Type (NEST) for the automotive industry.

In 5GAA, this task was given to WG2 which executed the actions and provided replies to GSMA, which acknowledged the work and made several changes to its GST specification. The following summary table defines which UCs are similar in terms of KPI requirements and assesses if they could be served by one of a set of different network slices (e.g. eMBB slice, URLLC slice, customised slice, etc.)

Figure 29 Summary of Uses Cases and Slicing Features

Use Case Family	Sub-Use Cases	Slicing Features Example
Real-Time Situation Awareness and High-Definition Map	Hazard Warning – Critical	eMBB (10ms)/URLLC
	Hazard Warning Indication – Non-Critical	eMBB
	HD Map Update for CAD	eMBB
Software Update	Software Update – Not Urgent	mIOT
	Software Update – Urgent	eMBB
Tele-Operated Driving	Tele-Operated Driving	URLLC (10ms)
	Tele-Operated Support via Remote Control	eMBB (20ms)/URLLC
	Autonomous Vehicles Parking by Remote Driving	URLLC (10ms)
High-Density Platooning	High-Density Platooning	URLLC (10ms)

WG2 also supported the work mapping 5GAA Use Cases to 3GPP Slice Service Types (SST).

Standardised Slice/Service Type (SST) values provide a way of establishing global interoperability for slicing so that PLMNs can support the roaming use case more efficiently for the most commonly, see TS 23.501.

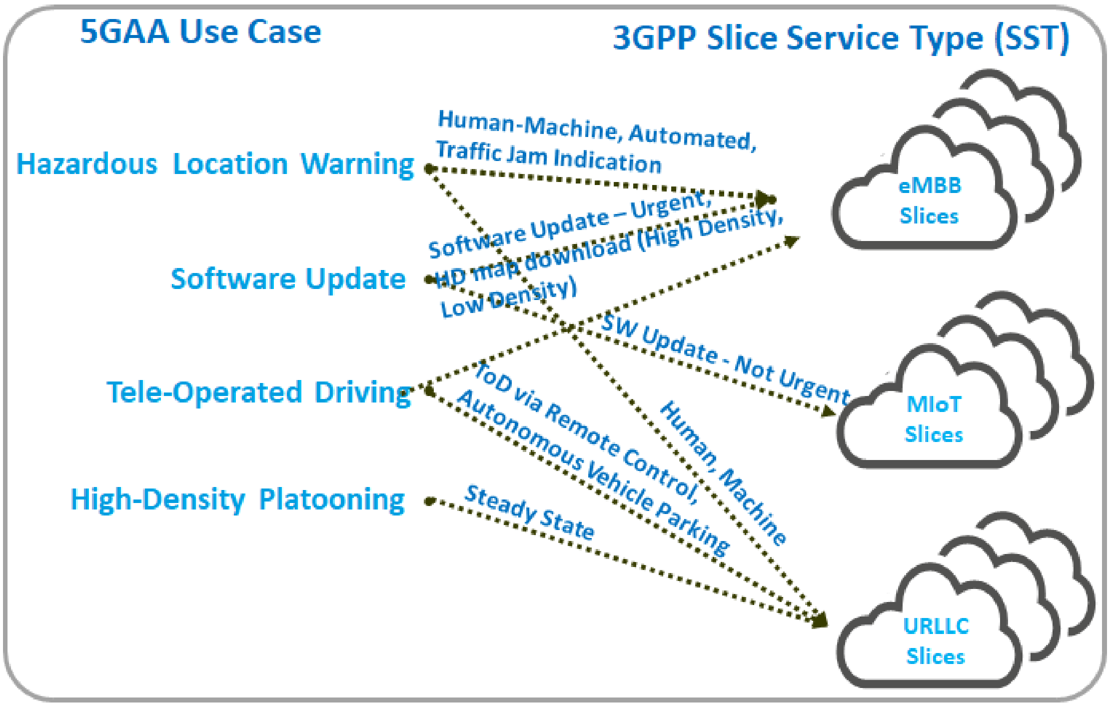


Figure 30 Use Cases and Slice Types

4 Business Roles Definition

4.1 Roles Related to 5G Networks and Network Slicing Management

The high-level role definition related to 5G networks and network slicing management is taken from 3GPP SA5 TR 22.830 (15.0.0) as shown in figure below, which includes:

- Communication service customer (CSC): Uses communication services.
- Communication service provider (CSP): Provides communication services. Designs, builds and operates its communication services. The CSP-provided communication service can be built with or without network slicing.
- Network operator (NOP): Provides network services. Designs, builds and operates its networks to offer such services.
- Network equipment provider (NEP): Supplies network equipment to the network. For the sake of simplicity, VNF Supplier is considered here as a type of NEP. This can also be provided in the form of one or more appropriate VNF(s).
- Virtualisation infrastructure service provider (VISP): Provides virtualised infrastructure services. Designs, builds and operates its virtualisation infrastructure(s). VISPs may also offer their virtualised infrastructure services to other types of customers including to CSPs directly, i.e. without going through the NOP.
- Data centre service provider (DCSP): Provides data centre services. Designs, builds and operates its data centres.
- NFVI supplier: Supplies network function virtualisation infrastructure to its customers.
- Hardware supplier: Supplies the hardware into the value chain.

The above is logical role definition. Depending on actual scenarios, each role can be played by one or more business entity simultaneously, or a business entity can play one or several roles simultaneously (for example, a company can play CSP and NOP roles simultaneously) according to 3GPP SA5 TR 22.830.

Such role model is mainly from a telecom perspective, when involving specific vertical industry, e.g. automotive, a complete ecosystem may involve more roles, which will be further analysed based on selected use cases.

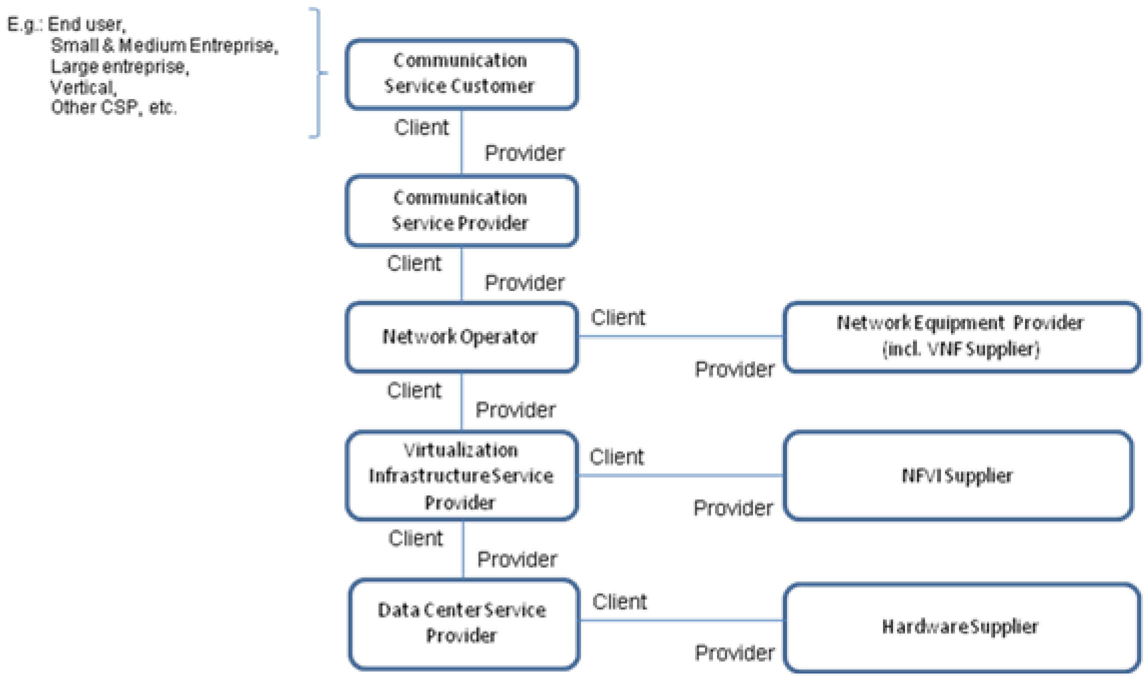


Figure 31 Roles of Players

4.2 Real-Time Situational Awareness and HD Map

This use case tries to describe when a host vehicle is made aware of some events on the route ahead. This can happen either by other vehicles (RVs) or via some backend/cloud service that collects and aggregates data from several vehicles and sends the warning/hazard information to the vehicle. Using this new information, the HV is able to set up a map of its environment while it is driving, which can help it to navigate in comfort and safety.

A vehicle's on-board computer can combine data received via C-V2X with information captured by on-board cameras to interpret road signs and objects. GNSS systems and precise location capability pinpointing the vehicle's location on 3D and HD maps can be updated in real time over a cellular network. The fusion of ever-evolving and improving sensors and computational machine intelligence drives an ecosystem of improved safety for drivers.

The particular uses cases within the scope of the business analysis are described in documents 5GAA T-180170 (Real-Time Situational Awareness, RTSA) and 5GAA T-180250 (HD Map Collecting and Sharing).

From the value network diagram below, the following roles have a technical impact in the overall use case Real-Time Situational Awareness and HD Maps:

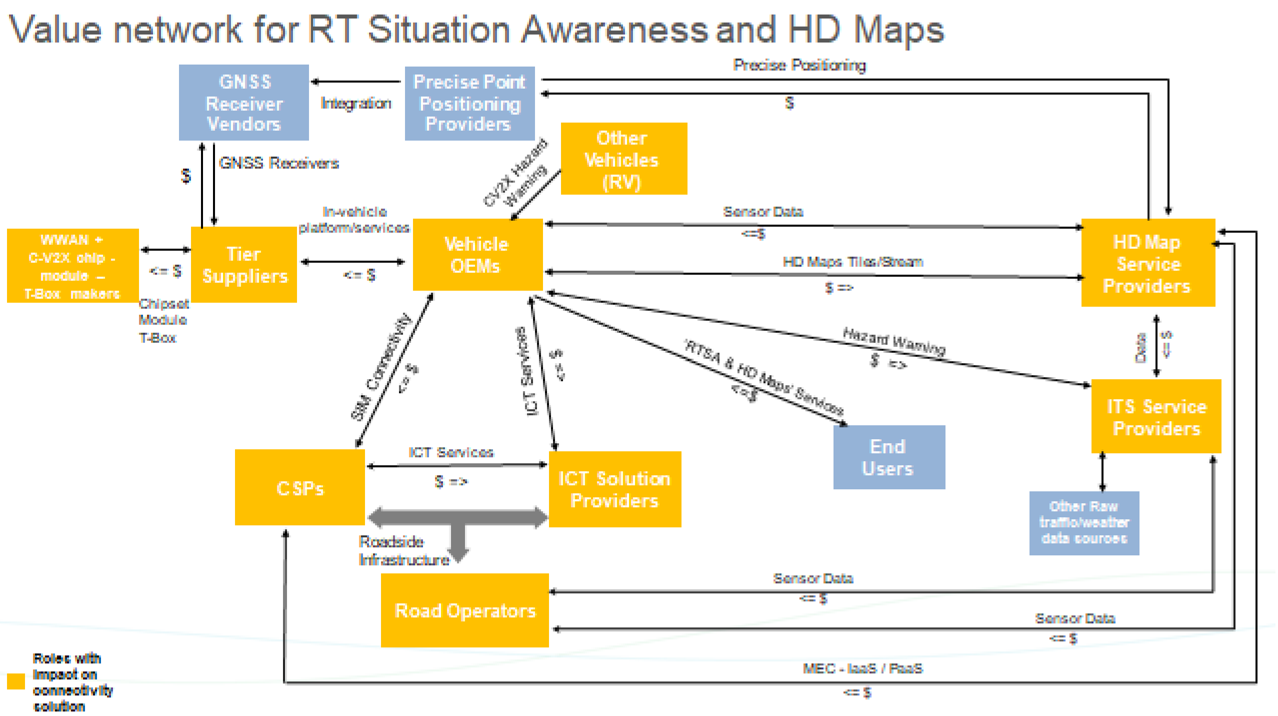


Figure 32 RTSA and HD Maps Value Network

- **Makers of chips, SIMs, CPUs and modules:** Suppliers of necessary components which are sold to the 'tier suppliers' who will in turn integrate them into parts for the vehicle OEMs.
- **Tier suppliers:** Parties that supply integrated parts to the vehicle OEMs for final assembly, incorporating:
    - Parts from the makers described above
    - Radio transmitter/receivers
    - The gateway module for RTSA and HD maps
    - Software, apps and OSS from the corresponding providers
    - All TCUs, head units (HU), ECUs, infotainment systems, UI systems and platforms, intelligent personal assistants, safety systems, ADAS, etc.

  For the purposes of RTSA and HD maps, all on-board systems should have extra storage space to hold both updates and older software that can be used as a fallback if problems arise.
- **Vehicle OEMs:** Source parts and products from tier suppliers and assemble them into finished vehicles, which they then sell to consumer and enterprise end-users, directly or through dealers. They also contract with CSPs directly, or

with telematics service providers for the necessary connectivity solution that enables all cellular communications of the vehicle. They also contract to map providers (or they even are shareholders of some players – e.g. HERE) and have relationships with ITS service providers.

- **ITS solution providers**: Collects traffic information and publishes to other vehicles in relation to accidents, traffic, adverse weather, road conditions, construction and other situations. Traditional providers of these services distribute relevant information via TMC or TPEG2 technologies as defined by www.tisa.org. These ITS services will evolve and potentially compete in tandem with C-V2X.
- **Road operators**: Road authorities and highway infrastructure entities that deliver transport infrastructure and services.
- **ICT solution providers:** Provide ICT infrastructure and services (typically cloud services, e.g. on Azure), which are necessary for the technical implementation of the Situational awareness and HD maps service. It must be noted that the role of the ICT solution provider may be played by CSPs, or through partnerships that include them.
- **Map service providers**: Deliver HD digital maps and other dynamic content for navigation and location-based services, including personal and in-car navigation systems, and provide data used in a wide range of mobile and internet map applications. The HD map providers can position themselves at the software as a service (SaaS) level within the cloud value chain.
- **Communication service providers:** Companies including mobile network operators (MNO) or specialised MVNOs (telematics service providers) that offer connectivity and other communication services to car OEMs for use by both the vehicles and their drivers (i.e. LTE and 5G mobile WWAN and C-V2X connectivity, including URLLC, over the carrier network). They also offer telecommunication services to consumer and business customers who use them in their vehicles, and different services to the OTA management platform, connectivity including C-V2X if necessary, mobile positioning if needed for the implementation of location-based OTA update policies, and potentially different added-value services (e.g. security, identity, integration, data and analytics services).
- Within the CSP role, we also include edge cloud provider companies that offer a component of edge cloud computing – typically infrastructure as a service (IaaS), platform as a service (PaaS) or SaaS – to other businesses or individuals. In this use case, HD map providers are considered 'as a services (aaS) HD maps' in the cloud value chain. The edge cloud service providers can offer the OEM/HD map companies IaaS and PaaS solutions to build out the HD map company's global deployment configurations, while meeting regional regulatory requirements.

  For clarity, the business analysis of this use case is related to network slicing and assumes that the MNO would operate an edge infrastructure where the map service provider will provide some type of application operated on that edge infrastructure which receives information from a HV vehicles about a hazard and this information is distributed by the edge application to other cars in the vicinity. Quality of service (QoS) can be applied to that slice. If the HD mapping application resides on the public cloud internet, QoS cannot be managed end to end but can be applied on the network slice from the car to the exit point on MNO network only.

The figure below presents all the stakeholders and the exchanges between them, which were shown graphically in the value network above. It is a tool that will eventually help reveal the possible ways in which service providers and suppliers can develop their products and services, and bring them to the market, enabling multiple use cases. Rows in the figure list the originators of a product/service/payment and columns list the recipients. The stakeholders are grouped as follows:

- Main roles: Those with a technical impact in terms of connectivity, including network slicing.
- Users: A role with a technical impact that corresponds to the end consumer of the service (i.e. private car owners or enterprise fleet operators).
- Enablers: Entities that help enable RTSA and HD map service.
- Authorities: Regulatory bodies that oversee and authorise RTSA and HD map service.

All monetary exchanges are shown in green shading. Some exchanges are shown in a dotted green pattern because they involve both payments ('$') and the provision of update files, i.e. when tier suppliers, vehicle OEMs and application and software providers supply update files to the OTA management platform for transfer to vehicles. Interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity are shown in red shading.

Figure 33 RTSA and HD Map Stakeholder Value Exchange

	Provides	Main Roles: Chip Makers	Main Roles: Tier Suppliers	Main Roles: Vehicle OEMs	Main Roles: Map Service Provider	Main Roles: ITS Service Provider	Main Roles: Road Operators	Main Roles: ICT Solution Providers	Main Roles: CSPs	Users: End Users	Enablers: Application & Software Providers	Enablers: Precise Positioning Providers	Authorities: Regulators
Main Roles	Chip Makers		Chips, SIMs, CPUs, Modules										
	Tier Suppliers	$		TCU, HU, ECU, IPA, Infotainment							$		
	Vehicle OEMs		$		Sensor Data, $	$		$	$	Vehicles with RTSA&HD Maps			
	Map Service Provider			HD Maps Tiles ,$			$		$			$	
	ITS Service Provider			Hazard Warnings			$						
	Road Operators				Road Data	Road Data							
	ICT Solution Providers			ICT Servcies			ICT Services		ICT Services				
	CSPs			Connectivity	MEC								
Users	End Users			$									
Enablers	GNSS Receiver vendors			GNSS Receivers									
	Precise Positioning Providers				Precise Positioning								
Authorities	Regulators				Approval	Approval							

All monetary exchanges are shown in green shading. Some exchanges are shown in a dotted green pattern because they involve both payments (“$”) and the provision of update files, i.e. when Tier Suppliers, Vehicle OEMs and Application & Software Providers supply updates files to the OTA Management Solution Providers for transfer to vehicles.
Interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity are shown in red shading.

4.1 Software OTA Updates

There are different ways to implement software OTA updates, and some of these do not involve the use of cellular connectivity over the commercial spectrum, such as wireless updates transferred over Wi-Fi. While these modes may be in widespread use, we will not study them here as the focus of our attention is the use of cellular connectivity for the purpose of OTA updates and in particular the impact of network slicing in the design and implementation of the service.

Therefore, the value network for software OTA updates shown below does not include actors such as dealers and repair shops that traditionally administer such updates. Likewise, wireless modes of OTA updates that involve Wi-Fi, or V2V transfer of updates, or even V2I transfers using some special RSUs are not considered. For simplicity, the value network depicts only OTA updates using cellular connectivity over the commercial spectrum.

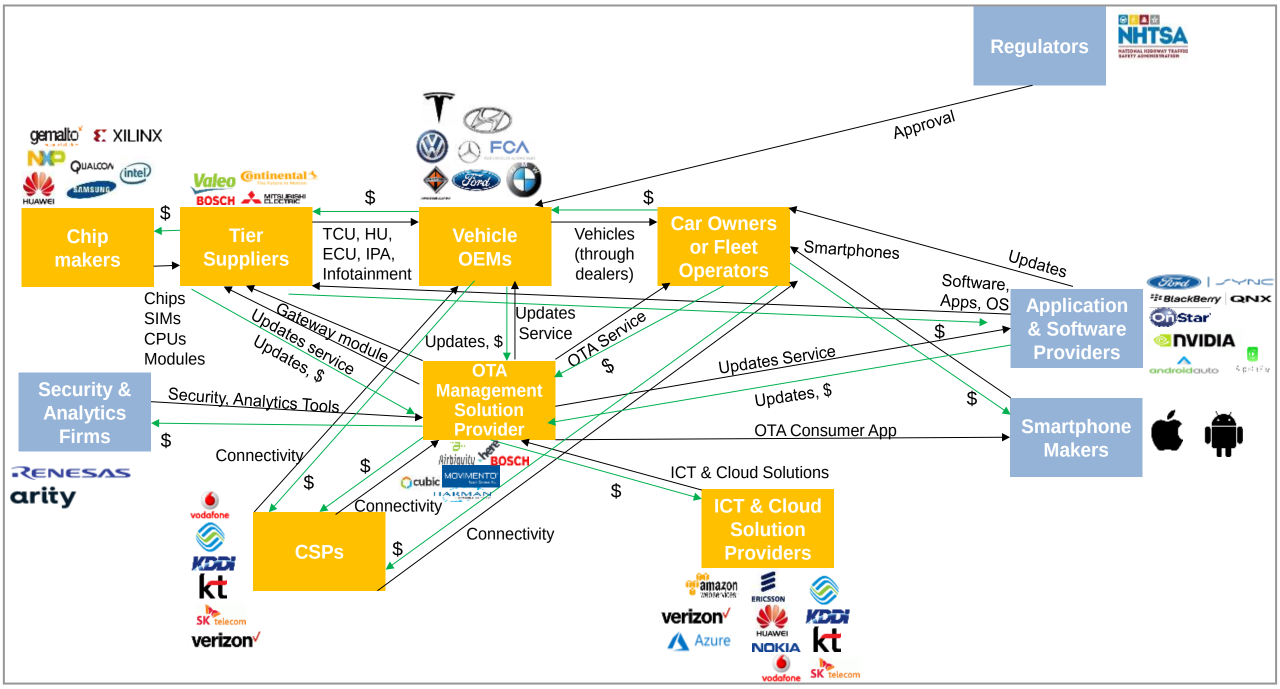


Figure 34 Software OTA Value Network

As can be seen in Figure 32 RTSA and HD Maps Value Network, there are seven roles with a technical impact in the case of software OTA updates:

- **Makers of chips, SIMs, CPUs and modules:** Suppliers of necessary components which are sold to the 'tier suppliers' who will in turn integrate them into parts for the vehicle OEMs.
- **Tier suppliers:** Parties that supply integrated parts to the vehicle OEMs for final assembly, incorporating:
  - Parts from the makers described above.
  - Radio transmitter/receivers.
  - The gateway module for RTSA and HD maps.
  - Software, apps and OSS from the corresponding providers.
  - All TCUs, head units (HU), ECUs, infotainment systems, UI systems and platforms, intelligent personal assistants, safety systems, ADAS, etc.

For the purposes of RTSA and HD maps, all on-board systems should have extra storage space to hold both updates and older software that can be used as a fallback if problems arise. In parallel, device-side OTA client software components (i.e. protocol/control – downloader – installer) must be installed by the device (TCU/HU/ECU) manufacturer on each device.

- **Vehicle OEMs:** Source parts and products from tier suppliers and assemble them into finished vehicles, which they then sell to consumer and enterprise end-users, directly or through dealers. They also contract with CSPs directly, or with telematics service providers for the necessary connectivity solution enabling all cellular communications of the vehicle. Most importantly, they collaborate with OTA management solution providers for the implementation and delivery of the OTA updates service.

- **OTA management solution providers:** The party that implements and delivers the OTA updates service. The solution includes an on-board component, usually taking the shape of gateway module or control agent that manages the downloading, storing, and application of software updates. In parallel, some OTA providers make aftermarket solutions available for the role of the gateway module, such as a hardware dongle device that plugs into the OBD-II port of any car.

  The core function of the OTA management platform is the orchestration of firmware updates, software updates, and data collection. The solution manages anything from individual configuration and setting files, through map and delta updates, and all the way to full software version images, bringing together multiple software tools and multiple software installers. It is usually implemented as a full-stack client/server software solution with its backend server components either installed on the OEM customer's IT premises or hosted by the OTA solution providers themselves.

  Other key components of the platform include:
    - Device management capabilities.
    - Automotive software catalogues.
    - Car component inventories.
    - Fast update technologies such as delta and compression mechanisms.
    - Provisions for regulatory compliance according to local requirements.
    - APIs to create and monitor targeted update campaigns to securely update map data, software and firmware inside a vehicle.
    - Campaign management and reporting functions providing information and insights on the success rate of device update campaigns.
    - Mobile application/consumer UI management.
    - Billing including management of revenue sharing.
    - Customer support integration.
    - Integration with existing server infrastructures and vehicle architectures, product lifecycle management (PLM) systems, parts management, licensing and reporting systems.

  Typical solutions include: Airbiquity's OTAmatic Software and Data Management Platform, Movimento's Automotive Intelligent Engine, Harman's Remote Vehicle Updating Service, Bosch's Mobility Solutions, and Here's OTA Connect.

  A vital aspect of the OTA updates service is the paramount importance of cyber security. Usually, OTA management solution providers work with partners from the security field to adopt their frameworks and encryption algorithms and make sure their systems meet security requirements. For example, Here uses Uptane, a security framework backed by the US Department of Homeland Security that was designed specifically for software that runs on connected and autonomous vehicles (CAVs). Harman has devised its own Automotive Cyber Security (TowerSec) intrusion detection and prevention system to ensure rapid identification, reporting and mitigation of malicious network activity. Bosch works with Escrypt, a leading security specialist for the automotive sector.
- **ICT solution providers:** Offer ICT infrastructure and services (typically cloud services, e.g. on Azure) to the OTA management solution providers, which is necessary for the technical implementation of the OTA updates service. It must be noted that the role of the ICT solution provider may be played by CSPs or through partnerships that include them. Likewise, several OTA solution providers have built their own cloud service delivery platforms, e.g. Bosch's IoT Cloud, and Airbiquity's Choreo.
- **Communication service providers:** Companies including mobile network operators (MNO) or specialised MVNOs (telematics service providers) that offer connectivity and other communication services to car OEMs for use by both the vehicles and their drivers (i.e. LTE and 5G mobile WWAN and C-V2X connectivity, including URLLC, over the carrier network). They also offer telecommunication services to consumer and business customers who use them in their vehicles, and different services to the OTA management platform, connectivity including C-V2X if necessary, mobile positioning if needed for the implementation of location-based OTA update policies, and potentially different added-value services (e.g. security, identity, integration, data and analytics services).
- **Car owners or fleet operators:** End users of the OTA service for their vehicles, and the assorted consumer hardware devices that may be used in the delivery of the service (e.g. aftermarket OBD-II dongle, or smartphone for the use of an OTA management application). At the same time, they have connectivity from a CSP which they may use in getting OTA updates from various sources: typically the OTA management solution provider that caters to their vehicle brand, but also directly from application service providers.

The figure below presents all the stakeholders and the exchanges between them, which were shown graphically in the value network above. It is a tool that will eventually help reveal the possible ways in which service providers and suppliers can develop their products and services, and bring them to the market under multiple use cases. Rows in the figure list the originators of a product/service/payment and columns list the recipients. The stakeholders are grouped as follows:

- Main roles: The six roles with a technical impact in terms of connectivity, including network slicing.
- Users: The seventh role with a technical impact that corresponds to the end consumer of the OTA updates service (i.e. private car owners or enterprise fleet operators).
- Enablers: Entities that help to enable OTA updates such as security and analytics firms, and smartphone makers, and also application and software providers who supply the software, applications, and operating systems used in the vehicle and which are subject to the OTA updates.
- Authorities: Regulatory bodies that oversee and authorise OTA updates.

All monetary exchanges are shown in green shading. Some exchanges are shown in a dotted green pattern because they involve both payments ('$') and the provision of update files, i.e. when tier suppliers, vehicle OEMs and application and software providers supply update files to the OTA management solution providers for transfer to vehicles. Interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity are shown in red shading.

Figure 35 SOTA Stakeholder Value Exchange

		Main Roles						Users	Enablers			Authorities
	Provides	Chip Makers	Tier Suppliers	Vehicle OEMs	OTA Mgnt Solution Provider	ICT Solution Providers	CSPs	End Users	Application & Software Providers	Smartphone Makers	Security & Analytics Firms	Regulators
Main Roles	Chip Makers		Chips, SIMs, CPUs, Modules									
	Tier Suppliers	$		TCU, HU, ECU, IPA, Infotainment	Updates, $				$			
	Vehicle OEMs		$		Updates, $		$	Vehicles				
	OTA Mgnt Solution Provider		Updates Service, Gateway Module	Updates Service		$	$	OTA Service	Updates Service	OTA Consumer App	$	
	ICT Solution Providers				ICT & Cloud Solutions							
	CSPs			Connectivity	Connectivity			Connectivity				
Users	End Users			$	$		$			$		
Enablers	Application & Software Providers		Software, Apps, OS		Updates, $			Updates				
	Smartphone Makers							Smartphones				
	Security & Analytics Firms				Security, Analytics Tools							
Authorities	Regulators				Approval							

4.2 Tele-Operated Driving

According to GSMA, in its ‘Network Slicing Use Case Requirements’ document from April 2018, **tele-operation** is defined as the use case class that describes the scenarios where a remote driver could directly control an autonomous-capable vehicle from a remote location such as a control centre for certain periods of time. The remote driver receives a video stream taken from the cameras on the vehicle. The real-time video provides elaborate ‘perception’ of the environment to the driver so that the diver can operate the vehicle as if he/she is personally inside the vehicle. Advanced video technology (e.g. VR) could further improve the experience of a remote driver.

Likewise, **remote driving** enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive by themselves, or remote vehicles located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. High reliability and low latency are the main requirements. This definition originates at 3GPP’s SA1 work on the enhancement of 3GPP support for V2X services (eV2X services). The consolidated requirements for each use case group were captured in TR 22.886, and a set of the normative requirements has been defined in TS 22.186. SA1 has identified 25 use cases for advanced V2X services and they are categorised into four use case groups: vehicles platooning, extended sensors, advanced driving and remote driving.

It is clear that every L4/L5 autonomous vehicle requires one or more ways to a remote control capability:

- **Tele-operated – or remote – driving** (these two terms will be used interchangeably, and in short as **ToD**): someone is actually driving the vehicle from a distance, controls it directly and can accelerate. This capability requires a highly reliable radio link with full round trip delay below 10ms. That is fast enough for instructions to be received and acted upon by the systems as quickly as the human eye can perceive change, and requires 5G (Uu URLLC).
- Teaching the AV what to do: someone issues commands for the AV to execute (also referred to as ‘**supervised autonomy**’). This can be done over the top OTT with LTE.
- To address the lack of ubiquitous 5G coverage for the next 5-10 years, a ToD solution should be able to revert to ‘command mode’ using LTE if necessary, at least bringing the AV safely to stop and call for help.
- It is unlikely that regulators will accept the absence of a human from the autonomous driving loop. For example, under current state regulations, any car operated on California streets without a person in the driver’s seat must be monitored electronically by someone who has the ability to take control. Similarly, Florida’s self-driving regulations require the vehicle’s operator – who doesn’t have to be inside the car – retain the ability to control, or at least stop, the car.

ToD is a use case that may be implemented in slightly different ways in terms of business model and go-to-market approach, depending on whether the in-vehicle equipment of the ToD solution has been installed in the factory during the vehicle’s production (“factory-fit” or “integrated”) or at a later stage (“retrofit” or “after-market”). It is foreseen that in the future all automated vehicles will have ToD integrated, therefore we will use this setting to describe the business roles. Although, Starsky Robotics, one of the pioneers of tele-operation, has announced that was designing an aftermarket retrofit kit that would give big-rigs autonomous capabilities [source: https://www.businessinsider.com/autonomous-trucks-tesla-uber-google-2017-6], the adoption of this solution is not expected to be significant given existing concerns regarding the safety of after-market solutions.

The value network for integrated ToD for **private passenger** automated and autonomous vehicles is shown below where yellow boxes indicate roles with a technical impact on connectivity solutions.

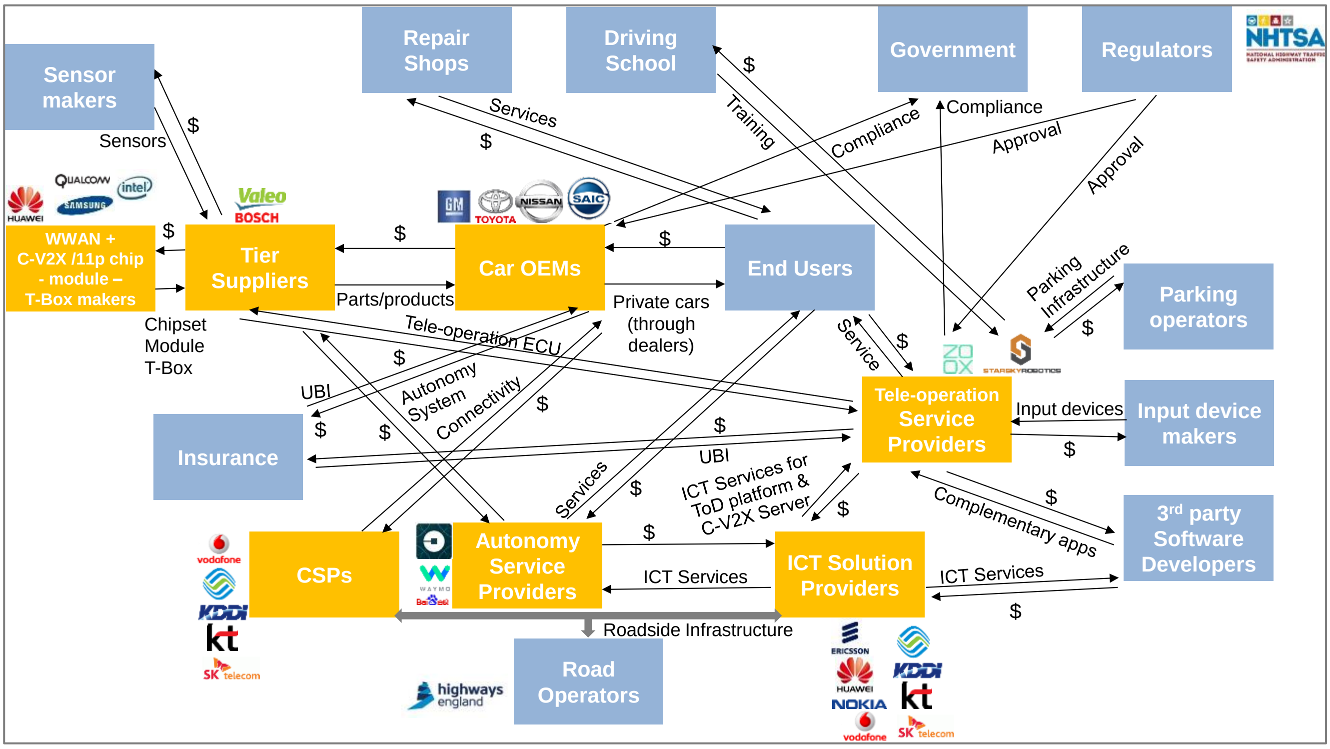


Figure 36 Tele-Operated Driving Value Network – Private Passenger

As can be seen in the value network above, there are seven roles with a technical impact in the case of ToD:

- **Makers of WWAN and C-V2X (or 11p) chips, modules and T-Boxes:** Suppliers of these necessary components, including the in-vehicle communications software, sell them to the tier suppliers who will in turn integrate them into parts for the truck OEMs.
- **Tier suppliers:** Parties that supply integrated parts to the car OEMs for final assembly. They have sourced the materials for these parts from different vendors, such as the makers described above, and autonomy service providers. In the ToD case, the tele-operation service providers are considered to be vendors who supply the in-vehicle ToD system and controls to the tier suppliers. Tier suppliers also source from sensor makers and integrate the following sensors that are necessary for ToD, among other uses:
  - Radar
  - LIDAR
  - HD cameras
  - Antennas
  - Microphone
  - Systems for precision location for route planning purposes (e.g. GPS, laser scanners, Simultaneous Location and Mapping systems, SLAM).
- **Car OEMs:** Source parts and products from tier suppliers and assemble them into finished cars, which they then sell to consumer end-users, directly or through dealers. They also contract with insurance companies to ensure that there is appropriate coverage of all types when the vehicle is remotely driven, and also with communication service providers for the necessary connectivity solution that enables tele-operation. OEMs that develop autonomy systems tend to also build their own ToD solutions, and these include both established brands like Toyota, Volvo, Nissan, GM, Ford and start-ups like Einride.
- **Tele-operation service providers:** Suppliers of the ToD system for automated passenger cars, which includes an ECU to be integrated into vehicles, and they operate a remote operation service manned by human operators that is consumed by end-users. Start-ups active in this field include Starsky Robotics, Zoox, Phantom Auto, Nutonomy and Drive.ai. The ToD service is being delivered through a remote control centre, which consists of the following components:
  - Remote monitoring and control software, i.e. the ToD software application that runs in the centre and the car, as well as any ancillary software provided by third-party software developers.
  - V2X server.
  - Remote management console with display, steering wheel, pedal combo, haptic system and VR equipment, supplied by input device makers.
  - Call centre and the associated equipment.

The remote control centre makes use of ICT services that ICT solution providers supply. Also, ToD service providers contribute data to insurers so that the vehicle is properly covered while remotely driven, and collaborate with other service providers, such as parking operators, to make sure the ToD service will be available in their premises in a safe, efficient and convenient way. Lastly, ToD service providers need to undergo a certification and licensing process to get approval of operation from the local authorities.

- **Autonomy service providers:** Suppliers of the autonomy system, which consists of the in-vehicle hardware and software parts, and they run the autonomous driving operation, control and management software on the autonomy server infrastructure, which is powered by ICT solution providers. Based on this infrastructure, they offer autonomy services to end-users. Autonomy service providers include both traditional automakers that explore autonomy, such as Ford, Volvo, Nissan and GM, as well as start-ups or disruptive mobility companies that work almost exclusively on autonomy projects (i.e. Nevs, Uber, Waymo, Nutonomy, Einride, and Starsky Robotics).
- **ICT solution providers:** Offer ICT infrastructure and services (e.g. cloud, V2X server) to participants that contribute to the technical implementation of the ToD service (i.e. ToD Service Providers, third-party software developers, autonomy service providers), and participate in the development and operation of the connectivity and computing roadside infrastructure that facilitates ToD. It must be noted that the role of the ICT solution provider may be played by communication service providers, or partnerships that include them.
- **Communication service providers:** Offer connectivity and other communication services to car OEMs for use by both the vehicles and their drivers (i.e. LTE and 5G mobile WWAN and C-V2X connectivity, including URLLC, over the carrier network), and also contribute the WWAN and C-V2X connectivity solutions required for the roadside infrastructure.

The figure below presents all the stakeholders and the exchanges of good and services between them, which were shown graphically in the value network above. It is a tool that will eventually help reveal the possible ways in which service providers and suppliers can develop their products and services, and bring them to the market to enable multiple use cases. Rows in the table list the originators of a product/service/payment and columns list the recipients. The stakeholders are grouped as follows:

- Main roles: The seven roles with a technical impact.
- Users: The role that corresponds to the end consumer of the ToD service (i.e. private car passenger).
- Enablers: Entities that enable ToD by offering ancillary or complementary functionalities or infrastructure, i.e. input device makers, sensor makers, third-party software developers, and road operators.
- Services: Companies that support the operation of ToD such as insurers, repair shops, driving schools, and parking operators.
- Authorities: Government and regulatory bodies that oversee and authorise ToD.

All monetary exchanges are shown in green shading, and they include payments (‘$’) and revenue sharing agreements (‘%’). Interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity are shown in red shading.

Figure 37 TOD Stakeholder Value Exchange – Private Passenger

	Provides	Main Roles							Users	Enablers				Services				Authorities
		Chip, Module, T-Box Makers	Tier Suppliers	Car OEMs	Autonomy SPs	ToD SPs	ICT Solution Providers	CSPs	End Users	Input Device Makers	Sensor Makers	3rd Party SW	Road Ops	Insurance	Parking Operators	Repair Shops	Drive Schools	Government/ Regulators
Main Roles	Chip, Module, T-Box Makers		Chip, Module, T-Box															
	Tier Suppliers	$		Parts, products	$	$					$							
	Car OEMs		$					$	Cars					$				
	Autonomy SPs		Autonomy System				$		Services									
	ToD SPs		ToD ECU				$		Service	$		$ and/or %		Data & Analytics	$		$	
	ICT Solution Providers				ICT Services	ICT Services for ToD platform & C-V2X Server						ICT Services	Roadside C-V2X Infra.					
	CSPs			Connectivity									Roadside C-V2X Infra.					
Users	End Users			$	$	$										$		
Enablers	Input Device Makers					Input Devices												
	Sensor Makers		Sensors															
	3rd Party SW					Compl. Apps	$											
	Road Ops								Roadside Infra.									
Services	Insurance			UBI		$												
	Parking Operators					Parking Infrastructure												
	Repair Shops								Services									
	Drive Schools					Training												
Authorities	Government/ Regulators			Approval/Incentives		Approval/Incentives												

The value network for integrated ToD for automated and autonomous **fleet vehicles** is shown below. It does differ in one significant aspect from the case of ToD for private passenger cars. In terms of stakeholders involved, fleet operators are the consumers of the ToD service, which provide a transport service to various customers (end-users). Importantly, fleet operators can also be the party that runs the ToD service for the vehicles in their fleet, using solutions by ToD service providers (e.g. ToD systems for urban mobility vehicles, or automated freight vehicles).

More specifically:

- **Fleet operators:** Include companies with commercial fleets like logistics service providers and integrated transportation service providers (e.g. Transdev), enterprises with corporate fleets like Rio Tinto, BHP Billiton, Fortesque and Suncor, and mobility-as-a-service providers like Uber, Lyft and Voyage with urban mobility vehicle fleets. They source vehicles from vehicle OEMs and they use their fleets in offering transport services to end-users, therefore they are the consumers of the ToD service. In order for the vehicles in the operators' fleets to support tele-operation, fleet operators need to have engaged with ToD service providers who offer them the required solution. Fleet operators use this solution to tele-operate their vehicles from remote control centres they establish and man. Another necessary ingredient for the fleet vehicles' tele-operation is connectivity, which communication service providers offer to the fleet operators. Additionally, the operation of remotely driven vehicles requires appropriate coverage by insurance companies, which the fleet operators need to purchase. In parallel, fleet operators have ToD-related exchanges with ancillary service providers and agencies they engage with:
    - Autonomy service providers for various services pertaining to the automated vehicles in their fleets.
    - Repair shops for repair and maintenance of the equipment involved in the delivery of the ToD service.
    - Driving schools for the specialised training required for remotely driving different types of fleet vehicles including heavy haul trucks.
    - Authorities for acquiring the licenses necessary to carry out tele-operation.

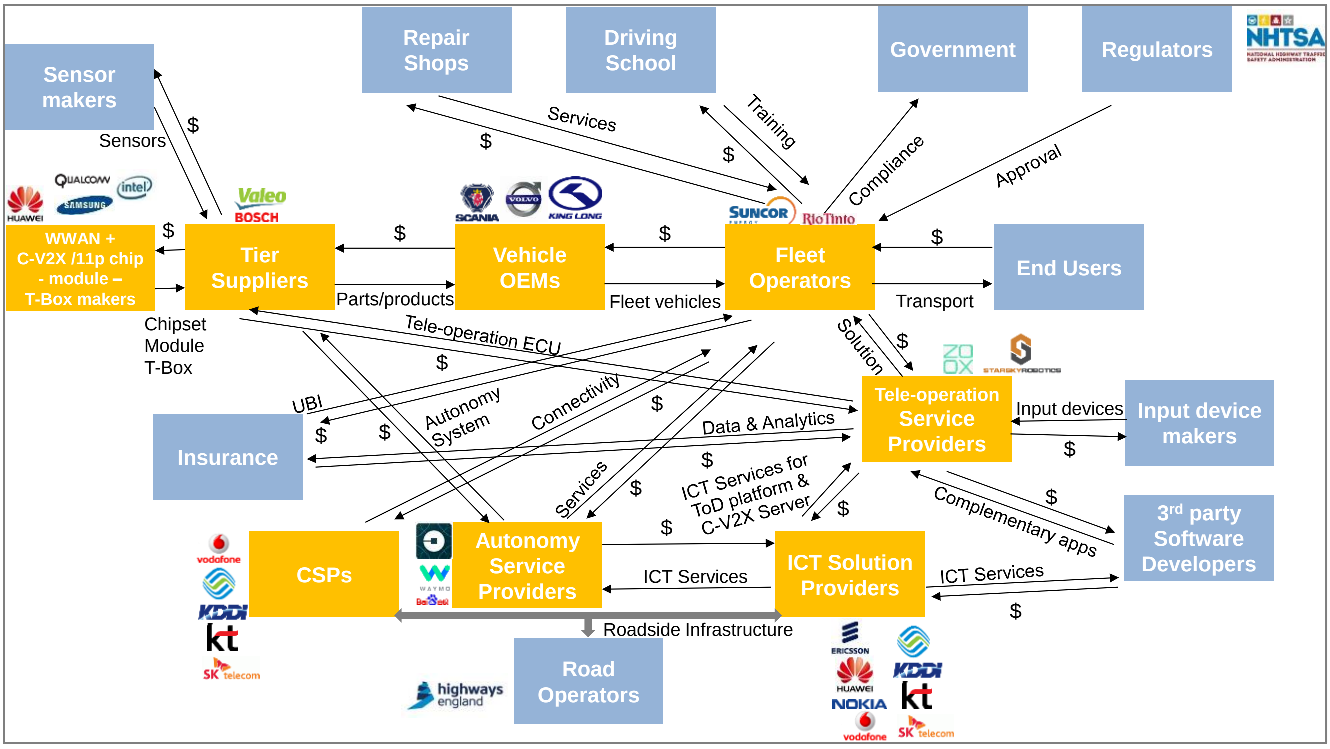


Figure 38 TOD Value Network – Fleet Vehicles

The figure below presents all the stakeholders and the exchanges between them, which were shown graphically in the value network above.

Figure 39 TOD Stakeholder Exchange – Fleet Vehicles

		Main Roles								Users	Enablers				Services			Authorities
	Provides	Chip, Module, T-Box Makers	Tier Suppliers	Vehicle OEMs	Autonomy SPs	Fleet Operators	ToD SPs	ICT Solution Providers	CSPs	End Users	Input Device Makers	Sensor Makers	3rd Party SW	Road Ops	Insurance	Repair Shops	Drive Schools	Government/ Regulators
Main Roles	Chip, Module, T-Box Makers		Chip, Module, T-Box															
	Tier Suppliers	$		Parts, products	$		$					$						
	Vehicle OEMs		$			Vehicles												
	Autonomy SPs		Autonomy System			Services		$										
	Fleet Operators			$	$		$		$	Transport				Tolls	$	$	$	Compliance, Tax
	ToD SPs		ToD ECU			Solution		$			$		$ and/or %		Data & Analytics			
	ICT Solution Providers				ICT Services	Connectivity	ICT Services for ToD platform & C-V2X Server				ICT Services		ICT Services	Roadside C-V2X Infra.				
	CSPs					Connectivity								Roadside C-V2X Infra.				
Users	End Users					$												
Enablers	Input Device Makers						Input Devices											
	Sensor Makers		Sensors															
	3rd Party SW						Compl. Apps	$										
	Road Ops					Roadside Infra.												
Services	Insurance					UBI	$											
	Repair Shops					Services												
	Drive Schools					Training												
Authorities	Government/ Regulators					Approval, Incentives												

Figure 40 depicts the association between the roles prescribed in the network slicing business role model and the stakeholders in ToD of automated and automatic fleet vehicles that were identified as playing a technically impactful role.

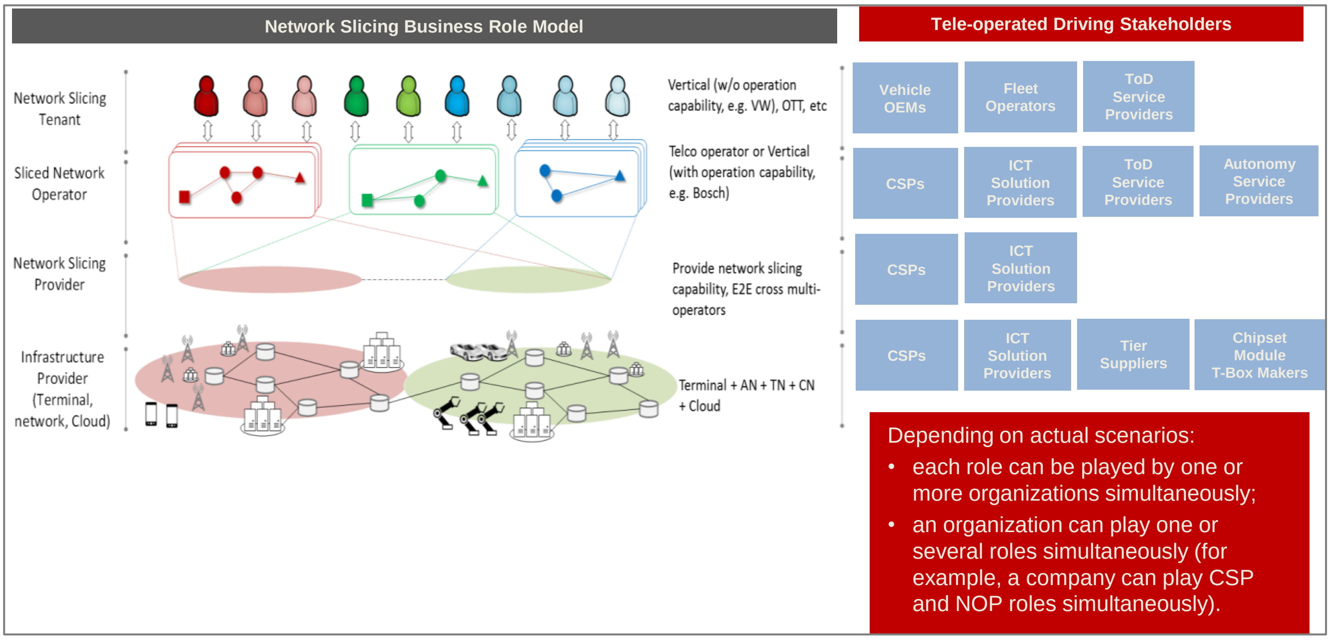


Figure 40 Network Slicing Business Role Model

Depending on the actual scenario, an organisation can play one or several roles simultaneously (for example, a company can play the network slicing Provider and the Sliced Network Operator roles simultaneously).

To deliver the overall benefits described above, ToD requires a highly reliable radio link with full round-trip delay below 10ms. This is fast enough that instructions can be received and acted upon by the systems as quickly as the human eye can perceive change. This will require 5G (Uu URLLC). More specifically, according to 3GPP's 'eV2X Requirements and KPIs, Enhanced Support for V2X Services' document, enabling a remote driver of V2X application to operate a remote vehicle requires the achievement of the following KPIs, for an absolute speed of up to 250km/h:

- Ultra-high reliability >99.999%
- Latency 10ms
- Data rate UL: 25Mbps, DL: 1Mbps

4.3 High-Density Platooning

High-density platooning is a use case that may be implemented in slightly different ways in terms of business model and go-to-market approach, depending on whether the platooning equipment has been installed in the factory during the truck's production ('factory-fit' or 'integrated') or at a later stage ('retrofit' or 'after-market'). It is foreseen that in the future most trucks will have platooning integrated, therefore we will use this setting to describe the business roles, and just point out the differences, if any, for the retrofit model.

Figure 41 shows the value network, there are seven roles with a technical impact in the case of integrated platooning:

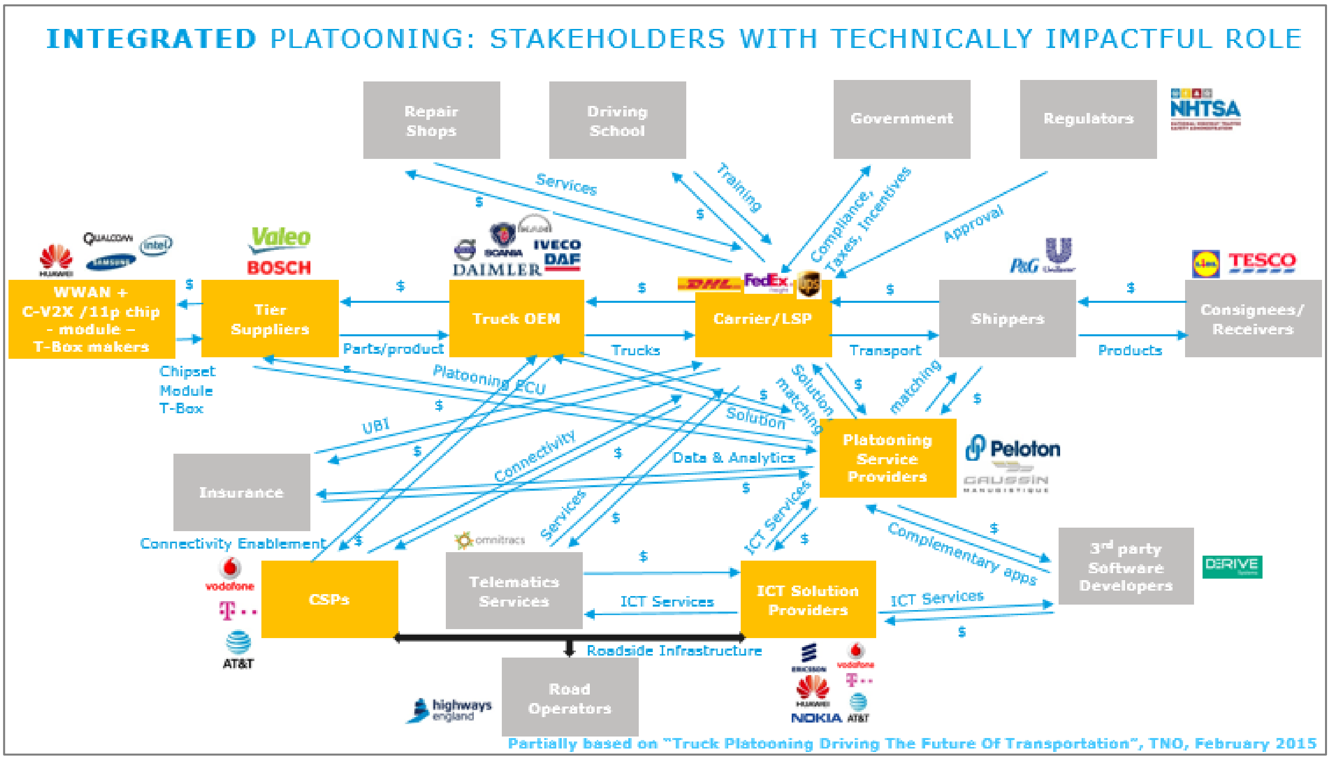


Figure 41 HD Platooning Value Network

- **Makers of WWAN and C-V2X (or 11p) chips, modules and T-Boxes:** Suppliers of these necessary components sell them to the tier suppliers, who will in turn integrate them into parts for the truck OEMs.
- **Tier suppliers:** Parties that supply integrated parts to the truck OEMs for final assembly. They have sourced the materials for these parts from different vendors, such as the makers described above. In the case of truck platooning, the platooning service providers are considered to be vendors who supply the in-vehicle hardware/software components of the platooning solution to the tier suppliers. These, according to Peloton, a leading platooning service provider, include:
  - Platooning ECU
  - Windshield camera
  - Display
  - Engage/disengage button
  - Antennas and wiring
- **Truck OEMs:** Source parts and products from tier suppliers and assemble them into finished trucks, which they then sell to fleet operators, such as carriers and logistics service providers, directly or through dealers. It is also possible that truck OEMs contract with platooning service providers so that the trucks have the platooning service operational upon leaving the assembly plant's door, under the responsibility of the OEM.
- **Carriers and logistics service providers:** Source trucks from truck OEMs and use their truck fleets in offering transport services to shippers, therefore they are the end-users of the platooning solution. In order for the trucks in the carriers' fleets to operate in platoon formations, carriers need to have engaged with platooning service providers who offer them services related to the platoon's operation and the matching of demand and supply for fleets of platooning trucks. Another necessary ingredient for the platoon's operation is connectivity, which communication service providers offer to the carriers/LSPs. Additionally, the platoon's operation requires appropriate coverage by

insurance companies, which the carriers need to purchase. In parallel, carriers and LSPs have platoon-related exchanges with ancillary service providers and agencies they engage with:
    - Telematics services providers for various fleet management services.
    - Repair shops for repair and maintenance of the platooning equipment.
    - Driving schools for the specialised training required for driving platooning trucks.
    - Government bodies and regulators for acquiring the licenses necessary to participate in high-density truck platooning.
- **Platooning service providers:** Suppliers of the platooning solution, which consists of the in-vehicle hardware and software parts, and the platooning operation, control and management software that runs on the platooning service network operation centre (NOC). Based on this infrastructure, they offer the platooning service to carriers and LSPs, and demand and supply matching platform services to them and shippers. It is also possible that the platooning service is offered to truck OEMs so that their trucks can perform platooning immediately upon their delivery to the fleet operators/truck buyers. At the same time, platooning service providers partner with:
    - ICT solution providers for the hosting and operation of the platooning service NOC, and the delivery of the platooning service.
    - Third-party software developers for utility software complementary to the core platooning proposition (e.g. miles-per-gallon optimisation software).
    - Insurance companies to which they provide data and analytics from the operation of platoon to be used in calculating premiums for trucking companies.
- **ICT solution providers:** Offer ICT infrastructure and services to all participants that contribute to the technical implementation of the platooning service (i.e. platooning service providers, third-party software developers, telematics service providers), and participate in the development and operation of the connectivity and computing roadside infrastructure that facilitates platooning. It must be noted that the role of the ICT solution provider may be played by communication service providers, or partnerships that include them.
- **Communication service providers:** Offer connectivity and other communication services to fleet operating companies (carriers/LSPs) for use by both the trucks and their drivers, and also contribute the WWAN and C-V2X connectivity solutions required for the roadside infrastructure. On top of that, they may provide connectivity enablement solutions for truck OEMs.

The case of retrofit platooning does not differ significantly in terms of the stakeholders involved. The only difference is that the in-vehicle platooning solution parts are not integrated by truck OEMs but are rather sold and installed by dealers who purchase them from the tier suppliers.

The figure below presents all the stakeholders and the exchanges between them, which were shown graphically in the value network above. It is a tool that will eventually help reveal the possible ways in which service providers and suppliers can develop their products and services, and bring them to the market to enable multiple use cases. Rows in the table list the originators of a product/service/payment and columns list the recipients. The stakeholders are grouped as follows:

- Main roles: The seven roles with a technical impact, analysed earlier.
- Users: The two roles that correspond to the end consumers of the transportation task of platooning trucks; shippers and consignees/receivers.
- Enablers: Entities that help enable truck platooning by offering ancillary or complementary functionalities or infrastructure, i.e. telematics services, third-party software developers, and road operators.
- Services: Companies that provide services that support the operation of platooning such as insurers, repair shops and driving schools.
- Authorities: Government and regulatory bodies that oversee and authorise truck platooning.

All monetary exchanges are shown in green shading, and they include payments (‘$’) and revenue sharing agreements (‘%’). Interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity are shown in red shading.

		Main Roles							Users		Enablers			Services			Authorities
	Provides	Chip, Module, T-Box Makers	Tier Suppliers	Truck OEMs	Carriers/LSPs	Platooning SPs	ICT Solution Providers	CSPs	Shippers	Consignees/ Receivers	Telematics Services	3rd Party SW	Road Ops	Insurance	Repair Shops	Drive Schools	Government/ Regulators
Main Roles	Chip, Module, T-Box Makers		Chip, Module, T-Box														
	Tier Suppliers	$		Parts, products		$											
	Truck OEMs		$		Trucks	$		$									
	Carriers/LSPs			$		1. $ 2. %		$	Transport		$		Tolls	$	$	$	Compliance, Tax
	Platooning SPs		Platooning ECU	Solution	1. Solution 2. Matching		$		Matching			$ and/or %		Data & Analytics			
	ICT Solution Providers					ICT Services					ICT Services	ICT Services	Roadside C-V2X Infra.				
	CSPs			Connectivity Enablement	Connectivity								Roadside C-V2X Infra.				
Users	Shippers				$	%				Products							
	Consignees/ Receivers								$								
Enablers	Telematics Services				Services		$										
	3rd Party SW					Compl. Apps	$										
	Road Ops				Roadside Infra.												
Services	Insurance				UBI	$ and/or %											
	Repair Shops				Services												
	Drive Schools				Training												
Authorities	Government/ Regulators				Approval, Incentives												

Figure 42 HD Platooning Stakeholder Value Exchange

The figure below depicts the association between the roles prescribed in the network slicing business role model and the seven stakeholders in truck platooning that were identified as playing a technically impactful role.

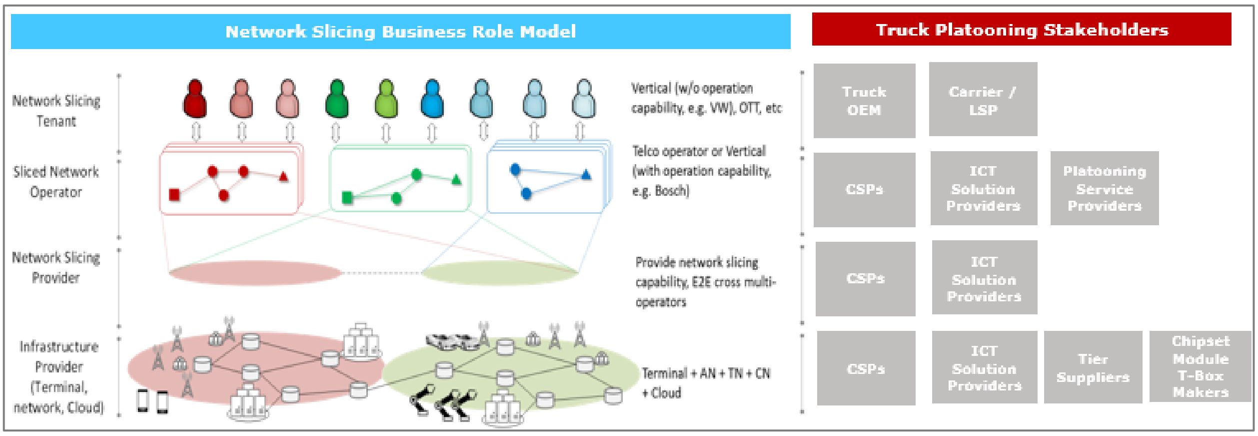


Figure 43 Business Roles and Players

Depending on the actual scenario, each role can be played by one or more organisations simultaneously, and an organisation can play one or several roles simultaneously (for example, a company can play the network slicing provider and the sliced network operator roles simultaneously).

5 Business Value Analysis

5.1 Real-Time Situational Awareness and HD Map

Intelligent transport systems have been identified by both public and private sector stakeholders as having major potential to help achieve the societal goal of improving road safety. One of the seven strategic objectives of the European Commission's Road Safety Programme[7] is to boost smart technology such that data and information can be easily exchanged between vehicles, between vehicles and infrastructure and between vehicles and vulnerable road users such as cyclists and pedestrians.

Road safety is a major societal issue with 25,100 people having lost their lives on EU roads in 2018[8].

Many vehicle OEMs see C-V2X, both short-range device to device and long-range cellular as the change agent for the safety agenda. It will support the OEM vision for the connected car that includes digital services to customers, however the primary service where the OEM can differentiate in the marketplace is safety. Safety features, convenience and advanced driver assistance and services are where brand net promoter score (NPS) can increase in line with customer exposure to a C-V2X driven safety ecosystem.

C-V2X is a key enabler within the overall ecosystem of safety. It introduces economies of scale and a long-term roadmap that improves the investment rationale for all stakeholders within the ecosystem. It introduces synergies with other broader advances in wireless technologies and ecosystems.

According to the use case grouping introduced in 5GAA WG1, the use cases in Wave 1 are classified into four groups in Figure 44: safety, convenience, advanced driving assistance, and VRU. The use cases RTSA and HD maps is within the advanced driver assistance category. As shown below, each use case can be composed of multiple user stories, wherein user stories can differ in terms of road configuration, actors involved, service flows, etc.

Safety	**Convenience**	**Advanced Driver Assistance**	**VRU**
Cross Traffic Left Turn assist	Software Update	Real-Time Situational Awareness and HD Maps	Vulnerable Road User
Intersection Movement Assist	Remote Vehicle Health Monitoring	Speed Harmonisation	
Emergency Brake Warning		HD Sensor Sharing	
Traffic Jam Warning		See Through	
		Cooperative Lance Change	

Figure 44 Wave 1: Categories and Use cases

C-V2X leverages communications capability for latency critical, local safety features.

<u>Benefits for OEMs</u>

Advanced Driver Assistance, Efficiency and Greenhouse Gas Emissions

RTSA and HD maps enable vehicles to see beyond the driver's field of view, providing an accurate representation of the road ahead and information on the surrounding environment. By enhancing navigation in a digitalised, HD platform, connected and autonomous features can be confidently deployed and adopted in the knowledge that there are fail-safe systems in place to support them. The car can sense the world around it and convey intent and situational awareness to other road users.

OEMs recognise that smart vehicles will be connected to the smart world around them via cellular networks. Competition in the OEM sector will drive the adoption of new features. Ford[9] in 2019 committed to enabling C-V2X on all cars starting in 2022.

Transport inefficiency cost $305B in the US alone (Inrix, Dec 2018), while 28% of all carbon emissions come from transportation[10].

World Health Organisation statistics show that 1.35M people die each year on the roads worldwide.

Safety

The partnership with MNOs that delivers network slicing and QoS will support OEMs on many levels, including the automotive safety integrity level (ASIL)[11] stamp marking the transfer of RTSA[12] messages from the host vehicle to RVs where reliability of message transfer can be enhanced via network slicing, thus offering improved QoS.

Quality and Customer Relationships

The quality of RTSA and HD maps will improve customer experience and help maintain the relationship with customers directly that can impact sales retention.

In the scenario where the OEM sells an option for auto-driving there is a certain expectation from the customer related to that service. In this scenario, the OEM can only fulfil the AD service by having certain services in place with safety and QoS underpinning the auto-driving service. The slicing mechanism with QoS can help OEM meet customer expectations.

Benefit for Mapping Companies

New revenues

A new player. the Intel-owned Mobileye[13], outlined its ADAS/HD mapping product at CES 2019. This example is documented to show the potential data transfer requirements for HD maps from car to cloud, and also serves as a current market example of HD maps deployment for use in L2+ ADAS features.

The HD mapping process of 'harvesting', 'aggregation' and 'localisation' is shown below. Harvesting and localisation happen in the car. Aggregation happens in the cloud.

This car-to-cloud solution for HD maps provides localisation and foresight which are critical components for autonomy.

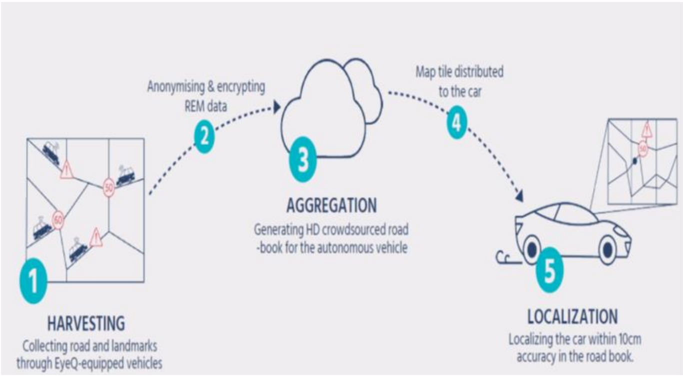


Figure 45 Mobileye HD Mapping Process

During harvesting, camera-equipped vehicles collect and analyse data in real time and compressed data is transferred to the cloud. The process of building maps is crowdsourced, leveraging the fact that most new cars come with a front facing camera. The in-vehicle camera images below, outlined with the yellow boxes, are landmarks from 'harvesting' and road segment data 'seen' by the car camera.

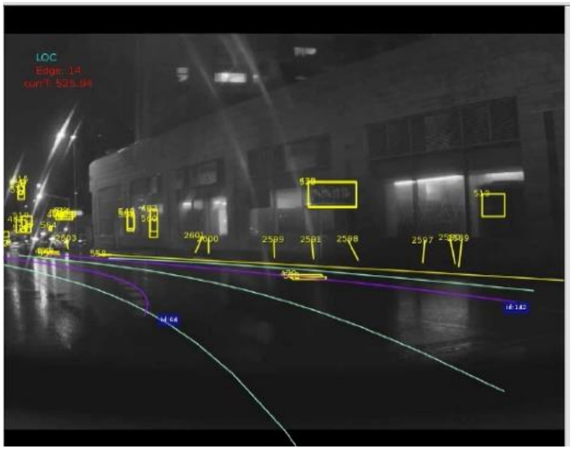


Figure 46 Localisation Process at Mobileye

During ‘localisation’ matches the car images to the data that is in the cloud in real time, the ‘REM roadbook product’. The car is therefore placed with 10cm accuracy on the road. (Note: REM = road experience management).

For the current product, Mobileye has outlined that the network data cost is approximately $1 per car per year due to small data map tiles. This currently presents a market opportunity to enhance current L2 cars to L2+ by streaming map tiles for collision avoidance features at a lower cost.

Data costs calculations for car-to-cloud solution

- 100km = 1MB
- 20,000km annually = 200MB
- 200MB < $1USD

using ‘REM roadbook’ for real-time detection of landmarks to localise the host car in the map sufficiently accurate sufficient for policy and vehicle control. This delivers a scalable solution for HD maps, ultra-high refresh rate with real-time updates over current ‘best effort’ mobile network.

Recently, Mobileye has mapped Japanese highway (25,000km of roads in cooperation with Zenrin maps and Nissan) delivering a REM product featuring

- 10KB per km compressed harvested data for car to cloud.
- Final map weighs only 400MB, map production is automatic.
- Each blue map tile represents 1km2 (see image below).
- Average tile size weighs only 30KB with accuracy <10cm

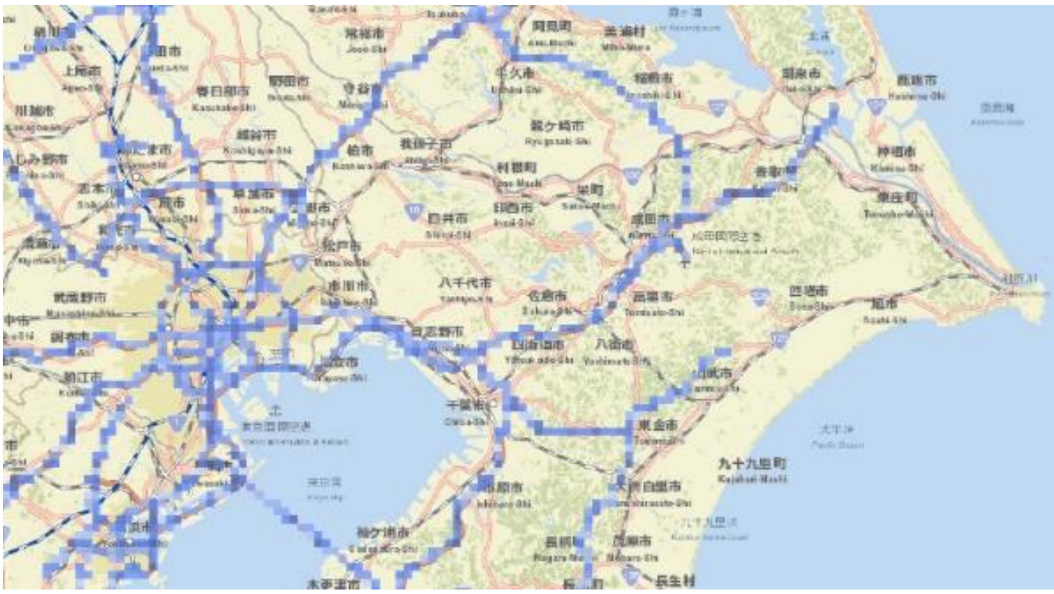


Figure 47 HD Maps Japan

For the more established players the business model for location services continues to evolve. Both HERE and TomTom license their map content on a custom basis to vehicle OEMs and other enterprises. However, in order to deliver location services to support a growing variety of use cases at scale, mapping companies are moving towards a platform approach, where location services are available via the cloud on a transactional basis.

For example, developers can use software development kits (SDKs) or application programming interfaces (APIs) that request map tiles, geocoding, reverse geocoding or directions on-demand within apps or web services. Each request for these services is a billable event, and therefore the success of the platform business model (and Google, HERE, Mapbox and TomTom) will be linked to strong demand for location services from across key sectors[14].

For example, analysis of specific mapping providers, HERE HD Live Map[15] is a dynamic digital representation of the road environment that utilises the camera and other sensory observations of millions of cars to 'self-heal'. This means that, as the world changes, the map corrects and calibrates itself to ensure it stays useful and trusted. It is designed to give vehicles an uninterrupted picture of the road environment – even when there is a truck or building blocking their view – with awareness of upcoming lane configurations and their meaning. For example, HERE and its regional mapping partners NavInfo of China, Increment P (IPC), Pioneer of Japan and SK Telecom of Korea announced that they have formed the OneMap Alliance to offer a global, standardised and dynamic high-definition map from 2020. The global HD map offering is aligned to the specification developed for HERE HD Live Map.

Also in March, 2019 TomTom[16] released its HD map horizon for automated driving. An HD map horizon helps vehicles to build a highly accurate virtual picture of the road ahead, enhancing driver safety and comfort. By streaming the latest TomTom HD maps via TomTom AutoStream through Elektrobit's 'EB robinos predictor' on-board software, the HD map horizon targets vehicles with a society of automotive engineers (SAE) automation level of 2 and higher. It is compliant with the automotive industry's advanced driver assistance systems interface specification (ADASIS) v3 protocol.

<u>Benefits for Users</u>

New Features

Car owners, drivers and passengers gain value from future safety upgrades related to RTSA and HD maps:

- Streamline access to new services and applications associated with hazard warnings.
- Facilitate enhancements to the existing safety functionality.
- Make the car safer and more capable over time.

<u>Benefits for Connectivity Providers</u>

New Revenues

Mobile network operators and other connectivity providers (e.g. telematics service providers) stand to gain new revenue from the growing amount of data to and from vehicles. Data volume will certainly increase, however new pricing will be most likely adopted given the expected large rise in data. Given the time sensitiveness of certain cases related to RTSA and HD maps, latency could be monetised as well. Use case aspects related to high-throughput delivery and/or low-latency delivery could relate to network slicing in Uu.

MNOs that expand their service offering to include edge computing may offer additional services in the ecosystem. The edge cloud service providers can offer the OEM/HD maps companies IaaS and PaaS solutions to build out the HD map company's global deployment configurations, while meeting regional regulatory requirements. Network slicing in this use case assumes that the MNO would operate an edge infrastructure with the map service provider providing some type of application that is operated on it, which receives information from a HV vehicles about a hazard, and this information is distributed by the edge application to other cars in vicinity.

The network slicing with QoS will advance and build a new concept of functional safety into a wireless network. MNOs must build a new concept including car + network to achieve higher reliability in the transmission of the signals. Therefore, MNOs can include these radio signals with QoS in a new safety concept in partnership with car OEMs.

"In the era of autonomous driving, cars will share and receive real-time data about what's happening on the road, and this is where HD maps and advanced connectivity will play a crucial role," said Ian Huh, SVP IoT/Data Division Head at SK Telecom. "With HD Live Map leveraging our 5G technology, SK Telecom[17] will be at the heart of a powerful unified service for automakers."

Automated vehicles generate upwards of 4TB per day from various sensors such as RADAR, LIDAR and cameras. These datasets are utilised within various stages of vehicle system development and consumer usage. During the development/trial phase, the majority of the sensor data is stored within in-vehicle storage and transported to data centre platforms for developing various deep-learning models, which are in turn deployed in vehicles for live object detection and classification. After the vehicle is sold, these models are periodically tuned with new datasets from live drives. Various wireless data uplink methods will be required depending on specific data modalities such as sensor data, vehicle diagnostics, positioning data and real-time situational data. (See 5G America White paper, Cellular V2X Communications Towards 5G, March 2018.)

So how much on a map can change in a year? In Germany alone, over a 12-month period, approximately 215,000km of road, 477,000 street names, 88,000 turn restrictions, 25,000 one-way streets, 2,800 roundabouts, 106,000 road directional signs and 62,000 speed limits are added or amended (HERE[18])

Figure 48 presents a comprehensive stack of parts, products and services, which are the ingredients needed to deliver RTSA and HD maps. This stack corresponds to a full-blown implementation of the RTSA and HD map service, which includes integration with other services and third-party systems that are likely to be part of a realistic integrated proposition. As was stated earlier, this picture corresponds to a RTSA and HD map service being delivered over cellular connectivity. Other wireless modes (e.g. Wi-Fi) or delivery mechanisms (e.g. USB sticks, dealer or repair shop visit) have not been analysed.

Figure 48 RTSA and HD Maps Technology Stack

RTSA & HD MAPS	Integration	OEM/other Platforms | Product LCM | Parts Mgnt. | Licensing Systems | Content Providers
	Administration	Reporting | BI | Analytics | Billing & Invoicing | Customer Care | Partner Support | CRM
	Consumer Applications	Customizable UI/store (on infotainment system or app) for new feature/service purchase
	Backend Web Portal	Ssubscriber / content management | Software Lifecycle Management
	HD Map Campaigns	APIs | HD Map product delivery | Tiles | Maps Stream | Regulation | Local requirements
	Fast Update Technologies	Delta and Compression mechanisms
	Cyber-Security & Identity	Security | Encryption algorithms | Digital Signature | Filters & Firewalls | Intrusion detection
	HD Map Management	Detection | Raw GNSS | Lane Geometry | Sign Face Position | Surface mark | Maplet
	Sensor Ingestion / Processing	Protocols | Catalogues | Sensor DataCcollection
	Device Management	Device Repository & Settings | Settings Orchestrator | Component Inventories | Protocols
ICT Solution Enablement	Cloud Services	Compute | Containers | Storage | Database Services
	Advanced Networking	C-V2X | MEC | RSU integration | Mobile Positioning
	WWAN	Connectivity (LTE and 5G NR) for V2N | Slicing (URLLC) | Telematics Service Providers
On-board Systems: Hardware, Software & Firmware	Gateway Module	Gateway module (secure element, gateway MCU, OTA processor) | control agent dongle
	ECUs	TCU | Head Unit and Interactive UI Systems & Platforms, Intelligent Personal Assistants, and Infotainment/Telematics Systems | ECUs (critical and non-critical systems: ADAS, Engine Control, Powertrain, Chassis, Convenience etc.)
	Chips & Modules	Chips, SIMs, CPUs, Modules
	UE	Radio Transmitter and Receiver

Benefits for Road Operators

"Road traffic automation must be accompanied by active cooperation between road operators and vehicle manufacturers and suppliers, to coordinate the different needs of all stakeholders from the outset to deliver the expected positive effects for the overall road traffic system. The direct exchange of information between vehicles and road operators is a basic prerequisite for achieving the objectives set out above," according to the Austrian road operator AFSINAG[19].

Road operator can contribute to

- Updating of HD maps – incl. inputs from infrastructure viewpoint (e.g. construction site layout)
- Supplementation of the systems in the vehicle and on the road through hybrid technologies
- Road qualification for automated driving functions

5.2 Software OTA Updates

It is generally accepted that OTA update solutions bring benefits to all stakeholders – including OEMs, vehicle owners and Connectivity providers – with the possible exception of dealers and repair shops that may worry about losing service revenue. According to Movimento, 50% of automakers are expected to deploy OTA updates by 2020. Of course, concerns have been expressed about the security of backend systems, which needs to be safeguarded in any case, but OTA delivery using cellular connectivity guarantees cyber security in the transport network sense.

Benefits for OEMs

Cost Savings

OTA updates, in general, lead to increased operational efficiency and productivity. Cisco predicted 40 million connected cars would be on the road by 2020, and argues that OTA updates could save car makers $35bn by 2022 by cutting trips back to the dealer to get updates down (source: BVRLA). More specifically:

- USB-based updates of modules at the dealers' premises or a service facility cost a lot of money and remote software upgrades can result in significant cost savings.
- OEMs gain the possibility to fix issues in the field without expensive call-back/repair processes. OTA updates reduce software recall- and warranty-related expenses, as a substantial percentage of warranty repair issues and recalls can be corrected OTA.

Recall Completion

According to online website Autotrader, the recall completion rate in 2015 was approximately 48%, down from 56% in 2014 (source: NHTSA). OTA updates can potentially increase dramatically the overall completion rates for software-related recalls as they allow updates to take place with less cost and time investment, and with increased comfort and convenience.

Quality and Customer Relationships

OTA updates have the potential to maintain and improve product quality efficiently and effectively, and in this way maintain and improve their ongoing relationships with car owners. More specifically:

- Using OTA updates, it becomes more economically feasible for OEMs to improve their product according to their clients' needs.
- OTA enables a new level of future-proofing. Tesla added hardware for L2-L3 autonomy in model D in November 2014, but software and apps were downloaded in October 2015.
- OTA updates enable high reliability and accuracy for navigation and ADAS via efficient ongoing map updates.
- OTA updates offer the highest level of protection and safety against car connectivity-related cyber security and malware threats with timely bug fixes and security updates.

According to Colin Bird, senior analyst of software, apps and services at IHS Automotive, "OTA updates have the ability to fundamentally transform the sales and customer retention models for OEMs by allowing these companies to maintain their relationship with customers directly throughout the lifecycle of ownership. Expanded OEM software expertise could have a significant impact on sales retention, customer satisfaction, brand equity and on franchise dealer networks."

Future Business

OTA updates offer a streamlined way to boost future business and generate incremental revenue from future functional software upgrades, by making it easy to add new features and functionality post-production. More specifically, OTA updates:

- Provide the ability to upgrade functionality (e.g. add new features to automotive infotainment systems over a vehicle's lifetime).
- Deliver post-sale vehicle performance enhancements.

- Enable the possibility to provide ‘in-App’ purchases (i.e. upgrade a feature later, which the customer did not buy initially) or even adopt ‘pay-per-view’ models (i.e. ‘lease’ ACC for the holiday trip, which might not be needed the rest of the time).

Benefits For Users

Cost Savings

Remote software upgrades eliminate the need to visit a dealer or other service facility.

Customer Satisfaction

- Module updates OTA are easier, time-saving and more convenient for customers, and improve satisfaction by making on-site appointments obsolete, eliminating trips to the dealership or repair shop for software upgrades or fixes, thus reducing the down-time.
- The owner of the vehicle has the reassurance that the vehicle is taking care of possible bugs or malfunctions ‘on its own’.
- OTA updates[20] deliver valuable novelty as well; according to a Tesla fan, “One of the greatest joys of owning a Tesla is being able to experience new features and functionality that get rolled out through over-the-air software updates.”

New Features

Car owners, drivers and passengers gain value from future functional software upgrades, as OTA updates:

- Streamline access to new services and applications.
- Facilitate enhancements to the existing functionality.
- Make the car safer and more capable over time.
- Guarantee that the customers always have the latest software release, ‘news’ and ‘functions’ available on their vehicle (e.g. navigation, services, infrastructure updates).

Benefits for Connectivity Providers

New Revenues

Mobile network operators and other connectivity providers (e.g. telematics service providers) stand to gain new revenue from the growing amount of data to and from cars.

Figure 49 presents a comprehensive stack of parts, products and services, which are the ingredients needed to deliver OTA updates. This stack corresponds to a full-blown implementation of the OTA service, which includes the integration with other services and third-party systems that are likely to be part of a realistic integrated OTA updates proposition. As was stated earlier, this picture corresponds to OTA updates being delivered over cellular connectivity. Other wireless modes (e.g. Wi-Fi) or delivery mechanisms (e.g. USB sticks, dealer or repair shop visit) have not been analysed.

Figure 49 SOTA Technology Stack

OTA Software Management Solution (backend)	Integration	OEM/other Platforms | Product LCM | Parts Mgnt. | Licensing Systems | Content Providers
	Administration	Reporting | BI | Analytics | Billing & Invoicing | Customer Care | Partner Support | CRM
	Consumer Applications	Customizable UI/store (on infotainment system or app) for new feature/service purchase
	Backend Web Portal	OTA data / app / subscriber / content management | Software Lifecycle Management
	Campaign Management	APIs | Campaign Management & Reporting | Regulatory compliance / local requirements
	Fast Update Technologies	Delta and Compression mechanisms
	Cyber-Security & Identity	Security | Encryption algorithms | Digital Signature | Filters & Firewalls | Intrusion detection
	Central Management & Control	Management console | Software tools & installers | Data collection | Quality | Auth | Push
	Software Catalogue	Automotive Software & Firmware Catalogues
	Device Management	Device Repository & Settings | Settings Orchestrator | Component Inventories | Protocols
ICT Solution Enablement	Cloud Services	Compute | Containers | Storage | Database Services
	Advanced Networking	C-V2X | MEC | RSU integration | Mobile Positioning
	WWAN	Connectivity (LTE and 5G NR) for V2N | Slicing (URLLC) | Telematics Service Providers
On-board Systems: Hardware, Software (incl. OTA clients) & Firmware	Gateway Module	Gateway module (secure element, gateway MCU, OTA processor) | control agent dongle
	ECUs	TCU | Head Unit and Interactive UI Systems & Platforms, Intelligent Personal Assistants, and Infotainment/Telematics Systems | ECUs (critical and non-critical systems: ADAS, Engine Control, Powertrain, Chassis, Convenience etc.)
	Chips & Modules	Chips, SIMs, CPUs, Modules
	UE	Radio Transmitter and Receiver

5.3 Tele-Operated Driving

McKinsey's use case framework will be employed in defining distinct service scenarios for business model analysis of ToD. In all cases of ToD, in highways or urban environments, the vehicle is driven by someone in a remote location, rather than someone in the vehicle.

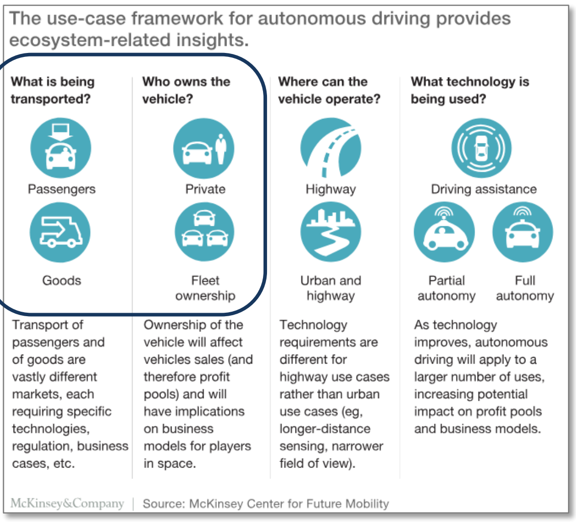


Figure 50 McKinsey Use Case Framework for ToD

This way we derive the four segments shown below, which we will then analyse in terms of ToD value proposition, service characteristics and pricing principles.

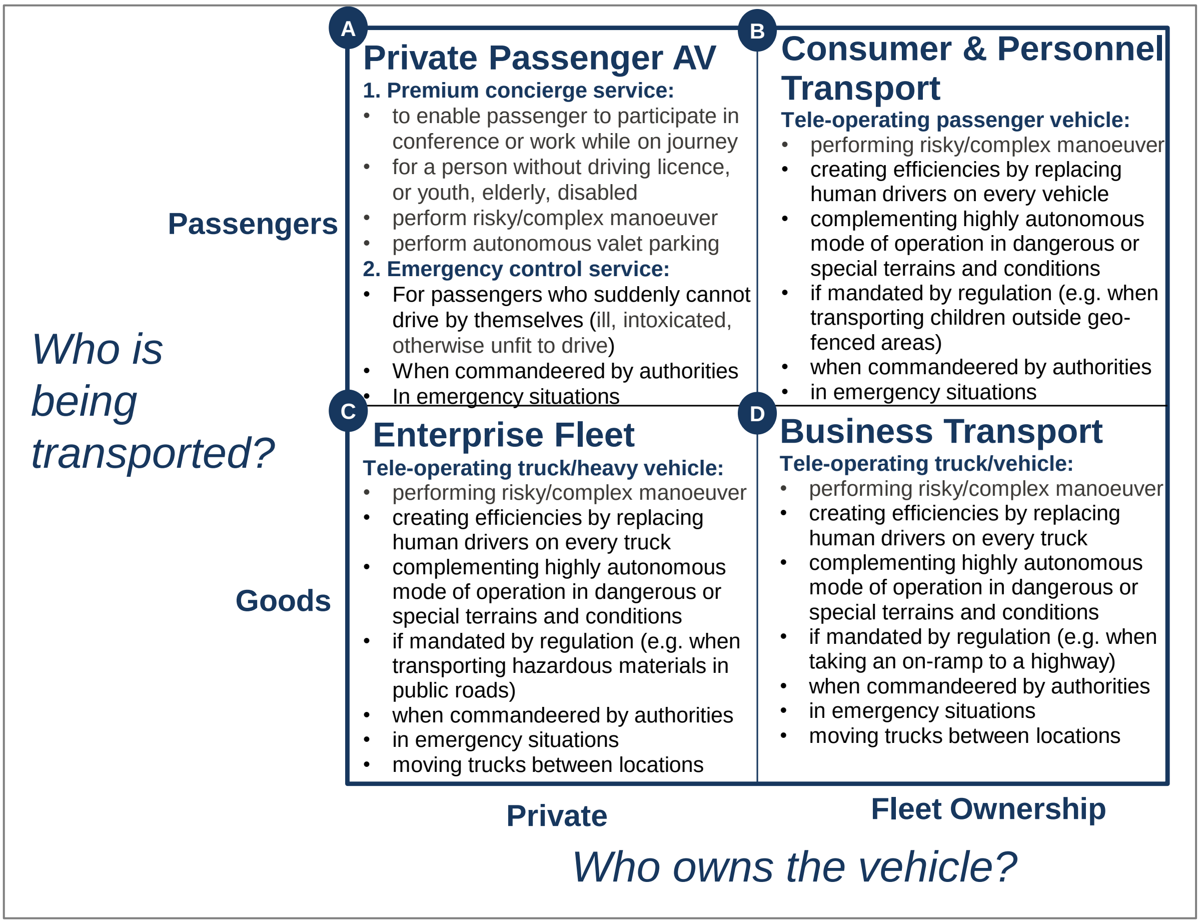


Figure 51 McKinsey Use case framework for ToD

A. Private Passenger AV – Value Proposition

Assumptions

- The AV comes equipped with a ToD system for automated passenger cars, which cooperates with a remote ToD solution.
- The AV OEM has the product ownership of the ToD service, is the charging party, and has the related responsibilities and liabilities.
- The actual delivery of the ToD service – which includes the provision/operation/maintenance of components, ICT services, NOC infrastructures, personnel and the associated services – may be carried out by other ecosystems partners, i.e. the ToD service providers.
- The value network that applies to this segment is the first one presented ('private passenger AVs').

Figure 52 Value Network Private Passenger AV

Services (can be available concurrently)	**Service Characteristics**	**Pricing Considerations**
1. Premium concierge service: • To enable passenger to participate in conference or work while on journey • For a person without driving licence, or youth, elderly, disabled • Perform risky/complex manoeuvre • Perform autonomous valet parking	• Discretionary • Luxury	• Premium pricing • Per event pricing to avoid abuse • Per mile (e.g. $1)/minute (e.g. $0.67)/action (e.g. $5) charge, or bundled (2 hours: $50/month)
2. Emergency control service: • For passengers who suddenly cannot drive by themselves (ill, intoxicated, otherwise unfit) • When commandeered by authorities • In emergency situations	• Urgent • Unplanned • Safety and/or security related	• Incorporated in car price, as the capability will most probably be a mandated standard for AVs

B. Consumer and Personal Transport – Value Proposition

Assumptions

- The AV comes equipped with a ToD system for urban mobility vehicles, which cooperates with a remote ToD solution.
- The ToD service is being offered by the tele-operation service provider that has the product ownership of this service, and the related responsibilities and liabilities. Many different types of organisations can fulfil this role.
- The value network that applies to this segment is the second one presented ('fleet vehicles').
- Fleet types include:
    - Consumer MaaS
    - Taxis
    - Car rentals
    - Law enforcement
    - Military personnel
    - Ambulances
    - School buses
    - Non-emergency medical transport
    - First responders
    - Government
    - Industrial estate
    - Campus
    - Sports estate (golf carts)
    - Gated community/estate (e.g. elderly)
    - Company fleets
    - Public transport

- Shuttle buses
- Tourist buses

Figure 53 Consumer and Personal Transport – Value Proposition

Tele-Operating Passenger Vehicle Service	**Service Characteristics**	**Pricing Considerations**
• Performing risky/complex manoeuvre • Creating efficiencies by replacing human drivers on every vehicle • Complementing L4/L5 mode of autonomous operation in dangerous or special terrains and conditions • If mandated by regulation (e.g. when transporting children outside geo-fenced areas) • When commandeered by authorities • In emergency situations	• Discretionary AND • Urgent • Unplanned • Safety and/or security related	Pricing incentives designed to maximise organisation benefit, i.e.: • Avoid unnecessary discretionary usage • Use ToD in discretionary cases whenever savings of all kinds are to be realised (e.g. time, avoiding vehicle damage etc.) Emergency usage is incorporated in car/service price, as the capability will most probably be mandated for AV

C. Enterprise Fleet – Value Proposition

Assumptions

- The AV comes equipped with a ToD system for automated freight vehicles, which cooperates with a remote ToD solution.
- The ToD service is being offered by the tele-operation service provider that has the product ownership of this service, and the related responsibilities and liabilities. Many different types of organisations can fulfil this role.
- The value network that applies to this segment is the second one presented (‘fleet vehicles’).
- Fleet types include:
  - Manufacturing
  - Ports
  - Airports
  - Construction
  - Mining
  - Military vehicles
  - Emergency response
  - Utilities
  - Garbage collection
  - Road sweeping

Figure 54 Enterprise Fleet – Value Proposition

Tele-operating truck/heavy vehicle service	**Service Characteristics**	**Pricing Considerations**
• Performing risky/complex manoeuvre • Creating efficiencies by replacing human drivers on every truck • Complementing highly autonomous mode of operation in dangerous or special terrains and conditions	• Discretionary AND • Urgent • Unplanned • Safety and/or security related	Pricing incentives designed to maximise organisation benefit, i.e.: • avoid unnecessary discretionary usage • use ToD in discretionary cases whenever savings of all kinds are to be realised (e.g. time, avoiding vehicle damage etc.)

• If mandated by regulation (e.g. When transporting hazardous materials in public roads) • When commandeered by authorities • In emergency situations • Moving trucks between locations		Emergency usage is incorporated in car price, as the capability will most probably be mandated AV standard

D. Business Transport – Value Proposition

Assumptions

- The AV comes equipped with a ToD system for automated freight vehicles, which cooperates with a remote ToD solution
- The ToD service is being offered by the Tele-operation Service Provider that has the product ownership of this service, and the related responsibilities and liabilities. Many different types of organisations can fulfil this role.
- The Value Network that applies to this segment is the second one presented ('fleet vehicles').
- Fleet types include:
    - Distribution
    - Logistics
    - Supply chain
    - Real-time freight
    - Haulage and bulk haulage
    - Integrated transportation solution providers

Figure 55 Business Transport – Value Proposition

Tele-Operating Truck/Heavy Vehicle Service	**Service Characteristics**	**Pricing Considerations**
• Performing risky/complex manoeuvre • Creating efficiencies by replacing human drivers on every truck • Complementing highly autonomous mode of operation in dangerous or special terrains and conditions • If mandated by regulation (e.g. when taking an on-ramp to a highway) • When commandeered by authorities • In emergency situations • Moving trucks between locations	• Discretionary AND • Urgent • Unplanned • Safety and/or security related	Pricing incentives designed to maximise organisation benefit, i.e.: • Avoid unnecessary discretionary usage • Use ToD in discretionary cases whenever savings of all kinds are to be realised (e.g. time, avoiding vehicle damage etc.) Emergency usage is incorporated in car price, as the capability will most probably be mandated AV standard.

To conclude the presentation of cases where ToD is to be used, here follows a list of 'edge cases' (i.e. anything peculiar and complex enough to upset a computer system), applicable to all AVs, that require the engagement of ToD, as partially compiled by Phantom Auto, a leading ToD solution provider.

- **Failure of the autonomous driving system**: If the autonomous driving functionality fails, even during parking manoeuvres, ToD guarantees service continuity.
- **Road construction:** Construction zones are often unmapped dynamic environments, with construction workers directing traffic and workers, and vehicles moving freely about.
- **Public safety authorities:** Police and other public safety officials may use hand signals or voice commands to alter vehicle travel.

- **Inclement weather:** Bad weather can impair an AV's ability to safely operate, e.g. it can be stuck in snow.
- **Passenger support:** Surveys show that 75% of Americans are fearful of being a passenger in an AV. On-demand human support increases trust and consumer confidence.
- **High pedestrian and vehicle traffic:** Areas with large amounts of vehicle or pedestrian traffic – especially urban – can create significant issues for AVs (e.g. it can be stuck behind a truck).
- **No lane markings:** Areas with no lane markings or faded lane markings can create significant issues for AVs.
- **Initial deployment of automated vehicles:** When the AV must be transported after production.
- **Hazard:** Movement in or around, for example, fuel stations or delivery depots.
- **Highway:** Joining or leaving a platoon, and using ramps to enter a highway or exit it and go to the final destination.
- **Emergency situations:** For example, rescue missions in disaster zones.
- **Summon feature:** A car backing out on its own from a parking space with the current sensors is dangerous.

Figure 56 presents an overview of the ToD system described.

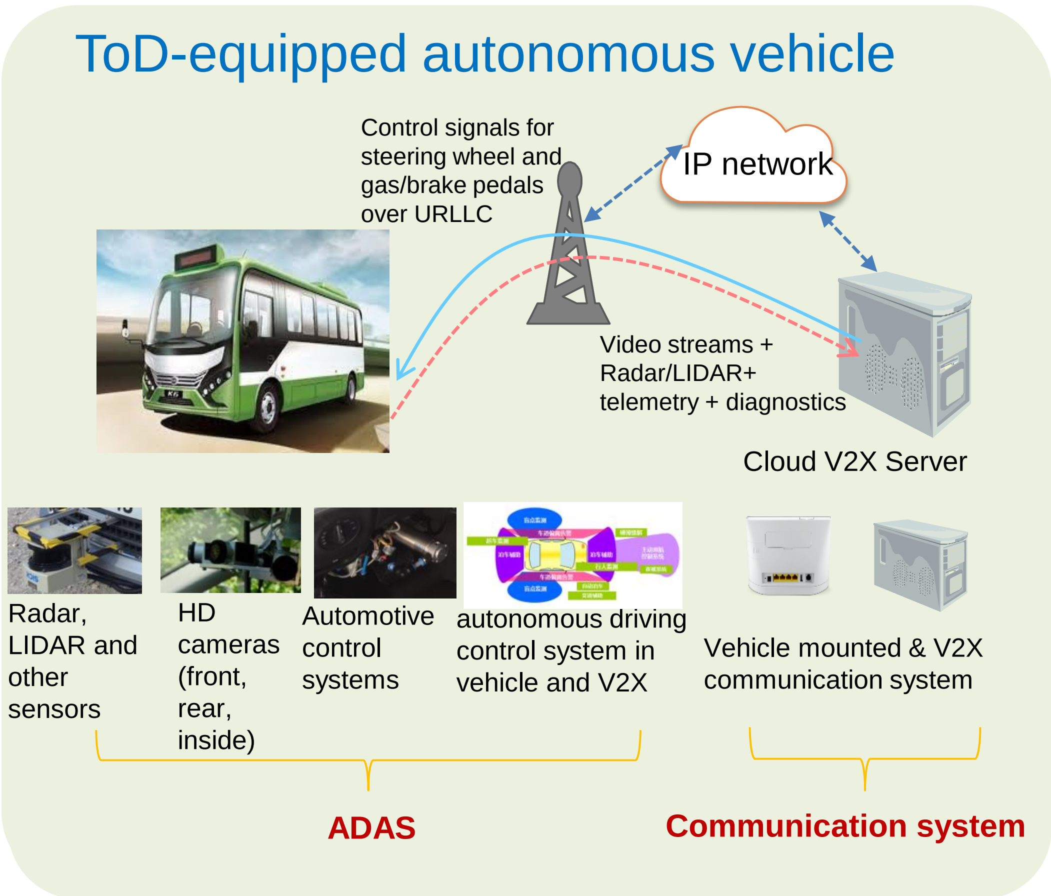


Figure 56 ToD Equipped AV

The following figure presents a comprehensive stack of parts, products and services, which are the ingredients needed to deliver ToD, along with the ecosystem members that provide each layer of the solution. This stack corresponds to a full-blown implementation of the ToD service, which includes the establishment and operation of a remote control centre that performs vehicle tele-operation, and the integration with other services and third-party systems that are likely to be part of a realistic integrated remote driving proposition.

Figure 57 ToD Technology Stack

ToD Service Business Users	Fleet Operators	Enterprises | Organizations | Logistics Service Providers | Carriers | Integrated Transportation Service Providers | Mobility-as-a-Service Providers
	AV Solution Providers	AV Systems | Automated Driving Software
	OEMs	Vehicles | ToD systems
ToD Service Providers 3rd Parties Integration & Enablement	Integration	ITS Systems (Public Transport, Smart Parking etc.) | Transport Control Centres | High Precision 3D Maps | Weather Information | In-car Infotainment
	Administration	Reporting | BI | Billing & Invoicing | Revenue Mgnt | Customer Care | Partner Support
	Ecosystem Services	User Mgnt/Security | Payments/Collections | Marketplace: Retailing/Discovery/Monetization
Remote Control Centre	Remote Operation Service	Call centre | Operator headsets | Computer systems
	Remote Management Console	Steering wheels | Pedal Combos | Displays | VR Equipment
	ToD Platform	ToD Software for remote monitoring & control | APIs for real-time assistance & guidance
ICT Solution Providers	Security & Identity	Data/System Security & Reliability | Trust Model | Certification Policy | Risk Management
	Cloud Services	Compute | Containers | Storage | Security & Identity | Database Services
	Advanced Networking	MEC | C-ITS integration | LTE Broadcast (GNSS offset, hazards, HD-map updates)
	C-V2X	V2X Server | LTE & 5G NR for V2V-V2I-V2P | Slicing (URLLC) | QoS
	WWAN	Seamless global connectivity (LTE and 5G NR) for V2N
Tier Suppliers	In-Vehicle ToD System	In-vehicle communication software | ToD ECU and Controls | Microphone | Antennas
	Autonomy Parts & Sensors	Computer | Radar | LIDAR | HD Cameras | GPS | Haptic System | Other sensors

5.4 High-Density Platooning

Truck platooning provides multiple and important societal and economic benefits. More specifically:

A. Decreased Damage Costs

Platooning can improve safety. The annual economic cost of truck and bus accidents in the USA is roughly $99 billion (source: Centers for Disease Control and Prevention, 2015). Some 94% of accidents and damages are caused by human error, according to NHTSA. In USA, the death toll in truck-involved crashes rose 17% from 2009 to 2013. Fatalities in truck-related crashes increased four years in a row, reaching 3,964 in 2013. Those crashes killed not only car drivers but also truck drivers and passengers (586 people in 2013 alone). In 2015, 4,067 people were killed and 116,000 people were injured in crashes involving large trucks, according to the latest figures provided by NHTSA. The Bureau of Labor Statistics (BLS) analysed fatality data from 2016 to identify the deadliest civilian occupations across the USA. The combined category of sales workers who drive and truck drivers was in the top spot with 918 fatalities. In Europe, according to the European Commission, 24,900 people fell victim to fatal road accidents in 2014. The European project Safe Road Trains for the Environment (SARTRE) found a 20% emission reduction through vehicle platooning, a 10% reduction in fatalities, and smoother traffic flow with potentially increased capacity (source: T. Robinson, E. Chan, and E. Coelingh, ‘Operating platoons on public motorways: An introduction to the SARTRE platooning programme’. In *17th World Congress on Intelligent Transport Systems*. Busan, Korea, 2010).

B. Reduced Insurance Premiums

Automated vehicles will make transportation much safer, i.e. will alter the frequency and impact of accidents – and the litigation that follows. While this might save insurers money on pay-outs in the near future, demand for insurance will ultimately decrease as risks of a car crash drop. In anticipation of this shift, insurers are rolling out usage based insurance (UBI) policies. One of the various types of insurance truckers pay is physical damage insurance: it covers any damage to equipment from various causes. Physical damage coverage is not required by law in USA, but it is important because it covers the investment in the truck. In addition, it covers a variety of incidents, such as collision, fire, theft, vandalism, and weather (hail or wind). Its average cost per year in the USA is $2000-$3000. Platooning, and complementary advanced driver assistance (ADAS) solutions, are likely to lead to physical damage insurance premiums being reduced significantly.

C. Asset Utilisation Optimisation (reduced truck idle time)

One of the factors that limits the revenue-generating ability of trucks is mandatory driver resting time (e.g. US law restricts driving to no more than 11 hours in a single day). Platooning, which allows drivers of trailing trucks to rest while in the cabin, can increase driving time significantly. What’s more, multiple drivers can take turns so the convoy can drive 24/7. This could also halve the time required to make a delivery.

D. Driver Efficiency Optimisation (reduced labour costs)

Driver shortage is a serious and very well documented problem for the trucking industry worldwide. Platooning can address it, while at the same time help contain driver costs. Driver wages/benefits is the greatest cost in US trucking, representing 39% of the total (source: ‘An Analysis of the Operational Costs of Trucking: 2016 Update’, American Transportation Research Institute, ATRI). Similarly, according to the French National Road Committee, the cost of a driver represents up to 38% of the total transport cost in 2016 for long-distance haulage. Platooning can help reduce labour costs in two ways:

1) A senior driver can drive in the leading truck; the driver(s) in the following truck(s) only need monitor and take control in complicated traffic conditions, i.e.:
    - They can be resting.
    - They can be junior drivers.
2) A longer-term vision is to remove the driver from the system, consistent with trends to replace human labour with robotics (i.e. replacing recurring operating expense with a one-time capital investment):
    - ‘Multiple trucks, one driver’ – the lead truck is driven by a driver or remotely (tele-operated) and the trailing trucks are driverless.
    - Autonomous truck platoon – Tesla has publicised such a plan.

E. Fuel Consumption Savings

Fuel is the second biggest cost in trucking. A heavy-duty vehicle (HDV) fleet provider generally owns many vehicles that travel over 200,000km per year. With an average fuel consumption of 0.3l/km and the current diesel fuel price in Sweden, for example, of $1.76/l, the fuel cost alone amounts to over $105,000 per year for a single HDV. In 2016, UPS' fleet of courier vehicles consumed 390 million gallons of fuel. All platooning trials have concluded that the achievable fuel consumption savings are remarkable. More specifically:

USA trials:

1. AT&T (based on PSA and Ministry of Transport sources): 12%-19% fuel cost savings.
2. Based on the 'Analysis of the Operational Costs of Trucking: 2016 Update' of American Transportation Research Institute (ATRI): Leading truck 4.5%-8%, trailing vehicle 10%-13%.
3. Texas A&M Transportation Institute tests (@55miles/h, 30-60ft): 4-5% lead truck, 8-10% second vehicle.
4. Peloton (as tested by the North American Council for Freight Efficiency): 4.5% fuel savings for the lead truck and 10% for the following truck in a two-truck platoon.

Dutch trials (source: TNO White Paper: Janssen R. et al, 'Truck Platooning Driving the Future of Transportation, February 2015', www.tno.nl): Lead truck 8%, second truck 13%.

Daimler Highway Pilot Connect trial findings: A 3-truck platoon can achieve a fuel saving of ~7% on average (measured for three semitrailer combinations at a constant speed of 80km/h): Lead truck 2%, middle vehicle 11%, rear vehicle 9%.

Volvo has implemented three-truck platoons and achieved fuel efficiency of: 3% for the lead truck, 7% for the second truck, and 6% for the third.

Also, there is a relationship between the truck separation distance and fuel savings, which means there are potentially further savings from the implementation of 5G C-V2X technology that theoretically, at least, allows closer distance between platooning trucks. This is a conclusion derived from most platooning trials around the world, as can be shown in Figure 58 (source: North American Council for Freight Efficiency's 2016 'Confidence Report on Two-truck Platooning').

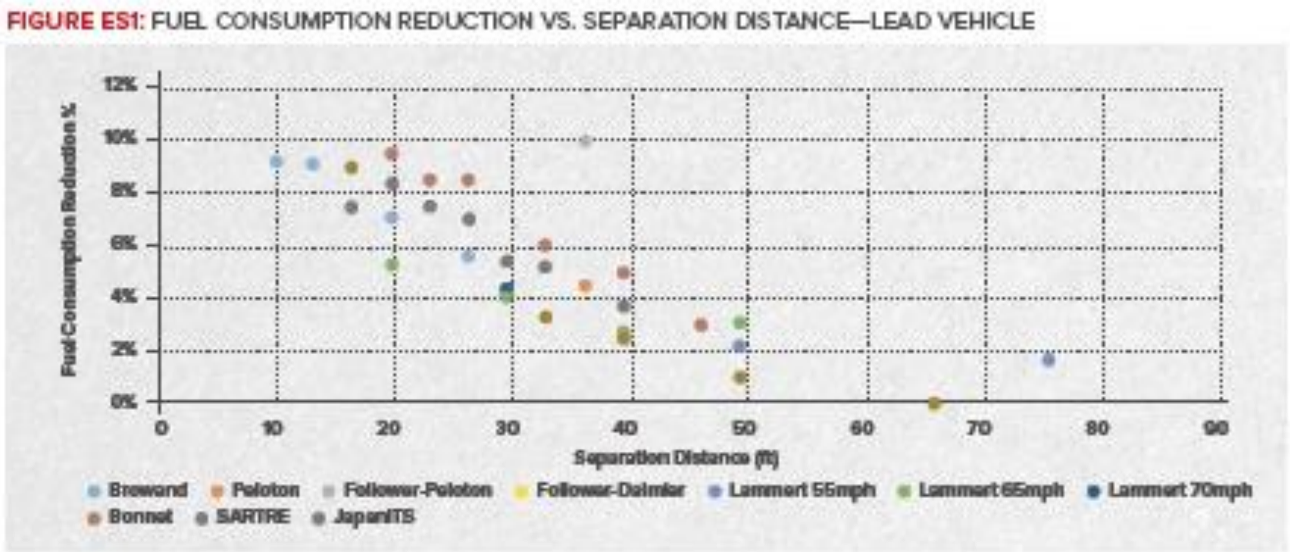


Figure 58 Fuel Consumption reduction vs Seperation Distance

As we saw, high-density truck platooning promises to deliver significant societal and economic benefits, but the first step in realising them is to enable 'multi-brand' and 'multi-hauler' truck platooning that allows collaboration across fleets. To operate in such a mode, platooning trucks need to be connected V2V, but beyond that wireless connections to enabled roadside infrastructure and platooning network operation centres are needed, as well as connectivity for accessing cloud services, interpersonal communication applications and sensor data exchange. The diagram from Telstra below shows graphically the necessity of connecting platooning trucks to a NOC in a realistic business setting.

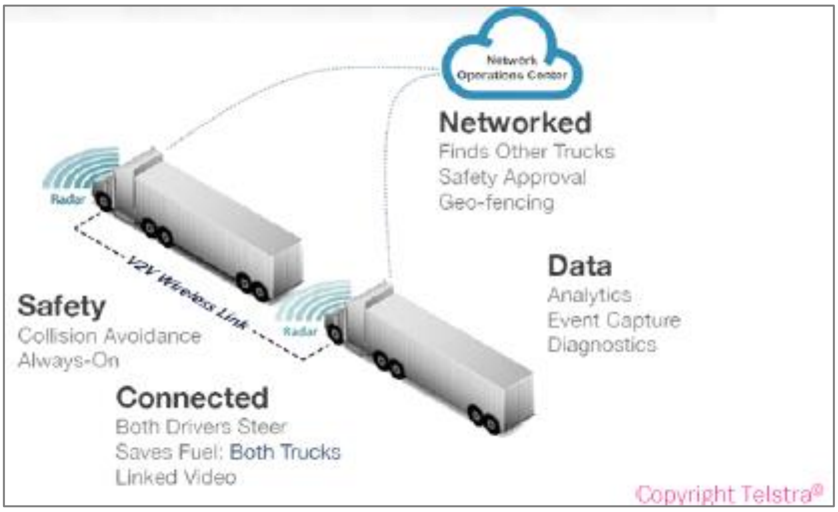


Figure 59 Telstra Platoon illustration

Further, excerpts from the leaflet by the Connecting Austria consortium[21] (Figure 60) show four cases where V2I connectivity is required for infrastructure-based platoon management with C-ITS.

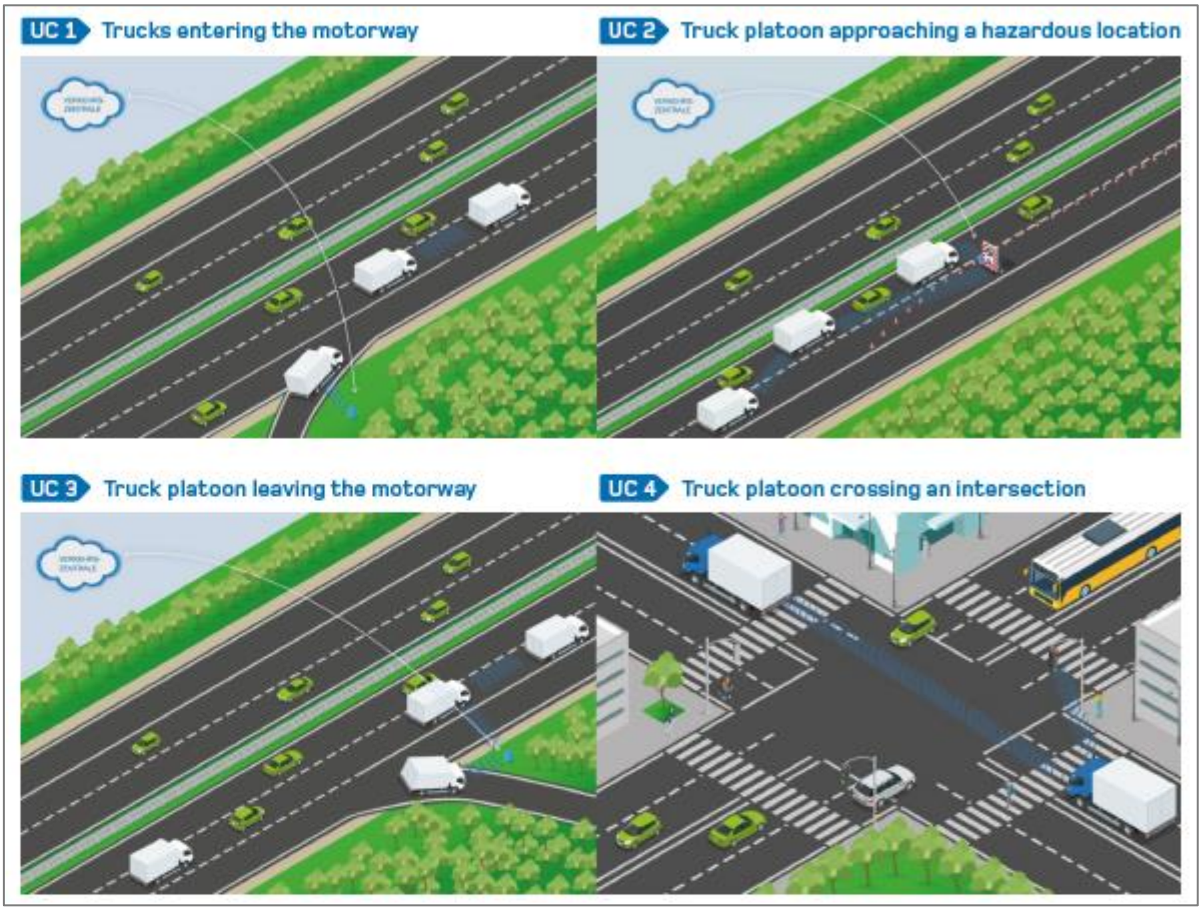


Figure 60 V2I Connectivity for Platoon

To implement such scenarios, a full-stack of services is required, but most importantly the deployment and use of different network slices. More specifically, platooning software makes use of the other vehicle’s sensor data to adjust performance of the first vehicle. The basis of platooning is therefore the networking among vehicles with precise awareness of their surroundings. Platooning uses C-V2X for V2V/V2I (i.e. mobile networking satisfying special performance and safety requirements through URLLC network slices; communications reliability: 99.999% at a latency of 10ms), combined with WWAN connectivity to backend NOC servers. Enhanced sensor sharing is required when the platoon leader is not able to oversee the situation of the platoon with its own sensors. In this case the main requirement is for throughput of 65Mbit/s.

Advanced telecommunications capabilities like network slicing guarantee integrity, durability, flexibility, and ease-of-use in day-to-day fleet operations. Truck platoons must be managed continuously by a cloud-based NOC that connects to vehicles through cellular communication. Real-time supervision enables dynamic adjustment to conditions, and can enforce limits to the operation of platoons to specified roads under safe driving conditions (where, when and how it is safe).

Furthermore, ‘see through’ functionality involves the sharing of sensor data and camera images between vehicles, enabling trucks to effectively see through other trucks in front of them. A heads-up-display or augmented reality display on the driver’s windshield would combine what a driver can see with what the vehicles in front can see. It needs perfect synchronisation of HD video streams; time alignment is crucial, so very low latency networks are needed. This requires 5G network slicing.

The figure below summarizes the communication services involved in platooning operation and the corresponding 5G slice types or LTE connectivity:

Figure 61 Communications Services in Platooning Operation

	URLLC	eMBB	LTE
V2V	X		
V2I	X		
Sensor Sharing		X	
V2N			X
V2P			X
P2P			X

Figure 62 presents a comprehensive stack of ICT products and services, which are the ingredients needed to deliver the full value of platooning, beyond the ‘tactical’ layer of ‘devices’ inside a truck (communication modules and SIM cards, as well as the platooning ECU and the complementary peripherals, materials and ADAS systems). This stack corresponds to a full-blown implementation of platooning, which includes the establishment and operation of a NOC that manages a fleet of connected platooning trucks (‘strategic’ layer), and integration with other services and third-party provider systems that are likely to be part of a realistic integrated transport and logistics proposition (the ‘services’ layer). The source of the concept of hierarchical platooning is Netherland’s TNO[22].

Figure 62 Platooning Technology Stack

SERVICES LAYER	3rd party enablement	Integration	Enterprise Systems (incl. Logistics & Fleet Management) | External Data | Government Systems | Road Network Monitoring & Management | Vehicle Management | Smart City
		Administration	Reporting | BI | Billing & Invoicing | Revenue Mgnt | Customer Care | Dealer Support
		Ecosystem Services	User Mgnt/Security | Payments/Collections | Marketplace: Retailing/Discovery/Monetization
		Application Services	API Management | Application Integration | Workflow
		Development Services	Software Build, Test, Deploy | Development templates
		Service Platform	Mobile development | Mobile Identity | Mobile notifications and over-the-horizon alerts
STRATEGIC LAYER	Network Operations Center	Monetization Analytics	Cross-fleet Reconciliation (manage fuel credits accrual & sharing across fleet operators)
		Analytics & Big Data	Predictive Maintenance | Image & Video Analytics | Driver Behavior | Insurance Analytics
		Platoon Management Platform	Road Conditions Monitoring & Prediction | Booking & Pricing | Allocation & Formation | Modelling | Real-time Monitoring & Management | Regulatory Data Logging & Reporting
		Cloud Services	Compute | Containers | Storage | Security & Identity | Database Services
		Security & Identity	Data/System Security & Reliability | Trust Model | Certification Policy | Risk Management
		Precision Location	Enabling Real-time HD local road & map updates, and navigation
	Connectivity	Advanced Networking	See Through | MEC | C-ITS integration | LTE Broadcast (GNSS offset, hazards, HD-map updates)
		C-V2X	LTE & 5G NR for V2V-V2I-V2P | Slicing (URLLC) | QoS
		WWAN	Seamless global connectivity (LTE and 5G NR) for V2N
TACTICAL LAYER	Devices	Communication Modules	Device Management and Security
		SIM Cards	Global SIM | eSIM | SIM Management

6 Potential Business Models and Go-to-Market

This section on potential business models analyses the use cases under the following three headings:

Adoption Drivers
- An analysis of the flow of venture capital funds into this area as a potential measure of future profit pools, an analysis of new entrants and emerging partnerships, as well as how mapping standards and volume of data transfer are evolving. New mapping content and emerging ecosystem is also presented. Separately, we look at what data types need to be transferred from car to cloud and back, and how 'dynamic, static and semi-static/dynamic data may impact adoption.

Market Opportunity Sizing
- Analysts reports where available of future market sizes are presented.

Business Models
- Potential go-to-market business models are presented.

6.1 Real-Time Situational Awareness and HD Map

Adoption Drivers

The section analyses the most important growth drivers for RTSA and HD maps:

Proliferation of Connected Cars

Fiat Chrysler Automobiles (FCA) global connectivity deployment plan entails that by 2022 all the new cars that it manufactures will be connected. According to Statista [source: 'Connected Car Report 2018'] there will be 343 million connected cars in circulation in 2023, which can both require RTSA and HD map updates and be able to receive them over cellular networks during the longer term.

Strategy Analytics' Infotainment and Telematics service estimates annual sales of navigation-enabled cars will continue to rise at a 6.9% CAGR, exceeding 60 million by 2025, with above average increases across BRIC countries. This will provide a continued growth opportunity for digital map and location service suppliers. **The total excludes HD maps** that will be required to safely guide autonomous cars, but includes connected cars which will have the ability to deliver live map-based services to users as part of the connected in-vehicle infotainment (IVI) experience.

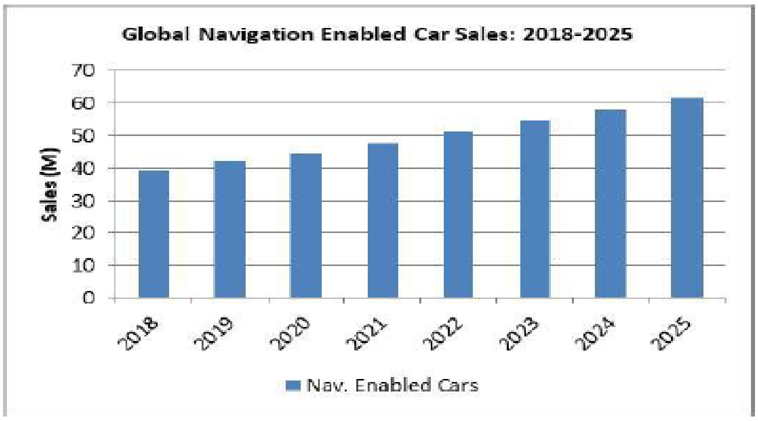


Figure 63 Global Navigation Enabled Car Sales

However, the research firm Strategy Analytics notes that over the **next five-years, the share of cars with HD maps will account for a negligible fraction of total cars sold**. Over the long term, Strategy Analytics expects embedded navigation to increase as assisted and autonomous driving relies on high-definition maps (i.e. vehicles need them to accurately calculate their position on the road). Both HERE and TomTom are vying to take a leadership position in supporting autonomous driving with their HD maps through partnerships with key stakeholders in the future value-chain for autonomous vehicles. Google is also taking a shot at the autonomous vehicle opportunity through Waymo, its self-driving project, while Mapbox is also building HD maps based on a crowd-sourced approach.

- TomTom claims its HD map covers more than 380,000km of roads across Europe, the United States and Japan.
- HERE predicted it would have over 1,000,000km of roads mapped in HD by the end of 2018.
- Waymo has outlined that its autonomous cars clocked a total of 10 million miles by the end of October 2018, and in December 2018 it launched the first commercial self-driving ride-sharing service, called Waymo One.
- Mapbox has not announced the extent of its HD map coverage. However, it states that it has the ability to deliver lane-level precision required to support Level 2 and Level 3 semi-autonomous driving using current probe GPS data. Mapboxs' Vision SDK for sensors which are deployed on vehicles via partnerships with companies such as Intel's Mobile Eye are among the company's other developments.

Partnerships, Innovation and VC Funding

High-definition maps are fundamental for autonomous vehicles to accurately calculate their position on the road. Mapping providers are vying to take a leadership position in supporting autonomous driving with their HD maps through partnerships with key stakeholders in the future value-chain for autonomous vehicles.

The 'static' maps available to OEMs today see broad street shapes and capture snapshots in time and are used in turn-by-turn navigation applications with overlaid advanced services, such as real-time traffic alerts and hazards. Unlike conventional digital maps, self-driving maps require almost constant updates. Mapping companies are now working on replacement products: 'dynamic' maps that represent lanes, curbs and everything else on the road. The maps needed for driverless cars are different from the current map applications because they will need to serve a 'safety critical function', rather than just being used for navigation.

The requirements of self-driving cars is the ultimate HD maps adoption driver. Intermediate versions, adding new layers of value to the current driving experience, will evolve within the connected/not-yet autonomous car. According to Tomaso Grossi, Senior Product Marketer at TomTom Automotive[23]: "We don't see HD maps as stand-alone products. They don't exist in a vacuum and must be used as part of the automated system in a vehicle.' He added: "We believe in a closed-loop system, whereby we produce the most accurate, robust and reliable maps in the cloud, deliver these systems to the car, and then leverage multiple sources – such as different types of vehicle sensors – to ensure this map is up-to-date, safe and matches reality."

The evolution to self-driving cars will require accurate maps. New HD mapping market entrants are giving rise to a flow of investment into the HD mapping domain and is a measure of the potential future profit pools. A range of start-ups prioritising automated crowdsourcing and the use of artificial intelligence (AI) and deep-learning technologies have emerged over the last couple of years. At the same time, a wave of partnerships across the technology ecosystem can be observed, aimed at increasing coverage, building HD maps for AVs, or acquiring AI-based mapping technology. For example:

- **Mobileye[24]**, a self-driving car firm acquired by Intel for $15 billion.

- **DeepMap[25]**, received $60M in Series B funding in 2018, bringing total investment to date to $92M, The US-based company provides high-definition mapping technology for self-driving vehicles and the latest funding round puts the company's valuation at $450M. Backers included NVIDIA, Andreessen Horowitz, Accel Partners, GSR Ventures, and Robert Bosch Venture Capital.

- **Mapbox** is a location data platform for mobile and web applications. The company provides building blocks to add location features like maps, search, and navigation into any experience. Mapbox has raised a total of $227.2M in funding over four rounds. In October 2017, the company raised Series C funding of $164M, led by Softbank.

- **Carmera** plans to crowdsource real-time data for maps and $20M in a Series B funding round led by GV, formerly known as Google Ventures. For example, Carmera leverages its fleet management technology (a separate product) that includes cameras and telematics, which are designed to monitor a client's assets and drivers, to autonomously update HD maps for self-driving vehicles. Carmera refers to its network of roving cameras as probes. For example, in the illustration below, a delivery van (purple vehicle) equipped with Carmera's[26] video hardware detects construction on a major thoroughfare. That information is processed and used to update the maps in an autonomous vehicle (red car), which could respond by changing the route or proceeding along the original route, depending on which arrival time is best.

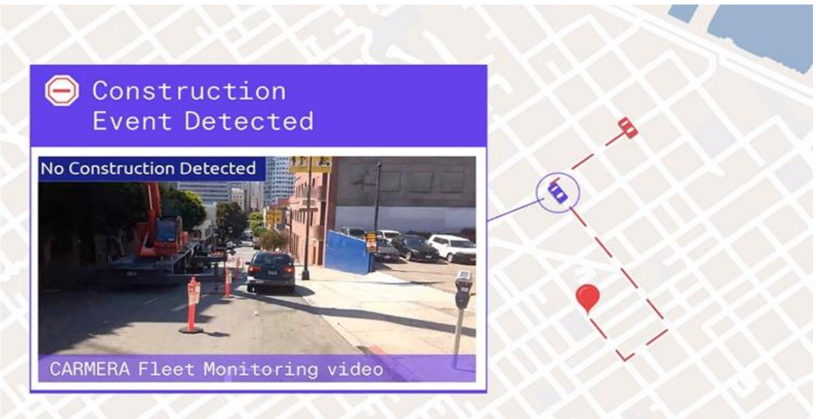


Figure 64 Carmera Illustration

- **Civil Maps**[27] provides a sensor-agnostic cognition platform and pipeline that enables city scale HD 3D mapping, edge mapping and localisation. The company has raised a $17M Series A round of funding, led by ARM.
- **Wayz.ai**[28]**,** a Chinese smart location and mapping service start-up announced that it has raised nearly $80M in Series A funding, which was invested in by BlueRun Ventures, Lightspeed China Partners, as well as the start-up's founder, etc. Wayz.ai was founded in 2017 by Vincent Tao, former CEO of the Chinese online TV provider PPTV. It is committed to providing intelligence solutions with the location-based service as a gateway, combining AI technologies with precision positioning, high-definition mapping, safety testing as well as location cloud platforms.

New Mapping Content and Emerging Business Ecosystems

Maps have traditionally mainly been used for outdoor road-based turn-by-turn navigation as part of automotive infotainment systems. A range of new use cases is now emerging including RTSA and HD maps. Technology suppliers and car OEMs are increasingly launching large-scale platforms, driving the need for map coverage and the one-stop-shop sourcing of global content.

The use of maps will be extended to more mission-critical applications like informational safety, active safety, and ADAS (Level 2+, semi-autonomous driving, and lower levels of automation), as well as advanced levels of automation (Level 4 to 5), from positioning to humanised driving. HD maps will also boost vehicles' visibility beyond the reach of their on-board sensors, to make autonomous driving more comfortable and reliable based on advanced path planning and information redundancy

The main technology trends that are transforming map-generation processes and content production include :

Sensor data crowdsourcing – The use of a wide set of fixed, mobile, and vehicle sensors, including LIDAR, image sensors, and even RADAR (e.g. Bosch radar road signature), as well as remote sensor data via V2X communication to build continuously updated maps based on real-time data. Camera sensor-based map-generating technologies retain the advantage of leveraging an already large installed base of vehicles equipped with camera sensors used for ADAS features, thereby accelerating the scale of the crowdsourcing effort.

Maps as a sensor – Maps are becoming integrated into the wider sensor fusion concept, complementing and enhancing on-board vehicle sensors and allowing on-the-fly computing to maps for lane-keeping, traffic sign recognition, and other functionalities.

Self-healing maps – Maps are increasingly updated automatically based on AI and deep-learning techniques to identify modified features, allowing automated, closed-loop map generation and update processes.

Cloud-based storage and processing – The dynamics in terms of real-time processes and computing described above mandate the use of cloud-based technologies. This will be driven by low-latency 5G connectivity in the future and edge cloud capabilities in particular, allowing reliable and low-latency uploading, processing, and streaming of mapping content, while still allowing for intelligent caching of local content to hedge against predictable loss of connectivity (i.e. hybrid approaches).

HD maps and simultaneous localisation and mapping[29] – This refers to the use of high-accuracy HD 3D environmental maps for relative positioning based on simultaneous mapping and localisation (SLAM) and time-of-flight (ToF) measurements. HD maps provide accurate (10cm to 20cm) and dynamic 3D renderings of the road environment, including details like slope and curvature of roads, lane markings, and roadside objects, such as sign posts, obtained using LIDAR-equipped data capture vehicles. While the need for maps is still questioned by some technology vendors touting the universal benefit of map-less systems that don't require vast on-board computing power or face information redundancy. These issues are relevant for highly reliable operation going forward.

Real-Time HD Mapping Standards

The size of maps has increased exponentially with higher accuracy requirements, especially in relation to HD 3D maps for driverless vehicles. This complicates sending map updates over-the-air (OTA) in terms of time, bandwidth usage, and cost requirements. But it also increases on-board storage and processing requirements (both in terms of computation and power consumption). This results in a need for light(er) weight 3D maps based on simplified models of the environment.

Real-time HD mapping is a critical ingredient for automated driving, although technical implementation strategies vary:

- In a minimum data transfer approach, path planning anomaly data can be shared within the bounds of privacy regulation. Anomaly data within a geofence/tile segment is shared while truncating vehicle start and destination points to protect user privacy.
- In 'map-light' approaches, high-definition maps are primarily used for navigation purposes and will be overlaid with real-time situational data (for example, accident notification, road construction).
- In 'map-heavy' approaches, HD maps play a much more critical role in path planning – even to a centimetre level of detail. Such scenarios will require maps that may be up to 1TB in size for a single city/neighbourhood. Not only will these maps need to be updated periodically without direct user interaction, they may even require on-demand updates as vehicles move across geographies. Deployment strategies that leverage roadside infrastructure and edge cloud solutions to deliver these map updates will become crucial to keep costs down.

The mapping ecosystem is currently experiencing a range of changes, including a lack of standards, Despite ongoing standardisation efforts, such as NDS, ADASIS, SENSORIS, TISA, etc., maps are still essentially proprietary datasets lacking interoperability between mapping suppliers. The lack of standards is also resulting in a need for hosting, development, and consulting services.

Navigation data standard (NDS) – A standardised binary database map format for automotive-grade navigation databases, co-developed by car OEMs and suppliers. NDS supports compatibility and interoperability, separation of application software and map data, and incremental updates. The not-for-profit NDS Consortium is headquartered in Germany. Members include automotive OEMs, map data providers, and navigation device and application providers (Daimler, BMW, VW, Hyundai, Nissan, Renault, Volvo, HERE, TomTom, Zenrin, AutoNavi, NavInfo, Baidu, Bosch, Harman, Elektrobit/Continental, Jaguar Landrover etc.).

Sensoris – Initially proposed by HERE as part of a 'sensor data ingestion interface' specification, this standard is now managed by ERTICO as a standardised interface specification. The first vehicle-to-cloud data standard has been released. The data specification covers input on weather environment, road infrastructure, traffic regulation, traffic events, and behaviour, as well as the in-vehicle status.

ADASIS – A map-based ADAS standard, specifying how maps can be used to enrich and improve ADAS services. The ADASIS v3.0 standard aimed at automated driving was released by ERTICO.

Vector Tile 3 (VT3) – From Mapbox[30], this specification is an open standard for powering HD vector maps, an updated format which can radically save bandwidth for streaming data to devices, reducing storage size for larger area coverage offline. With vector tiles, vector data is tiled in small pieces, distributed with low latency around the globe, and it can receive partial updates in real-time as the road network gets smarter. Basically, VT3 brings Snapchat-scale functional levels for HD automotive maps, giving a fleet the latest maps in the fastest way possible, anywhere in the world.

Open Autodrive Forum (OADF) – The overarching organisation overseeing multiple map standard initiatives, including NDS, Sensoris, and ADASIS, and aims to harmonise data flow and allow interoperability between data formats.

Data – Distributed Information

The overall platform design to support these use cases needs to consider a valid range, expiry time, the number of vehicles, and data volume of the distributed information required in the RTSA and HD maps ecosystem,

According to ISO, there are four layers of data:

- Dynamic (traffic light, VRUs).
- Semi-dynamic (congestion, stationary vehicle).
- Semi-static (planned road work, traffic management).
- Static (lanes, roads).

NTT Docomo presented (5GAA-A-170024) a view of the valid range and expiry time of distributed information to support understanding and adoption of RTSA and HD maps. Distributed information has 'valid range' and 'expiry time' depending on the contents and velocity, as shown in the figure below.

	Distributed information	Data rate
Dynamic information	Coordinated control (negotiation)	~2.5 Mb/s x #vehicles
	Sensor/ video/ object data • Depth, video, 3D grid occupancy, detected object data, etc. • Source: on-board sensors, RSU sensors • Distribution of aggregated data could also be considered	0.5~50 Mb/s x #vehicles (depending on the contents)
	Planned trajectory	~12.5 Mb/s x #vehicles
	Simple intention • Lane change, braking, etc.	~50 kb/s x #vehicles
	Traffic signal information	~1 kb/s x #signals
Semi-dynamic information	Accidents, traffic jam, parking lots, local proximity weather, etc.	
Semi-static information	Construction, road closure, wide area weather, etc.	
Static information	Road surface, lanes, structures, road side facilities, etc. * Some overlap with "2. Map/ vehicle management"	

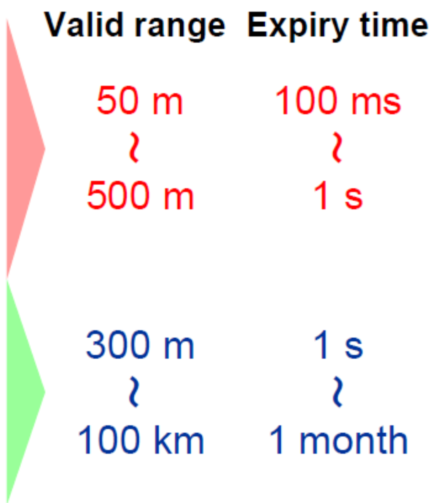


Figure 65 Distributed Information

The potential areas of connectivity support for environment perception is shown in Figure 66. While on-board sensors/cameras will play the core role for environment perception, connectivity can support the following areas:

- Proximity NLOS.
- Beyond sensor range.
- Wide area information.

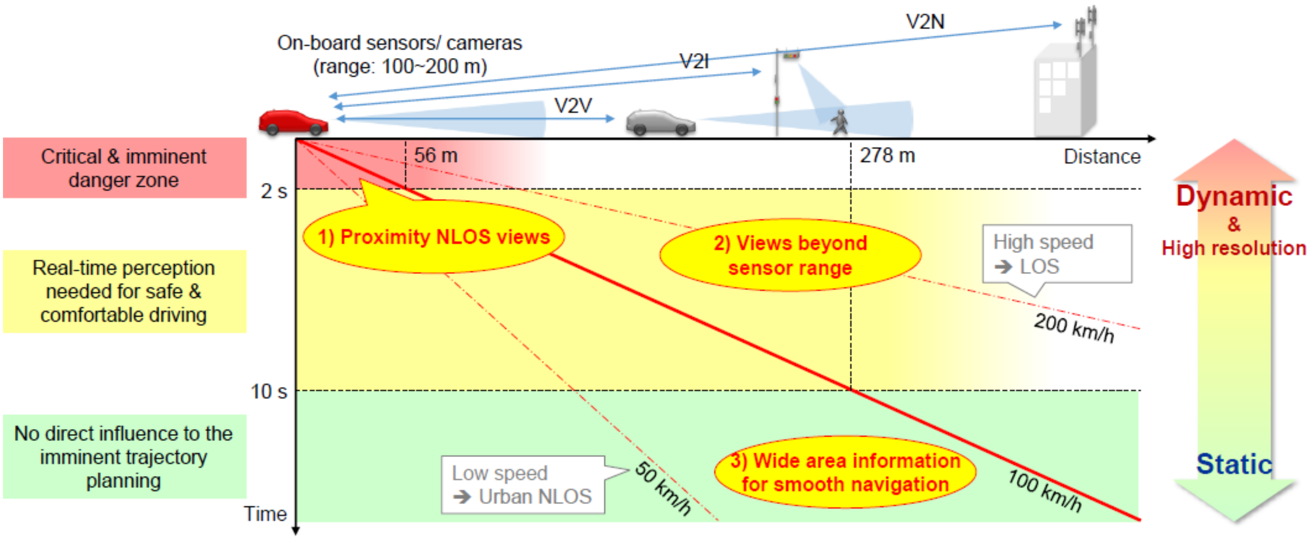


Figure 66 Environmental Perception

The evolution of the data and connectivity design framework for automotive applications is seen as an important growth driver for RTSA and HD maps.

Market Opportunity Sizing

The global market size for automotive HD maps will grow by $77.62M in the period 2018-2022. This report offers an analysis of the market based on end-user (passenger cars and commercial vehicles) and geography (the Americas, APAC, and EMEA). The automotive HD maps market research report further analyses the market's competitive landscape and offers information on several companies including TomTom, HERE, Intel, and NVIDIA.

The concept of autonomous vehicles is reaching maturity, with several leading companies striving towards expansion. This is a critical factor that is expected to boost the need for HD maps. Marketing campaigns and promotions have helped to increase the demand for, and acceptance of, semi-autonomous features in modern vehicles. In addition, the rise in electronic content per vehicle and electrification of automobiles are other factors that have widened the scope of telematics and other connected vehicle applications such as automotive HD maps.

Business Models

The business value for the provision of RTSA and HD maps may follow the current model where the mapping and traffic alerts service is sold to OEMs at a per vehicle cost (sold as a lifetime license for traffic service by a mapping provider to OEMs). The requirement for HD maps to continually update may produce an incremental CAPEX subscription charge. This can incrementally added to the lifetime license or proposed as a SaaS model to reflect the value of the HD map cloud service.

Separately on the network, looking into the value of network slicing and QoS, we can focus our analysis on the offerings and compensation of ICT solution providers and CSPs, as highlighted below. Telcos and ICT solution providers are keystone companies in that they enable the whole ecosystem.

		Main Roles								Users	Enablers		Authorities
	Providers	Chip Makers	Tier Suppliers	Vehicle OEMs	Map Service Provider	ITS Service Provider	Road Operators	ICT Solution Providers	CSPs	End Users	Application & Software Providers	Precise Positioning Providers	Regulators
Main Roles	Chip Makers		Chips, SIMs, CPUs, Modules										
	Tier Suppliers	$		TCU, HU, ECU, IPA, Infotainment							$		
	Vehicle OEMs		$		Sensor Data, $	$		$	$	Vehicles with RTSA&HD Maps			
	Map Service Provider			HD Maps Tiles ,$			$		$			$	
	ITS Service Provider			Hazard Warnings			$						
	Road Operators				Road Data	Road Data							
	ICT Solution Providers			ICT Services			ICT Services		ICT Services				
	CSPs			Connectivity	MEC								
Users	End Users			$									
Enablers	GNSS Receiver vendors			GNSS Receivers									
	Precise Positioning Providers				Precise Positioning								
Authorities	Regulators				Approval	Approval							

All monetary exchanges are shown in green shading. Some exchanges are shown in a dotted green pattern because they involve both payments ("$") and the provision of update files, i.e. when Tier Suppliers, Vehicle OEMs and Application & Software Providers supply updates files to the OTA Management Solution Providers for transfer to vehicles.
Interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity are shown in red shading.

Figure 67 Business Roles and Players

The **core telco services** and **advanced connectivity** offerings involved in RTSA and HD maps have been described in more detail earlier. They are bundled together in a comprehensive ICT solution covering all connectivity needs (i.e. interpersonal communication services, connectivity for vehicle internet connections, telematics and C-V2X services) of the stakeholders that require connectivity in order to enjoy the RTSA and HD map service (i.e. consumer and business vehicle users), offer it to their customers (i.e. OEMs) or implement it and delivery it on behalf of the RTSA and HD map solution providers).

This business model would represent a single, all-encompassing contract for connectivity, service level agreement and related ICT infrastructure support.

However, when specifically targeting RTSA and HD map services, the business connectivity and ICT service offering may be enhanced with the procurement of the V2X server, and the provision of the special C-V2X connectivity required for certain cases of urgent hazard and mapping updates (i.e. Uu URLLC) though network slicing.

The portfolio of ICT services can also include **ecosystem technical enablement** elements like precise positioning, which may be required for the implementation of location-specific updates and self-driving.

6.2 Software OTA Updates

Adoption Drivers

The most important growth drivers for OTA updates include the following:

Regulatory Pressure

According to an article[31] written by Adam Frost in May 2018, making OTA compliance mandatory is foreseen. More specifically, he says, "As conversations about connected and automates vehicles turn to safety standards and regulations, international law commissions and government bodies are working to make OTA compliance mandatory. The US Department of Transportation (USDOT), UK Department for Transport (DfT) and the German BMVI are working on national-level legislation involving OTA updates. On a global level, the UN Task Force (UNECE WP29) is expected to issue a recommendation in mid-2018, with a resolution expected in 2019."

The Value of Software Updates in Contemporary Cars

In car marketing, there is a saying that 'Software = features and features sell cars'. Therefore, if Software is upgradeable this means upgradable features. According to a comment from a Tesla fan[32], "One of the greatest joys of owning a Tesla is being able to experience new features and functionality that get rolled out through over-the-air software updates."

Proliferation of Connected Cars

FCA's global connectivity deployment plan entails that by 2022 all the new cars it manufacturers will be connected. According to Statista[33], there will be 343M connected cars in circulation in 2023, which will both require OTA updates and be able to receive them over cellular networks.

Massive Growth of Demand for Semiconductors

Thanks to developments in connected, automated, autonomous and electric vehicle innovation, the automotive market is driving massive growth in the semiconductor industry. Indeed, NXP Semiconductor[34] told *Electronica 2018* in Munich that the value and complexity of semiconductors in vehicles is set to jump in the next years as higher-level automation, electrification and 5G technologies are introduced on roads. Similarly, Intel seems to be betting on the future of transport being every bit as vital as its initial bet on the Pentium processor for computers during the PC age in the 1990s and on servers ahead of the cloud age[35].

Economics of Connectivity for OTA Updates

The analysis that follows aims at identifying the high-level connectivity requirements involved in all cases of OTA updates with the sole intent to arrive at conclusions as to the rational and realistic commercial 'packaging' and pricing of cellular connectivity (including network slicing-based approaches to it) for this use.

Therefore, this analysis is only concerned with the download of updates to a vehicle or a fleet, with vehicle(s) stationary or moving, and is not related to the installation of updates.

The propositions described here are the same in their main commercial aspects regardless of whether the vehicles are conventional, automated or autonomous, because there is no reason to differentiate them, as it will be revealed in the analysis below. Obviously, a 'product owner' burdened with paying for OTA connectivity may differ, between an OEM for a conventional vehicle and an autonomy service provider or a fleet operator in the case of autonomous vehicles, but the packaging logic or the pricing scheme do not need to change. For simplicity, we will always refer to the product owner as 'OEM'. Likewise, a bundle of connectivity for a conventional car may offer much less data volume per year or fewer updates per year than a bundle for an autonomous vehicle, but the propositions are similar otherwise.

In terms of connectivity economics, the main distinction is between:

- Optional updates, where the decision to update is at the discretion of the vehicle users (e.g. to get some new feature or application, like Tesla's 'advanced summon'), and it happens with their explicit consent as they will bear the costs.
- Required updates, where the decision to accept the update may require the consent of the vehicle users (this condition differs on a per case basis), but the initiative to prepare, serve and install the update belongs to the

vehicle OEMs (e.g. to implement an upgrade that is mandated, or obligatory for the vehicle and its components to maintain their function, or to address a malfunction or device failure that would be subject a recall and/or warranty provisions if the device warranty is still valid), who will also bear the costs.

A. Optional Updates

A1. Routine (non-urgent) Optional Updates

The economics of connectivity obviously have to do with the medium used in transferring the updates from their source system to the vehicle. There are two cases that we will examine: cellular connectivity using commercial spectrum, and other modes.

A1.1 Routine (non-urgent) Optional Updates Using Cellular Connectivity

In this case, the update (e.g. new feature) carries a premium price, which the vehicle user is invited to pay through a 'store' UI. This premium price is intended to compensate for the costs of two goods bundled together:

- New feature (revenues may therefore be shared with the provider offering the feature).
- Cellular connectivity to download the update (a fixed amount within, or a percentage of, the total price).

Depending on whether the cellular connectivity used for this purpose is provided through the user's SIM and consumer contract, or the vehicle's SIM and OEM contract, there are two options:

- If the user's SIM is used: The connectivity cost component contributes towards the data (MBs) needed but without consuming the user's allowance to account for interrupted downloads that need to be repeated, for instance. For example, a mobile operator may keep 30% of the premium price charged, and channel the download through an API that is not charged.
- If the vehicle's SIM is used: The connectivity cost component contributes towards the data (MBs) of the OEM's allowance consumed. For example, the OEM may consider 30% of the premium price charged as a contribution towards the total cost of their contract.

To cater for the case where the user initiates the download while roaming, we can simply differentiate the cellular connectivity price component in the bundle at the level of the 'store'. For example, a cellular connectivity 'mark-up' may be €1 when the vehicle is not roaming, and €2 when the vehicle is roaming.

Regarding capabilities that are offered through network slicing (i.e. low latency, high reliability, high security, download while moving at high velocity or in high density situations), two options can be offered to users, provided of course that their location is under 5G coverage:

- 'Economy class' download, using undifferentiated cellular connectivity.
- 'Business class' download, using 5G URLLC cellular connectivity.

Again, we can simply differentiate the cellular connectivity price component in the bundle at the level of the 'store'. For example, a cellular connectivity 'mark-up' may be €1 under LTE, and €2 under 5G URLLC.

A1.2 Routine (non-urgent) Optional Updates Using Other Modes

We assume that it makes sense to always offer an alternative to cellular connectivity for the download of updates. Indeed, all OEMs offer alternatives including: downloads over Wi-Fi, or transfer of updates via USB sticks or at service shops. Moreover, other alternative modes to cellular connectivity using commercial spectrum include vehicle-to-vehicle update transfers, and downloads from special RSUs over C-V2X.

In this case, the update will carry a 'basic' price, compensating only for the cost of the new feature. Of course, the user who bears all the expenses related to the update will need to cover all other charges that may apply, such as the expenses incurred at the service shop or related to the use of Wi-Fi.

A2. Urgent Optional Updates

By definition, optional updates cannot be urgent, as their download and implementation are at the sole discretion of the vehicle user.

B. Required Updates

It must be noted that required updates should only use the vehicle's SIM and the OEM's contract (not the user's) both because the costs must be borne by OEMs and because using the user's SIM would represent a liability risk for the OEM (e.g. if the user's allowance is not sufficient for a safety-critical update). For the same reasons, required updates do not carry a price (for the vehicle user) for the core benefit they deliver.

B1. Routine (non-urgent) Required Updates

Similarly to the optional updates, there are two cases that we will study concerning the medium used in transferring the updates from their source system to the vehicle: cellular connectivity using commercial spectrum, and other modes.

B1.1 Routine (non-urgent) Required Updates Using Cellular Connectivity

In this case, the update will be handled in a way that minimises the connectivity expense for the OEM, the party that bears the update costs. Levers to minimise the expense include:

- Insofar as cellular connectivity to download the update must be used (as opposed to other modes), the vehicle's SIM which is used for this purpose will connect to the system serving the update with undifferentiated (i.e. non-premium) cellular connectivity (e.g. LTE). The data (MBs) needed will be consumed from the bundle that the OEM has purchased from a mobile network operator or telematics service provider.
- Download while roaming will not be encouraged.

B1.2 Routine (non-urgent) Required Updates Using Other Modes

In this case, the update will be handled in a business-as-usual way, with the following options:

- Modes that bear incremental costs (e.g. visit to a service shop, or updates via USB stick) will continue with the traditional cost structures and bills of materials.
- Wireless modes that do not impose direct costs on OEMs (e.g. transfer of updates over Wi-Fi or V2V or V2I) will be favoured.

B2. Urgent Required Updates

Again, there are two cases that we will study concerning the medium used in transferring the updates from their source system to the vehicle: cellular connectivity using commercial spectrum, and other modes. Although, the urgency of a required update points towards the use of cellular connectivity in all cases, we cannot exclude the use of other modes since these are the current norm for both routine and urgent updates.

B2.1 Urgent Required Updates Using Cellular Connectivity

In this case, the update will be handled in a way that minimises the risk to passenger safety and other traffic participants (other vehicles' passengers, vulnerable road users, etc.). Depending on factors such as the availability of 5G URLLC coverage at the location of the vehicle, the time tolerance of the particular update, and the level of requirements around reliability, security, velocity and density, two situations are feasible:

- The download will take place using undifferentiated cellular connectivity.
- The download will take place using 5G URLLC cellular connectivity.

In both cases, the connectivity expense is born by the OEM, and the vehicle's SIM will connect to the system serving the update with, correspondingly, undifferentiated (i.e. non-premium) cellular connectivity (e.g. LTE) or 5G URLLC connectivity. The data (MBs) needed will be consumed from either the LTE bundle or the 5G URLLC bundle, both of which the OEM has purchased from a MNO or TSP. Obviously, the rate of bundle consumption differs depending on whether the vehicle is roaming or not.

B2.2 Urgent Required Updates Using Other Modes

In this case, the update will be handled in the particular business-as-usual way that has been optimised for handling urgent updates. Options may include:

- Visit to the nearest appropriately equipped service shop, with the traditional cost structure.
- Wireless modes (e.g. transfer of updates over Wi-Fi or V2V or V2I) that should be favoured not only for the absence of incremental cost, but also for the potential for a quick transfer of updates (even when the vehicle is moving) without the need to locate and visit a service shop.

Market Opportunity Sizing

IHS[36] estimates that 160 million vehicles globally will be OTA-capable in 2022, increasing from 14.5 million in 2015. As can be seen in the figure below, IHS segments over-the-air software updates (SOTA) and firmware over-the-air (FOTA) updates into five segments: map SOTA, apps SOTA, infotainment SOTA, telematics control unit (TCU) FOTA and electronic control unit (ECU) FOTA.

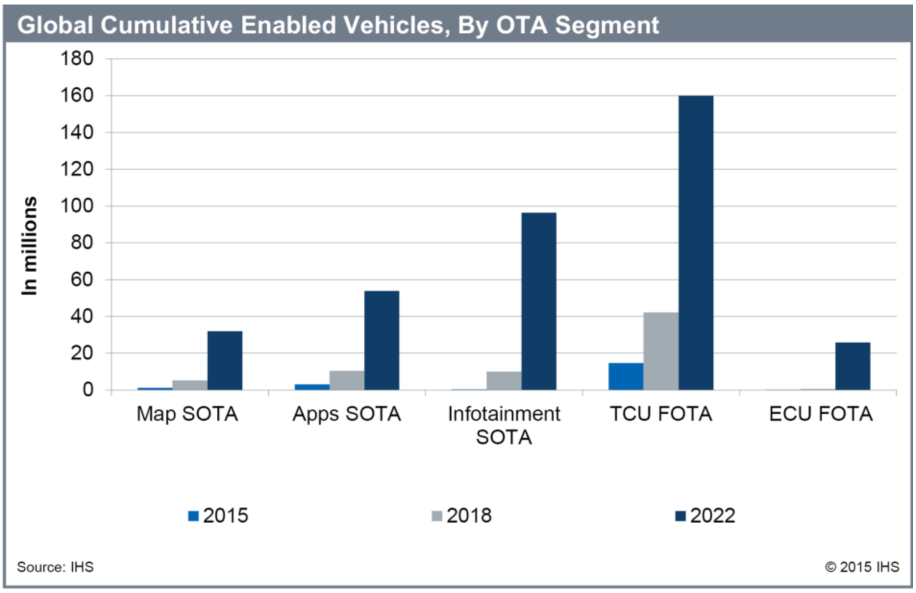


Figure 68 Global Forecast by OTA Segment

- Total vehicles in operations that are enabled with navigation map OTA updates are projected to grow from approximately 1.2 million units in 2015 to nearly 32 million units by 2022, according to IHS forecasts.
- App OTA updates target embedded applications or feature-driven software that is part of infotainment systems such as head-units or telematics systems. App OTA update-enabled vehicles in operation totalled approximately 3 million vehicles in 2015; by 2022, IHS expects that to increase to 53.8 million vehicles.
- Infotainment software updates, e.g. updates to the infotainment OS and user interface, which are more complex than software app updates because the programs can be quite large, will grow quickly over the next few years, starting from just over 200,000 units in 2015. According to IHS estimates, vehicles equipped with infotainment software OTA capabilities will increase to more than 96.4 million vehicles by 2022.
- TCU software OTA updates are currently being implemented via telematics systems. This is the largest segment in the industry: IHS forecasts nearly 14.5 million TCU OTA-enabled vehicles were on the road in 2015, with an estimated total of nearly 160 million vehicles on the road with TCU OTA capabilities by 2022.
- IHS predicts that there were about 86,000 vehicles on the road by the end of 2015 with core ECU OTA update support. That is very low but is expected to grow to approximately 25.7 million vehicles in total by 2022.

Regarding the addressable market opportunity across the landscape of software OTA updates, various participants stand to capture significant gains. More specifically:

Tier 1 suppliers can follow a two-sided approach and at the same time:

- Enhance their products by integrating OTA software into physical parts. Example: Mitsubishi Electric's OTA-enabled head units.
- Widen their portfolio by acquiring capabilities of OTA software suppliers. Example: Aptiv's acquisition of Movimento.

OTA management solution providers collect various types of fees for the tasks they perform, the most sizeable of which include:

- Engineering fees for setting up and tailoring their OTA solution to each OEM's system.
- Royalty fees for the OTA software.
- Revenue for administering updates per number of OTA clients served and volume of updates.
- Other value-added or ancillary services, such as cybersecurity, and data analytics and management.

Vehicle OEMs can realise both substantial savings and significant potential incremental revenues from OTA updates. More specifically:

- Reduced cost of recalls: IHS estimates this to $50-$200 per OTA event. Obviously, this will correspond to a reduction in car dealership revenues.

- Costs savings and increased efficiency in the production of vehicles: estimated at $30-$60 per car.

- IHS expects savings from OTA updates to total $35 billion by 2022 (up from an estimated $2.7 billion savings in 2015).

- Providing add-on services (e.g. functional improvements) for additional fees to consumers through OTA (a fee of $20-$100 per upgrade per car is considered reasonable). Obviously, this type of offering will not appeal equally to all potential customers, so further segmentation is needed to estimate the size of the opportunity. In parallel, this market exists today – albeit underdeveloped – as aftermarket offerings, and this means that augmented revenues are not going to be 100% incremental; rather that OTA updates will help grow this revenue stream remarkably because of ease of implementation, speed, convenience.

Telcos and ICT solution providers are 'keystone' companies in that they enable the whole ecosystem. So, we can analyse further the offerings and compensation of ICT solution providers and CSPs, as highlighted in Figure 69.

Figure 69 Main Roles and Compensation in Value Chain

	Provides	Chip Makers	Tier Suppliers	Vehicle OEMs	OTA Mgnt Solution Provider	ICT Solution Providers	CSPs	End Users	Application & Software Providers	Smartphone Makers	Security & Analytics Firms	Regulators
		Main Roles						**Users**	**Enablers**			**Authorities**
Main Roles	Chip Makers		Chips, SIMs, CPUs, Modules									
Main Roles	Tier Suppliers	$		TCU, HU, ECU, IPA, Infotainment	Updates, $				$			
Main Roles	Vehicle OEMs		$		Updates, $		$	Vehicles				
Main Roles	OTA Mgnt Solution Provider		Updates Service, Gateway Module	Updates Service		$	$	OTA Service	Updates Service	OTA Consumer App	$	
Main Roles	ICT Solution Providers				ICT & Cloud Solutions							
Main Roles	CSPs			Connectivity	Connectivity			Connectivity				
Users	End Users			$	$		$			$		
Enablers	Application & Software Providers		Software, Apps, OS		Updates, $			Updates				
Enablers	Smartphone Makers							Smartphones				
Enablers	Security & Analytics Firms				Security, Analytics Tools							
Authorities	Regulators				Approval							

The figure below provides further detail in the business of ICT solution providers and CSPs as potentially carried out in the case of OTA updates. As can be seen, they provide different kinds of offerings to different customer types. Each specific offering provides value (mechanisms of value creation are shown in black) and there are certain exchanges that are monetised (methods of value capture are shown in red) in a way that compensates ICT and telco companies adequately.

Figure 70 Business Profiles

Customers	Offerings	Core Telco Services	Advanced Connectivity	Ecosystem Tech. Enablement	Ecosystem Business Enablement	Apps & Platform	Data Monetization
		• Seamless Global Connectivity	• 5G, C-V2X, Slicing NFV/SDN, MEC	• API's, ID, Device, Location, OBD-II	• Distribution, Tech & Cust. Support, Payments, Billing	• App Dev, Promotion, Discovery, Monetization	• Advertis., Dyn. Pricing, eCommerce, Analytics
Users	• Consumers • Enterprise Users	• Global Connectivity and ICT for P2P and telematics applications • Contract for P2P/telematics connectivity & ICT	• Bundled Connectivity for C-V2X				
OEMs	• Passenger Vehicle OEMs • Truck OEMs • Autonomy Service Providers • Fleet Operators	• Global Connectivity and ICT for P2P and telematics applications • Contract for P2P/telematics connectivity & ICT	• Bundled Connectivity for C-V2X				
OTA Management Platfoms	• OTA Solution Providers	• Global Connectivity and ICT for business applications and OTA Service • Contract for business connectivity & ICT	• V2X Server • Connectivity for C-V2X • Contract for V2X-based OTA service enablement	• Positioning • Contract for use of positioning API		• Cloud Services • Security & Identity Services • Integration services • C-V2X system operation & maintenance • Cloud resource use fees • Security & Identity service fees • Integration service fees • C-V2X O&M service fees	• Data & Analytics services • Data & Analytics service fees

The **core telco services** and the **advanced connectivity** offerings involved in OTA updates have been described in more detail earlier. They are bundled together in a comprehensive ICT solution covering all connectivity needs (i.e. interpersonal communication services, connectivity for vehicle internet connections, telematics and C-V2X services) of the stakeholders that require connectivity in order to enjoy the OTA updates service (i.e. consumer and business vehicle users), offer it to their customers (i.e. OEMs) or implement/deliver it on behalf of the latter (i.e. OTA management solution providers).

This deal would be covered by a single, all-encompassing contract for connectivity and the related ICT infrastructure support.

However, when targeting specifically OTA solution providers, i.e. the company that will operate the central OTA management platform and deliver the OTA updates service, the business connectivity and ICT service offering may be enhanced with the procurement of the V2X server, and the provision of the special C-V2X connectivity required for certain cases of urgent OTA updates (i.e. Uu URLLC).

The portfolio of ICT services can also include **ecosystem technical enablement** elements like precise positioning, which may be needed for the implementation of location-specific OTA updates regulations.

Likewise, **IT and platform** (i.e. value-added) services can be offered to OTA service providers such as cloud infrastructure services, security and identity services, integration of the different solution components, and operation and maintenance of the C-V2X system.

Another potential service offered to OTA service providers is **data analytics.**

Depending on the complexity and the maturity of the relationship between the ICT solution provider/CSP party and the ToD service provider, it is possible to construct separate contracts for the different services above or arrive at an all-encompassing deal that covers them collectively.

6.3 Tele-Operated Driving

Adoption Drivers

ToD complements high-autonomy systems. Its adoption is both contingent and contributing to the adoption of driverless vehicles.

AVs address the need for cost efficiency and tackle the driver scarcity problem, but ToD boosts their acceptance and regulatory approval as it makes them as safe as legally mandated.

If the autonomous driving functionality fails for whatever reason, ToD guarantees service continuity. ToD is a robust fall-back solution that can increase the use of AVs.

Specific drivers for ToD adoption include:

1. Operating Cost Efficiency

A truly driverless truck would change the face of trucking. In a highly competitive industry operating on thin margins, drivers' wages and benefits are the largest cost, accounting for nearly half of a carrier's cost per mile. The first company that can eliminate drivers could undercut its rivals and dominate the market[37].

2. Driver Scarcity

The American Trucking Associations (ATA) estimates a shortage of nearly 50,000 drivers, with projections that the shortage could increase to 175,000 by 2025[38]. The Conference Board of Canada has said the country faces a shortage of about 25,000 truck drivers by 2020.

Rob Coneybeer, founder and managing director of Shasta Ventures in the US, which has invested in Starsky Robotics, said: "The trucking industry can't fill all the jobs it has ToDay. The delivery of goods isn't going anywhere, but the labor shortage in the industry looms large, threatening its long-term growth. That's where Starsky fits in. The company is not just amplifying the productivity of experienced drivers and helping the industry continue to grow, but it is also transforming logistics as we know it."

3. Safety

Automated trucks might also reduce the nearly 4,000 fatalities from large truck crashes that occur each year in the United States, some of which are known to result from driver fatigue[39]. In June 2018, a Waymo 'safety driver' fell asleep behind the wheel of a self-driving car prototype, causing a collision. Another Waymo driver was witnessed using, or trying to use, a cell phone while riding in the car.

According to Gartner[40], remote control increases safety, and there exist opportunities for 5G technology to expand and enhance AV safety systems. This is fostered by regulators' examination of the safety performance of AVs. Recent incidents involving AVs have sparked negative press and underscored the importance of public safety in self-driving cars. These events have also highlighted the challenges facing the industry to develop autonomous driving systems that can guarantee a safety performance above that of human drivers.

"AVs periodically face a set of conditions they cannot immediately navigate, which results in the need for a vehicle-human handover," explained a senior research analyst at Gartner. "This handover deactivates the autonomous mode and hands over control to a human driver – but such a handover is not always possible. One potential solution for these scenarios where a handover to the human driver fails is to use remote pilots. Human pilots can be the recipient of a planned remote handover or help recover an AV that has become stuck." The safe execution of human-led remote control of AVs would require the reliability and low latency that 5G networks could provide. Once initiated, the technology would allow human technicians in remote facilities to assess live video feeds and vehicle diagnostics from the AV, and take over driving control virtually. As the regulatory environment for AVs continues to evolve, regulators will likely begin to require remote control capabilities from AV OEMs or operators to improve safe operation on public roads.

Business Value

According to one American Transport Research Institute (ATRI) study[41], driver-related expenses (insurance premiums and driver wages and benefits) are increasing year after year, and in 2016 accounted for 48% of all trucking costs. According to data in the study from the US, savings from ToD can be significant, as can be seen below.

Figure 71 ToD Business Value Calculation – Savings

Trucking Operational Savings

Wage	Benefits	Insurance	Bonus
33% of total	*10% of total (@30% of wage)*	*5% of total*	*yearly*
$0.523/mile Or $20.91/h On average	$0.155/mile Or $6.18/h On average	$0.075/mile Or $3.00/h On average	Safe driving: $1499 On-time delivery: $1946 Attract driver: $979 Retain driver: $1143
Assuming driverless trucks replace conventional ones	*Assuming driverless trucks replace conventional ones*	*Assuming driverless trucks enjoy premiums reduced by 10%*	*Assuming driverless trucks replace conventional ones*
Savings = $143B per year	Savings = $42.4B per year	Savings = $2.05B per year	**1st year Savings per driver: $4,424** **Subsequent year Savings per driver: $4,588**

Professional truck drivers drove over 273.9 billion miles in 2015. These miles accounted for 14.2% of all motor vehicle miles and 29.8% of all truck miles.

Total = $187.45B

Other CAPEX/OPEX Savings

CAPEX

- Setting up camps for drivers

OPEX

- Fewer repairs
- Operating trucks at more fuel-efficient speeds
- Flying drivers to the site and subsistence costs
- Training costs

Expenditure

CAPEX

- Setting up the ToD service centre

OPEX

- Running the ToD system
- Maintaining the ToD system
- Training ToD operators
- ToD operator wages and benefits

In this case, savings accrue to the organisations operating the fleets – expenditure is born by the ToD service providers. Similarly, we can derive a calculation of new revenue, based on assumptions from credible sources.

Figure 72 ToD Business Value Calculation – New Revenues

Calculation	Assumptions
Total hours driven per day 200,000,000 hours/day	According to CarMedia Solutions (www.carmedia.tech), a car media platform company collaborating with Telefonica, estimates indicate that there will be approximately 10 million autonomous vehicles by 2022, many of them collecting passengers 24 hours a day, and therefore driving 200 million hours per day (assuming driverless vehicles can go for 20 hours a day, allowing for maintenance and loading and unloading times).
Total miles driven per day 6,000,000,000 miles/day	Assuming AVs will travel on 30 miles/hour on average
Total number of times when ToD will be needed per day Ranging from 1,074,000 times/day to 4,800,000 times/day	According to California state records, human operators of Waymo test vehicles took control 0.179 times for every 1,000 miles driven, while GM's Cruise Automation had a takeover rate of about 0.8. We will use these two values for a range.
Total number of times when ToD will be needed per year Ranging from 375,900,000 times/year to 1,680,000,000 times/years	Assuming AVs will travel 350 days a year
Total new revenues generated by ToD in a year ($) Ranging from $1.8 billion per year to $8.4 billion per year	Assuming a revenue of $5 for every time ToD is used

In this case, revenues accrue to the ToD service providers.

Now, If we want now to delve deeper into the value of network slicing and QoS, we can focus our analysis on the offerings and compensation of ICT solution providers and CSPs, as highlighted below. Telcos and ICT solution providers are keystone companies in that they enable the whole ecosystem. For simplicity, we show the exchanges that take place in the case of ToD for fleet vehicles.

Figure 73 Roles and Players

	Provides →	Main Roles								Users	Enablers				Services			Authorities
		Chip, Module, T-Box Makers	Tier Suppliers	Vehicle OEMs	Autonomy SPs	Fleet Operators	ToD SPs	ICT Solution Providers	CSPs	End Users	Input Device Makers	Sensor Makers	3rd Party SW	Road Ops	Insurance	Repair Shops	Drive Schools	Government/ Regulators
Main Roles	Chip, Module, T-Box Makers		Chip, Module, T-Box															
	Tier Suppliers	$		Parts, products	$		$					$						
	Vehicle OEMs		$			Vehicles												
	Autonomy SPs		Autonomy System			Services		$										
	Fleet Operators			$	$		$		$	Transport				Tolls	$	$	$	Compliance, Tax
	ToD SPs		ToD ECU			Solution		$			$		$ and/or %		Data & Analytics			
	ICT Solution Providers				ICT Services	Connectivity	ICT Services for ToD platform & C-V2X Server				ICT Services		ICT Services	Roadside C-V2X Infra.				
	CSPs					Connectivity								Roadside C-V2X Infra.				
Users	End Users					$												
Enablers	Input Device Makers						Input Devices											
	Sensor Makers		Sensors															
	3rd Party SW						Compl. Apps	$										
	Road Ops					Roadside Infra.												
Services	Insurance					UBI	$											
	Repair Shops					Services												
	Drive Schools					Training												
Authorities	Government/ Regulators					Approval, Incentives												

Figure 74 provides this type of further detail in the business of ICT solution providers and CSPs as potentially carried out in the case of ToD. As can be seen, they provide different kinds of offerings to different customer types. Each specific offering provides value (mechanisms of value creation are shown in black) and there are certain exchanges that are monetised (methods of value capture are shown in red) in a way that compensates ICT and telco companies adequately.

Figure 74 Business Profiles

Customers	Offerings	Core Telco Services	Advanced Connectivity	Ecosystem Tech. Enablement	Ecosystem Business Enablement	Apps & Platform	Data Monetization
		• Seamless Global Connectivity	• 5G, C-V2X, Slicing NFV/SDN, MEC	• API's, ID, Device, Location, OBD-II	• Distribution, Tech & Cust. Support, Payments, Billing	• App Dev, Promotion, Discovery, Monetization	• Advertis., Dyn. Pricing, eCommerce, Analytics
Business Users	• Enterprises • Organizations • LSPs & Carriers • ITSPs • MaaS Providers	• Global Connectivity and ICT for P2P and telematics applications • Contract for P2P/telematics connectivity & ICT	• Bundled Connectivity for ToD C-V2X				
Automotive OEMs & AV Solution Providers	• Passenger Vehicles • Trucks	• Global Connectivity and ICT for P2P and telematics applications • Contract for P2P/telematics connectivity & ICT	• Bundled Connectivity for ToD C-V2X				
ToD Service Providers	• Remote Control Centre • Remote Operation Service	• Global Connectivity and ICT for business applications • Contract for business connectivity & ICT	• V2X Server • Connectivity for ToD C-V2X • Contract for V2X-based ToD service enablement	• Positioning • Contract for use of positioning API	• Customer support bundled • Business services • Contract for business services (hosting NOC, call centre, billing, collections & reporting services outsourcing etc.)	• Cloud Services • Integration services • C-V2X system operation & maintenance • Cloud resource use fees • Integration service fees • O&M service fees	• Data & Analytics • Subscription/Membership

The **core telco services** and the **advanced connectivity** offerings involved in ToD have been described in detail earlier. They are bundled together in a comprehensive ICT solution covering all connectivity needs (i.e. interpersonal communication services, connectivity for vehicle internet connections and telematics, C-V2X services enabling ToD) of the stakeholders that may require connectivity in order to enjoy the ToD service (i.e. business users, automotive OEMs and AV solution providers). This deal would be covered by a single, all-encompassing contract for connectivity and the related ICT infrastructure support.

However, when specifically targeting ToD service providers, i.e. the company that will operate the remote control centre and deliver the remote operation service, the business connectivity and ICT service offering may also be enhanced with the procurement of the V2X server, the provision of the special C-V2X connectivity required for ToD (i.e. Uu URLLC).

The portfolio of ICT services can also include **ecosystem technical enablement** elements like precise positioning, and **ecosystem business enablement** functions such as customer support and various business services (most importantly, hosting the remote control centre and powering the call centre, but also billing, reporting and collections).

Likewise, **IT/platform** services, such as cloud infrastructure services, integration of the different solution components and operation and maintenance of the remote control centre and the associated systems, can be offered to ToD service providers.

Another potential service offered to ToD service providers is **data analytics.**

Depending on the complexity and the maturity of the relationship between the ICT solution provider/CSP party and the ToD service provider, it is possible to construct separate contracts for the different services above or arrive at an all-encompassing deal that covers them collectively.

6.4 High-Density Platooning

In the business roles section, we identified certain interactions that involve the implementation, provision, management and consumption of network slicing-based connectivity (shown in red shading). Now, we will attempt to elaborate on the business aspects of these interactions, including the value proposition (how the offering is creating value for the recipient), the value capture (how the interaction is monetised), and the applicable pricing schemes.

A. Provision of Chip, Module, T-Box/Platooning ECU/Tier Suppliers' Parts and Products

According to the North American Council for Freight Efficiency's (NACFE) 2016 'Confidence Report on Two-Truck Platooning', the incremental costs of the installed solution, per truck, are:

Collision avoidance technology:	$1,500
Cooperative adaptive cruise control:	$250
V2V radios for transmission:	$250
In-cab cameras:	$200
Other material or tech update during ownership:	$400
Labour to install:	$250
Total	**$2800**

B. Provision of Platooning Solution

Again, according to NACFE's study:

Annual subscription for the platooning service: **$200**

Given the requirements for platooning, which is a service whose performance is critical in terms of impact to human lives and hence must come with a strong SLA (i.e. pointing to URLLC with ultra-high reliability, ultra-low latency, and low bandwidth), it must be premium-priced but not prohibitive for adoption by all the trucks within the next decade.

Adjusting for exchange rates at the time, the figures for both A and B are in line with assumptions used in the SARTRE EU project (Commercial Viability, 2013) for estimated add-on cost per vehicle (€2000) and the cost of platooning service (€150/year/vehicle).

C. Provision of ICT Services

NOC services will be provided to platooning service providers, which will compensate the ICT solution provider by revenue sharing**.** For standard cloud services, ICT solution providers will receive an extra share.

D. Provision of Connectivity Services

For networking services, the following business casing assumptions apply:

- There may be a single subscription per platooning truck covering all cellular connectivity modes (including but not limited to live video and audio connections between the trucks, map and software updates), offering unlimited connectivity, across borders.
- A connected truck is 24/7 online, and enjoys dedicated cloud computing support.
- The average price may be $20/month/truck. The current US market standard add-on price for connecting a passenger vehicle to a mobile contract is – at least for AT&T - $20/vehicle/month for 22GB. One might argue that the price for unlimited connectivity, including premium 5G, should be higher, but on the other hand fleets

of different sizes could warrant bulk discounts. Therefore, this average price may serve as a good benchmark for our calculations.

- Platooning is a mission-critical and safety-relevant use case, which requires specific QoS guarantees for V2X to function properly. Therefore, the price could be even higher, especially upon market introduction.
- SIM card costs will be absorbed in the subscription fees.
- Roadside units do not create incremental revenues nor do they introduce incremental costs for this use case.

If we want now to delve deeper into the value of network slicing and QoS, we can focus our analysis on the offerings and compensation of ICT solution providers and CSPs, as highlighted below. Telcos and ICT solution providers are keystone companies in that they enable the whole ecosystem.

Figure 75 Roles and Players

		Main Roles							Users		Enablers			Services			Authorities
	Provides	Chip, Module, T-Box Makers	Tier Suppliers	Truck OEMs	Carriers/LSPs	Platooning SPs	ICT Solution Providers	CSPs	Shippers	Consignees/ Receivers	Telematics Services	3rd Party SW	Road Ops	Insurance	Repair Shops	Drive Schools	Government/ Regulators
Main Roles	Chip, Module, T-Box Makers		Chip, Module, T-Box														
	Tier Suppliers	$		Parts, products		$											
	Truck OEMs		$		Trucks	$		$									
	Carriers/LSPs			$		1. $ 2. %		$	Transport		$		Tolls	$	$	$	Compliance, Tax
	Platooning SPs		Platooning ECU	Solution	1. Solution 2. Matching		$		Matching			$ and/or %		Data & Analytics			
	ICT Solution Providers					ICT Services					ICT Services	ICT Services	Roadside C-V2X Infra.				
	CSPs			Connectivity Enablement	Connectivity								Roadside C-V2X Infra.				
Users	Shippers				$	%				Products							
	Consignees/ Receivers								$								
Enablers	Telematics Services				Services		$										
	3rd Party SW					Compl. Apps	$										
	Road Ops				Roadside Infra.												
Services	Insurance				UBI	$ and/or %											
	Repair Shops				Services												
	Drive Schools				Training												
Authorities	Government/ Regulators				Approval, Incentives												

Figure 76 provides this type of further detail in the business of ICT solution providers and CSPs as potentially carried out in the case of platooning. As can be seen, they provide different kinds of offerings to different customer types. Each specific offering provides value (mechanisms of value creation are shown in black) and there are certain exchanges that are monetised (methods of value capture are shown in red) in a way that compensates ICT and telco companies adequately.

Figure 76 Business Profiles

Customers	Offerings	Core Telco Services	Advanced Connectivity	Ecosystem Tech. Enablement	Ecosystem Business Enablement	Apps & Platform	Data Monetization
		• Seamless Global Connectivity	• 5G, C-V2X, Slicing NFV/SDN, MEC	• API's, ID, Device, Location OBD-II	• Distribution, Tech & Cust. Support, Payments, Billing	• App Dev, Promotion, Discovery, Monetization	• Ads, Dynamic Pricing, eCommerce, Analytics
Business Users	• Freight • Distribution • Haulage • Logistics • Other Company Fleets	• Global Connectivity and ICT for P2P and telematics applications • Contract for P2P/telematics/C-V2X connectivity & ICT	• Bundled C-V2X (multiple slices) and MEC for Platooning	• Bundled Positioning, global SIMs, and Device Management	• Customer support and billing bundled	• Cloud NOC • Bundled apps • Premium apps (e.g. See Through) • Managed service fees • In-App Purchase %	• Data & Analytics • Subscription/Membership • Outcomes-based Pricing
Apps	• Telematics / Tracking • Security & Maintenance • Media & Entertainment • Commerce & Productivity • Maps & Navigation • Mobility-as-a-Service					• Application development environment • Access to user base • Promotion, discovery, monetization • In-App Purchase %	• Data & Analytics • Subscription/Membership • Outcomes-based Pricing
Automotive OEMs	• Trucks	• Global Connectivity and ICT for P2P and telematics applications • Contract for P2P/telematics/C-V2X connectivity & ICT	• Bundled C-V2X (multiple slices and MEC) for Platooning	• Bundled Positioning, global SIMs and Device Management	• Customer support and billing bundled	• Cloud NOC • Bundled apps • Premium apps (e.g. See Through) • Managed service fees • In-App Purchase %	• Data & Analytics • Subscription/Membership • Outcomes-based Pricing

The **core telco services** and the **advanced connectivity** offerings involved in platooning have been described in detail earlier. They are bundled together in a comprehensive solution that also includes **ecosystem technical enablement** elements like precise positioning, global SIMs and device management, and **ecosystem business enablement** functions such as customer support and billing. This solution is covered by a single, all-encompassing contract for connectivity and the related ICT infrastructure support. The important point to note here, in terms of network slicing business models, is that the ARPU from this single contract will need to compensate for traffic from all use cases that involve truck and driver connectivity. Similarly, the margin must be high enough to at least cover the expenses incurred in developing, deploying and managing the advanced networking capabilities (5G, C-V2X, MEC, network slicing) needed to implement platooning and all other sophisticated truck connectivity and automation use cases. For the purposes of business casing, the revenues from the contract can be apportioned across use cases according to network and ICT resource usage.

For **NOC and cloud services** provided to platooning service providers and truck OEMs, the ICT solution provider will be compensated by revenue sharing or some form of managed service fee**.**

Another revenue stream comes from the **enabling of application development** and commercial availability through a **platform** targeting trucking industry participants. These services will be provided to service providers (e.g. independent software vendors and developers, or partners), which will use the platooning NOC to offer customers value-added services on the platooning platform, or other fleet management and logistics applications, complementary to platooning. ICT solution providers and telcos will be compensated on the basis of revenue sharing (30% is a market standard for app stores). To give an idea of the size of incremental revenue, the monthly subscription fee for the fleet management apps can be as low as $10/truck (current market standard for US for Zubie, Delphi etc.).

However, other benchmarks offer evidence for a higher price-point, at least during launch time and in developed economies. More specifically, Deutsche Telekom's 'Drive & Track' fleet telematics proposition in Germany has adopted a four-tier pricing scheme[42], as follows:

- **€18/month/vehicle** – Standard solution: It enables vehicle tracking in real time, as well as providing analyses of driving behaviour. Users also receive automated reports of excessive speed, abrupt braking, or rapid acceleration etc.
- **€23/month/vehicle** – Advanced solution: It lets users read vehicle and engine data from the vehicle's engine control module.
- **€32/month/vehicle** – Speedometer solution: It also makes it possible to download speed data for trucks.
- **€52/month/vehicle** – Fleet sharing solution: It enables multiple employees to access vehicles that are equipped with RFID card readers. Drivers can find and reserve available vehicles conveniently with an app and simply park in an agreed parking space after the trip. Fleet managers receive reports about location, status, and driving behaviour automatically, as this solution makes it possible to record and review every vehicle movement.

All packages include hardware and installation, and use of the customer portal. This pricing scheme absorbs the hardware and installation costs in the monthly subscription price, and the average price of the four solutions is €31.25/month/vehicle.

Another revenue stream is **advanced analytics** offered to business users, OEMs, and application providers for a subscription/membership fee, or outcome-based pricing (share fuel savings, shorten payback period, maximise platooning time). Of course, the question of who can use the data obtained through telematics and who controls them is still a big hurdle. Customers will be more willing to surrender their data if they can identify additional value and see benefits for themselves, for example cheaper insurance policies (source: Deloitte Global Truck Survey).

7 Conclusions

Network slicing enables connectivity differentiation based on both network capabilities and capacity.

Network slicing is a tool for mobile network operators to:

- Provide customised networks to satisfy diverse sets of use cases and requirements.
- Fulfil the diverse requirements in a cost-efficient way.

The sample automotive use cases that are forecast to benefit from this new concept of network slicing and are analysed in this report are:

- Tele-operated driving.
- Real-time situational awareness and HD map.
- High-density platooning.
- Software over-the-air updates.

The concept of network slicing has been developed in close cooperation between the telecom and automotive industries. This report has focused on aligning the service level requirements, or SLRs, of the uses cases with the network slicing key performance indicators, or KPIs. For each prioritised uses case, WG5 has analysed the business roles, business value and potential business models and go-to-market strategies for new services. This is important to understand as the business requirements will have a direct impact on technical solutions in terms of how to realise/implement the network slice, and what kind of operational functions of a slice need to be provided.

Work has been done in parallel to BARNS in a number of Standard development organisations (SDOs) and industry groups in order to further detail and standardise network slicing. Some examples are 3GPP, 5G-ACIA, ETSI, and GSMA.

Network slicing is a means for mobile network operators to fulfil the requirements of the vertical/automotive industry in a cost-efficient way.

Abbrevations

5G-PPP 5G infrastructure public-private partnership
5GS 5G system
5QI 5G QoS indicator
ADAS Advanced Driver Assistance systems
ADADIS Advanced Driver Assistance Systems Interface Specifications
AS Application server
ASIC Application Specific Integrated Circuit
AV Autonomous Vehicle
C-V2X Cellular vehicle-to-everything
CSP Communications service provider
E2E End-to-end
ECU Engine control unit
HD Map High-definition map
HV Head vehicle
ISG Industry specification group
KPI Key performance indicator
MEC Multi-access edge computing
MNO Mobile network operator
NF Network function
OEM Original equipment manufacturer
OTT Over-the-top
PaaS Platform as a service
QoS Quality of service
RFID Radio frequency identify
RTSA Real-time situational awareness
RV Remote Vehicle
SaaS Software as a service
SLA Service level agreement
SLR Service level requirement
SDK Software development kit
SDO Standards developing organisation
SOTA Software over-the-air
ToD Tele-operated driving
URLLC Ultra reliable low latency connection
WWAN Wireless wide area network

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