SWP3.6

Convergence Strategy (ITS G5 - Cellular)

WP3 - Functional specification

Version: 03.60

Release Date: 2016-07-29

Overview of changes

No.	Version	Status	Date	Type of Change
1	02.00	Released	2015-05-03	Second Release
2	03.00	Released	2015-07-14	Third Release
3	03.10	Released	2015-10-28	Third Release - Update
4	03.50	Released	2016-04-29	Third Release – Second Update
5	03.60	Released	2016-07-29	Third Release – Third Update

Table 1: Document History

Reference to the status- and version administration:

Status:

In progress — the document is currently in editing mode

Released — the document has been checked and released by quality assurance, it can only be modified if the version number is updated.

Versions:

Takes place in two stages. Released documents receive the next higher integral version number.

00.01, 00.02 etc. — Not released versions, with the status in progress

01, 02, etc. — Released version with the status released

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1 Document Information

1.1 Purpose of this document

This document presents the approach that ECo-AT will adopt towards convergence. In addition, it presents the main considerations regarding the use of the technologies involved in the proposed use cases and the entities involved in such process.

SWP2.6 analyses and describes the ways to achieve an independent implementation of the communication technology related to the use cases. Messages transmitted through ETSI ITS-G5 or cellular networks should convey the same information to the final user. Differences in terms of reliability, safety and delays appear to decrease more and more. The performance of traffic safety applications is determined by both the choice of technology as well as by the chosen implementation. Ideally, these two aspects should be designed together, so that the disadvantages of one are compensated with benefits of the other.

Regarding the approach, the most suitable access technologies (ETSI ITS-G5 or cellular) will be derived from the particular use cases, the appropriate communication method (broadcast vs. point-to-point) and the type of addressing (IP or geographically). Vehicles could then select the appropriate access technology based on performance indicators. In alternative, mobile devices could be used in vehicles not equipped with ETSI ITS-G5 technology.

1.2 Definitions, Terms and Abbreviations

Abbreviation / Term	Definition
IP	Internet Protocol
ITS	Intelligent Transport System
2G/3G/4G	Second/Third/ Fourth generation of Mobile telecommunications technology
TCC	Traffic Control Center
C-ITS-S	Central ITS Station
R-ITS-S	Roadside ITS Station
V-ITS-S	Vehicle ITS Station
PVD	Probe Vehicle Data
MBMS/eMBMS	(evolved) Multimedia Broadcast Multicast Service
HSPA	High Speed Packet Access
UMTS	Universal Mobile Telecommunications System

Abbreviation / Term	Definition
QoS	Quality of Service
RSU	Road-side Unit
RWW	Road Works Warning
URL	Uniform Resource Locator
IVI	In-vehicle Information
ISS	Intersection safety
CAM	Cooperative Awareness Message
DoS	Denial of Service
OEM	Original Equipment Manufacturer
DENM	Decentralized Environmental Notification Message
SPAT	Signal Phase and Timing message (SAEJ2735)
MAP	Message to convey local, detailed network topology in specific areas, as specified in ISO/PDTS 1909
HMI	Human Machine Interface
LTE	Long Term Evolution

Table 2: Definitions, Terms and Abbreviations

1.3 References

All references in this document can be found in the master table of references available in the "Eco-AT_SWP2.3_MasterTableOfReferences_v03.60.pdf" document.

2 Introduction

2.1 Rationale

The provided wireless access technology for the C-ITS communication, ETSI ITS-G5, is designed to increase the awareness horizon for the driver and to support time-critical applications. However, this happens at the cost of short range coverage and difficult communication conditions (e.g. shading by other vehicles, high relative velocities). On the other hand, mobile cellular networks (3G/4G), provide a relatively comprehensive and reliable communication, but at the cost of increased latency.

Neither of the two access technologies meets all use cases requirements perfectly. However, the drawbacks can be compensated by a suitable selection of the access technology, which is always determined by the application (see Figure 1). Finally, wireless communication can never be error-free, and thus applications must be developed so that they can deal with transient faults.

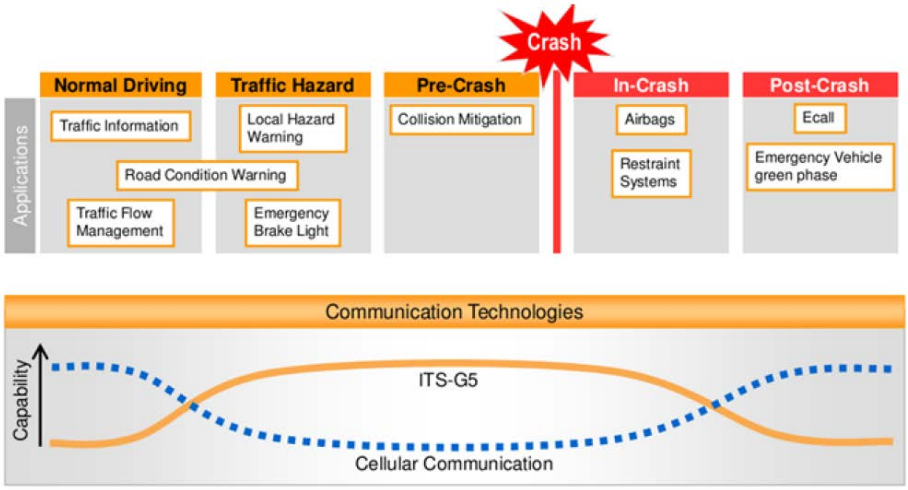


Figure 1: Time-critical and less time-critical applications versus wireless access technologies (ETSI ITS-G5 and cellular)

Message management could be difficult in cases where different communication methods are based on completely different approaches: An ETSI ITS-G5 message can be distributed to a variety of vehicles within a geographic region simultaneously per broadcast. In cellular networks a broadcast function is currently not supported, but has to be mapped onto point-to-point connections. The challenge now is to allow applications to access both basic technologies in order to achieve convergence of networks.

3 Communication Scenario

3.1 Interfaces involved

The communication scenario, considered herein, is based on the high level architecture described in [ECo-AT SWP2.3 system overview] and includes two communication paths between C-ITS-S and V-ITS-S. One using

ETSI ITS-G5 as an access technology, and the other using a mobile cellular network. The aim of the convergence strategy is to deliver the same information between TCC and V-ITS-S (end-to-end) on both paths as seen in the Figure 2.

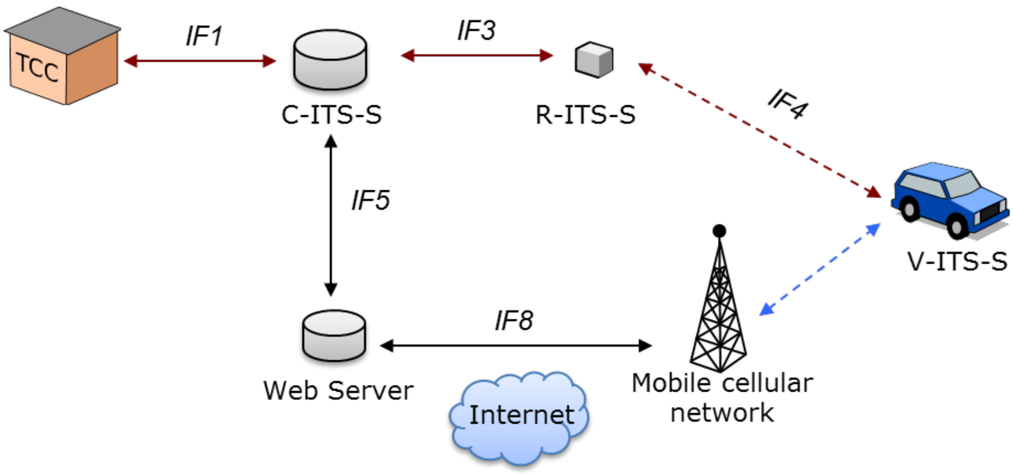


Figure 2: Communication paths from the TCC and C-ITS-S towards the V-ITS-S

In this scenario, traffic information and warnings are created within the TCC, while vehicle data is created by the V-ITS-S. The C-ITS-S is connected to an ETSI ITS-G5 access network consisting of multiple R-ITS-S. It is also connected (via Internet) to one or several mobile cellular networks. Vehicles communicate to C-ITS-S via ETSI ITS-G5 and/or potentially via cellular networks. The availability of the communication equipment within a vehicle or the coverage of R-ITS-S and mobile networks may limit the available options.

Under these preconditions, we imagine the following scenario: A vehicle equipped with ETSI ITS-G5 and cellular communication devices receives traffic information (e.g. traffic jams within a 15km radius) via cellular networks. Once it enters the coverage of a R-ITS-S, it receives new traffic information (e.g. for the next 10km on the highway ahead). When passing by the R-ITS-S, it also delivers CAMs. Once the vehicle leaves the coverage of the R-ITS-S, it continues to use the cellular link to receive traffic information. In this example the V-ITS-S is connected to different access technologies over time, and thus the communication paths change. The aim is to ensure that *the same* information coming from the TCC is delivered to the V-ITS-S using different communication paths.

These latter paths include the following interfaces of the high level architecture:

- End-to-end communication via ETSI ITS-G5:
  IF1: TCC <-> C-ITS-S
  IF3: C-ITS-S<-> R-ITS-S
  IF4: ETSI ITS-G5 (R-ITS-S <-> V-ITS-S)

- Communication via mobile cellular networks
  IF1: TCC <-> C-ITS-S
  IF5: C-ITS MOB (C-ITS-S <-> ITS WEB SERVER)
  IF8: WEB SERVER <-> ITS WEB CLIENT/V-ITS-S (not part of ECo-AT specification)

Note that the definition of the V-ITS-S is also not within the scope of the ECo-AT specification, therefore strategies for network selection and vertical handover are not considered.

It is obvious that both aforementioned communication paths can be used to transmit the same data content; however there are some differences in terms of functionality and performance of the used access technologies, which will be treated subsequently.

3.2 Technological aspects of ETSI ITS-G5 and Cellular Networks

In general, ETSI ITS-G5 is a low-latency (typically <5ms) wireless access technology, which is ideal for broadcast communication within a couple of hundred meters (local information dissemination). It is ideal for direct vehicle-to- vehicle communication and communication with roadside equipment. Regarding coverage, ETSI ITS-G5 uses a license-free band implying that there is only an upfront cost for deploying the technology (no subscriptions are required).

Cellular networks in current deployments have the advantage of a high coverage (in populated areas), but without (e)MBMS they can only serve unicast communication. The latency of cellular links depends on the used standard, where LTE/4G offers lowest latencies, while higher latencies are expected when using previous generations (e.g. HSPA, UMTS). Latencies in HSPA are around 100ms [ETSI 102 962] (uplink and downlink on dedicated channel), while LTE offers latencies between 10ms and 50ms (depending on QoS, packet size, terminal state, cell load etc.) [Lotterman et al.]. Cellular networks operate in a licensed spectrum and, therefore, a cost of use is charged to the user (subscriptions are required).

In Table 4, a comparison between the two technologies is outlined given the communication scenario that wants to be supported (communication between TCC and V-ITS-S) outlined in Figure 2.

Access technology	**ETSI ITS-G5**	**Cellular Networks**
Support for broadcast	Yes	Only with (e)MBMS If broadcast is not available, data has to be delivered via individual unicast transmissions, which can be realized via • Polling by the receiver of the data • Bidirectional connection
Support for unicast	Yes	Yes
Coverage	Depending on R-ITS-S deployment	Nationwide
Further issues		Cost of use charged to the user

Table 3: Technological aspects of ETSI ITS-G5 and Cellular Networks.

For assessing the requirements of using both access technologies for the ECo-AT use cases, we can look at the high level data flows: Road works warning (RWW), In-vehicle information (IVI) and Intersection safety (ISS) rely on an information dissemination towards vehicles within a certain geographic area, which we describe here as *group information and warning.* PVD relies on the delivery of data from individual vehicles to the TCC, which is referred to as *data collection*.

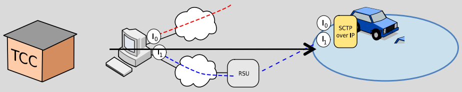
Data flow		
ECo-AT use cases	RWW, IVI, ISS and Other DENM applications	CAM Aggregation
Required type of communication (*how is the data sent?)*	Broadcast to vehicles (V-ITS-S) with a geographic scope	Unicast to a collection point
Addressing of the receiver *(to whom is the data sent?)*	• Addressing by geographic area • Implicit addressing by transmission range • Addressing via publish/subscribe	• Addressing by IP address or MAC address of the collection point (cloud server or R-ITS-S as transfer point) • Implicit addressing by using broadcasts, which are received by the collection point

Table 4: Use Cases data flows considerations

ETSI ITS-G5 as an access technology provides broadcast functionality and thus supports group information and warning. Single-hop broadcasts are limited to the communication range of the R-ITS-S, and the area of dissemination depends on the deployment of R-ITS-S. Data collection is possible by receiving probe data of vehicles within range of an R-ITS-S.

Cellular networks as access technology do not support broadcast (unless MBMS/eMBMS is deployed). Therefore, broadcasts to vehicles have to be realized by multiple unicast connections. There are several options to realize this: V-ITS-Ss could request relevant information after reporting their position. They could also subscribe to a service and maintain a connection, over which data is pushed. Data collection requires a simple unicast connection. Here, the cost of using the cellular network might be an obstacle to an extensive reporting of position data from vehicles to the C-ITS-S and finally to the TCC. When using cellular networks, it makes sense to combine both data flows: the vehicle reports position and traffic related information (e.g. speed, heading, environment data) to the infrastructure and receives traffic information, which is relevant for the reported position.

It is important to mention that in the context of Eco-AT, convergence will be only applied in downstream i.e. information goes from the C-ITS-S to the vehicles. Therefore, the considered use cases are RWW, IVI, Other DENM applications and ISS (if traffic lights information is available).

4 Convergence approach

4.1 How to achieve convergence?

The approach in ECo-AT, in order to achieve convergence, is to have a unique point in charge of creating and delivering C-ITS messages towards vehicles, either through R-ITS-Ss deployed along the roads or directly by means of a dedicated service over the internet. The C-ITS-S would act as a sort of communication gateway between the TCC and the V-ITS-Ss, assuring that the information generated in the TCC is delivered to the V-ITS-Ss efficiently. The convergence approach is summarized in the next figure, in three simple steps:

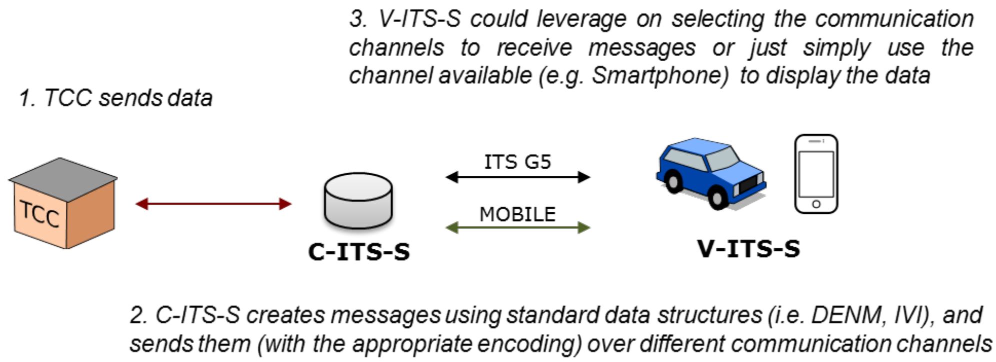


Figure 3 – Convergence approach in ECo-AT

The main arguments concerning the adopted convergence approach can be summarized in the following points:

- There is and there will be more than one access technology available for information exchange e.g. ETSI ITS-G5, Cellular Networks.
- C-ITS-S should take care of that the *same information* is provided on all relevant interfaces, whether the information is actively distributed (e.g. via broadcasts from relevant R-ITS-S) or provided upon request (e.g. via web service over a cellular data connection (e.g. 3G/4G) to a device requesting the information for its own area of relevance). Here, the term *relevance* refers to a geographic position, area, or driving direction etc., for which certain information can be useful.
- Users will then have the possibility to exploit that information according to their needs or options. For example, if no ETSI ITS-G5 equipment is installed, a smartphone can receive the data. Same information should be visualized in the vehicle to the driver despite the communication channel used to receive the data.

4.2 C-ITS-S considerations

The C-ITS-S is one of the most important components of the system since it is responsible for the accurate provision and delivery of the information to the V-ITS-S. The mechanisms that make available the information to be shared by several communication channels are developed and implemented within the C-ITS-S. It also supports the management of security mechanism of the system (e.g. access to PKI).

Inside vehicles information received through both ways of communication must be coherent. Anything else bears the high risk to be inconsistent, duplicated and lead to driver distraction or unsatisfied drivers / customers.

Main considerations from the C-ITS-S perspective, regarding the adopted convergence approach are the following:

- Message management: this is the main functionality that allows the management and delivery of messages. To guarantee that messages arriving to the V-ITS-S are consistent, C-ITS-S should create the messages and distribute them over all of the relevant interfaces. Furthermore, the C-ITS-S will use different methods for message delivery based on the interface used. For instance, the ITS WEB server can be seen as a "virtual" R-ITS-S with a large area covered and therefore, there is no need to select the events to be sent over to that entity through IF5: C-ITS MOB. The ITS WEB server will then have the role to manage the messages and all individual requests generated by the V-ITS-S based on its location.

- Security: This aspect is of high relevance considering the fact that exposing information towards the internet would "open" the C-ITS-S to the exterior. C-ITS-S should apply the required security mechanisms, especially for the interface IF5: C-ITS MOB (see Figure 2), to avoid any intrusions in the system or denial of service (DoS) attacks. From the implementation point of view, this issue is minimized by adding a dedicated ITS WEB server, which receives all requests from the vehicles and/or smartphones. This latter ITS WEB server should handle the required security mechanisms to reduce any possibility of external attacks towards the C-ITS-S.

4.3 V-ITS-S considerations

The V-ITS-S can be seen either as a vehicle equipped with ETSI ITS-G5 and/or mobile internet (3G/4G) communication or as a mobile device running an application able to interact with the C-ITS-S. Mobile internet over cellular communication (e.g. 3G/4G) is seen as a communication channel for content, which is also subject to ETSI ITS-G5 services.

From the vehicle perspective, the following elements are relevant when discussing convergence between ETSI ITS-G5 and mobile communication channels:

- Ad-hoc vs configuration: an ETSI ITS-G5 V-ITS-S will receive C-ITS messages from R-ITS-Ss or other V-ITS-Ss in an ad-hoc manner. The information is broadcasted by the R-ITS-S is relevant for the area around the R-ITS-S location. On the other hand (using cellular systems), configuration is needed on the V-ITS-S to know where and how to fetch messages from the C-ITS-S (e.g. IP address, URL, protocol) responsible for the area in which the V-ITS-S is currently situated. While this regional configuration could be statically set on the V-ITS-S system on some vehicle categories operating mostly in the same area (e.g. buses, taxis, city commuters) it is necessary for others (long haul freight transport, passenger cars driving long distance or crossing often "C-ITS-S responsibility borders") to dynamically adjust settings to the current C-ITS-S in charge.

- Communication cost: ETSI ITS-G5 is free to use whereas mobile communication requires a subscription from a telecom operator. Since C-ITS services do not need mobile communication to work, a "regular" V-ITS-S system does not need any subscription. OEM and service providers will need to decide based on their target market, business model and level of service if a mobile communication subscription shall be included in their V-ITS-S system, most likely used in common with other features of a service package (e.g. infotainment, telematics)

- Coverage area: C-ITS services relying on messages distributed on ETSI ITS-G5 depends on the deployment of R-ITS-Ss for the communication scenario outlined herein (TCC to V-ITS-S). As an example, even in the case of long lasting road works warning, an ETSI ITS-G5 equipped vehicle would have first to drive by one of the R-ITS-S sending out the corresponding DENM message to be aware of this road works. With this respect, the use of mobile communication channel virtually extends the deployment of C-ITS services in a region.

- Latency/scalability: For some C-ITS services, the timeliness of the information is very important and allows/denies certain features or level of service. For example in the case of intersections and SPAT/MAP information, red light violation warnings are very time sensitive, while informational services such as start/stop support have less requirements. The performance of mobile communication based services can also be affected by the number of users, which can have a much quicker uptake than for a pure ETSI ITS-G5 approach, looking at the smartphone business in the past years: load on the ITS WEB Server to answer thousands of requests per second, saturation of the cellular channel in crowded areas, level of service achievable on the V-ITS-S side in different operational conditions. It will be very interesting to look at the first operational feedback and experience from cities/services providers who implemented the mobile communication paradigm.

Moreover, regardless of which communication channel that is used to deliver the information and which module on the V-ITS-S communication layer handling the message, the message content (DENM, IVI, SPAT/MAP) should be identical to allow a transparent processing by the upper layers (facilities, applications, HMI). Care should be taken in the message management (both in C-ITS-S and V-ITS-S) to treat correctly the cases of duplicates, cancellation/negation received on both communication channels, etc. This implies careful considerations on the originator station id, sequence numbers and so on used at the C-ITS-S to provide messages on ETSI ITS-G5 (via R-ITS-Ss) and mobile communication channels.

5 Implementation

The implementation of the convergence concept will follow a content provider approach. The data generated by the C-ITS-S (i.e. DENM, IVI) will be delivered to an ITS WEB server through IF5: C-ITS MOB using the same specification of IF3: C-ITS-S<-> R-ITS-S. The main difference is that the WEB server is seen as a "virtual R-ITS-S" with a very large area of coverage and that the information exchanged with vehicles is only downstream.

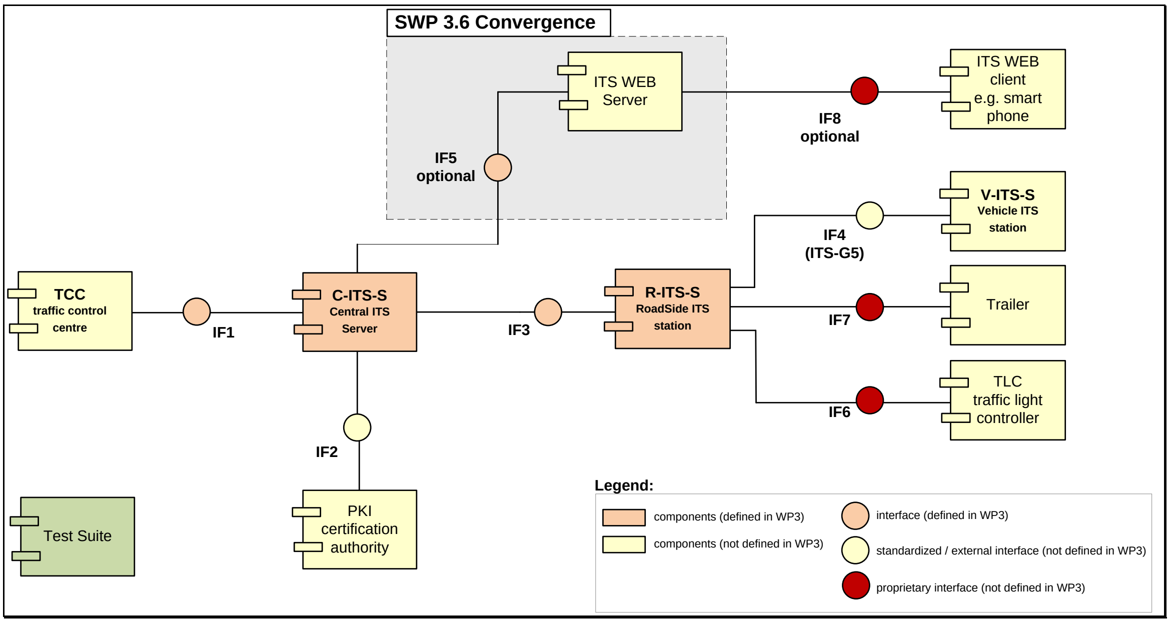


Figure 4 – Convergence implementation

The WEB server should behave as a content provider and will be in charge of the delivery of the information to vehicles and/or smartphones (apps). This latter “delivery“ interface (i.e. IF8) is out of scope of the Eco-AT project and remains as proprietary.

5.1 Interface IF5: C-ITS MOB

In order to maximize the tasks performed by the C-ITS-S and to avoid duplication of work, IF5 is an adapted version of IF3 with the difference that will only delivery information in downstream. The following section describes the considerations that should be taken into account while implementing the interface. The specification of IF5 is, as IF3, divided in two parts: Communication [ECo-AT SWP3.1 IF3 comm] and Device management [ECo-AT SWP3.1 IF3 management].

5.1.1 Communication

Considering only the downstream direction, the following data is sent:

- Event / traffic information (i.e. DENM)
- In vehicle Information (i.e. IVI Message)

Deployment of the convergence scenario is then simplified as follows:

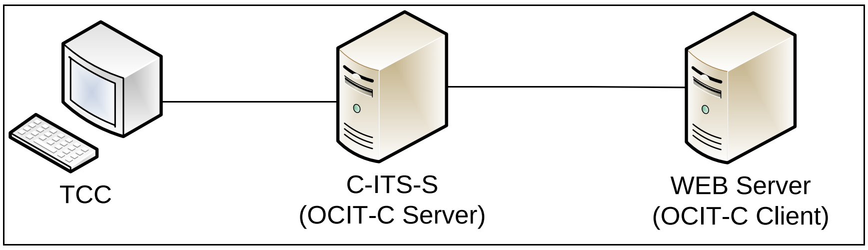


Figure 5: Deployment scenario

The Communication between the WEB server and the C-ITS-S is done via an IP based Link initiated by the WEB server. This means the C-ITS-S is always the OCIT-C Server and the WEB server will always be the OCIT-C Client. Since all communication is initiated by the WEB server also deployment scenarios which include a NAT on the network link between C-ITS-S to WEB server (e.g. UMTS uplink) can be handled.

The scenarios where the C-ITS-S sends messages (i.e. DENM and IVI), remain exactly as for IF3 (section 5) [ECo-AT SWP3.1 IF3 comm]. The encoding of the ITS-message payload (DEN, IVI, etc.) is defined by the WEB server implementation. On connection establishment, the WEB Server informs the C-ITS-S which encoding (UPER, XER, XER zipped is active). The rest of the scenarios (upstream data transfer, i.e. receiving sensor information and DENMs) are not considered by this interface.

The sequence diagrams are therefore simplified as follows:

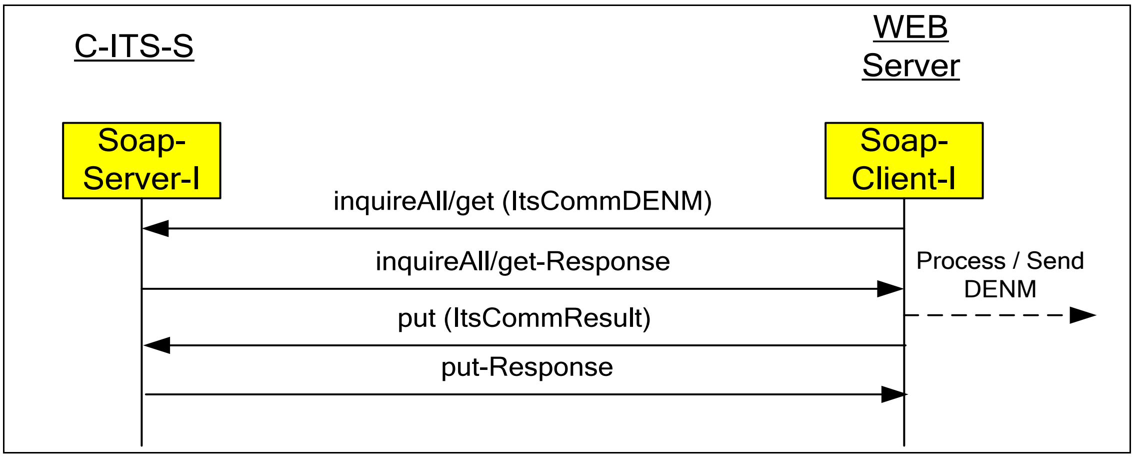


Figure 6: OCIT-C sample sequence diagram

A number of data objects are not relevant for this interface and are listed below:

- BTP-A DATA (IF3 section 6.1.2 [ECo-AT SWP3.1 IF3 comm])
- Communication Channel (IF3 section 6.1.6 [ECo-AT SWP3.1 IF3 comm])
- Transport Type (IF3 section 6.1.7 [ECo-AT SWP3.1 IF3 comm])

- Security Profiles (IF3 section 6.1.8 [ECo-AT SWP3.1 IF3 comm])
- Geo Destination (IF3 section 6.1.9 [ECo-AT SWP3.1 IF3 comm])
- Geo Source (IF3 section 6.1.10 [ECo-AT SWP3.1 IF3 comm])
- Geo Data (IF3 section 6.1.12 [ECo-AT SWP3.1 IF3 comm])

5.1.2 Device management

The device management services are equal to those described in IF3 [ECo-AT SWP3.1 IF3 management] with the difference that there FW update is not relevant for this case. The services then are:

- Auto discovery of C-ITS-S Server by WEB server
- Configuration / provisioning
  - at initial connect (Bootstrapping of "fresh" installed R-ITS-S)
  - re-provision or re-configure at any subsequent time
- Performance monitoring
- Configurable Alarm and Event notifications

The deployment scenario is depicted in Figure 5. The sequence diagram of a typical Device Management session is the same as for IF3 [ECo-AT SWP3.1 IF3 management] and presented in Figure 7.

The main considerations to be taken into account for this interface with regards device monitoring are the following:

- The firmware Upgrade Image ([ECo-AT SWP3.1 IF3 management] section 4.3.31) is not relevant for this interface and therefore this functionality should not be used.
- The choice reboot in the command within Data Object “DeviceCommand” (IF3 section 4.5.2 [ECo-AT SWP3.1 IF3 management]) should not be used for IF5.
- The data Object “DeviceReboot” is not relevant for this interface and therefore should not be used.
- The code 1: Firmware Upgrade image of FileType within Data Object “ DeviceDownload” (IF3 section 4.5.6 [ECo-AT SWP3.1 IF3 management]) should not be used for IF5.
- Within the parameter data model:
  - In order to differentiate a R-ITS-S from a WEB server, the key /device/ModelName should be “WEB server”.
  - The following keys are not relevant for this interface:
    - /its
    - /security
    - /security/ca/[N]

- /shortCollectionInterval,
- /longCollecationInterval/
- /cam/detectionZones/[N]
- /latitude
- /longitude
- /heading
- /witdth
- Length
- /cam/stationTypeGroupId/[N]

All other sections specified in IF3 [ECo-AT SWP3.1 IF3 management] remain the same for IF5.

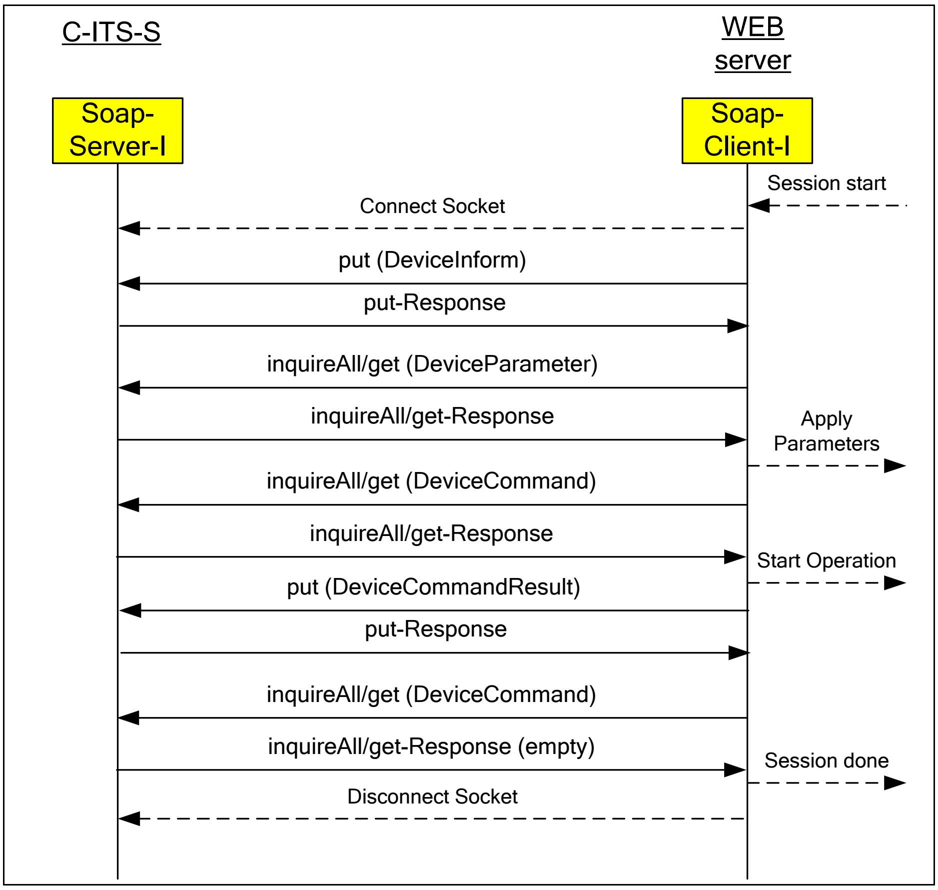


Figure 7: Typical DM Session sequence

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