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TECHNICAL SPECIFICATION

Intelligent Transport Systems (ITS); Infrastructure to Vehicle Communication; Part 2: Communication system specification to support application requirements for Tyre Information System (TIS) and Tyre Pressure Gauge (TPG) interoperability

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

The present document is part 2 of a multi-part deliverable covering Infrastructure to Vehicle Communication as identified below:

Part 1: "Electric Vehicle Charging Spot Notification Specification";

Part 2: "Communication system specification to support application requirements for Tyre Information System (TIS) and Tyre Pressure Gauge (TPG) interoperability";

Part 3: "Communications system for the planning and reservation of EV energy supply using wireless networks".

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

ITS stations are interacting together to satisfy a large diversity of customers' services.

The present document is developed in relation to the European Commission Mandate M/457 and in cooperation with CEN TC 301 TF2b.

Any communication technology enabling I2V communication can be supporting this application as long as the Tyre Pressure Monitoring System application functional and operational requirements are satisfied.

This TPMS application belongs to road safety application class but also to sustainability class through the possible CO_2 reduction provided that the vehicle tyres pressures are properly adjusted.

1 Scope

The present document provides a specification of the communication system required to support the requirements of Tyre Information System (TIS) application, TPG (Tyre Pressure Gauge) application and TPG operator application.

The TIS application has the objective to monitor in real time the pressure of the vehicle tyres, to advise the driver and to support him for the tyre(s) refilling if one or several tyre(s) are not at the recommended pressure. TPG application and TPG operator application have the objective to notify the TPG to road users and provide tyre pressure refilling service to vehicles, either manually, or automatically. Consequently, the communication system specification considers the various phases of the driver support process starting with the provisioning of available Tyre Pressure Gauge (TPG) locations, pairing the vehicle with a selected TPG and ensuring the data elements exchange required for the selected TPG to refill the concerned tyre(s) until reaching recommended pressure(s).

The present document is developed in accordance with requirements defined in CEN EN 16661 [1].

2 References

2.1 Normative 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 reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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 necessary for the application of the present document.

[1] CEN EN 16661:2015: "Road vehicles and Tyre Pressure Gauges (TPG) - Interoperability between Tyre Information Systems (TIS) and TPG - Interfaces and Requirements".

[2] ETSI EN 302 665 (V1.1.1): "Intelligent Transport Systems (ITS); Communications architecture".

[3] ECE/TRANS/WP.29/78/Rev.2: "United Nations Economic and Social Council; Economic Commission for Europe; Consolidated Resolution on the Construction of Vehicles (R.E.3); Revision 2".

NOTE: Available at: http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29resolutions/ECE-TRANS-WP29-78-r2e.pdf

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

[5] ETSI TS 102 894-2 (V1.2.1): "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary".

[6] ISO 639-1:2002: "Codes for the representation of names of languages - Part 1: Alpha-2 code".

[7] ISO/IEC 8825-2:2008: "Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER)".

2.2 Informative references

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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] IEEE 802.11p™: "802.11p-2010 - IEEE Standard for Information technology - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments".

[i.2] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate formats".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in CEN EN 16661 [1], ETSI EN 302 665 [2] and the following apply:

TIS application: vehicle ITS-S application implementing the application logic to trigger, manage and terminate the data exchange between vehicle ITS-S and TPG ITS Station or between vehicle ITS-S and TPG operator

TPG application: ITS-S application embedded at TPG ITS Station implementing application logic to trigger, manage and terminate the data exchange between TPG ITS-S and vehicle ITS-S, or between TPG ITS-S and TPG operator

TPG operator: operator in charge of managing at least one or a set of TPGs for at least one of the maintenance, operation, and/or reservation services

NOTE: Functionalities of the TPG operator may be embedded in TPG ITS-S or at central ITS-S.

TPG station: local facility that provides tyre pressure refilling service and is equipped with at least one TPG

NOTE 1: One TPG station may include more than one TPG.

NOTE 2: Typically, a TPG station includes other local facilities to support the tyre pressure refilling service provisioning, e.g. parking facilities, access control facilities. A TPG station may be combined with other local facilities such as parking station, public transport stations, etc.

3.2 Abbreviations

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

AAA	Authentication, Authorization, Accounting/Auditing
ASN.1	Abstract Syntax Notation One
DE	Date Element
DRM	Discovery Request Message
EOFM	End Of File Message
HMI	Human - Machine Interface
ITS	Intelligent Transport System
ITS-G5	Intelligent Transport System - Frequency band comprised between 5 855 MHz to 5 925 MHz
ITS-S	ITS station
MAC	Medium Access Control
PDU	Protocol Data Unit
PER	Packet Encoding Rules

TCM	TPG reservation Confirmation Message
SNM	Service Notification Message
TRM	TPG Reservation Message
TIN	Tyre Identification Number.
TIS	Tyre Information System
TPG	Tyre Pressure Gauge
TPMS	Tyre Pressure Monitoring System
URL	Uniform Resource Location
VDPM	Vehicle Data Provisioning Message
VDRM	Vehicle Data Request Message
WFC	Wheel Fitted Component

4 TIS, TPG application description

4.0 Introduction

The TIS application targets at improving the driving safety through the monitoring and adjustment of the vehicles' tyres pressures in case of unadapted pressure or under driver request. Moreover, the TIS application also contributes to reduce the CO_2 emissions for thermal propulsion vehicles since unadapted tyres' pressures also impact the vehicle fuel consumption. The tyre pressure refilling service is provided by a TPG to a vehicle. It may be realized manually or automatically, as defined in CEN EN 16661 [1]. For automatic refilling service, vehicle provides a set of vehicle data e.g. tyre placard table, tyre pressure level to TPG, for it to calculate the appropriate tyre pressure to be applied for vehicle tyres.

The TIS application, TPG application and TPG operator applications interact with each other for data exchanges to manage the TPG discovery, TPG reservation and tyre pressure refilling.

4.1 Application context overview

An example of the high level data exchanges between the TIS application, TPG application and TPG operator is illustrated in figure 4.1.1. It includes the following sub systems:

- TIS application embedded in vehicle: it is in charge of identifying the tyre pressure event e.g. low tyre pressure event, discovering the TPG nearby or along its itinerary, if applicable requesting the reservation of a TPG, and providing data to TPG for refilling;
- TPG application at road side: it is in charge of exchanging data with TIS application tp manage the refilling;
- TPG operator application at central server: it is in charge of providing TPG availability information to road users, managing the TPG reservation and managing TPGs in its operation networks.

In one possible implementation, other elements may be added to support the customers' services.

EXAMPLE: Personal ITS-S may be used for TPG discovery and reservation from user, whilst a telematics service provider may manage some tasks for TPG operators from backend.

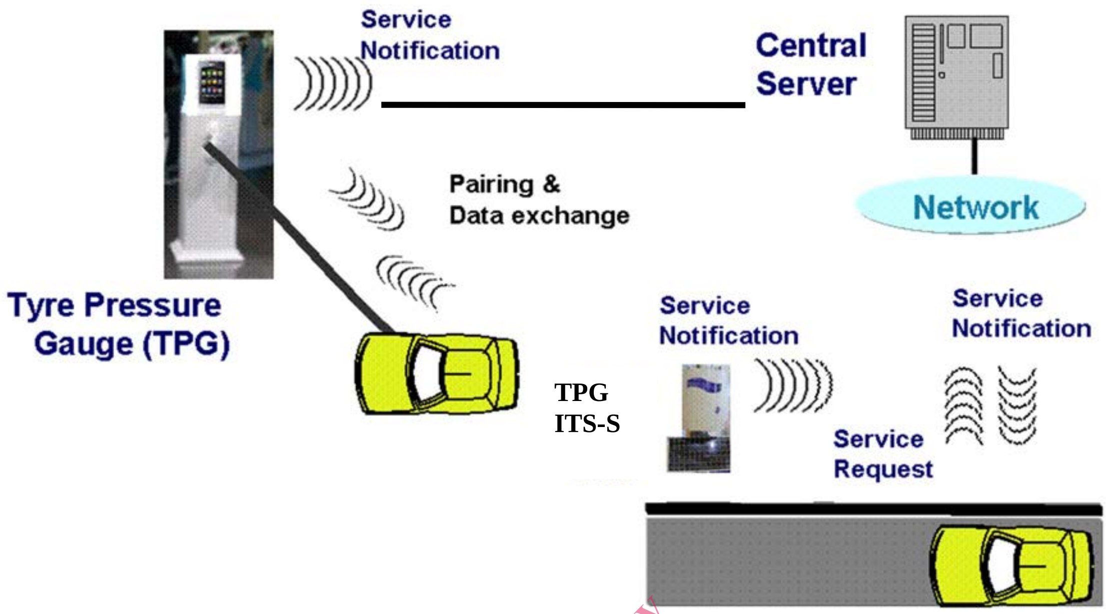

Figure 4.1.1: TIS, TPG, and TPG operator interaction overview

When the vehicle Tyre Pressure Monitoring System (TPMS) detects an abnormal tyre pressure event (e.g. under-inflation of one or more tyres), or when the driver wants to check or inflate at least one of its tyres, the TIS application triggers the TPG discovery and looks for the possible nearest available TPG stations. According to its embedded resources (communication, digital map) and available functionalities, the discovery may be realized by initiating a discovery request to the TPG operator at central server or at TPG station, or by receiving a service notification from the TPG operator, or by consulting the information contained in the embedded digital map containing the TPG station information.

A road side ITS Station (ITS-S) may be directly embedded into the TPG or connected with TPGs or with TPG operators, in order to receive real time availability information of TPGs. This road side ITS-S may be positioned on a geographical spot near by the road network, e.g. at the entry of a city or at the entry of a highway, in order to notify the local TPGs, their positions and availability to road users by a broadcasting service. A vehicle ITS-S may process the received TPG service notifications for the discovery purpose, or to update the embedded digital map for later usage.

Upon the discovery of an available TPG, the driver may decide to refill the vehicle's tyre(s). If the refilling need is confirmed, the driver may request the TIS application via the vehicle HMI to initiate the reservation of a TPG, or may directly go to the TPG station without reservation. In both cases, the driver can be guided to the selected TPG by means of its navigation system.

NOTE: The availability of reservation support may be included in a TPG service notification message.

Upon arrival at the TPG station, the TIS application pairs with a selected or the reserved TPG, then the TPG ITS-S establishes a point to point communication with the vehicle ITS-S for refilling operation. Data exchange requirements in this step is specified in CEN EN 16661 [1]. At the end of the refilling process, the TPG ITS-S sends an "End of Pairing" message which may contain the values of the tyre pressures actually provided.

4.2 Application evolution steps

The main application evolution steps are represented in the application state diagram as illustrated in figure 4.2.1.

Consequently, the following three steps are identified for TIS application:

- The discovery step of the nearest TPG by the vehicle, triggered by the detection of an abnormal tyre pressure event by the TPMS, or by the driver via HMI. The discovery step may further comprise an optional reservation process to enable end user to reserve one TPG, if the reservation service is offered by the TPG operator.

- The pairing step which consists of pairing the vehicle ITS-S with the TPG ITS-S which has been reserved/selected by the driver. This step is triggered by the driver at the arrival of the TPG.

- The tyre(s) refilling step which consists of adjusting the tyre(s) pressure(s) by TPG to vehicle according to data provided by the vehicle. This step is triggered by the TPG request message to TIS and is terminated with the reception of "end of pairing" message at vehicle ITS-S.

For the TPG application, the following steps are defined:

- Available: the TPG is available and operates correctly to provide refilling services. This step may be triggered by local TPG (e.g. system is ignited and correctly launched), or by a remote TPG operator.
- Reserved: the TPG is reserved during a time period. The refilling service is expected to be provided to the customer who has reserved the time slot. This step is triggered by the TPG operator that has confirmed the reservation with one customer.
- The pairing step which consists of pairing the vehicle ITS-S with the TPG ITS-S which has been reserved/selected by the driver. This step is triggered at the reception of the pairing data from customer or from vehicle ITS-S.
- Refilling ready: the TPG is correctly paired with the vehicle ITS-S. The TPG is ready to serve the customer for refilling. This step is triggered by the successful pairing and is terminated upon transmission of end of pairing" message to vehicle ITS-S after the refilling.

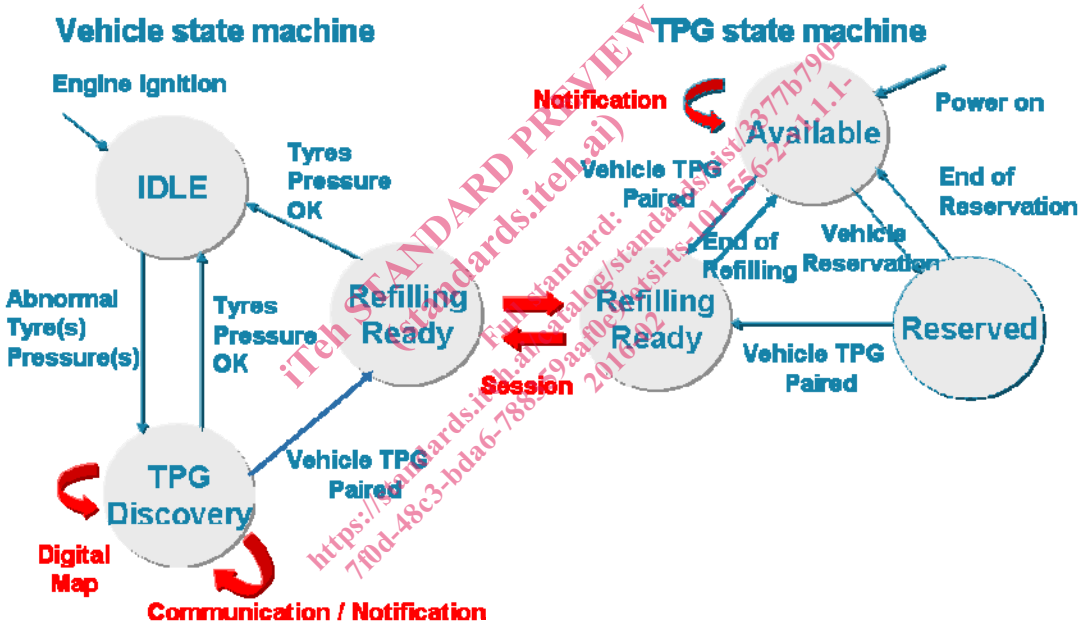

Figure 4.2.1: Application state machines

The interactions between the TIS application, the TPG application and the TPG operator are classified into three processes:

- TPG discovery process as defined in clause 4.3;
- TIS and TPG pairing process as defined in clause 4.4;
- Tyre refilling process as defined in clause 4.5.

4.3 TPG discovery process

The TPG discovery process identifies and locates one or more than one available TPGs being in the proximity of the vehicle or of a specific geographical location indicated by the driver. Following scenarios may be used for discovery process:

- If the vehicle is equipped with a navigation system, the TPG presence discovery may be realized by consulting its digital map data base which contains the TPG POIs. No communication is required for this scenario.

- A road side ITS-S broadcasts the availability of the TPG in local wireless network e.g. via ITS-G5 (IEEE 802.11p [i.1]) to oncoming vehicle ITS-Ss.

NOTE 1 : A service announcement message may be broadcasted before the transmission of the TPG service notification message. The service announcement message announces the availability of the service (i.e. TPG notification), and communication parameters for vehicle ITS-S to receive the service data.

NOTE 2: The specification of the service announcement message is out of scope of the present document.

- Vehicle ITS-S has Internet connectivity, it establishes communication directly with TPG operator by issuing a request, the TPG operator replies with TPG availability in accordance to customer request conditions e.g. search position, search range, TPG type, etc.

- The road side ITS-S provides Internet router functionalities to vehicle ITS-Ss that do not have Internet connectivity. It routes vehicle ITS-S request to the TPG operator and forwards the replies back to the requesting vehicle ITS-S.

NOTE 3: The availability of routing service at road side ITS-S may also be announced via a service announcement message.

NOTE 4: Access to the TPG operator service may be subject to conditions, e.g. contract, subscription.

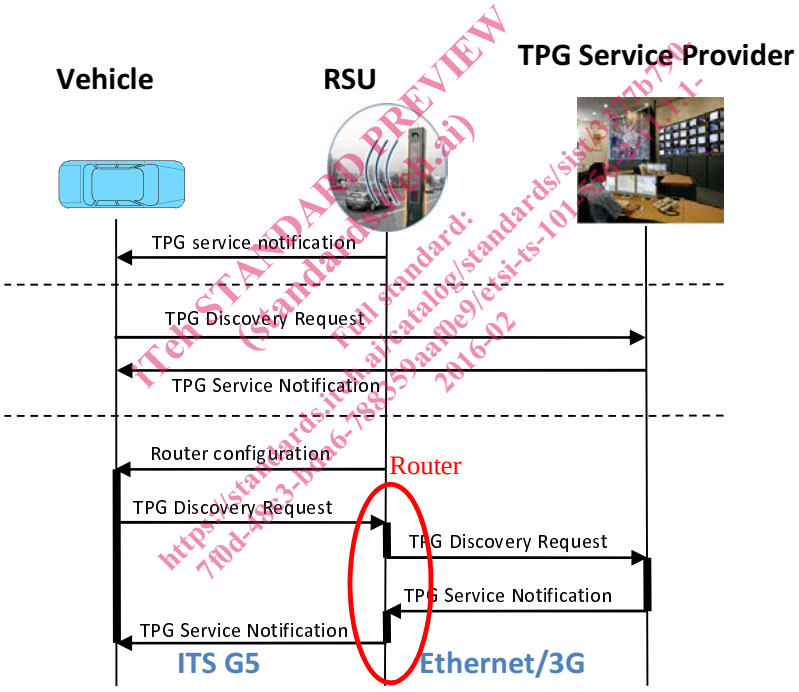

Figure 4.3.1: Examples of discovery scenarios

The discovery process enables TIS application to discover the available TPG according to its refilling needs. The available TPGs may be shown to users via e.g. HMI or over navigation system. The user then may select one of the available TPG as the next navigation way point.

Optionally and upon discovery of one available TPG, the customer may initiate the reservation request of a TPG if the reservation possibility is offered by the TPG operator. The reservation is triggered by the user (driver or passenger of the vehicle) by transmitting a reservation request to the TPG operator. The TPG operator verifies the reservation conditions and the availability of the relevant TPG, and proposes a reservation confirmation or declination message to the requesting user, including all reservation details and conditions.

If the reservation is confirmed, a reservation code may be generated by the TPG operator and transmitted to the requesting users. This reservation code may be used in TIS and TPG pairing step.

If the reservation is confirmed, the TPG operator changes the reserved TPG state from available to reserved, during the time period in which the reservation is effective. In case of cancellation (e.g. user no show up on time, reservation cancellation), the TPG operator puts the TPG back to available state for other users.

4.4 TIS and TPG pairing

Upon arrival at TPG, the TIS application may be required to pair with TPG application. An identification code is used for the pairing for vehicle and TPG to identify each other. This identification code is used by the TPG to address the vehicle for the provisioning of data required for the calculation of the pressures recommended for each tyre to be refilled. Optionally, an Authentication, Authorization, Accounting/Auditing (AAA) procedure may be launched for the pairing purpose:

- If a TPG has been reserved and the reservation has been confirmed by the TPG operator. A unique confirmation identification code is used for pairing. Optionally in addition, a TPG identifier may also be provided together with the reservation code. The provision of the identification code may be entered by driver on TPG HMI, or automatically by using a smart card.
- If the driver has not reserved a TPG, another identification code may be used. This identification code could be the vehicle registration number, the vehicle ITS-S network address (e.g. IPv6 address), the vehicle ITS-S MAC address, or simply a randomly assigned code assigned by the TPG operator on site.

NOTE 1: Depending on the implementation and the business model being used for the service provision, data being used for pairing may vary.

NOTE 2: It is out of the scope of the present document to specify the pairing procedure and data exchange needs.

NOTE 3: In one possible implementation, data exchange for pairing may not be required. For example, if the TPG service is free of charge and open to public, the identification of the vehicle ITS-S and TPG with each other is therefore not required. In this case, the pairing may be done by e.g. detection of physically connection of refilling cable to vehicle tyre, or by user confirmation via the TPG HMI.

4.5 Tyre refilling process

Data exchange for tyre refilling process and example of communication scenario are illustrated in figure 4.5.1.

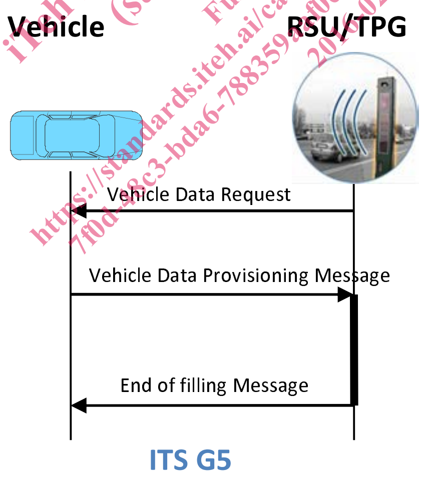

Figure 4.5.1: Flow diagram for the exchange of data between TIS and the TPG

As soon as the TPG and the TIS are paired, the TPG ITS-S sends a request to the Vehicle ITS-S, indicating basic operation information of the TPG. In CEN EN 16661 [1], the TPG may operate in three modes, respectively the fully automated mode, semi-automated mode and manual mode. Different vehicle data is required to be received by the TPG to support one mode. Therefore, the operation mode information is included in the vehicle data request, for TIS application to provide necessary data to the TPG application.

Upon reception of the vehicle data request, the TIS application transmits vehicle data to the requesting TPG.

Once the TPG receives vehicle data from the TIS application, the TPG application may adjust the refilling parameters accordingly e.g. calculation of the recommended refilling pressure. The tyres refilling process then starts. The refilling process may be illustrated by the TPG HMI. At the end of the tyres refilling process, the TPG application sends an "end of refilling" message to the TIS application, which may contain a service execution report.