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National Automatic Toll Collection System – Pilot Project (Part 1)

Gabriel Nowacki*
Izabella Mitraszewska*
Tomasz Kamiński*
Anna Niedzicka*
Ewa Smoczyńska*
Monika Ucińska*
Thomas Kallweit**
Robert Rozesłaniec***

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Abstract

This article presents selected issues concerning functional structure of the National Automatic Toll Collection System. The system includes the following elements: two on-board intelligent devices – OBU, two control gates, laboratory model of a National Centre for Automatic Toll Collection (NATCS). Poland and other EU member states should implement the European Electronic Tolling Service – EETS in accordance with the European Commission's decision of 6 October 2009. EETS should be available within three years (2012) for all vehicles over 3.5 tonnes and vehicles carrying more than 9 persons including the driver. This service will be available for other vehicles within five years (2014). Motor Transport Institute has created the structure of NATCS, as a hybrid pilot project to be used in researches on the implementation of the interoperable system in EU.
The tests results will be presented in the article – part 2.

* Motor Transport Institute, Transport Management and Telematics Centre, 03-301 Warsaw, 80 Jagiellońska Street, e-mail: gabriel.nowacki@its.waw.pl; izabella.mitraszewska@its.waw.pl; tomasz.kaminski@its.waw.p; anna.niedzicka@its.waw.pl; ewa.smoczynska@its.waw.pl; monika.ucinska@!its.waw.pl

** FELA Management AG, Basadingerstasse 18, CH-8253 Diessenhofen, e-mail: thomas.kallweit@fela.ch

*** AUTOGUARD S.A., 27 Omulewska Street, 04-128 Warsaw, e-mail: rozeslaniec@autoguard.pl

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1. Introduction

Electronic tolling systems, implemented in the Member States of the European Union are generally incompatible and can only communicate with their own recording equipment. Such lack of interoperability between tolling systems is particularly onerous for international road transport.

The European Commission has taken two mile steps in this regard. The first was a 2004/52/EC Directive of 29 April 2004 on the interoperability of electronic road toll systems in the Community. Then there was a decision of the European Commission of 6 October 2009 on definition of the European Electronic Toll Service (EETS), and system architecture.

In most EU countries (Austria, France, Spain and Italy) DSRC type systems of electronic tolling are used[1], that rely on dedicated short range radio (microwave frequency – 5.8 GHz).

The OBU on-board device, operating in the DSRC system is small (size similar to a packet of cigarettes). It is mounted on the windscreen inside the vehicle. However, the device is not very smart, very simple and only performs validation functions (read only), it has no display, and cannot receive or transmit any message. The DSRC system requires a well developed road infrastructure, at every crossroads, and gates must be installed at entrances to and exists from toll road sections (Fig. 1).

In the DSRC system, there are two types gates: communication Toll Gates and control gates, because their number is ten times greater than it is the case in the GPS/GSM.

In addition, data transmission is done using wired communications, and then it can take place over the Internet. The DSRC system will not be able to be incorporated into an integrated technology platform, as it will not even be able to collaborate with other national transport systems[2]. Even in the case of the DSRC system, which is provided by Kapsch, each country has a different type of OBU device. Another solution is to apply GSM or GPS systems (Fig. 2).

In this system, thanks to the GPS satellite positioning virtual control and tolling points established, the system can operate without the use of control gates. Data are transferred to the system directly from the OBU devices, using GSM communications.

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[1] DSRC (Dedicated Short Range Communication) – EN 12253. DSRC.EN 12795-EN 12834.. EN 13372. EN ISO 14906 – electronic tolling system – application interface. The currently used DSRC covers electronic tolling systems, mainly in Europe, Japan, and the US.

[2] This is the situation currently prevailing in Poland, traffic control systems in individual towns and cities are unable to cooperate with each other.

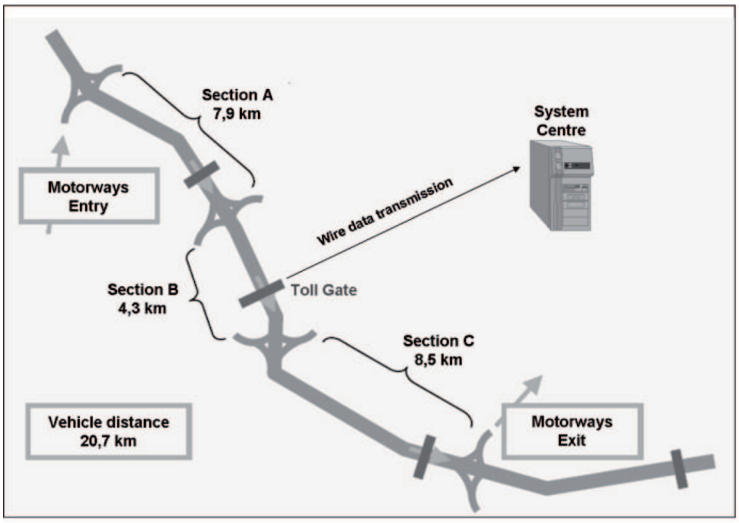


Fig. 1. Structure of the electronic tall collection system DSRC [1]

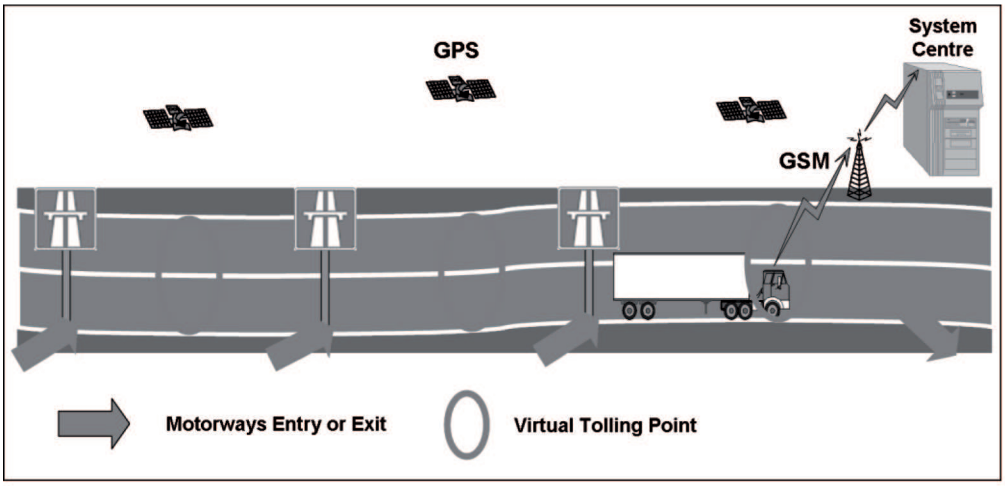


Fig. 2. GPS/GSM type system

According to the European Commission electronic tolling systems used in the European Union are not interoperable for the following reasons: differences in the concepts of tolling, technology standards, classifications, rates, discrepancies in the interpretation of laws (Fig. 3).

The European Commission has taken two mile steps in this regard. The first was Directive 2004/52/EC of 29 April 2004 on the interoperability of electronic road toll systems in the Community [3]. Then there was the decision of the European

Commission of 6 October 2009 on definition of the European Electronic Toll Service (EETS), and system architecture [2].

According to the European Commission decision 2009/750/EC, European Electronic Toll Service (EETS) should enable road users to easily pay tolls throughout the whole European Union (EU) thanks to one subscription contract with one Toll Service Provider and one single on-board unit (OBU). The mentioned decision was supported by standard EN ISO 12855 (CEN, Brussels, 05.02.2010) – tolling interoperability aims at enabling a vehicle to driver trough various Toll Domains while having only one OBU operating under contract with Toll Service Provider.

In accordance with the requirements of EU directives, conditions for achieving interoperability by EETS include activities related to the design, construction, commissioning, implementation, upgrading, renewal and maintenance of EETS infrastructure. These activities are designed to ensure the proper functioning of the subsystem installed.

For each of these subsystems, a relevant technical specification for interoperability – TSI determines primarily the basic technical parameters, which relate to the interoperability constituents and interfaces. TSI Specifications are integral components of the legislation which means that they are mandatory.

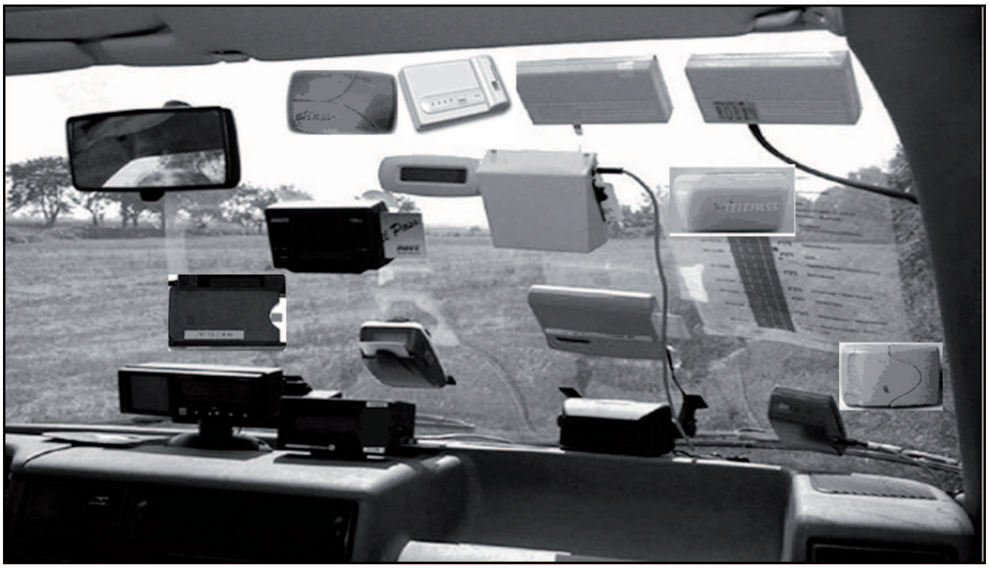


Fig. 3. Onboard OBU devices currently used on vehicles [4]

For many parameter values the required ones are defined by reference to relevant normalisation documents, particularly the European standards. Implementation of interoperability is a long-term and precise action. What comes to the fore in the implementation strategy for interoperability is the need for introduction of the EETS system, consisting of the following systems: DSRC, GSM, GNSS[3].

The Working Group No 1 (WG1) of Technical Committee 278 (Road Transport and Traffic Telematics) established in 1991 is responsible for electronic toll collection systems in European Union. ISO/TC 204 is the partner of CEN/TC 278 in ISO, responsible for the international standardisation of transport information, communication and control systems.

Authors have carried out the analysis of some systems functioning all over the world to choose the best one for Poland and other members sates of the European Union.

2. NATCS Functioning Structure

2.1. NATCS elements

The research team identified National Automatic Toll System (NATCS) functional structure – Fig. 4.
NATCS consists of the following elements (Fig. 4):
– intelligent on-board device called TRIPON-EU, which was installed in two test vehicles;
– OBU device installation system using a chip card;
– two control gates (with DSRC modem and a vision tolling system);
– laboratory model of national Centre for automatic tolling NATCC;
– a proxy server for data exchange between headquarters and the OBU system via GPRS;
– control centre to manage the OBU devices allowing for management of OBU and analyses of data relating to the collection of tolls;
– analytical tools for DSRC, image analysis and classification of vehicles.

The design of the system included the following technologies:
– satellite positioning via GPS, and Galileo in the future;
– wireless communication via GSM (TS 03.60/23.060);
– dedicated short range communications – DSRC (5.8 GHz).

2.2. Defined interfaces

The design defines a total of six major interfaces that are included in the proposed test system with OBU on-board device (Fig. 5).

[3] GNSS – Global Navigation Satellite System. GNSS-1 is based on existing segments of the orbit Navstar GPS and Russian GLONASS system. An integral part of the GNSS-1 is a system of differential (DGPS – Differential Global Positioning System). Development of GNSS-1 will be the GNSS-2. The constellation of navigation satellites will include the GPS Navstar satellites of II F type GLONASS M and new European satellites wit working name of Galileo.

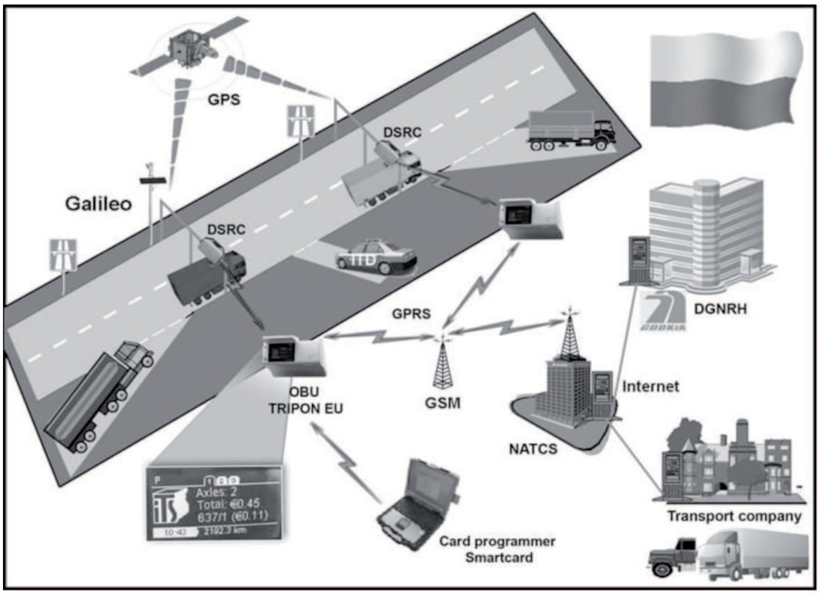


Fig. 4. Architecture of the National Automatic Toll Collection System

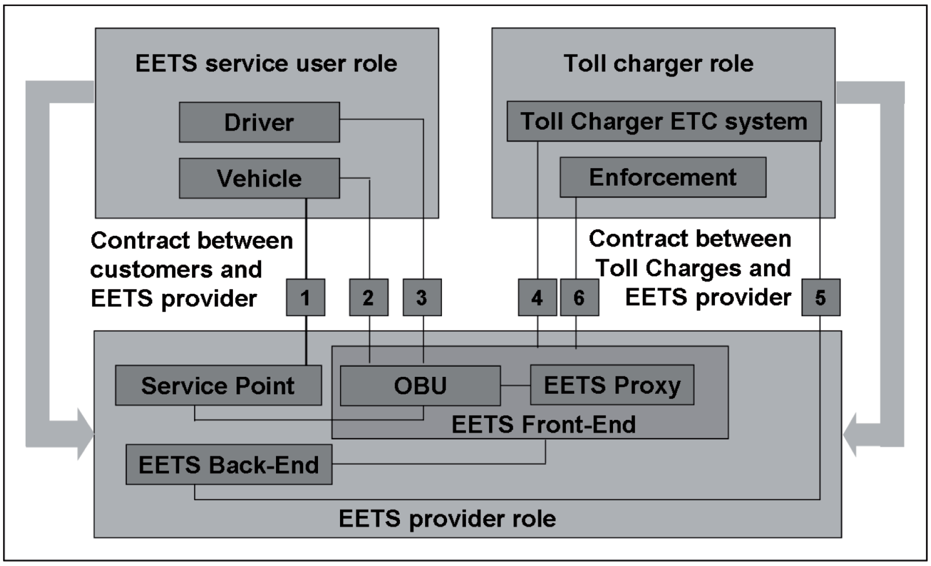


Fig. 5. Interfaces provided in the pilot project

1) Installation and maintenance contract for on-board equipment. OBU is configured using Smartcards.
2) Connecting to the vehicle. OBU is connected with the following points in the installation of vehicle: power, ground, ignition, tachograph.

3) OBU user interface. The screen displays the following information: the symbol of context (collection area) Toll (P for Poland), graphical representation of the Polish context of the toll (for example, outline of the borders of the country) declared number of vehicle axles, the total value of toll charged per vehicle run, amount due for passage of the current segment, the time and the amount of kilometres travelled from the time of installation.
4) DSRC Interface (5.8 GHz, IR) is used to conduct standard transactions with DSRC devices that are installed at tolling gate.
5) Data interface (from the tolling operator to the provider of the system). This is an ”internal” interface because in the test system there are no isolated places for toll collectors and suppliers of the system.
6) The tolling procedure was demonstrated with the use of DSRC antennas and ANPR cameras (Automatic Number Plate Recognition) on a test gate installed on a single lane.

2.3. OBU device

The onboard device TRIPON-EU (Fig. 6) is available in two different versions. The test system used the version mounted in a single casing collecting all components, including GPS and GSM antennas. This version is designed for installation on the windscreen of the vehicle.

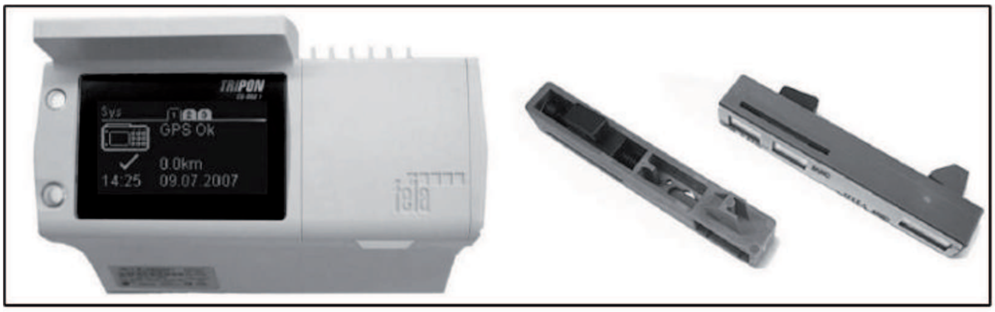


Fig. 6. An onboard OBU device and its mounting brackets

The OBU device should store the following data: vehicle class, vehicle weight, axles or class of emission, registration numbers and contractual details. Data can be entered into the device using a chip card.

The GPS module used in OBU devices supports computing navigation (DR, *dead reckoning)* to improve the accuracy of positioning.

GPS data (from satellites), supplemented by the results of computing navigation are used as an input for detection of on-ground facilities. Detected events are logged in the event file. The European EGNOS system can be enabled or disabled through the configuration file activated at the time of start-up. The device is designed to cooperate with Galileo.

Data recorded by the OBU onboard unit are transmitted to the internal components of the EETS system, using GPRS/GSM technology. The data transmission between the mobile onboard units and the internal elements of the system takes place via a proxy server, which operates completely independently of the billing and accounting system. Data is transferred in batches, which means that one does not need to maintain a permanent connection between onboard devices and the internal components of the system. This is one of the biggest advantages of the concept of smart clients. GPRS allows for even greater reduction of communications costs.

Tripon EU independently analyses the data (GPS location data, vehicle defined data, data on tariffs – fixed schedule of fees and other data) that are remotely transmitted, in real time, to the server. Data about events related to billing, and events relating to the control and supervision, is limited to a minimum, which significantly increases the throughput of the system and reduces the operating costs.

Depending on the required precision and an additional control, Tripon EU can operate in two positioning modes: using signals from GPS and being assisted by a signal trace from other onboard equipment. In order to verify system capabilities in both vehicles the OBU devices were checked using only the GPS signal and in conjunction with an additional device, from which passage signal was received. The comparison indicated a small discrepancy between the satellite positioning signal and the passage signal, indicating this by ”Delta Tacho +-x%” messages.

Fig. 7. OBU onboard unit – left: general view, right: display

Onboard equipment TRIPON-EU uses built-in GSM antennas, and there is no need for external antennas. The SIM card installed inside cannot be replaced by the user. For the convenience of testing, using the S button (send) one may activate a GPRS communication session at any time without having to wait for the next automatically initiated session. The onboard device TRIPON-EU can receive short text messages. These text messages can be displayed on the tab (Fig. 8) in the text message window.

Each received message can be: confirmed, denied, confirmed by way of a predetermined message or deleted by the driver.

Fig. 8. Onboard units OBU – SMS

For this purpose, appropriate options in the menu are provided. This functionality has been included to easily demonstrate the potentially available value added services that can be implemented on the platform TRIPON–EU.

The onboard TRIPON–EU device is equipped with a DSRC module (5.8 GHz, IR) DSRC (Dedicated Short-Range Communications). In cross-border traffic OBU device enables collaboration with GPS/GSM tolling systems (Germany, Slovakia) or DSRC systems used in other countries (Austria, Czech Republic, Italy, Spain, France). The basic standard used in these types of systems (DSRC) is the ISO EN 15509 standard (Media Transactions). The onboard TRIPON–EU unit makes use of such transactions in order to illustrate the possibility of tolling in cooperation with the vision system – ANPR.

Transactions can be configured in such manner, as to support DSRC attributes that are necessary in a specified tolling implementation.

Each onboard TRIPON-EU unit is equipped with a Smart Card interface, which can be used for calibration and initialisation purposes. When configuring the test system the Smart Cards will be used for: initiating onboard units with contract data, configuring parameters of onboard equipment, all operations with the use of cards can also be initiated via the GSM link.

OBU TRIPON–EU can be configured to operate as a less or more "intelligent" unit. For the purposes of technical tests in Poland the "more intelligent" mode of the device was selected. In this mode, all the events connected with the collection of tolls are detected in the onboard device and recorded in an event file. From time to time, the event file is transmitted via GPRS channel to proxy server. For the validation purposes data from the proxy server is exported in Excel or XML format. A controlling application of OBU onboard units – Control Centre provides access to data from any Web browser. Such access is only available to authorised users with an appropriate account (username, password). Accounts were made available to Autoguard company and the Motor Institute Transport for the entire testing period.

In order to conduct in-depth analysis, the onboard TRIPON–EU units were configured in such a way as to ensure that (essentially) raw GPS positions were transmitted to the server. In this way, the analysis involves both the file of events, as well as the raw GPS positions.

A properly installed onboard TRIPON–EU unit operates fully automatically. It is "woken up" by turning the ignition (Wake Up signal), when the ignition is on, it goes into standby mode and after a certain period of time – it goes into sleep mode.

Normally, the onboard TRIPON–EU unit can operate in one of several tolling modes. In the test system it was configured as an intelligent client, and it self-detected all events connected with the toll. In this mode, the device: works astronomically, it sums up the distance driven, detects all the events connected with the collection of tolls using satellite positioning system GPS, detects DSRC transactions, displays events on the screen, saves all events in the event file, the file periodically transmits events to the proxy server and receives data from the proxy server (data, status information, software updates). All messages and menu options are read from a text resource file.

Recorded events can be viewed directly on the onboard unit by pressing the DOWN button on its main screen.

The user interface of the onboard TRIPON–EU unit supports the following functions: screen sets of options (menu), the possibility of declaring the presence of a trailer.

For the convenience of testing, using the S button (send), one can initiate a GPRS communications session at any time without having to wait for next automatically initiated session. There is usually a standard screen displayed, showing the following information: toll context (collection area) symbol, (e.g. PL for Poland), graphic representation of the Polish context of the toll (for example, outline of the country borders) declared number of axles of the vehicle, the total value of toll charges per vehicle run, the charge for passage of the current segment, the time and amount of mileage from the time of installation.

A run begins at the moment of switching the ignition on when the onboard device is in STANDBY or SLEEP mode. The time of transition to standby mode and sleep mode are parameters that can be set using a Smart Card or from the GSM network. For test purposes, all screens were made available without any restrictions. In the implemented system a number of screens were not available to the user (driver), but only to personnel authorised to carry out in-depth analysis and the identification and examination of the sources of error. Using the TRAILER button one can display various declarations of trailers or the number of axles.

Esc + OK buttons display different information and configuration screens. The set of additional screens is implemented to enable displaying full details of the maintenance contract stored in the onboard device. These screens can also be displayed by pressing the ESC and OK buttons at the same time, and then selecting the appropriate options in the menu.

2.4. Control gates

The concept of toll control gates in the system tested in Poland is based on experiences of Fela company, collected during the operation of the Swiss system. The following devices are installed on control gates (Fig. 9):
– DSRC locator to carry out transactions with the traffic lane controller (according to EN 15509 standard),
– vision system ANPR (automatic number plate recognition and photographic documentation (ANPR, only from the front),
– a local driver software for the registration fee collection.

Fig. 9. Control gate at ITS in Warsaw

The DSRC locator conducts standard DSRC transactions (in accordance with CEN TC278/EN155509) detecting every vehicle passing through the gate.

Essentially the contract data is recorded, including registration numbers and characteristics of the vehicle.

The data collected should include in particular: the registration number and characteristics of the vehicle. This data is essential in the process of collection of fees – i.e. it is compared with the data incoming from the ANPR (automatic number plate recognition). The DSRC locator is mounted on the top of the gate, about 5-6 meters above the road. In addition to the beacon a so called "traffic lane driver software" should be installed on the gate, which will process data from the locator and control its operation during the transaction. The data should be periodically sent via Ethernet to the system's central unit.

The camera and the pulsed infrared radiation source are triggered by the PIR motion sensor. Together they record view of the vehicle from the front. During the test the views of the rear of the vehicles were also recorded. Sources of infrared radiation are offered with LED emitting waves of several different wavelengths: near infrared and infrared. The angle of the beam can be matched to the working distance. The LED based system made by Gardasoft VCubed is used as a source of intense infrared radiation useful in monitoring road traffic, for example: automatic recognition of vehicle registration numbers, management of speed of moving vehicles, identification of the types of vehicles. The source is suitable for the use during the day and night and in various weather conditions (snow, rain).

Using the trigger signal one synchronise the emitted radiation impulses with the exposure periods of the cooperating cameras. The remote communication port provides full control of beam intensity and width of the emitted pulses. The frequency of triggering impulses is internally limited to prevent damage to LEDs.

Depending on the location of gates and/or traffic conditions one can apply a variety of other triggering signals. The monochromatic ANPR camera will be equipped with an image converter with a resolution of 1620×1220 pixels and Gig-E interface. The controller installed inside the camera casing: transmits triggering signals to the camera/impulse source of infrared radiation, converts the signals from light sensor, based on signals from the light sensor generates the parameter settings of the camera/impulse source, controls the temperature in the camera casing (turn on/turn off the heating/cooling).

A photo of vehicle is transmitted to tolling server from a given traffic lane for further processing and is analysed in order to read the registration numbers. At the same time, it will serve as documentation if it is necessary to start tolling procedures.

To enable fully automatic gate operation, an ambient light sensor is used, whose signal is based on the control of the camera and the impulse infrared radiation source. The sensor is oriented on the detection of vehicles and has a dynamic range from 3 to 30,000 lux.

All data collected at toll control is transmitted to tolling system servers and is made available in the toll controlling software.

This software enables viewing of all collected images, results/details of ANPR algorithm operations and DSRC results.

For testing purposes, all registered images will be made available. This means that all the captured images will be saved. Since the function of automatic deletion of images will not be activated, many images will be saved following capturing resulting from false triggering. However, selecting the *Show Matches* option will limit result in displaying of only those that match the results of DSRC and ANPR.

The primary task of the test system is to present the technical capabilities of components and gaining and access to the data. However, it also takes into account aspects oriented on users of the final system, while the external parts of the system are tuned for specific operating requirements. Depending on the needs these may include: toll roads with manual collection of tolls, tolls road with automated tolling (DSRC), electronic tolling system for heavy vehicles (onboard GNSS/CN, EETS systems supplier), tolling via stationary, movable and/or mobile/handheld equipment, the interface of EETS providers, interface of state services (depending on operation model), interface of company operating the system.

The tolling system must be equipped with numerous interfaces. Each interface requires a detailed specification, although many of them are based on norms or otherwise they utilise standard protocols and safety mechanisms.

The pilot project is focused on interfaces associated with the road and external elements of the system operated by the user. Road related interfaces include (depending on the requirements of the system): GNSS interface (GPS, Galileo), CN interface (GSM), DSRC interface.

GNSS Interface (GPS – Galileo) – This interface is installed and can not be altered in any way. The onboard TRIPON–EU units record (in files) every instance of losing of GPS signal for more than a specified period of time.

DSRC Interface – DSRC interface (5,8 GHZ, IR) is fully compatible with the newest CEN DSRC standards.

DSRC Interface for tolling transactions – Such transactions make use of the model compatible with the EN 15509 tolling data transmission standard. This model was used in the test system. Currently the European Union is working on a new interface standard for the general tolling interface, in particular including GNSS solutions (ISO 13813).

DSRC Interface for auxiliary locators – In critical areas, or where GPS positioning accuracy is inadequate, the situation can greatly be enhanced by the auxiliary locators *(augmentation beacons)*. Augmentation beacons provided by FELA are powered by photovoltaic cells.

Augmentation beacons operate based on the same DSRC protocol as that specified in the above-mentioned standards. There is a one-way communication (from the locator to the onboard device) and takes the form of the direction-less broadcasted messages. This is how each locator transmits information about its location. The form of this information is identical to the form of position data from GPS receiver, or it is information directly identifying the toll due at that point of collection (which is most effective). The European Union is currently developing standards for *DSRC broadcast* transactions.

GSM Interfaces – In the modern electronic tolling systems key role is played by interfaces utilising GSM data communication.

GSM interface for onboard devices – This interface is used to exchange data with onboard equipment. Normally, the TRIPON device must communicate once a day to transmit the log file to the internal components of the tolling system and to download software updates. If necessary, the communication sessions can be initiated more frequently, and in the test system they were initiated every 4 hours or on demand. Each time the onboard device connects to the proxy server, it checks if there are any new updates and if that is the case, it downloads them immediately. This interface was built into the test system.

GSM interface for tolling – Data from mobile and portable tolling devices can be transferred to the internal components of the system (EFBO, Enforcement Back Office) via GSM links. In the case of fixed gates, however, it is recommended that instead of GSM links, the wired connections be used (due to costs, stability, bandwidth). In the test system, tolling data was broadcast over an Internet.

GSM Interface for augmentation beacons – Augmentation beacons must communicate with internal components of the system to configure and control their condition. For such purposes, the GSM interface is ideal. What is necessary here, is transfer of small amounts of data. Thanks to GSM connection augmentation beacons can be located virtually anywhere without any restriction.

WAN/Internet Interface – Many elements of the system communicated with the rest of the system via the Internet (WAN). These interfaces were used in the tested system.

2.5. Laboratory NATCC model

The laboratory model of National Centre for Automatic Toll Collection (NATCS) comprises of the following elements:

- Three PCs – one dedicated as a database server, the second one serves as application software server, while the third one is a user terminal,
- application and system software,
- databases,
- software and physical interfaces (between NATCC and OBU, between NATCC and control gates),
- user interface ((online WWW service).

PROXY Server – In the proposed solution the proxy server is the main element of the service provider's interface. It supports and controls OBU's sending and receiving of all data. The system operates using Linux and ensures stable operation.

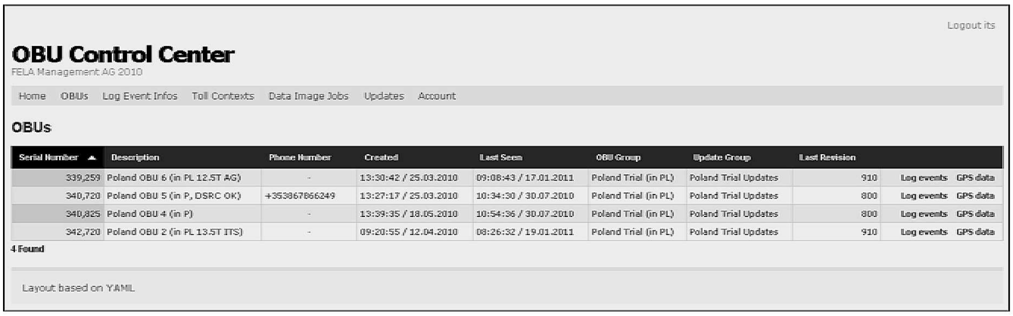
The task of the proxy server should include communication only, but also including SW updates of OBU devices. Toll tariff tables and geographic objects displayed on OBU's screen should be sent from a proxy server to the OBU. Data received from the OBU should be checked for consistency, and then made available for analysis.

OBU Control Centre – The system should include a program allowing for remote operation of the OBU device. This could be an "OBU Control Centre" for checking of the status of the OBU device, sending data to the OBU, controlling the output data, displaying of GPS route data (only in thin client mode), and allow export of data for further analysis by other programs. Export of all data for further analysis performed by using standard tools (e.g. Excel) should be done in XML or CSV. The program should also enable generation of reports, such as shown in Table 1.

Service software should allow to monitor the proper operation of all equipment installed on the gate. Due to the need to automate the test procedure, the checking should be performed with minimal involvement of the operator and should include control of the DRSC communications system and the vehicle classification module, as well as the plates detection process (ANPR). Moreover, if irregularities are detected during normal operation or inappropriate status of the OBU device is detected and transmitted via the DSRC, the data recorded by the gate should be saved, including relevant photographs documenting the passage of the vehicle. Based on the submitted data and photographs the operator will be able to attempt to assess the cause of failure and forward a repair crew to the place.

Table 1

A sample general report – list of events generated in the OBU Control Centre



Logout its

OBU Control Center

FELA Management AG 2010

Home OBUs Log Event Infos Toll Contexts Data Image Jobs Updates Account

OBUs

Serial Number	Description	Phone Number	Created	Last Seen	OBU Group	Update Group	Last Revision		
339,259	Poland OBU 6 (in PL 12.5T AG)	-	13:30:42 / 25.03.2010	09:08:43 / 17.01.2011	Poland Trial (in PL)	Poland Trial Updates	910	Log events	GPS data
340,720	Poland OBU 5 (in P, DSRC OK)	+353867866249	13:27:17 / 25.03.2010	10:34:30 / 30.07.2010	Poland Trial (in PL)	Poland Trial Updates	800	Log events	GPS data
340,825	Poland OBU 4 (in P)	-	13:39:35 / 18.05.2010	10:54:36 / 30.07.2010	Poland Trial (in PL)	Poland Trial Updates	800	Log events	GPS data
342,720	Poland OBU 2 (in PL 13.5T ITS)	-	09:20:55 / 12.04.2010	08:26:32 / 19.01.2011	Poland Trial (in PL)	Poland Trial Updates	910	Log events	GPS data

4 Found

Layout based on YAML

The databases are located on dedicated servers and kept synchronized. They have relational structure and are equipped with internal programming languages, using SQL to manipulate data.

The databases were developed using cluster solutions that ensure instant data recreation in the event of hardware failure.

Databases in NATCC are divided into the following groups: data on users, vehicles and tariffs, Physical Inventory, Dynamic Inventory.

Data on users, vehicles and tariffs – The required basic data on users include: name of company and its legal form, first and last name of representative, NIP *(Tax ID Number)*, REGON *(Statistical ID Number)*, official address and billing address, phone, e-mail, fax, username and password to log on the website, additional data for verification purposes (e.g. PIN), configuration data (selected way payment, manner of delivery of reports, etc.), list of vehicle IDs of the user.

For the purpose of testing two OBU devices were used, but in the middle of the test they were replaced with two new devices, and hence the table includes data on four logical devices, with different registration numbers. The database contains information about the vehicle controlled at the gates. Their scope includes: vehicle identifier and OBU device identifier, the country code, registration number, vehicle weight and weight set, the mass of the truck tractor, the number of axles.

Toll rates for each kilometre of road travelled are set individually by the European Union Member States. Decisions on inclusion or exclusion or any individual road segment are also made independently by each EU Member State. The system's database including tariffs must be continuously updated based on the laws of the State in which the system is installed.

The Motor Transport Institute, taking into account the views of drivers and ZMPD, proposed tolls taking into account the number of axles, the maximum permissible weight of the vehicle, the class of emission, and the distance travelled in km). In addition, the category of roads was taken into account: motorways, expressways, national roads. The rates of course require more detailed financial analysis, and can be increased, while the criteria used to rank the charges appear to be reasonable and appropriate (Tables 2, 3).

Table 2

Proposal of toll rates for Poland – motorways, expressways

Vehicles	Class		Emission class		
			EURO 0-II	EURO III	EURO IV and >
Trucks	3,5 – 12 t		0,312 PLN	0,273 PLN	0,234 PLN
	> 12 ton	2 axles	0,468 PLN	0,429 PLN	0,390 PLN
		3 axles	0,507 PLN	0,468 PLN	0,429 PLN
		4 axles	0,546 PLN	0,507 PLN	0,468 PLN
		5 axles and more >	0,585 PLN	0,546 PLN	0,507 PLN
Buses	3,5 – 12 t		0,234 PLN	0,195 PLN	0,117 PLN
	> 12 ton		0,390 PLN	0,273 PLN	0,195 PLN

Source: ITS, Warszawa, June 2010.

Table 3

Proposal of toll rates for Poland – national roads

Vehicles	Class		Emission class		
			EURO 0-II	EURO III	EURO IV and >
Trucks	3,5 – 12 t		0,273 PLN	0,234 PLN	0,195 PLN
	> 12 ton	2 axles	0,429 PLN	0,390 PLN	0,288 PLN
		3 axles	0,468 PLN	0,429 PLN	0,390 PLN
		4 axles	0,507 PLN	0,468 PLN	0,429 PLN
		5 axles and more >	0,546 PLN	0,507 PLN	0,468 PLN
Buses	3,5 – 12 t		0,156 PLN	0,117 PLN	0,078 PLN
	> 12 ton		0,312 PLN	0,234 PLN	0,156 PLN

Source: ITS, Warszawa, June 2010.

Currently the level of tariffs to be applied in the new toll system in Poland is unknown. Tadeusz Wilk, director of the Department of Transportation ZMPD, during the Polish Road Congress in June 2010, stated that the carriers were wary of high rates. In his opinion, they should be at the level of 20 to 46 groszes per 1 km. High tariffs are also something feared by Bolesław Milewski, president of the National Union of Transport Employers.

For proper operation of the system a Physical Inventory of spatial resources is required, which in this case implies the geographical coordinates of the beginnings and ends of segments, making up the toll roads, as well as the coordinates of the control gates. The coordinates are stored in the WGS-84 format (World Geodetic System '84), which is a set of parameters that describe the size and shape of the Earth and its gravitational properties.

The NATCC database includes coordinates for the route of Płońsk – Garwolin and Garwolin – Płońsk. The route is divided into segments. The segments were defined differently for different directions (different number of segments, tolling points at different locations.) In addition to geographical coordinates a number of other parameters are assigned to each segment, such as road type and amount of the toll.

The dynamic database of location information (Dynamic Inventory) stores data that may change over time, such as: location information from OBU modules about vehicles on toll sections of roads, messages from control gates received by DSRC devices, messages from control gates about vehicles photographed and identified registration numbers using the Automatic Number Plate Recognition technology (ANPR).

During the test, based on messages from OBU devices and with the use of location information from GPS system – the following number of test vehicles on toll roads was registered (Table 4).

Table 4

Number of segments registered with respect to individual OBU devices

OBU	Number of segments
Poland OBU 6 (in PL 12.5T AG)	234
Poland OBU 5 (in P, DSRC OK)	76
Poland OBU 4 (in P)	53
Poland OBU 2 (in PL 13.5T ITS)	467

Detailed location and vehicle travel information is assigned to each segment. Each record contains the following data: Timestamp – date and time of registration, Longitude – WGS 84 format, Latitude – WGS 84 format, Heading – [deg], Velocity – [km/h], Altitude – [m], Satellites – number of satellites "seen" at the time of measurement, PDOP – relationship between the error in the calculation of user's position and the error in the calculation of satellite's position, it informs when the location of satellites will allow to gain the most accurate result, the desired value of PDOP is less than 3, Tacho – vehicle mileage [m].

3. Conclusions

Electronic tolling systems, implemented in the Member States of the European Union are generally incompatible and can only communicate with their own recording equipment. Such lack of interoperability between tolling systems is particularly onerous for international road transport.

The European Commission has taken two mile steps in this regard. The first was Directive 2004/52/EC of 29 April 2004 on the interoperability of electronic road toll systems in the Community. Then was the decision of the European Commission of 6 October 2009 on definition of the European Electronic Toll Service (EETS), and system architecture.

The system created by Motor Transport Institute is a hybrid type system and includes the following elements: two on-board intelligent devices – OBU, two control gates, laboratory model of a National Centre for Automatic Toll Collection (NATCS). The pilot project of NATCS meets requirements of the 2004/52/EC Directive and European Commission Decision of 6 October 2009. Furthermore the NATCS is interoperable with different types of EETS systems in all European Union countries.

The pilot project of the Motor Transport Institute can be used in researches on the implementation of the interoperable system in EU member states.

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