



**5G META**

# **5G META: Monetizing Car Data**

## **White Paper**

[www.5gmeta-project.eu](http://www.5gmeta-project.eu)



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# TABLE OF CONTENTS

Legal Disclaimer .....	2
<b>LIST OF FIGURES.....</b>	<b>4</b>
<b>LIST OF TABLES .....</b>	<b>4</b>
List of abbreviations and acronyms.....	5
<b>EXECUTIVE SUMMARY.....</b>	<b>6</b>
<b>1. 5G-ENABLED DATA PLATFORM OVERVIEW.....</b>	<b>7</b>
1.1. Introduction to the 5GMETA platform .....	7
1.2. Key features .....	9
1.3. Unique Selling Points .....	10
1.3.1. Unique Selling Points for Data Providers .....	10
1.3.2. Unique Selling Points for Data Consumers.....	11
1.4. Product positioning.....	12
<b>2. DATA MONETIZATION FRAMEWORK.....</b>	<b>12</b>
2.1. Legal considerations.....	12
2.1.1. GDPR .....	13
2.1.2. Data Act.....	13
2.1.3. Interoperable Europe Act .....	13
2.2. Stakeholders .....	14
2.3. Data and money flows .....	16
<b>3. BUSINESS MODELS.....</b>	<b>18</b>
3.1. Competitive landscape .....	18
3.2. 5GMETA as a B2B data marketplace .....	18
3.3. Pricing strategies .....	18
3.4. Use case examples .....	20
3.4.1. Example 1: R&D Live Training Loop .....	20
3.4.2. Example 2: Dynamic route planning and parking support.....	21
3.4.3. Example 3: Driving Safety & Awareness.....	22
<b>4. GETTING STARTED WITH THE 5GMETA PLATFORM .....</b>	<b>24</b>
4.1. How to download code and sample datasets.....	24

4.2. Documentation and additional information .....	24
4.3. Business-oriented software extensions.....	25
4.3.1. Support of data transactions .....	25
4.3.2. Capture of technical and business requirements from platform stakeholders .....	25
4.4. Call to action.....	25
<b>5. LESSONS LEARNT AND RECOMMENDATIONS .....</b>	<b>26</b>
<b>6. BIBLIOGRAPHY .....</b>	<b>28</b>

## LIST OF FIGURES

Figure 1 Essential functionality of the 5GMETA Platform: connecting Data Producers and Data Consumers. Example with one Data Producer and one Data Consumer. ....	7
Figure 2 Conceptual architecture of the 5GMETA Platform .....	8
Figure 3 5GMETA as a hierarchical distributed platform .....	9
Figure 4 5GMETA Platform's key features .....	10
Figure 5 5GMETA relevant stakeholders .....	14
Figure 6 5GMETA data monetization framework .....	17
Figure 7 5GMETA's public GitHub repository .....	24

## LIST OF TABLES

Table 1 Unique Selling Points for Data Providers .....	10
Table 2 Unique Selling Points for Data Consumers.....	11
Table 3 5GMETA Platform roles .....	15
Table 4 Role of different stakeholders in the 5GMETA Data Monetization Framework .....	15
Table 5 Example of pricing strategy .....	20



## List of abbreviations and acronyms

Abbreviation	Meaning
AD	Autonomous Driving
ADAS	Advanced Driver Assistance Systems
API	Application Programming Interface
B2B	Business-to-Business
C-ITS	Cooperative Intelligent Transport Systems
CCAM	Connected, Cooperative and Automated Mobility
DL	Downlink
DMS	Driver Monitoring System
EU	European Union
GDPR	General Data Protection Regulation
ID	Identifier
IoT	Internet of Things
ML	Machine Learning
NR	New Radio
NSA	Non-Standalone
NWDAF	Network Data Analytics Function
OEM	Original Equipment Manufacturer
PaaS	Platform-as-a-Service
PLD	Parking Lot Detector
QoS	Quality of Service
RSU	Roadside Unit
SME	Small and Medium-sized Enterprise
TMC	Traffic Management Centre
UL	Uplink
USP	Unique Selling Point
V2X	Vehicle-to-Everything
WWD	Wrong Way Driving



## EXECUTIVE SUMMARY

The European automotive industry is experiencing a shift towards digital services and shared mobility, influenced by trends like electric vehicles and 5G/6G connectivity. The connected, cooperative and automated mobility (CCAM) market, with expected growth in connected vehicles and Vehicle-to-Everything (V2X) technology, has great potential in data-driven business models, supported by big data analytics. However, despite the rapid advancements in technology and the increasing availability of valuable data, most players in the CCAM sector have yet to fully capitalise on the opportunity to monetise the vast amounts of data generated by vehicles. This represents a major oversight, particularly when compared to the strategies employed by companies in other sectors that are successfully leveraging data as a key revenue stream. These forward-thinking businesses, including both emerging disruptors and established tech giants, have been quick to harness the potential of data-driven models to create substantial value.

In fact, companies across various traditional industries are now starting to follow suit. They are shifting away from purely hardware-focused offerings and embracing new, data-centric business models, such as software-as-a-service (SaaS) and subscription-based services. This transition reflects a broader trend toward digital transformation, where the focus is increasingly on creating ongoing customer relationships through recurring revenue streams rather than one-time product sales. For CCAM companies, tapping into this wealth of vehicle data could unlock new avenues for growth, enhance customer experiences, and create more sustainable business models in the long run.

To support companies looking to explore opportunities in this area, this white paper presents the key outcomes from the 5GMETA project, co-funded by the European Commission through the Horizon 2020 research and innovation programme (grant agreement No. 875131). The white paper describes the 5GMETA platform, which integrates the necessary tools to collect, curate, share, and monetize CCAM data. The platform fosters a data monetization ecosystem, enabling various stakeholders across the data value chain to more effectively and profitably leverage CCAM data. We explore the data monetization framework identified in the project and examine possibilities for the associated business models. Additionally, we explain how to use the platform, and the extensions required for the current business-to-business (B2B) platform. Finally, the white paper highlights the lessons learned from the project, offering practical recommendations for stakeholders to increase the chances of success of a CCAM data monetization ecosystem.



# 1. 5G-ENABLED DATA PLATFORM OVERVIEW

## 1.1. Introduction to the 5GMETA platform

Considering the huge amount of data that a single connected car can produce, it is not easy to deploy at scale a centralized Cloud-based solution that stores all data captured from a large number of vehicles and make them available to external applications or services. A more sustainable and feasible approach would involve a platform for live data delivery. This is precisely the approach followed by the 5GMETA Platform, in which third parties (Data Consumers) can subscribe to specific dataflows generated by Data Producers, and they decide what to do with the incoming data: process it, store it or discard it. The simplest case is depicted in Figure 1, in which one Data Consumer (a third-party application or service) is subscribed to a dataflow from a single Data Producer which is registered and is publishing data to this dataflow.

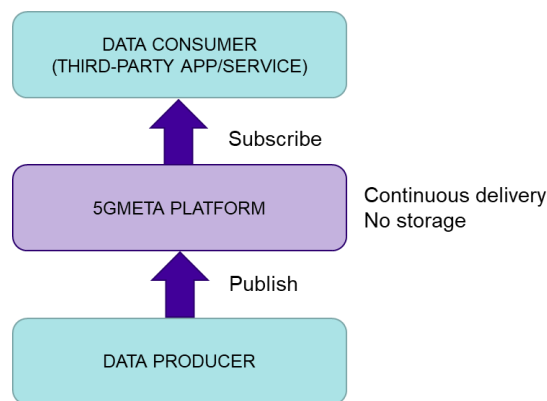


Figure 1 Essential functionality of the 5GMETA Platform: connecting Data Producers and Data Consumers. Example with one Data Producer and one Data Consumer.

A fundamental principle supported by the 5GMETA Platform is that of achieving a total decoupling between Data Producers and Data Consumers. This means that Data Producers do not need to be directly connected to Data Consumers. The 5GMETA Platform acts as a broker between Data Producers (vehicles or RSUs) and Data consumers (third-party applications or services).

However, the 5GMETA Platform is not a simple publish-subscribe broker, and it includes a coherent panel of functions for data management, data monetization and cybersecurity as well as providing data access mechanisms. 5G, Cloud and Edge Computing are the key enabling technologies for this vehicle data monetization platform. The following figure shows the conceptual architecture of the platform.



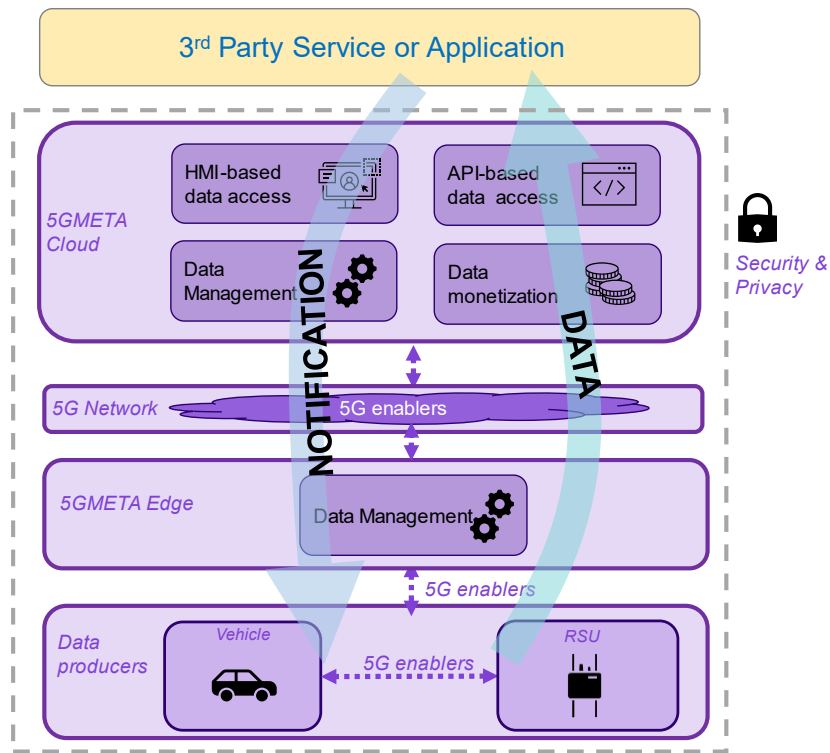
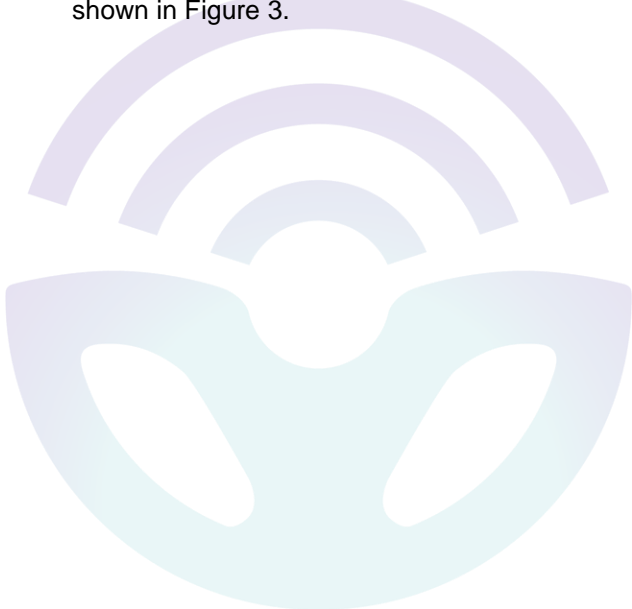


Figure 2 Conceptual architecture of the 5GMETA Platform

In contrast with a Data Lake, the 5GMETA Platform provides live data delivery. The users of the 5GMETA Platform receive the data from the subscribed dataflows in a continuous manner with no storage service within the 5GMETA Platform rather the required memory buffering. Therefore, the 5GMETA Platform is not a Data Lake, although it can be used to feed a Data Lake.

The 5GMETA Platform provides a data monetization opportunity to data owners. Therefore, thanks to the 5GMETA Platform, data owners are able to make money out of the data. Third parties consuming (i.e. paying for) data will not directly monetize data but will monetize their own services and applications that need data to be valuable. The 5GMETA Platform grants third parties access to data, but the data is not owned nor stored by the 5GMETA Platform. 5GMETA is a business-to-business (B2B) solution providing an open data-centric Internet of Things (IoT) messaging platform for CCAM applications and service providers.

The implementation heavily relies on IoT technologies deployed in cloud and edge infrastructures, as shown in Figure 3.





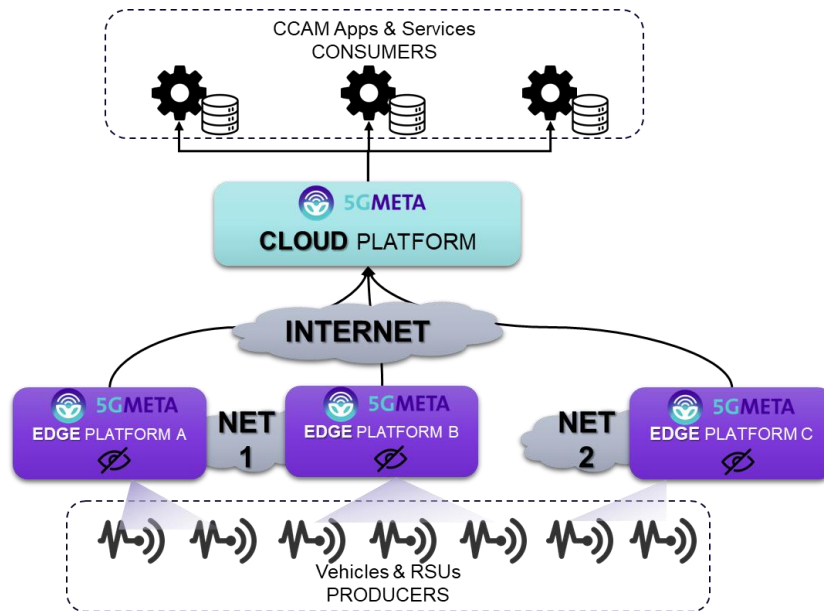


Figure 3 5GMETA as a hierarchical distributed platform

## 1.2. Key features

The key features of the 5GMETA platform are:

- **5G features-ready:** leverages 5G connectivity to enable instantaneous data sharing, crucial for time-sensitive applications like autonomous driving and smart city services. 5GMETA envisions the use of 5G New Radio (NR) for low-latency messaging, as well as edge computing to deploy low-latency CCAM services.
- **Open-source:** the platform's source code is publicly available under European Union Public License v1.2. Its dependencies (Open Source Mano, Kubernetes, Kafka, etc) are all available under open-source software licenses.
- **Layered architecture:** the 5GMETA platform has a hierarchical architecture, using the cloud layer to centralise the production and consumption, and the edge to gain the capillarity of the distributed edge infrastructure to perform data anonymization and sampling as close to the producing sensor and device as possible
- **Scalable:** designed to grow with the needs of the CCAM industry, supporting large-scale data transactions and a growing number of users.
- **Monetization:** each dataflow is associated with a concrete license that establishes the legal terms and conditions under which users can access, use, modify, and distribute the data. Only the data samples satisfying the license conditions are transferred and received by consumers. In addition, the data consumption and computing resources are metered. The latter might for example support a pay-as-you-go approach for pricing.
- **Efficient edge processing:** reducing operational expenditure as the consumers scale up, by means of cost-performance schemas on data scalability reusing the required processing to common pricing plans and data queries.
- **Geo-filtering:** regions of interest can be defined for geo-pinned data filtering when querying data.
- **Support of data producers' mobility:** vehicles are moving nodes that pose a great challenge for a multi-edge scenario. The platform includes edge discovery and handover mechanisms to seamlessly move from one serving edge to another.
- **Security:** the API access is secured with authentication, communication is encrypted and containers are signed to ensure trust.

- **GDPR-compliant data protection:** the platform is able to anonymize faces and vehicular plates from images and videos, in case the data producer is not doing it at the source. For the C-ITS messages the platform offers a message converter processing pipeline removing C-ITS fields which could include any identifier that could be used to match the message with a concrete person. Additionally, the 5GMETA platform generates a random ID for each data flow of a data producer, not linked with any personal, static or permanent information.
- **Data quality assurance:** based on ETSI TS 103 759 V2.1.1 [1], 5GMETA assigns to each dataflow a quality value to filter out non-valid data.

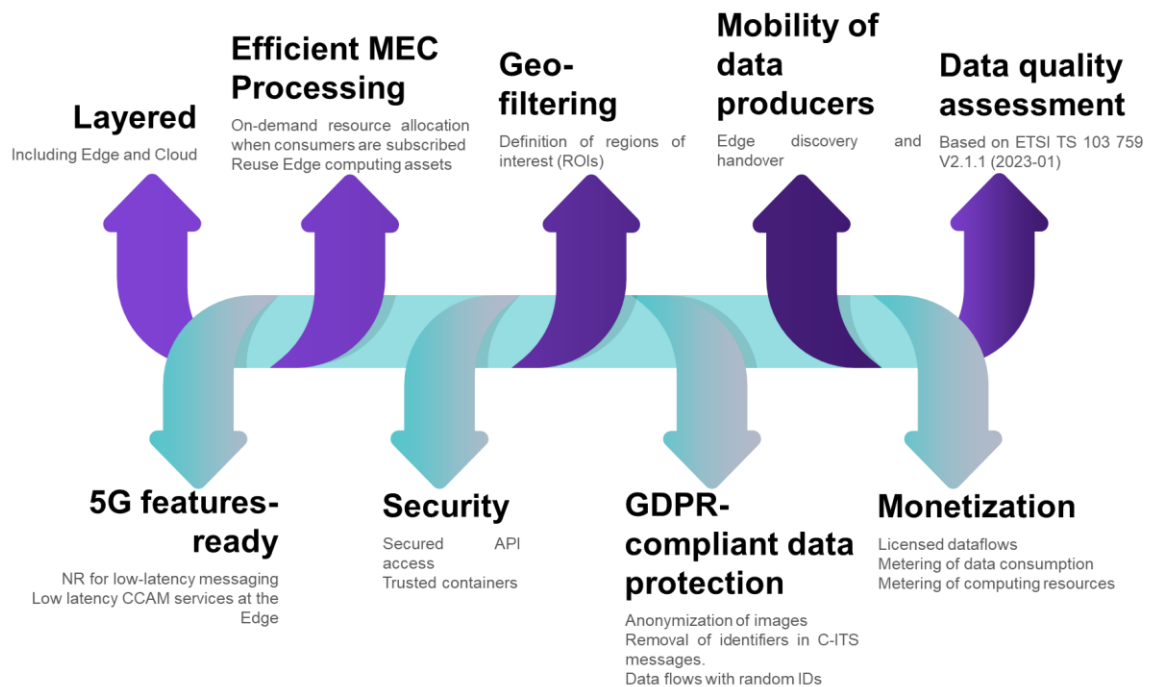


Figure 4 5GMETA Platform's key features

## 1.3. Unique Selling Points

### 1.3.1. Unique Selling Points for Data Providers

The 5GMETA platform's unique selling points (USPs) for data providers are listed in Table 1, describing how the platform's capabilities enable these USPs.

Table 1 Unique Selling Points for Data Providers

Unique Selling Point	5GMETA Platform's feature(s)
<b>New Revenue Streams for Existing Data:</b> Monetize untapped data for additional income	Capability to make data available for reuse, metering the data volumes consumed in a transparent manner controlled by licences.
<b>Broad Market Reach:</b> Streamline the process of selling data to multiple consumers	Using data channels that ease the multiplexing, filtering and demultiplexing of data in an efficient and scalable manner.

<b>Full Data Ownership Control:</b> Providers retain full ownership and control over their data.	The 5GMETA Platform facilitates access to the data, ensuring that no ownership rights are transferred. Moreover, the publish/subscribe model for data workflows keeps the control of data sharing to data producers.
<b>Low Operational Overhead</b>	Ready-made infrastructure for data sharing, reducing operational and technological overhead.
<b>Seamless Integration with Existing Systems</b>	The platform's open architecture allows for easy integration with existing data collection and IoT systems, minimizing disruption and ensuring a smooth experience for data providers.
<b>Regulatory Compliance:</b> Address GDPR obligations seamlessly	Respect personal data and competition law including anonymisation of images, videos and C-ITS messages, as well as random IDs for each data flow of a data producer, not linked with any personal, static or permanent information.
<b>Secure Data Transactions</b>	With advanced encryption and security protocols, providers can trust that their data is securely transmitted ensuring privacy.

### 1.3.2. Unique Selling Points for Data Consumers

The 5GMETA platform's USPs for data consumers are listed in Table 2, describing how the platform's capabilities enable these USPs.

Table 2 Unique Selling Points for Data Consumers

Unique Selling Point	5GMETA Platform's feature(s)
<b>Access to Diverse Real-Time Data:</b> Consumers gain access to a wide range of valuable, real-time data, enabling them to enhance their services and applications.	Accepts different data types and applies specific configurations and presets to efficiently and securely deliver large volumes of data samples in real time.
<b>Cost-Efficient Innovation:</b> Driving new use cases and markets in a cost-efficient way.	With access to a broad set of data, consumers can experiment with new services at lower costs, without needing to collect data on their own. 5GMETA is a versatile platform designed to support a diverse range of complex and varied use cases. Furthermore, 5GMETA continues as an open-source project open to the participation of different organisations and individuals.
<b>Tailored Pricing Solutions:</b> Flexible pricing models	Several parameters can be configured and are recorded to be considered on diverse pricing models including aspects such as licences,

	regions of interest, number of processing assets, data volumes or data qualities.
<b>Interoperability and Standardization:</b> Industry-standard interfaces for seamless data reuse	Employs standards on formats and protocols to deliver interoperable data ready to be processed and/or stored by consuming data-based services.
<b>Quality Assurance:</b> Integrated tools for data quality and data pipeline solutions	Enabling sampling policies to adapt to the required throughputs and service level agreements and analysing data flows to tag the quality level of the data sources.
<b>Scalable Data Acquisition</b>	Whether the need is small or large, the platform allows for scalable data access, enabling third parties to expand their data acquisition as their services grow.
<b>Secure and Compliant Data Access</b>	Built-in security features and compliance with data privacy regulations, minimising risks associated with data usage.

## 1.4. Product positioning

The 5GMETA Platform is positioned in the CCAM market as a Neutral Platform. Neutral platforms are defined as platforms that make automotive data available to interested third-party service providers in a safe and secure manner, without requiring those third parties to sign a contract directly with each automotive manufacturer or data provider.

Moreover, a distinctive feature setting the 5GMETA Platform apart from other Neutral Platforms lies in its unwavering commitment to addressing current and forthcoming regulatory obligations. Functioning as a Compliance-Focused Platform, 5GMETA positions itself as a leader by meticulously adhering to GDPR and the Data Act, prioritizing security, and privacy. To differentiate itself, the platform must be perceived as the forefront choice for harnessing car-generated data for innovative applications, aligning with the preferences of forward-thinking companies. Establishing itself as a trustworthy, long-term partner for both Data Providers and Data Consumers is essential, discouraging external deals that might undermine the platform's relevance. Recognizing that a marketplace's strength lies in its network effect, the primary objective is to attain critical mass, fostering an ecosystem where Data Providers and Data Consumers mutually thrive.

## 2. DATA MONETIZATION FRAMEWORK

### 2.1. Legal considerations

A key aspect of the market scenario is the legal framework that is (and will be) regulating the treatment and management of data, particularly in Europe. The three most important EU regulations in this regard are the GDPR [2], the Data Act [3] and the Interoperable Europe Act [4]. Overall, these three pieces of legislation form the foundation of the legal framework for the 5GMETA Platform's operations. An actor that wants to enter and operate in the CCAM space should produce a compliance strategy that implements a data management and security infrastructure to protect user data and be compliant with the stringent requirements of the GDPR, the Data Act and the Interoperable Europe Act.

In this context, a 5GMETA Platform Operator may leverage the stringent regulatory environment as a competitive advantage, by creating a legally compliant and user-friendly data marketplace.

### 2.1.1. GDPR

The General Data Protection Regulation (GDPR) [2] is a comprehensive EU regulation aimed at strengthening and harmonizing data protection laws across member states. Enforced since May 25, 2018, it replaced the 1995 Data Protection Directive. The GDPR is built on key principles such as lawfulness, fairness, transparency, purpose limitation, data minimization, accuracy, storage limitation, and security. It emphasizes the accountability of data controllers in ensuring compliance with these principles.

Individuals, referred to as Data Owners, are granted several rights under GDPR, including the right to be informed about data collection, access to their data, correction of inaccuracies, data erasure, restriction of processing, data portability, and the right to object to data processing. Organizations managing data must comply with various requirements, such as appointing a Data Protection Officer, conducting Data Protection Impact Assessments, obtaining clear consent, reporting data breaches, ensuring lawful international data transfers, and embedding privacy into business processes. Non-compliance with the GDPR can result in severe penalties, including fines of up to 4% of a company's global turnover or €20 million, whichever is higher. In essence, the GDPR is a robust regulation designed to safeguard individuals' privacy and impose significant responsibilities on organizations handling personal data.

### 2.1.2. Data Act

The Council of the European Union has adopted the Data Act [3], a regulation aimed at creating harmonized rules for fair access to and use of data across all economic sectors in the EU. The regulation seeks to ensure fairness in the distribution of value from data, stimulate a competitive data market, foster data-driven innovation, and increase data accessibility. This initiative positions the EU as a leader in the data-driven economy and supports the development of a European internal market for data.

Key provisions of the Data Act include obligations for manufacturers and service providers to allow users to access and reuse data generated by their products or services, and to share this data with third parties. The regulation also strengthens data portability rights, enabling easier transfer of data across different services. It covers connected devices like smart appliances and industrial machines and includes measures to protect trade secrets and intellectual property while encouraging data sharing. Additionally, the regulation provides guidelines for data sharing contracts, compensation, and public sector access to data in exceptional circumstances, such as emergencies. The Data Act also promotes interoperability standards and allows member states flexibility in implementing and enforcing the regulation.

The Data Act is part of the EU's broader strategy to build a fair and innovative data economy, contributing to the EU's digital transformation goals for 2030. It complements the 2022 Data Governance Act and is expected to be in force by the end of 2025.

### 2.1.3. Interoperable Europe Act

The Interoperable Europe Act, which entered into force in April 2024, aims to enhance cross-border data exchange and accelerate the digital transformation of the public sector within the EU, contributing significantly to the goals of the EU's Digital Decade, such as achieving 100% online availability of key public services by 2030. Interoperability is crucial for a functional Digital Single Market and enables more effective implementation of digital aspects in public policies across various sectors, including justice, health, and transport. The Act will benefit citizens, businesses, and public administrations by facilitating interconnected digital public services, such as mutual recognition of professional qualifications, vehicle data exchanges for road safety, access to social security and health data, and more. It is expected to save up to €5 billion annually.

To achieve these objectives, the Act introduces several key measures, including the establishment of a multi-level cooperation framework involving senior digital government practitioners, experts, and local actors to create a common interoperability agenda. It also mandates interoperability assessments for designing public services that are "interoperable-by-design," supported by guidelines from the European Commission. Additionally, the Act launches the 'Interoperable Europe Portal' to encourage the sharing of reliable interoperability solutions among public administrations. The regulation also strengthens innovation and policy support mechanisms, such as training, regulatory sandboxes, and public-private partnerships, to develop and scale up new solutions, applying to all public sector bodies within the EU, including its institutions.

The 5GMETA Platform can offer a structured and secure environment for data exchange between public sector bodies, private businesses, and other stakeholders. The platform can provide the technical infrastructure to enable seamless cross-border data exchanges, thanks to its distributed nature that supports the mobility of data producers, meeting the Act's goal of interoperability. It can provide transparency in data usage and ensure that the vehicle data from different countries and organizations is standardized and easily accessible. The platform can also act as a hub for the multi-level cooperation framework outlined in the Act. It can bring together digital government practitioners, businesses, and experts to collaborate on the development of interoperable solutions. Through a community-based approach, the platform can foster innovation and share best practices, ensuring that solutions are aligned with the common interoperability agenda.

## 2.2. Stakeholders

5GMETA's stakeholders analysis led to the final list of 15 main stakeholders, categorised into eight clusters as shown in Figure 5.

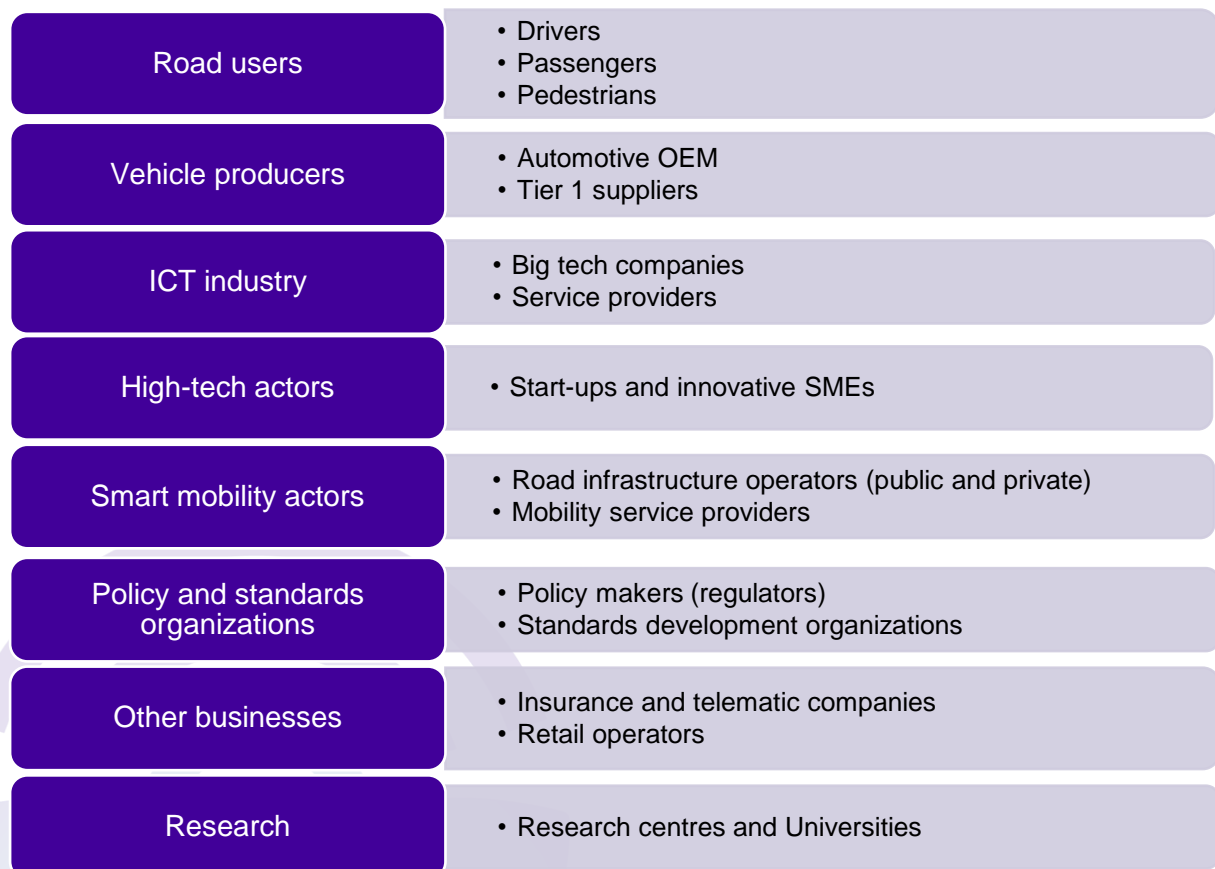


Figure 5 5GMETA relevant stakeholders

A summary of the roles that different stakeholders can play within the ecosystem of the 5GMETA Platform is presented in Table 3.

Table 3 5GMETA Platform roles

Role	Description
<b>Data Providers</b>	Data Producers: Individuals and companies that produce CCAM data streams and eventually, publish them onto the 5GMETA Platform, or hand them over to Data Owners. Data Owners: Companies that own CCAM data streams (produced by Data Producers).
<b>Data Consumers</b>	Companies (third parties) that subscribe to CCAM data streams available on the 5GMETA Platform to deliver third-party applications or services.
<b>Final users</b>	Individuals and companies that benefit from the third-party applications or services provided by Data Consumers.
<b>Platform maintainer</b>	The organisation that keeps the source code of the 5GMETA Platform maintained, with regular updates and patches.
<b>Platform operator</b>	Companies that deploy and operate a hosted version of the 5GMETA Platform.
<b>Business developer</b>	Responsible for linking OEMs and third parties. The primary focus is to identify opportunities for business growth (increasing the number of producers and consumers), build strategic partnerships, and enhance 5GMETA's market presence.

The stakeholders' roles in the 5GMETA Data Monetization Framework are summarized in Table 4.

Table 4 Role of different stakeholders in the 5GMETA Data Monetization Framework

		Data Providers	Data Consumers	Final Users
Road users	Road users			
Vehicles producers	OEMs, Tier 1 suppliers			
ICT industry	Big tech			
	Service providers			
High-tech actors	Innovative SMEs / start-ups			
Mobility actors	Road infrastructure operators			

		Data Providers	Data Consumers	Final Users
	Mobility service providers			
Policy and standards organization	Policy makers (regulators)			
	Standard organizations			
Other businesses	Advertisers			
	Retail centres			
	Insurances			
Research	Research / universities			

The table shows that Road Users are the only stakeholders that influence the ecosystem both as Data Providers and Final Users of the services produced by the third parties using 5GMETA data.

Among the Data Providers, only a few stakeholders are Data Owners:

- Vehicle producers and the Big-tech companies own data collected on the vehicles.
- Road infrastructure operators – as smart city authorities – own the data collected through sensors and devices on the roads.
- Service providers and other businesses (e.g., Insurances) can own cars' data.

Almost all the stakeholders can be Data Consumers. They are the third parties that can develop new business models using 5GMETA-enabled data. Finally, Policy and standards organizations are not directly involved in the data monetization flows but can influence the way data are produced, owned, and used.

### 2.3. Data and money flows

The 5GMETA Platform satisfies the simple principle that Data Providers have data that they want to monetise, and Data Consumers can create new applications or services with data obtained via the 5GMETA Platform.





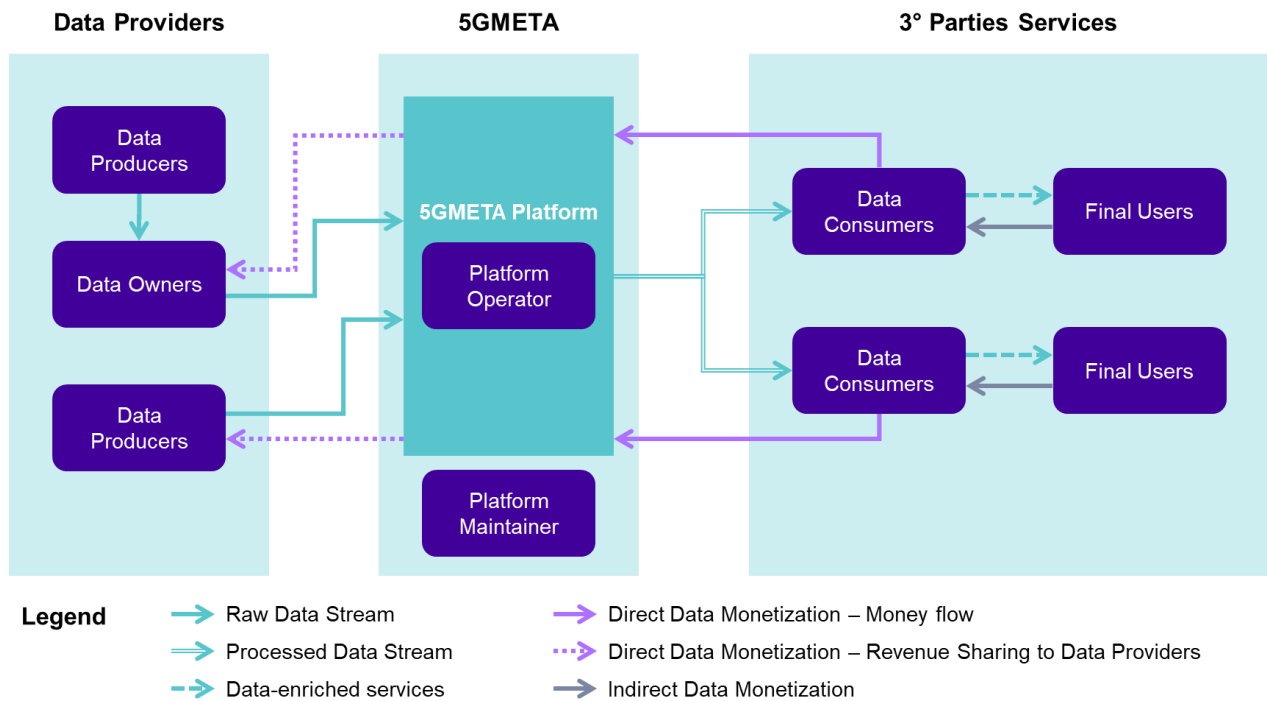


Figure 6 5GMETA data monetization framework

Figure 6 provides an overview of the data value chain (blue arrows) and of the data monetization flows (violet and grey arrows). The data value chain can be summarised as follows:

- Data Providers have interest in monetizing their data: therefore, they make their raw data available through the 5GMETA Platform to potential Data Consumers. Data Providers include Data Owners, Data Producers and other platform operators.
- The 5GMETA Platform, through its services and functionalities, processes such raw data (without storing it) and provides it to data consumers. Raw data is now enriched data.
- Data Consumers will make use of enriched data to develop new applications or services to be addressed to final users of mobility data.

For what concerns the data monetization flows, there are mainly three:

- The main monetization flow is represented by the violet arrows, which represent money flows that Data Consumers pay for enriched data. Such payment is addressed to the 5GMETA Platform Operator who intermediates **direct data monetization**.
- The dotted violet line represents the Revenue Sharing of the 5GMETA Platform Operator with Data Providers (Data Producers and Data Owners).
- The grey arrow represents the potential money flow addressed to the Data Consumers who, thanks to the enriched data, have developed new products or services that will be “sold” to their clients. In this case, we will call such flow an **indirect data monetization** flow enabled by the 5GMETA Platform.



## 3. BUSINESS MODELS

### 3.1. Competitive landscape

In the emerging CCAM market, many companies are developing new solutions using car's data, providing tailor-made services built on the analysis of specific end-users needs. Thus, the 5GMETA competitor analysis focused both on commercial and non-commercial initiatives highlighting their similarities and differences with the 5GMETA solution. Three major categories of commercial competitors were identified:

- **Neutral Platforms:** This group contains the companies that explicitly declare the neutrality feature in their value proposition. They are the most similar to the 5GMETA Platform and thus, can be considered the main benchmark. Neutral platforms are defined as platforms that make automotive data available to interested third-party service providers in a safe and secure manner, without requiring those third parties to sign a contract directly with each automotive manufacturer.
- **Platforms mainly addressed to OEMs:** This category includes companies that collect data from OEMs and enable OEMs, automakers, Tier 1 suppliers to develop new services leveraging on such data. They include mainly relevant examples from big tech companies.
- **Platforms addressed to different stakeholders:** This category encompasses the companies that collect data from OEMs and offer their data to potential data customers (not only OEMs), for developing new business models.

As described in Section 1.4, the 5GMETA Platform is positioned as a Neutral Platform. The industry is somewhat saturated due to the nascent stage of the business, and participants in this sector provide a diverse array of services, extensive market reach, and strategic partnerships, affording them a first-mover edge. This advantage is pivotal considering the significance of achieving critical mass and leveraging network effects in the context of an online marketplace.

### 3.2. 5GMETA as a B2B data marketplace

5GMETA is an innovative Business-to-Business (B2B) data marketplace specifically designed for the automotive and mobility sectors. The platform acts as a dynamic hub where various stakeholders in the automotive industry—including vehicle manufacturers, mobility service providers, infrastructure companies, and technology developers—can securely exchange and monetize data.

Leveraging the power of 5G technology, 5GMETA facilitates real-time data sharing and analytics, enabling companies to harness vast amounts of mobility and vehicle-related data to drive innovation, optimize operations, and create new business models. Whether it is enhancing autonomous vehicle systems, improving traffic management, or personalizing mobility services, 5GMETA provides the data infrastructure that makes these advancements possible. Therefore, 5GMETA empowers businesses in the CCAM sector to unlock the full potential of their data, driving forward the future of connected, autonomous, and smart mobility solutions.

### 3.3. Pricing strategies

Formulating an effective pricing strategy holds paramount importance for ensuring the commercial success of the 5GMETA Platform. Critical insights concerning the pricing dynamics of data streams in the CCAM market have surfaced from both primary and secondary market research [5]:

- A pervasive scepticism prevails among stakeholders, be they Data Providers or Data Consumers, regarding the tangible value they can derive from data.

- The incremental value introduced by utilizing data in services and products directed towards Final Users remains constrained, as a substantial volume of data is required to genuinely enhance existing solutions or forge new ones.
- Data Consumers exhibit price sensitivity, and their willingness to pay is limited.
- The failures observed in prominent market competitors can be attributed to a combination of timing issues and inadequate cost management.

The Platform Operator may choose many different pricing strategies to maximize the transaction value. The platform does neither impose any strategy nor any payment mechanisms. It acts as an enabler and additional module (e.g. based on RADIUS, on Customer Data Records, etc) can be used.

The basic following options are possible but it is very likely that hybrid strategies will appear on the market:

- **Volume-based pricing:** the more data are shared onto the platform, the higher is the monetary reward for Data Providers, regardless of whether their data are used or not by Data Consumers. This solution would need an initial filter that avoids useless data to reach the platform but could be attractive for Data Providers.
- **Data usage-based pricing:** the Platform Operator can charge Data Consumers based on the usage or consumption of data. This pricing scheme can involve metrics like the number of data records accessed, the volume of data streamed, or the duration of data usage (data streaming sessions).
- **Fixed price:** Data Providers can set a fixed price for their data, determining a specific amount they are willing to sell their data for. The platform can facilitate the transaction by connecting potential buyers with Data Providers who have listed their data at a predetermined price.
- **Data Subscription:** the Platform Operator can offer data on a subscription basis, where Data Consumer pay a recurring fee to access and utilize the data over a specified period. The Platform Operator can set the subscription price based on factors such as the data's uniqueness, quality, or frequency of updates.
- **Revenue sharing:** Data Providers can also opt for a revenue sharing model where they receive a percentage of the revenue generated by the Platform Operator from the sale or use of their data on the platform. This approach aligns the interests of Data Providers with the success of the platform and incentivizes them to provide valuable and sought-after data.
- **Tiered pricing:** the Platform Operator can offer data at different pricing tiers based on factors such as data quality, exclusivity, or additional services provided. Data Consumers can choose the tier that suits their needs, with each tier offering varying levels of access or additional features.
- **Auction or Bidding System:** Data Providers can participate in an auction or bidding system, where potential Data Consumers compete to acquire their data. Data Providers can set a minimum price, and interested Data Consumers can place bids to secure the data. This approach allows Data Providers to capture the maximum value for their data based on market demand.
- **Negotiated Pricing:** for unique or highly specialized data, Data Providers can engage in direct negotiations with potential Data Consumers to determine a mutually agreed-upon price. This approach provides flexibility and allows Data Providers to negotiate terms based on the specific characteristics and value of their data.

The final choice on the most effective pricing strategy is entrusted to the Platform Operator. Nevertheless, an overall pricing strategy is proposed hereinafter, based on the objective to completely intermediate the relationship between Data Providers and Data Consumers and to maximize the value captured.

In terms of pricing strategy, the pursuit of such goal translates in the maximization of the spread between the selling price (i.e. how much Data Consumers pay to access the data streams available on the 5GMETA Platform) and the cost price (i.e. how much Data Providers are paid for the data streams they publish on the 5GMETA Platform). Therefore, the pricing strategy must be crafted to limit as much as possible the disbursement to pay Data Providers and to push upwards the price paid by Data Consumers. In addition, the spread between the selling price and the cost price must also take into

account the variable costs arising from network services and cloud services that the Platform Operator will incur in order to deploy the 5GMETA Platform and provide the associated services. Starting from the pricing model options briefly introduced above, Table 5 presents an example of pricing strategy consistent with such goal.

Table 5 Example of pricing strategy

Goal	Minimize Cost Price	Maximize Selling Price
<b>Reference stakeholders</b>	Data Providers	Data Consumers
<b>Pricing model</b>	<p><b>Volume-based pricing:</b></p> <ul style="list-style-type: none"> <li>The more data are shared onto the platform, the higher is the monetary reward for Data Providers.</li> <li>Only data that are actually streamed to a paying Data Consumer are eligible.</li> <li>If the same data stream is accessed by more Data Consumers at the same time, the monetary reward for Data Providers is proportional.</li> <li>The unitary cost per streamed data point must be very low and carefully defined based on the sampling frequency of the data stream.</li> </ul>	<p><b>Tiered pricing &amp; Data Subscription:</b></p> <ul style="list-style-type: none"> <li>The Platform Operator offers data on a subscription basis, where Data Consumer pay a recurring fee to access and utilize the data over a specified period.</li> <li>The Platform Operator offers data at different pricing tiers based on factors such as data quality, exclusivity, or additional services provided.</li> <li>Data Consumers can choose the tier that suits their needs, with each tier offering varying levels of access or additional features.</li> <li>Each Tier includes a maximum number of data streams accessible, and only the top tier allows an unlimited number of data streams.</li> </ul>

### 3.4. Use case examples

5GMETA is a versatile platform designed to support a diverse range of complex and varied CCAM use cases, so is not limited to a concrete set of use cases. In fact, the spirit of 5GMETA is to stimulate the market to generate innovative use cases that make the most of car data. In the framework of the 5GMETA project, the consortium has implemented three use cases to showcase the possibilities of the platform. This section describes the potential business models of these three use case examples.

#### 3.4.1. Example 1: R&D Live Training Loop

In this innovative use case, the 5GMETA platform is used to provide new relevant vehicle sensor data to a third party for refining an autonomous driving (AD) or advanced driver assistance system (ADAS) machine learning (ML) model. Instead of storing locally or streaming the entire sensor data, the vehicle selects the data that make the ML model perform below an established threshold and sends them to the 5GMETA platform. Then, the third party, which subscribed to this dataflow, receives the data through the 5GMETA platform. The data can either be anonymized in the vehicle before uploading the data to the 5GMETA platform or in the 5GMETA edge using 5GMETA Platform's anonymization feature.

##### *Direct data monetization*

Corner cases, or outliers, are critical for validating autonomous driving systems because they represent rare or extreme scenarios that, while infrequent, can significantly impact the safety and performance of these vehicles. By analyzing data from these rare events, manufacturers can identify and address potential weaknesses in their systems, enhancing the overall reliability and safety of autonomous

vehicles. However, collecting such data in real-world conditions poses significant challenges due to the rarity of these events, safety concerns, and the substantial time and cost required to gather a diverse set of scenarios.

To overcome these challenges, original equipment manufacturers (OEMs) are investing in significant outlier datasets. These investments allow OEMs to conduct robust validation of their systems, identifying safety vulnerabilities and optimizing performance to ensure their vehicles can handle a wide range of situations. Additionally, thorough testing against outliers is essential for meeting stringent regulatory requirements, making these datasets valuable not only for improving technology but also for achieving compliance. As a result, there is a strong market demand for outlier data, creating monetization opportunities for those who can provide it.

### *Indirect data monetization*

McKinsey identifies nine car-data monetization Use Case clusters that provide value throughout the vehicle life cycle [6]. Among the identified use-case clusters, R&D optimization stands as the use-case cluster with the highest relative value pool by year 2030. The R&D Live training loop use case targets this use-case cluster.

As explained in the previous section about direct monetization, ML model refinement to meet CCAM requirements is a big challenge. This is why OEMs and TIER 1s are willing to pay to improve their MLOps pipelines and processes. A service as the one provided in this use case, would be of high interest for OEMs/TIER1s, as it would enable them to receive real-time relevant data, retrain their ML models and send notifications to vehicles about the availability of a new ML model ready for download. The company that provides this service would not necessarily be the owner of the data. The end user (OEM/TIER1) would pay a fee to the service provider, which can be a SME or start-up.

### *Monetization of 5GMETA Platform service*

Vehicles have currently several cameras (at least four), to generate a 360° surround view. Each connected vehicle could potentially be sending images from all onboard cameras, and in a scenario with thousands of connected vehicles, this would suppose dealing with a big volume of data. Thus, the charging rules of the 5GMETA Platform service can be based on the volume of data consumed and/or on the usage of computing resources. Alternatively, a constant fee can be charged to simplify the billing and potentially attract more customers.

## 3.4.2. Example 2: Dynamic route planning and parking support

In this use case, the Lazarus application is implemented as a 5GMETA client, using the 5GMETA data for a fee. With this data, Lazarus can offer innovative services to road users, enhancing their overall user experience while also generating significant financial revenue. The income potential relies on the number of users who choose to adopt this solution.

In the current context of traffic problems faced by cities today, Lazarus offers a solution for users who need mobility. When users decide to install Lazarus for free and have a mobility requirement, they can input their destination. Based on the user's profile and needs, Lazarus can provide the most suitable service, suggesting the optimal departure time, route, and arrival time, considering the traffic conditions.

Lazarus integrates three services to meet these mobility needs. Firstly, it offers a shared mobility service where Lazarus analyses the traffic conditions and recommends the most suitable option for the user, whether it's a vehicle, scooter, or bicycle. The user can reserve the chosen option at the same price as booking directly with the service provider. Secondly, Lazarus provides a parking reservation service, which is especially practical for users who want to find parking easily, especially in congested areas like city centres. This feature optimizes the user's time and fuel consumption. Finally, Lazarus offers a

carpooling service, enabling users to find the most suitable carpooling option for their desired route, departure, and arrival times. Through these free services provided by Lazarus, the application is rewarded by service providers with a percentage of each reservation made through the platform.

#### *Direct data monetization*

Lazarus and traffic jam prediction components need data from vehicles and roadside sensors for having up-to-date models, thus, being able to assess on live the mobility options for every user request. They can enhance their revenues thanks to the data obtained from the 5GMETA platform by offering well adapted mobility services for the citizens. Lazarus, along with Traffic Jam Prediction components, recognizes the importance of having access to real-time and up-to-date data to create highly customized and well-adapted mobility services for the citizens. Procuring 5GMETA data, enables to assess and provide tailored mobility options for every user request in real-time.

This strategic move not only enhances the application's capabilities but also opens new opportunities to boost their revenue streams through improved and user-centric service offerings.

#### *Indirect data monetization*

Lazarus and 5GMETA can establish partnerships with various stakeholders, creating a win-win scenario that benefits both businesses and the end-users.

- Cities can leverage the platform to provide reliable information to their citizens, enhancing the quality of services and mobility options available to residents.
- Mobility service providers can enhance their visibility. With this application, they can also elevate the user experience and tailor their services to meet the specific needs of different territories.
- Event organizers can offer convenient parking services to their clients during events.
- Travel agencies can efficiently manage their fleets during visits to city centres, optimizing their operations.
- Research Institutions can use the data for urban planning and transportation studies, leading to insights for better city management.

#### *Monetization of 5GMETA Platform service*

By leveraging the valuable insights obtained from the 5GMETA platform, 5GMETA can extend its impact across various sectors, improving mobility, enhancing services, and contributing to the development of smarter and more efficient cities. The use case gathers data from a multitude of diverse sources, facilitating data sharing through centralized access points.

Charging rules can be dynamically structured based on the number of data sources utilized and the geographical scope of the targeted area. Such adaptability, not only enhances the application's capability but also opens new opportunities to boost their revenue streams through improved and user-centric service offerings, thereby contributing to a more efficient and seamless urban mobility experience.

### 3.4.3. Example 3: Driving Safety & Awareness

This use case envisions a collaboration between automotive OEMs and road operators to enhance road safety and awareness of potential threats by proactively addressing driving misbehaviour situations. Automotive OEMs will equip new vehicles with ADAS that have remote operation capabilities. Meanwhile, road operators will develop services to detect driving misbehaviour and train their personnel to remotely manage or control these situations. The 5GMETA platform will facilitate data exchange between the OEMs and road operators, enabling them to detect and mitigate misbehaviour without needing direct communication.

The use case focuses on two specific scenarios. The first scenario involves situations where the driver is physically unfit to drive due to health issues, emphasizing the need to increase driving safety to prevent accidents. The second scenario addresses situations where the driver is physically capable but has impaired mental capacity, leading to behaviours such as wrong-way driving. Here, the focus is on increasing awareness among surrounding vehicles. These scenarios are explored in two sub-use cases: "Driver's Health Misbehaviour" and "Driving Misbehaviour," each targeting specific challenges associated with these situations.

### *Direct data monetization*

The services in this use case, by leveraging data from vehicles and various sensors, create a dynamic environment for real-time mobility solutions and safety enhancements. Direct data monetization strategies for these services include:

- Driver Monitoring System (DMS) Client: By using real-time data from the driver camera, DMS Client can enhance driver safety and behaviour analysis. Monetization involves offering premium packages to users for advanced safety features and insights drawn from their driving patterns.
- Video-based Wrong Way Driving (WWD) Detection: Utilizing video streams and neural networks, the WWD Detection service can identify wrong-way driving incidents. Direct monetization can be achieved by partnering with relevant stakeholders, such as municipalities or transportation departments, and providing them with real-time incident data for a fee.
- Parking Lot Detector (PLD): PLD leverages deep neural networks for parking space detection. Direct data monetization could involve offering parking lot occupancy data to businesses for better resource allocation, such as offering vacant spaces to users through partnerships with parking facilities.

### *Indirect data monetization*

In addition to direct monetization, the services within the use case can engage in indirect data monetization strategies:

- Driver Monitoring System (DMS) Client: Through partnerships with insurance companies, DMS Client can offer insights into driver behaviour, leading to safer driving practices. This can result in reduced insurance premiums, benefiting both users and insurance providers.
- Video-based Wrong Way Driving (WWD) Detection: Collaborating with traffic management authorities and municipalities, the service can enhance road safety and traffic flow. By offering aggregated data on wrong way driving incidents, the service can contribute to urban planning and transportation studies.
- Parking Lot Detector (PLD): Businesses and city planners can leverage PLD data for optimizing parking resources and urban mobility. By offering occupancy insights to parking facilities, event organizers, and travel agencies, the service indirectly benefits various stakeholders.
- Remote Assistance/Management: By providing real-time traffic and parking information to misbehaving vehicles, this service can indirectly contribute to reduced traffic congestion and improved overall road safety.
- Traffic Management Centre (TMC) Alerts: Municipalities and transportation agencies can benefit from timely alerts about dangerous situations. Indirect data monetization involves providing critical traffic data for optimizing traffic management strategies.

### *Monetization of 5GMETA Platform service*

The 5GMETA platform, serving as the backbone of these services, also offers avenues for monetization:

- Platform-as-a-Service (PaaS) Model: The 5GMETA platform can offer its computing resources for data fusion and analysis. It can charge users based on computation power requirements, providing customized access levels.
- Usage-based Pricing: Charging based on the usage of mobile edge computing instances, data processing volume, alerts generated, or user requests. Flexible pricing plans cater to varying user needs.

In essence, the services within the use case contribute to a data-rich ecosystem with opportunities for both direct and indirect data monetization. By offering valuable insights and solutions to improve road safety, traffic management, and urban mobility, these services create a win-win scenario for users, businesses, and city authorities.

## 4. GETTING STARTED WITH THE 5GMETA PLATFORM

### 4.1. How to download code and sample datasets

5GMETA has released an integrated open-source platform that bundles the required tools to facilitate user adoption. The open-source 5GMETA platform is accessible from a public repository (<https://github.com/5gmeta>) with an open-source license (European Union Public License v. 1.2). The repository has 19 software components developed, integrated and validated, ready to be deployed and used.



Figure 7 5GMETA's public GitHub repository

The datasets generated by the project's use cases are available in a public Zenodo repository (<https://zenodo.org/communities/5gmeta/>) with a license that allows re-distribution and re-use (Creative Commons Attribution 4.0 International).

### 4.2. Documentation and additional information

The documentation, examples and tutorials related to the 5GMETA Platform are available in this GitHub repository: <https://github.com/5gmeta/5gmeta-dev>.

In addition, these two videos are a good starting point to learn more about the motivation and the basic concepts of the 5GMETA Platform:

- Video 1: [The 5GMETA Project](#)



- Video 2: [The 5GMETA Platform](#)

The Road to Lisbon hackathon webinars are also a great resource:

- [Road to Lisbon 5GMETA Hackathon Webinar #1 Introduction to the Platform](#)
- [Road to Lisbon 5GMETA Hackathon Webinar #2 How to interface with the platform](#)
- [Road to Lisbon 5GMETA Hackathon Webinar #3 Choosing and using available data](#)

More information can also be found on the 5GMETA website (<https://5gmeta-project.eu/>).

### 4.3. Business-oriented software extensions

The 5GMETA platform is an open-source business-to-business software platform that requires some additional work in terms of development and customization before the platform can be successfully deployed in a production environment of a specific business. These extensions are necessary to ensure the platform fully aligns with the business needs and operates at the expected level of performance.

The two key features that need to be implemented are the support of data transactions and the capture of technical and business requirements from platform stakeholders.

#### 4.3.1. Support of data transactions

This extension should integrate several core functionalities to support the platform's operational needs in a production environment. It should include a secure payment gateway that enables businesses to handle financial transactions safely. It should support various payment methods, such as credit/debit cards, bank transfers, and digital wallets, ensuring flexibility and convenience for users. The billing system should automate invoicing, payment tracking, and reconciliation processes, providing detailed reports and analytics for transparency and financial management. By integrating these functionalities, the module would ensure that all data transactions are coupled with secure financial operations, enhancing trust and reliability within the B2B platform.

#### 4.3.2. Capture of technical and business requirements from platform stakeholders

This extension would help to align the platform's operation with the needs and expectations of its users. This extension would act as an interface between the stakeholders—such as data providers, data consumers, business partners, and regulatory bodies—and the platform operator, ensuring that all necessary requirements are identified, documented, and managed. To ensure clarity and traceability, the extension should be integrated with the platform operator's project management tools, allowing requirements to be tracked, refined, and validated as the platform evolves. It should support version control and change management, enabling stakeholders to review and update their requirements as needed. Additionally, the module could provide analytics and reporting features, offering insights into requirement fulfilment and highlighting any gaps or risks that need to be addressed. By centralizing the capture and management of requirements, this module could play a critical role in ensuring that the data platform is operated in line with stakeholder expectations, ultimately leading to a more successful and user-aligned product.

### 4.4. Call to action

We welcome contributions from professionals across all levels— developers, data scientists, or advocates for open-source software. The involvement can take many forms, from contributing to the codebase and refining documentation to participating in discussions that shape the future direction of 5GMETA.

Here are some ways to get involved:

- Review the codebase: access the [GitHub repository](#) to examine the source code and understand the architecture.
- Engage with the community: report issues and collaborate with other contributors.
- Contribute to development: explore the list of open issues and contribute by resolving existing challenges or proposing new enhancements.
- Promote the Project: help us expand our community by sharing 5GMETA within your professional network.

By contributing to 5GMETA, you are playing a critical role in building a robust, scalable, and accessible data platform that will benefit a wide range of users and organizations. We look forward to your participation and to the collective success of this initiative.

## 5. LESSONS LEARNT AND RECOMMENDATIONS

The 5GMETA project has generated valuable insights into the deployment and management of 5G networks, edge computing, data exchange, and procedural practices in research projects. One key lesson learned is the challenge of uplink/downlink (UL/DL) asymmetry in current 5G networks. While these networks are optimised for downlink traffic, driven by consumer demand for social media, web browsing, and video streaming, the 5GMETA platform required a greater emphasis on uplink traffic, as vehicles serve as data producers. This imbalance hindered the transmission of high-volume data, such as videos from vehicle sensors, and highlighted the need for more balanced or dynamically managed UL/DL data rates to support data-heavy applications in future 5G deployments.

Another significant issue encountered was related to slicing contracts, which are exclusively defined and controlled by MNOs. This limitation reduced the flexibility of the 5GMETA platform to offer dedicated service level agreements (SLAs) tailored to client needs. A clear recommendation emerged: MNOs should offer business-to-business models with APIs that allow third parties to manage slicing capabilities. The adoption of network analytics tools, such as the Network Data Analytics Function (NWDAF), would enable platforms like 5GMETA to better adjust to the required performance levels dynamically. Additionally, the project faced difficulties in accessing standard performance reports from 5G networks, restricting their ability to adjust quality of service (QoS) parameters dynamically. Allowing access to performance data would significantly enhance the decision-making capabilities of platforms and improve the overall user experience.

The complexity of obtaining experimental network permissions was another barrier that impacted the project's flexibility. For instance, in the Spanish trial site, the stringent procedures required to deploy experimental outdoor 5G networks forced the team to rely on commercial networks. These networks, primarily non-standalone (NSA) 5G, offered limited access to the full range of network features. Simplifying and expediting the permission process for experimental networks is essential to enable innovation in future research projects.

The compatibility of devices with the network configuration (supported bands, supported carrier aggregation combinations, etc.) plus signalling interoperability is still an issue as certification of mobile device is based on a common scheme (GSMA) which includes a limited number of tests in real networks. Consequently, devices may lose connectivity to the network or fall back to 4G, thus degrading the performance of applications relying on 5G connectivity and the related characteristics. In some cases, the mobile device may not be able to force its 5G configuration to avoid fallback to 4G. Therefore, field trial test programs should be initiated to address the specific configurations of the network.

The project identified a lack of definition regarding edge density and geographical coverage. Without clear standards or regulation, it was challenging to determine how many edge nodes would be required to cover a particular area. This made it difficult to define the platform's architecture and compute resource requirements. Similarly, business models for third-party applications operating on edge infrastructures were unclear, hindering the planning and exploitation of applications requiring edge processing. Additionally, the project confirmed that edge nodes deployed by MNOs often lack internet connectivity, restricting the ability to link edge computing resources with cloud services, a critical requirement for platforms like 5GMETA. Another challenge was the lack of edge roaming capabilities, meaning that edge services were restricted to users of specific MNOs. This issue prevented the federation of edge nodes across different MNOs, limiting the ability to provide seamless edge services to all users regardless of their mobile carrier. Encouraging standardization in edge discovery, handover, and address systems is necessary to avoid ad hoc solutions and ensure uniform deployment across regions.

Edge nodes should publish their serving region or the data that it is able to process according to local regulations. Otherwise, it is difficult to ensure that regional data regulations are followed. The lack of standards for data streaming, particularly for camera and lidar data transmission, also posed obstacles, necessitating the development of proprietary methods. Standardization in this area is critical to ensure the seamless integration of sensor data in future CCAM platforms.

Finally, the procedural challenges of working within the framework of research projects were evident. Standardization processes are notoriously slow, often taking years from the initiation of a work item to the final publication of a specification. This poses a significant risk for projects like 5GMETA, which may have key standardization contributions emerge toward the end of their lifespan. If no resources are reserved for the continuation of standardization efforts, these initiatives risk being discontinued. A potential solution is to establish a scheme that allocates a portion of the project's budget specifically for finalizing standardization activities, ensuring that valuable contributions are not lost.

In conclusion, the 5GMETA project has highlighted several technical, operational, and procedural challenges that need to be addressed for the successful deployment of future 5G networks, edge infrastructures, and data platforms. These lessons can guide future research and development efforts, helping to refine business models, improve technical standards, and streamline project management processes in a fast-evolving technological landscape.



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