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D4.2 Report on Billing and stakeholders architecture and ICTs recommendations

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Executive Summary

The aim of this document is to define the communications and the systems to bill the energy used in the recharging of electric vehicles (EVs). This includes the communication flow and data exchange required to implement the billing of the energy recharged and other related services.

When an EV user recharges its EV using the electric vehicle supply equipment (EVSE) of an e-mobility operator which is different from the e-mobility operator with whom he has an electricity supply contract, this situation may represents a roaming scenario. In order to overcome such type of situations, the billing information has to be independent of the owner of the EVSE, and of the energy supplier. Roaming is a general term used in the mobile industry referring to the extension of connectivity service in a location that is different from the home location where the service was registered. In order to allow this functionality in the EV billing process, a definition of the e-roaming concept is needed. E-roaming takes place when an EV user is a subscriber of a retailer of electricity and other services for mobility (E-mobility operator) that provides charging services, and the driver connects his EV to an EVSE which is not operated/owned by its e-mobility operator. In that case, after the validation and charging process, the driver pays for charging services to his e-mobility operator instead of paying to the EVSE operator. According to this definition, e-roaming could be at regional level, using infrastructure from another EVSE operator or from another e-mobility operator, or could be international roaming if the car is from another country and the user e-mobility operator is not present in that market.

In order to make e-roaming possible, all involved stakeholders will need to agree on one common system for payment. In this report, a proposal is presented for the sequence diagram that describes the data exchange between the different involved stakeholders. These stakeholders belong to both energy and ICT industry and have been identified according to the new roles involved in the billing process. Such actors are the clearing house operator, the aggregator, the control service provider, the energy charging gateway operator, the ICT gateway operator and the ICT network operator.

In order to enable control and billing of EV charging considering the new roles of the stakeholders previously quoted, information exchanges are required between them. The sequence diagrams for different stages of the charging process have been considered, namely billing of customer (flexible charging), billing of client (flexible charging) and clearing of metering data, delayed charge, request of load reduction, V2G request activated by aggregator and roaming in a foreign country. These communication flows describe just one of the possible implementation cases and can be used as reference cases for other specific situation by doing simplifications or modifications.

Another important application of ICT in this sector is controlling the relationship of the organization with its customers in order to be able to know matters of customers as who is the EV user, what are the EV user current commercial conditions, what products do the EV buy and how EV users communicate with each other, EV users preferences and their present as well as future needs. This complex world of applications and systems that implement all these functionalities to an organization that provides services to its customers is known as Customer Management and Billing (CM&B or CMB). To implement processes like complex billing of EVs, a complex and well planned CM&B system needs to be implemented to allow for all the envisaged business models. Such platform may be extremely expensive if developed and maintained exclusively for the purpose of EV charging, and therefore, sharing of existing CM&B systems should be always analysed.

Finally, simulations have been derived to determine the behaviour of the EV users regarding recharging process in the different scenario worlds. The results obtained have been used to estimate the amount of data and frequency of communications needed for the billing process. The maximum data bandwidth during a day required for billing has been estimated for both North and South

regions. The results have been expressed for percentages of EV penetration and for each of the scenario worlds described in this project.

The simulation results have noted that during the evening and night, most EVs are connected, while during the rest of the day most EVs are on the road. The network occupation depends on how many EV are connected at a given time. This means that there are periods of time when the capacity of the network is underused. As billing data is not time critical and does not necessarily need to be in a real-time manner, the available capacity during the day could be used for sending billing information not only immediately after charging the EV. This is recommended in order to avoid having communication networks over dimensioned, which can increase significantly the ICT infrastructure costs.

1 Introduction

The EV is a new load that will need to be accommodated and supplied by the electricity system. As any other loads, the energy supplied to recharge the EV needs to be invoiced accordingly. However, the EV has its own characteristics that will cause this process to require a number of peculiarities in comparison to the standard billing. Compared to current power systems, power systems with massive EV-applications present unprecedented challenges to the ICT-infrastructure coupled to the electricity system. An efficient billing of the services provided both by the grid to the vehicles and by the vehicles to the grid will be an integral part of the future ICT solution.

The current document presents the work performed in Task 4.2 of WP4. The aim of this task is to define the communications and the systems to bill the energy used in the recharging of the car, as possibly other related services. This billing information has to be independent of the owner of the EVSE, and of the energy supplier. There is a unique bill of the E mobility operator independently from the network the users are connected to or even the country. In that sense, a definition of the possible E-roaming scenario has been done.

Another aim of the work is to identify the stakeholders and roles that interact in this billing process, in order to study the data exchange required for billing the recharge and other services of EV. In this document, communication flows were described for different scenarios, providing sequence diagrams with the information interchanged during different stages of the charging process.

Alongside this communication flows, this work also includes simulations of the recharging process that have been used to estimate the data traffic required for billing. The results are presented for each of the possible scenario worlds defined in this project (conservative, pragmatic and advanced).

2 Roaming

In this section, an introduction is given explaining what roaming stands for in today's GSM systems. Afterwards, there is an explanation of what roaming will mean for billing of electric vehicles.

2.1 Roaming concept in GSM world

Before explaining the roaming concept in the mobile phones industry, the GSM network is explained. The GSM Network consists of three main parts: the Mobile Station (MS), the Base Station Subsystem (BSS) and the Network & Switching Subsystem (NSS).

The Mobile Station (MS) is the device carried by the subscriber. At the same time, it consists of two elements, the Mobile Equipment (ME) and the Subscriber Identity Module (SIM). The ME is a hand portable device or a vehicle mounted unit. The SIM contains customer related information such as identification, secret key for authentication, etc.

The Base Station Subsystem (BSS) is the element that controls the radio link with the mobile station (MS). The BSS is composed of the Base Transceiver Station (BTS), which defines a cell and is responsible for radio link protocols with the MS, and the Base Station Controller (BSC), which controls multiple BTSs and manages radio channel setup and handovers. The BSC is the connection between the MS and MSC.

The last element is the Network & Switching Subsystem (NSS), which is the responsible of mobility management and switching of calls. These calls can be performed between mobile users, and between mobile and fixed network users. The NSS is formed by the Mobile Switching Centre (MSC) and network databases.

The Mobile Switching Centre (MSC) is the central component of the NSS, and it operates all switching functions for the mobiles within its jurisdiction. In that sense, the MSC is the interface between the mobile and other networks, including the fixed one. The functions that are carried out by this element are:

- Manages the location of mobiles
- Switches calls
- Manages Security features
- Controls handover between BSCs
- Resource management
- Interworks with and manages network databases
- Collects call billing data and sends to billing system
- Collects traffic statistics for performance monitoring

The network databases are formed by several databases that storage all the information needed to make the calls possible. For example, the Home Location Register and the Visitor Location Register together with MSC provides the call routing and roaming capabilities of GSM. These network databases are:

- Home Location Register (HLR) contains all the subscriber information for the purposes of call control, and location determination. There is logically one HLR per GSM network, although it may be implemented as a distributed database.
- Visitors Location Register (VLR) is only a temporary storage while the particular subscriber is located in the geographical area controlled by the MSC/VLR. It contains only the necessary information provision of subscribed services.
- Authentication Center (AuC) is a protected database that stores the security information for each subscriber (a copy of the secret key stored in each SIM).

- Equipment Identity Register (EIR) is a list of all valid mobile equipment on the network.

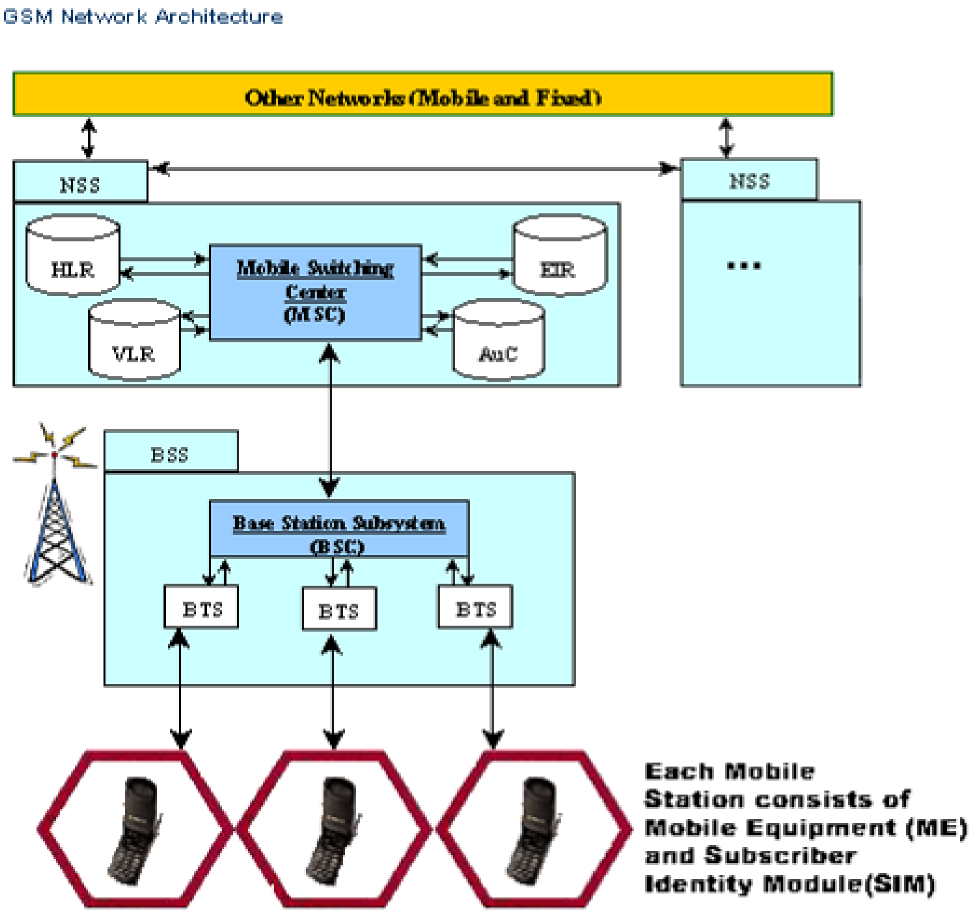

Figure 1: layout of generic GSM network [3].

In Figure 1 there is a layout of a generic GSM network with all the elements described above. When the MS turns on in a different network than the subscribed by the user, the VLR detects a foreign number. Then, it talks to its HLR through an international gateway or connection and then, the HLR sends the subscriber required information back. In that process, the important actors are both databases VLR and HLR, which in that case, will be owned by different Service Providers. Over them, a hub communicates the different database's Service Provider.

Example of roaming in GSM with internet data connection

When you travel abroad and you turn your handset or laptop on, it attempts to communicate with a local GSM or 3G network. In that case, you are allowed to choose your own preferred network via the handset menu. The local network picks up the signal from your device, notes that you are a visitor and attempts to identify your subscribed network. If there is an agreement between your home network and the visited network abroad and your network operator allows you to roam, your device will then be able to access data roaming services. In some cases, the local network may only offer limited data services such as SMS and GPRS-enabled services, such as e-mail, but not 3G/mobile broadband services.

When you use the mobile internet abroad, including push e-mail, handset internet and mobile broadband services (also called Packet Switched Data (PSD)), your connection is established by the visited operator's network back to your home operator's network. Then, the visited operator's network passes your internet traffic via international data transit to and from your home network. In that sense, it is your home network the responsible of connecting you to the internet, your e-mail accounts and the rest of data services used.

After using roaming services, the network operators need to exchange the billing information in order to charge the roaming customers. For all data services and voice calls, the visited network captures the details of every session in a Call Detail Record (CDR). The information recorded are basically related to the location, sending party, receiving party, time of connection, session duration and size (measured in kB or MB). The visited network operator then uses these details to calculate the roaming charge payable by your home network. The data records, including the applicable wholesale charges, will be saved in a Transferred Account Procedure (TAP) file. TAP files are sent from the visited network to your home network, typically by using the services of a data clearing house. A data clearing house acts as a 'hub' for the distribution of TAP files and provides the home network with services such as reporting to assist the home network in running its roaming business. Your home network then pays the visited network the appropriate wholesale charges.

Finally, the internet data services need to be paid. When a customer connects to internet while roaming, the retail price he pays has to cover the following elements: signalling network fees, the wholesale charge for using the data connection on the visited network, costs for the international transit of the data, costs for connecting to the internet from the home network, data clearing house fees, other costs (e.g. commercial costs, IT costs, prepay checks), the home operator's retail costs and taxes, such as VAT. The usage of these internet data services is generally measured by data volume usage, which is highly dependent on the type of device and services used. The visited network operator, however, has no visibility of what type of data services visiting customers are using and therefore the wholesale price charged to the home operators can only be based on the data volume used per customer.

2.2 EV roaming

The explanation of the GSM roaming concept has shown the needs for the cooperation of different stakeholders in order to offer their customers unrestricted service independent of their location. It has been clearly shown, that the case of roaming always appears, when a stakeholder cannot serve its own customer directly anymore.

Roaming is a general term used in the mobile industry referring to the extension of connectivity service in a location that is different from the home location where the service was registered. E-roaming in the electric vehicle concept is defined when all the following conditions are met: an EV user is a subscriber of e-mobility operator that provides charging services. The driver connects his electric vehicle to an EVSE which is not operated by his e-mobility operator. After the validation and charging process, the driver pays for charging services to his e-mobility operator not the EVSE operator.

Roaming is for service and billing, and an agreement between the entities is needed. Roaming could be at regional level, using infrastructure from another EVSE operator or from another e-mobility operator, or could be international roaming if the car is from another country and the user e-mobility operator is not present in that market. An alternative to e-roaming is that EV owners can pay directly for the service using a prepaid card or a credit card. Discriminatory access or non-discriminatory access concepts are part of the business model and would be agreed between the different parties, if not imposed by legislation.

The Clearing House (CH) definition in the e-mobility sector is wider than the current one used in the financial market, and it includes technical aspects regarding agreements, contract relations, and security certificates. It has been discussed to change de name of the CH (i.e. to Interoperability Hub) in order to avoid misleading confusions about the term, but CH is already used in many e-mobility projects (such as GeM) so it was greed to keep the name, and take into account the increased functionalities. CH could have also different functionalities depending of the regulation and the market present in the different countries. For example, in Spain, it would have a role more related with service providers (in terms of billing, and contracts) and not related with energy stakeholders. In other markets the CH will need a communications with traditional energy stakeholders like DSO, MPO, etc. The CH functionalities are not linked to roaming scenarios, so it could be used in common billing scenarios as described in D4.2 communications flows.

Regarding roaming scenarios:

- CH has to be considered as one possible option to operate the infrastructure. It is possible to have an agreement with e-mobility operators without using a CH. This solution could be useful at the low rate EV penetration so could be in the pragmatic world.
- CH is the neutral entity mediating between two partners to provide validation services for exchange of technical information, contract relations or security certificates.
- CH offers functionality such as checking for roaming agreements and routing, aggregation and retrieval of mobility services. General routing of messages (for example for billing) will be supported. It will deal with charges for the service, additional roaming fees, information about the transferred units, the parties participating in the agreement.

Roaming also usually takes place, when the customer goes abroad. Similarly, when electric vehicles move around like people do nowadays with their cell phones, they have to connect to charging poles in many different locations and most likely they will have to connect to charging poles owned by different companies. However, we assume that every user of an EV will only want to have a contract with one e-mobility operator who bills all the energy that the user consumes with his EV – regardless of the place where he connects to the grid. Therefore, there is (almost) no fixed geographical area where a user can be served only by his contractor. This makes up the first and most obvious difference between GSM and EVs and it is one of the reasons why this document follows its own definition of roaming rather than the definition given for GSM.

Additionally, there is another very important difference between GSM and the electric energy sector that requires its own definition of roaming. The EV user can NEVER be served only by the stakeholder he has a contract with. Due to the unbundling, there are always many stakeholders involved, e.g. the retailer and the grid operator – just to mention two.

3 Billing of flexible charging and storage

3.1 Introduction

This section describes in detail the data exchange required for billing of charging and other services of electric vehicles. It is meant to be used to estimate the amount and frequency of data exchanged between all stakeholders involved in this process. The communication flows of this section describe all possible data exchange that can be imagined in any of the scenarios worlds contemplated in this project. Different components can then be used in order to evaluate the ICT requirements of specific concepts, which are defined later in other work packages.

Due to the reasons stated above, data exchanges described in this document can be taken as an example from which, depending on the specific situation, simplifications can be made or new process can be added to form a more simple or complex case. The cases shown in this document are not directly aligned with the different scenario worlds, as they can be used in more than just one scenario.

To align the description of billing activities with other work packages, there is a short description of stakeholders before presenting the communication flows. This includes the description of how these stakeholders interact with each other in the billing process and why they play an important role. Afterwards, different elements of the billing process are described in detail by giving a sequence diagram of the data exchange between the stakeholders and the different roles respectively. The sequence diagrams also contain all the required information about the amount of data of any interaction between stakeholders as well as the exchange frequency of this kind of data.

3.2 Stakeholders - Roles and Relations

The development of ICT solutions with respect to a mass of electric vehicles requires a description of the different roles of the energy and ICT industry as well as their relations.

The ENTSO-E (European network of transmission system operators for electricity) already developed a "role model" in [1] for roles of the energy industry

"A role model of this nature shall be the formal means of identifying roles and domains that are used in information interchange in the electricity market. It therefore can affect the way business processes are designed for automation. It ensures that the information exchanged between parties corresponds to a process managed within the electricity market between distinct roles that are assumed by specific parties.

The necessity for such a model arises from the possibility of a single party in the market to assume multiple roles." [1].

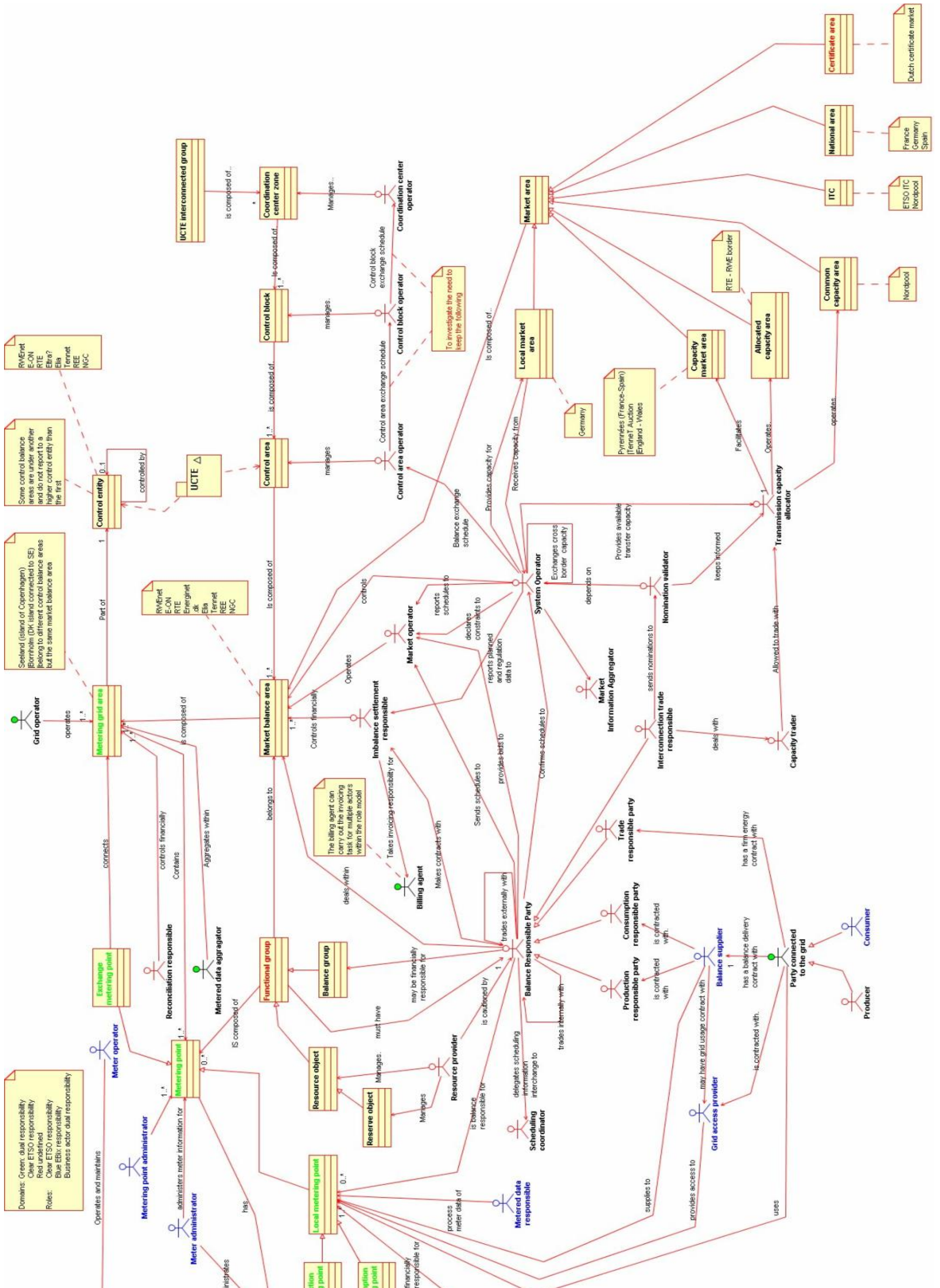

Figure 2: "The Role Model" of ENTSO-E [1]

For the purposes of the G4V project a simplified role model is needed which bases on the stakeholder analysis of WP2. In general, this role model is set up on the 'entso-e role model' not to the same scale but only takes roles into account that affect the scope of the project. In order to establish a connection to the ICT solutions of WP4, the identified stakeholders and functions of the stakeholder analysis have to be transferred into such a role model. The executions of the 'entso-e role model' stay unaffected.

Figure 3 gives a summary of the stakeholders and functions of the stakeholder analysis at a glance. In this picture it has been focused to depict the stakeholders of the ICT and energy industry.

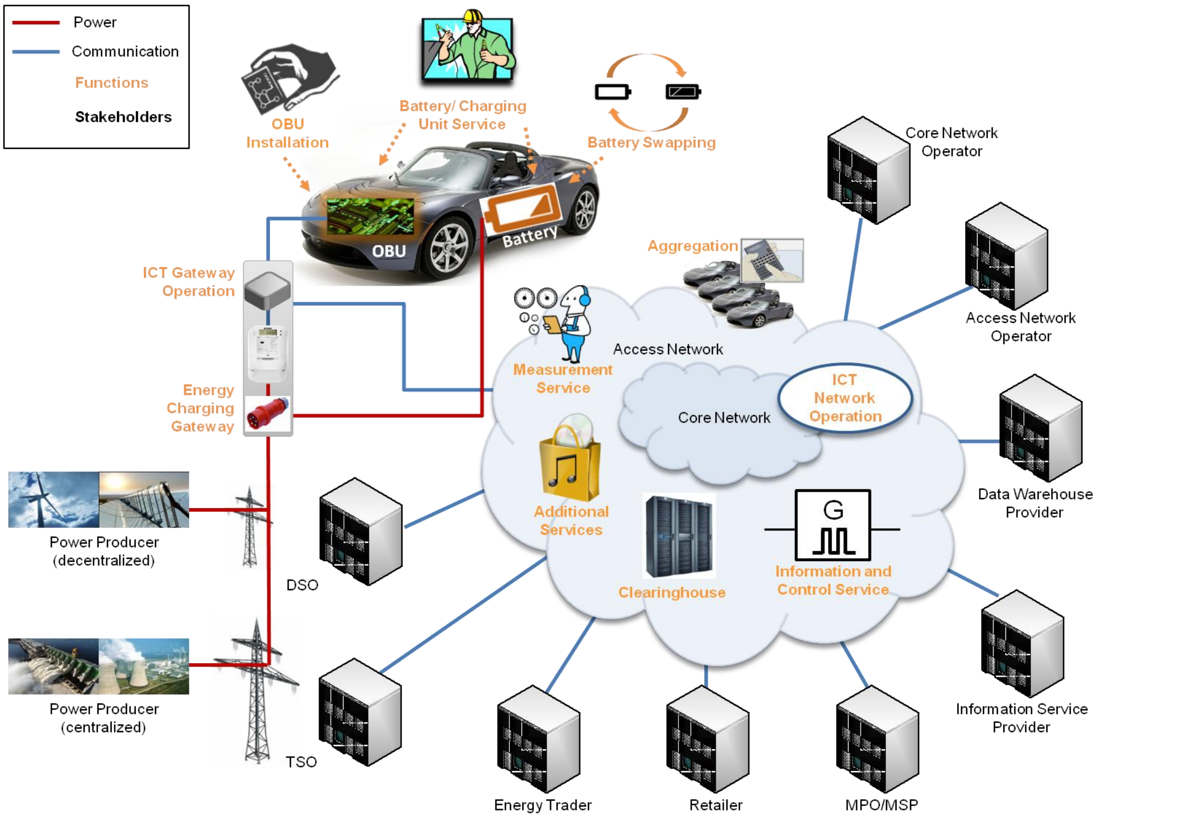

Figure 3: overview of stakeholders and functions

Figure 4 depicts the elaborated role model with respect to e-mobility, differentiating between stakeholders (grey heads) and roles (red heads). Stakeholders are types of legal entities who occur in existing industries and unite several roles to a specific business model or regulated business. Roles represent functions and responsibilities of an indivisible value added step. The role model (Figure 4) considers the roles as independent business units although they are combined to several business models in WP2. "A role represents the external intended behaviour of a party. Parties cannot share a role. Businesses carry out their activities by performing roles, e.g. system operator, trader. Roles describe external business interactions with other parties in relation to the goal of a given business transaction." [ENTSO-E].

The analysis of roles and relations focuses on selected stakeholders and roles of the Stakeholder Analysis document, which are relevant for the purposes of WP4. So the selected stakeholders and roles have a decisive importance with regard to the development of information and data flows. These flows constitute a part of the ICT solutions for electric vehicles that are focused on WP4.

E-mobility operator is a new role that could be assumed by either the actual retailer or the new aggregator. For that reason, in the communication flows of this document, the e-mobility operator is not contemplated and its role is performed by the retailer or the aggregator.

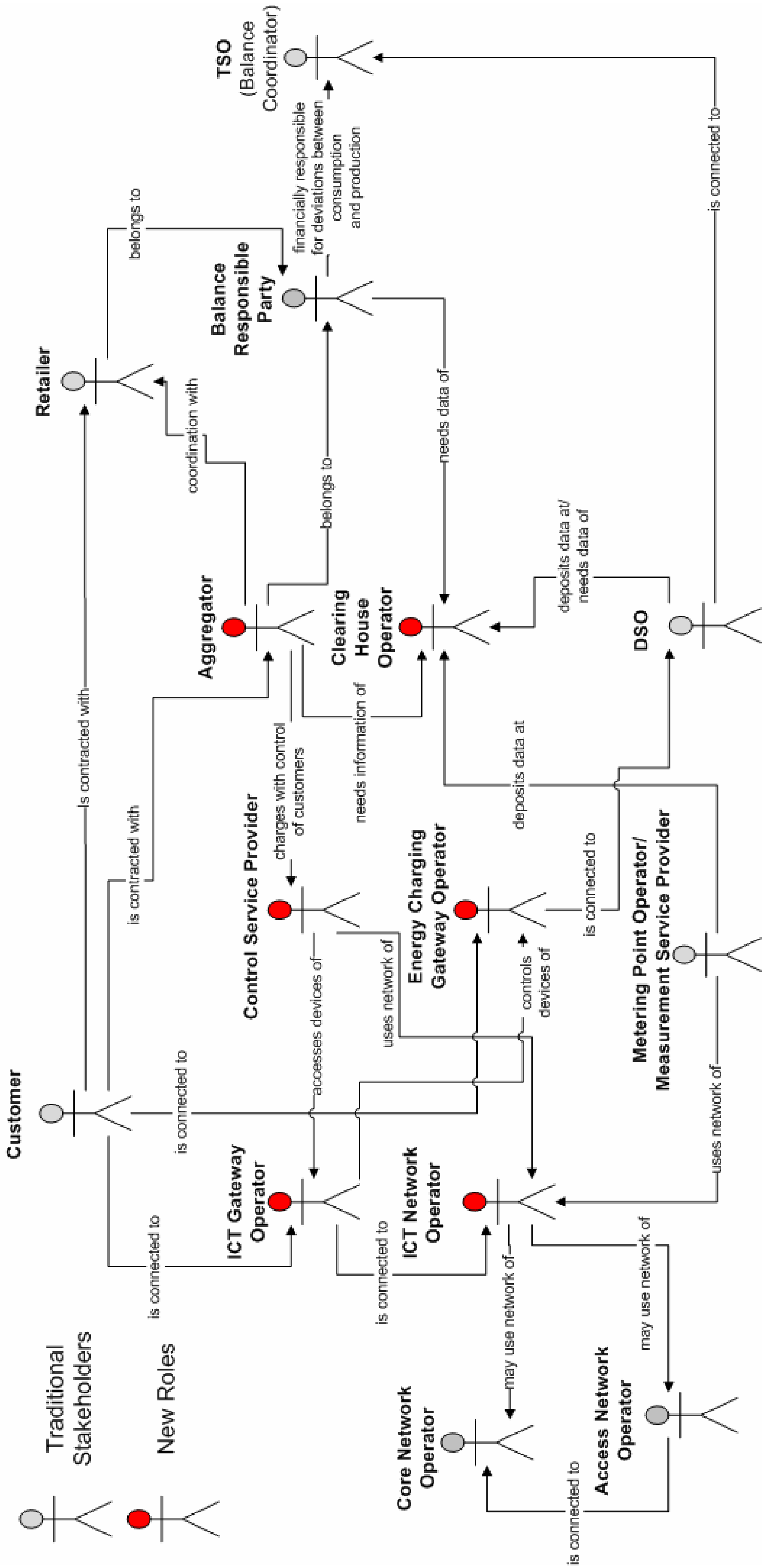

Figure 4: stakeholder – roles and relations

3.2.1 Stakeholders

The description of stakeholders equals that of the stakeholder analysis.

Customer

The Vehicle Owner owns an electric vehicle. Depending on the identification process the vehicle owner and/or the vehicle user has a contract with the retailer and is financially responsible for the charged energy.

Retailer

The retailer sells electricity to final consumers. Private customers usually have all-inclusive contracts which include the supply of electric energy and the grid access and usage. In this case the retailer is the only interface with the customer and is responsible for the invoice of the contract. For larger customers the electricity and the grid access may be sold separately. That means the retailer only sells and bills the electricity. The charge for the grid access and usage is subject to the DSO. The retailer procures the electricity for his customers on the wholesale market for electricity.

Balance Responsible Party

The Balance Responsible Party is financially responsible toward the TSO for the deviations in each quarter-hour between the consumption of his customers and the purchased production of electric energy. Balance in this context signifies that the quantity contracted to provide or to consume must be equal to the quantity really provided or consumed. Such a party is often owned by a number of market players especially retailers. This is the only role allowing a party to buy or sell energy on a wholesale level.

TSO (as Balance Coordinator)

The TSO is the responsible entity for operation, maintenance and expansions of the extra high voltage network (>110 kV) for long-distance transportation of electricity. The TSO is also responsible for the safe operation of the overall system in a control area which implies a stable system frequency and keeping voltage levels within specified limits. In order to achieve safe system operation the TSO procures and manages ancillary services. For frequency control, active reserve power is procured by the TSO and deployed for the Balance Responsible Parties operating in his control area.

DSO

The DSO is the responsible entity for operation, maintenance and expansions of the electricity grid that is used to supply the end consumer with electricity. Typically the network includes the medium and low voltage level. In some countries the distribution network also includes the high voltage level. Quality and security of supply are important issues for the DSO. Quality is reflected by keeping the voltage deviations from the nominal level within certain limits. Security implies a sufficient number of different assets with adequate capacities. The DSO is a regulated stakeholder as well and is also obliged to provide non-discriminatory and transparent access to its network to all requesting other market participants.
With reference to the billing of customers the DSO provides standardized load profiles of typical customer groups. A future group which requires standardized load profiles may be the EVs.

MPO/MSP

The Metering Point Operator (MPO) installs and maintains the metering point. The Measurement Service Provider is responsible for the execution of the measurement. Traditionally these activities were usually provided by the DSO as it is still the case in many countries.

Access Network Operator

The Access Network Operator has two main functions. First he installs, operates and maintains the communication access lines ("last mile") to the customers. Depending on the communication technology the access can be wired as well as wireless. Secondly he aggregates different access networks and provides an interface connection to the core network. The Access Network Operator enables direct contact to the terminal of the customer. Otherwise he doesn't provide any services to the customer. The access network is regulated by the regulator because of its character of a monopoly.
In comparison to the core network the access network has low transmission capacities. The capacities depend on the deployed communication technology.

Core Network Operator

The Core Network Operator installs, operates and maintains the assets of a core network. The employed assets depend on the communication technology. The Core Network Operator mainly assumes routing and transmission of information deriving from an access network. In addition he provides services which mainly refer to the quality of routing and transmission (e.g. latencies) as well as participant management and messaging.
In comparison to the access network the core network has higher transmission capacities. Capacities depend on the deployed communication technology.

3.2.2 Roles

The description of roles is derived from the formulation of functions identified in the stakeholder analysis.

Clearing House Operator

The Clearing House Operator operates the Clearing House and provides the required products and services to the various customers. Main services are the authentication of customers and the provisioning of billing data.

Aggregator

The Aggregator with reference to e-mobility aggregates the decentralized feed-in of electric vehicles to tradable products for several stakeholders as the DSO, TSO and the Retailer. The Aggregator belongs to a Balance Responsible Party which has to handle a balance group.

Control Service Provider

The Control Services Provider generates and implements information and control signals and transmits them to the ICT Gateway by using various ICT Networks. Control signals and (price) information are mainly used to affect the charging process of the customer.

Energy Charging Gateway Operator

The Operator of the Energy Charging Gateway Operator installs, maintains and operates the equipment which physically supplies electricity to the vehicle with a switch that can close or open the supply. In every type of a "smart" charging pole which is connected to an ICT Network, the energy charging gateway has to be technically coordinated with the ICT Gateway.

ICT Gateway Operator

The ICT Gateway Operator installs, maintains and operates the ICT Gateway. The installation may take place in the mechanical housing of the Energy Charging Gateway. The ICT Gateway controls the isolating switch of the Energy Charging Gateway and communicates with the Vehicle OBU in the car.

ICT Network Operator

The ICT Network Operator operates several kinds of ICT Networks by using various communication technologies and standardized protocols.

3.3 Communication flows

In order to enable control and billing of EV charging, communications is required between the stakeholders and roles described above. The following section gives detailed information about the communication flow during different stages of the charging process, providing sequence diagrams and a short description as well as data volumes and frequency of communication.

The flows and the cases described below are one of the possible implementations. They can be taken as reference cases from which, depending on the specific situation, simplifications or modifications can be made. One of these situations that can determine the communication flow is the place where the EV is charged (home charging, at work, street, or for public parking). In that sense, some of these advanced models, such as flexible charging or V2G, are unlikely to appear outside domestic charges, they should be considered as well for other possible situations. For that reason, no distinctions are made between the places where the EV is charged.

Authorization process

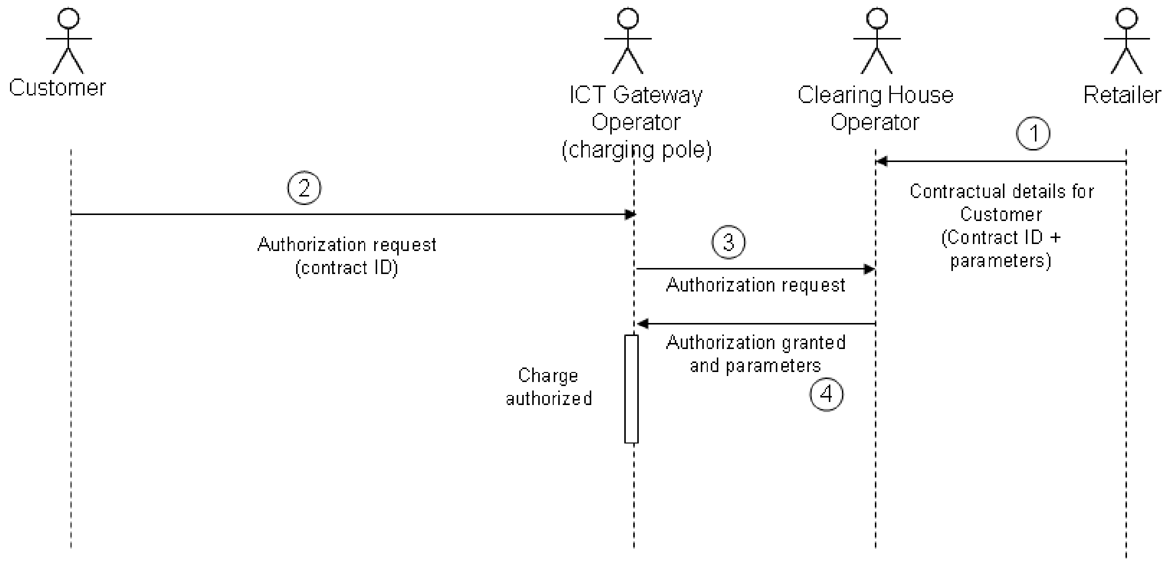

Figure 5: Authorization process

This flow shows the communication needed to perform the authorization process, i.e. all the actions needed to authenticate the contract that shall be used for energy billing and to authorize the charge process. It is important to note that this is a generic flow, which shows the communication among the actors involved in this process and that it is not dependant on the specific technology that the Customer uses to provide the contractual information (e.g. RFID or Plug&Charge).

1. When the Customer subscribes a contract with the Energy Retailer, the Retailer provides the relevant contractual information to the CH for its processing.
2. Customer accesses the charging infrastructure requesting for an authorization. This request contains the contract ID and it is a responsibility of the ICT Gateway Operator of accepting and managing the transmission and reception of information associated with that authorization.
3. The ICT Gateway Operator forwards the request to the CH, which already has the contractual information for that client.

4. If the contractual position is valid, the CH replies to the ICT Gateway Operator granting the authorization and providing additional parameters to be used during the charging process (e.g. the maximal contractual power, or the tariffs to be used, depending on specific market regulations).
5. After receiving the authorization, the charge operation can begin.

3.3.1 Billing of Customer (flexible charging)

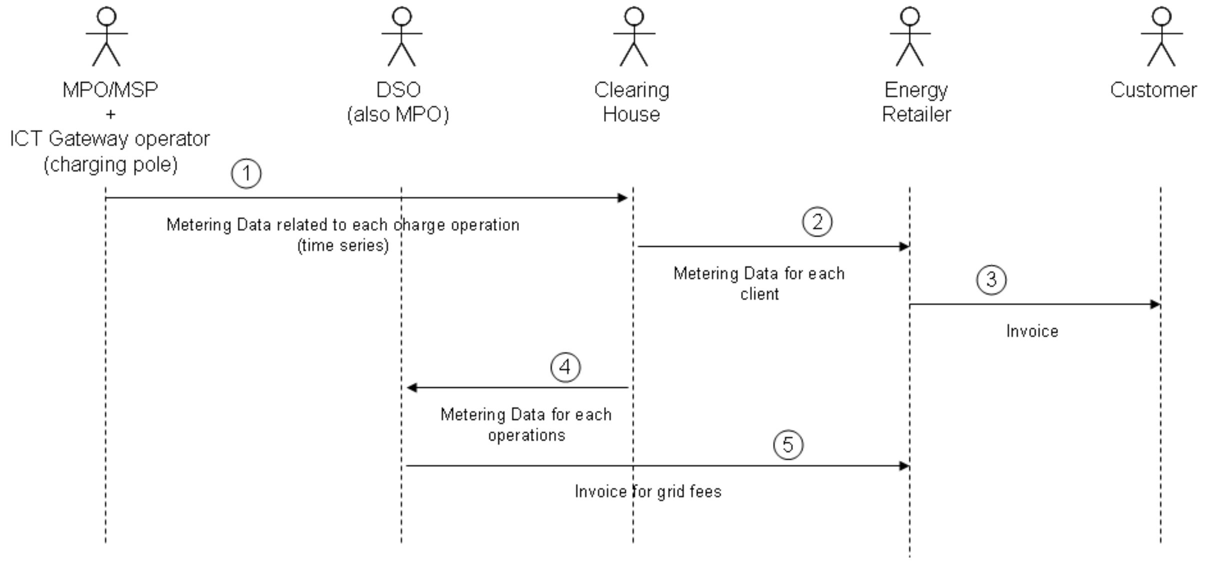

Figure 6: Billing of customer

This information flow shows the sequence of messages needed to bill the Customer for the energy taken for charging the EV. In this special case, the DSO is also a MPO/MSP, hence it has the responsibility for metering data. Next sequence flow shows the most general case with all the roles separated. Moreover, in this example, the DSO outsourcers the data warehousing activity to the CH: the CH performs all the technical activities needed to collect, store and dispatch metering information. It is worth underlying that, also in this case, metering responsibility is still up to the DSO. Finally, the charging point integrates both the smart meter (MPO/MSP) and the ICT equipment (ICT GW Operator).

1. The ICT Gateway Operator sends detailed metering data (time series) to CH for each charge operations (metering data are provided by the meter inside the charging point)
2. The CH sends, to each Retailer, the metering data for its Customers.
3. The Retailer, using the metering data, can bill the Customer. Depending on the details provided by metering data, the ER can implement more or less complex commercial offers (e.g. TOU tariffs).
4. The CH provides to the DSO all the metering data for all the charging point in its grid.
5. Based on these data, the DSO can bill the Energy Retailer for the grid usage.

3.3.2 Billing of client (flexible charging) and clearing of metering data

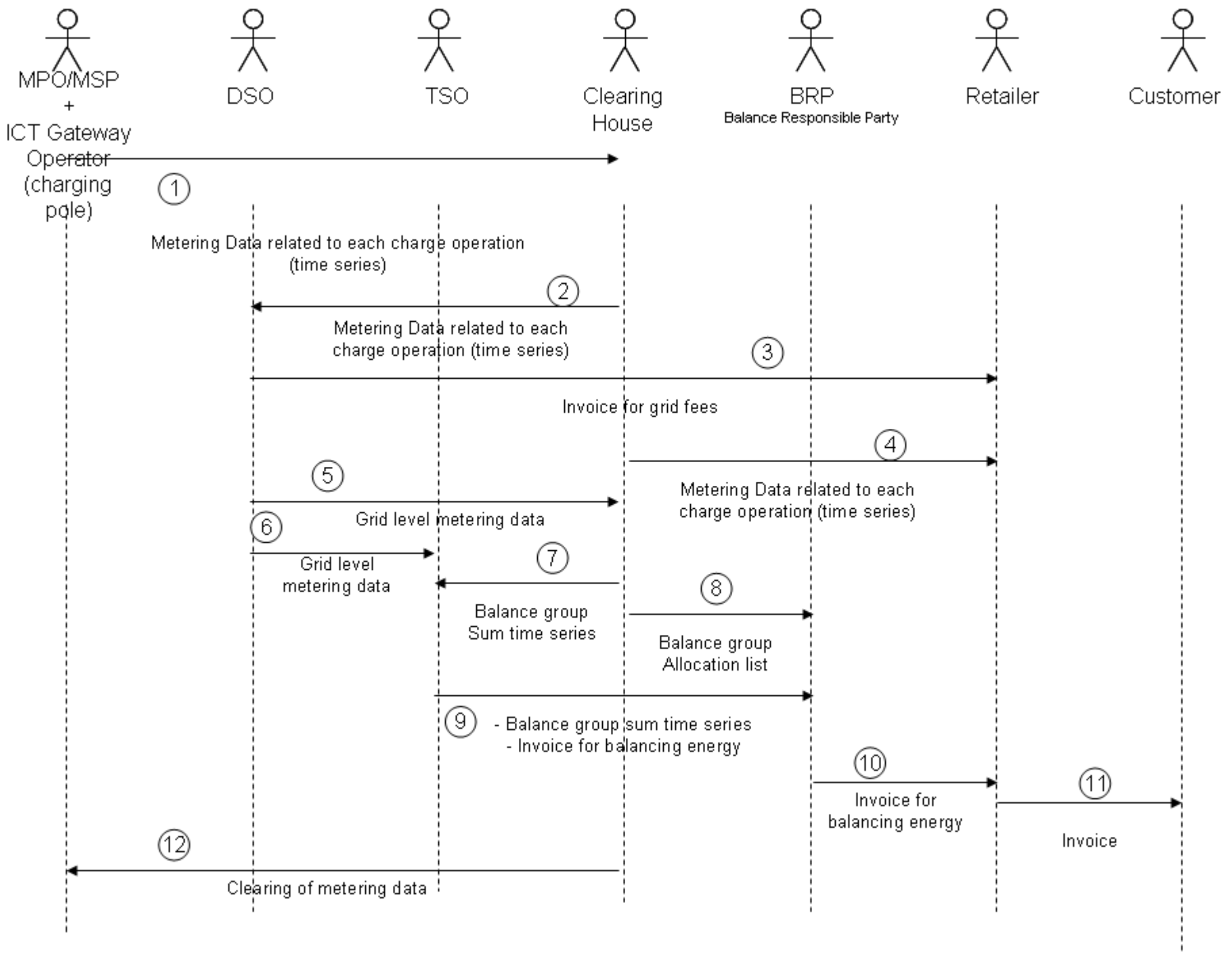

Figure 7: billing of client and clearing of metering data

This flow shows a more complete scenario, where every technical function is performed by a separated actor. Moreover, it shows all the data exchange needed to assure the clearing of metering data.

1. The ICT GW Operator sends to the CH the metering data collected by the Measuring Point (MPO/MSP). Inside the CH databases, allocation of measurement data are associated to the respective DSO (by Measuring Point Number) and to respective Retailer by Customer Identification Number (CID);
2. The CH sends collected data (time series) to the respective DSO associated to the Measuring Points within the network area (basis for account with Retailers, verification of losses);
3. The DSO periodically bills the Retailer for the grid fees;
4. The Clearing House sends time series to each Retailer, which contains load profiles of each charging operation of Retailer's Customers;
5. The DSO periodically sends the CH:
   - grid time series containing load time series of respective grid which are generated by collected data of MPO/MSPs and measurement data of measuring points at the border to other grids (basis for clearing process);
   - accounting data for grid usage for each Measuring Point of the respective DSO;
6. The DSO sends grid time series periodically to TSO containing load time series of respective grid which are generated by collected data of MPO/MSPs and measurement data of measuring points at the border to other grids;

7. Periodically the CH sends to TSO sum time series of each balance group based on collected data of MPO/MSPs amount of data;
8. Periodically the CH sends to BRP balance group an allocation list created by Clearing House and containing the allocation of customers to the respective balance group;
9. Periodically the TSO sends BRP:
   - sum time series of balance group matched with grid time series for respective Balance Responsible Party;
   - charges balance energy which is purchased by the TSO (unless Balance Responsible Party purchases balance energy himself);
10. Balance Responsible Party charges balance energy for Retailers allocated to his balance group (not applicable if Retailer and Balance Responsible Party are one entity);
11. Retailer charges energy to Customer (could contain different prices for respective energy purchase, maximum of occupied power, ...) and grid usage (possibly flexible);
12. Clearing process is carried out to match collected measurement data with historical data of this Metering Point in order to verify the measurement results. In addition, measurements of the DSO within his grid may allow conclusions regarding to the load profile of the respective Metering Point.

3.3.3 Delayed charge

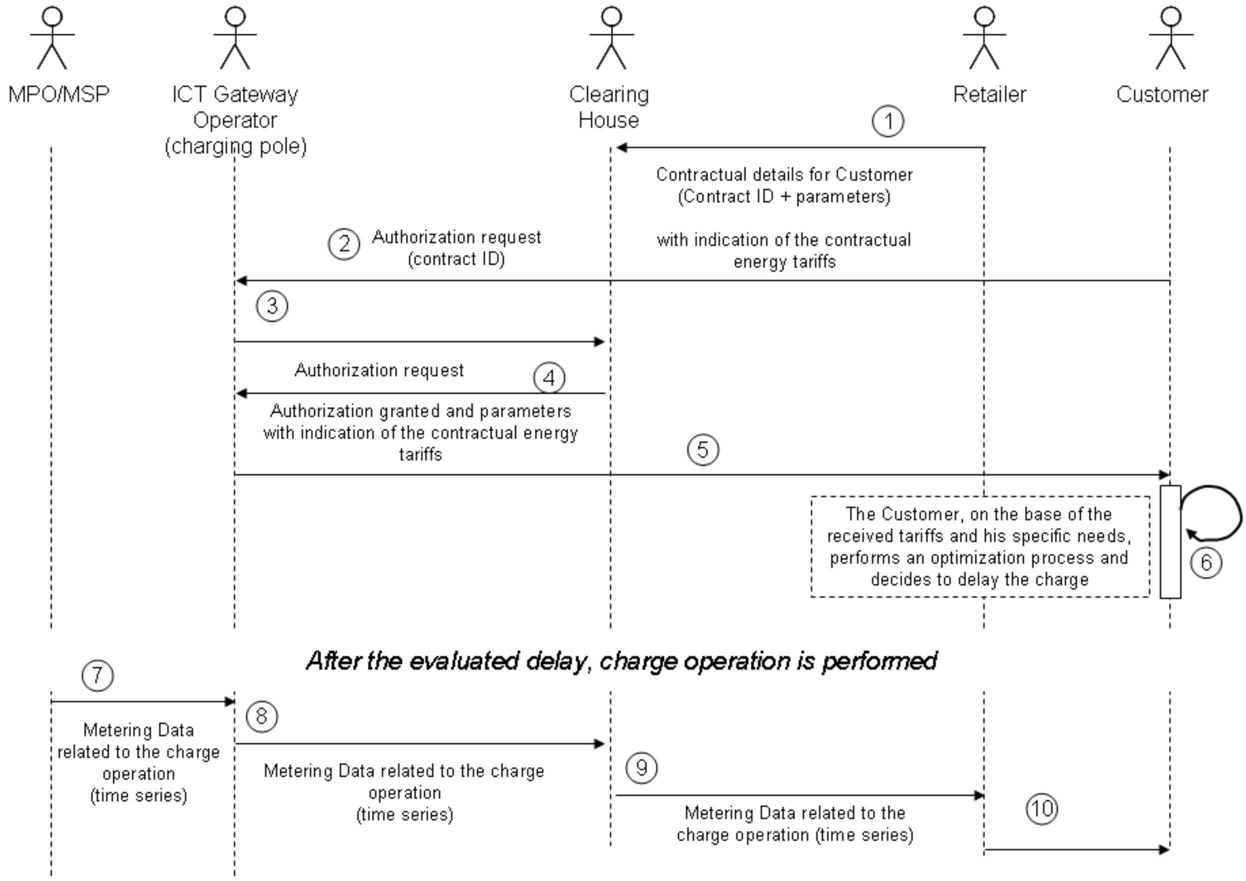

Figure 8: delayed charge

This flow shows an example of the kind of functionalities that is possible to achieve using the flexible charging illustrated in previous communication flow. In this example, the Retailer's contract envisages different tariffs depending on the time in which energy is taken (TOU tariffs). Hence, the charge could be delayed in order to use a more convenient energy tariff (for example at night).

1. When the Customer subscribes a contract with the Energy Retailer, it provides the CH with the relevant contractual information, possibly including the specific energy tariff for that particular Customer;
2. The Customer accesses the charging infrastructure requesting for an authorization. This request contains the contract ID, and the ICT Gateway Operator has the responsibility of accepting and managing that request;
3. The ICT Gateway Operator forwards the request to the CH, which already has the relevant contractual information for that Customer;
4. The CH replies to the ICT Gateway Operator, granting the authorization and providing all the needed contractual parameters including the TOU schedule;
5. The ICT GW present the tariffs to the Customer (for example transmitting them directly to the EV via a communication channel between charging pole and EV);
6. After receiving the authorization and the tariffs, the Customer can decide to postpone the charge in order to reduce the overall cost of the charge. This optimization shall most likely performed automatically by the OBU on the EV, which knows how much energy is needed and when the Customer needs to use the EV again;
7. When the charge operation is completed, metering data are collected from the smart meter (managed by the MPO/MSP). This metering data will show that the Customer has delayed the charge and will permit the Retailer to bill him accordingly;
8. The ICT GW transmits metering data to the CH;
9. The CH sends the Retailer the metering data;
10. The Retailer can bill the Customer taking into account the applicable tariffs.

3.3.4 Request of load reduction

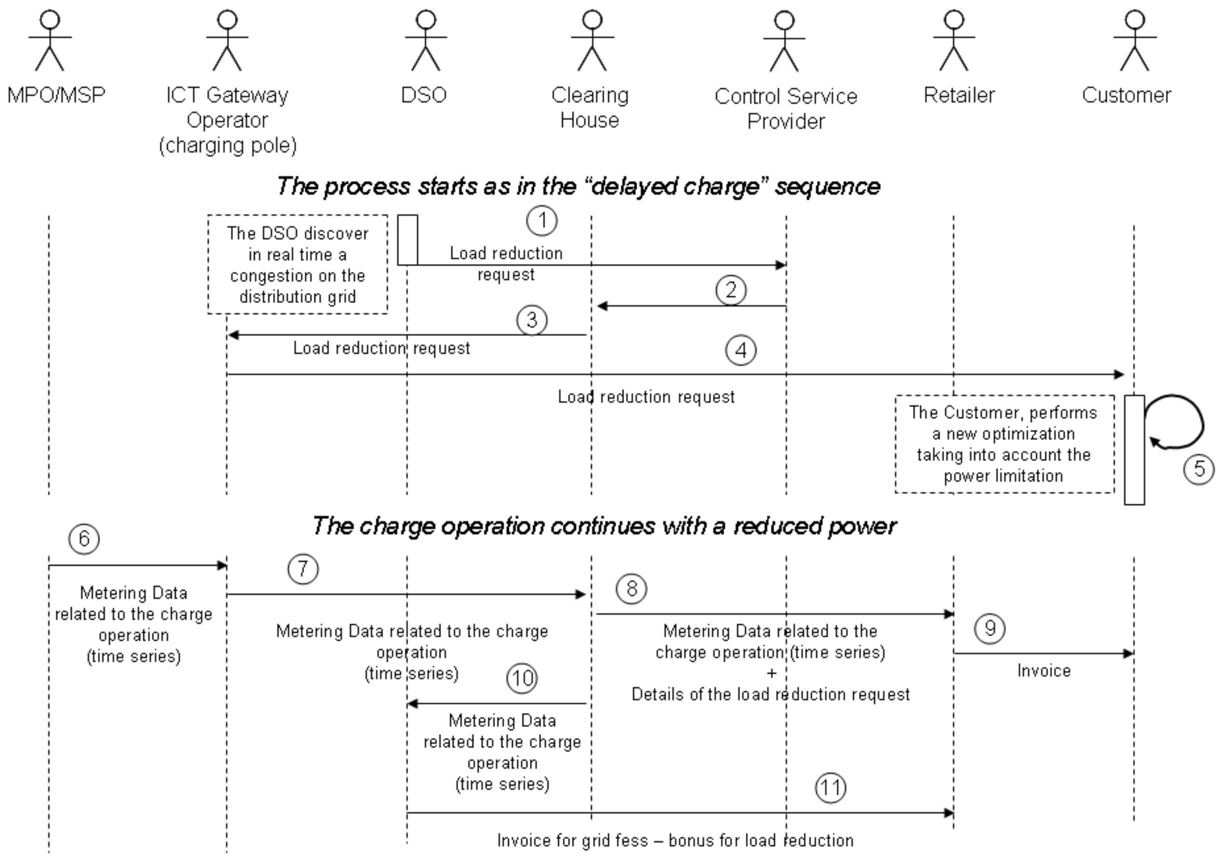

Figure 9: Request of load reduction

In this example, there is a request coming from the DSO in order to reduce the load when a congestion is detected on the distribution grid. The charge process starts normally with a standard sequence, as the one presented in the "delayed charge" communication flow.

1. The DSO detects in real time that there is a congestion on a portion of the distribution grid and evaluates that a reduction of the load can solve the situation. Hence, the DSO sends to the Control Service Provider a request for load reduction in a given area;
2. The Control Service Provider forwards the request to the Clearing House;
3. The CH forwards the request to all the ICT Gateways (charging points) in use in the portion of the grid affected by the congestion;
4. The ICT GW forwards the request to the Customer. Practically, the request will be forwarded to the EV using a possible communication channel, such as the Power-Line Communication (PLC) or the Pulse Width Modulation (PWM) pilot signal;
5. In case of intelligent EV, a new optimization procedure can be performed to evaluate a new charge profile. In the case of a simple EV, there is just a reduction or full cut of power;
6. When the charge operation is completed, the metering data is collected from the meter (managed by the MPO/MSP);
7. The ICT GW transmits metering data to the CH;
8. The CH sends the Retailer the metering data and, in addition, transmits the information that a power limitation event has been required by the DSO;
9. The Retailer can bill the Customer taking into account also a special bonus to compensate the power reduction request;
10. The CH provides the DSO all the metering data for all the charging process;
11. Based on this data, the DSO can bill the Retailer for the grid usage. A special bonus shall be applied in order to compensate the Retailer, which will in its turn compensate the Customer.

3.3.5 V2G request activated by Aggregator

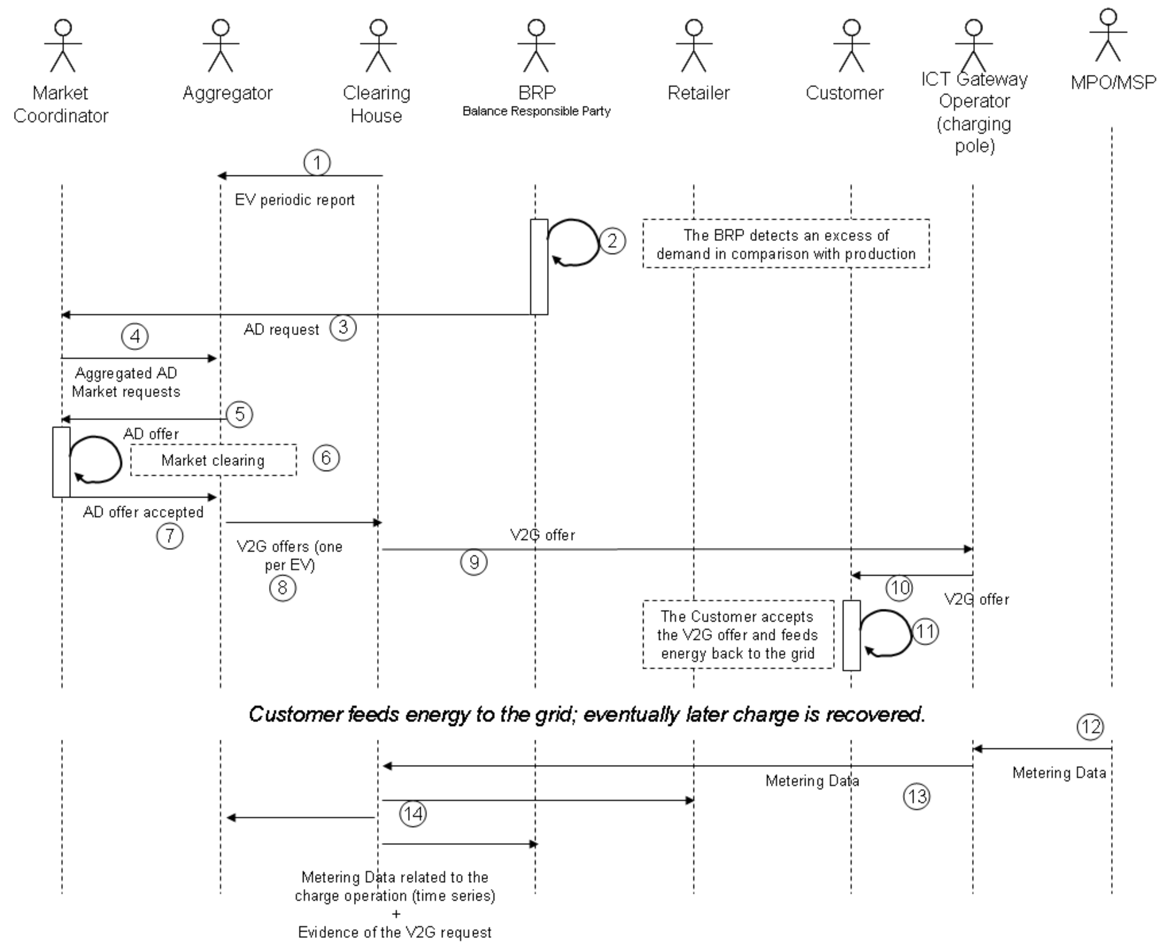

Figure 10: V2G request activated by aggregator

This example shows the case of an Active Demand (AD) request, coming from a BRP, which starts a V2G service.

A new actor is shown here: the **Market Coordinator**. The Market Coordinator has the role of coordinating the Active Demand services market, which will be the place where AD services are to be traded. Most likely, this market shall be a branch or a sub-function of existing energy markets and will have its own market clearing procedures. In this example, the Market Coordinator:

- Accepts AD requests (volumes and prices) from different purchasers;
- Aggregates them;
- Request Aggregators to send offers (in response to aggregated requests);

When all the Aggregators have sent their offer (volumes and prices), the Market Operator:

- Performs the market clearing process;
- Establishes the price of AD services and decides which offers and which requests are to be accepted;

Active Demand market procedures are not specific to electric mobility and are the research topic of other FP7 projects, such as Address™ project. Hereafter, this example has not the purpose to provide a description of AD market, but just to illustrate possible areas of synergy between AD market and electric vehicles. In the following example, the Customer is required to provide energy back to the grid (V2G), but it is possible to use the same process to activate other kind of services (load reduction, charge delay, etc.).

1. The CH periodically sends to all the Aggregators an updated report of the status of the EV belonging to Aggregator's Customers (which are in charge and where). This periodic report shall be a service offered by the CH to all the Aggregators;
2. The BRP detects that there is an excess of energy demand and estimates that an AD service could solve the issue;
3. The BRP makes an AD request in the Market Coordinator;
4. The Market Coordinator combines all the AD requests and sends to all the Aggregators the result of this combination;
5. Each Aggregator, on the base of the status of its Customers (both residential and EVs) makes an offer to the Market Coordinator;
6. The Market Coordinator performs a clearing procedure to decide:
   - which offers and requests are accepted;
   - the closing price for AD services;
7. The Market Coordinator sends a confirmation back to each Aggregator accepted
8. The Aggregator sends AD offers to all its Customers. For EVs, it sends a request to the CH containing the list of the Customers involved. The offer specifies the remuneration for the V2G service;
9. The CH forward the request to all the ICT GW where specified Customers are charging;
10. The ICT GW forwards the request to the Customer. This step can be done via a direct communication between ICT GW and EV;
11. The Customer accepts to participate in the AD service and starts feeding energy to the grid (V2G function). At the end of the AD service, normal charge can be recovered. Depending on the remaining time, all the supplied energy can be retrieved back in the battery or not. The first case is called *"inclusive charging"*, while in the second is called *"exclusive charging"*;
12. At the end of the charge process, the meter (managed by the MPO/MSP) provides metering data as a bidirectional load profile. In this way, it is possible to demonstrate the participation of the Customer in AD service;
13. Metering data is provided by the ICT GW to the CH;
14. The CH can send metering data to all the interested stakeholders, together with the indication that the Customer has been offered to participate to an AD service. In this example, communication flows are depicted for the Retailer, the Aggregator and the BRP.

The economical clearing of the AD service shall be performed based on the metering data provided by the CH to all the relevant stakeholders. In this example, the BRP will pay the Aggregator, which will pay the Customer. Because AD modifies the behaviour of Customers, it is possible that, due to load reduction or delay, other stakeholders could receive economical losses (for example the Retailer). The compensation of such economical losses depends on the regulation policies and on the commercial agreements among the stakeholders. Anyway, this process is not strictly related to the communication flows and has not been shown here.

3.3.6 Roaming in foreign country

Just like in the GSM example, this document defines roaming as a case, where a user goes abroad and still wants to use the services by the retailer he or she has a contract with. Unlike the GSM example, the grid that the user connects to is not the entity that is crucial to the fact that this case shall be called "roaming".

This is the most important content differentiating "roaming " from the electric sector: in the electric sector, all retailers have access to provide to their customers in all physical locations served by the electricity markets they are operating in, which usually have national dimension.

Therefore, roaming in the electric sector only occurs when a retailer contract is used in a market where that retailer is not present in. In that case a partnership with a retailer operating in that market needs to be the vehicle for the customer to have coverage and use his contract in that market.

In this case, additional communication effort is required which is described below.

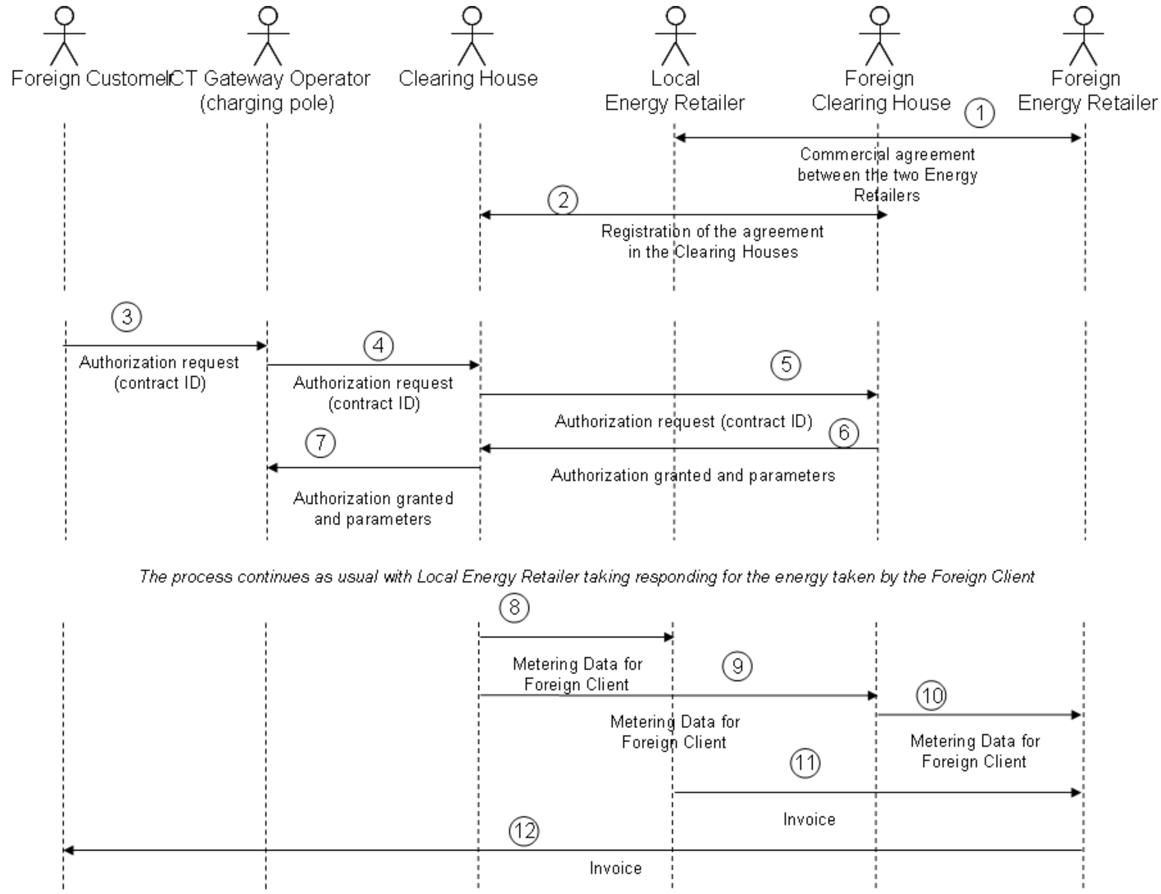

Figure 11: roaming in foreign country

1. The Foreign Retailer and the Local Retailer enter into an agreement to offer roaming service;
2. This agreement is also stored in the Clearing House and in the Foreign Clearing House (FCH);
3. The Foreign Customer accesses the charging infrastructure requesting for an authorization. This request contains the contract ID;
4. The ICT Gateway Operator forwards the request to the CH, which recognize it as a foreign customer. From the content of the contract ID, the CH recognizes also the correct FCH to contact;
5. The CH forwards the request to the FCH;
6. If the contractual position is valid, the FCH replies to the CH granting the authorization and providing additional parameters to be used during the charging process;
7. The CH forwards the authorization response to the ICT GW that allows Foreign Customer to use the charging point as if he was a local customer of Local Retailer;
8. When the charging operation is completed, the CH collects metering data as usual and forwards them to the Local Retailer;
9. CH also forwards the same data to the FCH;
10. FCH forwards the metering data to the correct Foreign Retailer;
11. Local Retailer bills the Forward Retailer for the energy taken by its Foreign Customer;
12. Foreign Retailer can in turn bill the Foreign Customer for the energy taken abroad, adding also a premium price for the roaming service.

3.4 Monetary flow

Banking, services and utilities industries have been a fundamental client and dynamotor of ICT technologies and applications. Most of the services provided by ICT in these industries are about controlling the money exchanges, keeping track of the services provided, rating them, invoicing the customer, and keeping track of the payments.

Another important application of ICT in this sector as well as in other industries is controlling the relationship of the organization with its customers. That includes knowing who the customer is, knowing what are his current commercial conditions applied by the organizations (now, before and maybe in the future), knowing what products he buys and how they relate to each other, knowing his preferences and his present as well as future needs.

This complex world of applications and systems that implement all these functionalities to an organization that provides services to its customers is known as Customer Management and Billing or CMB. In particular a large part of that world is what is normally called commercial and industrial billing or C&I, which deals with complex contract making, rating and billing of small to large clients.

Most stakeholders involved in electric mobility will need to have some sort of CM&B system, as most of them will have customers and will charge them by the services provided. However a CM&B system is normally only used to its full extension in a utility or an infrastructure service provider like an Internet Service Provider (ISP) or mobile network company. Therefore for the description of a CMB system we will be focused here on a system that would possibly be shared by the Energy Charging Gateway and ICT Gateway Operator(s), the DSO/MPO, and the Retailer (s), to demonstrate the full length and scope of such a system.

CMB is a system designed to implement business processes by applications, giving the user (an organization user) full control over them. Business processes have always a large amount of organization specific specifications but are also very similar from organization of different kinds when it comes to the main processes that govern the organization. CMB is an area where it is clear that ICT has helped to implement management practices and in its turn has helped to revolutionize those same practices and foster their utilization in many different organizations, helping to harmonized and consolidate how a company’s CMB (in the management sense) should be managed.

Business processes are normally clustered by front-office and back-office. Front-office processes are those directly connected with the customer or customer contact, such as the processes for running a callcenter, registering a complaint, issuing a budget, creating a new customer or customer product, etc. Back-office processes are those connected with the execution of all of the organizations activity, such as managing the transactions, managing stocks, making sales forecasts, etc.

Although this segmentation of processes is helpful for management it is also a good practice to have user easy access to information provided by both types of processes.

Application architecture

Figure 12 displays possible application architecture to implement the business processes of cmb for a utility scale organization.

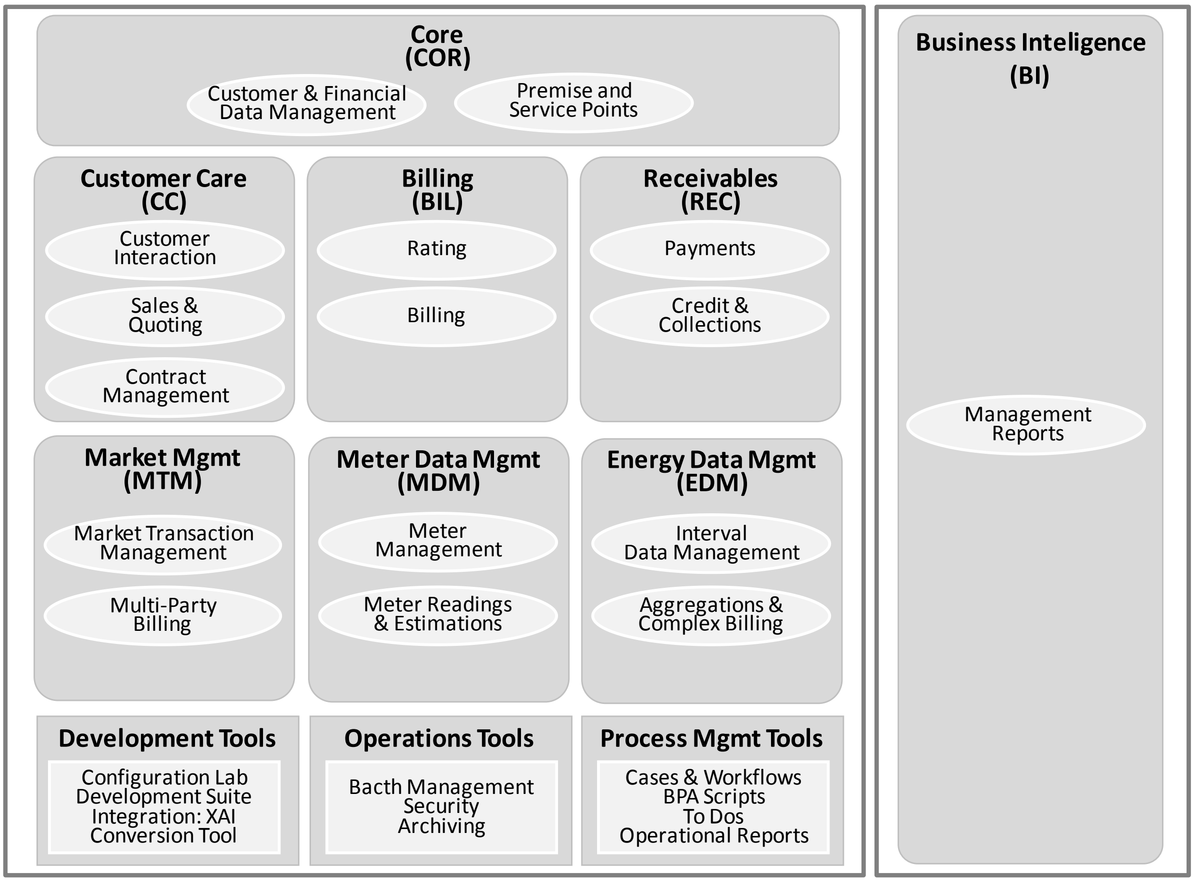

Figure 12: Possible application architecture. Different vendor architectures may apply.

Main applications

Core

On the Core level two main applications normally exist, the Customer & Financial Data management where all the integrated management of the customer is performed, including its data, services provided applied rates, payments etc.; and the Service Points where all data regarding the charging poles and customer wallboxes should be available, including the applied access rates, transactions, etc.

Business Inteligence (BI)

The business intelligence application allows the processing, display and treatment of data according to the criteria of the organization managers, rather than the operational organization of the applications. The BI allows a proper analysis and reporting of the organizational data, about the sales performances with customers, efficiency of the network, economic feasibility and budget management and prediction. It is this application that can give the fundamentals for prices calculation, profitability and actual costs.

Customer Care

On the customer care group of applications the services provided to the customer are managed, including the offers of those services, the maintenance of those services and the supporting contracts, the registering of all contacts with the customer, claims, returns, etc. From these applications depends a big part of overall customer satisfaction.

Billing

Billing first involves rating the provided services according to the commercial conditions. Rating is applied to individual units with established prices. Billing is applied to the aggregated information of all the individual rated units. In complex commercial activity, normal in very competitive environments, billing is a huge application, and it is here where all the calculations, using many different formulas with different parameters, are executed for charging and paying customers. In the case of electric vehicles, rating can be using the kWh supplied, the time periods of the day, the average power in 15 or 30 minute intervals of the charging session, the type of charging pole, the location of the charging pole, the type of customer, the customer commercial conditions, volume based discounts, etc. Billing also has to calculate taxes according to the services, fixed fees, etc. The final bill reflects all the payable parts and is delivered by the billing application.

Receivables

The receivables application is about making sure the bill is paid either directly or through credits conceded by the organization. The receivables are a fundamental application to get the actual money for the provided services as it automates this humanly difficult process.

Management Layer

On the Management layer of applications the control is executed over the transactions or charging sessions, receiving the correct metering data associated with the transactions, and calculating deviations and settlement events. Typically the information that allows multi-party billing and integration is processed by these applications so it can then be treated by the normal billing process.

Tools Layer

Any set of applications needs tools to be used, changed and customized, and in competitive environments these need to be executed by business users without the intervention of IT staff, or major training and preparation. Therefore CMB systems provide the users with tools that allow them to create new processes, change existing ones, make available information to a process where before it was not and other change possibilities.

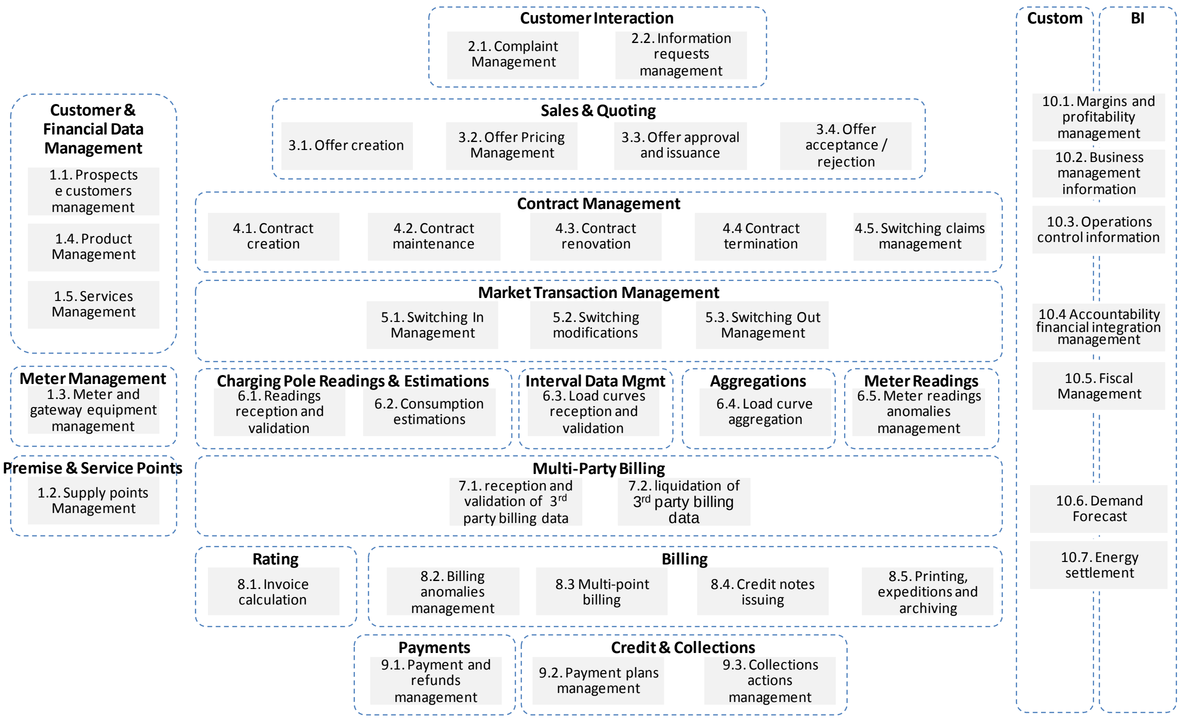

Figure 13: Integrated application support to front-office and back-office business processes.

Figure 13 presents the mapping between the main processes and the applications that execute them. The system, if implemented in a Service Oriented Architecture or SOA, has the services that the applications use to implement the processes decoupled from the applications themselves. This allows for virtually any application to access a service with any information available on the system.

The order of the processes can however be generically viewed as occurring from top to bottom and left to right, with the business intelligence feeding back to the initial applications in terms of configuration.

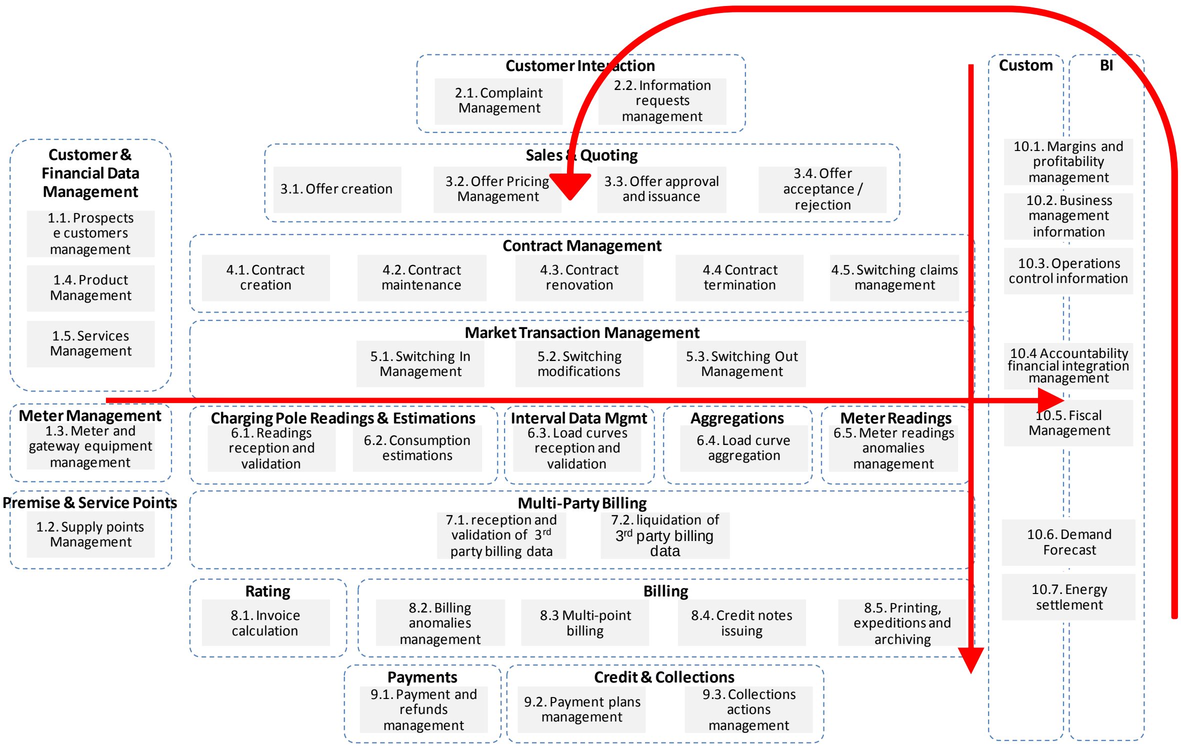

Figure 14: Figure 13 with typical process flow direction

Starting with a fully described transaction P6.1 (
Figure 15 process 6.1) which should have at least the customer identified, the charging point where the energy was supplied, the amount of energy, the load curve, etc, the rating is applied to the transaction in P8.1. The rating is defined based on the offer pricing to that customer P31.1 to P3.4 and what was finally agreed on the contract, P4.1 to P4.5. It may also be based on customer data like promotions, discounts, etc from P1.1. After the rating, the billing is processed, from P8.2 to P8.4, and the payments and credits (depending on the customer) are collected in P9.1 to P9.3.

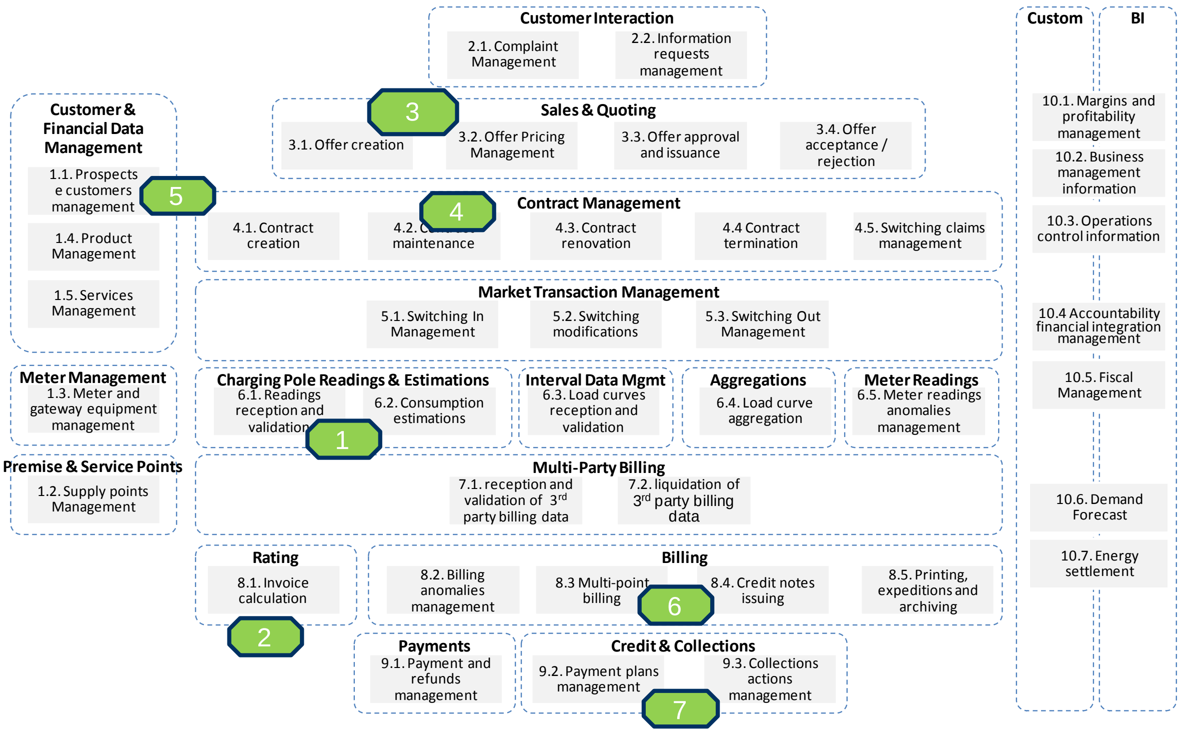

Figure 15: Figure 13 with steps for the process executed after a fully described transaction

In order for this architecture to be flexible and allow for management of smart grids and electric vehicle charging, some of the applications and processes defined in Figure 13 will need to be very well integrated between front and back office processes, in particular sales, demand forecast, load curve aggregations, and rating. For the services provided by the aggregator/retailer it is likely that the process starts at the business intelligence layer, with the identification of the demand forecast P10.6 (Figure 16) and awareness of the operations control information P10.3. That information will allow the sales department operating on the market for auxiliary services, to make offers of aggregator services to the market in P3.1 to P3.3. Those offers may be accepted in P3.4 and then they need to be delivered.

Based on the information about the customer's contracts and service agreements, the sales department will now need to make new offers, but this time to the end user, for them to behave in order for the electric vehicles to provide auxiliary services. As offers are accepted and rejected, the information will pass on to the rating engine as well as to the customers register. Once the service provisioning is fully negotiated, the transaction may start and the process continues. For the system to work well, it is also required that the sales processes are of great flexibility in designing contracts for new clients, without the need for IT interventions on the applications.

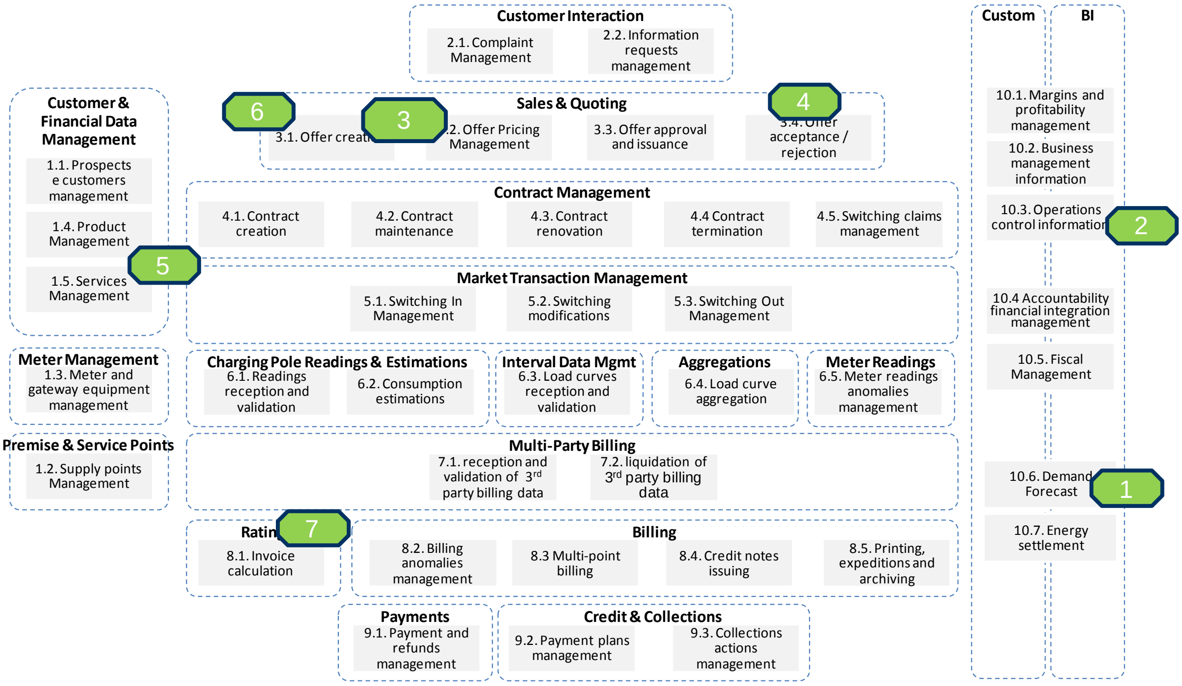

Figure 16: Figure 13 with steps for the process of preparing a flexibility service by the aggregator/retailer

Implementation of CMB systems

CMB systems constitute a big investment to any organization, but one that needs making if the organization wants to be competitive in providing its products and services in a flexible way that can quickly react to market changes and customer needs. CMB systems change the way the organizations manage themselves and provide a tremendous increase in the capability, efficiency and effectiveness of the sales, operations and business management teams of the organization.

To implement processes like complex billing of EVs, multi-retailer infrastructure operation, real-time management, integration of normal electric contract with mobile EV contract, load management, V2G, etc, a complex and well planned CMB system needs to be implemented to allow for all the envisaged business models. Such a platform may be extremely expensive if developed and maintained exclusively for the purpose of EV charging, and therefore, sharing of existing CMB systems should be always analysed.

4 Simulation of the recharging process

4.1 Scenario of the simulation

Three scenarios with regard to charging of electric vehicles will be researched and compared. These three charging scenarios are:

1. Conservative;
2. Pragmatic;
3. Advanced.

Scenario 1: Conservative charging

Scenario:	Conservative charging
Description:	Existing electric vehicles are plugged directly after the driver arrives at his or her location, after which the car start charging immediately. The aim of this scenario is to derive the load profile of electric vehicles that are charged uncontrolled (conservative). These profiles are used to study their effect on the substation peak load.
Approach:	• Measurement data of driving behaviour (departure time, arrival time, location, distance driven) from RWTH is being used to develop a statistical model that can generate a charging pattern for a single electric vehicle. • These charging patterns are aggregated for a specified number of electric vehicles. • The charging patterns are added to measured substation loads, obtained from different regions/countries in Europe. The number of households and average number of cars per household must be known for the area covered by the substation. These numbers are needed to calculate electric vehicle penetration levels. • The total substation load is compared with the specifications (nominal load) of the substation and the penetration degree of electric vehicles.
Expected results:	List and amount of required communication messages in order to achieve the required billing, etc. • Location of charging, time of charging, charge power and amount, vehicle (owner) identification, … For each substation, the following results will be obtained: • The increase in substation peak load for different penetrations of electric vehicles with respect to the ‘traditional’ peak load. • The maximum penetration of electric vehicles that can be sustained by the existing substation. • The time(s) that substation peak loads occur. • The factor the substation needs to be increased in order to facilitate 100% penetration of electric vehicles.

Scenario 2: Pragmatic charging

<table>
<tr><td>Scenario:</td><td>Pragmatic charging</td></tr>
<tr><td>Description:</td><td>In the pragmatic scenario the charging power is variable. In this scenario the charging power is the power needed to charge the battery to a 100% State of Charge (SoC) in the time that a vehicle is connected, with respect to minimum and maximum power limits.

The EV owner connects his EV and gives the time that he wants the EV to be ready for use with a fully charged battery. A price incentive should influence the choice.

The charge power is calculated and set by the EV charger using the SoC, the battery capacity and the predicted charge time.

Example:

An EV that needs 12kWh of energy to charge the battery to a 100% SoC will get a charging power of 2kW when the given connection time by the owner is 6 hours.

In the simulations all the connection times are known and used as the time to charge the batteries.</td></tr>
<tr><td>Approach:</td><td>• Obtaining the time connected of the electric vehicles.
• The charging pattern model from scenario 1 is modified to incorporate the variable charge power.
• The charging patterns, made with the new model, are aggregated for a specified number of electric vehicles.
• The charging patterns are added to known/measured substation loads.
• The expected load is compared with the specifications of the substation and the penetration degree of electric vehicles.</td></tr>
<tr><td>Expected results:</td><td>List and amount of required communication messages in order to achieve the required billing etc

• Location of charging, time of charging, charge power and amount, vehicle (owner) identification, delayed charging or not (in case of override functions) …
For each substation, the following results will be obtained:

• The increase in substation peak load for different penetrations of electric vehicles with respect to the ‘traditional’ peak load.
• The maximum penetration of electric vehicles that can be sustained by the existing substation.
• The time(s) that substation peak loads occur.
• The factor the substation needs to be increased (if necessary) in order to facilitate 100% penetration of electric vehicles.
• The reduction of substation peak load with respect to scenario 1.</td></tr>
</table>

Scenario 3: Advanced charging

Scenario:	Advanced charging
Description:	The aim of this scenario is to use Smart Grids with an intelligent ICT architecture in order to optimize the substation load, i.e. reducing its peak load, resulting in a flatter load profile. The electric vehicles actively participate in the electricity market and react on changes in the electricity price (demand response).
Approach:	• ECN's PowerMatcher smart grids technology is used to intelligently charge the electric vehicles. • The model developed in scenario 1 is accompanied by an intelligent coordination algorithm. • Using the PowerMatcher Simulation Tool, the behaviour of the electric vehicles in optimizing the substation load is simulated for different penetration levels.
Expected results:	List and amount of required communication messages in order to achieve the required billing and intelligent charging • Price signal and time of these signals, location of charging (not only home, but real location including identification of charging pole etc), time(s) of charging, (time(s) of not charging?), charge power and amount, vehicle (owner) identification, delayed charging or not (in case of override functions) … For each substation, the following results will be obtained: • The increase in substation peak load for different penetrations of electric vehicles with respect to the 'traditional' peak load. • The maximum penetration of electric vehicles that can be sustained by the existing substation. • The time(s) of substation peak loads. • The factor the substation needs to be increased (if necessary) in order to facilitate 100% penetration of electric vehicles. • The reduction of substation peak load with respect to scenario 1.

4.2 Results of the simulations

This section describes the results of the simulation of the recharging process taken into account the simulation scenarios of section 4.1.

The results at the local units of two regions (all urban) are presented in sections 4.2.1 and 4.2.2. The regions are respectively:

1. North, this region includes Sweden, where people make significant more use of electricity, compared to other regions, e.g. electrical house warming in a colder climate.
2. South, this region includes Portugal, Spain and Italy, where the electricity use of people is less, compared to the North region.

Results of the Central region could not be presented because no data was available.

The results in this section are presented in the six tables (Table 1 to Table 6). Each section has three tables showing the different charge controls, respectively:

1. Conservative,
2. Pragmatic,
3. Advanced.

The Table structure is the same for each table. Each table has two main columns with the battery use. The two battery use scenarios are:

1. Standard (only for driving the vehicle),
2. V2G included (only for the Advanced scenario).

The two main columns are separated in the following two sub-columns with the following charging places scenarios:

1. Home,
2. Home and work.

The charging place scenario “Everywhere” is not simulated, because it is expected that the difference with the “Home and work” scenario is marginal.

Four rows with actual data are given, depending on the percentage of EV, namely:

1. 25%,
2. 50%,
3. 75%,
4. 100%.

In the conservative and in the advanced scenario the used charging power is limited to 3.7kW only. In the pragmatic scenario the charging power is variable. In this scenario the charging power is the power needed to charge the battery to a 100% State of Charge (SoC) in the time that a vehicle is connected, with respect to minimum and maximum power limits.

The figures of data given in each table square of Table 1 to Table 6 contains:

1. maximum percentage of EV’s connected [%] per 24h, (plot over 24h of selected results),
    a. this figure can be used to calculate worst-case situations.
2. average charge time per EV within a 24h period [h],
    a. this figure can be used to calculate the amount of data traffic during charging.
3. average V2G energy per vehicle per day, [Wh] (only for the Advanced scenario),
    a. this figure can be used to calculate the impact of V2G.

4.2.1 Region North simulations

Table 1. Region North, Conservative charging

	Region North, Conservative charging	
	Standard charging	
% EV	Home	Home and work
25	1: **96 %** 2: **1.69 h**	1: **96 %** 2: **1.79 h**
50	1: **93 %** 2: **1.64 h**	1: **92 %** 2: **1.82 h**
75	1: **94 %** 2: **1.82 h**	1: **93 %** 2: **1.78 h**
100	1: **94 %** 2: **1.87 h**	1: **92 %** 2: **1.86 h**

Table 2. Region North, Pragmatic charging

	Region North, Pragmatic charging	
	Standard charging	
% EV	Home	Home and work
25	1: **96 %** 2: **14.1 h**	1: **96 %** 2: **15.6 h**
50	1: **93 %** 2: **13.2 h**	1: **92 %** 2: **15.4 h**
75	1: **94 %** 2: **13.3 h**	1: **93 %** 2: **15.4 h**
100	1: **94 %** 2: **13.7 h**	1: **92 %** 2: **15.3 h**

Table 3. Region North, Advanced charging

	Region North, Advanced charging		
	Standard charging		V2G included
% EV	Home	Home and work	Home
25	1: **96 %** 2: **1.87 h**	1: **96 %** 2: **1.84 h**	1: **96 %** 2: **2.05 h** 3: **18 Wh**
50	1: **93 %** 2: **2.03 h**	1: **92 %** 2: **1.99 h**	1: **93 %** 2: **2.39 h** 3: **36 Wh**
75	1: **94 %** 2: **1.98 h**	1: **93 %** 2: **1.93 h**	1: **94 %** 2: **2.57 h** 3: **59 Wh**
100	1: **94 %** 2: **2.05 h**	1: **92 %** 2: **2.00 h**	1: **94 %** 2: **2.80 h** 3: **75 Wh**

In Figure 17 the percentage of vehicles connected to the EV-pole at home and work are presented for the region North, this figure counts for all the scenarios.

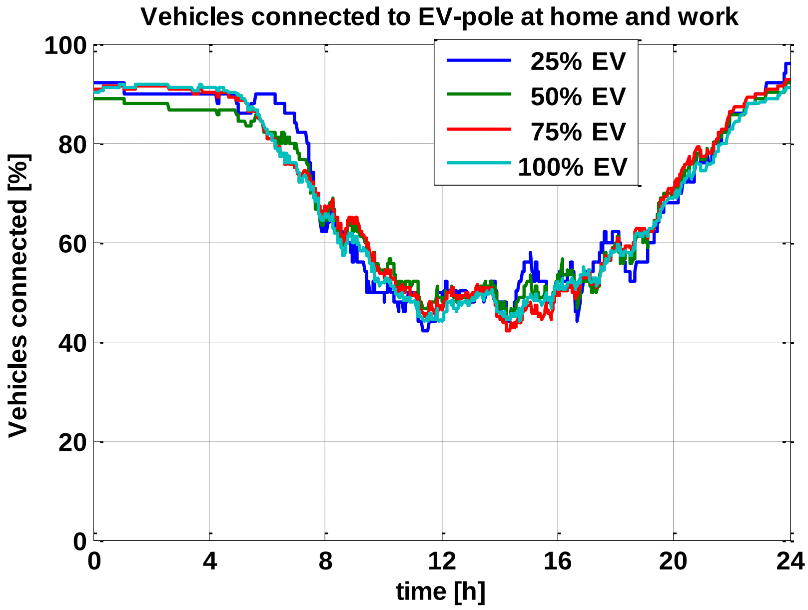

Figure 17: Vehicles connected to the EV-pole at home and work, this figure counts for all the scenarios.

The percentage of vehicles that are actually under charge must be equal or smaller than the percentage of vehicles that are connected to the EV-poles. In Figure 18, Figure 19 and Figure 20 the percentage of vehicles under charge at home and work are presented for the region North, respectively for the scenarios: conservative, pragmatic and advanced

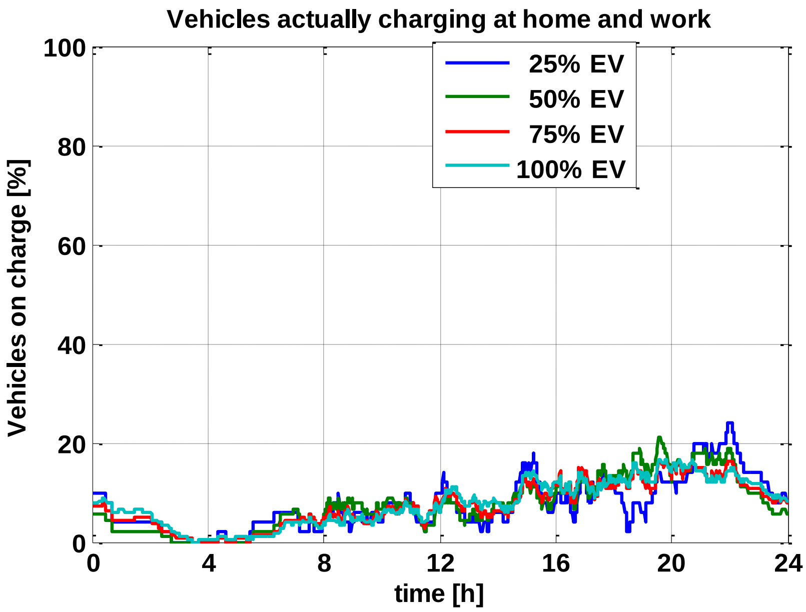

Figure 18: Vehicles actually charging at home and work in the conservative scenario.

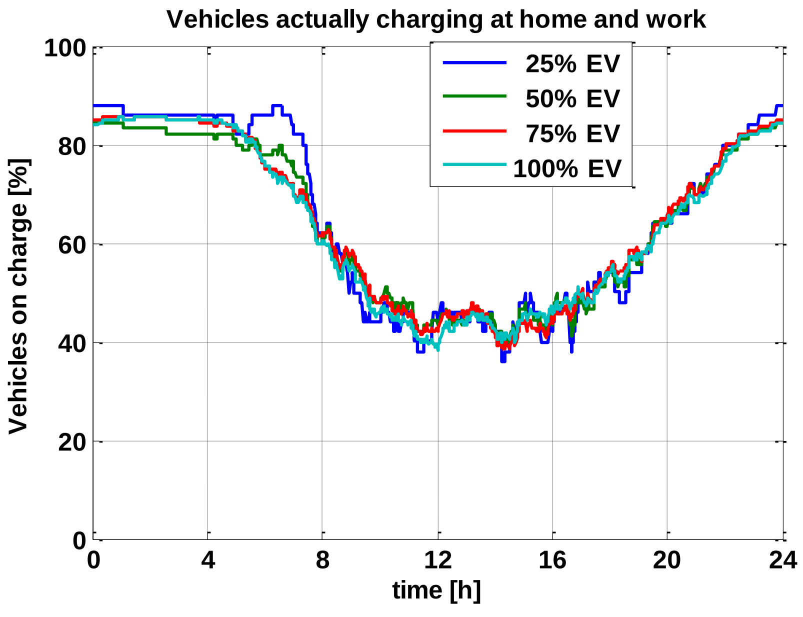

Figure 19: Vehicles actually charging at home and work in the pragmatic scenario.

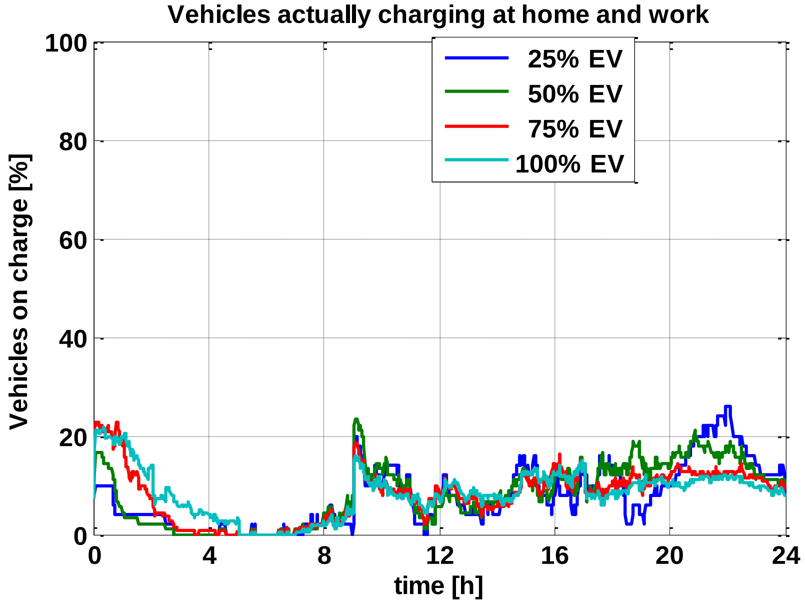

Figure 20: Vehicles actually charging at home and work in the advanced scenario.

4.2.2 Region South simulations

Table 4. Region South, Conservative charging

	Region South, Conservative charging	
	Standard charging	
% EV	Home	Home and work
25	1: **94 %** 2: **1.92 h**	1: **92 %** 2: **1.94 h**
50	1: **94 %** 2: **2.04 h**	1: **92 %** 2: **1.95 h**
75	1: **94 %** 2: **1.95 h**	1: **91 %** 2: **1.96 h**
100	1: **94 %** 2: **1.95 h**	1: **91 %** 2: **1.98 h**

Table 5. Region South, Pragmatic charging

	Region South, Pragmatic charging	
	Standard charging	
% EV	Home	Home and work
25	1: **94 %** 2: **13.8 h**	1: **92 %** 2: **15.3 h**
50	1: **94 %** 2: **13.4 h**	1: **92 %** 2: **15.7 h**
75	1: **94 %** 2: **13.6 h**	1: **91 %** 2: **15.7 h**
100	1: **94 %** 2: **13.6 h**	1: **91 %** 2: **15.9 h**

Table 6. Region South, Advanced charging

	Region South, Advanced charging		
	Standard charging		V2G included
% EV	Home	Home and work	Home
25	1: **94 %** 2: **2.26 h**	1: **92 %** 2: **2.13 h**	1: **94 %** 2: **3.70 h** 3: **144 Wh**
50	1: **94 %** 2: **2.15 h**	1: **92 %** 2: **2.05 h**	1: **94 %** 2: **3.52 h** 3: **137 Wh**
75	1: **94 %** 2: **2.16 h**	1: **91 %** 2: **2.07 h**	1: **94 %** 2: **3.53 h** 3: **137 Wh**
100	1: **94 %** 2: **2.20 h**	1: **91 %** 2: **2.10 h**	1: **94 %** 2: **3.59 h** 3: **139 Wh**

In Figure 21, the percentage of vehicles connected to the EV-pole at home and work are presented for the region South, this figure counts for all the scenarios.

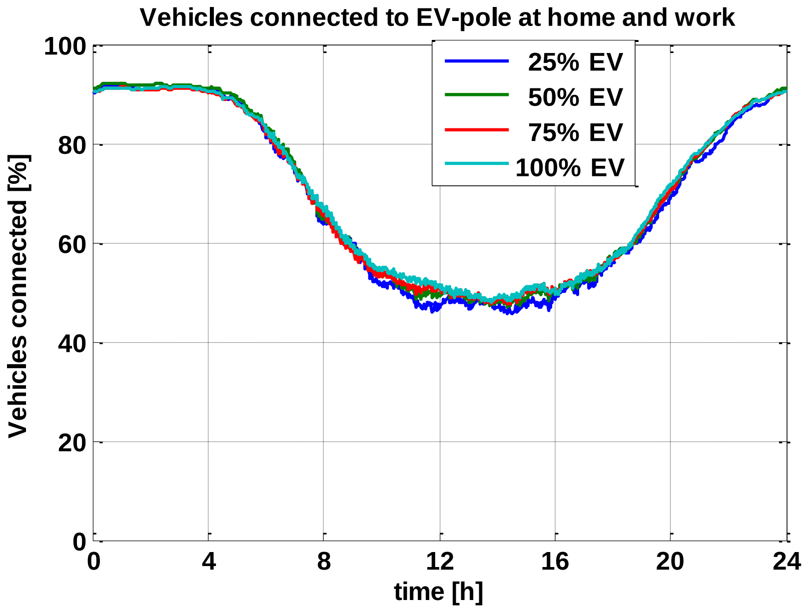

Figure 21: Vehicles connected to the EV-pole at home and work, this figure counts for all the scenarios

The percentage of vehicles that are actually under charge must be equal or smaller than the percentage of vehicles that are connected to the EV-poles. In Figure 22, Figure 23 and Figure 24 the percentage of vehicles under charge at home and work are presented for the region North, respectively for the scenarios: conservative, pragmatic and advanced.

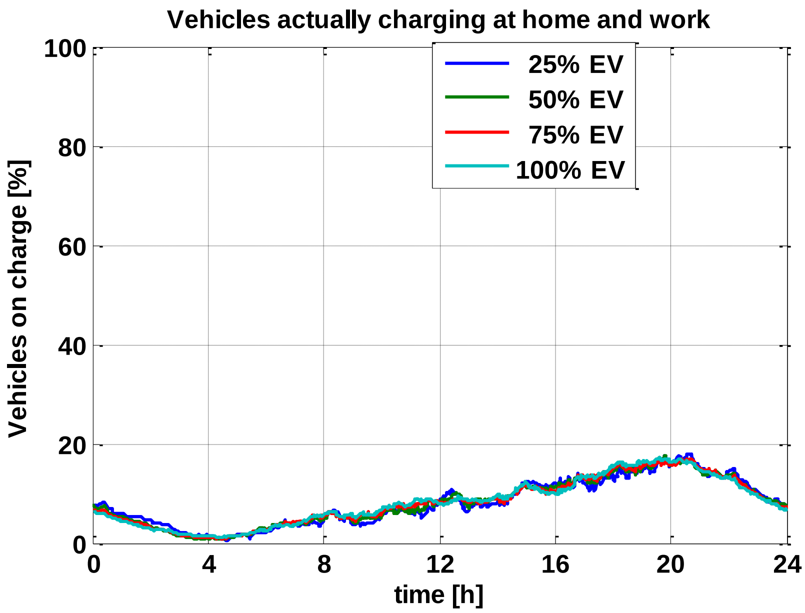

Figure 22: Vehicles actually charging at home and work in the conservative scenario.

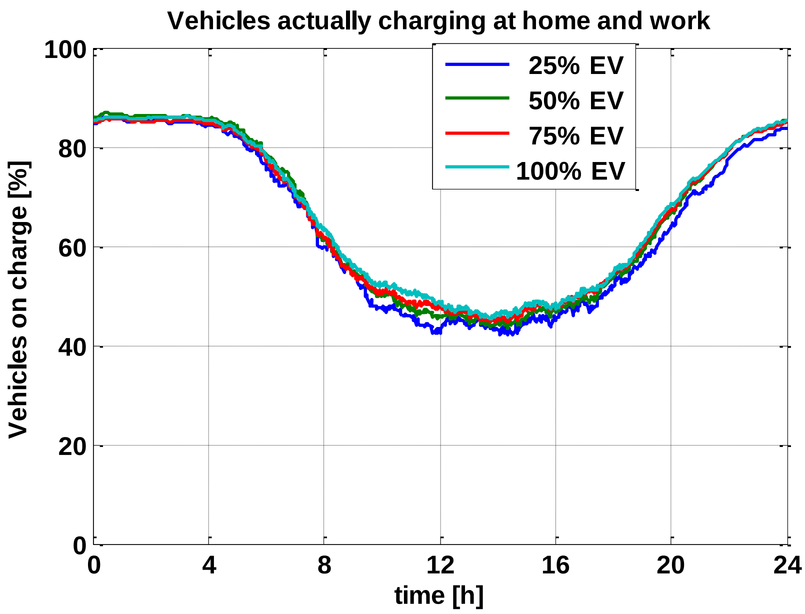

Figure 23: Vehicles actually charging at home and work in the pragmatic scenario.

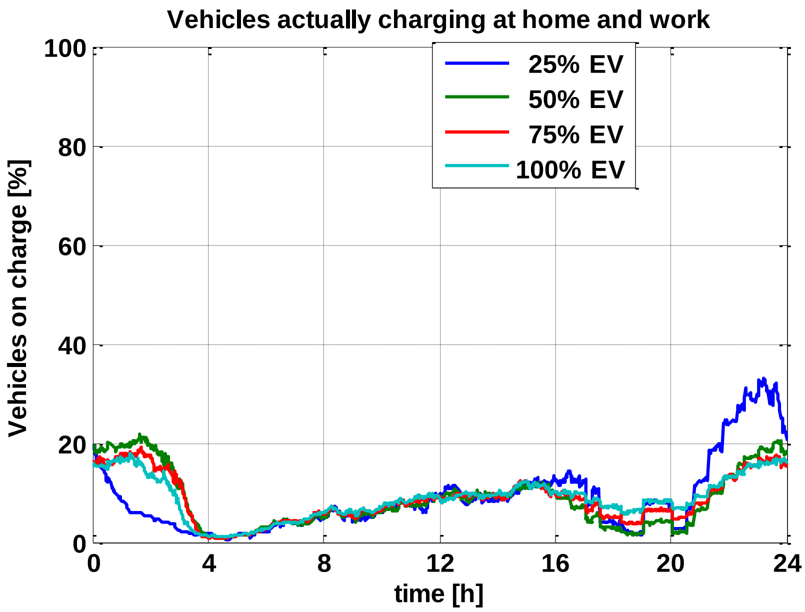

Figure 24: Vehicles actually charging at home and work in the advanced scenario.

4.2.3 Data traffic required for billing

In this section, the data traffic required for billing and control will be estimated on higher levels according to Figure 25. This figure shows a possible data transport structure. This data has to travel from many EV poles to the local unit level 1, the average distance is assumed to be 5 km. The sub-aggregator on level 2 collects data from the level 1 local units, the average distance is assumed to be 30 km. The main-aggregator above level 2 collects data from the level 2 sub-aggregators, the average distance is assumed to be 150 km.

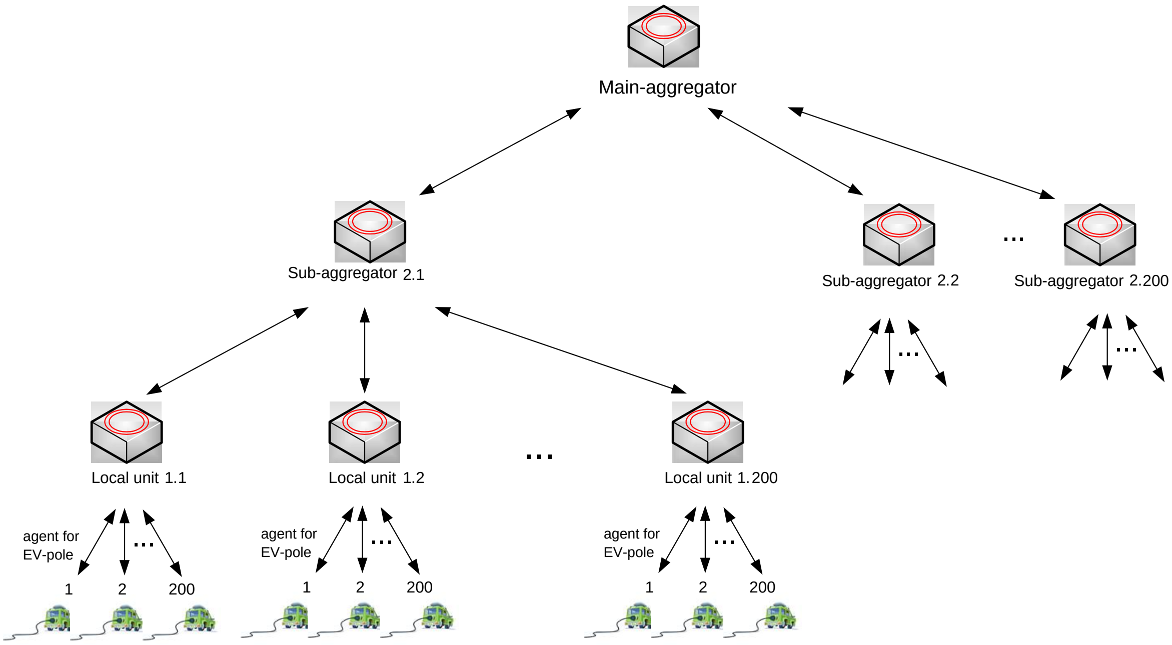

Figure 25: EV topology set-up example, based on [2].

Data structure set-up according to Figure 25 covers the following EVs and aggregators, taking an example that could be valid for a country like the Netherlands [2]:

- level 1: 200 local units (for example substations) with max. 200 EV's each connected
- level 2: 200 sub-aggregators with 200 level 1 local units each connected

- level 3: main-aggregator with 200 level 2 sub-aggregators connected.

The total number of EVs in this data structure set-up example equals 200 x 200 x200=8 million.

Types of data traffic at the EV-pole:
- control (bids at Advanced charging);
- power monitoring;
- billing.

Data traffic for Billing

According to the EV data structure set-up example of Figure 21, the Local unit collects the following data from the EV-poles (see Figure 26):
- power monitoring;
- control information;
- consumption information;
- price information.

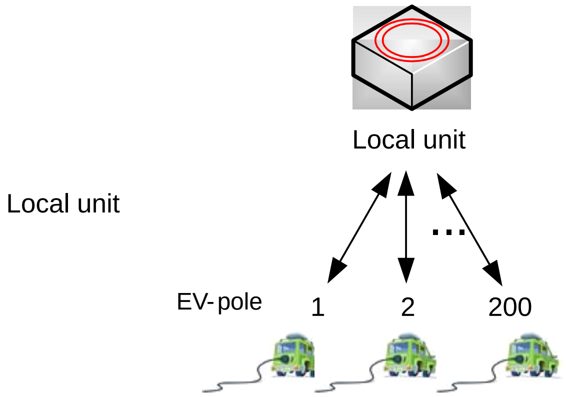

Figure 26: The local unit collects billing data from 200 EV-poles

The latter two, consumption information and price information, are used to calculate the needed information for Billing. This Billing information will be send to the main-aggregator via a sub-aggregator. In this system the main-aggregator collects the Billing data of 8 million EV-poles. Below a list is given of the information to be send from the EV-pole to the Local unit.

Billing data from the EV-pole to the Local unit:
- EV-pole identification;
- EV identification;
- start time of the charging;
- stop time of the charging;
- charged energy;
- other data.

The number of characters for this string is estimated to be 200. The Local unit sends this data further via the sub-aggregator to the main-aggregator, see Figure 27. A list is given below of the information sent from the EV-pole to the main aggregator.

Billing data from the Local unit to the sub-aggregator and the main-aggregator:
- Local unit identification;
- billing data from all the EV-poles 1 to 200.

It is assumed that the main-aggregator has all the local price profiles.

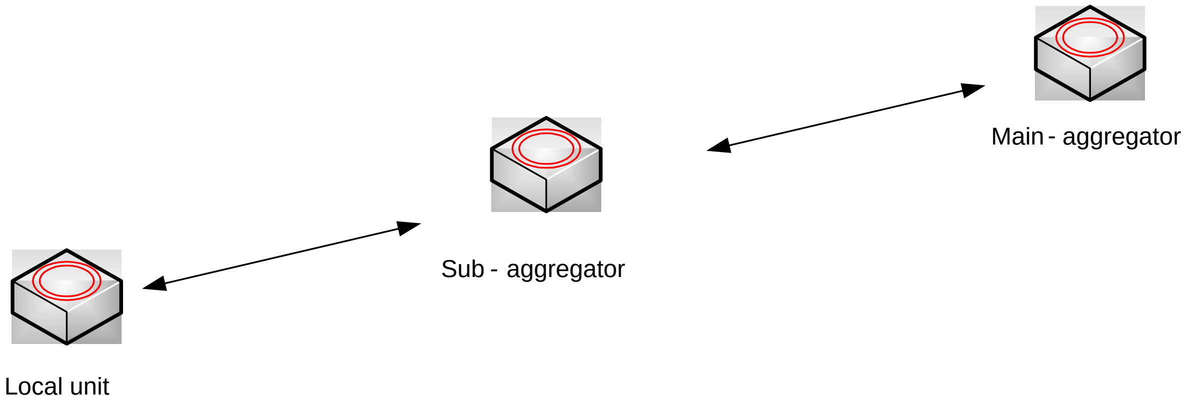

Figure 27: Each Local unit send its billing data via the sub-aggregator to the main-aggregator.

At the local unit, 200 EV poles are connected to it. Data has shown that approximately 94% is connected at peak level for all scenarios. This means approximately 188 EV poles have an EV connected at maximum at any given time. This does not mean that those 188 vehicles are also charging. The actual charging is done within this connection time. It depends on the charging scenario how many vehicles are actually charging. For example, in the Conservative and the Advanced scenario of the region North, we see that this is in the order of 20% at maximum, see Figure 18 and Figure 20. This means that at a penetration of 200 EVs, approximately 40 are simultaneously being charged. In the Pragmatic scenario of the region North approximately 87% are simultaneously being charged at maximum, see Figure 19. Here this means that at a penetration of 200 EVs, approximately 174 are simultaneously being charged.

The messages necessary for billing are being sent only during the actual charging time and not the connection time. Although in the underlying simulations the charging power was assumed to be constant during the charging time, for practical systems this is not realistic, therefore we allow for a varying charging power during the whole charging time and a constant power at short fixed time intervals of 5 minutes. From this follows for the Conservative and the Advanced scenario that at maximum, 40 billing messages are being generated per time interval of 5 minutes. Assuming that the EVs will change their behavior once every 5 minutes, this means that 40 messages will be sent per 5 minutes. Having billing messages of 200 characters, the system must be able to send 40 x 200 = 8,000 characters per 5 minutes. When we take one character to be eight bits, a throughput at the local unit of 64,000 bits per five minutes is required. This entails to 213.3 bits/second for the Conservative and the Advanced scenario. For the Pragmatic scenario this figure entails to 928.0 bits/second.

For the next level according to Figure 27, things will scale up by factor of 200 as the individual billing exchanges cannot be aggregated. So for the Conservative and the Advanced scenario, now we need a bandwidth of 42.7 kbps at the sub-aggregator. Finally, at the main-aggregator level, things will scale up again by a factor of 200 and thus we now need a bandwidth 8.5 Mbps for the Conservative and the Advanced scenario. For the Pragmatic scenario where 87% are simultaneously being charged, these figures entails to respectively 185.6 kbps and 37.1 Mbps.

To calculate a worst-case situation, the bandwidth per line at the EV pole to the local unit must be at least: 200 x 8 = 1,600 bits per five minutes, or in other words: 5.33 bits per second. The bandwidth per line from the local unit to the sub-aggregator must be: 5.33 x 200 = 1.07 kbps, while the bandwidth per line at the main-aggregator level: 1.07 x 200 = 213.3 kbps. This means that the total data-flow to be handled at the main-aggregator level equals: 213.3 x 200 = 41.7 Mbps. These numbers assume a continuous rate without interruption. This is unrealistic however. Depending on the protocols used, data collisions can occur which results in resending data and thus adding to the needed bandwidth. This can especially be true when a network is operated at its maximum throughput. Also, a problem in the network can occur and data cannot be sent anymore. Now the network has to play catch-up and thus additional bandwidth is required.

Looking at the connection times in Figure 28, we see that during the night most of the network bandwidth is being used by the charging algorithm. However, during the day there is much less data traffic generated by the algorithm. This valley can be used for sending over the billing data at the EV pole level. At higher levels (local unit, sub-aggregator and main-aggregator) this will work less due to the fact that while the real time data is aggregated, the billing data is not and accumulated instead. Here we need to invest in more network capacity.

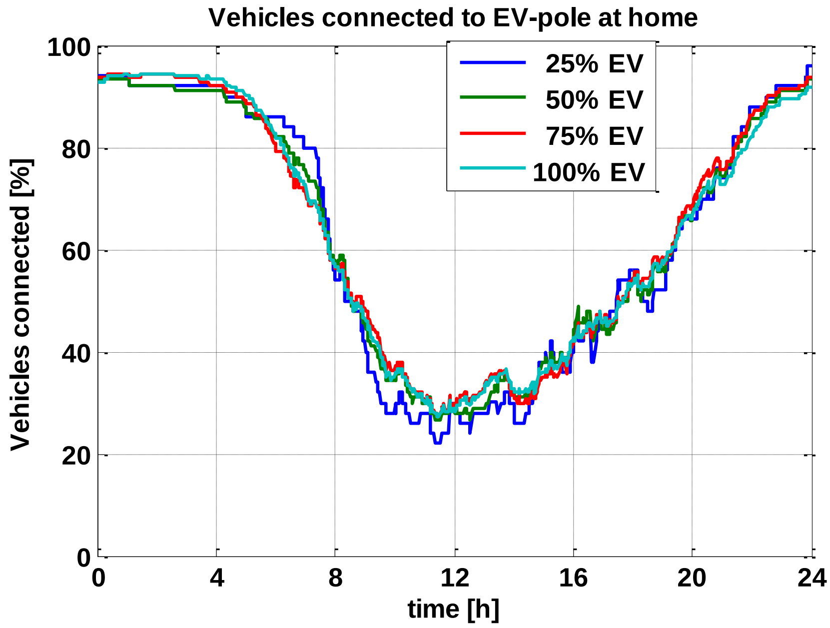

Figure 28: Vehicles connected to the EV-pole at home for the North region, this figure counts for all scenarios.

Most of the cabling is found at the lowest level of the network and there we can intermit the real time data with billing data. Since billing data does not necessarily need to arrive in a timely manner, one only needs to assure that it arrives within an acceptable period. It is okay for the billing data to be delayed by the network. By implementing a quality of service (QoS), the real time data takes priority over the billing data ensuring that the network will correctly handle the real time data. Any bandwidth that is not used can and will be used for billing. When the number of connected cars will drop, more bandwidth will become available for the billing data. Thus, in the end the billing data is also delivered.

Table 7 below summarizes the maximum data bandwidth during a day required for billing, expressed for a number of scenarios and percentages EV penetration. This data concerns the aggregated data flow at the units of Figure 27.

Table 7. Region North, max. data bandwidth during a day required for billing

Region North for 25 to 100% EV	Max data bandwidth during a day, required for billing		
	Standard charging		
	Conservative	Pragmatic	Advanced
Local-unit	213.3 bps	928.0 bps	213.3 bps
Sub-aggregator	42.7 kbps	185.6 kbps	42.7 kbps
Main-aggregator	8.5 Mbps	37.1 Mbps	8.5 Mbps

Due to the estimations and the nature of the input parameters, the results obtained can be only considered as trendsetting. However, these calculations can be used in the adjustment of the results when more accurate input data will be available.

Very importantly it is also necessary to remark that the bandwidths described above only consider the size of the raw message. Depending on the protocol used, different overhead size should be added to have the final size of the messages.

4.2.4 Conclusions regarding data traffic during the charging process

For operating an intelligent algorithm like the advanced scenario, it is required that there is a two-way communication system in place. Without such a network, no information about the state of the individual end points can be known and thus, the system as a whole, cannot make any decision on what would be an optimal solution. Whether or not you have a system that makes decisions centrally or locally, either the decision, or the information on which to make a local decision needs to flow to the end points, thus necessitating a two-way communication network.

Now that this communication network is available, it can be used to transport billing data as well. Looking at Figure 29, we can see that the network is not solely occupied by the communications of the intelligent charging algorithm. It depends on how many electrical vehicles are connected at a given time. During the evening and night, most EVs are connected, while during the remainder of the day most EVs are on the road. Even looking at Figure 29, we can see that for both charging at Home and charging at Home and Work, we see that most EVs are connected during the evening and night. This means there is unused capacity for the communication network and this can be used for sending billing information. For getting the billing information across the communication network without interrupting the real-time data of the intelligent charging algorithm, the two types of data stream will get different priorities by means of the Quality of Service that is provided by modern communication networks.

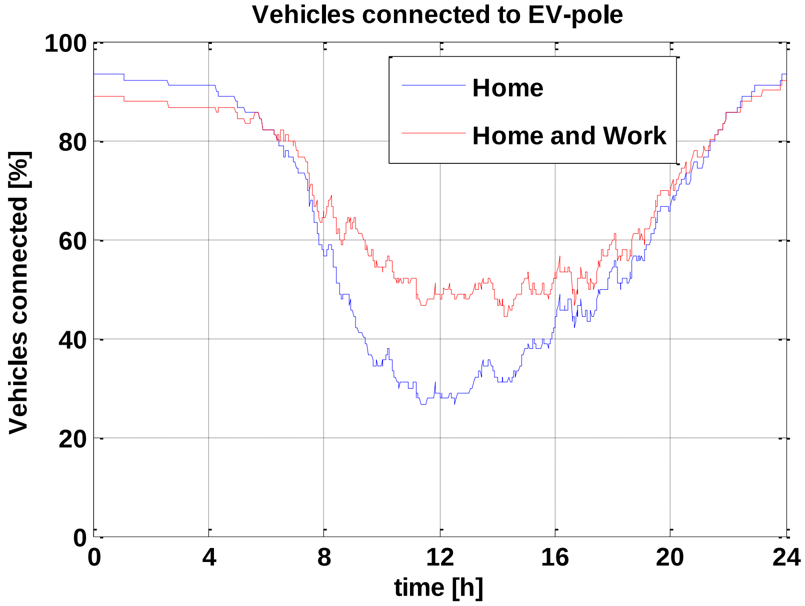

Figure 29: Vehicles connected to the EV-pole at home (blue) and at home and work (red) for a 50% EV penetration.

5 Conclusions

The communications and the systems to bill the energy used in the recharging of electric vehicles (EVs) is a main issue for the deployment of EV that needs to be analysed in order to define the communication flow and data exchange required to implement the billing of the energy recharged and other related services.

One of the significant results of the billing process analysis is the need of defining the e-roaming concept, which has been considered similar to the term used in the mobile industry. E-roaming takes place when an EV user recharges its EV using the electric vehicle supply equipment (EVSE) of a e-mobility operator which is different from the e-mobility operator with whom he has an electricity supply contract. As e-roaming could be at a regional level or at international level, it is necessary to establish a common system for payment to make e-roaming possible.

The communication flows of the process for billing of customer (flexible charging), billing of client (flexible charging) and clearing of metering data, delayed charge, request of load reduction, V2G request activated by aggregator and roaming in a foreign country have been formulated. These sequence diagrams have permitted to identify both energy and ICT stakeholders, namely clearing house operator, the aggregator, the control service provider, the energy charging gateway operator, the ICT gateway operator and the ICT network operator, and their roles. Moreover, these communication diagrams can be taken as a reference cases to be modified or simplified to adapt them to specific situations as the studied cases show just one of the possible implementations.

A complex set of applications and systems to control the relationship between the organization and the customers and also to bill and manage payments, also known as Customer management and billing (CMB) is needed to implement the billing processes. However, such a platform may be extremely expensive if it is exclusively for the purpose of EV charging, and therefore, sharing of existing CMB systems should be always analysed.

The behaviour of the EV users has been simulated in order to assess the communication requirements regarding billing for the different scenarios worlds, the different regions considered, the use of battery, the charge location and the penetration of EV. The results show that during the evening and night the EVs are mainly being charged, while during the day most of the EVs are on the road. This fact means that there is unused capacity for the communication network and this can be used for sending billing information. For getting the billing information across the communication network without interrupting the real-time data of the intelligent charging algorithm, the two types of data stream will get different priorities by means of the Quality of Service that is provided by modern communication networks.

6 Future Research Topics

This report offers a wide overview of the billing infrastructure trends for the deployment of electric vehicle. The open issues that have been identified for further research are listed below:

- In this document, some of the possible implementation cases regarding the billing process have been described. They are only reference cases and many other cases or behaviours could be considered for other specific situation by doing simplifications or modifications. Some further cases could be studied, taking into account for example the place where the EV is charged.
- In order to save on the deployment of a communications network for billing, integrating this system with the control communications in real time should be studied. In section 4, this issue has been partially addressed, but further work could be done. In a similar way, the possibility that both interfaces could share the same physical communication path should be considered.
- For the anticipated large scale roll-out of electric vehicles, an early agreement on international standards in the ICT interfaces is as essential as the standardisation of physical interfaces like interconnectors. Therefore initiatives on standardised data objects and communication protocols with respect to electric vehicles billing should be achieved.
- The V2G services that an EV can provide have been considering such capability within market environment. However, EV with V2G capability can help to improve power quality in the facility it is connected to if the discharge converter is an active-front-end device. This kind of devices can provide power conditioning within the facility, as for example ride-through capability and active filtering of harmonics. However, a real-time communication will be needed for the operation. Moreover, such kind of service is not considered in current market operations. Thus, the role of supervising and coordinating the billing of power quality services has to be investigated.

7 References

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