Technical Report

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Intelligent transport systems — Seamless positioning for multimodal transportation in ITS stations —

Part 1: General information and use case definition

Systèmes de transport intelligents — Positionnement homogène pour le transport multimodal dans les stations ITS —

Partie 1: Informations générales et définition de cas d'utilisation

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

A list of all parts in the ISO 6029 series can be found on the ISO website.

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

As new forms of mobility service (e.g. e-mobility, delivery robot, autonomous driving) are emerging in the intelligent transport systems industry, the nomadic device is acquiring an indispensable role.

One use of nomadic devices is in positioning systems, in which mobility service platforms use the position data gathered via the nomadic devices of passengers. Current positioning systems rely on Global Navigation Satellite System (GNSS) technology. The functionality of such systems is occasionally constrained by network interference, a GNSS-denied environment or data loss. A seamless positioning system enables interoperability between ITS domains for the provision of a seamless location-based service.

The main objective of the seamless positioning system described in the ISO 6029 series is to support the development of a robust and ubiquitous indoor and outdoor seamless positioning solution for a mobile user (e.g. multimodal transportation) so that anyone can benefit from mobility services, regardless of location, environment and disability.

The seamless positioning system consists of three domains:

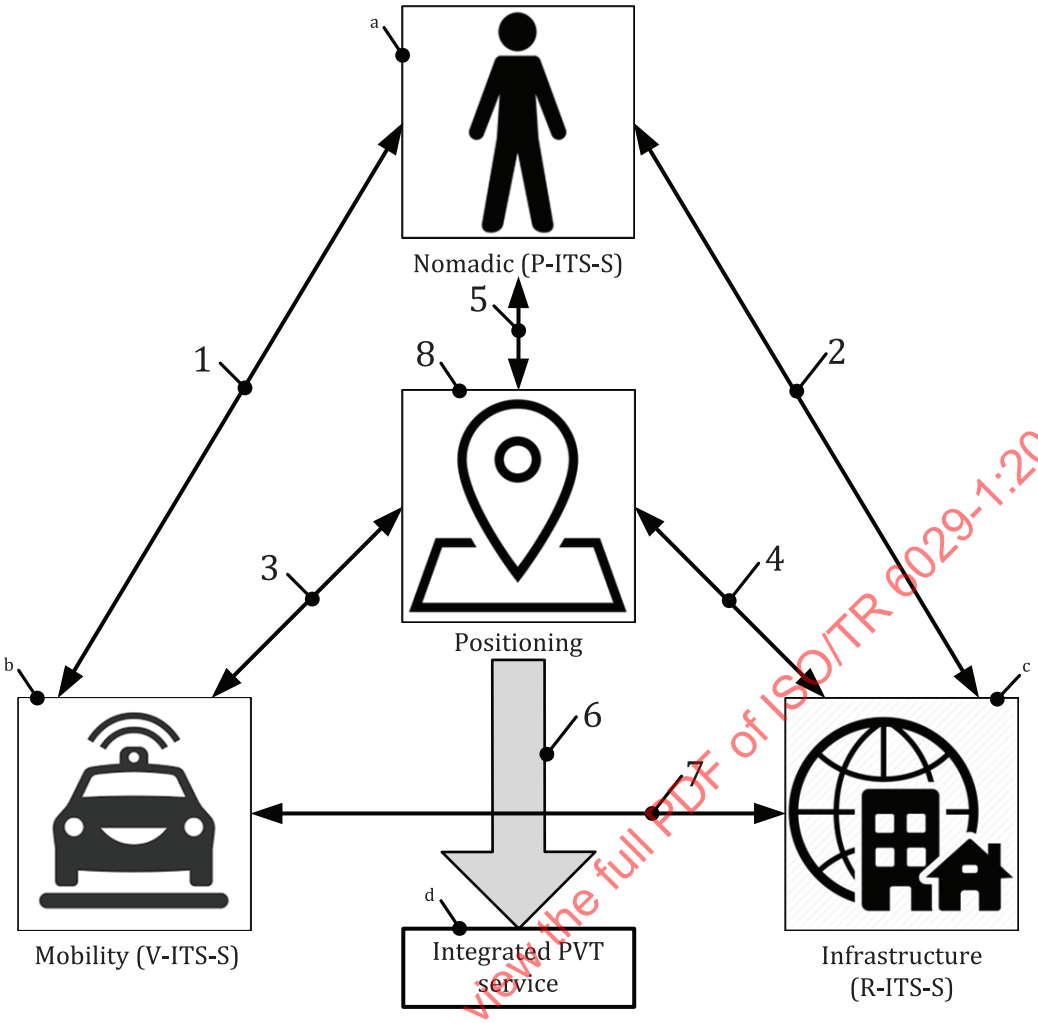
— nomadic device [e.g. personal intelligent transport system station (P-ITS-S)],

— mobility [e.g. vehicle intelligent transport system station (V-ITS-S)], and

— infrastructure [e.g. roadside intelligent transport system station (R-ITS-S)].

The system integrates multiple data from different domains and provides positioning data [e.g. position, velocity, time (PVT service implemented in the ITS-S)] in a seamless manner.

Figure 1 shows the seamless positioning system described in the ISO 6029 series.



Key

1 exchange of data between P-ITS-S and mobility containing mobility/personal data and network environment
2 exchange of data between P-ITS-S and infrastructure containing personal data and infrastructure information
3 exchange of data between mobility end and sensor-fusion positioning application
4 exchange of data between infrastructure end and sensor-fusion positioning application
5 exchange of data between P-ITS-S and sensor-fusion positioning application
6 seamless positioning calculation
7 positioning exchange use cases
8 positioning domain of all devices in P-ITS, V-ITS and R-ITS domain
a The P-ITS domain is represented by ITS-compliant nomadic devices carried by human beings.
b The V-ITS domain is represented by ITS-compliant vehicles.
c The R-ITS domain is represented by ITS-compliant roadside infrastructure devices.
d Outcome is the integrated position, velocity and time service provision.

Figure 1 — Seamless positioning system

The objective of the seamless positioning system is based on:

— extensibility, e.g. artificial intelligence, block-chain, sensor-fusion technology;

— simplification, e.g. standardized message format based on ISO/TS 21184 (GTDM), IEC 61162[6] and NMEA 0183;[7]

— reliability, e.g. system reliability, data precision, fast first to fix, dilution correction factors;

— application, e.g. the ISO 17438 series, autonomous driving features, location-based service, safety-related industry.

Intelligent transport systems — Seamless positioning for multimodal transportation in ITS stations —

Part 1: General information and use case definition

1 Scope

This document describes use cases related to seamless positioning systems for multimodal transportation in ITS stations. The use cases define the effectiveness of the seamless positioning concept model based on the P-ITS-S to conclude basic PVT service results using available sensors when mobility is moving indoor and outdoor in a network on/off situation. Use cases are provided for each stage in different environments, e.g. indoor, outdoor, tunnel and out-of-network area when travelling starts or ends. Within the use cases, the nomadic device implements a personal ITS station (P-ITS-S) to achieve compatibility with other ITS stations as referenced in this document.

The main purpose of this document is to describe the overall concept model, which specifies:

— the concept model and actors for each domain;

— the relationship of actors under the material domain;

— the message sequence diagrams for each domain; and

— the data transmission list for each actor to provide a seamless indoor and outdoor positioning system through sensor data fusion.

In addition, this document provides:

— basic principles used in its drafting; and

— a gap analysis, consisting of a formal study of:

  — the status of seamless positioning technology and implementations,

  — how seamless positioning technology intends to evolve, and

  — how to close the gap between current and future technology and implementations.

This document compares desired and actual outcomes and pinpoints opportunities for improvement.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21177, *Intelligent transport systems — ITS station security services for secure session establishment and authentication between trusted devices*

ISO 21217, *Intelligent transport systems — Station and communication architecture*

ISO/TS 21184, *Cooperative intelligent transport systems (C-ITS) — Global transport data management (GTDM) framework*

ISO/TS 21176, *Cooperative intelligent transport systems (C-ITS) — Position, velocity and time functionality in the ITS station*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21217, ISO 21177, ISO/TS 21184, ISO/TS 21176 and the following apply.

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

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

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

3.1
infrastructure communication
I-COMM
infrastructure (R/C-ITS-S) data exchange

3.2
infrastructure location profile handler
I-LPH
infrastructure location-based positioning data profile function

3.3
infrastructure floor profile handler
I-FPH
infrastructure triangulation measurement-based positioning data profile function

3.4
motion
change in the position of an object over time, represented by change of coordinate values with respect to a particular reference frame

[SOURCE: ISO 19116:2019, 3.18, modified — the Example has been removed.]

3.5
motion positioning station gateway
M-PSG
ITS-based positioning device

3.6
motion registration information
M-RI
motion-based registration information

3.8
motion status profile handler
M-SPH
motion detection and status profile function

3.9
multimodal
involving several modes, modalities, or maxima

3.10
personal floor profile handler
P-FPH
P-ITS-S-based altitude positioning data profile function

3.11
personal location profile handler
P-LPH
P-ITS-S-based positioning data profile function

3.12
personal registration information
P-RI
user profile-based registration information

3.13
personal status profile handler
P-SPH
P-ITS-S-based motion activity profile function

3.14
positioning
POS
moving object position data

3.15
positioning accuracy profile handler
POS-APH
positioning data precision profile function

3.16
positioning fusion profile handler
POS-FPH
positioning data fusion profile function

3.17
positioning status profile handler
POS-SPH
positioning data status profile function

3.18
positioning velocity profile handler
POS-MPH
positioning data-based velocity profile function

4 Abbreviated terms

BP	basic principle
GLONASS	Russian global navigation satellite system
GNSS	global navigation satellite system
GPS	global positioning system
GW	gateway
I-COMM	infrastructure communication
IEEE	Institute of Electrical Engineers
I-FPH	infrastructure floor profile handler
IMU	inertial measurement unit

I-LPH	infrastructure location profile handler
ITS	intelligent transport system
KPI	key performance indicator
LaaS	logistics as a service
M-PSG	motion positioning station gateway
M-RI	motion registration information
M-SPH	motion status profile handler
MaaS	mobility as a service
MAC	media access control
ND	nomadic device
P-FPH	personal floor profile handler
P-ITS-S	personal intelligent transport system station
P-LPH	personal location profile handler
P-RI	personal registration information
P-SPH	personal status profile handler
POS	positioning
POS-APH	positioning accuracy profile handler
POS-FPH	positioning fusion profile handler
POS-SPH	positioning status profile handler
POS-MPH	positioning velocity profile handler
PVT	position, velocity, time
RFID	radio-frequency identification
R-ITS-S	roadside intelligent transport system station
RSSI	received signal strength indicator
TaaS	transportation as a service
TTFF	time to first fix
UWB	ultra-wide band
V-ITS-S	vehicle intelligent transport system station

5 Gap analysis of seamless positioning systems

5.1 Key performance indicator (KPI)

5.1.1 Current KPIs

The applicable KPIs for the ISO 6029 series are based on SAE J2945/7.[5]

5.1.2 Future KPIs

The future KPIs are based on the tiers that are listed in the performance requirements of SAE J2945/7. Since the seamless positioning system operates based on network data, future KPI development considers the data attributes. Table 1 defines the KPIs for the ISO 6029 series.

Table 1 — Future KPI

Properties	KPI	Measure (unit)	Notes
time	latency	ms	Measure of delay to retrieve positioning data from other positioning handler.
	packet delivery time	ms	Measure of positioning data propagation and transmission time between positioning handlers.
	TTFF	ms	Measure of the first position fixed time. This is required for position initialization.
accuracy	position	cm, m	Measure of the level of positioning data accuracy. The level of accuracy varies for various sources of positioning data.
	time	ms	Measure of time accuracy for data received.
throughput	coordinate data	bit/s	Data throughput is sorted by the data source. The KPI is determined by the amount of data processing per second.
	RSSI data	bit/s	
	IMU data	bit/s	
	image sensor data	Mbit/s	

5.2 Market applicability

The following is a list of prospective areas where the ISO 6029 series is applicable.

— Logistics (e.g. LaaS, last mile delivery).

— Autonomous driving technology (e.g. indoor driving, passing tunnel, basement).

— Multimodal transit service (e.g. bus, taxi, subway, shared mobility, MaaS, TaaS).

— Disabled and elderly person pick-up service (e.g. where person needs to be picked up directly from the facility).

5.3 Market benefits

ISO 6029 series benefits all mobility-related areas with respect to service quality and efficiency:

— efficiency (e.g. less driving, less energy consumption, short-cut routing etc);

— time saving (e.g. delivery, transfer, wait time, etc);

— expansion of the driving territory of an autonomous vehicle (e.g. parking lot, basement, tunnel, etc).

6 Basic principles and use cases overview

6.1 Basic principles

Basic principles (BPs) have been established for the development of this document.

— BP1: Seamless positioning use cases describe the positioning data handover process between positioning data handlers.

— BP2: Seamless positioning use cases of the same subject are combined in one seamless positioning use case group.

— BP3: Seamless positioning use cases are described from a P-ITS-S and V-ITS-S point of view.

— BP4: Dataset and data exchange within seamless positioning systems are developed to provide flawless and continuous positioning data in a stable manner.

— BP5: All communication messages are compatible with ISO/TS 21184.

— BP6: All data definitions are compatible with ISO/TS 21184.

— BP7: All security-related statements are compatible with ISO 21177.

— BP8: All access control policy-related statements are compatible with ISO 21177 and ISO/TS 21184.

— BP9: The gap analysis addresses current versus future performance of seamless positioning systems.

6.2 Use case groups and associated use cases

Table 2 provides an overview of the main use case groups and associated use cases.

Table 2 — Use case groups (UCG) and associated use cases (UC)

#	UCG name	UC name reference
1	Nomadic device (ND) — Positioning	UC 1.1 — Indoor positioning based on network connected environment
		UC 1.2 — Indoor positioning based on network disconnected environment
		UC 1.3 — Outdoor positioning based on network connected environment
		UC 1.4 — Outdoor positioning based on network disconnected environment
2	Mobility — Positioning initialization	UC 2.1 — Initial positioning when mobility is on the move outdoors
		UC 2.2 — Positioning data validation in radio-shadow/distorted areas (outdoor)
		UC 2.3 — Positioning data update based on RSSI (indoor)
3	Mobility — Tunnel	UC 3.1 — Positioning in tunnel based on map data
		UC 3.2 — Positioning calibration in tunnel based on the latest location
4	Mobility — Entrance point (from outdoor to indoor)	UC 4.1 — Indoor positioning using wireless communication network
		UC 4.2 — Indoor positioning using IEEE 802.11 wireless LAN
		UC 4.3 — Indoor positioning using short-range wireless network
5	Mobility — Exit point (from indoor to outdoor)	UC 5.1 — Map-based positioning when vehicle is on the move to outdoors
		UC 5.2 — The latest location-based positioning when vehicle is on the move outdoors
6	Mobility — Shadow zone (indoor)	UC 6.1 — Positioning in indoor shadow zone (spiral structure)
		UC 6.2 — Positioning in indoor shadow zone (straight vertical)
7	Mobility — Distorted area of positioning data	UC 7.1 — Distorted area with positioning support system (outdoor)
		UC 7.2 — Distorted area without positioning support system (outdoor)

7 UC definition

7.1 UCG Nomadic device (ND) — Positioning

7.1.1 General

This UCG defines the use cases based on network availability of the nomadic device (ND) and the PVT service as a result using the internal sensors.

7.1.2 UC 1.1 — Indoor positioning based on network connected environment

Table 3 specifies UC 1.1 — Indoor positioning based on network connected environment.

Table 3 — UC 1.1 — Indoor positioning based on network connected environment

Item	Description
Title	UC 1.1 — Indoor positioning based on network connected environment
Goal	to retrieve positioning data in a seamless manner in a connected area
Actor	P-ITS-S (ND)
Input	request for indoor positioning
Output	indoor positioning data
Function	indoor positioning data containing information from infrastructure access point data (e.g. IEEE 802.11 wireless LAN, Bluetooth, RFID, etc)
Classification	mandatory

7.1.3 UC 1.2 – Indoor positioning based on network disconnected environment

Table 4 specifies UC 1.2 — Indoor positioning based on network disconnected environment.

Table 4 — UC 1.2 — Indoor positioning based on network disconnected environment

Item	Description
Title	UC 1.2 — Indoor positioning based on network disconnected environment
Goal	to retrieve positioning data in a seamless manner in a disconnected area
Actor	P-ITS-S (ND)
Input	request for indoor positioning
Output	indoor positioning data
Function	indoor positioning data are gathered using dead reckoning method based on the latest positioning data
Classification	mandatory

7.1.4 UC 1.3 — Outdoor positioning based on network connected environment

Table 5 specifies UC 1.3 — Outdoor positioning based on network connected environment.

Table 5 — UC 1.3 — Outdoor positioning based on network connected environment

Item	Description
Title	UC 1.3 — Outdoor positioning based on network connected environment
Goal	to retrieve positioning data with satellite-based positioning system
Actor	P-ITS-S (ND)
Input	request for outdoor positioning
Output	outdoor positioning data
Function	outdoor positioning data are gathered with satellite positioning information (e.g. GNSS, GPS, GLONASS, BeiDou, Galileo, etc)
Classification	mandatory

7.1.5 UC 1.4 — Outdoor positioning based on network disconnected environment

Table 6 specifies UC 1.4 — Outdoor positioning based on network disconnected environment.

Table 6 — UC 1.4 — Outdoor positioning based on network disconnected environment

Item	Description
Title	UC 1.4 — Outdoor positioning based on network disconnected environment
Goal	to retrieve positioning data in a seamless manner in network disconnected outdoor
Actor	P-ITS-S (ND)
Input	request for outdoor positioning in network disconnected outdoor
Output	outdoor positioning data
Function	outdoor positioning data are calculated using dead-reckoning method from the latest positioning data
Classification	mandatory

7.2 UCG Mobility — Positioning initialization

7.2.1 General

This UCG defines the use cases based on the positioning initialization process by network condition.

7.2.2 UC 2.1 — Initial positioning when mobility is on the move outdoors

Table 7 specifies UC 2.1 — Initial positioning when mobility is on the move outdoors.

Table 7 — UC 2.1 — Initial positioning when mobility is on the move outdoors

Item	Description
Title	UC 2.1 — Initial positioning when mobility is on the move outdoors
Goal	to initialize mobility's position
Actor	M-PSG
Input	request for outdoor positioning initialization
Output	initialized outdoor position data
Function	retrieve mobility's initial position before making the move using satellite positioning information
Classification	mandatory

7.2.3 UC 2.2 — Positioning data validation in radio-shadow/distorted areas (outdoor)

Table 8 specifies UC 2.2 — Positioning data validation in radio-shadow/distorted areas (outdoor).

Table 8 — UC 2.2 — Positioning data validation in radio-shadow/distorted network area (outdoor)

Item	Description
Title	UC 2.2 — Positioning data validation in radio-shadow/distorted network area (outdoor)
Goal	to validate positioning data which was gathered in radio-shadow/distorted network areas
Actor	M-PSG
Input	request for outdoor position validation
Output	outdoor position data validation result
Function	validate positioning data which was gathered from radio-shadow/network distorted areas
Classification	mandatory

7.2.4 UC 2.3 — Positioning data update based on RSSI (indoor)

Table 9 specifies UC 2.3 — Positioning data update based on RSSI (indoor).

Table 9 — UC 2.3 – Positioning data update based on RSSI (indoor)

Item	Description
Title	UC 2.3 — Positioning data update based on RSSI (indoor)
Goal	to retrieve indoor positioning data with RSSI
Actor	M-PSG
Input	request for indoor positioning data
Output	indoor positioning data
Function	retrieve indoor positioning data based on RSSI
Classification	mandatory

7.3 UCG Mobility — Tunnel

7.3.1 General

This UCG defines the use cases where the mobility is passing through a tunnel. The methodology differs according to the available data. Use cases are specified based on the positioning methodology.

7.3.2 UC 3.1 — Positioning in tunnel based on map data

Table 10 specifies UC 3.1 — Positioning in tunnel based on map data.

Table 10 — UC 3.1 — Positioning in tunnel based on map data

Item	Description
Title	UC 3.1 — Positioning in tunnel based on map data
Goal	to retrieve positioning data while in tunnel with map data
Actor	M-PSG
Input	request for vehicle's positioning data which was gathered while passing the tunnel
Output	positioning data
Function	retrieve positioning data while passing the tunnel with dead-reckoning and map-matching methods.
Classification	mandatory

7.3.3 UC 3.2 — Positioning calibration in tunnel based on the latest location

Table 11 specifies UC 3.2 — Positioning calibration in tunnel based on the latest location.

Table 11 — UC 3.2 — Positioning calibration in tunnel based on the latest location

Item	Description
Title	UC 3.2 — Positioning calibration in tunnel based on the latest location
Goal	to calibrate positioning data while in tunnel with the latest location information
Actor	M-PSG
Input	request for calibrated vehicle's positioning data
Output	calibrated positioning data
Function	retrieve referencing positioning data and gather IMU data while passing a tunnel and then calibrate gathered data to determine its position
Classification	mandatory

7.4 UCG Mobility — Entrance point (from outdoor to indoor)

7.4.1 General

This UCG defines the use cases where the mobility makes an entrance from the outdoor to indoor. The process differs depending on the available source.

7.4.2 UC 4.1 — Indoor map transmission using wireless network

Table 12 specifies UC 4.1 — Indoor map transmission using wireless network.

Table 12 — UC 4.1 — Indoor map transmission using wireless network

Item	Description
Title	UC 4.1 — Indoor positioning using wireless communication network
Goal	to receive indoor map data and initiate indoor positioning through wireless communication network
Actor	M-PSG
Input	request for indoor map data through wireless communication network
Output	indoor positioning
Function	retrieve indoor map data and start indoor positioning using wireless communication network
Classification	mandatory

7.4.3 UC 4.2 — Indoor map transmission using IEEE 802.11 wireless LAN

Table 13 specifies UC 4.2 — Indoor map transmission using IEEE 802.11 wireless LAN.

Table 13 — UC 4.2 – Indoor map transmission using IEEE 802.11 wireless LAN

Item	Description
Title	UC 4.2 — Indoor positioning using IEEE 802.11 wireless LAN
Goal	to receive indoor map data and initiate indoor positioning through IEEE 802.11 wireless LAN
Actor	M-PSG
Input	request for indoor map data through IEEE 802.11 wireless LAN network
Output	indoor positioning
Function	retrieve indoor map data and start indoor positioning using IEEE 802.11 wireless LAN network
Classification	mandatory

7.4.4 UC 4.3 — Indoor map transmission using short-range wireless network

Table 14 specifies UC 4.3 — Indoor map transmission using short-range wireless network.

Table 14 — UC 4.3 — Indoor map transmission using short-range wireless network

Item	Description
Title	UC 4.3 — Indoor positioning using short-range wireless network
Goal	to receive indoor map data and initiate indoor positioning through short-range wireless network
Actor	M-PSG
Input	request for indoor map data through short-range wireless network
Output	indoor positioning
Function	retrieve indoor map data and start indoor positioning using short-range wireless network
Classification	mandatory

7.5 UCG Mobility — Exit point (from indoor to outdoor)

7.5.1 General

This UCG defines the use cases where the mobility makes an exit from the indoor to outdoor. The process differs depending on the available source.

7.5.2 UC 5.1 — Map-based positioning when vehicle is on the move to outdoors

Table 15 specifies UC 5.1 — Map-based positioning when vehicle is on the move to outdoors.

Table 15 — UC 5.1 — Map-based positioning when vehicle is on the move to outdoors

Item	Description
Title	UC 5.1 — Map-based positioning when vehicle is on the move to outdoors
Goal	to position the vehicle position with map-matching platform
Actor	M-PSG
Input	request for outdoor map-matched positioning data
Output	outdoor positioning
Function	switch to outdoor positioning with map-matching feature
Classification	mandatory

7.5.3 UC 5.2 — The latest location-based positioning when vehicle is on the move outdoors

Table 16 specifies UC 5.2 — The latest location-based positioning when vehicle is on the move outdoors.

Table 16 — UC 5.2 — The latest location-based positioning when vehicle is on the move outdoors

Item	Description
Title	UC 5.2 — The latest location-based positioning when vehicle is on the move outdoors
Goal	to locate vehicle position with dead reckoning data based on the latest position information
Actor	M-PSG
Input	request for outdoor positioning with dead-reckoning data
Output	outdoor positioning
Function	switch to outdoor positioning with dead-reckoning data
Classification	mandatory

7.6 UCG Mobility — Shadow zone (indoor)

7.6.1 General

This UCG specifies the use cases where the mobility travels floor to floor within a building. The positioning process differs depending on the available source.

7.6.2 UC 6.1 — Positioning in indoor shadow zone (spiral structure)

Table 17 specifies UC 6.1 — Positioning in indoor shadow zone (spiral structure).

Table 17 — UC 6.1 – Positioning in indoor shadow zone (spiral structure)

Item	Description
Title	UC 6.1 — Positioning in indoor shadow zone (spiral structure)
Goal	positioning a mobility travelling floor to floor in spiral manner
Actor	M-PSG
Input	request for positioning using dead-reckoning and elevation sensor
Output	indoor positioning floor to floor
Function	when the mobility makes a move floor to floor in spiral manner, dead-reckoning and elevation data are being used to determine its position
Classification	mandatory

7.6.3 UC 6.2 — Positioning in indoor shadow zone (straight vertical)

Table 18 specifies the UC 6.2 — Positioning in indoor shadow zone (straight vertical).

Table 18 — UC 6.2 — Positioning in indoor shadow zone (straight vertical)

Item	Description
Title	UC 6.2 — Positioning in indoor shadow zone (straight vertical)
Goal	positioning a mobility travelling floor to floor in straight vertical manner
Actor	M-PSG
Input	request for positioning using elevation sensor
Output	indoor positioning floor to floor
Function	when the mobility makes a move floor to floor in a straight vertical manner, elevation sensor data are used to determine its position then switch to applicable indoor positioning method
Classification	mandatory

7.7 UCG Mobility — Distorted area of positioning data

7.7.1 General

This UCG specifies the use cases where the mobility travels through a distorting network area (network noise). The positioning process differs depending on the available source.

7.7.2 UC 7.1 — Distorting network area with positioning support system (outdoor)

Table 19 specifies the UC 7.1 — Distorting network area with positioning support system (outdoor).

Table 19 — UC 7.1 — Distorting network area with positioning support system (outdoor)

Item	Description
Title	UC 7.1 — Distorting network area with positioning support system (outdoor)
Goal	to retrieve positioning data with the aiding from A-GPS
Actor	M-PSG
Input	request for positioning data
Output	outdoor positioning data with A-GPS
Function	switch to A-GPS positioning data while travelling network distorting environment
Classification	mandatory

7.7.3 UC 7.2 — Distorted area without positioning support system (outdoor)

Table 20 specifies the UC 7.2 — Distorted area without positioning support system (outdoor).

Table 20 — UC 7.2 — Distorted area without positioning support system (outdoor)

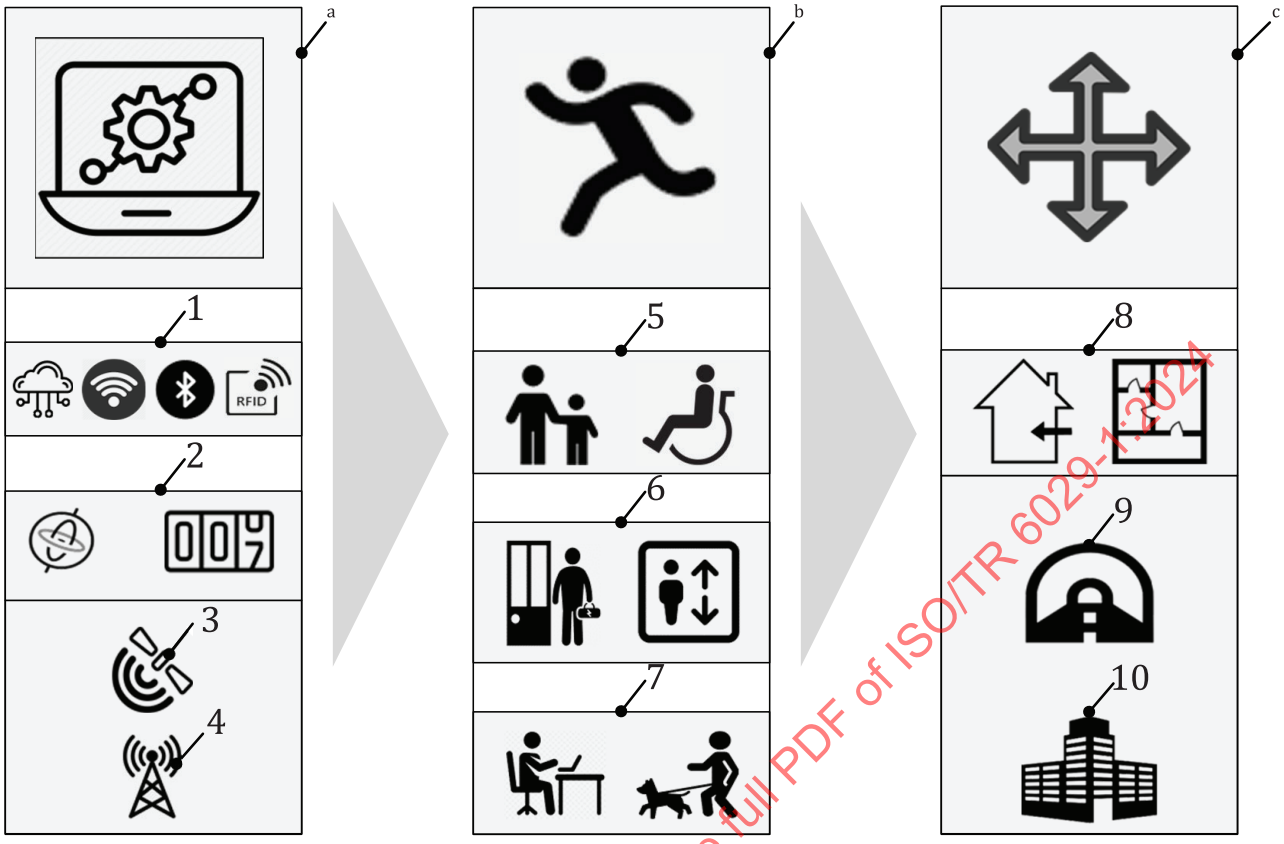
Item	Description
Title	UC 7.2 — Distorted area without positioning support system (outdoor)
Goal	to retrieve positioning data with dead reckoning system where outdoor area has distorted network
Actor	M-PSG
Input	request for positioning data with dead reckoning data
Output	outdoor positioning data from dead reckoning data
Function	switch to dead reckoning data while travelling network distorting environment
Classification	mandatory

8 Seamless positioning concept model

8.1 Overview

8.1.1 Seamless positioning service outline

The concept model specified in this document provides a seamless positioning service to users who need mobility-related services. Based on the user's circumstance and characteristics, use cases and applicable techniques are determined. In this document, the use cases and techniques are addressed from an ND application perspective. Figure 2 shows the seamless positioning service outline.



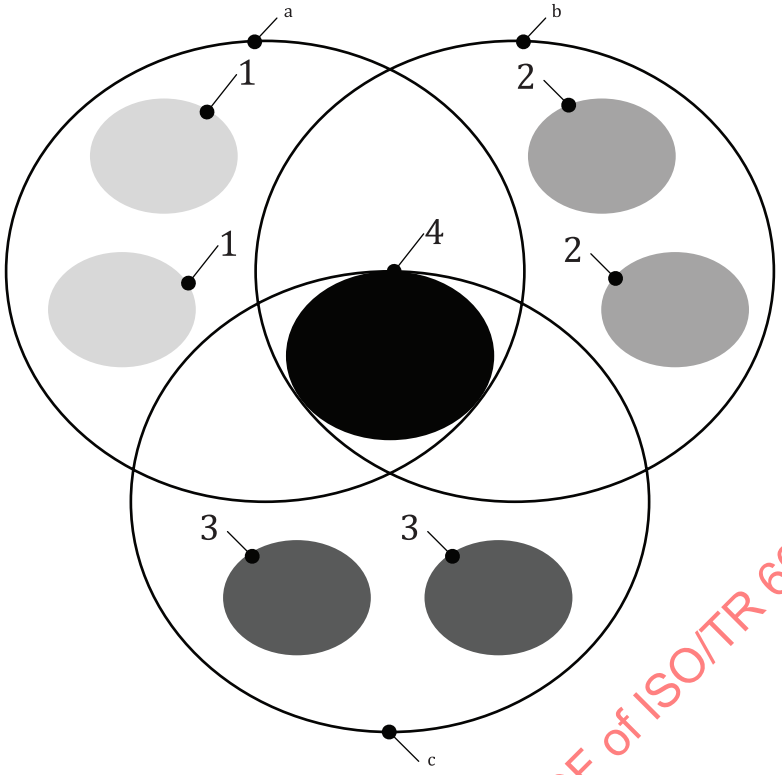
Key

a	Positioning related technologies (e.g., satellite, sensor, network-based).	5	personal characteristics (e.g. disabled, elderly, etc.)
b	Data from P-ITS-S (ND).	6	mobile state identification (e.g. elevator, entering building, etc.)
c	Seamless positioning.	7	activity identification (e.g. sitting, walking, etc.)
1	wireless network	8	indoor environment (e.g. GNSS-denied, etc.)
2	sensor (e.g. IMU, odometer, etc.)	9	signal-loss (e.g. tunnel, GPS-denied area, etc.)
3	satellite (e.g. GPS, GNSS, Galileo)	10	distortion (e.g. urban canyon, weak signal, etc.)
4	cellular network (WAN)		

Figure 2 — Seamless positioning service outline

8.1.2 Common actors concept model

The conceptual aspects of the seamless positioning systems are illustrated in Figure 3. Figure 3 illustrates the overall ITS domains along with actors. Each domain contains actors performing independently. The actors which gather positioning-related data are categorized as a common actor for sensor fusion positioning application (key element 4).



Key

a	Nomadic (P-ITS-S) domain.	1	nomadic (P-ITS-S) actors
b	Mobility (V-ITS-S) domain.	2	mobility (V-ITS-S) actors
c	Infrastructure (R-ITS-S) domain.	3	infrastructure (R-ITS-S) actors
		4	common ITS actor

Figure 3 — Common actors concept model

8.2 Definition of domains

8.2.1 General

Table 21 defines the domain items.

Table 21 — Domain items definitions

Domain	Item(s)	Description
Nomadic (P-ITS-S)	Subject	device being carried around and send position data through wireless network
	Features	production, distribution, consumption
	Category	provide positioning related service and mobility service
	Role	provide passenger or mobility's current position information and carry out mobility service solely or through exchanging data among other domains.
Mobility (V-ITS-S)	Subject	carry out mobility service or mobility service provider
	Features	production, distribution, consumption
	Category	provide the nearest available mobility and carry out mobility service
	Role	provide positioning related service, check passenger boarding and gather mobility trip information data solely or through exchanging data among other domains.

Table 21 *(continued)*

Domain	Item(s)	Description
Infrastructure (R-ITS-S)	Subject	infrastructure maintenance agency (public/private sectors)
	Features	production, distribution
	Category	positioning data or traffic data
	Role	send positioning data to cloud server, which is gathered through trigonometric measurement among nomadic device, mobility, network access point.
Positioning	Subject	seamless positioning feature
	Features	production, management, service
	Category	seamless positioning data and service
	Role	provide seamless PVT service through data exchange between cloud server and sensor fusion interface

8.2.2 Role of personal device (ND) domain and actors

The role of the personal device (ND) is to receive satellite-based positioning data (e.g. GNSS) along with any applicable information (e.g. IEEE 802.11 wireless LAN, Bluetooth, RFID, UWB) to determine its position. The personal device also detects the passenger's motion to determine the activity (e.g. walking, idling, running, on board, deboard). Table 22 provides information about subsequent actors along with the attributes of data.

Table 22 — Personal device (ND) actors information

Actor (ID)	Attribute	Attribute function
P-ITS-S (ND)	Type	device
	Information	wireless network and position data and transmission
	Interface	cellular, IEEE 802.11 wireless LAN, UWB, BT, RFID
	Sensor	GNSS, IEEE 802.11 wireless LAN, BT, UWB, RFID
	GW actor	yes
	Function	subject of P-ITS-S: 1) acts as a processor and stores sub-actor information; 2) provides seamless positioning with built-in sensors and data processing through wireless network; 3) sends position and routing data.
P-RI	Type	information
	Information	user type (e.g. driver, passenger), gender (e.g. male/female), age (e.g. adult/teenager), disability types (e.g. physical, visual impairment, hearing impairment)
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	registration information for positioning and routing
P-SPH	Type	application
	Information	check P-ITS status (e.g. active/inactive) and passenger boarding
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	detect passenger's motion with IMU sensor of the device and check passenger's boarding and deboarding with short-range wireless network

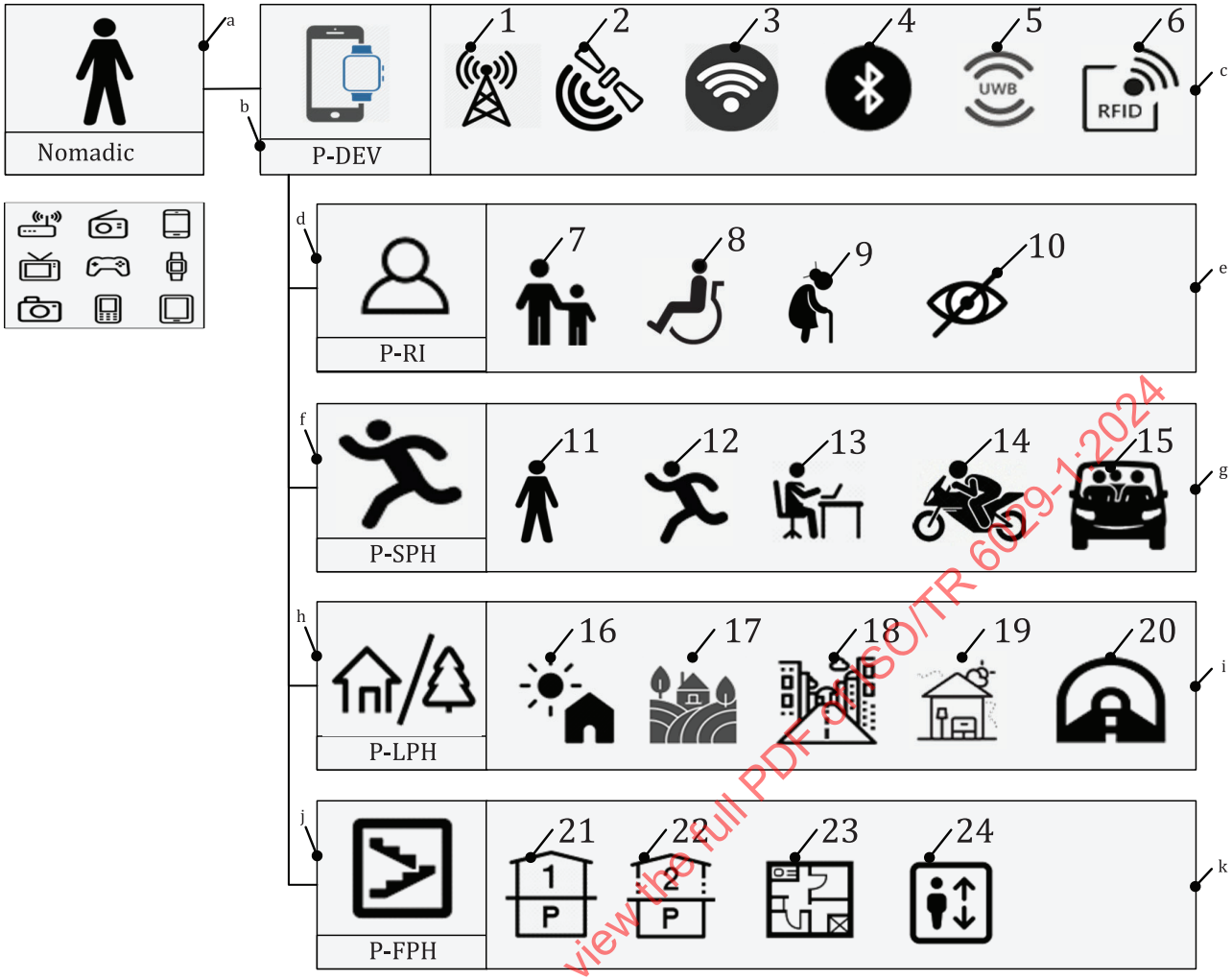
[a] Not applicable.

Table 22 *(continued)*

Actor (ID)	Attribute	Attribute function
P-LPH	Type	application
	Information	seamless positioning with P-ITS-S
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	determine the positioning environment (e.g. urban, rural, indoor, tunnel, etc.) along with lateral, longitudinal and roadway type information using sensor or map, AP, routing data
P-FPH	Type	application
	Information	indoor altitude (floor) from nomadic device or mobility
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	check altitude (floor) information using sensor or map, AP, routing data

[a] Not applicable.

Figure 4 shows the P-ITS-S (ND) actors.



Key

a P-ITS-S domain.
b P-ITS-S device.
c P-ITS-S communication interfaces.
d Personal registration information.
e Personal profile classification.
f Personal status profile handler.
g Status profile classification.
h Personal location profile handler.
i Location profile classification.
j Personal floor profile handler.
k Floor profile classification.
1 network-based cellular
2 satellite-based GPS, GNSS, etc.
3 local area wireless networking
4 short-range wireless networking
5 ultra-wide band networking
6 radio-frequency identification networking
7 person with child
8 disabled person
9 elderly person
10 blind person
11 person in standstill
12 person running/walking
13 person sitting
14 two-wheeled mobility on board
15 mobility on board
16 open terrain
17 radio-shadow area
18 urban canyon
19 indoor
20 tunnel
21 one-story building
22 multi-story building
23 floor plan
24 elevator

Figure 4 — Personal ITS station actors

8.2.3 Role of mobility domain and actors

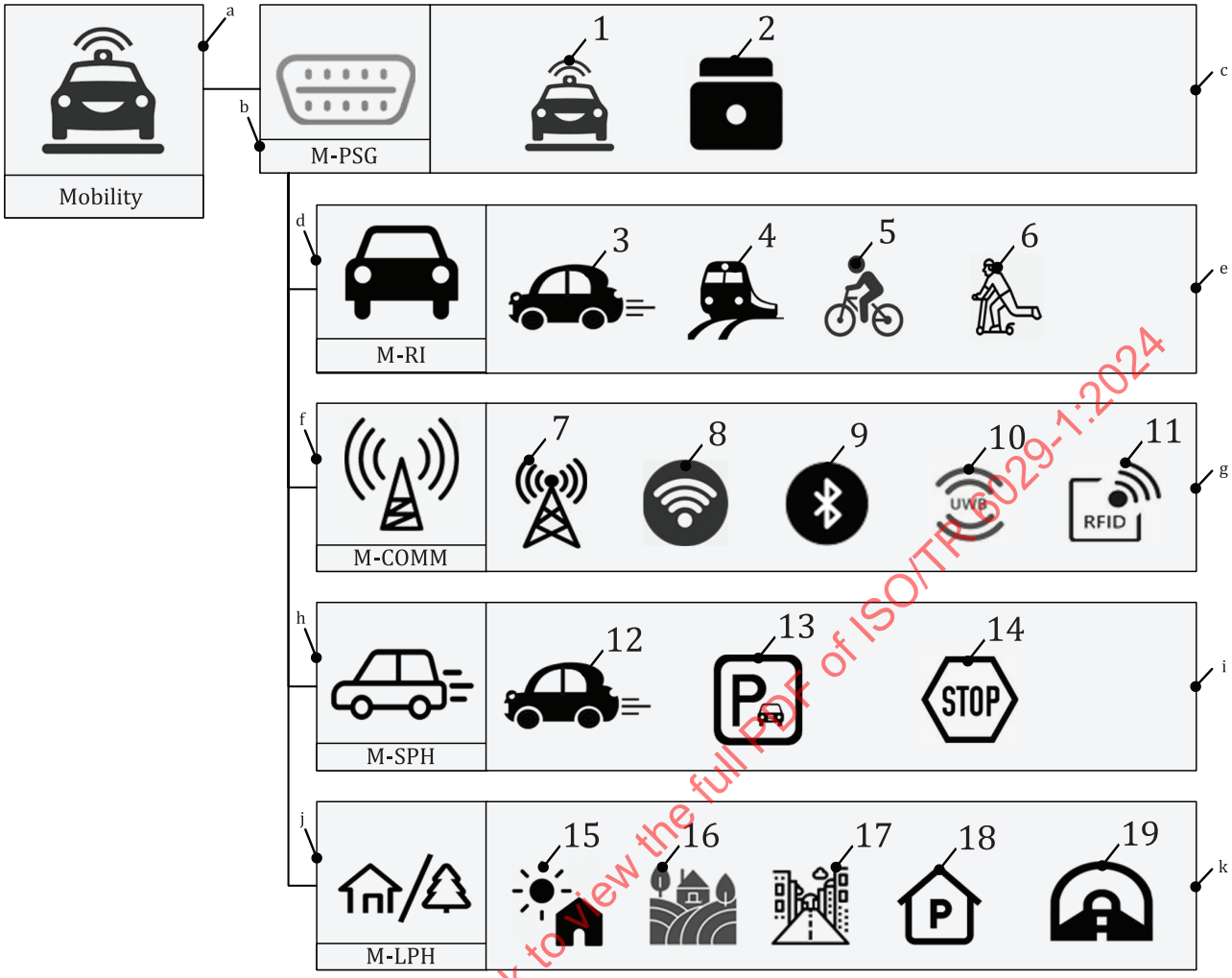
The role of the mobility domain is to determine its position by gathering any applicable data when the user is on board. The data from mobility domain is gathered through a gateway e.g. V-ITS-S. Table 23 provides information about subsequent actors along with the attributes of data in respect to the mobility domain.

Table 23 — Mobility actors information

Actor (ID)	Attribute	Attribute function
M-PSG	Type	device
	Information	positioning data recognition
	Interface	vehicle internal network
	Sensor	GNSS, IMU, odometer, LiDAR, radar, image sensor (e.g. camera)
	GW actor	yes
	Function	subject of mobility: 1) acts as a processor and store sub-actor information; 2) provides seamless positioning with built-in sensors and data processing through wireless network.
M-RI	Type	information
	Information	vehicle: 15-seater bus, heavy-duty vehicle, trucks, sedan, train, bike, bicycle, e-mobility etc., fuel: electric/hydrogen, hybrid, gasoline, diesel, etc., type: personal, lease, sharing, public (e.g. police/firefighting/medical) etc.
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	registration information for positioning and routing
M-COMM	Type	device
	Information	send positioning data through cellular network
	Interface	cellular, IEEE 802.11 wireless LAN, UWB, BT
	Sensor	—[a]
	GW actor	yes
	Function	send position and routing data
M-SPH	Type	application
	Information	detect mobility travelling and check passenger boarding
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	detect mobility travelling with mobility embedded sensors and check passenger boarding with nomadic device.
M-LPH	Type	application
	Information	provide seamless positioning of mobility and analyze circumstances e.g. lateral, longitudinal, crossroad, etc.
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	determine the positioning environment (e.g. urban, rural, indoor, tunnel, etc.) along with lateral, longitudinal, crossroad information using sensor or map, AP, routing data.

[a] Not applicable.

Figure 5 shows the mobility actors.



Key

a Mobility domain.
b Mobility station gateway.
c Mobility data classification.
d Mobility registration information.
e Mobility type classification.
f Mobility communication interfaces.
g Mobility communication interfaces classification.
h Mobility status profile handler.
i Mobility status classification.
j Mobility location profile handler.
k Mobility location classification.
1 in-vehicle data
2 unified vehicle interface protocol data
3 vehicle mobility registration information
4 transit information
5 personal mobility registration information
6 micro mobility registration information
7 satellite-based communication technology
8 local area wireless networking
9 short-range wireless networking
10 ultra-wideband wireless networking
11 radio-frequency identification networking
12 mobility on the road
13 mobility parking status
14 mobility idling status
15 open terrain
16 radio shadow area
17 urban canyon environment
18 indoor
19 tunnel

Figure 5 — Mobility actors

8.2.4 Role of infrastructure domain and actors

The role of the infrastructure domain is to broadcast any infrastructure-related data to determine P-ITS-S' and mobility's positions.

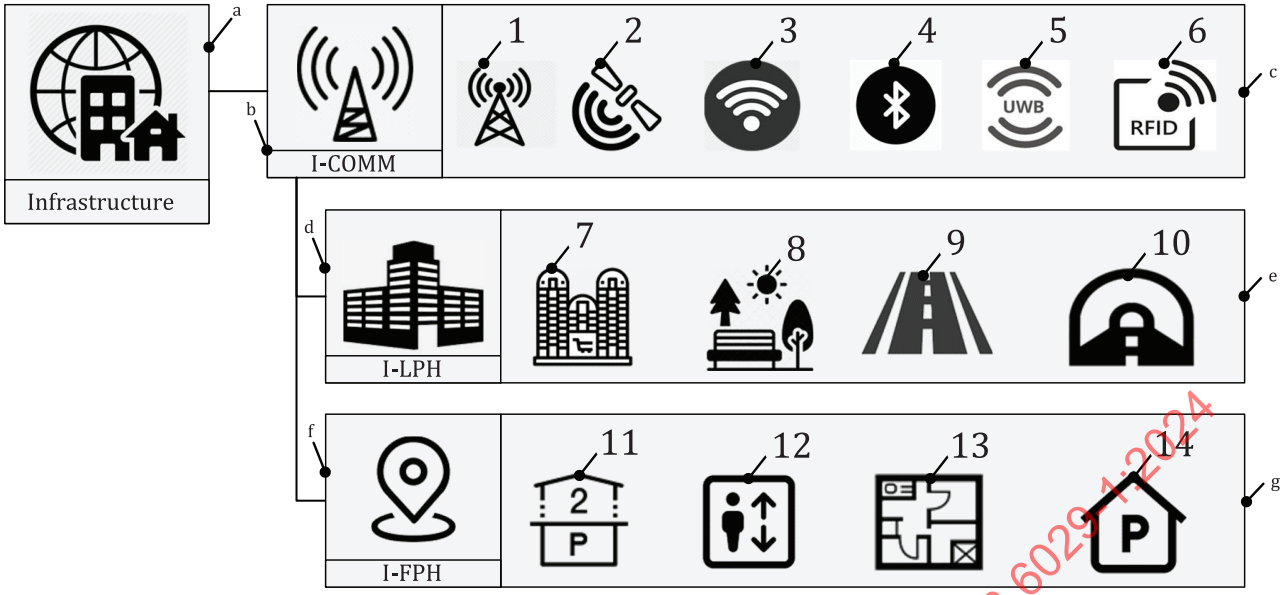
Table 24 provides information about subsequent actors along with the attributes of data in respect to the infrastructure domain.

Table 24 — Infrastructure actors information

Actor (ID)	Attribute	Attribute function
I-COMM	Type	device
	Information	access point serial key and signal strength for positioning
	Interface	wireless mobile communication, IEEE 802.11 wireless LAN, UWB, BT, RFID
	Sensor	—[a]
	GW actor	yes
	Function	subject unique serial key of hardware to nomadic device or mobility to identify particular spot: 1) hardware serial key value (e.g. MAC address); 2) AP signal strength for triangulation measurement; 3) RFID: check nomadic device or mobility passing through a particular spot.
I-LPH	Type	information
	Information	infrastructure serial key matching record (e.g. address, tunnel ID, etc.)
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	mapping local positioning data with infrastructure (e.g. road, tunnel, building, etc.) data through cloud server.
I-FPH	Type	Information
	Information	infrastructure information (e.g. floors, elevator, fingerprint map).
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	get triangulation measurement data along with the infrastructure positioning data (floor/elevation) of nomadic device or mobility.

[a] Not applicable.

Figure 6 shows the infrastructure actors.



Key

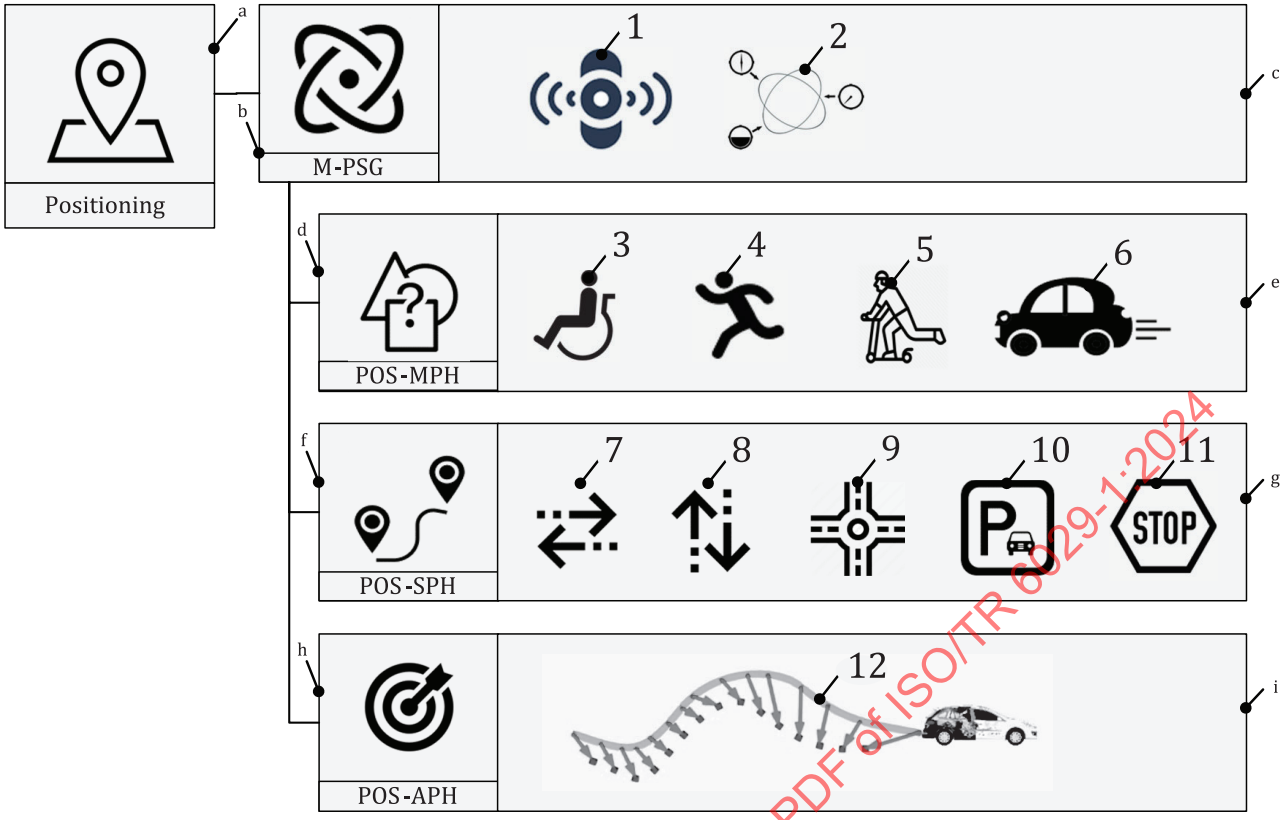
a	Infrastructure domain.	5	ultra-wideband
b	Infrastructure communication handler.	6	radio frequency identification
c	Infrastructure communication interfaces classification.	7	urban canyon
d	Infrastructure location profile handler.	8	open terrain
e	Infrastructure localization actors' classification.	9	roadway
f	Infrastructure floor profile handler.	10	tunnel
g	Infrastructure floor classification.	11	multi-story building
1	communication repeater information	12	elevator
2	satellite-based communication	13	floorplan
3	local area wireless networking	14	single-story building
4	short-range wireless		

Figure 6 — Infrastructure actors

8.2.5 Role of positioning domain and actors

The role of the positioning domain is to provide positioning data by integrating data from each domain.

Figure 7 shows the positioning actors.



Key

a	Positioning domain.	3	disabled person
b	Fusion profile handler.	4	running person
c	Sensor data actors.	5	riding on micro mobility
d	Velocity profile handler.	6	on board
e	Velocity actors.	7	longitudinal direction
f	Positioning status profile handler.	8	lateral direction
g	Circumstance actors.	9	4-way stop
h	Accuracy profile handler.	10	parked
i	Accuracy analysis.	11	idling
1	single sensor data	12	machine learning
2	multi-sensor data		

Figure 7 — Positioning actors

Table 25 provides information about positioning data by integrating data from each domain.

Table 25 — Positioning actors information

Actor (ID)	Attribute	Attribute function
POS-FPH	Type	application
	Information	detect PVT of Mobility
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	send the result (PVT) to actors (device) for seamless indoor/outdoor positioning based on information collected from other sources
POS-MPH	Type	application
	Information	gather moving object speed (P-ITS-S, transportation)
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	receive sensor data of available mobility (P-ITS-S, transportation). determine speed of moving object referring to registration of the object.
POS-SPH	Type	application
	Information	determine precise location and status of moving object (P-ITS-S, transportation)
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	check available sensor data and routing data saved in cloud server and mobility map. determine mobility's positioning data and detect its status on the road (e.g. lateral, longitudinal, crossroad, parking, stop, etc.).
POS-APH	Type	application
	Information	mobility accuracy value
	Interface	—[a]
	Sensor	—[a]
	GW actor	no
	Function	check mobility accuracy by comparing and analysing routing data which is saved in the cloud server or mobility map.

[a] Not applicable.

8.3 Relationship between actors under domain

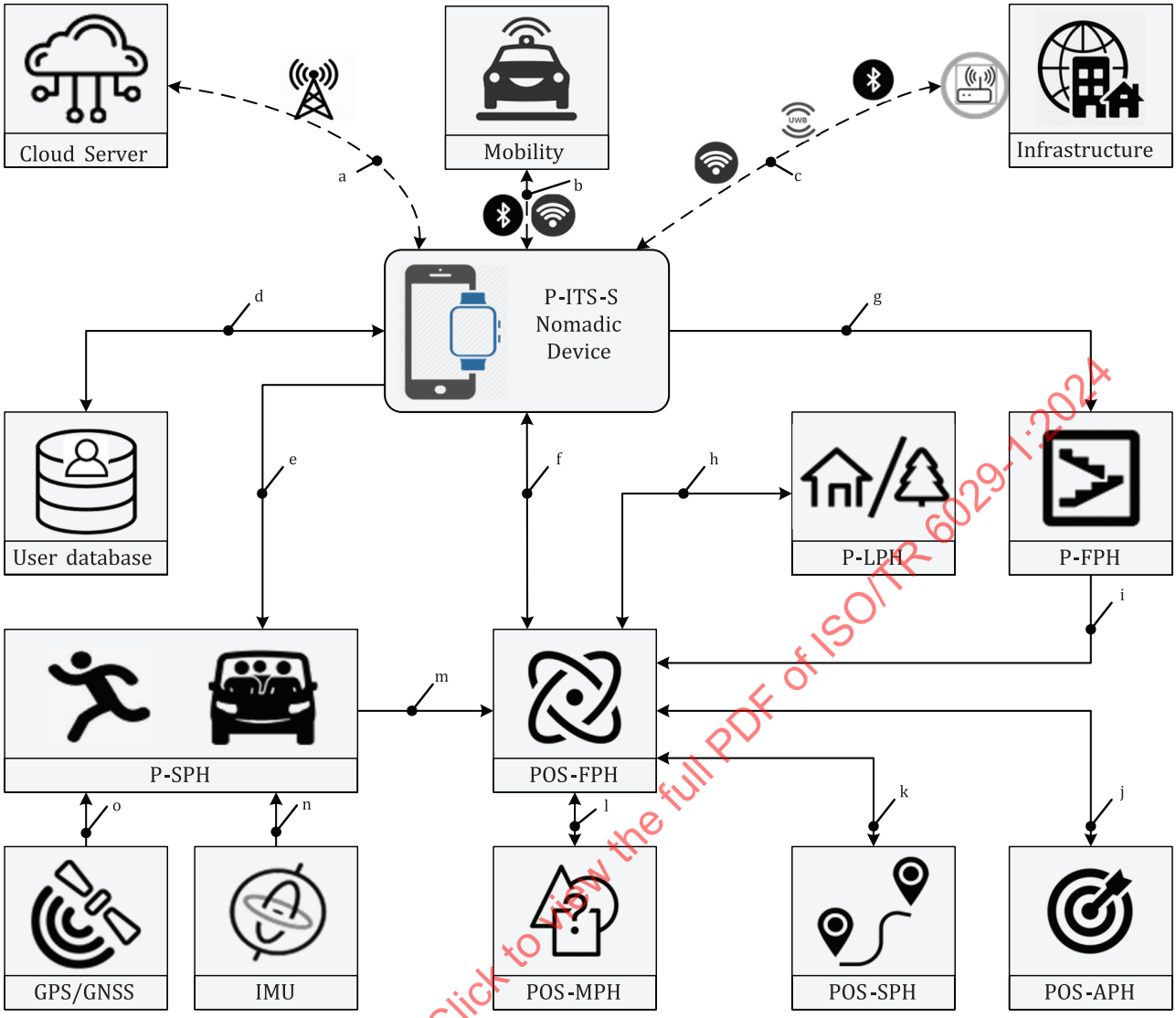
8.3.1 General

The purpose of this subclause is to address the relationship between actors within the specific domain (see 8.2.2 to 8.2.5). Each domain consists of actors which handle positioning-related information. These actors interoperate with each other by use cases. The diagram represents communication between actors within a domain. A solid line indicates the case where the data are sent directly from the other actor while a dashed line indicates the case where data are gathered through an external source (e.g. server, access point address).

8.3.2 P-ITS-S domain actors

The P-ITS-S domain contains various actors which have their own purpose. These actors interoperate with each other to carry out a seamless positioning service using data gathered through P-ITS-S. P-ITS-S domain actors gather user data along with positioning-related data and send them to the positioning fusion profile handler (POS-FPH) to determine its position in a seamless manner.

Figure 8 shows the P-ITS-S and material domain.



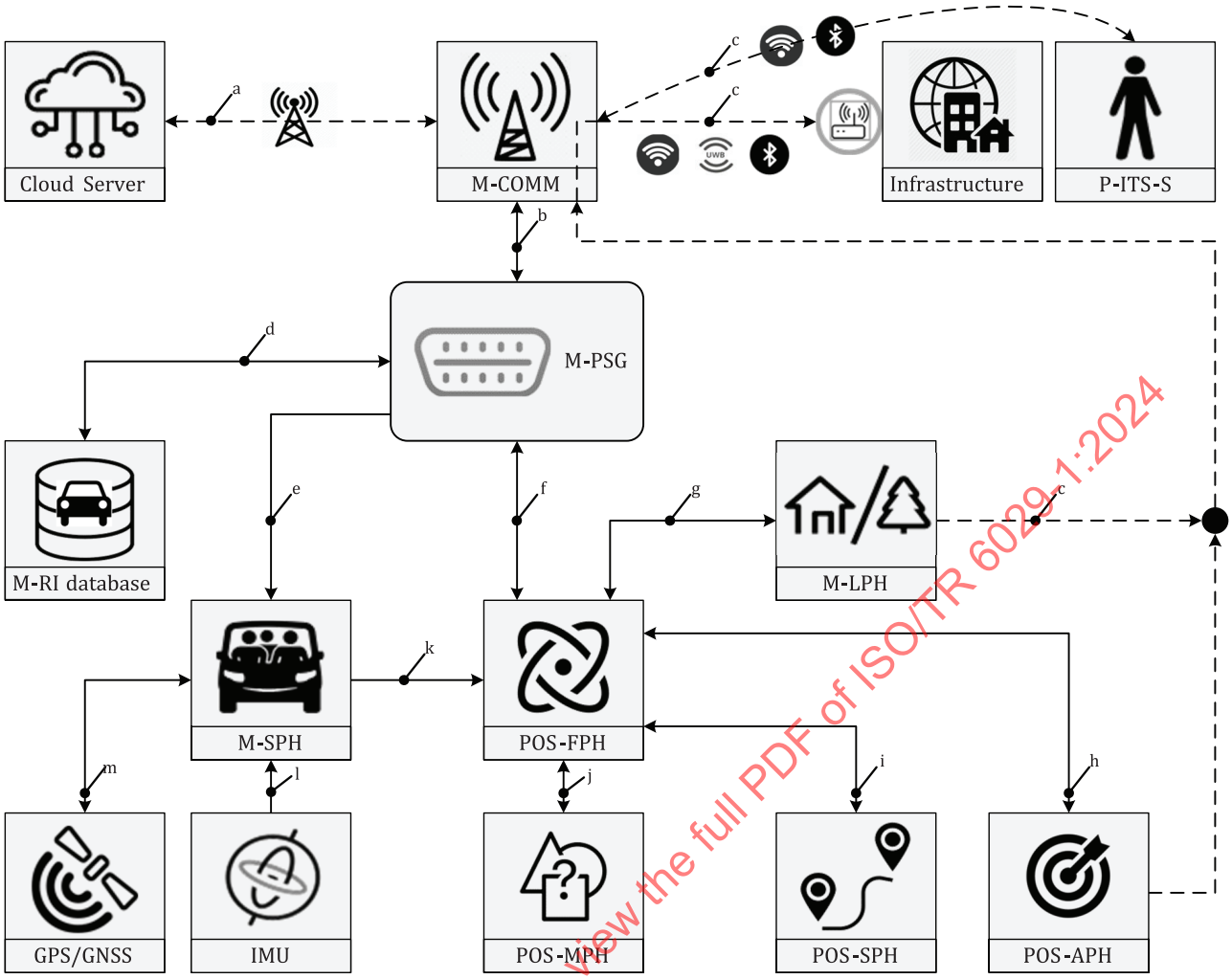
a Cloud server.
b Communication between mobility.
c Communication between infrastructure.
d User database.
e Status profile handler.
f Positioning fusion profile handler.
g P-ITS-S floor profile handler.
h P-ITS-S location profile handler.
i Send floor profile information to FPH.
j Positioning data accuracy profile handler.
k Positioning status profile handler.
l Positioning velocity profile handler.
m Send P-ITS-S status profile information to FPH.
n IMU sensor data.
o GPS/GNSS data.

Figure 8 — Personal ITS station and material domain

8.3.3 Mobility domain actors

Actors in the mobility domain gather mobility-related information and mobility service users (e.g. driver, passenger, customer, etc.) information along with positioning data. See ISO 24011, ISO 17573-1 and ISO/TR 21724-1 for definitions of mobility service users.

Figure 9 shows the mobility service users.



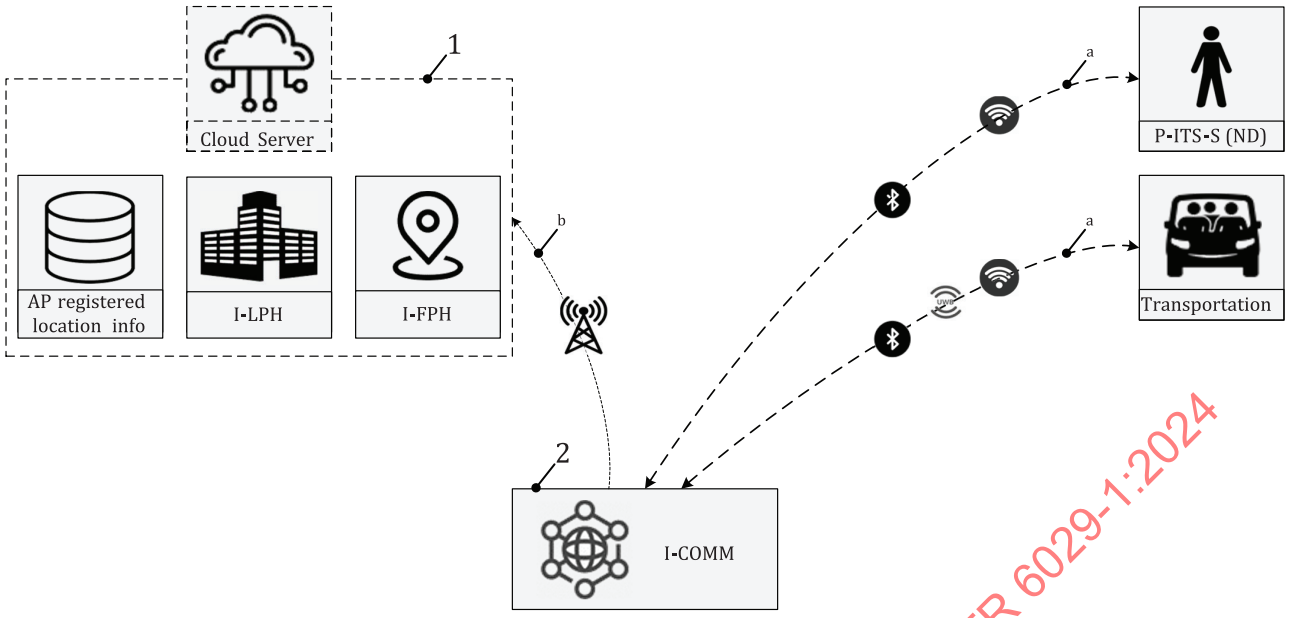
a Communication with cloud server.
b Mobility station gateway communication.
c Communications between domains.
d Mobility registration information database.
e Status profile in mobility perspective.
f Positioning fusion profile handler.
g Location profile handler.
h Positioning accuracy profile handler.
i Positioning status profile handler.
j Positioning velocity profile handler.
k Mobility status profile handler to positioning fusion profile handler.
l IMU to mobility status profile handler.
m GPS/GNSS to mobility status profile handler.

Figure 9 — Mobility service users

8.3.4 Infrastructure domain actors

The infrastructure domain provides any applicable infrastructure information (e.g. IEEE 802.11 wireless LAN access point, HD map, building map) for seamless positioning service.

Figure 10 shows the transportation infrastructure.



Key

1 cloud server containing access point registered location and supplemental location-related information

2 unique access point information (e.g. MAC address, AP address etc.)

a Register access point unique information and request to calculate with triangulation.

b Send registered location information and calculated value.

Figure 10 — Transportation infrastructure

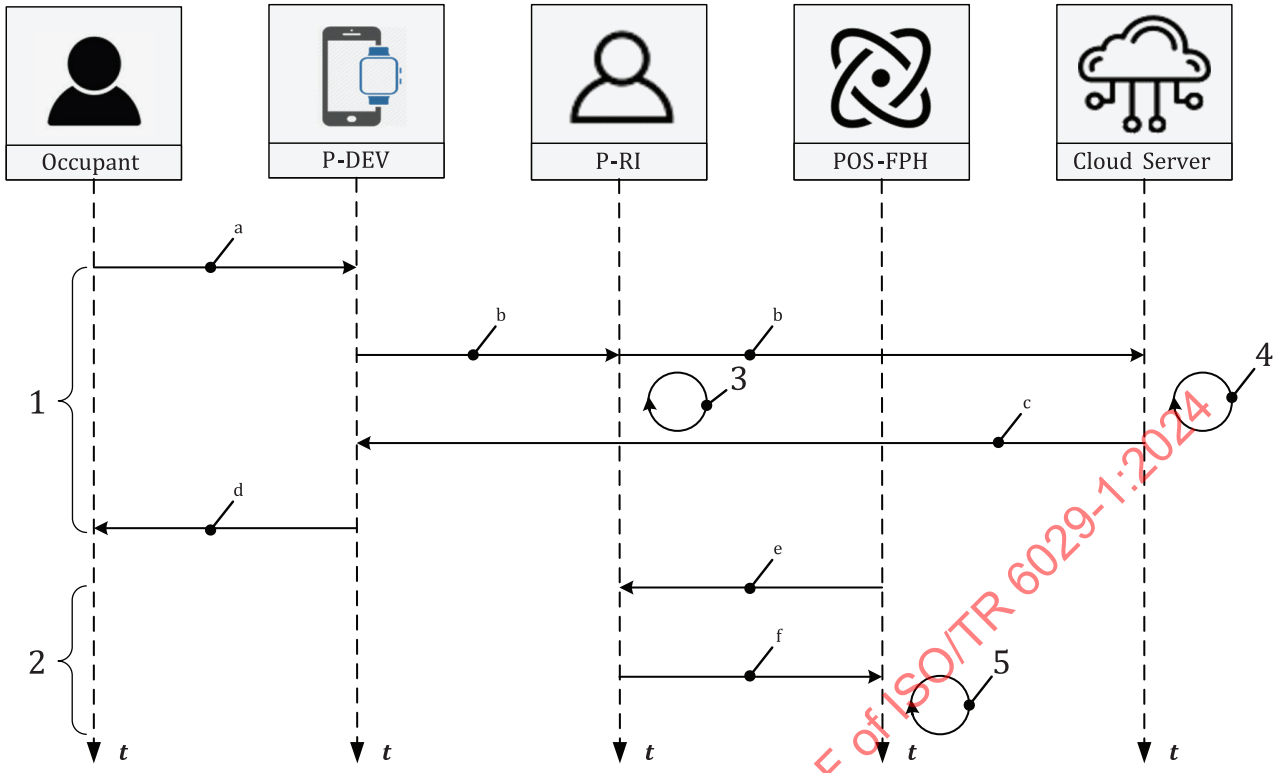
8.4 Domain-specific information sequence diagram

8.4.1 General

The purpose of this subclause is to describe the data exchange sequence of positioning data throughout the process.

8.4.2 P-ITS-S (ND) information registration and search information sequence diagram

Figure 11 shows the process from the personal information registration and data search process. The seamless positioning system uses personal information (e.g. age, disability type, gender) to identify the user's condition and locate the user's initial position.



Key

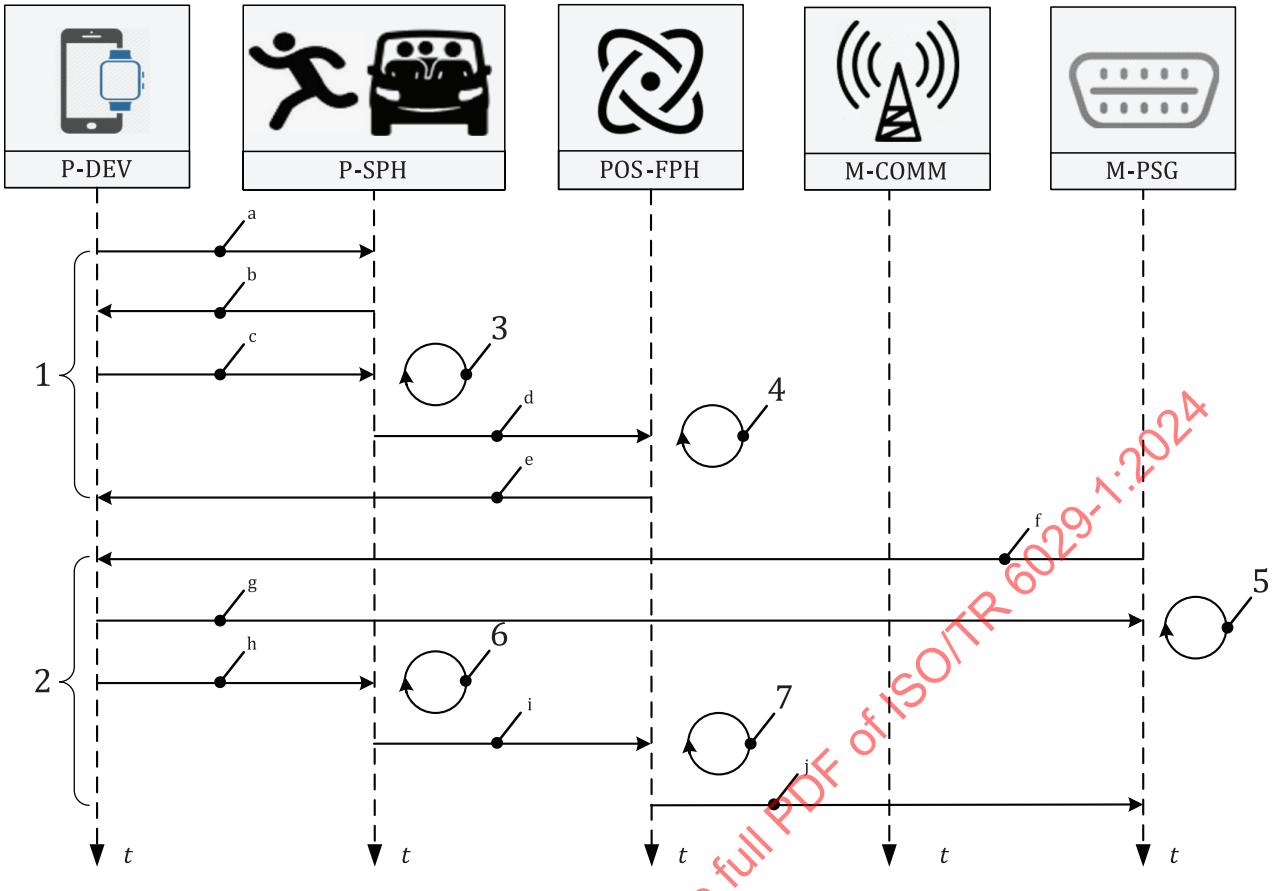
1	personal information registration	a	Personal information input e.g., gender, age, disabilities.
2	personal information search	b	Personal information registration request.
3	personal information registration retries	c	Search result.
4	personal information registration retries	d	Search result.
5	personal information search for PVT service	e	Search request for personal information.
		f	Search result.

Figure 11 — Personal information registration and search sequence diagram

8.4.3 Mobility information sequence diagram

8.4.3.1 Motion and passenger boarding detection

Figure 12 shows the motion and passenger boarding detection and the interworks between P-ITS-S and M-PSG when a passenger is boarding. During the process, the seamless positioning system changes from P-ITS-S' positioning reference to the motion positioning reference.



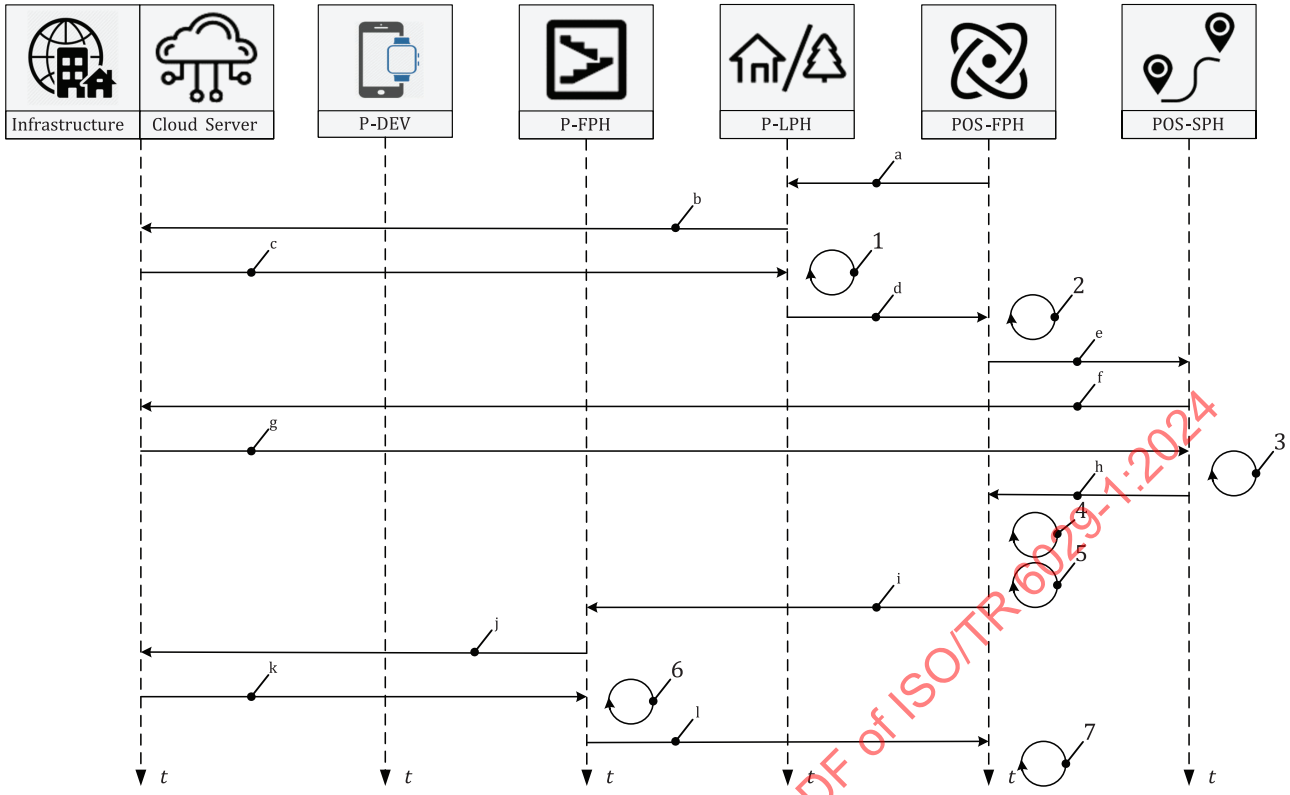
Key

1	motion detection	c	Acquire sensor data.
2	passenger boarding	d	Determine motion occurrence, send result.
3	sensor data acquiring retries	e	Initiate sensor monitoring for routing.
4	motion occurrence, send result	f	Pairing request.
5	motion occurrence	g	Send pairing result (e.g. passenger boarding detection).
6	motion – boarding detection	h	Send connection information.
7	request motion routing information for P-ITS-S routing	i	Send boarding status.
a	Motion detection request.	j	P-ITS-S routing request to motion routing information.
b	Request motion sensor data.		

Figure 12 — Motion and passenger boarding detection sequence diagram

8.4.3.2 Environmental classification

The environmental classification process is needed to determine the positioning reference source by distinguishing indoor and outdoor. Figure 13 shows the process of identifying indoor and outdoor reference and the environmental classification e.g. urban, rural, tunnel, floor, altitude, etc.



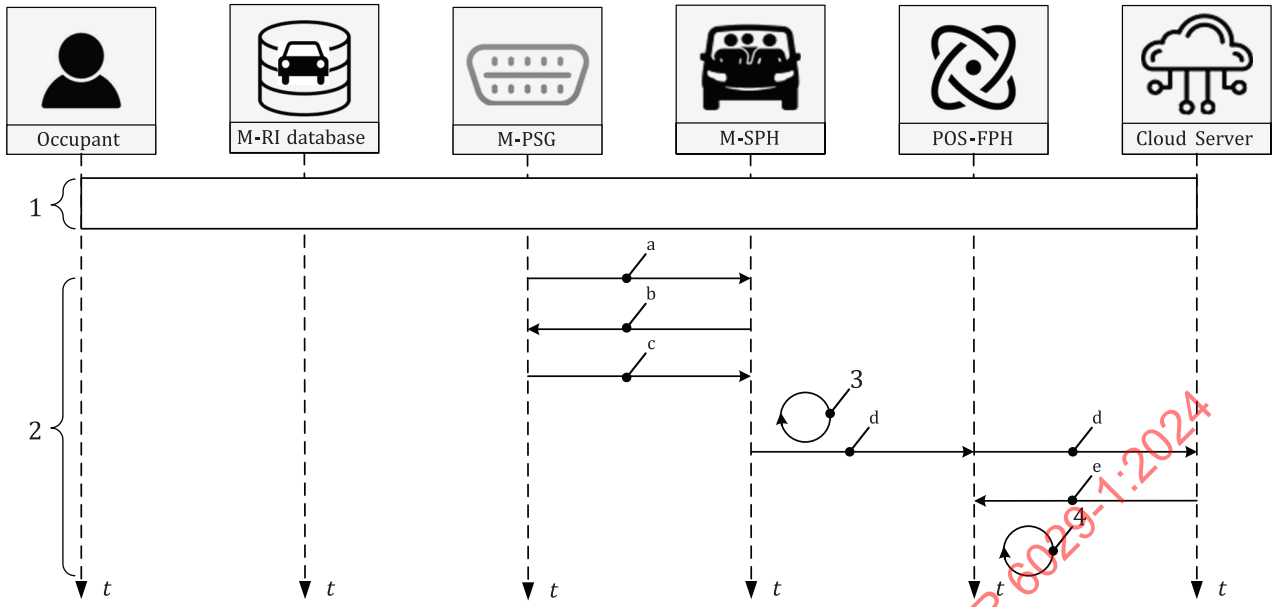
Key

a	Request positioning data to distinguish current location.	1	distinguish indoor/outdoor or urban/rural etc.
b	Check location with a map data or available infrastructure access information.	2	outdoor: request for available road infrastructure data and roadway condition information e.g., direction, stop, junction, overpass
c	Send location data via cloud service (P-ITS-S) map and access point registration information (if AP and GNSS data are received simultaneously, check routing path to determine the latest location).	3	outdoor: sensor fusion, distinguish result
d	Distinguish indoor/outdoor or urban/rural, etc.	4	outdoor: determine location
e	Request road infrastructure and roadway status information e.g. direction, stop, junction, overpass.	5	indoor: request floor, altitude information
f	Check routing path.	6	indoor: determine floor and altitude information
g	Send routing data to cloud server or within P-device.	7	indoor: sensor fusion, determine location
h	Send distinguished result.	k	Send registration information.
I	Check building floor level.	l	Send determined floor and altitude information.
j	Check access point registration information in cloud server.		

Figure 13 — Environmental classification sequence diagram

8.4.3.3 Motion information registration and search

Figure 14 shows the process of the motion information registration and information search through the server. The motion information is used as a positioning subject for the seamless positioning system.



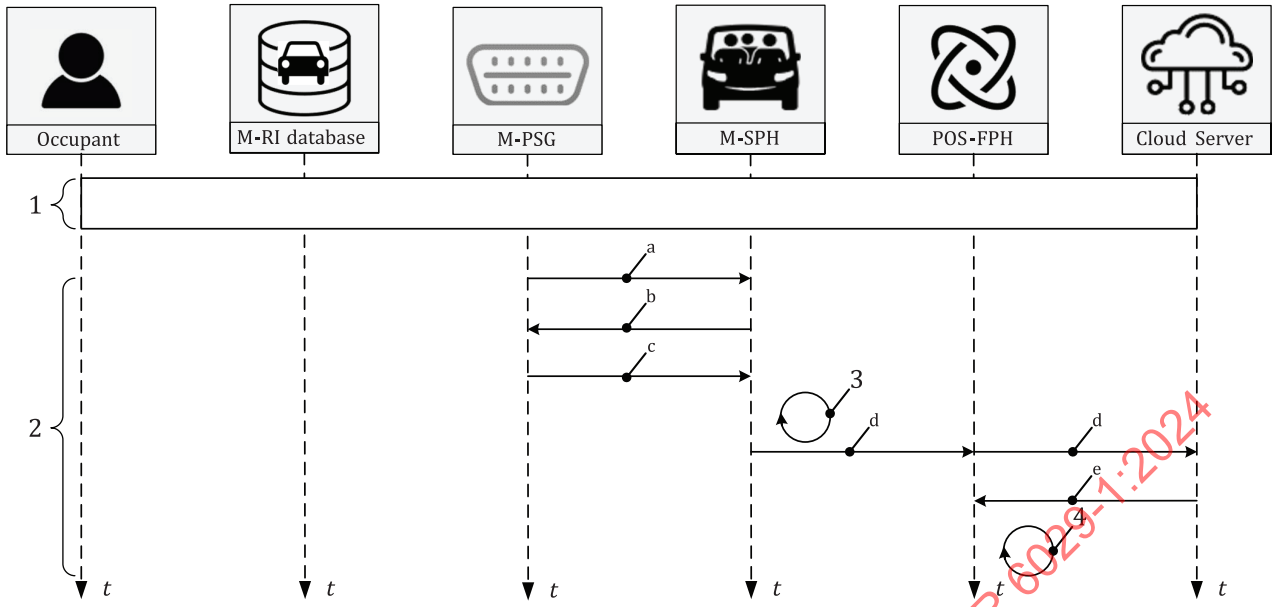
Key

a	Request transportation status monitoring.	1	detect boarding
b	Start sensor monitoring.	2	detect driving, stop, parking
c	Receive sensor data.	3	detect driving, stop, parking
d	Send status information.	4	search registered transportation information
e	Send search result.		

Figure 14 — Motion information registration and search sequence diagram

8.4.3.4 Motion and passenger boarding detection

Figure 15 shows the mobility moving detection process which is initiated from the P-ITS-S motion detection process and the motion and passenger boarding detection sequence diagram.



Key

a	Request transportation status monitoring.	1	detect boarding
b	Start sensor monitoring.	2	detect driving, stop, parking
c	Receive sensor data.	3	detect driving, stop, parking
d	Send status information.	4	search registered transportation information
e	Send search result.		

Figure 15 — Motion and passenger boarding detection sequence diagram

8.4.3.5 Distinguishing of urban, rural, tunnel or floor

Figure 16 shows M-PSG identifying environmental conditions with any available infrastructure information and the sequence diagram for distinguishing environmental conditions (e.g. urban, rural, tunnel or floor).