New Hardware Platform Supporting Interoperability of European Electronic Tolling Systems

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Abstract
The next logical step for free traffic flow in tolling environments is the convergence of existing GNSS and DSRC based systems into interoperable clusters of tolling systems, which is driven by the European Community through the vision of European Electronic Tolling Service (EETS). Even though the deadlines defined in the European Commission's decision have come and passed, EETS still remains elusive. In practice, EETS is still struggling to become reality. Current tenders for new tolling schemes in Belgium and Russia differ significantly from existing tolling networks in Slovakia, Germany and Switzerland. The French "ecotaxe" system, with its interoperability with the VIA-T tolling standard in Spain, would have been a perfect example of regional EETS, but its scheduled start by the end of 2013 has been postponed. We describe a new On Board Unit platform which can bring the vision of EETS closer to practice.

Keywords:
Global Navigation Satellite System, European Electronic Tolling Systems, On Board Unit

Introduction

In recent decades, tolling in Europe was introduced in major steps. At first, manual tolling was set up to pay for the construction and operation of individual tunnels, bridges, and highways. Tolling systems based on manual plazas then migrated to electronic tolling. The introduction of Dedicated Short Range Communication (DSRC) microwave devices for frequent users reduced waiting times at tolling stations and allowed for more convenient methods of payment, such as monthly billing. In parallel, new toll systems on a national scale emerged.

Seven European states have now introduced nationwide truck tolling schemes: Switzerland, Austria, Germany, the Czech Republic, Slovakia, Poland, and Hungary. These systems use either DSRC or Global Navigation Satellite Systems (GNSS) for a multi-lane free flow approach and are covered by a single national operator. The various European electronic road

toll systems introduced at local and national levels from the early 1990s onwards were not interoperable and, with a few exceptions, are still not interoperable today. These systems oblige drivers to affix several electronic On Board Units inside their vehicle in order to be compliant to the various systems encountered on their routes. In view of the growth of international road traffic, the objective to internalize road externalities has gained particular weight.

Figure 1 - Multiple OBUs in today's trucks

Reaching Tolling Interoperability in Europe

The next logical step towards user-friendliness and the free flow of traffic throughout Europe is the convergence of these existing systems into interoperable clusters of tolling systems. The vision of EETS is the integration of all tolling systems and national operators throughout Europe, thus enabling road users to easily pay tolls throughout the EU with one subscription contract, with one service provider, and with a single on-board unit. By limiting cash transactions at toll stations and doing away with the cumbersome procedures for occasional users, EETS could facilitate daily operations for road users, improve traffic flow and reduce congestion.

The European Commission's Directive 2004/52/EC and the related Decision 2009/750/EC aim to achieve interoperability of all the electronic road toll systems in the European Union in order to avoid the proliferation of incompatible systems, which could compromise both the smooth operation of the internal market and hinder the achievement of transport policy objectives The directive therefore stipulates that a European Electronic Toll Service shall be established that covers all the road networks and tolled infrastructure in the Union where road-usage is declared electronically by means of a single On Board Unit.

Meeting individual national requirements for EETS

A future EETS-compliant OBU must meet all requirements as defined by the national toll charger. For example, in Germany it is required that upon passing a tolled road section, the OBU confirms the payment of the toll fee by showing the paid amount on the display. In the microwave-based systems installed in Austria, Poland, and the Czech Republic, the OBU makes a tone each time a gantry of a tolled road segment has been passed, thus informing the user that he has been charged for the road segment via electronic payment. Also in Slovakia, the GNSS-based OBU must emit a tone to confirm that a tolled road section has been passed and paid for –in this case the smart-client OBU confirms a passage of a "virtual gantry" which is defined in the geographic data stored on the OBU. According to the tolling laws in these countries, truck drivers in Slovakia (as in other neighboring countries) are required to report potential technical errors when the OBU does not properly acknowledge the passage of tolled road segments. These are the type of national regulations which an EETS OBU must be compliant with, and which the new OBU platform is able to achieve.

Meeting the requirements of new tolling projects

The deadlines set forth by the European Commission's decision with respect to EETS have come and passed. There are many reasons for this, but nonetheless progress has been made recently in order for EETS to become a reality. A prime example is the new tolling service in France which has been rescheduled to go live in 2015. The French approach is unique in that it will expand on its existing tolling policies currently operating on approximately 8,000 km of tolled motorways. All trucks in France above 3.5 tons should be equipped with new Hybrid On Board Units using GNSS technology for the automatic payment of tolls on the new tolled network of 15,000 km. These mandatory OBUs also contain a 5.8GHz DSRC microwave interface, allowing for the automatic payment at all of the existing toll plazas of motorways already subject to tolls.

With this new tolling approach, Europe is witnessing the first implementation of a fully interoperable hybrid tolling system. The French system will be "hybrid" in two ways: in terms of technology, supporting GNSS as well as DSRC tolling, as well as in terms of organization, serving both the new nationwide truck tolling system and of the existing private road operators. The project in France even goes one step further into the direction of EETS. The DSRC interface of the OBU is fully compatible with the Spanish VIA-T microwave standard. Therefore trucks driving in France can use the roads in Spain without having to change the OBU.

Since the introduction of EETS did not unfold the way the European Commission expected, a new project called REETS (Regional EETS) was established to test the EETS concept in

"regional" tolling clusters that could grow, merge and finally result in the wide-scale configuration originally envisioned. The new French écotaxe project, with the extension of interoperability to Spain, would be a perfect example of REETS going into operation.

Looking at the actual tender of Belgium, the chance to enlarge this REETS area was not taken, because the requirements differ significantly from the French project: the Belgian state will assume the role of the Toll Charger (TC), at least initially. The tolling scheme will be distance-based instead of section-based and has a complex rate zone concept comprising zones, street categories and driving direction. The whole street network in Belgium will be tolled – although in the beginning, parts of network will have zero toll rates. Additionally, truck drivers must be provided an option for checking their accounts via the OBU display. Interoperability with the French project is not part of the tender. On the other hand, the new Russian tolling project currently being tendered makes the use of GLONASS mandatory, thus making interoperability with European systems using only GPS and GALILEO much more difficult. In order to address this issue, the new OBU platform supports all of these different GNSS solutions.

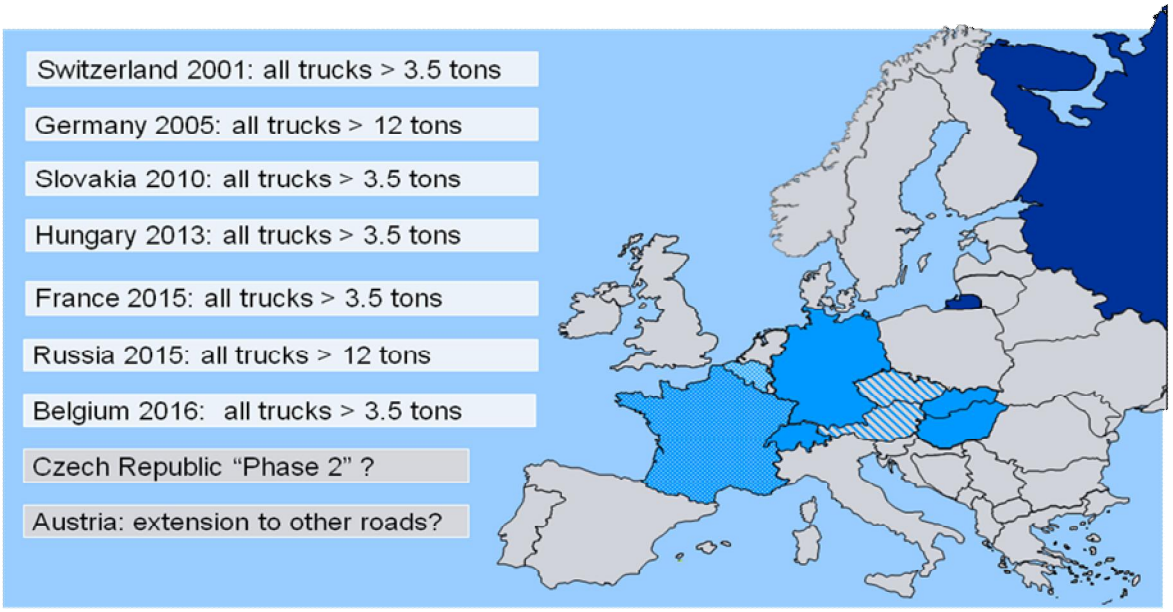

Figure 2 - the spread of Satellite-Based Systems in Europe

The evolution of satellite-based tolling solutions

In order to secure the successful functionality of EETS in the future, one must also address the ongoing trends of nationwide tolling schemes throughout Europe. As Figure 2 illustrates, GNSS-based tolling solutions will soon dominate the European landscape. The new OBU platform addresses the ongoing technical evolution of GNSS-based tolling systems. As an example, it will be required that OBUs can receive software updates and changes to the geographic data of the tolling domain over the air at any time. This also applies to firmware

updates of hardware components such as the GSM module, the GPS receiver, or the DSRC module. Such updates must be performed over the air without disturbing the underlying tolling application, thus securing the toll revenue income. These types of requirements are also met by the new OBU platform.

A most recent example of the required robustness of the GNSS OBU platform has been the rapid expansion of the tolling network in Slovakia at the beginning of 2014. Within three months, the expansion of the Slovak National Truck Tolling scheme from 2,447 kilometres to 17,762 kilometres has been implemented, making the Slovak system the largest in the European Union at the beginning of 2014. The map of the original tolled road network is shown in Figure 3.

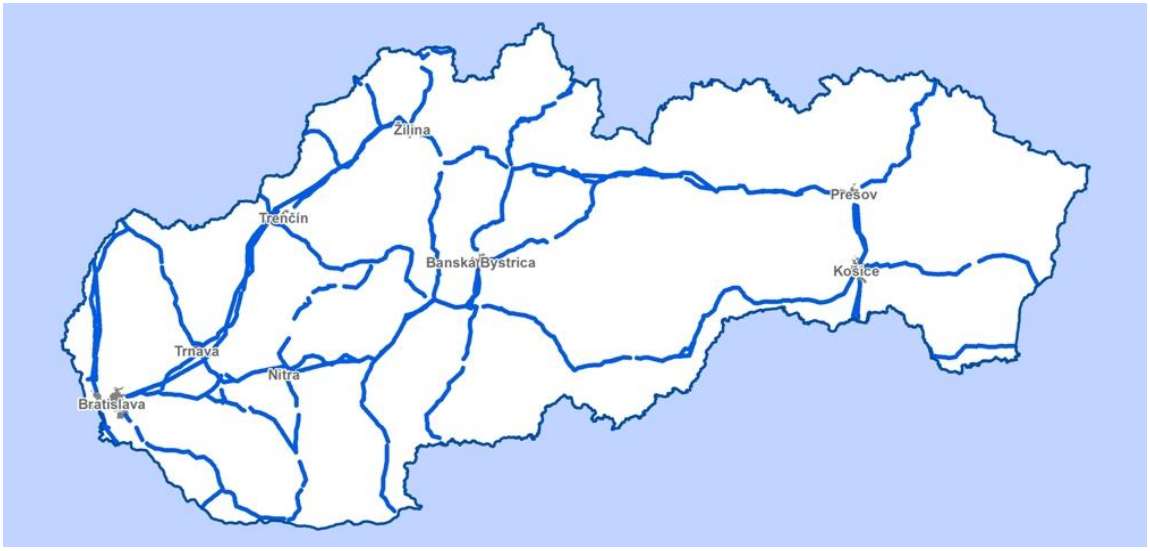

Figure 3 – Tolled Road Network in Slovakia until end of 2013

A total of 3,162 new road segments have been added to the geographic model that is stored in more than 200,000 On Board Units. In order to implement the expansion of the tolled road network, thousands of so-called "virtual gantries" have been added to the existing geographic model (originally consisting of 1,132 road segments), for a total of 4,294 road segments from the beginning of 2014. The map new tolled road network is shown in Figure 4.

From 1st January 2014, each OBU receives the update automatically from the moment it is activated (i.e. when the tolled vehicle turns on its engine). For vehicles entering the country from abroad, the OBUs are updated from the moment they enter the tolled road network of Slovakia. The Slovak GNSS OBU must be able to upload the new geographic network consisting of 3,162 "virtual gantries" in real-time, without any interference to the tolling application. Such demanding requirements must be met by an EETS-compliant OBU.

Figure 4 - Tolled Road Network from beginning of 2014

Growing need to support multiple satellite positioning systems

For the Russian nationwide tolling scheme, the use of GLONASS is mandatory. Furthermore, the new truck tolling tolling scheme in Belgium also requires the use of the Russian satellite positioning system in addition to GPS and GALILEO. The use of multiple GNSS signals is not only becoming a requirement for tolling systems; the parallel usage of GPS, GALILEO and GLONASS will become a valuable asset to improve accuracy in critical situations, such as detecting parallel road having different toll tariffs. Figure 5 shows the tracking data of the new OBU using both GPS and GLONASS, placed in a vehicle driving along a parallel road in Bratislava that is separated from the motorway by a single wall. It is clearly visible that the vehicle equipped with the new GNSS OBU was on the parallel road and not on the motorway.

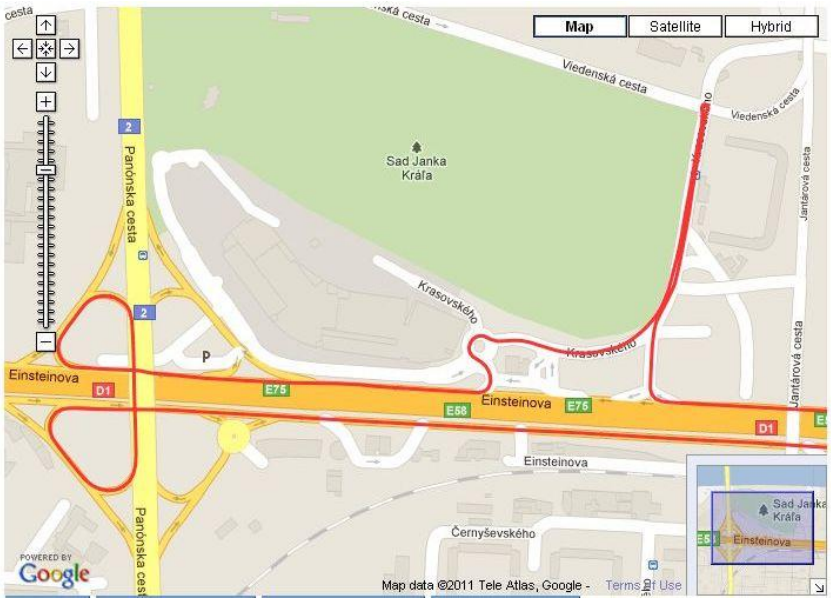

Figure 5 - A trip in Bratislava, on a parallel road to the motorway

One of the major challenges for GNSS-based tolling has been the level of accuracy possible in urban canyons, where the number of reliable satellite signals is reduced significantly. By using both GPS and GLONASS simultaneously, about twice as many satellite signals can be received on average, thus improving position accuracy dramatically. The new OBU platform has demonstrated the improved accuracy of using multiple GNSS signals, as shown by a trip in the financial district of Singapore – one of the most demanding environments with respect to urban canyons that can be found in the world. Figure 6 illustrates a trip taken between the high-rise buildings in Singapore, using both a conventional GPS-based OBU, as well as the new OBU having the combined GPS-GLONASS chipset. The improved accuracy of the raw tracking data of both OBUs is clearly visible.

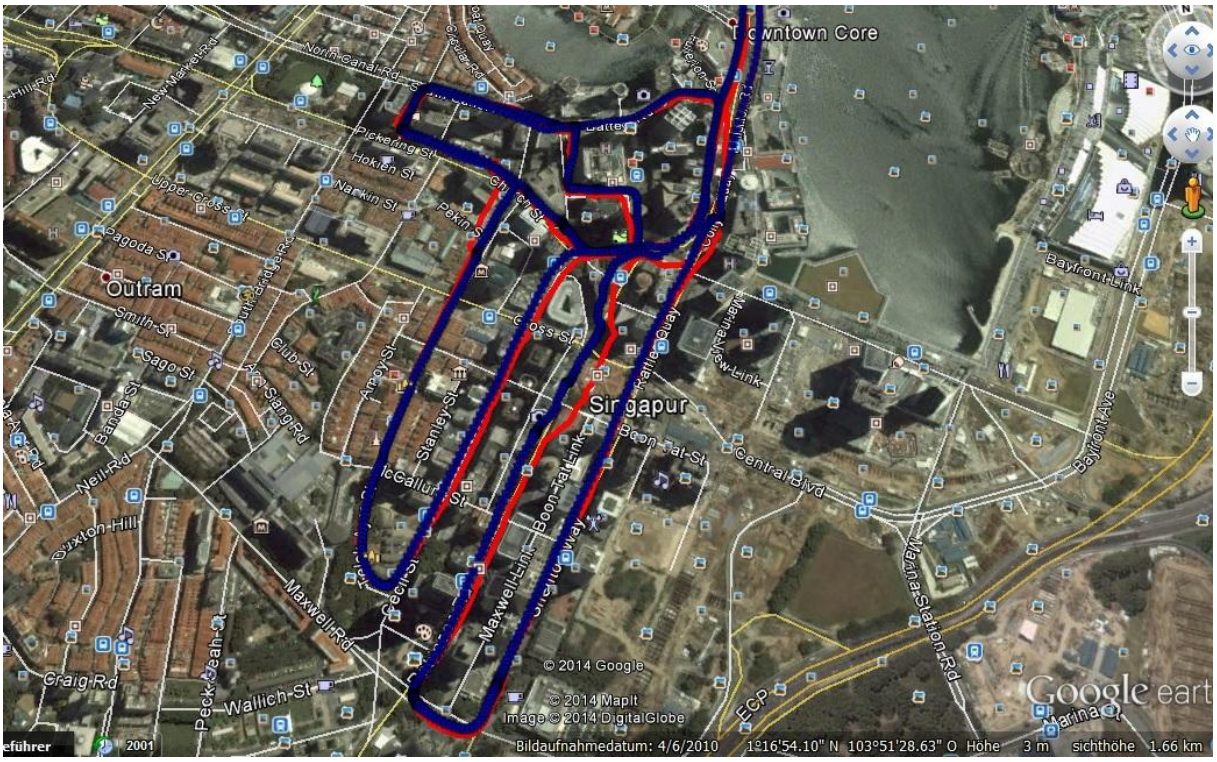

Figure 6 - A trip through the financial district of Singapur with the old OBU (red) and the new GPS/GLONASS OBU (blue)

Summary

With each country having his national characteristics and specialties of tolling, the demands on a potential European-wide EETS provider remain very demanding. The sum of all technical requirements set forth by the incumbent and upcoming national Toll Operators continues to increase steadily. For example, an OBU which needs to work in all European countries could be complex and expensive; it must support all different tolling schemes, two different DSRC standards, different display options, and all other national flavors. The new

OBU platform we presented addresses these issues, enabling the use of a single OBU in all the tolling domains of Europe and beyond. In order to secure compliance to each of the national tolling scheme, the local toll contexts can be updated via the GPRS interface into the OBU when changing the country – much in the way that the new tolling context in Slovakia has been changed at the beginning of 2014. We have demonstrated that the new OBU platform is prepared to support the future vision of having a single contract with a single OBU which can effectively manage the compliant operation throughout Europe, effectively managing all the national variation to tolling schemes – both today and in the years to come.

Furthermore, by using GPS, GLONASS, and GALILEO, the new GNSS-based OBU platform can overcome many of the limitations that have been faced in demanding environments where the position data of a single satellite system has been insufficiently accurate. Thanks to the increased position accuracy demonstrated by the combined use of these GNSS signals, we can anticipate a significant reduction in the implementation cost of future GNSS schemes, further reducing the need for the installation of supporting roadside infrastructure for nationwide tolling systems.