AUTONOMOUS ELECTRONIC TOLL COLLECTION SYSTEM AS A PART OF LOGISTIC INFORMATION SYSTEM

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Abstract

The paper deals with the design of a possible technical solution of utilisation of an autonomous (satellite) system of electronic toll collection in the framework of a logistics information system. The introduction is dedicated to general characteristics of autonomous electronic toll collection system and the state in the Slovak Republic. The principles that were respected during the design are defined. Further the On-Board Unit (OBU) is analysed and then its specifications and restrictions, the communication OBU with the sensors (e.g. RFID) and OBU with tracking system is solved. Finally the overall description of the designed solution and possible multiple utilisation in practise is presented.

Keywords: Toll, logistics, T&T, on-board unit, RFID

1. INTRODUCTION

Charging of road infrastructure is used as a financial instrument or measure for traffic regulation [1]. The framework for technological solution of electronic toll collection defines Directive on the interoperability of electronic road toll systems [2]. The Directive determines that toll systems based on On-Board Unit (OBU) should use at least one of mentioned technologies (satellite positioning, mobile communications using the GSM / GPRS - Global System for Mobile Communications / General Packet Radio Service, 5.8 GHz microwave technology). Generally deployed systems so can be microwave or satellite also referred to as autonomous (based on satellite positioning and mobile communications) [3].

Despite of incontestable advantages of satellite technology (flexibility, potential to offer value added services, technological readiness for European Electronic Toll Service, …), the technology has been enforced relatively moderately (Germany, Slovakia, Hungary). The modern satellite toll system in Slovakia was deployed in 2010 [1]. Meanwhile the system has proved its effectiveness, reliability and flexibility. Taking into account modern technological solution, the question of possible multiplicative utilisation of available resources has raised [4]. On the other hand there are many areas where the telematics resources can solve specific technical requirements, e.g. in asset management [5], logistics [6, 7, 8], Smart City [9] and so on.

In generally the toll system can be divided into a number subsystems: central equipment (CE), On-Board Unit (OBU) and enforcement (can be realised as fixed, portable and mobile one). The principle (**Figure 1**) of the autonomous (satellite) toll system is that OBU receives signals from GNSS (Global Navigation Satellite System) satellites (currently specifically GPS - Global Positioning System) on base which the location of the vehicle is determined and thereby the use of particular charged road segment [10]. The decision of using particular charged segment can be realised in OBU (so called thick client) or in CE (so called thin client), Slovak solution is somewhere between this approaches - a part of this process is realised in OBU, the rest in CE. The information from OBU is necessary to transmit to CE so what a mobile communication network serves on (it ensures so called wide area communication). On the purposes of enforcement (and in microwave systems also for tolling) a microwave technology dedicated short range communication (DSRC) is used (it ensures so called spot communication with enforcement gates, enforcement portable devices and enforcement vehicles).

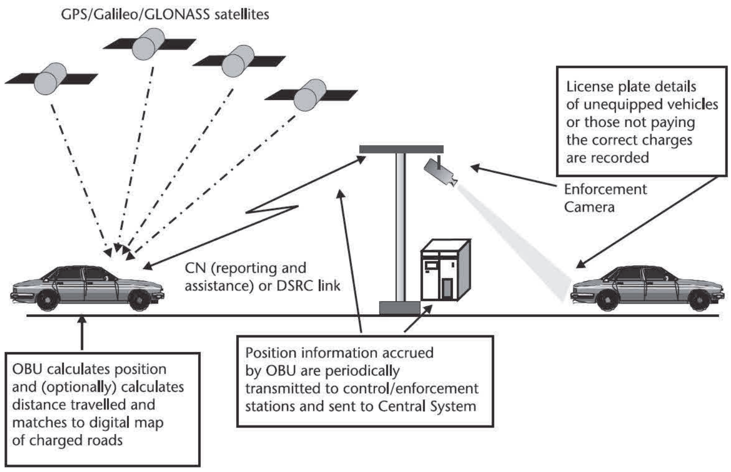

Figure 1 Principle of a satellite system [10]

2. ELECTRONIC TOLL COLLECTION IN SLOVAKIA

Since the beginning of operation of the system in Slovakia, electronic toll collection has been applied on vehicles and vehicle combination over 3.5 tones (excluding vehicles exempted from tolling duty according to toll) which are obligatory equipped OBUs, while the other vehicles (up to 3.5 t) are charged in time (via vignettes, since 2016 via e-vignettes). Till the end of 2013 charging was applied on motorways, highways and selected 1st class roads and legislative changes were related to issues which had been brought by practice application of the law. Since beginning of 2014 essential changes has been introduced namely in that the selected road network has been significantly extended on all 1st, 2nd and 3rd class roads (even though some 1st class road sections and all roads of 2nd and 3rd class roads with null rates, whereby nonzero rates were applied on tolling of town and village passing roads at the beginning of 2014), system of discounts from toll rates has been introduced (up to 9% according distance travelled), strict liability has been introduced and European electronic toll service has been legislatively adopted [11].

After the changes, the coverage of toll scheme is almost all roads in Slovakia (just local, commercial and specific roads are not covered). Particularly, as of October 2016, total length of the motorways, expressways, 1st, 2nd and 3rd class roads in Slovakia is 18019 km of which 17559 km are selected in the framework of toll scheme (**Figure 2**). The selected road network is covered by 4134 toll sections and the scheme registers more than 255 thousands OBUs.

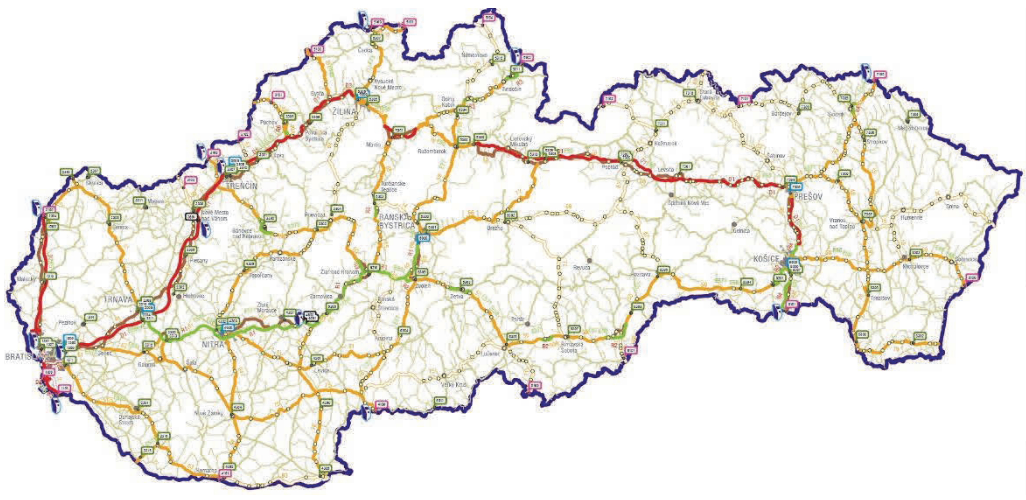

Figure 2 Map of selected roads in 2016 [12]

Since first statutory the text of Act on electronic toll collection, the Directive [2] has been took over into Slovak legislation. Followed description shows that the Slovak OBU disposes all of the required technologies what means that from technical point of view it fulfil the requirements on interoperability.

3. PRINCIPLEAS AND OBJECTIVES OF DESIGN

The basic idea, according to the above mentioned, is to utilise available resources disposable in the framework of electronic toll collection system, i.e. mainly OBU and communication infrastructure. It is evident that it is necessary to consider all aspects of applicability of available OBU for supposed purposes so that the designed solution will not require essential modification of OBU or even development of new OBU type.

From point of view of functionality of the system, there are defined fundamental borders that have to be kept. Primarily it should not affect functionality, reliability and security of toll collection procedures what secondarily means that the toll system disposes sufficiency of computational, communication and energy resources in the all affected subsystems and levels.

In term of operation of toll system - of the relationship charger-operator of the toll system (i.e. considering the relationship of toll collection for a road use of charged road segments vs. alone operation of toll system - what compensation for system operation service to operator from charger is related with) - it is necessary to monitor costs initiated by a new service, i.e. investment and operation costs associated with a new commercial service in regard to using of resources procured as toll collection service.

The investment and operation costs have to be adequate to benefits of the T&T (Track & Trace) service, i.e. in order to be such service a commercially interesting. This should be also supported by that the service should be public available through various communication means and be sufficiently flexible and scalable. It also means the flexibility in defining of the range of monitored data (mainly related to load) including the trigger of the data transmitting (e.g. periodically or after the change of state or data), flexibility in the placement and RF (Radio Frequency) parameters of a RFID (Radio Frequency Identification) reader and flexibility in the defining of user interface (e.g. dispatcher workplace) to communicate with the server (T&T centre).

4. USE OF TOLL OBU

According to the above mentioned analyse it follows that OBU is an effective navigation (it includes GPS module) and communication means (it includes DSRC and GSM / GPRS module). That means it can be utilised in a number manners, one of the way of using are applications safety, in logistics - mainly for T&T purposes and many others [4].

Three versions (generations) of on-board units have been used for electronic toll collection (**Figure 3**) so far, mainly different in human - machine interface - Continental VDO 1374 [13], Sitraffic Sensus Unit [14] and Billien OBU 5010 [15], while all of them dispose basic required means for localization (GPS module) and mobile communication (GSM module). According to available information all types are equipped with service interface which detailed specifications are not known but it can be assumed that this service interface is USB type. Other interface for contact with the surroundings usable for communication with RFID reader or sensor network is not currently available [4]. It can be also assumed that more modern OBUs would be possible to equip with other types of interfaces either wired (e.g. serial interface, CAN - Controller Area Network) or wireless (Bluetooth, ZigBee) because the new generation OBUs are considered also for other telematics applications. In all variants of OBU the coordinates of the vehicle obtained from embedded GPS receiver are acceptable in respect of accuracy and periodicity.

From point of view of communication facility, OBU dispose of two communication modules: DSRC and GSM / GPRS. In term of communication with CE (and by that also for communication with considered T&T system) DSRC is nonutilisable in regard to spot type of communication. Moreover, with respect to typical characteristics of DSRC (communication range in order of meters, installation of OBU behind the front screen, communication zone of OBU directed at front of vehicle), DSRC communication is not usable either for communication with RFID reader located at cargo space (additionally it would be uneconomical because RFID reader should be equipped by DSRC interface).

Figure 3 OBU used in the Slovak electronic toll collect system

A possible solution of this problem is presented on the **Figure 4**. The principle of this solution consists in using of matching node that shall convert the data from RFID reader placed on the cargo space of vehicle into data format of OBU interface. Certainly it has a consequence of need of OBU software (adding appropriate application) and adaptation the interface towards the driver (HMI) to be able to handle the application.

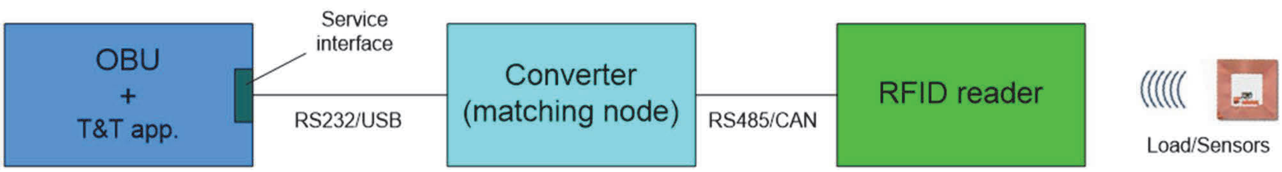

Figure 4 Principle of interconnection of RFID reader network with on-board unit

Hence for communication OBU with T&T system, it remains communication by means of mobile network GSM - data transmission in packet mode, i.e. GSM / GPRS. Directly, i.e. that application dedicated to T&T in OBU should communicates with T&T system, it is no possible because GSM / GPRS module in OBU (for security reasons) can communicate via one phone number (that is primary dedicated to send toll data). Consequently CE has to also have a function of an interagent that has to filter data received from OBU (evidently functionality of CE has to be accordingly extended). On principle it is shown on the **Figure 5**. From point of view of transfer rate and periodicity of data sending, the proposed system will communicate in real time - a communication delay can be caused on the side of OBU (the toll data transfer will have higher priority), by delay in GSM network and by filtering of received data from OBU in CE.

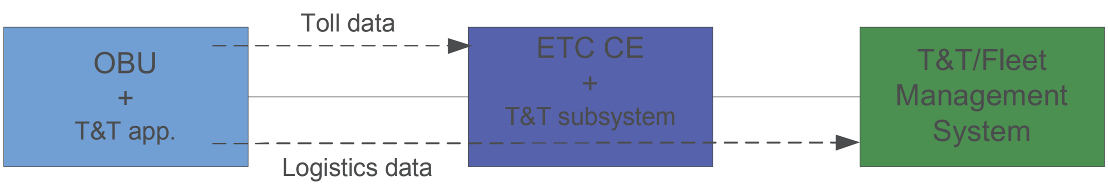

Figure 5 Communication OBU with T&T system

5. OVERALL PROPOSAL

Overall solution of T&T system based on toll OBU results from presented analyse and deduced characteristics and restrictions and partial conclusions. In addition to the primary function, OBU will have implemented additional application that will in charge of communication with RFID reader, with driver and with T&T central system.

Considering the volume of data transfer related to T&T is not crucial (approx. from hundreds of B to a few of kB), it can be assumed that the GSM / GPRS transmission will be suitable for this application. CE has to be supplemented on subsystem (as far as the hardware is sufficiently dimensioned, it will include just implementing the software application) that will filter data generated by OBU to toll data and T&T data and monitor selected performance parameters characterising costs of T&T service. Toll data will be processed the same way as it has been so far and T&T data will be redirected to deployed T&T system (that can serve as an system for fleet management because the data from OBU can contain identification of the shipment - via ID of RFID reader, ID OBU or vehicle´s licence plate, and also the time and position data or sensor data respectively). T&T system will be in charge of communication with CE (and then also with OBU), process and store the data and provide the processed data via client (end user) access.

T&T system (**Figure 6**) can be utilised by different users as hauliers, shippers, forwarding houses, logistics centres and freight terminals (e.g. because of planning of capacities), traders or manufacturers (e.g. for just-in-time production), perhaps even authorities.

It is evident that in the framework of one realised shipment, a number of subjects can have an access to certain data concerning a particular transport or load. So a set of procedures has to be defined that determines which of subjects will be an “administrator” of the shipment in T&T system and it will define access rights for other subjects to access the particular data.

For access of all mentioned groups of users it is necessary to choose the most versatile solution, so the T&T system should provide standard but secure web interface for all practically used platforms. User interface should allow not only providing of visual information, but also administration and setting up (e.g. defining of user interface and the range of data transmitted from RFID / sensor to OBU). Furthermore the obtained data should be possible to forward to existing information systems that the mentioned subjects dispose (e.g. ERP, CRM).

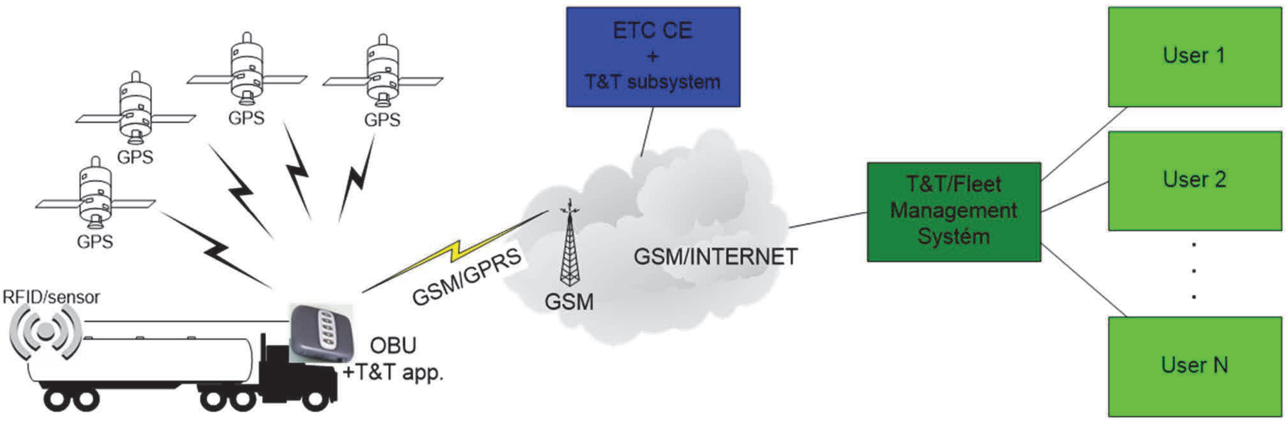

Figure 6 Overall solution of T&T system

6. CONCLUSION

The presented proposal presents a general solution, it is not restricted only to Slovak conditions, because the mentioned specifics of the Slovak electronic toll collection system are not crucial. Therefore the proposal is possible to apply and adapt to other autonomous toll schemes or different telematics systems based on satellite navigation and mobile communication. The principle is that there is no need to deploy a new system, but the proposal is only based on the amendment of RFID technology and software upgrade.

The scope of the possible users is relatively broad. In commercial area it is potentially all subjects linked with road or intermodal transport as manufacturers, carriers, shippers, dealers, logistics centres, freight terminals and so on. This is the primary determination of the T&T system. Secondarily T&T system T&T system can serve state to tracking of goods flows, either for statistical purposes or objectives in tax and custom supervision. The generated data (data on traffic intensities, road segments utilisation, OD matrices, …) are interesting not only for government but also road owners and administrators.

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