Modeling Virtual Sensors for Electric Vehicle Charge Services

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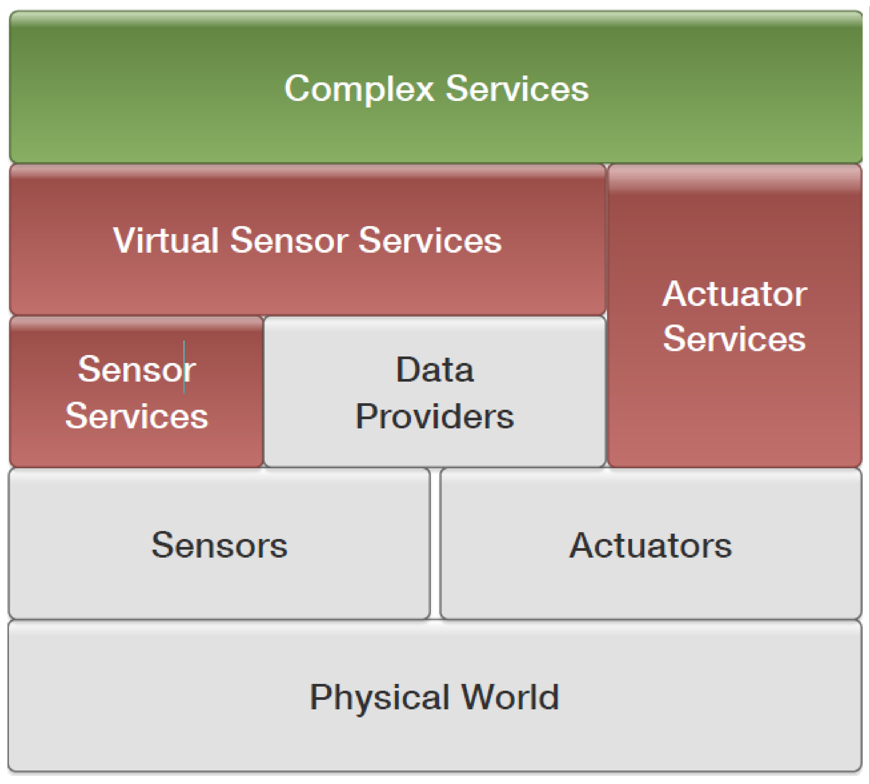
ABSTRACT

This paper proposes innovative services in the electromobility framework with the goal of enhancing the electric vehicle charging experience. In this context, the objective is to provide a smart charging service that helps drivers to make the best choice for charging their electric vehicles, according to the vehicle real-time position, battery type and autonomy. Moreover, the drivers are allowed to book the preferred charge option according to availability and cost of the charge points. To this purpose, two virtual sensors are designed and defined that allow to perform the smart charging searching service. In particular, an algorithm and a UML diagram are adopted to describe the virtual sensors operations and cooperation. In addition, the proposed virtual sensors functioning and interactions are described as Discrete Event Systems modeled in a Petri Net framework.

VIRTUAL SENSOR AS A BUSINESS SERVICE



In the context of business market for advanced and complex services, there is an increasing need of using common standards for defining data formats, data exchange, communication framework in order to facilitate and accelerate service deployment, service integration and facilitate innovative service definition. Business developers need to start from high level components that are easy to use, easy to integrate with legacy software and easy to reuse to create novel complex services.

To this aim, a common framework for the definition and the execution of the services has to be developed. This common framework typically is build up starting from the definition of a Common Data Format (CDF), a common service definition methodology and a common invocation procedure. The Common Data Format can be used by developers to cope with interoperability issue among new services and legacy systems.

Virtual Sensor service: It is a specialized service that derives new data or information from existing and available data by physical sensors. It encapsulates a data processing algorithm to obtain the required output data by elaborating the input data;
Such VSs are increasing their role in the business market as:

- the amount of data acquired by physical operator is increasing;
- the algorithms to manage such big data streams are complex due to management of data origin, data privacy, data protection, etc.;
- the systems to perform such elaboration are complex.

A VS can perform such operation and it can be used as a building block for generating complex services. In the following we present two different VS services and how to connect them to create a complex service.

VIRTUAL SENSORS FOR ELECTRO-MOBILITY

VS1: CHARGE POINT AVAILABILITY

The VS1 analyses the Charge Points (CPs) availability in the driver's neighborhood in a specific time horizon and provides the list of CPs with their geographical position and technical information.

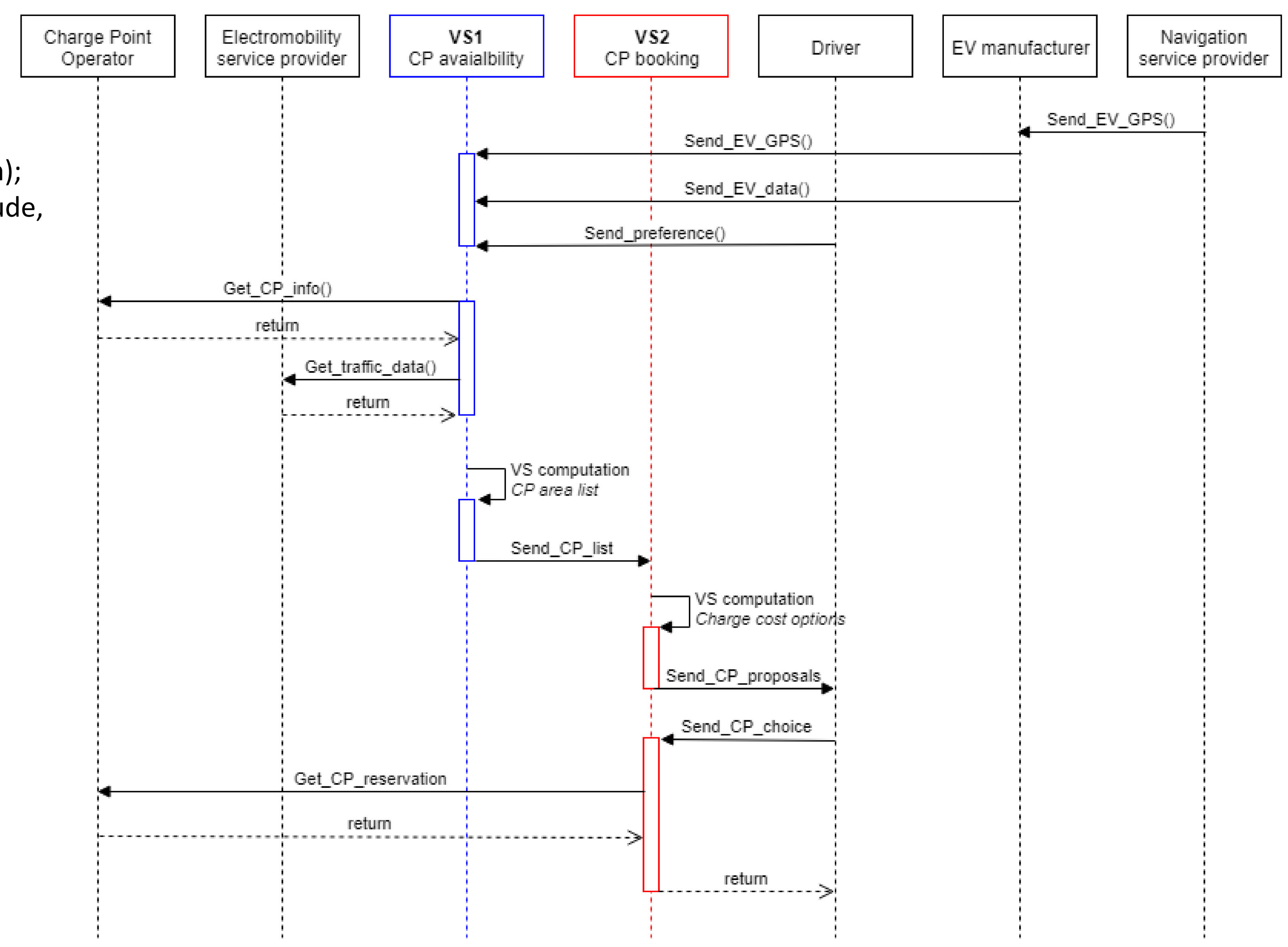
Inputs

- EV GPS position (latitude, longitude);
- EV residual battery charge (% or km);
- EV battery capacity and type;
- Charge time slot preference (hh.mm-hh.mm.);
- CP GPS position (latitude, longitude);
- CP occupancy status;
- CP booking requests;
- Traffic data.

Output

- CP selection range (km);
- GPS coordinates (latitude, longitude);
- Charge power (kW);
- distance (km);
- occupancy time slot (minutes);

Algorithm 1:
1: START.
2: The driver asks for VS service and the vehicle sends the required data to VS.
3: VS requests data to the involved actors (see Fig. 2).
4: Actors reply to VS requests.
5: VS computes the maximum area reachable by the EV: $A_{max} = GPS_{pos} + km_{res}$. Set $j = 1$,$S_A = \emptyset$.
6: VS computes A_j: $A_j = A_{max} - K * j$. Set $j = j + 1$, $S_A = S_A \cup A_j$. Set m cardinality of S_A.
7: If $A_j \geq K$, then go to STEP 6.
8: Set $j = 1$.
9: Select area A_j.
10: VS provides the CP list in the area $\bar{A} = A_j$. Set $j = j+1$.
11: If $j \leq m$ go to Algorithm 2.
12: END.



VS2: CHARGE POINT BOOKING

The VS2 operations are based on the output of VS1. The VS2 computes the charge session cost and allows to book the charge point. It refers to the CPs in the selected area Ai by VS1 and computes the cost for charging the EV battery, based on the energy tariff and the actual charge autonomy.

Inputs

- VS1 inputs;
- EV charge level/km autonomy;
- CPs tariff (e/kWh)

Outputs (for each CP)

- selection range (km);
- GPS coordinates (latitude, longitude);
- status (free/occupied);
- distance (km);
- CP tariff (e/kWh);
- Complete charge cost (e);
- Desired charge cost (e);

Algorithm 2:
1: START.
2: VS computes the unitary percentage charge cost of the EV battery:
$1\%_{EV} = BatterySize/100$;
$1\%_{EV}Cost = 1\%_{EV} * UnitaryCost$.
3: $\forall$ CP of $\bar{A}$, VS computes the complete charge cost:
$\%Miss = 100 - \%Res$;
$CC_{cost} = \%Miss * 1\%_{EV}Cost$.
4: $\forall$ CP of $\bar{A}$, VS computes the desired charge cost:
$DC_{cost} = (\%DC - \%Res) * 1\%_{EV}Cost$.
5: VS adds cost options to CP list in $\bar{A}$.
6: CP is chosen/booked by the driver based on the availability and cost.
7: If no CP is chosen in $\bar{A}$ go to STEP 9 of Algorithm 2.
8: VS sends CP choice to other actors.
9: END.

PETRI NET MODELING

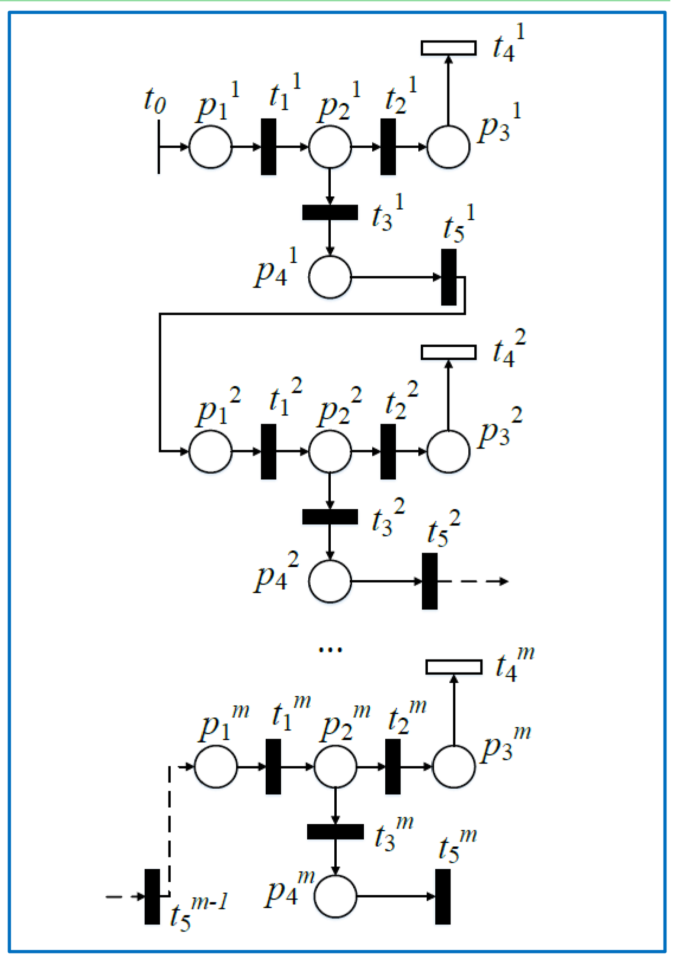
VS1 IMPLEMENTATION SCENARIO

TABLE I
PLACE MEANINGS IN THE AREA A_j OF VS1

Place	Description
p_1^j	VS1 is operative
p_2^j	VS1 is on standby waiting EV driver decision
p_3^j	EV is charging its battery
p_4^j	The new area A_{j+1} is chosen by the EV driver

TABLE II
TRANSITION MEANINGS IN THE AREA A_j OF VS1

Transition	Description	δ_i^j
$t_0 \in T_I$	VS1 service is requested	0.0
$t_1^j \in T_D$	CP list of A_j is trasmitted to VS2	0.1
$t_2^j \in T_D$	The driver decides to charge the EV in area A_j	syn
$t_3^j \in T_D$	The driver decides to change area	syn
$t_4^j \in T_E$	The EV charging is completed	syn
$t_5^j \in T_D$	VS1 returns to be operative for the area A_{j+1}	0.1



VS2 IMPLEMENTATION SCENARIO

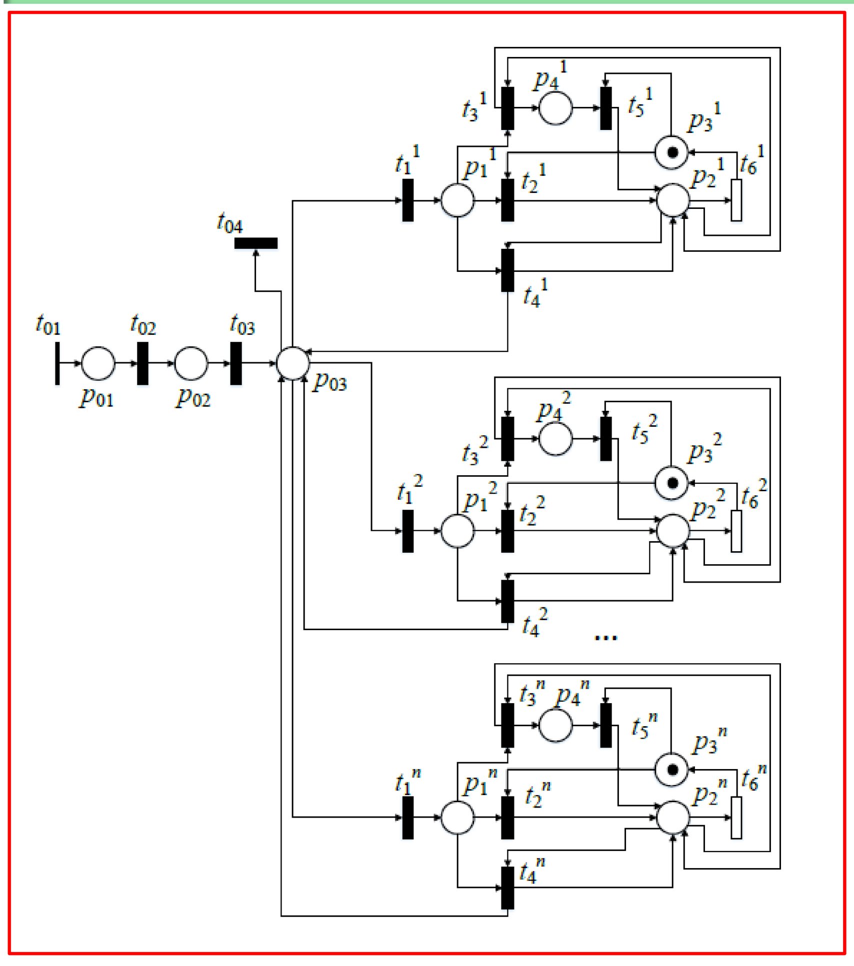


TABLE III
PLACE MEANINGS IN THE PN OF VS2

Place	Description
p_{01}	All needs data of VS1 are received by VS2
p_{02}	VS2 is operative (CP cost calculation)
p_{03}	The CP charging costs are trasmitted to the EV driver
p_1^i	The driver decides to charge the EV in CP_i
p_2^i	The CP_i is occupied
p_3^i	The CP_i is available
p_4^i	The EV driver decides to wait the CP_i availability

TABLE IV
TRANSITION MEANINGS IN THE PN OF VS2

Transition	Description	δ_i^j
$t_{01} \in T_I$	VS1 data are received by VS2	0.0
$t_{02} \in T_D$	VS2 calculates the charging costs	1.0
$t_{03} \in T_D$	VS2 trasmits the charging costs to the EV driver	0.1
$t_{04} \in T_D$	EV driver decides to change area	3.0
$t_1^i \in T_D$	The driver chooses to charge the EV in CP_i	3.0
$t_2^i \in T_D$	The EV starts its charging in CP_i	2.0
$t_3^i \in T_D$	The driver decides to wait the CP_i availability	1.5
$t_4^i \in T_D$	The driver decides to choose another CP_i or to change area	1.5
$t_5^i \in T_D$	EV starts its charging in CP_i after the wait	2.0
$t_6^i \in T_E$	The EV charging is completed in CP_i	60.0

REFERENCES

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CONCLUSIONS

This paper proposes innovative services to facilitate the electric vehicle smart charging. To this aim, two virtual sensors (VSs) are presented, providing services devoted to the charge station finding and booking and the charge cost determination. In particular, the VSs operations are described by means of two algorithms and the interactions between the VSs and the electromobility stakeholders are represented by a UML sequence diagram. Moreover, the VSs functions are described in a Petri Net framework.
Future works will define suitable KPIs in order to verify the VS performances and the PN models will be simulated in specific scenarios. Moreover, new services will be proposed to enhance the EV usage.