INTELLIGENT TRUCK PARKING BASED ON AN AUTONOMOUS ELECTRONIC TOLL COLLECTION SYSTEM

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Abstract

In many countries the solution of truck parking has been solved in last two decades. State of the art electronic toll collection systems can be utilised in many ways. Mainly autonomous (satellite) electronic toll systems can be seen as a more general transport telematics platform. To avoid multiple devices that the driver should use during his driving, the paper deals with the possible solution of intelligent truck parking system based on the infrastructure of autonomous electronic toll collection system.

Initially the applicability of the toll on-board unit and other subsystems of electronic toll collection system is analysed. Then the functional requirements for intelligent truck parking system are specified. Afterwards the proposal of the system architecture is mentioned. The suggested proposal shows that the intelligent truck parking system based on electronic toll system should be not only possible, but also effective solution.

Keywords: Intelligent Truck Parking, Autonomous Electronic Toll System, On-Board Unit

1. INTRODUCTION

Road charging is worldwide used as a financial instrument or/and measure for traffic regulation [1]. The European framework for technological solution of electronic toll collection (ETC) 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). So deployed systems can be microwave or satellite (also referred to as autonomous ones which are based on satellite positioning and mobile communications) [3].

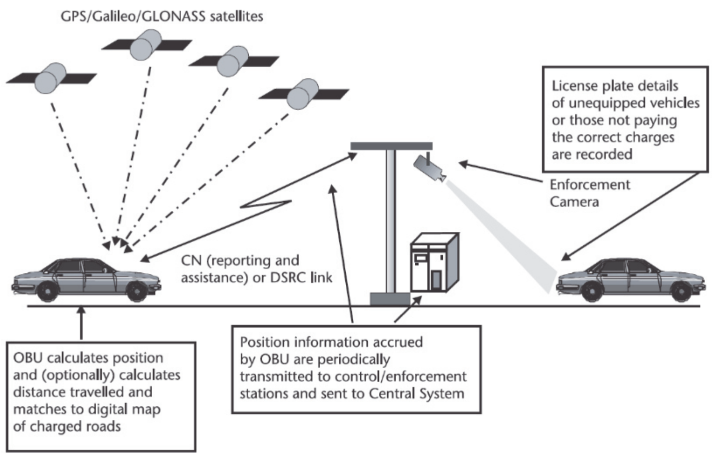

Figure 1 Principle of a satellite system [9]

In spite of undisputed advantages of satellite technology (flexibility, effectiveness, reliability, potential to offer value added services, …), the technology has broken through relatively moderately (Germany, Slovakia, Hungary). Taking into account modern technological solution (in Slovakia the ETC system was deployed in 2010 [1]), 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], parking management [6], track&trace [7], Smart City [8] and so on.

Generally the ETC system can be divided into three subsystems: central equipment (CE), On-Board Unit (OBU) and enforcement. 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 [9]. The information from OBU is necessary to transmit to CE so what a mobile communication network serves on. On the purposes of enforcement (and in microwave systems also for tolling) a microwave technology dedicated short range communication (DSRC) is used.

2. SLOVAK ELECTRONIC TOLL SYSTEM

Since the beginning of operation of the system in Slovakia, ETC has been applied on vehicles and vehicle combination over 3.5 tones (excluding vehicles exempted from tolling duty according to law) which are obligatory equipped by OBUs. Till the end of 2013 charging was applied on motorways, highways and selected 1st class roads. Since beginning of 2014 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) [10]. After the changes, the coverage of toll scheme is almost all roads in Slovakia (just local, commercial and specific roads are not covered). Particularly, 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.

Since first statutory the text of Slovak 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 technologies that Directive requires.

Figure 2 Map of road networks in Slovakia - tolled roads in 2017 [11]

3. PRINCIPLEAS OF THE PROPOSAL

As it was mentioned above, the basic idea of the proposal is to utilise the available resources of the ETC system and avoid to build a dedicated ITP system. The available resources are centralised in two ETC subsystems: CE and OBU. Therefore it is firstly necessary to assess applicability of the subsystems in the framework of the ITP system and propose the unavoidable modifications and upgrades of OBU and CE.

It is evident that the changes would be appropriate (relative to separate ITP system) and the modification of the ETC system must not affect its functionality, reliability and security as well. Secondarily it means that the ETC system disposes a sufficiency of computational, communication and energy resources in the all affected subsystems and levels.

From operation point of view, the relationship between toll charger and ETC system operator has to be negotiated within consideration that a new service will be offered with resources of previously procured system. On the one had there is an utilisation of existing ETC system and on the other hand there are costs caused by investments and operation of a new commercial service. Investments and operation costs have to be adequate to new ITP service revenues to be a commercially interesting. The service should be public one and available through various communication means and be sufficiently flexible and scalable.

4. DEFINITION OF CONDITIONS FOR ITP

To define functional requirements for ITP, it is necessary to respect European trends in the area of harmonisation of ITS (Intelligent Transport Systems) services. Besides framework that defines Directive 2010/40/EU on ITS [12], Development guidelines were defined for ITS services in the framework of the project EasyWay, namely ones also for Intelligent truck parking and secure truck parking [13]. Harmonised requirements on the service were defined from point of view of functional requirements, organisational issues, technical requirements and levels of service from point of view of security. Regarding to organisation scheme of the service (for example for the cases that operators of the parking spaces are different subjects and they have various business conditions and goals), it is not possible to define all details regarding to technical conditions for service.

Truck drivers, hauliers and dispatchers need the information on petrol stations or rest areas on the routes not only pre-trip but also on-trip. It can be realised via information providers. Generally the information providers can be public or private ones. A typical functional architecture from point of view of information flow is segmented into three sub-functions - a vertical line consist of: (static and dynamic) data collection, management of information, transmission of information. Then the using of information follows.

The basic functional requirement is that functional decomposition and provision of standard interfaces should be realised to be ensured interoperability in case the service is carried out by more than one subject. For each of sub-functions it is necessary to define a set of functional requirements. Moreover to ensure full interoperability a set of organisational (e.g. roles, processes, workflows, contracts and agreements, management plans, data maintenance, …) and technical (data exchange standard including used profile) requirements has to be defined.

Regarding to logical structure, ITP system usually consists of four basic components:

- devices for data collection - purpose: parking data collection (e.g. calculation of arriving and departing vehicles),
- central and local parking information system - purpose: data processing and fusion, i.e. conversion of raw data into usable information,
- telecommunication and information networks - purpose: transfer of data/information between system components,
- devices for distribution and dissemination of information - purpose: broadcasting and displaying the information via different media.

5. STRUCTURE OF ITP SYSTEM

Mentioned components of ITP information system can be arranged into centralised or decentralised structure. In case of centralised system (**Figure 3**), the control units on all parking places in the system will process data collected from sensors and detectors and transmit them to central parking information centre. There the data will be processed on information and submitted to particular information media. So this way the all processes will be performed centrally and local controllers have a limited function.

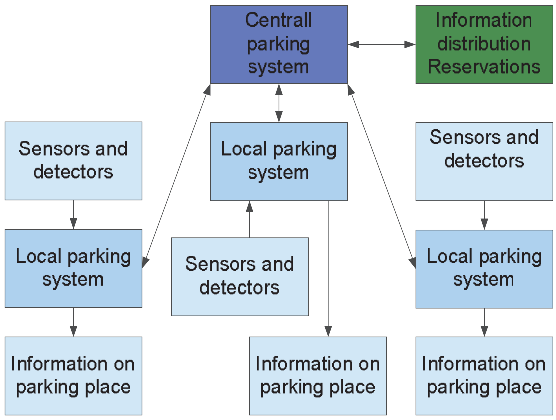

Figure 3 Basic components of centralised ITP information system

The advantages of such structure are:

- information management is simpler and the operation of the system is more flexible,
- parking and road information devices (typically variable message signs - VMS) can be utilised for different purposes, not strictly only for parking information,
- such solution is more suitable for integration ITP system into complex system of traffic management,
- system upgrades and supplementing of another kind of information dissemination are easier,
- local system requires fewer functions and by that the local system is cheaper.

The main disadvantages of the solution are:

- more communication is required,
- information process takes more time.

Distributed parking information system will process parking data to information on the local level and consequently information transmit to relevant display devices and also to database of central parking information system.

The advantages of distributed system are followed:

- less communication needed,
- system is more reliable and has less risks because data processing is distributed onto a number of local parking systems.

Disadvantages of such structure are:

- more complex local controllers are required,
- devices for information displaying is not possible to use for displaying other information,
- adding of a new displaying device is more difficult.

Obviously a hybrid solution exists as well - it works as a centralised solution at ideal conditions but, in case of failure of a component, it switch into predefined distributed solution. Such benefit requires additional costs.

From the mentioned analyse follows that central solution of ITP in Slovakia will be advantageous from point of view of availability of information for end users (getting information via mobile ICT devices has been still more preferred) and, in case of reservation service, the service will be available centrally for end users. Essentially it means that all supplementary operations with data will be realised centrally (e.g. occupation prediction) and equally processed information will be distributed from centralised point towards end users.

Regarding to organisational and operational issues in Slovak conditions two solutions can be considered:

- building up a separate (dedicated) ITP central system (**Figure 4a**),
- incorporating of ITP central system into National traffic information centre (NTIC), (**Figure 4b**).

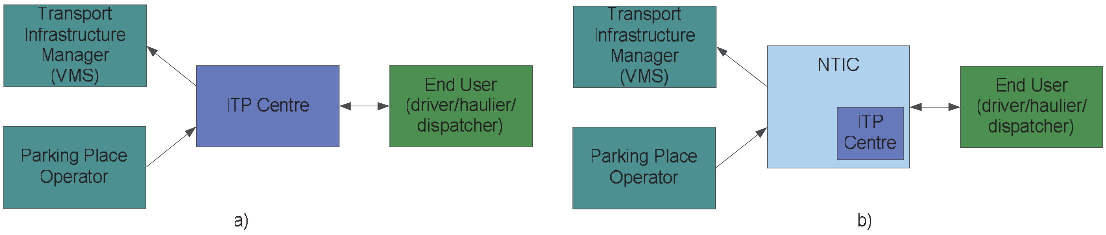

Figure 4 Logical architecture of a) dedicated ITP system and b) ITP system incorporated in the framework of NTIC - an example for information and reservation service

Figure 5 OBUs used in the Slovak electronic toll collect system

Obviously neither second approach should result in the situation that ITP system will be a separate system because it can be integrate into NTIC afterwards. Logically when the NTIC has been in operation yet it is naturally that the ITP system should be integrated in NTIC from the beginning.

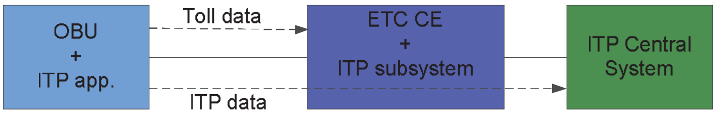

Figure 6 Idea of data interconnection of ETC and ITP system

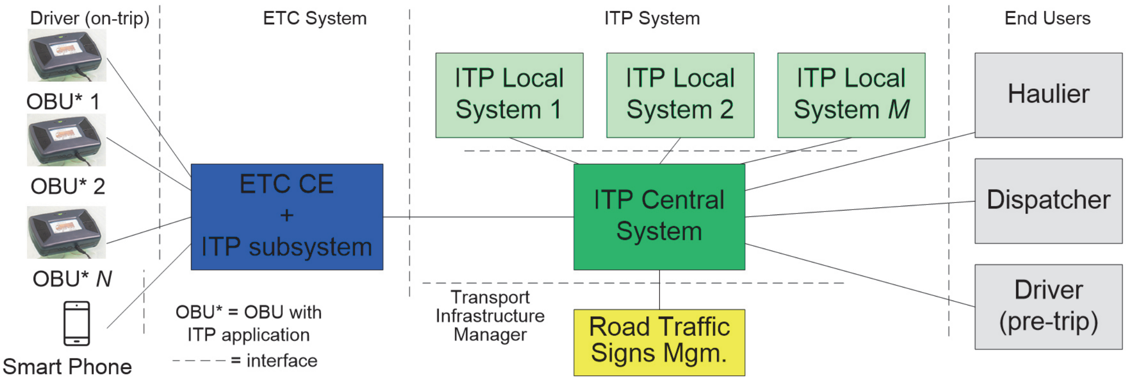

Figure 7 Structure of the system proposal

As it was aforesaid above, two subsystems of ETC system would be affected by building up of ITP system based on the utilisation of the resources of EFC system. One of the subsystem is OBU. During operation of Slovak ETC system three generations of OBU has been used (**Figure 5**). OBU utilisable for such application has to been upgraded or of new type (with more suitable human-machine interface). In both cases OBU has to be extended on dedicated ITP application that would utilise available OBU´s modules (processor, memory, GPS, GSM/GPRS). It also lead to upgrade a map data (parking places, specific roads, …). In respect of basic ETC service, it is evident that this service has to have a priority and the OBU´s trusted environment dedicated to ETC cannot be affected. It is obviously that instead of OBU any end user smart device (typically smart phone) can be utilisable for ITP purposes.

Similarly CE has to be supplemented on dedicated ITP subsystem which main functionality would be filtering data received from OBU, i.e. ITP data are redirected to ITP central system (**Figure 6**). An interface towards ITP central system has to be part of this upgrade (because it concerns a data exchange between ITS systems the format of data exchange should be DATEX II (**Figure 7**).

6. CONCLUSION

The paper presents a possible utilisation of infrastructure of autonomous ETC system for purpose of ITP application. Modern user-friendly OBUs can serve as end-user devices for additional transport telematics services so that utilise available resources of OBU (mainly localisation and communication functionalities) or other subsystems respectively. The proposal shows that solution is possible and cost-effective.

ACKNOWLEDGEMENTS

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