New Application Markets for Intelligent Transport Systems using Positioning and Communication Technologies: Generic Pay Per Use Platform

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ABSTRACT
This paper analyses the design, development and implementation of a common flexible interoperable and easily extendable ITS platform for several applications such as Electronic Fee Collection System (EFC), Congestion Charge, Urban Parking management and Pay Per Use type of vehicle insurances based on satellite positioning. All these applications run on a generic platform based on positioning and communication technologies. This new Pay Per Use (PPU) system will allow, for example, users to travel across Europe and pay for tolls using a single contractual system, avoiding queues at toll stations. Additionally, due to the nature of the overall scheme, other valuable outcomes, such as pay per use insurance services or real time traffic management systems, will be obtained.

INTRODUCTION
During the last quarter of the 20th Century, there have been major technological advances in vehicle platforms and technological infrastructures. Connectivity and wireless communications between individuals, and individuals- machine have increased dramatically.
The current EGNOS system and the forthcoming Galileo Satellite Navigation System will provide higher levels of service guarantee, integrity and availability which are key factors for the development of new applications with severe requirements in the Intelligent Transport area. As car navigators are already quite common and advanced driver assistance systems are being introduced the next logical step will be towards the creation and exploitation of differencing factors provided by Galileo. Opportunities for improving Safety, increasing Traffic Management capabilities, providing Satellite-Based Tolling (Virtual Tolling) and developing any other innovative applications will be explored in the near future.
GALILEO in combination with new technologies such as GPRS, WIFI or UMTS will contribute to the development of a wide range of applications and services covering many economic activities and all segments of society. Road, rail, see and air transport will benefit from the hybridization of these technologies. The position accuracy will increase dramatically to the point where automatic guidance in all of these areas could be not only a dream but reality.
Nowadays, one of the most important applications of the navigation systems is remote services. Applications such as the electronic-fee-collection, truck fleet control or antitheft devices imply millions of users through the roads of the whole world.

STATE OF THE ART
Satellite Tolling
The first approach for satellite tolling is the German Toll Collect [1], which has been operational since 1st of January 2005. The company is a consortium led by DaimlerChrysler and Deutsche Telekom which have patented the system under German patent document DE 44 02 613 A1. This new toll system, called LKW-MAUT, is a tax for trucks based on the distance driven in kilometres, number of axles and the emission category of the truck.
The toll system is not based on toll booths or plazas on the highways themselves, but instead it is based on several methods: On Board Units (OBU), manual payment terminals and via the Internet. OBUs work via GPS and the on-board odometer or tachograph is used as a back-up to determine how far the truck has travelled by reference to a digital map. GSM is used to authorise the payment of the toll via a wireless link.
The main advantage derived of this system is that it has clearly demonstrated the reliability of toll systems based on satellite technology. Nevertheless, this system has some weak points as addressed in [2]: "However this system is its own impediment especially because of its dual approach (manual and electronic). Such approach incurs high operating costs, which, at over 20%, are much higher than those of other existing system". Additionally, Toll Collect has been made overly complex in an attempt to solve inherent GPS-related shortfalls. The main problem lays on the use of GPS which suffers from two crucial weaknesses when used for secure applications such as electronic tolling systems: there is no contractual service guarantee (the system belongs to the US Department of Defence and can be switched off or suffer a signal degradation without previous notification), and, the GPS lacks integrity, which means that there

is absolutely no guarantee that the GPS error might not sometimes be so big as to cause errors in toll calculations. Studies conducted by the London Transport Authority [3] have shown that, although the GPS error is statistically very small nowadays (even below 10 m), there are still occasions when the error might be as big as 1000 m and it might quite often (1% of cases) be several tens of meters. In fact, the German system has been fitted with roadside devices to solve this error. These are redundant devices that make the system expensive and cumbersome to set up; they would also be unnecessary if the positioning system guaranteed integrity, something that is impossible today using GPS alone. Additionally, there is another potential vulnerability in systems using only GPS signals. As the GPS signal is not authenticated, any broadcasted synthetic signal can distort the OBU making the complete tolling system into an easily vulnerable system to fraud.

Vehicle Insurance

Market analysis of satellite-based applications for road users which has been carried out in the GIROADS project suggests that pay-per-use insurance should become a normal practice in the future, with 80% – 90% of drivers covered in this way by 2020 – 2025. Estimates for the shorter term suggest that 5% of the European market may be covered by 2009, rising to 30% by 2012.

Benefits claimed for PPU insurance include more personalised premiums, promotion of good driving habits and a reduction in road accident casualties.

Currently, there is a pilot program underway in the United States. OnStar, joined with a national insurance company to offer a mileage discount program. Offered exclusively to motorists who own GM vehicles equipped with OnStar, this program will provide owners with the opportunity to earn an extra discount based on the miles they have driven. GM motorists have the potential to receive up to a 40% discount and save hundreds of dollars annually

Norwich Union, the UK's largest insurer, has offered this kind of insurance for about a year. Their system is GPS-based, charging by time and location as well as mileage. In Japan, Aioi has started offering it with an odometer-based system, according to Cascadia Scorecard. However, these are individual initiatives to test the future product acceptance among users. What these initiatives clearly show is an arising need of an homogenized platform for computing the vehicles insurances.

New Traffic control tools based on OBU

Nowadays traffic management is a priority problem for some cities. The existing traffic management tools are static in the sense that they do not response to traffic events (accidents, congestion) in real time, preventing further drivers getting into the conflictive area. Hence, taking advantage of the on-board unit new tools for traffic management can be designed to deal with the problem.

Recently, researchers from the University of California, Berkeley, and Nokia have tested new technological approaches that could soon transform the way drivers navigate through congested highways and obtain information about road conditions. In the unprecedented field experiment, transportation researchers tested the feasibility of using GPS-enabled mobile phones to monitor real-time traffic flow while preserving the privacy of the phones' users.

Each car was equipped with a Nokia N95 mobile phone that ran special software to periodically send anonymous speed readings from the integrated GPS to servers that then computed traffic conditions. Information was displayed on the Internet, allowing viewers to visualize traffic in real time. An independent tracking feature allowed the command center set up in Union City to track the position of the cars to coordinate the experiment and ensure the safety of the participants. These initiatives could become a realistic product if the on-board unit installed in each vehicle broadcast anonymously the proper information. Nevertheless, there is a long way to cover, requirements, protocols and privacy issues must be taken into account and must be well defined and legislated.

SYSTEM ARCHITECTURE

The implementation of such a system involves an on-board device including a GNSS receiver and mobile network communication equipment connected to a back office or control centre where the vehicle information is received, processed and the fee is charged. This back office will also be responsible for distributing toll revenues and proportional refunds to the corresponding road authority.

Different mobile communication solutions will be analysed in order to define and implement the most efficient transmission channel (in terms of bandwidth, availability, continuity, cost, privacy and reliability). Current edge technologies such as 3/3.5G (UMTS, HSDPA/HSUPA) will be used, as well as near future evolutions like HSOPA shall also be considered. Generally, all pertinent technologies under definition in the context of 3GPP LTE (Long Term Evolution) should be studied and considered for the further enhancement of the platform.

Figure 1 shows the overall architecture of the system.

On-board Unit: The OBU is composed by different elements

- The combined GPS/Galileo/EGNOS receiver shall improve the current available positional precision, checking data integrity via the EGNOS and Galileo systems. Vehicle position shall be available over 99% of the time to ensure the correct operation.

- Communication modules for transmitting the position and charging characteristics. In addition to the precise position and data integrity monitoring performed on the device, this data will be transmitted to a central control system through a communication module incorporated into the receiver. Nowadays, the typical communication channels for this type of application are GSM/GPRS. New communications channels that could provide major benefits in terms of bandwidth and latency (to improve response time). These communications networks are: UMTS networks, HSDPA/HSUPA technologies, "Beyond 3G" standards and protocols, and in general, all future emergent standards from organisations such as like OMA and the 3GPP. Data encryption and protection, along with the most efficient radio access method, data encapsulation, format and protocols for transmission will be analysed.

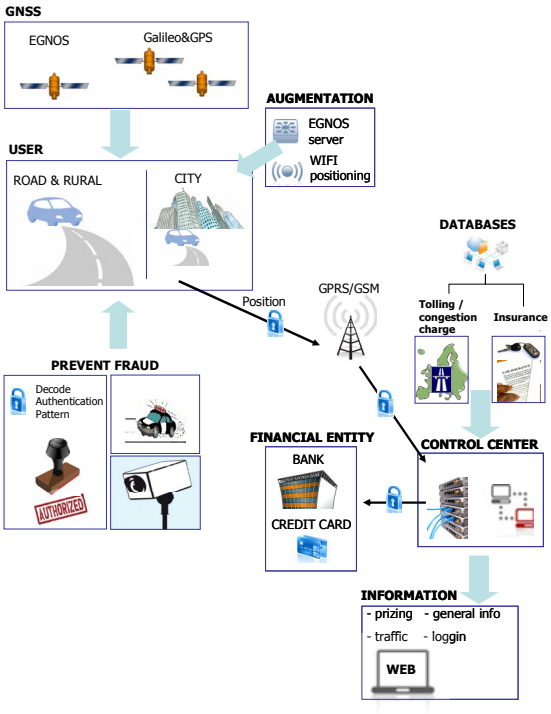

Figure 1: System Architecture

- HW/SW anti-tampering solutions. GNSS and communication on-board units (OBU) must be designed to prevent any kind of tampering or manipulation by users/drivers.

The OBU shall have a reference design that may be manufactured by different companies. The OBUs could have different characteristics and target prices. Every OBU shall be implemented and tested to demonstrate their ubiquitous compatibility. For this purpose, a set of well defined interface and communication protocols must be defined. The OBUs to be used in the tolling system shall fulfil the following requirements:

- Meet general requirements in terms of availability, accuracy and integrity;
- meet communication standards ; and
- certified by an authorised entity

The Control Centre or Back Office is composed by several elements:

- SW authoring tools to facilitate and provide flexibility to include new tolling routes, change tolling schemes on road or urban segment, parking fees, insurance fees etc. The system must be designed to be scalable and adaptable for future application schemes.

- Database that will support a large number of simultaneous users. One of the most critical components of the system is the database since it must be designed for always-on operation whilst being scalable and extensible through the addition of new services or features.

- Distributed control centre, which means that each region should have their regional control centre for managing the vehicles travelling on their infrastructure. The control centres shall be interoperable and with a standard interface in order to allow communication with most (if not all) of the commercial OBUs.

DESCRIPTION OF THE HIGH LEVEL OPERATION OF THE SYSTEM

Analysing the system's high level operation at an early development phase is crucial to guarantee the success of the road pricing platform. The complete system can be divided into four different services that work individually (Figure 2):

User Service: User Services aim at providing the road user an easy means of settling their Paying account (Tolling, Congestion Charging, Parking, Insurances etc.). It must be taken into account that this service must interact with a number of charging services and technology providers. Therefore, standards and open interfaces are required.

Charging Services: The role of Charging Services is to identify when a road charge is due, calculate (or receive from the OBU the total amount per road/area) the amount and bill the user.

Compliance Enforcement: The role of Compliance Services is to verify that all road users are complying with the rules of the scheme.

Operation and Management: The role of Operation and Management is to define the road pricing and the related scheme ensuring that these are compliant with the system. Additionally, it holds the final responsibility to manage the system as a whole

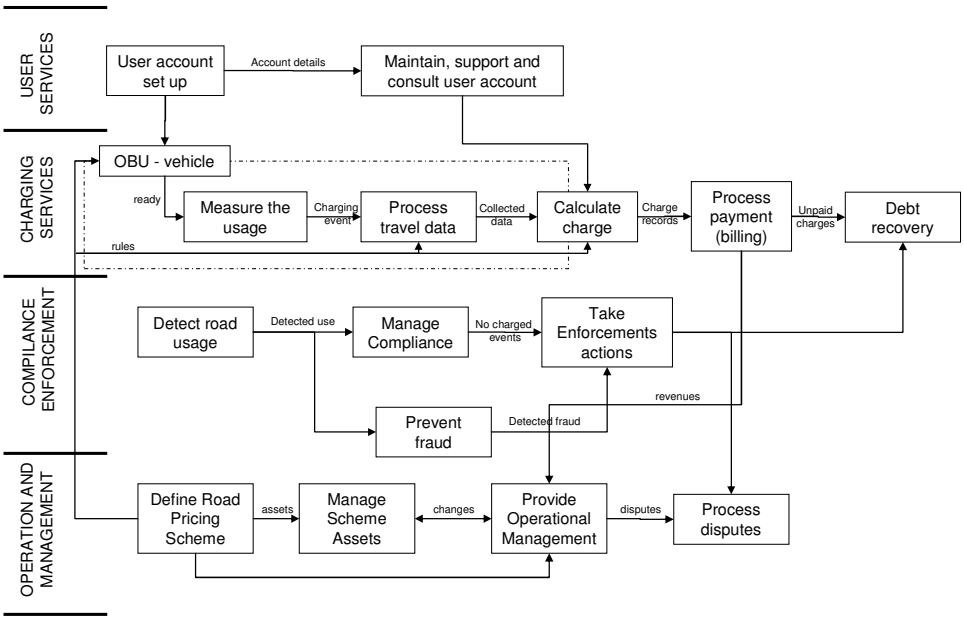

Figure 2: Preliminary System high level operation chart

CONCLUSIONS

This work presents a discussion on a new Pay Per Use applications. Some innovative methods to raise revenues for road agencies or charging congestion, recently adopted or being planned for adoption by several countries have been analysed.

It has been shown that GNSS based systems for road user-charging are feasible, since location and time are continuously available anywhere. Additionally, GNSS based systems offer high geographic charging flexibility.

The required robustness, availability and affordability of GNSS based systems will improve over time because of Galileo.

Finally, this study aims at exploiting the capabilities offered by EGNOS and Galileo to provide such new applications. A extended service concept of road tolling is addressed in the present paper, but also additional pay per use services on motorways as well as in urban environments (parking and access to restricted zones) are described.

Independent of the service scenario, common services applicable to each category of users are also considered, including the distribution of real time traffic data. Other interesting services are also presented such as pay per use insurance that can be easily implemented by the same satellite based tolling system. Nowadays, it is noted that the user community sees with good eyes this kind of innovative actions which will help to have a more adequate inssurance.

REFERENCES

[1] http://www.toll-collect.de

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[3] London transport authorities, “Feasibility study of road pricing in the UK - Full report”