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Intelligent transport systems — Mobility integration — Role and functional model for mobility using low earth orbit (LEO) satellite system

Systèmes de transport intelligents — Intégration des services de la mobilité — Modèle de rôle utilisant des satellites en orbite terrestre basse (LEO)

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Foreword

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

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Introduction

Recent implementation of low earth orbit (LEO) satellite communication systems (e.g. OneWeb, Starlink) offer advantages in large coverage area, capacity, access, latency, and resilience compared to other systems; these characteristics offer benefit when used for smart mobility services.

This document defines a role and functional model of LEO.

The background information can be found in References [12] to[24].

Intelligent transport systems — Mobility integration — Role and functional model for mobility using low earth orbit (LEO) satellite system

1 Scope

This document describes a basic role and functional model for mobility services using low earth orbit satellite systems. It provides:

a) a description of concept of a role and functional model using a low earth orbit satellite system for mobility services;

b) a description of the concept of operations, and the role models;

c) a conceptual architecture between actors involved;

d) references for the key documents on which the architecture is based;

e) a mobility service use case summary.

In-vehicle control system is not in the scope of this document.

This document scope is limited to mobility services using physical and digital infrastructure.

NOTE The physical infrastructure facilities include for example, battery charging facilities, dynamic charging facilities for battery electric vehicles, physical infrastructure markings, physical traffic regulation signs, mobility monitoring facilities, emergency response service support facilities, traffic operation control centre facilities, fee collection service facilities (e.g. road usage fee), battery EV charging facilities, online reservation and online mobility usage fee payment facilities, and other infrastructure platform facilities that support ITS mobility services.

This document can contribute to the development of mobility service standards using LEO satellite system business cases.

2 Normative references

There are no normative references for this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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/

4 Abbreviated terms

AM automated mobility

BEV battery electric vehicle

EFC electronic fee collection

EV electric vehicle

FCV fuel cell vehicle

LEO low earth orbit

5 Advantages of low latency in LEO satellite constellation

— LEO (LEO (<2 000 km, but often <500 km orbit) satellite constellations promise lower latency than traditional satellite systems because signals only need travel a tenth or less of the distance required by geosynchronous orbiting satellites (geosynchronous orbits are 22,500 km altitude).

— These constellations are planned to use hundreds (OneWeb) or thousands (Starlink) of satellites with future upgrades to potentially include more than 30,000 satellites.

— Starlink also plans to use a laser-based inter-satellite communication path when communicating parties access the network through different satellites. This will take advantage of the superior speed of laser signals in a vacuum, compared to fiber-optic links that are typically used between ground stations.

— LEO satellites connect with ground stations with radio wave path such as Ka (12 GHz) and/or Ku (24 GHz) bands as gateway to the ground network.

— Devices on the ground connect to the LEO service through a terrestrial network to the ground station, or directly to the LEO satellite using a constellation-specific satellite antenna.

— Mobility service providers can provide services through LEO satellites in addition to conventional ground communication media, if necessary, as backup.

— A few satellites can provide service to an entire region without creating un-serviced zones; additional satellites can serve an increased user density and expand geographic coverage.

— Compared to terrestrial wired networks, LEO constellations can more readily provide low latency, high capacity, to remote and rural locations.

— LEO constellations offer a resilience advantage over other communications techniques that rely on a single point through which all data flows.

6 Downsides of using satellites and LEO

There are still unknown factors related to LEO operations that may impact ITS, such as:

— the effects of severe weather on Ku/Ka transmissions;

— life cycle cost impact;

— use of LEO constellations by moving vehicles, i.e. how hard is it for a moving vehicle to track the satellite;

— how large the antenna is, and if it can be mounted on a personal device.

7 Private 5G/6G

For ITS V2X use case, to realize cost effective service, private 5G/6G can be one candidate tool as next generation mobility services and could be used conjunction with an LEO. This statement is speculative but needs more analysis to tell the reader how LEO use might be leveraged by projections of cellular evolution. Such speculation includes LEO to be part of 6G or is it an alternative. Satellite communication can as well be complemented by wireless local access network as well as DSRC 802.11p/bd in the transport sector.

8 Mobility role model example

Figure 1 shows an example of mobility service role model. In this example, mobility service users are connected to service providers through satellite(s) or private 5G/6G through ground network/ satellite(s).

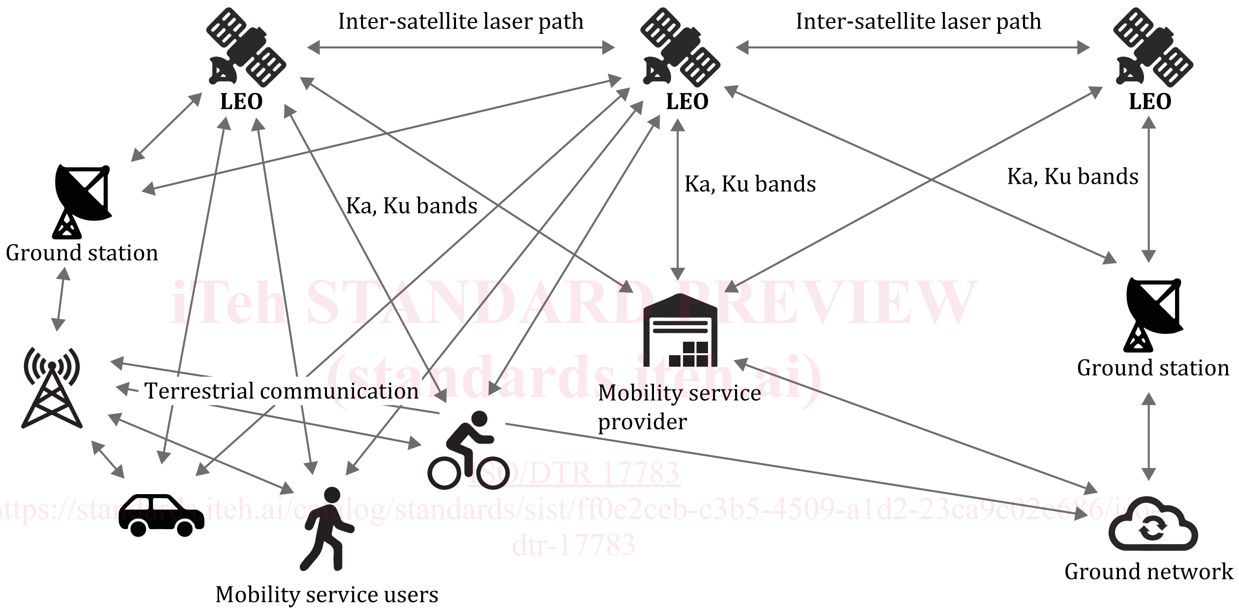

Figure 1 — LEO satellite system use example

Conventional DSRC and private 4G/5G cellular network might be utilized in addition to LEO.

9 Definition of service domains suitable to utilizing LEO satellite systems

9.1 General

LEO satellite systems may support ITS service implementations but should be assessed considering physical infrastructure needs and predicated on LEO offering improvements in safety or mobility over other communications technologies. While LEO offers broad and flexible coverage, the urban environment is not ideal for LEO systems. First, cities are dense and have many potential users that can saturate satellite communications links. Second, urban canyons and other occlusions can block access to the satellite network. Third, cities are not the target for satellites because cities include users close to one another, who should be better served by terrestrial communications.

Service applications using LEO can include but not limited to:

— critical safety information provision; low latency in receiving service is key to implementation;

— safety driving support; same as above;

— infrastructure planning; latency is not important;

— dynamic traffic management; same as above;

— traffic rule enforcement; same as above;

— dynamic map updates; same as above;

— emergency evacuation support; same as above;

— kerb side management (service robots); same as above.

Where applicable, mobility services already defined by the local authority can be applicable.

Further research or development of digital infrastructure is needed for efficient use of LEO in ITS.

9.2 Referenced target use cases

Mobility service applications rely upon data collected through applications, in many cases large volumes of data. Service quality depends upon the quality and quantity of data held and maintained by the relevant operating entity, e.g. a smart city data manager. Those mobility services can be grouped into two categories: the services provided by the authority/jurisdiction or road operator; and the services provided by public and private service providers. The applications offered and managed by the authority/jurisdiction or road operator can be further classified into four groups as “infrastructure operation management,” “traffic management,” “road traffic operation management” and “enforcement.” The applications provided by the service providers can be offered through public or private sectors.

Many of these use cases presume an urban environment. This might not be the best use for LEO. It might be, but it is not obvious. However, expected use cases of LEO might be of that focus on transportation safety concerns unique to environments that do not typically have access to terrestrial communications, e.g. locations that are remote and rural environment.

The number of emerging mobility service applications for smart city deployment are growing rapidly in recent years. The following list provides examples of those applications:

— avalanche and falling rock warnings;

— disaster information provisioning systems for safer and timely evacuation activities emphasizing the widespread dissemination;

— tachograph monitoring over remote areas (such as the long drives road trains take in Australia);

— other services unique to remote and rural environments;

— traffic management applications to ease traffic congestion and maintain safety in urban areas;

— road traffic operation applications to realize efficient and safer use of infrastructure;

— electronic fee collection (EFC) support for urban-ITS traffic management to realize dynamic road pricing;

— weigh in motion to ease heavy good transport vehicles;

— dangerous goods/hazardous materials transport management to enforce geo-fencing;

— infrastructure services applications for efficient and automated maintenance works;

— access control in urban area to enhance vehicle entry to certain area;

— traffic signal (SPaT-MAP): signal phase and timing and road topology messages information provisioning for safer and efficient traffic flow in the urban area;

— law enforcement applications to regulated freight vehicles such as overloaded vehicle shut out from certain urban area;

— remote digital tachograph monitoring to maintain safe freight transport vehicle movement;

— heavy vehicle air quality controls and geo-fencing in certain urban area;

— emission control of vehicle entering certain urban area to enforce geo-fencing in certain area of the smart city;

— autonomous vehicle applications such as monitoring, emergency controls, override command, regulated information provisioning;

— urban/suburban/expressways mobility mode-specific safety information provisioning and traffic monitoring;

— dynamic map management including probe data collection, data aggregation, managing digital twin in the cloud and provisioning of safety information;

— EFC from services such as parking, event admission, car sharing;

— vehicle remote maintenance applications such as over the air software updates;

— freight vehicle management applications supporting efficient and safer transport fleet operations;

— electric vehicle charging applications such as booking, monitoring, fee collections with security management;

— fuel cell vehicle charging applications;

— intelligent parking such as automated valet parking supporting systems;

— car sharing management including booking, matchmaking between user and driver, safety information provisioning;

— public transit information provisioning to users in timely and dynamic real time basis;

— taxi fleet management applications such as booking, matchmaking between users and drivers, safety information provisioning;

— dynamic map utilizing service applications for automated driving buses, shuttles, freight vehicles for efficient and safer operations;

— tourist information/advice provisioning service applications to inbound users;

— bicycle/motor cyclist’s ITS service applications such as vulnerable road user safety information provision services;

— kerb side management (service robots).

Major use cases and business cases for smart city mobility service applications (those currently available and future ones) are shown here for information only. Further applications can be expected to be developed in the future depending upon how the smart city mobility regulators can implement their initiative with the local government.

9.3 Infrastructure operation management

9.3.1 General

The use cases that fall into the “infrastructure operation management” category are infrastructure service applications focusing on service vehicle operational efficiency and automated maintenance.