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Intelligent Transport Systems (ITS); Pre-Standardization Study on payment applications in Cooperative ITS using V2I communication

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

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Executive summary

The present document provides a pre-standardization study for the deployment of C-ITS for charging and tolling operation. The proposed changes and adaptations to the C-ITS protocols would allow local road charging and payment applications to benefit from the deployment of C-ITS, with a minimal impact on existing standards.

The document starts with a general description of the existing payment applications in the transport domain. The main driving application is the European road tolling system which is presently implemented using the CEN DSRC standards. The present document describes the typical tolling zone geometry in this system and gives more details on its implementations such as the toll plaza with or without barriers and the free flow systems where electronic equipment is mounted on gantries in order not to force the traffic to slow down and/or inhibit lane changes. The road tolling technology can also be used for other payment applications including the management of parking space, energy charging and the access to city centres or ferries. Further use cases are envisaged including the payment at drive-through locations.

In a second step, the document proposes an architecture to perform the tolling transaction, leveraging the C-ITS technologies. In an existing DSRC system, the transaction equipment is deployed in every lane. In the proposed solution, a single R-ITS-S is able to operate the entire toll station, executing the payment transaction and communicating with the C-ITS enabled vehicles passing the tolling area. As the C-ITS technologies cover a larger area than the DSRC system, two major challenges need to be solved by this architecture:

- reliable geolocation of the connected vehicles when passing the toll area in the different lanes;
- security of the wireless communication and payment information during the transaction process.

The reliable geolocation of the vehicles in the tolling gate lanes is obtained at the R-ITS-S by applying corrections to the position broadcasted by vehicles in the CAM. A secure exchange of information allows to execute the payment operation while the vehicle crosses the toll gate. With the proposed application, the customer does not provide any payment data until its application is able to authenticate the service provider.

A proof-of concept of the proposed application, combining the geolocation and the secure exchange of payment information has been implemented using the ITS-G5 technology. The present document describes the configuration of this test as well as the results obtained. An analysis of these results is provided. They show that the proposed method fulfils the requirement of an accuracy lower than one metre (indeed 0,3 metre was observed) to perform the ETC transaction and that in all the test runs, the lane used by the vehicle has been successfully identified. The security procedure used by the application has also been validated, in both cases when the provided vehicle identification is valid and invalid.

Finally, the present document proposes the required changes and adaptations of the C-ITS protocols for the support of the payment application. The adaptations are presented for each of the relevant protocol layers. Management entity, N&T and Access layers are not impacted, while new functions are introduced at the facilities and application level, as well as in the security entity. Performance considerations related to the impact on the C-ITS channel occupancy are computed, showing that only in peak hours the channel utilization would have to be carefully balanced.

1 Scope

The present document identifies potential requirements for the set of payment applications (including positioning and security requirements) and investigates possible updates and changes to the existing set of ETSI Cooperative ITS standards using V2I communication to support locally hosted payment applications including Electronic Fee Collection (EFC) and other general payment applications.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Directive (EU) 2019/520 of the European Parliament and of the Council of 19 March 2019 on the interoperability of electronic road toll systems and facilitating cross-border exchange of information on the failure to pay road fees in the Union.

[i.2] Commission Implementing Regulation (EU) 2020/204 of 28 November 2019 on detailed obligations of European Electronic Toll Service providers, minimum content of the European Electronic Toll Service domain statement, electronic interfaces, requirements for interoperability constituents and repealing Decision 2009/750/EC.

[i.3] ISO 17573-2: "Electronic fee collection -- System architecture for vehicle related tolling -- Part 2: Terminology".

[i.4] CEN EN 15509: "Electronic fee collection - Interoperability application profile for DSRC".

[i.5] ISO 14906: "Electronic fee collection -- Application interface definition for dedicated short-range communication".

[i.6] ISO 15628: "Intelligent transport systems -- Dedicated short range communication (DSRC) -- DSRC application layer".

[i.7] CEN/TS 16986: "Electronic Fee Collection - Interoperable application profiles for information exchange between Service Provision and Toll Charging".

[i.8] ISO/TS 17575: "Electronic fee collection -- Application interface definition for autonomous systems".

[i.9] CEN/TS 16331:2012: "Electronic fee collection. Interoperable application profiles for autonomous systems".

[i.10] IEEE Std 1609.11-2010™: "IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)".

[i.11] ARIB STD T-75: "Dedicated Short-Range Communication System", Version 1.0, September 2001.

[i.12] ETSI ES 200 674-1: "Intelligent Transport Systems (ITS); Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communications (DSRC); Part 1: Technical characteristics and test methods for High Data Rate (HDR) data transmission equipment operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band".

[i.13] ETSI EN 302 890-1: "Intelligent Transport Systems (ITS); Facilities layer function; Part 1: Services Announcement (SA) specification".

[i.14] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate formats".

[i.15] Francesco Dionori et al: "Technology options for the European electronic toll service", EC study, April 2014.

[i.16] ETSI TR 103 300-1: "Intelligent Transport System (ITS); Vulnerable Road Users (VRU) awareness; Part 1: Use Cases definition; Release 2".

[i.17] Malalatiana Randriamasy: "Localization and secure transmissions for Vehicle to Infrastructure communication (V2I): Application to the electronic toll service using the ITS-G5 technology", PhD thesis, May 2019.

[i.18] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), OJ 2016 L 119/1.

[i.19] Malalatiana Randriamasy, Adnane Cabani, Houcine Chafouk, Guy Fremont: "Reliable vehicle location in electronic toll collection service with cooperative intelligent transportation systems", PIMRC 2017.

[i.20] Malalatiana Randriamasy, Adnane Cabani, Houcine Chafouk, Guy Fremont: "Evaluation of methods to estimate vehicle location in Electronic Toll Collection Service with C-ITS", Intelligent Vehicles Symposium 2018: 748-753.

[i.21] "Geolocation Process to Perform the Electronic Toll Collection Using the ITS-G5 Technology". Malalatiana Randriamasy, Adnane Cabani, Houcine Chafouk, Guy Fremont: IEEE Trans. Vehicular Technology 68(9): 8570-8582 (2019).

[i.22] ISO/IEC 27001:2013: "Information technology -- Security techniques -- Information security management systems - Requirements".

[i.23] Malalatiana Randriamasy, Adnane Cabani, Houcine Chafouk, Guy Fremont: "Formally Validated of Novel Tolling Service With the ITS-G5", IEEE Access, vol. 7, pp. 41133-41144, March 2019.

[i.24] The AVISPA team. AVISPA v1.1 User Manual, June 2006. .

NOTE: Available at http://www.avispa-project.org/package/user-manual.pdf.

[i.25] ETSI EN 302 637-2: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.26] Commission Delegated Regulation (EU) 2020/203 of 28 November 2019 on classification of vehicles, obligations of European Electronic Toll Service users, requirements for interoperability constituents and minimum eligibility criteria for notified bodies.

[i.27] ACEA Position Paper: "Access to vehicle data for third-party services", December 2016.

[i.28] CEN/TR 16690: Electronic Fee Collection - Guidelines for EFC applications based on in-vehicle ITS stations.

[i.29] CEN ISO/TS 17444-1: "Electronic fee collection -- Charging performance -- Part 1: Metrics".

[i.30] CAR 2 CAR Communication Consortium: "Basic System Profile", Document number RS-2037, Release 1.4.0, September 2019.

[i.31] ISO 17573-1: "Electronic fee collection -- Systems architecture for vehicle-related tolling -- Part 1: Reference model".

[i.32] ETSI TS 101 556-1: "Intelligent Transport Systems (ITS); Infrastructure to Vehicle Communication; Electric Vehicle Charging Spot Notification Specification".

[i.33] ETSI TS 101 556-3: "Intelligent Transport Systems (ITS); Infrastructure to Vehicle Communications; Part 3: Communications system for the planning and reservation of EV energy supply using wireless networks".

[i.34] ISO 12855:2015: "Electronic fee collection -- Information exchange between service provision and toll charging".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

charging: electronic fee collection payment process

DSRC: Dedicated Short-Range Communication used for tolling applications (as specified in ISO 15628 [i.6])

electronic fee collection: fee collection by electronic means (see ISO 17573-2 [i.3])

enforcement: measures or actions performed to achieve compliance with laws, regulations or rules (see ISO/TS ISO 17573-2 [i.3])

localization augmentation: information delivered to on-board equipment about the current geographical location or the identity of a charge object (see ISO/TS ISO 17573-2 [i.3])

EXAMPLE: This may happen for example when the satellite signals are insufficient for adequate positioning.

on-board equipment: all required equipment on-board a vehicle for performing required Electronic Fee Collection (EFC) functions and communication services (see ISO/TS ISO 17573-2 [i.3])

roadside equipment: fixed or movable equipment located along or on the road

NOTE: Derived from ISO/TS ISO 17573-2 [i.3], can be applied to both ETC and ITS.

toll: charge, tax, fee, or duty in connection to using a vehicle within a toll domain (see ISO 17573-2 [i.3])

toll charger: entity which levies toll for the use of vehicles in a toll domain (see ISO 17573-2 [i.3])

toll declaration: statement to declare the usage of a given toll service to a Toll Charger (see ISO 17573-2 [i.3])

toll domain: area or part of a road network where a certain toll regime is applied (see ISO 17573-2 [i.3])

toll regime: set of rules, including enforcement rules, governing the collection of tolls in a toll domain (see ISO 17573-2 [i.3])

toll service: service enabling users to pay toll (see ISO 17573-2 [i.3])

toll Service Provider: entity providing toll services in one or more toll domains (see ISO 17573-2 [i.3])

transport service: transport infrastructure related service which is offered to the user (see CEN EN 15509 [i.4])

3.2 Symbols

For the purposes of the present document, the following symbols apply:

a longitudinal acceleration

δ	steering wheel angle
θ	direction of the vehicle
v	speed
w	yaw rate
(x, y)	UTM coordinates

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC-CR	ACcess CRedential
ACEA	Association des Constructeurs Européens d'Automobiles
ANPR	Automatic Number Plate Recognition
BO	Back Office
BST	Beacon Service Table
CA	Constant Acceleration
CAM	Cooperative Awareness Message
CAN	Controller Area Network
CCC	Compliance Check Communication
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CRL	Certificate Revocation List
CTRA	Constant Turn Rate and Acceleration
CTRV	Constant Turn Rate and Velocity
CV	Constant Velocity
C2C-CC	Car 2 Car Communication Consortium
DCC	Decentralized Congestion Control
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short-Range Communications
EC	European Commission
ECC	Electronic Communications Committee
EDM	Enhanced Dynamic Model
EETS	European Electronic Tolling Service
EFC	Electronic Fee Collection
EGNOS	European Geostationary Navigation Overlay Service
ETC	Electronic Toll Collection
ETSI	European Telecommunications Standards Institute
FA	Facilities to Application
GDPR	General Data Protection Regulation
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HDR	High Data Rate
HLPSL	High-Level Protocol Specification Language
HMI	Human-Machine Interface
HSM	Hardware Secure Module
IEEE	Institute of Electrical and Electronics Engineers
ISMS	Information Security Management System
ITS	Intelligent Transport Systems
LAC	Localisation Augmentation Communication
MEMS	MicroElectroMechanical System
MDR	Medium Data Rate
MLFF	Multi-Lane Free-Flow
MMI	Man-Machine Interface
OBE	On-Board Equipment
OBU	On-Board Unit (alternative for OBE)
OSI	Open Systems Interconnection
OTA	Over-The-Air
PAN	Personal Account Number
PKI	Public Key Infrastructure
PoC	Proof of Concept
PoTi	Position and Time

RF	Radio Frequency
R-ITS-S	Roadside ITS Station
RLAN	Radio Local Area Networks
RSE	Road Side Equipment
RSU	Road Side Unit (alternative for RSE)
RTI	Road information Systems
RTK	Real-Time Kinematic
RTTT	Road Transport & Traffic Telematics
RX	Receive
SAEM	Services Announcement Extended Message SCH Service Channel
TC	Toll Charger
TLS	Transport Layer Security
TSP	Toll Service Provider
TX	Transmit
UID	Unique IDentifier
UTM	Universal Transverse Mercator (coordinates)
V-ITS-S	Vehicle ITS Station
VRU	Vulnerable Road User
VST	Vehicle Service Table
WAVE	Wireless Access in Vehicular Environments
WG	Working Group

4 Payment use cases

4.1 Overview

In clause 4, a general description of the existing payment applications in the transport domain is given. The main driving application is the European road tolling system which is actually implemented using the CEN DSRC standard CEN EN 15509 [i.4]and the ETSI HDR DSRC standard ETSI ES 200 674-1 [i.12] based on the corresponding EC directive [i.1]and its Delegated Regulation [i.26] and Implementing Regulation [i.2]. This technology can also be used for other payment applications including the management of parking space and the access to city centres. Further use cases are envisaged including the payment at drive-through locations.

4.2 Electronic Toll Collection

4.2.1 Overview

Typical implementations of a tolling system are the following:

- Toll plaza systems with up to 40 parallel lanes (typically around 10 to 20 lanes in each traffic direction).
- Free-Flow tolling systems with a maximum of 6 parallel lanes (typically 3 to 4 lanes in each traffic direction).

Toll plaza systems are typical for tolling of motorways and are mostly located in large open areas with good GNSS reception. Free-flow tolling systems are more versatile and can be used both for motorway tolling even under complex infrastructural conditions such as tolling of narrow urban highways or inside tunnels, as well as for urban charging systems applied in environments with "urban canyons".

Other technology combinations are possible such as:

- GNSS based tolling, with enforcement based on DSRC (e.g. ETC used in Germany).
- Video tolling and enforcement based on license plate recognition.

For these two combinations, the operation is similar to free flow tolling: the OBUs are controlled by roadside equipment installed on gantries.

The traffic demand determines the configuration of the deployed tolling system. Table 1, derived from an EC study on European electronic toll service (EETS) [i.15] and road operator measurements, shows the capacity according to the tolling technology.

Table 1: Capacity depending on the tolling technology

Source	Capacity (vehicles / hour /lane)		
	ETC with barriers	ETC reduced speed	Multilane free flow
Villalonga (2010)	650-750	1 200	N/A
Dancso (2008)	500-600	1 000	3 000
SANEF measures	600	800	N/A

The ETC transaction takes place according to the sequence described in Table 1 titled "Overview of DSRC L7 and EFC functions" given in section 6.1.3 of CEN EN 15509 [i.4]. This table describes the DSRC-L7 services and EFC functions involved in the transaction. See also clause A.4 for related information.

NOTE: The OBU tag emits the beep after the SET_MMI message described in the table.

4.2.2 Plaza systems

4.2.2.0 General considerations

Three types of tolling systems in plazas need to be differentiated:

- automatic barrier (stop&go); generally, toll lanes are of different types: ETC, automatic machines, manual (toll collector);
- automatic ETC lane (reduced speed);
- non-stop ETC lanes.

Figure 1: Toll plaza with non-stop ETC lane (far left), stop&go ETC (centre lanes) and automatic lane (right)

Figure 2: Toll plaza with non-stop ETC lanes (left), stop&go ETC and automatic lanes (right)

4.2.2.1 Example of French System

In France, two types of ETC system with barriers exist: the stop-and-go mode, and the non-stop mode with reduced speed.

For the stop-and-go mode, when the driver crosses the toll gates, he has to stop until one beep from the OBU tag sounds shortly.

For the non-stop mode with reduced speed (30 km/h, 50 km/h), the beep from the tag is emitted a few seconds earlier than the stop-and-go mode.

This is possible since there are two RSUs in the concerned lane. Indeed, the transaction occurs a few meters before the barrier with the first RSU, and the second RSU relays the communication if the communication with the first RSU was interrupted.

4.2.3 Free flow tolling systems

Infrastructure based multilane free flow systems use Road Side Equipment (RSE) configured with electronic equipment mounted on gantries in order to not force the traffic to slow down and/or inhibit lane changes. There are as many RSE as lanes on the road. The equipment has three functions (see also Annex A):

- localisation;
- charging via RF communication;
- enforcement using local cameras.

Localisation is important even in the case of a free flow tolling system as it enables the activation of cameras that record the license plate number if the transaction is not successful (back office processing).

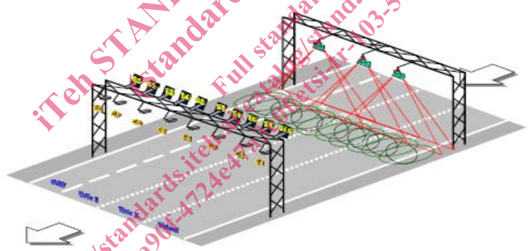

Figure 3: Free-flow situation

Figure 4: Typical free-flow installation with three lanes