combining infrastructures for efficient electric mobility

Deliverable D200.2

Overall architecture and functional design for e-mobility cooperative infrastructures

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authors

ROIU Daniel	CRF
LIN Lan	Hitachi Europe Ltd.
KOBAYASHI Yuichi	Hitachi Europe Ltd.
KLAUDEL Witold	Renault SAS
DEFLORIO Francesco	POLITO
GUGLIELMI Paolo	POLITO
MASUCH Nils	DAI laboratory
LUTZENBERGER Marco	DAI laboratory
Nadim El Sayed	Technische Universität Berlin
MAISONOBE Jean-Christophe	CG38
Arnaud Kaiser	CEA
Alexandru Petrescu	CEA

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contact information

Coordinator
Dr. Massimiliano Lenardi
Hitachi Europe Limited

955 route des Lucioles “Ecolucioles B2”
06560 Valbonne Sophia-Antipolis France

phone: +33 (0)4 89 87 41 00
e-mail: Massimiliano.Lenardi@hitachi-eu.com

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Executive Summary

The eCo-FEV project aims at achieving a breakthrough in Fully Electric Vehicle (FEV) introduction by proposing a general service platform for integration of FEVs with different infrastructure systems cooperating with each other – thus allowing precise FEV telematics services and charging management services based on real time information.

The general concept of eCo-FEV is based on the development of innovative next generation electric mobility (E-mobility) infrastructure by mutual system cooperation among FEV and independent FEV-related infrastructures being networked. The cooperative E-mobility infrastructure enables the information collection from independent infrastructure systems and provides data aggregation functionalities to enable cloud based high quality FEV services for FEV users. For this purpose, an eCo-FEV system is defined and will be developed by the consortium. Multiple cloud based FEV services will be developed and demonstrated. eCo-FEV system includes sub systems integrated at FEV, at road side, at charging infrastructure and at backend to realize FEV assistance services before and during a trip and charging.

In previous deliverable D200.1 [1], eCo-FEV consortium has defined a set of use cases, by illustrating the relationship between existing FEV related infrastructure systems and eCo-FEV system. This set of use cases provides services to FEV user or to FEV fleet operator to improve the FEV usage efficiency in real travelling and traffic situations. Each use case is defined in a way to guide the system architecture design instead of imposing any system architecture. The present deliverable takes D200.1 as inputs and targets at defining the architecture of the eCo-FEV system. Different viewpoints are taken to describe the eCo-FEV system. eCo-FEV system architecture is defined as an ensemble of sub systems，namely in vehicle On Board Unit (OBU), road side unit (RSU), charging infrastructure system and eCo-FEV backend sub system. These sub systems are interacting with each other, and with different FEV related infrastructure systems, in order to realize the eCo-FEV use cases. It should be noted that, given the eCo-FEV project's specific purpose of developing an innovative charge while driving (CWD) inductive charging system，the charging infrastructure system is considered as sub system of eCo-FEV system. In a real deployment, a charging infrastructure may be considered as external actor of the eCo-FEV system, similar to other infrastructure systems e.g. traffic infrastructure system.

The present deliverable will be provided to WP230 for specification definition, to WP300 for system development and to WP400 for testing scenario definition.

Glossary

eCo-FEV system: ensemble of On Board Unit (OBU), road side unit (RSU), charging infrastructure system and an eCo-FEV backend

eCo-FEV backend: sub system of eCo-FEV system that includes middleware in the generic domain, providing backend support and functions.

OBU: sub system of eCo-FEV system that is integrated in FEV providing telematics services and charging assistance for FEV user.

RSU: sub system of eCo-FEV system that is deployed at road side, providing either telematics services or charging assistance services for FEV.

charging infrastructure: sub system of eCo-FEV system, including road side charging equipment (Electric Vehicle Supply Equipment EVSE) and EVSE operator backend system (EVSE operator).

1. Introduction

1.1. Document scope

eCo-FEV system aims at developing an innovative next generation E-mobility infrastructure by mutual system cooperation among FEVs and independent FEV-related infrastructures being networked, in order to provide high quality navigation and charging assistance services to FEV users. It collects FEV relevant information from different infrastructure systems and provides data aggregation functionalities for service providers to develop and provide cloud based FEV services.

The present deliverable is the second part of the multiple deliverables for eCo-FEV system definition:

- D200.1: Uses case definition and requirements
- **D200.2: System architecture**
- D200.3: System and component specifications (i.e. Specifications)

It targets at defining architecture of the eCo-FEV system, in order to support the eCo-FEV use cases as defined in D200.1 [1].

Following steps are taken for the architecture definition:

1. eCo-FEV system overall architecture definition

Different viewpoints are taken to describe the eCo-FEV overall architecture, such as system viewpoint, communication viewpoint, information viewpoint and technology viewpoint. This step will enable a high level understanding of roles and functionalities of eCo-FEV system, as well as its relationship with system external actors i.e. FEV and FEV related infrastructure systems.

With this step, a set of eCo-FEV sub systems are identified.

2. eCo-FEV system functional design

The eCo-FEV system functional design defines the main architectural elements that deliver the eCo-FEV functionality. In this step, we target at defining the overall functional architecture of the eCo-FEV system by allocating required functionalities as defined in [1] to eCo-FEV sub systems as identified in previous step. With this high level functionalities allocation, roles and responsibilities of each sub system are defined. Furthermore, based on the agreed functionalities allocation, data exchanges and interactions among eCo-FEV sub systems and with external infrastructure systems for each use case are defined, in forms of UML sequence diagram.

3. eCo-FEV sub system functional design

Based on high level functional design and interaction design realized in step 2, we are able to proceed with the functional design of each eCo-FEV sub system. In this step, functional components of each eCo-FEV sub system is identified and described.

It should be noted that, the present deliverable does not specify the interactions of sub components as identified in step 3. Such interactions will be realized in D200.3 deliverable as interface specifications.

The proposed architecture should be flexible and modular, being able to accommodate different infrastructure systems, satisfying local requirements at the implementation site and enable additional services, facilitating the exploitation of the system. For this purpose, standardized interfaces are identified and used, wherever applicable.

1.2. Document structure

The present deliverable is organized as following:

- Overall architecture definition is defined in chapter 2. It summarizes eCo-FEV overall system from multiple viewpoints, corresponding to abovementioned step 1 architecture design.
- Chapter 3 provides definition of eCo-FEV system high level functional architecture as required in step 2. Furthermore, this chapter includes sequence diagram for each eCo-FEV use case, illustrating the information exchanges between eCo-FEV sub systems and between eCo-FEV sub systems with external actors.
- Chapter 4 includes functional design of each eCo-FEV sub system.
- Chapter 5 concludes the present deliverable.

2. Overall architecture

eCo-FEV system targets at providing mobility and charging assistance services for FEV before and during the trip and charging. FEV range may be impacted by many factors, e.g. traffic condition, road condition, weather condition, user driving pattern etc. During trip, FEV may need to be recharged in order to extend the FEV range to cover the desired distance. FEV trip plan needs to consider the charging plan, which may be impacted by charging facilities availability. For FEV service providers, all these situations may need to be considered along the whole trip, in order to provide a high quality, precise and robust FEV services. Large amount of data needs to be collected from different infrastructure systems and from FEV itself, data aggregation functionalities may further improve the data quality for FEV service providers. Such data collection and data aggregation may require important computing resource for FEV to realize, therefore, eCo-FEV consortium targets at developing a backend platform for these tasks and support service providers to provide real time FEV services to FEV. This base principle is used to guide architecture design of the eCo-FEV system.

The eCo-FEV system architecture may be described from different viewpoints:

- **System viewpoint**: providing a high level overview of the eCo-FEV system architecture and identifying eCo-FEV sub systems.
- **Communication viewpoint:** considering the communication needs and defining network architecture of the eCo-FEV system. Existing communication standards (long and medium range: IEEE.802.11p, 3G/4G) to be considered are identified.
- **Information viewpoint:** identifying the main information exchange interfaces and potential data exchange protocols to be used for communication between eCo-FEV sub systems, between eCo-FEV system and infrastructure systems and potentially between sub components of the eCo-FEV sub system. These interfaces are essential for design of a modular architecture of the eCo-FEV system. Standardized and already deployed interfaces are considered, wherever applicable.
- **Technology viewpoint:** defining potential software execution environment, application and communication platforms to be used for eCo-FEV sub system development.

2.1. System viewpoint

A high level architectural overview of the eCo-FEV system is illustrated in Figure 2.1. The eCo-FEV system includes the following sub-systems:

- **Road Side Unit (RSU)**: A RSU includes communication hardware (e.g. Wi-Fi, UMTS, etc.), application unit hardware and potentially gateways to interface with road side infrastructure or with charging infrastructure. The main roles of RSUs are: traffic information broadcasting (traffic events, traffic conditions, estimated travel times), personalized service information (subscription, user request, information supply) and location based non-safety information broadcasting (EVSE status, real time information from Transport Public Management Center, road signage information). It may further be used as infrastructure router for connectivity management between an OBU and the eCo-FEV backend or charging infrastructure
- **eCo-FEV backend:** eCo-FEV backend is a backend system that includes at least a middleware platform for infrastructure data collection and potentially data aggregation functionalities, and one service provider platform that provides FEV services to customers. Additionally and according to the business strategy, other backend systems may be included in eCo-FEV backend such as an ID provider that manages the ID and contract information of customers. eCo-FEV backend includes at least one server and eventually a load balancer in order to distribute workload across multiple processing units.
- **Charging infrastructure:** charging infrastructure includes EV supply equipment (EVSE) at road side for EV charging and a backend operator (EVSE operator). EVSE includes communication hardware (e.g. Wi-Fi, UMTS, etc.), application unit hardware and energy provision equipment (inductive power transfer or conductive power transfer). EVSE operator is in charge of managing, operating and monitoring EVSEs. EVSE also provides services to assist the FEV charging process such as Authentication, Authorization, Accounting (AAA), charging monitoring etc. The EVSE Operator is the backend of the charging infrastructure. It communicates with a set of charging station control units, for gathering monitoring and status information, and triggering some actions, (such as booking). It implements the Server-side of the AAA for the charging process. On the other hand it communicates with the eCo-FEV backend for reporting the status of the charging facilities (monitoring) and providing accounting information. In the scope of eCo-FEV project, either existing charging infrastructures are used, or new charging infrastructure is built e.g. charge while driving infrastructure. For this

reason, charging infrastructure is included as eCo-FEV sub system. However, it should be highlighted that, eCo-FEV system architecture should not be limited only to any specific charging infrastructure. The eCo-FEV system targets at developing a standardized interface with different charging infrastructures.

On Board Unit (OBU): OBU is integrated in FEV. It includes communication hardware (e.g. Wi-Fi, UMTS, G5…), application unit hardware, vehicle gateway to interface with FEV electronic system, at least one HMI device and the in vehicle charging systems (e.g. inductive power transfer, conductive power transfer, etc.). The OBU provides telematics services and charging assistance for FEV users.

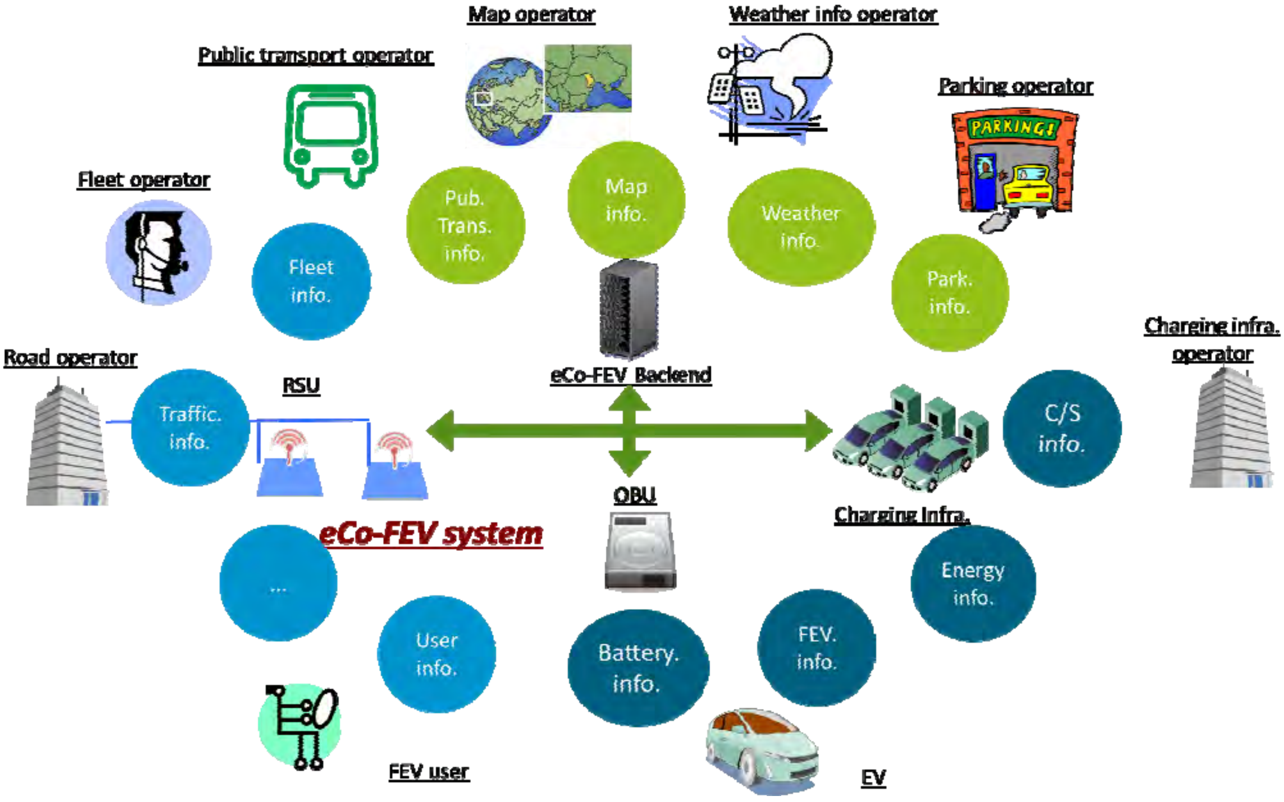

Figure 2.1: eCo-FEV high level overview

As defined in [1], eCo-FEV sub systems interact with a list of external operators and infrastructure systems, in order to realize electric mobility services. In another word, these operators and infrastructure systems provide information required for the management of FEVs and realization of a set of user services.

The list of eCo-FEV use cases and identified external actors are defined in [1].

2.2. Communication viewpoint

2.2.1. **Communication overview**

The communication infrastructure must be able to route messages from their source to the destination as effective as possible, regardless of location of the vehicles. Standardization plays an essential role for this purpose, in order to ensure the communication interoperability.

The process of global standardization is focusing both the development of new radio technologies specifically designed for ITS services (e.g. the 5.9 GHz band) and the use of existing systems such as cellular technologies.

Regarding 5.9 GHz band at least 3 different organizations are working at the standardization:

- In Europe (ETSI) - ETSI TC ITS that is harmonizing, with the support of Car to car communication consortium (C2C-CC), the input carried out by the most important R&D ITS projects: CVIS, SAFESPOT, GeoNet, etc. A European Profile of ITS G5 access technology standard has been delivered by ETSI [2].
- In USA (IEEE) - IEEE 802.11p, P1609 and automobile standard body SAE (DSRC)
- Global (ISO) - ISO TC204 WG16 (CALM)

eCo-FEV will provide ITS G5 technology compliant with ETSI standards, since ETSI standards on ITS G5 technologies are considered by Industrial Consortium such as C2C-CC as European Profile for future deployment.

Given the availability at test sites, eCo-FEV mainly considers ITS G5 technologies and cellular communications, even though eCo-FEV architecture is not limited to any specific communication technologies. ITS G5 technology is operating on 5.9GHz radio spectrum allocated to the Intelligent Transportation System (ITS) is Europe, it provides low latency ad hoc communications between vehicles, and between vehicles and road side unit (RSU) located within the proximity of the transmitting node. RSU may therefore disseminate traffic information and FEV services data to FEV users e.g. charging spot PoI information. Infrastructure nodes may also play the role of router, bridge or gateway to connect FEV to eCo-FEV backend. However, the usability of G5 to connect FEV with eCo-FEV backend highly depends on density with which RSUs are deployed. Alternatively, cellular networks remain as alternative communication technologies for FEV and infrastructure communication. Of course, other communication technologies may also be used e.g. Wi-Fi. The communication overview of the eCo-FEV system is illustrated in Figure 2.2.

Multiple communication links are relevant for eCo-FEV system:

- **V2V:** direct communication between vehicles. It is based on ITS G5 technologies as standardized in [2]. In eCo-FEV, V2V plays a minor role for use cases, for example, it may be used to extend communication coverage for information provided by road side to vehicles via intermediate vehicles. V2V is being now standardized and planned to be deployed in Europe, with main purposes of improving road safety and traffic efficiency by direct ad hoc communication between vehicles and road side without requiring communication infrastructure support. Given this, we consider V2V as the "by default" system that will be equipped by FEV, providing an additional communication channel for FEVs.
- **V2I:** communications between FEVs and RSU. It may be based on ITS G5 technologies or other technologies e.g. Wi-Fi. Furthermore, V2I also indicates communications between FEVs and eCo-FEV backend or with any other backend infrastructure operators as defined in [1]. It may be based on cellular technologies such as 3G. Alternatively, RSU may be used as router to route the data from vehicle (over G5) to backend (over cellular technologies).
- **I2I**: communication between RSU and eCo-FEV backend or between eCo-FEV backend and any operators' infrastructure systems as defined in [1]. It may be based on wired communication (e.g. optic fibre network) or wireless communications (e.g. cellular networks).

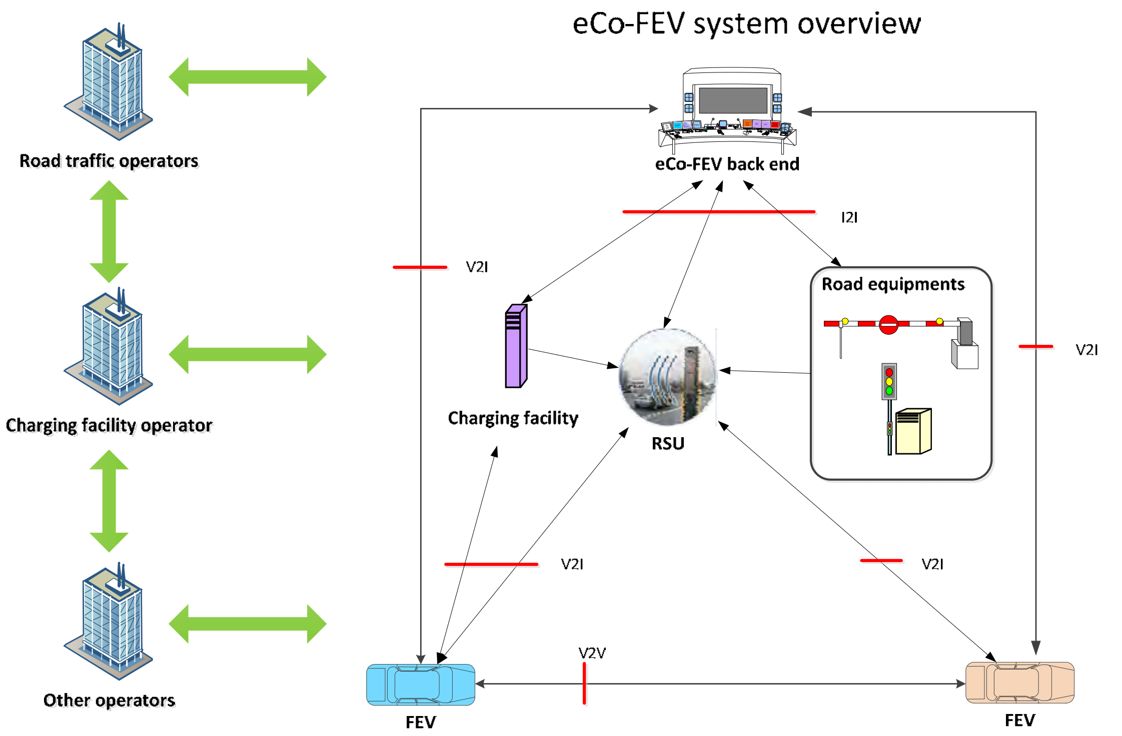

Figure 2.2: eCo-FEV communication overview

Use cases of eCo-FEV are realized via cooperative Intelligent Transport Systems (C-ITS), enabling communications and information exchanges between multiple road actors, infrastructure systems and service providers. Within C-ITS, communication party is named as ITS station (ITS-S) as defined in [3].

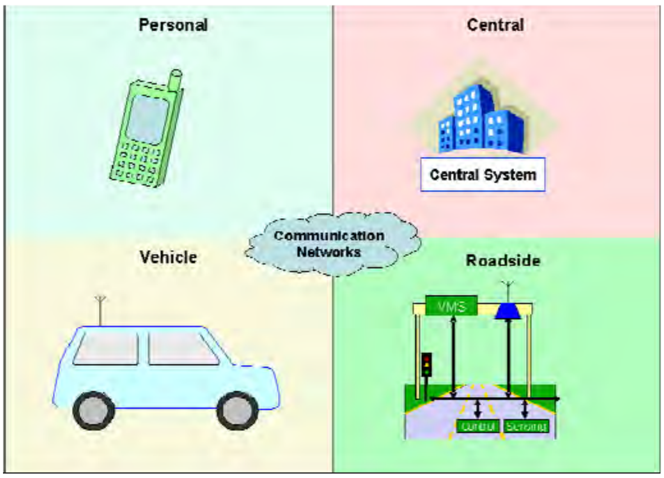

Figure 2.3: European ITS communication architecture

Four types of ITS-Ss are defined in ETSI standards as illustrated in Figure 2.3.

- **Vehicle ITS-S**: a vehicle ITS-S is implemented in vehicle and provides ITS applications to vehicle users. Within the scope of eCo-FEV, the vehicle ITS-S is implemented in OBU sub system. The OBU is connected with in vehicle systems e.g. vehicle electronics systems or FEV charging systems, and exchanges information with other vehicle ITS-Ss, road side ITS-Ss and the central ITS-S.
- **Road side ITS-S:** a road side ITS-S is implemented at road side and provides ITS applications to vehicle users or services operators. Within the scope of eCo-FEV, the road side ITS-S is implemented in RSU sub system. The RSU comprises wireless or wired communication device and exchanges information with vehicle ITS-Ss or central ITS-S. RSU may be deployed and managed by road operator or services providers targeting at providing services from road side. Accordingly to the deployment strategy, a road side ITS-S may connect with other road side equipment e.g. traffic equipment or charging equipment.
- **Central ITS-S:** a central ITS-S is implemented at backend such as road traffic centers, service center etc. in order to provide services to vehicle users or to other services providers. Within the scope of eCo-FEV, any server of eCo-FEV backend is implemented as central ITS-S. The eCo-FEV backend exchanges information with vehicle ITS-Ss, road side ITS-Ss and other infrastructure operators as defined in [1]. It should be noted that these infrastructure operators may also be considered as central ITS-S. Being external actors of the eCo-FEV system, these central ITS-Ss are not implemented by the project. However, the interfaces for data exchanges between eCo-FEV backend and external central ITS-Ss are developed.
- **Personal ITS-S:** a personal ITS-S is implemented at personal devices e.g. smartphones and provides ITS applications to users. Within the scope of eCo-FEV, personal ITS-S is not implemented. However, eCo-FEV system may also provide services to personal ITS-S user.

2.2.2. eCo-FEV network architecture

Figure 2.4 represents a top level abstraction of eCo-FEV network architecture considering multiple network domains. This network architecture is derived from standardized ITS network architecture [4].

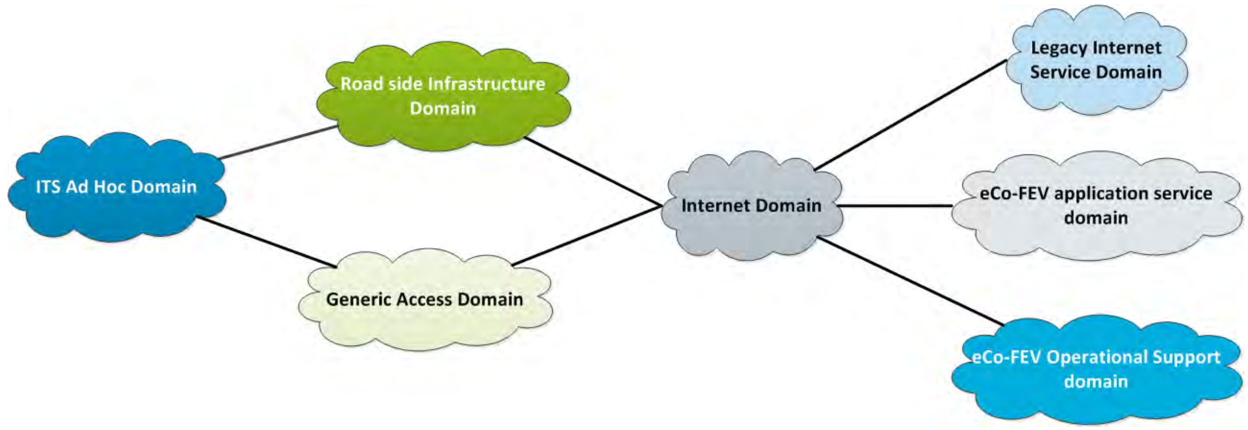

Figure 2.4: eCo-FEV communication network architecture

The domains can be classified into:

- **The ITS Ad Hoc Network Domain** comprises ITS-Ss, including OBUs and RSUs and enables ad hoc communication between them (V2V, V2I). Communication in this domain is based on ITS G5 wireless technologies and allows for mobility of the (Vehicle) ITS Stations forming arbitrary network topologies without need for a coordinating communication infrastructure.
- **The Roadside Infrastructure Network Domain** is a local network domain that provides network access for RSU and OBU. It may be based on wireless or wired technologies enabling OBUs to communicate, no longer directly in ad hoc mode, but via the RSU infrastructure network. The Road side infrastructure network can also provide access to a core network in the Internet Domain. Typically, this access is provided intermittently due to the limited wireless coverage of the short-range wireless technology used in ITS ad hoc network. In eCo-FEV, OBU may communicate with RSU for exchanging data for charging, technologies such as Power Line Communication (PLC) or Wi-Fi for inductive charge while driving may be used.
- **The Generic Access Network** (e.g., UMTS, WLAN hotspots) domain can be used to connect OBUs or RSUs directly to the Internet Domain, which comprises the core network, bridging different network domains. The communication of ITS-Ss via the Generic Access Network requires support from communication infrastructure (i.e., base stations or access points) and is thus not based on ad hoc networking.
- Further, the **Internet Domain** facilitates access of ITS-S to various services. The Legacy Internet Service Domain refers to IP capable nodes providing a wide range of Internet services, such as World Wide Web (WWW), email and many others. The eCo-FEV

Application Service Domain provides eCo-FEV services for FEV and users from eCo-FEV backend as well as the communication between eCo-FEV backend with other operators' backend centres e.g. road traffic centers and vehicle-to-business communication. Finally, eCo-FEV Operational Support Domain provides support for the operation of eCo-FEV services, e.g., payment and billing network to provide payment and billing services or security support.

2.2.3. Network mobility management

One of the important communication requirements to realize eCo-FEV use case is the connectivity between user (i.e. FEV) and service providers (i.e. a backend service provider). In order to benefit from eCo-FEV service, FEV may need to dialogue with service providers located in the Internet Domain at any place at any time. Communication link should be flexibly established, taking advantage of any available networks. For some use cases, connectivity continuity should be ensured while FEV is in mobility. An overview of FEV connectivity is depicted in Figure 2.5. OBU is equipped with three wireless communication antennas of different technologies, namely 802.11b/g/n (Wi-Fi), 802.11p (G5) and 3G/4G (cellular). For local V2V and V2I communication, due to the high mobility of FEVs, network topology may change rapidly. A geographical position based networking protocol (GeoNetworking) may be used to route the packet according to the geographical position of nodes. GeoNetworking routing protocols are defined in ETSI TC ITS [5]. As for connectivity of FEV to eCo-FEV backend, depending on the radio coverage of the area where the FEV is localized, FEV will be able to switch from an Access Network to another (handover) in order to stay connected. The continuity of the connectivity will be ensured by the use of IPv6 protocols that provide mobility support, such as MIPv6 (Mobile IPv6) [6] and NEMO (Network Mobility) [7]. Basically, these protocols rely on the use of a Home Agent that forwards data from the FEV to a distant Correspondent Node (CN) (e.g. eCo-FEV backend) and vice-versa as depicted in Figure 2.5. The support of mobility is essential to avoid the interruption of established communication sessions between a device inside the FEV and a CN each time a handover is performed.

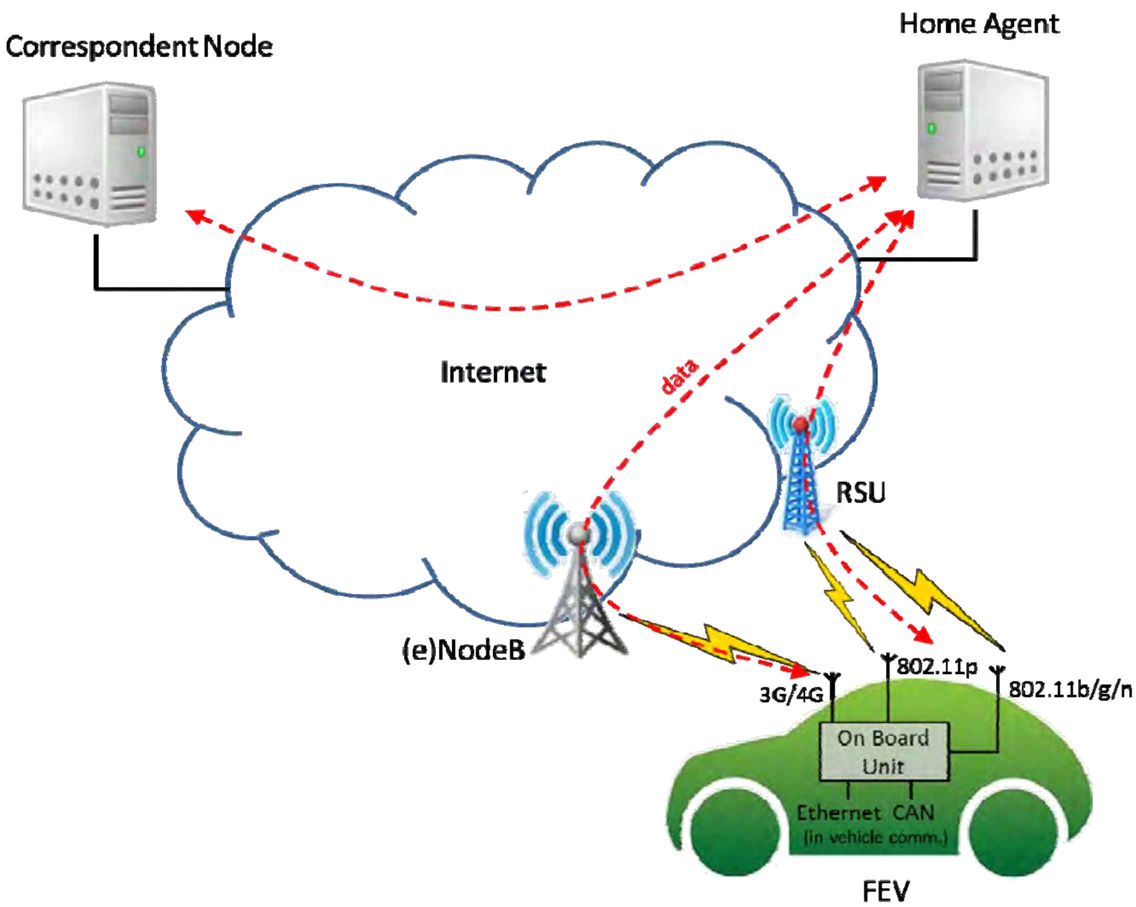

Figure 2.5: overview of FEV connectivity

2.3. Information viewpoint

The ambition of the eCo-FEV project is to play the role of facilitator between the travelers and already existing transport operators. Meanwhile the eCo-FEV project will create a new set of "roles" that will be distributed among the already exiting transport operators and will give the opportunity to new actors to enter the transport business. The challenge for the eCo-FEV informational architecture comes from the requirement of its flexibility necessary to fit various business models. To meet these challenges, on one hand, the eCo-FEV system has to propose an integration bus with a set of new services, on the other, it has to respect already existing standardized interfaces supported by the existing Information Systems.

From information viewpoint the entire eCo-FEV system can be represented by Figure 2.6.

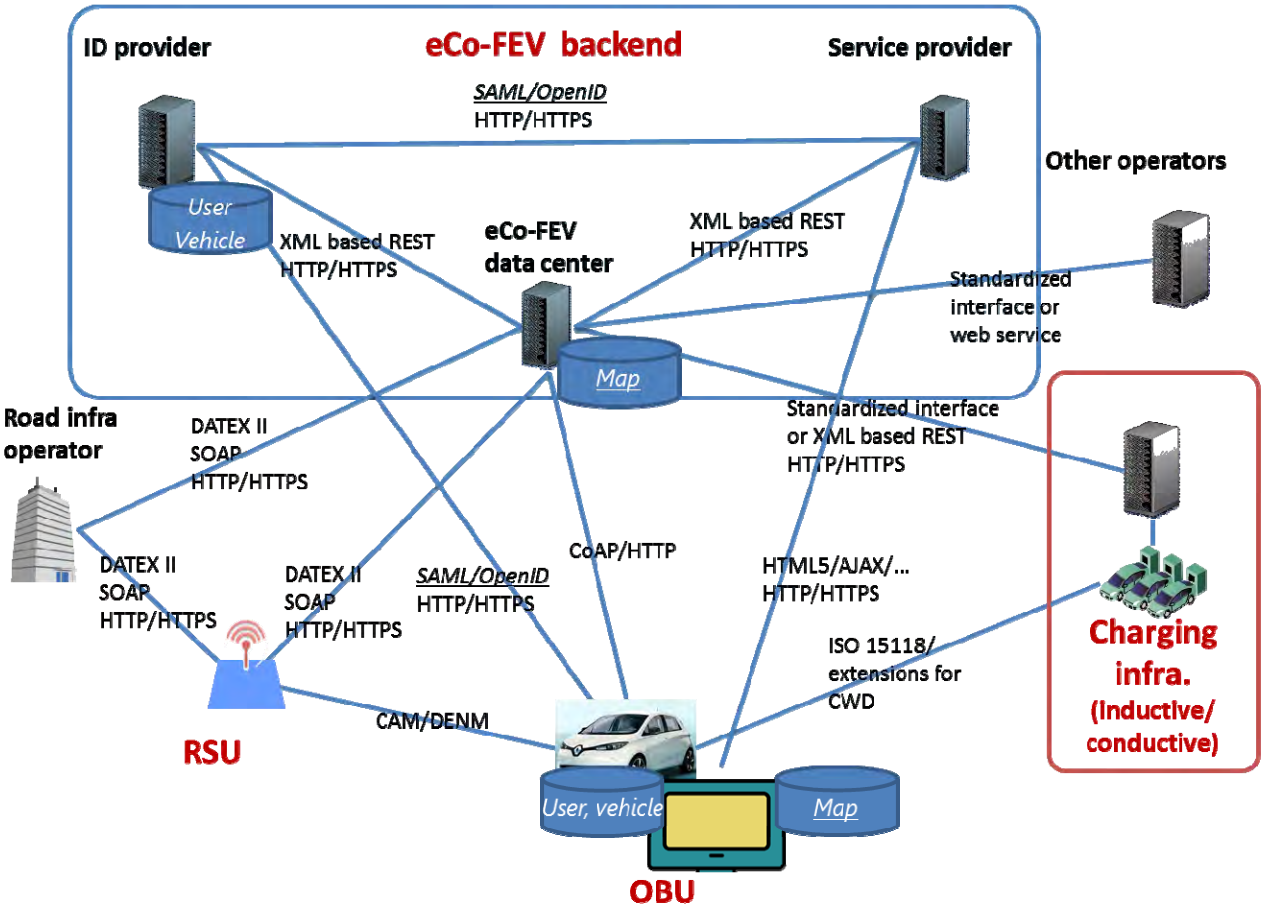

Figure 2.6: eCo-FEV ecosystem, information viewpoint

Systems within the blue block will be implemented as a part of the eCo-FEV backend. Other eCo-FEV sub systems (e.g. OBU) and external infrastructure systems as defined in [1] are located outside the blue block. These systems exchange information with eCo-FEV backend, either via wireless or wired communication. These interfaces are exposed interfaces, in order to facilitate information exchange. Preferably, standardized interfaces will facilitate flexible business model set up and system interoperability. On the other hand, it is important to underline that eCo-FEV backend functions may be distributed within more than more central ITS-Ss, and these functions can be delivered by various actors in one possible implementation. Some of such functions should be multi-instantiated (i.e. delivered simultaneously by multiple actors) during the deployment phases. The architecture has to support the possibility of multi-instantiation and multi-sourcing (i.e. various implementations) for these functions if necessary. Example for the eCo-FEV backend function multi-instantiations is the Identity Management, e.g. car makers or service providers may require the control of their customer and vehicle relationship management. It is also important to underline that car makers will continue the promotion of “personal assistant” functionalities offered by their information systems. To fulfil these objectives and requirements, the standardization of certain eCo-FEV backend internal interfaces will be necessary. Another example is an open interface of the eCo-FEV backend system to applications (open API for applications), so that different FEV service operators (e.g. service providers, OEMs) may operate their services with support of eCo-FEV backend.

We propose to discuss the following exposed interfaces:

2.3.1. Identity management interfaces

The “Identity management interfaces” (e.g. [8], [9], [10]) are in charge of authentication and identity information retrieval. It allows the separation between the resources providers and authentication/authorization providers. In other words we are looking for the possibility of using the authentication and authorisation facilities delivered by one actor (so called “identity provider”) to grant access to the resources managed by another actor (called “service provider”).

This approach allows the “Single Sign On” in large lightly coupled Internet ecosystem and reduces the number of the registration processes the end-user has to complete.

We propose to study the possibility if introducing of the OpenID technology [8] based on [9].

Figure 2.7 gives the principles of the approach:

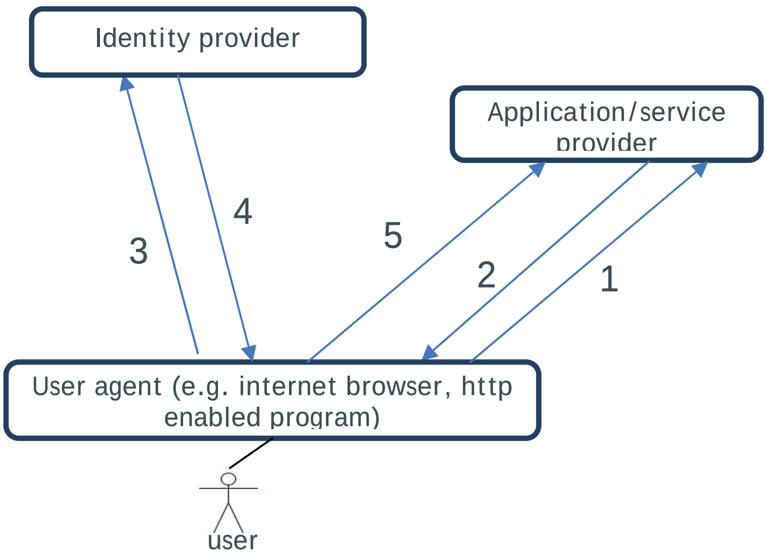

Figure 2.7: General authentication principles

The sequence of exchanges is the following:

1. The user requests access to an application hosted by the services provider
2. The service provider redirects the user to an Identity provider that manages the user ID and user authentication.
3. The user requests the authorization token and identity claims from the identity provider
4. The identity provider delivers the authorization token and redirects the user to the service provider
5. The user access the application hosted by the service provider

According to the design options this process can be totally hidden to user or can require an interaction with the user.

In addition the approach is useful for the N-tier (multi-tier) applications where the secondary tiers have to grant the access to resources on behalf of the end-user which are authenticated to the front-end (i.e. tier 1) layer, as illustrated in Figure 2.8.

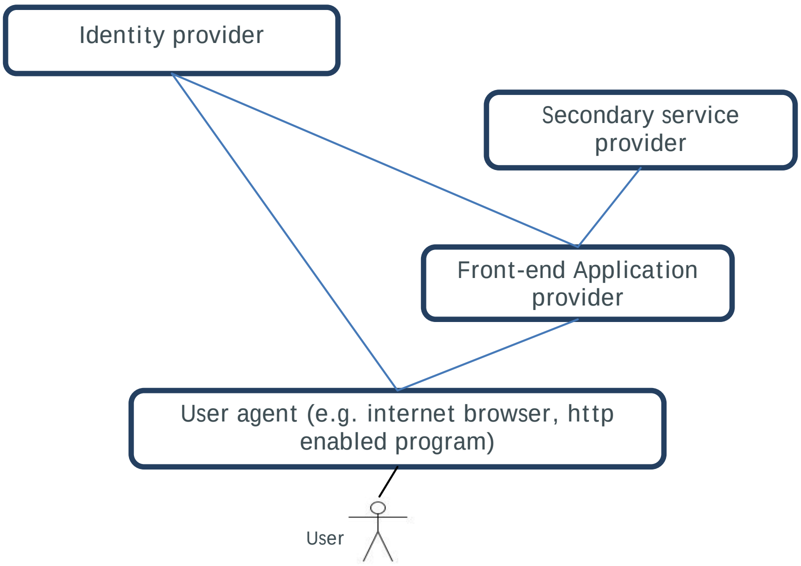

Figure 2.8: N-tier application authentication

2.3.2. Generic web-services

We propose to deliver the main eCo-FEV FEV user services in form of REST web-services ([12]). We propose to build the eCo-FEV xml namespace which will contain the description of all eCo-FEV specific definitions. Unless otherwise specified, XML-based REST interfaces over HTTP will be used for data exchange between the eCo-FEV backend sub components, between the eCo-FEV backend and other eCo-FEV sub systems. For communication between the eCo-FEV backend and existing infrastructure systems, existing interfaces may be used. In case secure communication is required, XML-based REST interfaces over HTTPS may be used.

2.3.3. FEV charging interface: ISO 15118

ISO 15118 [13] specifies the communications between Electric Vehicles (EV), including Battery Electric Vehicles and Plug-In Hybrid Electric Vehicles, and the Electric Vehicle Supply Equipment (EVSE). As the communication parts of this generic equipment are the Electric Vehicle Communication Controller (EVCC) and the Supply Equipment Communication Controller (SECC), ISO 15118 describes the communication protocol and data exchanges between these components.

Currently ISO 15118 is focusing on wired charging technologies Power line communication (PLC). On the other hand, recently ISO/IEC has started standardization work to enable the wireless communication for charging by extending the already published ISO 15118 standard series. eCo-FEV will consider this standardization work and provides potential contributions. In particular, eCo-FEV will contribute to standardization for CWD procedure.

In addition, ETSI TC ITS WG1 is currently defining a standard (ETSI TS 101 556-3) to support the charging infrastructure reservation by FEV user during the trip via wireless communication. This standard work is on-going. eCo-FEV project will consider implementing this standard according to the progress or provide potential contributions to ETSI TC ITS.

2.3.4. Generic M2M interfaces

For FEV data collect functionality we propose to follow the IETF initiative for the domain of machine to machine communication and the CoAP protocol (IETF [14]).

The Constrained Application Protocol (CoAP) is a specialized web transfer protocol for use with constrained nodes and constrained (e.g., low-power, lossy) networks. The protocol is designed for machine-to-machine (M2M) applications such as smart energy and building automation. CoAP provides a request/response interaction model between application endpoints, supports built-in discovery of services and resources, and includes key concepts of the Web such as URLs and Internet media types. CoAP is designed to easily interface with HTTP for integration with the Web while meeting specialized requirements such as multicast support, very low overhead and simplicity for constrained environments.

This interface may be used for communication between FEV and eCo-FEV backend for the collection of battery and FEV info and optionally for sending notification messages from eCo-FEV backend to FEV.

2.3.5. Generic interfaces for services providers

A generic API provided by eCo-FEV backend to service providers enables different providers to implement their applications in order to benefit the support of eCo-FEV backend. This interface enables an application to retrieve data collected by eCo-FEV backend, to request functional support to eCo-FEV backend such as identity management and route search support. This open interface further enables the modularity of eCo-FEV system architecture.

Generic web-services as defined in clause 2.3.2 may be used for this API implementation.

2.3.6. DATEXII interface

DATEX II is designed as the protocol used for information exchange between traffic management centres. Within the scope of SCORE@F project [14], DATEX II is also implemented as protocol for communication between RSUs and traffic management centre. DATEXII protocol enables exchange of traffic related information among different actors. The specifications of DATEX II are realized by EASYWAY project [15] and standardized in CEN TC 278. The deployment of DATEX II within many European Countries has started.

Version 2.0 of the DATEX II will be used as interface between eCo-FEV backend and road infrastructure operator.

2.3.7. C-ITS messages

A set of standardized message sets are defined for vehicular communications in Cooperative ITS system, among them the Cooperative Awareness Message (CAM) [5] that shares the vehicle position and attributes information with other vehicles and infrastructures; Decentralized Environmental Notification Message (DENM) [17] that informs the detected road hazard situations from vehicle ITS-S or road side ITS-S to other vehicles; service announcement message (SAM) (standardization on-going) that announces the available services and communication technologies used to access the service; and the FEV C/S POI notification messages [18] that provides location based information of the EVSE and potentially the availability information of EVSE. The description of CAM and DENM messages are summarized in Table 2.1 and Table 2.2, respectively.

Name	Cooperative Awareness Message (CAM)
Interface	V2V, V2I, I2V
Description	CAMs are distributed within the ITS-G5 (802.11p) network and provide information of presence, positions as well as basic status of communicating -S to neighbouring ITS-Ss.

Generation	All ITS-S shall be able to generate, send and receive CAMs, as long as they participate in Cooperative ITS networks
Frequency	Typically 1-10 Hz
End to end latency	Typically less than 100 ms on communication
Media	ITS G5 (802.11p) Control channel CCH
Communication	A CAM is broadcasted to neighbour ITS-Ss within the direct communication range.
Encoding	ASN.1 unaligned packet encoding
Content	A CAM is composed of a common ITS Protocol Data Unit (PDU) header, and a sets of containers that includes information of vehicle movement, vehicle type, vehicle role, vehicle basic sensor information such as acceleration, vehicle light status, vehicle yaw rate, etc.

Table 2.1: CAM description

Name	**Decentralized Environmental Notification Message (DENM)**
Interface	V2V, V2I, I2V
Description	Decentralized Environmental Notification Messages (DENMs) are mainly used to alert road users of the detected events
Generation	The general processing procedure is as follows: • Upon detection of an event, the ITS-S immediately broadcasts a DENM to other ITS-Ss located inside a geographical area and which are concerned by the event. • The transmission of a DENM may be repeated with a certain frequency. • The DENM broadcasting may persist as long as the event is present.
Frequency	Application dependent, typically 1 – 10 Hz
Latency	Application dependent
Media	ITS G5 (802.11p)
Communication	A DENM shall be disseminated to as many ITS-Ss as possible located within the relevance area. The DENM dissemination shall rely on the functionalities of the ITS networking and transport layer, in particular on GeoNetworking functionalities
Encoding	ASN.1 unaligned packet encoding
Content	A DENM PDU is composed of a common ITS PDU header and a DENM. The header includes basic information including the protocol version, the message type and the generation time of the message. A DENM consists of three fixed order parts: the management container, the situation container and the location container.

Table 2.2: DENM description

2.4. Technology viewpoint

For OBU sub system, at least the following sub components are required for eCo-FEV and integrated into FEV:

- **Communication module:** allows OBU to communicate with other eCo-FEV sub systems and with other FEV internal electronic systems. For OBU and RSU, short-range communication media (i.e., IEEE802.11p) and cellular based communication will be included. The communication module also includes adequate routing functionalities for message dissemination. For eCo-FEV, the geographic location based routing protocol (geoNetworking) and legacy IPv6 stack plus mobility support functionalities are required. The communication module may be implemented as an in vehicle router.
- **Application unit:** handles main operations of the FEV applications. In eCo-FEV, Linux-based devices may be used, in which an application and a middleware platform are installed. The vehicle CAN and a GPS module are connected to AU. In order to accommodate development realized by different partners, an open software development platform should be selected (e.g. OSGi). Application unit may be integrated with communication module in one hardware, or may be integrated in a FEV electronic control unit (ECU).
- **HMI device:** handles interactions with EV users such as a navigation application. HMI device is connected with AU via wired or wireless communications (e.g. Bluetooth) to present application results and to provide user instructions to applications. Since some new applications need to be installed here, it should allow easy development and extension (e.g., Linux-based, Android-based).

For RSU subsystem, at least a communication module and application module are required:

- **Communication module:** this communication module provides the same functionalities as the one used in OBU. Additionally, depending on RSU deployment, RSU may include wired communication capacity to communicate with backend servers e.g. traffic management center, eCO-FEV backend etc.
- **Application unit:** handles main operations of the RSU applications. In eCo-FEV, Linux-based devices may be used. A GPS module is connected to AU. If required, a RSU may be connected with road infrastructure sensors and/or charging infrastructure sub system. In order to accommodate the development realized by different partners, an open software development platform should be selected (e.g. OSGi). Application unit may be integrated with communication module in one hardware.

eCo-FEV backend shall include at least one server. In order to enable flexible deployment setup, more than one server may be included. For eCo-FEV backend sub system, the following modules are required:

- **Communication module:** e.g. wired communication to Internet Domain. It is required for each server included in eCo-FEV backend.
- **eCo-FEV backend middleware platform:** implements a middleware platform including common functions required by eCo-FEV use cases. eCo-FEV backend platform provides an Application Programming Interface API to eCo-FEV application platform. It also includes gateway functions to exchange information with external infrastructure systems and with FEVs.
- **eCo-FEV application platform**: implements the eCo-FEV applications upon eCo-FEV backend platform. eCo-FEV application platform may be integrated with communication module and eCo-FEV back end middleware platform into one server.
- **other platforms**: as described in chapter 2.3, in order to enable a flexible eCo-FEV backend deployment, additional platforms may be implemented in an individual server e.g. ID management platform.

For charging infrastructure sub system, the following modules are required:

- **Charging infrastructure back end system** (EVSE operator): EVSE operator is a backend system that manages a set of Electric Vehicle Supply Equipment (EVSE). It interacts with energy suppliers to distribute energy to EVSE in order to ensure the charging demand, and ensures the operation of the EVSEs and charging management e.g. client AAA. It should provide the EVSE availability information to eCo-FEV backend.
- **Charging equipment EVSE**: road side equipment that provides energy to FEV, either via conductive or via inductive charging.
- **Communication module SECC**: SECC communicates with FEV for authentication and management of charging procedure. It also communicates with EVSE operator for management and operation procedures. Within the scope of eCo-FEV, the PLC communication or wireless communication (ITS G5) may be used for communication between EVSE and FEV. In case G5 is used as wireless communication technology, the CCU of RSU may be used as router by charging infrastructure. For communication between EVSE and EVSE operator, specific EVSE operation network may be used.
- **Charging station (C/S) control unit**: This control unit is an application unit implementing functionalities for FEV user authentication, charging monitoring and if

necessary the user accounting. In case G5 is used as wireless communication technology, these functionalities may also be implemented in RSU AU. The charging equipment, SECC and charging station control unit consist an EVSE. They may be implemented in one hardware.

It should be noted that, one important research innovation of the eCo-FEV project is to develop the charge while driving charging infrastructure in Italian Test Site. In a real deployment, the charging infrastructure may be already deployed and considered as existing infrastructure and external actor of the eCo-FEV system.

3. eCo-FEV system functional design

3.1. System functional overview

The functional design defines the main architectural elements of the eCo-FEV system. In this chapter, the main eCo-FEV system's functional structure including the key functional elements, their responsibilities, and the interactions between them will be described using interaction models. Taken together, this will show how the system will perform the required functions as described in [1]. As presented in [1] two levels of use cases are defined in eCo-FEV. The primary use cases provide services to FEV users or commercial vehicle fleets. The realization of the primary use cases rely on a set of secondary use cases that provides services by connecting eCo-FEV system with different infrastructure operators and with FEV. A secondary use case may be used by multiple primary use cases.

As mentioned in previous chapter, the principle adopted by eCo-FEV consortium for the eCo-FEV system architecture definition is to provide eCo-FEV services from backend, allowing collection and processing of large amount of data from multiple infrastructure systems and from FEVs. Based on this, a high level functional architecture of the eCo-FEV system is defined in order to allocate main functionalities to each sub system. This high level functional architecture is illustrated in Figure 3.1. As shown in figure, eCo-FEV backend provides trip and charging assistances services to assist FEV before and during trip. For this purpose, eCo-FEV backend manages relevant information from FEVs and collected from infrastructure systems. eCo-FEV backend may apply data aggregation functionalities for collected data. Furthermore, eCo-FEV backend manages the identity and access rights for FEV users according to the business model. OBU receives information from eCo-FEV backend and realizes navigation applications. RSU is equipped at road side, allowing provision of local information to FEV users or providing communication capacity between road side equipment/charging equipment with FEVs and with backend.

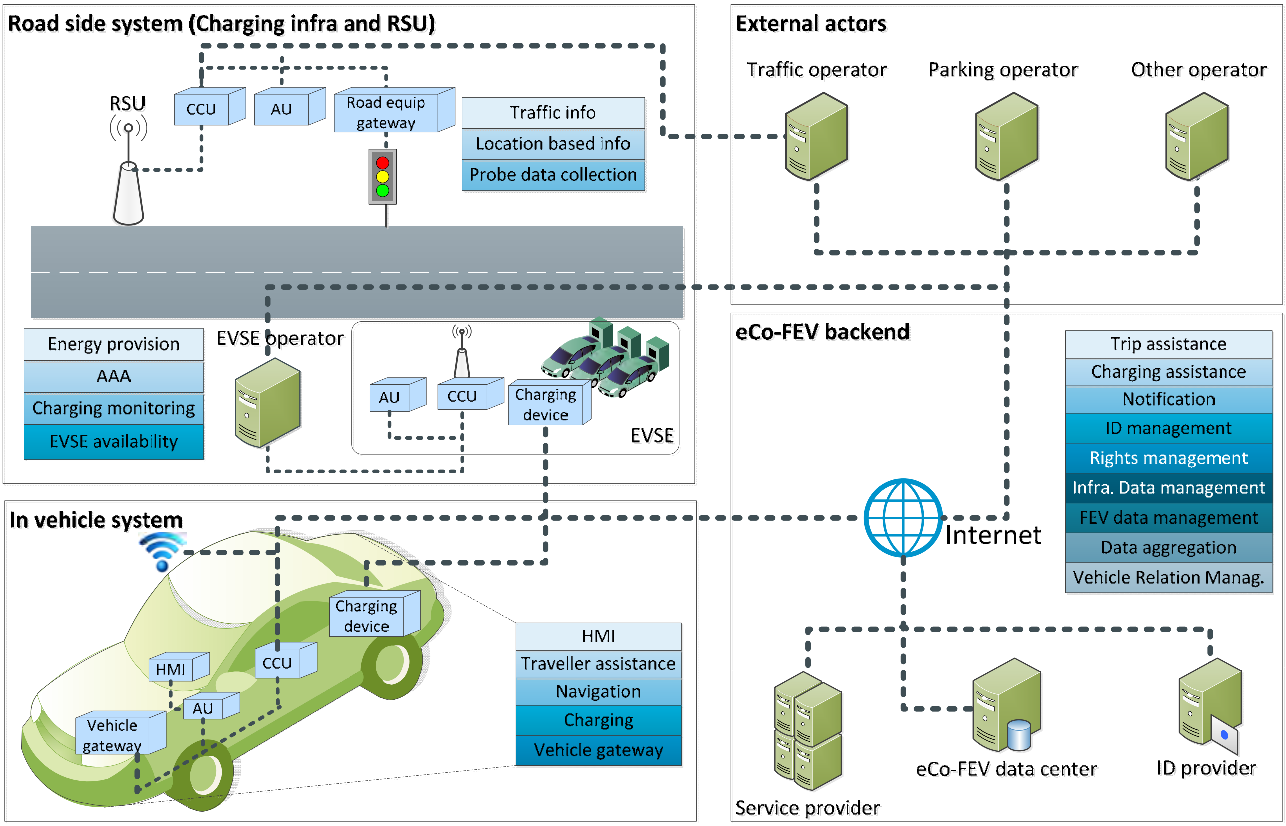

Figure 3.1: eCo-FEV system high level functional architecture

3.2. Use case sequence diagrams

With the agreed high level functional architecture, detailed information exchanges between eCo-FEV sub systems and with external actors will be defined. UML sequence diagram is used for this purpose.

By defining the sequence diagram for each use case, functionalities distributions at eCo-FEV sub systems can be derived. It enables the definition of functional architecture of each eCo-FV sub system.

3.2.1. **UC101: eCo-FEV subscription**

eCo-FEV traveller submits a subscription request to eCo-FEV backend. Traveller may be required by eCo-FEV backend to confirm the subscription. According to the requirements of application providers, eCo-FEV traveller may be required to provide information during the subscription such as personal information of eCo-FEV traveller, charging contract ID or even payment details etc. By subscription, an eCo-FEV traveller is subscribed to a set of services provided by eCo-FEV back end, e.g. navigation service, reservation assistance etc. It should be noted that according to the business model, user subscription data may be managed by service providers. In this case, the service subscription may be managed directly by such service providers. eCo-FEV backend shall provide functions to verify and validate the user data, manage user subscription data and generates login information for subscription requesting party e.g. eCo-FEV traveller, or eCo-FEV traveller & FEV. A subscription may be linked to a predefined set of service level agreement (SLA) (e.g. contract). This information is also managed by eCo-FEV backend.

Once the subscription is validated, log in information is provided back to eCo-FEV traveller in format of e.g. user ID and password.

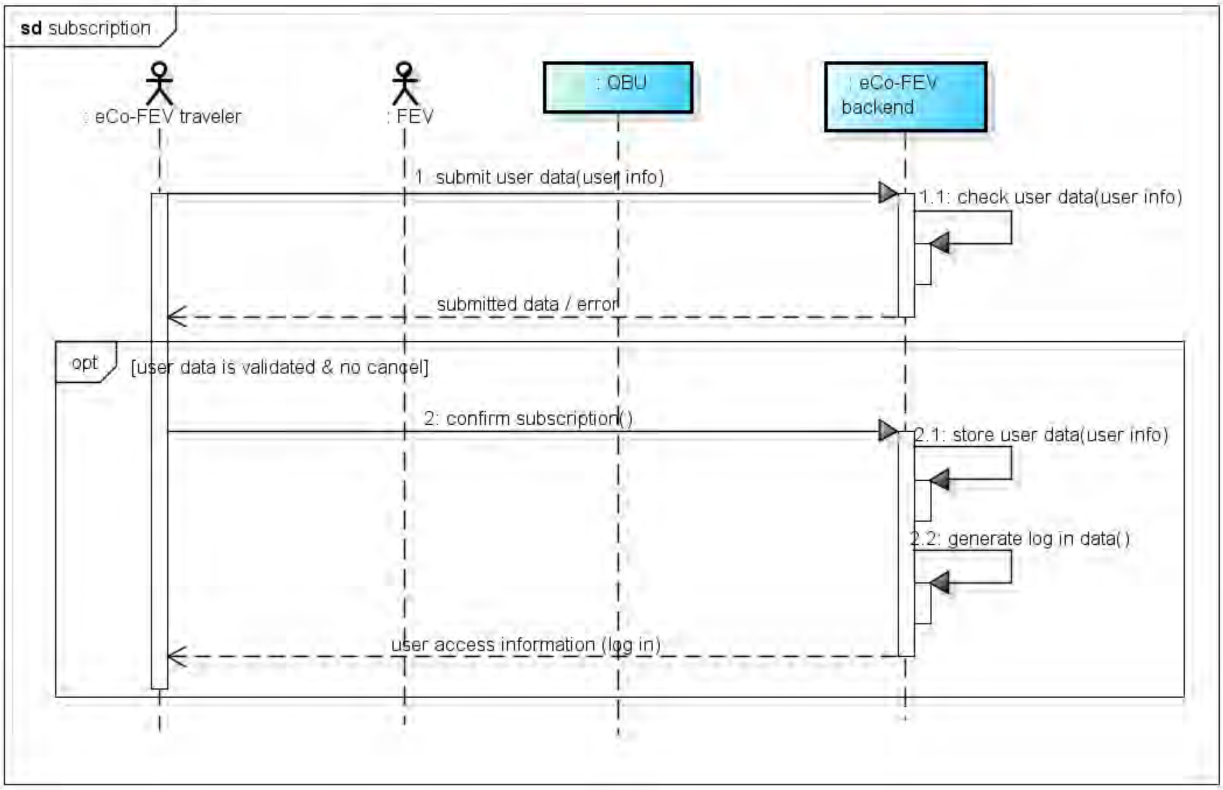

Figure 3.2: eCo-FEV subscription

3.2.2. **UC102: Login**

This use case enables eCo-FEV traveller to log in to eCo-FEV backend. eCo-FEV traveller may directly log in by web (Figure 3.3) or via OBU HMI (Figure 3.4). eCo-FEV backend shall provide functions to verify the login data and authenticate eCo-FEV traveller to access corresponding services that she/he is entitled to. For single sign on authentication, an authorization token may be delivered to eCo-FEV traveller or OBU upon successful login. Therefore, eCo-FEV backend shall include functions to generate, manage and verify the validity of authorization token. With a successful log in, user rights and responsibilities with regards to the eCo-FEV backend associated to the subscription contract are confirmed.

It should be noted that, according to the deployed business model and targeted services provided to eCo-FEV traveller, eCo-FEV traveller may log in from different places (e.g. at charging infrastructure, at parking entrance) and log in may be managed and verified by different operators. eCo-FEV project assumes log in directly by web and log in via OBU HMI as basic scenarios

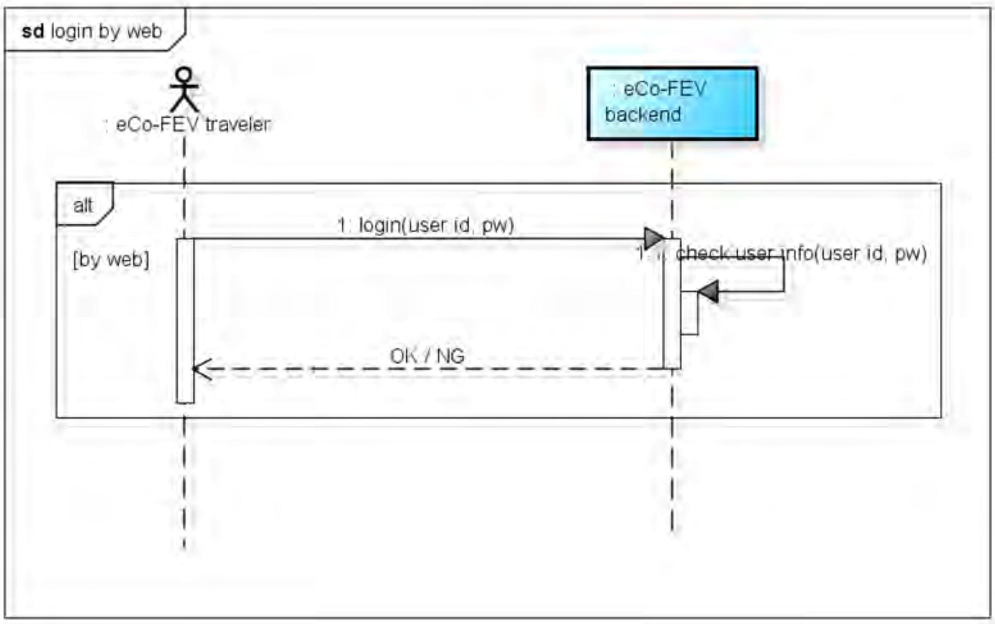

Figure 3.3: Login by web

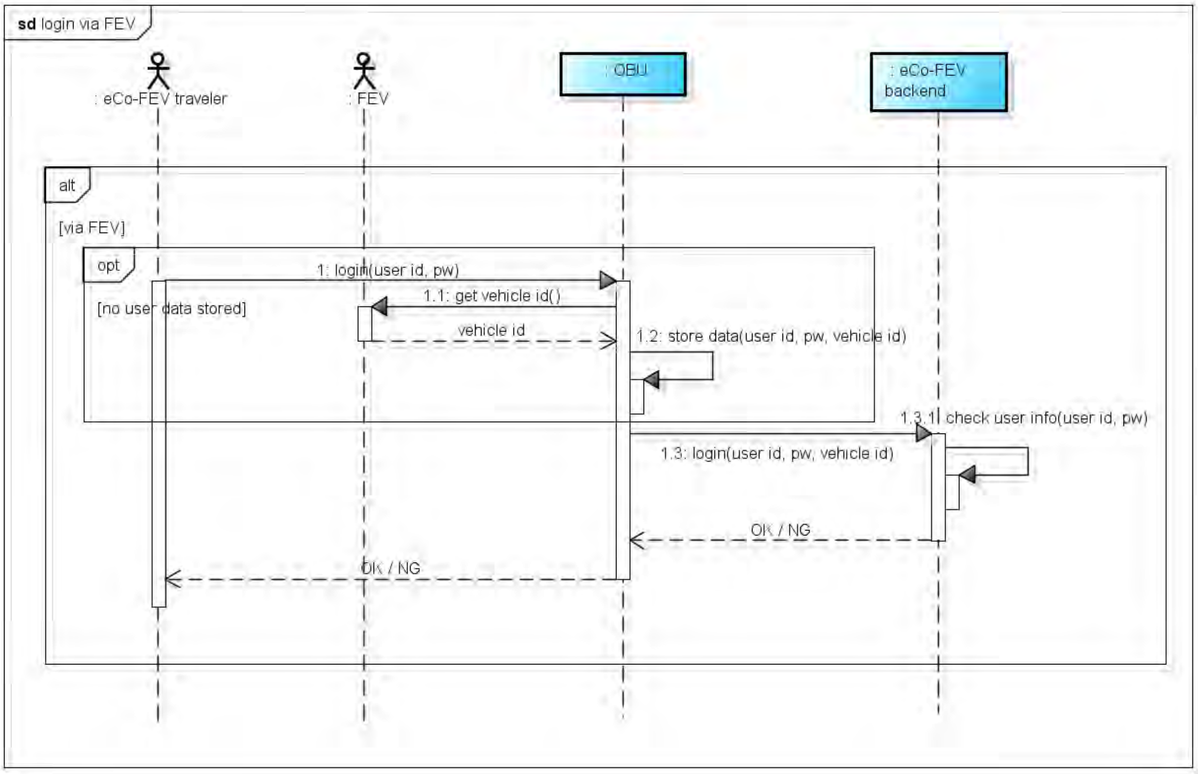

Figure 3.4: Login via FEV

3.2.3. **UC103: Free driving assistance**

In a free driving scenario, eCo-FEV backend provides assistance to FEV to monitor the traffic condition and charging facility accessibility and optionally POI information along the traveling. If requested by eCo-FEV traveller, eCo-FEV backend provides ad hoc trip assistance accordingly. eCo-FEV backend shall provide functionalities to monitor the FEV position and status, and verifies if a traffic or weather event is relevant to FEV.

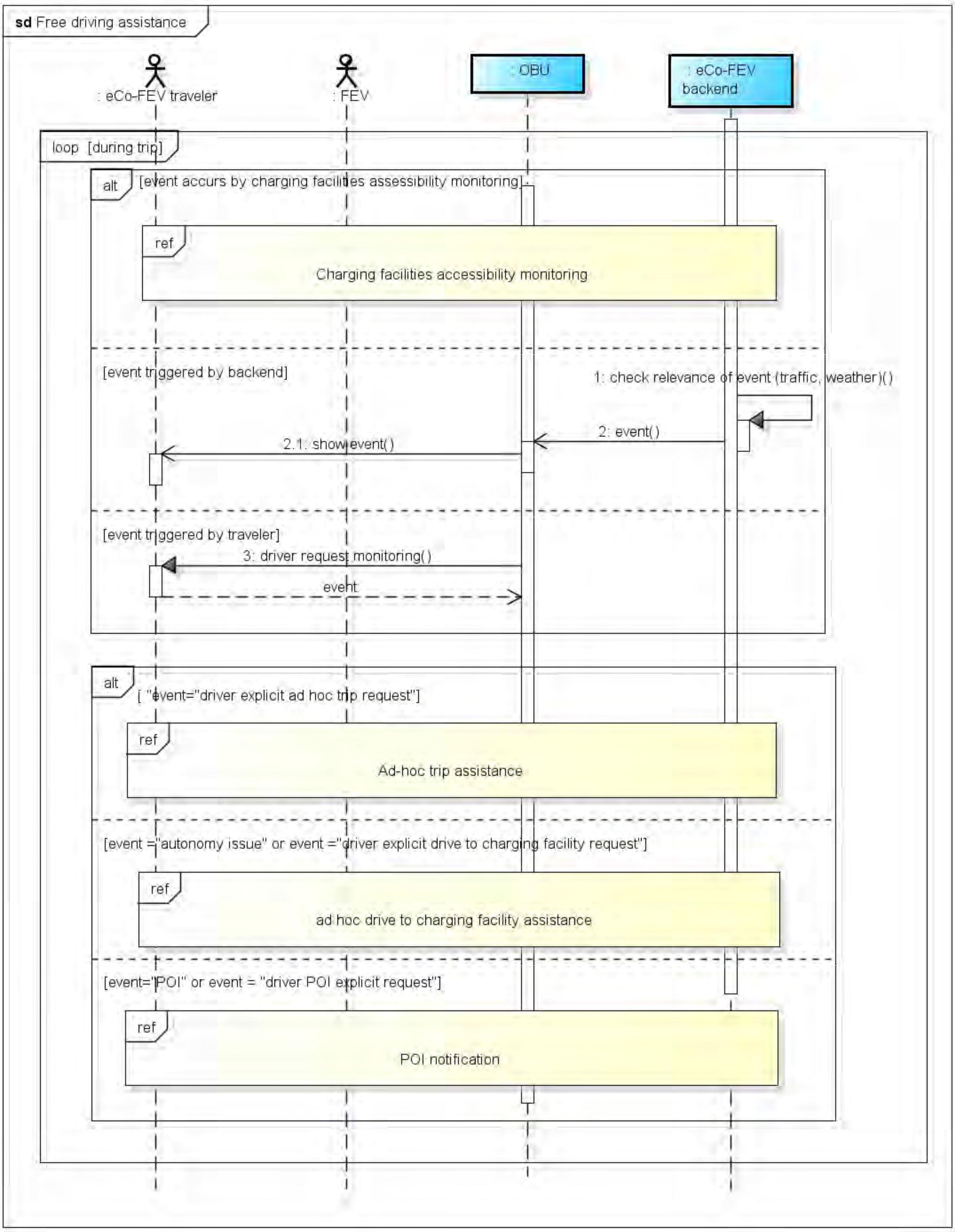

Figure 3.5: Free driving assistance

3.2.4. **UC104: Trip planning**

eCo-FEV traveller sends a trip planning request to eCo-FEV backend via OBU. eCo-FEV backend collects relevant information from infrastructure systems and calculates one or more than one trip itineraries and charging plan for eCo-FEV traveller. eCo-FEV traveller selects the desired itinerary and informs eCo-FEV backend. Optionally, eCo-FEV backend may undertake facilities booking for eCo-FEV traveller, if booking required information are known by eCo-FEV backend e.g. via subscription. The itinerary and charging plan calculation may need to be repeated, in case of user request modifications or facility booking problems. eCo-FEV backend shall provide functions to calculate the itinerary suitable to user preferences by taking into account the traffic condition and charging/parking facilities availability.

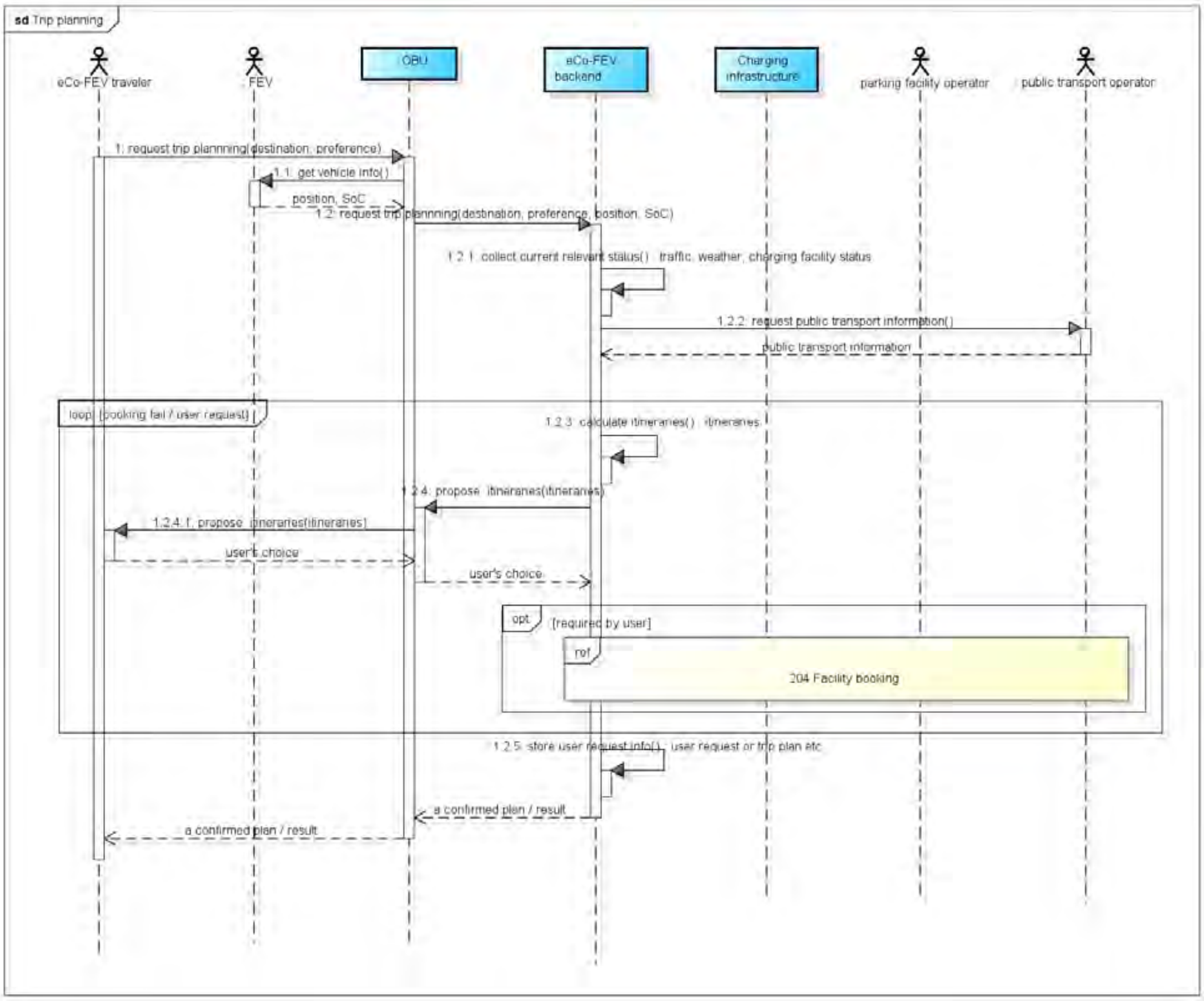

Figure 3.6: Trip planning

3.2.5. **UC105: Trip assistance**

The trip assistance may be requested by eCo-FEV traveler via on board HMI, OBU transmits the trip plan information to eCo-FEV backend. Alternatively, if the trip planning use case is realized just before the trip, the trip assistance may be triggered directly by the eCo-FEV backend according to the plan confirmed during trip planning use case. During the trip, the eCo-FEV backend informs eCo-FEV traveller of unexpected situations along the planned itinerary, or optionally propose alternative itinerary and charging plan. Based on the choice made by eCo-FEV traveler on the proposed alternative trip plan, the eCo-FEV backend may further proceed to realize the facilities booking and/or facilities cancellation accordingly. The trip assistance procedure will then continue based on the new trip plan, until the eCo-FEV traveler reaches its final destination.

The eCo-FEV backend shall be able to estimate the impact of an unexpected event on the trip plan of an eCo-FEV traveller. If the unexpected event prevent that the original travel plan is respected within a predefined margin, an alternative itinerary may be provided by eCo-FEV backend to eCo-FEV traveller.

3.2.6. **UC106: Ad hoc drive to charging facility assistance**

eCo-FEV traveller sends a request to eCo-FEV backend requiring assistance to drive to a reachable charging facility. eCo-FEV backend shall estimate the remaining range of FEV by considering traffic conditions and FEV status. Then it looks for available charging facilities within the estimated range and calculates a route to the charging facility selected by eCo-FEV traveller. During travelling towards the selected charging facility, eCo-FEV backend informs eCo-FEV traveller of relevant unexpected situation and if necessary, readjusts the itinerary or selects another charging facility within the estimated range of FEV. In this step, the same procedure as trip planning and trip assistance use case is required.

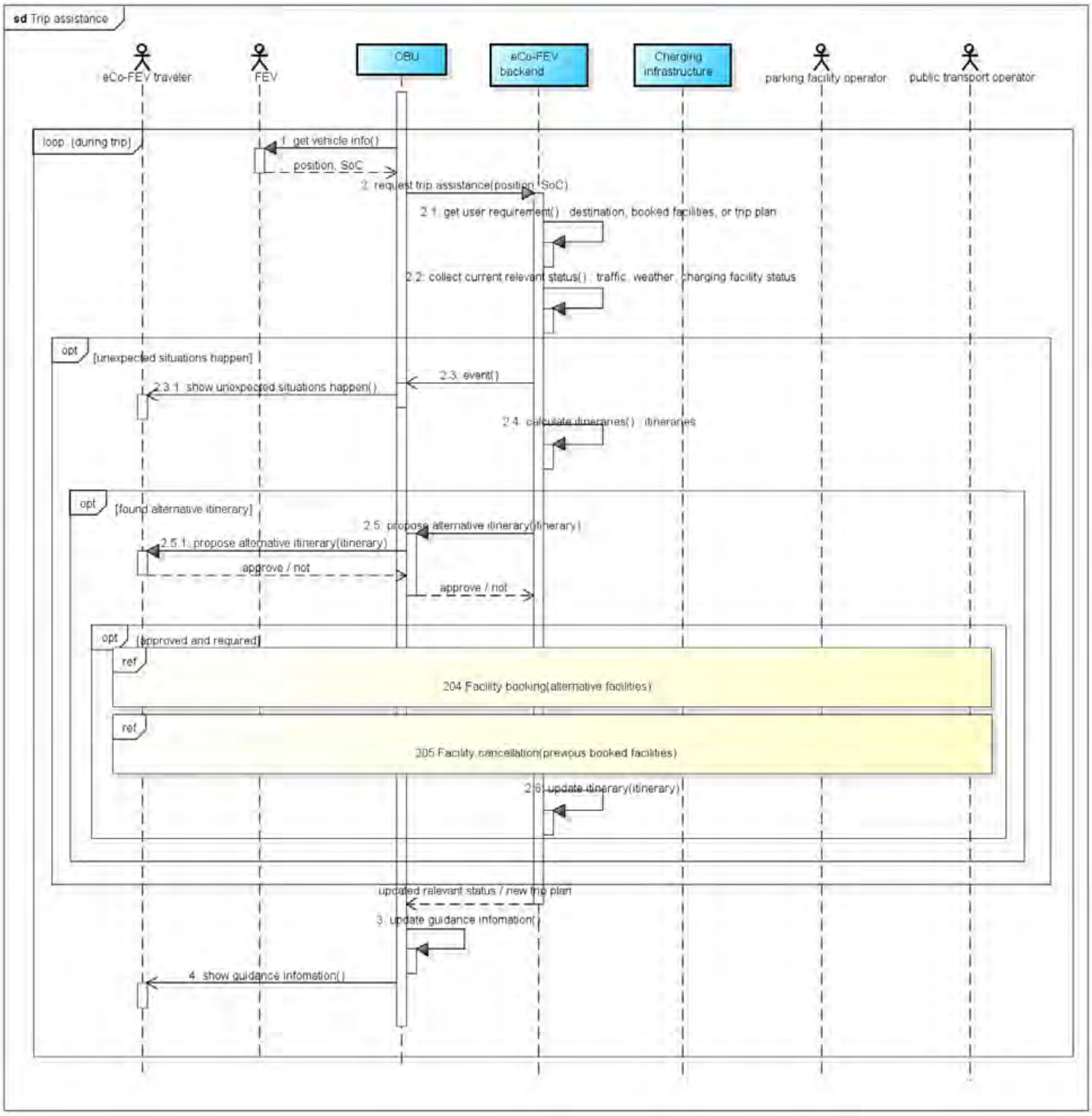

Figure 3.7: Trip assistance

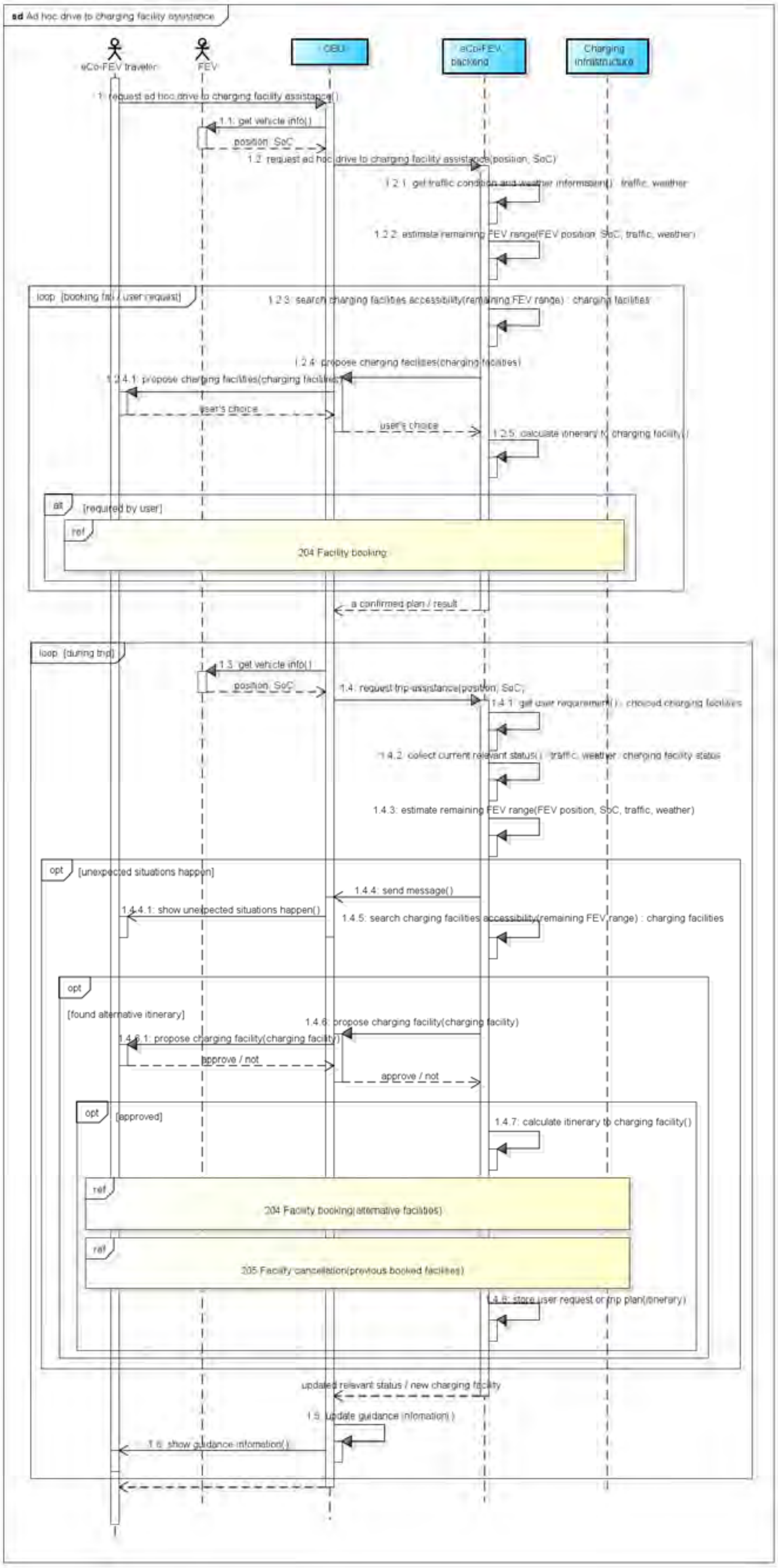

Figure 3.8: Ad hoc drive to charging facility assistance

3.2.7. UC107: Ad hoc trip assistance

eCo-FEV backend assists eCo-FEV traveller to plan an ad hoc trip and assists eCo-FEV traveller along the trip. Therefore, it incorporates the trip planning and trip assistance use cases.

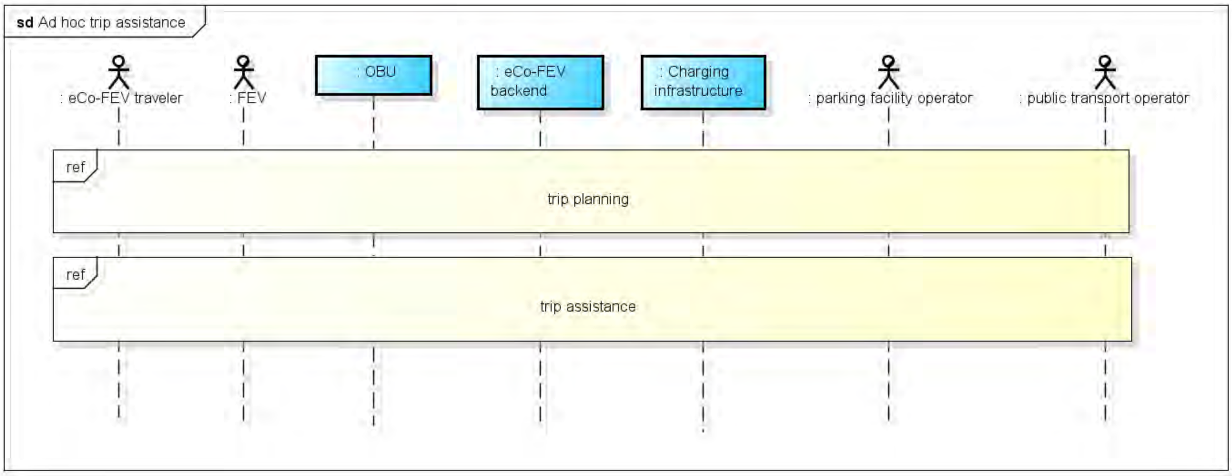

Figure 3.9: Ad hoc trip assistance

3.2.8. UC108: Delivery planning

eCo-FEV backend provides service for delivery fleet operator to set up delivery itinerary and delivery FEV charging plan. Receiving the delivery plan information from FEV delivery fleet operator, eCo-FEV backend calculates appropriate delivery itinerary suitable to the delivery plan, by considering relevant information e.g. traffic condition, weather condition, and in particular charging needs of FEVs during the delivery mission. Based on approved plan by delivery fleet operator, eCo-FEV backend may provide facility booking assistance. The confirmed trip plan is provided to delivery fleet operator and if necessary to relevant delivery FEV driver.

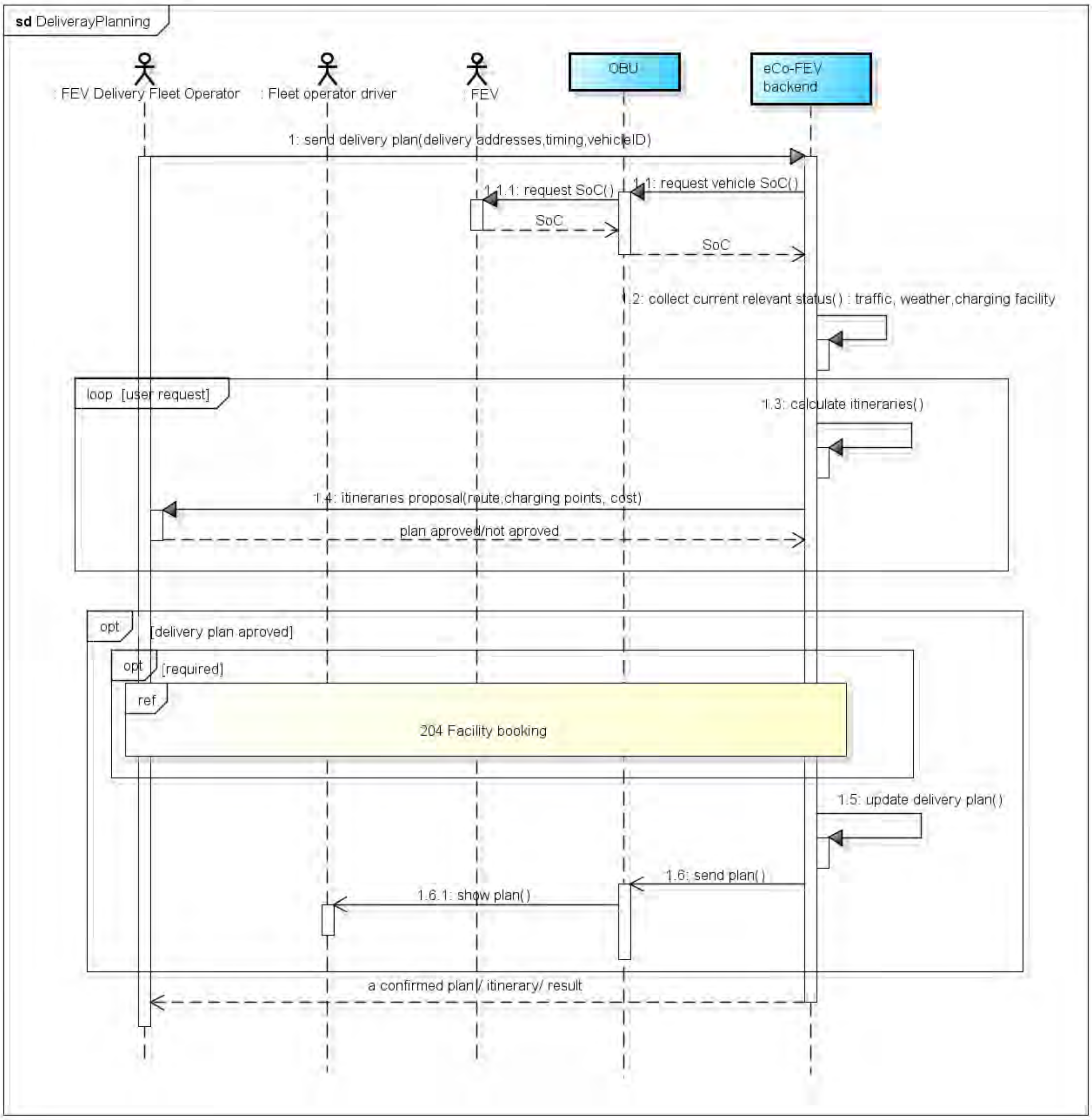

Figure 3.10: Delivery planning

3.2.9. **UC109: Delivery assistance**

eCo-FEV backend provides trip assistance for delivery FEV fleet. The assistance may be requested by operator or by driver. The eCo-FEV backend periodically estimates if the original trip plan is respected and when unexpected situation happens, eCo-FEV backend may recalculate the itinerary for delivery FEV. A new trip plan with the corresponding charging plan is provided to delivery operator for confirmation, and then transmitted to corresponding delivery fleet driver.

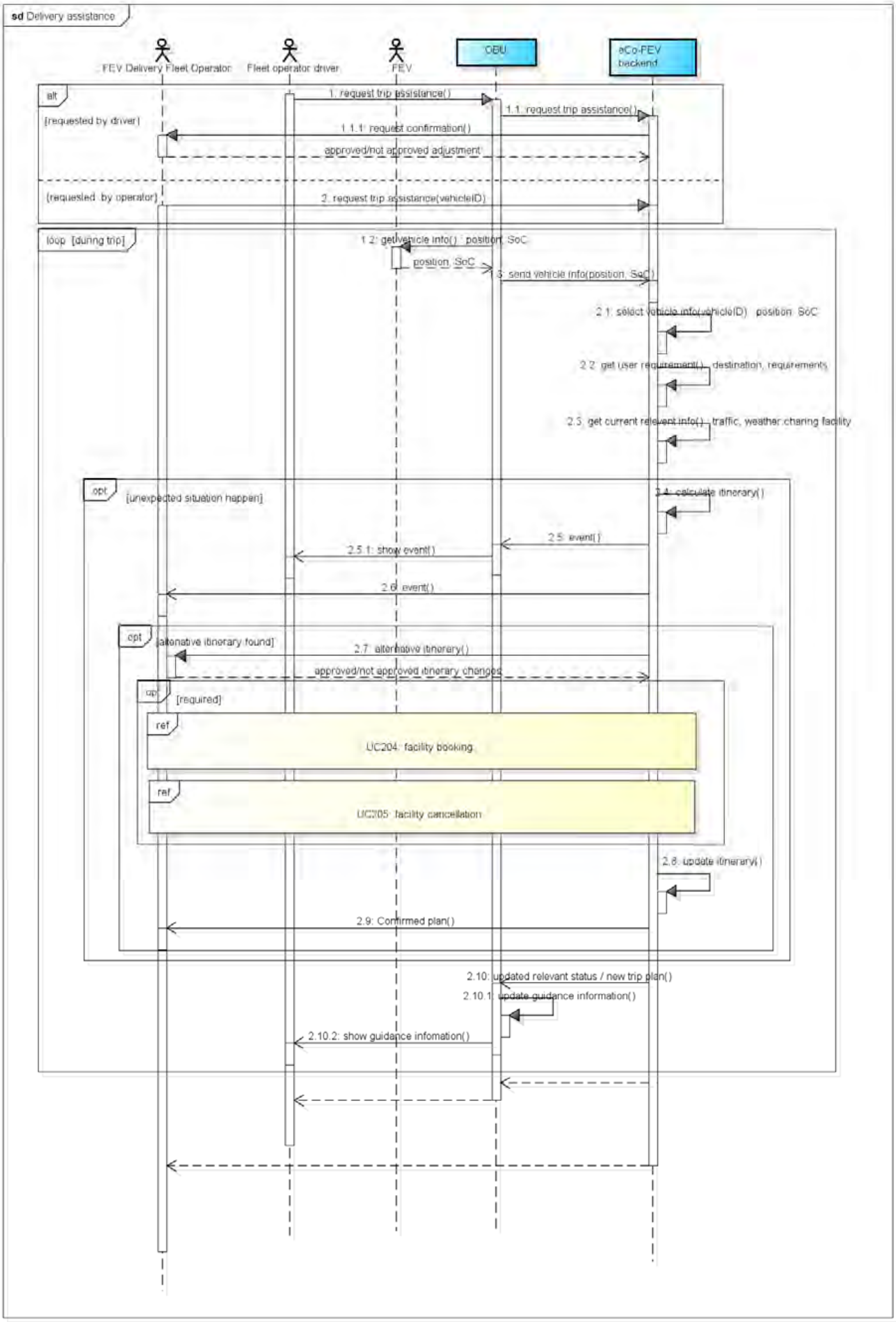

Figure 3.11: Delivery assistance

3.2.10. **UC110: Delivery planning adjustment**

Delivery planning adjustment may be either triggered by delivery FEV driver or directly by the delivery fleet operator. At receiving the adjustment request, eCo-FEV backend checks the current position and State of Charge (SoC) of requesting FEV, and calculates itineraries based on received adjustment request. Once an itinerary is selected by the operator, eCo-FEV backend books the required facilities or cancel previously booked facilities that are not any more relevant for the new itinerary. The final confirmed trip plan and charging plan is then sent back to fleet operator and to driver for navigation guidance. This use case may be seen as an extension of delivery assistance use case, in which the assistance request consists of an adjustment of delivery plan.

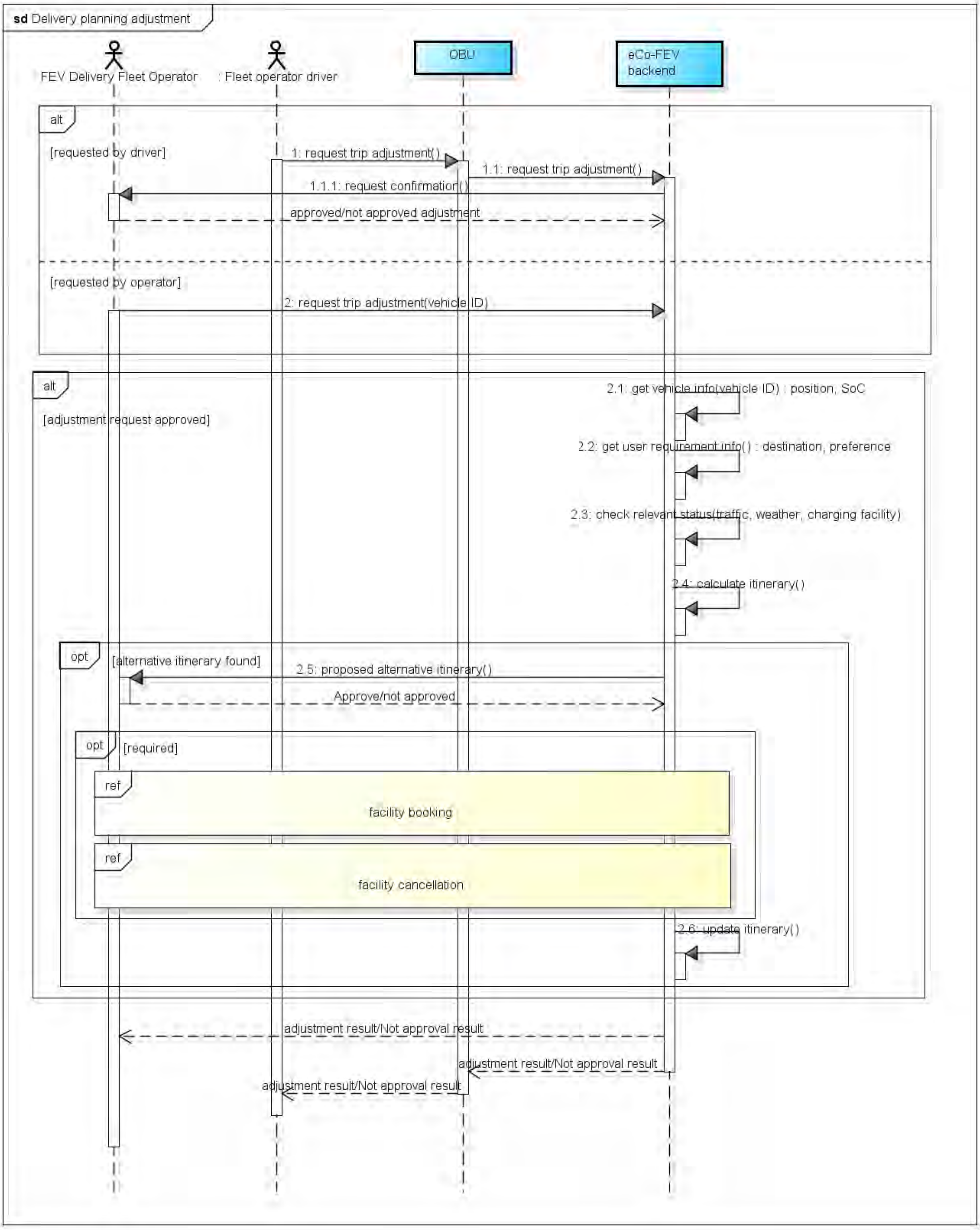

Figure 3.12: Delivery planning adjustment

3.2.11. UC201: Charging facilities accessibility monitoring

Charging facilities accessibility may be realized periodically during the trip or under the request from eCo-FEV traveller. At the reception of the request, the eCo-FEV backend collects the relevant traffic, weather information in order to estimate the estimate range of FEV. Then eCo-FEV backend search the C/S within the range, and match the C/S availability time slot with the estimated arrival time of FEV to the C/S in question. eCo-FEV backend shall provide functionalities to estimate the remaining range of FEV and look for the available charging facilities within the estimated range. The accessibility status of charging facilities is then shown to eCo-FEV traveller as reply to user request.

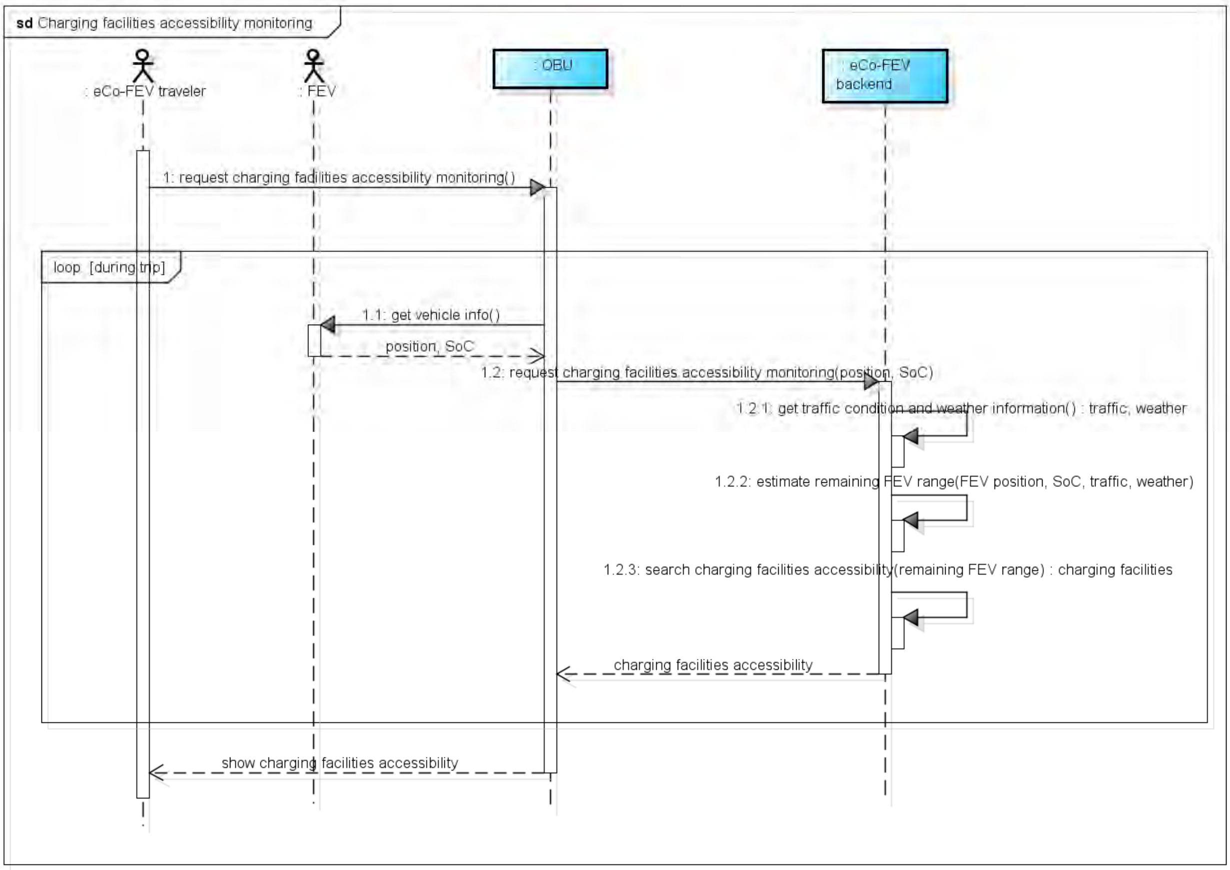

Figure 3.13: Charging facilities accessibility monitoring

3.2.12. **UC202: Charging monitoring**

This use case monitors the battery status information during trip and under charge. In case of battery problem, abnormal battery SoC deviation, or charging problem is detected, information is sent to eCo-FEV traveller, who may trigger a trip adjustment or request drive to another available charging facility. The charging problem or battery problem may be detected either by eCo-FEV backend or by charging infrastructure. In first case, eCo-FEV backend shall provide functionalities to store FEV SoC historical data and estimate abnormal battery deviation situations or battery problems. For this, specific data mining or data aggregation algorithm may be used, e.g. algorithms as described in UC 214 VRM use case.

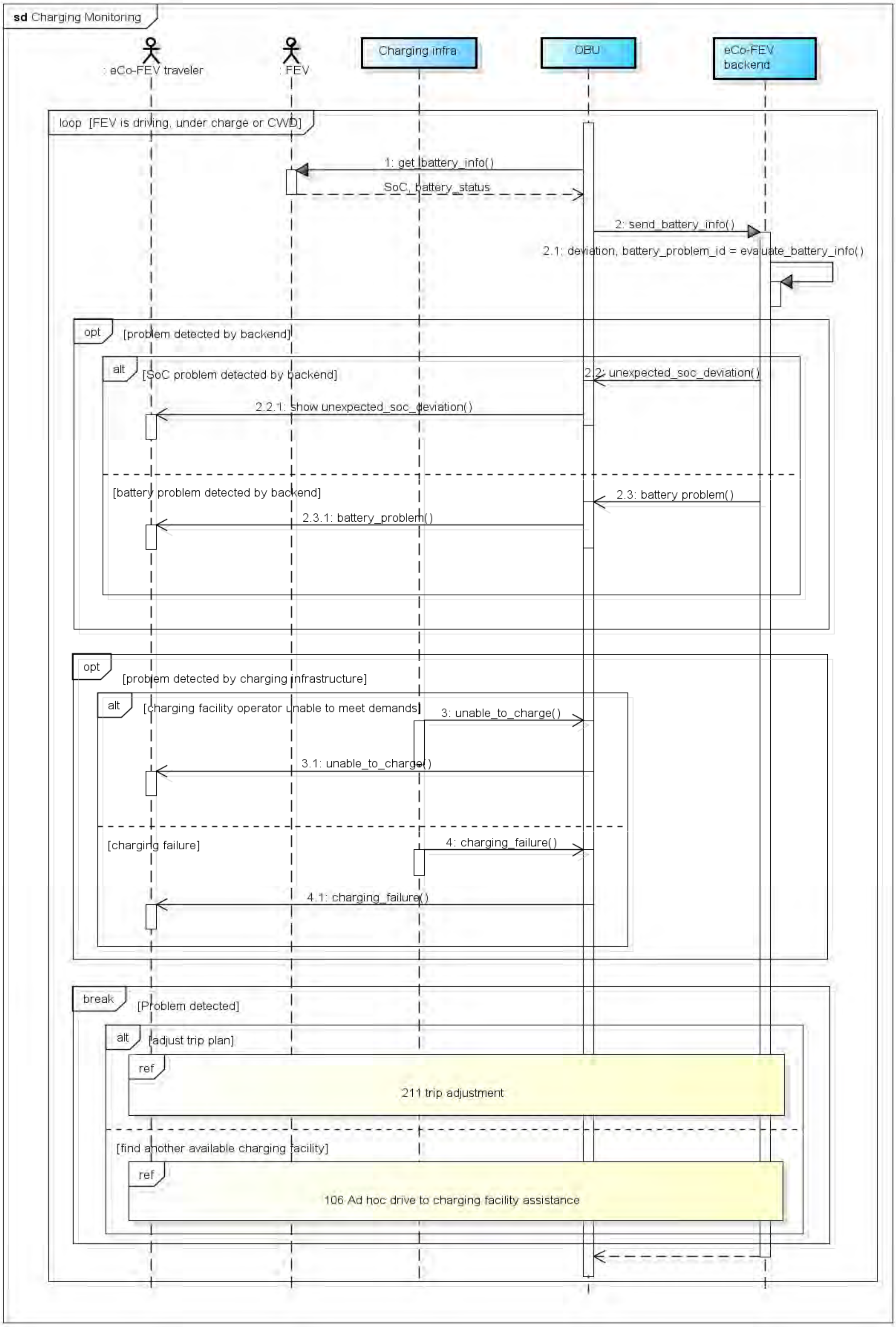

Figure 3.14: Charging monitoring

3.2.13. UC203: Facility access control

eCo-FEV backend may have booked facilities for eCo-FEV traveller and received booking confirmation information. When eCo-FEV traveller arrives at booked facility, eCo-FEV backend delivers an authorization ticket to OBU. OBU provides the authorization ticket to facilities operators to acquire access to the facilities.

For charging facility booking, eCo-FEV traveller may provide the contract ID to charging infrastructure. With an AAA procedure, access of eCo-FEV traveller may directly be granted. eCo-FEV project does not considers the scenario where booking is done directly by eCo-FEV traveller, because it represents the conventional booking scenario already deployed.

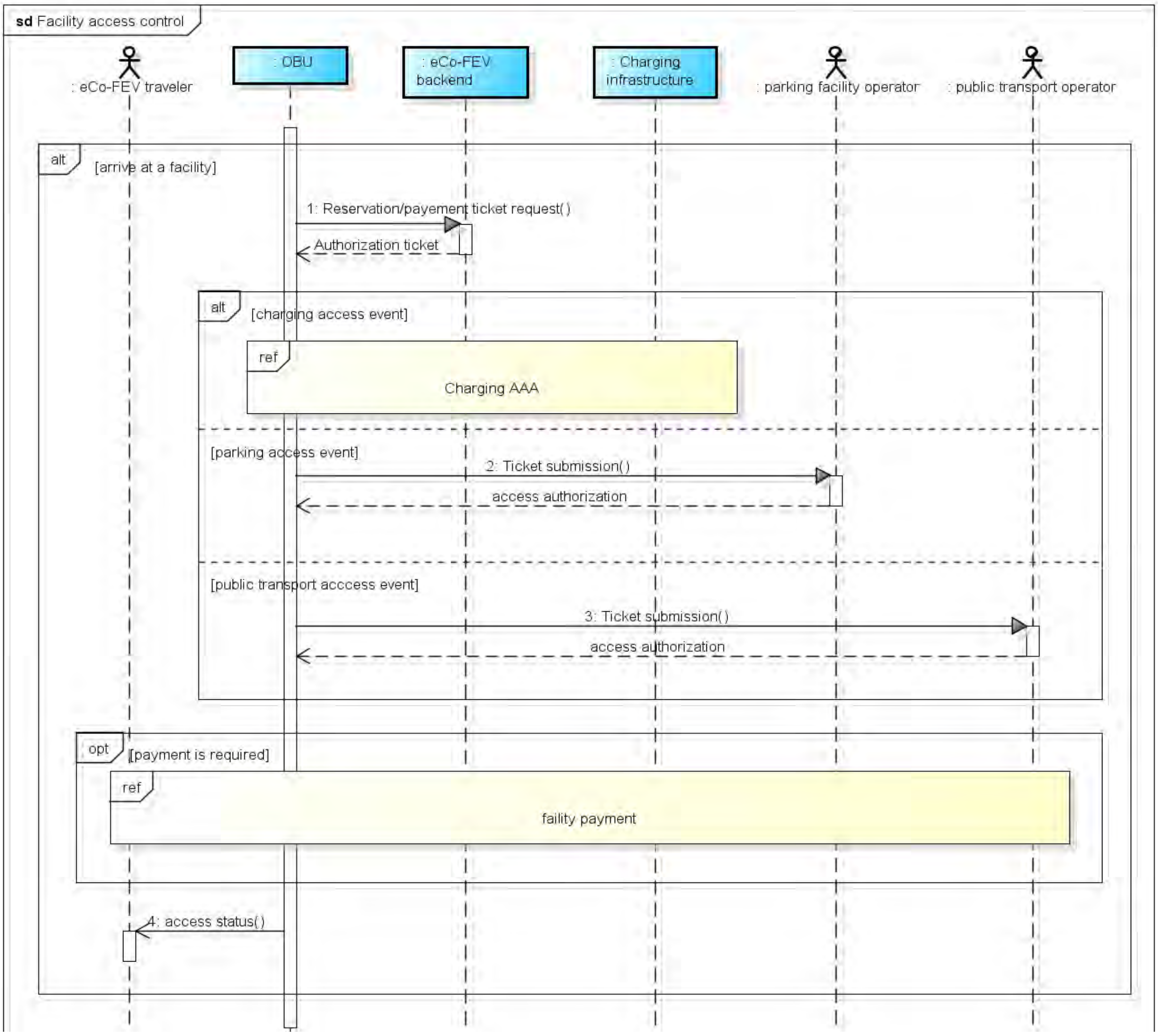

Figure 3.15: Facility access control

3.2.14. **UC204: Facility booking**

In this use case, eCo-FEV backend provides facilities booking service for eCo-FEV traveller. For simplicity reason, the sequence diagram only illustrates the booking procedure for charging facilities. Similar procedure may apply for other facilities e.g. parking facilities or public transport facilities.

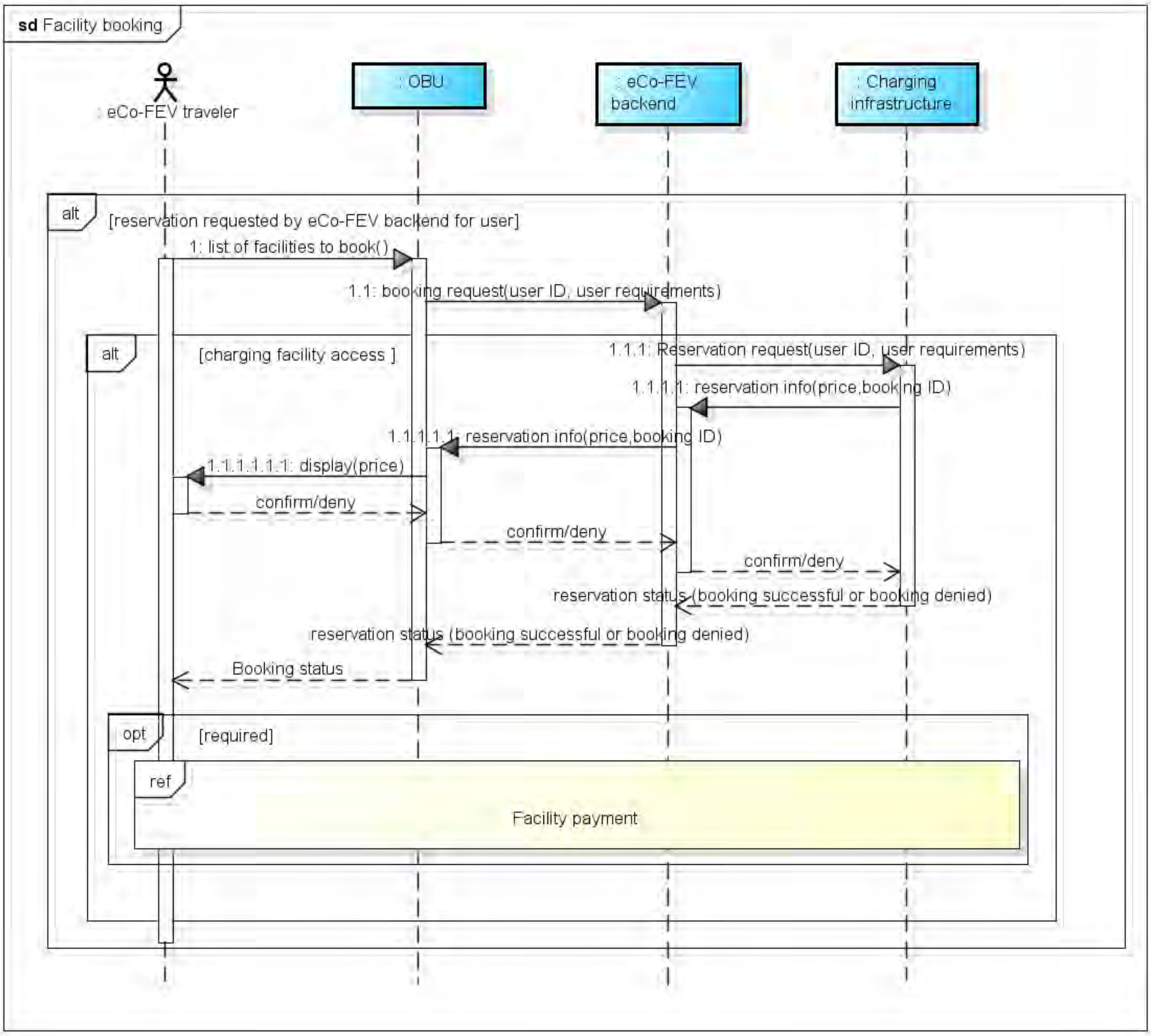

Figure 3.16: Facility booking

3.2.15. **UC205: Facility cancellation**

In this use case, eCo-FEV backend provides facilities booking cancellation service for eCo-FEV traveller. For simplicity reason, the sequence diagram only illustrates the cancellation procedure for charging facilities. Similar procedure may apply for other facilities e.g. parking facilities or public transport facilities.

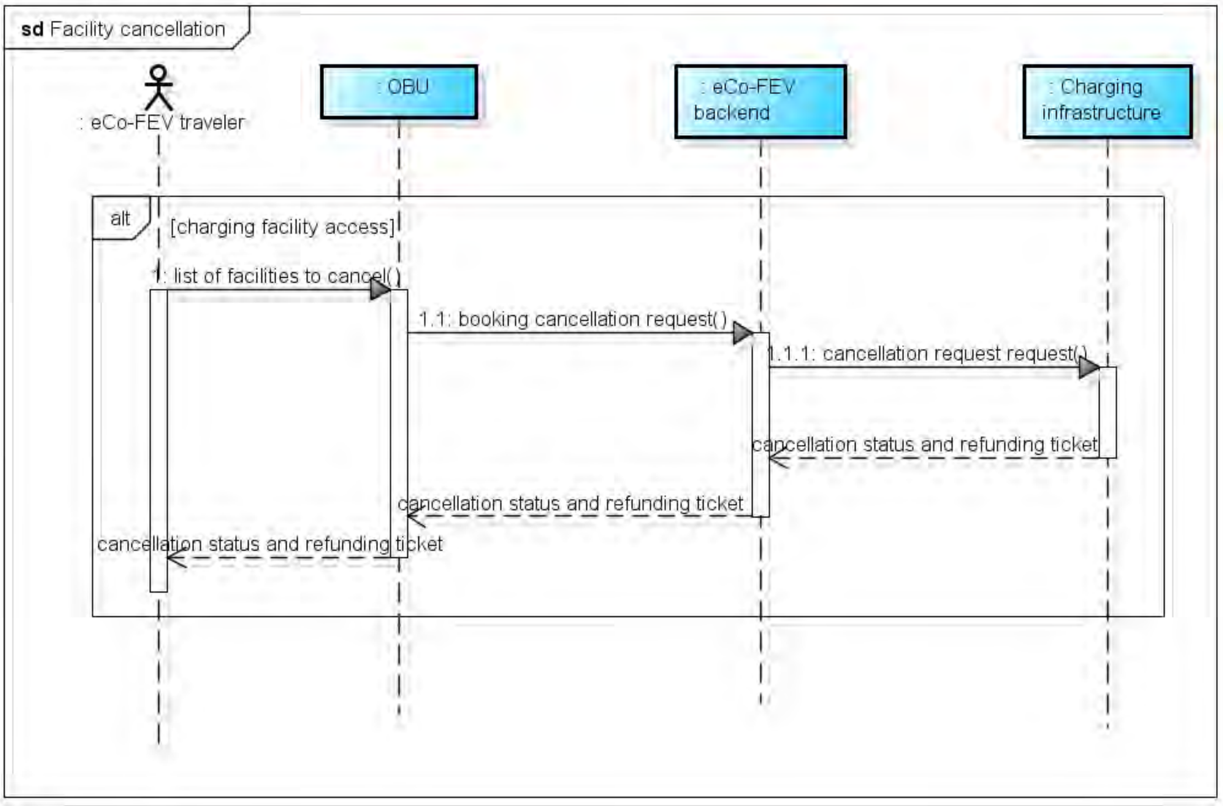

Figure 3.17: Facility cancellation

3.2.16. **UC206: Facility payment**

Facilities operators request payment to eCo-FEV traveller. Multiple payment modes may be used according to business model set by service providers. Therefore, eCo-FEV system should adapt to the payment mode required by service providers. For this reason, this use case does not include a sequence diagram, since there are no specific requirements to eCo-FEV sub systems compared to a normal payment procedure.

3.2.17. **UC207: Public transport monitoring**

eCo-FEV backend collects public transport information from public transport operators. Both push and pull modes may be used. In a push mode, based on predefined update parameters e.g. update frequency and update conditions etc., public transport operator transmits periodically updated public transport information to eCo-FEV backend. In a pull mode, eCo-FEV backend may send a request to public transport operator to obtain update information. For both modes, eCo-FEV backend should update the public transport database. An eCo-FEV backend application may consult this database if necessary.

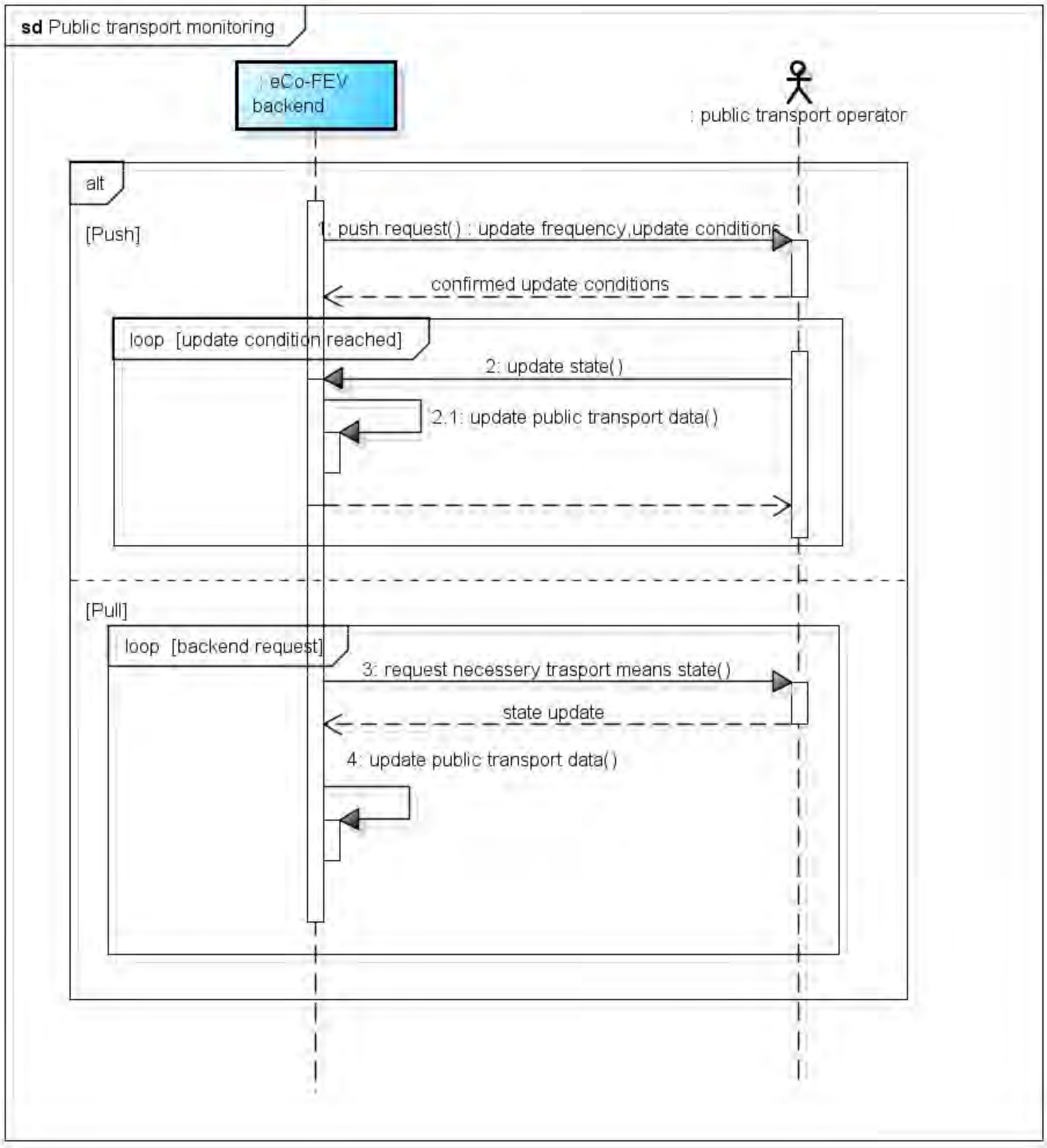

Figure 3.18: Public transport monitoring

3.2.18. UC208: Traffic condition monitoring

FEV energy consumption varies based on unexpected traffic and driving conditions such as traffic jam and weather conditions. Therefore, in order to ensure a good quality of services for FEV users from the eCo-FEV system, the traffic condition information may be used to precisely guide the FEV users with regards to traffic conditions and weather conditions. Road traffic is monitored by road infrastructure operators such as urban traffic management centers or highway operators, from whom the real time traffic information may be received. Furthermore, eCo-FEV system may collect other related information from other operators, such as weather condition information from weather info operators. eCo-FEV backend collects traffic and weather condition information from traffic and weather info operators. Similar to public transport monitoring, both push and pull modes may be used. In addition, eCo-FEV backend may collect probe data from FEV and aggregate all received information for traffic condition database update.

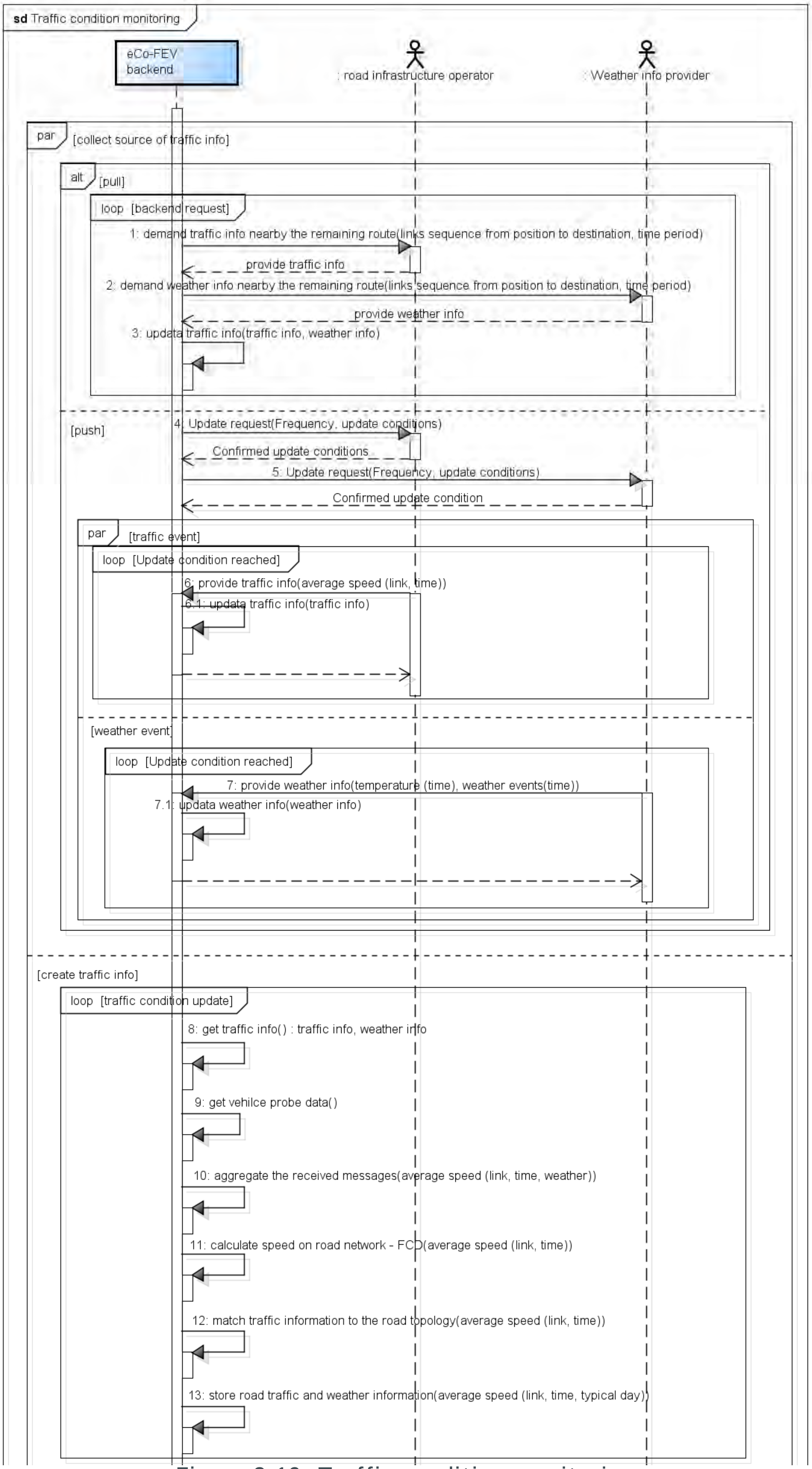

Figure 3.19: Traffic condition monitoring

3.2.19. UC209: Charging facility status monitoring

eCo-FEV backend collects charging facility status information from charging infrastructure. Similar to public transport monitoring, both push and pull modes may be used. In a push mode, based on predefined update parameters e.g. update frequency and update conditions etc., charging infrastructure (more precisely, the system operating and monitoring the C/Ss) transmits periodically updated C/S status information to eCo-FEV backend. In a pull mode, eCo-FEV backend may send a request to charging infrastructure to obtain update information. For both modes, eCo-FEV backend should update the C/S status database. An eCo-FEV backend application may consult this database if necessary. The criteria for which the TC/S status information should be provided may be defined by eCo-FEV backend (e.g. all C/Ss within a predefined area, C/Ss of a specific charging mode, C/Ss operated by specific operator etc..), according to e.g. business agreement between application providers and charging infrastructure operators.

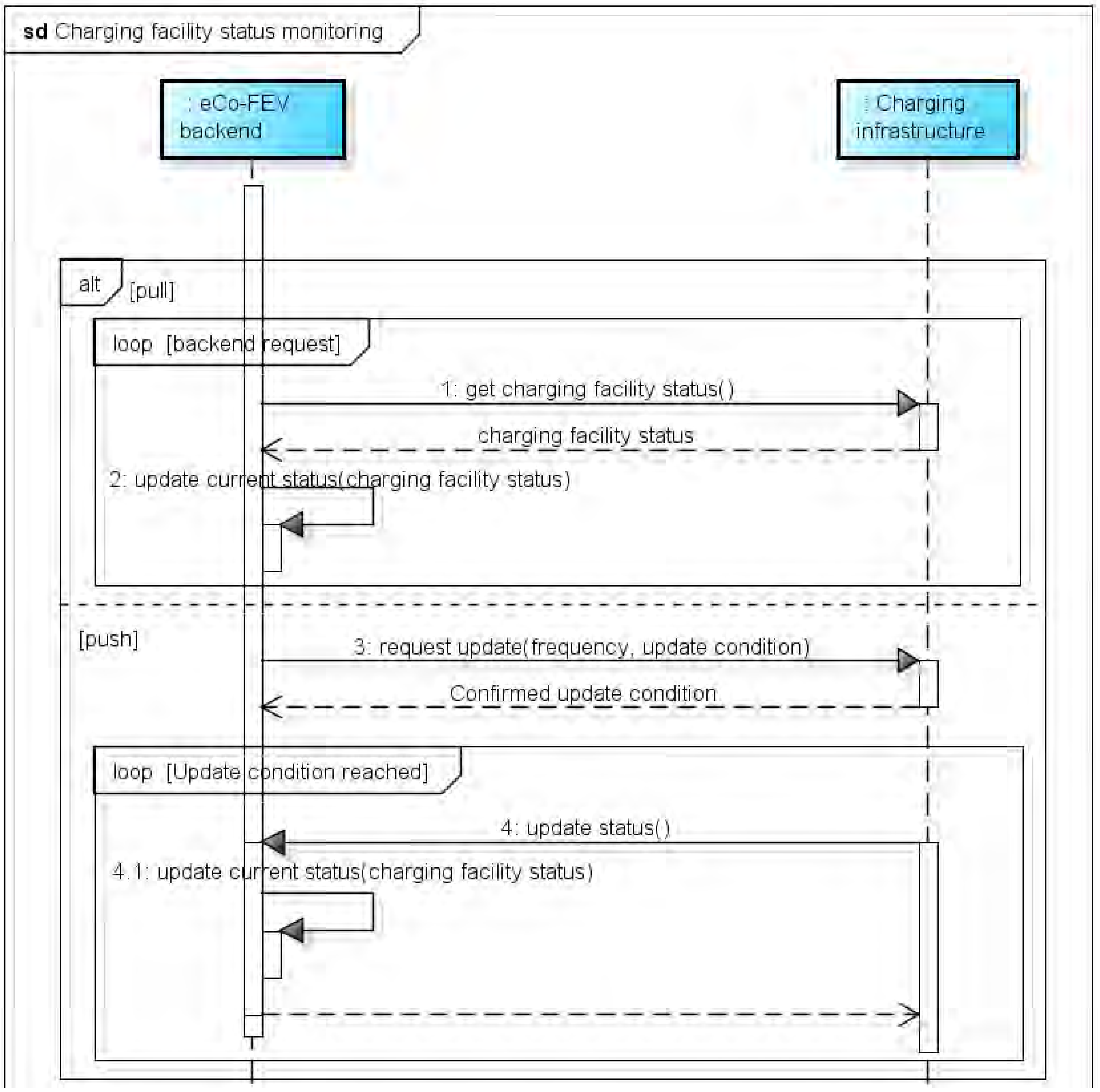

Figure 3.20: Charging facility status monitoring

3.2.20. **UC210: POI notification**

eCo-FEV backend provides point of interest (PoI) information to FEV users. PoI may be either requested by eCo-FEV backend, or broadcasted by RSU. In the latter case, eCo-FEV backend match the PoI information to the position and coverage range of RSU, then provides the information to corresponding RSU for broadcasting.

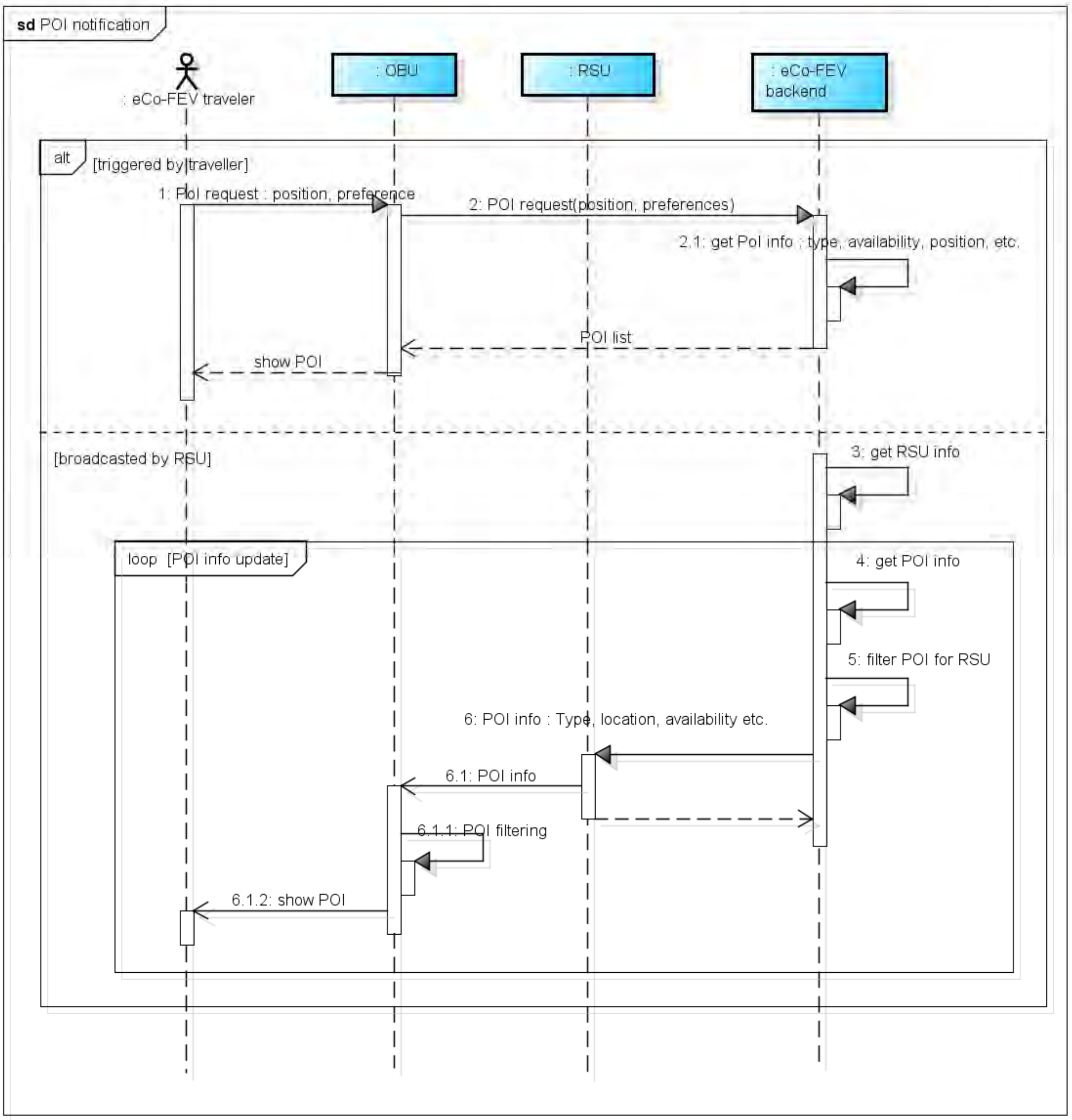

Figure 3.21: POI notification

3.2.21. **UC211: Trip adjustment**

Trip adjustment follows similar steps as trip planning. If eCo-FEV traveller modifies partially the original trip plan, eCo-FEV backend needs to retrieve original trip plan in order to propose alternative trip plan.

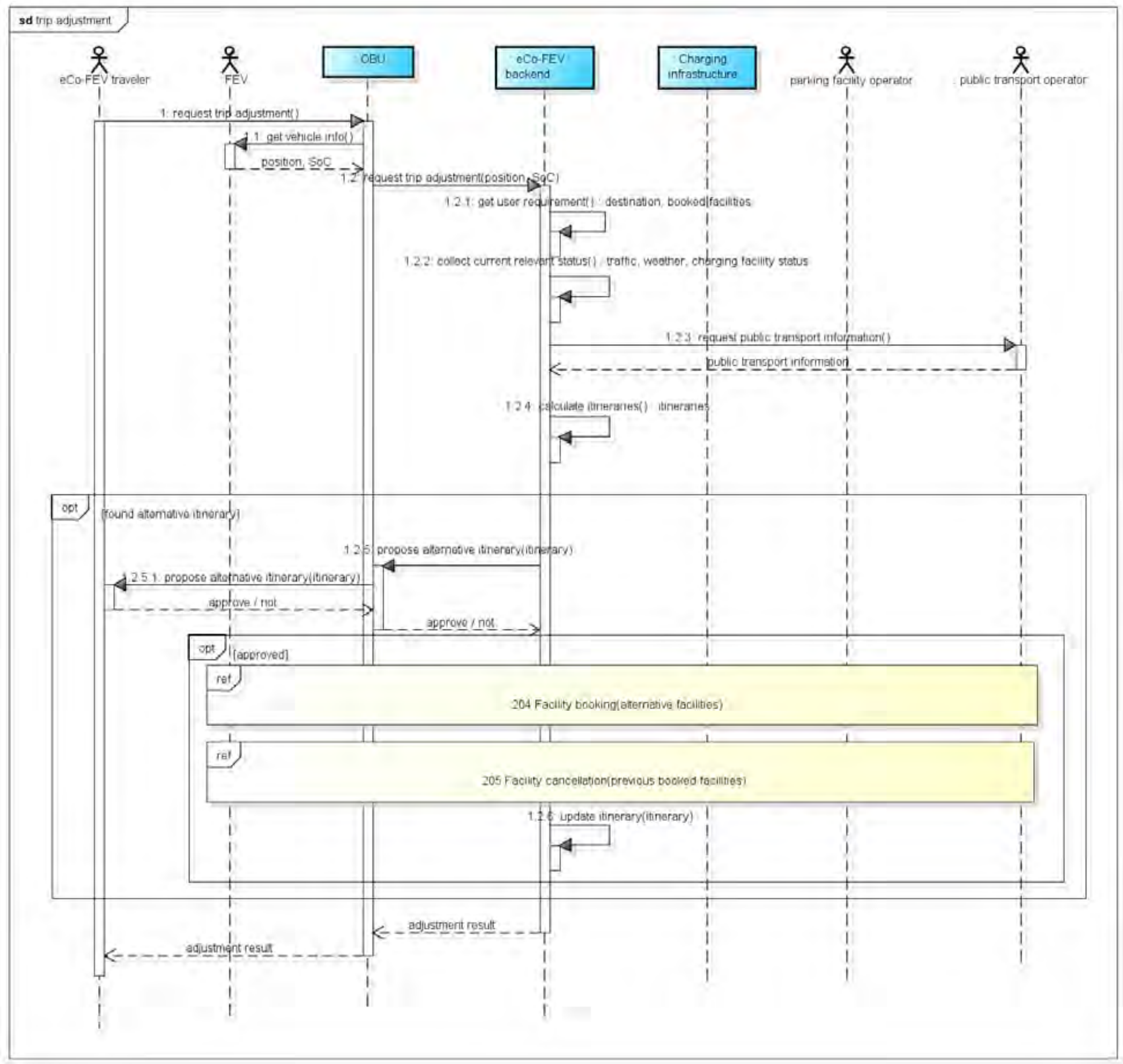

Figure 3.22: Trip adjustment

3.2.22. **UC212: Trip, facility choice and booking**

This use case has been incorporated in trip planning, charging facilities accessibility monitoring and facilities booking use cases. Therefore, no sequence diagram is required.

3.2.23. **UC213: Trip monitoring**

eCo-FEV backend monitors FEV along the trip, by collecting frequently FEV position, SoC or other information (e.g. energy consumption) and updates the FEV database at eCo-FEV backend. eCo-FEV backend sends an update request to OBU in order to trigger the trip monitoring, and OBU should confirm such request before starting to transmit FEV information accordingly. Additionally, eCo-FEV backend may send request to OBU to provide updates information. The received FEV data is fed to update the FEV database in eCo-FEV backend. An eCo-FEV backend component (e.g. applications) may consult the most recent or historical FEV data by consulting this database.

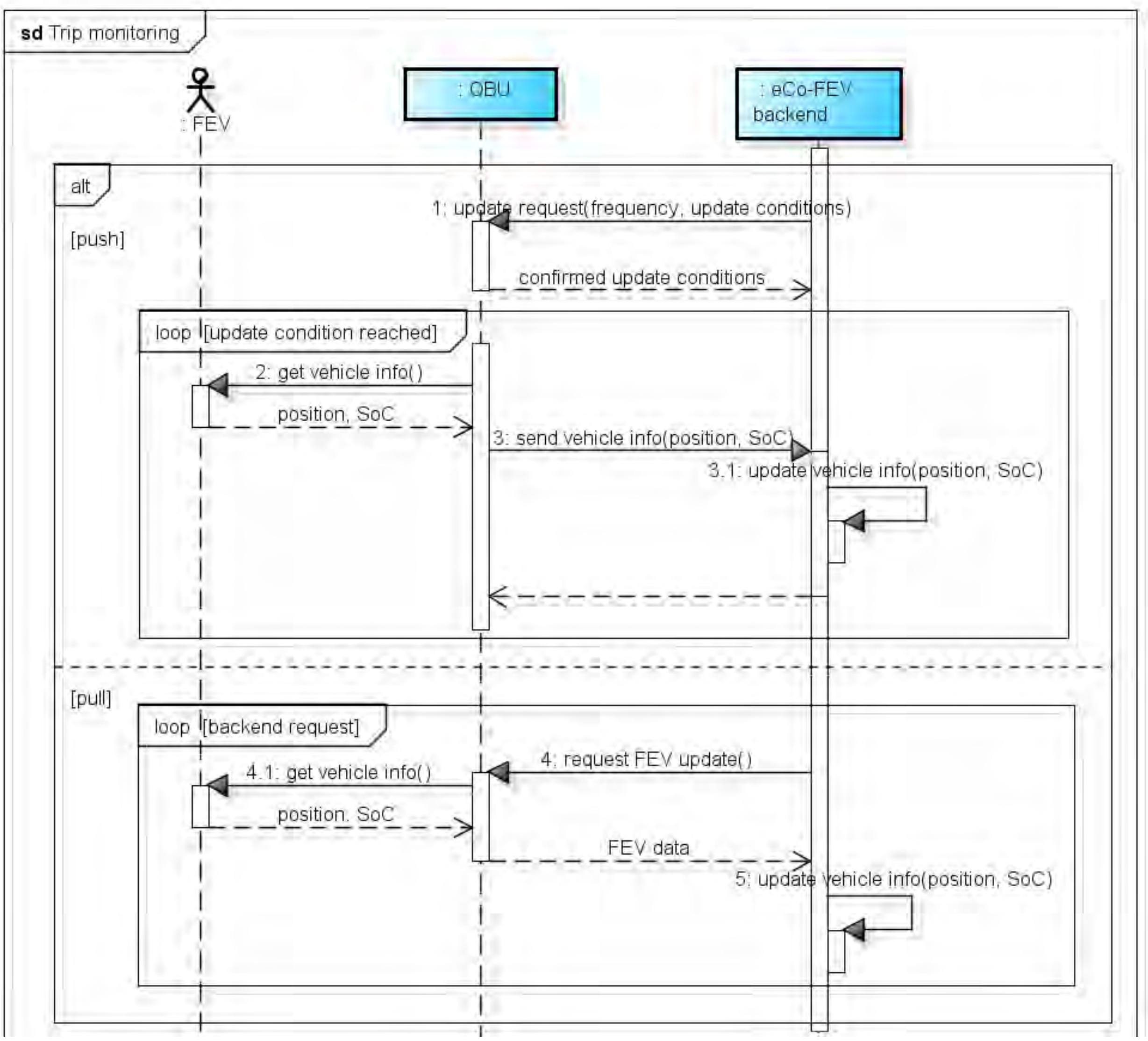

Figure 3.23: Trip monitoring

3.2.24. UC214: Vehicle Relationship Management

eCo-FEV backend stores historical data of relevant information (FEV SoC evolution, traffic and weather conditions, user travelling and driving pattern) in order to estimate State of Health (SoH) of FEV battery and derive personalized advices to eCo-FEV traveller to improve the SoH. Specific data mining and data aggregation algorithms may be used for this purpose. Alternatively, eCo-FEV backend may also provide energy demand evolution information to charging infrastructure, for it to adjust the energy distribution in a smart grip deployment network.

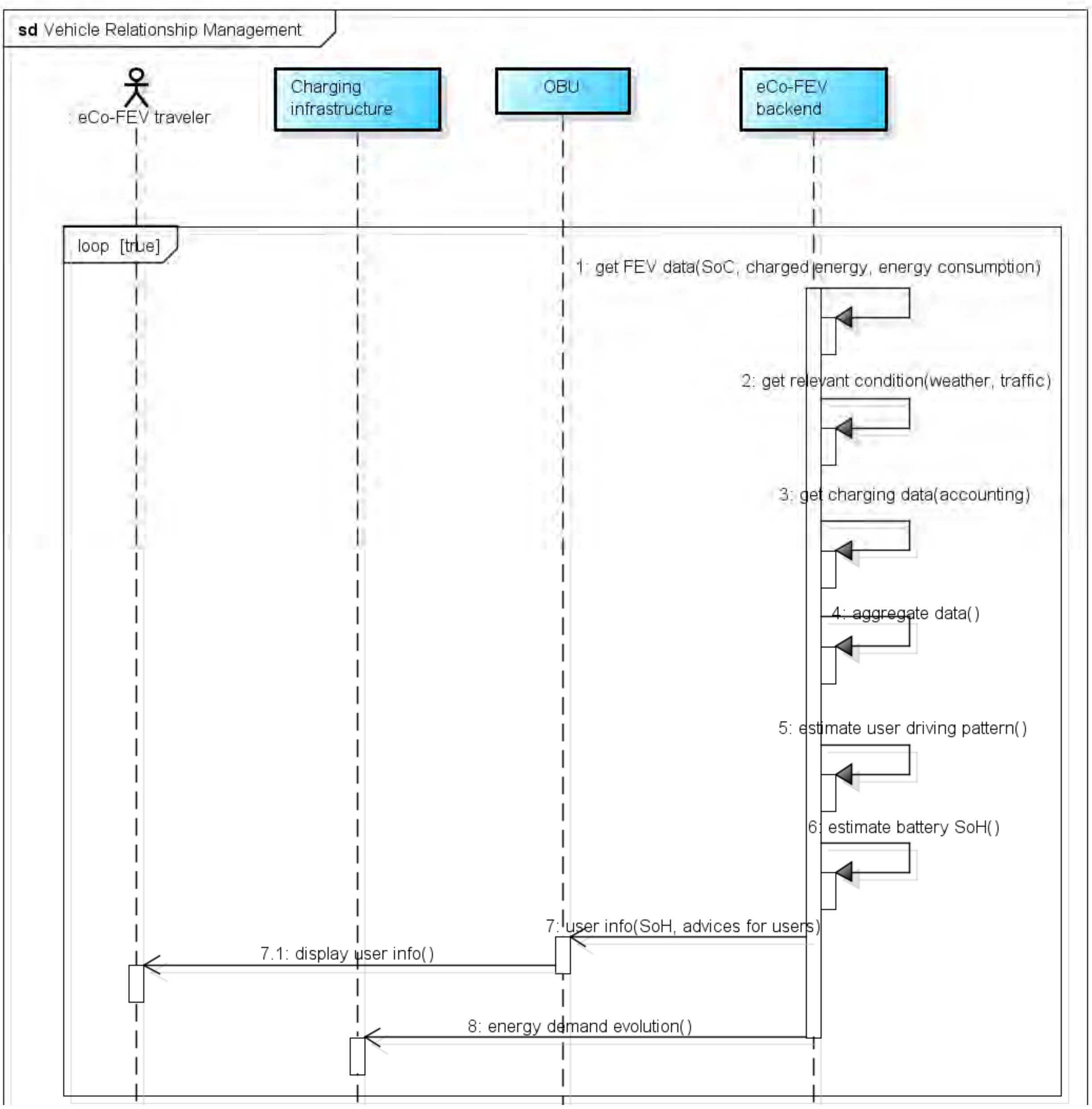

Figure 3.24: Vehicle Relationship Management

3.2.25. UC215: CWD charging management

This use case was not included in [1], it is added based on functional analyse required for CWD. It describes the charging procedure for CWD. Even though charging procedure based on wired communication has been standardized in [13], specific requirements apply for CWD during the charging procedure. For example, charging infrastructure should inform FEV via wireless communication instructions that FEV should apply in order to be charged e.g. speed limit, driving position etc. Given the technical challenge for developing CWD, charging infrastructure and OBU informs to eCo-FEV the provided and received energy in order for it to estimate the deviation between the provision and consumption. eCo-FEV backend should inform charging infrastructure whether a or several FEVs may request (e.g. FEV have booked the charging infrastructure) to use the charging infrastructure so that the charging infrastructure may do proper preparation. Such information may either be pushed by eCo-FEV backend upon monitoring of FEV activities, or requested by charging infrastructure to eCo-FEV backend by sending a request to eCo-FEV backend regularly. For simplicity reason, the sequence diagram only illustrates the request mode.

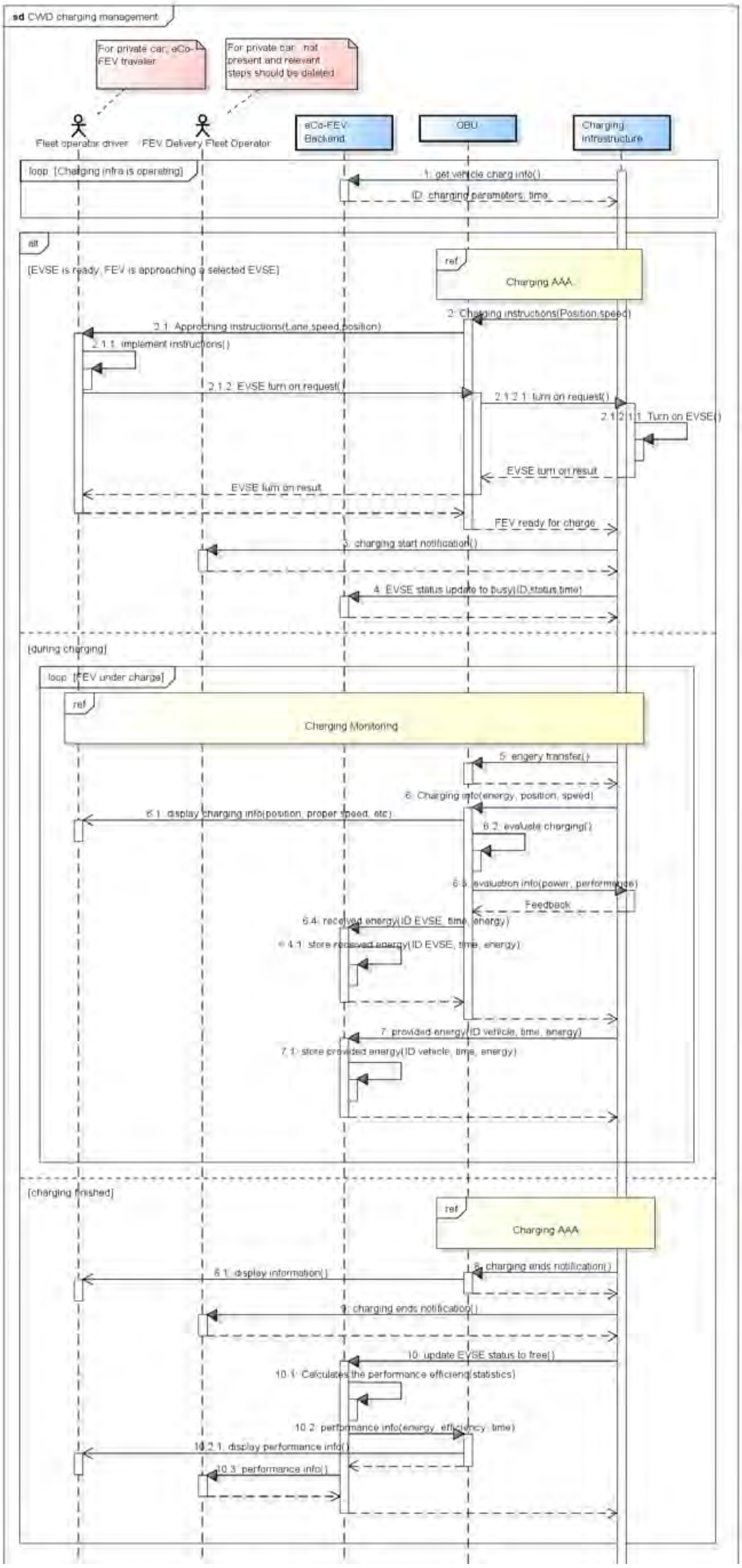

Figure 3.25: CWD charging management

3.2.26. UC216: Charging AAA

This use case was not included in [1], it is added based on functional analysis required for CWD. It describes the AAA procedure for charging preparation. In order to highlight the detailed data flow for AAA and clarify the roles and responsibilities between EVSE and EVSE operator, it is decided that the sequence diagram includes the data exchanges between EVSE and EVSE operator. Such detailed design will facilitate the functional design of CWD charging infrastructure.

AAA procedure is called at start and end of charging, in order to estimate the consumed energy i.e. counting by FEV during the whole charging procedure. OBU may be required to provide contract ID with utility provider during the authentication process.

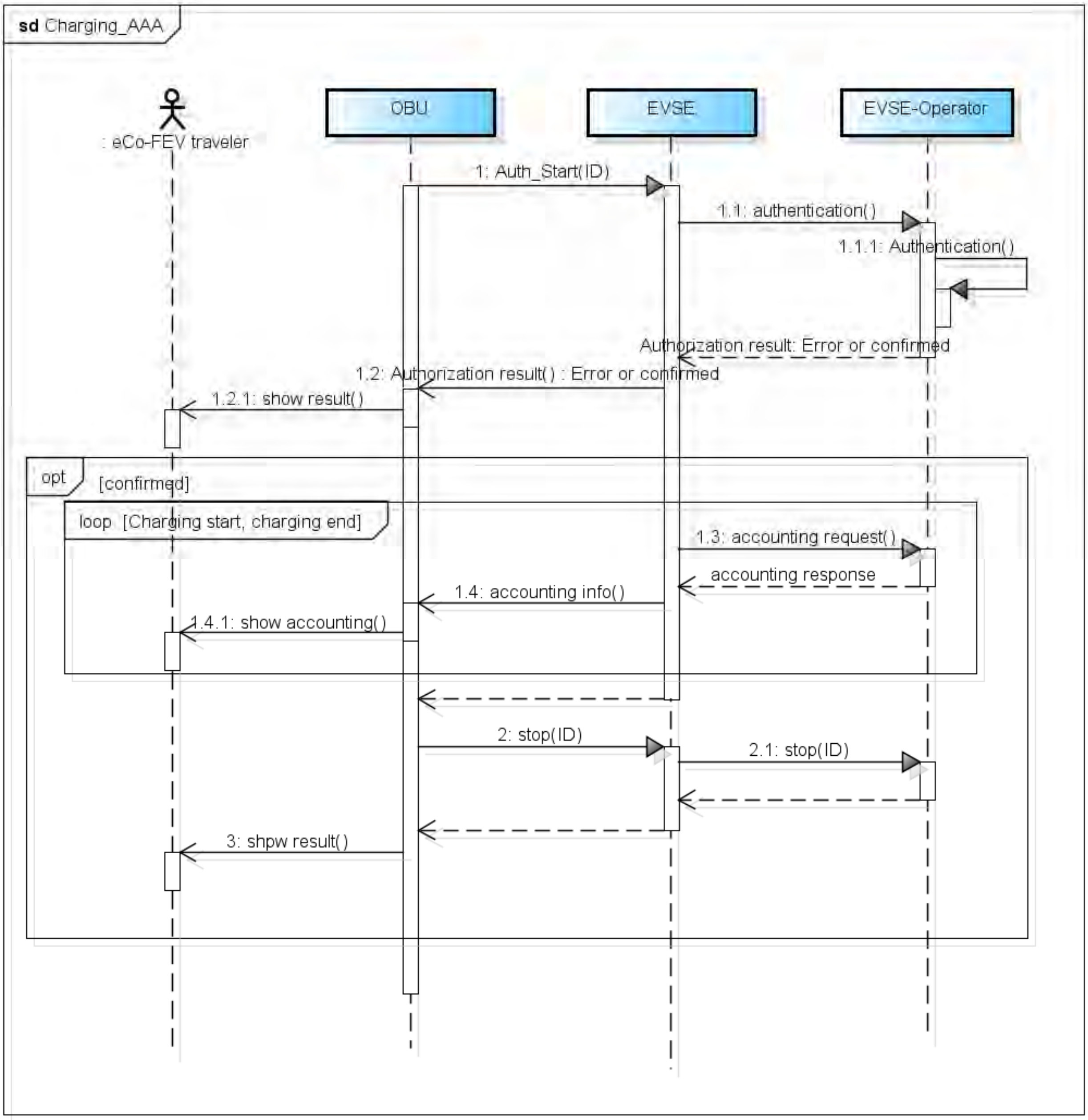

Figure 3.26: Charging AAA

4. Subsystems functional design

4.1. On Board Unit subsystem

4.1.1. **OBU overall architecture**

The OBU is mounted to FEV in order to support eCo-FEV applications and provide services to user. It needs to be integrated with FEV existing systems and connect to the FEV FEV charging device. The OBU subsystem needs to satisfy basic requirements from interface and hardware perspective, as listed in Table 4.1, in order to achieve the objectives of the eCo-FEV project.

#	Basic Requirements
1	Communication with eCo-FEV Backend Infra. (ITSG5 or Cellular)
2	Communication with RSU. (ITS G5 or WiFi)
3	Communication with in-vehicle system and vehicle battery (CAN)
4	Communication with charging infrastructure (PLC, inductive charging)
5	HMI device to show eCo-FEV APPs including navigation guidance info
6	Machine to install eCo-FEV platform and applications
7	ITS G5 antenna, UMTS antenna, GNSS antenna, WiFi antenna (optional)

Table 4.1: Basic requirements for OBU subsystem

4.1.1.1. Wireless charging FEV

The basic vehicle architecture for the wireless charging case is illustrated in Figure 4.1. Some HW components have to be integrated with the existing FEV equipment (high voltage battery, inverter and traction motor). One of the components to be added is the on board vehicle ITS-S that contains an Application Unit, a Communication Unit and the HMI device.

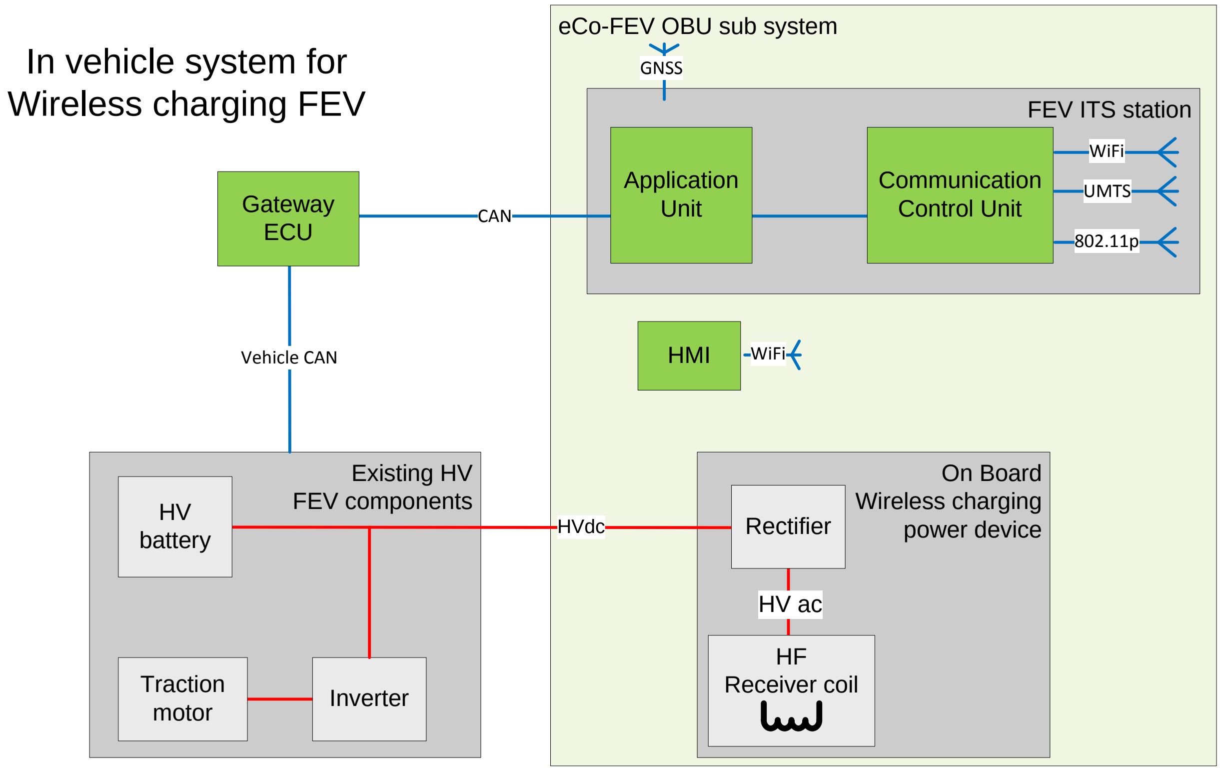

Figure 4.1: Wireless charging vehicle subsystem overall architecture

An in vehicle gateway is also needed to collect the data (battery SOC, instantaneous power consumption, …) from the in-car OEM CAN bus network, processing it and feeding it to the on board ITS-S. In the case of the wireless charging (static and while driving) a power device, containing a high frequency caption coil and a diode rectifier, is connected on the high-voltage (HV) DC bus with the existing HV components.

4.1.1.2. Conductive charging FEV

The basic vehicle architecture for the conductive charging is illustrated by Figure 4.2. Many of the hardware and the software components are already present on the existing FEV (high voltage battery, rectifier, application unit, communication unit, HMI). Some of them have to be modified or added to fulfil eCo-FEV requirements. During the charging process, FEV is connected with charging facility with HV ac for energy provision and with PLC for data communication.

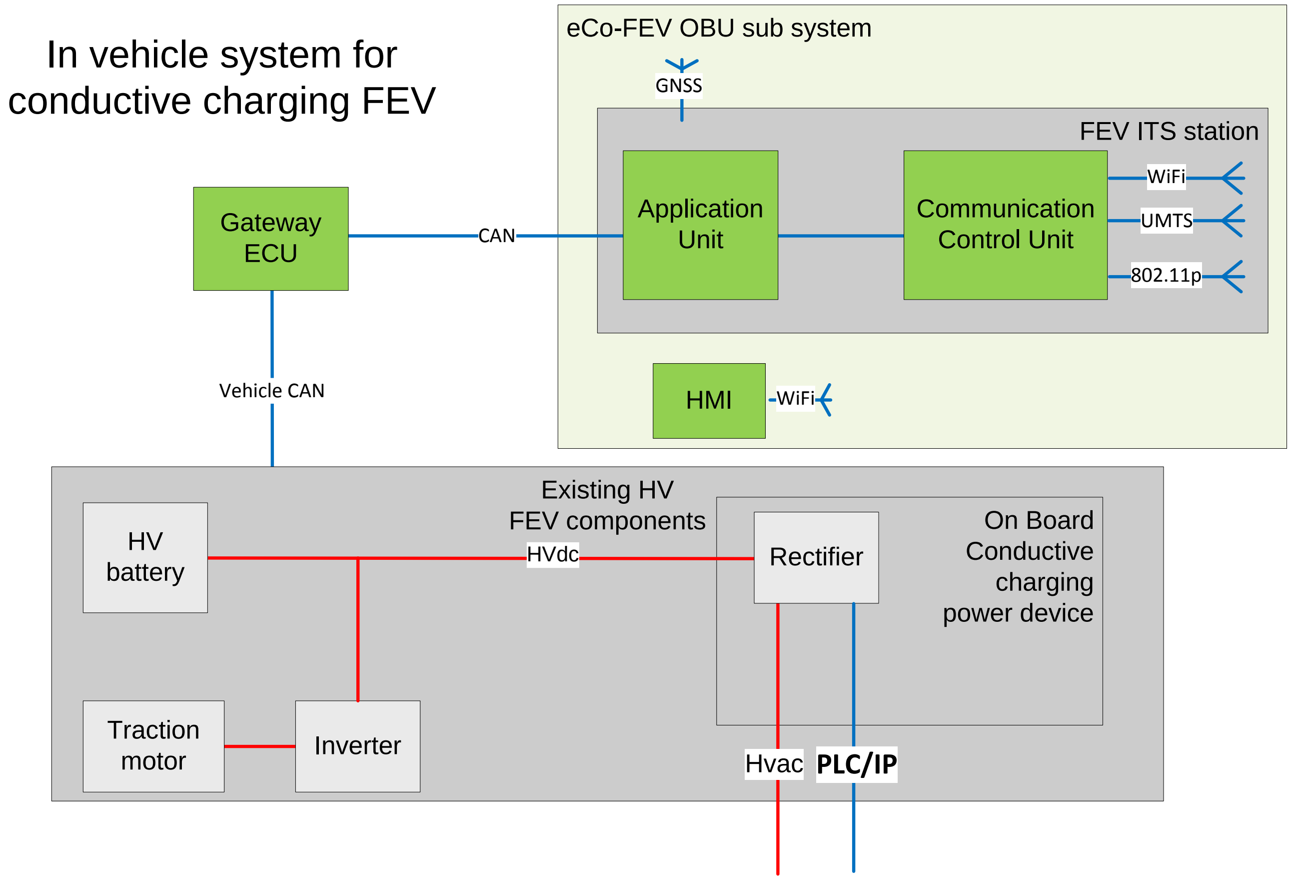

Figure 4.2: Conductive charging vehicle subsystem overall architecture

4.1.2. FEV ITS station functional architecture

The FEV integrates an FEV ITS station (FEV ITS-S) that implements the eCo-FEV applications for FEV users and required communication capabilities. This FEV ITS station is designed based on standardized ITS reference architecture in [3] Figure 2.3. As illustrated in Figure 4.1 and Figure 4.2, this OBU includes three physical components: an application Unit (AU), a Communication Control Unit (CCU) and a Human Machine Interface (HMI) device. According to the information exchange needs and application requirements, these components are connected with each other, with other FEV in vehicle systems and with external communication networks. For this reason, several antenna systems are installed in OBU.

Short description of FEV ITS-S and the main interfaces is provided in Table 4.2.

OBU sub system	Short description
Application Unit (AU)	The AU implements applications and facilities layer of the standardized ITS station. AU is connected with in vehicle systems CAN bus via an in vehicle-gateway, in order to receive in vehicle data, e.g. battery status information, vehicle sensor information etc. Furthermore, AU is connected with CCU, in order to send and receive messages from and to other eCo-FEV sub systems via the communication capacities provided by CCU. Finally, AU should be connected with HMI device of FEV, in order to provide application processing results to HMI for further presentation to FEV user. AU should also receive from HMI the user request for application processing. From communication viewpoint, the AU can be considered as a communication host.
Communication Control Unit (CCU)	CCU implements the networking & transport layer and access layer of the ITS station. It provides communication capacities to other eCo-FEV systems i.e. RSU, eCo-FEV back end via wireless communications. It should be highlighted that, for communication between FEV and charging infrastructures, the required communication capacities (e.g. inductive charging or conductive charging) will be supported by FEV on board charging device. Therefore, this communication is not included in the CCU. The CCU is connected with AU (e.g. via Ethernet) in order to send and receive application and facilities layer messages to other eCo-FEV sub systems. The CCU includes at least ITS G5 and UMTS communication capacities. The CCU can be considered as a router.

Table 4.2: Sub systems of FEV ITS-S

Based on eCo-FEV high level functional architecture and analysis of use case sequence diagrams as presented in chapter 3, it is possible to define the functional architecture of the AU and CCU respectively, by identifying the main functional components of each. These functional components are interacting with each other, either via a physical interface or via Application Programming Interface API in order to realize the eCo-FEV applications and services to FEV user. At the writing time of the present document, we do not further specify each of the identified components, neither the interfaces nor data exchange flows between these components. These specifications will be realized in D200.3 system specifications. The functional architecture of the FEV ITS-S AU is illustrated in Figure 4.3. This functional architecture is defined based on ITS station reference architecture as defined in [3]Figure 2.3.

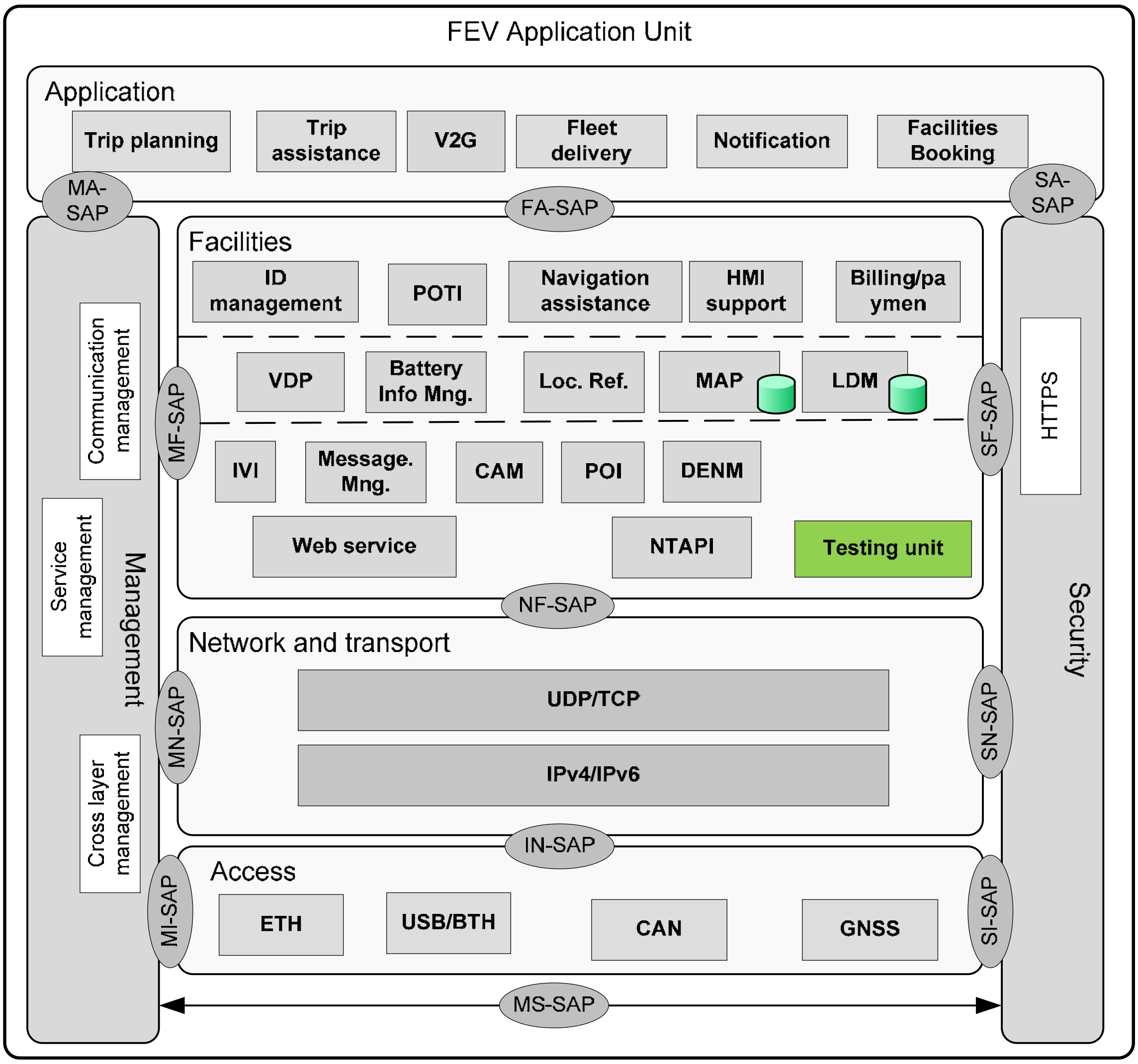

Figure 4.3: FEV ITS-S AU functional architecture

A short description of the identified sub components is summarized in Table 4.3.

Functional component	Short description
Application layer	*FEV applications as implemented for eCo-FEV use cases*
Trip planning	This application provides an HMI interface to FEV user to enable him/her plan the trip and enters the personal preference. It may also interact with FEV user for the eventual route adjustment or route re-planning. Once the trip planning is done, this application triggers the trip assistance application.
Trip assistance	This application provides trip assistance information to FEV users, including navigation assistance and charging assistance.
V2G	This application implements the vehicle to grid (V2G) for FEV. For conductive charging, it may have been implemented in FEV existing system compliant to standards [13] and therefore not present. For CWD, this application should be modified based on [13] according to CWD

	requirements. It may either be implemented in FEV ITS-S, or in wireless charging device.
Delivery assistance	This application is special implementation of trip assistance for the delivery use cases using FEV fleet.
Notification	This application provides notification information to FEV users during the trip or before the trip. The notification information is mainly provided by other eCo-FEV sub systems, e.g. real time travel information, multimodality transport information, charging Point of Interest information, battery shortage information etc. Alternatively, some notification may also come from FEV in vehicle system e.g. detected battery failure, battery shortage information, charging start/end notification etc.
Facilities booking	This application assist FEV users to manage the booking/reservation of infrastructure facilities, and if required to manage the payment and billing for the corresponding booking.
Facilities layer	*Functional components required to support eCo-FEV applications*
ID management	This facility manages the identity information of FEV and/or the user of FEV and/or specific services (e.g. contract ID for charging, log in info for eCo-FEV backend). Such information is required for the FEV subscription and authentication procedure in eCo-FEV backend or charging. In some situations, ID information may be temporally valid and updated from time to time, in order to meet privacy protection requirement.
POTI	This facility provides real time geographical position/time information of FEV, in order to enable the location based applications and services. For FEV used in eCo-FEV, a GNSS receiver is used to provide real time POTI information. Potentially, position augmentation and time synchronization technologies may be used to improve the information quality and availability such as data fusion of GNSS data with in vehicle sensor data. Given that eCo-FEV use cases are not safety critical applications, such augmentation may not be needed.
Navigation assistance	This facility calculates the suitable navigation route according to the route planning requirements set by FEV users or by eCo-FEV backend. It also provides navigation assistance for FEV users such as turning guidance, location based information provision etc.
HMI support	This facility manages information exchanged between AU and HMI device. It supports duplex data exchange between AU to HMI.
Billing/payment	This facility is in charge of triggering the billing and payment data exchange with an external service provider based on request from application. It also manages the communication session required for the billing and payment data exchange.
Vehicle Data Provider (VDP)	This facility provides gateway functions to vehicle CAN bus in order to receive in vehicle data which is required for the application and facilities layer processing. Data such as vehicle sensor data and charging system data may be provided via CAN bus to this facility.
Battery Info Management	This facility manages the FEV battery status information received from FEV battery and charging device. This facility may provide current or historical battery status information to eCo-FEV backend or to V2G application. Alternatively, this facility may include simple data processing functionalities to aggregate the battery information before sending in order to save the communication bandwidth.

Location Referencing (Loc. Ref)	This facility provides location referencing information additional to the geographical coordinates, enabling the matching of FEV position to road topology. Multiple location referencing methods may be used. A commonly used location referencing method between FEV, RSU and back end system will enable the receiver of the information correctly estimate the position of the sender within the road network. In eCo-FEV, the location referencing information being used may be a map based location referencing (e.g. Alert C) or map independent location referencing (e.g. as being used in DENM).
MAP	Map database being used by FEV applications. Openstreetmap [20] is used for eCo-FEV project for testing purpose.
Local Dynamic Map(LDM)	Embedded database that includes dynamic (or static) information at the vicinity of the FEV e.g. received messages from other FEVs or RSUs in neighbourhood. Furthermore, it may also store information of ego FEV such as its position, speed and vehicle sensor information etc. LDM is updated periodically along the FEV driving. It provides an interface to applications, allowing the retrieval of data required for application processing.
CAM	Standardized Cooperative Awareness facility that generates transmits and receives Cooperative Awareness Message (CAM). The received CAMs are sent to LDM for update. CAM is standardized by ETSI [5].
DENM	Standardized Decentralized Environmental Notification basic service that generates transmits and receives Decentralized Environmental Notification Message (DENM). The received DENMs are sent to LDM for update. DENM is standardized by ETSI [12].
PoI	Standardized Point of Interest basic service that receives Point of Interest Message (PoI). The received POIs may be sent to LDM for update or directly sent to applications that request the information. POI for FEV charging station is standardized by ETSI [18]. Other types of POIs may be defined in eCo-FEV.
Message management	Facility that transmits and receives other types of messages as required by the information exchange as defined in chapter 3.2 of the present document
Web service	Facility that implement web service functionalities (e.g. SOAP, REST) and related higher layer protocol (e.g. HTTP).
NTAPI	Facility that provide API for data exchange between AU and CCU.
Testing unit	Facility that logs the testing data for test and evaluation. It may not be present in a real deployed product.
Networking & transport layer	*Communication capacities for communications between AU and CCU/HMI.*
TCP/UDP	TCP/UDP transport protocol used for communication between AU and CCU/HMI.
IPv6/Ipv6	Network layer protocol used for communication between AU and CCU/HMI.
Access layer	*Access technologies for communications between AU and CCU/HMI.*

ETH	Ethernet connections between AU and CCU.
USB/BTH	USB (wired) or Bluetooth (Wireless) connections between AU and HMI
CAN	CAN bus connection with other in vehicle systems
GNSS	Interface to GNSS receiver
Management layer	*Management functions for AU operation and cross layer*
Service management	Functionalities that manage the AU operations, e.g. configuration, AU status management, software management etc. It processes received Service Announcement Messages (SAM) from road side or from backend, and interacts with applications to access to services using communication means as included in SAM.
Communication management	Functionalities that interact with NTAPI to decide the communication stack being used for message transmission from OBU to external networks.
Cross layer managements	Functionalities that manage the communication between AU and other FEV systems e.g. CCU, HMI, CAN bus etc.
Security layer	*Security functions*
HTTPS	Secure communication for HTTP connection

Table 4.3: FEV AU functional components

The functional architecture of the FEV ITS-S CCU is illustrated in Figure 4.4.

This functional architecture is defined based on ITS station reference architecture as defined in [3]Figure 2.3. It includes functionalities of access and networking & transport layer.

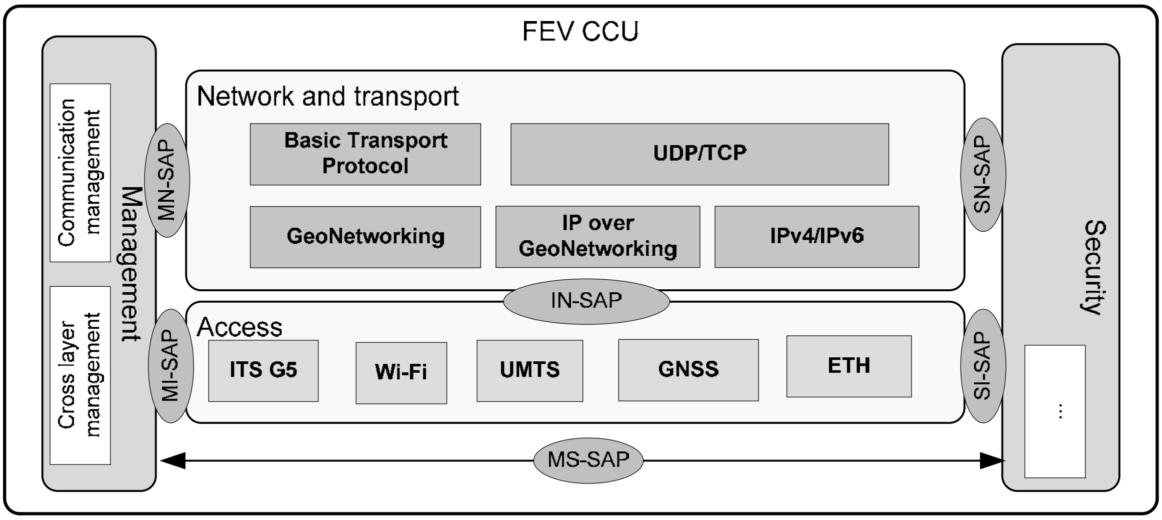

Figure 4.4: OBU CCU functional architecture

A short description of the identified sub components is summarized in Table 4.4.

AU functional component	Short description
Networking & transport layer	*Communication capacities for CCU.*
BTP	Basic transport protocol used for geoNetworking protocol stack BTP is standardized by ETSI [19]
geoNetworking	Standardized geolocation based networking protocol and networking functionalities. GeoNetworking is standardized by ETSI [5]
TCP/UDP	TCP/UDP transport protocol used for IP communication
Ipv6/Ipv6	Network layer protocol used for communication between CCU and external networks and between CCU and AU/HMI. In order to support the FEV network mobility, NEMO [6] protocol is implemented in Ipv6 protocol stack.
IP over geoNetworking	Functionalities that enable the transmission of Ipv6 packet over geoNetworking protocol stack.
Access layer	*Access technologies for communications between AU and CCU/HMI.*
ETH	Ethernet connections between AU and CCU.
ITS G5	5.9GHz based ITS G5 technologies as standardized by ETSI [2]. It provides direct ad hoc communications between FEVs and between FEV and RSUs.
UMTS	UMTS communication technologies for communication between FEV with back end and with other infrastructure systems.
GNSS	Interface to GNSS receiver
WiFi	WiFi connection between FEV ITS-S and HMI, or between FEV ITS-S and RSU or EVSE of the charging infrastructure.
Management layer	*Management functions for AU operation and cross layer*
Communication management	Functionalities that interact with AU to decide the communication stack being used for message transmission from OBU to external networks.
Cross layer managements	Functionalities that manage the communication between AU and other FEV systems e.g. CCU, HMI, CAN bus etc.

Table 4.4: FEV CCU functional components

4.2. Charging infrastructure subsystem

The subsystems of the two different solutions for the charging infrastructures have different communication structures depending on the power transfer solution. They have been divided into wireless and conductive charging to easily identify the common functions without losing the peculiarity of each solution.

In particular the conductive stationary charging infrastructure has well standardized power hardware, while the CWD charging has different prototype solutions not standardized yet. In eCo-FEV, existing conductive charging infrastructure will be used. The inductive charging infrastructure in particular supporting the charge while driving will be developed and specified.

#	Basic Requirements
1	Communication with eCo-FEV Backend (web service)
2	Communication with FEV charging devices.
3	Communication with the on-site power delivery
4	Machine to install charging equipment EVSE (conductive or wireless), including energy provision system and a control unit
5	EVSE operator that monitors operation of EVSE

Table 4.5: Basic requirements for charging infrastructure subsystem

4.2.1. **Wireless charging infrastructure**

The basic architecture for the wireless charging station is illustrated in Figure 4.5. The charging infrastructure includes two main parts: charging equipment EVSE that is mounted at road side for energy provision and related data management; and a backend system EVSE operator that manages the operation of EVSE.

Short description of wireless charging infrastructure main components and the main interfaces is provided in Table 4.6.

Charging infrastructure sub system	Short description
EVSE	EVSE is further composed of the HW components for the electric power transfer, it will be purposely realized and coordinated with the one mounted on the FEV. One of the components to be added in EVSE is the charging station control unit that manages the V2G data exchanges with OBU and with EVSE operator. It may be considered as the communication counter part of EVSE operator for required data exchange for AAA and EVSE operation monitoring. EVSE is connected with EVSE operator within a specific EVSE operator network using IP communication.
EVSE operator	EVSE operator is a backend system that manages the operation of EVSE. It manages the

	AAA procedure for FEV charging and monitors the charging process from backend. EVSE operator provides charging facilities status information to eCo-FEV backend in charging facility status monitoring.
RSU	Figure 4.5 illustrates RSU. For CWD, RSU may be used as alternative of PLC for conductive charging system in order to facilitate charging data exchanges between OBU and EVSE. RSU is therefore used as router.

Table 4.6: Sub systems of wireless charging infrastructure

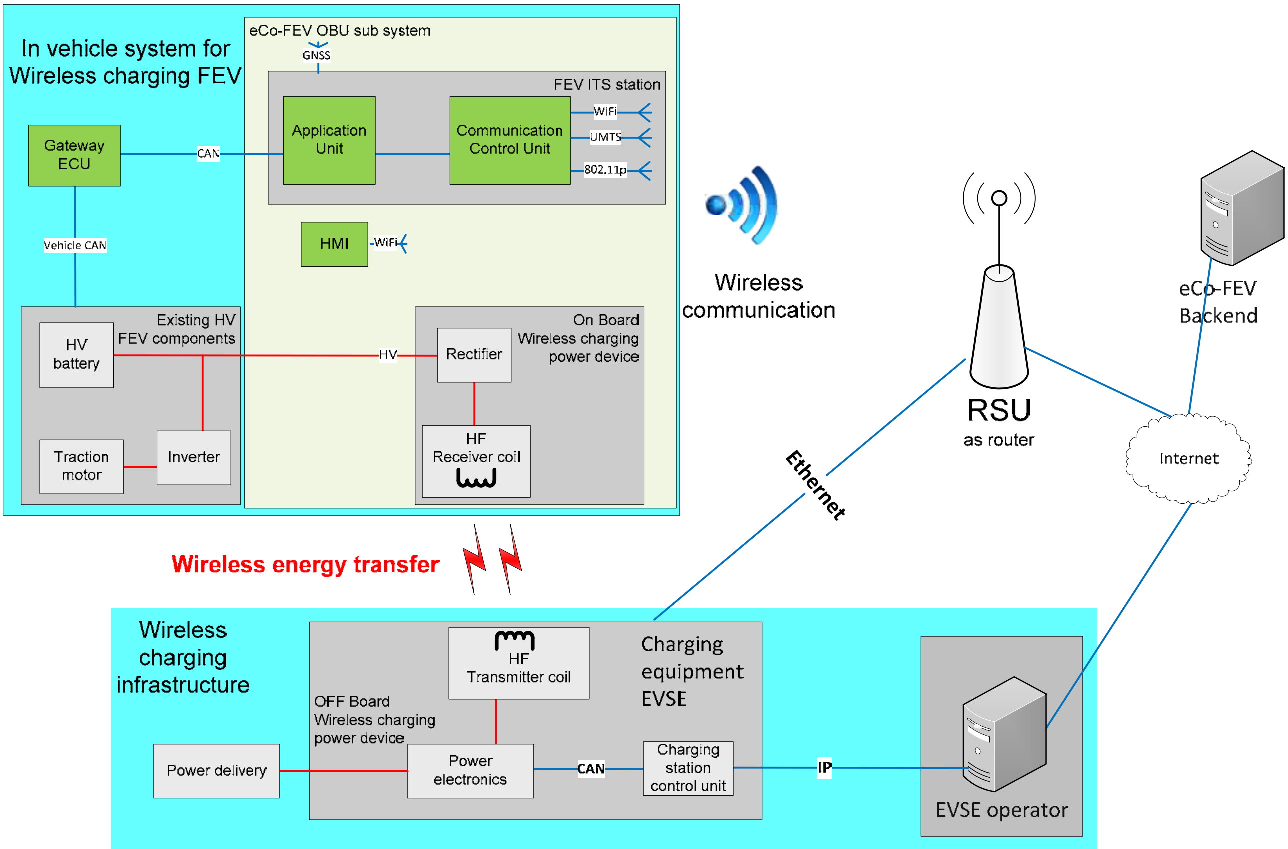

Figure 4.5: Wireless charging infrastructure subsystem overall architecture

4.2.2. **Conductive Charging Station subsystem**

The basic architecture of the charging station for the conductive charging is illustrated by Figure 4.6. Many of the hardware and the software components are already present on the existing charging infrastructure (Protection features, circuit breakers in HW, application unit, communication unit). Some of has to be modified or added to fulfil the eCo-FEV requirements. As illustrated by Figure 4.6, PLC is used for charging data exchange between FEV and EVSE, therefore, usage of RSU is not required. However, in one potential deployment, one may integrate RSU with charging infrastructure in order to realize specific user services e.g. booking, payment or location based services.

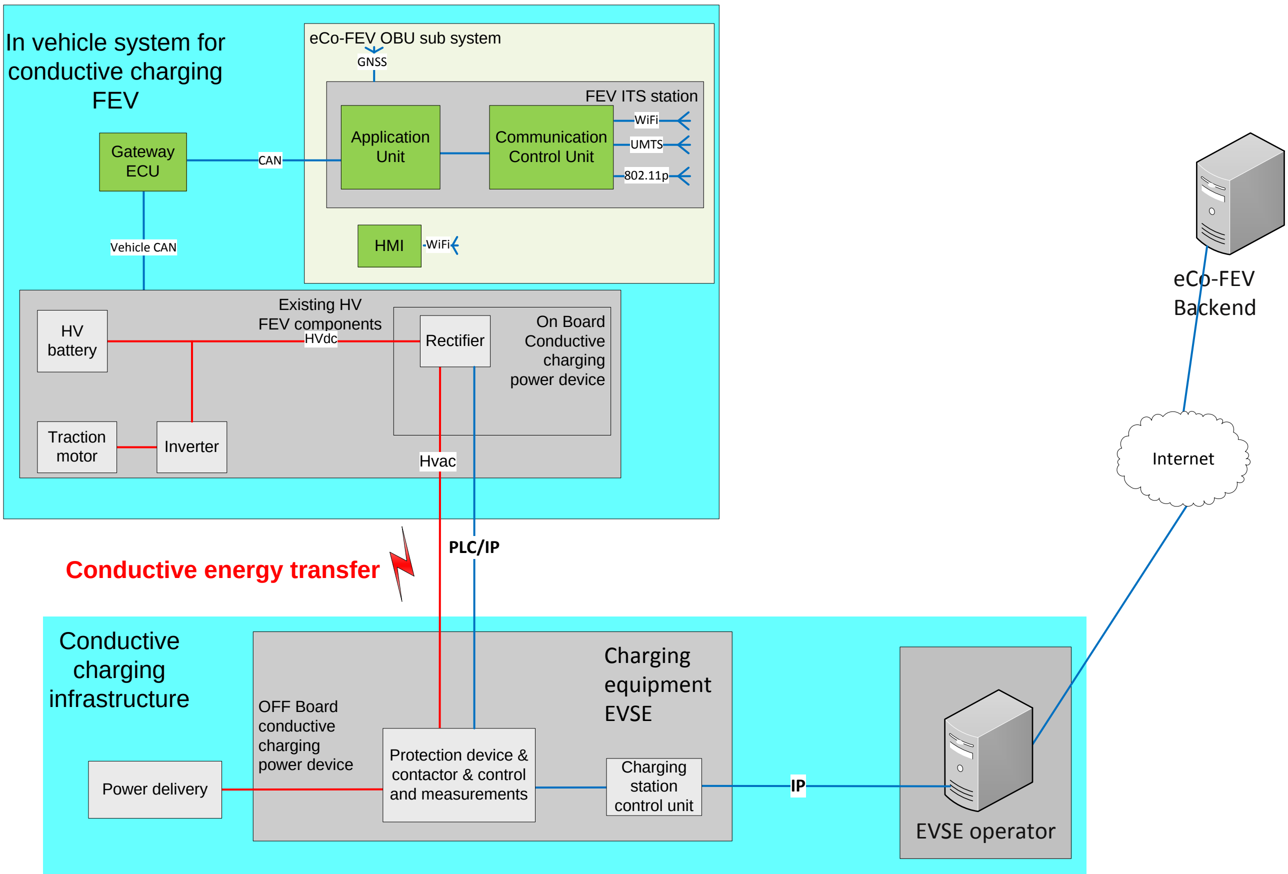

Figure 4.6: Conductive charging infrastructure subsystem overall architecture

4.2.3. C/S Control Unit

The C/S Control Unit is the part of the charging infrastructure which manages and controls the power electronics of the charging facility. On the other hand it communicates with the EVSE-Operator for achieving AAA services and providing monitoring information. The implementation of these functions may be differing between the conductive and the inductive charging case in order to adapt to specific requirements of charging mode.

The functional architecture of the C/S control unit is illustrated in Figure 4.7. Short description of functional components is presented in Table 4.7.

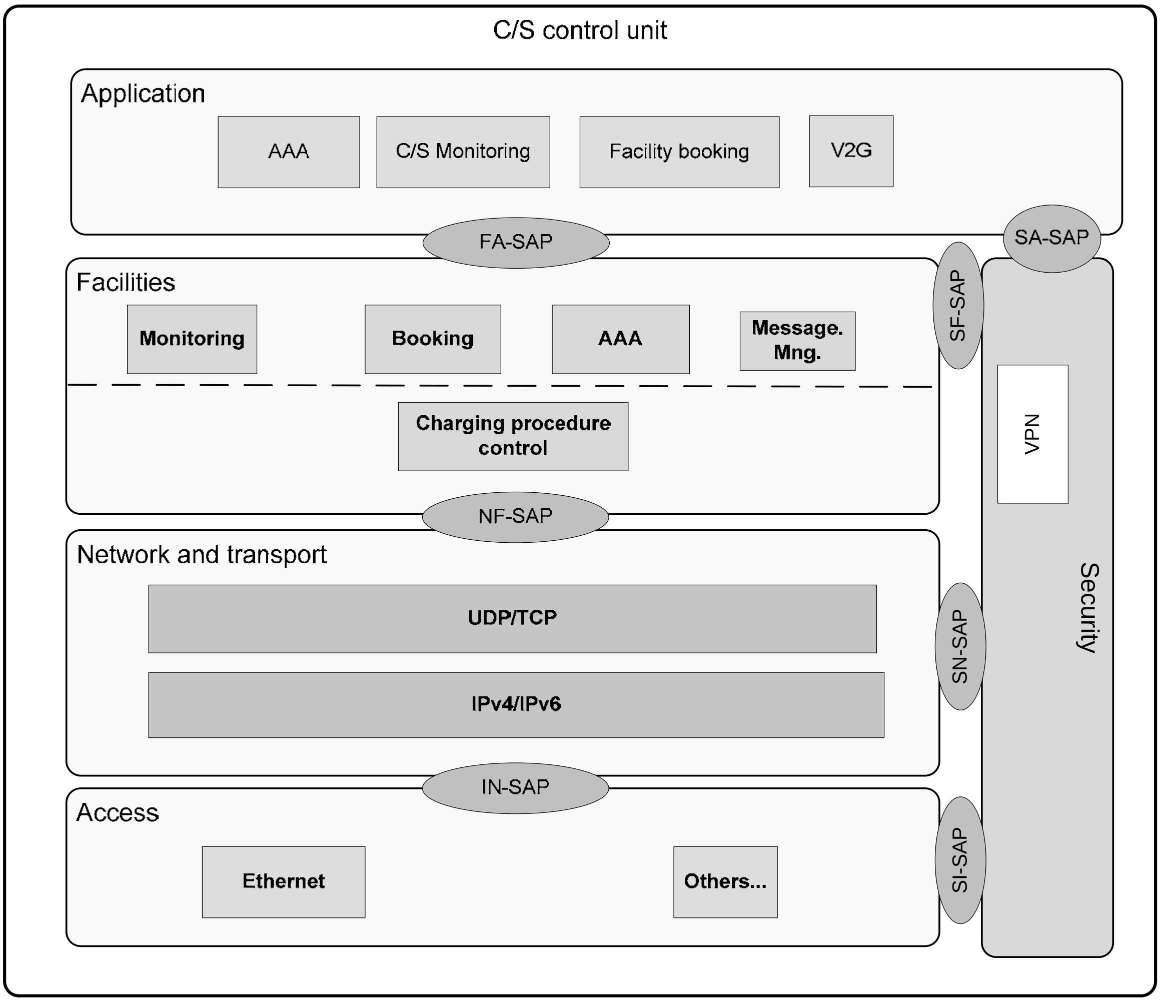

Figure 4.7: C/S control unit functional architecture

Functional component	Short description
Application layer	*Charging infrastructure applications*
AAA	Authentication, Authorization and Accounting of the charging process. This application is done in collaboration with the EVSE-Operator
C/S Monitoring	This application is done in collaboration with the EVSE Operator. It periodically informs about the operational and technical status of the charging facility.
Facility Booking	Reserving the Charging facility for a certain FEV
V2G	Managing the feeding process at the charging facility
Facilities layer	*Functional components required to support eCo-FEV applications*
Monitoring	Periodically, reporting the status of the charging infrastructure, also providing the ability for remotely triggering some actions by the EVSE Operator.

Message management	Facility that transmits and receives other types of messages as required by the information exchange.
Charging procedure control	This facility provides the control and management of the charging facility, during the charging process.
AAA	This facility implements the Client side of the AAA.
Booking	Facility that implement the reservation of the Charge point
Networking & transport layer	*Communication capacities for communications between C/S Control Unit and the EVSE Operator*
TCP/UDP	TCP/UDP transport protocol used for communication between C/S Control Unit and the EVSE Operator.
Ipv6/Ipv6	Network layer protocol used for communication between C/S Control Unit and the EVSE Operator.
Access layer	*Access technologies for communications between C/S and CCU*
ETH	Ethernet connections between C/S Control Unit and the EVSE Operator.
Other	Connection to the power electronics of the charging facility. Connection to the OBU of the FEV.
Security layer	*Security functions*
VPN	VPN connection to the EVSE-Operator.

Table 4.7: C/S Control Unit functional components

4.2.4. **EVSE Operator**

The EVSE Operator subsystem is the backend of the charging infrastructure. It communicates with a set of charging station control units, for gathering monitoring and status information, and triggering some actions, (such as booking). It implements the Server-side of the AAA for the charging process. On the other hand it communicates with the eCo-FEV backend for reporting the status of the charging facilities (monitoring) and providing accounting information.

The functional architecture of the C/S control unit is illustrated in Figure 4.8. Short description of functional components is presented in Table 4.8.

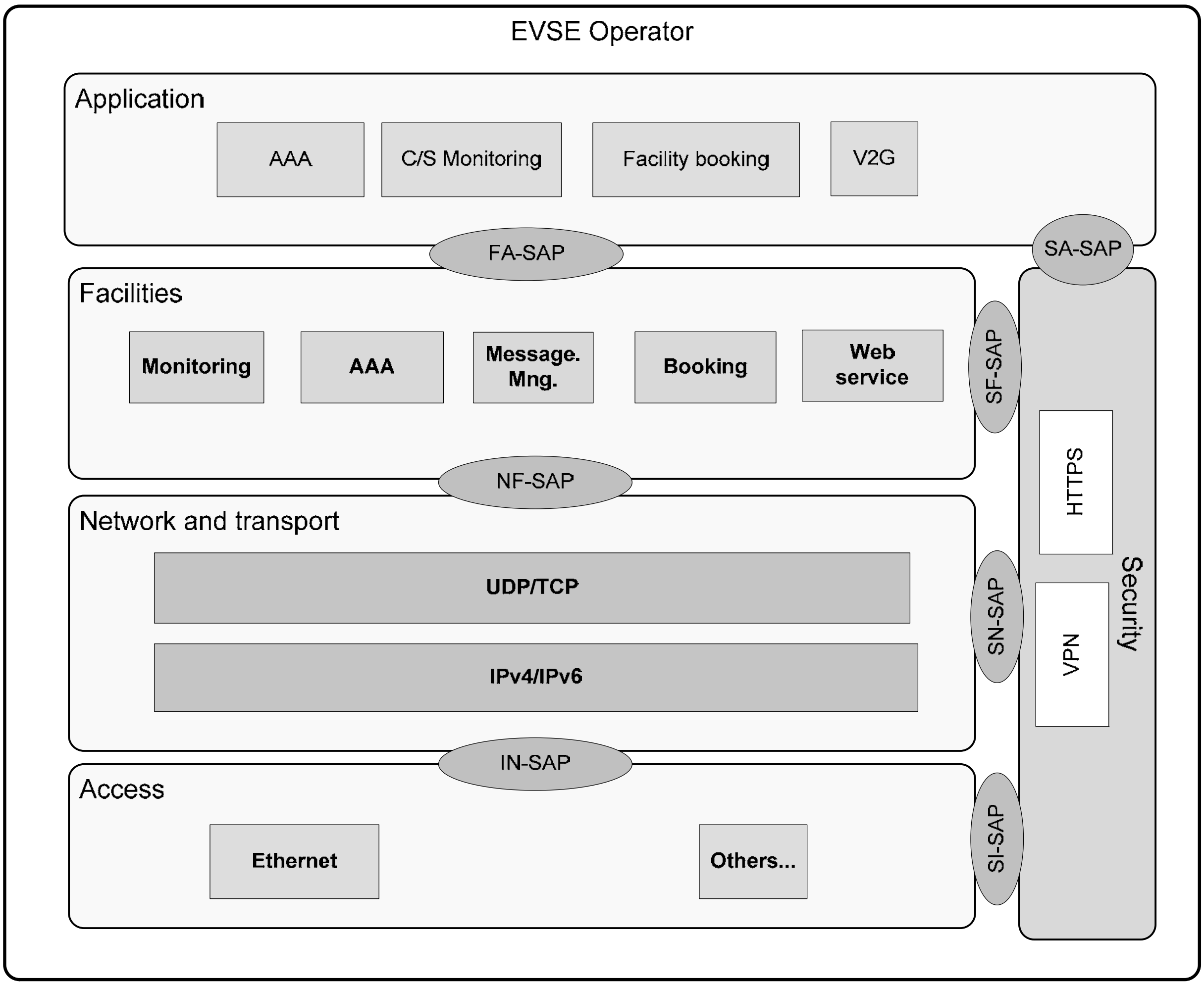

Figure 4.8: C/S operator functional architect

EVSE Operator functional component	**Short description**
Application layer	*Charging infrastructure applications*
AAA	Authentication, Authorization and Accounting of the charging process. This application is done in collaboration with the C/S Control Unit.
C/S Monitoring	This application is done in collaboration with the C/S Control Unit. It periodically gathers information about the operational and technical status of the charging facility.
Facility Booking	Reserving the Charging facility for a certain FEV
V2G	Managing the feeding process at the charging facility
Facilities layer	*Functional components required to support eCo-FEV applications*
Monitoring	Periodically, reporting the status of the charging infrastructure, also providing the ability for remotely triggering some actions by the EVSE Operator.

Message management	Facility that transmits and receives other types of messages as required by the information exchange.
AAA	This facility implements the Server side of the AAA.
Booking	Facility that implement the reservation of the Charge point
Web service	Facility that implements web service interface for communication with eCo-FEV backend.
Testing unit	Facility that logs the testing data for test and evaluation. It may not be present in a real deployed product.
Networking & transport layer	*Communication capacities for communications between C/S Control Unit and the EVSE Operator on one hand and with the eCo-FEV backend on the other hand*
TCP/UDP	TCP/UDP transport protocol used for communication between C/S Control Unit and the EVSE Operator.
Ipv6/Ipv6	Network layer protocol used for communication between C/S Control Unit and the EVSE Operator.
Access layer	*Access technologies for communications between C/S and CCU*
ETH	Ethernet connections with EVSE Operator and with eCo-FEV backend
Security layer	*Security functions*
VPN	VPN to the C/S control Units
HTTPS	HTTPS communication with eCo-FEV backend

Table 4.8: EVSE Operator functional components

4.3. Road side unit subsystem

4.3.1. RSU overall architecture

The RSU sub system is placed at road side, it provides services to FEVs and communication capacities to connect FEVs and road side and backend infrastructures. In the scope of eCo-FEV, two scenarios of RSU deployment are planned:

- The RSU is controlled by road IT infrastructure operators (e.g. traffic management center) and provide traffic information to road users. It receives dynamic traffic information either directly from the road side sensors, or from services providers (e.g. traffic management center or private service provider such as PoI service provider) then broadcasts the information to road users in its vicinity. This deployment scenario is the one implemented in French Test site of eCo-FEV project.

- The RSU is mounted to charging infrastructure and provide communication capacities for information exchange between FEV and charging infrastructure before and during the charging. This deployment scenario is the one implemented in Italian Test site of eCo-FEV project.

The RSU subsystem needs to satisfy basic requirements from interface and hardware perspective, as listed in Table 4.9, in order to achieve the objectives of the eCo-FEV project.

#	Basic Requirements
1	Communication with eCo-FEV Backend Infra.(Cellular)
2	Communication with OBU. (ITS G5 or WiFi)
3	Optional communication with road side equipment (existing interfaces of road side equipment)
4	Optional communication with charging equipment (ETH or wireless)
5	Communication with traffic management center
6	Machine to install eCo-FEV platform and applications
7	Communication control unit

Table 4.9: Basic requirements for RSU subsystem

Figure 4.9 shows the overall architecture of RSU. The interface to get access to Internet (i.e. Generic Access Domain and Road Side Unit domain) and to communicate with other ITS stations (i.e. ITS Ad hoc domain) are not directly illustrated in the figure, these communications are realized by Communication Control Unit integrated in RSU. In addition, sensor interface is given to connect with different sensors (e.g. traffic, rain, temperature sensors) as well as interface to connect with traffic light controller. Optionally, RSU may with charging infrastructures. Within the scope of eCo-FEV, RSU is used as router enabling data exchange between FEVs and inductive charging infrastructure for charge while driving.

The RSU is designed based on standardized ITS reference architecture as illustrated in [3]. As illustrated in Figure 4.9 , this RSU includes two physical components: an application Unit (AU) and Communication Control Unit (CCU). AU and CCU provide similar functionalities as in OBU. According to the information exchange needs and application requirements, these components are connected with each other, with road side infrastructures (e.g. road sensors, charging infrastructures) and with external communication networks. For this reason, several antenna systems are installed in RSU.

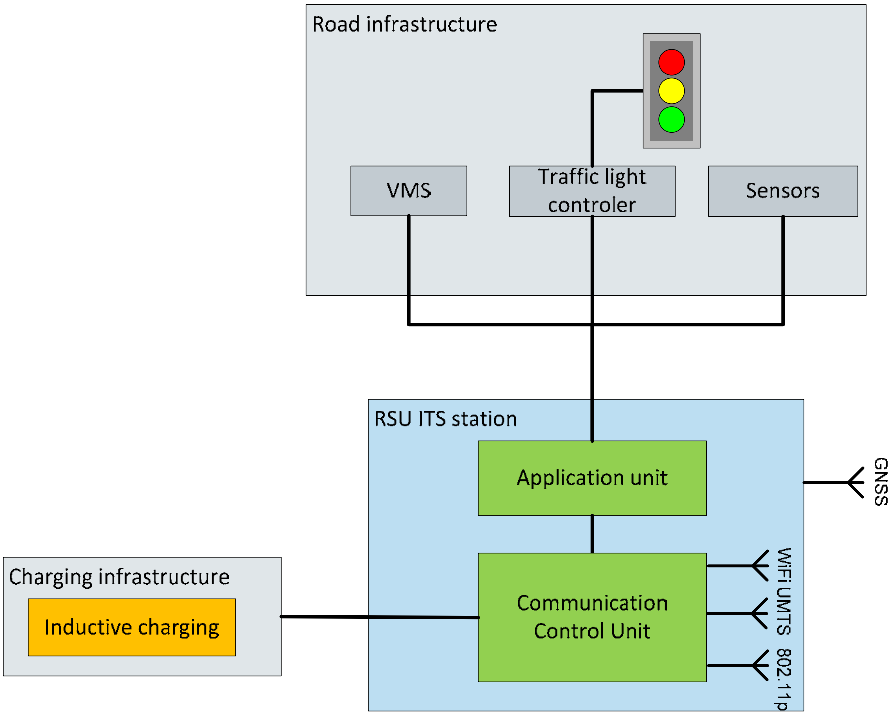

Figure 4.9: Road Side Unit subsystem overall architecture

4.3.2. **Road side ITS-S functional architecture**

Figure 4.10 shows the functional architecture of road side ITS-S AU by layer.

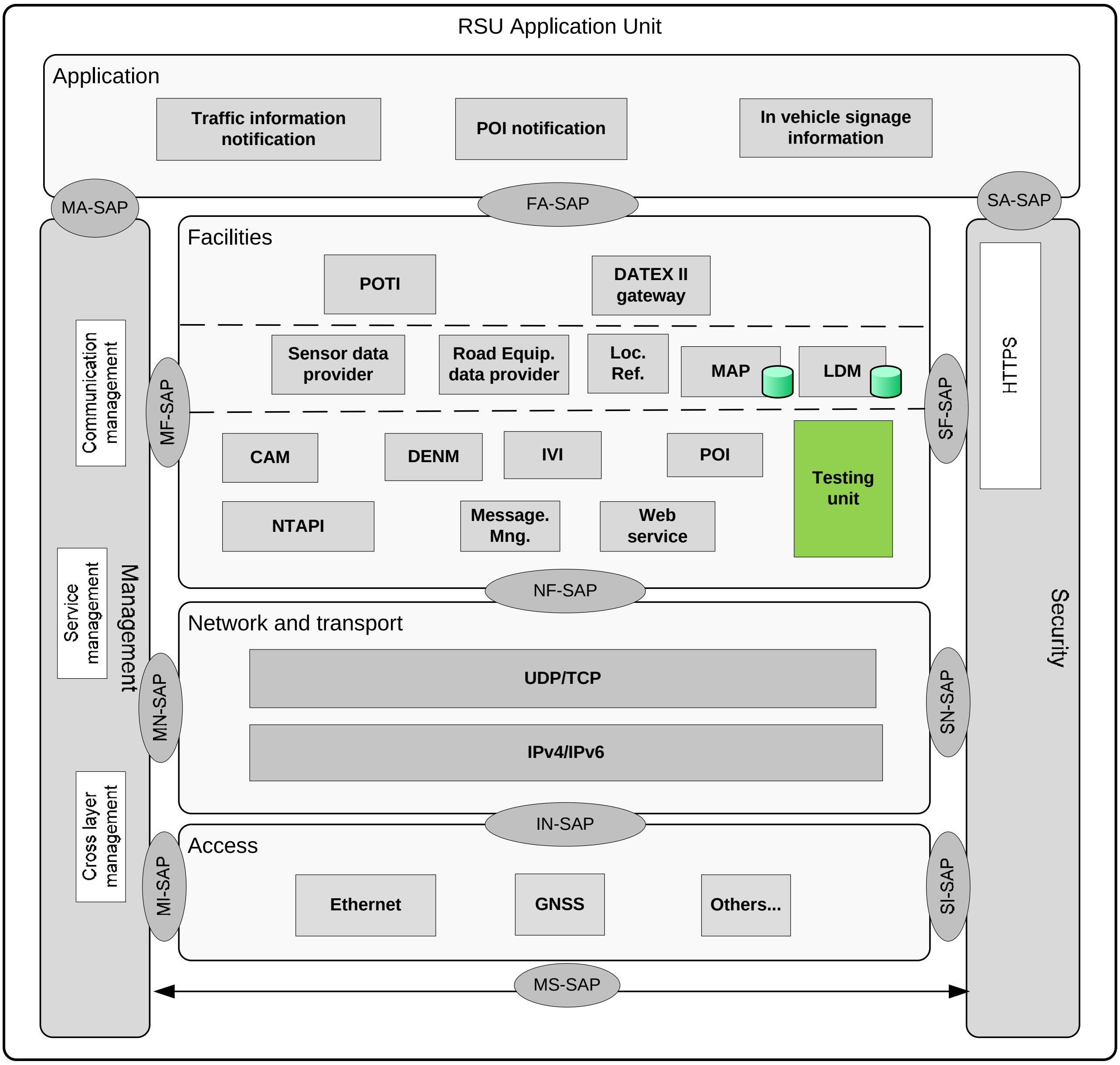

Figure 4.10: RSU Application unit functional architecture

A short description of functional components are provided in Table 4.10

AU functional component	Short description
Application layer	*RSU applications as implemented for eCo-FEV use cases*
Traffic information notification	This application provides real time traffic information from RSU to FEVs. The real time traffic information is received from road traffic operator, from eCo-FEV backend or from road side sensors or equipment connecting directly to RSU.
PoI notification	RSU broadcasts PoI notification information to road users, including e.g. charging spot notification information.

In vehicle signage information	RSU broadcasts dynamic or static road side signage information for in vehicle presentation.
Facilities layer	*Functional components required to support eCo-FEV applications*
DATEX II gateway	This facility provide gateway functionalities to support DATEX II standard, which is an European standard for data exchange of traffic information between operators, between operator and road side equipment.
POTI	This facility provides real time geographical position and time information of RSU, in order to enable the location based applications and services.
Sensor data provider	This facility interfaces with road side sensors in order to receive sensor information.
Road equipment data provider	This facility interfaces with road side equipment e.g. traffic light etc. in order to receive information.
Location Referencing (Loc. Ref)	This facility provides location referencing information additional to the geographical coordinates, enabling the matching of position to road topology. Multiple location referencing methods may be used. A commonly used location referencing method between FEV, RSU and back end system will enable the receiver of the information correctly estimate the position of the sender within the road network. In eCo-FEV, the location referencing information being used may be a map based location referencing (e.g. Alert C) or map independent location referencing (e.g. as being used in DENM).
MAP	Map database being used by FEV applications i.e. OpenstreetMap [20] as used by project for testing purpose.
Local Dynamic Map(LDM)	Embedded data base that includes dynamic (or static) information at the vicinity of RSU e.g. received messages from FEVs or other RSUs in neighbourhood. Furthermore, it may also store information of the ego RSU such as its position, sensor information etc. LDM is updated periodically. It provides an interface to applications, allowing the retrieval of data required for application processing.
CAM	Standardized Cooperative Awareness facility that generates transmits and receives Cooperative Awareness Message (CAM). The received CAMs are sent to LDM for update. CAM is standardized by ETSI [5].
DENM	Standardized Decentralized Environmental Notification basic service that generates transmits and receives Decentralized Environmental Notification Message (DENM). The received DENMs are sent to LDM for update. DENM is standardized by ETSI [12].
PoI	Standardized Point of Interest basic service that generates and transmits Point of Interest Message (POI). POI for FEV charging station is standardized by ETSI [18]. Other types of POIs may be defined in eCo-FEV.
IVI	Facility that generates the In Vehicle Information message to provide road side signage information.
Message management	Facility that transmits and receives other types of messages as required by the information exchange as defined in chapter 3.2 of the present document.

Web service	Facility that implement web service functionalities (e.g. SOAP, REST) and related higher layer protocol (e.g. HTTP).
NTAPI	Facility that provide API for data exchange between AU and CCU.
Testing Unit	Facility that logs testing data for RSU. This component may not be present in a real product implementation.
Networking & transport layer	*Communication capacities for communications between AU and CCU*
TCP/UDP	TCP/UDP transport protocol used for communication between AU and CCU.
Ipv6/Ipv6	Network layer protocol used for communication between AU and CCU.
Access layer	*Access technologies for communications between AU and CCU*
ETH	Ethernet connections between AU and CCU.
GNSS	Interface to GNSS receiver
Management layer	*Management functions for AU operation and cross layer*
Service management	Functionalities that manage the AU operations, e.g. configuration, AU status management, software management etc. It may receive service announcement messages (SAM) from backend, in order to discover the provided services types as well as the method and communication path to access to service. It may also generate SAM to inform FEV about the provided services by RSU and the communication means that enables the service access.
Communication management	Functionalities that interact with facilities and applications to decide the communication stack being used for message transmission from RSU to external networks.
Cross layer managements	Functionalities that manage the communication between AU and other FEV systems e.g. CCU, HMI, CAN bus etc.
Security layer	*Security functions*
HTTPS	Secure communication for HTTP connection

Table 4.10 : RSU AU functional components.

The functional architecture of the RSU CCU is identical to the CCU of OBU, as defined in clause 4.1.2 of the present document.

4.4. eCo-FEV backend subsystem

The eCo-FEV backend subsystem needs to satisfy basic requirements from interface and hardware perspective, as listed in Table 4.11, in order to achieve the objectives of the eCo-FEV project.

#	Basic Requirements
1	Communication with FEV
2	Communication with Road IT Infra. System and other eCo-FEV external systems
3	Communication with Charging Infrastructure
4	Communication with RSU
5	Server(s) to install eCo-FEV platform and applications

Table 4.11: Basic requirements for eCo-FEV backend subsystem

A high level functional architecture of the eCo-FEV backend sub system is illustrated in Figure 4.11. eCo-FEV backend connects with FEV and other infrastructure systems via Internet domain. eCo-FEV backend functionalities may be implemented in more than one physical entity i.e. backend servers. The detailed implementation framework will be decided in WP300 of the eCo-FEV project. In the present deliverable, functional architecture of the eCo-FEV backend will be defined.

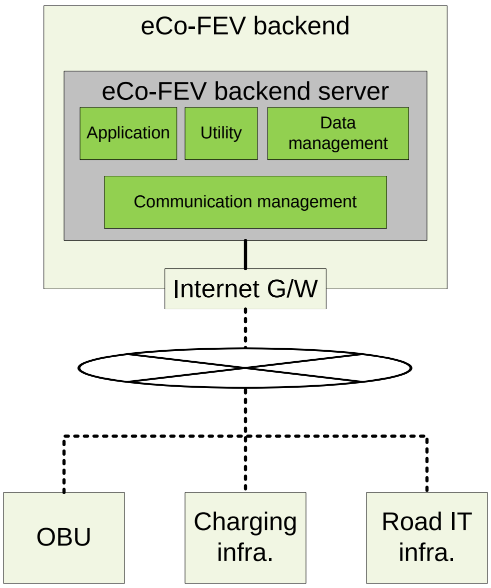

Figure 4.11: eCo-FEV backend sub system overall architecture

The functional architecture of eCo-FEV backend is introduced in Figure 4.12. eCo-FEV backend includes 5 functional layers (Communication management layer, Data Management layer, Utility layer, App support Utility layer and Application layer). For each layer, a series of components is present.

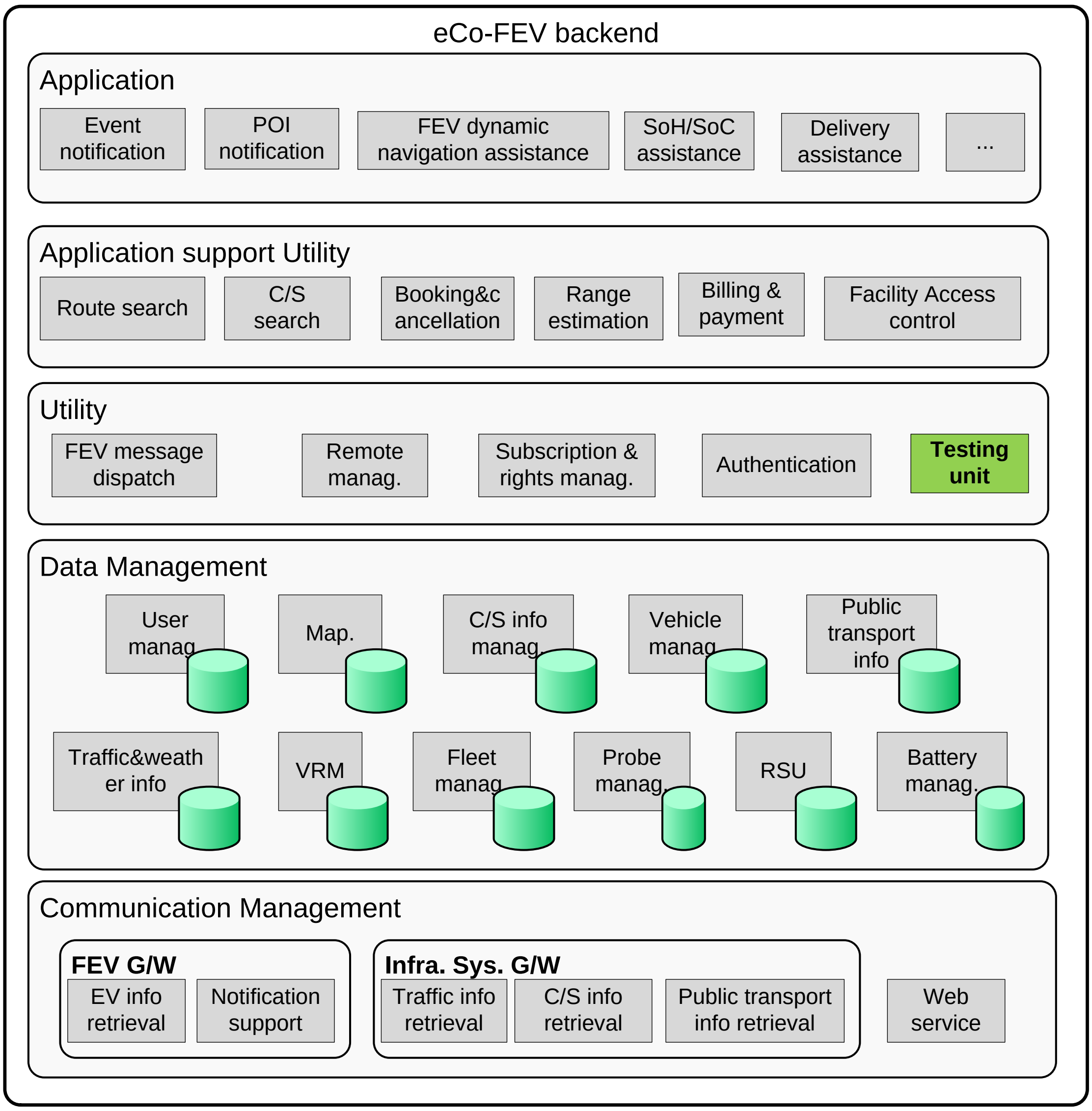

Figure 4.12: eCo-FEV backend subsystem functional architecture

4.4.1. **Communication management layer**

In this layer there are components which enable the eCo-FEV backend to connect with other eCo-FEV sub systems and with external actors such as OBU, road IT infrastructure or charging infrastructure. Table 4.12 contains the description of components included in this layer.

Component	Short description

EV Info Retrieval	Interface to receive EV information data such as probe data and battery data etc. from FEV
Notification Support	Interface to send notification message to FEV
Traffic Info Retrieval	Interface to collect traffic information from Road IT infrastructure
C/S Info Retrieval	Interface to collect EVSE status information from charging infrastructure
Public transport Info Retrieval	Interface to collect public transport information
Web service	Web service interface to enable users to access eCo-FEV backend services

Table 4.12: Components in communication management layer

4.4.2. Data Management layer

In this layer there are components to manage data such as user data, vehicle data, traffic data, C/S data and etc. Table 4.13 contains the description of components included in this layer.

Component	Short description
User management	Database and management functions to manage user data including user id, user name, password, user profile etc.
Map	Map database and map services, e.g. map matching. Openstreetmap [20] will be used by project for testing purpose.
C/S Info management	Database and management functions to manage EVSE data including static information e.g. id, name, address, position, and etc. and dynamic information e.g. availability. Optionally, it may include C/S status forecast information.
Vehicle management	Database and management functions to manage vehicle data including id, type and etc.
Public transport info	Database and management functions to manage public information data retrieved from public transport operator
Traffic & weather info	Database and management functions to manage real time traffic and weather data and/or forecast data received from Road IT infrastructure
VRM	Database and management functions to manage Vehicle Relationship Management data.
Fleet management	Database and management functions to manage delivery fleet information.
Probe management	Database and management functions to manage FEV probe data including time, position, velocity etc.
Battery management	Database and management functions to manage FEV battery status information.

Table 4.13: Components in data management layer

4.4.3. **Utility layer**

In this layer there are components that are required for the operation of eCo-FEV backend. Table 4.14 contains the description of components included in this layer.

Component	Short description
FEV Message Dispatch	Functionality to dispatch FEV message to relevant functions/applications.
Remote Management (Notification)	Functionality to construct and generates notification messages to FEVs or to RSUs.
Authentication	Functionality to authenticate user and vehicles.
Subscription/right managements	Functionality to manage user subscription process and manage user's access rights.
Testing unit	Functionality that logs test data. This component may not be present in a real deployed product.

Table 4.14: Components in utility layer

4.4.4. **Application support Utility layer**

In this layer there are components that provide common functionalities to support application. Table 4.15 contains the description of components included in this layer.

Component	Short description
Route search	Functionality to calculate route using digital map database based on predefined criteria. Optionally, it may provide generate route guidance information for FEV according to the calculated route.
C/S search	Functionality to select relevant and available EVSE from C/S info database according to the predefined selection criteria.
Booking and cancellation	Functionality to manage the facilities booking and cancellation process, if required by application.
Range estimation	Functionality to estimate the remaining FEV range based on real time traffic info and FEV battery info.
Facility access control	Functionality to verify the accessibility of a charging or parking facility with regards to the FEV and relevant booking.
Billing and payment	Functionality to initiate and manage the billing and payment procedure when required by application.

Table 4.15: Components in application support utility layer

4.4.5. **Application layer**

This layer includes components for eCo-FEV applications. Table 4.16 contains the description of components included in this layer.

Component	Short description
Event notification	Application to monitor events such as traffic accident, changing C/S status and etc. and notify the event to EV user who needs it if detected
PoI notification	Application to notify C/S POI or other POI to FEVs, either requested by FEV or triggered by eCo-FEV backend for POI information broadcasting
FEV dynamic navigation assistance	Application to provide navigation assistance to FEV
SoC/SoH assistance	Application to provide battery management assistance to FEV
Delivery assistance	Application to provide assistance for delivery fleet operator and for delivery fleet FEV driver

Table 4.16: Components in application layer

5. Conclusion

The objective of eCo-FEV project is to provide a set of user services (applications) to FEV users and to infrastructure operators, in order to improve the FEV mobility and the infrastructure management efficiency. The eCo-FEV architecture will support and implement the services (use cases) defined in D200.1, having as main objective the improvement the FEV usage efficiency in real travelling and traffic situations.

With Deliverable D200.2, the project partners in WP200 created the basis for the following activities in this work package (WP230 specification) as well as in other work packages as WP300 for system development and WP400 for testing scenario definition.

The architecture has been described from different viewpoints, such as system viewpoint, communication viewpoint, information viewpoint and technology viewpoint enabling a high level understanding of roles and functionalities of eCo-FEV system. Main sub systems have been identified as: On Board Unit (OBU), road side unit (RSU), charging infrastructure and eCo-FEV backend. High level functional architecture of the eCo-FEV system is defined, based on which the interactions between sub systems have been presented in UML sequence diagram.

Furthermore, according to the information exchange needs and use cases requirements, the sub systems functional design has been performed by identifying the functional components of each layer implemented in the application and the communication units. Each of the components has been briefly described in the present document. The specification of each of the identified components, of the interfaces and the data flow between these components will be performed in the D200.3 system specifications deliverable.

The proposed architecture is flexible and modular, being able to accommodate different infrastructure systems, to satisfy local requirements at the implementation site, to enable additional services and to facilitate the exploitation of the eCo-FEV system. For this purpose, standardization of the main exposed interface is essential from eCo-FEV project viewpoint. One of main expected outputs of eCo-FEV project will be technical contributions to the implementation of existing standard, amendment of existing standards and potential identifying the needs of new standard. Such modular and flexible architecture further enables the flexible setting of eCo-FEV system business for potential deployment.

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Acronyms

AAA	Authentication, Authorization, Accounting
AC	Alternating Current
API	Application Programming Interface
AU	Application Unit
BTP	Basic Transport Protocol
C2CCC	Car to Car Communication Consortium
C-ITS	Cooperative ITS
C/S	Charging Station
CALM	Communications Access for Land Mobiles
CAM	Cooperative Awareness Message
CAN	Controller Area Network
CCU	Communication Control Unit
CEN	European Committee for Standardization
CN	Correspondent Node
CoAP	Constrained Application Protocol
CWD	Charging While Driving
DC	Direct Current
DENM	Decentralized Environmental Notification Message
DSRC	Dedicated Short Range Communications
ECU	Electronic Control Unit
ETH	Ethernet
ETSI	European Telecommunication Standard Institute
EV	Electrical Vehicle
EVCC	Electric Vehicle Communication Controller
EVSE	Electric Vehicle Supply Equipment
FEV	Full Electrical Vehicle
G5	Telecommunication technology of vehicular ad hoc network
GNSS	Global Navigation Satellite System
HV	High Voltage
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol

HTTPS	HTTP Secure
HW	Hardware
ID	Identity
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
Ipv6	Internet Protocol version 6
ITS	Intelligent Transportation System
ITS-S	ITS Station
IVI	In Vehicle Information
LDM	Local Dynamic Map
M2M	Machine to Machine
MIPv6	Mobile Ipv6
NEMO	Network Mobility
OBU	On Board Unit
OEM	Original Equipment Manufacturer
OSGi	Open Services Gateway initiative
PLC	Power Line Communication
PoI	Point of Interest
POTI	Position and Time
REST	Representational State Transfer
RSU	Road Side Unit
SAE	Society Of Automobile Engineering
SAM	Service Announcement Message
SECC	Supply Equipment Communication Controller
SLA	Service Level Agreement
SOAP	Simple Object Access Protocol
SoC	State of Charge
SoH	State of Health
SW	Software
TC	Technical Committee
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UML	Unified Modeling Language
UMTS	Universal Mobile Telecommunications System

URL	Uniform Resource Locator
V2G	Vehicle to Grid
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VDP	Vehicle Data Provider
VPN	Virtual Private Network
VRM	Vehicle Relationship Management
WWW	World Wide Web
XML	Extensible Markup Language