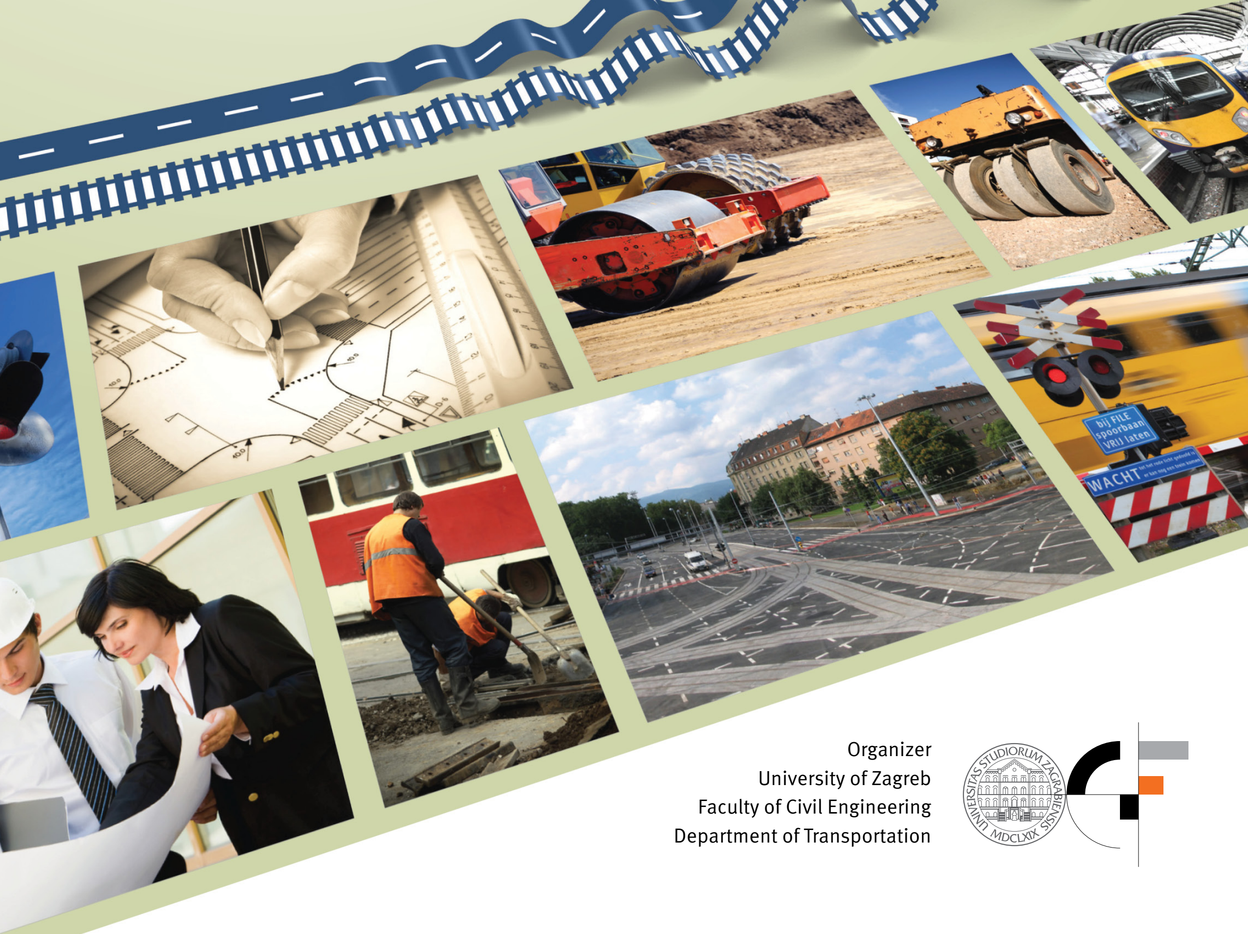
CETRA[2012]

2nd International Conference on Road and Rail Infrastructure

7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

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2nd International Conference on Road and Rail Infrastructures – CETRA 2012
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Road and Rail Infrastructure II

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THE POLISH SCIENTIFIC RESEARCHES ON ELECTRONIC TOLL COLLECTION AREA

Gabriel Nowacki
Motor Transport Institute, Poland

Abstract

This article presents tests results of the pilot project – The functional structure of the National Automated Toll Collection System (NATCS). During the tests OBU automatically charged a fee (toll), taking into account the category of vehicle (admissible mass, the number of axes), the category of emissions, and distance of road travelled. OBU is equipped with GPS, GSM and Dedicated Short Range Communication (DSRC) modules, which ensure its interoperability with other European Electronic Tolling Systems (EETS) in the EU Member States. The system meets the requirements of 2004/52/EC Directive and the EC Decision from the 6th of October 2009. Tests proved high effectiveness of automatic number plate recognition, being 99, 9%. The analyses of PDOP (Position Dilution of Precision) parameters showed that 90% had the value below 1, and 8% value from 1 to 3. Based on tests, the maximum number of satellites for localization was – 11 and minimum – 5, that create value 99%.

Keywords: EETS, NATCS, DSRC, interoperability.

1 Introduction

There are two different types of European Electronic Tolling Service (EETS): Dedicated Short Range Communication (DSRC) and GPS/GSM based systems.
In most EU countries (Austria, France, Spain and Italy) DSRC type systems of electronic tolling are used, 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. 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. 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. 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.
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.

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 [1]. 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 [3].
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, GNSS1. 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.
The best universal solution in complicated situation in UE is implementation of hybrid system (includes: DSRC, GSM, GPS technology), the researches developed in Czech Republic, NATCS is mentioned type of system.

2 Researches characterisation of NATCS

2.1 Test structure of NATCS

The research team identified KSAPO's functional structure, which consists of the following elements:
· Intelligent on–board device called TRIPON-EU, which was installed in 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 KCAPO,
· 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 onboard device TRIPON-EU (Fig. 1) 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.

Figure 1 An onboard OBU device and its mounting brackets [4]

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 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 technology (packet data transmission system used in 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 the control and supervision, are 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 assisted by a signal trace from other onboard equipment. In order to verify system capabilities in both vehicles 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 these by 'Delta Tacho +-x%' messages.
On–board equipment TRIPON-EU uses built–in GSM antennas, 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.
The device board TRIPON - EU 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 unit TRIPON – EU makes use of such transactions in order to illustrate the possibility of tolling in cooperation with the vision system – ANPR.

2.2 Tests results of NATCS

Tests of the NATCS system, including control of OBU devices, tolling segments at selected sections of roads as well as control gates were conducted in July and August, while vehicles passing through the control gates were registered from 1st July to 30th November 2010. The tests of the system were conducted by Motor Transport Institute, FELA Management AG and Autoguard SA.
The architecture of the system is in conformity with Directive 2004/52/EC and decision of the European Commission of 6th November 2009 as well as the CE and ISO standards.
During the test four OBU Tripon EU units were examined, whose task was to detect all events associated with the collection of toll directly in OBU, as well as in the log file and display them on the screen. OBU is also meant to send log files to the proxy server and receive data from the

server (data, status information and software updates.) For testing purposes four vehicles were added to the database
Out of the several proposed test route options we chose the Płońsk–Garwolin, Garwolin – Płońsk route, as the most diverse one that allows for checking the greatest number of elements of the system, including in the immediate vicinity of the route the both control gates and allowing the use of as many as three actual segments of expressways:

- two segments of expressway S7,
- one segment of expressway S17,
- two segments of National Roads.

On the basis of recorded data, transmitted by the vehicle in the form of messages, it was possible to recreate the exact route of the vehicle with the OBU device.
One of the most important parameters determining the accuracy of measurement and transmitted in location messages is PDOP (Position Dilution of Precision) – defect in determination of position precision. PDOP is a coefficient describing the relationship between the error of user's position and the error of satellite position.
The value of any of the parameters equal to 0 means that at any given time measurement of position is impossible due to interference, weak signals from the satellites, too few visible satellites, etc. The smaller the value of this parameter (but greater than zero), the more accurate is the measurement. The following descriptions signal quality depending on the value of PDOP are assumed: 1 (perfect), 2–3 (excellent), 4–6 (good), 7–8 (moderate), 9–20 (poor),› 20 (bad).
The data of the PDOP parameter obtained in the tests was presented on Fig. 2. The horizontal axis (X) depicts are values for PDOP. The vertical axis (Y) depicts the number of measurements (in percentages) during which a given value of PDOP was obtained. The stats were calculated based on 4627 measurements of position.
Average value of PDOP for all OBU was 90 % of perfect and 8% excellent values. Analysis of the measurement data of the PDOP parameter and the number of satellites used during the test showed that 90% of the PDOP measurements were lower than 1, which should provide accuracy of location accuracy with error of no more than 6 meters.

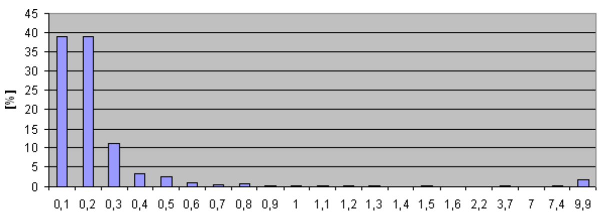

Figure 2 Results of PDOP

The number of satellites used for measurements of all OBU devices is presented in Fig. 3. For purposes of KSAPO it was assumed that GPS receiver in OBU should track at least 5 satellites, for more accurate calculations and in the event of loss of signal from one of them.

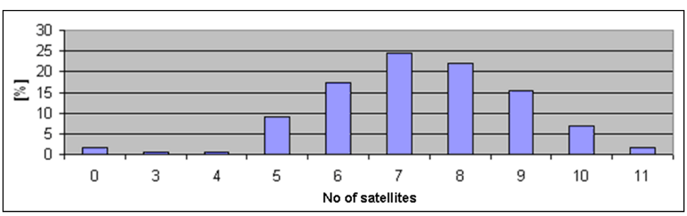

Figure 3 Number of used satellites for localization

The presented data shows that the maximum number of satellites used in for the purpose of location was 11, and in the case of 99% of measurements at least 5 satellites were used (the detailed results of satellites: (5 – 10%, 6 – 17%, 7 – 25%, 8 – 22%, 9 – 16%, 10 – 7%, 11 – 2%).
As part of the project two DSRC gates with tolling system were prepared. This has allowed for testing of the following functions:
· operation of DSRC microwave devices
· operation of visual system ANPR system (automatic number plate recognition).

From 1st July to 30th November 2010, 2964 vehicles passing through control gates were registered n the database of the system. Not all vehicles were equipped with OBU.
During the tests at the ITS Demo and Autoguard Demo gates, using the DRSC system, passage of 24 test vehicles was recorded. During the tests at the ITS Demo gate as many as 667 photographs of passing vehicles were taken.
During the tests at the Autoguard Demo gate 2297 photographs of passing vehicles were taken. Example of the vehicle photo is presented in Fig. 4.
The registered vehicle was equipped with a French made OBU device – Passango (DSRC). It was fully identified in the system as a user, which means that the KSAPO system is interoperable and can work with both, systems of DSRC type as well as GPS / GSM systems.
During each and every passage the operation of control gates as well as the conformity of the DSRC data with the ANPR (automatic number plate recognition) reading was verified. For the purpose of the second stage the onboard OBU devices were replaced with new ones. Due to a mistake the devices were wrongly installed, however the system immediately discovered the error.
Also the operation of the control gates was tested – mainly with respect to the detection of various vehicle speeds. Thanks to this, it was possible to adjust the software and then to check the newly replaced onboard OBU devices with respect to the correctness of detection of vehicles coming up to the control gate at especially small selected speeds. The system detects vehicles travelling at speeds of 1 to 200 km/h.

Figure 4 Picture of WWY 07512, PTM, 5 Przemysłowa Street, 07–200 Wyszków

Legend: Date (ANPR): 28.09.2010 09:25:53; Reg. no. (ANPR): WWY 07512; Accuracy: 0.980; Gate ID: 3; Gate name: Autoguard Demo; Date (DSRC): 28.09.2010 09:25:54; Country code: F (France), Registration number (DSRC): WWY 07512; Context data: WWY 07512; OB ID: 1103467888; Vehicle ID: 2147483647; Emission class: 1; Vehicle class: 1; Vehicle weight: 18000; Total weight: 40000; Number of axles: 5; Means of payment: 2147483647.
In addition to test the drives and the checking of the functionality of the, the efficacy of the gates was checked, recording all vehicles passing at the premises of Motor Transport Institute

and at the premises of the AutoGuard company in various weather conditions and at various times of day. The efficacy of automatic detection of number plates was 99,9%. All the segments were identified correctly by the onboard devices, and there were no problems in this respect. Each segment consisted of three points, and in order for each one of them to count, all three segments had to be detected by the OBU device. As a result of this drivers who will cut through toll roads, or only pass through them, will not be registered in the system.
The tests were successful and confirmed the efficacy of the selected solutions in accordance with the assumptions of the project.

3 Conclusions

During the test of NATCS phase, from 1st July till 30th November 2010, 2964 vehicles passing through control gates were registered in the database of the system. In addition to testing the drives and checking the functionality, the efficacy of the gates was checked, recording all vehicles passing at the premises of Motor Transport Institute and at the premises of the AutoGuard company in various weather conditions and at various times of day.
The functional structure of NATCS is according to directive 2004/52/EC, decision of European Commission from 6th October 2009 and CEN standards. The efficacy of automatic detection of number plates was 98%, and thanks to proceeding data by analyze stand, the efficacy of the system increases to 99.9%. Analysis of the measurement data of the PDOP parameter and the number of satellites used during the test showed that 90% of the PDOP measurements were lower than 1, and 8% had value from 1 to 3.
For the purposes of NATCS it was assumed that GPS receiver in OBU should track at least 5 satellites, for more accurate calculations and in the event of the loss of signal from one of them. Tests results showed that in the case of 99% of measurements at least 5 satellites were used for the purpose of location,
The NATCS turned out to be flexible when it comes to extending toll collection to every road category, every category of vehicle and, what's more, in terms of cost efficiency in implementation and operation. Another advantage is an absence of the need for new road infrastructure (gantries), while the operators can keep using the existing infrastructure. System works without toll booths, extra lanes, speed restrictions or complex structures along toll roads. Furthermore the system ability to support other value–added services on the same technology platform. Tests of NATCS project has been a complete success. The system uses GPS/GSM technologies, but also recognises devices such as DSRC and OBU. During tests, the system recognised four Tripon – EU OBU's, French made DSRC Passango device and a German made Toll Collect device of the GPS/GSM type, installed in a vehicle which did not participate in the test, but accidentally ran through the control gate. This implies that the NATCS system is interoperable and can cooperate with both GPS/GSM systems as well as with DSRC types of systems existing in other EU Member States.
Acknowledgement: The paper has been prepared with framework of NATCS Pilot Project, N R10 0001 04.

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