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Intelligent transport systems — Service architecture of probe vehicle systems

Systèmes intelligents de transport — Architecture de services des systèmes de véhicules traceurs

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

More and more attention has been paid to safety, comfort, mitigation of impacts on the environment, and energy efficiency in transport systems. The use of probe data (specified in ISO 22837) is considered to be a key factor of a solution for the above issues.

This document defines a service architecture of probe vehicle systems (PVS). PVS functionalities can be implemented in an ITS station unit specified in ISO 21217 applying applicable protocols specified in other standards. Examples of applicable protocols are the local dynamic map specified in ISO 18750 and generic ITS station facilities layer services specified in ISO/TS 17429. The service architecture classifies ITS services which using PVS. This classification defines service domains for cooperation between PVS.

This document does not prescribe a physical communication medium for transmitting data/information to or from vehicles. This document is intended to be independent of any particular communication medium and to be compatible with any medium that is selected by system developers.

This document focuses on services that can be developed using public sector probe data that are generated by vehicles. The private sector can offer additional applications that require sign-in and identification; however, this document focuses on public sector applications that can be developed using anonymous probe data (specified in ISO 24100).

This document is an extension towards more general and global applicability of FHWA-JPO-13-091.

Intelligent transport systems — Service architecture of probe vehicle systems

1 Scope

This document specifies a service architecture that defines the framework and domain for classification of probe vehicle systems (PVS), which are systems that collect probe data from private vehicles and that process the probe data statistically towards useful information that finally can be provided to end users.

This document focuses on services that can be developed using public sector probe data that are generated by vehicles. It specifies the following items related to PVS:

— service framework of probe vehicle systems;

— definition of service domain of PVS.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
personally identifiable information
information that can be used in a given context to identify, contact, or locate a single person, or to identify an individual in context

4 Abbreviated terms

DSRC	dedicated short range communications
IPR	intellectual property rights
PII	personally identifiable information
PVS	probe vehicle system
V2I	vehicle-to-infrastructure (communications)
V2V	vehicle-to-vehicle (communications)
Wi-Fi	wireless fidelity

5 Service framework of probe vehicle systems

5.1 Basic concept of probe data

Probe data is data generated by vehicles (light duty, transit, freight and motorcycles, etc.) about their current position together with a time stamp. Probe data also include additional data elements provided by vehicles that have added intelligence, e.g. to detect traction information, brake status, hard braking, flat tyre, activation of emergency lights, anti-lock brake status, air bag deployment status, and windshield wiper status. Probe data from vehicles can be generated by devices integrated with the vehicles' computers, or nomadic devices brought into the vehicles.

Probe data does not include data that have been derived outside of the vehicle, even if these data were aggregated from data generated by vehicles. For example, travel times that are derived from position data (i.e. measurement from road–side equipment or gantry) are not classified as probe data.

Probe data can be generated or transmitted at various frequencies and trigger mechanisms using a range of wireless communication technologies, including dedicated short-range communications (DSRC)/ITS-M5 specified in ISO 21215, cellular network technologies, Wi-Fi using IEEE 802.11, worldwide interoperability for microwave access (WiMAX) standardized in IEEE 802.16, etc.

5.2 Concept of service architecture

Probe data can be collected from many vehicles. The ability to develop probe vehicle systems in a consistent and uniform manner reduces development time and cost. There are many ways that probe data elements and probe messages can be defined. In addition, system providers can select any system facility and communication medium.

Figure 1 illustrates the high-level concept of the probe data service framework, defining a reference structure of service using probe vehicle systems and providing illustrative examples of applications. Probe data from vehicles will be processed, cleaned and aggregated to generate information required by the applications. For example, probe data from vehicles can be used for a traveller information application. Instantaneous location and speed data collected from multiple vehicles that act as probes will be cleaned and aggregated to generate link travel times. Probe data from vehicles will also be used to generate origin-destination information (demand). The origin-destination information and link travel times will be used by the traveller information application to generate guidance on mode, route, and departure times, which will then be displayed on congestion maps, transmitted to vehicles for in-vehicle display, and transmitted to travellers on their personal communication devices.

The service architecture focuses on services and applications that can be developed using public sector probe data that are generated by vehicles (see dotted box in Figure 1), i.e. by devices that are integrated with the vehicles' system or by nomadic devices brought in to the vehicle. At this stage, data from external sensors (e.g. weather stations), transit and freight-specific data (e.g. transit schedules, truck loads), private sector probe data, and data from travellers' personal communication devices are outside the scope of this document. This document focuses on applications that can be developed using probe data that are within the scope. A probe service provider that provides as a public sector shall consider any other stakeholders based on the concept of service framework and architecture.

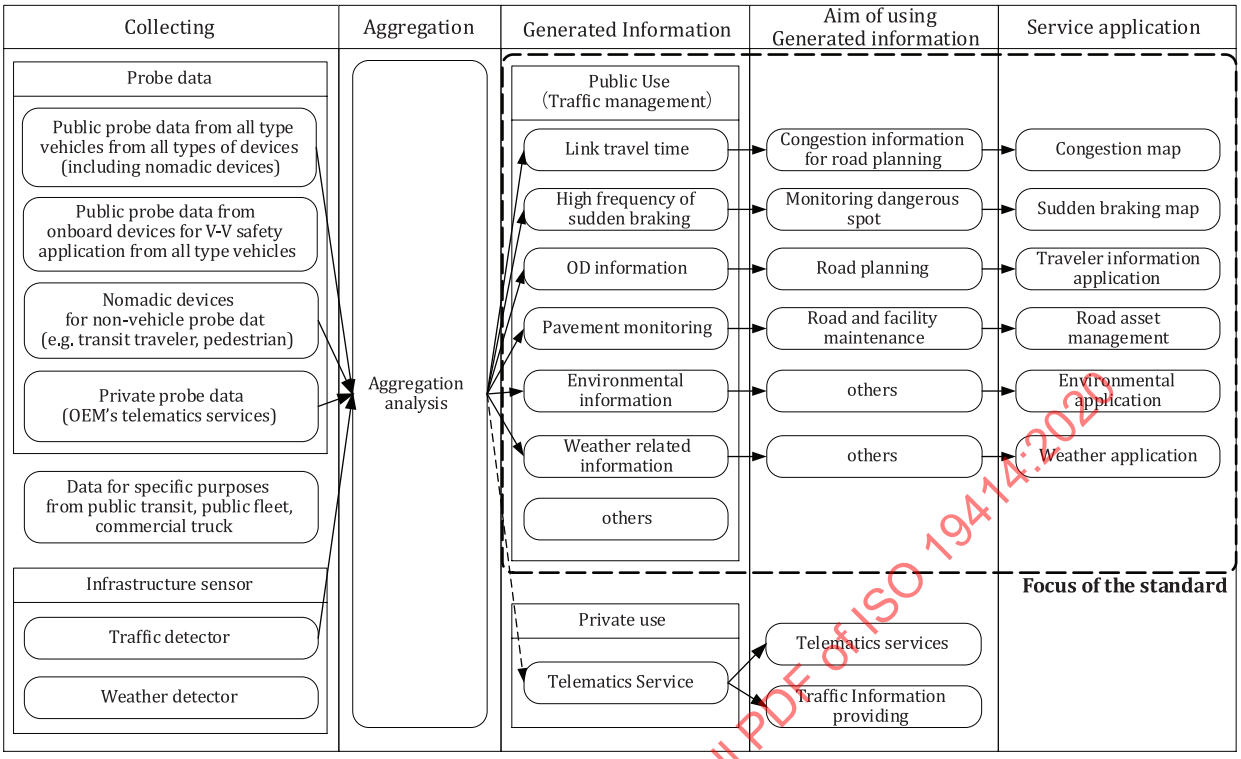

Figure 1 — Concept of service framework and architecture

A probe service provider should consider that probe data are collected from diverse sources and for diverse purposes and can be of lasting value to a broad range of researchers, private sector partners, and system operators, if the data:

a) are available;

b) are of sufficient quality and consistency required for the applications that are being developed;

c) are anonymized to protect the privacy of individuals whose trips constitute the probe data;

d) are formatted to comply with a standard to allow interoperability;

e) have supporting metadata to facilitate use of the data;

f) are easily accessible;

g) have clearly identified licensing and intellectual property rights (IPR) to enable use of the data without violating any rights.

5.3 Probe vehicle factors

5.3.1 General

The factors specified in 5.3 should be considered for cooperation between probe vehicle systems (PVS).

5.3.2 Quality assurance

The quality of policy and investment decisions is dependent on the quality of the data that informs the decision-making process. A review of the probe data sets reveals whether data have been verified for accuracy and consistency. However, none of the data sets identify the actual quality of the data. Agencies have their own internal procedures for performing quality control checks. When assessing if the data are of sufficient quality for conducting research, it is important to determine how the

data provider defines accurate or consistent data and what quality assurance processes are used. A consistent definition of what constitutes accurate or consistent probe data needs to be established and adopted by public and private sector data providers. In addition, quality assurance processes need to be established.

5.3.3 Privacy

Probe data that are publicly available need to comply with fair information principle practices to protect personally identifiable information (PII). Data capture efforts reveal whether data providers have established processes to remove PII from probe data. These range from eliminating the start and end segments of a trip, to assigning new IDs to a trip every day, to assigning temporary random IDs to a trip that only persist for part of the trip. A consistent approach to anonymizing probe data needs to be established and adopted by public and private sector data providers.

5.3.4 Standards

Detailed standards for data and interface are critical for interoperability. Integrating data from multiple sources, especially in real time, requires detailed guidelines and standards. Mobility and environmental applications will examine communications other than DSRC, such as cellular, Wi-Fi, for data exchange, and will heavily rely on data from travellers' portable devices in addition to data from vehicles and the infrastructure. Standards need to be established to reflect the evolving needs of probe data research that capture a wide range of communication technologies, and data sources.

5.3.5 Metadata

Metadata is critical to increasing the usability of the probe data. A review of the probe data sets reveal whether data providers include data dictionaries and supporting documentation. One or more metadata standards for probe and supporting data need to be established and adopted by public and private sector data providers to increase usability of their data.

5.3.6 Storage and access

To allow service providers easy access to probe data collected from various efforts, data needs to be readily and easily accessible. Decentralized storage and selective federation are emerging data management practices to improve quality management and data integration without full centralization.

5.3.7 Data ownership and IPR

To enable broad sharing of probe data, it is critical to protect the IPR of entities that sponsor or conduct the data capture and management efforts. Having no clearly defined licensing agreement can cause ambiguity to data ownership and rights of use. Where data are observed to have value to a broad set of stakeholders, this issue can become a serious and contentious issue. A licensing agreement also provides a mechanism to indemnify the data provider from any liabilities. Clear guidelines need to be established for identifying data ownership and licensing, including IPR, of probe data, supporting data, and processing tools.

6 Definition of service domains using service architecture

6.1 General

Prioritization criteria for the service architecture of PVS should be defined as follows:

a) use of probe data;

b) near-term deployment readiness (i.e. algorithms that are already in place or research will be ready for prototyping in 18 months to two years);

c) promotion of international standards harmonization;

d) public sector application;

e) expressway/freeway application.

The service architecture combines service applications that target a common problem into a specific target area. It describes seven target areas as a reference. Seven such target areas have been identified for potential collaboration on further research or deployment. The seven target areas and their component applications are outlined in 6.2.

6.2 Reference target areas

6.2.1 Traffic management measures estimation and traveller information applications

6.2.1.1 Traffic management measures estimation application

Traffic management measures estimation application uses probe data to estimate key measures of interest for traffic management including travel times (origin-destination specific, facility-specific), speed profiles, flows (origin-destination specific, facility-specific), and queues (including location and length).

This application:

a) Collects speed, location, and time stamp from a vehicle;

b) Scrubs data to remove PII;

c) Stores vehicle's travel history at a centre;

d) Matches scrubbed data against digital road maps to calculate vehicle's travel time,

e) Calculates travel times of multiple vehicles using above steps;

f) Calculates a travel time for the roadway section;

g) Analyses road sections that have lower speeds or higher congestion, and identifies the frequency and characteristics of occurrence; and

h) Provides basic information for use in highway administration for analysis of road network performance and development of road improvement plans.

6.2.1.2 Traveller information application

Traveller information application uses real-time and historical probe data, and other supplementary data (including tolling, parking availability, etc.) to recommend trip departure time, mode, route, travel cost, and approximate trip time, via vehicle-to-infrastructure (V2I) and infrastructure-to-mobile communications. Speed, location, and time stamp are collected from vehicles in real-time, scrubbed to remove PII, and stored at a centre. Scrubbed data are matched against digital road maps to calculate the travel time for a road section. The required travel time and state of congestion are determined for each section, and this information is provided to drivers and others.

This application:

a) collects speed, location, and time stamp from a vehicle;

b) scrubs data to remove PII;

c) stores the vehicle's travel history at a centre;

d) matches scrubbed data against digital road maps to calculate a vehicle's travel time;

e) calculates travel times of multiple vehicles using above steps;

f) calculates travel time and congestion for the roadway section; and

g) provides information to drivers and others.

6.2.2 Safety applications

6.2.2.1 Queue warning application

Queue warning application aims to minimize or prevent impacts of rear-end or secondary collisions by using V2I communications and vehicle-to-vehicle (V2V) communications to detect existing queues and/or predict impending queues; and communicate advisory queue warning messages to drivers upstream of roadway segments with existing or developing vehicle queues.

This application:

a) collects speed, transverse and lateral acceleration, location, and time stamp from vehicles in real-time;

b) scrubs data to remove PII;

c) stores data at a centre;

d) matches scrubbed data against digital road maps to estimate current locations of tail-ends of congestion, and detect presence of stopped vehicles or obstacles on the road; and

e) provides information to drivers and others.

6.2.2.2 Determination of accident-prone location application

Determination of accident-prone location application uses historical and real-time probe data and incident data logs, to detect and/or predict locations that are accident prone, and communicate the information to vehicles via V2I communications.

This application:

a) collects speed, transverse and lateral acceleration, location, and time stamp from vehicles;

b) scrubs data to remove PII;

c) stores data at a centre;

d) matches scrubbed data against digital road maps to identify potential accident hotspots and locations;

e) provides information to highway managers who use it to identify strategies to prevent accident and congestion; and

f) provides information to drivers.

6.2.3 Freight operations applications

6.2.3.1 Freight-specific dynamic travel planning and performance application

The freight-specific dynamic travel planning and performance application provides traveller information, and dynamic routing, and enables performance monitoring by leveraging existing data in the public domain, as well as emerging private sector applications.

This application:

a) collects state of travel of a logistics vehicle, including speed, location, and time stamp;

b) stores data at a centre; and

c) provides data to logistics companies that manage and operate logistics.

6.2.3.2 Detection of pavement deterioration due to heavy vehicles and determination of travel routes of heavy vehicle application

Detection of pavement deterioration due to heavy vehicles and determination of travel routes of heavy vehicle application aims to help highway managers in identifying routes where road pavement should be inspected for deterioration and determining travel routes of heavy vehicles.

This application:

a) collects location and time stamp data from heavy vehicles;

b) stores data at a centre;

c) matches data against digital road maps to calculate routes that were taken by heavy vehicles; and

d) provides archives to highway managers in identifying routes where road pavement should be inspected for deterioration and determining travel routes of heavy vehicles.

6.2.3.3 Intermodal drayage operations optimization application

The intermodal drayage operations optimization application combines container load matching and freight information exchange systems to fully optimize drayage operations, thereby minimizing bobtails/dry runs and wasted miles and spreading out truck arrivals at intermodal terminals throughout the day.

6.2.4 Freeway-based dynamic speed harmonization application

Dynamic speed harmonization application aims to maximize throughput and reduce crashes by using V2I and V2V communications to detect impending congestion that can necessitate speed harmonization, generating appropriate target speed recommendations for upstream traffic, and communicating the recommendations to the affected vehicles using either infrastructure-to-vehicle communications or V2V communications.

This application:

a) collects speed, acceleration/deceleration, location, time stamp, status of ABS and brakes, etc. in real time from vehicles;

b) scrubs data to remove PII;

c) stores data in a centre;

d) determines traffic conditions (such as reductions in traffic flow rates and occurrence of congestion) using real-time and historical data;

e) develops target speed recommendations by lane; and

f) provides target speed recommendations to drivers.

6.2.5 Non-signal related environmental applications

6.2.5.1 Determination of road environment application

Determination of road environment application uses probe data to provide basic information for use in highway administration, including determination of environmental problems and development of countermeasures.

This application:

a) collects speed, acceleration/deceleration, location, time stamp, vehicle type, and other data from vehicles;

b) stores data in a centre;

c) matches data against digital road maps to estimate carbon dioxide emissions and noise, etc., based on speed and acceleration/deceleration data; and

d) analyses data to determine frequency of worsened environmental conditions and characteristics of occurrence.

6.2.5.2 Eco-driving promotion application

Eco-driving promotion applications aim to provide drivers with information such as sections with poor fuel efficiency per unit distance. Speed, location, time stamp, and vehicle type are collected in real-time from vehicles.

6.2.5.3 Eco-lanes application

Eco-lanes application (or concept) seeks to encourage the use of dedicated freeway lanes by vehicles operating in eco-friendly ways, such as ECO-speed harmonization, eco-Cooperative Adaptive Cruise Control (ECO-CACC), and wireless charging of electric vehicles moving at freeway speeds.

6.2.5.4 Dynamic low emission zone application

A dynamic low emissions zone application (or concept) seeks to provide an incentive for environmentally friendly transportation choices or to restrict access to specific categories of high-polluting vehicles within a geographically defined area or zone for the purpose of improving the air quality within the zone.

6.2.6 Road and infrastructure deterioration diagnosis applications

Road and infrastructure deterioration diagnosis application makes use of probe data to detect deterioration of road surfaces, including the presence of potential potholes and rough road surface locations, and provides recommendations of road locations needing maintenance to maintenance managers and vehicle operators.

This application:

a) collects speed, location, time stamp, and other CAN bus data, vertical acceleration from on-board units and smart phones, and camera images, etc. from vehicles;

b) scrubs data to remove PII;

c) stores data in a centre;

d) matches data against digital road maps to estimate locations of deteriorated pavement and uneven surfaces; and

e) provides information to road management operators, which is used to improve the efficiency of road management operations, including identifying locations where road pavement should be inspected.

6.2.7 Road weather management applications

6.2.7.1 Enhanced maintenance decision support system application

Enhanced maintenance decision support system application aims to acquire road-weather data from connected vehicles, including snow ploughs, maintenance vehicles, and other general public vehicles

