molière

MOBILITY SERVICES ENHANCED BY GALILEO & BLOCKCHAIN

D4.2 - GNSS & Blockchain integration

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Table of Contents

1. Executive Summary

The present deliverable outlines the importance of accurate and reliable satellite technology, in particular for geolocation, in the mobility landscape.

Today, more than ever, cities offer an ever-increasingly wide range of modes of transport: from ride-hailing to car-sharing, from micromobility to buses on demand; and these are just examples of the wide variety of mobility service providers that operate all around the world; initially in major cities, but increasingly in smaller ones and rural areas, where mobility requirements are vastly different.

None of these developments would be possible without reliable geolocation via satellite technology. Users' and vehicles' geolocation data points are a common feature of mobility data in Molière which are acquired by combining signals from Galileo and other GNSS in sight. There are important advantages and benefits from Galileo: most importantly, accuracy, continuity, integrity, and robustness to spoofing and jamming. All these advantages and others are explained throughout the document and exemplified through relevant use cases.

The document is divided into five main sections. The introduction focuses on the importance of using satellite technology and geolocation in today's mobility world. The following section focuses on the definitions of the main properties that characterize a high-quality GNSS. The next section presents several mobility-related use cases that depend on the high-quality GNSS parameters that Galileo offers. Then, we discuss how blockchain technology can maximize the utility of geolocation data by supercharging a mobility ecosystem. Last but not least, we zoom in more detail on the importance of accurate geolocation in a particular use case in the MaaS market.

2. About Molière

Urban mobility is becoming an issue of great importance in today's society due to the increasing population movements toward big cities and the exponential growth of cities in developing countries. The landscape of urban mobility is evolving faster than ever due to a combination of social, economic, and technological changes. The traditional options of walking, taking public transportation, or buying a car have now been extended to a wide range of new, flexible mobility services, such as vehicle sharing and ride-hailing.

In this context, a new mobility paradigm is needed to shift from disconnected to complementary. Promoting more sustainable, affordable, equitable, and accessible mobility is achievable by using micromobility and shared mobility services to fill the gaps in public transportation. The goal is to reduce dependence on single occupancy private vehicles.

Molière aims to help achieve that goal by building the world's best open data commons for mobility services - the "Wikipedia of public transport and new mobility data". The Molière MDM will utilize blockchain technology to analyze geo-location data from Galileo and use it to demonstrate a diverse set of relevant mobility scenarios to help address the needs of cities, public transport authorities, mobility service providers, and end-users.

3. Introduction: the importance of satellite technology and geolocation in the mobility market

Never before has such a wide range of choices to travel from point A to point B existed, nor as much information about mobility services available for travel in real time. Today, more than ever, cities have a great variety of mobility service providers (MSPs), public and private, that offer access to a variety of services (buses, trains, bikes, e-bikes, e-scooters, mopeds and others) to move around according to the needs of citizens at each point in time.

Geolocation plays a key role in this growing mobility ecosystem. The use of positioning technologies for the geolocation of vehicles and final users' smartphones represents a key enabler for more efficient planning and operating mobility services. Without this technology, most of the aforementioned MSPs simply *could not operate*, and the rest that could operate would do so with a significantly lower quality of experience.

Fundamentally, when a user wants to use and locate the closest vehicle e-scooter or bike using a smartphone application, they are benefitting from satellite technology and accurate geopositioning. When citizens locate and book a shared car on the street or when a user orders a taxi and wants to see where the driver is from the MSPs or other apps, they are also benefiting from satellite technologies. Just the same, the ability to accurately forecast the time-to-arrival of transit (mass transportation) vehicles such as buses depends on the ability to track their position in real time.

Users are demanding more and better services, better and seamless mobility experience so the accuracy of the geolocation signal and also other features that we are going to describe throughout the document are key enablers to the adequate functioning of any service.

In this context, as is explained in more detail in the following sections, the incorporation of Galileo positively impacts many existing applications in urban mobility and opens the way for new services and better adoption in cities.

So far, this section has focused on the accurate collection of geolocation data as a key requirement of modern mobility services. The other side of the coin is how the data is stored, distributed and used in a way that maximizes its utility to society as a whole.

The *statu quo* is that each service collects data on its vehicles, and stores it in its own isolated computer infrastructure, which is selectively shared, often via non-standard data formats and APIs. This leads to fragmentation, in the sense that there is no common infrastructure to interoperate with such data and services.

In this aspect, blockchain infrastructure is a high-potential enabler. The key advantage that blockchain technology provides is a neutral, common-ground infrastructure that can be owned by a consortium of organizations (private blockchains) or as a true "commons" owned by the public who has an interest in maintaining, using and improving its infrastructure (public blockchains).

Molière enables the ecosystem to organize around a blockchain layer that facilitates data publication, enrichment/rectification, its selective distribution, the establishment of protocols for data exchange and operations such as booking reservations of mobility services, thereby maximizing the utility of the data obtained and contributed by all parties (and the mobility services they provide). This building block will facilitate cross-provider integrated mobility experiences, and will, in the scope of Moliere, be demonstrated via a Mobility-as-a-Service type application, but that could extend to other models such as Mobility on Demand or the enrichment of commercial applications that can include mobility as a complementary service.

4. The Global Navigation Satellite System (GNSS)

Global Navigation Satellite System (GNSS) refers to a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location.

By definition, GNSS provides global coverage. Examples of GNSS include Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) and China's BeiDou Navigation Satellite System.[2]

In order to assess the quality of GNSS signals, the following parameters are used:

- Availability: the percentage of time that the position or timing solution can be computed by the user.
- Accuracy: the difference between the real and computed position or time.
- Continuity: the ability to function without interruption once the operation has started.
- Integrity: the measure of trust that can be placed in the correctness of the position or time estimate provided by the receiver.
- Time To First Fix (TTFF): a measure of a receiver's performance covering the time between activation and output of a position within the required accuracy bounds.
- Robustness to spoofing and jamming: a qualitative parameter that looks at the type of attack or interference which the receiver is capable of mitigating. Spoofing is the transmission of counterfeit GNSS signals that may force a receiver to compute an erroneous position and lead the user to believe they are in a different location from where they effectively are. Jamming is the intentional transmission of radio frequency signals that can interfere with GNSS signals leading to a degradation or blocking of GNSS navigation and timing services.[3]
- Authentication: the ability of the system to assure users that they are utilizing signals and/or data from a trustworthy source, and therefore that they are protected from spoofing threats.[4]

The error of the measurements and lack of accuracy of a standard GNSS receiver cannot be ignored at street level resolution. This is a problem in GPS and GLONASS which the European GNSS constellation Galileo aspires to solve by reducing the error component of the measures up to a few centimeters. The source of the error is mostly due to multipath fading of the received GNSS signal. This is especially critical in urban environments as applied to almost any shared

[2] European Union Agency for the Space Programme. https://www.euspa.europa.eu/european-space/eu-space-programme/what-gnss

[3] GSA. (2018). PRS. Luxembourg: European Union https://www.gsa.europa.eu/security/prs

[4] GSA. (2019). GNSS Market Report. Issue 6. Luxembourg: Publications Office of the European Union

mobility services, where the GNSS signal is likely to be received multiple times with different power levels and time delay.

5. Applications of Galileo: Use Cases.

This section covers some of the most important applications of GNSS in mobility. The goal of this section is to describe different use cases where Galileo technology is necessary and relevant, showing also the GNSS parameter that most influences the quality in each use case.

Use case	Description	Relevant GNSS Parameter
Geofencing in cities	Geofencing refers to the creation of virtual perimeters for real-world geographic areas, that is the process of determining when a device has entered or left a predetermined geographic boundary. Poor location accuracy can cause significant problems when used for geofencing. If geolocation is not accurate, distinguishing between nearby areas (a street vs a sidewalk, or a park vs a bike path) becomes challenging. This can lead to users receiving incorrect directions, triggering unpredictable, automatic changes in device behaviour (for example, misdetection of a low-speed area, where both false positives and false negatives can have fatal consequences). All micromobility services (scooters, bikes, e-bikes, moped sharing) and car sharing/pooling services should use an accurate geopositioning if they want to engage customers and reduce the churn rate. EGNSS can avoid this situation by positioning the vehicle more accurately.	Accuracy, integrity
The challenge of geo-positioning in urban areas	High buildings hamper GNSS geopositioning because they obstruct the direct line-of-sight visibility to satellites, and additionally give rise to non-direct line-of-sight signals or multipath bound inaccuracies. Whether a person is on a scooter, a car or just walking, in urban areas where buildings can block signals from navigation satellites, the use of hardware capable of combining inputs from different satellites, i.e., GPS, GLONASS and Galileo is key to improve the accuracy and the availability of the vehicle position and thus the quality of the service.	Accuracy, availability, continuity

	One of the main benefits of Galileo, compared to other GNSS, is that Galileo has higher resiliency against multipath, meaning it will determine location more accurately. Multipath errors are as of today one of the major error sources for conventional GNSS receivers. A multipath error is caused by the reception of signals arriving not only directly from satellites, but also reflected from the local objects in the environment. Basically, a multipath error will cause your location to be less accurately determined.[5]	
Better policy outcomes through geopositioning	Accurate geopositioning can help ensure that a micromobility service for example has sufficiently allocated vehicles to underserved neighbourhoods or making sure that the provider does not flood the streets with more vehicles than they have licensed. For these types of policies, accurate location data such as from the Galileo programme presents a highly reliable signal and an opportunity to drive better usage of our cities' mobility infrastructure	Accuracy, integrity
Accuracy and precision matters for Autonomous Vehicles	Autonomous driving is not a distant vision: it will be part of everyday life in some cities in a few years from now. To actually become reality, several technologies will have to reach maturity and be rolled out in concert. Driverless cars promise to open up new mobility options for people with impairments and aging populations, reduce car accidents and even free up the space wasted in parking. There is no way to make all this happen without accurate and reliable geopositioning. So, once again, Galileo plays a key role. Furthermore, the Galileo system (differently from other GNSS) authenticates its satellite signals by incorporating a digital signature to the navigation data that certifies its sources. This allows Galileo users to assess the trustworthiness of the signals, making them more robust against spoofing attacks (disguising a communication from an unknown source as being from a trusted source)[6]	All (Accuracy, integrity, continuity, availability, Robustness to spoofing and jamming and Authentication)

[5] Galileo for urban mobility: moving cities ahead with space data. Paper ID 993
[6] ibid

Active Travel	Active mobility or active travel is becoming more and more popular. People are now using more than ever non-motorized vehicles like bicycles to move around the city. Knowing where you walk or cycle really matters, especially the first time you arrive in a city is critical and if the location is not good enough the user experience can be damaged. For example, if you are walking on an elevated pedestrian lane, but the location pointer shows you on the ground-level sidewalk, then you would simply receive wrong instructions and lose your way. If we want to improve people's health and at the same time promote sustainable mode of transport, we need to provide accuracy to pedestrians and cyclists and Galileo again plays a key role in.	Accuracy

6. Blockchain Integration

6.1 A mobility ecosystem

So far, this document has focused on the challenges behind the collection of accurate geolocation data, what characteristics define a high-quality source of geolocation data, and relevant use cases that showcase the utility of accurate geolocation in mobility. This section focuses on maximizing the utility of such data once it has been collected.

Loosely speaking, mobility services operate their services in overlapping areas to form *mobility networks* that citizens rely on for their mobility needs. The various mobility services operate in coopetition (defined as "the act of cooperation between competing companies").

One can easily think of examples of clearly complementary mobility services. For example, scooters can provide first and last mile coverage for trips enabled by longer-distance rail. In other cases, services can more easily be perceived as competitors. However, most often, this is so only in a very narrow interpretation of market forces. In practice, even mobility services that are closest in their offerings (and therefore often compete for users) in practice cooperate to provide wider or higher-quality coverage in an area. For example, they provide vehicles that are closer to one citizen, or that serve its needs better depending on their unique and changing needs.

An example of this effect is the following. Picture a city with a single small taxi operator. This city is better served by *many* such small taxi operators instead. And, despite the apparent competition, all these operators can be considerably more successful when operating simultaneously "in competition" since users will tend to take more taxi rides if they know a taxi will always be available in short notice to go anywhere in the area. Similar arguments can be extended to micro-mobility devices, and between modes; for example, a citizen may decide not to buy a car if sufficient alternatives exist, even if they at times are competing to serve a user.

The state of the art nowadays is mobility services are not tightly connected and integrated. Mapping applications are as of today pervasive, but they do not offer direct access to operate such services (for example, they require external apps for booking), and they do not contain the ever-increasing full range of mobility services that are available.

We argue that blockchain technology allows mobility services to better interoperate. One may wonder why MSPs, especially private ones, may wish to enable interoperability, if they are competitors. The answer is that, more often than not, mobility services are complementing one another, even if, on the surface, they are competing (whether they perceive reality in these terms is another matter).

Such an infrastructure can be used to store mobility data in a standardized format; to distribute it among participants as desired (private blockchains offer the ability to restrict access, while public blockchains do not); to formalize the exchange of data between parties and tightly define the operations that can be made to the data by each party (via smart contracts); and, finally, they can support the exchange of value between participants (via cryptocurrencies or, more realistically in the current environment, "stabletokens" that represent units of value pegged to, for example, the Euro, the US dollar, or any other currency).

6.2 Governance

One important challenge that arises when this layer is established as a true commons is that of *governance of a commons infrastructure*. When an infrastructure is a commons, who is in charge of decisions? A revolutionary concept enabled by blockchain infrastructure is that of a Decentralized Autonomous Organization (DAO). One such organization can be put in charge of managing the commons, enabling 1) decision making via voting mechanisms; 2) appointing representatives where blockchain-based voting is not an appropriate decision-making mechanism; 3) distributing voting rights according to the interests of the commons; 4) establishing fees and rewards to access and maintain the infrastructure; 5) managing a development fund to incentivize stakeholders to contribute to the commons.

Deliverable D4.1 of Moliere presents a basic implementation of this idea, where Moliere nodes can cover geographical areas, and token-based voting can be deployed to maintain a registry of what nodes can cover what areas. New tokens can be minted in exchange for the development of new features of the platform, and token votes can also determine strategic changes or consensus on the application of upgrades.

The intended impact is, any mapping application can access Moliere to pull data from mobility services to enable journey planning. And mapping applications are eventually replaced for full mobility applications that enable bookings, enable crowdsourcing of data points, and provide a fully integrated mobility experience.

6.3 Incentivization of growth

So far, this section has discussed the need for collaboration and interoperability in mobility ecosystems, and how to govern a *commons* infrastructure. We next move onto the topic of how to incentivize mobility service providers to actually connect to this infrastructure.

As discussed, the status quo is that mobility service providers are siloed, each with its own app or ticketing systems. There is a greater good to be had when all these providers connect to a global mobility infrastructure such as Moliere. In fact, when Moliere is established as a global mobility infrastructure, it is in the best interest of providers to join it. But before that, what incentive exists to compel mobility providers to join Moliere? A clear, direct incentive must exist, because connecting a mobility service to a new infrastructure carries direct integration costs.

The answer to this is the creation of incentives via the awarding of governance tokens to those companies who actually connect to the network and participate in the delivery of quality mobility services.

The stakeholders involved in this incentivization scheme are mobility service providers, node operators (who operate the Moliere infrastructure) and front-end applications (usually mobile apps).

The network as a whole, then, periodically reviews the mobility services exchanged on the network, and computes a reward for each involved party as a function of the number of mobility services participated in, the area where these services are rendered, the value of the service, or other factors that the token holders who invest in the network's governance deem of importance. Then, this reward is awarded to each stakeholder.

6.4 Proof of mobility service and Galileo

One of the key aspects to incentivizing growth in a decentralized network is to avoid bad players (who can almost certainly participate in the system due to its decentralized nature) misreporting or pretending to deliver mobility services just to capture rewards. Throughout this section, we will refer to a party engaging in such undesirable practices as an *attacker*. To picture a simple scenario, think of an app or mobility service provider faking activity to attempt to capture a token reward, which they would then sell on cryptocurrency markets for monetary gain.

As a consequence of these opportunities for fraud and deception, the network needs to verify which real mobility services *are* being delivered. Solving this issue is harder than it seems, because, in decentralized systems, trust between parties is low to nonexistent, and adding a requirement that parties need to collectively trust one another is undesirable.

Completely removing the possibility of fraud could only be achieved via combining proofs of the existence of a vehicle, its location and how it changes over time, and in fact that one mobility service (and only one single mobility service) was rendered and paid for in connection with the movement of the vehicle by a real person. **Moreover, with Galileo's unique Open Service Navigation Message Authentication (OSNMA), a data authentication function for the Galileo Open Service worldwide users, freely accessible to all, GNSS receivers will rest assured that the received Galileo navigation message is coming from the system itself and has not been modified.**

We argue, though, that in practice sufficient mitigations can be introduced such obvious fraud is caught and working around countermeasures is more expensive than the reward that can be captured. We call these mitigating measures *proof of mobility service* (PoMS), which is admittedly a misnomer, since, as explained, the objective is to reduce the likelihood of fraud by adding fraud detection countermeasures, rather than *proving* a mobility service happened.

PoMS requires every stakeholder to cryptographically sign the operations they perform and, most importantly, include a geolocation tag as appropriate. Geolocation from Galileo is at the heart of this scheme, as inaccurate, unreliable or insecure geolocation would be an unsuitable basis on which to build PoMS.

For example, an app can request a taxi from points A to B. The app captures this information from the end-user's device. Then, the Mobility Service Provider (MSP) also captures it. Likewise, the node that interconnected the app and the MSP too records this information. Then any party with access to these signatures can at least attest that all parties agree a service *was* performed. Note that all this information can be stored on a blockchain as an ideal use case.

This mechanism makes it necessary for an attacker to create fake services in both an app and a mobility service provider. Nodes observe such operations, hence attacker-controlled MSPs are forced to advertise non-existent mobility services to a node.

The next step is to then cross-reference activity between different apps and MSPs. If certain MSP are reporting a disproportionate amount of activity linked exclusively to a select group of apps, to the detriment of the users of other apps, even though they are offered in a location and time where other apps' users are actively using similar services, then such mobility services become ineligible for incentives.

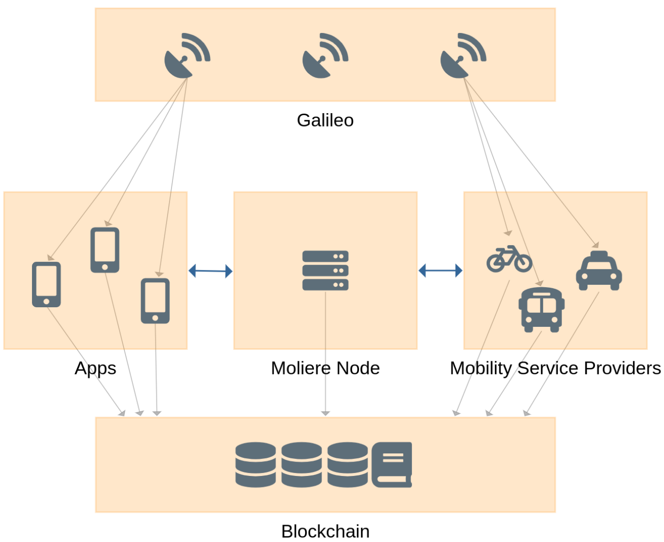
The next level of protection is adding *trusted geolocation* in vehicles. Since Galileo signals are authenticated, a Moliere-certified, secure, tamper-proof piece of hardware installed in mobility devices can capture this information and announce its location. This data can be independently cross-referenced with the data provided by MSPs and apps. This makes it harder for an attacker to fake mobility services, since it now has to physically move a piece of equipment from A to B.

As a final layer of protection, the governance layer of Moliere can maintain a greenlist or a redlist of providers who are deemed good faith actors and therefore are eligible for rewards.

6.5 Integration of Galileo and blockchain

The diagram below describes the integration of all these data sources. Geolocation data is determined by using Galileo signals by both Apps and Mobility Service Providers. Then, it is embedded in all the operations that apps and MSPs exchange. Nodes are witnesses of these operations. All of these stakeholders report the data into the blockchain layer, which timestamps and records data entries, serving as an immutable ledger that can be trusted to record this information.

In summary, accurate and reliable geolocation is the foundation for the operation of high-quality, modern mobility services; also, it is crucial that such data is made available on an infrastructure that fosters interoperation. To serve as a commons mobility infrastructure, Moliere adds a governance layer that guarantees its decentralized operation. And finally, to promote the growth of the infrastructure, incentives can be added that once again depend on accurate geolocation to be independently performed by all parties and to store this information securely on a ledger, so it can later be cross-referenced and verified independently.



7. Bringing accurate geopositioning to the MaaS market

As discussed, accurate geolocation is a requirement to enable modern mobility services and adding a blockchain layer to facilitate interoperability between mobility services dramatically improves the efficiency of a mobility ecosystem.

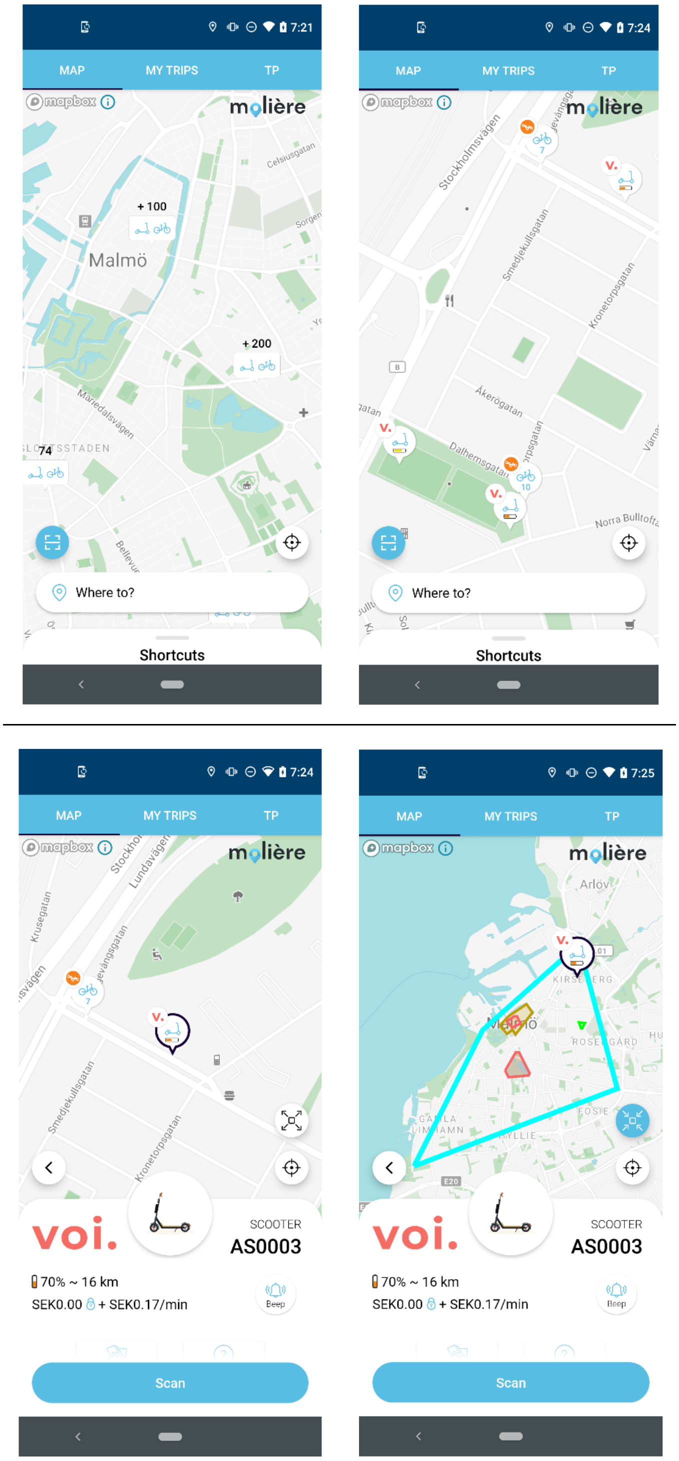
In Moliere, one of the use cases under development is a Mobility-as-a-Service demo application. Mobility-as-a-Service integrates various forms of transport services into a single mobility service accessible on demand. We have chosen to develop a MaaS app because it showcases both the use (and the need for) of accurate geolocation, as well as the advantages of enabling interoperability with the Moliere data marketplace.

The following screens are taken from the Moliere MaaS platform to show the importance of geolocation. As the reader can observe in the first screen, the user is able to discover the availability of mobility service providers in a certain region (number, type of vehicles and their accurate position displayed on a map).

On the second and their screen, the user zooms to a specific area in Malmo Region and discovers and then chooses one provider (in this example VOI Scooters) close to their location. Note that accurate geopositioning is critical for the user to be able to locate the vehicle; it is a recurrent problem that, when geolocation is inaccurate, users can struggle to find the vehicle.

In the last screen, the user selects a VOI scooter and is able to see the “not parking area”, showcasing the need for accurate geolocation for the purpose of geofencing. Again, none of these steps would be possible if we did not have the infrastructure and technology to obtain and share reliable positioning information. The necessary high degree of accuracy, continuity, availability, and integrity of the geolocation signal is attained with Galileo technology.

Finally, note how the construction of a MaaS-type app is greatly simplified with Moliere’s blockchain layer: rather than building a mobility aggregator with a small subset of mobility providers, with Moliere’s Mobility Data Marketplace it is possible to build an app that can interoperate with all the mobility service providers integrated in the marketplace, which, as an open infrastructure, can service many apps (or other kinds of frontend applications) with a unified interface.


7:21
MAP
MY TRIPS
TP
molière
+ 100
Malmö
+ 200
74
Where to?
Shortcuts
7:24
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MY TRIPS
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molière
voi.
SCOOTER
AS0003
70% ~ 16 km
SEK0.00 + SEK0.17/min
Beep
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MAP
MY TRIPS
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voi.
SCOOTER
AS0003
70% ~ 16 km
SEK0.00 + SEK0.17/min
Beep
Scan

8. Conclusions

While micromobility and shared mobility have been able to demonstrate a quantifiable modal shift away from private car usage and less sustainable modes of transport, many of the challenges are yet to be addressed. By integrating effective geopositioning into the mobility offer, users will gain the assurance that their experience is seamless and compliant with safety regulations.

As we have already mentioned throughout the deliverable, having an accurate and reliable geopositioning technology is a key enabler for the functioning of the mobility market. Without this technology, almost all the mobility services providers that we are seeing on the streets today would not be there and users would not be as engaged as they will be with Moliere's Mobility Data Marketplace.

Geolocation data is therefore a key enabler for modern, high-quality mobility services. However, this data tends to be siloed, diminishing its utility. Blockchain technology promotes data sharing and interoperation between mobility providers in a mobility ecosystem, which boosts the utility of geolocation data to society as a whole, therefore improving the productiveness of the Galileo satellite network.

The Moliere project will be demonstrating the geoposition accuracy of Galileo through multiple methods through the use of mobility services. First, Moliere will partner with micromobility providers to offer the Galileo data feeds directly into micromobility devices, via on board units such as provided by partners including OCTO Telematics, or through third party sources. Second, Moliere will partner with cities looking to demonstrate the use cases of higher accuracy Galileo satellite data to drive better compliance and improve public safety. And finally, Moliere will through the Mobility Data Marketplace make Galileo satellite data available to mobility developers and other partners who want to gain access to improved geopositioning for related on-demand services, such as food & grocery deliveries, parcel shipping, and urban logistics.