

A Novel Approach to Road User Charging based on Cellular Networks and UCPI[®]

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Abstract

A new generation of Road User Charging (RUC) systems based on Wide Area Network (WAN) wireless communication and positioning is entering the market. The main advantages with these systems compared to Dedicated Short Range Communication (DSRC) based systems are their flexibility in supporting different charging methods and tariffs and the reduced infrastructure cost. The standard approach to implement WAN tolling systems is to use a combination of GPS, GPRS or SMS. This paper introduces the novel Unique Cell Point Identification (UCPI[®]) technology that uses GSM as a standalone technology for RUC. Large cost savings can be achieved by utilising an autonomous cellular system.

Keywords

RUC, GSM, UCPI[®], GPRS, GPS, EFC, ETS, Cellular Positioning, Vehicle Tracking

Introduction

The huge increase in road traffic is leading to congested road networks, severe environmental issues and high road wear. The development within communication and sensor technologies the last decades render it possible to use Road User Charging (RUC) as an excellent way of managing traffic flows on selected parts of the road network. RUC can be used for decreasing congestion levels, reducing environmental impacts, fairly distributing costs of road wear and funding of e.g. road works, environmental research, alternative transportation systems etc. However, current RUC systems, e.g. Dedicated Short Range Communication (DSRC) systems are relatively static as well as expensive to setup and operate, and this paper presents a novel approach solely relying on cellular networks that is both cost efficient and flexible.

Background

RUC has mainly been deployed using DSRC-based communication between an On Board Unit (OBU) and a dedicated roadside infrastructure. This technology has drawbacks in expensive roadside infrastructure and a lack of flexibility in charging methods. Lately there has been an increased interest in RUC systems that use Wide Area Network (WAN) communication and positioning [1, 2]. These systems are characterised by their ability to support flexible charging methods and the reuse of existing communication and positioning systems. WAN based systems are often

further divided into thin- and thick client systems, where a thin client system refer to an OBU that is simpler and cheaper and has more frequent communication requirements with a central system than a thick client system.

Current WAN-based systems typically use GPS for positioning in combination with a cellular network device, e.g. a GPRS-module, for the communication with the central system. A cost-efficient alternative is to use the cellular network for the communication as well as for the positioning. Due to the low accuracy of standard positioning methods such as Cell Global Identity (CGI) + Timing Advance (TA) and Enhanced Observed Time Difference (E-OTD), this has not been done until now. For a description of standard cellular positioning methods such as CGI+TA and E-OTD, see e.g. [3, 4].

In collaboration with Linköping University, FlexToll[®] has developed a new positioning technology called Unique Cell Point Identification (UCPI[®]), which is a technology relying on a completely different approach than standard cellular positioning methods. The patent pending UCPI[®] technology is tailor-made for RUC and uses special tracking algorithms in order to determine when a FlexToll[®] OBU is entering a predefined area or road section. The vehicles can also be observed within the area or road section for more flexible charging methods or value-adding services.

System description

The developed system consists of a FlexToll[®] OBU, which is a standard GPRS-module equipped with UCPI[®] extensions and a back-office system, see *Figure 1*. The OBU monitor the GSM network and communicates with the back-office system in order to determine the location of the OBU or to report traversed sections or areas that has a road charge. The system can be implemented as a thin or thick client solution, depending on user needs and e.g. communication costs. It is possible to communicate with the device from the central system in order to support e.g. enforcement strategies.

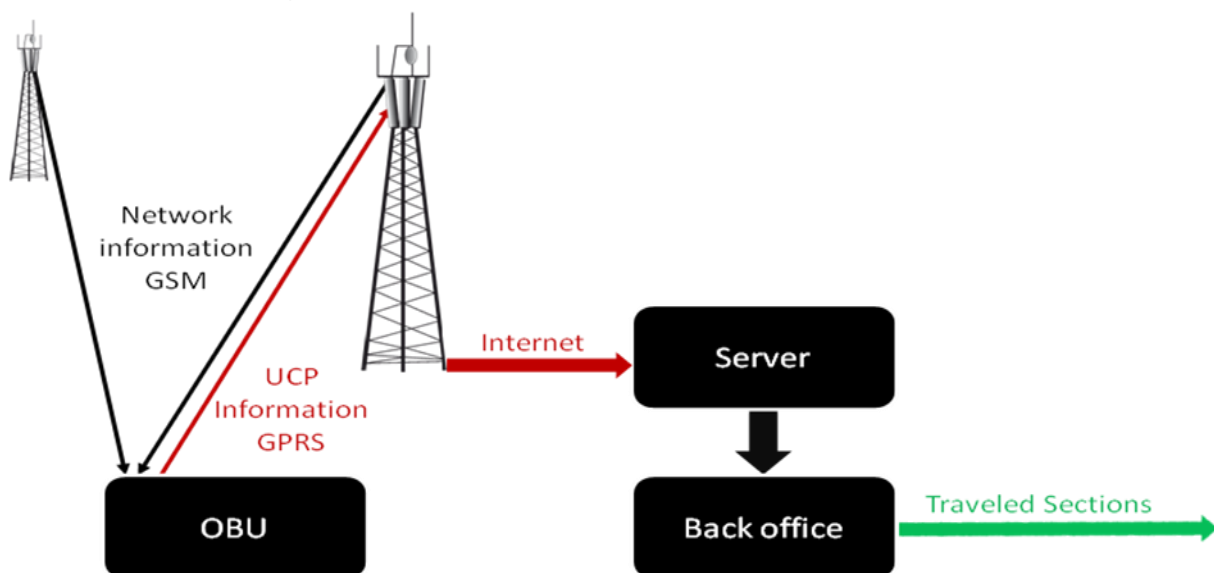


Figure 1. Overview of the FlexToll[®] system.

Functionality

The developed system has all the advantages that a WAN-based system has, i.e., the existing mobile phone infrastructure is reused and the system supports flexible charging methods, charging areas and tariffs. It has also inherent support for using the same OBU in different countries.

An important advantage is the easy installation of the OBU. Due to its small size and the option of different placements in the vehicle, the installation cost can be kept at a very low level. This is increasingly important when the managed fleet is very large. The lack of a GPS receiver also keeps the processing requirements of the OBU at a minimum level which renders it possible to operate the OBU solely on battery power and without needing to install it in the vehicle.

A solely cellular based system does not have the problem as the GPS regarding vehicles with metallic wind screens or wind screens covered with snow and dirt. A cellular based system is also less susceptible to jamming signals.

Position coordinates are not sent from the FlexToll[®] OBU, which can be used to keep the communication cost down. Further more it has an importance due to the aspect of personal integrity. The system does not keep track on exact coordinates of the user, instead only the charging-related information is extracted, i.e. which charged area or road section the user has traversed.

Enforcement can be supported by allowing trusted parties to retrieve state information from the OBU at all times. The system also has the flexibility to cooperate with other technologies e.g. with a GPS/GPRS-based OBU.

Field tests

The system has recently been evaluated in a road network in Linköping, Sweden. The results of the evaluation show that the flexible low cost system has a large potential in charging road sections in rural and suburban areas. The system has also been evaluated for area charging in an urban environment with very promising results. Results from these trials are to be published shortly.

Conclusions

UCPI[®] is a cellular tracking technology used by FlexToll[®] in order to handle autonomous cellular road user charging. By using the UCPI[®] technology it is possible to use the GSM network as a standalone technology for road user charging. This implies large cost savings but also flexible tolling in combination with robust performance and advantages in preserving personal integrity.

Apart from being a cost-efficient alternative for RUC, the UCPI[®] technology is also very interesting as a complementing GPS technology to improve accuracy in challenging environments, e.g. urban canyons.

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