Technical Report

ISO/TR 17783

First edition
2024-04

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

Systèmes de transport intelligents — Intégration de la mobilité — Rôle et modèle fonctionnel des services de mobilité qui utilisent les systèmes de satellites en orbite terrestre basse (LEO)

Reference number
ISO/TR 17783:2024(en)

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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 implementations of low Earth orbit (LEO) satellite communication systems (e.g. OneWeb,[13] Starlink[19]) offer advantages in terms of large coverage area, large capacity, multi-modal mobility access, low latency and resilience compared to other available communication service systems. These characteristics of LEO offer benefits when used for smart city or community mobility integration services. This document describes a role and functional model of LEO in the context of use cases for intelligent transport systems (ITS).

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

Background information on LEO is provided in the Bibliography.

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

1 Scope

This document describes a basic role and functional model for mobility services using low Earth orbit (LEO) satellite systems for ITS services. This document provides:

a) a role and functional model using a LEO satellite system for mobility services;

b) a description of the concept of operations (CONOPS), and the relevant 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 systems are not within the scope of this document.

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

NOTE 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 electric vehicle charging facilities, online reservation and online mobility usage fee payment facilities, and other infrastructure platform facilities that support ITS mobility services.

2 Normative references

There are no normative references in 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

3D HD three-dimensional high definition

AI artificial intelligence

AM automated mobility

CCTV close circuit television

CONOPS concept of operations

DSRC dedicated short-range communications

EFC electronic fee collection

EV electric vehicle

FCV fuel cell vehicle

LEO low Earth orbit

QoS quality of service

WIM weigh in motion

5 Advantages of low latency in LEO satellite constellation

— LEO (<2 000 km, but often <500 km orbit) satellite constellations promise lower latency than traditional satellite systems because signals need to travel less distance than that required by ordinal geosynchronous orbiting satellites (geosynchronous orbits are 36 000 km altitude).

— It is planned that these constellations will use hundreds (OneWeb) or thousands (Starlink) of satellites with future upgrades to potentially include more than 30 000 satellites.

— Starlink 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 fibre-optic links that are typically used between ground stations.

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

— There are plans for direct communication from LEO to handheld nomadic devices using the 5G frequency spectrum. This would eliminate the need for a cellular base station on the ground.

— There is a plan to use the current cellular frequency spectrum for direct connection to mobile phones on the ground.

— 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 communication techniques which rely on a single point through which all data flows.

6 Disadvantages of using satellites and LEO

There are still unknown factors related to LEO operations that can 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;

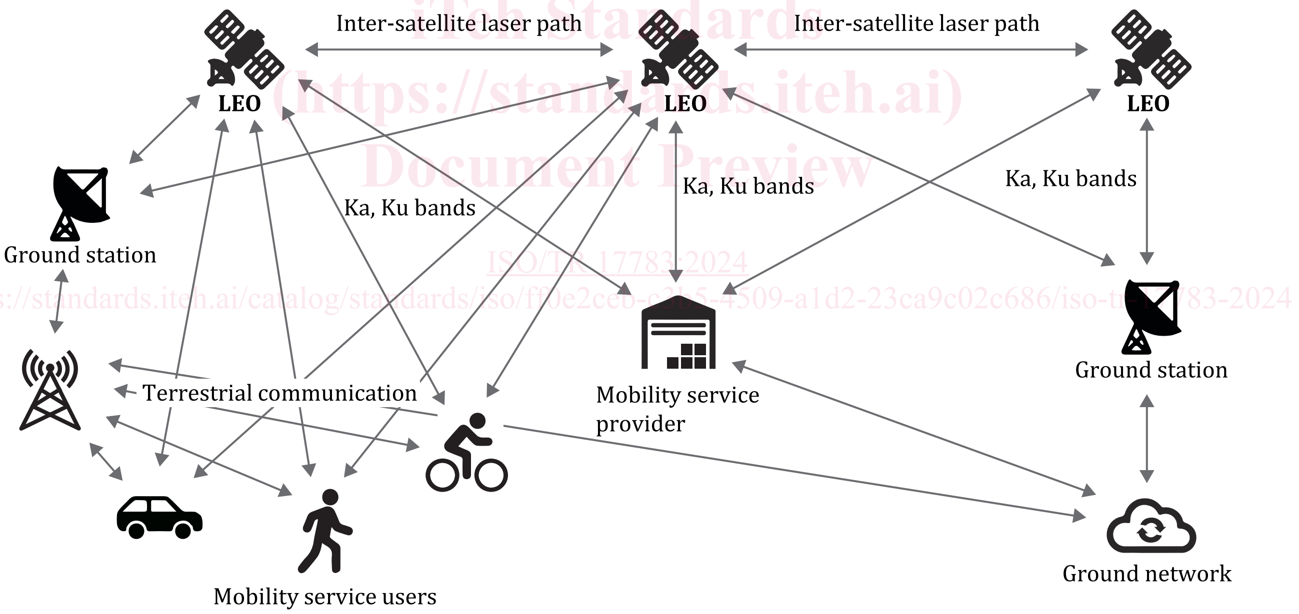
— how large is the antenna, and can it be mounted on a personal device.

7 Private 5G/6G

For ITS V2X use cases, one potential tool for achieving cost effective service in next generation mobility services is private 5G/6G, which could be used in conjunction with LEO. This statement is speculative, and further analysis is needed of how LEO use can potentially be leveraged by projections of cellular evolution. Such speculation includes considering whether LEO is part of 6G or an alternative. Satellite communication can also be complemented by wireless local access networks and DSRC 802.11p/bd in the transport sector.

8 Mobility role model example

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



NOTE Conventional DSRC and private 4G/5G/6G cellular network could potentially be utilized in addition to LEO.

Figure 1 — LEO satellite system use example

9 Definition of service domains suited to utilizing LEO satellite systems

9.1 General

It is possible that LEO satellite systems will support ITS service implementations. However, such scenarios ought to be assessed taking into account physical infrastructure needs. Further, they ought to be 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 a suitable target for satellites because cities include users close to one another, who would be better served by terrestrial communications.

Service applications using LEO can include, but are not limited to:

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

— safety driving support (low latency in receiving service is key to implementation);

— infrastructure planning (latency is not important);

— dynamic traffic management (latency is not important);

— traffic rule enforcement (latency is not important);

— dynamic map updates (latency is not important);

— emergency evacuation support (latency is not important);

— curb-side management; service robots (latency is not important).

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, these are 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. Mobility services can be grouped into two categories: services provided by the authority/jurisdiction or road operator; and 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:

1) infrastructure operation management;

2) traffic management;

3) road traffic operation management;

4) enforcement.

The applications provided by the service providers can be offered through public or private sectors.

Many of the use cases in this document presume an urban environment. This is not necessarily the best use for LEO. Expected use cases of LEO will potentially focus on transportation safety concerns unique to environments that do not typically have access to terrestrial communications, e.g. locations that are in a remote and rural environment.

The number of emerging mobility service applications for smart city deployment have grown rapidly in recent years. The following list provides examples of such applications:

— avalanche and falling rock warnings;

— disaster information provisioning systems for safer and more 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;