Feasibility analysis and development of on-road charging solutions for future electric vehicles

Review of existing ICT solutions and technical benchmarking

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List of abbreviations

ABBREVIATION	DESCRIPTION
AAA	Authorization and Accounting
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
ANPR-Camera	Automatic Number Plate Recognition Camera
API	Application programming interface
CACC	Cooperative Adaptive Cruise Control
CAN	Controller Area Network
CEDR	Conference of European Directors of Roads
CEN	European Committee for Standardization
CI	Charging Infrastructure (Electric Vehicle Supply Equipment – EVSE)
CIO	Charging Infrastructure Operator
CPC	Charging Procedure Control
CPU	central processing unit
CSCU	Charging Station Control Unit
CWD	Charge While Driving
DRMS	Demand Response Management System
DSCH	DER energy or/and ancillary services schedule
DSL	Digital subscriber line
DSO	Distribution System Operator
DSRC	Direct Short-Range Communication
DXX.X	Deliverable XX.X
EAP	Extensible Authentication Protocol
EAP-PEAP	EAP-Protected Extensible Authentication Protocol

EAP-SIM	GSM Subscriber Identity Module
EAP-TLS	EAP-Transport Layer Security
EC	European Commission
ECS	Energy Consumption Schedulers
EDF	Edge Distribution Function
EMIX	Energy Market Information Exchange
EMS	Energy Management Systems
ETSI	European Telecommunications Standards Institute
EV	Electric Vehicle
EVB	Electric Vehicle Backend
EVCSN	Electric Vehicle Charging Spot Notification
EVSE	Electric Vehicle Supply Equipment
EV-VMU	Electric Vehicle-Vehicle Management Unit
FABRIC	FeAsiBility analysis and development of on-Road chargIng solutions for future electric vehiCles
FEMP	FABRIC Electric-Mobility Platform
FEV	Fully Electric Vehicle
FIVE	Framework for harmonized Implementation of VMS in Europe
FTP	File Transfer Protocol
GPS	Global Positioning System
HDR	High Dynamic Range
HMI	Human-Machine Interface
ICT	Information and Communications Technology
ICT	Intelligent Transport Systems
ID	Identifier

ISA	Intelligent Speed Adaptation
IT	Information Technology
LBPE	Lane Boundary Pixel Extractor
LCS	Lane Control Signals
LDI	Lane Departure Identification
LDW	Lane Departure Warning
LMP	Locational Marginal Pricing
MB	Mega-Bit
MIB	Management Information Base
NN	neighbourhood network
NTP	Network Time Protocol
OBU	On-board unit
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
OIDs	Object Identifiers
OSCP	Open Smart Charging Protocol
PCC	Predictive Cruise Control
PE-Road	Power Electronics on Road
PE-VEH	Power Electronics on Vehicle
PNA	Plate Numbers of the vehicles
RAC	Remote Appliance Controllers
RADIUS	Remote Authentication Dial In User Service
RAM	Random Access Memory
REST	Representational State Transfer
RTP	Real-Time-Pricing

SITAF	Società Italiana per il Traforo Autostradale del Fréjus per Azioni
SMD	Standard Market Design
SNMP	Simple Network Management Protocol
SP	Sub-project
TUB	Technischen Universität Berlin
UC	Use Case
USB	Universal Serial Port
VIN	Vehicle Identification Number
VMS	Variable Message Sign
VSA	Vendor Specific Attributes
WAN	wide area network
WP	Work-package
WPT	Wireless Power Transfer
XML	Extensible Markup Language
XSD	XML Schema Definition

Executive Summary

The FABRIC Integrated Project aims to open the way for large deployment of electro-mobility focusing on the technological feasibility, economic viability and socio-environmental sustainability of dynamic on-road charging of electric vehicles. This is the first deliverable within FABRIC Sub-Project (SP) 2, dealing with the Information and Communications Technology (ICT) solutions required in order for on-road electric charging (wireless power transfer – WPT) to function.

This report reviews the existing ICT products and services that could be used or be relevant for the design and implementations of the FABRIC system's scenarios of use. The ICT solutions described in this document are related to the requirements identified in WP 2.2. This review has been the basis for the benchmarking process which aimed at identifying the components that will be inserted from the shelf or adapted or developed from scratch for the FABRIC architecture. The process described in this deliverable also includes a gap analysis providing indications about what requirements for-dynamic charging ICT solutions cannot be satisfied by the current state of the art. In order to cover the identified gaps, preliminary solution proposals and indications for research are reported. Within this document, we also assess interoperability issues and suggest feasible solutions.

The overall analysis was divided into six main areas, which were investigated by the various Fabric partners according to their expertise. The areas are the following:

- User accounts, booking and billing
- Dynamic routing for EVs
- Vehicle identification, charging lane access control and management
- ICT control of wireless power transfer (smart metering)
- Driving assistance while charging
- Distribution supply operator and grid management

After conducting the state of the art and the gap analysis, we provide a prioritization of the solutions based on the relevance for FABRIC considering the experimental feasibility test challenge and the business cases for deployment (e.g., for billing and maximizing the energy transfer also by keeping the right trajectory of the vehicle during the dynamic charging).

The main conclusions with respect to the planned demonstrations within the FABRIC project are:

- Dynamic routing for EVs: not relevant to the demonstration but a valuable (though not essential) user service in a wider demonstration. Existing navigation technology is suitable and can be adapted.
- Lane Keeping assistance: Needs adaptation since charging lanes will be narrower than normal lanes. Alternatively, drivers could be given real time information about the efficiency of energy transfer (if the trajectory and speed does not abide by certain parameters, the result will simply be that power transfer is inefficient and the driver is paying for more power than he receives, but can make the choice to stop the charging if informed of such a low level of efficiency).
- Distribution System Operator (DSO) and grid management: Adaptations are needed in order to ensure real time performance that will ease the integration of dynamic wireless charging

infrastructure, in a secure and energy efficient manner. For typical functionalities such as metering, billing and overall management, protocols of conventional charging schemes can be re-used. However for more sophisticated operations such as demand side management and load balancing, novel methods needs to be developed. FABRIC aims to develop Demand Side Management will provide architectural and functional paradigms required to boost deployment of technologies that enable the seamless integration of dynamic wireless charging infrastructures to the grid

- User accounts: Account management solutions from the eCo-FEV project can be used to meet FABRIC needs.
- Booking: Fast identification and authorisation method may be needed. There is a need for more study into the relevance and needs for booking for static and dynamic charging. Data model needed between the different systems in EV identification.
- Billing: not relevant to the demonstration but a prototype system would require billing without a physical contact with the driver (clearing-house system similar to interoperable electronic toll collection systems). A data model between the different systems used for billing is needed.
- Vehicle identification, charging lane access control and management/enforcement: Messages for EVs need to be defined for use on different supports (in-car, VMS, detection…). Risk of different means of detection being used by different systems.
- Smart metering: Fast measurement techniques needed for dynamic charging. Need to define data model for sending measured energy.

1 Introduction

1.1 Introduction to FABRIC and to SP2: ICT Solutions

Electromobility is expected to be an essential component in the pursuit of the decarbonisation of road transportation and mobility. Issues concerning current on-board battery packs (high weight and cost) limit the usage of fully electric vehicles (FEVs) predominantly to urban/local trips. For this, on-road power transfer solutions are being investigated, since they would allow practically all of the drawbacks of on-board battery pack to be avoided or circumvented.

In this context, the principal motivation for the FABRIC project is the feasibility assessment of on-road charging solutions, including their technological feasibility, socio-economic viability and environmental sustainability from all perspectives. The ultimate aim of FABRIC is to provide a pivotal contribution relevant to electro-mobility in Europe, identifying the expected benefits and required costs so that the investments required for research, development and implementation in each of the components of the mobility system of the future can be fully understood, quantified and ratified.

FABRIC is undertaking an in-depth assessment of user and technological requirements across the main areas which this technology could impact, such as road and energy infrastructure, and will identify gaps between current capability and what is required for such a system to succeed and provide the anticipated benefits.

Sub-Project 2 (SP2) of FABRIC is one of four technical SPs in the project. It deals with solutions related to Information and Communications Technologies (ICT). ICT can offer solutions to the challenges of electro-mobility provided that there is a holistic approach, bringing vehicle, driver and infrastructure together in a highly integrated environment where information is securely, swiftly and reliably communicated and processed. A future where each node in this system is aware of the system's status and the end user is able to pre-book infrastructure, charge the EV, and pay seamlessly and effortlessly is feasible and can be envisioned. This can be achieved by a feasible FABRIC implementation, providing the necessary ICT infrastructure (including Intelligent Transport Systems – ITS) is deployed.

Work-Packages of SP2 cover user needs and system concept/functionalities (WP22), technical benchmarking of ICT solutions (WP23: reported in this deliverable), architecture and system specifications (WP24), design of ICT applications (WP25) and verification (WP26).

1.2 Purpose of WP23 and contribution to FABRIC objectives

Work package 23, of which this deliverable is the result, reviews the existing ICT solutions. The ICT solutions described in this document are compared against the requirement identified in WP 22. This review is the basis for the benchmarking process to identify the most suited components to be adopted or adapted for FABRIC. It performs a gap analysis with the preliminary proposed on-road charging ICT solutions. In order to cover the identified gaps, the result of the gap analyses assesses the adaptations and the new solutions. Within this document, we assess interoperability issues and suggest feasible solutions. The specifications of the component that will be used in the FABRIC architecture are defined in WP 24.

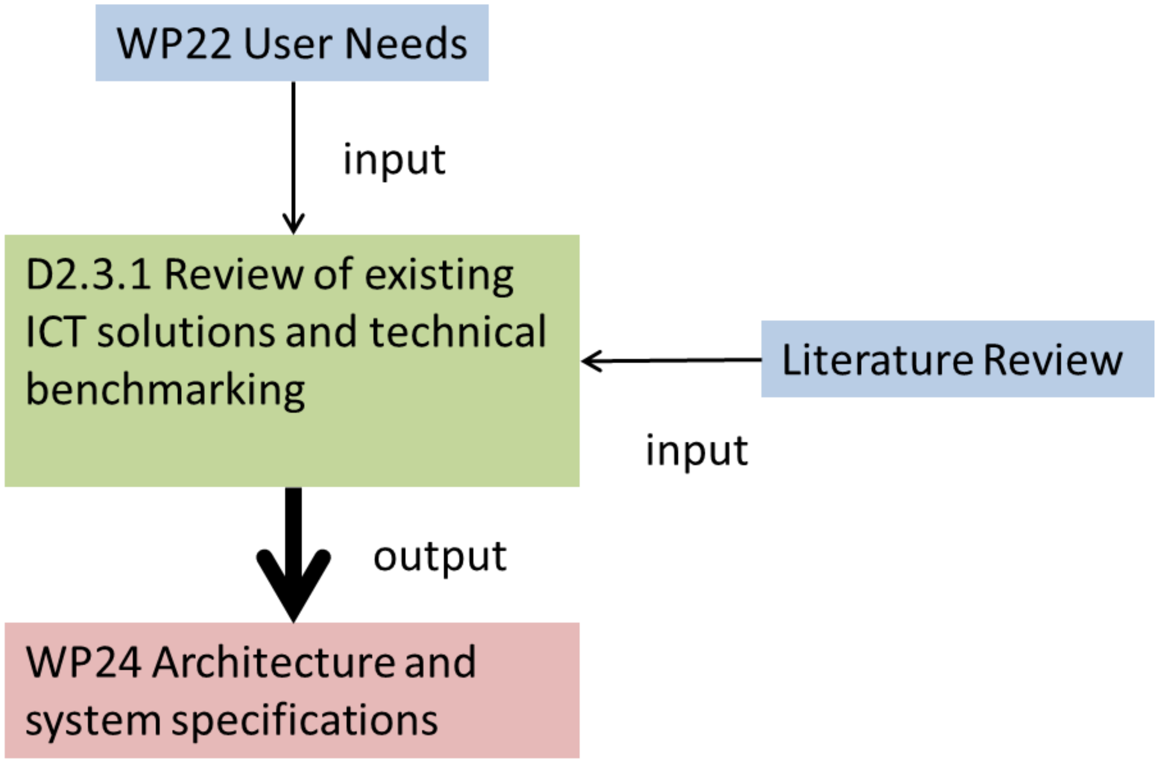

Figure 1: Inputs and outputs for D2.3.1

1.3 Deliverable structure

Following this introductory chapter, this deliverable is organised as follows:

- Chapter 2 reviews existing ICT solutions for preliminary use cases
- Chapter 3 performs the gap analysis between existing ICT solutions and the needs of FABRIC project and analyses the interoperability issues
- Chapter 4 presents the conclusions regarding the suitability of ICT solutions.

2 Existing ICT solutions for preliminary use cases

2.1 Approach

2.1.1 Methodology

This chapter is structured around the functional requirements defined in FABRIC Deliverable D22.1 "User needs system concept and requirements for ICT solutions". These requirements were categorised into six classes as follows:

- A: User accounts, booking and billing;
- B: Dynamic routing for Electric Vehicles (EVs)
- C: Vehicle identification, charging lane access control and management/enforcement
- D: ICT control of Wireless Power Transfer (WPT)
- E: Driving assistance while charging
- F: Distribution System Operator (DSO) and grid management.

For each group of functional requirements, several different individual functions were defined in D22.1 and for each one, different ICT solutions are possible. This chapter focuses on proprietary solutions and developments of (publicly available) research projects, with a FABRIC partner being allocated to each of the six functional requirements above. Not all the solutions covered may be appropriate to FABRIC: the goal was to analyse what exists and then (in Chapter 3) judge the suitability for FABRIC.

The different functions are listed at the beginning of each sub-chapter (see FABRIC D22.1 for further details of the functional requirements). The ICT solutions are then described for all these individual functions within the class, as in many cases the same ICT system fulfils several individual functions.

2.1.2 Overview of main FABRIC sub-systems

Deliverable D22.1 defined the main FABRIC sub-system as follows:

- On Board Unit (OBU): OBU is integrated into the EV. It includes communication hardware (e.g. Wi-Fi, UMTS, G5…), application unit hardware, vehicle gateway to interface with EV electronic system, at least one HMI device and the in vehicle charging system.
- EV Backend (EVB): Electric vehicles from different vehicle manufacturers have their own protocol, communication technology and services; in the FABRIC scenario different OEMs are foreseen therefore the EV OEM backend is the interface with the FABRIC platform.
- FABRIC Electric-Mobility Platform (FEMP): This represents the FABRIC backend system; it includes at least a middleware platform for infrastructure data collection and potentially data aggregation functionalities, and one service provider platform that provides EV services to customers. Additionally and according to the business strategy, other backend systems may be included such as an ID provider that manages the ID and contract information of customers.
- Charging infrastructure (CI): This includes EV supply equipment at road side for Wireless Power Transfer (WPT) to EVs.
- Charging Infrastructure Operator (CIO): This is CI backend comprising the infrastructure management and operator interface. Therefore it includes communication hardware (e.g. Wi-Fi, UMTS, etc.), application tool, and energy provision equipment for power transfer. The backend operator is in charge of managing, operating and monitoring all functionalities. It also provides

services to assist the EV charging process such as authentication, authorisation, accounting, monitoring of power transfer, etc.

- Road Side Unit (RSU): An RSU includes communication hardware (e.g. Wi-Fi, UMTS, etc.), and potentially gateways to interface with road side infrastructure or with WPT infrastructure. It main purpose is to enable communication between EV and charging control infrastructure.
- Distribution System Operator (DSO): This concerns the provision of energy and its pricing, managed by the DSO, which interfaces with the FEMP and the CIO.
- Energy Retailer (ER): Supplies the power via the DSO, using the CI. Also interfaces with the FEMP regarding energy pricing/payment.
- Road Operator (RO): Its role is to provide traffic and weather information to the FEMP. In a scenario where the RO also operates the CI, this would be merged with the CIO and would also perform access control and enforcement functions (if needed, i.e. in a closed access system).

Figure 2 below illustrates the relationships between these sub-systems.

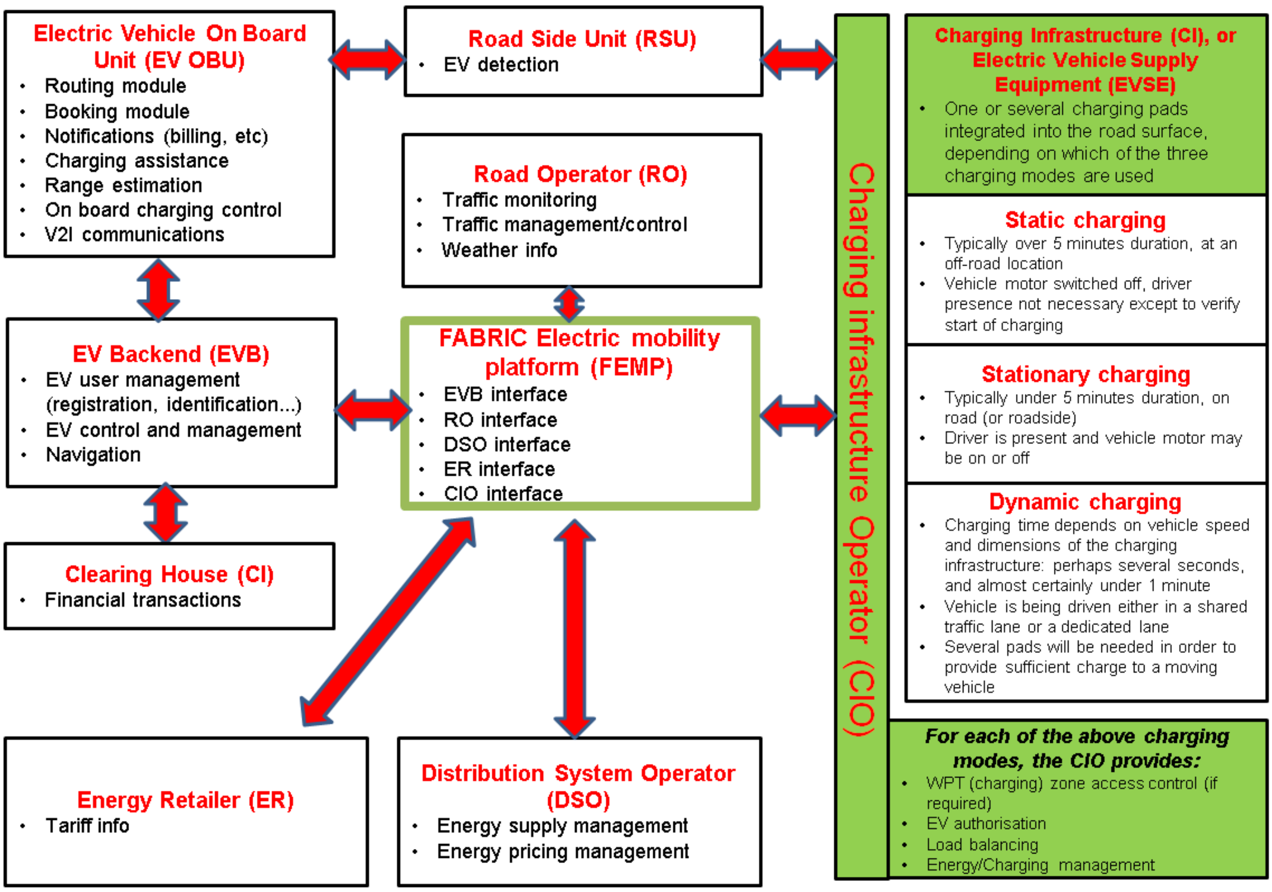

Figure 2: FABRIC high level sub-systems

2.2 User accounts, booking and billing

The Class A group of functions as defined in FABRIC D22.1 concerns the FABRIC Electric-mobility platform (FEMP), the On Board Unit (OBU) and EV Backend (EVB). The individual functions are as follows:

- A1: User Account creation and maintenance
- A2: FABRIC Charging Infrastructure Booking
- A3: Changes to FABRIC Charging Infrastructure Booking
- A4: Billing
- A5: Clearing House.

2.2.1 User account

As defined in the user and system requirements, the FABRIC platform shall provide means for the creation and management of an interoperable user account in order to facilitate post-trip billing for electricity from different service providers. Two main use cases are concerned: driver-owner registration and user account management.

In the context of charging on the road related systems, three ICT solutions originating from European projects are worth mentioning as potential directions in terms of user account management: Green eMotion [1], Mobility 2.0 [2], and eCo-FEV [3].

2.2.1.1 Green eMotion

The Green eMotion project focuses on an interoperable electro mobility system for the European market. It includes in its proposed IT architecture interfaces that enable charging infrastructure from competing companies to interoperate. A virtual marketplace is created to enable the different actors to interact and to allow for new high-value transportation services as well as EV-user convenience in billing. The marketplace includes: interoperable processes for billing of energy and value-add services such as charging spot reservation and navigation services.

Figure 3 shows a mock-up website of the virtual marketplace. Users and service providers can register and login to have access to services such as searching for charging spots (end users) or adding new added value services (service providers).

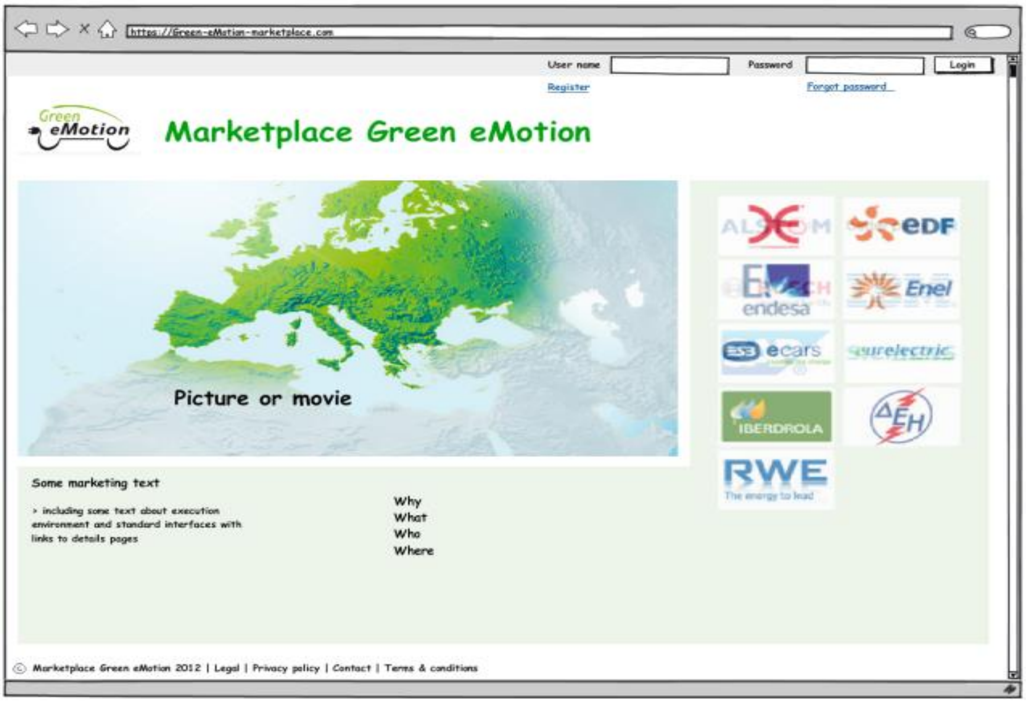

Figure 3: Virtual marketplace of Green eMotion project

2.2.1.2 Mobility 2.0

The Mobility 2.0 project focuses on an in-vehicle co-operative commuting assistant for FEVs which seamlessly takes the driver through the three-stage process of available parking reservation, vehicular navigation through sparse areas, and navigation via public transport in dense urban areas. One of its components called *Identity & Entity* manages all user accounts, registered vehicles and is responsible for carrying out authorization of associating user with vehicles. Additionally it stores information about user defined journeys. This allows the user to connect to the server from different devices and have the journeys information synced among devices and service.

The main functionality of *Identity & Entity* component is to login/logout and associate/dissociate a user with a vehicle. During the login, the system checks if the user currently is authorized and if so, it returns a session id. A configurable timeout that determines the lifetime session is assigned. This session is stored and provides a secure way for the rest of the user-server interactions to avoid intruders to get sensible information. The association process checks that the user and vehicle are authorized and that the vehicle belongs to the user.

2.2.1.3 eCo-FEV

The eCo-FEV project aims to develop a cooperative architecture in order to combine the information of several infrastructures for FEVs and users. The *eCo-FEV backend* is its core component that enables the integration of heterogeneous services and components in order to assist the FEV driver with services such as route management, real-time traffic information, battery management, and charging station operations for booking, billing and accounting.

By means of a HMI (Figure 4), the end user can register and log in to the *eCo-FEV backend*. The *eCo-FEV backend* provides functions to verify the login data and authenticate eCo-FEV travellers 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* includes

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. 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 4: eCo-FEV backend log in website

Upon the user registration, a vehicle can be associated with the user account (Figure 5). The Vehicle Identification Number (VIN) together with the vehicle registration code serve to verify that the vehicle model entered is correctly authenticated and associated with the correct user account. The registration code could be provided, for example, during the purchase of the vehicle in the car dealer.

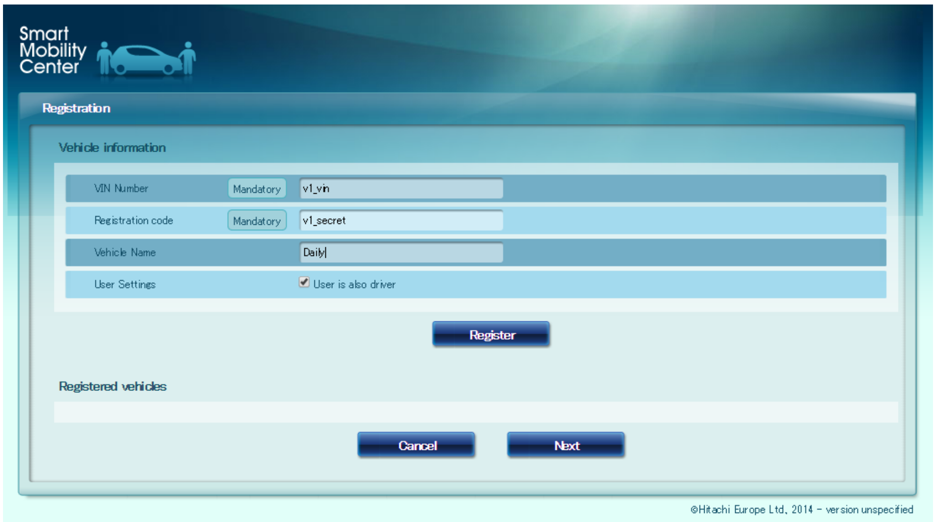

Figure 5: eCo-FEV backend registration website

Finally, the eCo-FEV platform supports the Open ID technology which allows commonly used IDs such as Google, Facebook, and Yahoo, to be used as means of authentication. Figure 6 shows one example where a Google account is used to register or log in an eCo-FEV user.

Figure 6: eCo-FEV backend log in website with open ID (e.g., Google)

2.2.2 Booking

The Charging Infrastructure Component at the Italian test-site at SITAF as developed in the eCo-FEV project will be used for the FABRIC project. This system support booking of the charging infrastructure by the driver of the electric vehicle.

This is divided in two Sub-Components (Figure 5):

- **EVSE Operator**: hosted at a remote location in TUB premises.
- **Charging Station Control Unit (CSCU)**: installed on the Test-Site.

Together they provide different functionalities related to the charging process on one hand and for E-mobility service providers on the other hand. These functionalities including Authentication, Authorization and Accounting (AAA), Booking, and Charging Station Monitoring are partially implemented on both CSCU and EVSE-Operator. They two sub-components use standardized protocols for these functionalities, thus each sub-component could interact with any counterpart following the standards.

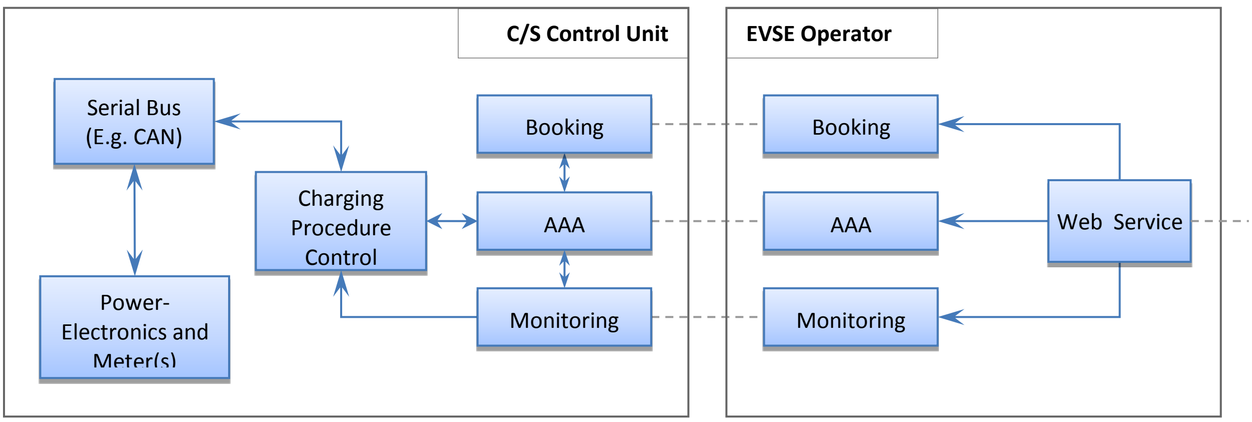

Figure 7: Charging Infrastructure overview

For the AAA functionality the two sub-components use RADIUS protocol (Remote Authentication Dial In User Service) [4]. It covers AAA (Authentication, Authorization, Accounting) and can be extended with own

VSAs (Vendor Specific Attributes), e.g. meter values. RADIUS is a common protocol in telecommunication applications (e.g. DSL, Enterprise Wi-Fi deployments), with various server implementations available (open source and commercial), e.g. FreeRADIUS [5] (most popular solution). It supports flexible authentication methods using Extensible Authentication Protocol (EAP) [6] (about 40 EAP methods are available, e.g. EAP-MD5, EAP-TLS, EAP-SIM, PEAP), and can handle multi-operator scenarios ("Roaming").

As for the Booking and Monitoring functionalities the two sub components use the Simple Network Management Protocol (SNMP) [7], which is an extensible management protocol where data is organized in Management Information Base (MIB) with a hierarchical structure (Tree) using Object Identifiers (OIDs). SNMP support different operation modes (Polling, Push, and Notification/Trap) used for the different functionalities. With poling the EVSE Operator polls the status of the CSCU, the meter values of the charging session, or other parameters. Using the push mechanism, EVSE Operator applies a Booking on the CSCU. In case of error CSCU send a trap to the EVSE Operator. There are many SNMP implementations available, CSCU uses NetSNMP [8], a popular implementation on Linux that allows defining own MIB. On the other hand several enterprise monitoring systems are available such as Nagios [9], and Centreon [10].

CSCU

The Charging Station Control Unit (CSCU) (Figure 6) is an i368 board with a 498 MHz CPU and 256 MB RAM, equipped with two USB 2.0 ports, and two Ethernet ports. One of the USB ports is connected to an USB-CAN adapter for (Controller Area Network) [11] [12]CAN-communication. It runs a Debian Based operating System with a customized kernel (CAN Kernel Modules), and a Read-Only file system.

Figure 8: CSCU Hardware

The CSCU run the TUB's own software implementation in C/C++ using external libraries (e.g. RADIUS, SNMP …). Beside AAA, Booking, and Monitoring functionalities the CSCU has a three more functionalities (Figure 9):

- CAN – Bus Communication (CAN)
- Charging Procedure Control (CPC)
- Plate Number Acquisition (PNA)

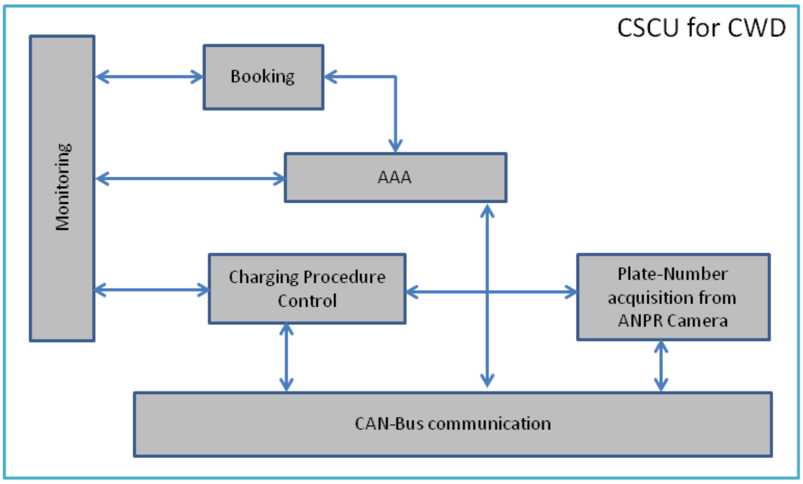

Figure 9: CSCU Functionalities

The CAN Bus communication component monitors the messages on the CAN Bus, which is shared between the CSCU, the Power Electronics on Road (PE-Road), the Power Electronics on Vehicle (PE-VEH), and the Electric Vehicle-Vehicle Management Unit (EV-VMU). The CAN Bus component is also responsible for sending and receiving CAN Messages. The Charging Procedure Control Component is the heart of the CSCU and it links all the functionalities together. Last functional component is the Plate Number Acquisition. The CSCU is connected via Ethernet an Automatic Number Plate Recognition Camera (ANPR-Camera), which pushes the Plate Numbers of the vehicles passing by to an FTP [13] server that is running on the CSCU. The PNA extracts this information and delivers it to the CPC.

EVSE Operator

The EVSE Operator (Figure 10) can communicate with several CSCUs. It is hosted at the Technical University of Berlin (TUB) premises, and runs an entity of FreeRADIUS for AAA, which uses a local MySQL Database for local users. Furthermore it monitors the different CSCUs and applies respective bookings using an implementation of the SNMP protocol. The EVSE Operator furthermore implements the Central System of the Open Charge Point Protocol (OCPP) [14] for those CSCU that support it.

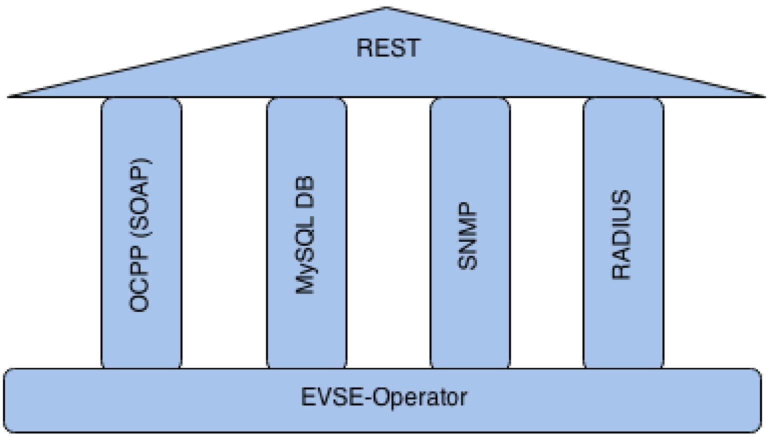

Figure 10: EVSE Operator Functionalities

For the different E-Mobility service providers, the EVSE Operator implements a REST-based [15] (REpresentational State Transfer) Web Service. This web service definition is an Open Interface based on XML Schema Definition (XSD) [16] developed in the eCo-FEV Project. Using this Web Service, Chosen E-Mobility service providers are able to query the status of all the different Charging station and are able to place bookings for their EV-users.

2.3 Dynamic routing for EVs

Electric vehicle navigation system can fulfil many FABRIC requirements such as trip planning, low charge level warning, routing to charging infrastructure. The individual functions within Class B (Dynamic routing) are as follows:

- B1: Itinerary choosing
- B2: Locating infrastructure
- B3: Availability of charging infrastructure
- B4: Route calculation
- B5: Targeting charge level
- B6: Charging location choice
- B7: Saving preferences
- B8: Trip Timing
- B9: Low Charge warning
- B10: Closest Infrastructure Routing

Electric vehicle navigation system can calculate 3 types of routes. It can calculate the shortest distance route, the fastest route and the energy efficient route. The fastest route will rely on the availability of real time information concerning traffic congestion, weather conditions and road works. If the fastest route will pass by a highway where the driver can drive at a high speed than his energy consumption will increase considerably .The energy efficient route will let the driver reach his destination using minimum battery power. The energy efficient route will depend on road grade and traffic state. A congested road will maximize the use of generative brake leading to more energy stored in the EV battery. The EV will generate power while going downhill and will consume power to go uphill.

The navigation system will calculate the driving range and display the reachable area on top of the map.

Figure 11: Reachability map: example of Renault ZOE

Once the driver has set his destination, the electric vehicle will check if the EV energy battery is enough to reach that destination. If the destination cannot be reached within the battery level, the navigation system will show a warning and suggest to the driver to go to a charging station.

Figure 12: Warning battery level Renault ZOE

The navigation system stores the charging stations locations and related information. This information is helpful to let the driver decide which charging station is more suitable to his needs. The navigation system displays the charging power. The charging power will decide the charging duration.. The navigation system displays the charging cost per unit time, the maximum charging time, the charging stations owner and affiliated network.

Figure 13: FIAT 500e charging station information

The navigation system can pre-check the availability of the charging station in real time. This option will ensure that the driver will not find the charging station out of service when he reaches it.

Figure 14: BMW i3 pre-check charging stations availability

The navigation system suggest to the driver to choose a charging station near departure location, along the road or near the destination. The navigation system can update its database related to charging station location and related information to take in consideration new installed charging stations. If the battery energy level is low, the navigation system will show a low charge warning and suggest to the driver to go to a charging station.

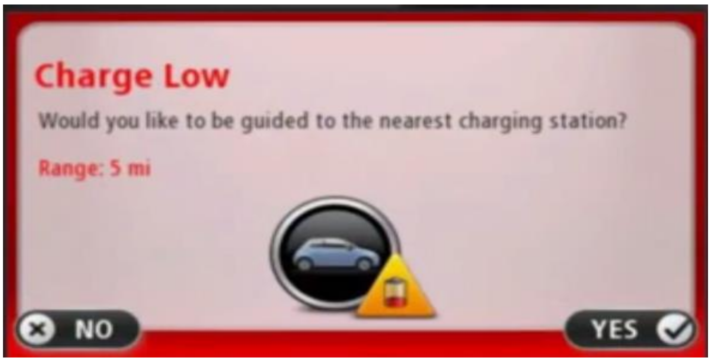

Figure 15: Low charging warning Fiat 500e

2.4 Vehicle identification, charging lane access control and management/enforcement

Functions in the FABRIC “Class C” of functional requirements consider the vehicle access to the charging infrastructure (whether it is physically segregated or not), including the identification of vehicles (e.g. pre-booked or not), management of booking/access (according to available charging capacity and road conditions) and, where appropriate, enforcement to prevent unauthorised access or use. The individual functions are as follows:

- C1: Identification of EVs
- C2: Charging infrastructure access control
- C3: Emergency Control of Charging Lane.

2.4.1 Vehicle identification

Identification of registered or pre-booked vehicles can be achieved by two main means:

- Automatic Number-Plate Recognition (ANPR) cameras
- Dedicated Short-Range Communication (DSRC).

2.4.1.1 Automatic Number-Plate Recognition

Automatic Number-Plate Recognition (ANPR) – also known as Automatic Licence Plate Recognition – is based on artificial vision (Optical Character Recognition – OCR) allowing the recognition of vehicle number plates in images. Its main current applications are for automated enforcement such as speed and red light cameras (also bus lanes, railway level crossings, etc), for security and access control (e.g. car parks) and for free-flow road tolling facilities (to allow checking off vehicles which have an account or are exempt on a "white list" and sending bills to the others).

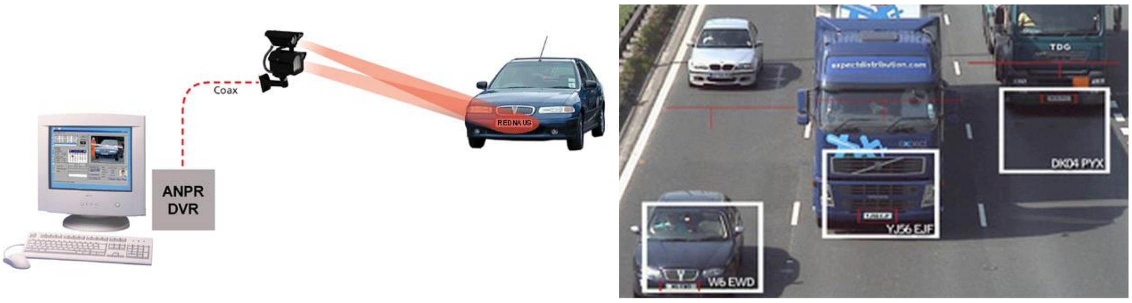

Figure 16: ANPR technology

Systems commonly use infrared lighting to allow the camera to take the picture at any time of the day. Reliability has improved considerably over the years and some systems are able to offer recognition rates between 95 and 98%, often at high speed. However performance is not perfect, particularly in places where many different styles of number plate are in use (large percentage of foreign vehicles or where personalised or customised plates are common, with different character fonts or other symbols on the number plate). The implication of any inaccuracies for FABRIC is more likely to be a case of a valid and booked vehicle not being recognised than recognising and charging a non-valid vehicle, as due to the fact that only a minority of vehicles would be WPT-equipped in the medium term.

ANPR uses a Capture Unit and a Process Unit. The Capture Unit is the roadside equipment that comprises the camera and its housing, with infrared focus. The data from several Capture Units is sent to a centralised Process Unit which comprises a computer with frame-grabber and recognition engine. An all-in-one configuration is also possible, with the Process Unit integrated into the camera housing. This is more reliable (a Process Unit failure would shut down only one camera and not all of them) and requires less communication infrastructure, but is more expensive in terms of equipment and the camera site would require to be more robust (security against natural causes and human interference).

Two types of ANPR configurations are the ANPR engine and ANPR equipment. The ANPR engine is the simpler one: it recognises the number plate directly from images stored in a hard disk. This type of software allows use of images that have already been obtained from other sources; hence it is more suitable for re-identifying already known vehicles. The ANPR equipment (which incorporates the ANPR engine) also

includes the hardware required to capture the vehicle images and to recognize the number plate. This would therefore be suitable for an open FABRIC application. A restricted or closed application, e.g. using physical barriers which open only if a registered vehicle is recognised, would be simpler and can just use an ANPR engine, however this would not be suitable for an on-road charging facility that aims to attract maximum use, including from “out of area” drivers.

2.4.1.2 Dedicated Short-Range Communication

Dedicated Short-Range Communications (DSRC) is a set of radio channels that are devoted to Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) wireless communications. The aims of V2V and V2I communications are, among others:

- To enhance the awareness of vehicles drivers about the surrounding environment (presence and position of other vehicles, pedestrians, obstacles and other objects).
- To rapidly disseminate emergency-related messages (e.g., accident ahead), in order to promptly trigger appropriate countermeasures (e.g., emergency braking).
- To inform vehicles drivers about nearby road works, speed limits, traffic conditions, etc…
- To allow road operators to obtain information about the vehicles circulating on a road such as, e.g., their identity, position and route.

DSRC is used in most EU countries for a variety of ITS services. A common one is Electronic Toll Collection, such as the Liber-t system in France and Telepass in Italy. Other applications include priority at traffic lights, freight tracking, activation of access (barriers, signals, garage doors, etc).

The systems consist of Roadside Units (RSUs) and On-Board Units (OBUs) with transceivers and transponders. The standards specify the operational frequencies and system bandwidths, but also allow for optional frequencies which are covered by national regulations.

Communications in the European DSRC band feature the periodic broadcast of *Cooperative Awareness Messages* (CAMs), containing data about vehicles speed, position and heading. CAMs are broadcasted by each vehicle on a regular basis, and include the unique identifier of the broadcasting vehicle in the message header, thus enabling CAMs receivers to know the position of a given vehicle at a given time instant.

Vehicles circulating on a road/lane could be identified by placing a DSRC receiver in the vicinity of the road, and analysing received CAMs messages. The accuracy of vehicle position included in CAMs messages depends on the accuracy of the GNSS receiver of the considered vehicle, and it is usually in the order of few meters.

2.4.2 Dynamic guidance and lane control (roadside systems)

Variable Message Signs (VMS) are widely used to give traffic information (such as journey time information to downstream destinations, information on congestion or incidents), instructions or re-routing advice. The electronic signs may feature text, pictograms or a combination of both. Dynamic Parking Guidance Systems are a simpler form of VMS used mostly in urban areas to guide drivers to available parking spaces, showing numbers of spaces in different nearby car parks.

Lane Control Signals (LCS), or dynamic lane allocation signals, are used as a form of traffic control to open or close lanes, for example on urban motorways, viaducts or tunnels (in case of incidents), in the case of tidal flow systems (reversible lanes) or part-time use of the hard shoulder (emergency lane) as a traffic lane

or lane for specific vehicles (bus lane, etc.). They may show a lane open, closed, open to certain vehicles only, show warning signs on certain lanes, or display a variable speed limit.

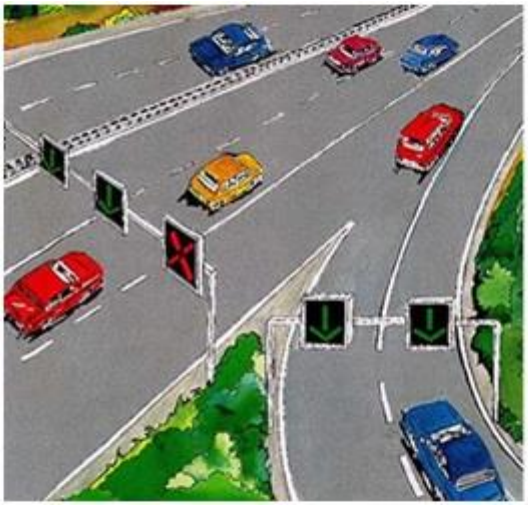

Figure 17: Lane Control Signals

All of these systems are quite mature and widespread, and are provided by numerous manufacturers.

They must be linked to a Traffic Control Centre and road monitoring equipment.

VMS and LCS could quite easily be adapted for providing guidance and control for on-road charging systems as well as integrating such systems with traffic management. Main traffic management functions include guidance to charging facilities in order to reduce the distance travelled by EVs looking for a charging area, and possible priority measures such as (possibly temporary) access to bus lanes or other restricted infrastructure, as well as priority parking.

For example, VMS may be used to inform about a nearby facility and its status, or to direct EV users wishing to charge to an alternative on-road facility in case a charging zone is not available for use.

In the case of a charging lane on a multi-lane road or motorway, LCS can be used to indicate the charging lane and possibly reserve its use for EVs only (or certain classes of other vehicles only, e. g. public transport) in order to ensure its availability for charging. LCS may also be used to set a specific speed limit for the charging lane, lower than the speed for the other lanes of the road.

The relevance of such systems depends on the prevalence of on-road charging areas and their use: VMS messages which are only relevant to a very small proportion of road users risk being ignored. Specific symbols or messages on VMS for EV charging do not exist (at least they are not harmonized), but this could be achieved in the same way as for other road signage and VMS strategies (e.g. through CEDR working groups).

2.5 ICT control of Wireless Power Transfer

These functions (Class D) cover the metering of power used (either in-vehicle or off-vehicle) and other ICT elements during the power transfer itself. The individual functions, as defined in Deliverable D22.1, are as follows:

- D1: Metering of energy transfer

- D2: Energy cut-off function.

2.5.1 Smart metering infrastructure

Smart metering is among the most essential applications of the emerging smart grid. The EU issued a mandate M441 in March 2009 in order to accomplish an interoperable smart meter roll-out in Europe. In response CEN/CENELEC/ETSI composed the "Functional reference architecture for communications in smart metering systems"

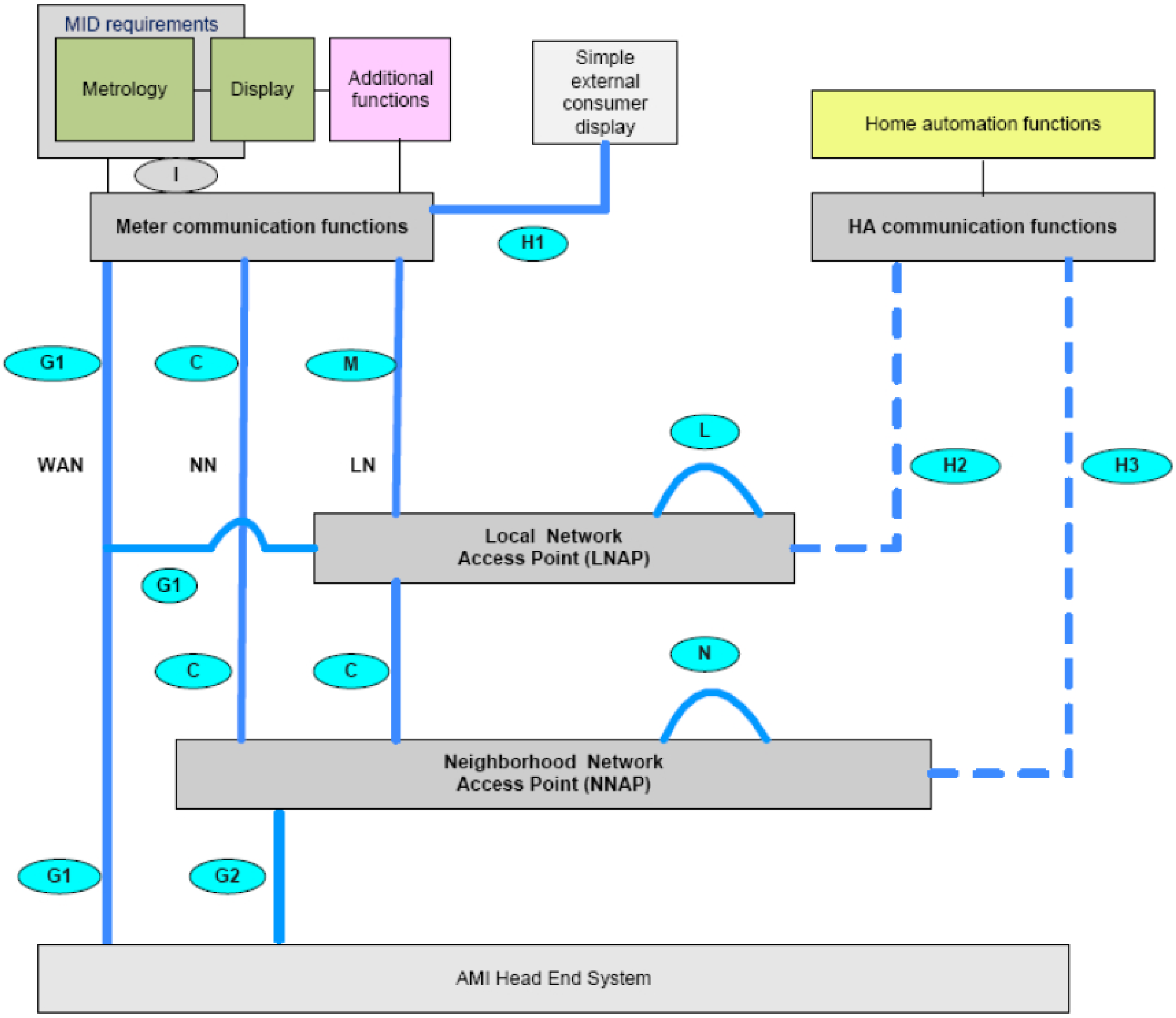

Figure 18: Reference architecture diagram for smart metering communications

The smart meter communication system consists of:

a) a head end system and metering end devices,

b) the communication system between them which could include

- a wide area network (WAN) which connects the head end system to local metering systems and networks

- a neighbourhood network (NN) covering premises
- a local area network (LAN) covering the premise

For extensive information regarding the recommended protocols per communication system please refer to [17].

In addition to the communication requirements required for such a system it is important to highlight the expected functionality of such systems. The principal objective of smart meters is to provide accurate measurements of electric parameters in an automated way. Typical smart meter measurements include

- Voltage
- Current
- Power factor
- Frequency
- Real power (kWh)
- Reactive power (kVARh)

In addition to power consumption monitoring and registering, smart meter system enable the collection of data relative to power outages such as

- interruption time
- restoration time
- pre-outage real power (kW)
- pre-outage reactive power (kVARh)

Complementary to performing measurements, numerous scientific papers and projects recommend the utilization of smart meters as field devices that enable both direct and indirect demand side management. Such a recommendation stems from the fact that smart meters are physically placed near to energy consumption nodes and could be physically integrated within the same device. The combined use of metering and demand management services in a single device increases efficiency and leads to convergence of communication standards from metering and demand side management. Therefore at the customer premises level it is possible to combine interfaces for smart metering and energy management as presented in table 2, in the same device. Moreover smart meter interfaces have been used by numerous European projects as gateways to the EVSE (Electric Vehicle Supply Equipment) thus enabling both direct and indirect demand side management policies within Electric Vehicle charging use cases. In the following paragraphs an analysis of communication standards for metering will be presented. Moreover information models that support energy management will be presented in order to highlight extensions that could be integrated by current metering communication standards in order to enable services for flexible load management in the context of dynamic wireless charging.

Smart meters are currently integrated in a chip, as semiconductor companies have been providing solutions on silicon. Some examples include

- Texas instruments [18]
- ST semiconductors [19]
- Maxim [20]
- Microchip

Moreover major original equipment manufacturers include

- Itron [21]
- Landis+Gyr [22]
- Sensus [23]
- Elster [24]
- Siemens

2.5.1.1 Smart meter communication protocols

As depicted in Figure 18, according to the nature of the communication, three groupings of communication technologies and protocols exist. In the following table a classification of current existing communication technologies and standards is listed.

Table 1: Summary of smart metering communication protocols

Name	OSI layer	Relevance to metering access	Description
IEC 61850	5-7	NNAP	Power utility automation
IEC 61334 PLC	1-2	NNAP	Distribution automation using distribution line carrier systems
PRIME PLC	1-2	NNAP/LNAP	Power line Intelligent Metering Evolution
IEC 62056-21 / IEC 61107	1-2	LNAP	Local end to end communications protocol
SITRED	1-7	NNAP	ENEL's proprietary smart metering protocol
SML	4-7	NNAP	Smart Meter Language
EN 13757 / M-Bus	1,2,7	LNAP	Meter Bus
DLMS/COSEM or IEC 62056	5-7	NNAP	Companion Specification for Energy Metering
IEC 62056-31 ”Euridis”	1,2	LNAP	Use of local area networks on twisted pair with carrier signalling
KNX	5-7	LNAP	KNX for energy and smart metering
LonWorks/LonTalk	1-7	LNAP	Local operating network
BACnet	5-7	LNAP	A Data Communication Protocol for Building Automation and Control Networks
ZigBee (Smart Energy Profile)	1-3	LNAP	Low cost, low power, wireless networking for device monitoring

Name	OSI layer	Relevance to metering access	Description
			and control
Homeplug (Command & Control)	1-2	LNAP	Command and control PLC
6LoWPAN	3	LNAP/NNAP	IPv6 for Low Power Wireless Personal Area Networks
DPWS	6	LNAP/NNAP	Device Profile for Web Services

The aforementioned communication protocols cover requirements for smart metering across the whole OSI stack. As observed many mature technologies exist in order to establish basic connectivity requirements that will enable remote monitoring of smart meter's by supervising management systems. However interoperability with the emerging smart grid requires the integration of communication protocols that address data model and communication session requirements of emerging smart grid applications that could be enabled by smart metering systems, such as direct or indirect demand side management.

DLMS/COSEM is an example of a protocol defining data model definitions that could be used by direct demand side management applications to enable centralized direct load balancing in the case of EV charging. In this case a charge profile is generated by the application for each charging session in order to both optimize grid operations and thus achieve the demand side management objectives and additionally ensure end user satisfaction by providing a charging profile that minimizes charging duration and associated costs. The charging profile can be transmitted by the application to the EVSE (Electric Vehicle Supply Equipment), through the smart metering system co-residing with the EVSE.

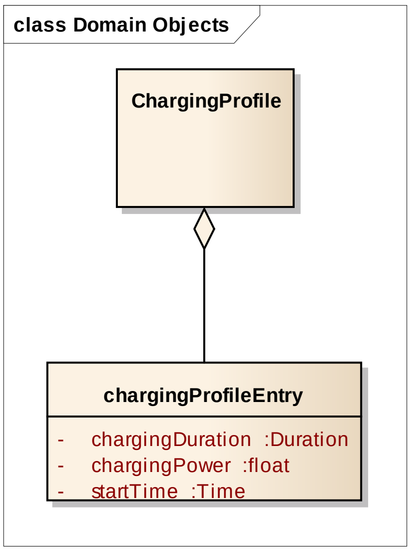

Figure 19: Charging profile object

The following structure summarizes the composition of a charging profile in terms of DLMS/COSEM objects.

```
Structure
{
        Scheduler Id            octetstring
        Array of structure
        {
                startTime                       dateAndTime
                charginPower            double-long-unsigned
                chargingDuration                duration
        }
}
```

Similar DLMS/COSEM structures can be constructed in order to enable indirect load management applications, i.e. applications that are based on dynamic pricing schemes.

The aforementioned examples depict how the use of a standardized data model can enable the creation of smart grid applications that could reside along with smart metering systems. Such an aspect could be the objective of further research in the domain of smart metering protocols.

2.5.1.2 *Smart metering infrastructure management*

In addition to the smart metering infrastructure numerous ICT solutions exist for demand analytics and metering management. Some indicative integrated meter management frameworks are provided by

- IBM [25]
- Schneider Electric [26]
- Landis+Gyrd [27]
- GE [28]
- Sensus [29]
- Elster [24]
- Siemens [30]

2.5.2 Energy cut-off function

Power cut-off devices detect a change in the power voltage and interrupt the electrical flow when it passes a threshold value. Cut-off devices are frequently used in different domains to protect against power surges but can also be used to cut off when power transfer drops below a certain level. Already in the electric vehicle domain, electrical cut off exists for example in the case of a collision, where the G forces involved operate a cut-off switch. This functionality will be included in the ICT developed in WP25 during Year 2 of FABRIC.

2.6 Driving assistance while charging

Function E1 "Driving assistance while charging" (from D22.1) specifies that during the charging process, while driving, information on lane approaching and charging process shall be provided to the driver.

Several Advanced Driver Assistance Systems (ADAS) and automated vehicle control applications (either on the market or under development/trials) have the potential to fulfil the requirements of FABRIC in terms of either advising or imposing a specific speed, inter-vehicle headway and trajectory. Systems may be "open" in that they advise or warn the driver about certain actions or conditions but do not control the vehicle, or "closed" in that they restrict the driver's actions in some way, for example limiting the maximum speed.

2.6.1 Cruise Control systems

Adaptive Cruise Control (ACC) [31] adapts the vehicle's speed to the vehicle in front. A distance measuring system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the ACC vehicle's path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the distance, or time gap, between the ACC vehicle and the leading vehicle.

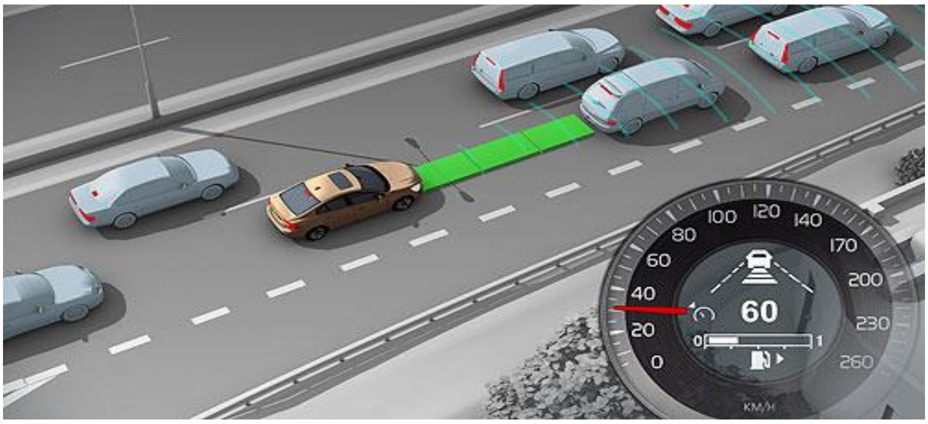

Figure 20: Adaptive Cruise Control

Predictive Cruise Control (PCC) [32] is a cruise control system which uses vehicle, infrastructure and topographic data to anticipate a fuel saving driving style. Currently systems focus on the topography. Changes in the road environment such as a change in gradient ahead of the vehicle are predicted and the speed is adapted for optimal fuel economy.

Cooperative Adaptive Cruise Control (C-CACC) [33] is an enhancement to adaptive cruise control systems that can optimise a vehicle's speed profile by adding communication with other vehicles and/or infrastructure.

2.6.2 Intelligent Speed Adaptation/Assistance (ISA)

Intelligent Speed Adaptation (ISA) [34] is a technology which assists the driver in keeping to the speed limit. Several versions have been developed and tested:

- Open ISA: advisory systems that warn the driver that he is driving faster than allowed on the given road, but do not control the vehicle in any way.

- Half-open ISA: these use a haptic accelerator pedal that increases the counter pressure when the speed limit is exceeded, so speeding is still possible but less likely as it requires a greater level of pressure on the pedal.
- Closed ISA: systems which directly intervene to make speeding harder or impossible. As opposed to cruise control, the system does not impact the speed if it is lower than the speed limit: it only reacts to speed limits. If the car is passing from a zone with higher speed limit into one with a lower limit (e.g. entering an urban area) then the vehicle is automatically and gradually slowed down to the new limit.

ISA requires a highly detailed digital map with speed limits, satellite GPS, and a display (integrated dashboard or stand-alone monitor) showing the speed limit for the current road section.

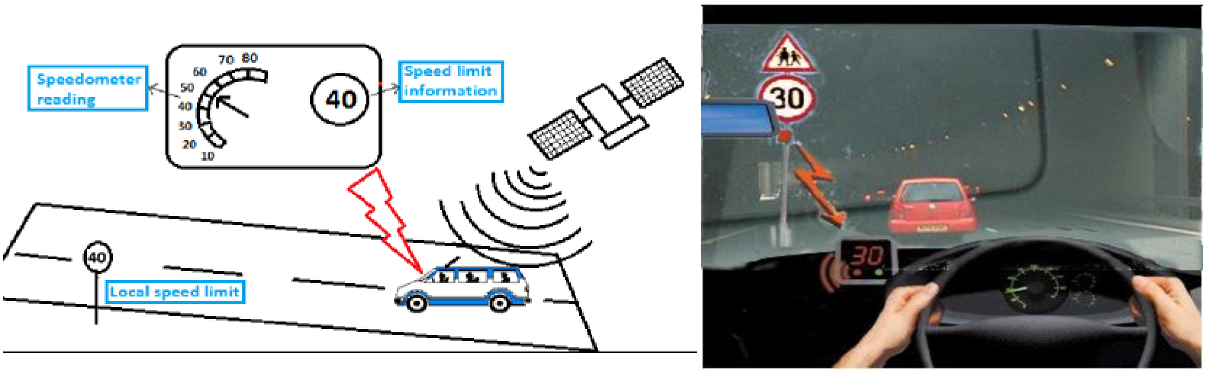

Figure 21: Intelligent Speed Adaptation

2.6.3 Lane Departure Warning (LDW) system

2.6.3.1 Introduction

LDW [35] (or lane keep assist) is an in-vehicle electronic system that monitors the position of the vehicle within the lane and warns the driver if the vehicle crosses lane markings without using the turn indicator.

It employs a simple, low-cost camera, which together with processing software watches how close the driver is to the road surface markings. It alerts the driver when he is about to drift across, but only if the turn indicator is not on. Lane departure warning has emerged as a key tool for driver safety. The technology has evolved over the last few years to lane keep assist, where the car automatically corrects course if it reaches the lane markings, and now a higher level of lane keep assist that automatically keeps the car centred on the road. The corrections are subtle and the driver can always override the car and turn the wheel manually.

LDW is now a well-established tool that can enable the driver to keep the vehicle centred in the lane for long distances. Obviously, this depends on the quality and continuity of lane markings. For clear safety reasons, all LDW systems cut out after a few seconds if they detect no hands on the steering wheel.

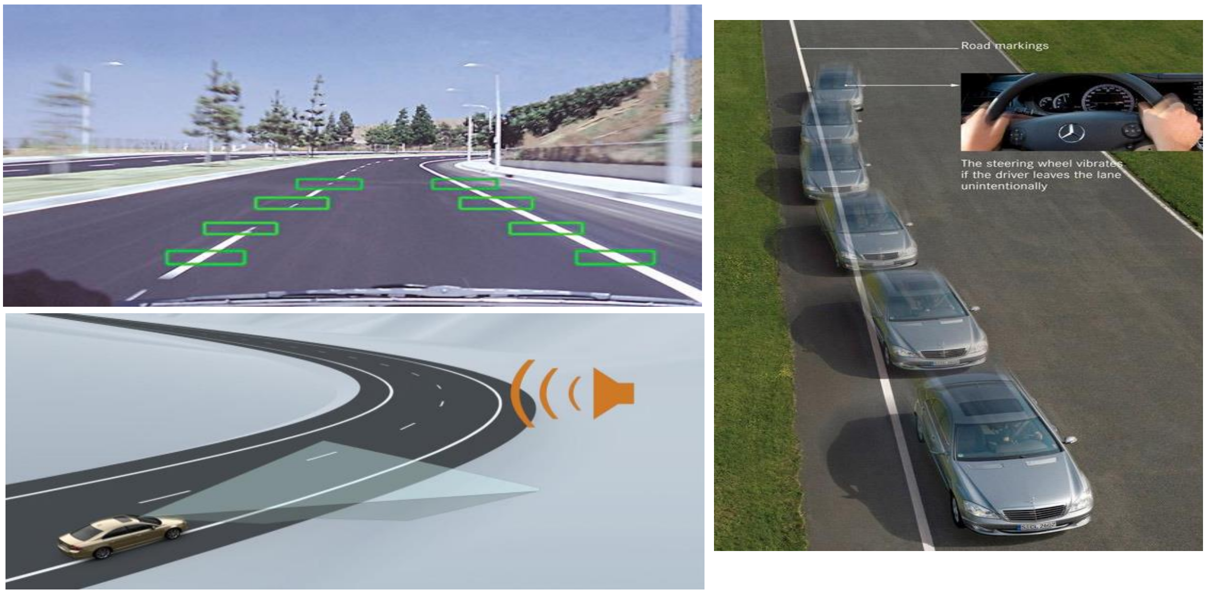

Figure 22: Lane Departure Warning

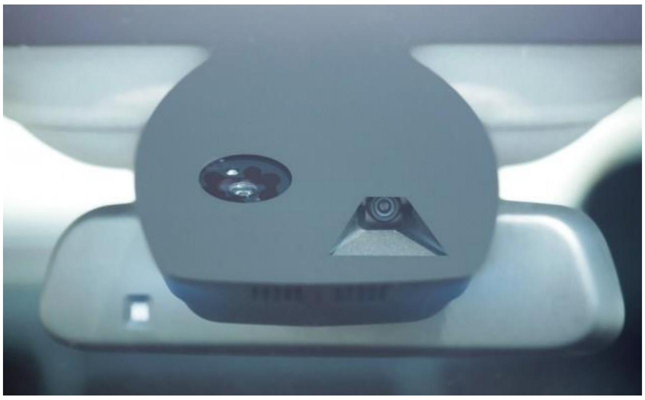

Figure 23: Camera used for lane detection

Several techniques have been used to detect the road boundaries. In this section we present some of these methods and related studies about design, implementation and testing of lane detection systems.

2.6.3.2 Techniques of Lane Keeping

Lane detection (or lane/road departure warning) is a well explored field of academic and scientific research in Advance Driving Assistance Systems (ADAS), which involved development and testing of a number of algorithms and solutions.

A major issue is that the Lane Departure Identification (LDI) based on the angular information of lanes (Orientation angle of lane boundary) tends to provide a high false warning ratio. This is related to where and how the camera is fixed on the vehicle (height from road surface and distance from the left and right sides of the vehicle) and therefore careful calibration is required. In particular, -performance is affected by various noise factors. For instance, visibility of lane markings is affected by fading; moreover, multiple lanes are present on a road, which complicates the computation. Such factors are major obstacles in identifying the road lane boundaries [36].

To improve the lane detection accuracy, different image pre-processing techniques are frequently applied. These techniques are the transformation of an image into hue–saturation values and the application of

morphological filters to reduce noise, the use of a Canny edge detector that produces single-pixelwide edges, histogram equalization, filtering, and various types of clustering and polyline extraction. The Hough transform (HT) is used to detect any arbitrary shape and shows robust performance in different conditions.

In the lane departure warning, the system uses the instantaneous information from the lane detection to calculate the angular relations of the boundaries (calculation of angles from the camera to the point on each lane boundary that is being detected). The system sends a suitable warning signal to drivers according to the estimated danger degree of the departure. As anticipated, this technique is quite prone to false warnings.

2.6.3.3 Lane Keeping related studies

Lee and Yi [37] proposed a lane boundary pixel extractor (LBPE) technique to increase the robustness of lane detection, which enhances the LDI by finding pixels that are possibly a part of lane boundaries. The ratios of the orientations and location parameters of the left and right lane boundaries are used to recognize the lane departure. However, an important condition is that the optical axis of a camera mounted on a vehicle coincides with the centre of the lane.

For lane detection, Wang et al. [38] proposed the B-Snake method and achieved efficient tracking. Wu et al. [39] used a fan-scanning detection method but has the limitation of less accuracy. Mu and Ma [40] used piecewise fitting for lane detection but suffered from more false alarms. Parajuli et al. [41] obtained good lane detection results using local gradient features, but this approach shows poor performance in shadows and gives more false alarms. Lee and Yi [37] proposed LDI based on the LBPE, the HT, and linear regression, that considering eight parameters for the departure calculation.

Lee [42] proposed a lane departure detection method that finds the lane orientation using an edge distribution function (EDF) and identifies the changes in the traveling direction of a vehicle. However, the EDF may fail in curved roads with dashed lane markings. Jung and Kelber [43] proposed a new lane departure warning system based on a linear–parabolic lane boundary model. Lane boundaries are detected using a combination of the EDF and a modified HT. Lane departure detection is carried out using the orientation of both lane boundaries at each frame. The main limitation of this technique is when vehicles are present in front of the camera; erroneous indications are seen in the output results. As angle based measurements are sensitive to smaller deviations in the lane departure, this technique gives more false warnings.

A novel algorithm is presented by Xu and Wang [44] developed a lane departure warning system that monitors the distance between a car and road boundaries. The lens distortion and non-fixed principal points, if ignored, affect the results. Wang et al. [45] applied a fuzzy method for the lane detection and extraction of departure warnings. A self-clustering algorithm, the fuzzy C-mean, and fuzzy rules were used to process the spatial information and the Canny algorithm to obtain good edge detection. Saleh et al. [46] provided a model for sharing the steering control between a driver and an automation system to increase stability in the presence of driver behaviour uncertainty.

Wu et al. [39] proposed a lane departure technique using the angular relationship of the lane boundaries, but it suffers from reasonable detection failures and, hence, low accuracy. Furthermore, this technique requires the information of the vanishing point of lanes for the detection of lanes. In the absence of the information on the vanishing point of lanes, the lane detection accuracy falls to a very low value, such as 73.21% which reduce the lane departure/drift detection. Mu and Ma [40] proposed lane detection based

on object segmentation and piecewise fitting; their study has the common problem of false lane detection, and it requires a dim light environment for image pre-processing.

2.6.3.4 Commercial Lane Keeping System

In the last part of this sub-section we briefly introduce some of the commercial products already available on the market. The MobilEye's system for lane detection and keeping is employed by OEM such as AUDI AG, Adam Opel AG, BMW, Chrysler, General Motors, Ford Motor Company, Honda, Hyundai Kia Motor Company, Jaguar Land Rover, Mitsubishi Motor Company, Peugeot Citroen, Volvo, Yulon Motors and Scania [48].

The MobilEye system has a windshield module that is an HDR (high dynamic range) CMOS camera with the MobilEye SeeQ2 image processing board. It mounts next to the rear view mirror and takes up about as much space as a toll tag transponder. There's an LCD display called EyeWatch that is mounted on the dash to receive the alerts, and an audio alert module.

Figure 24: Component of the MobilEye system

Figure 25: The MobilEye display mounted the dasboard shows that the vehicle diverted from the lane

Valeo produces Guideo, an aftermarket driver assistance system which integrates four functions in one module: Lane Alert lane-departure warning, an Optilane lane-keeping system, a visual recording of the vehicle's direction in the event of abrupt acceleration or deceleration, and a Beep&watch warning for the driver when movement is detected in front of the vehicle, e.g., when a vehicle begins moving at a traffic light.

The system consists of a central camera module, mounted to the rear-view mirror, that activates at vehicle start-up and works in lighting conditions to <1 lux. The CMOS camera, which has a mass of 145 g (5.1 oz.) and is 120 x 75 x 37 mm (4.7 x 3.0 x 1.5 in), is detachable.

The technology is adjustable for use in all types of light-duty vehicles. [42]

The image below illustrates the camera of Guideo system (for lane recognition) and the remote control to operate control the system.

Figure 26: Guideo System

The 4th generation of the Continental Multi Function Mono Camera (MFC4x0) provides driver assistance functions like lane departure warning, traffic sign assist and intelligent headlamp control. Functionalities of object detection for forward collision warning and pedestrian detection are also available.

Figure 27: Multi Function Mono Camera - MFC400 by Continental

Figure 28: Continental lane keeping solution

2.6.3.5 Application to FABRIC

All these three systems (ACC, ISA and LDW) have been developed as safety applications but are also potentially valuable for a dynamic on-road charging system.

ACC can be used also to keep two dynamically-charging electrical vehicles at a distance which enables the WPT to properly function for each vehicle.

A given WPT installation is expected to be less efficient (or have less time to provide the necessary power) at higher speeds, so a maximum or recommended driving speed should be set according to the road type and the configuration/performance of the charging infrastructure. ISA systems in EVs can detect the posted recommended or maximum speed limits on the lane and advice the driver (or force the car) to keep within that limit.

LDW is a potentially important application in terms of keeping EVs in the correct trajectory for the charging infrastructure. However, the required trajectories are expected to be more restrictive than those possible for keeping a vehicle within a standard traffic lane (particularly on higher speed roads where lanes are wider). Thus, special road markings may be needed, to precisely indicate to the driver the required trajectory of charging EVs. In any case, an LDW system of an EV would need to be adapted in order to meet the specific requirements of the new application.

2.7 Distribution System Operator (DSO) and grid management

The Class F group of functions relates to the requirements of DSO. They are as follows:

- FI: FABRIC smart grid communications
- F2: Energy tariff information
- F3: Low latency communications between the FEMP and the DSO system
- F4: Standardised object data model
- F5: Secure connection between the DSO/energy retailer and the FEMP
- F6: FABRIC demand information availability
- F7: Local Grid Power Capacity Interface

- F8: FABRIC to DSO/energy retailer interface maintenance
- F9: Communications logging
- F10: Time synchronisation.

2.7.1 Generic grid applications

When considering grid applications as a collection of functionalities that would benefit the electricity grid overall, the following classification of applications applies:

- Supply optimization: Efforts to improve reliability and efficiency of the delivery systems
- Demand optimization: Techniques to provide flexibility to the end user and to maintain the supply and demand balance along distribution feeders
- Asset management: Monitoring and management of electrical infrastructure in addition to the deployment of strategies to reduce failure and extend the lifetime of electrical infrastructure equipment.

In order to deploy applications as mentioned above an integrated ICT framework must be designed and implemented. Applications must be driven by clearly defined objectives resulting in requirements for smart grid enabled system architectures.

As the contemporary smart grid consists of multiple actors, when assessing grid related applications specific to a given technology, such as dynamic wireless or conductive charging in this case, it is necessary to identify the natural domain of the technology in order to form a cluster of applications that can build a domain that is interoperable with other domains of the contemporary smart grid. In the following paragraphs, such an attempt will be made so as to identify:

1) generic applications that are typically required by a domain of the smart grid;

2) applications that are essential in order to perform Electric Vehicle charging based for both dynamic wireless and static conductive cases;

3) innovative applications towards an efficient, sustainable operation of the grid.

Following the aforementioned classification, applications will be briefly analysed with respect to their objectives and their status within the market. Additionally as many dependencies exist among various applications of the smart grid, it is essential to outline them and additionally analyse communication technologies and protocols that, enable or with modifications could enable, an end to end integration addressing an aspect of supply, demand optimization and asset management.

2.7.2 Classification of FABRIC modules within the smart grid ecosystem

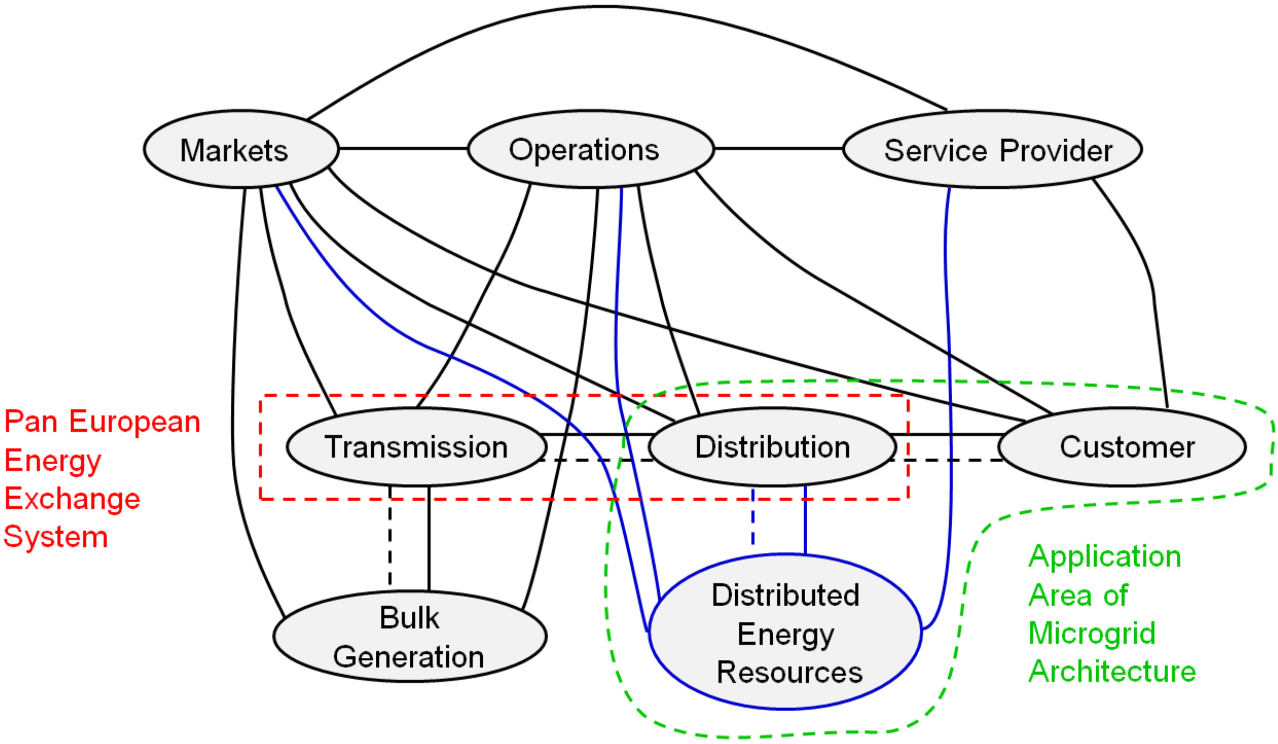

Figure 29: CEN/CENELEC/ETSI Smart grid reference architecture

The energy grid is moving towards a major update that targets energy consumption and production efficiency along with reliable, uninterrupted operation in a manner that is environmentally friendly. In order to successfully fulfil such goals a diverse set of applications must be employed across all major nodes of the “smart” grid. Major European standardization bodies have defined reference architecture and basic functions to be implemented across smart grid actors. Figure 29 depicts the reference architecture defined by CEN/CENELEC/ETSI.

FABRIC aims at building an ecosystem that will enable the overall integration of wireless power transfer to the overall charging ecosystem. FABRIC's ecosystem consists of two components, the FABRIC off board system and the on board system. FABRIC's off board platform targets at integrating the WPT systems with the energy grid by providing core services such as load control and auxiliary services such as billing, booking services. The off board platform has been additionally divided into the FABRIC electro mobility platform system and the FABRIC charging infrastructure system.

According to the smart grid reference architecture actors of this domain support business processes ranging from traditional utility services such as billing and customer account management, to enhanced customer services such as the management of energy use. Therefore the FABRIC electro-mobility platform can be naturally categorized as an actor of the service provider domain. A detailed overview and analysis of services, applications and protocols that support the development of a complete WPT ecosystem will be presented in the following paragraphs.

FABRIC's charging infrastructure systems and the on board charging system aim at providing core services that have to do with the charging process itself, thus these systems can be classified as customer related actors. More information regarding these actors will be additionally provided in subsequent paragraphs.

2.7.2.1 FABRIC off board platform applications

FABRIC's off board comprises the Electro mobility platform and the charging management systems. In the previous paragraph these modules have been categorized according to the smart grid reference domain classification. As mentioned in the previous paragraph FABRIC's electro-mobility platform is an actor of the service provider domain. The following table summarizes applications identified by the smart grid reference architecture for the service provider domain

Table 2: Typical applications for service providers in the smart grid

Example Application Category	Description
Customer Management	Managing customer relationships by providing point-of-contact and resolution for customer issues and problems.
Installation & Management	Installing and maintaining premises equipment that interacts with the Smart Grid.
Building Management	Monitoring and controlling building energy and responding to Smart Grid signals while minimizing impact on building occupants.
Home Management	Monitoring and controlling home energy and responding to Smart Grid signals while minimizing impact on home occupants.
Billing	Managing customer billing information, including sending billing statements and processing payments.
Account Management	Managing the supplier and customer business accounts.
Emerging Services	All of the services and innovations that have yet to be created. These will be instrumental in defining the Smart Grid of the future.

As expected the aforementioned list presents generic functions to be extended according to specific requirements of a smart grid actor. Typical requirements that usually apply to end service providers that address energy consumption processes such as Electric Vehicle charging processes include the modulation of consumption patterns in order to facilitate reliable, efficient and sustainable energy consumption. Demand side management shifts, shapes the load in order to satisfy the aforementioned objectives. Many strategies have been proposed in the literature in order to enforce demand side management. However all categories can be classified to the following two

- Direct load management
- Indirect load management

In direct load management the load of a system is directly modulated by a supervisory control system. In indirect load management a signal is transmitted to consumers in order to motivate or deter energy consumption. Both cases are being taken into consideration within the definition of the preliminary reference architecture, as they have been considered when composing the set of preliminary use cases.

The corresponding use cases have been formulated in FABRIC as

- #2.1: EV charging supply management (Direct load management)
- #3.1: Energy supply tariff modulation (Indirect load management)

For more information about these use cases please refer to D4.3.1 FABRIC Final Use Cases.

Another essential component of FABRIC is the charging management system. It comprises of the modules that are responsible of providing essential charging functionalities to the customer. When considering the connection of the consumer to the grid two main components are considered.

- The smart meter
- The Energy Management System

Smart metering systems account for the energy consumed across various sub-domains of the customer (charging infrastructure in the case of dynamic wireless charging), whereas the energy management system provides the necessary interfaces to implement applications such as direct and indirect load management. To summarize, at the customer's level and when referring to the grid interface the following applications are considered

Table 3: Grid related applications of the charging infrastructure

Example Application Category	**Description**
Smart metering	Real time measurements of electric characteristics and integration of network interfaces in order to enable remote monitoring
Energy Management	Interfaces facilitating indirect and direct load management during charging operations. Real time control of charging operation according to profiles provided by the direct load management module.
Micro-grid generation	Generation and consumption of renewables sourced energy within the charging infrastructure. Integration of distributed energy sources with the grid.

2.7.2.2 Application analysis

Applications referenced in previous paragraphs will be presented and analysed with respect to their equipment, their interfaces and communication protocols required to function. Existing and under development approaches will be presented in order to assess the interoperability of the integrated system in the next chapters

2.7.2.3 FABRIC off board platform applications

Table 2 lists some indicative applications that apply to any service provider domain in the Smart Grid. The following applications from Table 2 will be presented as they apply to core issues related to FABRIC's smart grid integration objectives.

- Installation and management
- Billing
- Direct load management
- Indirect load management
- Smart metering
- Real time energy management
- EV charging management
- Micro grid generation.

2.7.2.4 Installation and management applications

The range of devices and equipment required to connect systems to the smart grid is constantly increasing and so is the information associated with it. "Smart" devices such as smart meters, communication nodes and relays are being integrated to the utility, electric distribution network thus creating new needs and manners to manage related information flows. Novel asset management systems required in order to handle complexity and "everyday needs" of such microprocessor based systems. Processes such as firmware update, configuration change, patch installation and status monitoring must be performed in a secure manner that ensures the safe, efficient and reliable operation of the grid.

Major information technology enterprises have brought asset management solutions for the emerging smart grid. Oracle recently introduced the "Oracle utilities Operational Device Management" [49] systems which "*handles critical functions, such as managing and tracking updates and patches, as well as supports governance and regulatory audits and smart grid Network Operations Center (NOC) processes*". The solution provided by Oracle addresses near real time rather than transactional events in a manner that enables convergence of IT with operational technology. Microprocessor based devices are managed through their lifecycle according to strict security policies beyond requirements for plants and linear assets. The following types of smart grid devices can be managed by the proposed suite.

- Meters
- Access points of communication relays
- Communication components attached to various devices

The operations supported by the device management software include

- Device tracking
- Firmware updates
- Compliance
- Configuration
- Cycle inspections
- Installation, removal, exchange of equipment

For more information regarding this tool please refer to [49].

Another solution that enables device lifecycle management has been proposed by CISCO. The CISCO connected grid network management system [50] is a software platform that enables the management of a multiservice network including smart metering systems, distribution automation and distributed intelligence. The features of the solution include

- GIS map dashboard visualization and alarm notifications
- Group based configuration management for field area routers and smart meter endpoints
- Rule-engine infrastructure for threshold based event generation
- Integration API for integration with operational systems
- Disaster recovery systems

Another software solution provided by Trilliant, is the UnitySuite [51] software component (can be a part of a greater software package the Trilliant platform), that manages multiple technologies in order to enable "smart" distribution, smart metering, and smart consumer applications. The core sub systems of the package include:

- Communication device management system: securely manages communications for millions of devices, with powerful connection and routing information, security, device reports, and communication protocol library.
- Network element management system: cost effectively and securely manages and operates field networks to ensure optimal functioning, with comprehensive coverage, network monitoring, and alerts.
- Consumer engagement management system: provides secure and scalable tools to implement consumer-facing demand response and energy efficiency programs.
- Metering management system: enables flexible, reliable and efficient meter data acquisition and processing for Advanced Metering Infrastructure (AMI).

The package enables the management of all smart devices in a single which is capable of managing millions of devices across multiple tech vendors and types of protocols.

2.7.2.4.1 Communication protocols for installation and management applications

Smart grid systems consist of a large amount of networked end devices that should be managed and monitored in order to maintain the secure and reliable operation of the grid network. Some indicative domains of management have been mentioned in the previous paragraph.

One common aspect spanning all types of devices is the fact that they are all networked, thus it is important to have automated mechanisms for network management. SNMP (Simple Network Management Protocol) provides such functionality and has been used by many smart grid management systems in order to configure and manage networked devices. Management applications host a SNMP manager, whereas agent applications implement SNMP agents. Typical use cases of SNMP include

- IP configuration;
- Bandwidth and usage statistics;
- Collection of error reports and logs;
- Monitoring of CPU and Memory use;
- Device status polling.

Additionally according to the device type and application domain of the infrastructure related management communication protocols may apply. Some indicative that standards implement device management in addition to other application related functionalities are

- Modbus
- IEC 61850 [52]
- Distributed Network Protocol [53]
- Open Smart Grid Protocol [54]
- OCPP 2.0 [14]
- DLMS/COSEM [55]
- ...

From this long list of applications it is essential to note that OCPP 2.0 (Open Charge Point Protocol) is among the most related to the specifics of Electric Vehicle charging. OCPP offers standardized IP datagram based logical views of hardware and software components that make up a typical charge point, which can be used for monitoring and controlling charging points and their subcomponents.

The data model of a charging device is a hierarchical view that consists of *components* that have *properties* that are described by *variables* that have certain *values.* For more information regarding the exact data modelling representation and the manner in which management systems can read or set device values through the OCPP 2.0 protocol, please refer to the respective specification [56]. In addition to device managing OCPP 2.0 supports firmware update and upgrade and diagnostics log file communication. When a Charge Point must be updated the central management system informs the device about the firmware file to be downloaded. While download and installation of the file is ongoing, the charge point may notify the central management system about the status of the download.

2.7.2.4.2 Billing applications

With the evolution and gradual installation of smart meters in the grid infrastructure billing has become an evolving domain. Billing applications have been integrating requirements for dynamic pricing such as Time Of Use (TOU) rates in order to support demand side management schemes and operations that enable efficient energy generation and consumption.

Most information technology solutions proposed for billing, usually come as a part of greater integrated solutions that address the needs of smart grid service providers. In the following paragraphs some indicative applications along with their characteristics will be presented.

Siemens EnergyIP [57] supports interval billing based high granularity readings (5, 10, 60 minutes) in order to support novel pricing schemes in additional to classic register billing schemes. Moreover detailed analytics schemes enable an up-to-date end month-to-date information summaries.

The Oracle utilities, billing component aims at supporting complex billing structures. Additionally it supports exception handling procedures to efficiently calculate accurate bills. The supported pricing schemes include, Standard Market Design (SMD), Locational Marginal Pricing (LMP), wholesale transmission billing. Open Access Transmission Tariffs, full ancillary services, Real-Time-Pricing (RTP) and others. Features include

- **Automated bill calculation**. *Calculate any bill using any pricing structure. Automate data import; bill calculation, and data export for any billing schedule.*
- **Simplified product creation.** *With more than 50 preconfigured statements and 200*

functions create algorithms for loading, manipulating, and managing interval data.

- **Dynamic configuration**. *Customize standard products and tariffs to individual or groups of accounts based on account-specific attributes.*
- **Powerful, flexible billing rules.** *Handle virtually any billing calculation and business process across commodities, geographies, segments, and jurisdictions.*
- **Comprehensive billing modes.** *Support automated batch billing, manual bill review, bill correction/adjustment, cancel/rebill, and current/final bill.*
- **Billing checklist and exception management.** *Work queue functionality allows billing exceptions to be analysed and routed for review, resolution, and approval.*
- **Account management.** *Find, view, graph, and edit customer, account and complex interval usage data through intuitive, browser-based user interface.*
- **CIS integration.** *Integrate Oracle Utilities Billing Component with any Customer Information System (CIS), bill printing mechanism, secured Web site, or analysis program.*
- **Integrated financials and collections**. *Automate financial and collection business processes with Oracle Utilities Receivables Component.*

2.7.2.4.3 Communication protocols for billing applications

Billing is an essential aspect of any smart grid service provider and is closely related to informing users about the tariff that applies, accurately measuring energy consumption, optionally informing users about the cost of consuming energy during charging operations and finally creating invoices. OCPP 2.0 supports former operations by defining detailed use cases and data models for billing. OCPP 2.0 defines pricing as a three step process when considering the end user.

1. Presenting pricing to the user before charging operation
2. Presenting pricing information during charging operations
3. Presenting the total cost of charging after charging

Obviously calculation of the cost requires accurate measurement collection. In OCPP 2.0 metering measurement collection is addressed within the context of device management. Other protocols that could be used in order to collect measurements from the smart metering infrastructure can be found in the smart metering infrastructure section of this document.

2.7.2.4.4 Demand side management. (Direct load management)

Many schemes for direct load management have been proposed in scientific and technical literature. A generic overview of load management in terms of load balancing has been presented in D4.2.1: "Assessment of the technical feasibility of ICT and charging solutions" chapter 4.6. In the following paragraphs an overview of current application targeting direct load management will be presented.

Trilliant's smart grid platform supports direct load management by supporting switching of appliances on and off during peak demand periods. Remote Appliance Controllers (RACs) allow utilities to turn specific appliances on and off during peak demand periods and critical events. Moreover Trilliant proposes the Smart Grid Communications Platform [58] in order to enable two way communications for signalling.

SilverSpring networks proposes the Demand Optimizer tool [59]. This component targets at peak load reduction and cost efficiency increase through process automation. Major capabilities of the Demand Optimizer include

- DR portfolio management and optimization across programs

- Efficient customer engagement
- Precise forecasts of load and load shed potential
- Near real time, automated measurements and verification

Siemens proposes the Demand Response Management System (DRMS) [60] . This system provides an efficient way to plan and execute load shedding at grid locations where the utility has more benefit.

DRMS can be configured to automatically execute DR events on loads serviced by specific substations or feeder lines when they are under operating stress and threaten reliability. Surgical DR gives utilities the ability to limit or avoid outages, restoration costs, and contributes to longer, better performing assets.

Landis+Gyr propose an advanced load management solution [61] which included direct load control options. These options are enabled by switches that are available to communicate over either the smart meter network or through a standalone gateway using the cellular communications system. These intelligent load devices allow the utility to measure the amount of available load that can be curtailed, as well as verifying load control events have occurred. In addition the switches provide sensing capabilities to detect abnormal conditions and performing automatic load shedding. The applications that can be supported by the ecosystem include

- Demand response: Load reduction during peak hours.
- Infrastructure management: Protection from over loading which improves reliability and reduces the need for immediate investment to accommodate peak loads
- Capacity management: Solutions that exploits load reduction and micro generation in order to obtain economic benefits from the grid.
- EV Charging stations: Allows utilities to control EV charging operations in a manner that can be driven by real time dynamic tariffs
- Renewable integration: Monitoring, forecasting and balancing circuits while integrating intermittent power supplies.

2.7.2.4.5 Communications for direct demand side management.

In order to enable direct demand side management at a system level within the EV charging environment communication frameworks are required in order to interface the actual EV charging equipment (EVSE) which resides at the customer domain within the smart grid reference architecture, to the demand side management application that optimizes charging operations at an aggregated level.

A protocol that has been designed for this purpose by the Open Charge Alliance is OCPP (Open Charging Point Protocol). OCPP 2.0 defines the technologies, services and data models required in order to form a set of operations that enabled demand side management through smart charging. The goal of this protocol is to harmonize operations with the emerging ISO 15118 [62] standard which enables dynamic control of the charging session and additionally introduces the idea of a charging profile, i.e. a 2d array that assigns time to various charging power levels, thus enabling an optimized schedule of charging for electric vehicles. Moreover OCPP introduces emerging web technologies such as RestFul WebServices [63] and WebSockets [64] as the main technological frameworks of information exchange. Additionally information is modelled in JSON in a lightweight fashion that reduces overhead and increases interoperability with existing web based software libraries. Smart charging is an essential aspect of OCPP 2.0. Extensive use cases, messaging schemes, services and data models are defined in order to fully support smart charging in synch with the emerging V2G 15118 protocol. More information about the OCPP2.0 specification can be found at the

following [65]. OCPP 2.0 is designed to be interoperable with ISO/IEC 15118; therefore it reduces associated integration efforts on the EVSE side of the system.

In addition to OCPP2.0 another protocol that enabled direct demand side management is DLMS/COSEM [55]. This protocol is heavily used in the smart metering domain and will be analysed with respect to its applicability to DSM in sub-sequent paragraphs.

The aforementioned protocols target communication requirements of the charging operator to end user link. An additional aspect of smart charging is related to the control of the aggregated load profile due to charging, according to requirement's coming from the Distribution System Operator. The Open Charge Alliance is in the process of drafting the Open Smart Charging Protocol (OSCP). This protocol essentially targets at communicating the distribution system net capacity to the charging service operator. The charging service operator then is responsible of decomposing the aggregate net capacity and assigning it to the actual charging sessions through an interface as the ones referred above.

In addition to the aforementioned protocol under composition, IEC 61850 part 7-420, an extension of the protocol to support distributed energy resources, provides communication layers to support DSO to charging service operator requirements. The overall communication sequence defined by IEC 61850 is based on the client-server approach. Logic nodes represent the functionality of the device to be remotely controlled (server) and form a communication abstraction layer. Part 7-420 introduces the DER energy or/and ancillary services schedule (DSCH), which is a logical node structure that can be read or written. This structure contains an array of timestamps and values that could represent the distribution's network capacity, voltage profile etc. The DSCH structure is additionally adopted in IEC 61850-90-80 extension, which defines data models specifically for electro mobility.

2.7.2.4.6 Demand side management. (Indirect load management)

Indirect load management is an alternative strategy to shape demand in a decentralized manner. In this case a "smart" pricing scheme is formed according to the utility's/service provider criteria, that are usually driven by objectives such as energy efficiency and reliability of the grid. Prices are then broadcasted through a communication medium and then are either intercepted by the end user who decides to consume or not. Alternatively automated embedded controllers that reside along with electrical appliances could determine switching operations. Such systems are equipped with an energy consumption scheduling module which optimizes the switching decision making process. To summarize indirect load management consists of the following operations

- Smart pricing: Schemes that indirectly propose demand patterns that are typically driven by Day Ahead Pricing schemes (DAP)/Real Time Pricing, Time Of Use schemes (TOU), peak time rebates. An interoperable data model for pricing has been defined in the OASIS “Energy Market Information Exchange (EMIX) Version 1.0” [66].
- User information: Integrated communication and information technology systems that aim at informing the user about pricing schemes. Such systems typically include: Utility/Service provider website, Email, Text messages, Automated Voice calls, Energy Orbs, Smart meters.
- Automated Energy Consumption Scheduling: Given energy price values the device's load is scheduled in a manner that minimizes the load.

User information applications usually aim at providing an interface that enables easy perception regarding consumption data. PJM's (PJM is an American regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia.) energy orb

informs users about ongoing demand response events. The following events are associated with distinct colours in order to inform users about events in the wholesale energy market.

- Solid blue Standby/ No event currently underway
- Solid yellow Warning/ Day ahead event warning
- Pulsing yellow Warning/ An event will occur later in the day
- Solid Red Activation/Event in progress and another declared for the following day
- Solid Green Testing/ Demand response notification system been tested

Similar concepts include the use of smart phones and end user applications such as "The Energy detective" [67] and "Siemens EcoView" [68]. Such applications provide users with analysed information about real time power consumption measurements (metering systems) and real time updates of electricity price values.

As real time pricing schemes are accompanied by a huge information flow, automated decision systems must take care of making the correct demand shaping decision. In general energy consumption scheduling devices must be easy to integrate with existing smart appliances and target at satisfying user's energy consumption needs.

Regen [69] proposes an indirect demand side management solution which is based on consumer based energy scheduling. In this case, energy consumption schedulers (ECS) are attached to appliances in order to enable end node active load management. Controllers are interconnected through a ZigBee network, in order to enable information exchange among various appliances in the premises of an industrial/home installation. Controllers broadcast power readings to each other every 30 seconds and then each controller makes a decision every few minutes in order to ensure the most efficient use of energy. A gateway interfaces the system to external parties by providing a Web-Service based API. Typical loads that apply to this application include among others, air conditioning units, lightning, electric heating, pumps, EV charging and other discretionary loads.

In demand bidding the demand side management application notifies consumers about future deviations in power supply. Consumers respond with their response to the event in addition with the desired cost incentive. The demand side management application selects the best bids and informs the end customer. The advantage of this approach with respect to smart pricing is that the DSM application becomes aware of the participation of consumers in future charging operations and therefore optimizes the utilization of future supply capacity. Data models for energy bidding have been described in OASIS Energy Market Information Exchange (EMIX) Version 1.0.

2.7.2.4.7 Communications for indirect demand side management.

OCPP 2.0 additionally defines features that enable indirect side management. This is performed through dynamic pricing. OCPP2.0 defines use cases and data models for variable pricing, thus enabling the use of TOU, RTP pricing strategies. The associated data model object in the OCPP 2.0 is the PriceScheme object and consists of the following structure attributes

- priceSchemeId: Unique identifier of the price scheme
- displayText: Optional. Description of the price scheme for display
- connector: Optional. The type of connector to which this price scheme applies. If absent, the scheme applies to all connectors

- expiryDate: Optional. The point in time at which this scheme ceases to be valid. Use this to prevent the use of an expired price scheme when the Charge Point is offline for a long period of time
- tariff: Mandatory. One or more tariffs that make up the price scheme

The indirect demand side management application can send this object to the EVSE in order to announce time of use or real time pricing rates. The announcement can be further disseminated to vehicles through ITS road side units (RSU) in order to encourage or discourage charging during certain periods of the day.

ETSI (European Telecommunications Standard Institute) has produced relevant technical specification that addresses this topic. The Electric Vehicle Charging Spot notification Specification (ETSI TS 101 556-1) defines the use of ITS cooperative communications in order to enable the broadcasting of information about Points of Interest to ITS Stations. Such information includes charging pricing information. The specification describes some functional requirements for the associated infrastructure and additionally defines the format of the charging notification message.

The charging spot notification message consists of the following elements

- ITS PDU Header
- Specific POI Header
- Charging station information
  - Charging Station Header
  - Array of Charging Spot Data Elements

Pricing information is included within the Charging Station Header. The pricing element is defined as a sequence of current energy or battery rates, each including

- Charging type (energy, battery, etc.)
- active time interval in seconds starting from EVCSN (Electric Vehicle Charging Spot Notification) generation time
- unit of charging
- price level per unit

The charging spot notification specification applies to all types of charging, including the dynamic wireless case, since Charging Spot Data Elements includes the definition of the type of the charging spot. Additionally, fields have been reserved for future definition of additional charging types, thus ensuring a future proof specification. For more information please refer to [70].

Indirect demand side management requires the dissemination of charging pricing information from the grid all the way to the end user or an entity (agent) that decides to charge or not on behalf of the end user. Existing charging infrastructure and protocols support such a scheme. For example by cascading OCPP 2.0 and EVCSN a standardized and reliable communication link between the demand side management application and the end user can be formed. However OCPP 2.0 targets the internal communication requirements of charging service providers. Even though, technically DSO's or energy retailers could use OCPP in order to directly transmit tariff information to EVSEs, practically communication between DSO's/ Energy retailers and charging service providers may require an additional dedicated protocol. In this direction the Open Charge Alliance is drafting the Open Smart Charging Protocol. The main goal of this protocol is to communicate physical net capacity from the DSO to the back office of the charging operation.

However FABRIC recommends including communication of tariff in this protocol in order to enable indirect demand side management.

IEC 61850 part 7-420 is an extension of the protocol to support distributed energy resources. The overall communication sequence is based on the client-server approach. Logic nodes represent the functionality of the device to be remotely controlled (server) and form a communication abstraction layer. Part 7-420 introduces the DER energy or/and ancillary services schedule (DSCH), which is a logical node structure that can be read or written. This structure contains an array of timestamps and values that could represent pricing information or other parameters such as a power schedule, voltage profile etc. The DSCH structure is additionally adopted in IEC 61850-90-80 extension, which defines data models specifically for electro mobility.

2.7.3 On board applications

EV's represent moving dynamic loads which in the simplest scenario could be manipulated by grid operators in a fashion that optimizes their storage capacities and simplifies grid integration. In order to enable the use of a demand side management strategy, EV's must implement modules that will; either co-operate with central load control modules (direct load control) if charging rates are controlled by the vehicle itself or possibly embed a load scheduling agent that participates in pricing and bidding of charging power (indirect load control). In both cases the demand side management module must implement a communications interface in order to either receive updates from the central scheduling module or in order to receive pricing schemes and participate in energy bidding in the case of indirect load management. In order to support direct load control, ISO/IEC 15118 incorporates load schedules in its data model and therefore the "automotive" side of the specification could be used by the demand side management module in the vehicle. Additionally pricing and tariff details are supported by ETSI EVCSN as demonstrated in previous paragraphs. Energy bidding data models have been defined by the OASIS “Energy Market Information Exchange (EMIX) Version 1.0”; however more complete definitions are required with respect to specific use cases in order to ensure maturity and interoperability of such implementations.

3 Gap analysis and Interoperability

3.1 Approach

The gap analysis and interoperability considerations are provided for each class of functional requirements together. The approach is based on that followed in FABRIC WP33 on Technical Benchmarking for charging solutions.

3.1.1 Gap analysis

This chapter identifies the gaps between the existing solutions described in Chapter 2 and the needs of the FABRIC system (and hence the needs of its users, operators and other stakeholders). It assesses the ability of the current solutions to fulfil the system's needs and what improvements would be needed. It also provides a ranking of the importance of meeting each need, from low to very high. To ensure consistency with FABRIC Deliverable D33.2 "Gap Analysis", which performed this task with respect to charging solutions, a parallel methodology is employed with respect to ranking the **priority** and **severity** of the gap.

The **priority** refers to the importance of meeting the requirement, ranging from low to very high, as follows:

- **Low:** The needs and requirements are not essential to the systems operation or safety, usually guidelines or "nice to have" recommendations. These can be considered once the system is fully developed. For example, dynamic guidance to charging facilities fall under this category, as a FABRIC charging system can function without such guidance.
- **Medium:** These are the needs, requirements, standards and regulation that the system should comply with, but are not essential for the fundamental operation of the system. However, the requirements must be fulfilled in order to install and use the systems in public domain. For example; requirements on location of the road side equipment, connection between roadside equipment and on road infrastructure. These standards aim to ensure that safety and drive quality are not compromised; however, it is not essential to meet these requirements during test track trials.
- **High:** These are the needs and requirements that are important to meet; these are the standards, regulations or design requirements that will take the system from the test tracks to the actual road trials.
- **Very High:** These are essential needs and requirements that must be addressed immediately in order to make sure the solution is technically feasible.

The severity of the gap refers to the level of work needed (in terms of innovation or development) to meet the requirement. The three ranks (as used in D33.2) are as follows:

- **Need for further development:** The current system fails to meet the requirement but with minor modifications and developments, the system should meet the requirement.
- **Need for innovation:** New specifically designed equipment, a new protocol or a new standard is required to meet the requirements.
- **Major work required:** The system exceeds current limits or does not meet requirements. Requires major system improvements, efficiency improvements, new systems or legal changes.

3.1.2 Interoperability analysis

ICT interoperability considerations are highly relevant for a future large-scale roll-out of a FABRIC-type charging solution, but less so for the immediate purposes of the FABRIC demonstrations.

As for conventional plug-in charging, as well as for other ITS applications (a key area for potential comparison is electronic toll collection), interoperability should cover the technical functionality of the service and the payment. The goal should be to enable users across Europe to access services in different countries in a seamless way without the need for duplicate on-board equipment or multiple accounts. As with other ITS applications, interoperability issues focus on:

- Technical interoperability: concerning on-board WPT and ancillary ICT equipment such as communication technology and driver interface;
- Procedural interoperability: contractual agreements between infrastructure and DSO operators and payment service providers;
- Treatment of "out of area" or occasional users who may not have an account with the local service provider or may have a foreign registered car, foreign credit card/bank account, etc.;
- Protection of personal data and system security.

FABRIC D33.3 "Interoperability considerations" (confidential deliverable) graded interoperability as follows, hence for consistency the same scoring system is used in this report:

- Score 1 = Systems perfectly interoperable (no structural changes are needed).
- Score 0.5 = Systems partially interoperable (systems need some changes in order to be interoperable).
- Score 0 = Systems not interoperable (lack of compatibility which cannot be adjusted without major effort).

The approach in D33.3 was to compare the interoperability of pairs of different charging solutions whereas here the scoring is more on a general level as interoperability needs may be (a) between ICT systems performing the same function but at different locations (different deployments), or (b) ICT systems performing different functions at the same location that need to interact with each other.

3.2 User accounts, booking and billing

3.2.1 Gap Analysis

3.2.1.1 User Accounts

- Gap priority: **Low**
- Gap severity: **Need for further development** (HMI for booking while driving)

From the user and system requirements for user account management, two main use cases are listed: (1) driver-owner registration and (2) user account management. In Section 2.2.1, we listed three European projects that present potential ICT solutions in this direction.

The user account management solutions proposed in Green eMotion, Mobility 2.0 and eCo-FEV share basic features. They all allow for basic user registration and association (ownership) with a particular vehicle. The main differences lie in the applications and services that can be associated with a user account. The Green eMotion project focuses on interoperability of service providers and billing. However, value-adding services such as charging spot reservation and navigation services are not part of their core functionality. Mobility

2.0 provides user account management that is responsible for carrying out authorization of associating user with vehicles and, additionally, stores information about user defined journeys. However, there is no support for associating booking or billing of charging spots with the user account. Finally, the *eCo-FEV backend* provides all functionalities needed for user registration, ownership as well as additional features linked to the user account such as billing and booking of charging stations. It additionally supports different types of charging spots such as Charge While Driving (CWD) spots.

Overall, the *eCo-FEV backend* is a suitable complete candidate to FABRIC, since it meets the two basic requirements of driver-owner registration and user account management in addition to support to booking and billing of different types of charging spots.

3.2.1.2 Booking and Billing

Gaps with existing booking and billing approaches relate to the fact that the existing solutions have static charging in mind. Static charging allows for a very long charging time and in addition there are no time constraints for the EV identification and authorization which can last several seconds.

On the other hand FABRIC deals with dynamic charging and stationary charging. The gaps with existing solutions are:

1. Speed of identification and authorization for dynamic charging should be much faster than the methods used for static charging. Depending on EV speed while charging the identification/authorization should take only a few (3-5 ms) milliseconds per charging pad. The whole contact duration of the EV with the charging pad for 120km/h is less than 30ms.
2. Need for booking for the stationary and dynamic charging should be investigated. In case booking is necessary there should be a mechanism to take into account delays in reaching the charging infrastructure since the EV is on the move prior to the charging booking. Since the charging duration is very short compared to static charging, the delay could easily be longer than the actual charging duration so current booking methods may be irrelevant.
3. Different systems should be used in dynamic charging for the identification of the EV. Billing process should probably be different for two reasons:
    - The EV is on the move and there is no physical contact of the user with the EVSE (to use a credit card for example).
    - The billing process should take into account the difference between the transmitted energy and the energy that is actually received by the EV. For static plug-in charging the losses are negligent but for dynamic wireless charging the losses can be more than 20%.

3.2.2 Interoperability Analysis

- Technical interoperability: **1**
- Procedural interoperability: **0.5**
- Treatment of “out of area” or occasional users: **0.5**
- Protection of personal data and system security: **0.5**

3.3 Dynamic routing for EVs

3.3.1 Gap Analysis

- Gap priority: **Low**
- Gap severity: **Need for further development** (incorporation of dynamic information on status/ availability of charging facility)

FABRIC deliverable D22.1 cited dynamic EV routing functions. State of the art electric vehicle navigation systems do not currently support the charging infrastructure availability function and the targeting charge level function. However they could be adapted to route EVs to charging lane infrastructure and extended to support booking of charging infrastructure. Improvements would allow the user to set a target charge level range to be achieved by the arrival at the destination.

Charging infrastructure availability support (B3 – AVAIL requirement)

The availability of the charging infrastructure can be affected by many factors such as the number of charging request, the number of the EV using the infrastructure and traffic state. The information regarding charging infrastructure will enable the navigation system to calculate energy efficient route with minimum recharging actions and minimum recharging cost and duration.

When the charging infrastructure is not available, the navigation system should re-route the EV to alternative available charging infrastructure. In case of delay, the navigation system should notify the charging infrastructure to update the booking status. The navigation system should help reduce the number of the recharging request sent to the recharging infrastructure backend and relief the charging lane traffic.

Targeting charge level (B5 – TARGET requirement)

The EV user will set a charging level to be reached at the destination. This function will enable the driver to maximize visited location and drive back to the start location. The navigation system should calculate the route that respects this targeted charge level. In case a recharging action is needed to meet the charge level target, the navigation system will take necessary actions. These actions will require querying charging infrastructure availability and issuing charging request.

3.3.2 Interoperability analysis

- Technical interoperability: **1**
- Procedural interoperability: **0.5**
- Treatment of “out of area” or occasional users: **1**
- Protection of personal data and system security: **1**

As the car navigation industry has grown so has incompatibility between navigation systems and the databases that store important location information. Additionally, there is a need to more easily develop navigation system applications. ISO (International Organization for Standardization) is contributing solutions to those issues with an International Standard for a navigation system application programming interface (API).

Car navigation systems use map databases to give precise driving directions, or to determine the vehicle's location and provide information about nearby points of interest, such as restaurants and hotels. Some newer systems can also receive and display information on traffic congestion and suggest alternate routes.

ISO 17267:2009, *Intelligent transport systems – Navigation systems – Application programming interface (API),* will help facilitate the interoperability between navigation systems and map databases by providing an interface that will make information accessible and retrievable as well as assist developers of navigation systems.

This standard describes what data may be retrieved from a database, defines the interface for access and specifies a set of navigation function calls. It also describes the design of the API and gives examples of its intended use. Furthermore, it specifies the criteria used to determine if a data access library is in accordance with the standard.

While ISO 17267:2009 is primarily targeted at self-contained in-vehicle systems, it is expected to be usable by other applications that use map data results in essentially the same way. For example, it may be usable in a client/server environment and/or by distributed navigation systems and location-based services without further specialization.

ISO 17267:2009 is not restricted to physical media and is independent of any underlying physical storage format. [71]

3.4 Vehicle identification, charging lane access control and management/enforcement

3.4.1 Gap analysis

- Gap priority: **Low**
- Gap severity: **N/A**

VMS and LCS could quite easily be adapted for providing guidance and control for on-road charging systems.

For example, VMS may be used to inform about a nearby facility and its status, or to direct EV users wishing to charge to an alternative on-road facility in case a charging zone is not available for use.

In the case of a charging lane on a multi-lane road or motorway, LCS can be used to indicate the charging lane and possibly reserve its use for EVs only (or certain classes of other vehicles only, e. g. public transport) in order to ensure its availability for charging. LCS may also be used to set a specific speed limit for the charging lane, lower than the speed for the other lanes of the road.

The relevance of such systems depends on the prevalence of on-road charging areas and their use: VMS messages which are only relevant to a very small proportion of road users risk being ignored. Specific symbols or messages on VMS for EV charging do not exist (at least they are not harmonized), but this could be achieved in the same way as for other road signage and VMS strategies (e.g. through CEDR working groups).

Existing systems are fully capable of fulfilling FABRIC functions: this is relevant to functions B2 (Locating infrastructure), B10 (Closest infrastructure routing), C2 (Charging lane access control) and C3 (Emergency

Control of Charging Lane). Applications such as VMS and LCS are fully ready and deployable. Only decisions on symbols to use and strategies for signing need to be made.

3.4.2 Interoperability analysis

- Technical interoperability: **0.5** (risk of different means of detection being used by different systems)
- Procedural interoperability: **0.5**
- Treatment of "out of area" or occasional users: **0.5**
- Protection of personal data and system security: **0.5**

The two main areas of standardisation relating to VMS are:

- CEN – the European Committee for Standardisation, which worked on harmonising technical display parameters, aiding readability of VMS ;
- CEDR – Conference of European Directors of Roads, which had an action in the late 1990s called FIVE (Framework for harmonised Implementation of VMS in Europe), which recommended general design principles for VMS.

Deployment guidelines for speed and lane control on motorways have been developed by the EasyWay European deployment project to harmonise development and deployment of VMS across Europe. Within EasyWay, the "Mare Nostrum" initiative worked on harmonising messages and pictograms on VMS. This was not technical or design harmonisation, but work to enable VMS messages to be more easily understood by drivers, in particular foreign drivers, by making messages as clear and language-independent as possible.

3.5 ICT control of Wireless Power Transfer

3.5.1 Gap Analysis

- Gap priority: **Very high**
- Gap severity: **Need for further research and development; Major work required**

For plugged-in solutions, the energy sent to the EV is easily measured and there are no loses. But for wireless static and much more for dynamic there are significant loses. In this case we have to decide if we will bill the energy transmitted or the energy received. One option is to bill the average energy and another option is to let the market decide for this, so the different energy retailers will enter in competition and bill the drivers in different way depending on the energy price and their marketing strategy. Billing the user can also depend on his driving style inside the charging lane, so we can bill more the driver who exceeds the maximum driving speed inside the charging line since this will increase the energy loss. Measuring the energy is also a topic of research within FABRIC project. The energy can be measured at the charging infrastructure and at the EV. The measuring method will also affect the billing. Standardisation of ICT for all phases of wireless charging (data structure) is needed in order to guarantee systems interoperability.

These gaps have to be addressed before large scale deployment of dynamic charging.

3.5.2 Interoperability analysis

Since WPT systems are not widely deployed, and for the dynamic charging mode they are largely still at a technical development stage, an interoperability analysis of the ICT control requirements is not possible at this stage. However, regarding smart metering, technical interoperability will be ensured by EU Mandate

D441 (2009), but communication protocols need to be integrated to enable interoperability with smart grids (see Chapter 2.5.2).

3.6 Driving assistance while charging

3.6.1 Gap analysis

- Gap priority: **Very high**
- Gap severity: **Need for further research and development; Major work required**

ACC, ISA and LDW have been developed as safety applications but are also potentially valuable for a dynamic on-road charging system. ACC can be used also to keep two dynamically-charging electrical vehicles at a distance which enables the WPT to properly function for each vehicle. Given the stricter requirements for dynamic charging trajectories, major adaptations and improvements are expected with respect to the state of the art approaches.

A given WPT installation is expected to be less efficient (or have less time to provide the necessary power) at higher speeds, so a maximum or recommended driving speed should be set according to the road type and the configuration/performance of the charging infrastructure. ISA systems in EVs can detect the posted recommended or maximum speed limits on the lane and advice the driver (or force the car) to keep within that limit.

LDW is a potentially important application in terms of keeping EVs in the correct trajectory for the charging infrastructure. However, the required trajectories are expected to be more restrictive than those possible for keeping a vehicle within a standard traffic lane (particularly on higher speed roads where lanes are wider). Thus, special road markings may be needed, to precisely indicate to the driver the required trajectory of charging EVs. In any case, an LDW system of an EV would need to be adapted in order to meet the specific requirements of the new application.

3.6.2 Interoperability analysis

- Technical interoperability: **0.5** (different systems in different vehicles, different ways of marking the lanes at different sites – systems need to recognise a charging lane and its parameters / tolerance levels)
- Procedural interoperability: **0.5**
- Treatment of “out of area” or occasional users: **0**
- Protection of personal data and system security: **0**

Interoperability is likely to concern input data formats (e.g., geographic) and output data formats (e.g., on the instructions to be provided to the driver and the accuracy and reliability of the assessment) and timing. These, however, are second step aspects with respect to the recognition algorithms that need to be developed.

ISO 17361:2007 standard specifies the definition of the system, classification, functions, human–machine interface (HMI) and test methods for lane departure warning systems. This norm can be used to specify the lane keeping system performance requirements and proceed to the necessary tests. [72]

3.7 Distribution System Operator (DSO) and grid management

The requirements of ICT applications for grid management will be compared to currently available solutions in order to identify areas which require additional design or implementation effort. The identification of these gaps will guide subsequent activities in the development of both FABRIC off board and on-board solutions.

3.7.1 Gap analysis

- Gap priority: **Low / High** (depending on requirement: see Table 4 below)
- Gap severity: **Need for further development / Need for innovation** (see Table 4 below)

Information exchange between the FABRIC Electro mobility Platform (FEMP) and the Distribution System Operator (DSO) or Energy retailer must be performed in a standardized and interoperable manner. Existing smart grid protocols and standards support the exchange of voltage, pricing, power profiles within their data model definition. Indicative protocols include

- IEC 61850 substation automation
- Open Smart Charging Protocol (OSCP)
- OASIS Information Model for Energy and Market information

IEC 61850 is a mature standard that incorporates the DSCH schedule which can be used to define smart grid related information elements. OSCP is currently under development therefore no detailed information data models are publicly available. OASIS Information Model for Energy and Market information is a mature standard that defines the information data model for energy pricing. IEC 61850 could be used as the basic standard for communications between the DSO and FABRIC's Electro Mobility Platform. However modifications must be made in order to customise the semantic layer of the information model. For example DSCH schedules must be formulated to reflect aggregate power, voltage and power profiles.

OSCP is a communications protocol that may include information models that are specific to charging; therefore it is promising solution that could minimize efforts related to data model customization in future implementations. The aforementioned protocols can use data model definitions for pricing as defined in the OASIS Information Model for Energy and Market standard.

3.7.1.1 Low latency communications (Requirement F3)

Low latency communications between FABRIC and the DSO/Energy retailer are required in order to enable the reliable operation of the dynamic wireless charging system. This requirement addresses the whole OSI (Open System Interconnection) communications stack as it can be fulfilled only if optimal strategies are deployed at all levels. At the physical, medium access layer current broadband technologies can address low latency requirements successfully. Network and transport layer protocols that are appropriate for smart grid communications have been presented in RFC6272. An assessment of higher layer protocols such as IEC 61850 and OSCP must be performed in order to investigate their performance in terms of real time, low latency performance.

3.7.1.2 FABRIC to DSO/energy retailer security (Requirement F5)

Security is a major if not the biggest concern in the development of smart grid applications. Reliable and secure operation of the power grid is tightly coupled with ICT security. Smart grid oriented applications as the ones presented in the aforementioned section typically use TLS (Transport Layer Security) in order to secure communications. Even though TLS uses a combination of efficient asymmetric and symmetric

cryptography algorithms it greatly relies on the reliability of the public key infrastructure (PKI), thus web based applications could be subject to Man in the Middle attacks, therefore the use of strategies such as strong client authentication should be enforced in order to enhance TLS enabled security. IEC 62351 defines the use of smart grid protocols such IEC 61850, IEC61870, IEC 61970 along with the TLS security layer in order to. The aforementioned threat is only an example of the vulnerabilities that currently exist. A more detailed assessment and a compilation of requirement's has been reported in D24.1.

3.7.1.3 FABRIC demand information availability (Requirement F6)

Standards that cover topics such as data modelling for demand information and messaging sequences for demand exchange have been defined in protocols such as IEC 61850 and are being under development in protocols such as OSCP. Moreover from the service provider perspective information regarding demand can be monitored by the internal metering system on the basis of existing metering infrastructure and application solutions that have been presented in previous paragraphs. Therefore from a technical perspective existing solutions can support the exchange of information regarding, demand consumption (from FABRIC to DSO).

3.7.1.4 Local Grid Capacity Information (Requirement F7)

Protocols such as IEC 61850 and OSCP have been explicitly developed to support information such as net power capacity from the DSO to service providers (FABRIC). Such information can be used within the FABRIC Electro-mobility Platform (FEMP) for a wide range of operations such as demand side management. Such solutions have been commercially deployed as reported in previous paragraphs. However since demand side management is a rather versatile subject that can be driven by various optimization objectives it is necessary to identify optimal strategies that would be beneficial for charging infrastructure operators. Within FABRIC this topic will be further investigated.

3.7.1.5 FABRIC to DSO/energy retailer interface maintenance (Requirement F8)

Information exchange between FABRIC and DSO/energy retailer must be ensured in order to enable the use of smart grid enabled applications. Therefore redundancy in communications must be deployed. Nevertheless backup plans that ensure the reliable and safe operation of the charging infrastructure in case of a disruption should be further investigated in order to enable safe decoupling of the charging infrastructure systems (FEMP) and DSO systems

3.7.1.6 Communications logging (Requirement F9)

Most existing applications incorporate auditable logging systems for process monitoring and identification of malfunctions.

3.7.1.7 Time synchronization (Requirement F10)

Many grid related applications such as demand side management require time synchronization. Time synchronization can be enabled by the use of protocols such are network time protocol (NTP) or GPS (Global Positioning System). Such strategies have been widely deployed and tested in many ICT systems.

3.7.1.8 Overall application integration

In order to construct an overall framework for overall integration of applications for energy management a global framework that aggregates functionalities of smart grid service providers has been defined as the Energy Management Systems (EMS). The interfaces of this component have been defined in the IEC 61970 series of standards which defines the respective application program interfaces.

3.7.1.9 *Gap analysis summary*

Table 4: Gap analysis summary for DSO and grid management

Gap	Priority	Severity of the gap
Distribution system operator and grid management.		
Current information models for distributed energy resources may have to be semantically adapted in order to reflect net power capacity and pricing schemes	HIGH	Further improvement
Low latency communication link between DSO/Energy retailer and charging infrastructure	HIGH	Further improvement
Demand side management control strategies	HIGH	Further research
Security in communications between DSO/Energy retailer and FABRIC	HIGH	Further research
Redundancy in energy retailer/DSO interfaces	Low	Further work required
Time synchronization between DSO/energy retailer interfaces	Low	Further work required
Integration of ICT applications for energy management	HIGH	Further improvement

3.7.2 Interoperability analysis

- Technical interoperability: **1**
- Procedural interoperability: **0.5**
- Treatment of "out of area" or occasional users: **N/A**
- Protection of personal data and system security: **0.5**

FABRIC targets at creating an ICT ecosystem that will support wireless charging operations while assuring smooth grid integration via energy and power management applications such as demand side management (Direct load control) and incentive based strategies. As FABRIC's ICT infrastructure implements both the service provider and end user domain of the smart grid ecosystem, it is essential to design system wide interfaces that would enable interoperability with the overall smart grid ecosystem and especially the DSO/ energy retailer. Interoperability can be assessed with respect to the following parameters:

- Technical
  - Basic connectivity
  - Network interoperability
  - Syntactic interoperability
- Informational
  - Semantic understanding
  - Business context
- Organizational
  - Business procedures
  - Business objectives
  - Economic/Regulatory Policy

FABRIC will implement a DSO/Energy retailer interface on the basis of generic and standardized communication interfaces. Though standards are created to target interoperability, modifications and

further definitions may be required in order to enable interoperability between systems. The following table summarizes interoperability aspects of the main standards and protocols considered within FABRIC.

Table 5: Interoperability matrix for power and energy management

	Technical			Informational		Business		
Protocol	Basic connectivity	Network interoperability	Syntactic interoperability	Semantic understanding	Business context	Business procedures	Business objectives	Economic regulatory policy.
IEC 61850	Not applicable	Not applicable	✓	✓	!	!	!	*
OSCP	Not applicable	Not applicable	✓	✓	✓	✓	✓	*
OCPP	Not applicable	Not applicable	✓	✓	☒	☒	☒	*
EMIX 1.0	Not applicable	Not applicable	✓	✓	✓	✓	✓	*
IEC 61970 [73]	✓	✓	✓	✓	✓	✓	✓	✓

As basic connectivity between service providers and customers can be obtained by IP based communications only higher layer protocols that could be used to enable energy and power management applications (either direct demand side management or indirect demand side management) have been defined in the aforementioned table. For a definition of standards and protocols that are compliant to the smart grid please refer to the information report RFC 6272 [74].

IEC 61850 addresses the need of a global communication infrastructure for power utility automation by providing the definition of a hierarchical data model and logical functions that address the needs of grid automation. In order to address the needs of power and energy supply management and scheduling, IEC61850 has defined the DSCH (Distributed resources scheduling) which can be used to model time series of power, price, energy. This information can be transferred between DSO interfaces and service providers such as FABRIC by implementing its Application Common Interface (ASCI). It should be noted that IEC 61850 covers a wide area of utility automation applications and is not specific to electro mobility. It is not a custom protocol for DSO/Energy Retailer to charging infrastructure providers; therefore it is not a protocol that has been created to address this specific use. Therefore there is no guarantee that DSO's will use it to satisfy power and energy management as defined in FABRIC.

OSCP as a protocol that will be defined specifically to communicate physical net capacity from the DSO (or site owner) to the back-office of the charge spot operator. The protocol can be used to communicate a 24 hour prediction of the local available capacity to the Charge Spot Operator. The Service Provider will fit the charging profiles of the electrical vehicles within the boundaries of the available capacity. As such it fits

exactly the needs for high level aggregated power scheduling, thus by definition it addresses the associated business objectives and procedures. However the protocol is currently being drafted, thus there is no concrete documentation publicly available.

OCPP defines an extensive model for power supply and management within the charging infrastructure; therefore it does not directly address requirements for communication between systems such as FABRIC Electro mobility Platform (FEMP) and DSO's/Energy retailers (x). However OCPP's data model defines the charging scheduling element which could be used to represent aggregated net capacity information in order to support the communication of forecasted net capacity and pricing schemes from DSO's/Energy retailers to the FEMP.

EMIX 1.0 (Energy Market Information Exchange Version 1.0) defines the model of standard exchange of prices and product definitions in energy markets. This data model could support the exchange of pricing information and the development of indirect strategies for demand side management such as energy bidding. Therefore it is a standard that provides a means of integration with energy retailer and energy markets.

IEC 61970 defines the integration of energy management applications in a control centre environment. Additionally it defines protocols for the exchange of information to systems external to the control centre environment, including transmission, distribution and generation systems external to the control centre that need to exchange real-time data with the control centre and finally defines suitable interfaces for data exchange across legacy and new systems. Therefore it can serve as a reference framework for interoperability between the integrated energy management system of FABRIC and DSO.

*EU Mandate M/468 'Charging of electric vehicles' supports the enforcement of smart charging strategies thus all of the aforementioned protocols support such schemes.

3.7.3 Possible improvement within the project

In this section proposals for possible improvements in state of the art of communication protocols and applications for some selected requirements will be reported.

3.7.3.1 Information model (Requirements F1, F2, F4)

Well defined information models have been defined for DSO, Energy retailer interfaces of charging infrastructures; however most data model definitions are based on assumptions targeting plug-in charging systems. FABRIC will evaluate these data models and propose amendments and extensions for inductive wireless charging infrastructures if required.

3.7.3.2 Low latency communications (Requirement F3)

FABRIC will assess the communication technologies referenced in previous paragraphs in order to build a communication stack that enables reliable and low latency communications between the DSO/Energy retailer and the FABRIC Electro Mobility Platform (FEMP). Additional amendments to high layer protocols may be proposed in order to address requirements specific to inductive wireless charging infrastructures.

3.7.3.3 Local Grid Capacity Information (Requirement F7)

Local grid capacity information will be utilized by FABRIC's demand side management application in order to enable grid friendly integration of EV's. Based on application requirements, proposals for higher level protocols and grid capacity information update schemes will be proposed.

4 Conclusions and recommendations for FABRIC and beyond

After examining existing research projects concerning user accounts and booking for charging stations, the eco-FEV project backend proved to be the most suitable candidate for FABRIC needs because it supports user registration, ownership, booking of charging stations (including charge while driving spots) and billing. Billing will not be demonstrated in FABRIC ICT application because it is not an ICT function, but rather a business process.

The state of the art navigation system of electric vehicle answers the FABRIC need in terms of trip planning and routing calculation. Thus, it will not be demonstrated because it is being studied in many R&D projects that are specifically oriented towards optimal routing and also because it is not foreseen in the demonstrations of FABRIC which also has no testing facilities to demonstrate such capability (long trips would be needed).

The efficiency of the energy transfer between the charging pad and the vehicle pad will depend highly on the position of the vehicle and its speed inside the charging lane. Development of a specific assistance system for keeping the vehicle in a right trajectory within the dynamic charging corridor (by warning the driver about the correct trajectory) has emerged as a necessity, overcoming the state of the art.

The assessment of the existing ICT solutions for the distribution system operator and grid management revealed some gaps related to demand side management and load balancing. Load balancing is thus needed in order to test the compliance of the existing standard with the wireless charging dynamic needs and provide the required architecture to integrate the dynamic charging infrastructure to the grid.

The following table summarizes the main topic addressed in this deliverable and their suitability for the FABRIC needs and developments.

Table 6: Assessment summary of ICT solutions

Functionality/ Solution	Relevance for FABRIC demonstration	Needed adaptations/ improvements over the state of the art	Interoperability issues	Comments
Dynamic routing for EV	Not relevant	Need to add support for charging infrastructure availability and booking	Likely to concern mainly geographic data formats across different map providers.	This aspect is not critical to the dynamic wireless charging feasibility

Functionality/ Solution	Relevance for FABRIC demonstration	Needed adaptations/ improvements over the state of the art	Interoperability issues	Comments
Lane Keeping assistance	Relevant	Need major adaptation since the charging lane is narrower than a normal lane. Use of real-time information about energy transfer may be considered alternatively	Mainly related to input (e.g., geographic) and output data formats (e.g., on the instructions to be provided to the driver and the accuracy and reliability of the assessment) and timing.	This function is important to increase the energy transfer efficiency from the road to the vehicle.
Distribution System Operator and grid management	Relevant	Adaptations are needed in order to ensure real time performance that will ease the integration of dynamic wireless charging infrastructure, in a secure and energy efficient manner	For typical functionalities such as metering, billing and overall management, protocols of conventional charging schemes can be re-used. However for more sophisticated operations such as demand side management and load balancing, novel methods needs to be developed.	FABRIC will aim at developing Demand Side Management will provide architectural and functional paradigms required to boost deployment of technologies that enable the seamless integration of dynamic wireless charging infrastructures to the grid

Functionality/ Solution	Relevance for FABRIC demonstration	Needed adaptations/ improvements over the state of the art	Interoperability issues	Comments
User accounts	Relevant	eCo-FEV user account management solutions can be used to meet FABRIC needs	No interoperability issue	
Booking	Relevant	Fast identification and authorisation method may be needed. Investigation needed into the relevance of booking for static and dynamic charging	Data model between the different systems in EV identification	
Billing	Not relevant	A system for billing without a physical contact with the driver	Data model between the different system used for billing	Billing is a management process which needs support by ICT.
Vehicle identification, charging lane access control and management/enforcement	Relevant	VMS symbols and messages for EV need to be defined	Risk of different means of detection being used by different system	

Functionality/ Solution	Relevance for FABRIC demonstration	Needed adaptations/ improvements over the state of the art	Interoperability issues	Comments
Smart metering	Relevant	Fast measurement techniques for dynamic charging	Define data model for sending measured energy	

5 References

[1] “greenemotion,” [Online]. Available: http://www.greenemotion-project.eu/.

[2] “mobility2,” [Online]. Available: http://mobility2.eu/.

[3] “ecoFEV,” [Online]. Available: http://www.eco-fev.eu/.

[4] “Remote Authentication Dial In User,” [Online]. Available: http://en.wikipedia.org/wiki/RADIUS.

[5] “FreeRADIUS,” [Online]. Available: http://freeradius.org/.

[6] “Extensible Authentication Protocol,” [Online]. Available: http://en.wikipedia.org/wiki/Extensible_Authentication_Protocol.

[7] “Simple Network Management Protocol,” [Online]. Available: http://en.wikipedia.org/wiki/SNMP.

[8] “NetSNMP,” [Online]. Available: http://www.net-snmp.org/.

[9] “Nagios,” [Online]. Available: http://www.nagios.org/.

[10] “Centreon,” [Online]. Available: http://www.centreon.com/.

[11] “ISO 11898,” [Online]. Available: http://en.wikipedia.org/wiki/ISO_11898.

[12] “CAN Bus,” [Online]. Available: http://en.wikipedia.org/wiki/CAN_bus.

[13] “File Transfer Protocol,” [Online]. Available: http://en.wikipedia.org/wiki/File_Transfer_Protocol.

[14] “Open Charge Point Protocol,” [Online]. Available: http://www.ocpp.nl/.

[15] “REST,” [Online]. Available: http://en.wikipedia.org/wiki/Representational_state_transfer.

[16] “XML Schema Definition,” [Online]. Available: http://en.wikipedia.org/wiki/XML_Schema_%28W3C%29.

[17] “Functional reference architecture for communications in smart metering systems,” [Online]. Available: ftp://ftp.cen.eu/cen/Sectors/List/Measurement/Smartmeters/CENCLCETSI_TR50572.pdf.

[18] “Texas Instrument,” [Online]. Available: http://www.ti.com/ww/en/more/solutions/smart-metering.shtml.

[19] “ST Microelectronis,” [Online]. Available: http://www.st.com/web/en/catalog/apps/SE408/AS417?sc=metering.

[20] “Maxim,” [Online]. Available: http://www.maximintegrated.com/en/landing/index.mvp?lpk=634.

[21] “Itron,” [Online]. Available: http://www.maximintegrated.com/en/landing/index.mvp?lpk=634.

[22] “landis and Gyr,” [Online]. Available: http://www.landisgyr.com/.

[23] “Sensus,” [Online]. Available: http://sensus.com/en/web/int/water-management-solutions/product-line/intelligent-metering.

[24] “Elster electricity,” [Online]. Available: http://www.elster.com/en/electricity.

[25] “IBM smart grid,” [Online]. Available: http://www.ibm.com/smarterplanet/us/en/smart_grid/nextsteps/solution/K626033G66635H91.html.

[26] “Schneider Electric,” [Online]. Available: http://www.schneider-electric.com/solutions/ww/en/sol/26048618-end-to-end-smart-metering-solutions.

[27] “LandisGyr smart,” [Online]. Available: http://www.landisgyr.gr/ecologic-analytics-and-landisgyr-to-pre-integrate-smart-metering-solutions/.

[28] “GE smart metering,” [Online]. Available: http://www.gedigitalenergy.com/Meters.htm.

[29] “Sensus smart metering,” [Online]. Available: http://sensus.com/el/web/uk/solutions/smart-metering.

[30] “Elster smart metering,” [Online]. Available: http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/smart-metering/data-management-solutions/Pages/overview.as.

[31] “Autonomous cruise control system,” [Online]. Available: http://en.wikipedia.org/wiki/Autonomous_cruise_control_system.

[32] C. F. Caruntu, “Networked Predictive Cruise Control for Road Vehicles,” in *19th International Conference on Control Systems and Computer Science (CSCS)*, Bucharest, 2013.

[33] “Cooperative Adaptive Cruise Control,” [Online]. Available: http://en.wikipedia.org/wiki/Cooperative_Adaptive_Cruise_Control.

[34] N. Agerholm, R. Waagepetersen, N. Tradisauskas and H. Lahrmann, “Intelligent speed adaptation in company vehicles,” in *Intelligent Vehicles Symposium, 2008 IEEE*, Eindhoven, 2008.

[35] “Lane departure warning system,” [Online]. Available: http://en.wikipedia.org/wiki/Lane_departure_warning_system.

[36] S. Lockhande and V. Gaikwad, “Lane Departure Identification for Advanced Driver Assistance,” *IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS,* 28 Jul 2014.

[37] J. W. Lee and U. K. Yi, “A lane-departure identification based on LBPE, Hough transform, linear

regression," *Comput. Vis. Image Understanding,* vol. 99, no. 3, p. 359–383, Sep 2005.

[38] Y. Wang, E. K. Teoh and D. Shen, "Lane detection and tracking using B-Snake," *Image Vis. Comput,* vol. 22, no. 4, pp. 269-280, April 2004.

[39] C. F. Wu, C. J. Lin and C. Y. Lee, "Applying a functional neurofuzzy network to real-time lane detection and front-vehicle distance measurement," *IEEE Trans. Syst.,Man, Cybern,* vol. 42, no. 4, pp. 577-589, Jul 2012.

[40] X. Ma and C. Mu, "Lane detection based on object segmentation and piecewise fitting," *TELKOMNIKA Indonesian J. Elect. Eng,* vol. 12, no. 5, p. 3491–3500, May 2014.

[41] A. Parajuli, M. Celenk and H. Riley, "Robust lane detection in shadows and low illumination conditions using local gradient features," *Open J. Appl. Sci.,* vol. 3, no. 1B, pp. 68-74, Mars 2013.

[42] J. W. Lee, "A machine vision system for lane-departure," *Comput. Vis. Image Understanding,* vol. 86, pp. 52-78, Apr 2002.

[43] C. R. Kelber and C. R. Jung, "Lane following and lane departure using a linear-parabolic model," *Image Vis. Comput.,* vol. 23, no. 13, p. 1192–1202, 2005.

[44] H. Wang and X. Xu, "Camera calibration based on perspective geometry and its application in LDWS," *Phy. Procedia,* vol. 33, p. 1626–1633, 2012.

[45] J. G. Wang, C. J. Lin and S. M. Chen, "Applying fuzzy method to visionbased lane detection and departure warning system," *Expert Syst. Appl.,* vol. 17, no. 1, p. 113–126, Jan 2010.

[46] L. Saleh, P. Chevrel, F. Claveau, J. F. Lafay and F. Mars, "Shared steering control between a driver and an automation: Stability in the presence of driver behavior uncertainty," *IEEE Trans. Intell. Transp. Syst.,* vol. 14, no. 2, p. 974–983, 2013.

[47] C.-J. L. a. C.-Y. L. C.-F.Wu, "Applying a functional neurofuzzy network to real-time lane detection and front-vehicle distance measurement," *IEEE Trans. Syst.,* vol. 42, no. 4, p. pp. 577–589, Jul. 2012.

[48] "MobilEye," [Online]. Available: http://www.mobileye.com/markets/oem/.

[49] "Oracle utilities Operational Device Management," [Online]. Available: http://www.oracle.com/us/industries/utilities/utilities-operational-device-ds-1689619.pdf.

[50] "Cisco Connected Grid Network Management System," [Online]. Available: http://www.cisco.com/c/en/us/products/cloud-systems-management/connected-grid-network-management-system/index.html.

[51] "Trilliant UnitySuite," [Online]. Available: http://trilliantinc.com/platform/unitysuite.

[52] "IEC 61850," [Online]. Available: http://en.wikipedia.org/wiki/IEC_61850.

[53] "Distributed Network Protocol," [Online]. Available: http://en.wikipedia.org/wiki/DNP3.

[54] "Open smart grid protocol," [Online]. Available: http://en.wikipedia.org/wiki/Open_smart_grid_protocol.

[55] "DLMS/COSEM," [Online]. Available: http://en.wikipedia.org/wiki/IEC_62056.

[56] "DLMS specification," [Online]. Available: http://www.dlms.com/conformance/specification/index.html#0000009bea0e5d501.

[57] "EnergyIP," [Online]. Available: http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/software-solutions/emeter/pages/energyip.aspx.

[58] "Trilliant smart grid communication platform," [Online]. Available: http://trilliantinc.com/platform.

[59] "SilverSpring Smrt Optimizer Tool," [Online]. Available: http://www.silverspringnet.com/products/utilityiq-applications/demand-optimizer/.

[60] "Siemens DRMS," [Online]. Available: http://w3.usa.siemens.com/smartgrid/us/en/demand-response/demand-response-management-system/Documents/DRMS_SellSheet_V2.pdf.

[61] "Lndis+Gyr Load Management," [Online]. Available: http://www.landisgyr.it/webfoo/wp-content/uploads/2012/09/D000043134_a_LM_Brochure_EN.pdf.

[62] "ISO 15118," [Online]. Available: http://www.iso.org/iso/catalogue_detail.htm?csnumber=55365.

[63] "REST," [Online]. Available: http://en.wikipedia.org/wiki/Representational_state_transfer.

[64] "WebSocket," [Online]. Available: http://en.wikipedia.org/wiki/WebSocket.

[65] "OCPP final version," [Online]. Available: http://www.openchargealliance.org/sites/default/files/OCPP 2.0 Final Version %28RC 2.0%29 not yet fully imple.

[66] "OASIS eMix," [Online]. Available: https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emix.

[67] "The Energy Detective," [Online]. Available: http://www.theenergydetective.com/.

[68] "Siemens EcoView," [Online]. Available: https://w3.usa.siemens.com/buildingtechnologies/us/en/energy-efficiency/retail-and-commercial-systems/eco-view-from-siemens/Doc.

[69] "Regen," [Online]. Available: http://www.regenenergy.com/solutions/.

[70] "ESTI TS," [Online]. Available: http://www.etsi.org/deliver/etsi_ts/101500_101599/10155601/01.01.01_60/ts_10155601v010101p

.pdf.

[71] "ISO:17267," 2009. [Online]. Available: http://www.iso.org/iso/home/news_index/news_archive/news.htm?refid=Ref1285.

[72] "ISO:17361," 2007. [Online]. Available: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=41105.

[73] "IEC 61970," [Online]. Available: http://en.wikipedia.org/wiki/IEC_61970.

[74] "RFC 6272," [Online]. Available: https://tools.ietf.org/html/rfc6272.