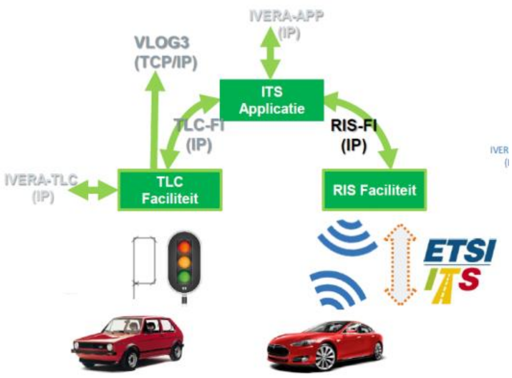
Intelligente Verkeers Regel Installatie (iVRI) – Fase 1

Deliverable F: iTLC Architecture

Architectuuroverzicht voor VRA en referentiearchitectuur voor de informatieketen



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VOORWOORD

In juni 2015 is opdracht verstrekt door het Ministerie van Infrastructuur en Milieu via het Beter Benutten Vervolg (BBV) programma aan vier VRA leveranciers om te komen tot een gezamenlijke definitie van VRA standaarden ten behoeve van connected en coöperatieve functionaliteit.

Dit document vormt Deliverable F van de afgesproken leverdelen in de opdrachtverstrekking, omschreven als "Architectuuroverzicht (fysiek en functionele blokken) voor VRA en referentiearchitectuur voor de informatieketen".

Deze deliverable beschrijft in het Engels de architectuur van het intelligente verkeersregeltoestel (iTLC).

Dit document is tot stand gekomen door samenwerking van de vier leveranciers in de werkgroep bestaande uit:

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NB. De rest van dit document is geschreven in het Engels om internationale uitwisseling te ondersteunen.

The rest of this deliverable has been written in English to facilitate international exchange.

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ABSTRACT

The document describes the architecture of the 'intelligent Traffic Light Controller'. It has been defined within the 'Beter Benutten Vervolg' program (BBV) of the Ministerie van Infrastructuur en Milieu[1] (IenM).

The architecture allows for integration of the C-ITS domain with the TLC domain by allowing ITS Applications to use facilities from both the Traffic Light Controllers (TLC) and Roadside ITS stations (RIS) and therefore enable the implementation of various ITS use-cases related to TLC's.

The 'TLC-Facilities' and 'RIS-Facilities' describe the functionality of respectively TLC and RIS. The goal of the architecture is to provide the TLC Facilities and RIS Facilities functionality to ITS Application by defining open interfaces.

Because the interfaces are based on standard networking technologies, ITS-Applications using these interfaces are allowed to be distributed on any hardware-platform, locally and remote.

Existing TLC-interfaces are also considered as part of the iTLC architecture.

ABSTRACT [*Dutch*]

Dit document beschrijft de architectuur van het intelligente verkeersregeltoestel (iTLC). Het is opgesteld in het kader van het 'Beter Benutten Vervolg' programma (BBV) van het Ministerie van Infrastructuur en Milieu (I en M).

De architectuur maakt integratie van het C-ITS domein en het VRI domein mogelijk. Hierdoor kunnen ITS applicaties gebruikmaken van zowel de faciliteiten van verkeersregeltoestellen (TLC) als van wegkant ITS stations (RIS). Zo kunnen verschillende TLC gerelateerde ITS use-cases geïmplementeerd worden.

De 'TLC Faciliteiten' en 'RIS Faciliteiten' beschrijven de functionaliteit van respectievelijk TLC en RIS. Het doel van de architectuur is om aan de ITS applicaties de functionaliteit van de TLC- en RIS Faciliteiten beschikbaar te stellen door open interfaces te definiëren.

Omdat de interfaces gebaseerd zijn op standaard netwerk technologie, is het aan ITS Applicaties toegestaan om over verschillende hardware platforms gedistribueerd te worden, zowel lokaal als op afstand.

Bestaande TLC interfaces worden beschouwd als onderdeel van de iTLC architectuur.

[1] English: Ministry of Infrastructure and the Environment

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1 Introduction

1.1 Purpose and scope

This document describes the architecture of an Intelligent Traffic Light Controller (iTLC), which will be used to integrate the C-ITS domain (connected and cooperative communication with road users) with the TLC domain. The key elements and interfaces of this architecture are outlined in Figure 1.

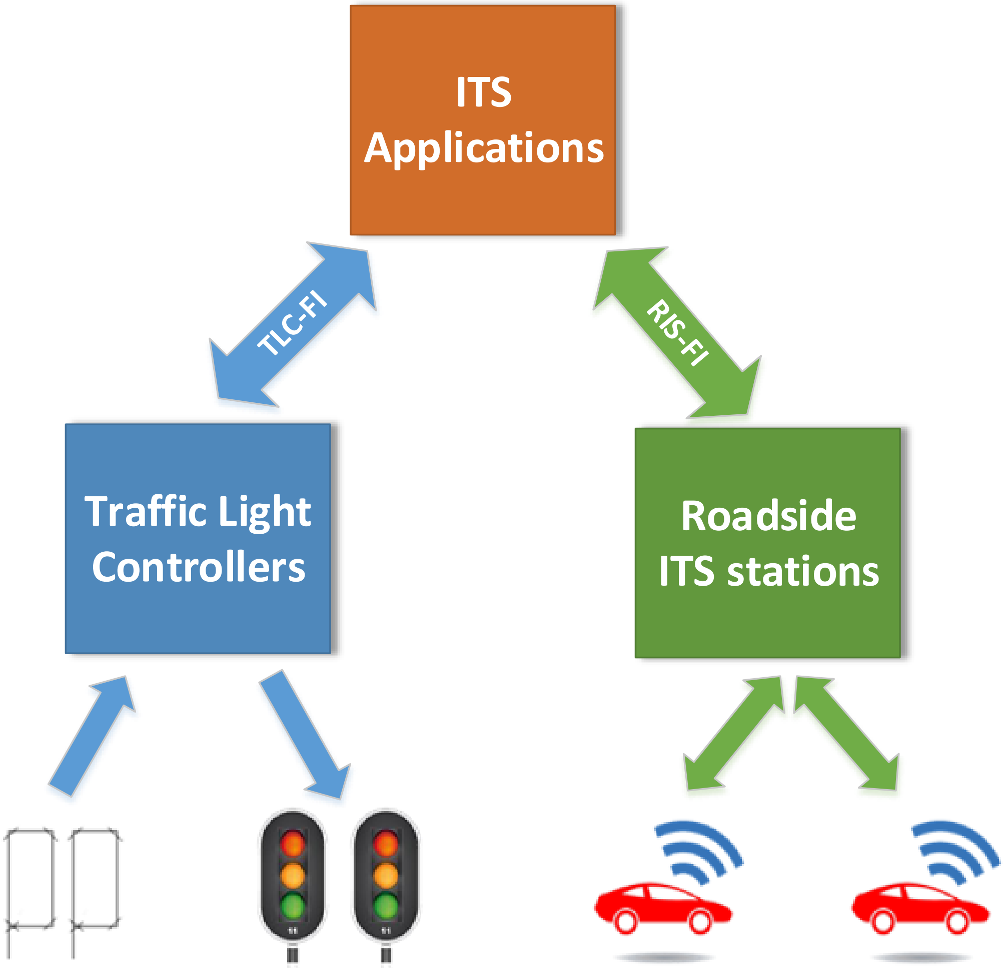


Figure 1 System overview

The document describes an architecture to be implemented on iTLC in the Netherlands. It has been defined within the 'Beter Benutten Vervolg' program (BBV) of the Ministerie van Infrastructuur en Milieu[2] (IenM). The purpose of this document is to describe the architecture in such a way that the goals and concerns of the stakeholders are met.

The architecture encompasses existing TLCs and new to-be-deployed TLCs. Existing TLCs need to be upgraded with the new functionality and interfaces, feasibility depends on the type of TLC.

[2] English: Ministry of Infrastructure and the Environment

The intention of the architecture is to allow ITS Applications to use facilities from both the TLC and C-ITS domains through either cooperative (short range) or connected (long-range) channels. The interfaces to a TLC and a Roadside ITS Station are open specifications enabling different vendors to build ITS Applications using both TLCs and Roadside ITS stations (RIS) to support various ITS use-cases.

A special type of ITS Application can act as a traffic control application requesting traffic light signal states to the TLC. This way the ITS Application is decoupled from the TLC and RIS by open protocols, which enables various parties to provide such applications.

As a side effect, the IVERA management protocol needs modifications. One reason is the changed deployment of traffic control applications forcing a split up of the IVERA objects to be managed. Another reason is the need for some new objects needed to manage ITS Applications connected to the TLC.

1.2 Audience

This document has been written for:

- Road authorities
- ITS Application providers
- TLC manufacturers
- RIS manufacturers

1.3 Reader advise

The reader is assumed to have knowledge of the ITS- and TLC-domains.
The architecture is documented according to the architectural design approach as described in section 1.4.

1.4 Architectural design approach

The architecture is described according to methodology introduced by Rozanski and Woods, See [Ref 21]) which implements the ISO42010 Systems and software engineering – Architecture description ([Ref 22]).

The methodology is stakeholder centric. It aims to describe the architecture from the point of view of various stakeholders and their concerns with the architecture. Different views capture relevant concerns of stakeholders, important quality attributes are defined and each view is enriched with input from these quality attributes. I.e. each view is seen from a different perspective. Viewpoints as defined in [Ref 21] are used as template models to construct the necessary views, by re-using architectural knowledge.

The following views are presented in this architecture description:

- Context view in chapter 5
- Functional view in chapter 6, 7, 8, 9 and 10
- Deployment view in chapter 9
- Information view in chapter 11
- Concurrency view in chapter 13
- Operational view in chapter 13

The quality attributes are described in chapter 14.

1.5 Normative references

[Ref 1] CEN/ISO TS18750:2015
[Ref 2] ETSI TS 102 723-2, V1.1.1
[Ref 3] ETSI EN 302 637-2, V1.3.2
[Ref 4] ETSI EN 302 637-3, V1.2.2
[Ref 5] ETSI EN 302 895, V1.1.1
[Ref 6] ETSI TR 102 863, V1.1.1
[Ref 7] ISO/TS 19321:2015
[Ref 8] Draft ISO/TS 19091 v5.14
[Ref 9] Draft ISO/TS 19091 Annex D v012
[Ref 10] SAE J2735 PropDft FEB2015
[Ref 11] ETSI TS 102 965,4 V1.2.1
[Ref 12] RFC 5905
[Ref 13] Beter Benutten Vervolg, project iVRI, Deliverable G1, IRS RIS Facilities Interface v1.2
[Ref 14] LDM Object Dictionary v1.2
[Ref 15] Beter Benutten Vervolg, project iVRI, Deliverable G2, IRS TLC Facilities Interface v1.2
[Ref 16] Beter Benutten Vervolg, project iVRI, Deliverable E “Uitwerking Use Cases”

1.6 Informative references

[Ref 17] ETSI EN 302 665, V1.1.1
[Ref 18] ETSI TS 103 097, V1.2.1
[Ref 19] Bijlage 1 Plan van Aanpak.pdf, 18 mei 2015, definitief t.b.v. DO BBV 26/5/2015
[Ref 20] Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM); Rationale for and guidance on standardization, ETSI TS 102 894-1 V1.1.1 (2013-08)
[Ref 21] Software Systems Architecture: Working with Stakeholders Using Viewpoints and Perspectives, Second Edition; Nick Rozanski; Addison-Wesley Professional, 2011
[Ref 22] Systems and software engineering -- Architecture description; ISO/IEC/IEEE 42010
[Ref 23] Bijlage 2 Toelichting op de offerte-uitvraag.pdf
[Ref 24] Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary ETSI TS 102 894-2 V1.2.1 (2014-09)

2 Acronyms, abbreviations and concepts

Acronyms and abbreviations

BBV	Beter Benutten Vervolg: Program for standardization of interfaces with TLCs for connected and cooperative functionality
CAM	Cooperative Awareness Message; ETSI defined service and message used for ITS-Station presence, location and status
CCOL	Traffic control algorithm implemented in the C programming language
CEN	European Committee for Standardization
C-ITS	Cooperative ITS functionality for exchange of data between in-vehicle and or road side devices making use of either cellular or short range wireless communication
C-ITS-S	Central ITS station
CVN	Contactgroep Verkeersregeltechnici Nederland[3]
DENM	Decentralized Environmental Notification Message; ETSI defined service and message used to defined and location notable events (e.g. Road works, accidents, stranded vehicles, congestion)
EMV	EMergency Vehicle
ETSI	European Telecommunications Standards Institute
HSM	Hardware Security Module
IDD	Interface Design Description
IenM	Ministerie van Infrastructuur en Milieu[4]
IRS	Interface Requirements Specification
ISO	International Organization for Standardization
iTLC	Intelligent TLC performing traffic light controller functions and allowing for ITS applications
ITS	Intelligent Transport Systems

[3] Group of traffic control specialists/engineers in the Netherlands
[4] Ministry of Infrastructure and the Environment

ITS Station	Functional entity specified by the ITS station reference architecture (see ETSI EN 302 665, V1.1.1)
IVERA	Management protocol for traffic light controllers in the Netherlands
IVI	In Vehicle Information (see ISO/TS 19321:2015)
KAR	Korte Afstands Radio[5]; system used to implement prioritization of special vehicles like public transport
LDM	Local Dynamic Map; Concept of data store containing a reflection of physical infrastructure and current on-street traffic and environment
MAP	Message to convey the current road topology to road-users, often used in conjunction with SPAT
N&T	Networking & Transport, a conceptual layer of the ETSI ITS-S reference architecture (see [Ref 17])
NEN	NEderlands Norm
PTV	Public Transport Vehicle
RIS	See R-ITS-S
RIS-FI	RIS Facilities Interface
R-ITS-S	Roadside ITS Station, responsible for a geographic area.
RSU	Roadside Unit
RWS-C	Traffic control algorithm implemented in the C programming language
SPAT	Signal Phase And Timing message; used to convey the current status of one or more signalized intersections
TCS	Traffic Control System
TLC	Traffic Light Controller; controls the signalling of one or more intersections
TLC-FI	TLC Facilities Interface
TMS	Traffic Management Centre
VIS	See V-ITS-S

[5] Short Distance Radio

V-ITS-S	Vehicle ITS Station
VLOG	Traffic data log

Concepts

Traffic Control Application	Application which implements a traffic control algorithm and is able to request signal group states
CVN-C Application	A traffic control application which implements control through the CVN-C interface
ITS Control Application	A Traffic Control Application which uses TLC- and/or RIS-interfaces
ITS Application	An application which supports one or more ITS use-cases. Range of possible ITS Applications include an ITS Control Application
RIS Facilities	Component providing RIS Facilities to users (internal and/or external). Includes amongst others: • Access to information stored in the LDM • Services to trigger C-ITS messages
TLC Facilities	Component providing facilities of a TLC to users (internal and/or external). Includes amongst others: • Access to information from the TLC • Services to trigger actuators
TLC Middleware[6]	Component of a traffic light controller responsible for physically activating signal groups and process hardware for detection

[6] Dutch: Procesbesturing

3 Stakeholders and requirements

3.1 Stakeholders

- Beter Benutten; funds the development of the interface descriptions and architecture to allow an open market
- Road authorities; it is in their interest to be able to deploy iTLCs, independently of a manufacturer, but with standard interfaces and clearly defined behavior.
- TLC manufacturers; who implements the defined architecture and standard interfaces into the various TLC products
- RIS manufacturers; who implements the defined architecture and standard interfaces into the various RIS products
- Certification bodies; who needs to make sure the system complies with regulations and standards
- Standardization bodies; where applicable, the architecture, concepts and interfaces need to comply with standards and regulations
- Application providers
- Road users
- Maintenance engineers

3.2 Overview of requirements

This section contains high level requirements relevant for the architecture presented.

Req-ID	REQ-01
Title	ITS G5 message handling
Description	iTLC is able to receive and transmit ITS G5 messages
Source	Bijlage 1 Plan van Aanpak.pdf, 18 mei 2015, definitief t.b.v. DO BBV 26/5/2015
Comment	

Req-ID	REQ-02
Title	Equal and symmetric access to facilities
Description	ITS Applications can use both TLC Facilities as well as RIS Facilities
Source	Bijlage 2 Toelichting op de offerte-uitvraag.pdf
Comment	

Req-ID	REQ-03
Title	ITS Applications may be deployed on multiple platforms
Description	ITS Applications can for instance be deployed to a TLC, RIS, Central location etc.
Source	Bijlage 2 Toelichting op de offerte-uitvraag.pdf
Comment	

3.3 System scenarios

A separate working group (BBV WG2) is developing use-cases for the iTLC. These use-cases form the basis for the functional and quality scenarios described below. They also serve as a validation and illustration role after this architecture design is complete, both on paper and as the starting point for the tests of an architectural prototype.

3.3.1 Functional scenarios

The following use-cases (see [Ref 16]) are elaborated as functional scenarios and will be used to verify the architecture:

3.3.1.1 Information

- U08A - TIME TO GREEN
- U08B - TIME TO RED

3.3.1.2 Optimization

- U07B - GAP MEASUREMENT
- U07I - COOPERATIVE GREEN WAVE

3.3.1.3 Prioritization

- U04A - GREEN EXTENSION HEAVY GOODS VEHICLES
- U05A - CONDITIONAL PRIORITY FOR PUBLIC TRANSPORT

3.3.2 System quality scenarios

3.3.2.1 Signal Phase And Timing (SPAT)-transmission

This scenario describes the way changes in actual signal group states are used to disseminate SPAT-messages. It also describes the (maximum) latencies and possible failures. See section 14.11.

4 Architectural forces

4.1 Goals

Main goals and business drivers:

- Allow for vendor-independent development and deployment of ITS Applications, supporting ITS use-cases. It should be possible to execute vendor-independent applications within the iTLC context.
- Allow for traffic control using existing standards as CCOL, RWS-C based on CVN-C, as well as other existing and future traffic control algorithms.
- Enable ITS applications to access TLC Facilities and RIS Facilities regardless of the TLC- or RIS-vendors.
- Enable ITS Applications to be deployed on a TLC, RIS or somewhere else.

4.2 Constraints

- Technical capabilities of the installed base TLCs
- Architecture description must comply with applicable international and national standards (for example as published by ETSI, CEN/NEN and ISO)
- The iTLC still has to comply with all the existing national and international standards like NEN3384, EN12675 and EN50556 etc.

4.3 Principles

Principle Reference	PR-1
Principle Statement	Traffic Light Controller is responsible for safely realizing traffic signal images.
Rationale	TLC actually controls and guards the statuses of the signal groups. It must do this in compliance with national and international standards.
Implications	Topology relevant information for traffic safety must be managed by the TLC.
Further Information	

Principle Reference	PR-2
Principle Statement	Comply with international and national standards.
Rationale	Defined architecture shall be aligned with international developments, possibly usable outside the Netherlands as well.
Implications	Use architectural descriptions described in standards. E.g. • ETSI reference architecture of an ITS-S
Further Information	

Principle Reference	PR-3
Principle Statement	ITS Applications (for example a Traffic Control Application) must be able to access both RIS and TLC Facilities. Multiple ITS Applications can operate at the same time.
Rationale	Market principle, different manufacturers of applications must be given equal opportunities to access TLC and RIS

	Facilities.
Implications	The interfaces to the facilities must have mechanisms to allow for multiple applications interacting with them
Further Information	

Principle Reference	PR-4
Principle Statement	Open standards and protocols shall be used as far as possible.
Rationale	Market principle, different manufacturers of applications must be given equal opportunities to access TLC- and RIS-Facilities.
Implications	
Further Information	

Principle Reference	PR-5
Principle Statement	Access to RIS Facilities shall be independent of TLC Facilities (and vice versa).
Rationale	Vendor independent solution, allows for instance for situations where there is no TLC nor RIS.
Implications	
Further Information	

Principle Reference	PR-6
Principle Statement	Interfaces with the TLC and RIS Facilities should allow for international adoption.
Rationale	Alignment with international standards
Implications	
Further Information	

5 Context view

Describes the relationships, dependencies and interactions between the iTLC and its environment (the people, systems and external entities that it interacts with).

5.1 Context diagram

The following figure describes the top-level context with main interactions.

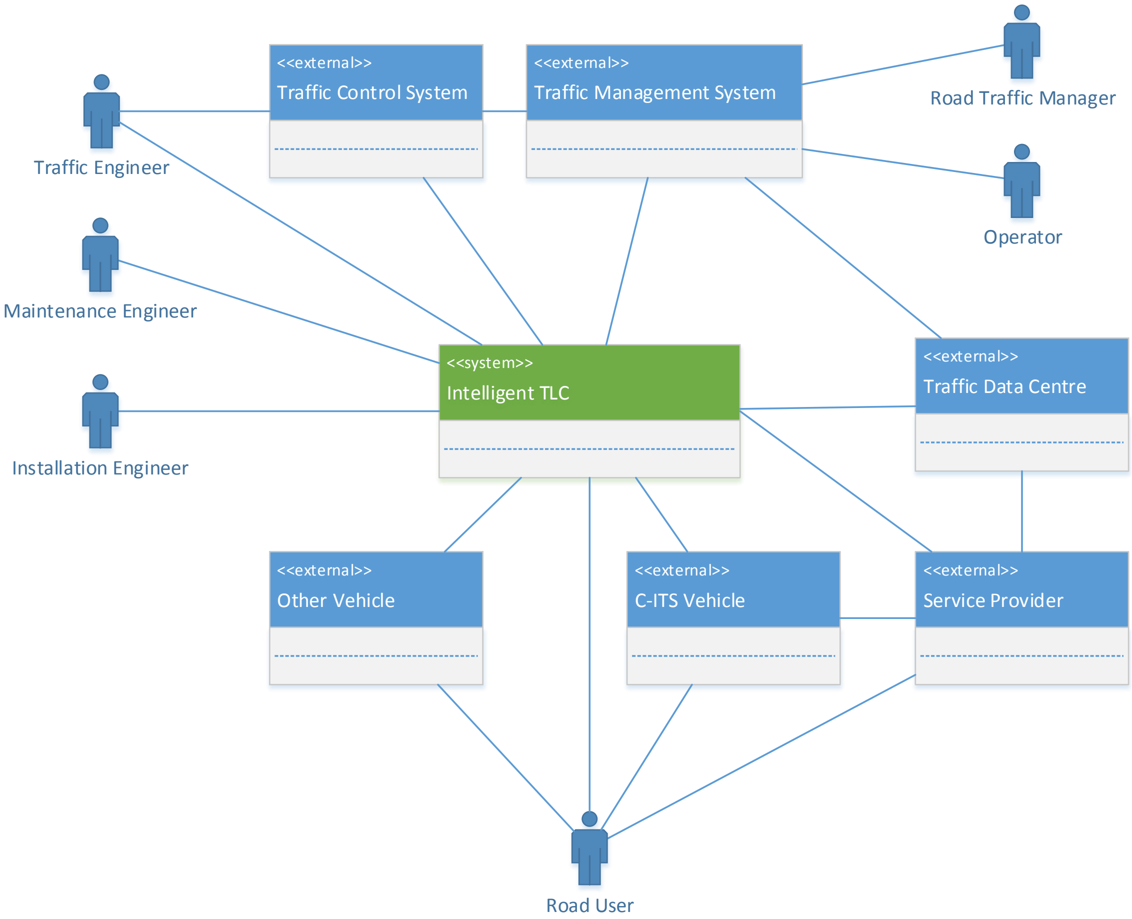


Figure 2 Context diagram

External entity	Who
Traffic Engineer	Responsible for implementing, defining, designing and functional maintenance of traffic algorithm for the Traffic Control System and/or Intelligent TLC.
Maintenance Engineer	Responsible for operational maintenance of the Intelligent TLC by using diagnostic facilities.
Installation Engineer	Responsible for deployment of hardware, software and infrastructure of the Intelligent TLC.
Road Traffic Manager	Responsible for determining and setting of traffic management policies.
Operator	Executes policies for the traffic system by using the

	Traffic Management System.
Traffic Control System	External system implementing a traffic control algorithm actively influencing the Intelligent TLC to control traffic. Realizing set traffic control policies.
Traffic Management System	External system responsible for monitoring, evaluation and management of the functional and technical state of the Intelligent TLC and Traffic Control System. Used to set high-level policies. Translates policies to required behavior of the underlying systems.
Traffic Data Centre	Responsible for collecting, aggregating, distributing and managing (e.g. deleting) of traffic data.
Service Provider	Responsible for providing services to one or more customers. Customers can include other systems and end-users.
C-ITS Vehicle	A vehicle equipped with ETSI cooperative functionality using ITS G5 or cellular technology. Complies with the definition of a Vehicle ITS Station (V-ITS-S). For instance a car, lorry or a bicycle.
Other Vehicle	Other vehicle, not being a C-ITS Vehicle.
Road User	A person participating in the traffic. Can be equipped with a personal nomadic device such as a mobile phone, or Personal-ITS-Station.

Table 1 Description of external entities as used in context diagram

5.2 Interaction scenarios

Relevant interaction scenarios can be found in [Ref 16].

6 Functional view

6.1 High level view

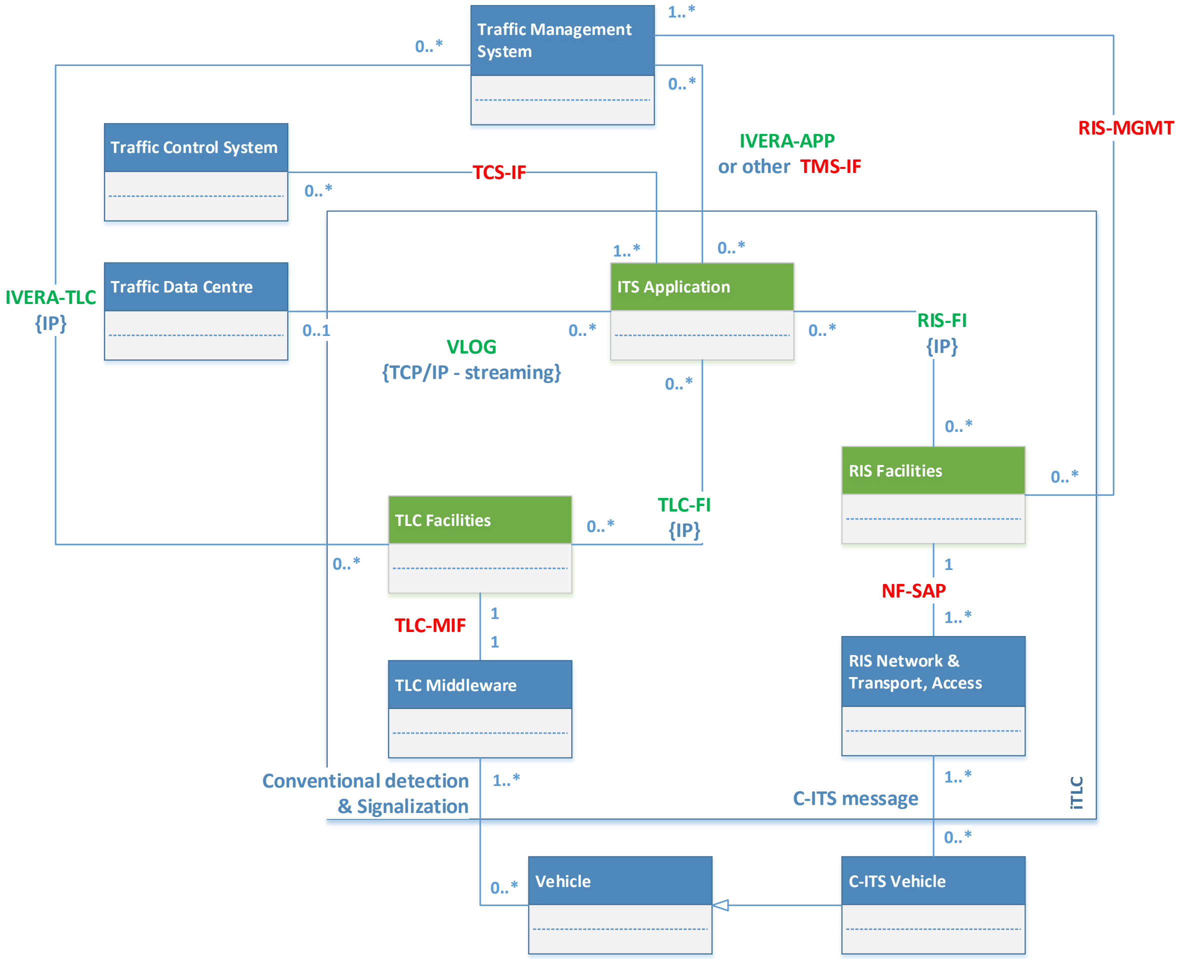


Figure 3 Functional model

Figure 3 provides a high-level view of the functional blocks of the iTLC and major relevant relations with external entities. Note that the relations in some cases define an interface between blocks.

The green interfaces are or will be standardized as part of this architecture:

- TLC-FI (TLC Facility Interface)
- RIS-FI (RIS Facility Interface)
- VLOG
- IVERA-TLC (part of IVERA related to TLC-management)
- IVERA-APP (part of IVERA related to management of ITS Control Applications)

The red interfaces are proprietary and out-of-scope of this document:

- TCS-IF (Traffic Control Centre Interface)
- TMS-IF (Traffic Management Centre Interface)
- RIS-MGMT (Roadside ITS Station Management)

- TLC-MIF (Traffic Light Controller Middleware Interface)
- NF-SAP (Network Facilities Service Access Point).

The ITS Application can take many forms and will in the broad sense support one or more ITS use-cases. To fulfill its use-case it interacts with facilities offered by TLCs and RISs.

Both the TLC and RIS Facility layers make information and control methods of their own domain available to ITS Applications. Based on access rights, certain ITS Applications can access particular information and/or methods. In particular, write access rights to request traffic signal images and intersection control modes is granted only to specific applications to guarantee consistent signal images.
There may be multiple different ITS Applications executed simultaneously, where each of these applications supports different use-cases and require their own access to the RIS and TLC Facilities.

Note that when more than one ITS Application produce VLOG data, the iTLC is responsible for providing one single consistent VLOG stream to the Traffic Data Centre.

6.2 iTLC conceptual layers

The following figure shows the iTLC functional blocks in relation with existing conceptual functional blocks of the TLC and RIS.

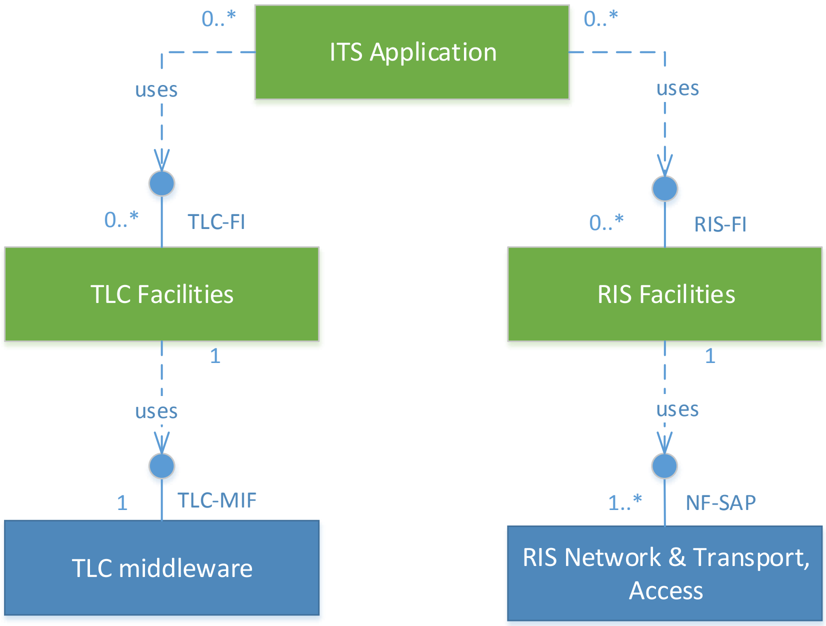


Figure 4 Multiple applications

This architecture is an addition to current TLCs, all containing some sort of conceptual TLC middleware layer[7]. This layer is responsible for actuation of signal groups as well as processing of detection. It may consist of a supervision circuit to assure traffic safety

[7] Dutch: Procesbesturing

according to the applicable norms. As can be seen in Figure 4, the TLC Facilities is added as a new interface layer on top of the traditional TLC middleware layer.

Figure 4 shows that multiple ITS applications can use RIS and TLC Facilities, but also that each of those facilities can be used by multiple ITS applications.

In the following chapters, for each of the functional blocks of the iTLC the functional view is described.

7 Functional view - ITS Application

In Figure 5 the interfaces and functional blocks of an ITS Application as used in an iTLC are shown. Note that the functional blocks are defined on a high level as the functionality of an ITS Application may vary considerably.

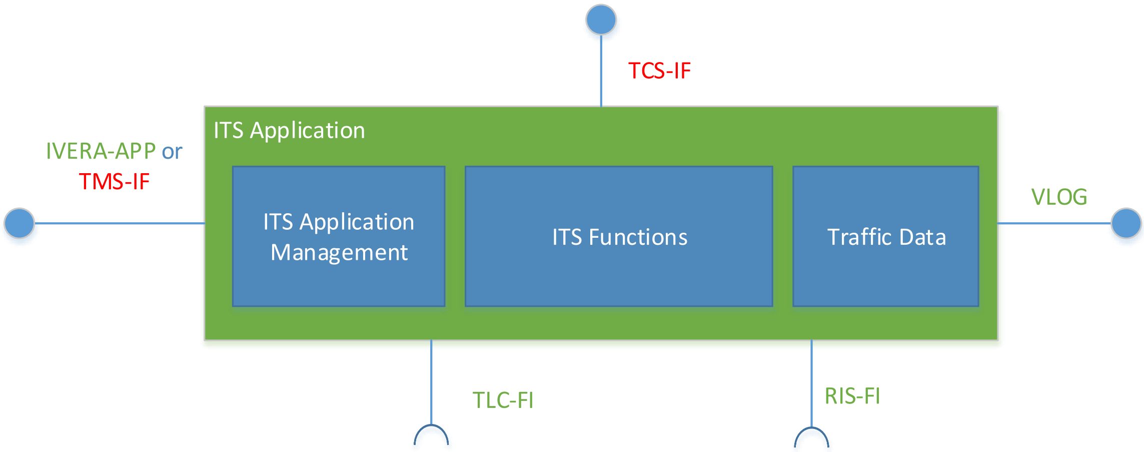


Figure 5 ITS Application - functional blocks

Element Name	**ITS Application**
Responsibilities	Supports an ITS use-case by using the TLC and/or RIS Facilities
Functional blocks	**ITS Application Management** An ITS Application can be managed by a management system. Management for instance comprises setting of parameters and reading logbooks. **ITS Functions** There are a wide range of ITS Applications, this block fulfils the functions of each ITS Application. **Traffic Data** The Traffic Data supports a continuous stream of traffic control related events, which can be retrieved from the **VLOG** interface by a Traffic Data Centre or an internal component for rerouting. Traffic control related events are for example detection-, input-, output- and group events. Also signal group timings and predictions. An ITS Control application (see 8.1) may implement this functionality.
Interfaces – Provides	**TMS-IF** (optional)**:** Vendor-dependent management interface

	IVERA-APP (optional): Specific implementation of a TMS-IF, used for functional management in case the ITS application is for example a CCOL or RWS-C traffic control application. **TCS-IF** (optional)**:** Interface for functional influence of the ITS Application when acting as a traffic control application. This interface may be proprietary or standard. **VLOG** (optional): Used to provide traffic data from the ITS Application to a Traffic Data Centre. VLOG supports 1 VLOG client at the same time.
Interfaces – Requires	**TLC-FI** for interaction with a TLC **RIS-FI** for interaction with a RIS

A non-exhaustive list of ITS Applications in this context:

- Traffic control algorithm
- Heavy vehicle detection, extension and priority (Tovergroen)
- Speed advice for bicycles and vehicles
- Platoon detection (vehicle, bicycle)

8 Functional view - TLC Facilities

In Figure 6 the interfaces and functional blocks of the TLC Facilities layer as used in an iTLC are shown.

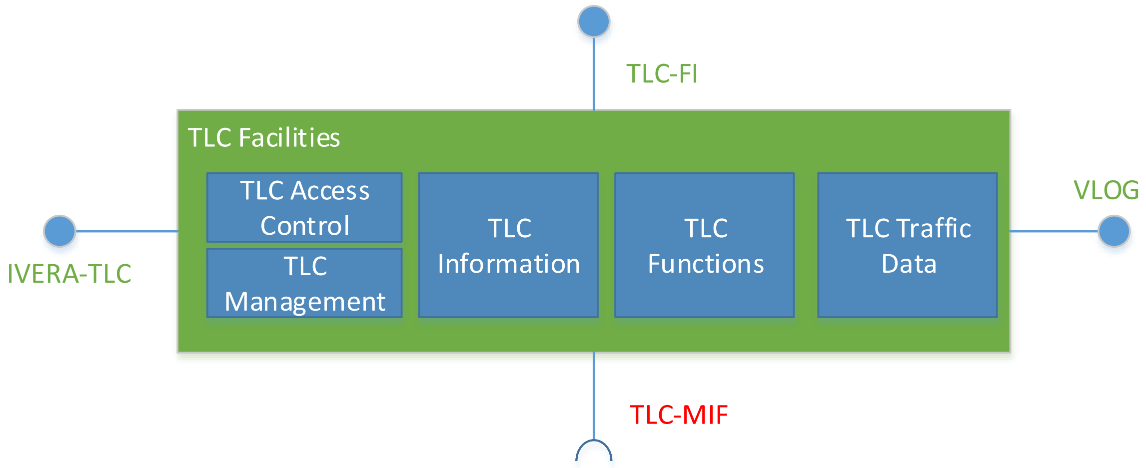


Figure 6 TLC Facilities layer - functional blocks

The responsibilities of the TLC Facilities as used in the iTLC are described in the following table. Each functional block will be elaborated in detail later:

Element Name	**TLC Facilities**
Responsibility	TLC Facilities provides Traffic Control functionality to ITS Applications, by giving access to TLC Functions and TLC Information through the TLC-FI interface. The TLC Facilities supports multiple ITS Applications at the same time. The TLC is **UTC-time** synchronised.
Functional Blocks	**TLC Access Control** ITS Applications first need to **authenticate/authorize** themselves with the TLC-FI in order to use the TLC Facilities. This login leads to registration of the ITS Application, while predefined permissions for reading and updating TLC Information are granted. **TLC Management** The TLC supports **multiple IVERA** connections in order to be managed remotely. Management comprises setting of parameters, selecting programs, reading logbooks, reading group-, detection- and intersection status. It is also used for setting the permissions for ITS Applications, and reading the status of the ITS Applications.

	TLC Information The TLC Information is the collection of all kinds of runtime TLC Objects that is exchanged between the TLC and multiple ITS Applications over the TLC-FI interface. **TLC Functions** The TLC Functions is the collection of all kinds of TLC related functions, needed to support a proper exchange of TLC Objects, and processing by the TLC middleware. **TLC Traffic data** When more ITS Applications are able to generate VLOG data for the same intersection over time, this block may be used to reroute the VLOG data from the active ITS application to the Traffic Data Centre.
Interfaces - Provides	**TLC-FI**: Used for operational interaction with the TLC. TLC-FI supports at least 10 different ITS Applications simultaneously. **IVERA-TLC**: Used for operational and functional management of the TLC. IVERA-TLC supports at least 4 different IVERA clients at the same time. **VLOG**: Used to provide traffic data to a Traffic Data Centre. VLOG supports 1 VLOG client at the same time.
Interfaces - Requires	**TLC-MIF**: interface with TLC-Middleware, used by TLC-Facilities to for example control outputs and acquire inputs. This interface is vendor specific.

8.1 TLC Access Control

The responsibility of the TLC Access Control as used in the TLC Facilities is described in the following table:

Element Name	**TLC Access Control**
Responsibility	The TLC Access Control provides the TLC with defined and secure **entrance** and **exit** for the different types of ITS Applications over the TLC-FI.
Functionality	Each ITS Application has to log in to the TLC Facility layer with a **username**/**password**. The same username/password combination may be used by multiple ITS Applications. The ITS Application is notified of the success (or failure) of authentication. After a number of subsequent **incorrect login** attempts, the TLC Access Control shall deny following attempts to login by the ITS Application. A new access may be allowed after administrator intervention or a timeout period. Registration failures shall be logged; log files may be accessed using the Management Entity. In case of a **successful login** the ITS Application is registered in the TLC Access Control registration by its unique **Application-ID**. The TLC Access Control returns information to the ITS Application, which tells the ITS Application what it can expect from the TLC Facility layer, in terms of permissions for reading and updating TLC Information. In case an ITS Application decides to **logoff** from the TLC Facility layer, it will be unregistered from the TLC Facility layer. The TLC Facility layer continuously checks if an ITS Application is still alive.
Permissions	The TLC Facility layer grants permissions to ITS Applications based on the used username/password combination. Permissions for access to TLC Information are configured per type of Application. The following Application-types are defined: **ITS <u>Control</u> application** An ITS control application has permissions to **control signal groups**, and set signal group timing and predictions. It has also permissions to update output states. On top of the registration of ITS Applications in general, an ITS control application has to inform the TLC about the dimensions of control (intersection identification, signal groups, detector, input and output configurations). Only if these dimensions match the dimensions of the intersection as known by the TLC, the ITS control application is allowed to control signal groups.

	ITS <u>Provider</u> application An ITS provider application has no permissions to control signal groups, or set signal group timing and predictions, but it has permissions to **update output states**. It can be used for different kind of TLC related functionality. **ITS <u>Consumer</u> application** An ITS consumer application has no permissions to control signal groups, or set signal group or update output states. An ITS consumer application is only allowed to read data from the TLC Facility layer.
Priority	For ITS Applications a **priority** is configured in the TLC Facility layer. The priority is related to the Application-ID. Requests of an ITS Application with a higher priority are processed first.
Interfaces	By using the IVERA-TLC interface, it is possible to inquire the status of the configured ITS-Applications. In addition, the IVERA-TLC interface permits to read and update the **permissions** and **priority** for each ITS-Application.

8.2 TLC Management

The responsibility of the TLC Management as used in the TLC Facilities is described in the following table:

<table>
<tr><th>Element Name</th><th>TLC Management</th></tr>
<tr><td>Responsibility</td><td>The TLC Management provides the Traffic Management Centre with access to the TLC Objects.</td></tr>
<tr><td>Functionality</td><td>The TLC Management supports the information exchange over the IVERA-TLC interface. All TLC related IVERA objects as described in the IVERA Object Definition are supported.

To support management of ITS Applications that can be connected to the TLC extra IVERA objects need to be defined:

1. ITS Application permissions
2. Supported ITS-Application-ID’s
3. ITS Application priorities
4. ITS Application state

ITS Application Type permissions
For each ITS Application Type (Control, Provider and Consumer) it must be possible to read and update the permissions per data type.

Supported ITS-Application-ID’s
For all ITS Applications, that are allowed to connect to the TLC-FI, it must be possible to read and update their (unique) ITS-Application-ID’s.

ITS Application priorities
For each ITS Application(-ID) a priority (in service, time) can be read or updated.
A control application is a special case in this; if a control application is in control its actual priority is temporarily increased (the initial assigned priority stays unchanged).

ITS Application state
For each ITS Application it must be possible to read the session state.

Possible states are described in detail the IRSIDD [Ref 15].</td></tr>
<tr><td>Permissions</td><td>Depending on the IVERA login level the objects mentioned can be read or written.</td></tr>
<tr><td>Interfaces</td><td>The TLC Management Centre is connected to the TLC over the IVERA-TLC interface.</td></tr>
</table>

8.3 TLC Functions

The responsibilities of the TLC Functions, as used in the TLC Facilities, are described in the following table. The typical TLC Functions for controlling the signal groups, reading and writing inputs and outputs, as well as the **safety** CPU (complying to the international standards) are assumed to be present in the TLC and well known, and not elaborated in the table below.

Element Name	TLC Functions
Responsibilities	The TLC Functions provides the TLC with defined and secure functionality needed for handling the TLC-FI data exchange. The following TLC Functions are distinguished: 1. Providing the detector states and speed information 2. Providing public transport vehicle information 3. Providing emergency vehicle information 4. Providing prioritization states 5. Controlling and providing the signal group states 6. Checking and correcting signal group timing and predictions 7. Switching and providing the intersection state(s) 8. Switching the intersection program(s) (control application) 9. Providing the input states 10. Controlling and providing the output states 11. Providing the multifunctional variables 12. Providing topology and meta data 13. Time synchronization **Detector states and speed information** In the TLC Facilities, update of the detector states is made available. The TLC Facilities performs the mapping from physical devices to detectors, check the detector behaviour and state, and is able to switch detectors on or off or traffic dependent (SWICO). For other intelligent detectors the TLC Facilities performs the mapping, the right presentation of the vehicle information like speed, length etc. **Public transport vehicle information** The TLC Facilities receives the PTV-messages from KAR, VECOM or equivalent systems and makes the corresponding vehicle information available on the TLC-FI. **Emergency vehicle information** The TLC Facilities receives the EMV-messages from KAR, VECOM or equivalent systems and makes the corresponding vehicle information available on the TLC-FI. **Prioritization states** The selected ITS Control application provides the TLC-FI with the

	state of prioritization states for each signal group. **Controlling and providing the signal group states** The TLC Facilities first determines which ITS control application is allowed to control the signal groups of which intersection, based on the selection, quality-attributes (like number of occurred errors) and priority made by manual panel, clock, central system or TLC itself. If the requested program is available the TLC will 'start' the program, and from that moment on the TLC will use the signal group state requests, timings and prediction of the selected control application (for the corresponding intersection). The TLC Facilities will try to realize the requested group states, and will report back the realized signal group states. **Checking and correcting signal group timing and predictions** The signal group timing and predictions received from ITS control applications will only be handled by the TLC for the selected and active control application. They are checked and corrected by the following rules: 1. Current signal group state and corresponding (expired) minimum time must be smaller than the reported remaining time of that state (for each signal group) 2. Current signal group state and corresponding (expired) clearing times to other signal groups must be smaller than the predicted time to the next green state. 3. The total of the predicted green phases of different signal groups, may never lead to a future conflict. 4. The signal group timing must be consistent with the real signal group state. 5. In case the intersection state is not 'CONTROL' the signal group timing and predictions are cleared. The signal group timing and prediction is received from the control application with a relative time (relative to the current time) or absolute time. In case of relative time the TLC Functions will calculate an absolute timestamp. In case of absolute time the TLC will use this time, as long as the control application is UTC-time synchronized. The corrected timing and predictions are made available in the TLC-FI for other ITS Applications. If the TLC is not UTC-time synchronised timing and predictions are cleared in the TLC-FI. Each signal group timing and prediction has a lifetime. If the lifetime expires the timing and predictions are cleared. **Switching and providing the intersection state** ITS control applications are allowed to request from the TLC to go to another intersection state (e.g. DARK or AMBER BLINKING), as long as they are 'in control'. Depending on priority of different sources that

	can request for another intersection state, the TLC will honour the request. Multiple ITS Applications are able to read the current intersection state of the TLC at the same time. **Switching and providing the intersection program (control application)** As soon as the ITS Control Application is selected, the TLC informs the control applications to start or stop. The TLC is always responsible for safe switching on and off procedures, as well as **safe switching over** procedure. In case of errors with a selected and active ITS control application, the TLC must be able to switch over to a backup application or AMBER BLINKING. **Providing the intersection program** Multiple ITS Applications are able to read the current selected program number in the TLC. **Providing the input states** Multiple ITS Applications are able to read the input states from the TLC. **Controlling and providing output states** ITS Applications are able to read and update output states from the TLC. Only ITS control or provider applications can update the outputs. There may be several ITS Applications updating the same output at the same time. The TLC Functions will make sure that the last update is used. **Providing multifunctional variables** Multiple ITS control or provider applications can read and update the multifunctional variables. These are predefined and free-usable variables in the TLC-FI. Multifunctional variables are set with a lifetime. If the lifetime expires the multifunctional variable is cleared. There may be several ITS Application updating the same multifunctional variable at the same time. The TLC Functions will make sure that the last update is used. **Providing topology and meta data** ITS Applications can request topology data from the TLC. The Topology data source is in the TLC. The TLC checks the Topology data on consistence (e.g. by checksum, but also logical), every time it is updated. If the consistence is ok, the data is also checked against the conflict matrix (which is part of the topology data). If that is correct too, the topology data is provided at the TLC-IF. ITS Applications can request meta data from the TLC. The meta data describes for instance the signal groups, detectors, inputs and outputs. The TLC provides this information based on the TLC-

	configuration at the TLC-IF. Finally, the version of the TLC-IF is available. **Time synchronization** The TLC must be UTC-Time synchronized, in order to be able to calculate correct signal group timing and predictions for the TLC-FI.

8.4 TLC Information

The responsibilities of the TLC-Information as used in the TLC-facilities are described in the following table:

Element Name	**TLC Information**
Responsibilities	The TLC Information describes what information, related to the TLC, can be exchanged between the TLC Facilities layer and an ITS Application. TLC Information elements are dedicated to an intersection (iTLC supports multiple intersections). **Detection state** Authorized ITS Applications can retrieve the real detector information from the TLC. The TLC-FI provides for each detector e.g. the following attributes: 1. Occupied / not occupied 2. Occupation time 3. Upper behaviour / under behaviour 4. Hardware error 5. Flutter behaviour 6. Software switch (SWICO) The detector meta data can also be read from the TLC Facilities. **Intelligent detection** Authorized ITS Applications can retrieve vehicle information from more intelligent detectors of a TLC. The TLC-FI provides for each intelligent detector e.g. the following attributes: 1. Vehicle classification 2. Speed 3. Length 4. Direction The detector meta data can also be read from the TLC Facilities. **Public transport message** Authorized ITS Applications can retrieve public transport messages (like KAR or VECOM) from the TLC. The TLC-FI provides the information received from devices like KAR or VECOM. **Emergency vehicle message** Authorized ITS Applications can retrieve emergency vehicle messages (like KAR and VECOM) from the TLC. The TLC-FI provides the information received from devices like KAR or VECOM.

	Prioritization state The selected ITS Control application updates the state of running prioritization requests per signal group. These states are available for all ITS applications. **Signal group state and control** Authorized ITS Applications can retrieve the **real signal group state** from the TLC intersection. The TLC-FI provides the following attributes: 1. Internal state 2. External state 3. Functional state 4. Time in the current state The signal group meta data can also be read from the TLC Facilities. Authorized and selected ITS Control Applications can update the **signal group states** of the corresponding intersection. The TLC provides the following attributes that can be updated: 1. Internal state 2. External state 3. Functional state The TLC itself determines which control application is allowed to set signal group state (per intersection). The TLC will always take care of the minimum times, clearing times and conflicts, in order to avoid unsafe situations caused by TLC signals at the intersection. A TLC shall allow an ITS control application to control the signal groups using either ’external state’ or ‘functional state’. The ‘internal state’ is used for information only. **Signal group timing and prediction** The authorized and selected ITS control application can set the signal group timing and prediction information into the TLC Facility layer (per intersection). The TLC provides the following attributes for a SG-state that can be updated: 1. Time to next green 2. Time to next yellow 3. Time to next red ITS control applications may provide multiple sequential SG-states for one direction. The TLC will check and correct the timing and prediction according to rules. Only the validated timing prediction is made available to other ITS Applications. ITS Applications can retrieve the signal group timing and prediction information from the TLC Facility layer (for SPAT messages).

	Multifunctional digital inputs All ITS Applications can retrieve the state of digital inputs of the TLC (like parallel signals, bridge signals, etc.). Digital inputs can only be set by the TLC itself. The TLC-FI provides for each input the following attributes: 1. Value 2. Time since last change 3. Software switch (SWICO) The input meta data can also be read from the TLC Facilities. **Multifunctional digital outputs** ITS Applications can retrieve the actual state of digital outputs of the TLC (like parallel signals, pushbutton wait signals, acoustic signals, etc.). ITS Control and provider applications can set the digital outputs. Multiple applications may have permissions to set digital outputs at the same time. The TLC will map the outputs to e.g. the physical digital outputs or to signals on the manual panel for visualization etc. The TLC-FI provides for each output the following attributes: 1. Value 2. Time since last change 3. ITS Application that last changed the value The output meta data can also be read from the TLC Facilities. **Intersection state** Authorized ITS Applications can retrieve the real intersection state (e.g. CONTROL, ALLRED, AMBER BLINKING or DARK) from the TLC. The active ITS control application can request to set the intersection state. The TLC will execute the request depending on the priority of different possible sources that can request the intersection state (like clock, manual panel, central system etc.). The TLC is responsible for executing these state transitions according to the applicable standards, and configured minimum timings. **Intersection program** Authorized ITS Applications can retrieve the actual program(s) (like CCOL1, CCOL2 etc.) that is active in the TLC. The TLC will select the actual program depending on the priority of different possible sources that can request a program (like clock, manual panel, central system etc.). The selected program must be present and able to control the intersection.

	Intersection error state Authorized ITS Applications can retrieve the intersection error state. The TLC updates the intersection error state automatically. It is not possible to reset errors over the TLC Facility Interface. **Multifunctional Variables** Authorized ITS Applications can read and update multifunctional variables. The TLC hosts these variables. These variables can be used for iTLC internal interaction between the different ITS Applications mutually and the TLC, they are project specific. The ITS Application ID that last changed the multifunctional variable is made available as meta information. **Special function variables** The TLC-FI provides default the following variables (as signal group- or intersection-properties): 1. Heavy vehicle (HGV) detected 2. Prioritization request for specified vehicle (E.g. cooperative implementation of current KAR-systems) 3. Platoon of vehicles detected 4. ‘Magic’ GREEN (special green priority for HGV, in Dutch known as Tovergroen) active in this intersection 5. Reason for waiting 6. GREEN WAVE active in the intersection The TLC-FI provides also project specific variables that can be freely defined. **Topology / Meta data** ITS Applications can read meta data and topology data from the TLC Facilities. The TLC hosts this information.

8.5 TLC Traffic Data

The responsibilities of the TLC Traffic Data as used in the TLC Facilities is described in the following table:

Element Name	TLC Traffic Data
Responsibility	The TLC Traffic Data provides the TLC with defined and secure (rerouting and) streaming of Traffic Data (VLOG) from traffic control applications to VLOG TLC outlet.
Functionality	The TLC subscribes to the VLOG-information of the ITS control application that currently runs the TLC intersection(s). Only in case a (Traffic Data Centre) client is connected to the VLOG outlet of the TLC-itself. During rerouting, the TLC will stream the received VLOG-messages to its own VLOG server port to the Traffic Data Centre. In case the TLC needs to switch over from one ITS control application to another, the VLOG stream is rerouted. In case multiple ITS control applications run multiple intersections, multiple VLOG outlet ports are present in the TLC. Note**: File based VLOG** is stored on the same platform where the ITS control application runs. This might be the TLC.
Interfaces	VLOG interfaces from an ITS control application to the TLC. VLOG interface from the TLC to a Traffic Data Centre.

9 Functional view - RIS Facilities

Below, the functional view of the RIS Facilities is described.
Where possible, the descriptions are limited to functionality not already mentioned in ITS-standards; applicable ITS-standards are listed instead.

In addition, it does not describe the Facilities layer in detail, but describes the (requirements of the) parts of the Facility layer needed to provide the required services through the FA-SAP of the Facilities layer.
Detailed design and implementation of different parts is vendor specific.

Referenced standards can be either normative or informative (see reference tables).

9.1 RIS Facilities within ITS-S reference architecture

The RIS Facilities as depicted in Figure 3 is in fact part of the ETSI ITS-S reference architecture (see [Ref 17]), whereas FA-SAP is implemented by RIS-FI:

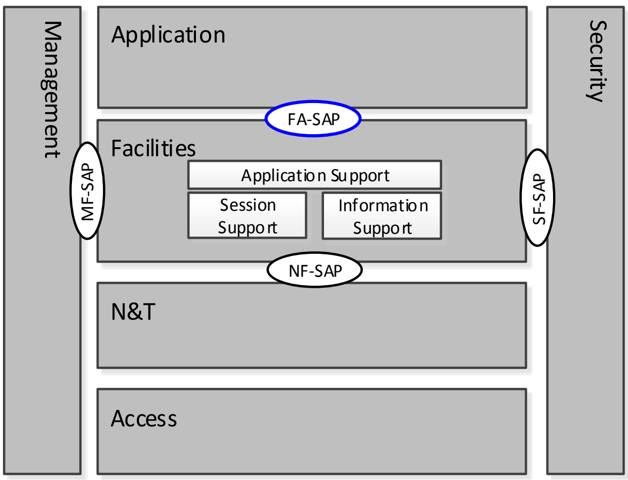


Figure 7 Position of RIS Facilities and FA-SAP in ETSI ITS-S reference architecture

The Facilities-layer interfaces with other building blocks of this reference architecture.
In order to be able to describe the relations between the Facilities and these other blocks, the following summarized description is given (partly from [Ref 17]):

The layer "Applications" represents the ITS-S applications making use of the ITS-S services to connect to one or more other ITS-S applications. An association of two or more complementary ITS-S applications constitutes an ITS application which provides an ITS service to a user of ITS. Within the scope of this document, the applications within this layer are defined as “ITS Application”.

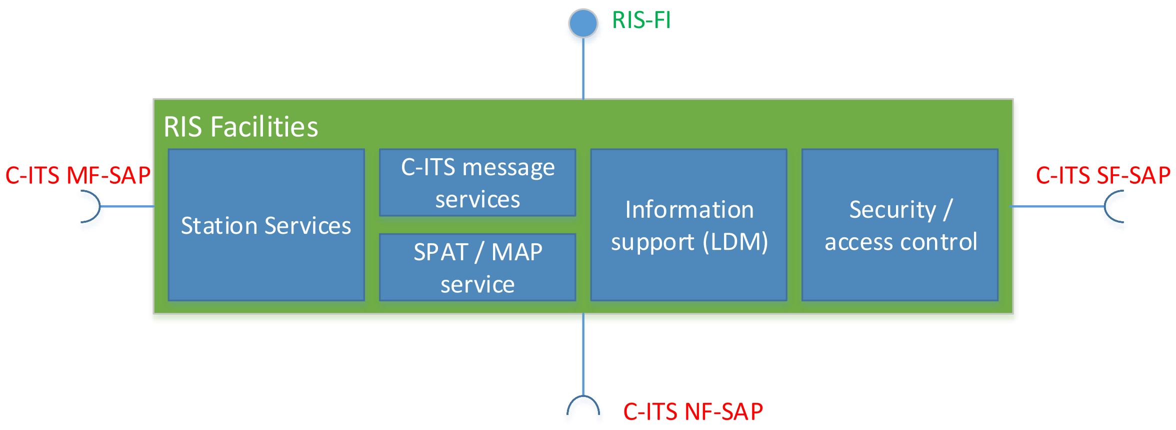
The left hand side of Figure 7 represents the entity "Management" which is in charge of managing communications- and security-parameters in the ITS station. This entity grants access to the Management Information Base (MIB), see [Ref 2]. It provides a way for secure maintenance allowing application management (installation, de-installation, updates), station management (configuration) and management of security (certificate updates, permissions, etc.). The “Management”-entity provides the RIS-MGMT interface as depicted in Figure 3.

The right hand side of Figure 7 represents the entity "Security" which provides security services to the communication protocol stack (Access, Networking & Transport (N&T) and Facilities), to the Applications and to the management entity. "Security" can also be considered as a specific part of the management entity.
It provides authentication- and authorization-services as well as security-profile management; it can also contain management of crypto-keys and certificates.

The RIS Facilities presented in the figures below provide the required functionality also based on interactions with the security entity via the SF-interface and the management entity via the MF-interface.

9.2 RIS Facilities in iTLC

Figure 8 shows the interfaces and functional blocks of the RIS Facilities layer as used in an iTLC. Each functional block will be elaborated in detail later. Where applicable, the interfaces are renamed according to the iTLC-definitions.



The responsibilities and interfaces of the RIS Facilities as used in an iTLC are described in the following table:

Figure 8 RIS Facilities layer - functional blocks

Element name	**RIS Facilities**
Responsibilities	Provides cooperative functions to ITS Applications through the RIS-FI. The RIS Facilities must support multiple sessions as multiple ITS Applications can use the RIS Facilities at the same time. **C-ITS message services** <u>C-ITS message transmission</u> Applications can provide the RIS Facilities with new message-data, or can update or terminate previous message-data. Message-data is stored in the Local Dynamic Map (LDM). The C-ITS message services of the RIS Facilities generate different kinds of C-ITS messages according to the message-data

	supplied by ITS Applications. This service also implements the protocol operation of various C-ITS messages according to standards (for example described in [Ref 4] for DENM's). <u>C-ITS message reception</u> Received C-ITS messages are stored and processed by the C-ITS message services. Each received message can add or update information of objects (e.g. 'ITS Station') stored in the LDM. ITS Applications can use the RIS-FI to query the LDM Object Dictionary to retrieve the status of these objects. **SPAT / MAP service** The RIS Facilities of an iTLC always includes a SPAT/MAP service. This service not only implements the standard protocol operation as described above, but also autonomously generates SPAT- and MAP-messages based on information provided by ITS Applications (e.g. TLC Adapter Application), and broadcasts these at the intersection. Therefore, it is described as a separate functional block. **Information Support (LDM)** <u>Georeferenced data model</u> The RIS Facilities also maintains a geo-referenced data model, the Local Dynamic Map. The LDM contains a real-time mapping of relevant static, temporary and dynamic infrastructure and non-infrastructure elements and objects around the ITS Station. Functions of the LDM include amongst others the mapping of positions of ITS Stations onto topology-elements of the intersection. For example, a CAM of a vehicle received through the NF-SAP is stored in this model; the position of the vehicle is then mapped onto the applicable driving-lane. <u>LDM Object Dictionary</u> The RIS Facilities provides a LDM Object Dictionary, which ITS Applications can use to retrieve information about objects stored in the LDM. Retrieval of information is possible by means of query, subscribe/notify, timed-interval, event based, filtered, prioritized, etc. according to [Ref 1], [Ref 5] and [Ref 6]. By providing access to this model, it can decouple C-ITS messages from ITS Applications by allowing them to obtain the information (as Data Consumers) stored in the LDM. ITS Applications can act as Data Providers themselves by using the RIS-FI to store objects not directly related to C-ITS messages in the LDM. By doing this, ITS Applications are also decoupled mutually. **Security / access control** The RIS Facilities performs above described services according to security-constraints (e.g. permissions). It first provides a way in which ITS Applications can register

	themselves with the RIS Facilities after which certain access-rights/permissions are granted to this ITS Application. The security constraints are resolved by using the C-ITS SF-SAP. **Station Services** For management purposes, it provides quality-, operational and statistical information about the state of the RIS Facilities by using the C-ITS MF-SAP. In addition, the management-interface can be used to change the security-configuration. Optional, the MF-SAP provides means for debugging the RIS Facilities (e.g. monitor/log received and transmitted ITS-G5 messages.
Interfaces – Provides	**RIS-FI**: used by ITS Applications to access provided facilities
Interfaces – Requires	**C-ITS NF-SAP** **C-ITS MF-SAP** **C-ITS SF-SAP**

9.3 Description of functional blocks of RIS Facilities

Below, each functional block as depicted in Figure 8, is described in detail.

9.3.1 Security / Access Control

This functional block enables authorization and authentication of ITS Applications before they can access the services provided by the RIS Facilities. It uses SF-SAP to implement certain features (or possibly, some features may be implemented within the Security entity itself).
Requirements as defined in standards:

> From ETSI TR 102 863, V1.1.1: "*In order to avoid potential abuse of LDM data by 3rd-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.*"
>
> From ETSI EN 302 665, V1.1.1: "*Every ITS application class/ITS application shall be uniquely identified by an application identifier in order to be handled in ITS*". See also ETSI TS 102860.

In accordance with applicable standards, an ITS Application shall register itself with the RIS Facilities before the RIS Facilities processes any further requests of this Application.

In order to do so, 'Security and Access Control' implements:

1. Authentication
2. Authorization, based on roles (with permission-set)

9.3.1.1 Authentication

Authentication is used to make sure that for a connecting ITS Application:

- the ITS Application can trust the RIS Facilities
- the RIS Facilities can trust the ITS Application

An ITS Application needs to be authenticated by the RIS Facilities to be able to use the provided services. This is done by starting an in-band login-procedure (handled by Facilities) where the ITS Application identifies itself by using a username and password.

The ITS Application is notified of the success (or failure) of authentication. After 5 subsequent registration-failures, the account shall be disabled (no further registration is possible without intervention). Registration failures shall be logged; log files may be accessed using the Management Entity.

The ITS Application may deregister itself from further using the RIS-FI.

The login-procedure can take place while one of the following levels of security applies to the Facility:

1. Rely on physical security of the network; the login procedure can be sniffed and repeated by an attacker.
2. A simple security enhancement is the use of a VPN tunnel. This protects against attacks in the global network but at the VPN end points the login procedure is still visible.
3. Add TLS with single side authentication; the RIS Facility needs a certificate to identify itself. After successful handshake the in-band login procedure is encrypted. However, the application-id and password as used by the ITS Application might be visible to others and can be copied.
4. Add TLS with client side authentication; the ITS Application needs a certificate to identify itself. The private key belonging to the certificate can be stored in a HSM to protect it against theft. With this mechanism in place the in-band login procedure could be skipped.

The plain and TLS versions of the RIS Facilities can use different well-known port numbers. A RIS with enhanced security can disable access on the plain port.

Whereas the Facilities supports all 4 levels of security, the applicable security level is determined per project.

9.3.1.2 Authorization

The RIS Facilities uses the Security entity to check if the ITS Application is authorized to further use the RIS-FI.

An ITS Application identifier (username as used during login) is used to authorize the ITS Application by matching the identifier with table of known ITS Applications or Application classes, as stored in the Security entity. Each known identifier is assigned one or more groups.

Each group refers to permission-attributes at API-level (e.g. adding of IVI message-data may be restricted, or: which LDM-information may be accessed (read) or changed, etc.), which then are applicable to any future requests of the connecting ITS Application.

The ITS Application is notified of the applicable permissions.

While the ITS Application is authorized, it may use the services provided by RIS-FI, according to allowed permissions. For each API-request, the applicable permissions (per ITS Application) shall be evaluated before the request is processed any further by the RIS Facilities.

Permissions may change over time:

- Some roles/permissions may be assigned to one ITS Application at a time, although multiple ITS Applications are (potentially) permitted to act as this role based on their credentials. In these cases, the RIS Facilities is responsible to determine which ITS Application is allowed (exclusively) to this role, and must revoke/re-assign actual permissions/roles amongst available ITS Applications.
- Permissions/roles can be (partially) revoked for a specific ITS Application by the Security-layer; usage of RIS-Facilities by this ITS Application is permitted according to the new applicable permissions/roles.

To inform an already registered ITS Application of a change of permissions, a ‘Permission Changed’-event will be added to the RIS-FI.

9.3.1.3 Groups and Permissions

Groups of permissions are defined to determine which permissions apply to an ITS Application.
Each ITS Application is assigned one or more groups.

Management of assigned roles, available roles and permissions is done using the Management-entity.

The different groups with specific permissions are described in [Ref 13].

9.3.2 C-ITS message services

This functional block contains the infrastructure services responsible for transmission and reception of C-ITS messages.

In addition, the C-ITS message services notify the LDM of received C-ITS messages.
The C-ITS message service as defined in this architecture, will consist of at least the following services for transmission and reception of C-ITS messages:

Message type	Purpose	Standards
SPAT	Disseminate information about signal group state and timing	SAE J2735 PropDft FEB2015 Draft ISO/TS 19091 v5.14 Draft ISO/TS 19091 Annex D v012
MAP	Dissemination of road topology	SAE J2735 PropDft FEB2015 Draft ISO/TS 19091 v5.14 Draft ISO/TS 19091 Annex D v012
IVI	Provides information of physical road signs, virtual signs or road works.	ISO/TS 19321:2015
DENM	Decentralized environmental notifications	ETSI EN 302 637-3, V1.2.2
CAM	Cooperative awareness messages	ETSI EN 302 637-2, V1.3.2*, especially requirements regarding RIS’s*

Table 2 Supported C-ITS messages

Reception of messages
According to various standards (e.g. [Ref 4]) the data of the received messages as listed in Table 2 shall be stored in the LDM.

For signed messages, the services shall check the message content against the Application identifier ITS-AID[8] ([Ref 11]) and Service Specific Parameters (SSP's) as contained in used certificate. If the message content is not consistent with the SSP or the signature could not be validated, the message shall be marked as 'not trusted' or dropped before delivered to the LDM.
For not signed messages the message shall be marked as 'not signed' before delivered to the LDM.

Transmission of messages
Authorized ITS Applications can add LDM Objects with parameters to the RIS Facilities which could lead to C-ITS message transmission. Amongst others, parameters can include dissemination area, repetition and traffic class.

If such a request is in accordance with the permissions of requesting ITS Application, the RIS Facilities handles the request by the executing following actions (in arbitrary order):

- adding/updating the LDM Object to the LDM
- generating a message payload and starts transmission of the message according to specific protocol handling.
- sending a response (with LDM object identifier) to the requesting ITS Application

The RIS Facilities and underlying layers send C-ITS messages according to available security certificates. If such certificates are not available and signing is requested, the response for the ITS Application will contain an error.

An ITS Application may also update or delete a previously added LDM object by using the LDM object identifier as received during the creation-request of the object. Updating a LDM object may change the C-ITS message content, whereas deleting a LDM object terminates the transmission of a C-ITS message.

Processing an ITS Application request (add, update or delete) includes validation of given parameter-values.

9.3.3 SPAT/MAP service

The RIS Facilities in an iTLC always contains a SPAT/MAP-service.
In addition to applicable standards (see Table 2), this service is responsible for:

- Autonomous periodically broadcasting MAP-messages according to intersection-topology (available in LDM)
- Autonomous broadcasting of SPAT-messages according to (signal group-) information, supplied by ITS Applications. A new SPAT-message is created periodically each second, or when updated SPAT-information is available.

[8] This is not the same identifier as the Application-ID used for the ITS Application authentication function of section 9.3.1

A SPAT-message as broadcasted by the RIS Facilities minimally contains the mandatory information. This at least includes:

- general status of the iTLC (IntersectionStatusObject)
- actual state of each signal group (MovementPhaseState)

Signal group states and timing are added to the LDM as (part of) a LDM Object, with a lifetime indication. When states or timing is changed, this LDM Object needs to be updated by an ITS Application (typically the TLC Adapter Application). If no actual data is available, the SPAT-service shall broadcast a SPAT-message containing the status "noValidSPATisAvailableAtThisTime".

A MAP-message contains, besides the mandatory fields, at least also:

- "connectsTo"-element of a GenericLane-instance (in laneSet) for ingress lanes.

See also sections 10.4 and 10.5 for common scenarios.

Additional information may be added to the SPAT-payload; this depends on the completeness and quality of information supplied by ITS Applications and the way this information is processed by the LDM.
Examples are:

- TimeChangeDetails (could be added to inform Vehicle ITS stations (VIS's) of signal group timing).
- Prioritization States (to inform vehicles about status of prioritization requests)

9.3.4 Station Services

'Station Services' offer a number of services regarding the RIS itself.

9.3.4.1 Configuration

By using the Management Entity, the Station-configuration can be changed.

The Configuration facility contains the configuration-items of (amongst others) the RIS Facilities. The configuration-items can be changed by using the Management Entity (which is vendor specific) of the RIS.
The following configuration-items should at least be available:

- station type, e.g. vehicle profile or roadside unit profile
- station capabilities, e.g. the supported ITSC communication channels and other static or variable information related to the station itself
- permissions and roles
- known ITS Applications and Application classes with assigned roles
- security certificates

Although the way in which the Management Entity is used and accessed is vendor specific, it shall be subject to security constraints to prevent unauthorized access.

9.3.4.2 Information services

This service provides static and dynamic information of the ITS station as may be required by ITS Applications and other facilities. This could include statistical information needed for evaluation, reporting (SLA) and active performance-monitoring purposes of the RIS.

The way in which statistics are collected, is vendor specific.

9.3.4.3 Time synchronization

The TLC Facilities, RIS Facilities and ITS Applications shall be time-synchronized to UTC-time within 100 ms accuracy. ITS Applications can request the synchronized system time from the RIS although it is advised to use standardized methods like NTP (RFC 5905).

All timestamps used at RIS-FI and TLC-FI are in UTC; if needed, the Facilities may convert the timestamp into TimestampITS, as defined in [Ref 24].

9.3.4.4 Logging

The RIS maintains several log files containing errors and significant events about the operation of the RIS.
At least, the following is logged:

- registration attempts and result
- role switches
- SPAT-performance (SPAT data availability)
- information about transmitted and received ITS-G5 messages (may contain message content as well)

These log files can be accessed by using the Management Entity.

9.3.5 Information support (LDM)

Key functional component of the RIS Facilities is the LDM. This is a dynamic data store, which contains a geographical view of the world around the RIS. It contains information that ranges from static data such as road topology elements to dynamic objects such as vehicles. The LDM is responsible for making a consistent world-view available to the ITS Applications. It decouples ITS messages from the information they consists of and makes this information available for use by ITS Applications based on geometry.

In the scope of this document, the services provided by the LDM are described from a roadside point-of-view. E.g. the geographical maintenance area of the LDM is fixed (stationary map).

The position of the LDM within the RIS Facilities layer, as well as the services and interfaces of the LDM are described in ETSI EN 302 895, V1.1.1. See also ETSI TR 102 863, V1.1.1 and CEN/ISO TS18750:2015.
Information is stored at various *conceptual* layers of the LDM (see figure below) as described in e.g. ETSI TR 102 863, V1.1.1, par. 4.1.

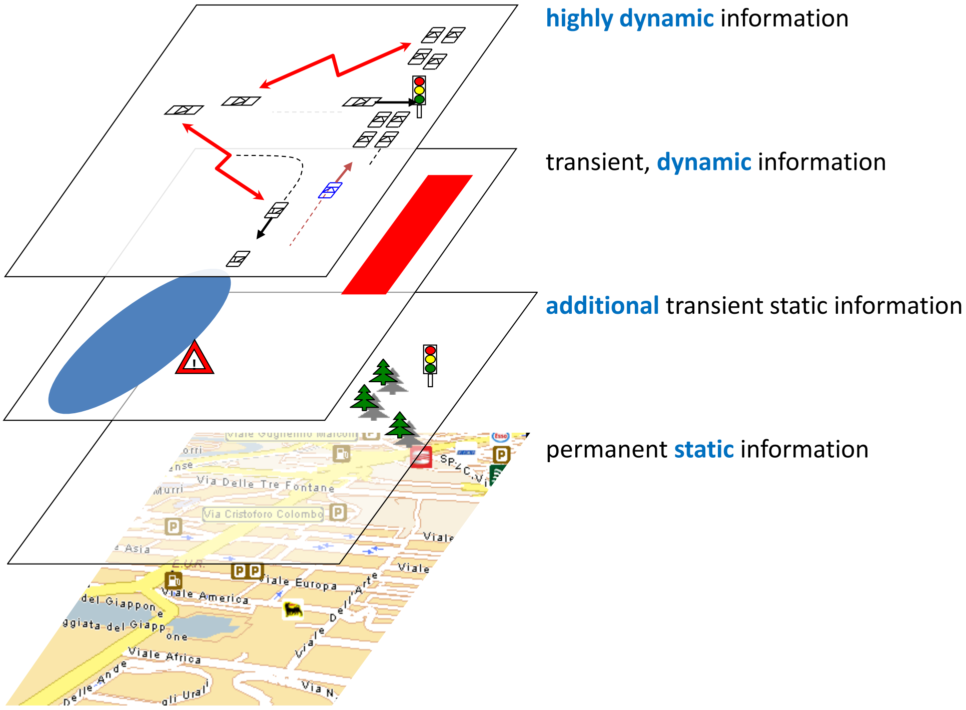


Figure 9 Local dynamic map, model-view from SafeSpot/CVIS

The model consist of 4 layers, with increasing dynamics:

- Layers 1 & 2 represents the road-topology and geometry. In a RIS, layer 1 is not necessarily available as a tiled image (however, could be optionally available for example to create a graphical image with content on a user-interface).
- Layers 3 & 4 together represent the objects (events, ITS Stations, …) which are using (and mapped onto) the road-topology. Layer 3 could contain event like weather situation or traffic information, whereas layer 4 could contain vehicle information.

These layers are geographically related to each other.
This model is frequently updated by the LDM as well as in time as in space (space is not relevant for RIS Facilities of iTLC).
The LDM removes outdated information (e.g. based on lifetime of a LDM Object) from the model.

In addition to the contents of referred standards, the following responsibilities are part of the LDM:

- Maintaining relationships between dynamical objects (like vehicles) and topology-elements (e.g. driving lanes) by map matching the objects onto the topology.
- Maintaining relationships between static objects (like signal groups, stop bars or inductive loop detection) and more dynamical objects (like vehicles) by using concepts like ‘reference track’.

Optionally, vendor specific services like aggregation of data could be available.

The data of the layers as described above are stored in the LDM as LDM Objects. All LDM Objects available to ITS Applications are described in the LDM Object Dictionary (see [Ref 13]).

Authorized ITS Application can act (dependent on applicable roles, see section 9.3.1.3, “Groups and Permissions”) as Data Provider as well as Data Consumer (see below).

9.3.5.1 Data Providers

Data Providers can request the storage of information in the LDM. The LDM must validate the provided information (e.g. relevance checking) before storing or updating a LDM Object.

For example, a specific instance of an ITS Application could be a TLC Adapter Application responsible for storing relevant TLC information available at the TLC-FI into the LDM. Therefore, the TLC Adapter Application must be able to act as a LDM Data Provider. This implies that during authorization, the TLC Adapter Application must be identifiable by the RIS Facilities as such, and the assigned role “LDM Data Provider” will be applied during validation of API-requests of the TLC Adapter Application.
The LDM is responsible for maintaining a consistent data set (for example in the case when different ITS Applications added events for overlapping geographical areas with different content).

9.3.5.2 Data Consumers

Data Consumers can use the LDM Object Dictionary to retrieve information about LDM Objects from the LDM by using subscribe/notify-pattern and spatial queries, giving access to:

- Map data & road topology
- State and relationships of dynamic objects (like ‘Car’)

See also the IRSIDD of RIS Facilities in [Ref 13].

9.3.5.3 LDM Object Dictionary

To allow ITS Applications vendor independent usage of the information support (as provided by the LDM) of the RIS Facilities of an iTLC, the LDM Object Dictionary is defined.

This dictionary [Ref 14] describes the minimal content of a LDM:

- Definition of mandatory LDM Object Types
- For each LDM Object Type the mandatory and optional properties are defined.

Besides the specification of LDM Objects in the LDM Object Dictionary, it should be possible for ITS Applications to add non-standard attributes to already defined LDM Object Types, allowing for vendor/project specific solutions.
ITS Applications are *not* able to add an LDM Object Type not defined in the LDM Object Dictionary.

9.4 Description of Interfaces

Below, the interfaces needed by and provided by the RIS Facilities are described.

9.4.1 RIS Facilities Interface (RIS-FI)

The RIS-FI interface implements the FA-SAP interface of the C-ITS reference stack as depicted in Figure 10 below:

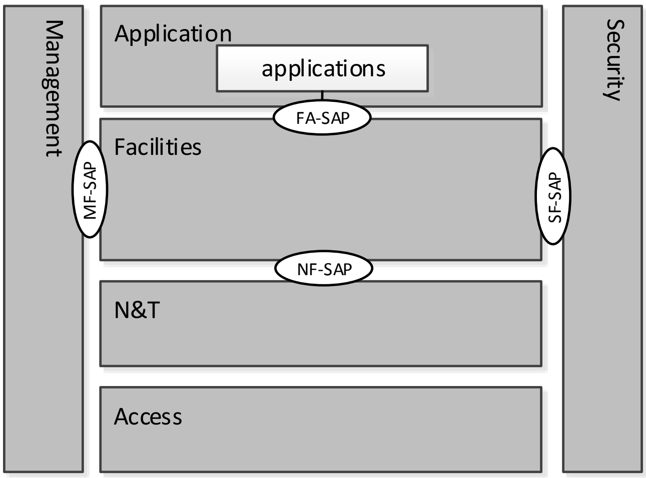


Figure 10 C-ITS Facilities layer

The RIS-FI can be used by multiple ITS Applications at the same time and can be used to add, update or delete LDM Objects.
The interface is IP-based.

Below, a high-level description of RIS-FI is given. The RIS-FI requirements are elaborated in [Ref 13], Beter Benutten Vervolg, project iVRI, Deliverable G1, IRS RIS Facilities.

9.4.1.1 RIS-FI high level description

The RIS-FI provides for the following:

- Authentication and authorization of ITS Applications
- Register and deregister of ITS Applications with RIS-FI
- Means to add, update and delete LDM Objects (by using LDM Objects, transmission of ITS G5 messages can be triggered, updated or deleted).
- Execution of spatial queries of LDM Objects
- Subscribe to data-changes of specified objects from the LDM Object Dictionary
- Allow for subscriptions on other data (like security permissions)
- Means to publish information (periodically, or event based) to subscribed ITS Applications
- Query RIS ITS Station information (e.g. synchronized time)

To allow for efficient information distribution of above listed information amongst ITS Applications, the RIS-FI supports the two data-distribution patterns:

- Subscribe/notify
- Request/reply

If required by the ITS Application, replies/notifications supplied by RIS-FI can be:

- filtered on 2 levels (as specified in CEN/ISO TS18750:2015):
    - first level filtering
    - second level filtering (optionally for RIS Facilities)
- Ordered output as described in ETSI EN 302 895, V1.1.1, “Ordering Data Request Results”
- Periodically (in case of notifications)

Only subscriptions and requests of authorized ITS Application are processed; otherwise, these are dropped (ITS Application is notified with ‘not-authorized’-reply).
The RIS-FI supports at least 10 concurrent ITS Applications.

9.4.1.2 QoS

ITS Application can request certain level of QoS by specifying a priority-level and application role.
See [Ref 13] for elaboration of levels and roles.

9.4.1.3 Alive checking

The RIS Facilities shall be able to determine whether an ITS Application is still connected and responding.
Non-responding of disconnected ITS Applications shall be detected and deregistered.
Checking is based on a bi-directional heartbeat-message (keep-alive); see for elaboration [Ref 13].

9.4.2 Interface “MF-SAP“

The interface with the Management entity is described in:

> ETSI TS 102 723-5: "Intelligent Transport Systems; OSI cross-layer topics; Part 5: Interface between management entity and facilities layer".

9.4.3 Interface “SF-SAP“

The interface with the Security entity is described in:

> ETSI TS 102 723-9: "Intelligent Transport Systems; OSI cross-layer topics; Part 9: Interface between security entity and facilities layer". *(not released at the time of writing this architecture)*

9.4.4 Interface “NF-SAP“

This is a vendor specific interface and is outside the scope of this document.

10 Functional view - Scenarios

10.1 Coexistence of several types of Traffic Algorithms

Current TLCs contain existing traffic control applications based on CVN-C. Some use-cases do not involve changing the traffic algorithms, to enable quick deployment with minimal impact in such situations, the existing traffic control application can stay in the TLC without using the TLC-FI interface as long as the TLC Facilities allow this. The architecture supports this, also an upgrade path is possible where existing CVN-C based traffic control applications can reside outside the TLC and interface with the TLC-FI by means of a CVNC-2-TLCFI adapter component.

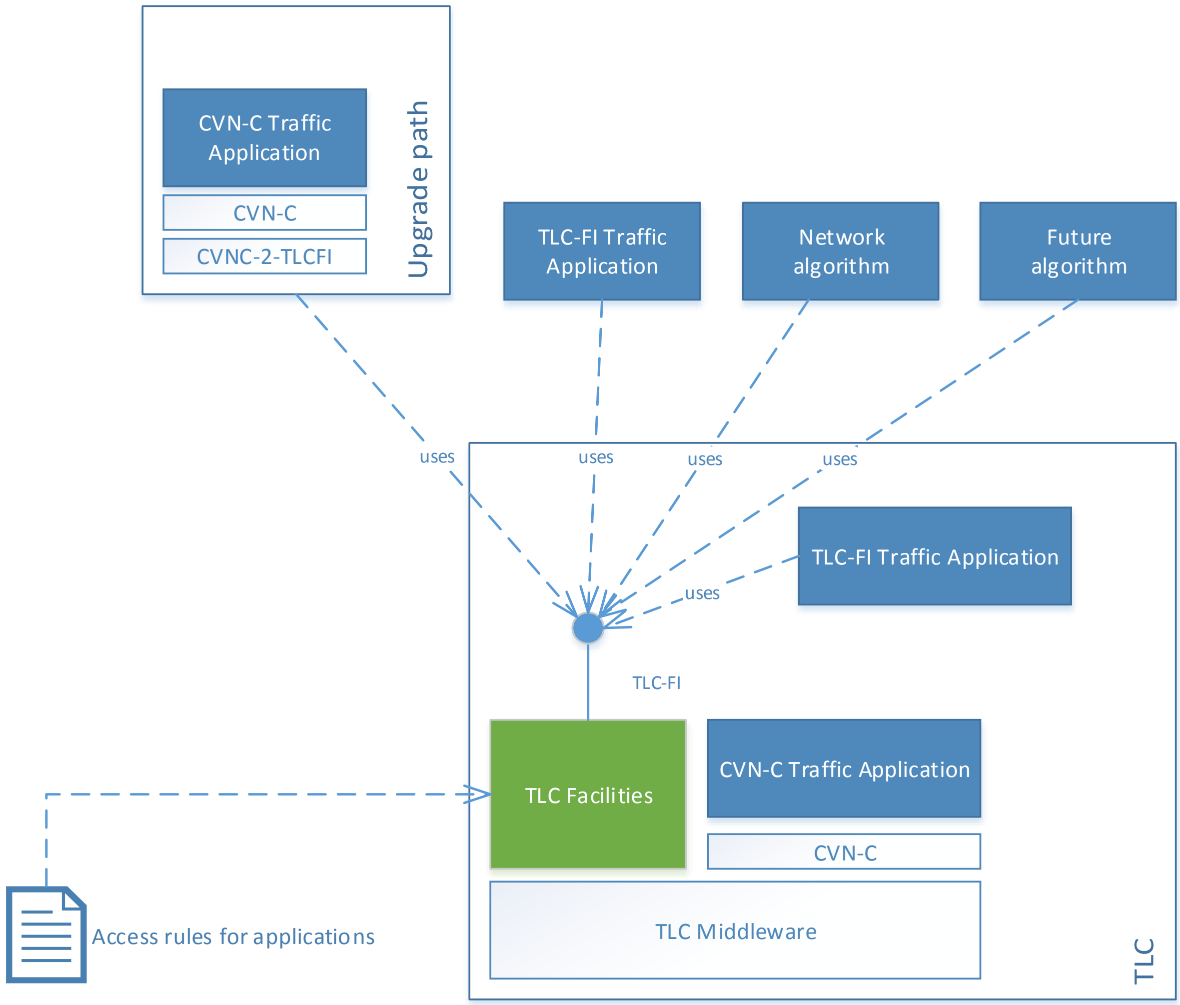


Figure 11 Co-existence of traffic control applications

10.2 Decouple ITS Application logic by using the LDM

ITS Applications can exchange/share information by using the LDM of the RIS Facilities.

One example is an ITS Application (TLC Adapter Application) dedicated to updating the LDM with current signal group states. Another ITS Application (Warning Application) may subscribe itself with the LDM to signal group state-events and vehicle-events. In case of a possible red-light negation, it may transmit a warning (DENM) by using the RIS Facilities.

In this way, there is no need for the Warning Application to subscribe with the TLC Facilities to the signal group state, although it is possible when needed.

10.3 Example of a Public transport application

The TLC receives KAR/detection messages from public transport vehicles (PTVs). The ITS Application (PTA) has subscribed to this information and receives this when it is received by the TLC and made available on the TLC-FI.

The RIS Facilities receives CAM messages from PTVs, the ITS Application has subscribed to this information and receives this when it is made available on the RIS-FI.

If the PTA wants to grant priority, it send this request to the TLC-FI. The ITS Control Application receives this information as it is subscribed to this information. The ITS Control Application handles the request and sends the result (status of the request and actuated state timing) to the TLC-FI.

An ITS Application (TLC Adapter Application) should be subscribed to this information and performs the needed actions. This can be the ITS Application that is responsible for updating all the SPAT message-data, but it can also be an application that only writes this particular information to the RIS-FI.

10.4 Add topology to LDM

Example scenario, where TLC Adapter Application uses TLC-FI to get Topology and add this to the LDM by using the RIS-FI:

1. Topology is stored in TLC
2. Topology is added to LDM by an ITS Application, using both TLC-FI and RIS-FI
3. RIS Facilities is responsible for periodically transmitting MAP-messages.

10.5 Broadcasting SPAT-messages

Example scenario, using a TLC Adapter Application and a Traffic Control Application (both variations of an ITS Application), assuming Topology is known and MAP- and SPAT-messages are already periodically transmitted:

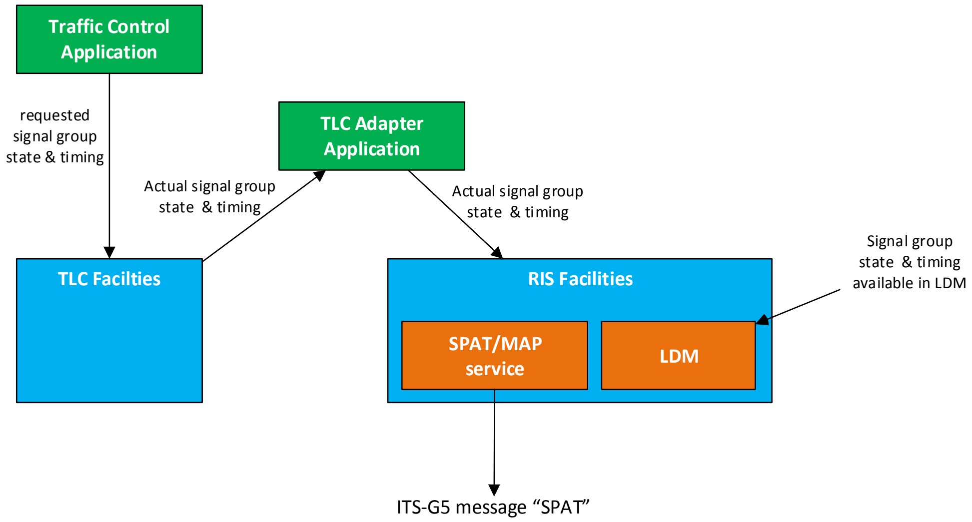


Figure 12 scenario: broadcasting SPAT-messages.

1. Traffic Control Application requests signal group states and timing by using TLC-FI
2. TLC Facilities controls signal groups according to request and within safety boundaries
3. TLC Facilities advertises on TLC-FI current signal group states and timing
4. TLC Adapter Application (subscribed to current signal group states and timing) receives update and provides the update states to the RIS-FI
5. RIS Facilities updates the information in the LDM
6. SPAT/MAP-service generates the used SPAT-payload by using updated signal group states.

11 Deployment view

This view describes the deployment of the functional elements of section 6 to run-time processing platforms and places these platforms in physical locations. The deployment views following in this chapter are intended as examples of deployment.

The following run-time processing platforms are identified:

- TLC ; Traffic light controller, from the point of view of this document this is the platform on which the TLC function resides including signal group actuation and detection
- TLC extension processor; Platform, which extends the TLC functionality in case the TLC cannot perform all the iTLC functions required
- RIS ; from the point of view of this document this is the platform on which the RIS function resides
- RIS modem ; Interfaces with the lower layers of the ITS-S stack
- ITS Application processor ; platform containing ITS applications
- Integrated iTLC processing platform ; platform containing both the TLC and RIS functionalities

The following physical locations are used in this section:

- Cabinet - physical compartment where the TLC is mounted
- Road-side - location somewhere next to the road
- Central processing location - central location not necessarily close to the road-side physical elements where functionality is deployed
- Central data and management location - location where services such as Traffic Management is executed and Traffic Data is deployed

The following functional elements must be deployed:

- ITS Application(s)
- TLC Facilities
- RIS Facilities

The following functional elements are not defined in section 6, but they have an important supporting role for the deployment variants and will also be identified in the deployment views:

- TLC middleware
- Network & Transport ; ITS-S stack layer
- Access; ITS-S stack layer

To which platforms and on which location these elements are deployed depends on amongst others the following factors. This list is by no means complete and a deployment scenario should be chosen based on the requirements for each individual location.

- Expected processing power needed by an element
- Expected network load and network latency requirements
- Ability of existing systems to be upgraded to iTLC capabilities. Some (older) systems may have restrictions that require addition of processor platforms. E.g. systems with insufficient processing power, security support or other facilities not conforming to the iTLC Architecture
- Required availability of a service

Depending on the function the ITS Application performs, its requirements on the processing platform and environment, it can be deployed on different locations and on different processing platforms.

11.1 Run-time platform models

In the following views, run-time processing platforms are shown in their physical location and functional elements are assigned to these platforms. The connections between the platforms are defined and variants of deployment is shown. To each connection, the relevant protocols that will use these connections depicted, for the RIS-FI interface the <<RIS-FI>> protocol, etc.

11.1.1 Base platform deployment

This view forms the base of all the coming views. It contains the essence of the deployment intended by the Intelligent TLC architecture, namely:

- A TLC containing TLC Facilities and ITS Applications
- A RIS containing RIS Facilities and ITS Applications
- An ITS Application processor containing ITS Applications

ITS Applications residing on any of these platforms can access the RIS and TLC Facilities.

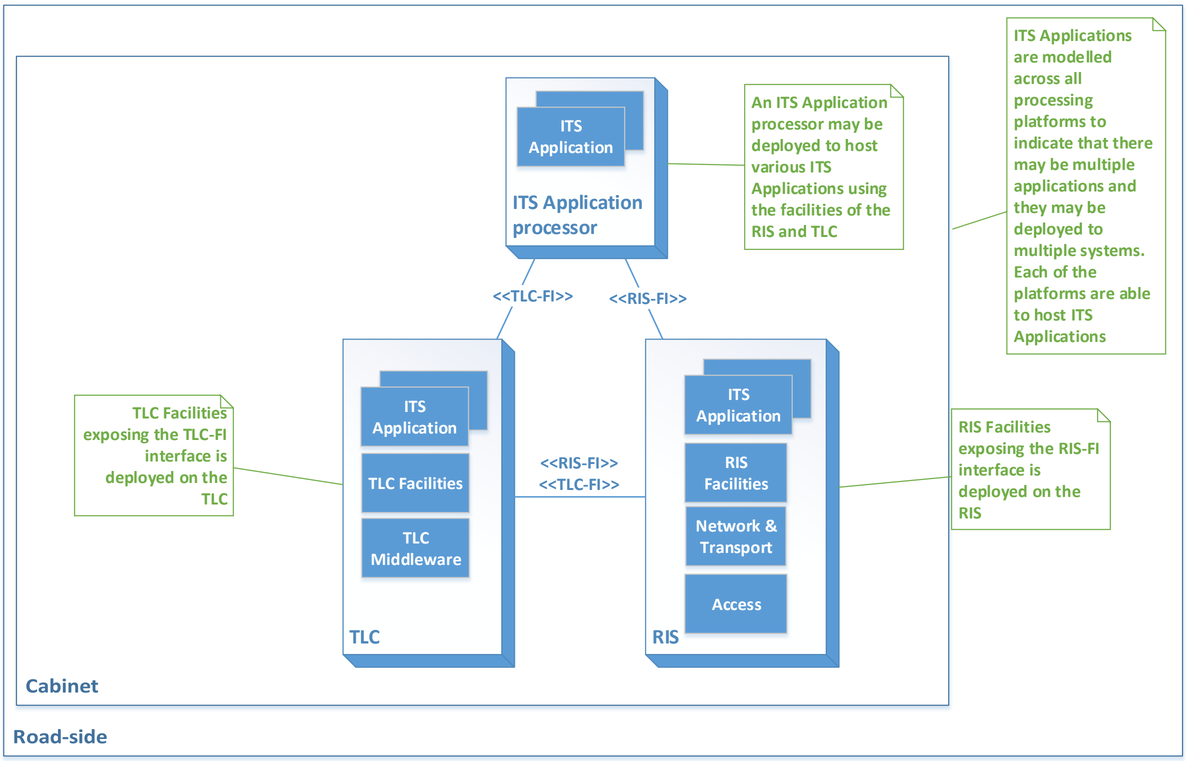


Figure 13 Deployment 1: Base platform deployment (TLC+RIS+ITS Application host)

11.1.2 Basic platform deployment

This view is a likely variant of 11.1.1 where a complete iTLC is deployed by adding a RIS to a TLC.

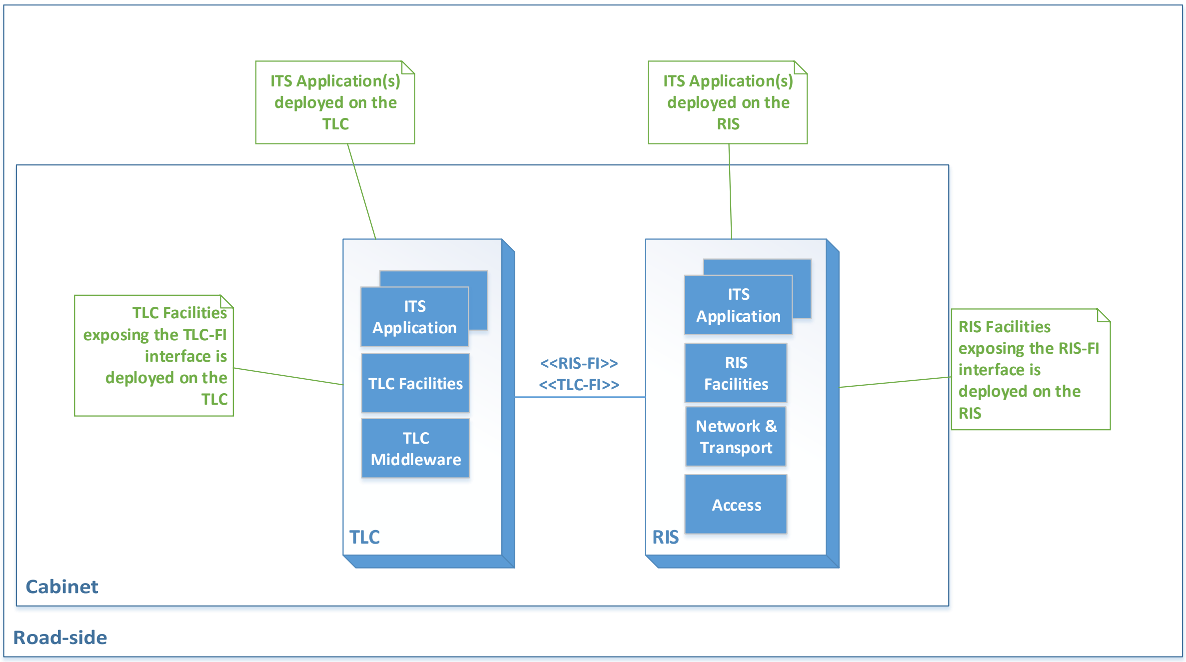


Figure 14 Platform 1: Basic platform deployment (TLC + RIS)

11.1.3 TLC and RIS deployment variants

This view is a variant of the base deployment view of Figure 13. The view shows that it is possible to deploy a TLC and/or RIS with the functional elements organized on different processing platforms.

Reasons for such a deployment may be:

- Existing deployed TLC cannot host ITS applications and TLC Facilities due to resource requirements
- RIS may need to have a technical separation to place the modem in a suitable location

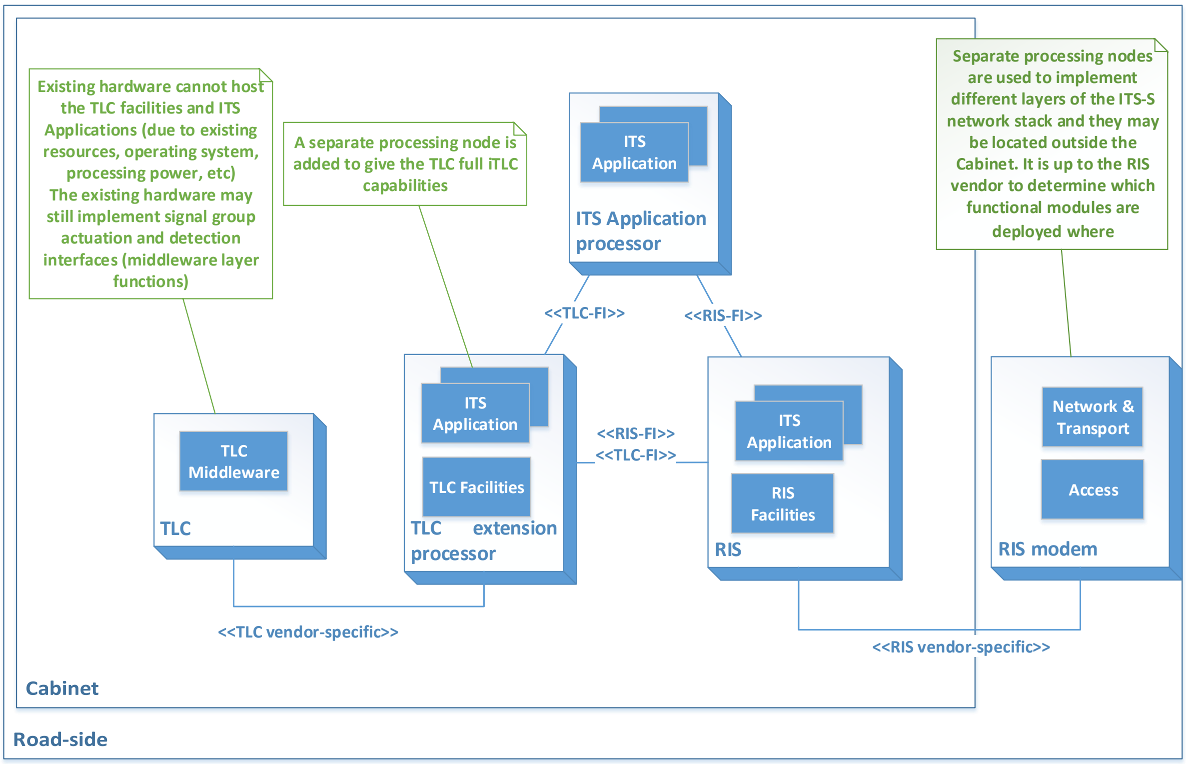


Figure 15 Deployment 2: Combined TLC and RIS deployment variants

11.1.4 Integrated iTLC processing platform

The previous views showed deployment with a clear separation between the TLC and RIS functionalities. Figure 16 shows a variant with an integrated TLC and RIS processing platform. This platform may internally consist of separate execution environments (e.g. for security reasons) and still a separate ITS Application processor may be deployed interacting with the integrated iTLC processing platform.

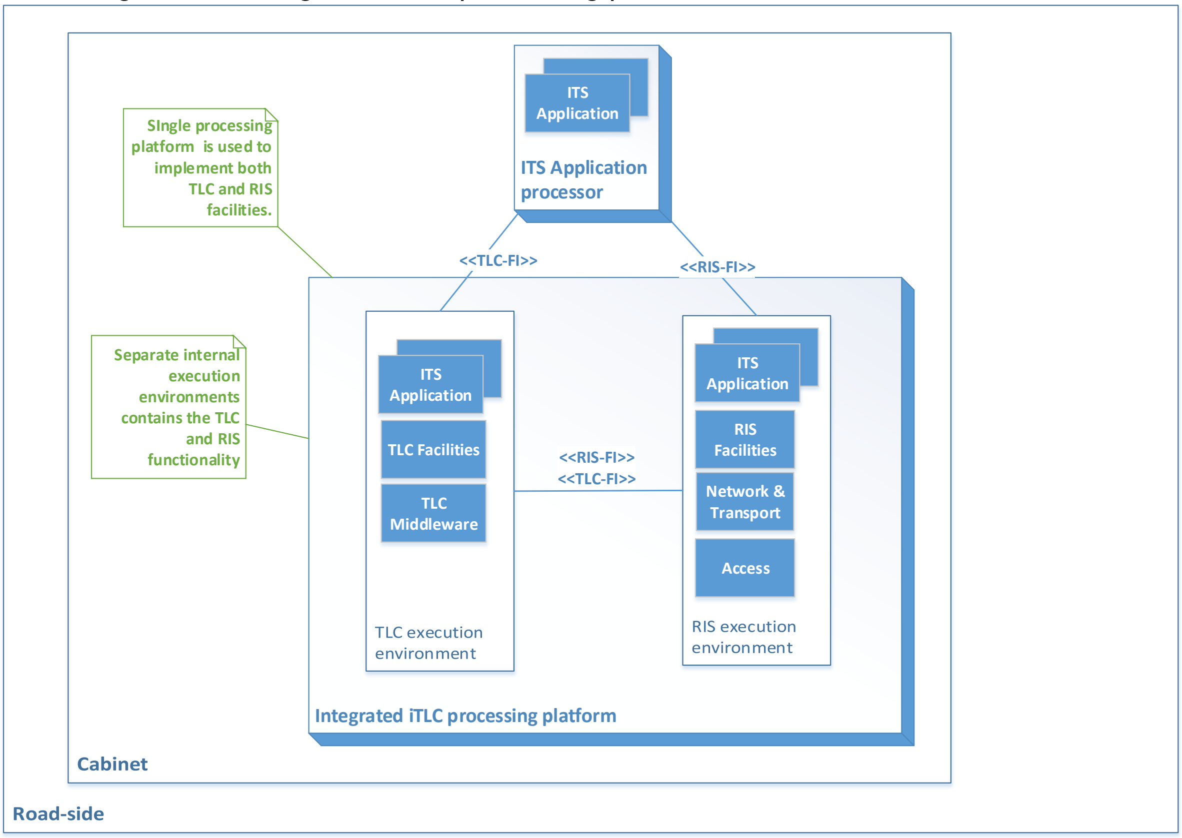


Figure 16 Deployment 3: Integrated iTLC processing platform

11.1.5 Central location deployment variant

Figure 17 shows a deployment variant where parts of the functionality is deployed in processing nodes in the central location.

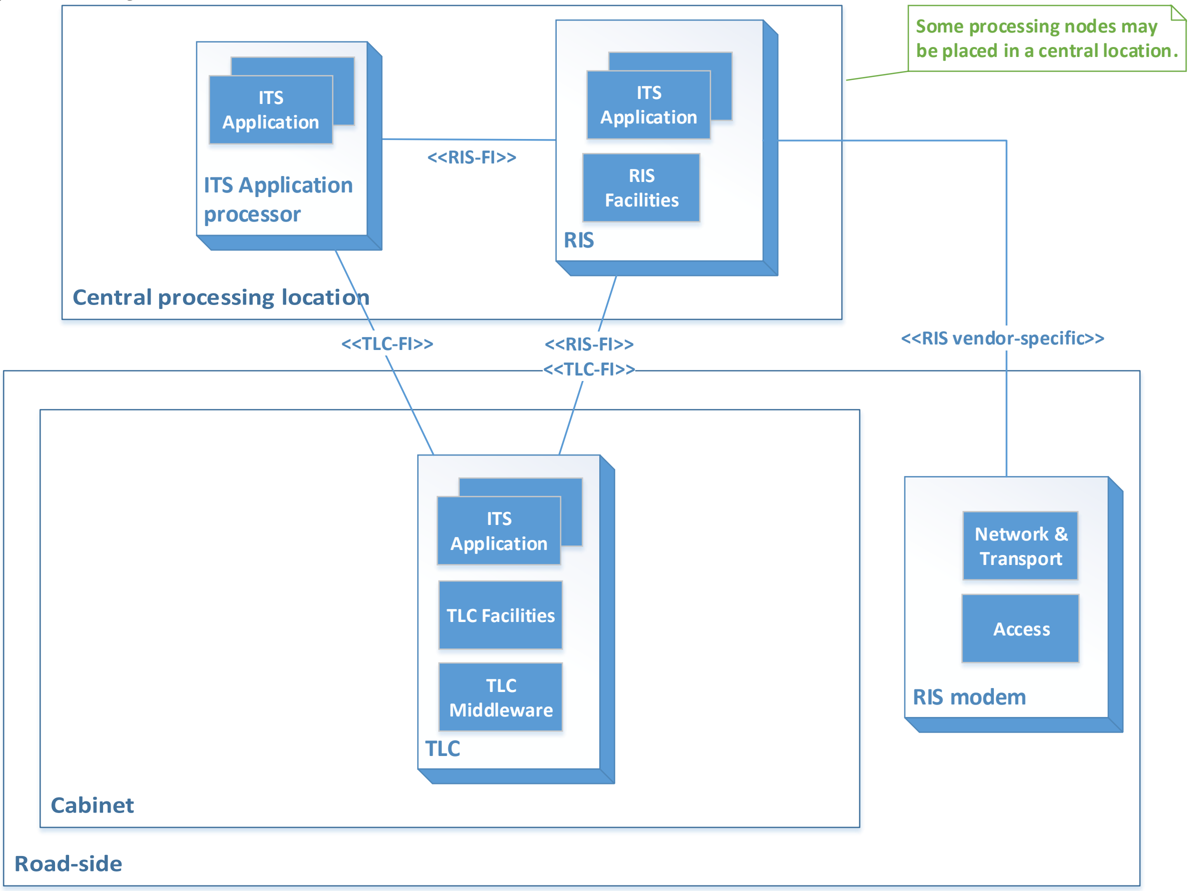


Figure 17 Deployment 4: Central deployment variant

11.2 Platform deployment scenarios

This section describes different scenarios applied to the deployment views of section 11.1. A specific concern is addressed and examples of deployment is shown.

11.2.1 CVN-C based Traffic Control Applications

The iTLC is a next step in the evolution of TLCs. The architecture allows for an evolutionary transition from the current situation with CVN-C based traffic control applications (marked in brown), such as CCOL 8 and RWS-C 1.1, into TLC-FI based ITS Applications. The following scenarios show possible deployment variants of CVN-C Applications applied to the base deployment view shown in Figure 13 of section 11.1.

Figure 18 shows a scenario with the deployment of a CVN-C Application on a TLC where the application has no access to the RIS facilities. Note that this is a limitation of the CVN-C Application and not of the TLC itself as any TLC being part of an iTLC deployment must be able to host an ITS Application.

The reason for such a deployment scenario can be that the CVN-C Application doesn't require any data exchange between the CVN-C Application and the RIS Facilities. This deployment scenario can be implemented when an Intelligent TLC is needed, but the current traffic application is sufficient. Additional ITS Applications can then still utilize the TLC and RIS facilities to implement specific use-cases.

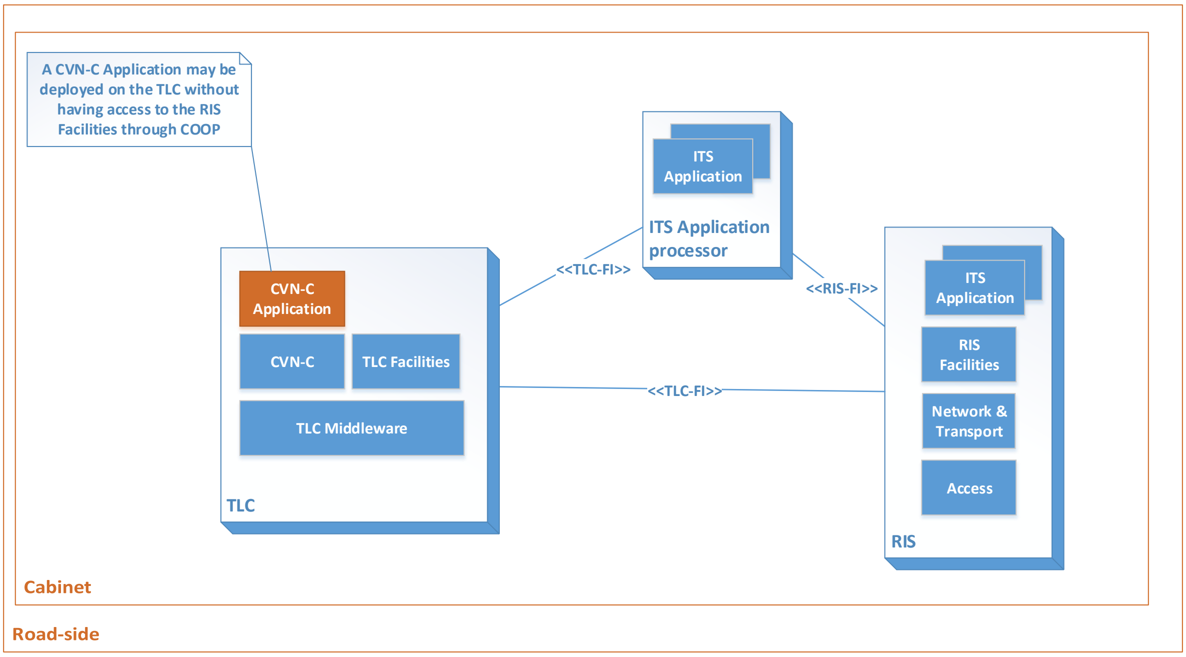


Figure 18 Scenario 1: Non-ITS CVN-C Application

Figure 19 shows the next iteration of the scenario in Figure 18, the same TLC now contains a CVN-C Application which is an ITS Application, it can access the RIS Facilities through the RIS-FI interface.

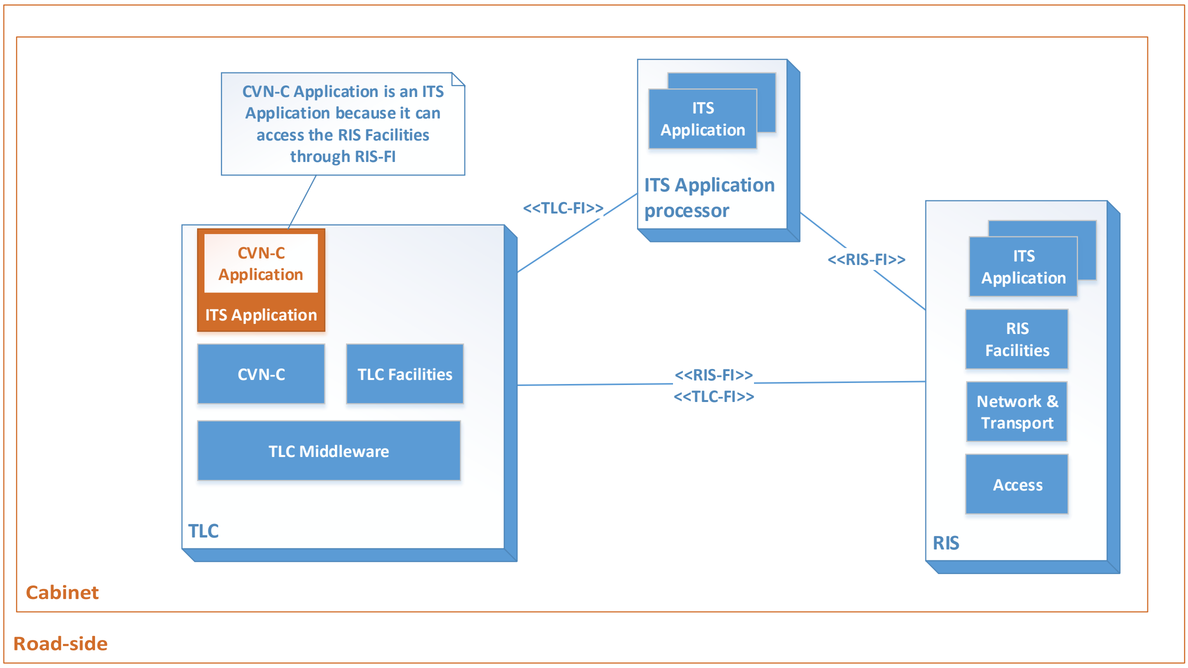


Figure 19 Scenario 2: CVN-C Application

Figure 20 shows a variant of Figure 19 where the TLC has been extended with an extra processing node as defined in the deployment variant of Figure 15. This deployment may still have a non-ITS CVN-C Application deployed to handle backup programs when the internal link goes down.

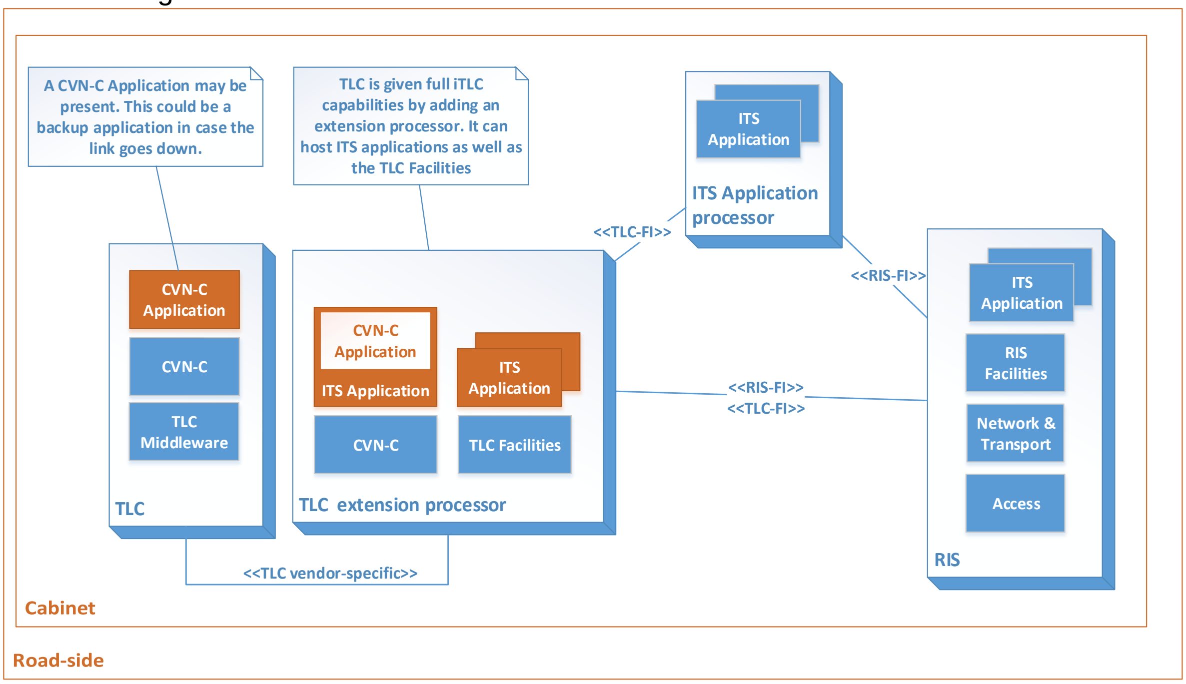


Figure 20 Scenario 3: CVN-C Backup Traffic Application

Figure 21 shows the deployment of a CVN-C Application on a TLC provides the TLC Facilities, but not the CVN-C interface. The CVN-C Application deployed on the TLC is created in such a way that it interacts with the TLC Facilities using TLC-FI. The view indicates that this can be done using an adapter layer CVNC-2-TLCFI.

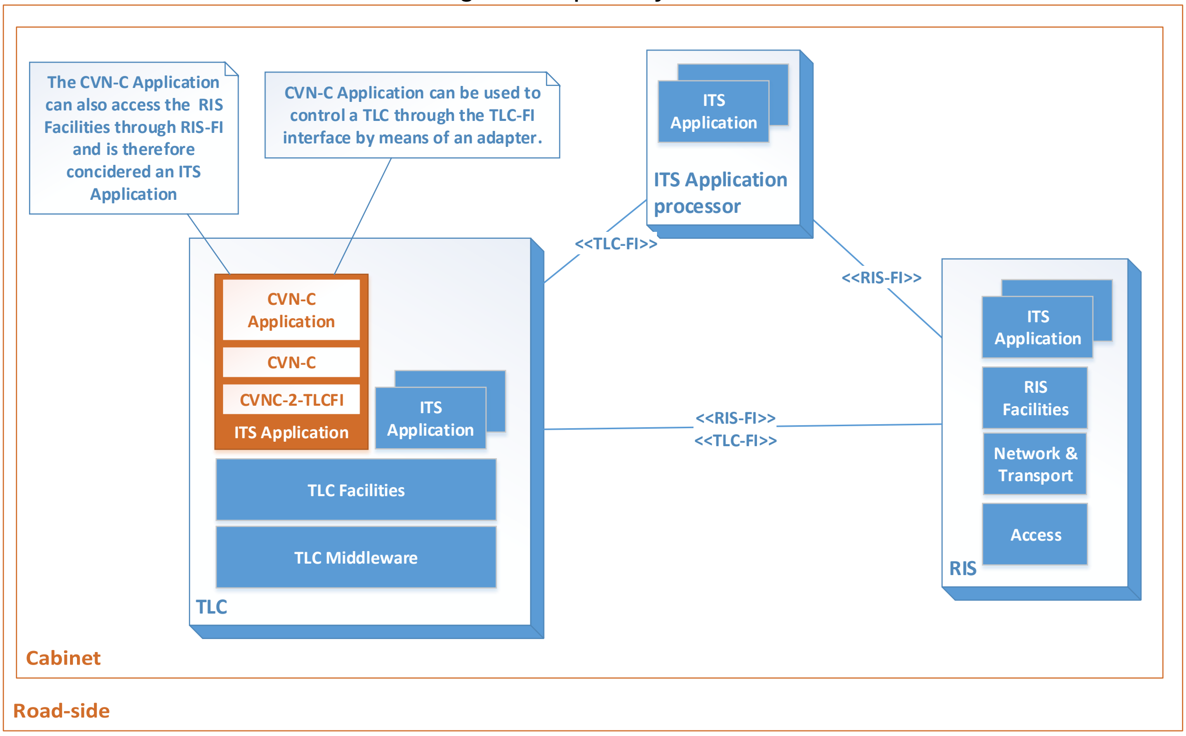


Figure 21 Scenario 4: CVN-C Application with TLC-FI adapter.

11.3 Network infrastructure

In the following views, the deployment of the functional elements on run-time platforms in their physical location defined in section 11.1 is shown in a network context. Connections identified are replaced by network connections and elements. For clarity, external elements are added to the views. Figure 22 shows a network infrastructure in case of mainly locally deployed components. Figure 23 shows a network infrastructure in case of more distributed deployed components.

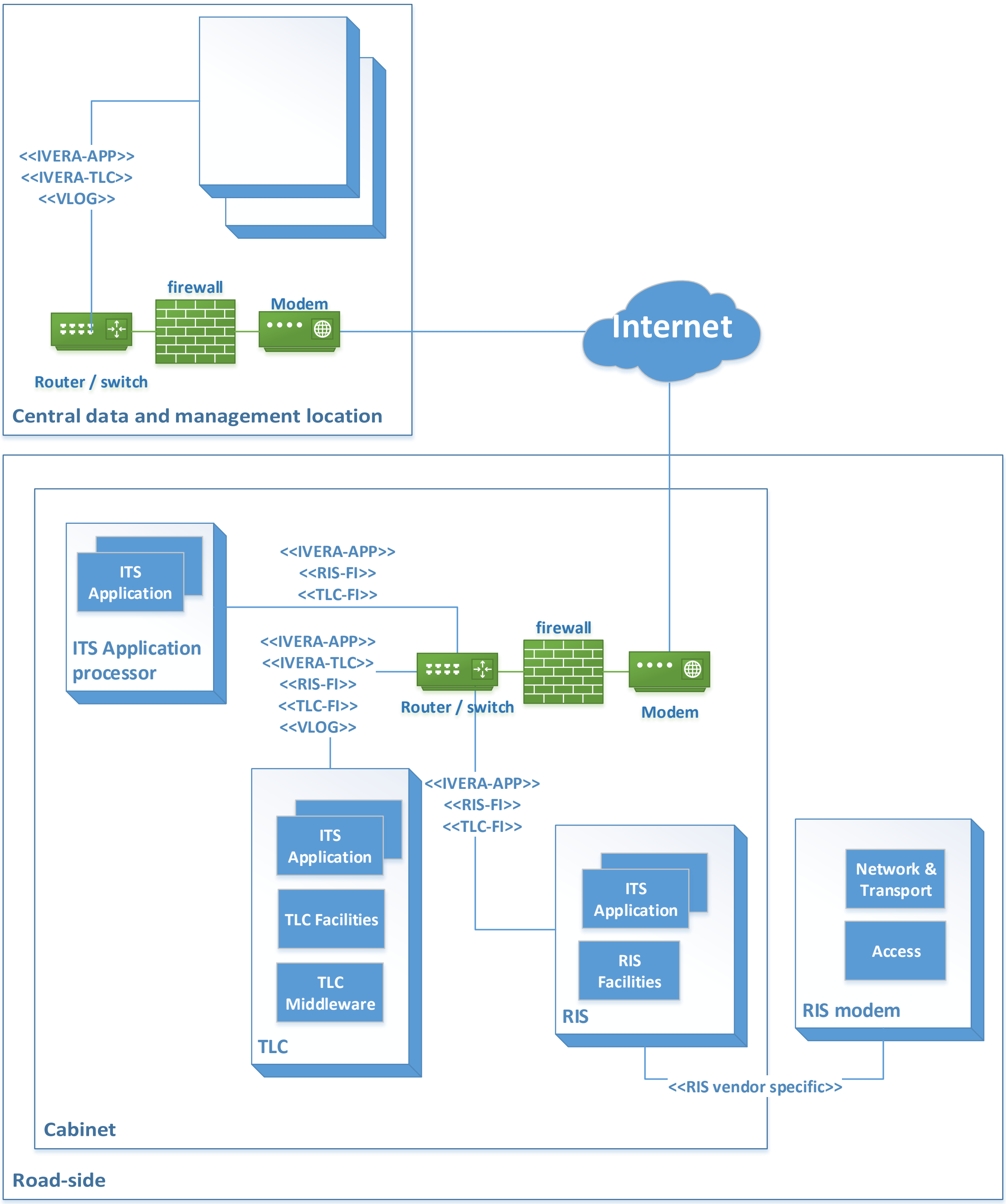


Figure 22 Network infrastructure road-side

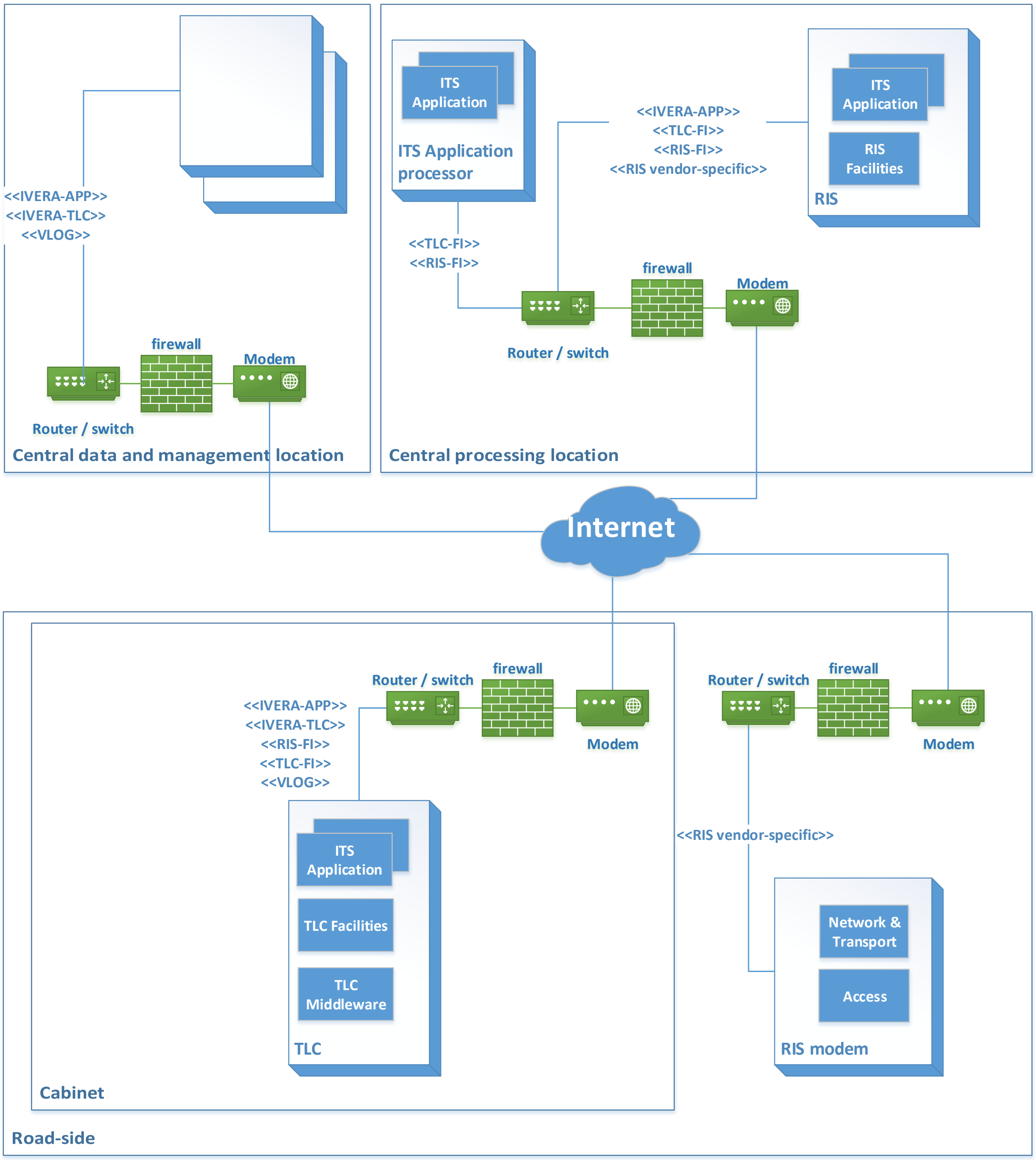


Figure 23 Network infrastructure central processing variant

11.4 Hosting ITS Applications

Within the deployment models described in this chapter, it is indicated that ITS Applications may be deployed on different hardware platforms:

- ITS Applications processor
- TLC
- RIS

It is possible that the vendor of an ITS Application is not the vendor of the platform, or the vendor of a platform offers as a service to host ITS Applications on their platform.

For this purpose, the vendor of a processing platform shall publish the facilities offered by the platform along with the requirements and limitations imposed on the ITS Applications.
At all times, it shall be clear who is responsible for the security established in this architecture based on the requirements and facilities offered.

12 Information view

The Information view of the system defines the structure of the system's stored and transient information and how related aspects such as information ownership, flow, currency, latency and retention will be addressed.

The functional view defines three main functional components, the TLC Facilities, RIS Facilities (including LDM) and ITS Applications. From the point of view of this architecture these functional components each run in their own process with inter-process communication defined by the TLC-FI and RIS-FI interfaces, see also chapter 13.

From their role these components contain different sorts of data items.

- RIS Facilities contains a LDM as local data exchange and storage point.
- TLC Facilities contains TLC objects about the intersection. This is typical data such as signal group states and detection.
- ITS Applications are responsible for managing their local data. That means e.g. initializing and storing of parameters. Information management within ITS-Application is highly application specific and outside the scope of this view.

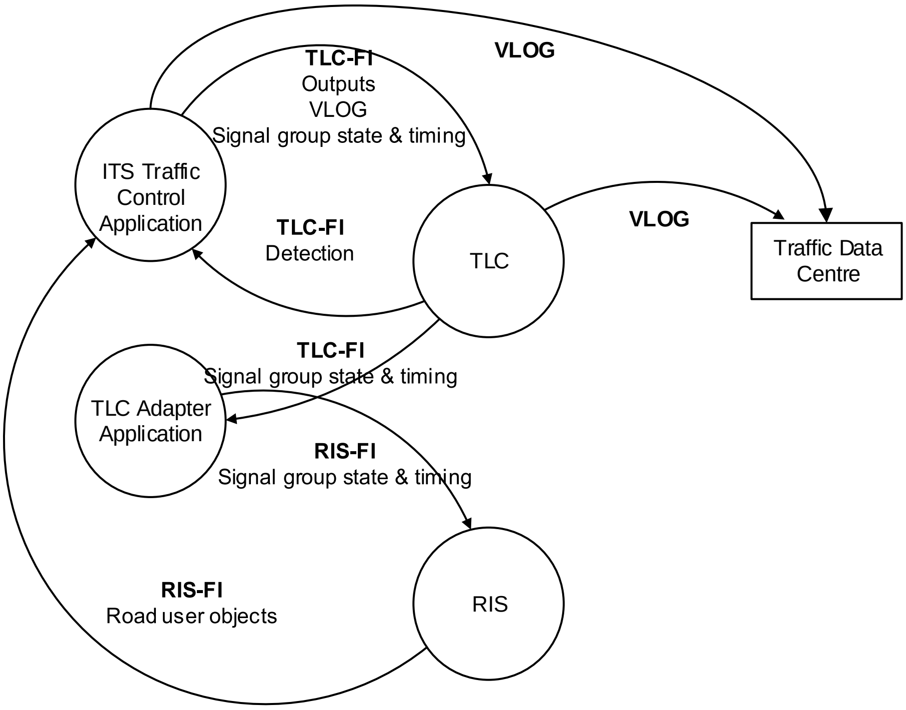


Figure 24 Example data flows

Data flows are implemented by messages on the RIS-FI and TLC-FI. The messages are initialized by an ITS Application. The VLOG interface is also depicted to describe in this architecture.

12.1 TLC

The TLC provides the following interfaces:

- TLC-FI
- IVERA-TLC
- VLOG

The TLC provides data objects related to

- Traffic signals
- Detection
- Inputs
- Outputs
- Multifunctional variables

A detailed description can be found in chapter 8.

12.1.1 Startup state

The TLC Data Objects are available after startup. The time to build up the actual information depends on detection- and input unit start-up times. In general these units have a shorter start-up time as the TLC-FI itself. Exceptions on this can be e.g. video detection systems. Outputs are initialized at an defined state so the related object data is also available. The objects are available at the moment TLC-FI is accessible. Because the VLOG information is created by an ITS Application, the VLOG-stream will become available after an ITS Application is connected to TLC-FI and is “in control”. IVERA-TLC will also be accessible after startup.

12.1.2 Data storage

The TLC objects are stored in volatile memory and initialized at startup.
Settings, configuration, logs and topology are stored in persistent memory.

12.1.3 Data throughput

Two aspects are relevant: latency and message load. Message load consist of message count and data volume. A high message load will normally have a negative impact on the latency. The latency requirements are mentioned in section 14.1.1. How is handled with load conditions is mentioned in section 14.1.3.

12.1.4 VLOG Data

A traffic control application can create VLOG data. Streaming VLOG data is provided to the TLC or directly to the Traffic Data Centre. The TLC takes the streaming VLOG data from the traffic control application that is in control and makes it available at the VLOG interface. This way the TLC can assure that the VLOG data comes from the appropriate traffic control application.

12.2 RIS

The RIS provides the following interfaces:

- RIS-FI
- RIS-MGMT

The RIS provides data objects related to

- ITS Stations
- Road objects

The objects are stored internally in a LDM. A detailed description can be found in section 9.3.5.

12.2.1 Startup state

The LDM may not contain highly dynamic information at startup. ITS station objects will be created after receiving this information. Typically, these objects are stored in volatile memory. If a LDM is restarted and the lifetime of these objects is not expired a LDM might contain these objects. This way a valid view is available at startup. The other solution is to wait for messages to build up a new view. The time to realize this new view depends on the update frequency of the object. For example a CAM message is send minimal every second resulting in an object into the LDM within a second.
Static objects will be available.
Special care should be taken for semi dynamic information. The RIS is not able to handle this correctly because updates during the time the LDM was not available can be missed. Semi dynamic information will be stored in persistent memory. At startup, the lifetime of the objects is evaluated and processed. This means that a data provider should resend updates that are not confirmed by the RIS-FI. (Messages that are send during the time the RIS-FI was not available.) The RIS-FI should store semi dynamic information before sending a confirmation.

12.2.2 Data storage

The storage capacity should be enough to contain minimal the expected number of objects in the area that should be covered. In normal situations calculate with 5 meters occupied space for each ITS Station and take the total length of all the corridors in the area to calculate the expected number of objects. Objects related to infrastructure are known and appropriate storage need to be available. Depending the local situation, also other (human) ITS-stations/objects may be expected, an assumption should be made with respect to the data storage. The data storage might be evaluated after some time of use.

Three types of data objects are considered: Highly dynamic information,
Semi-dynamic information and Static information. Each type of object may have other data storage requirements. The implementation and so the storage is Vendor dependent.
A implementation can be:
Static information - Stored in persistent memory.
Semi-dynamic information - Stored in volatile memory and persistent memory.
Highly dynamic information - Stored in volatile memory.

12.2.3 Data throughput

The LDM is provided with information from the ITS-G5 interface and RIS-FI. This can theoretically result in more than 1000 updates per second, but the messages are aggregated in the LDM Objects resulting in less object updates. At the RIS-FI messages are processed with highly dynamic information at highest priority and static information at lowest priority.
Two aspects are relevant: latency and message load. Message load consist of message count and data volume. A high message load will normally have a negative impact on the latency. The latency requirements are mentioned in section 14.1.2 How is handled with load conditions is mentioned in section 14.1.3.

12.3 ITS Application

From the view of the architecture an ITS Application does not store data, however it can have data for own use. The ITS Application should arrange storage and handling of this data. In case of a CVN-C Application this includes persistence of parameters by the CVNC-

2-TLCFI adapter component. The IVERA-APP or another interface can be used to manage data and settings.
An ITS Control Application can generate VLOG data and makes this available on its VLOG interface.

13 Concurrency view

13.1 Processes

Three separate concurrently running processes are distinguishable.
Inter-process communication is defined by the TLC-FI and RIS-FI interfaces.

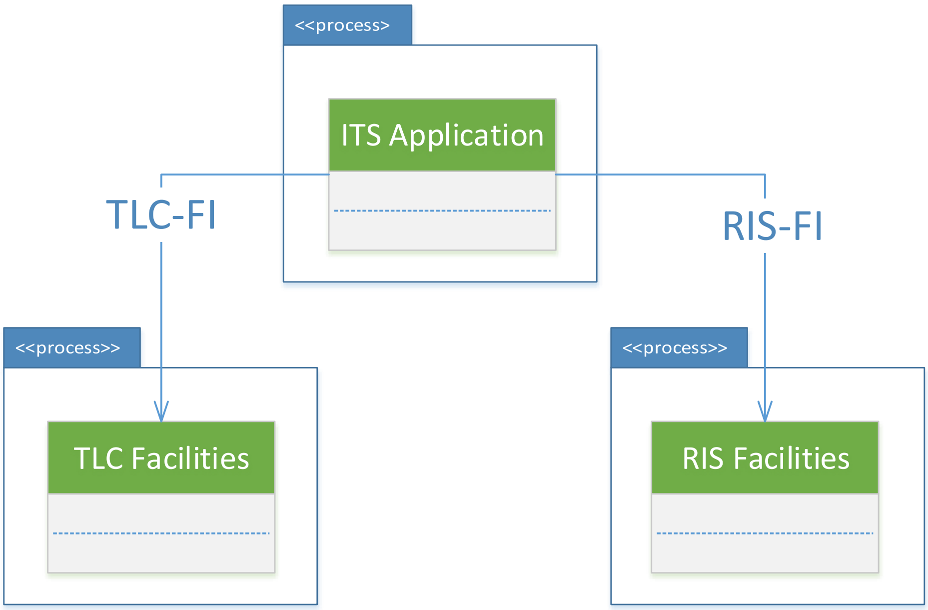


Figure 25 Functional block - process mapping

Each of these main functional blocks may consist of several internal functional blocks. These internal functional blocks may require internal separate processes or threads and consequently inter-process communication. The internal architecture is beyond the scope of this architecture description.

13.1.1 ITS Application

This process may use the TLC-Facilities and/or RIS-Facilities to implement an ITS-use case.
It runs concurrent of other ITS Applications.
In this architecture, there is no explicit interface defined between ITS Applications; information exchange is done by using either the TLC-FI or the RIS-FI.

13.1.1.1 ITS Application Management

The ITS Application may provide the Traffic Management Centre with access to read and write the IVERA Objects through the IVERA-APP interface. There may be multiple TMC's connected simultaneously as IVERA-APP clients. The IVERA-APP acts as an asynchronous service, allowing request/replies as well as notifications:

- Each request is handled asynchronous of other requests.
- Notifications are sent asynchronously to subscribed IVERA-APP clients.

IVERA Objects are not protected against being changed by multiple sources simultaneously, nor are there any checks within the IVERA-APP protocol to guarantee consistency within or between objects. IVERA-APP clients are responsible for consistency.

13.1.2 TLC Facilities

There is one instance of this process per iTLC available; it can be used by multiple ITS-Applications.

13.1.2.1 TLC Facilities Interface

An ITS Application can use services provided by TLC Facilities by using the TLC-FI.
The TLC-FI acts as an asynchronous service, allowing request/replies as well as notifications:

- Each request is handled asynchronous of other requests.
- Notifications are sent asynchronously to subscribed ITS Applications.

Timeouts on requests are handled by the ITS Application issuing the request.
Non-responding or disconnected clients are detected by the TLC-Facilities by using a periodic heartbeat-message.

13.1.2.2 TLC Management

The TLC Management functional block provides the Traffic Management Centre with access to read and write the IVERA Objects through the IVERA-TLC interface. There may be multiple TMC's connected simultaneously as IVERA-TLC clients. The IVERA-TLC acts as an asynchronous service, allowing request/replies as well as notifications:

- Each request is handled asynchronous of other requests.
- Notifications are sent asynchronously to subscribed IVERA-TLC clients.

IVERA Objects are not protected against being changed by multiple sources near-simultaneously, nor are there any checks within the IVERA-TLC protocol to guarantee consistency within or between objects. IVERA-TLC clients are responsible for consistency.

13.1.3 RIS Facilities

There is at least one instance of this process per iTLC available; it can be used by multiple ITS-Applications.
An ITS Application can use services provided by TLC Facilities by using the TLC-FI.
The TLC-FI acts as an asynchronous service, allowing request/replies as well as notifications:

- Each request is handled asynchronous of other requests.
- Notifications are sent asynchronously to subscribed ITS Applications.

Timeouts on requests are handled by the ITS Application issuing the request.
Non-responding or disconnected clients are detected by the TLC-Facilities by using a periodic heartbeat-message.

14 System qualities

“Facilities” used below without being preceded by “RIS” or “TLC” is assumed to apply to both RIS and TLC Facilities.

14.1 Performance and scalability

Latency requirements are depicted and described below.
Subsequently, other performance- and scalability-requirements are described.

14.1.1 Latency requirements TLC & TLC Facilities

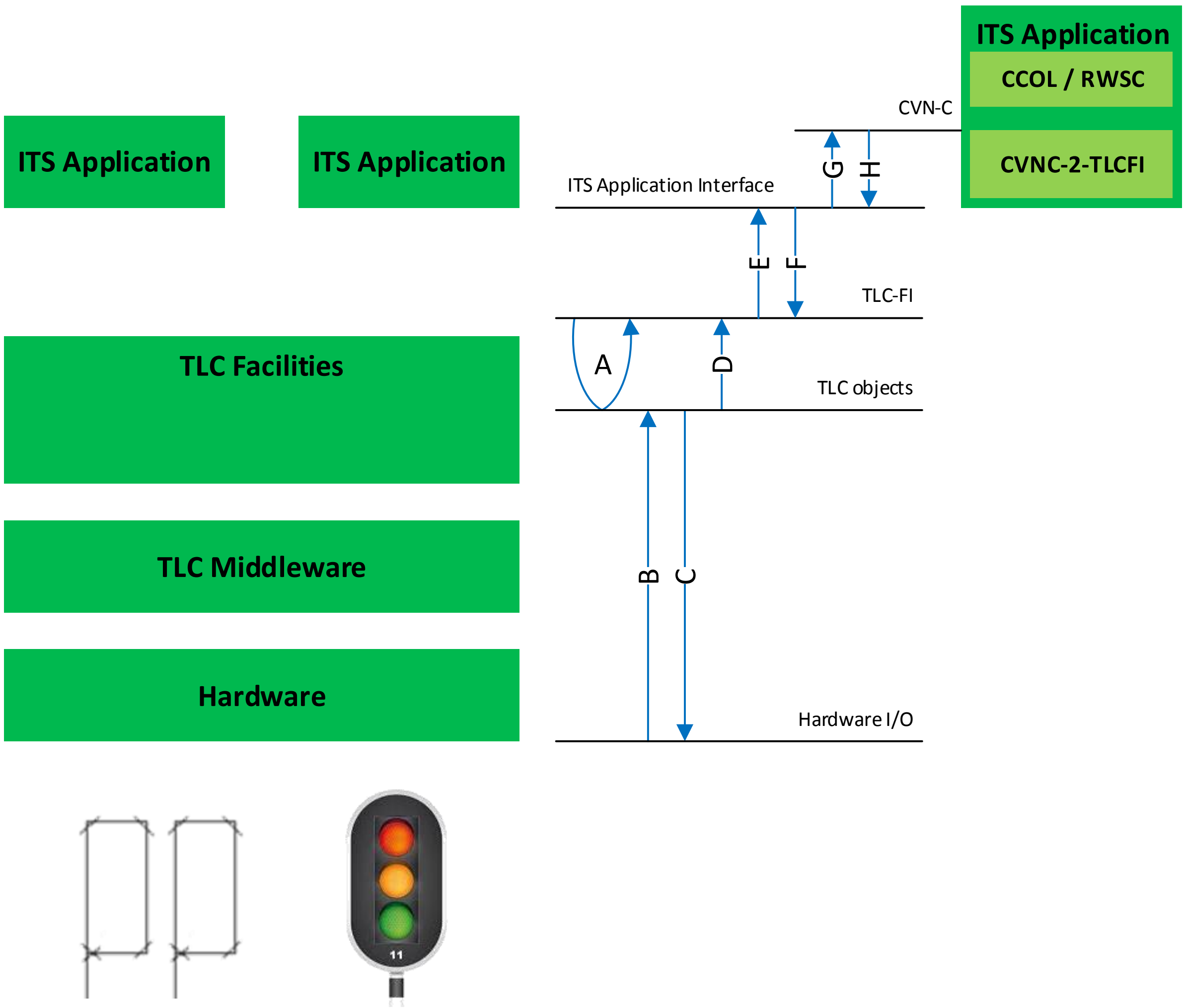


Figure 26 Latency requirements – overview TLC & TLC-FI

Latency requirements are documented in the table below, the paths defined are shown in Figure 26.

ID	Path	Requirement	How Met
		TLC	
QA_PERF_001	A	Latency between request at TLC-FI and resulting response at TLC-FI must be known. Includes checking permissions & data-validity checking and processing (updating internal TLC objects).	Maximum latency: 100 ms. See [Ref 15].
QA_PERF_002	B	Latency between change of hardware inputs and internal state of TLC objects.	Several performance classes are defined in [Ref 15] The applicable class is vendor specific. Applicable performance class can be requested from each TLC-FI.
QA_PERF_003	C	Latency between updated internal TLC objects (like 'requested output-states') and actual changed hardware outputs.	Several performance classes are defined in [Ref 15] The applicable class is vendor specific. Applicable performance class can be requested from each TLC-FI.
QA_PERF_004	D	When ITS provider applications change TLC objects of the TLC Facilities, the updated TLC object shall be made available (published) to consumers within specified time.	Maximum latency: 50 ms. See [Ref 15].
QA_PERF_005	E	Maximum latency of transportation of information from TLC-FI to ITS Applications.	Depends on used network-layer. Advise: 75 ms
QA_PERF_006	F	Maximum latency of transportation of information from an ITS Application to TLC-FI.	Depends on used network-layer. Advise: 75 ms
QA_PERF_007	G	Maximum latency of optionally used CVNC-2-TLCFI-adapter	Maximum latency: 20 ms.
QA_PERF_008	H	Maximum latency of optionally used CVNC-2-TLCFI-adapter	Maximum latency: 20 ms.
QA_PERF_009	x	Latency between status change of signal group and internal state of TLC object. NB: includes the latency in the exceptional case the safety-facility kicks in	Maximum latency: 50 ms.

14.1.2 Latency requirements RIS Facilities

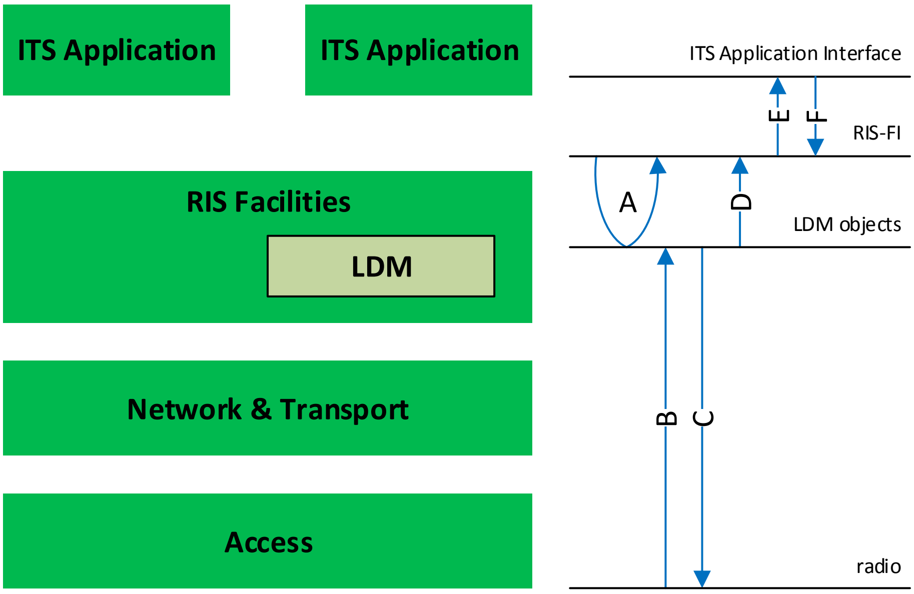


Figure 27 Latency requirements – overview RIS & RIS-FI

Latency requirements are documented in the table below, the paths defined are shown in Figure 27.

ID	Path	Requirement	How Met
		RIS	
QA_PERF_009	A	Latency between request at RIS-FI and resulting response at RIS-FI. This includes checking permissions, validation of request-data, processing and transmission of respond at RIS-FI	Maximum latency: 100 ms. See [Ref 13]
QA_PERF_010	B	Maximum latency between the reception of an ITS-G5 message and the update of a corresponding LDM Object	Maximum latency: 70 ms. Vendor specific implementation in RIS.
QA_PERF_011	C	Maximum latency between an update/addition of a LDM Object and the delivery of an ITS-G5 message at the radio-modem	Maximum latencies: SPAT : 100 ms. MAP : 100 ms. DENM : 100 ms. IVI : 100 ms. Vendor specific implementation in RIS.
QA_PERF_015	D	Maximum latency between an addition/update/delete of a LDM object and a transmitted notification to subscribed ITS Applications	Maximum latency: 50 ms. See [Ref 13].
QA_PERF_016	E	Maximum latency of transportation of information from RIS-FI to ITS	Depends on used network-layer. Advise: 75 ms.

ID	Path	Requirement	How Met
		Applications.	Also part of SPAT-latency scenario, see section 14.3.
QA_PERF_017	F	Maximum latency of transportation of information from an ITS Application to RIS -FI.	Depends on used network-layer. Advise: 75 ms. Also part of SPAT-latency scenario, see section 14.3.

14.1.3 Other performance and scalability requirements

ID	Requirement	How Met
	System	
QA_PERF_018	The architecture must guarantee the system quality of service faced with a heavy load. For instance, some ITS Application subscribes to “the world” and wants to know about “the world” every 100ms while Traffic Control Applications may suffer from this.	Implement measures: • Quality of Service • Application update frequency • Content characteristics See [Ref 15].
QA_PERF_019	The Facilities shall be synchronized with UTC time with accuracy of 100 ms.	When a time difference > 100 ms with UTC is encountered, the facilities shall achieve the proper time within 10 seconds preferable in a gradual way without making any time jumps. In case this is not possible, the local time shall be immediately set to a new time indicating this in appropriate logging (e.g. VLOG). Use standardized time sources. For example GPS or NTP-servers. Specific case: when TLC Facilities is not time-sync’ed (deviation > 100 ms), no SPAT timing estimates shall be published by TLC Facilities. Sanity-check on requests/replies: include absolute timestamp in certain messages. See also IRSIDD’s [Ref 13] and [Ref 15].

ID	Requirement	How Met
QA_PERF_020	The RIS-FI and TLC-FI shall conserve processing power and network bandwidth as much as possible.	Only changes to relevant information is sent to subscribed applications, repeated identical data is not needed by the interfaces. Information is filtered. See also IRSIDD's [Ref 13] and [Ref 15].
	TLC Facilities	
QA_PERF_021	TLC-FI shall be able to handle • a number of concurrent ITS applications • a number of active subscriptions (per ITS application and total) • a number of requests/replies per second (per ITS application and total) • a number of notifications per second (per ITS application and total)	The actual numbers the interface must be able to handle is documented in the IRSIDD, see [Ref 15]
	RIS Facilities	
QA_PERF_025	RIS-FI shall be able to handle • a number of concurrent ITS applications • a number of active subscriptions (per ITS application and total) • a number of requests/replies per second (per ITS application and total) • a number of notifications per second (per ITS application and total)	The actual numbers the interface must be able to handle is documented in the IRSIDD, see [Ref 13]
QA_PERF_026	At least, the RIS Facilities shall be able to process at least 250 received ITS-G5 messages per second (for rationale, see Appendix A)	Vendor specific implementation

14.2 Security

ID	Requirement	How Met
	System	
QA_SEC_001	Each ITS Application must be authenticated and authorized by the Facilities before being allowed to access other functions of the RIS-FI or TLC-FI	See section 9.3.1 and 8.1
QA_SEC_002	The Facilities may revoke the authorization of an ITS Application while an ITS Application is connected	See section 9.3.1 and 8.1
QA_SEC_003	It shall be possible to enforce encryption of each connection between an ITS Application and RIS-FI or TLC-FI. When encryption is required, authentication and authorization must be done within an encrypted communication channel.	The TLC and/or RIS Facilities can apply security policies such as encryption using TLS for a connected application. An application may then only connect after encrypting its communication accordingly. No encryption may be necessary when the iTLC and all of its components are deemed to be in a trusted environment (inside cabinet, VPN). See section 9.3.1
QA_SEC_004	RIS-FI or TLC-FI requests of ITS Applications are processed according to the actual permissions of the calling ITS Application	See section 9.3.1 and 8.1
QA_SEC_005	Results of registration-requests shall be logged	Accessible by management interface See section 8.2
	TLC Facilities	
QA_SEC_007	After successful registration of an ITS control application, during its lifetime (and connection with TLC-FI), the TLC Facilities denies subsequent registration requests of the same ITS control application instance.	See section 8.3
	RIS Facilities	
	N/A (see "Facilities" above)	

14.3 Safety

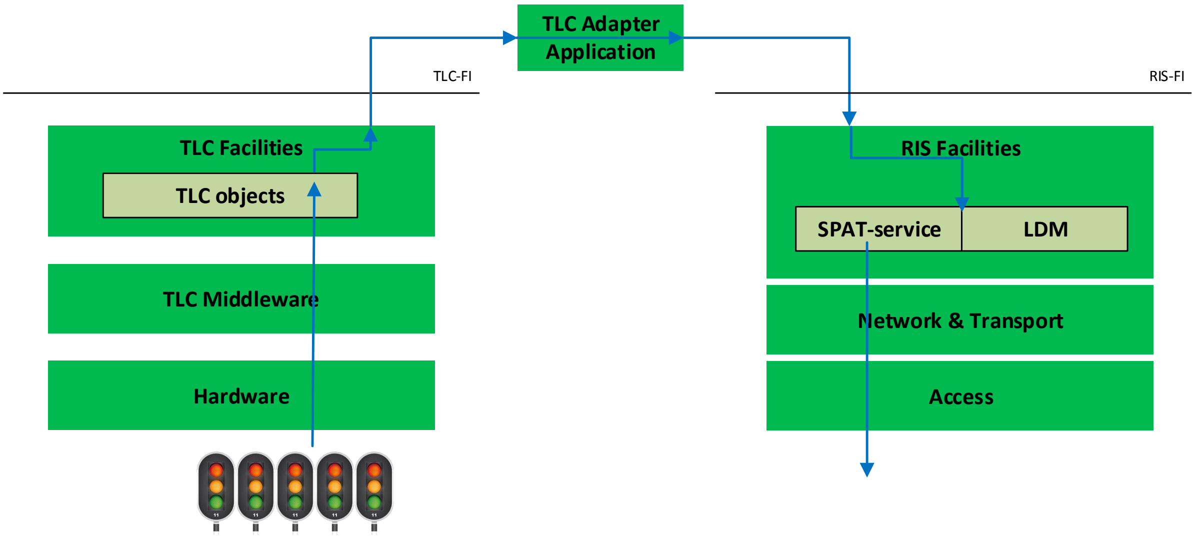


Figure 28 Latencies signal group state-change to SPAT-message (see QA_SAFE_002)

ID	Requirement	How Met
	System	
QA_SAFE_001	SPAT-payload shall be consistent with actual displayed images at traffic lights.	See section 8.3
QA_SAFE_002	Maximum latency between update of hardware signal group states and dissemination of SPAT-message including the updated data at Access –layer of the RIS	See sections 14.1.1 and 14.1.2, and Figure 28 Max latency: 150 ms.
	TLC Facilities	
QA_SAFE_003	The TLC Facilities shall validate the functional configuration of a traffic control application before it is allowed to request signal group changes	Configuration of intersection (name) signal groups (count) and detection (count) is validated during the application setup process.
QA_SAFE_004	The TLC Facilities shall translate signal group requests from traffic control applications to actual actuation according to safety constraints	Safety (clearance times, minimum timing, etc.) is configured in the TLC Facilities. TLC Facilities considers these when performing the actuation and publishes its expected timing for switching.
QA_SAFE_005	The TLC Facilities shall only publish signal group time estimates that are safe from a traffic safety point-of-view.	See chapter 8.3
QA_SAFE_006	TLC Facilities shall allow maximum of one traffic control application per	See chapter 8.3

ID	Requirement	How Met
	intersection to control signals groups).	
	RIS Facilities	
QA_SAFE_007	SPAT-service shall transmit a SPAT-message at every update of SPAT-data, and at least once a second.	See section 9.3.3, “SPAT/MAP service”
QA_SAFE_009	If no recent SPAT-data is available (see QA_SAFE_010) a SPAT-message with status “noValidSPATisAvailableAtThisTime” shall be sent.	Implement status “noValidSPATisAvailableAtThisTime” See IRSIDD of RIS-FI, [Ref 13].
QA_SAFE_010	The RIS Facilities shall remove signal group state change estimates from the LDM and stop transmitting these in case the responsible ITS Application (TLC Adapter Application) doesn’t provide new estimates in a timely manner. This may be due to for instance application malfunction or network problems.	Network problems are detected with a keep-alive mechanism. Application malfunction is detected when lifetime of LDM Object times out before receiving new estimates. An ITS Application responsible for this function must be able to provide a continuous signal image for all signal groups around an intersection.

14.4 Availability and resilience

ID	Requirement	How Met
	System	
QA_AVAIL_001	It shall be possible to detect a connection failure between an ITS Application and the Facilities	The Facilities maintain a keep-alive mechanism. See IRSIDD, [Ref 15] and [Ref 13].
	TLC Facilities	
QA_AVAIL_002	An iTLC shall be able to provide operational availability (control traffic) even if the network connection between a designated traffic control application and the TLC Facilities is lost due to for instance a broken cable or the unavailability of a suitable traffic control application	The architecture allows for brief interruptions of the network connections as the actual controlling of signal groups is done using functional methods such as STOP/GO instead of a direct coupling with the real-time behavior. This allows for the TLC to perform proper transitions. The architecture allows for an internal backup traffic control application, which can control traffic while the network connection is lost for a long time. See chapter 8.3.
QA_AVAIL_003	Failure of (communication with) a traffic control application is detected by TLC Facilities within 1000ms. After 2000ms handled by switching to an available traffic control application or amber flashing.	Every 500ms sending a keep alive message. See chapter 8.1.
QA_AVAIL_004	The TLC Facilities shall monitor the quality of a connected ITS application controlling traffic and switch over to another application in case the quality of the application is not sufficient. Possible reasons for insufficient qualities: • Application itself decides that its requested signal group states are not followed by the TLC Facilities (self-assessment) • Signal groups are not activated within timeout (signal group activation supervision) • Slow or bad network connection causing excessive timeouts (Facilities assessment)	See IRS/IDD [Ref 15].
QA_AVAIL_005	The TLC Facilities shall be able to perform traffic control when the TLC	TLC-FI defines no direct reliance on UTC timestamps when

ID	Requirement	How Met
	Facilities is not synchronized with the actual time. For instance due to not being able to access an NTP server.	controlling signal groups, relative times are used.
QA_AVAIL_006	When the TLC Facilities detects it is not time-synched within 100ms of the real time, all estimates explicitly related to this UTC time must be cleared.	See safety model, section 8.3
QA_AVAIL_007	Inputs (and multifunctional variables) should be set to unknown if the source is no longer available	An input or multifunctional variable gets a (default) lifetime
	RIS Facilities	
QA_AVAIL_008	If signal group state and timing is not updated each 1000ms, the SPAT-service sends "no spat data available."	See section 9.3.3
QA_AVAIL_009	The RIS Facilities must clear the signal group states and state change estimates when they are not updated within set lifetime.	An ITS Application providing signal group states shall provide a lifetime of this information. When this lifetime expires, the information is removed by the RIS Facilities. See section 9.3.3

14.5 Evolution

ID	Requirement	How Met
	System	
QA_EVO_001	Extension of or addition to the set of information exchanged/provided by RIS-FI or TLC-FI shall not necessarily lead to a change of data encoding or a change of transport mechanism.	RIS-FI and TLC-FI defined with extension of methods and data objects in mind.
QA_EVO_002	The RIS-FI and TLC-FI must allow for new encoding types or transport mechanisms	Facilities publish their capabilities of encoding and transport. An ITS Application may request transport and encoding. Messages contain encoding identifier and encoded data.
QA_EVO_003	It must be possible for an ITS Application to determine the specification of the data exchanged over the TLC-FI and RIS-FI	Organizational: The TLC-FI and RIS-FI interface specifications need to be standardized and managed, Technical: The TLC-FI and RIS-FI contains version number of the protocols and data elements as

ID	Requirement	How Met
		standardized.
QA_EVO_004	An ITS Application communicating using an older X-FI protocol specification than its peer must still be able to read encoded messages sent using the newer protocol version	
	TLC Facilities	
	N/A	
	RIS Facilities	
QA_EVO_005	RIS Facilities shall be prepared to be able to use different media to disseminate messages.	Vendor specific

14.6 Accessibility

Not applicable as the system is not directly used by people.
(Maybe Maintenance/Support Engineer is an exception; access to the system is however vendor specific).

ID	Requirement	How Met
	N/A	

14.7 Internationalism

	Requirement	How Met
	System	
QA_INTL_001	The Architecture must allow for deployment outside the Netherlands	Standardized signal group states are used (according to SAE2735) Possibility to execute traffic control using STOP/GO (green, red) statements and allowing the TLC to handle transitions with respect to safety timing. The architecture has no explicit dependency on a specific traffic control philosophy.
QA_INTL_002	Naming of interface-objects / topics etc. in English language	All deliverables
	TLC Facilities	
QA_INTL_003	TLC-FI supports all signal group state changes as used in EU. Only local allowed states are actuated. On not allowed state requests, an error is replied.	
	RIS Facilities	
	N/A	

14.8 Location

ID	Requirement	How Met
	System	
QA_LOC_001	It must be possible to deploy functional elements of the architecture in different locations	Deployment variants offer options for deployment
QA_LOC_002	All time-references at RIS-FI and TLC-FI are UTC-timestamps (incl. leap seconds). If needed for further processing, timestamps are converted by Facilities to TimestampIts as defined in [Ref 24].	See IRSIDD, [Ref 13] and [Ref 15].
	TLC Facilities	
n/a		
	RIS Facilities	
QA_LOC_004	RIS Facilities need to be able to determine if a registered ITS Application is still (logical) connected and alive.	See section 9.4.1.3

14.9 Regulation

ID	Requirement	How Met
	System	
	N/A	
	TLC Facilities	
QA_REG_001	The addition of the TLC Facilities interface does not have any effect of the TLC's Traffic Safety regulation as specified in Dutch and/or European standards.	The TLC itself handles safety as part of the conceptual TLC middleware layer.
	RIS Facilities	
QA_REG_002	RIS shall comply with ETSI standards.	
QA_REG_003	The RIS Facilities adhere to all relevant privacy standards.	

14.10 Testability

	Requirement	How Met
	System	
QA_TEST_001	The TLC and RIS Facilities shall maintain basic statistics of their operation	See section 9.3.4.2 and 8.2 Vendor specific implementation
QA_TEST_002	The TLC and RIS facilities shall maintain an event log containing errors and significant events pertaining to their operation	See section 9.3.4.4 and 8.2 Vendor specific implementation
QA_TEST_003	An error log is available with different error-levels and possible a root cause algorithm.	See section 9.3.4.4 Vendor specific
QA_TEST_004	An event log is available. This includes registrations, role switches and other relevant events.	See section 9.3.4.4 and 8.2
QA_TEST_005	TLC-FI and RIS-FI could have a Test account	Vendor specific
	TLC Facilities	
	N/A	
	RIS Facilities	
QA_TEST_006	Logging of transmitted and received ITS-G5 messages is available at the RIS Management-interface.	See section 9.3.4.4

14.11 System quality scenario "SPAT transmission"

This scenario described the way changes in actual signal group states are used to disseminate SPAT-messages. It also describes the (maximum) latencies and possible failures.

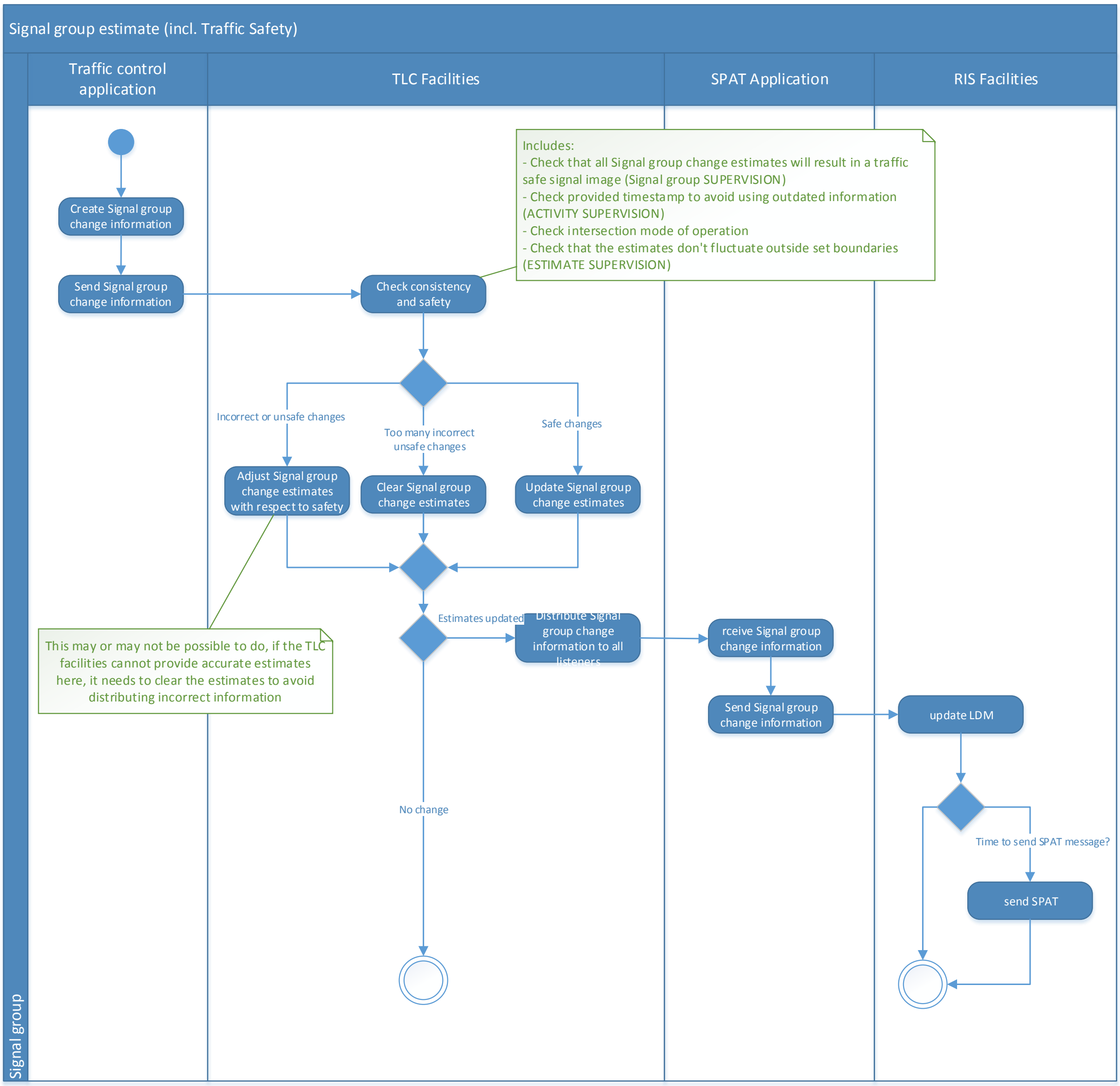


Figure 29 Signal group estimate (SPAT data)

Appendix A. Estimation of ITS-G5 message rate at RIS

According to QA-attribute “Performance” QA_PERF_026, the RIS Facilities shall be able to at least process a minimum of 250 received ITS-G5 messages per second.

This minimum number is based on received CAM’s only and is estimated by evaluating measured traffic intensity of an average intersection.

By calculating the density (using an assumed average velocity) the number of ITS-vehicles within the ITS Stations (RIS) radio-coverage can be calculated. For this number of vehicles, with an estimated Cam generation-frequency, the total number of CAM’s received at a RIS is determined.

Assumptions:

- Velocity at intersection(-arms): 60 km/h
- Radio-coverage: 500 m (radius)
- Number of vehicles equipped with WifiP: 24% (in 2021) of total vehicles
- CAM generation frequency: 5Hz

Freeflow velocity	Coverage ITS-station	Cooperative vehicles	CAM frequency	CAM smart verification
kilometers per hour	radius [km]	with coop technology	Hz	percentage
60	0.5	24%	5	25%
			optrek- en afrem-gedrag niet separaat gemodelleerd	

Intensity per ingress-arm

Starttijd	Intensity - Ingress Vehicles per hour A325	Batavierenweg	Nijmeegsev	Pleyweg	Density - ingress vehicles per kilometer A325	Batavieren	Nijmeegsev	Pleyweg	Density - ingress & egress vehicles per kilometer A325	Batavieren	Nijmeegsev	Pleyweg	Cooperative vehicles within ITS-station coverage
00:00	130	110	83	109	2	2	1	2	4	4	3	4	7
01:00	70	53	50	51	1	1	1	1	2	2	2	2	4
02:00	45	27	26	34	1	0	0	1	2	1	1	1	2
03:00	72	36	27	49	1	1	0	1	2	1	1	2	3
04:00	71	38	28	86	1	1	0	1	2	1	1	3	4
05:00	174	83	84	220	3	1	1	4	6	3	3	7	9
06:00	674	300	158	726	11	5	3	12	22	10	5	24	31
07:00	1733	835	348	1221	29	14	6	20	58	28	12	41	69
08:00	1691	820	345	1101	28	14	6	18	56	27	12	37	66
09:00	1352	782	336	991	23	13	6	17	45	26	11	33	58
10:00	1551	821	406	989	26	14	7	16	52	27	14	33	63
11:00	1686	981	475	1050	28	16	8	18	56	33	16	35	70
12:00	1756	1055	600	1188	29	18	10	20	59	35	20	40	77
13:00	1874	1131	662	1363	31	19	11	23	62	38	22	45	84
14:00	1873	1250	679	1371	31	21	11	23	62	42	23	46	86
15:00	1925	1277	714	1339	32	21	12	22	64	43	24	45	88
16:00	2146	1525	898	1523	36	25	15	25	72	51	30	51	102
17:00	2215	1457	873	1725	37	24	15	29	74	49	29	58	105
18:00	1465	1036	526	1060	24	17	9	18	49	35	18	35	68
19:00	1088	839	346	846	18	14	6	14	36	28	12	28	52
20:00	800	693	298	660	13	12	5	11	27	23	10	22	41
21:00	598	536	288	587	10	9	5	10	20	18	10	20	33
22:00	570	454	219	410	10	8	4	7	19	15	7	14	28
23:00	399	312	171	243	7	5	3	4	13	10	6	8	19

Starttijd	Cooperative messages for ITS-Station per sec custom	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
00:00	9	4	7	11	14	18	22	25	29	32	36
01:00	4	2	4	6	7	9	11	13	15	17	19
02:00	3	1	2	3	4	6	7	8	9	10	11
03:00	4	2	3	5	6	8	9	11	12	14	15
04:00	4	2	4	6	7	9	11	13	15	17	19
05:00	11	5	9	14	19	23	28	33	37	42	47
06:00	37	15	31	46	62	77	93	108	124	139	155
07:00	83	34	69	103	138	172	207	241	276	310	345
08:00	79	33	66	99	132	165	198	231	264	297	330
09:00	69	29	58	87	115	144	173	202	231	260	288
10:00	75	31	63	94	126	157	188	220	251	283	314
11:00	84	35	70	105	140	175	210	245	279	314	349
12:00	92	38	77	115	153	192	230	268	307	345	383
13:00	101	42	84	126	168	210	252	293	335	377	419
14:00	103	43	86	129	172	216	259	302	345	388	431
15:00	105	44	88	131	175	219	263	307	350	394	438
16:00	122	51	102	152	203	254	305	355	406	457	508
17:00	125	52	105	157	209	261	314	366	418	470	523
18:00	82	34	68	102	136	170	204	238	272	307	341
19:00	62	26	52	78	104	130	156	182	208	234	260
20:00	49	20	41	61	82	102	123	143	163	184	204
21:00	40	17	33	50	67	84	100	117	134	151	167
22:00	33	14	28	41	55	69	83	96	110	124	138
23:00	23	9	19	28	38	47	56	66	75	84	94

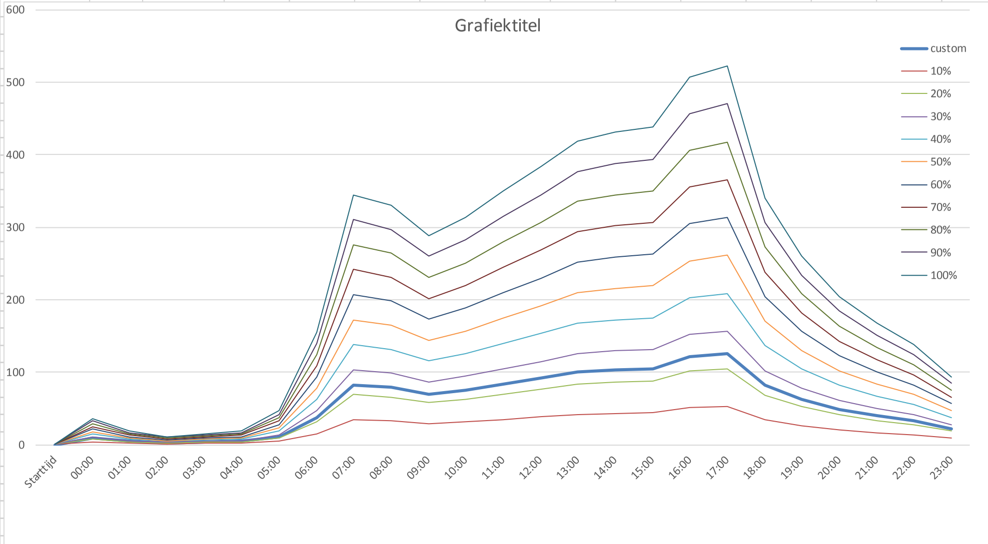


Figure 30 Appendix B. Estimation of ITS-G5 message rate at RIS