Tele-operated Driving
Use Cases, System Architecture and Business Considerations

5GAA Automotive Association

White Paper

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1. Introduction

The evolution of driving automation technology is gradually reducing our dependence on human drivers. Tele-operated Driving (ToD) technology separates drivers or driving automation systems from the physical vehicle, effectively operating it from a remote location. ToD thus enables shared remote assistance or remote driving services from a central location, which has the benefit of reducing labour costs (fewer drivers), while improving safety and comfort for the drivers. Such ToD services can:

- remotely address the corner cases associated with automated vehicle operations, and which automated driving systems cannot handle, or
- remotely perform specific driving tasks of non-automated vehicles without the physical presence of a driver in the vehicle (e.g. automated factory parking and valet parking, remote driving in industry areas or on ordinary public roads).

This 5GAA white paper describes the technical and business framework, and a visionary roadmap for ToD services. Different ToD types, which are classified according the impact on the operation level of an automated vehicle, are studied under the different environments such as automated vehicle parking areas, or public roads or even using different mobile networks.

Accordingly, this document is structured in a way that introduces the taxonomy of ToD and different ToD deployment stages, highlighting how ToD operators engage in the act of driving and the Society of Automotive Engineers (SAE) driving automation level of the vehicle, among other operations. The general considerations for all presented ToD stages are summarised from technical and business perspectives. These cover the requirements on the vehicle subsystem, ToD operator subsystem, ToD infrastructure subsystem, and communication subsystem from a technical point of view. Whereas stakeholders, market considerations, business modelling techniques, and the value network details are given in the business-related subchapter.

Subsequently, in the three main sections, the different ToD deployment stages of the ToD evolution roadmap are described in detail with their specific E2E ToD system architecture, business dimensions for the stakeholders, and go-to-market considerations.

This white paper is an abstract of the following published 5GAA ToD technical reports, where interested readers can find further technical details and business considerations on ToD services. It does not contain confidential information or business secrets of any provider or operator of ToD technology, and does not recommend the taking of any particular action. Instead, the purpose of this white paper is to contribute to improved understanding of the technical and business challenges facing ToD, and to offer an analytical framework for how providers might consider those challenges.

- D1.1: Tele-operated Driving (ToD); Use Cases and Technical Requirements [1]
- D2: Tele-operated Driving (ToD); System Requirements Analysis and Architecture [3]
- D3: Tele-operated Driving (ToD); Business considerations [4]

Contents

2. References

[1]	5GAA T-210051, Technical Report, Cross Working Group Work Item; Tele-operated Driving (ToD); D1.1 Use Cases and Technical Requirements v2.0, July 2021
[2]	5GAA Technical Report, C-V2X Use Cases and Service Level Requirements Volume II
[3]	5GAA A-200145, Technical Report, Tele-operated Driving (ToD), D2: System Requirements Analysis and Architecture
[4]	5GAA B-210002, Technical Report, Tele-operated Driving (ToD), D3: Business Considerations, July 2021
[5]	5GAA Technical Report, Safety Treatment in Connected and Autonomous Driving Functions Report, March 2021 5GAA Whitepaper, MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements, June 2020
[6]	5GAA XW7-200012, Technical Report, Network Reselection Improvements (NRI)
[7]	SAE J3016_202104, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.
[8]	5GAA Whitepaper, A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs, Sept. 2020 (This reference is being updated when this whitepaper is published.)
[9]	5GAA T-210023, Draft Automated Valet Parking Use Case Description, Bosch and BMW, March 2021.
[10]	5GAA B-200041, Technical Report, Business Aspects and Requirements of 5G Network Slicing (BARNS) Report
[11]	ECE/TRANS/WP.29/2020/80, UN Regulation on Uniform Provisions Concerning the Approval of Vehicles with regards to Software Update and Software Updates Management System, United Nations Economic Commission for Europe
[12]	5GAA TR A-200055, 5GS Enhancements for Providing Predictive QoS in C-V2X, 2020.
[13]	C-Roads, C-ITS IP Based Interface Profile, V1.8.0, March 2021
[14]	ISO 26262 Series Standards on "Road Vehicles – Functional Safety"
[15]	5GAA A-200094, V2X Application Layer Reference Architecture, June 2020
[16]	3GPP TS 23.261, 5G; Service Requirements for the 5G System (3GPP TS 22.261 version 16.15.0 Release 16).

3. Abreviations

For the purposes of the present document, the following abbreviations apply:

App	Application
AS	Application Server
AVP	Automated Vehicle Parking
AVPS	Automated Vehicle Parking System
CV	Controlled Vehicle
C-V2X	Cellular Vehicle to Everything
DDT	Dynamic Driving Task
HD	High Definition
HV	Host Vehicle
ISP	Internet Service Provider
ITS	Intelligent Transport Systems
Mbps	Megabits per second
MEC	Multi-access Edge Computing
MNO	Mobile Network Operator
NRI	Network Reselection Improvements
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
PLMN	Public Land Mobile Network
QoS	Quality of Service
RTA	Road Traffic Authority
RTTI	Real-Time Traffic Information
SIM	Subscriber Identity Module
SRTI	Safety-Related Traffic Information
STiCAD	Safety Treatment in Connected and Automated Driving
ToD	Tele-operated Driving
WG	Working Group
XWI	Cross-working Group Work Item

4. Definitions and taxonomy for Tele-operated Driving

Tele-operated Driving (ToD) means part or all of the tasks in the act of driving a vehicle are performed by a remote operator, usually over wireless communications. ToD can be classified into four types [1] according to the engagement of the ToD operator in three level of driving operations, i.e. Strategic-level Operation, Tactical-level Operation, and Real-time Operational and Real-time Tactical level functions. The last level is also known as Real-time Dynamic Driving Task (DDT) including Object and Event Detection and Response (OEDR) as well as sustained lateral and longitudinal vehicle motion control as defined in [7]:

- **Non-ToD**: The ToD operator is not engaged in the act of driving, i.e. taking no role in the act of driving. All three of the above levels of driving operations are performed by an in-vehicle user or system.
- **Dispatch ToD**: The ToD operator takes the role of the *Dispatcher*, which only performs the Strategic-level Operations of driving, while the Tactical and Real-time DDT are performed by the in-vehicle user or system. For driving automation systems, this type of ToD corresponds to the Dispatch Function in driverless operation defined in [7].
- **Indirect Control ToD**: The ToD operator takes the role of the Indirect Controller (Remote Assistant) to perform the Tactical-level Operations, which corresponds to the Remote Assistance function for driving automation systems defined in [7][1]. If needed, the Indirect Controller may also perform Strategic-level Operations[2]. In Indirect Control ToD, the Real-time Dynamic Driving Tasks are performed by an in-vehicle user or system.
- **Direct Control ToD**: The ToD operator takes the role of the Direct Controller (Remote Driver), to perform all or part of[3] the Real-Time DDT. If needed, the Direct Controller may also perform the Tactical and Strategic-level Operations of driving[4].

[1] When engaged in the act of driving, the remote operator of Indirect Control ToD may disengage the in-vehicle system from performing DDT, by either taking over all DDT tasks, i.e. the role of Direct Controller, or by bringing the vehicle to a minimal risk condition.

[2] When Indirect Control ToD is engaged, the ToD operator may also perform Strategic-level Operations such as reselecting the route, when such operations are needed to complete the act of driving, e.g. to avoid a blocked road.

[3] When Direct Control ToD is engaged, part of the DDT functions, e.g. lateral and/or longitudinal vehicle motion control, may be performed by the in-vehicle user or system, e.g. through adaptive cruise control and/or lane-keeping, while the ToD operator (Direct Controller) is still responsible for the Object and Event Detection and Response task.

[4] When Direct Control ToD is engaged, the ToD operator (Direct Controller) may also perform Strategic-level Operations such as reselecting the route and Tactical-level Operations such as replanning the pathway, when such operations are needed to complete the act of driving, e.g. to avoid a blocked road or get around an obstacle on the road.

[5] The ToD operator can be a remote user [7] or a remote system.needed to complete the act of driving, e.g. to avoid a blocked road or get around an obstacle on the road.

[6] Situations that automated driving systems cannot manage, e.g. unannounced areas of road construction or large objects in the lane.

Table 1 summarises the refined taxonomy based on [1] and [4].

ToD Type (Role of ToD operator[5])	**Act of Driving**		
	Strategic Functions (Travel planning, route and itinerary selection)	Tactical Functions (Pathway planning in difficult situations[6])	Real-time Operational and Real-Time Tactical Functions (Real-Time Dynamic Driving Task)
Non-ToD (No Role)	In-vehicle user or system	In-vehicle user or system	In-vehicle user or system
Dispatch ToD (Dispatcher)	ToD operator	In-vehicle user or system	In-vehicle user or system
Indirect Control ToD (Indirect Controller or Remote Assistant)	ToD operator (if needed[2])	ToD operator	In-vehicle user or system
Direct Control ToD (Direct Controller or Remote Driver)	ToD operator (if needed[4])	ToD operator (if needed[4])	ToD operator (all or part of DDT[3])

Table 1: The role and engagement of the ToD operator in the act of driving in different types of ToD

5. Visionary roadmap for deployment of ToD services

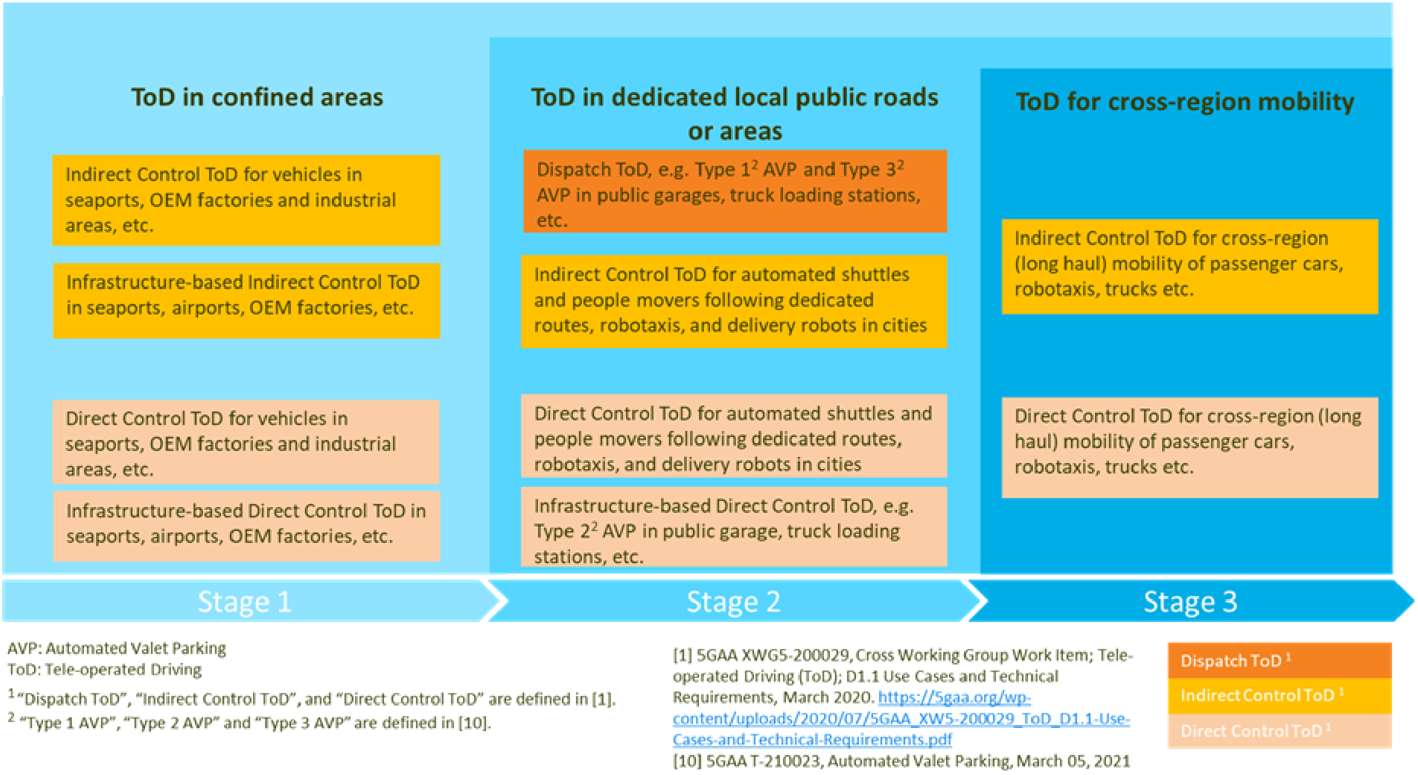

Figure 1: Visionary roadmap for ToD services

5GAA envisages a progressive deployment roadmap for ToD services consisting of three stages, namely ToD in confined areas, ToD in dedicated local public roads or areas, and ToD for cross-region mobility, as shown in Figure 1.

In the first stage, ToD services are provided to vehicles of a single automotive OEM operating in confined areas, e.g. mining sites, seaports, OEM factories industrial areas. Such areas usually have restricted access control for human and other types of traffic. The operational environments in this stage, including necessary infrastructure supports, are under the control of the premises owner, which in many cases is also the ToD service provider. Usually, a Non-Public Network (NPN) with 3GPP or non-3GPP access technologies or public communication network from a single Mobile Network Operator (MNO) is used for supporting the ToD use case in confined areas.

In the second stage, ToD services can be provided to vehicles from multiple automotive OEMs operating in dedicated public areas or on dedicated public roads in a city. Typical scenarios in this stage include ToD supports to:

- Automated shuttles, buses, and other vehicles primarily for transporting people and for last-mile mobility services whose operation follow predetermined routes on public roads.
- Infrastructure-based automated valet parking services for automated passenger vehicles in public garages or for logistic trucks in automated truck loading stations.
- Robotaxis and delivery robots operating in dedicated districts of a city.

The communication networks covering the service area, which can be dedicated districts in a city or dedicated parking garages, can be from a single or multiple MNOs.

In the third stage, ToD services are provided for cross-region (long-haul) mobility using ordinary public roads. Multiple ToD service providers may provide ToD services on the same cross-region corridor. Switching between networks from different MNOs is foreseen, if the network from a single MNO cannot provide full coverage for the service area, e.g. when the corridor is across a country border.

In each stage, depending on the use cases, a ToD operator can take the role of Dispatcher, Indirect Controller, or Direct Controller for tele-operated vehicles, corresponding to the three types of ToD services defined in the previous section. When the ToD operator takes the role of Direct Controller, the vehicle may have a low driving automation level engaged during the ToD operation, e.g. level 2 or lower according to the SAE definition. When the ToD operator takes the role of Dispatcher or Indirect Controller, high SAE driving automation level, e.g. level 4 or higher, may need to be engaged at the tele-operated vehicle.

It is foreseen that the market rollout of ToD services follows this three-stage roadmap to assist and complement automated vehicles in field operation, thereby facilitating and accelerating the realisation of connected and automated mobility, c.f. the 5GAA Visionary Roadmap for Advanced Driving Use Cases [8][7].

[7] The 5GAA C-V2X Roadmap [8] is being updated when this whitepaper is published.

6. General considerations for ToD Stage 1 – 3

Progress in automotive, information and communication technologies has made ToD for both Direct Control and Indirect Control types possible. The technical requirements analysis in 5GAA study [3] lay the foundation for implementing E2E ToD systems with state-of-the-art technologies. Business modelling analysis in 5GAA [4] also outlines the methodology for analysing potential business models and go-to-market strategies for ToD services.

6.1. General technical considerations

A ToD system typically includes the vehicle subsystem, the ToD operator subsystem, and communication networks enabling low latency and reliable communication between vehicles and the ToD operator. For ToD use cases that rely on sensor data from infrastructure, the infrastructure subsystem is also an essential part of the ToD system.

6.1.1. Vehicle subsystem

In most ToD use cases, the vehicle needs to share sensor information with the ToD operator to construct the “perception” of the driving environment. As studied in [3], such sensor information may include, among others, video and audio streams from onboard cameras and microphones, data from LiDAR, RADAR, ultrasonic sensors, HD map, and precise positioning information. Data from other common vehicle systems, such as ABS, ESP, lane-keeping, and extra sensors like accelerometers and gyroscopes can also be used for improving situation awareness and driving experiences for the Remote Driver. Moreover, trustworthy information received via C-V2X direct and network communications can further improve situation awareness and driving safety for the ToD operator.

In Dispatch ToD or Indirect Control ToD, vehicles must be able to validate and automatically follow the route or trajectory information received from the ToD operator. For Direct Control ToD, the vehicle must be able to process and execute the remote-driving commands, according to the onboard security check. To validate the received instructions and commands from the ToD operator, vehicles need to know the associated communications latency information. This makes it important for vehicles and the ToD operator to receive notifications about the communication latency and other Quality of Service (QoS)-related information from the communication networks, e.g. via the 5G Network Exposure Function (NEF).

For safety reasons, the vehicle must be able to detect when the ToD system is malfunctioning and override the ToD vehicle subsystem to bring the vehicle to a "minimal risk" state, e.g. loss of connectivity to the ToD operator, intrusion to the vehicle, or any other problem leading to the creation of faulty actuation data.

It is important for the proper and sustainable operation of a ToD system that the vehicle is capable of calibrating and synchronising the perception sensors and actuators, as well as receiving ToD system functionality, software and parameter updates as an integral part of the overall automated vehicle update regulations (e.g. the software update management system). [11]

Other functionalities, such as establishing a video and/or audio link to the ToD operator, as well as the storing of ToD-relevant data for later inspection and analysis, may also be important vehicle requirements, subject to the applicable regulations.

Vehicle sensor and actuator technologies in and on modern vehicles [3] have shown a maturity level that fulfils technical requirements for automated driving, according to the SAE L3 (Level 3). Such technologies also serve as the basis for ToD.

6.1.2. ToD operator subsystem

End-to-End ToD system efficiency relies on well-organised and user-friendly cockpit components consisting of low-latency sensors, mechanical or electrical HMI, and highly reliable, real-time and low-latency video capabilities for human ToD operators.

Technical requirements for the ToD operator subsystem can be different for humans or machine operators. For the human ToD operator, the subsystem should be able to construct and display the real-time environment information based on the received video signals and other sensor data with acceptable user experience for the engaged ToD operation. Other information such as vehicle capability, ToD types, connection quality to the vehicle, which are used by the ToD operator in decision-making, should also be acquired and displayed via the HMI in textual and visual ways. For a machine ToD operator, instead of video signal, the subsystem should be able to use recognised objects, audio signals (e.g. for emergency vehicles), and digital maps.

The ToD operator subsystem should be able to receive driving instructions or commands from a human or machine operator and send them to the vehicle subsystem within the latency constraint, as discussed in Section 6.1.4.

When the MNO network provides information about the QoS of the communication link or about the expected QoS changes, the ToD operator system should be able to adjust the ToD operation based on such information, e.g. changing the ToD type or the vehicle speed.

To safely perform ToD operation with either human or machine operators, the ToD operator subsystem should be able to detect hazardous situations and disengage the ToD function in a safe manner, e.g. when any part of the ToD system is malfunctioning, or the vehicle exits the Operational Design Domain (ODD).

For field ToD operation, the human ToD operator or the machine ToD operator system shall be qualified and authenticated by the system before engaging in the operation.

For commercial operations, the ToD operator subsystem should support operational functions such as billing and charging.

The ToD operator subsystem may involve additional advanced technologies to improve the remote operation of vehicles. On the one hand, for safety reasons, human sensors can monitor the health and physiological parameters of the human ToD operator in real time. On the other hand, tactile feedback from the wheel and pedal sensors can be provided to the human ToD operator. These, together with high-resolution displays, or new and emerging immersive glasses, can further improve environmental awareness and the user experience of the ToD operator, as analysed in [3].

6.1.3. Infrastructure subsystem

An infrastructure subsystem, if available, can provide more sensor information and improve the perception range, and thus increase safety when performing the ToD operation in various scenarios. Additionally, infrastructure supported ToD requires seamless and reliable fixed-sensor coverage in the operation area and considerable edge-compute capabilities to generate a digital twin of the environment and, in some cases, automatically perform the ToD operation. Therefore, it is likely to be deployed in well-defined environments like manufacturing compounds, harbours, airports, etc. or where a sensor and edge-infrastructure environment are implemented for a wider range of use cases. [3]

6.1.4. Communication networks

Reliable and low latency two-way communication between the ToD operator and the vehicle(s) is essential for both Direct Control and Indirect Control ToD operations.

The E2E service-level latency requirements depend on many factors, such as the type of ToD and vehicle speed. Direct Control ToD and higher vehicle speed in general have more stringent service-level latency requirements than Indirect Control ToD and lower vehicle speed. The E2E service-level latency consists of both application latency and communication latency. Studies in [2] and [3] show that the typical E2E service-level latency requirement for Direct Control ToD with a vehicle speed of 50 km/h is about 120 ms, including both uplink (vehicle to ToD operator) and downlink (ToD operator to vehicle) parts. Wireless communication networks that provide a round-trip communication latency of 50 ms to 60 ms can support such ToD use cases. On the other hand, the Indirect Control ToD and lower vehicle speed has more relaxed latency requirements, e.g. 300 ms E2E service-level latency for a vehicle driving at a speed of 10 km/h. [2]

The data rate between the vehicle and the ToD operator is usually uplink intensive, especially for human ToD operators who rely on video signals from vehicles to perceive the environment. Table 2 from [3] shows examples of information types and related data rates for various ToD use cases. It should be noted that not all information types in Table 2 are required in every ToD use case.

Information Type	Data Rate	Note
Uplink (vehicle to ToD operator)		
Video (for human ToD operator)	Up to 32 Mb/s	From the vehicle to the ToD operator: ~8 Mbps are needed for a progressive high-definition video/camera (h.264 compression), assuming four cameras are needed (one for each side). [2] Reliability: 99%
Object information	Up to 4 Mb/s	Sensor data (interpreted objects) can also be provided from the vehicle to the ToD operator, assuming 1 kB/object/100 ms and 50 objects. [2] Reliability: 99%
Audio	~96 kb/s	Audio signal provides acoustic environmental information to the ToD operator. Audio signal may be embedded in the video stream. This signal can also be used for the ToD operator to have interactive audio communication with the passengers onboard.
Vehicle information (e.g. speed, acceleration, vehicle position)	~0.2 Mb/s	50 km/h is considered the maximum speed for remote steering under highly uncertain conditions. In the ToD support case or in ToD for automated parking use cases, the vehicle speed is assumed to be no more than 10km/h and 20 km/h, respectively.
Downlink (ToD operator to vehicle)		
Vehicle manoeuverer commands (Direct Control ToD type)	~ 400 kb/s	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 20 ms (maximum 50 messages per second) [2] Reliability: 99.9% or higher
Driving path or trajectory (Indirect Control ToD type)	~ 25 kb/s	Data from the provided paths are several kbps (e.g. 100 points and 32 bytes for each point). [2] Reliability: 99.9% or higher
Keep alive signal	~0.2 Mb/s	An example of this signal is the cyclic status message from Automated Valet Parking System (AVPS) to the vehicle for the AVP use case. [9] This signal is only needed when there is no periodic high frequency transmission of driving instruction commands from the ToD operator to vehicle, e.g. in Indirect Control ToD.
Control signals (e.g. for camera setting)	negligible	This signal is not a continuous data stream and is considered as a very low data rate transmission.
Video/Audio (communication with ToD operator)	Video ~ 8 Mb/s Audio ~ 96 kb/s	These signals are applicable only when the human ToD operator needs interactive audio and/or video communication with the passengers in the vehicle.

Table 2: Example information type and data rate for ToD services

The wireless communication link may fail during the ToD operation. When such failure occurs, safety measures at the vehicle side should be able to detect it and take the necessary steps to ensure safety, e.g. bringing the vehicle to the minimal risk state. However, when the ToD service is engaged, such events should happen very rarely to ensure an acceptable availability of the ToD service. For this reason, the communication network should meet very high reliability [16] requirements, e.g. 99.9% or higher.

Field tests have shown the capability of 4G networks in supporting initial implementation of ToD services of both, Indirect Control ToD type and Direct Control ToD [3]. Established coverage of 4G networks is also important for ToD service availability in operational rollout phase. 5G networks are needed for deploying ToD services, not only to benefit from the significantly reduced latency below 10 ms, but also to meet the increasing system capacity demand in a broad ToD deployment.

The QoS of 3GPP networks ensures the operation of ToD services even with limited network resources by providing differentiated handling and capacity allocation to ToD flows in the network. The predictive QoS studied in 5GAA [12] is the mechanism to enable mobile networks to provide in-advance notifications about anticipated QoS changes to the vehicle and ToD operator. Predictive QoS makes it possible to adjust ToD application behaviour in response to the predicted QoS, to improve system safety and user experience. The network should provide QoS status information, e.g. measured latency and data rate, and information about the expected QoS changes (i.e. QoS prediction), when such information is available at the network, to the vehicle and/or the ToD operator e.g., via the NEF of 5G system.

A “network slice” is a logical process that provides specific network capabilities and characteristics in order to serve a defined business purpose for a customer. The fundamental 5G system architecture and associated key technology components are maturing to enable network slicing like this. [10] Customised network slices for guaranteed Service-Level Agreements (SLAs) can support independent business functions covering ToD services with different performance, functional and operational requirements.

6.1.5. Other general technical considerations

Safety considerations

As failures in ToD may lead to severe harm to people and damage to property, Functional Safety needs to be considered in the design of the overall system. Up to what extend this needs to be done and which system parts are influenced depends on the ToD function mode itself. Specifically, it is a matter of the detailed system design.

The 5GAA study on Safety Treatment in Connected and Automated Driving Functions [5] shows both Direct and Indirect Control modes of ToD bare safety risks that need consideration within Functional Safety measures. A reasonable approach would be to consider the communication domain as an open channel, also known as "black channel", and concentrate on safe monitoring of this open channel both at the vehicle and back-end sides in view of Functional Safety. This still calls for requirements from the communication part, but they relate largely to the availability of the service rather than the Functional Safety perspective, as defined in ISO 26262. [14]

Security

A ToD service should be provided only to authenticated service subscribers. All subsystems of a ToD system should be protected from security threats. Most importantly, it must be ensured that attackers cannot get control of the vehicle.

From a communication perspective, between the ToD operator and the vehicle and among other ToD system components, the communication should be mutually authenticated and encrypted, to ensure E2E information integrity and confidentiality, as well as the authenticity of communicating entities. State-of-the-art E2E security solutions can be applied for this purpose, such as Transport Layer Security (TLS) using certificates from a Public Key Infrastructure (PKI), which are widely used for session-based communication applications on the Internet.

Cloud-based implementation for application servers

For commercial deployment of ToD services, the ToD system may involve cloud-based implementations of application servers located at the back-ends of automotive OEMs, service providers, and traffic authorities. Given the potential large number of different automotive OEMs, ToD service providers, and traffic authorities in the world, robust Interchange Functions are needed to scale up communications among back-end systems from different stakeholders, and to avoid full mesh connectivity in ToD Stage 2 and Stage 3. Such Interchange Functions can provide agreed interfaces towards back-end systems of different stakeholders and enable scalable information exchange, such as ToD service discovery, service reservation, and even real-time safety related traffic information for ToD operation. Such Interchange Functions may be implemented as part of commercial digital map services or as a standalone service [13].

6.2. General business considerations

The business modelling analysis of ToD performed by 5GAA, and presented in this white paper (summarising the results of [4]), does not pretend to provide an exhaustive analysis of all possible challenges and corresponding solutions regarding business models, governance challenges, or go-to-market constraints. But it does aspire to identify the different elements that should be taken into account when considering the deployment of a ToD ecosystem from a business perspective. These elements are the same across the different ToD deployment stages, and can be categorised as follows:

1. **Initial stakeholder identification**, capturing both the stakeholder roles and the entities that can take up this role.
2. **Detailing of operational processes**, which determines how the different identified stakeholders can collaborate.
3. **Identification of go-to-market constraints**, based on insights gathered on stakeholder identification and the detailing of operational processes.
4. **Examples on how the business modelling techniques defined earlier by 5GAA in the Business Aspects and Requirements of 5G Network Slicing (BARNS)** methodology [10] can also be applied to different ToD deployment scenarios. Five ToD use cases have been analysed in [4] using this methodology, which consists of the following steps:
   A. Definition of assumptions regarding functional roles, to ensure that the business analysis of the use case represents realistic situations.
   B. Depiction of the value network details as a graph, and textual detailing of the different links in the graph. An example of such a graph is depicted in Figure 2.
   C. Summary of the value network details in a table, where value creation mechanisms are shown in red, and value capture mechanisms in green. Table 3 illustrates this.
   D. Optimisation of the value network table, e.g. clearing away situations where a specific stakeholder has no value creation whatsoever (visually recognised by fully red columns in the table), etc.
   E. Reflections of a possible go-to-market strategy in a table, following a template that contains the following elements: who to sell, what to sell, how to sell (channel, approach). An example is given in Table 4.
   F. Textual reflections on pricing strategy.

For more details regarding how this methodology can be applied to several ToD use cases, spanning the different ToD deployment stages, we refer the reader to [4]. That report is intended to provide valuable first insights and inspiration to enable stakeholders with a keen interest in realising and deploying Tele-operated Driving products to commence with their own business and governance modelling. It takes all specific individual characteristics of the deployment scenario into account, while making use of the generic considerations and methodologies that were introduced in this study.

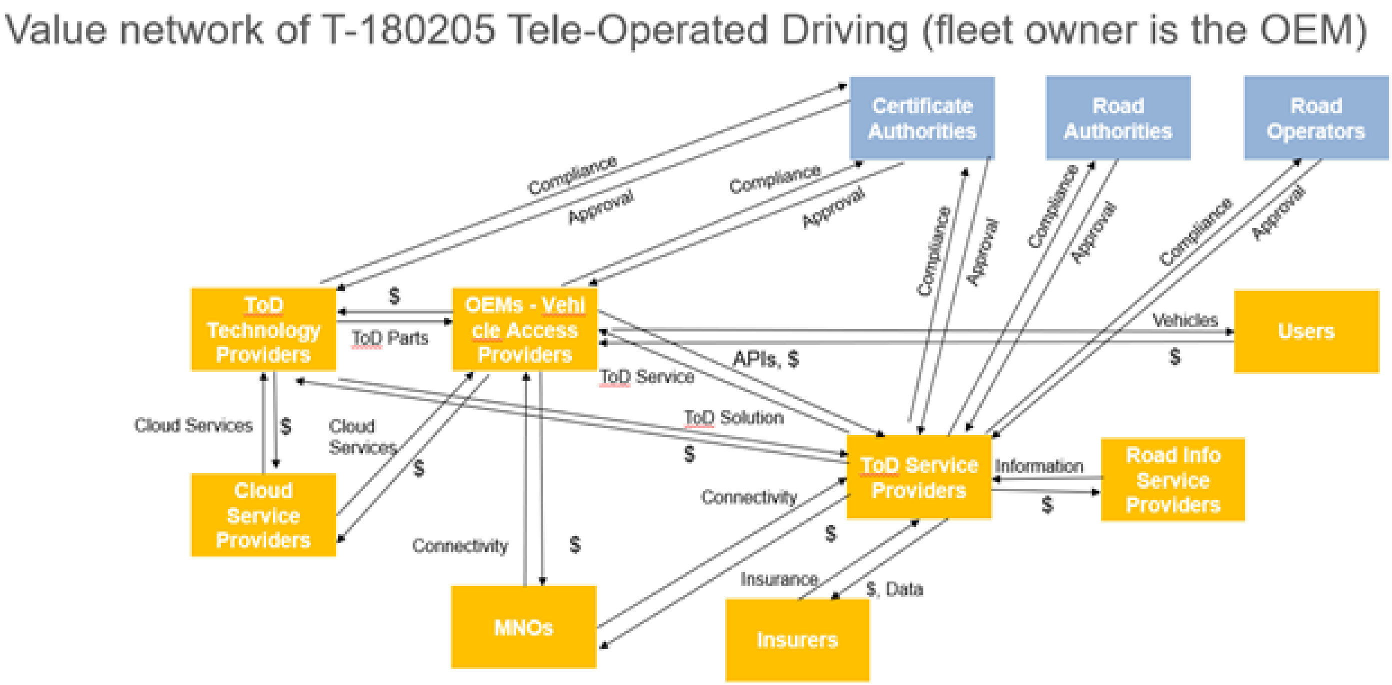

Figure 2: value network presented as a graph, for use case T-180205 Tele-operated Driving (fleet owner is the OEM)

	Providers	Main Roles					Enablers	Services	Customers	Authorities
		ToD Technology Providers	OEMs/Vehicle Access Providers	ToD Service Providers	Cloud Service Providers	MNOs	Road Information Service Providers	Insurers	Users (Enterprises, Consumers)	Certification, Road Authorities & Operators
Main Roles	ToD Technology Providers		ToD Parts	ToD Solution	$					Compliance
	OEMs/Vehicle Access Providers	$		$, APIs	$	$			Vehicles	Compliance
	ToD Service Providers	$	ToD Service			$	$	$, Data		Compliance
	Cloud Service Providers	Cloud Services	Cloud Services							
	MNOs		Connectivity	Connectivity						
Enablers	Road Information Service Providers			Information						
Services	Insurers			Insurance						
Customers	Users (Enterprises, Consumers)		$							
Authorities	Certification, Road Authorities &Operators	Approval	Approval	Approval						

Table 3: Value network presented in a table, for use case T-180205 Tele-operated Driving (fleet owner is the OEM); value creation mechanisms are shown in red, and value capture mechanisms in green

Go-to-Market Strategy options for ToD Service Providers selling to OEMs

Offering	Who To Sell	What To Sell	Examples on How To Sell
Delivery of ToD service	Vehicle OEMs	ToD service delivered as follows: - Support of Indirect and Direct Control modes of ToD, depending on type of vehicle and situation - Support of retrofit and factory fit ToD solutions as needed - Support of well-defined Operation Design Domains - With SLAs regarding the Control Centre, the time available for response to request for service and the time available for service delivery completion - With contract describing the insurance necessary to cover for liabilities related to humans and vehicles	Direct sales to OEMs with partner ToD Technology Provider(s)
			Indirect sales to ToD Technology Provider(s)
			Direct sales to OEMs

Table 4: Example go-to-market strategy presented in a table, for use case T-180205 Tele-operated Driving (fleet owner is the OEM)

7. Stage 1: ToD service in confined area

7.1. Overview

In ToD Stage 1, tele-operated vehicles operate in confined areas like automotive OEM factories, seaports, airports, etc. This is the first stage of commercial deployment of ToD services and has relatively relaxed technical, business, and legal requirements compared with Stage 2 and Stage 3 intended for public roads and areas.

Using the methodology developed in [1] for studying ToD use cases, Table 5 summarises the characteristics of ToD use cases and service scenarios of this stage. The characteristics cover whether the deployment of such services involve single or multiple service providers, automotive OEMs, Road Traffic Authorities (RTAs), and MNOs, which then impact the system architecture and go-to-market considerations.

Use cases and service scenarios of in ToD Stage 1	ToD Service Provider	OEM	RTA	MNO
Indirect Control ToD or Direct Control ToD for vehicles in seaports, OEM factories, and industrial areas, etc[8].	Single	Single	N/A	Single
Infrastructure-based Indirect Control ToD or Direct Control ToD in seaports, airports, OEM factories, etc[9].	Single	Single	N/A	Single

Table 5: Service scenarios and characteristics of ToD Stage 1 – ToD services in confined areas

[8] The related use case descriptions and service-level requirements are specified in [2] Section 5.4.10 Tele-operated Driving, Section 5.4.11 Tele-operated Driving Support, Section 5.4.12 Tele-operated Driving for Automated Valet Parking.

[9] The use case description and service-level requirements of infrastructure-based Tele-operated Driving can be found in Section 5.4.8 of [2].

7.2. Example application-level system architecutre

The ToD system architecture of an example Stage 1 use case – ToD service for automated car parking in automotive OEM factories – is shown in Figure 3. This system architecture diagram, like other system diagrams in this white paper, is based on the 5GAA V2X Application Layer Reference Architecture [15] and [3][10]. Meanwhile, Table 6 outlines the relevant system components. It is worth noting that these components are also fundamental blocks for ToD system architectures in Stage 2 and Stage 3.

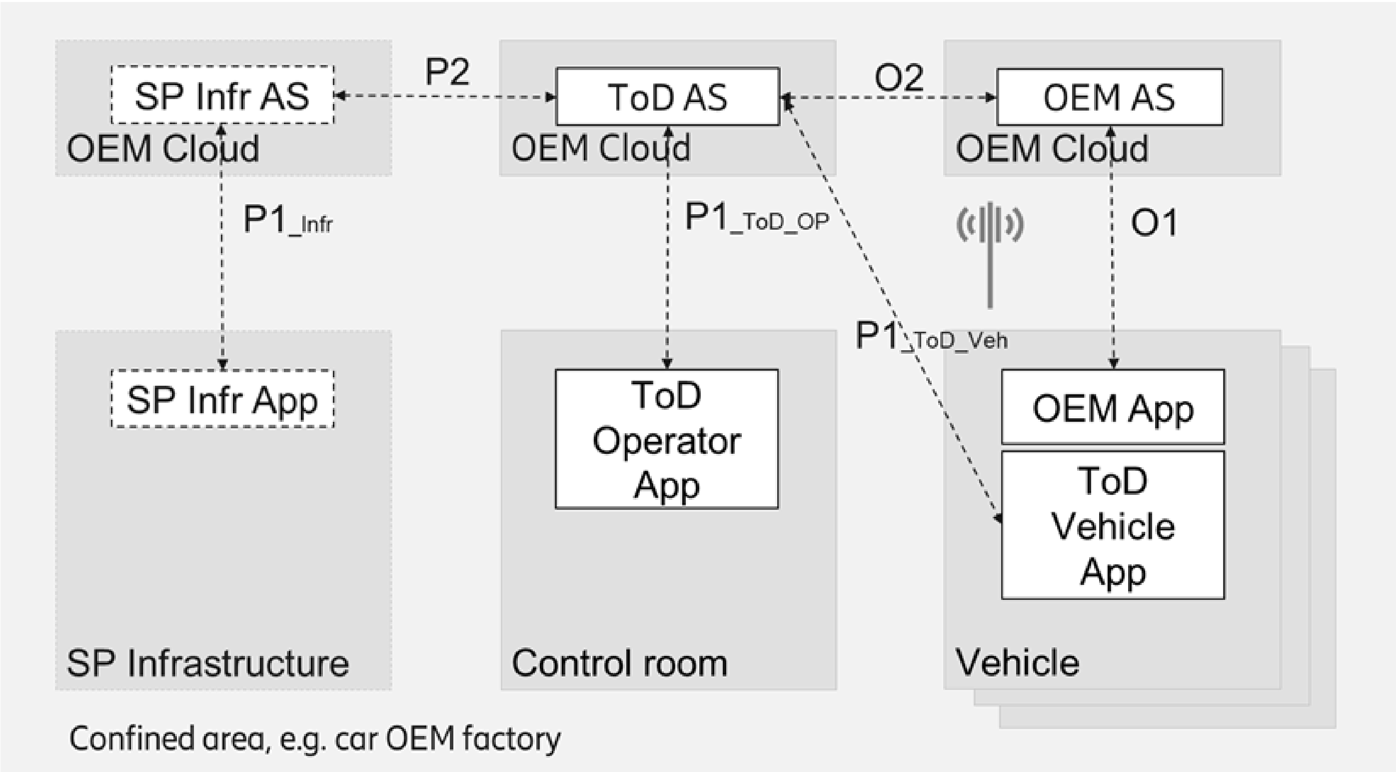

Figure 3: Deployment view of ToD architecture in confined areas, e.g. OEM factory (ToD Stage 1)

[10] Details of interfaces in ToD system architecture for ToD Stages 1, 2, and 3 can be found in [3] Section 5. The naming of system components and interfaces follows the convention from [15].

Component Acronym	Component Function
ToD AS	ToD Application Server enables secure communication between trusted ToD Operator App and ToD Vehicle App that is controlled by the OEM AS in the cloud and OEM App on the vehicle. It manages registration and authentication requests from ToD Operator Apps and from ToD Vehicle Apps. It handles ToD service requests from either a ToD Operator App or a ToD Vehicle App. It is deployed by ToD Service Provider.
ToD Operator App	ToD Operator Application provides ToD Operator functionalities in ToD services. Functionalities include receiving information and data from ToD Vehicle App, RTA AS, and/or SP Inf AS, helping the ToD Operator to build environmental perception, performing the driving tasks, transmitting commands to the ToD Vehicle App, etc. It is deployed by ToD Service Provider using technologies provided by a ToD technology provider.
OEM AS	Original Equipment Manufacturer Application Server is the trust anchor for all vehicles coming from this automotive OEM. The OEM AS communicates with OEM App and is responsible for secure and trusted remote access from or to vehicles. It is deployed by the car OEM.
OEM App	Original Equipment Manufacturer Application integrates services offered by the OEM AS towards vehicles. For ToD services, the OEM App communicates with OEM AS and is responsible for secure and trusted remote access from or to vehicles. It is deployed by the car OEM.
ToD Vehicle App	ToD Vehicle Application provides all functionalities and software/hardware components on a vehicle for ToD operation with a ToD Operator App. Functionalities include detecting abnormal events and requesting ToD support, collecting and sending sensor and camera data to ToD Operator App, receiving and executing commands from ToD Operator App, etc. It is deployed by the Car OEM using technologies provided by a ToD technology provider.
SP Infr AS	Service Provider Infrastructure Application Server offers infrastructure management and monitoring capabilities to the Service Provider infrastructure application for the deployment of the ToD Application. It is deployed by the Infrastructure Service Provider. Note: SP Infr AS is an optional component and only present in the architecture when information from the service provider infrastructure is required by the ToD use case.
SP Infr App	Service Provider infrastructure Application is supported by the Service Provider Infrastructure Application Server and used for operators to monitor and control the deployment of the ToD Applications. It is deployed by the Infrastructure Service Provider Note: SP Infr App is an optional component and only present in the architecture when information from the service provider infrastructure is required by the ToD use case.

Table 6: ToD application layer architecture components

This architecture is applicable to both Indirect Control ToD and Direct Control ToD services. The full ToD systems in ToD Stage 1 are often under the control of the premises owners, i.e. the car OEM in this example. As studied in [3], in ToD Stage scenarios no requirement is foreseen on interoperability among different OEMs and Service Providers. Therefore, interfaces among system components, e.g. the interface P1_ToD-Veh between ToD AS and ToD Vehicle App and the interface O2 between OEM AS and ToD AS, may use proprietary protocols in this stage. Standardised protocols can of course also be used, subject to the decision of the system owner. Communication between vehicles and the OEM cloud are realised using non-public networks, e.g. non-public cellular networks and WiFi, or using public mobile network from an MNO with or without network slicing.

7.3. Stakeholders

When identifying the different stakeholders, it is important to distinguish between a functional classification and identification of the actual entities. The former is a generic way of describing which roles should be taken up within the ToD ecosystem, to enable a functional, safe and profitable E2E ToD solution. The latter identifies possible candidates to take up those roles. The identified stakeholders relevant for ToD Stage 1 (confined area), both in perspective of function and entity, are presented in Table 7. More details regarding the function with every stakeholder role can be found in [4].

Stakeholder role	Possible entities that can take up this role
Fleet Owner	Vehicle OEM (light vehicles, buses and shuttles, trucks, emergency response vehicles, industrial vehicles, agricultural vehicle, delivery bots); leasing company; rransport and logistics company
User	Fleet owner
Shipper	Manufacturer of goods; retailer
Vehicle Access Provider	Vehicle OEM
Mobile Network Operator (MNO)	MNO providing nationwide coverage in a single country; operator of private mobile network in specific confined area
Internet Service Provider (ISP)	Fixed-connectivity only ISP providing nationwide coverage in a single country; MNO also providing nationwide fixed network connectivity in a single country
Cloud Service Provider	Over-the-top cloud service provider; MNO providing cloud services (central but connected to the core network, or MEC)
ToD Technology Provider	Vehicle OEM; specialised ToD technology company
ToD Service Provider	Vehicle OEM; transport and logistics company; specialised ToD service provider company
Infrastructure Service Provider	Terminal owner (harbour, airport, logistic hub); owner of manufacturing plant;
Certificate Authority	Specialised CA company
Insurer	Bank; insurance company

Table 7: Functional classification of ToD stakeholders, and mapping to entities for ToD Stage 1 (confined area)

7.4. Go-to-market considerations

Combined, these insights into initial stakeholder identification and detailing of the operational processes resulted in the identification of several go-to-market considerations, which must be implemented by all market players independently. These considerations are captured in [4]. For some of them, first thoughts have also been included for inspiration only. The specific considerations relevant for ToD Stage 1 deployment, from a technical perspective, are related to the feasibility of supporting the stringent QoS requirements of ToD, the feasibility of autonomous technology to guarantee safety in case of connectivity issues, the flexibility of choosing operator station locations, cost versus safety-improving redundancy, and interface standardisation needs.

From a legal and business point of view, the relevant considerations for ToD Stage 1 relate to regulations that apply even in confined areas (e.g. employee safety regulations), assignment of the Vehicle Access Provider role, connectivity cost, tele-operator labour cost, insurance cost, and industry acceptance of the ToD concept.

Assuming that ToD has been identified as the method of choice to handle “edge cases” for automated vehicles, or specific driving tasks for non-automated vehicles in the confined area, one of the most important business decisions of the entity controlling this area (i.e. seaport, airport, OEM plant, industrial estate) is who will play the role of the ToD Service Provider: the controlling entity itself (e.g. OEM in the case of OEM plant) or some other company. Each option has pros and cons, in terms of costs and other business dimensions (presented in further detail in Section 10 of [4]), and the decision depends on the particular circumstances and would be made on a per-case basis.

More specifically, it is self-evident that the role of the OEM is dominant in how the use case will be delivered (including who will play the role of Vehicle Access Provider), given that the scenarios discussed in this context involve a single OEM. Further, the scenarios involve a single MNO, therefore it is likely that the relationship between OEM and MNO extends to connectivity and other telecoms services (to be consumed at the confined area where the use case is being delivered), thus beyond the facilitation of ToD alone. Finally, the acceptance of ToD – which for the most part is a support function of automation – must be considered certain, provided that the use of automated vehicles in logistics operations is accepted by shippers. It may as well be proven that tele-operation facilitates the acceptance of automation itself since remote assistance or remote driving provides means for successful handling of the edge cases of automation.

8. Stage 2: ToD service on public roads in city or dedicated public areas

8.1. Overview

In ToD Stage 2, the scope is enhanced/extended to public areas and roads including parking areas, highways, city roads, etc. Through the larger scope of ToD in this scenario and the regional regulation and settings to be applied, the number of stakeholders increases, which also leads to new technical, business, and legal requirements compared with Stage 1 ToD. This section first reviews the use cases and service scenarios relevant in ToD Stage 2. Subsequently, the system deployment is outlined with an example of a public garage offering Automated Valet Parking (AVP). Finally, the new stakeholder and go-to-market considerations for ToD on public roads and areas are reviewed.

Based on findings detailed in [1], Table 8 summarises the characteristics of ToD use cases and service scenarios in ToD Stage 2. Providing ToD services in public roads and areas must comply with regional traffic regulations, even though vehicles may only operate in dedicated areas or follow predetermined routes. Some services like AVP in public garages are provided to vehicles from different car OEMs. Such characteristics impose additional technical, architecture, and regulatory challenges on ToD service deployment compared to ToD Stage 1.

Use cases and service scenarios of in ToD Stage 2	ToD Service Provider	OEM	RTA	MNO
Indirect Control ToD or Direct Control ToD for automated shuttles or people movers with predetermined route[11]	Single	Single	Single (pre-determined route in city)	Single/ Multiple
(Infrastructure based) Automated valet parking with Direct Control ToD or Indirect Control ToD in public garages[12]	Single/ Multiple	Multiple	N/A	Single/ Multiple
Indirect Control ToD or Direct Control ToD for regional robotaxis or delivery robots15	Single/ Multiple	Single/ Multiple	Single	Single/ Multiple

Table 8: Service scenarios and characteristics of ToD Stage 2 – ToD services in dedicated local public roads or areas

[11] The related use case descriptions and service-level requirements are specified in [2] Section 5.4.10 Tele-operated Driving and Section 5.4.11 Tele-operated Driving Support.

[12] The related use case descriptions and service-level requirements are specified in [2] Section 5.4.12 Tele-operated Driving for Automated Valet Parking and Section 5.4.8 Infrastructure-based Tele-operated Driving.

8.2. Example application level system architecture

Automated Valet Parking Type II[13] uses infrastructure-based Direct-Control ToD to provide valet parking services for vehicles in public garages. As an example of ToD Stage 2 scenarios, Figure 4 shows the ToD system architecture for AVP in public garages.

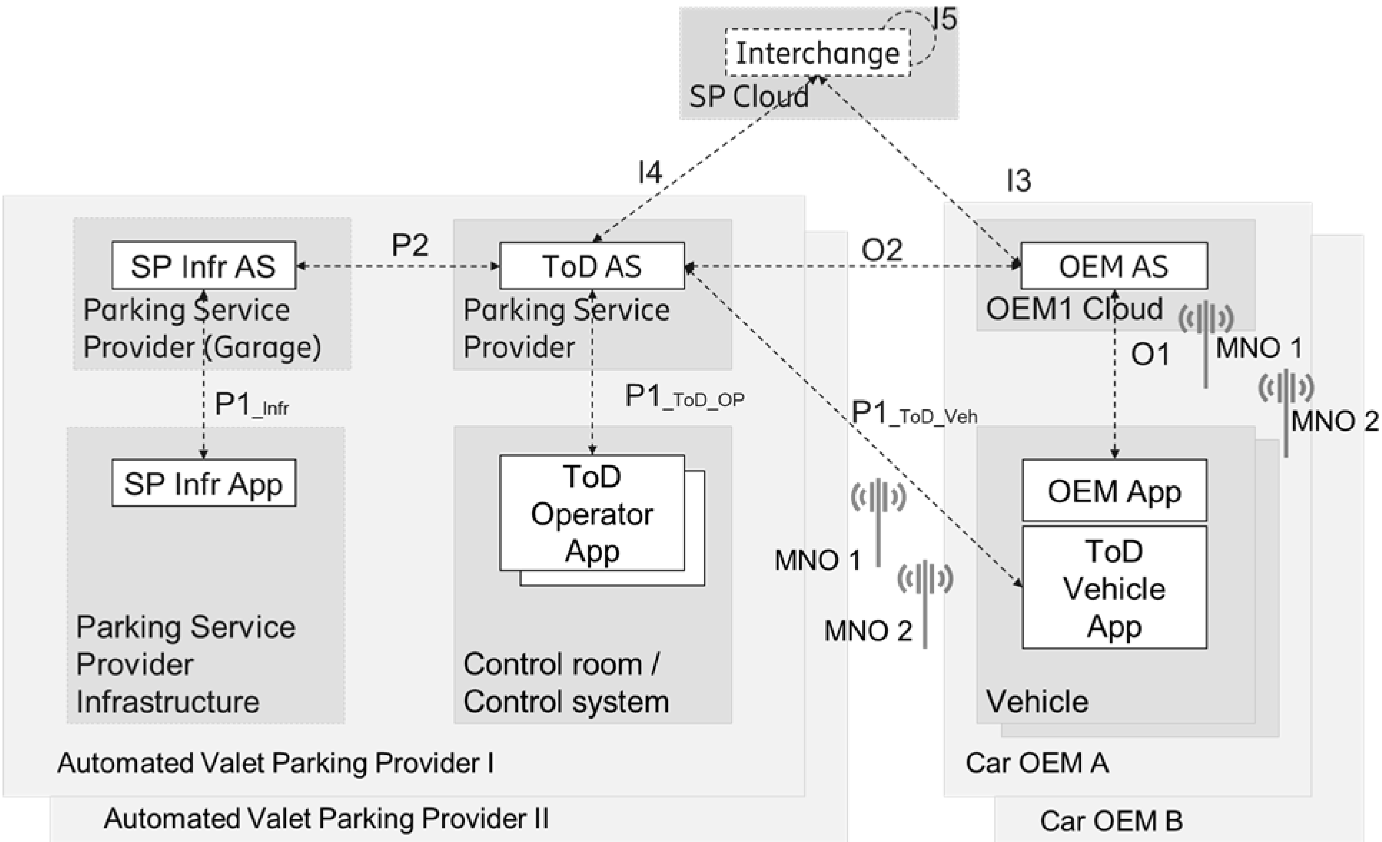

Figure 4: Deployment view of architecture for AVP in public garages (ToD Stage 2)

The main difference between Figure 4 and Figure 3 is that ToD system components in this case do not belong to a single entity. Services provided on public roads or in public areas, such as AVP, may be consumed by vehicles from different OEMs. Furthermore, in addition to system components already explained in Table 6, Table 9 introduces the Interchange Function as a new system component for AVP, as illustrated in Figure 4.

[13] The related use case descriptions and service-level requirements are specified in [2] Section 5.4.12 Tele-operated Driving for Automated Valet Parking and Section 5.4.8 Infrastructure-based Tele-operated Driving.

Component Acronym	Component Function
Interchange	Given the large number of different RTA and SP infrastructures in the world, Interchange Functions are needed to scale up and secure the message exchanges between RTA ASs, OEM ASs and SP ASs. It can be deployed by Service Provider, Mobile Network Operator, or Road Traffic Authority. Note: Interchange is an optional component and only present in the architecture when scalability becomes a challenge to data exchange among ITS back-end systems for ToD services.

Table 9: Additional optional application layer system component in Figure 4

As vehicles from different car OEMs may use the ToD service from the AVP Service Provider, which can be the garage operator, interoperability between the Service Provider systems and vehicles from different car OEMs becomes important for mass deployment of such services. This also raises the need for standardisation or agreement among stakeholders on certain interfaces, e.g. O2, P1_ToD-Veh, I3, I4, and I5.

During the AVP service, communications between vehicles and the OEM cloud and between vehicles and the service provider systems (garages) can be realised using non-public network or public cellular network from one or multiple MNOs, to support Indirect Control ToD or Direct Control ToD operations.

8.3. Stakeholders

The main difference between Stage 1 and Stage 2 is the movement from confined areas to public roads or areas. As a result, more ToD use cases become possible, and additional stakeholders need to be added. These are described in Table 10.

Stakeholder role	Possible entities that can take up this role
Fleet owner	Consumer owning a personal vehicle; taxi company; public transport company
User	Consumer using a personal leased vehicle; transportation service provider
Passenger	Person using a personal vehicle (driver, other passenger); client of taxi company; client of public transport company
Transportation Service Provider	Vehicle OEM; transport and logistics company; taxi company; public transport company
ToD Service Provider	Taxi company; public transport company
Road Authority	Municipality; Ministry (regional or national); European Commission; United Nations
Road Operator	Municipality; Regional or national road operator; Private road operator (highways, tunnels, bridges, ...)
Road Information Service Provider	Road operator; commercial Real-Time Traffic Information (RTTI) service provider; Safety-Related Traffic Information (SRTI) source (vehicle OEM or neutral server provider)
Interchange Service Provider	Road operator; 3rd party Service Provider; Mobile Network Operator
Infrastructure Service Provider	Parking lot owner (municipality, private parking lot company)
Certificate Authority	Road Authority; Road Operator;

Table 10: Functional classification of additional ToD stakeholders compared to Stage 1, and mapping to entities for ToD Stage 2 (local public roads or areas)

8.4. Go-to-market considerations

The movement from confined areas to public roads or areas in Stage 2 brings additional go-to-market considerations, as presented in [4]. The specific considerations for ToD Stage 2 deployment from a technical perspective are related to the prediction of QoS degradation to allow for proactive mitigation. From a legal, liability and business point of view, the relevant considerations for Stage 2 relate to legislation allowing ToD on public roads, as well as rules on national roaming, liability agreements, operator education, willingness-to-pay, insurance cost, passenger acceptance, and network coverage.

Similarly to Stage 1, the entity controlling the task of transporting people/goods and using ToD services in the Stage 2 setting under study (e.g. transportation service provider with fleets of automated shuttles/people movers/robotaxis, logistics company with delivery robots, garage owner) has a key business decision to make as far as ToD is concerned; whether they will play the role of the ToD Service Provider themselves or hire a different company for it. Obviously, a decision will be taken on a per-case basis, considering pros and cons around costs and other elements. However, it is noteworthy that pricing of the ToD service may vary widely depending on who is offering it.

Regarding end users, tele-operation could be considered a critical support functionality of all automated vehicles that target consumers or are people movers (shuttles, taxis, buses etc.), regardless of whether it is implemented as Indirect Control ToD or Direct Control ToD. Therefore, the decision to pay for AVP offered by a private AV, or to pay for transportation on a public AV, involves all aspects of the parking or transportation service respectively, including the occasional remote driving of the vehicle in question, and the corresponding fees to cover all expenses, including those related to tele-operation. Further details are presented in Section 10 of [4].

9. Stage 3: ToD services for cross-region mobility

9.1. Overview

In comparison with ToD Stages 1 and 2, the deployment of ToD services in Stage 3 may involve multiple ToD Service Providers to support vehicles from different OEMs using mobile networks of multiple MNOs in cross-region mobility, as summarised Table 11. The vehicle may travel across regions that are under the management of different RTAs.

Service scenarios	ToD Service Provider	OEM	RTA	MNO
Indirect Control ToD or Direct Control ToD for cross-region (long haul) mobility of passenger cars, robotaxis, trucks, etc.[14]	Multiple	Multiple	Multiple	Multiple

Table 11: Service scenarios and characteristics of ToD Stage 3 – ToD services for cross-region mobility

9.2. Example application level system architecture

The example ToD architecture for cross-region mobility in ToD stage, shown in Figure 5, also includes components from RTAs (i.e. RTA AS and RTA App), as explained in Table 12, which are the main differences observed when comparing system architectures in ToD Stage 1 and Stage 2. The system architecture in Figure 5 is applicable to services using either Indirect Control ToD or Direct Control ToD.

[14] The related use case descriptions and service-level requirements are specified in [2] Section 5.4.10 Tele-operated Driving, Section 5.4.11 Tele-operated Driving Support, and Section 5.4.8 Infrastructure-based Tele-operated Driving.

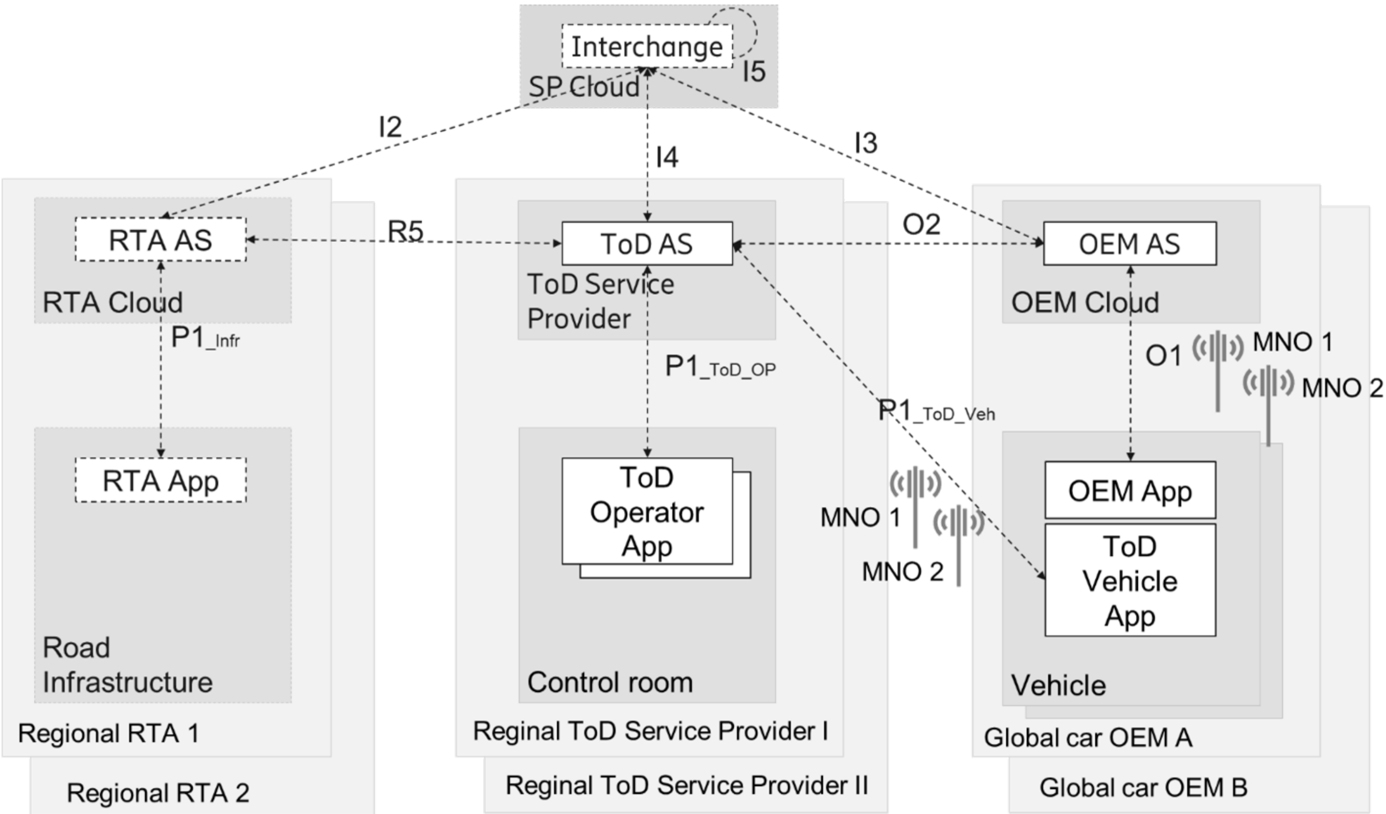

Figure 5: Example deployment view of architecture for ToD services for cross-region mobility (ToD Stage 3)

Note: Though not shown in Figure 5, information acquired by the vehicle using direct communication with the road infrastructure such as traffic lights and other vehicles can be provided to the ToD operator in order to support the operation, in addition to information acquired using other sensors.

Component Acronym	Component Function
RTA AS	Road Traffic Authority Application Server offers traffic efficiency and traffic safety information to ToD Operator Apps via the ToD AS. Furthermore, RTA AS manages the road infrastructure, such as variable road signs, traffic lights and video surveillance cameras. It is deployed by the Road Traffic Authority. Note: RTA AS is an optional component and only present in the architecture when information from the RTA is required by the ToD use case.
RTA App	Road Traffic Authority Application integrates the services offered by the RTA AS into the road infrastructure. It is deployed by Road Traffic Authority. Note: RTA APP is an optional component and only present in the architecture when information from the RTA is required by the ToD use case.

As in the AVP scenario in ToD Stage 2, vehicles from different car OEMs may use the ToD service from different service providers. Additionally, vehicles operating in a cross-regional corridor may also interact with ToD Service Providers and RTAs in different regions. Cross-OEM, Service Provider, and RTA interoperability becomes important for mass deployment of such services. This also highlights the need for standardisation or agreement among stakeholders on certain interfaces, e.g. interface O2, P1_ToD-Veh, R5, I2, I3, I4, and I5, as well as the agreement on procedures for changing the ToD operator, handover between different ToD Service Providers, and between mobile networks during an active ToD session, as discussed in [3].

Communications between vehicles and the OEM cloud and between vehicles and ToD Service Providers can be realised using public mobile networks from MNOs in different regions with improved network reselection performance at network borders, as studied in [3].

9.3. Stakeholders

The main difference between Stage 2 and Stage 3 is the transition from local public roads or areas to cross-regions. As a result, a focus on international operation and service aggregation could be added, as described in Table 13.

Stakeholder role	Possible entities that can take up this role
Mobile Network Operator (MNO)	MNOs providing nationwide coverage in neighbouring countries; MNO roaming aggregation authority (e.g. on top of MEC services of MNOs).
Internet Service Provider (ISP)	Fixed-connectivity only ISP providing nationwide coverage in neighbouring countries; MNO also providing nationwide fixed network connectivity in neighbouring countries.
Cloud Service Provider	Cloud services aggregation authority (e.g. on top of MEC services of MNOs, see GSMA MEC Operator Platform for more background information).

9.4. Go-to-market considerations

The move to cross-regional ToD introduces two additional considerations to [4]. From a technical perspective, this relates to seamless cross-border connectivity handovers to allow for Direct Control ToD. From a business perspective, this stage introduces one new consideration regarding the cross-border collaboration between MNOs that may be directly or indirectly competing. Regarding this topic, we may note that tele-operation is an important ingredient in the safe provision of automated/ autonomous transportation and therefore the ultimate decision-maker for its implementation in terms of wireless connectivity is the OEM. OEMs contract with MNOs for this service, who then provide cellular connectivity in all areas required by the OEM customer, including rural road networks and borders (where the MNOs under contract on both sides of the border need to cooperate), under strict SLA terms. Fortunately, MNOs in neighbouring countries in general have roaming agreements with all their major counterparts across the borders, and these agreements are gradually extended beyond LTE to cover IoT and 5G. MNOs with more roaming partners could provide better vehicle connectivity services for their customer OEMs. Therefore, MNOs stand to benefit by showing their readiness, versatility and flexibility to work successfully and seamlessly with as many other MNOs as possible, and especially with the MNO chosen as the OEM's contracting party on the other side of the border. It is often the case that OEMs contract with a single MNO for a region covering more than one country. The preceding analysis still applies on this occasion, with the difference that now agreements between local MNOs and the prime contractor MNO are largely transparent to the OEM.

10. Conclusions and considerations for the future

For the three ToD stages presented (ToD in confined areas, ToD in dedicated local public roads or areas, and ToD for cross-regional mobility) the general development of automotive, information and communication technologies has made both Direct Control and Indirect Control implementations possible.

Vehicle sensor and actuator technologies on modern vehicles [3] have shown a maturity level that fulfils technical requirements for automated driving, according to the SAE L3 (Level 3). Such technologies also serve as the basis for ToD. Whereas the technical readiness of the ToD operator subsystem depends on low latencies of the sensors, mechanical or electrical HMI, and real-time low-latency video capabilities for human ToD operators and QoS of the communication link with high reliability. The grade of the communication network subsystem, as noted in field tests, showed the capability of 4G networks in supporting initial implementation of ToD services for both Indirect Control ToD and Direct Control ToD [3]. 5G networks are needed for deploying ToD services, not only to benefit from the significantly reduced radio communication latency (below 10 ms), but also to meet the increasing system capacity demand in a broad ToD deployment. Besides data performance (low latency and high throughput), an established network coverage is also important for ToD service availability in operational rollout. To facilitate broad deployment of ToD services, especially for Stage 2 and 3 in the ToD service roadmap, it is suggested that the relevant MNO(s), road operator(s) and authorities/stakeholders work together on implementing proper cellular network coverage for the relevant road networks and improving network reselection performance, as suggested in [5] and [6]. Furthermore, spectrum regulators need to consider a foreseeable increase in spectrum demand for V2N communication, driven by ToD services, as they strive to improve transport and mobility services.

An overview is given in this white paper regarding the business modelling analysis, summarising the detailed results of 5GAA technical report [4]. Different elements of the business modelling are identified when considering the deployment of a ToD ecosystem, from a business perspective. These cover various business aspects, such as initial stakeholder identification and role setting, the collaborative operational processes between these roles, the network value chain, and first insights informing go-to-market considerations.

Detailed technical and business analyses are provided for the three different ToD stages taking into account the service scenarios, with examples of application-level system architectures and the characteristics of different stakeholders, their components and functions.

For ToD Stage 1 (ToD service in confined area), where tele-operated vehicles operate in confined areas such as automotive OEM factories, seaports, and airports. A good example of a ToD service deployment scenario for automated car parking at automotive OEM factories is given with the appropriate technical system architecture diagram. Here, it covers and explains the required system component provided by each involved party (e.g. the OEM, MNO), a single representation of their role in ToD Stage 1 use cases. The fundamental blocks of these ToD system architectures are explained, including the required framework for each party, e.g. the ToD Application Server which is responsible for secure communication (i.e. for registration and authentication requests) between the trusted ToD Operator App and ToD Vehicle App.

For ToD service decisions in confined areas, the single most important business consideration is who will be the ToD Service Provider. This could be the OEM itself at OEM plants, or a business unit within port authorities/operators, or a contracted company specialised in ToD services. The decision depends on the particular on-site circumstances and could be made on a per-case basis. The business analysis would also cover the cost of connectivity, service/labour costs, insurance costs and the degree to which tele-operation facilitates/promotes acceptance of greater automation on location.

For Stage 1, considering the readiness of current automotive, information and communication technologies, the relatively relaxed cross-stakeholder interoperability requirements, and lighter legal constraints in confined areas, such as automotive OEM factories and seaports, deploying ToD in such confined areas is less challenging and actually happening earlier than ToD deployment in public areas and roads described in Stage 2 and Stage 3.

In the ToD Stage 2, tele-operated service compared to Stage 1 is extended on public roads in city or dedicated public areas. Therefore, the number of stakeholders increases, appearing either as multi-OEMs, multi-MNOs, or new parties such as road authorities. This requires high levels of interoperability between the OEM and Service Providers, which raises the need for standardisation or agreements among stakeholders. Furthermore, additional legal regulation needs to be considered for providing ToD services in public areas.

The party controlling the transportation task in ToD Stage 2 (similar to Stage 1) has the same key business decision to make, whether they will act as ToD Service Provider themselves or hire a different company to play that role. What is noteworthy is that pricing of the ToD service may vary widely depending on who is offering it, e.g. the public area controlling entity (public garage operating company) or an independent contracted company offering the ToD service. ToD pricing (direct customer) can be based on different variables (e.g. number of vehicles served, duration of service coverage, duration of actual ToD service engagement, number of actual ToD service engagement instances), and so will influence the final cost, e.g. a public AV involving all aspects of the parking or transportation service respectively, including the occasional remote driving of the vehicle and corresponding fees.

In Stage 2, ToD services are provided to vehicles, which may be from different OEMs, in dedicated public areas and public roads. To this end, an appropriate ecosystem and legal framework, including standards (e.g. for interfaces between vehicles and ToD Service Providers and among the back-ends from OEMs and Service Providers), needs to be established with a concerted effort from all stakeholders to enable scalable ToD service deployment in Stage 2.

For Stage 3, where vehicles travel across multiple regions, collaboration and switching mechanisms of ToD operation processes among ToD Service Providers, communication networks supporting cross-border mobility, and compatible regional regulatory frameworks pose additional deployment challenges compared to Stage 1 and Stage 2. This raises the need for standardisation or agreement among stakeholders on procedures for changing ToD operator, handover between different ToD Service Providers and between mobile networks during an active ToD session. Studies for improving network reselection performance at network borders, as in [7][3], can contribute to better user perception of ToD and the level of service and quality it provides. The main difference between Stage 2 and Stage 3 is the transition movement from local public roads or areas to cross-regions. As a result, a focus on international operation and service aggregation among MNOs, ISPs and cloud service providers is important when setting up their ToD business framework, providing and guaranteeing network coverage in neighbouring countries with strict SLAs for roaming and for fixed network connectivity in neighbouring countries.

In summary, it can be seen that Tele-operated Driving is expected to play an important role in modern transportation and mobility systems, not only for accelerating the deployment and assisting the operation of automated vehicles, but also for accomplishing specific tasks. Automotive, information and communication technologies are advanced enough and capable of implementing both Direct Control and Indirect Control ToD. However, for scalable ToD deployment in realistic scenarios on public roads and in cross-regional mobility, joint efforts are still needed from all relevant industry, authorities and stakeholders involved in standardisation, mobile network coverage, as well as establishing an appropriate ToD legal framework and ecosystem.

Annex <A> Change History

Date	Meeting	TDoc	Subject/Comment
2021.0?.??		5GAA T-210029	Initial draft
2021.07.15		5GAA T-210029	Comments from David and some proposed resolutions from me Text updates in section 4.0 and 5.0. Updated Figure 1 (SAE level bar was removed) according to discussion in the white paper group last week Updated Figure 2 by Eugen based on discussion in the last ToD call. i.e. corrected the labels of arrows between “ToD Technology Providers” and “Certificate Authorities”, and between “ToD service Providers” and “Insurers”
2021.07.22		5GAA T-210029	Updated chapter 6.1 by replacing bullets with descriptive text.
2021.07.23		5GAA T-210029	Incorporated comments and inputs to sections 6, 7, 8, 9 for vF2F#19 discussion.
2021.07.28		5GAA T-210029	Included online edits and comments for vF2F#19 ToD session, and comments from Panos to section 7.4, 8.4 and 9.4. “Go-to-market considerations”.
2021.08.30		5GAA T-210029	Summary text on Go-to-market Considerations were added to section 7.4, 8.4 and 9.4.
2021.10.05		5GAA T-210029	Additional text inputs from Panos to sections 7.4, 8.4, and 9.4 on Go-To-Market Considerations. Editor comments were added to the introduction and conclusion parts.
2021.10.07		5GAA T-210029	Added text to the “introduction’ and “conclusion” parts Cleaned up texts in section 4 – 9. Added commented from the ToD call on the 7 of Oct.
2021.10.13		5GAA T-210029	Added more comments and proposed resolutions to sections 1, 2, 7, 8, and 9. Added text to the Conclusion section.
2021.10.14		5GAA T-210029	Resolve the comment in section 5 on reference to 5GAA C-V2X Roadmap [8]. Added comments on the agreed way-forward on Go-to-Market considerations in section 7.4, 8.4, 9.4. Added new text and placeholder in the Conclusion section.
2021.10.19		5GAA T-210029	Updated text from Panos on go-to-market considerations in section 7.4, 8.4, and 9.4. Text draft added to the conclusion section.
2021.10.20	ToD call	5GAA T-210029	All comments are resolved. Whitepaper content was approved in the ToD call as the stable draft.

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