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Intelligent transport systems (ITS) — Network based precise positioning infrastructure for land transportation —

Part 1: General information and use case definitions

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Foreword

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

A list of all parts in the ISO 22086 series can be found on the ISO website.

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Introduction

This document provides the framework guidelines to identify lane-level positioning technologies with the land transportation service requirements and related standards required to deploy, manage, and operate network-based precise positioning infrastructure for land transportation. The purpose of the system is to generate and transmit the GNSS correction and integrity information to land transportation users including drivers, pedestrians, riders, etc. in order to enable them to perform lane-level positioning with low-cost GNSS receivers on nomadic devices at a high confidence level. The system design following the requirements of ITS and automotive services that are closely related to traffic safety and traffic efficiency is defined.

Intelligent transport systems (ITS) — Network based precise positioning infrastructure for land transportation —

Part 1:
General information and use case definitions

1 Scope

This document provides the framework guidelines on technologies related to the network-based precise positioning infrastructure for land transportation (NETPPI-LT) that allows land transportation users or objects carrying nomadic devices, equipped with low-cost global navigation satellite systems (GNSS) receivers and wireless communication transceivers, to perform lane-level positioning and integrity monitoring. These technologies will unlock enhanced intelligent transport systems (ITS) services and applications and will increase traffic operation/management efficiencies and traffic safety by reducing economic and social costs from traffic jams, traffic accidents, and environmental pollution.

The framework described in this document includes:

— reference architecture for the NETPPI-LT enabling lane-level positioning and integrity monitoring on personal ITS devices;

— guidelines for providing a real-time lane-level positioning service based on GNSS with the aid of the NETPPI-LT;

— guidelines to facilitate the practical implementation of the NETPPI-LT for engineers including related use cases.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 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/

3.1.1
reference station
implementation of a NETPPI-LT subsystem which captures signals/data from visible GNSS satellites and monitoring information (pressure, temperature, humidity, image, etc.) at a known position with clear sky view and no radio interferences, and includes wired or wireless links to send the collected data to the control station

3.1.2
control station
implementation of a NETPPI-LT subsystem which generates the GNSS carrier phase measurement correction and integrity information based on the information received from multiple reference stations, and sends the correction and integrity information to wireless communication/broadcast systems (cellular networks, WAVE, DMB, etc.) for data transmission to drivers or pedestrians with nomadic devices

3.1.3
monitoring station
implementation of a NETPPI-LT subsystem which tests validity of the information, originated by the control station, and gives feedback to the control station for the system management

3.1.4
base station
implementation of a NETPPI-LT subsystem which is a part of wireless communication/broadcast systems and provides the correction and integrity information, originated by the control station, to drivers or pedestrians carrying nomadic devices

3.1.5
nomadic device
implementation of any type of nomadic device which captures carrier phase measurements for ranging to visible GNSS satellites, receives the correction and integrity information, originated by the control station, via wireless links including cellular networks (LTE families, 5G), WAVE, DSRC, DAB, DMB, etc., and determines its own position along with integrity by using the received data

3.2 Abbreviated terms

5G	fifth-generation mobile communications
C-ITS-S	central intelligent transportation system station
DAB	digital audio broadcasting
DMB	digital multimedia broadcasting
DSRC	dedicated short-range communications
GNSS	global navigation satellite systems
IMU	inertial measurement unit
ITS	intelligent transportation system
LTE	long term evolution
NETPPI-LT	network based precise positioning infrastructure for land transportation
R-ITS-S	roadside intelligent transportation system station
RTCA	Radio Technical Commission for Aeronautics
RTCM	Radio Technical Commission for Maritime Services
WAVE	wireless access for vehicular environment

V2I vehicle-to-infrastructure

V2V vehicle-to-vehicle

V2X vehicle-to-everything

4 Document overview and structure

This document provides all documents and references required to support the implementation of the requirements related to GNSS-based positioning with lane-level accuracy on nomadic devices. This series of standards consists of the following parts.

— Part 1: General information and use case definitions

This part provides an overview of the document set and structure along with the use case definitions and common set of resources (definitions, references), which are used for all subsequent parts.

— Part 2[1)]: Functional requirements and data interface

This part provides functional requirements of nomadic devices for the NETPPI-LT services and data interface between the infrastructure side and nomadic device.

5 General information

5.1 Purpose of this document

This document addresses three major areas:

— Identify the requirements of application level framework for the NETPPI-LT (lane-level positioning and integrity monitoring) services that can be frequently inserted, modified, and deleted;

— Identify the general information for all subjects related to the NETPPI-LT services from the perspectives of infrastructure and personal station (nomadic device);

— Specify the general use cases that should be included for the NETPPI-LT services.

5.2 Overview of NETPPI-LT

Existing ITS services and applications require road-level (meter) positioning accuracy, and commercial nomadic devices or ITS stations meet this requirement with low-cost standalone GNSS receivers that exploit code phase measurements for ranging to the satellites and may have the aid of mobile networks.

Emerging ITS services and vehicle technologies including autonomous vehicles, platooning, and collision avoidance demand lane-level (sub-meter) positioning accuracy, which cannot be achieved with the low-cost standalone GNSS receivers on the nomadic devices at a high level (95 % or more) of confidence. Integrity is another requirement to provide reliable services, but it cannot be provided on the standalone receivers.

The concept of the NETPPI-LT is to provide GNSS-based lane-level positioning and integrity monitoring services to land transportation users and objects carrying nomadic devices including cellular (smart) phones, navigators, etc. that are able to receive GNSS carrier phase measurements and to receive the GNSS correction and integrity information, originated by the control station, via wireless links (e.g. DAB, DMB, LTE, 5G, WAVE). The nomadic devices might be connected to external positioning personal stations that have the above functionalities. The correction information assists the nomadic devices to mitigate the effects of ionospheric and tropospheric delays, satellite clock errors, and ephemeris errors etc. in the range measurements. The integrity information provides reliability of the correction information and is used to determine integrity of the positioning result.

1) Under development. Current stage 0.00.

Figure 1 presents a reference architecture of the NETPPI-LT and an outline of data flow from the infrastructure to any type of nomadic device performing lane-level positioning and integrity monitoring using satellite navigation. The main components of the NETPPI-LT and their key roles are as follows:

— *Reference station* plays a role that collects GNSS range and quality measurements and senses the presence of intentional or unintentional threats to the GNSS measurements with different monitoring sensors including camera, weather sensors, and others. The collected data from GNSS and monitoring sensors is transmitted to the control station. The system may have a single reference station or multiple reference stations; the number of stations depends on the coverage of the NETPPI-LT service. Its functionalities may be implemented into the R-ITS-S.

— *Control station* generates the GNSS correction information used for ranging error removal on nomadic devices, with the combination of measurements from the reference stations. The integrity information, which describes the extent of belief on the correction information, is generated through a sequence of integrity tests. The control station offers the correction and integrity information via wireless links to land transportation users or objects carrying the nomadic devices to perform lane-level positioning and integrity monitoring. Its functionalities may be implemented into the C-ITS-S.

— *Monitoring station* tests if the information from the control station is valid for lane-level positioning and gives the feedback to the control station. Its installation is optional, but would be needed for the system operation and management. Its functionalities may be implemented into the R-ITS-S.

— *Base station* forwards the information, originated by the control station, to users over wireless links. The base station configuration follows the standards of the communication system used for data transfer. The link may indicate a data channel of one of the communications systems including cellular networks, WAVE, DSRC, DAB, DMB, etc.

— *Nomadic device* is capable of receiving GNSS carrier phase measurements for ranging and receiving the correction and integrity information from the control station. Based on the data, it determines its own position, along with integrity that gives how reliable the position estimate is.

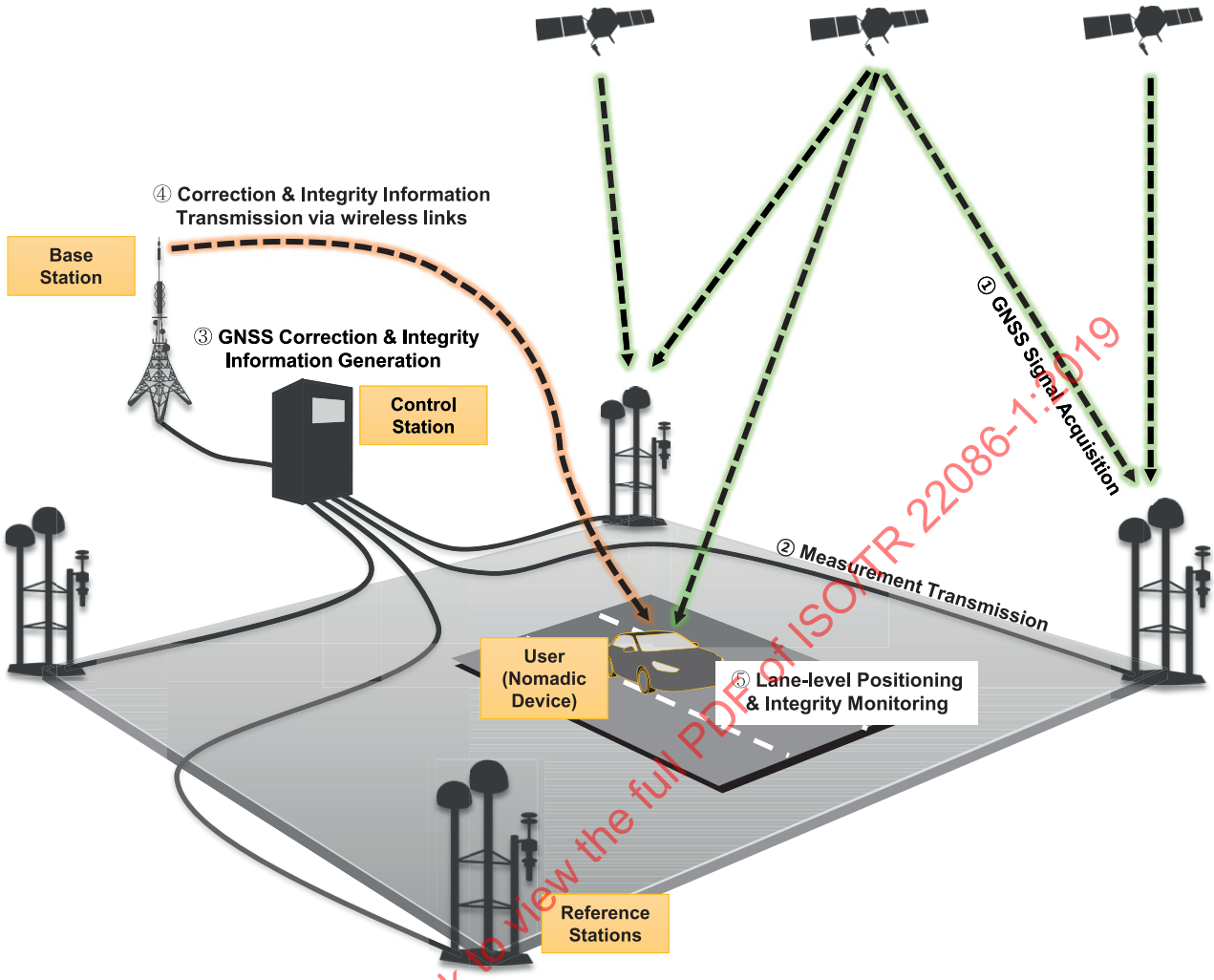

Figure 1 — NETPPI-LT framework

The issues for the implementation of the NETPPI-LT include:

— Reference stations may be installed free of physical and electrical threats that may interrupt reception of GNSS signals.

— Reference stations may periodically provide measurements from GNSS receivers and monitoring sensors which have stable and high performance not to introduce large hardware errors in the measurements. The GNSS receivers equipped on the reference stations also may receive GNSS signals propagating through different frequencies for capturing ionosphere delays in the range measurements.

— Control station may be installed free of physical and electrical threats that may harm the system operation.

— Control station may be equipped with high-throughput data processor such that the delay during data reception, validation, and generation remains negligible for the system operation.

— Control station may identify the occurrence of an ionosphere event and its change with the measurements from the reference stations.

— Control station may monitor the quality of GNSS signals and the satellite status and may detect anomalies in the GNSS measurements from the reference stations.

— Control station may alert system administrators and users (nomadic devices) if the protection level, computed by the monitoring station, exceeds the alert limit.

— Nomadic devices may provide carrier phase measurements with a single-frequency GNSS receiver and receive information from the control station via wireless links.

— Nomadic devices may be assisted by different sensors (e.g. IMU, vision, odometer) to improve availability of lane-level positioning under GNSS-deprived areas.

— Nomadic devices may be able to compute their protection levels in real time based on their own positioning measurements and the information from the control station, and they may provide valid warnings to the users or relevant applications when the protection level exceeds an alert limit, i.e. the largest position error acceptable for the operation.

— Monitoring stations may have wired and/or wireless links to the control station to give feedback on the downlink status (e.g. detection of data loss during transmission, transmission delay) and the positioning results including a position estimate and associated protection level.

— Base stations may send the information from the control station to the target nomadic devices that want to take the NETPPI-LT service.

— All the subsystems related to data reception, communication, and processing may be equipped with backup power supply for blackout and may configure in a dual structure (i.e. backup infrastructure) to guarantee continuity and availability in case of system failure.

— Termination of the NETPPI-LT service may be considered in the absence of a backup system under system failure. The occurrence of the termination should be noted to all the nomadic devices in service.

— Data format and transmission to the user device may be defined by a protocol (e.g. RTCA, RTCM) depending on the communications systems. The limitations (e.g. bandwidth, delay, policy) of the communications systems may yield different protocols.

— Data collected from and generated by any subsystem may be stored at an internal/external storage device for use in accident and incident investigations.

6 Use case overview and definitions

6.1 General

The main purposes for reference for developing standards are to define the service platform with the related use cases.

6.2 Use case overview

6.2.1 Basic principles for use cases

Basic principles have been established as a framework to define the use cases:

— The use cases of lane-level positioning describe the enhancements of existing ITS services based on the position information.

— The use cases in this document define sample cases that are available with lane-level positioning for transport users including drivers, public transport trippers, pedestrians, and transportation managers, who are carrying personal stations with the support of GNSS and wireless communications.

The lane-level positioning services may include the following group of use cases:

— Safe driving: hazardous road driving support, road construction/maintenance zone driving support, stationary/slow-moving vehicle collision prevention, first priority vehicle support, lane-level navigation, etc.

— Intersection approach and clearance: intersection collision avoidance, adaptive traffic signal control, etc.

— Public transportation safety: public transportation route/stop guidance, etc.

— Transportation vulnerable support: school/silver zone safety support, pedestrian safety, etc.

6.2.2 Use case clusters

Table 1 provides an overview about the different use case categories. The use cases are grouped into use case clusters.

Table 1 — Use case clusters and associated use case overview

# – Title of use case cluster	Brief description
1. Safe driving	This cluster describes ITS services focused on enhancing the traffic safety and flow by providing a warning message to vehicles on hazardous roads. Upon receiving the warning message including the existence of hazards with their lane-level positions, the vehicles on the roads might in advance determine which lanes to use in order to avoid conflict and traffic accidents from the hazards. Services related to lane change guidance for safety and traffic efficiency are included in this cluster. — UC 1.1 – Hazardous road driving — UC 1.2 – Road construction/maintenance zone driving support — UC 1.3 – Stationary/slow-moving vehicle collision prevention — UC 1.4 – First priority vehicle support — UC 1.5 – Lane-level navigation
2. Intersection approach and clearance	This cluster specifies services to improve the safety and efficiency at intersections with the avoidance of sudden stop, overspeed, signal violation, and wrong lane violation. It may include traffic control applications that adaptively change traffic signal timing for each lane based on the actual traffic demand. Functions of lane-based congestion control may be included in this use case cluster. — UC 2.1 – Intersection collision avoidance — UC 2.2 – Adaptive traffic signal control
3. Public transportation safety	This cluster deals with public transportation safety issues that may occur while changing lanes for routes and stops. It may include guidance services that inform caution to vehicles nearby buses or taxis which will make lane changes. Accordingly, the vehicles may make plans for the use of lanes and speed to secure safety. Such services are applicable to general vehicles of which routes are given with navigation services. — UC 3.1 – Public transportation route/stop guidance — UC 3.2 – Restricted traffic lane violation

The detailed definition of each use case is defined in 6.2.

6.3 Use case definitions

The clause defines the aforementioned use cases that enhance the safety of drivers, riders, passengers, and pedestrians based on the lane-level position information.

6.3.1 UC cluster 1 — Safe driving

6.3.1.1 UC 1.1 — Hazardous road driving support

This use case describes the safety guidance procedure when a vehicle is approaching a pothole.

Table 2 describes the UC 1.1 — Hazardous road driving support.

Table 2 — UC 1.1 — Hazardous road driving support

Use case name	UC 1.1 — Hazardous road driving support
Goal	Provide a "warning" notification/indication to the driver of the vehicle that may be sustained in an accident from a pothole on the road.
Actor	Control station (C-ITS-S), Base station, Nomadic device
Use case input	The following inputs need to be considered: — The lane-level position of potholes (road surface conditions) and corresponding weather conditions (optional) on the road; — Lane-level road map; — The lane-level position of the vehicle.
Use case output	The following outputs need to be considered: — Warning if the vehicle is in the lane with potholes ahead; — Speed reduction guidance to avoid the accident; — Lane change guidance to avoid the accident.
Brief description	When a nomadic device finds that the vehicle is approaching potholes based on the information from the device itself and the database servers, which may be included in the C-ITS-S, the nomadic device makes an alert to the driver to avoid the potholes by changing lanes.
Classification	Mandatory

6.3.1.2 UC 1.2 — Road construction/maintenance zone driving support

This use case describes the safety guidance procedure when a vehicle is approaching a road construction/maintenance zone. This use case may be extended to the lane merging scenario.

Table 3 describes the UC 1.2 — Road construction/maintenance zone driving support.

Table 3 — UC 1.2 — Road construction/maintenance zone driving support

Use case name	UC 1.2 — Road construction/maintenance zone driving support
Goal	Provide a "lane closed" notification/indication to the driver of the vehicle approaching the road construction/maintenance zone.
Actor	Control station (C-ITS-S), Base station, Nomadic device

Table 3 *(continued)*

Use case input	The following inputs need to be considered: — Road construction/maintenance zone in lane-level; — Lane-level road map; — The lane-level position of the vehicle.
Use case output	The following outputs need to be considered: — Warning to notify that lane is closed ahead; — Lane change guidance to avoid an accident.
Brief description	When a nomadic device finds that the driving lane of the vehicle is closed ahead, the nomadic device makes an alert to the driver to make a lane change.
Classification	Mandatory

6.3.1.3 UC 1.3 — Stationary/slow-moving vehicle collision prevention

This use case describes the safety guidance procedure when a vehicle is approaching stationary/slow-moving vehicles.

Table 4 describes the UC 1.3 — Stationary/slow-moving vehicle collision prevention.

Table 4 — UC 1.3 — Stationary/slow-moving vehicle collision prevention

Use case name	UC 1.3 — Stationary/slow-moving vehicle collision prevention
Goal	Avoid a collision with stationary/slow-moving vehicles on the road.
Actor	Control station (C-ITS-S), Base station, Nomadic device
Use case input	The following inputs need to be considered: — Dynamics information (position, speed, acceleration, etc.) of vehicles on the road; — Lane-level road map; — The lane-level position of the vehicle.
Use case output	The following outputs need to be considered: — Speed reduction guidance to avoid a collision; — Lane change guidance to avoid a collision.
Brief description	When stationary/slow-moving vehicles on the same lane are reported, the nomadic device provides a “warning” notification/indication to the driver.
Classification	Mandatory

6.3.1.4 UC 1.4 — First priority vehicle support

This use case describes the handling procedure to assign a lane to be temporarily available for first priority vehicles such as ambulances, patrols, and fire trucks.

Table 5 describes the UC 1.4 — First priority vehicle support.

Table 5 — UC 1.4 — First priority vehicle support

Use case name	UC 1.4 — First priority vehicle support
Goal	Provide a "priority lane" notification/indication to the vehicles (drivers) to make a lane change and not to use the lane for first priority vehicles.
Actor	Control station (C-ITS-S), Base station, Nomadic device
Use case input	The following inputs need to be considered: — The lane-level positions of the vehicles on the road; — Lane-level road map; — A request to assign a priority lane.
Use case output	The following outputs need to be considered: — Broadcasting to notice a specific lane assigned for first priority vehicles; — Lane change guidance for each vehicle following the provided message.
Brief description	According to a request for priority lane assignment, a central system, i.e. C-ITS-S, assigns a lane as the priority lane temporarily and broadcasts a "priority lane" notification/indication to the vehicles. As long as the assignment is available, first priority vehicles are only allowed to use the lane, and general vehicles are informed to use other lanes.
Classification	Mandatory

6.3.1.5 UC 1.5 — Lane-level navigation

This use case describes the routing and guidance service where the lane-level route to the destination is provided. The route needs to be determined according to the traveling time and the safety issues described in 6.2.1.1 to 6.2.1.4.

Table 6 describes the UC 1.5 — Lane-level navigation.

Table 6 — UC 1.5 — Lane-level navigation

Use case name	UC 1.5 — Lane-level navigation
Goal	Provide a lane-level route to the destination to the driver.
Actor	Control station (C-ITS-S), Base station, Nomadic device
Use case input	The following inputs need to be considered: — The lane-level position of the vehicle; — Lane-level road map; — Road surface and weather conditions; — Road construction/maintenance zone in lane-level; — Vehicle counts, speed, and occupancy per lane; — Temporarily unavailable lanes.

Table 6 *(continued)*

Use case output	The following outputs need to be considered: — Lane-level routes to the destination; — Speed limit guidance; — Lane change guidance.
Brief description	The nomadic device with a routing service provides lane-level routes from the current position of the vehicle to the destination. The routes are determined according to the traveling time and the safety issues, and one of them needs to be selected by the driver. During driving, proper notification/indication is informed with corresponding guidance.
Classification	Mandatory and/or optional

6.3.2 UC cluster 2 — Intersection approach and clearance

6.3.2.1 UC 2.1 — Intersection collision avoidance

This use case describes the handling procedure of vehicles approaching intersections for collision avoidance.

Table 7 describes the UC 2.1 — Intersection collision avoidance.

Table 7 — UC 2.1 — Intersection collision avoidance

Use case name	UC 2.1 — Intersection collision avoidance
Goal	Provide an "entering vehicle" notification/indication for collision avoidance at an intersection.
Actor	Control station (C-ITS-S), Base station, Nomadic device
Use case input	The following inputs need to be considered: — The lane-level positions of the vehicles approaching the intersection; — Lane-level road map.
Use case output	The following outputs need to be considered: — Broadcasting the "entering vehicle" notification/indication to the vehicles approaching the intersection; — Speed reduction guidance or immediate stop for the approaching vehicles; — Broadcasting the "clearance" notification/indication to the approaching vehicles if the entering vehicle leaves the intersection.
Brief description	When a vehicle enters an intersection, its status is broadcasted to other vehicles approaching the intersection. Those vehicles receiving the "entering vehicle" notification/indication reduce their speeds or make an immediate stop.
Classification	Mandatory

6.3.2.2 UC 2.2 — Adaptive traffic signal control

This use case describes the handling procedure of traffic signal depending on lane-level traffic demands (e.g. vehicle counts, occupancy) on the road.

Table 8 describes the UC 2.2 — Adaptive traffic signal control.