FOURTH GENERATION ON BOARD UNIT
FOR COST-EFFECTIVE AUTOMATED ELECTRONIC TOLLING

Norbert Schindler

Intelligent Traffic Solutions, Electronic Tolling
Siemens Mobility Division
Erdberger Lände 26
A-1030 Vienna
norbert.m.schindler@siemens.com

ABSTRACT

Within a few years Europe will witness a broad installment base of On Board Units (OBUs) using the Global Navigation Satellite System (GNSS) and GSM (Global System for Mobile communication) for fully automated open road tolling of comprehensive road networks. While Germany currently has over 700,000 GNSS / GSM OBUs installed, several million OBUs based on these technologies should be deployed by 2012. In the Netherlands alone, it is anticipated that over 8 million such units will be needed. Thus, innovative new OBU technology is needed to meet the increasing demand for compactness, efficiency, and cost-effectiveness. The new generation of GNSS OBUs will no longer require complicated installation procedures in the vehicles that are required to use them. We describe our development of a fourth generation OBU technology based on a fully integrated chipset which will include GNSS, GSM, and data security functionality.

KEYWORDS
On Board Unit, Global Navigation Satellite System, Open Road Tolling, Electronic Tolling

INTRODUCTION

Electronic Tolling Systems are enjoying increasing popularity as a cost-effective alternative to traditional manual tolling at toll plazas on toll roads. In recent years, open road tolling systems have been launched not only on a number of motorways, but also for national road networks. Switzerland started with the introduction of a kilometer-based scheme for all trucks above 3.5 tons on its entire road network in 2001, its second generation system is being launched in 2009. Austria deployed a distance-based tolling system on all of its 2000 km of motorways for all trucks and buses above 3.5 tons in 2004. The following year, Germany started its nationwide scheme on all of its 12,000 km of motorways for trucks over 12 tons. In 2007, the Czech Republic launched its scheme on 1000 km of its motorways for trucks over 12 tons, and this year Slovakia is implementing its scheme for all trucks over 3.5 tons on 500 km of motorways and 2000 km of first class roads, to be launched in 2010. Holland is preparing to build the most extensive road user pricing system in the world - involving over 8 million vehicles on the entire Dutch road network of more than 130,000 kilometers - by 2012.

Each of the nationwide schemes installed in Europe so far were made possible only through significant investment costs (hundreds of millions of Euros) either in roadside infrastructure (for tag & beacon systems) or in complex satellite-based On Board Units. The larger the tolling road networks become, the greater the need for cost-effective satellite solutions will be. After Switzerland started with its first generation units, Germany deployed over 700,000 second generation OBUs over the past few years. In 2010, Slovakia will be the first to

introduce an obligatory, third generation “plug and play” windshield-mounted OBU. This new generation will have integrated GPS (Global Positioning System) and GSM modules along with their corresponding antennas, as well as a built-in Dedicated Short Range Communication (DSRC) microwave module to enable tolling data to be read directly from the OBU (for enforcement purposes). This unit will be much smaller in size and will cost about half as much as those of the previous generation deployed in Germany, and will not require costly professional installation.

However, by 2011, there will be a significant leap in the technological advancement of this OBU technology based on GNSS and GSM communication. Innovative new approaches for OBU hardware and software are needed in order to meet the increasing demand for compactness, efficiency, and cost-effectiveness. Siemens is currently developing a fourth generation OBU technology based on a fully integrated chipset which will include GNSS, GSM, and data security functionality. These units will also have the capacity to store maps of the extensive road networks of the countries which deploy them, such as France, Poland, Sweden and the Netherlands. The OBUs will communicate to a so-called “frontend proxy” also referred to as an Electronic Tolling Back Office (ETBO). Depending on the needs of the tolling operator, the tolling application - which determines the fees to be levied on the vehicles based on time, location and vehicle category – will reside partly on the OBUs hardware and partly on the ETBO server hardware.

FIRST GENERATION: SWITZERLAND

On January 1st, 2001, Switzerland introduced a kilometer-based tax on heavy goods vehicles, know as LSVA[1]. The tax replaced the flat-fee vignette levied on all domestic and international trucks above 3.5 tons. Each travelled kilometer, regardless of road category, is charged. The OBU is mandatory only for the nationally registered trucks of Switzerland, foreign trucks can use the manual booking system available at each border crossing.

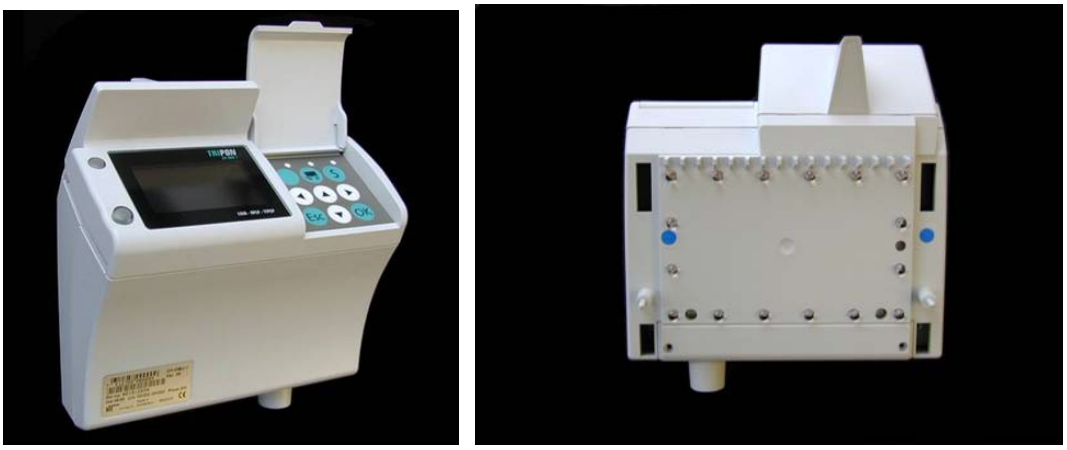

Figure 1 - The windshield-mounted “TRIPON” OBU, front (left) and back (right).

Initially, 55,000 trucks were equipped with an OBU which has the purpose of logging the number of kilometers travelled and writing this information on a chip-card. The OBU does not calculate the fees and does not perform any data transmission. The installation of the Swiss OBU must be performed by an authorized automotive workshop.

[1] In German: **LSVA** (**L**eistungsabhängige **S**chwer**v**erkehrs**a**bgabe)

The primary data source of the OBU is the truck's tachograph, which serves as the legally recognized source of the distance travelled. GPS has been shown to measure the distance more accurately and is therefore used to verify the exact distance travelled. A DSRC interface is built in to detect border crossings, effectively activating and de-activating the units when they enter and leave the country, respectively. A movement sensor detects whether the OBU has been illegally disconnected when the vehicle is in motion.

Although the principle of counting kilometers is simple, the OBU is rather complex. It consists of the following components:

- Tachograph connection
- Power connection
- GPS receiver and internal GPS antenna
- Trailer sensor
- Chipcard reader
- Motion sensor
- DSRC interface (based on the standard CEN TC278 at 5.8 GHz)
- Physical interface for programming and data access
- Internal Battery
- A set of light-emitting diodes (LEDs) on the backside for enforcement purposes

In 2009, a new generation OBU will be introduced to Switzerland. New features of this OBU include:

- DSRC interoperability with Austria (CEN TC278) as well as with also Italy (UNI).
- Bluetooth interface
- Increased data security

Figure 2 - The new generation windshield-mounted OBU for Switzerland.

SECOND GENERATION: GERMANY

On January 1st, 2005, Germany introduced a distance-based fee for all trucks on its 12,000 km motorway network. Two years after the system was launched, a number of first-class roads were also added to the tolled road network where a dramatic increase in truck traffic took place once the motorways were tolled. More than 700,000 OBUs have been installed. Vehicles without OBUs use the manual booking system which has been made available since

the high cost of the OBU and the required installation by an authorized automotive workshop would be considered discriminatory for occasional users.

Unlike Switzerland, tolling in Germany is based on tolled road sections, each having a corresponding fee (based on the road category). Thus, a digital map of all roads in the tolled network is stored in the OBU. Based on the GPS signal, the OBU can recognize each tolled section the vehicle has passed. The section and the cumulative fee for the trip are visible on the liquid crystal display (LCD). In instances where toll-free parallel roads are in the vicinity of the tolled road network, supporting gantries are installed at the roadside to ensure that the OBU recognizes the correct road section.

The OBU stores all recognized road sections, applies the corresponding fees (which also depend on the vehicle category), and makes the entire toll calculation. The German OBU is therefore a so-called “thick client” or “intelligent OBU,” since the entire digital map and toll tariff structure is stored on the unit. When changes are made to the road network or the applicable fees, the units are updated via GSM Short Message Service (SMS). The result of the toll calculation is sent to the tolling back office via the GSM network, if not periodically during the trip, at least at the end of each trip. A confirmation per SMS is then sent back to the OBU to verify the data transmission and to ensure that fees are charged only once. The SMS communication between the OBU and the back office is encrypted to ensure data security.

Two OBU types have been made available, the DIN-slot OBU (having the size of a car radio) and a dashboard-mounted OBU (since a DIN slot might not be available). A majority of the installed OBUs are dashboard-mounted.

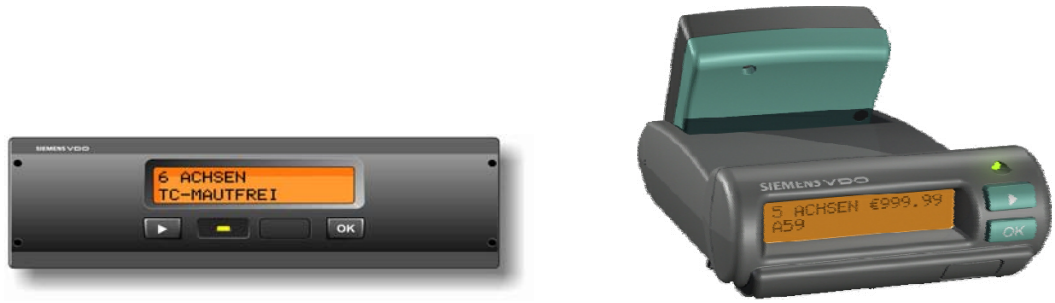

Figure 3 - The German DIN-slot OBU (left) and dashboard-mounted OBU (right).

The second-generation OBU consists of the following components:

- Tachograph connection
- Power connection
- GPS receiver and connection to an external GPS antenna
- GSM module for SMS communication
- Gyroscope
- External DSRC interface (based on the standard CEN TC278 at 5.8 GHz)
- External infrared interface (for enforcement purposes)
- Physical interface for programming and data access
- Internal Battery

The tachograph connection is used to verify the calculation made based on the GPS signals. In combination with the built-in gyroscope, it allows for section recognition when GPS signals are not available.

THIRD GENERATION: SLOVAKIA

In 2010, Slovakia will introduce a distance-based fee for all trucks above 3.5 tons on its major road network. For the first time, the motorway network is no longer the focus of a nationwide tolling scheme. Tolls are levied on a total of 2,400 km of roads – about 2000 km of which are first-class roads. The true flexibility and strength of GNSS-based solutions is thus taken advantage of, as the costs of constructing roadside infrastructure for more traditional tolling approaches would be far too prohibitive. Similar to Germany, tolling is based on the recognition of road sections which may have differing tariff categories.

A mandatory "plug and play" windshield-mounted OBU will be introduced, costing no more than the fee that users in Germany and Switzerland are obliged to pay to have OBUs professionally installed. The new Slovak OBU can be installed by the driver within a few minutes, requiring only a power connection (e.g. by means of the cigarette lighter). No tachograph connection is needed since the advanced Siemens "Waypoint Algorithm" and the gap completion algorithm ensure effective section recognition exceeding 99.8%[2]. GPS, DSRC and GSM communication modules are built into the unit.

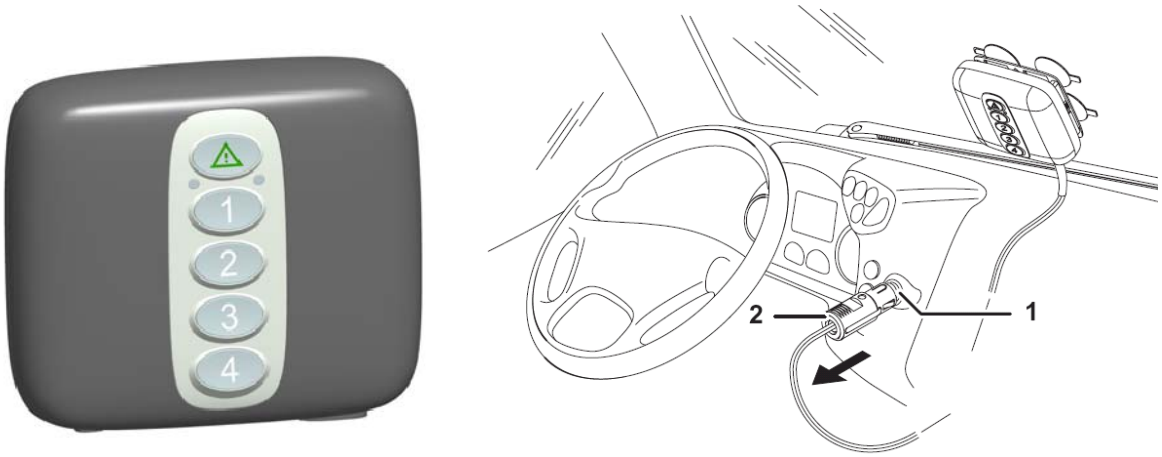

Figure 4 - The Slovak "plug and play" windshield-mounted OBU.

Unlike the second-generation German OBU, the Slovak OBU does not perform the cost calculations and thus does not have a display of the cumulative costs. It does, however, store all data of the tolled road network, producing an audible beeping tone to inform the user that a section was recognized and will be charged, similar to the way a DSRC tag beeps when it passes a gantry on the motorway. The OBU is still a "thick" client, but does not store tariff information. Using the General Packed Radio Services (GPRS) data transfer service of the GSM network, the OBU sends frequent and packetized data about the recognized toll sections to the tolling back office, where the final toll calculation is performed. The GPRS communication between the OBU and the back office is encrypted and watermarked to ensure data security and data integrity. GPRS is not only far more cost-effective than SMS data services, but also guarantees the transfer of data within the GSM network. For changes to the road network or for updates to the OBU application software, data is likewise received by the

[2] The Slovak Road Authority (NDS) required a "Functional Test of Concept" within 20 days of the contract award, to prove that all requirements were technically met. Nearly 20,000 kilometers of test driving with 10 vehicles yielded a result of 99.86% or correctly detected toll sections.

OBU via GPRS. The OBU platform is based on open source technologies and interfaces, such as Linux, Java, and HTTP.

Since the OBU is easy to install, there is no need for a manual booking system thus resulting is less overall system costs. Due to the optimization of OBU communication with the back office, GSM costs have been significantly reduced as well.

The new third-generation OBU consists of the following components:

- Power connection
- GPS receiver and internal GPS antenna
- GSM module for GPRS communication
- Motion sensor
- DSRC interface (based on the standard CEN TC278 at 5.8 GHz)
- Internal Battery

THE FOURTH GENERATION

The third generation OBU in Slovakia has proven to be a significant step in the evolution of GNSS-based OBUs. A new generation of OBUs, based on the foundations set forth by the system architecture of Slovakia, is currently under development. By 2011, this new OBU can be deployed in Slovakia as well as in other countries which plan to introduce electronic tolling systems. Currently, a number of European countries are already very advanced in their preparations for the introduction of nationwide tolling schemes. They include France, Poland, Slovenia, Sweden, Holland and Belgium. These countries alone will create a growing demand for robust GNSS OBU solutions which will by far exceed anything seen by the tolling industry until now. Through technological developments and the economies of scale, we can expect a rapid drop in OBU hardware costs in which compact but intelligent GNSS OBUs will provide a platform beyond tolling applications.

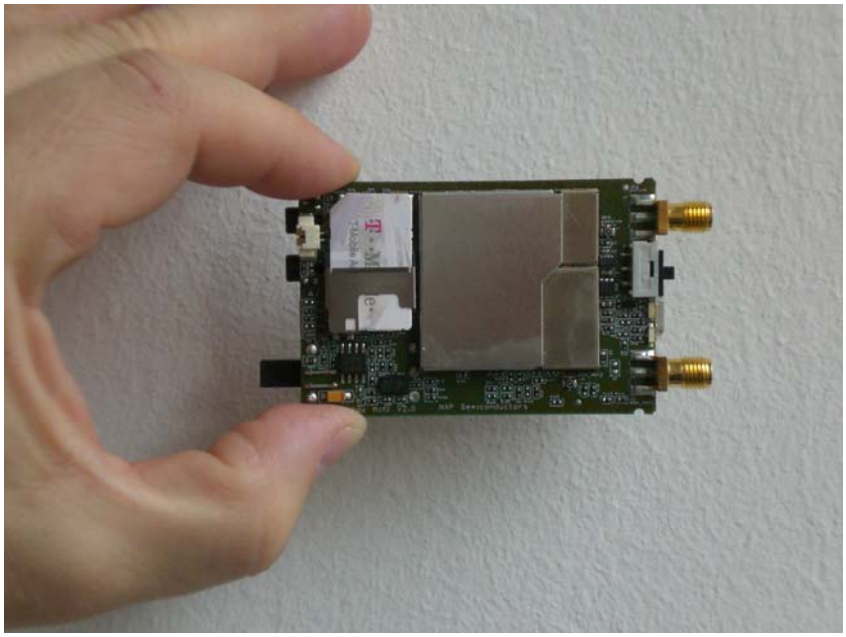

Figure 5 - Prototype of the fourth generation “plug and play” windshield-mounted OBU.

The fourth generation OBU will be a windshield-mounted OBU, similar to its predecessor, yet much more compact, i.e. about the size of a pack of cigarettes. It will also include GNSS and GSM communication antennas, and will be easily installable by the vehicle user. The new chipsets in these units can support Near Field Communication (NFC) and GSM/GPRS functionality to ensure efficient and secure data transfer between the OBU and the ETBO. The division of "intelligence" between the OBU and the ETBO will become increasingly more flexible, supporting both intelligent "thick client" solutions as well as "thin client" solutions, depending on the needs and requirements set forth by the tolling operators and (national) road authorities.

Figure 6 - One of the design studies for the fourth generation OBU.

Like its predecessors, the fourth generation OBU will to take into account the demanding automotive conditions inside the vehicle, such as extreme temperatures, vibrations, and radio interference issues with in-vehicle electronics. Interfaces for flexible telematics applications, such as additional traffic information and road-safety applications, will be provided on the integrated single-chip platform. The OBU hardware will be based on open standards, allowing for an increased flexibility for tolling applications as well as telematic applications.

As Figure 7 illustrates, the OBU software can be broken down into two basic parts. At the lower level, the operating system, the Java virtual machine, and hardware drivers form the basis upon which the application software is built.

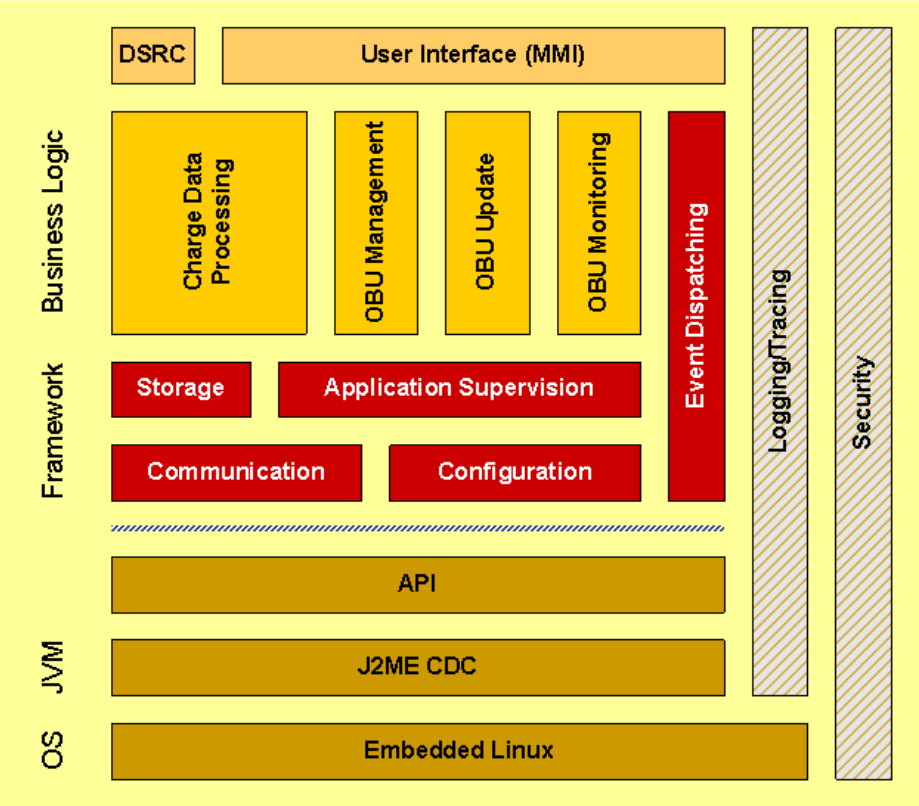

Figure 7 - Embedded Application Architecture of the New OBU Generation

CONLCUSION

Siemens draws on its experience in the development and deployment of previous GNNS OBUs generations to establish potential improvements in system efficiency and effectiveness in this new generation of technology. Each step along the evolution path has been essential in reaching the level of optimization we are now approaching. None of these innovations would be possible if not for the risk taken on behalf of road authorities in Switzerland, Germany and Slovakia. These countries were determined to find an optimal solution for the demands they faced in introducing tolling schemes, and were willing to support the implementation of technologies that were unknown to the area of road user charging until now. As the practical experience with GNSS tolling increases, the amount of risk involved in implementing new systems will become far more manageable. Thus, we can expect a large deployment of GNSS-based solutions over the next years.