TECHNICAL REPORT

ISO/TR 17424

First edition
2015-05-01

Intelligent transport systems — Cooperative systems — State of the art of Local Dynamic Maps concepts

Systèmes intelligents de transport — Systèmes coopératifs — État des connaissances des cartes dynamiques locales

Reference number
ISO/TR 17424:2015(E)

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 204, *Intelligent transport systems*.

Introduction

Intelligent transport systems (ITS) means to apply information and communication technologies (ICT) to the transport sector. ITS can create clear benefits in terms of transport efficiency, sustainability, safety and security.

To take full advantage of the benefits that ICT-based systems and applications can bring to the transport sector, it is necessary to ensure interoperability among the different systems.

Cooperative systems are ITS (Cooperative ITS) systems based on vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I, I2V) and infrastructure-to-infrastructure (I2I) communications for the exchange of information. Cooperative systems have the potential to further increase the benefits of ITS services and applications.

Cooperative ITS is a subset of the overall ITS that communicates and shares information between ITS stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems.

The European Commission issued Mandate M/453 [6] [7] to invite the European Standardization Organizations (ESOs) (CEN, CENELEC and ETSI) to prepare a coherent set of standards, specifications and guidelines to support the European Community's wide implementation and deployment of Cooperative intelligent transport systems (Cooperative ITS).

CEN and ETSI have formally accepted the Mandate and will develop standards (EN) and technical specifications and guidelines requested as far as possible within the timescale required in the Mandate. (see Reference [7])

Annex C of Reference [7] proposes a "List of minimum set of standards and allocation of responsibility between CEN and ETSI – Mandate M/453".

ISO/TC 204 decided in 2009 to join CEN's efforts and to create a new working group (WG 18) under the Vienna agreement. This Technical Report is considered by non-European NSOs as important enough to justify having it under ISO lead.

Different ITS stations (vehicle, nomadic, roadside and central) exchange geographically located information, which is of importance for the different cooperative applications (standards to be developed under the responsibility of CEN and ISO).

This Technical Report delivers information about the status at the time of publication of the Local Dynamic Map (LDM) concepts as they have been developed in the different R&D projects in Europe, Japan and the USA.

It presents different architectures, implementations, LDM functional blocks and the related standardization activities. It can identify gaps, lacks and inconsistencies between Cooperative ITS Reference Station Architecture and existing implementations. It proposes actions for future standardization activities and harmonization needs. Activities within ISO/TC 204 WG 3 and ETSI TC ITS at the time of publication are considered.

This Technical Report falls within the agreed scope of work of ISO/TC 204 WG18 and CEN TC 278 WG16.

Intelligent transport systems — Cooperative systems — State of the art of Local Dynamic Maps concepts

1 Scope

This Technical Report surveys the status of Local Dynamic Map (LDM) regarding architecture, implementation, and standardization efforts. It summarizes the high level architectures of the most important implementations and compares it with the CEN/ETSI/ISO ITS-Station architecture.

This Technical Report derives out of the application needs the requirements for a global LDM concept in terms of functionality, technical and legal aspects.

A gap analysis with existing specification and standards will be performed and recommendations towards SDOs and decision bodies will be made.

This Technical Report does not give any decision on how or whether one of the solutions described is commercially feasible to be considered as an implementable offer to the user.

This Technical Report considers the most important documents and research projects to the knowledge of the authors, but does not claim to be complete or free of any mistakes.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 24532, *Intelligent transport systems — Systems architecture, taxonomy and terminology — Using CORBA (Common Object Request Broker Architecture) in ITS standards, data registries and data dictionaries*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 24532 and the following apply.

3.1
Local Dynamic Map
LDM
conceptual data store which is embedded in an ITS station containing topographical, positional and status information within a dedicated geographic area of interest, relevant to ITS stations

Note 1 to entry: The LDM is supported by service functions, which ensure the accessibility, integrity, and security.

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

API	Application Program Interface
BSA	Basic Set of Applications
CA	Cooperative Awareness
CAM	Cooperative Awareness Message

CN	Cooperative Navigation
COOPERS	COOPERative systems for intelligent road Safety
CS	Communities Service
CSM	Cooperative Speed Management
CVIS	Cooperative Vehicle-Infrastructure Systems
DENM	Decentralized Environmental Notification Message
FA	Facilities/Applications
ICT	Information and Communication Technology
ITS	Intelligent Transport System
IRIS	Intelligent Cooperative Intersection Safety system
LBS	Location-Based Service
LCM	Life Cycle Management
LDM	Local Dynamic Map
MF	Management/Facilities
NF	Networking and Transport/Facilities
POI	Point of Interest
RHW	Road Hazard Warning
RSU	Road Side Unit
SAP	Service Access Point
SF	Security/Facilities
TPEG	Transport Protocol Experts Group
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
WLAN	Wireless Local Area Network

5 Content and structure

How a LDM is built, which elements are needed and how they are implemented, strongly depends on the role of an ITS station.

Figure 1 — Viewpoints in respect of the LDM

5.1 Required LDM Elements (subsystems or functions)

A typical LDM consists of following subsystems:

- LDM management, including
  - means for synchronizing content in-between LDMs,
  - means for updating content, and
  - means for removing outdated data elements;
- LDM Data Storage
  - data storage, which covers small to huge implementations supporting personnel devices, infrastructure systems, in-vehicle platforms, service providers and management centres;
- LDM Security
  - means for data security;
- LDM Content Integrity
  - means for maintaining data integrity and quality, and

  - decision rules on conflicting data;
- LDM Privacy Policy Advisor
  - rules on how to deal with privacy-affected static, quasi-static and dynamic content;
- LDM Arbiter/Screening, prioritizing
  - means for putting multiple queries according their priority to the data storage and retrieving the response;
- LDM SAPs/Data access
  - interface for writing elements into and retrieving elements from the data storage;
- LDM Broker
  - shared data management for multiple application access.

All the data elements and their attributes put in and out the LDM have to comply with the definition given in the LDM Data dictionary.

5.1.1 Data elements and protocols

The input to the LDM may come from many sources likely using different protocols. Messages originating from vehicles, for instance CAM and DENM, use a highly condensed protocol format to keep channel blocking at a minimum. There is only a minimum of additional information contained in the message itself to decide on reliability and confidence. Other input sources are radio broadcasts (RDS, DAB, DVB, DMB) using, e.g. TMC or TPEG protocol, traffic centre using DATEX/DATEX2 or HTML-based application data exchange format and so on. If data from different sources addressing the same event have a contradicting meaning, the following additional decision-relevant information has to be considered to get the most accurate information:

- Who is the issuer of the information?
- How and when was the information generated?
- What is the accuracy of the information?
- How was the information transmitted?
- Where and under which condition is the information valid?

5.1.1.1 TPEG in detail

Detailed information on TPEG is provided in [21].

TPEG (Transport Protocol Experts Group) specifications[9] offer a method for transmitting multimodal traffic and travel information, regardless of client type, location or required delivery channel (e.g. DAB, HD radio, Internet, DVB-x, DMB, GPRS, Wi-Fi ...). Language independence has also been a prime principle in the design.

5.1.1.1.1 How does TPEG work?

In contrast to TMC (event-based road traffic information), TPEG refers to a whole set or toolkit of specifications, for offering a wider range of services to a wider range of users and devices.

TPEG services are defined in a modular way and can therefore vary in a number of "directions":

- application, e.g. Road Traffic Messages, Public Transport Information or Parking Information. Each Application is uniquely identified by an Application ID (AID) that are allocated by the TPEG Application Working Group (TAWG) of TISA;

— transmission method, e.g. DAB digital radio, DMB, Internet;

— location referencing method, e.g. table-based (using for example TMC location tables) or on-the-fly (using a method that gives a location reference that works with or without maps and does not require a look-up table to decode in the receiver);

— device, e.g. intended for vehicle navigation systems, Internet browsers or mobile devices;

— conditional access: whether data are sent for free or only to users/devices who have somehow established the right to receive it, e.g. by paying a subscription. Encryption of TPEG data are possible by means of Standardised Encryption Indicators, which are allocated by the TPEG Application Working Group (TAWG) of TISA.

The term "profile" is used to define a combination of the above which, together, make up what one might think of as a single TPEG service. For example:

— displaying traffic incidents on a map graphic and supporting re-routing or route optimization;

— displaying public transport status information on a cell phone screen.

5.1.1.1.2 TPEG Service IDs

Any TPEG-service is uniquely identified worldwide by a TPEG Service ID (SID) consisting of three elements called SID-A, SID-B, SID-C, as described in ISO/TS 18234-2. TISA, as worldwide registrar for TPEG SID, is responsible for allocating and maintaining TPEG Service IDs in a Registry to ensure a worldwide unique identification of a TPEG service.

Each TPEG Application is assigned a unique number called the Application Identifier (AID) which is standardized in ISO/TS 18234-1. An AID is defined whenever a new application is developed. The AIDs allocated at the time of publication of this Technical Report are the following (see Table 1):

Table 1 — TPEG AID table

AID Number (Hex)	Application	Abbreviated term
0	Service and Network Information application	SNI
1	Road Traffic Message application	RTM
2	Public Transport Information application	PTI
3	Parking Information application	PKI
4	Congestion and Travel Time application	CTT
5	Traffic Event Compacy application	TEC
6	Conditional Access Information application	CAI
7	Traffic Flow and Prediction	TFP
8	Fuel Price Information	FPI

5.1.1.2 DATEX/DATEX2

Detailed Information on DATEX/DATEX2 are provided in[22].

5.1.1.2.1 Background

Delivering European Transport Policy in line with the ITS Action Plan of the European Commission requires coordination of traffic management and development of seamless pan-European services. With the aim to support sustainable mobility in Europe, the European Commission has been supporting the development of information exchange mainly between the actors of the road traffic management domain for a number of years. In the road sector, the DATEX standard was developed for information exchange between traffic management centres, traffic information centres and service providers and constitutes the reference for applications that have been developed in the past 10 years. At the time of publication of this Technical Report, the second generation DATEX II specification also pushes the door wide open for all actors in the traffic and travel information sector.

Much investment has been made in Europe, both in traffic control and information centres over the last decade and also in a quantum shift in the monitoring of the trans-European transport network (TEN-T). This is in line with delivering the objectives of the EasyWay programme [17] for safer roads, reduced congestion and a better environment. Collecting information is only part of the story; to make the most of the investment data needs to be exchanged both with other centres and, in a more recent development, with those developing pan-European services provided directly to road users. DATEX was originally designed and developed as a traffic and travel data exchange mechanism by a European task force set up to standardize the interface between traffic control and information centres. With the new generation DATEX II, it has become the reference for all applications requiring access to dynamic traffic and travel-related information in Europe.

5.1.1.2.2 Organization: SG - TG - User Forum

The DATEX II specifications are maintained at the time of publication by a stakeholder organization that has been created under the EasyWay programme. In EasyWay, DATEX II is included in a set of European Studies (ES) that deal with pan-European consensus forming and harmonization. DATEX II is covered by European Study 5, chaired by Germany at the time of publication.

ES5 has been structured into two working groups:

— The Strategic Group (SG) steers the work programme of ES5 and reports to the EasyWay Steering Committee and the European Commission. SG itself takes care of liaison with other relevant stakeholder groups and outreach activities, for instance the organization of a DATEX II User Forum. Technical day-to-day work is assigned by the SG to a dedicated technical working group.

— The Technical Group (TG) receives its terms of reference from the SG, and also reports back on its progress. The TG consists of technical experts that deal with the day-to-day management of the DATEX II specifications, which includes user support and user feedback via this website, but also all technical work required in preparation of the DATEX II standardization. TG therefore works in close cooperation with CEN/TC 278/WG 8.

The organizational structure presented is seen as a temporary solution during the life of the EasyWay programme. In parallel to the work programme described above, the SG and the TG work together on defining a long term, self-sustained organizational structure for the time after EasyWay.

5.1.1.2.3 Standardization

DATEX II is intended to become a multi-part standard, maintained by CEN/TC 278 (see www.itsstandards.eu). The first three parts of the CEN DATEX II series [i.e. CEN/TS 16157 (all parts)] deal with the most mature and widely used parts of DATEX II: the modelling methodology (called Context and framework) as CEN/TS 16157-1, Location referencing as CEN/TS 16157-2 and the most widely used DATEX publication for traffic information messages (called Situation publication) as CEN/TS 16157-3.

A fourth part of the CEN DATEX II series, VMS publications, is being proposed for standardization to CEN/TC 278. More parts are to follow, including other data publications for example measured data and elaborated data.

5.2 LDM: state of the art

5.2.1 Proposed LDM Architectures

5.2.1.1 SAFESPOT

See also Specification[12].

Enabled by advances in communication technology, cooperative systems are seen as the next logical step beyond autonomous driving assistance systems, for safety and comfort applications for road traffic. In cooperative systems, autonomous information from stored digital maps and from vehicle sensors is supplemented with cooperative information received via radio links from other vehicles and the infrastructure.

A new spatial database concept, named local dynamic map, reflecting all relevant static, temporary and dynamic information in the perception vicinity of a stationary object (road side unit) or moving object (vehicles and other road users), is considered as a core element of cooperative systems. The local dynamic map is a highly dynamic data store with a relation to the road network, which enables storage and updating of objects including type, position and other characteristics, and retrieval of selected information for further processing and situation analysis, such as calculation of trajectories, and detection of hazardous obstacles and potential conflicts with other road users. If the object that maintains the local dynamic map is moving, the map window is moving as well, with the object as its centre point. The local dynamic map is constructed on top of a digital map database for ITS applications, and conceived as a four layer structure with increasing dynamics, and specified as a logical object model, which may serve as the basis for specifying the API, and for its actual implementation. The four layers represent, respectively: a) the static (semi-permanent) digital map database; b) similar static information that is not (yet) incorporated in the digital map database; c) temporary and dynamic information (such as weather and traffic conditions); and d) dynamic and highly dynamic information concerning moving objects (vehicles, vulnerable road users and animals). This Technical Report provides the specification of the local dynamic map.

The local dynamic map has a central position in the architecture of the SAFESPOT system. Only the sensor data processing and fusion module of the system will have write access to the local dynamic map for transactions. All modules and applications of the system, including the data processing and fusion module, will have access to the local dynamic map for queries. This implies that all temporary and dynamic information that is stored in the local dynamic map passes through data processing and fusion. For instance, sensor information that is used by an application is not directly retrieved from the sensor, but as processed information from the local dynamic map.

The local dynamic map may be implemented as a relational or an object-oriented database. The static map data of layer 1 may be used by directly accessing the physical storage format of the digital map database or by transferring the static map data for the perception horizon also to the relational or an object-relational database. Positions of dynamic objects will be maintained both as absolute position and as map matched position to the map database road centre, possibly with lateral offset.

The local dynamic map is described as a logical object-oriented model in a UML (Unified Modelling Language) static structure diagram. On top of the main class hierarchy is the WorldObject, with main subclasses Feature and DynamicObject. Feature and its subclasses cover all map-related static objects (layers 1 and 2). The class DynamicObject has two main subclasses, ConceptualObject and MovingObject. ConceptualObject and its subclasses cover the temporary weather and traffic related in Deliverable D3.3.3 - Dissemination Level: RE (restricted) SAFESPOT - Contract IST-4-026963-IP SF-D333-local-dynamic-map-spec-v07.doc 12 / 86 SINTECH formation of layer 3. The class MovingObject covers the dynamic and highly dynamic information of layer 4. It has subclasses LivingObject (with subclasses Pedestrian, Bicyclist and Animal), Trailer and MotorVehicle (with subclasses TwoTrackVehicle and PoweredTwoWheeler). In addition to the main hierarchy, various classes are defined that are associated with classes in the main hierarchy. Examples are the GeometryObject (associated with WorldObject) to express the geometry of an object, MotionState and Trajectory (associated with MovingObject) and Driver (associated with MotorVehicle). Another class associated with MotorVehicle is EgoMotorVehicle, covering information that is only present in the own (ego) local dynamic map. This Technical Report provides class diagrams of various parts of the complete class diagram. In addition the whole structure of the model is described in a text diagram, and the details of each of the classes (positing in the hierarchy, attributes and operations) in a set of tables.

The API will consist of two parts, a transaction part and a query part. The transaction part needs to be able to create (including attribute initialization) and remove instances of all defined DynamicObject types (layers 3 and 4), and to set and change object attributes values (including uncertainty values) of dynamic objects that are stored in the local dynamic map, as well as of static objects for which dynamic attributes are defined. The query part of the API needs to be able to extract information from the local dynamic map concerning all object types (i.e. including the static map and map-related information of layers 1 and 2). It needs to be able to query the database using filters for geographic location (geometry objects of various kinds as well as map database links), object types and object attributes. Database queries for moving objects in relation to map database links need to be able to include, in addition to the link to which the ego object is associated, relevant links ahead of the moving object (much like an ADAS Horizon). This enables the system to be aware of moving objects on those links that may be encountered by the ego object in view of their driving directions. The API may be described in terms of SQL statements, object-oriented query statements, or more generic function calls. Although this Technical Report provides a description of the API, precise definition of the API was still underway at the time of publication. In addition to queries on demand, a subscription mechanism will be defined for automatic notification, which will push information concerning objects to applications when certain predefined conditions are met. Although this mechanism is sometimes referred to as continuous querying, it will actually reduce the number of regular active queries that applications need to make to avoid the risk of using dated information, and thereby reduce computational load on the system.

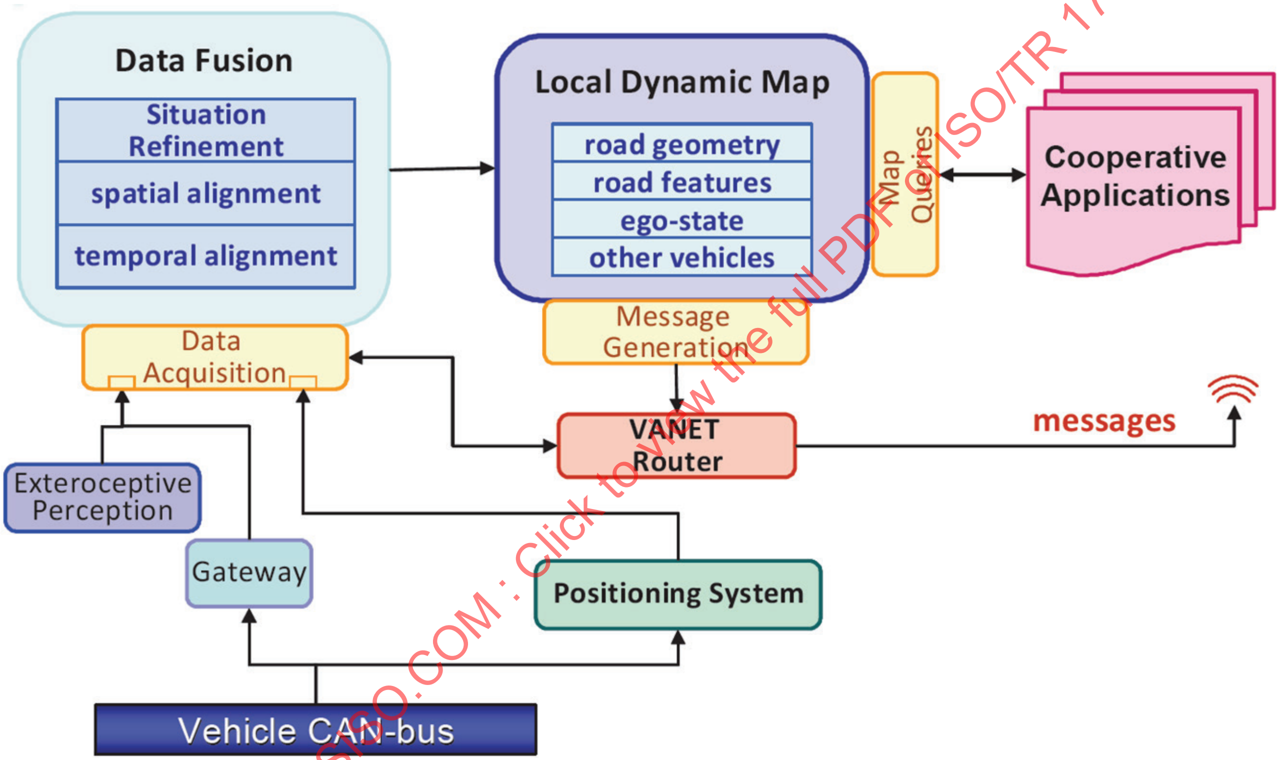


Figure 2 — Driver warning of dangerous situations via Car2X-communication and local dynamic maps

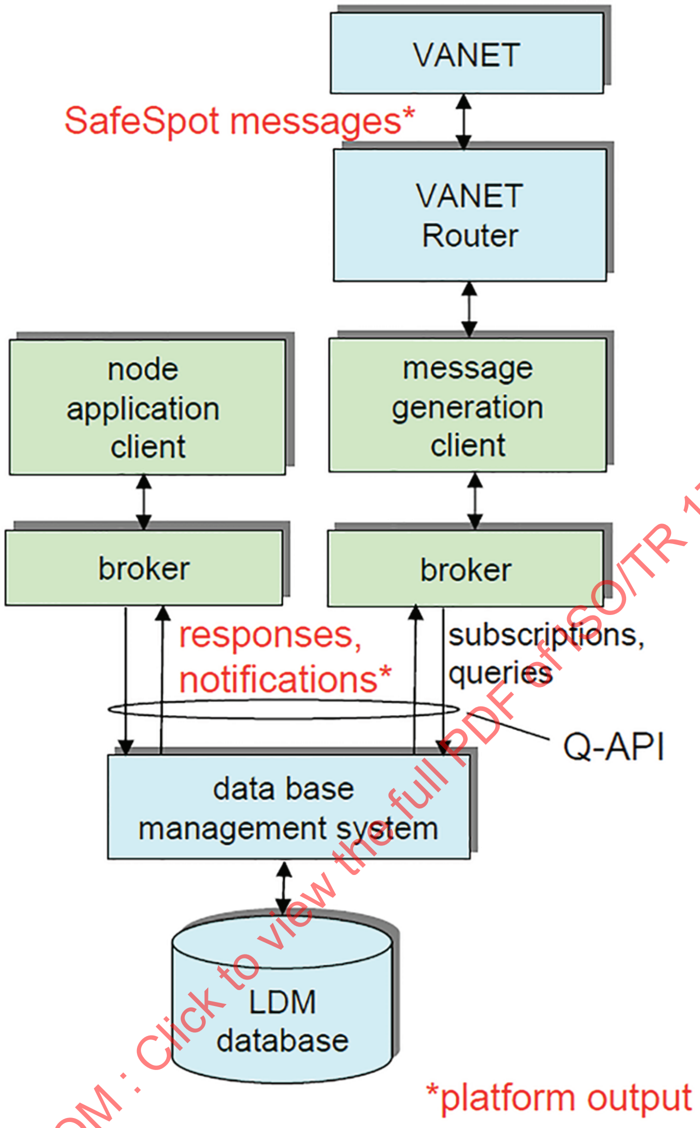


Figure 3 — Vehicles as sensors for cooperative systems

See Specification[12].

Local Dynamic Maps: Focuses on extending digital maps to incorporate real-time environmental conditions. Static and dynamic data handling and access functions and location referencing for data exchange are considered the most relevant technologies.

Example of an application using LDM given in[21].

[Intelligent Cooperative Intersection Safety System (IRIS): A SAFESPOT Application

Local Dynamic Map features

The LDM is the link between the data fusion process and the applications. Therefore, any information (static and dynamic) required by the applications has to be stored in the LDM. The LDM is a real-time geometric representation of relevant infrastructure and non-infrastructure features and objects near the RSU[3]. It consists of four layers. The first layer contains the standard static map of the map providers. The second layer includes additional static information of the surrounding environment of the RSU; in case of IRIS a detailed description of the intersection. As Figure 4 shows, the database contains the location of traffic signs (purple dots) and traffic lights (blue dots). Furthermore, the layer stores information on the operational status such as operating, manual operation (police officer) or out of operation/technical failure of the controller and for each signal group of the traffic light control the current traffic light status, the residual time of the current traffic light status and the next traffic lights status. These data are important for IRIS in order to compute the interactions of the vehicles with the status of the traffic lights at the controlled intersection. In addition, the road marking, lane dividers, pedestrian crossings and the reference tracks (green lines) are an important component of this layer.

IRIS accesses the static content of the second layer by the means of special pre-stored queries that are realized through database views. The advantage of these views is the independency of different physical storage formats and database structures maintained by the different map providers for the static map content.

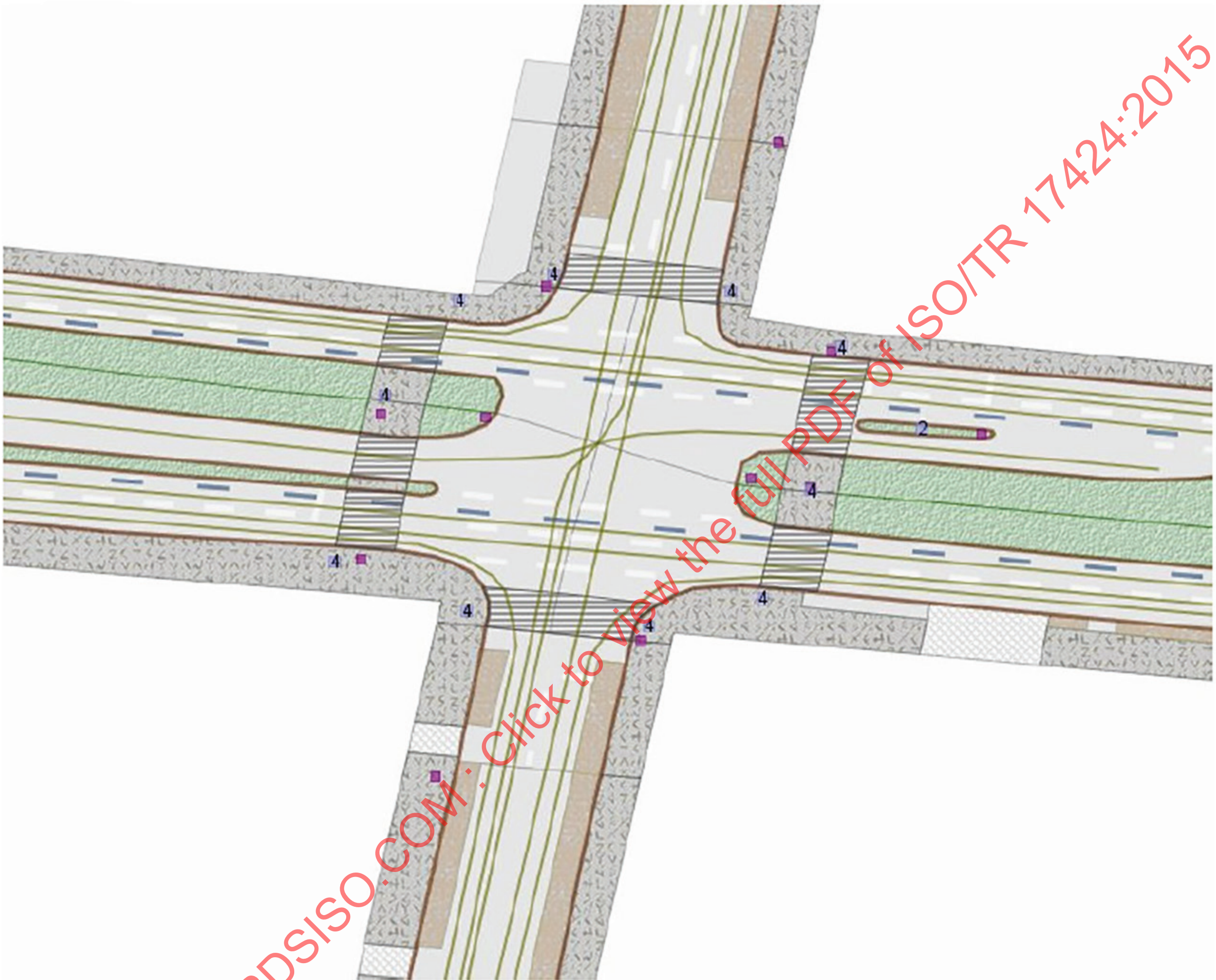


Figure 4 — Visualization of the static map content of the LDM at an urban intersection

Beside the static content layers, layers 3 and 4 contain the dynamic data elements of the LDM. Dynamic information such as for rain or congested road element is stored in the third layer. The fourth layer contains the most dynamic data elements of the moving objects. It provides the possibility to store for each moving objects the absolute and map matched position. Furthermore all additional attributes on the objects gathered by the data sources and refined by the data fusion, such as vehicle type, speed, acceleration and the vehicle trajectories, can be written in that layer.

The SAFESPOT applications need to access the dynamic content of the fourth layer in a fast and reliable way. For this purpose, the LDM provides a data access library containing the API. The basic API provides very generic queries which are SQL like. The object oriented API focuses on functions, which are more complex, or need further LDM support, also due to performance reasons. Based on the available data in the LDM, the applications fulfil the assessment of the situation near the RSU.

Concept description

The IRIS surveys signalized urban intersections by tracking all individual movements of road users (drivers, pedestrian and cyclists), which can be regarded as a microscopic procedure [19]. By analysing the individual vehicle movements, IRIS tries to identify dangerous situations as early as possible in order to warn or intervene as effectively as possible. The whole IRIS procedure is performed periodically in a loop and consists of five subsequent main parts (see Figure 5 below):

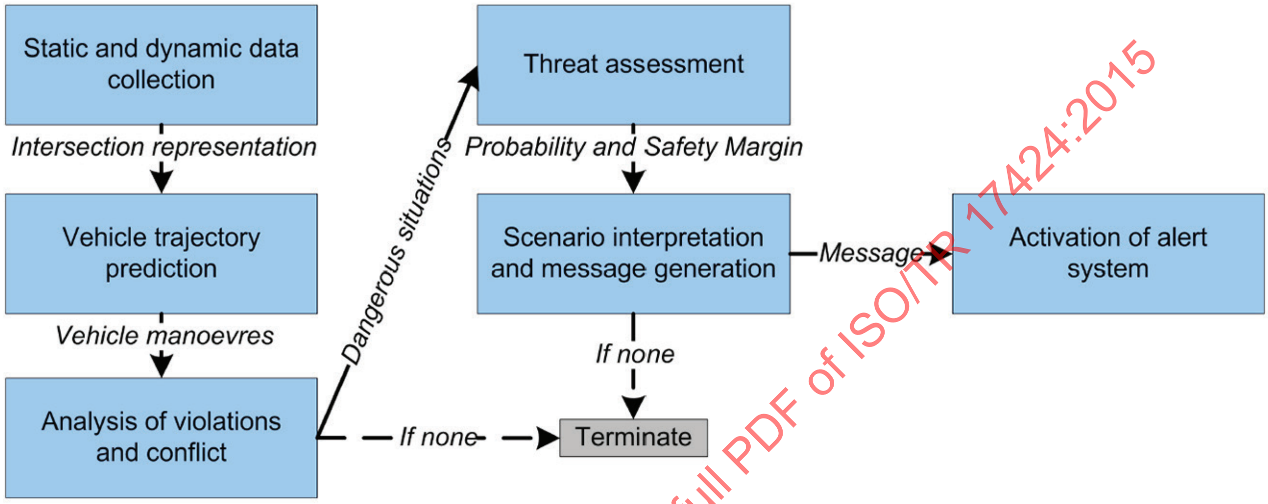


Figure 5 — Functional description of IRIS

1) **Receive LDM data:** this component reads the static data describing the intersection geometry from the LDM database. This is done once at the initialization phase of the application. The dynamic data are constantly queried from the LDM.

2) **Vehicle trajectory prediction:** the prediction is based on the known position of the vehicles, and the vehicle dynamics such as speed and acceleration. By the use of additional information, such as the indicator usage or the lane the vehicles are driving on, the future route of the vehicle can be estimated. Furthermore, the prediction of the trajectories is based on the reference tracks. These tracks can be regarded as static representations of the typical driving lines of vehicles at intersections. The predicted trajectory will comprise 10 additional future positions of the vehicle and an assigned likelihood with a time resolution of one second.

3) **Situation analysis:** all potential conflicts of vehicle movements are determined together with probabilities by examining all combinations of the predicted trajectories of the vehicles and cyclists. The indicator of a potential conflict is not only the spatial intersection of two trajectories. This intersection has to occur also in approximately the same point of time. This part of the analysis module supports the safe right and left turning at the intersection. Combining the traffic lights status and the predicted trajectories red light violation by passenger cars or emergency vehicles can be detected. The result is a list of critical/dangerous situations specifying their expected point in time and their likelihood to happen. The prediction will not consider the cross-correlations of vehicles driving on different reference tracks, i.e. the movements of two vehicles of different reference tracks are independent from each other. The reason for this restriction is to reduce algorithmic complexity. However, cross-correlations of predicted vehicle trajectories on the same reference tracks are considered in order to take into account the vehicles that are on the same track downstream. If no conflicting trajectories are identified the process terminates.

4) **Threat assessment:** the task of the threat assessment is the identification of the level of risk of a potential accident. This is achieved by considering the likelihood of a potential accident, which mainly depends on the accuracy of the predicted trajectories. Furthermore, the time-to-collision is computed. The time-to-collision can be defined as the remaining time for two road users to collide if

they continue their speed and stay on the same path[10]. Based on this, the situation can be assigned to the safety margin concept of SAFESPOT[11]. The concept classifies three stages of warning and actions to take:

i) Comfort Area: the situation should be communicated to the driver, but the driver has to react in a very comfortable way to avoid the accident;

ii) Safety Area: the situation is relevant for safety and the driver has to react timely to avoid the accident;

iii) Critical Area: the situation is critical for safety and the driver has to react in a very fast way and with the correct manoeuvre to avoid the accident.

5) Measure generation: based on the assessed threat, the appropriate messages need to be created. Thus, each scenario requires a different decision from IRIS, which may result in different sets of messages in order to prevent collisions.

6) Alert device control: the last action in the course of events is the control of the corresponding alert subsystems or devices, respectively. In principle, three different types of measures are carried out:

i) warning messages that will be sent to the drivers using wireless communication,

ii) local traffic light control changes in order to lengthen red light times of certain signal groups and

iii) warning message to vulnerable road users via icons and acoustics through roadside alert systems.

5.2.1.2 CVIS

5.2.1.2.1 Positioning, Maps and Local Referencing (POMA)

See Reference [8].

5.2.1.2.1.1 Context Diagram

The Context Diagram is the base for the detailed design of the external interfaces reported in this Technical Report. The following definitions are used.

Core POMA entities:

— Vehicle Positioning Box: a POMA module installed in the vehicle and delivering X, Y coordinates with quality attributes (e.g. integrity, accuracy level…) based on sensor data fusion.

— Infrastructure Positioning Box: a POMA module installed in the infrastructure (e.g. road side cabinet) and delivering X, Y coordinates with quality attributes (e.g. integrity, accuracy level…) based on sensor data fusion.

— Map-matching: a POMA module translating the output of the POMA positioning box (X,Y with quality attributes) to the road network representation (map) and delivering addresses or link IDs with quality attributes (e.g. integrity of the output).

— Map update server: a POMA module delivering map update files in given data formats (e.g. XML). Map updates can be pushed to or pulled from applications.

— Geospatial platform: A POMA module offering access to georeferenced content (e.g. map, traffic related to infrastructure elements) via basic navigation modules such as geocoder (e.g. from GPS location to infrastructure elements), reverse-geocoder, map display, and route calculation.

— Georeferenced language: A XML language used to exchange georeferenced content. This language includes specific tags to code location data (e.g. AGORA-C, X-Y …) at different abstraction level (point, area …) and to codes events and status data.

— API: a set of request/response protocols (typically XML format).

5.2.1.2.1.2 Other entities of relevance to POMA

— Map update module: a module that takes map updates, compiles them and stores them in the local map database.

— Map DB: a local map database compiled into a vendor specific format.

— External content: any set of static or dynamic geo-referenced data which can be layered on top of a map.

— The environmental conditions (e.g. urban canyons) are not under influence by CVIS, but place requirements on the positioning capabilities, such as accuracy and integrity, especially for GNSS systems.

5.2.1.2.2 Design of POMA

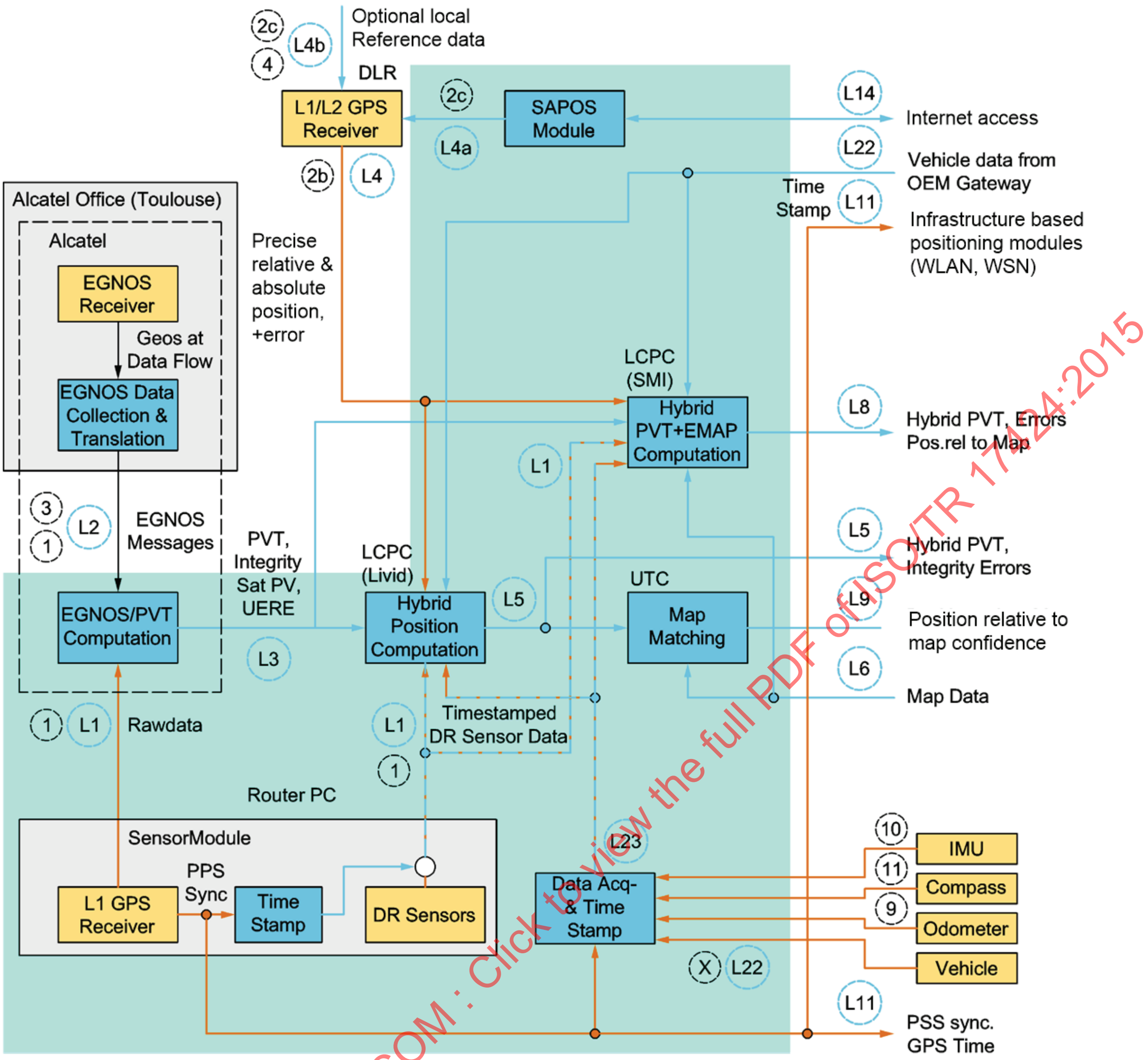
Upon the context specification given in the previous paragraph, the architectural design of POMA led to three separate parts of the POMA system:

a) the POMA in-vehicle positioning box;

b) the POMA infrastructure positioning box;

c) the POMA server components.

The collection of these three parts complies with all requirements on POMA and implements the external interfaces as given in the next paragraphs.



Key

→ (blue)	Processed Data	(yellow box)	Sensors
→ (orange)	Sensor Data	(blue box)	POMAModule
1	Physical Interface	PVT	Position, Velocity, Time
L1	Logical Interface		

Figure 6 — Functional architecture of the on-board positioning part

Figure 6 above presents the internal functional design of the in-vehicle positioning box of POMA with external interfaces. Positioning data are delivered via two Positioning Interfaces:

— the raw position calculated by the Hybrid Fusion module using Sensor Data;

— the map-matched position using the

— standard map from the Map Module,

— enhanced map from the EMAP Module, and

— Road Side Positioning Module.

The raw data interface (1, L1) serves as time server for all local devices within CVIS. This timing interface provides a UTC time (by GPS) as soon as the GPS receiver has reached operational conditions and receives enough satellite signals. This time will be used by COMM to time stamp data communicated over the CALM interface. Several issues with time stamping have been agreed in WP3 harmonization meetings and corresponding email discussions according the following agreements:

— Before operational conditions (ample satellite signal received, and proper initialization of the GPS receiver to operational) are fully met, timing given at this POMA interface cannot be relied on. During these phases, COMM will provide an ntp service over the communications device to synchronize time with the central CVIS time.

— The signal at the raw data interface is optimized for speed. Hence, no correction factors will be applied. Hence, the data by applications and other CVIS components that use correction factors will deviate in position vectors as well as that time corrections might be applicable. COMM agreed that this dispersion in data and time stamping does not hamper the COMM intended use (e.g. prioritization of messages).

Figure 7 below presents the internal functional design of the infrastructure positioning box (wireless sensor network positioning and WLAN positioning) of POMA with external interfaces.

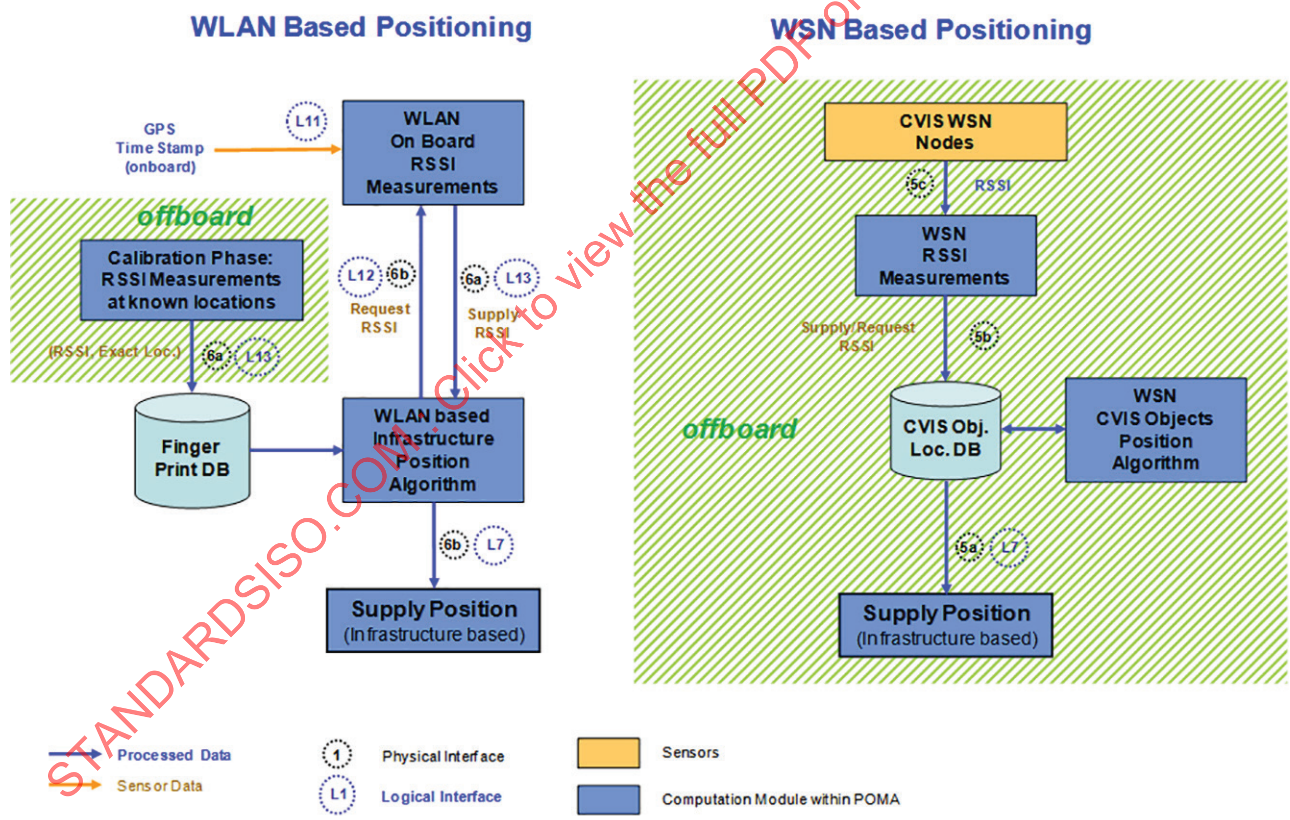


Figure 7 — Functional architecture of the positioning module (Infrastructure)

Figure 8 below presents the internal functional design of the server components and in-vehicle map components of POMA with external interfaces and the connection to the other in-vehicle positioning components.

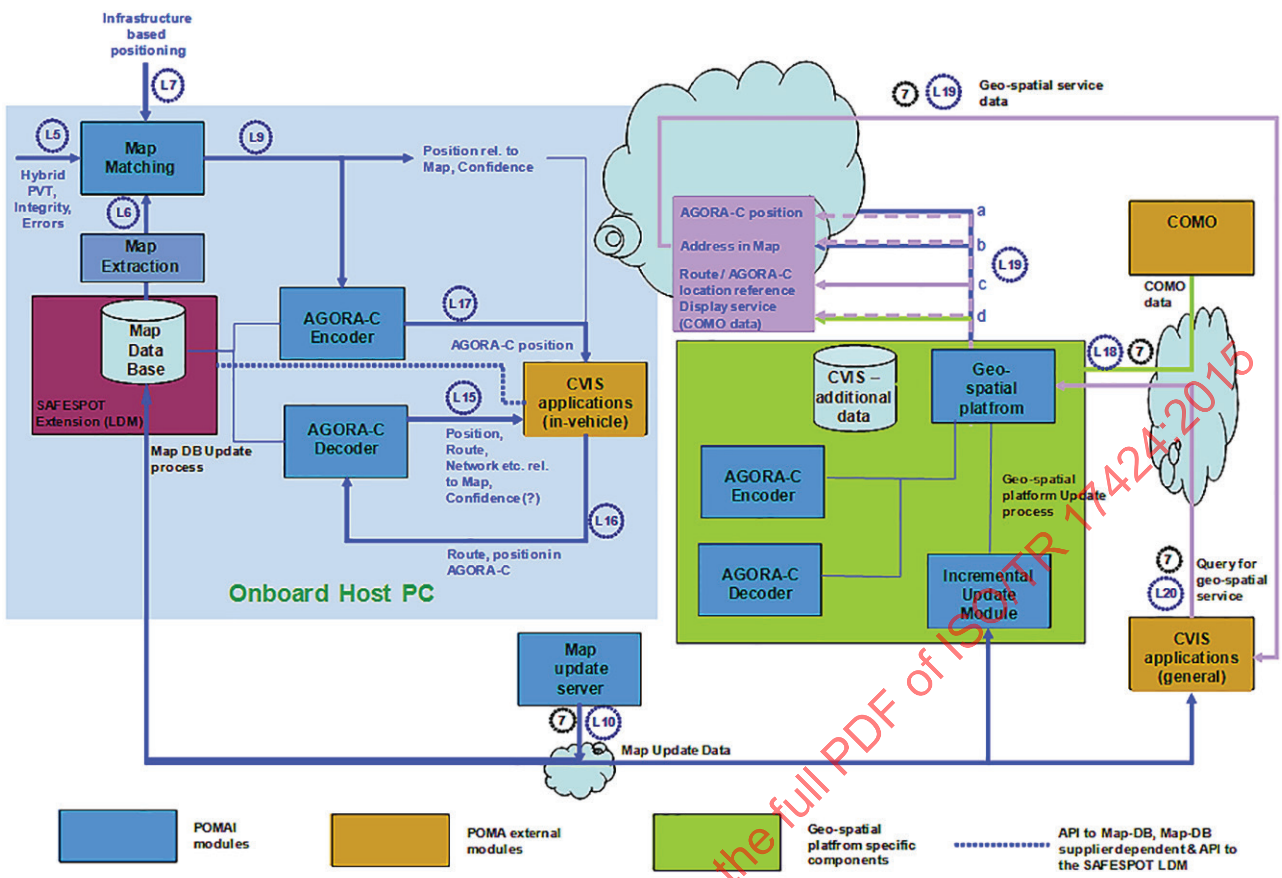


Figure 8 — Functional architecture of the map module

See Reference [20].

5.2.1.3 Cooperative Awareness

If all vehicles are equipped with communication devices and regularly broadcast their positions, speed and directions, a so called Local Dynamic Map (LDM) can be constructed. A LDM would also contain static map information and temporary information about e.g. road conditions communicated from selected road-side units. The cooperative awareness messages are the foundation of many applications [4],[5]. This realization implies that time-triggered messages are broadcasted periodically by all vehicles. Since the messages are repeated periodically and do not signal imminent hazard the requirement on reliability is moderate. The LDM based applications can predict trajectories on vehicles depending on previously received messages even if some messages are lost. The LDM can be used to predict dangerous situations before they actually occur. For example, “it will be a collision within four seconds if all vehicles maintain the same speed and direction”. The system can thereby extend the horizon of awareness of the driver. In order to avoid a system with invisible, mute vehicles, a high penetration is likely needed. However, also at lower penetration rates cooperative awareness messages could be used as application enhancement and driver guidance. Since messages are broadcasted by all vehicles regularly, there is limited need to retransmit them or let them propagate beyond communication range. Instead, more effort should be put on selection of appropriate communication ranges since the needs are likely different in urban areas as compared to inter-urban.

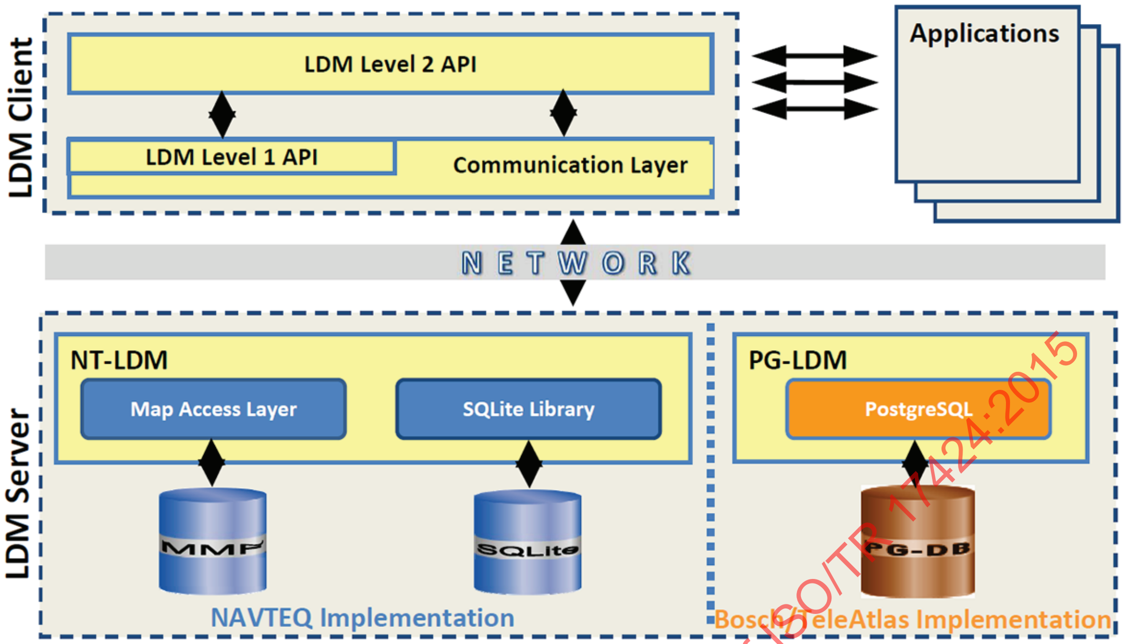


Figure 9 — LDM architecture

5.2.1.4 Cooperative ITS Station architecture

The objective of ETSI/TR 102 863[3] is to identify and characterize the elements of the LDM to be standardized to ensure interoperability between distributed applications and to provide applications support. It is also to identify and characterize the interfaces between the LDM, the other facilities functions, and the distributed application elements which need to be standardized.

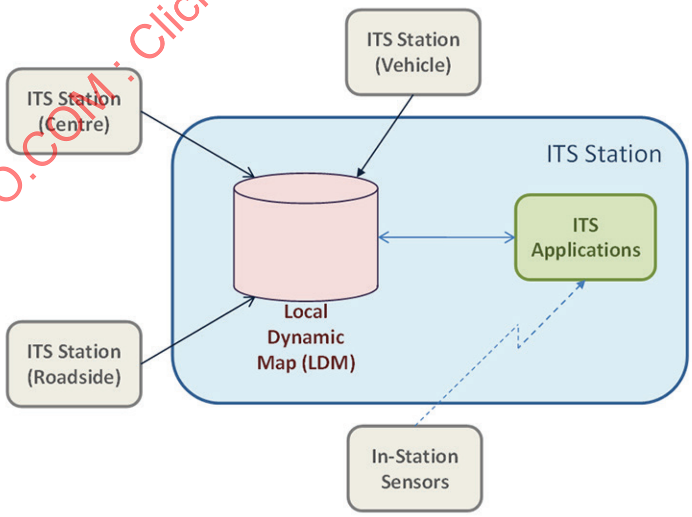


Figure 10 — Relationship between LDM and its information sources

The LDM contains information on real-world and conceptual objects that have an influence on the traffic flow. The LDM is not required to maintain information on the ITS station it is part of but may do so if necessary in a particular implementation.

Data describing real-world objects can be categorized in four different types as follows:

a) Type1: permanent static data, usually provided by a map data supplier,

b) Type 2: transient static data, obtained during operation, e.g. changed static speed limits,

c) Type 3: transient dynamic data, e.g. weather situation, traffic information.

d) Type 4: highly dynamic data, e.g. CAM.

The LDM will not contain type 1 data. Not all ITS stations require type 1 data. In case type 1 data are needed by an application within an ITS system (e.g. a navigation application), these data will be optimized and stored for the respective specific application. At the time of publication of this Technical Report, it is not feasible to define one common map data format and specify the required standard interfaces to access these data that meet the requirements for all ITS stations.

NOTE Further study is required to determine how accurate local digital mapping information can be received, stored and provided by the LDM for applications which would benefit by having such information available.

As the LDM data are potentially relevant for applications that make use of type 1 data, the location referencing data that are required for relating type 2, type 3 and type 4 information to the type 1 map data should be provided. This location referencing is a complex operation and requires adequate location referencing methods. As not all ITS applications that potentially use LDM require location referenced information, the use of these data are not mandatory.

ITS applications need to process static, temporary and dynamic data from other ITS stations in the surrounding area of the host station (vehicle and roadside). Relevant data need to be stored and maintained in the LDM. The information in the LDM is received from relevant messages such as ITS CAM messages, DENM messages and TPEG messages. Since the contents of these messages are used by several applications, the plausibility and authorization checks are recommended to be done directly by the LDM.

Upon request from a specific ITS application, the required objects need to be extracted and passed directly to the appropriate application(s) where they are processed. For reasons of efficiency, a notification mechanism which provides an application with new information under certain application-defined trigger conditions could be provided by the LDM. Applications require mechanisms to update the LDM by storing processed information on the required objects back into the LDM so that it can be made available to other applications.

The method of updating LDM information is an implementation issue and, thus, not part of ETSI/TR 102 893 [5].

Host information such as vehicle internal sensor data will not be available in the LDM.

5.2.1.4.1 ITS station reference architecture

Within the ITS station reference architecture, the LDM is part of the facilities layer and covers information and application support.

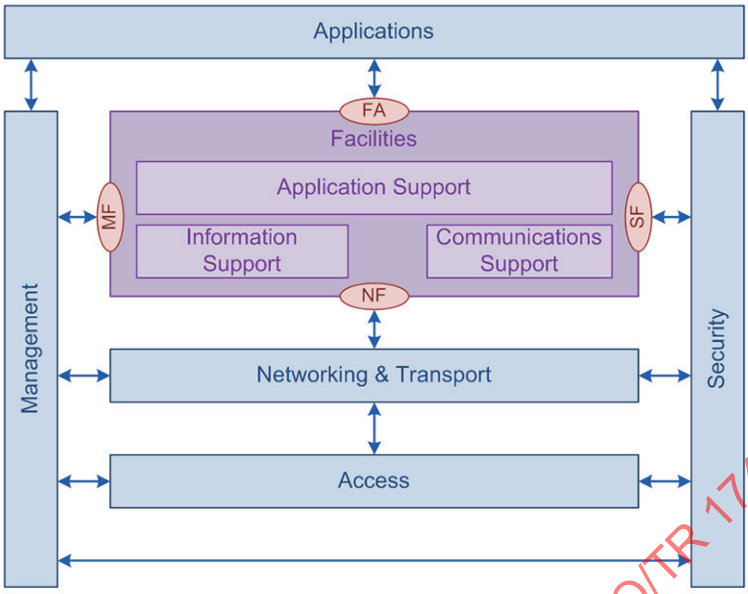


Figure 11 — ITS station reference architecture

5.2.1.4.2 ITS facilities layer architecture

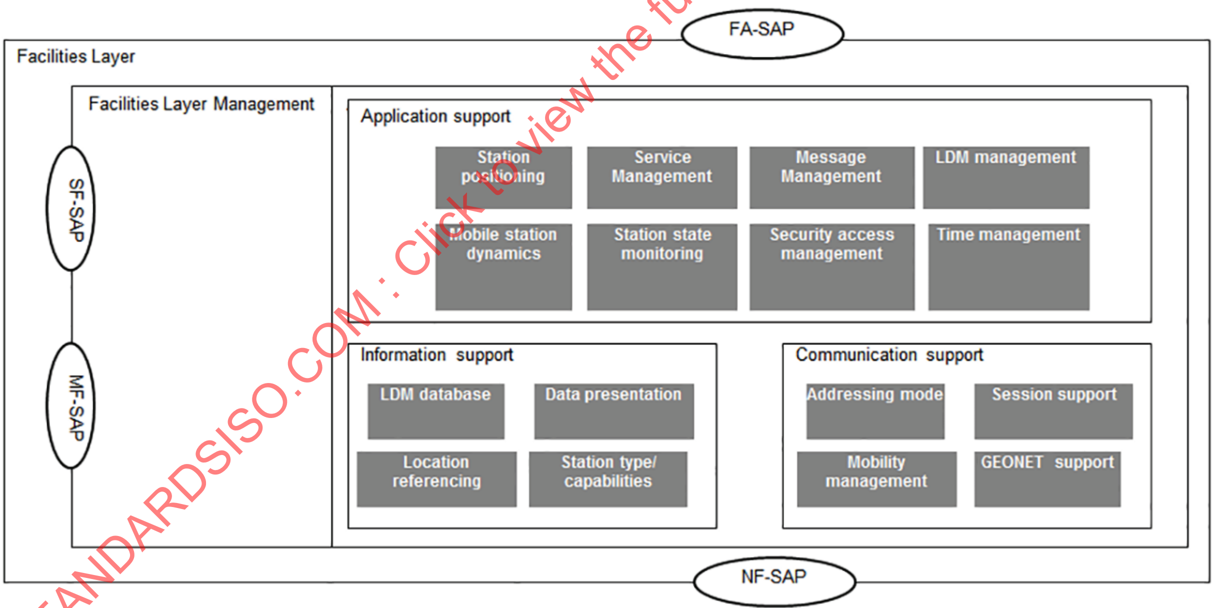


Figure 12 — ITS Application/Facilities overview

5.2.1.4.3 LDM architecture

The ITS reference architecture specifies two main components of the LDM:

— LDM Management;

— the Data Store.

The LDM internal architecture can be extended as shown in Figure 13.

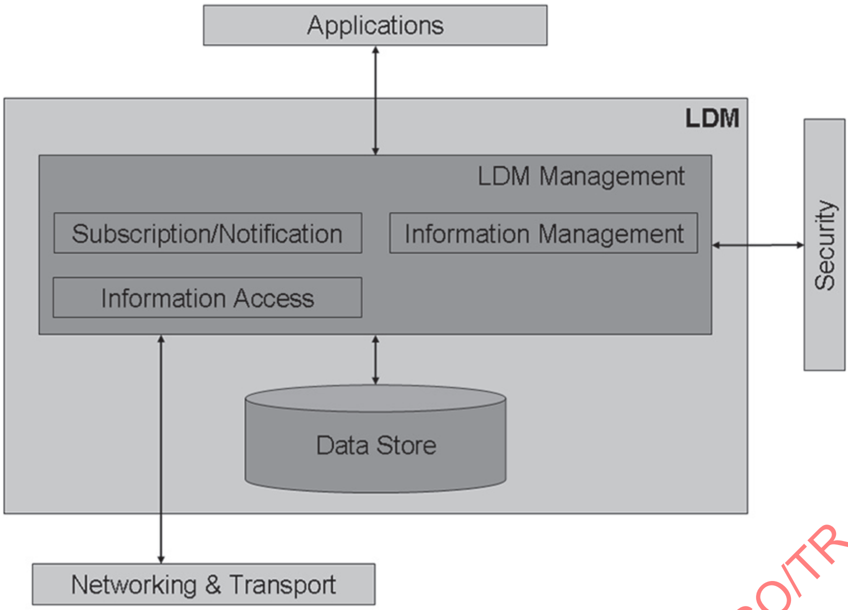


Figure 13 — LDM architecture

The specified functionality is provided by the following modules within LDM Management:

— Subscription/Notification module;

— Information Management module;

— Information Access module.

Each module performs, at least, the specific functions listed below:

— Subscription/Notification functional roles:

  — handling subscription/un-subscription requests for notification coming from applications;

  — filtering mechanisms to allow an application specific subscription to information. Properties upon which filtering can be based may include:

    — message source;

    — message type;

    — spatial criteria (for example, distance of source from the ITS station);

    — message count;

    — object dynamics (moving or static);

    — object direction;

    — object age; or

    — a combination of properties.

  — sending notification to the subscribed application. When an event triggers the required notification, it is transmitted to the requested application;

  - — providing requested information together with a notification.
- — Information Management functional roles:
  - — receiving information from CAM, DENM or TPEG messages;
  - — storing received and validated information in the LDM data store;
  - — handling LDM maintenance:
    - — discards irrelevant or corrupted information;
    - — performs regular clean-up operations on the data store according to the data management rules that are set by the ITS station or by the applications.
  - — handling application requirements: applications can set information relevance rules in the LDM management module. An example of such a relevance rule is that information from sources that are more than one kilometre away are to be discarded.
- — Information Access module functional roles:
  - — receiving requests from application information;
  - — decoding and filtering information requests by type, location and other criteria (frequency, priority, etc.);
  - — ensuring that security constraints are obeyed;
  - — retrieving information from the LDM data store; and
  - — passing back information to the requesting application.

LDM Management components interact directly with the Data Store using the following actions:

- — storing relevant information;
- — supporting insertion, update and delete functions.

Furthermore, LDM Management interacts with Applications, Security and Communication Support layers.

Applications layer roles which are LDM access related:

- — subscribe to notification services that are offered by the Subscription/Notification functional entity;
- — process the retrieved information and, potentially, write the result back in the LDM so that other applications can access the processed information;
- — set the LDM management rules for managing information that is written in the LDM by the application.

5.2.1.4.4 LDM Security Function SAP

The LDM - SF-SAP interface provides access to the ITS station security functions.

In order to avoid potential abuse of LDM data by third-party ITS applications, it will be necessary to implement information access control functions. An application will need to identify itself and be authenticated before it can be authorized to access specific LDM information. The ITS Security Functions (SF) will provide the mechanism required for authentication but it is an LDM function that uses this mechanism to grant or refuse access to information.

NOTE The methods used by the LDM and the procedures invoked through the LDM SF SAP in order to provide strong information access control functions as well as the means of reporting and managing authorization failures should be the subject of future ITS standardization.

5.2.1.5 SpeedAlert (EU FP5 Research Project) [13]

5.2.1.5.1 SpeedAlert objectives

The overall objective of the SpeedAlert initiative is to promote and enable the deployment of in-vehicle speed alert system that can contribute to improve road safety.

— Firstly, such speed alert systems will increase the awareness of drivers on speed limits and speed recommendations. In earlier generations, static speed limits displayed on road signs but an evolution will be foreseen to also cover variable speed limits relevant to dynamic environmental conditions (weather, traffic, road).

— Then, when increased driver awareness leads to adapting the speed of the vehicle it will in parallel support legal speed regulations and consequently reduce the number of speed-related accidents, especially in speed-sensitive locations (urban areas) such as near schools with vulnerable pedestrians.

— Finally, it will provide system solutions to support the implementation of intelligent speed limits initiated by means of Variable Message Signs (VMS).

In order to achieve this general objective, SpeedAlert activities are focused on the following specific objectives:

a) Establish a common classification of speed limits in Europe relevant to speed alert applications;

b) Define the system and service requirements of in-vehicle speed alert application;

c) Define functional architecture and associated technical building blocks;

d) Harmonize definition of speed alert concepts;

e) Identify requirement for standardization.

The Speed Limits Database is already identified as one of the main issues, not only from a technological point of view but also from a legal and organizational one. The Speed Limits Database is requested for all technical concepts, except the Global Infrastructure based where speed information is transmitted locally by roadside equipment.

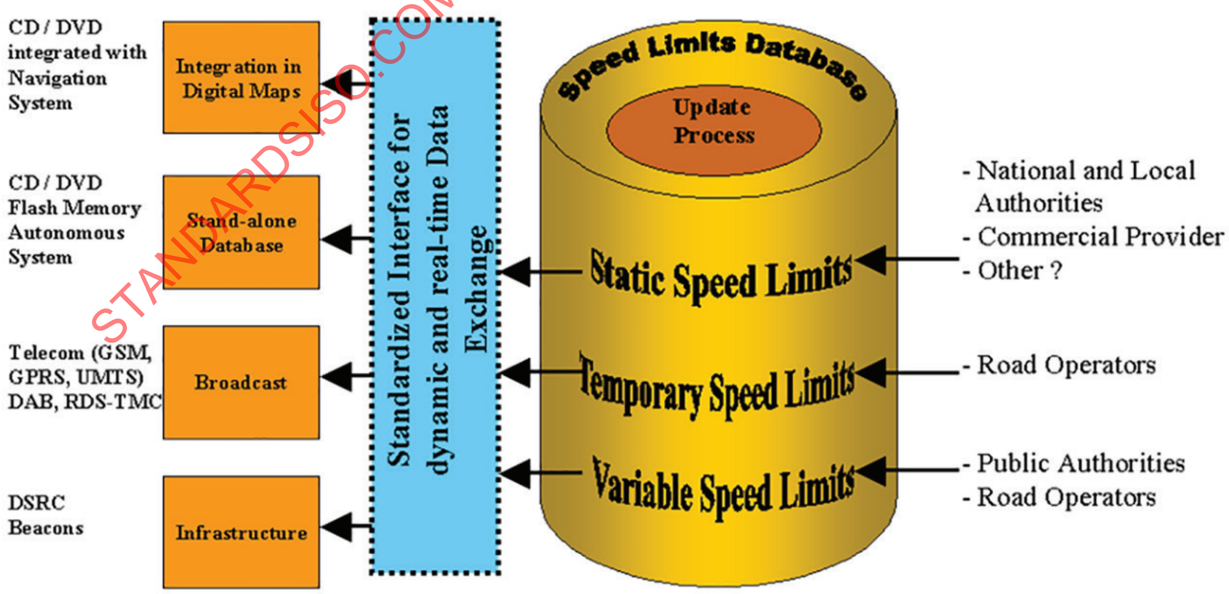


Figure 14 — Speed limits database

5.2.1.5.2 Content management

The On-Board Unit may have access to several independent data streams. To extract the SpeedAlert relevant data, several instances of a “Content Manager” should be involved.

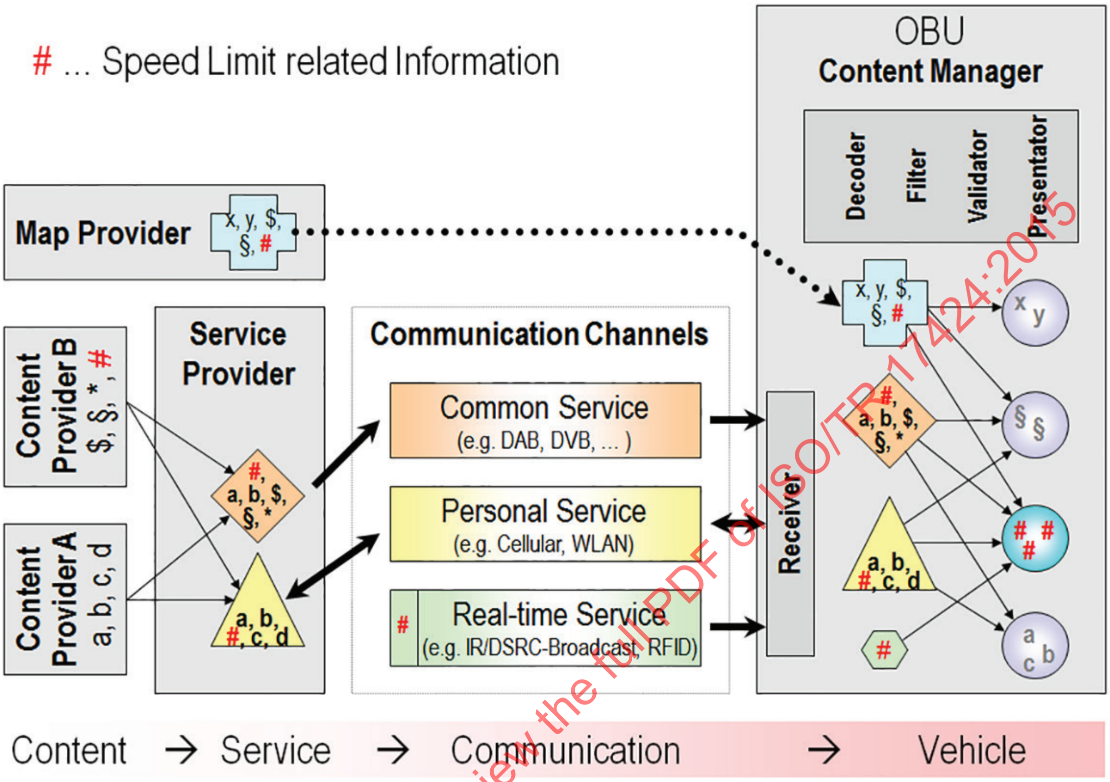


Figure 15 — Dataflow in the view of different media

5.2.1.5.2.1 Decoder

The Content Decoder should ensure that the content originating from each source is converted to a common data format for the Content Filter.

5.2.1.5.2.2 Content Filter

The Content Filter detects and extracts the SpeedAlert relevant parts out of the data stream and forwards it to the Validation Unit.

5.2.1.5.2.3 Validation

The speed limit information originating from multiple sources (e.g. Maps and DAB) may be complementary or overlap. Overlapping information could be supportive, inconsistent or even contradictory.

In either case, this information is relevant to the user but should be handled by the Validation Unit. The rules should be defined in detail. In general, real-time information is more accurate than update information which is more accurate than the basic map information.

5.2.1.5.2.4 Presentation

It may be useful in case of multiple information sources also to introduce a “trust-level” for the information content.

5.2.1.5.3 Main Results

To come to a feasible result of the project the following recommendations and further remarks should be given:

a) Concerning speed limit data capturing, processing and provision:

— for the handling of data further aspects for the use of data are important. Countries follow different strategies and priorities with regard to data usage;

— the methods by which European public authorities perform speed limit data capture are very different and therefore no recommendations can be given here as to how public authorities should proceed in future. It is acknowledged that these authorities will have an important role in this enabling process in the future;

— the process for data transfer has to be worked out more in greater detail depending on how the data are available; format aspects have more or less lower priority for this process;

b) To finalize speed limit data capturing, processing and provision:

— a commitment from the public sector as well as the private sector (namely infrastructure suppliers, map makers, the car industry, the car supplier industry and service providers) is needed;

— the roles and responsibilities on both sides, industry and public authorities should be clarified;

— additional experience in the development of speed limit data integration within onboard systems will enable this process to be refined;

— a detailed consideration of the business plan aspects of speed alert data provision will subsequently need to be performed for all relevant sector actors.

c) It is necessary to have different ways of updating the speed limit information in the vehicle:

— version by CD-Rom;

— general updates via air-link;

— dynamic information via direct VMS-vehicle-communication.

d) Public Private Partnerships (PPP) on a high level as institutional platform between public authorities and the industry is seen as the major instrument in order to setup a speed limit data delivery chain with an essential aspect of road safety.

e) A speed alert application can be established using the technical solutions available up to the time of publication of this Technical Report.

f) Legal aspects (mandatory or not) are not discussed in the scope of this project, but will influence the design, the business case and the roll out of speed alert and speed recommendation systems. The provision of relevant speed information basically relates to HMI issues, not to legal aspects. Speed adaptation through outside interference, however, causes a number of legal concerns, as driver responsibility would be overruled leading to a number of liability aspects.

g) The business case is not developed today. Although some business aspects will be covered in WP4 the main focus of the project is on the functional requirement definition (WP2), the development of technical building blocks for a speed alerts system (WP3) and the harmonization of speed alert concepts (WP4). For the implementation, however, business case considerations for each stakeholder of the value chain are essential. Costs and savings for national governments based on infrastructure investments, less speed-related accidents, cost and revenues for speed limit database operators to collect, process, update and sell speed information data, costs and revenue for digital map producers and related sales media, cost and revenue car manufacturers to offer upgraded navigation systems at a price the customer is willing to pay for, and last but not least customer cost/benefit reflections, etc. will determine next to mandatory introduction if theory will lead to practical implementation.

