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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The present document specifies the Parking Information Service (PI Service) and how a Vehicular ITS Station (V-ITS-S) can disseminate to other ITS-Ss information about the occupancy of available parking spaces. Moreover, the present document also describes a mechanism to indicate for an ITS-S the parking space to be allocated by a V-ITS-S.

The PI service maintains a dynamic database about the free parking spaces. Using this information the V-ITS-Ss are able to find parking spaces faster, more predictably and closer to their destination. This reduces the frustration of the drivers, improves the driving experience and reduces the collision risk and the unnecessary rounds while looking for available parking spaces. To further optimize the user experience, the V-ITS-Ss are also able to share their intention about the parking space to be occupied. With this information, the other V-ITS-Ss in the proximity can avoid competing for the same parking space and as such, they can navigate to a space which will be empty by the time of their arrival. The PI service interprets electric charging spaces as specially featured parking spaces; thus, it enables the dissemination of charging spaces as well.

The PI service describes the Parking Information Message (PIM). The PIM helps to disseminate information about parking spaces and about the parking spaces intended to be allocated by certain V-ITS-S.

The present document provides a messaging specification, covering the necessary interoperability elements. An informative application specification is also provided to enhance the understanding of the context.

1 Scope

The present document specifies a facility layer service for providing parking space availability and intention information from vehicular ITS-Stations to other ITS-Stations.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 836-4-1: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality; Release 2".

[2] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate formats; Release 2".

[3] ETSI TS 102 894-2: "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary; Release 2".

[4] Recommendation ITU-T X.691 (2021-02): 'Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER)'.

[5] ETSI TS 102 965: "Intelligent Transport Systems (ITS); Application Object Identifier (ITS-AID); Registration; Release 2".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

[i.1] ETSI TS 103 916: "Intelligent Transport Systems (ITS); Parking Availability Service; Release 2".

[i.2] ETSI TS 103 898: "Intelligent Transport Systems (ITS); Communications Architecture; Release 2".

[i.3] ETSI TS 103 938: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM); Release 2".

[i.4] ETSI EN 302 890-1: "Intelligent Transport Systems (ITS); Facilities layer function; Part 1: Services Announcement (SA) specification".

[i.5] ETSI TS 102 940: "Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management; Release 2".

[i.6] ETSI TS 103 141: "Intelligent Transport Systems (ITS); Facilities layer function; Multi-Channel Operation (MCO) for Cooperative ITS (C-ITS); Release 2".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

parking space: physical space where it can be reasonably expected that parking and/or stopping is possible for a defined set of vehicle types

3.2 Symbols

For the purposes of the present document, the following symbols apply:

IF.Control	Interface required by the PI service to management plane entity(ies)
IF.Security	Interface required by the PI service to security plane entity(ies)
IF.DataCollect	Interface provided by the PI service for making collected PIMs available
IF.DataOut	Interface required by the PI service to disseminate PIM
IF.DataIn	Interface required by the PI service to gather PIMs and other service data

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

API	Application Programming Interface
ASN.1	Abstract Syntax Notation One
DDP	Device Data Provider
DE	Data Element
DF	Data Frame
FoV	Field of View
GNSS	Global Navigation Satellite System
ITS	Intelligent Transport Systems
ITS-S	Intelligent Transport Systems Station
LDM	Local Dynamic Map
MCI	MCO Control Information
MCO	Multi Channel Operation
MIB	Management Information Base
MTU	Maximum Transmission Unit
PCI	Protocol Control Information
PI	Parking Information
PIM	Parking Information Message
PI service	Parking Information service
POTI	Position and Time management
SA	Service Announcement
UPER	Unaligned Packed Encoding Rule
V-ITS-S	Vehicular ITS Station
VEI	V2X Exchanged Information

4 PI service contextual introduction

4.1 Background

Vehicular mobility is a key element in our current society. Due to the large number of cars and trucks, the parking of these vehicles became an increasing challenge. In urban areas, especially in historical districts, the available space on streets is limited. Allocating parking spaces on the narrow streets further limits the available space. As a result, the number of parking spaces are limited in typical urban environments, while the demand for parking is persistent. The high number of one-way streets, the limited number of opportunities to turn around and the low number of available spaces result that many drivers need to spend additional time to circle around its destination while trying to find an empty parking space. A similar situation occurs in the case of large open-air parking facilities. In these parking lots there are usually a low number of entrance points to the nearby facility. For example, in the case of airports, the shuttle bus only has a limited number of stops. A train station or a mall has only a small number of entrances. Thus, finding a space near the subject point of interest is sometimes cumbersome, since most of the users of the parking facility try to get a space near the entrance area in order to limit the distance to be walked. As a result, drivers need to either walk more if they have decided to take a remote parking space or they need to make multiple circles in order to find a space close to the destination. Any of these cases makes finding a parking space frustrating, time-consuming and unpredictable.

4.2 Application specification

To address the challenges listed in the clause 4.1, the present document suggests the following application.

Each vehicle implementing this service collaborates with each other by sharing their detected parking spaces and optionally the parking space they intend to occupy as well. The vehicles are equipped with the necessary sensors to detect empty parking spaces and with the necessary communication units that help to share this information. Vehicles may also incorporate additional data, like the location of the available (but not necessarily empty) parking spaces that increase the overall performance of the application. Then, vehicles exchange the parking space information so that with this information they can all implement a function that helps the driver to find a parking space near his/her destination.

To avoid race conditions, where multiple drivers are about to occupy the same space, the service implements a method to indicate the parking space someone is about to occupy. With this approach, other vehicles can avoid attempting to park to a location that is at the moment empty but will be occupied by the time the vehicle arrives at the parking space.

The present document describes how to implement the messaging, as well as how to select the parking spaces subject to dissemination, how to prioritize them and how to handle cases when not all spaces can be sent. The details can be found in the following clauses.

In the next subclauses, some key technical challenges and their resolution were listed.

4.3 Sharing parking information

Today's vehicles are equipped with numerous sensors, including GNSS, cameras, radars and ultrasonic sensors. Using sensors of the vehicles it became possible to detect empty parking spaces. For example, a vehicle can use its ultrasonic sensors on its side to detect an empty location. The detected parking spaces can then easily be localized via combining the absolute position of the vehicle (calculated by the GNSS) and the relative position of the parking space to the vehicle.

However, restricted parking spaces, garage entrances and similar open spaces may pose challenges to the detector systems. Luckily, the location information of the parking spaces is more or less static. This means that static preloaded data can be used on a vehicle to validate the detected empty parking space. Using this method the number of false positive detections can be reduced. For example, a garage entrance may look like an empty space from the ultrasonic sensor's perspective, but it can be filtered out using the available parking space data. On top of the pure detection the sensors can gather additional features of the parking space such as size and charging availability.

4.4 Competition for the same parking space

In case only empty parking space information is distributed; vehicles will tend to compete for the same parking spaces typically located near the entrance of a facility. This would result that in many cases vehicles will not be able to park at the desired location because by the time the vehicle arrives at the parking space, it will be already occupied by a different vehicle. In order to mitigate this issue, vehicles can share their intended location so that other vehicles can aim for a different unoccupied space.

4.5 Managed facilities with PAS

In some cases, the infrastructure is capable of detecting empty parking spaces and share this information with the drivers. For example, some sensors built under the concrete pavement can detect if a car parked above it, or an ultrasonic sensor mounted to the ceiling can detect if a vehicle parked beneath it. This information can be shared with the vehicles by other means then the PI service as well, for example, using the Parking Availability Service [i.1]. In case the vehicle enters a managed facility where the free parking space information is available; the PI service may adapt its behaviour and only reports the found misalignments so that the parking lot operator can detect sensory errors on its own side.

4.6 Scalability

In order to improve scalability, in case a certain location has many empty parking spaces, the PI service will not send individual empty space information. Instead, it will distribute general emptiness information (e.g. via the segment-based approach).

4.7 Service triggering options

On the V-ITS-S side, PI service may activate the generation of PIMs in case the vehicle reaches a speed where the sensor detection is available and road conditions allow the parking space detection (for example, the vehicle drives in the rightmost lane).

5 PI service functional description

5.1 PI service in the ITS communication architecture

The PI service is a facility layer entity of the ITS-S architecture as defined in ETSI TS 103 898 [i.2]. It may interface with other entities of the facilities layer and with the ITS-S application layer to collect relevant information to generate the necessary messages to implement the service and to forward the consumed message content for further processing. The PI service within the ITS-S architecture and the logical interfaces to other layers and potentially to entities within the facility layer are presented in Figure 1.

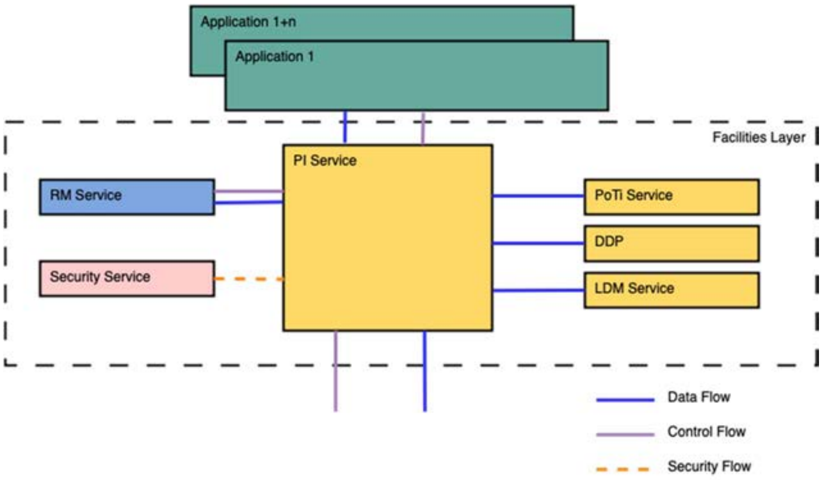

Figure 1: PIS within the ITS-S communication architecture

In a vehicle ITS-S the entities for the collection of data may be the Device Data Provider (DDP) and the Position and Time management (PoTi) and for the consumed data the Local Dynamic Map (LDM). The DDP may be connected to the vehicle network and provides the vehicle status information and parking detection information. The PoTi provides the position of the ITS-S and time information. The LDM as outlined in ETSI TS 103 938 [i.3] is a database in the ITS-S, which may be updated with the consumed data. ITS-S applications may retrieve information from the LDM for further processing. The PI service may also interface with the Service Announcement (SA) Service [i.4] to indicate the ITS-S's ability to generate PIMs and to provide details about the communication technology used. The PI service may also interface with resource management entities (specified in ETSI TS 103 141 [i.6]).

The PI service interfaces through the IF.N&T with the networking & transport layer for exchanging of messages with other ITS-Ss, the IF.Security with the Security entity to access security services for message transmission and, the IF.Control with the Management entity and the IF.DataCollect with the application layer if consumed data are provided directly to the applications.

The functionalities of the PI service are defined in clause 5.2, and the interfaces in clause 5.3.

5.2 PI service functional architecture

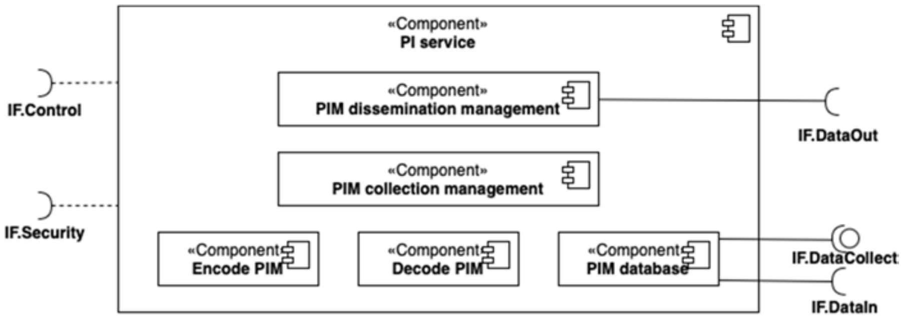

Figure 2: Functional block diagram of the PI service

For sending and receiving PIMs, the PI service shall provide the following sub-functions, as depicted in Figure 2:

- Encode PIM:
  - This sub-function constructs the PIM according to the format specified in Annex A.
- Decode PIM:
  - This sub-function decodes the consumed PIMs.

- PIM dissemination management:
  - This sub-function implements the protocol operation of the originating ITS-S, as specified in clause 6.1, including in particular:
    - Activating and terminating the PIM dissemination operation.
    - Determining the PIM generation frequency.
    - Triggering the generation of PIM.
    - Collecting and assembling the data for a PIM.
- PIM collection management:
  - This sub-function implements the protocol operation of the receiving ITS-S, including in particular:
    - Triggering the "decode PIM" function upon the reception of a PIM.
    - Providing the consumed PIM data to LDM and/or ITS-S applications of the receiving ITS-S.
    - Optionally, checking the information of consumed PIMs.
- PIM Database:
  - This sub-function implements the protocol operation of storing and updating an internal list of parking spaces, including in particular:
    - Storing the parking spaces (both locally perceived and received ones).
    - Determining if two parking space detection from different sources are identical.
    - Updating the parking space list based on the most recent information from one or multiple sources.

The interfaces to other entities and layers are defined in clause 5.3.

NOTE 1: The PIM Database has in some sense a similar functionality as the LDM. However, LDM typically handles messages, whereas the PIM database handles individual parking spaces.

NOTE 2: The PI service may use additional data sources, e.g. static maps or other communication services to improve the overall application performance. However, that information is normally not exchanged as part of the PI service.

5.3 Interfaces of the PI service

5.3.1 Interface to ITS-S applications

An ITS-S application is an application layer entity that implements the logic for cooperative parking space sharing use cases. An informative list of design requirements is provided in Annex E. For the provision of consumed data the PI service provides the interface IF.DataCollect to LDM or to ITS-S application layer, as illustrated in Figure 2.

NOTE: The interface to the ITS-S application layer may be implemented as an API and data are exchanged between the PI service and ITS-S applications via this API.

5.3.2 Interface to management plane entities

The PI service may exchange primitives within the entity(ies) in the ITS management plan via the interface IF.Control as depicted in Figure 1. Such primitive may include e.g. configuration parameters used by the service.

NOTE: The specifications of the interface between the PI service and the management entity is out of scope of the present document.

5.3.3 Interface to security plane entities

The PI service may exchange primitives with the security entity of the ITS-S via the IF.Security interface as depicted in Figure 1 using the IF.Security interface provided by the security entity as depicted in Figure 2.

NOTE 1: Specifications of the interface between the PI service and the security entity is out of scope of the present document.

In case the facility layer security is used, for ITS stations that use the trust model according to ETSI TS 102 940 [i.5] and ITS certificates according to ETSI TS 103 097 [2] and that are of type [Itss_WithPrivacy] as defined in ETSI TS 102 940 [i.5], the PI service shall interact with the ID management functionality of the Security entity to set the actual value of the ITS-S ID in the ITS PDU Header of the PIM. When the Security entity is triggering an Authorization Ticket change, the PI service shall change the value of the ITS-ID in the component ItsPduHeader.stationId accordingly and shall not send PIMs with the previous ID anymore. The PIM shall also stop sending any detections that already existed in the PIM database by the time of the pseudonym change.

NOTE 2: Due to priority mechanisms implemented at lower layers, the sending ITS-S may apply reordering of the messages contained in its buffer. Queued messages which are identified with the old ITS-ID are discarded as soon as a message with the new ITS-ID is sent. Implementers should be aware that whether or not messages previously queued prior to an ID change event get transmitted or not is implementation dependent.

NOTE 3: ITS stations of type [Itss_NoPrivacy] as defined in ETSI TS 102 940 [i.5] and ITS stations that do not use the trust model according to ETSI TS 102 940 [i.5] and ITS certificates according to ETSI TS 103 097 [2] do not need to implement functionality that changes ITS-S IDs (pseudonyms).

To avoid similarities between successive PIMs, all detected parking spaces shall be reported as newly detected ones in the PIM following a pseudonym change.

5.3.4 Interface DataIn, DataOut and DataCollect

The PI service shall pass the PIM for dissemination via the IF.DataOut to either another facilities layer entity such as Resource Management or a lower layer functionality such as the Networking & Transport layer as specified in Table 1.

The PI service shall gather PIM via the IF.DataIn from either another facility layer entity such as Resource Management or a lower layer functionality such as the Networking & Transport layer as specified in Table 1.

Table 1: PIM exchanged over Interfaces In and Out

Category	Data	Data requirement	Mandatory/Optional
Data passed from the PI service to the ITS networking & transport layer	PIM	*{pim}* as specified in Annex A	Mandatory
	SCI	Security Control Information: ITS-AID and SSP that shall be listed in the Authorization Ticket that is associated to the private key that signs the message at the Networking & Transport layer.	Optional, present only if ETSI ITS security ETSI TS 103 097 [2] at the network layer is used.
	PCI	Protocol Control Information, depending on the protocol stack applied in the networking and transport layer.	Optional
Data passed from the ITS networking & transport layer to the PI service	Received PIM	*{pim}* as specified in Annex A	Mandatory
	SCI	Security Control Information: ITS-AID and SSP that are listed in the Authorization Ticket attached to the message, and the result of the security check at Networking & Transport layer.	Optional, present only if ETSI ITS security ETSI TS 103 097 [2] at the network layer is used.

The PI service may request data from the PoTi service using the IF.DataIn.

NOTE 1: The specifications of the interface between the PI service and the PoTi service is out of scope of the present document.

The PI service may request data from the DDP using the IF.DataIn.

NOTE 2: The specifications of the interface between the PI service and the DDP is out of scope of the present document.

The PI service may provide PIMs to the LDM using the IF.DataCollect.

NOTE 3: The specifications of the interface between the PI service and the LDM is out of scope of the present document.

6 PIM dissemination requirements

6.1 PIM dissemination concepts

6.1.1 PI service activation and termination

6.1.1.1 Overview

The PI service supports multiple means for service activation and termination. The exact method applied for activation and termination shall be configured via the *ActivationTerminationMethod* configuration parameter (a default configuration set is provided in Annex F). The value of the configuration parameter refers to the respective subclause below. As long as the PI service is active, the PIM generation shall be triggered and managed by the PI service.

NOTE: The detection functionality has a separate lifecycle from the service itself (represented via the DDP in Figure 2). This means that even if the service is activated, the vehicle may not add any new parking spaces, e.g. due to driving with too high speeds.

6.1.1.2 Simple PI service activation and termination

If *ActivationTerminationMethod* is set to 1, then this activation and termination method shall be used.

For vehicle ITS-S, if enabled by configuration, the PI service shall be activated upon the ITS-S activation.

NOTE: SA messages may help finding the ITS stations with enabled PI service.

6.1.1.3 Request-based PI service activation and termination

If *ActivationTerminationMethod* is set to 2, then the activation and termination method detailed in this clause shall be used.

The ITS-S operating the PI service shall advertise the PI service (via e.g. the SA service (ETSI EN 302 890-1 [i.4])). The advertising message shall contain the channel where the PI service is available.

NOTE 1: The usage of service advertisement does not necessarily imply that the PI service and the service advertisement are operating on separate channels.

The advertising message shall contain an application-specific data field which shall be filled with the UPER-encoded *PimAdvertiseApplicationData* data structure defined in Annex A.

NOTE 2: If SA service (ETSI EN 302 890-1 [i.4]) is used, then the application-specific data corresponds to the SAMapplicationData service info extension in the *chOptions.extensions* field in the related *ServiceInfo* entry.

An application layer entity may indicate its need to find a parking space (via IF.DataIn). The ITS-S implementing the PI service may receive a request for parking space information from other remote ITS-Ss. The request for parking space is indicated via an advertisement message containing the PI service info where the *request* field of the *PimAdvertiseApplicationData* embedded into the *SAMapplicationData* data element is set to true. The PI service shall be active if there is an active request from an application layer entity to find a parking space or if at least one request for parking space has arrived in the last *ActivationTerminationMethod2RequestTimeout*. In any other cases the PI service shall be in terminated state.

If the PI service is requested by an application layer entity to find a parking space, then it shall set the *request* field of the *PimAdvertiseApplicationData* embedded into the application-specific advertisement data element to true in its advertisement service messages. In any other cases the *request* value shall be set to false.

The advertisement service operation details, such as the repetition rate are out of the scope of the present document.

6.1.2 PIM generation management

6.1.2.1 PIM generation rules for vehicle ITS-S

The PI service disseminates the PIMs in generation cycles. During a PIM generation cycle, zero, one or more messages are generated and sent out by the PI service. Each PIM in a generation cycle contains different parking space information. The union of the messages in a generation cycle contain all parking spaces subject for dissemination. The method for selection of parking spaces for dissemination is detailed below.

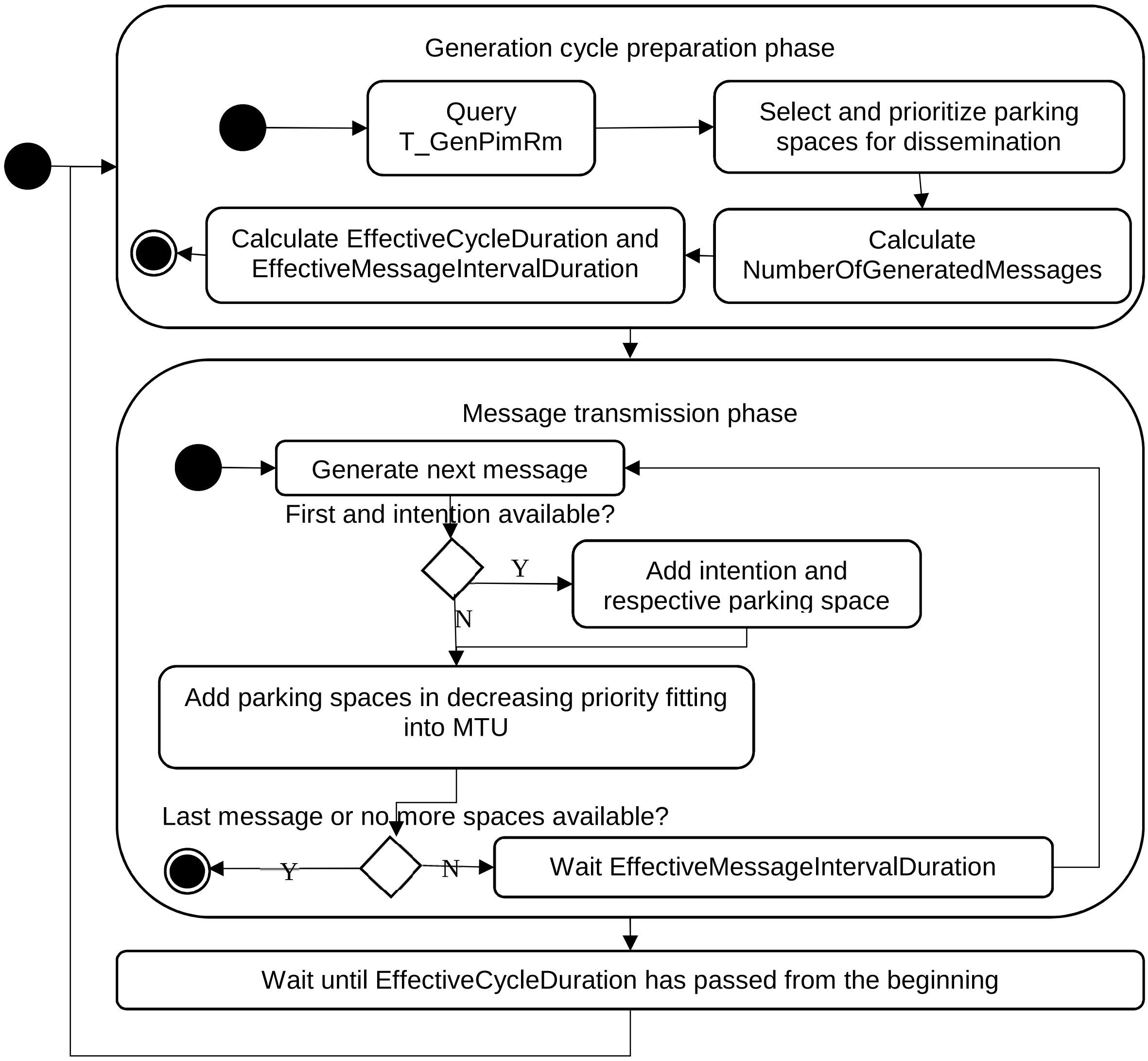

Figure 3: PIM generation state diagram

Regarding the PIM generation, the following constraints shall apply:

- Minimum time elapsed between two consecutive PIMs ≥ *T_GenPimIntervalMin*.
- Duration of a PIM generation cycle ≤ *T_GenPimCycleMax*.
- Duration of a PIM generation cycle ≥ *T_GenPimCycleMin*.

- $T\_GenPimCycleMin \leq T\_GenPimCycleMax$.
- $T\_GenPimIntervalMin \leq T\_GenPimCycleMax$.

Within these limits the duration of the PIM generation cycle and the effective duration of the PIM generation cycle and the interval between two consecutive PIMs during the cycle is calculated the following way:

1) The PI service queries the T_GenPimRm from resource management. T_GenPimRm shall be set in a way that $T\_GenPimIntervalMin \leq T\_GenPimRm$ and $T\_GenPimDcc \leq T\_GenPimCycleMax$. If T_GenPimRm is outside of these limits, then T_GenPimRm shall be updated with the respective limit. T_GenPimRm shall determine the minimum duration between two consecutive PIM generations in order to reduce the PIM generation according to the channel usage requirements of the resource management, if implemented. This facilitates the adjustment of the PIM generation rate to the remaining capacity of the radio channel in case of channel congestion.

2) The PI service selects the parking spaces subject of dissemination. The selection algorithm is specified by the configuration parameter *ParkingSpaceSelectionAlgorithm*. The configured selection algorithm shall be used for the selection of parking spaces detailed in Annex G.

The selection algorithm may run before each message is generated.

The PI service prioritizes the selected parking spaces. The prioritization algorithm is specified by the configuration parameter *ParkingSpacePrioritizationAlgorithm*. The configured prioritization algorithm shall be used for prioritizing the parking spaces detailed in Annex H.

If any new detection is obtained during the generation cycle, it shall be also prioritized and added to the selected parking spaces list subject for dissemination.

Minimum requirements, such as size, detection probability, plausibility checks, are out of scope of the present document and are to be added to the profile document.

3) The PI service determines the maximum number of packets that can be sent during the message generation cycle. The maximum number of messages to be sent is calculated the following way:

$$MaxNumberOfMessage = \left\lfloor \frac{T\_GenPodamCycleMax}{T\_GenPodamDcc} \right\rfloor$$

The number of messages required to send all selected parking spaces shall be estimated respecting the *MTU* on the specific channel (*NumberOfRequiredMessages*). The number of generated messages shall be calculated using the following formula. If possible within the constraints defined above, one additional message is allocated to disseminate new messages consumed during the current PIM generation cycle:

$$NumberOfGeneratedMessages = min \begin{cases} MaxnumberOfMessages \\ NumberOfRequiredMessages + 1 \end{cases}$$

NOTE 1: A communication profile may set up limitation for the length of each generated parking space detection in order to optimize the operation of the service.

NOTE 2: The association of the parking spaces to the messages is equivalent to the bin packing problem, which is an NP-complete optimization problem. The present document does not require the parking space - message association to be optimal.

4) The effective cycle time shall be calculated using the following formula:

$$EffectiveCycleDuration = \max \begin{cases} T\_GenPodamCycleMin \\ T\_GenPodam\_Dcc * NumberOfGeneratedMessages \end{cases}$$

NOTE 3: As a consequence of Step 3 and 4, $T\_GenPodamCycleMax \geq EffectiveCycleDuration$ always applies.

The effective message interval duration is calculated using the following formula.

$$EffectiveMessageIntervalDuration = \frac{EffectiveCycleDuration}{NumberOfGeneratedMessages}$$

5) If there are any generated messages, then the first generated message shall be sent out immediately. Each other messages shall be sent out subsequentially with a wait duration of *EffectiveMessageIntervalDuration*. The messages shall be assembled the following way:

   a) If the PI service maintains an active intent for the ITS-S, then it shall be put it to the first PIM in the generation cycle. The parking space intended to be occupied shall also be included in the first PIM. If the intended space is not stored in the individual parking space format, then a new individual detection shall be generated and added to the *subjectParkingSpace* optional field of the intent indication.

   b) Then, parking spaces shall be attempted to be added, respecting the MTU of the current channel in decreasing priority order. Before adding a particular parking space to the message, the selection criteria for that parking space shall be reevaluated and the space shall only be added if the selection algorithm still selects it for dissemination.

6) The next generation event shall start after *EffectiveCycleDuration* measured from the current generation event.

NOTE 4: In the worst case for scheduling, the same information is repeated each $2 * T\_GenPodamCycleMax$, if the parking space is still considered to be selected.

NOTE 5: In some cases, lower priority messages will be sorted out and not be sent, especially if $T\_GenPodamCycleMax$ is low, the channel congestion is high, and there are many detected parking spaces.

6.2 PIM dissemination constraints

6.2.1 Security constraints

6.2.1.1 Introduction

Clause 6.2.1 is applicable to ITS stations that use the trust model according to ETSI TS 102 940 [i.5] and ITS certificates according to ETSI TS 103 097 [2].

NOTE: For other scenarios, the trust model and the mechanisms for trust enforcement for inter-connected ITS stations can be agreed among participating actors.

The security mechanisms for ITS consider the authentication of messages transferred between ITS-Ss with certificates. A certificate indicates its holder's permissions to send a certain set of messages and optional privileges for specific data elements within these messages. The format for the certificates is specified in ETSI TS 103 097 [2].

Within the certificate, the permissions and privileges are indicated by an identifier (the ITS-AID) and optional attributes of a given AID, allowing for definition of different levels of permissions/rights (the SSP).

The ITS-Application Identifier (ITS-AID) as given in ETSI TS 102 965 [5] indicates the overall type of permissions being granted. For example, there is an ITS-AID indicating that the sender is entitled to send PIMs. The Service Specific Permissions (SSP) is a field that indicates specific sets of permissions within the overall permissions indicated by the ITS-AID: for example, there may be an SSP value associated with the ITS-AID for PIM that indicates that the sender is entitled to send PIMs for a specific role.

The following security objectives and required security services are identified:

- For establishing PIM secure communications, the Message Signature service as specified in ETSI TS 103 097 [2] shall be supported by ITS-S sending/receiving PIM.
- A PIM shall be accepted by a receiving ITS-S if it is consistent with the ITS-AID and SSP of the signing certificate (authorization ticket).
- Signed message shall use the ITS-AID as specified in ETSI TS 102 965 [5].

6.2.1.2 Service Specific Permissions (SSP)

PIMs shall be signed using private keys associated to Authorization Tickets that contain SSPs of type BitmapSsp as specified in ETSI TS 103 097 [2].

The SSP for the PIM shall be of CHOICE BitmapSsp. It is defined by a variable number of octets and shall correspond to the octet scheme illustrated in

Figure 4. This octet scheme allows the SSP format to accommodate current and future versions of the present document.

0							
0	1	2	3	4	5	6	7
Octet 0							

Figure 4: Format for SSP Octet Scheme (BitMapSsp)

The SSP has a maximum length as specified in ETSI TS 103 097 [2]. The first octet shall reflect the version of the SSP (see Table 2). In the current version of the present document, the SSP field contains only the SSP version byte.

Table 2: Octet Scheme for PIM SSPs

Octet #	Description	Value
0	SSP version control	1

At reception of a message, the ITS-S shall check whether the message content is consistent with the ITS-AID and SSP contained in the Authorization Ticket in its signature. If the consistency check fails, the message shall be discarded.

6.2.2 General priority constraints

If the GeoNetworking/BTP stack is used, the priority constraint shall be as given by the Traffic Class as specified in ETSI TS 103 836-4-1 [1].

7 Format Specification General Structure of a PIM PDU

7.1 PIM structure

7.1.1 General structure of a PIM

A PIM is a PDU composed of one common ITS PDU header, a management container, a detections container and two intent indication containers (arrival and departure). The general structure of a PIM is illustrated in Figure 5.

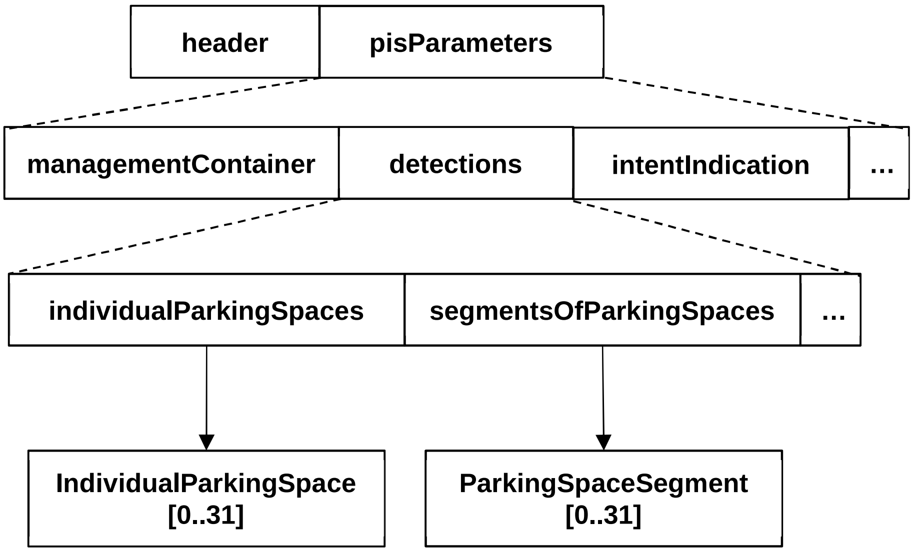

Figure 5: General Structure of PIM

The *header* is a common header for facility layer PDUs.

The *pisParameters* represent the payload in the PI service PDU. It includes the *managementContainer*, the *detections* and the *arrivalIndication* and *departureIndication* containers.

7.1.2 The management container

The *managementContainer* component holds the message segmentation information. The PI service may distribute the information selected for transmission to multiple packets. The total and number of these packets and the ordinal number of the actual packet are present in the segmentation information component.

7.1.3 The detections

The *detections* component contains information about detected parking spaces. There are multiple possible ways of describing detected parking spaces. The possible representation options of the detections are detailed in Annex C. PIMs with zero total number of detected parking spaces are allowed if an intent is shared in the message.

7.1.4 The arrival indication

The *arrivalIndication* component points to a parking space that the sender vehicle intends to occupy in the future. The *spaceId* and the *reporter* fields identify the parking space described in the *detections* component of a particular PIM. The intent indication may also include information regarding the estimated arrival time of the sender vehicle (*estimatedCompletionTime* field).

7.1.5 The departure indication

The *departureIndication* component points to a parking space that the sender vehicle intends to leave in the future. The *spaceId* and the *reporter* fields identify the parking space described in the *detections* component of a particular PIM. The intent indication may also include information regarding the estimated departure time of the sender vehicle (*estimatedCompletionTime* field).

7.2 PIM format specification

The PIM format shall be as specified in ASN.1 in Annex A of the present document.

DEs and DFs that are not defined in the present document shall be imported from the common data dictionary ETSI TS 102 894-2 [3] as specified in Annex A.

Detailed descriptions of all components of PIM are in Annex B of the present document. Unaligned Packed Encoding Rules (UPER) as defined in Recommendation ITU-T X.691 [4] shall be used for PIM encoding and decoding.

Annex A (normative): Link to the ASN.1 specification

This clause provides the normative ASN.1 modules containing the syntactical definitions of the PIM PDU, its containers, and the data frames, and data elements defined in the present document. The semantical specification of the PIM components, its containers, the data frames, and data elements is contained in the same module, in the form of ASN.1 comments. For readability, the same semantical specification is presented in a different format in Annex B.

The *PIM-PDU-Descriptions* module is identified by the Object Identifier *{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) pisPduRelease2 (104072) pim (1) major-version-2 (2) minor-version-1(1)}*. The module can be downloaded as a file as indicated in Table A.1. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.1: PIM-PDU-Descriptions ASN.1 module information

Module Name	PIM-PDU-Descriptions
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) pisPduRelease2 (104072) pim (1) major-version-2 (2) minor-version-1 (1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cp_ts104072/-/raw/v2.1.1/asn/PIM-PDU-Descriptions.asn
SHA-256 hash	88fad57f0e956d3999ecd446f69c1084d9f67b3d897bbaa3a969fc69cb63fd19

The *PIM-SA-Application-Data-Descriptions* module is identified by the Object Identifier *{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) pisPduRelease2 (104072) saApplicationData (2) major-version-2 (2) minor-version-1 (1)}*. The module can be downloaded as a file as indicated in Table A.2. The associated SHA-256 cryptographic hash digest of the referenced file offers a means to verify the integrity of that file.

Table A.2: PIM-SA-Application-Data-Descriptions ASN.1 module information

Module Name	PIM-SA-Application-Data-Descriptions
OID	{itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) pisPduRelease2 (104072) saApplicationData (2) major-version-2 (2) minor-version-1 (1)}
Link	https://forge.etsi.org/rep/ITS/asn1/cp_ts104072/-/raw/v2.1.1/asn/PIM-SA-Application-Data-Descriptions.asn
SHA-256 hash	15bcbdda4be0fc8aa7fdcd4d614bf1cffb12c963d80d67c15d83117a39d62af7

Annex B (informative): Specification of PIM in readable format

The present document provides the specification of PIM containers, data elements and data frames at the following URL:

- https://forge.etsi.org/rep/ITS/asn1/cp_ts104072/-/tree/v2.1.1/docs

Annex C (informative): Diagrams About the Parking Space Location Description

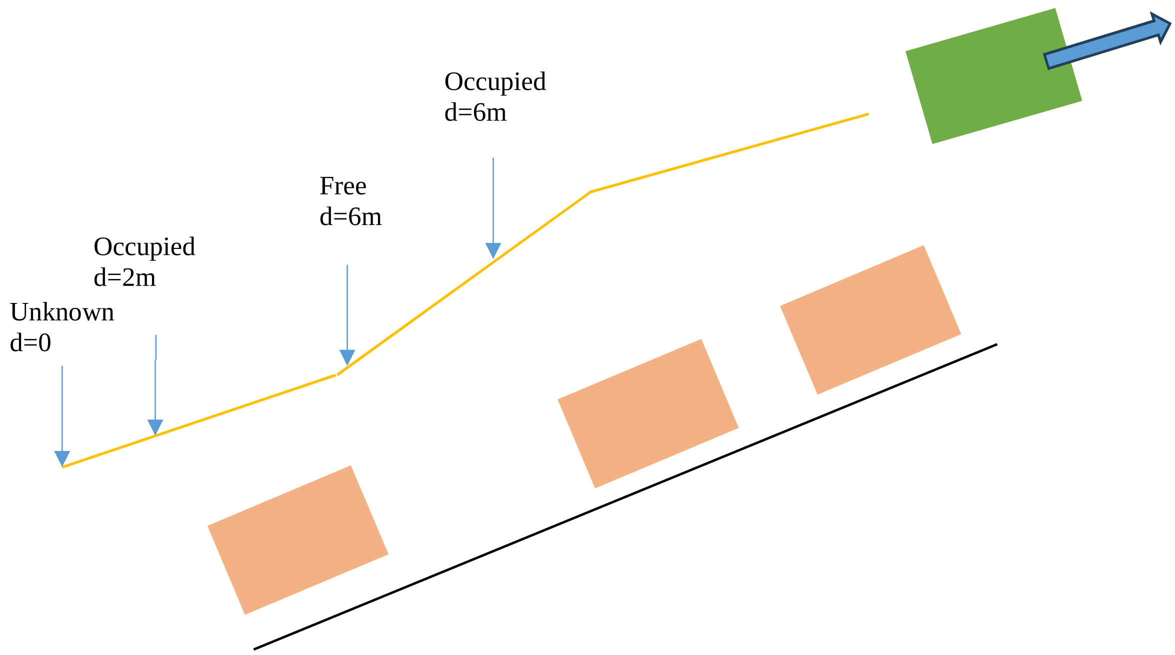

Figure C.1: Subsequent Parking Spaces On The Right

Figure C.1 shows the description of subsequent parking spaces on the right. The Unknown section represents a location where data is not available. Occupied and free shows the beginning of an occupied or free section, respectively. Multiple spaces can be grouped this way. As depicted on the last Occupied point, the spaces may be grouped.

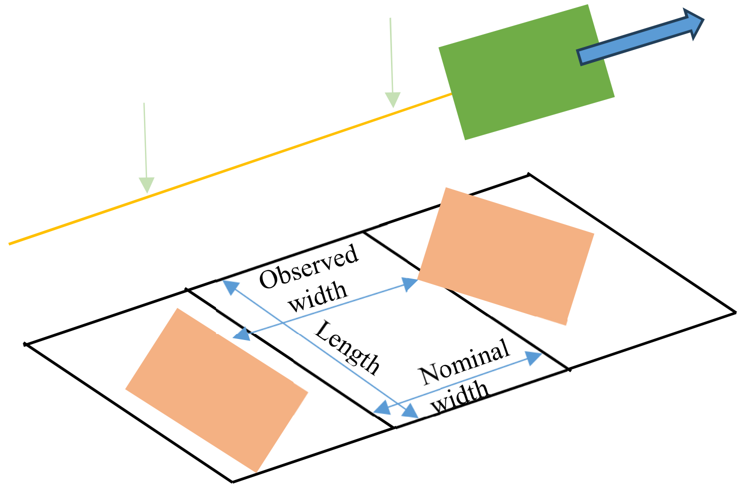

Figure C.2: Determining the size of the parking space

Figure C.2 shows how the receivers can decide if it fits to a parking space. In case of segment-based description (depicted by light green), the distance between the two segment markings shows the nominal width. The observed width is perpendicular to the direction of the parking space, and it measures the smallest width where the parking vehicle needs to fit. In case of parallel parking spaces, the observed length is the same as the segment size for a single empty space. In case of perpendicular parking spaces, the observed width is the same as the segment size for a single empty space.

Annex D (normative): Metrics definition for the parking space detection data structures

D.1 Distance of detection to a certain point

For the distance between a certain point and a parking space, the following metric shall be used:

- The distance between the position described in the field "position" and the point shall be used for an *IndividualParkingSpace*.
- The closest distance between the path and the point shall be used for a *ParkingSpaceSegment*.

D.2 Time of detection

For the time of detection, the following metric shall be used:

- The endTime for an IndividualParkingSpace (described in the detectionMetaData field).
- The endTime (described in the detectionMetaData field) plus the maximum of the sum of timeDeltas in spacesOnTheLeft and spacesOnTheRight for a ParkingSpaceSegment. This effectively defines time of the latest detection.

Annex E (informative): Assumed user needs

In this informative annex, a list of assumed user needs is provided. These requirements are listing features that the service should support.

The service should support the transmission and dissemination of information about a parking space detected by a sender vehicle.

The service should support both centralized and decentralized operation. In the centralized operation mode, the parking facility or area is monitored by infrastructure sensors or other appropriate means, in a way that empty parking space information is recognized and shared with the vehicles implementing the service and vehicles only play a minor role as additional sensors (e.g. to correct false detections by the central system). In the decentralized operation individual vehicles should be able to implement the service without any infrastructure support. The vehicles should be able to detect empty parking spaces via e.g. sensors and share this information via their communication unit.

The service should support special parking attributes, for example, electric vehicle charging spaces.

The service should support sharing the intent of individual vehicles. Using this information, the service can implement an optimization algorithm, which allocates the ideal parking space for a certain vehicle.

ITS-Ss can also request a parking space automatically or after a user input if no optimized allocation is active. In this case ITS-Ss can send out an intent and spaces are virtually allocated to them for a short period.

The service should support the cancellation of its previously shared intent.

The service should keep empty spaces broadcasting even if the originating ITS-S of the parking space information already left the proximity. As a result, the service should maintain a local distributed database, a.k.a a local dynamic map (empty space list). Therefore, the system should delete occupied or defective spaces after a certain amount of time, which can be configured on application layer.

The broadcasting frequency should consider the information update events.

The local distributed map (empty space list) should be updated in a way that:

- Detections from the same spaces should be fused
- The physical information should be fused with the regulatory information (if available)
- Freshly allocated empty spaces should be marked as allocated
- A timestamp should provide details about the age of the information
- False Detections or state changes can be corrected by newer data
- Vehicles can flag parking spaces or equipment as defective in case using the space or its features was not possible

The local distributed map should be limited within a certain location, the list propagated by an ITS-S should not contain parking spaces further away than a certain distance.

The service should support detection error reporting in order to indicate if the space was not free or it is an unavailable/invalid location.

The service should have interfaces to the driver and/or to the ADAS to indicate the possible invalidity of a certain parking space.

The service should support reinforcement of the detection of a certain empty parking space.

The service should be aware of the number of other participants in the vicinity and may stay active even though the car has been switched off in case it is the only participating station to avoid a loss of information.

Annex F (informative): Default configuration set for the service

Default parameters settings for PIM generation are specified in Table F.1.

Table F.1: Default parameter settings for PIM generation

Parameter	Value
T_GenPimIntervalMin	100 ms
T_GenPimCycleMin	100 ms
T_GenPimCycleMax	2 s
MTU	1 200 Bytes
ParkingSpaceSelectionAlgorithm	1
ParkingSpacePrioritizationAlgorithm	1
SelectionAlgorithm1RelevanceDistance	2 km
SelectionAlgorithm1MaxDetectionAge	5 min
ActivationTerminationMethod	1
ActivationTerminationMethod2RequestTimeout	30 s
SegmentNewPathPointHeadingThreshold	10 deg
SegmentNewPathPointLateralDistanceThreshold	2 m
PriorizationAlgorithm2MaxDetectionAge	5 min

Annex G (normative): Parking space selection algorithm

G.1 Simple parking space selection algorithm

This parking space selection algorithm shall be used if the configuration parameter *ParkingSpaceSelectionAlgorithm* is set to 1. A parking space shall be selected by this algorithm if all of the following conditions apply:

- The detected parking space is closer to the disseminating ITS-S than *SelectionAlgorithm1RelevanceDistance*.
- The detection time of the parking space is not older than *SelectionAlgorithm1MaxDetectionAge*.
- If the parking space was not detected by the disseminating ITS-S, and the disseminating ITS-S did not consume the same parking space detection from any other remote ITS-S since *T_GenPimCycleMax*. This condition shall run before each message is generated.

NOTE: The operation of this algorithm implicitly requires the ITS-S to listen for and store parking spaces from other ITS-Ss.

Annex H (normative): Parking space prioritization algorithm

H.1 Simple parking space prioritization algorithm

This parking space prioritization algorithm shall be used if the configuration parameter *ParkingSpacePrioritizationAlgorithm* is set to 1. The parking space priority shall be determined based on the time of detection defined for the particular parking space in ascending order. The latest message shall have the highest priority.

NOTE: This algorithm does not differentiate whether the parking space is a remote or a local one.

H.2 Advanced parking space prioritization algorithm

H.2.1 Overview

This parking space prioritization algorithm shall be used if the configuration parameter *ParkingSpacePrioritizationAlgorithm* is set to 2.

This parking space prioritization algorithm requires that the configuration parameters are selected in a way that always exactly one message shall be generated in each message generation cycle ($NumberOfGeneratedMessages = 1$), if there is at least 1 available parking space.

H.2.2 General aspects

The following procedure aims to use the available communication resources, optimizing the usefulness of the shared information for the receiving ITS-Ss.

This shall be done by evaluating the metrics defined in the following subclauses.

Some metrics compare the information available in the Local Environment Model (LEM) of the transmitting ITS-S to the information potential receiving ITS-Ss are assumed to already have. The knowledge already available to the potential receiving ITS-Ss is referred to as V2X Exchanged Information (VEI). The VEI shall be estimated as the union of information which the transmitting ITS-S received from other ITS-Ss and information shared by the transmitting ITS-Ss itself.

After calculating the single priority metrics as defined in the following subclauses, the overall priority to disseminate the respective parking space shall be calculated as the mean value of the single values:

$$priority = \frac{(OccupancyDeviationPriority + VeiInformationAgePriority + DetectionAgePriority + FreeSpacePriority)}{4}$$

The calculation of priority coefficients are detailed below.

H.2.3 Intermediate Step for Segment-based Parking Space Information

In case the parking space information to be prioritized does not represent individual parking spaces but segments of parking spaces, the segments shall be cut into sub-segments in a way that each sub-segment is either completely free or completely occupied. Each individual sub-segment shall then be evaluated in the way described in this annex. After prioritization, neighbouring sub-segments selected for dissemination may be re-combined to larger segments.

H.2.4 Occupancy Deviation Priority

To prioritize the dissemination of parking spaces with an occupancy status different to the status recorded in the VEI, the O*ccupancyDeviationPriority* shall be calculated as:

$$OccupancyDeviationPriority = \begin{cases} if\ Occupancy\ Status_{VEI} \neq Occupancy\ Status_{LEM}: 1 \\ else: 0 \end{cases}.$$

H.2.5 VEI Information Age Priority

To prioritize the dissemination of parking spaces with a higher information age in the VEI, i.e. parking spaces that no update was transmitted about by any ITS-S for a longer period of time, the *VeiInformationAgePriority* shall be calculated as:

$$VeiInformationAgePriority = \frac{AoI}{MaxAoI}$$

AoI shall be the time since the last update about the respective parking space was either transmitted by the ego ITS-S itself or received from any other ITS-S.

MaxAoI shall be the maximum *AoI* calculated for any of the parking spaces currently evaluated for dissemination.

H.2.6 Detection Age Priority

To prioritize the dissemination of parking spaces which were detected more recently by the transmitting ITS-S, the *DetectionAgePriority* shall be calculated as:

$$DetectionAgePriority = \begin{cases} 1 - \frac{DetectionAge}{MaxDetectionAge}, & 0 \leq DetectionAge \leq MaxDetectionAge \\ 0, DetectionAge > MaxDetectionAge & \end{cases}$$

DetectionAge shall be the time since the parking space was last detected by the sensor system of the transmitting ITS-S. *MaxDetectionAge* shall be configured by the $PriorizationAlgorithm2MaxDetectionAge$ configuration parameter.

PriorizationAlgorithm2MaxDetectionAge shall be the maximum acceptable detection age before the information is considered outdated and shall be set as indicated in Annex F.

NOTE: Usually $PriorizationAlgorithm2MaxDetectionAge = SelectionAlgorithm1MaxDetectionAge$ applies.

H.2.7 Free Space Priority

To prioritize the transmission of free parking spaces over occupied parking spaces, the *FreeSpacePriority* shall be calculated as:

$$FreeSpacePriority = p(parking\ space\ free)$$

p(parking space free) shall be the probability, as indicated by the transmitting ITS-S's sensor system, that the respective parking spot is free.

History

Document history		
V2.1.1	July 2025	Publication