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Using GNSS Technology to Combine Fleet Management Functionality with the European Electronic Toll Service

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Abstract

Global Navigation Satellite System (GNSS) has recently become the core technology for distance-based electronic truck tolling schemes throughout Europe. The implementation of the European Electronic Toll Service (EETS) has become a major game-changer in the way that revenues from road pricing are collected in Europe, facilitating a major advancement of a new sector of ITS service provision that will greatly simplify cross-border commercial transportation. International EETS providers are currently overtaking the responsibility of collecting toll fees from national toll chargers. We can and should expect that an increasing number of fleet management providers will provide tolling services in addition to the telematic services that they currently offer. This paper reviews how these services have already been combined in practice and describe a solution suitable for deployment throughout Europe, meeting both the requirements of EETS and the practical fleet management needs of freight forwarding companies.

Keywords:

European Electronic Toll Service (EETS), Global Navigation Satellite System (GNSS), Fleet Management

Introduction

Road pricing embodies an important aspect of equitable and efficient intelligent transportation systems [Cascetta, 2017]. Effective distance-based tolling also enables improvements in the governance of road networks. Many European countries have formulated and implemented nationwide truck tolling policies [Gutiérrez, 2013]. At the beginning of 2020, eight states in the European Union have been operating nationwide distance-based charging schemes for heavy goods vehicles. Five of these systems already rely on satellite-based technologies, with two more European countries planning to launch their own GNSS-based tolling systems [Schindler, 2019]. The flexibility of satellite positioning technology allows for all road categories to be tolled – not just motorways, highways, or expressways. Rather than tolling specific road networks, this approach enables cost-effective tolling of selected vehicle categories on *all* roads.

As satellite-based tolling systems spread throughout Europe, we witness a complete transformation of

the way nationwide tolling schemes are operated. Until recently, each country had a single national toll operator, with a specific On-Board Unit (OBU) hardware designed exclusively for the payment of distance-based tolls on its own road network. Now, in 2020, the European Electronic Toll Service (EETS) framework is sweeping across Europe. Commercial vehicles that are obliged to pay distance-based tolls will be able to select a single Toll Service Provider, equip their vehicle with a single GNSS-based On-Board Unit, and can travel throughout Europe without having to register in each individual country [European Commission, 2004; European Commission, 2011].

This transition depends largely on the advancement of satellite-based technologies and reliable connectivity that must enable efficient toll collection and enforcement. [Kozlowski, 2017]. While toll roads have relied on toll plazas (and, more recently, tag-based electronic fee collection) to ensure efficient governance of road networks and revenue collection, they have been heavily dependent on expensive roadside infrastructure that is rapidly becoming obsolete. Furthermore, the need for the deployment of roadside equipment results in a general inflexibility in applying road pricing schemes to other roads that are not currently equipped with toll booths or tag readers. Given that network-based schemes involving multiple national and local roads are seen as the most equitable road pricing approach [Levinson, 2010], solutions that are less dependent on expensive infrastructure are rapidly gaining more attention in the transportation industry.

Among others, automated number plate recognition (ANPR) systems have been successfully installed in London, Stockholm and elsewhere to implement congestion charging schemes. Although ANPR technology cannot provide 100% reliability with respect to enforcement, the deployment of camera-based technologies is considered to be one of the most likely solutions to more equitable and flexible road pricing. On the other hand, satellite-based solutions that capture the distance and time travelled by the vehicle within a defined geographic area can further enable effective toll collection throughout the entire road network with limited and randomized enforcement controls.

Meanwhile, heavy goods logistics – the industry that is targeted by EETS - is directly related to a more immediate challenge faced by European cities: last-mile delivery [Cardenas, 2017]. If a similar technological approach can solve both freight logistics and urban delivery issues, which includes commercial vehicle parking, then such an integrated solution can quickly gain traction in the market and affect the shaping of future transport policies.

As the market develops, new stakeholders will be able to provide synergies that will encourage the introduction of new technical innovations and business models [Azmat, 2020]. We therefore examine the intersection of fleet management and GNSS-based tolling in light of the major changes currently taking place thanks to the advancement of EETS.

Advancement of GNSS-Based Tolling and its Impact on Road Pricing

Although the standardization of dedicated short-range radio communication (DSRC) microwave technology for distance-based tolling in Europe played a significant role in the advancement of EETS, the real potential for establishing tolling service provision throughout Europe was unleashed by the advancement of affordable and accurate satellite-based solutions. With the Russian deployment of GLONASS in 2011 and the launch of initial services of the European Galileo system in 2016, European Toll Service Providers could take advantage of multi-constellation GNSS. In combination with the American GPS and China's BeiDou-3, there are now four global navigation satellite systems offering excellent coverage. With the civilian-operated Galileo system, which reaches its full operational constellation in 2020, Europe now has a solid foundation upon which countless services in the transport sector can be offered reliably. Furthermore, Galileo provides an authentication service to ensure that the GNSS signal is genuine and therefore immune to spoofing attacks that could otherwise lead to a significant loss of tolling revenues [Diani, 2013].

GNSS is now a mass-market technology with a much-reduced per-vehicle cost for road pricing. Due to the unprecedented deployment of GNSS receivers in smartphones (and other devices) around the world, excellent positioning solutions are now being provided at an exceptionally low cost [Walker, 2018]. This new development is transforming the electronic tolling industry in Europe, making the transition to EETS easier through the deployment of OBUs that operate both in satellite-based and microwave-based tolling domains. Until recently, most state-regulated National Toll Chargers have required the registration of each vehicle using the tolled road network within their borders, and have made the use of their proprietary tolling solutions compulsory. It has been a great burden on truck drivers (and the international transportation companies they work for) to have to register their vehicles and install a separate OBU in each country they drive through. With the spread of EETS Providers, this enormous overhead for the transportation industry will become obsolete [Molina, 2016].

The formation of standardized solutions across the European Union facilitates the contribution of new technology companies in the area of road pricing and thus instigates competition and improves quality of service for those required to pay for the use of the road network. With increased competition, new services such as fleet management can be offered in combination with tolling services on a single platform that can significantly reduce the overall operational cost for fleet owners. This benefits the overall economic growth in the Union by simplifying the movement of goods between member states.

The Evolution of the European Electronic Toll Service

Belgium became the cradle of EETS when, in 2016, it introduced a GNSS-based nationwide distance-based charge for vehicles above 3.5 tons with its Viapass tolling system on 6,700km of roads

Figure 1 - The different OBUs of the accredited service providers in Belgium (courtesy of Viapass).

in Flanders and Wallonia, as well as all of the roads in Brussels. Since satellite-based tolling solutions are inherently flexible, the Viapass system has the capacity to expand to 50,000 km of the road network. In Belgium, for the first time, users of the toll system could choose among different EETS Toll Service Providers (TSPs) from the first day of operation. Various TSPs offer clients tolling services in Belgium with their individual OBU-based solutions [Erker, 2019].

Initially, there were only two toll services to choose from when the Viapass system was launched. By the end of 2019, a total of five TSPs have become accredited EETS providers in Belgium in addition to the national service provider of Viapass that is obliged to provide the mandatory OBU to each tolled vehicle that does not have a device already installed by one of the TSPs. In 2020, another three TSPs should be accredited as well. Whereas EETS providers in Belgium made up for approximately 25% of the market share by the end of 2019, it is anticipated that this should increase to more than 40% by the end of 2021, according to statements made by Viapass. This demonstrates the enormous impact that EETS is already having on the tolling in Europe today.

With EETS, the national Toll Charger accepts the final toll charge calculated by the Toll Service Provider, regardless of the detailed implementation. Therefore, in Belgium and in other European member states that accept EETS providers, the TSPs are granted varying degrees of flexibility with respect to the technical implementation of their services. This creates a new value-chain of tolling technologies and services that allow vendors to focus on their core business and offer solutions to multiple new EETS providers that are now emerging throughout Europe [Schindler, 2019]. Some of the key elements of the emerging service value-chain:

- OBUs that operate both in microwave-based and satellite-based tolling environments, enable secure GSM communication to a proxy server, and provide access to toll transaction data to the Toll Chargers' enforcement authorities;

- tolling software solutions that reliably and efficiently collect and store the trip data in a given toll domain, thus forming the basis for calculating the fees for each trip on the tolled road network;
- map matching services that use the trip data to detect the distance-based fees based on the requirements specified by the Toll Charger;
- front-end tolling services that could combine all of the above, with a business model very similar to that of a GSM network provider;
- payment service providers that are specialized in handling the registration, distribution of OBUs, and automatic payment of toll charges in all Toll Domains.

Whereas the first registered EETS providers were primarily companies in the toll operations business, a majority of EETS providers registered today are fuel service providers – with limited or no previous experience in road telematics and distance-based tolling. It is only logical, therefore, that experienced fleet management companies would be in an ideal position to extend their service portfolio to include EETS provision.

Combining Fleet Management with Distance-Based Electronic Tolling in Hungary

In 2013, Hungary became the third country in the European Union to launch a nationwide truck tolling system using GNSS technology. Due to its geographic location, major European transit routes use the Hungarian road network with more than half of commercial transportation coming from foreign vehicles. In order to mitigate the high level of wear and tear of the Hungarian road network by the transit traffic, the Hungarian authorities sought to implement a solution which was easy to install, highly secure, flexible, reliable, and independent of technology suppliers. A tender process for a nationwide solution was unsuccessful, however, since the winning bidder failed to sign the delivery contract due to the short and unnegotiable implementation timeline. As a result, a pragmatic and original approach was taken in order to implement a nationwide tolling scheme within just a few months [Varga, 2018]. With little time and resources available for the development of the distance-based tolling scheme, the Hungarian State decided to allow local fleet management companies to use their existing hardware solutions for the electronic declaration of the tolls.

Figure 2 - Some of the Fleet Management Tracking Devices Used in the Hungarian Toll System

Hungary was therefore the first country to establish a nationwide truck-tolling scheme using multiple service providers as opposed to having a single national operator that supplied each vehicle participating in the system with a standardized On-Board Unit to ensure the quality of service that guarantees a reliable level of accuracy in measuring and charging vehicles use of the tolled road network. The distance-based fees for all trucks above 3.5 tons on 6,500 km of designated sections of the Hungarian public road network can be paid either by manual ticketing or by using the positioning information of satellite-based fleet management devices offered from one of 22 registered Toll Declaration Operators (TDOs). Each of these TDOs already provided fleet management services and were able to use the GPS tracking devices (Figure 2) that were already installed in their clients' vehicles to automatically transmit all positioning data of the travelled routes to the TDOs. The TDOs determine, through their own individual algorithms, whether their clients' vehicles travelled on a tolled road section.

The Hungarian implementation of tolling is similar to the EETS-oriented approach, in which a number of Toll Service Providers offer electronic tolling services to their respective clients. However, the Hungarian TDOs work primarily as fleet management operators and provide the additional service of performing electronic toll declarations using the tracking device that is already installed in the vehicle. Most TDOs could not operate profitably if they did not offer fleet management or other services. The burden of ensuring correct toll-declaration lies on the TDO: the tracking device in the vehicle requires a good satellite signal and needs to transfer the positioning data within 15 minutes at least 95% percent of the time. If the positioning information is inaccurate or GSM coverage is poor, the TDO can be penalized. While this approach allows enforcement officers to catch violators "just in time," it is demanding both for users who opt for the electronic approach and for the service providers who need to ensure that the tolls are declared within this very short time frame.

Unlike similar tolling schemes in other countries, the HU-GO system does not rely on the use of DSRC interfaces to the OBUs for enforcement. Instead, camera-based technology is used to read the number plates of the passing vehicles and determine whether those vehicles are compliant with the toll system. It is for this reason that real-time, reliable connectivity becomes one of the core elements of GNSS-based tolling and road pricing schemes. Although network coverage can be unreliable, especially in rural areas, new telecommunications technologies, such as 5G (fifth generation wireless technology for digital cellular networks) and Narrowband IoT (Internet of Things) can enable better connectivity for multiple ITS applications.

Thanks to the fact that Hungary was the first country to implement the innovative electronic vignette system back in 2008, camera-based automatic number plate recognition (ANPR) technology was already in place and could also be used to monitor compliance to the new truck tolling system. Furthermore, by passing the responsibility of accurate toll charging on to the TDOs in the form of required Service Level Agreements (SLAs), rather than defining strict technical requirements with respect to the hardware functionality of the OBUs as is the case in other GNSS-based tolling schemes

in Europe, the Hungarian Authorities were able keep the cost of building and operating the new Hungarian tolling scheme to an absolute minimum.

Consequently, the Hungarian approach has become a role model: Bulgaria's new nationwide tolling scheme is based on the recommendations by the World Bank, which authored a 200-page study that endorsed the deployment of satellite-based technology for tolling trucks and an electronic vignette (e-vignette) for light vehicles, based primarily on the model that was already implemented in Hungary [World Bank, 2015]. For its truck tolling scheme on 6,000km of national roads, Bulgaria not only plans to rely on National Toll Providers that already offer fleet management services, but also foresees the acceptance of international EETS providers similar to the toll system in Belgium. In contrast to Belgium, however, no "default" national provider has been contracted that would guarantee the required level of service to enable the compliant use of the tolling system in Bulgaria for all potential users.

New Mobility Services using GNSS Technology

While GNSS-based solutions are rapidly gaining traction in tolling applications, the scope of these technologies is significantly wider. With highly accurate geo-positioning and reliable connectivity, transportation service providers can offer additional applications such as parking, navigation, usage-based insurance, and congestion charging that cuts across jurisdictions (cities, regions, and countries) and stakeholders (commercial fleets, last-mile deliveries, and passenger vehicles). These value-added services can be realized by using the same infrastructure that has been established by tolling and fleet management providers [Schindler, 2018], as illustrated in Figure 3.

One such integrated mobility platform with a focus on parking was recently patented by Parkofon in the United States (US Patent 10636306; EP and Singapore patent pending). A suitable technological approach includes many of the elements that have been defined in the specification of EETS. Additionally, geo-positioning accuracy is far more challenging to achieve in urban settings than it is on

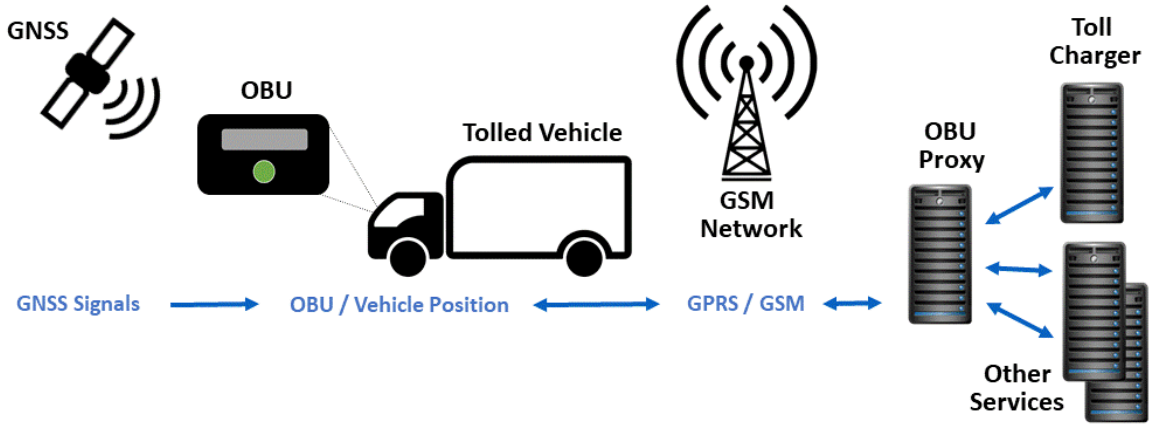

Figure 3 – Using the GNSS-based tolling platform for multiple mobility services

motorways. Such positioning accuracy is particularly important for the implementation of the parking and insurance use cases that require locating the vehicle precisely within the parking space, or in the accurate reconstruction of the driving trajectory prior to an accident or within a prescribed route. Figure 4 shows the key elements of the patented system that can serve both existing GNSS-based tolling and fleet management applications as well as multiple other mobility services.

Relying on the combination of GNSS-based signals, an inertial navigation system and digital geofenced maps, the major advantage of this technology is in its minimal reliance on roadside equipment and infrastructure. While enforcement is an important aspect in tolling, as evident in the Hungarian road pricing system, secure connectivity and low-cost ANPR deployments can help reduce the burden on road administrations and allow for the deployment of such systems in the shortest possible time frame and on multiple vehicle types, potentially including taxis and ride-hailing passenger cars. Existing GNSS-based tolling and fleet management applications for heavy goods vehicles provide an ideal environment for testing and evaluating such integrated mobility service systems.

These technologies, which have already been successfully demonstrated in multiple transportation environments, can eventually be integrated directly inside connected vehicles that are now being developed by the automotive sector. Through the use of real-time cloud connectivity and edge computing, these embedded solutions can significantly reduce the deployment cost of new mobility services throughout multiple jurisdictions.

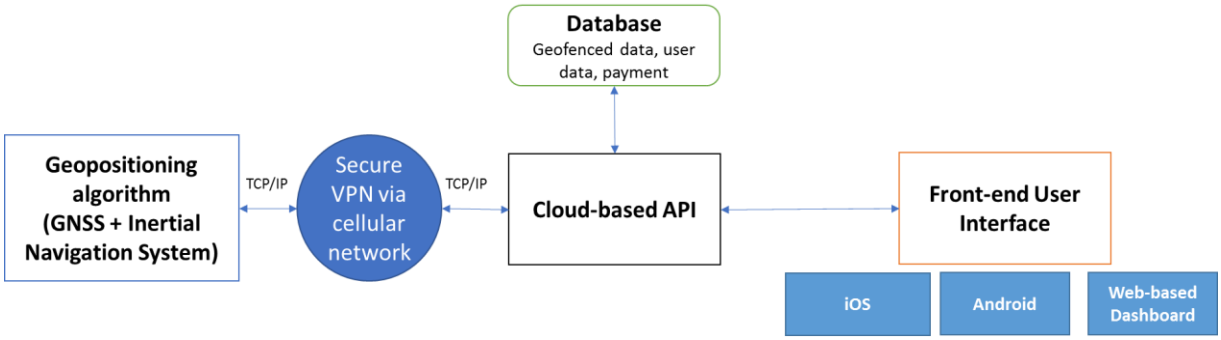

Figure 4 - Integrated GNSS-based mobility services platform

Discussion

Before connected vehicles with embedded telematics and real-time connectivity become omnipresent, standards and interfaces need to be developed across multiple transportation applications that will enable fast deployment and market value of such embedded technology in future. In order to provide a multi-functional mobility platform, further development and integration must be achieved in order to ensure highly accurate and reliable geo-positioning; real-time, secure connectivity; and compliance to the standards and requirements established within the European Union.

Whereas EETS has defined important standards in the domain of electronic tolling, many other mobility services, such as fleet management, last-mile delivery and parking, have yet to be standardized in a manner that that will guide technology providers to establish interoperable mobility services. International standards organizations, including ISO TC204 and CEN TC278, provide important fora for experts to contribute to these technological advancements.

The mobility and transportation market involve multiple stakeholders: national governments, cities, fleets, automakers, hardware and software providers as well as telematics and transportation experts. Integrated standards will take time to develop and deploy, particularly with regard to equity and social impacts that such transportation policies can create. It is likely that the market will create new pressure on governments to react sooner to rapid innovation development, similar to how proliferation of Uber and e-scooter providers made cities reassess their taxi and micro-mobility policies within a very short time.

Given contemporary technology developments, we expect that integrated mobility service providers will emerge in the nearest future offering both hardware and software front-end solutions. Such integrated services will likely require the creation of industry consortiums to apply the expertise of multiple players to difficult transportation challenges. Today, fleet operators often must develop own software to enable tolling and fleet applications using OBU telematics.

A simpler, integrated solution with a cloud-based application program interface (API) and database directly delivered by the technology provider can enable many more fleet operators, including small ones, to enable additional services in their business models and increase the efficiency of traffic management and monitoring. With this broader offering, more mobility stakeholders, including cities and last-mile delivery companies, can be interested in promoting such integrated technology platform across various applications.

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