EV: Communication Infrastructure Management System

Anitha Dhianeshwar (*Author*)
TCoE – IITM
IIT Madras
Chennai, India
anitha@tcoe.iitm.ac.in

Dr.Prabhjot Kaur (*Author*)
EE Department
IIT Madras
Chennai, India
prabhjot@tenet.res.in

Sreehari Nagarajan (*Author*)
Chakra Network Solutions Private Limited
Chennai, India
sree@chakranetwork.com

Abstract— **Green transport, a transport that has minimal or no dependence on fossil fuels and hence minimal or zero-carbon foot print is the need of the hour. The factors inhibiting the proliferation of this are lack of implementations of international standard – for charging between Electric Vehicle (EV) and Electric Vehicle Supply Equipment (EVSE), for communication between EVSE and a Central Management System (CMS). This paper explains the criteria for ranking of different standards for EV-EVSE communication for low voltage DC chargers and also shares implementation results of the same. The next leg of the communication i.e., between EVSE and CMS implementation is also discussed. The CMS design incorporates open-APIs enabling development of mobile applications, so as to provide a holistic platform for enabling EV proliferation. The results of initial implementation of end-to-end stack is also presented.**

Keywords— ***EV, EVSE, CMS, Mobile Application, DC charging protocols***

I. Introduction

Proliferation of EVs depends on access to charging infrastructure. The following are the components that constitute this infrastructure (i) EVSE (ii) CMS (iii) Mobile application for the EV user/driver.

EVSE or the charge points is the charging equipment that is required to charge the vehicles (EV). CMS is an invaluable tool that the power-DISCOMs need at their disposal, so that consumption from power-grid is monitored and electric vehicles are charged with time of day metering. The mobile application, among other things, is for the user to figure out the available charging stations and reserve for a charging session and also to obtain the billing details based on the time of day metering.

For these components to work in tandem, standardized communication framework is of paramount importance. For example, the EVSE has to communicate with EV to guarantee, safe and secure supply of energy. EVSE also needs to handle user authorization, billing and other information related to the charging process - and this requires communication with the CMS. The EV user interacts with the CMS for the access of information and to obtain desired services from a charging station using a standards-based communication.

International Communication standards are available to help in structured communication between EV-EVSE and EVSE–CMS. Implementation of these standards are the cornerstones on which the deployment, operation and maintenance of a charging infrastructure depends on. This paper discusses the requirements for the Communication Infrastructure Management System (CIMS) - a term that encompasses EV-EVSE communication, EVSE-CMS communication and EV User mobile app - CMS communication, to enable the communication among these components.

A detailed study on the available EV charging communication standards, their comparison is presented. Implementation of the chosen EV charging communication standard, along with EVSE-CMS implementation and CMS-EV User mobile apps is also discussed.

II. CIMS Requirements

The EV eco system is made up of the following actors: Electric Vehicle, Electric Vehicle User/Driver, Electric Vehicle Supply Equipment (i.e. Chargers) and a Central management system. Fig. 1 presents the architecture of CIMS. This section provides the high-level requirements for each of the three building blocks in the CIMS architecture

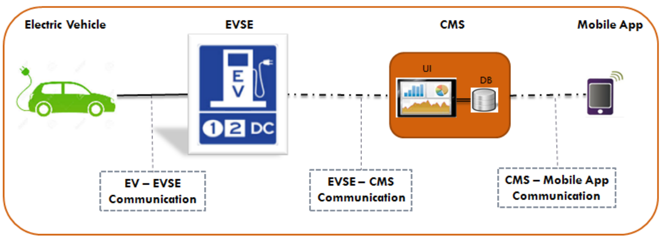

Fig.1 CIMS Architecture

A. EV – EVSE Communication

In the EV - EVSE communication, the protocol has to first recognize the battery and charger followed by the monitoring of the parameters of charger and Battery Management System (BMS), like voltage, current and temperature. The whole charging process is to be managed by EVSE according to the charge control algorithm within a stipulated time limit, along with the relevant error handling at each stage.

For DC fast charging mode, there are international standards available for communication between EV and EVSE. These standards are analyzed, compared and the criteria for ranking standards is explained in detail in Section III on Communication Protocols.

B. EVSE – CMS Communication

The EVSE needs to communicate with CMS and authorize the user, before electric vehicle supply equipment can start or stop charging. It needs to update CMS with the details like its firmware version, vendor make, model number, information about the charging sessions, provide periodic heart beats, error conditions in the EVSE, metering values for the charging sessions. These meter values along with the timestamp helps is the Time of Day metering.

CMS will communicate with EVSE for information on the firmware update and for obtaining the meter values to provide extra information about the metering values. The CMS can request an EVSE for reservation and cancellation based on the request from the EV user

The goal for EVSE- CMS communication is to develop an interoperable system for charging points with vendor independence. The OCPP is an open standard application protocol for between EVSE and CMS.

C. CMS – Mobile Application Communication

The mobile application communicates with CMS using JSON (Java Script Object Notation) over HTTP to enable features and services to the EV User. The application aids EV user in locating the nearby and compatible charging stations, check its availability and reserve/cancel reservation at a charge point. It also provides charging history along with consumed units and Time of day (ToD) billing cost in detail.

III. EV - EVSE COMMUNICATION PROTOCOLS

A. EV – EVSE Protocol Analysis

The Communication between EV - EVSE has to follow certain algorithm and sequence to achieve the goal of charging the EV. Conformity to the International standards for the digital communication helps to assure that the system is safe, reliable and interoperable.

IEC 61851-23[1] defines the requirements for the DC charging system and details three systems based on the physical layer, application layer support and the output voltage range. The IEC 61851-24[2] is the standard for the digital communication between a DC EV Charging station and the EV, for the control of DC charging.

Based on the physical layer, EVSE communicates using CAN bus or through Power Line Communication (PLC). Table I details the EVSE Classification based on their corresponding physical and application layer support details.

Table II provides an overview of the three protocols based on the communication speed, data format and the number of charging stages

TABLE I. SYSTEM BASED EVSE CLASSIFICATION

#	System	Physical Layer	Application Layer	Protocol Name	Voltage
1	System A	CAN 2.0[3]	CAN	CHAdeMO[4]	Up to 500V
2	System B	CAN 2.0	CAN	GB/T 27930[5]	Up to 1500V
3	System C	PLC	IPV6	ISO 15118 - 2[6]	Up to 1000V

TABLE II. PROTOCOL OVERVIEW

#	Protocol Name	Communication Speed	Data Format	Charging Stages
1	CHAdeMO or JIS/TSD 0007	500 Kbps	Standard CAN 11 bit Identifier	4
2	GB/T27930	250 Kbps	Extended CAN 29 bit Identifier	4
3	ISO15118 -2	- (IPV6)	Efficient XML Interchange (EXI) Format	18

1) Parameters for protocol comparison

Table III lists the parameters that are considered for evaluating the different protocols. The table also describes why these parameters are important for the evaluation and also provides the weightage given to each of the parameters. The broad criteria used for choosing these protocols included, existing vehicle design in the automotive industry, additional effort of incorporating the communication protocol in the design and existing vehicle's incumbent communication bus standards.

TABLE III. PROTOCOL COMPARISON PARAMETERS

#	Parameters	Description – Why this parameter is important for protocol finalization?	Weightage
1	CAN Compliance	"De-facto" Vehicle Standard Interface	20%
2	Implementation Easiness	How easy is it to implement the protocol - Would be easy if it is an extension of something already present - say for e.g. based on CAN data frame format	10%
3	Additional Controller Cost	To check, if any additional controller stands out to be an overhead in the implementation of messages.	10%

4	Granularity of charging parameters	Granularity of Mandatory / Optional Parameter counts at each stage during the charging - More granular the parameters, richer the protocol is.	15%
5	Extendibility	The protocol extendibility support with further version release	10%
6	Connector cost	For economies of scale - What is the cost of the connector that supports this protocol	5%
7	Safety aspects	Coverage of safety aspects like cable check, welding detection, protection against electric shock, indirect contact etc.	10%
8	Supported charging modes	Constant current mode and / or Constant voltage mode. Some battery chemistry work better based on the charging mode	10%
9	Certification cost	Cost incurred in the certification of the protocol - Presumably a one-time cost for one version of implementation of the protocol	10%
10	Validity period of protocols	To help us to avoid in investing in a protocol that is set to expire in near future	5%

2) Protocol Ranking Analysis

For reasons of brevity, in the following analysis System A or CHAdeMO is referred to as A, System B or GB/T 27930 is referred to as B and System C or ISO 15118 -2 is referred to as C.

For each protocol, each of the parameters in Table III is given a score based on the adherence or compliance of the protocol to the parameter on a scale of 0 to 10(with 10 indicating complete adherence and 0 indicating no-adherence). Higher the adherence, higher the score. Some of the prominent parameters where there are differences between the protocols is explained below

a) Compliance to CAN: A & B supports CAN whereas C supports PLC. This is reflected in the following score line of A - 10, B- 10, C- 0.

b) Implementation Easiness: The mapping of protocol messages to CAN framing is straight forward in A & B whereas in C the mapping of IPV6 messages to CAN needs extra effort thus A and B out-scoring C to end up with the following scores - A - 10, B- 10, C- 2.5

c) Additional Controller Cost: As C supports IPV6 based messages , mapping of these messages to CAN frame requires an additional controller whereas for A & B message mapping is straight forward and hence A and B again outscore C for a score line that reads A-10, B-10, C-0

d) Granularity of charging parameters : Number of parameters supported by A,B and C are 37,70 and 66 respectively and this is reflected in their score which reads as A- 7, B – 10, C – 9

e) Connector Cost : The connector cost for EVSEs implementing protocol B is the least expensive followed by C and A and resulting in a score line of A- 6, B – 10, C – 8

f) Charging Mode : B supports both charging modes, with A & C supporting Constant current mode which leaves the scores at A- 5, B – 10, C – 5

Since there is not much of a difference between these protocols in terms of validity period and certification costs, these are not scored. Table IV provides a detailed comparison of the parameters, relevant weightage, score, weighted score and ranking derived from these values.

Based on the ranking results, B merged on top followed by A and C in that order. Based on this, as a first step, implementation of GB/T 27930 protocol between EV – EVSE was taken up.

TABLE IV. PROTOCOL RANKING

#	Parameter	Weightage	Score			Weighted Score		
			CHAdeMO	*GB/T 27930*	*ISO 15118 -2*	*A*	*B*	*C*
1	Compliance to CAN	20%	10	10	0	2	2	0
2	Implementation Easiness	10%	10	10	2.5	1	1	0.25
3	Additional Controller cost	10%	10	10	0	1	1	0
4	Granularity of charging parameters	15%	7	10	9	1.05	1.5	1.35
5	Extendibility	10%	10	10	10	1	1	1
6	Connector Cost	5%	6	10	8	0.6	1	0.8
7	Safety Aspect	10%	10	10	10	1	1	1
8	Validity period of protocols	5%				0	0	0
9	Constant Ct /Constant volt: Charging Mode	10%	5	10	5	0.5	1	0.5
10	Certification Cost	5%				0	0	0
	SUM	100%	68	80	44.5	8.15	9.5	4.9
					Rank	2	1	3

B. *EVSE – CMS Protocol*

OCPP 1.5[7] provides 25 operations for the EVSE – CMS communication with 10 operations initiated from EVSE and 15 operations initiated from CMS. Table V & Table VI details the EVSE and CMS initiated operations and their description respectively.

TABLE V. EVSE INITIATED OPERATIONS

#	Operation	Description
1	Authorization	To authorize user before the charging session starts
2	Boot Notification	To inform central system about the Charge box configuration details
3	Data Transfer	To send vendor specific information to central system
4	Diagnostics Status Notification	To inform about the completion of diagnostics file upload to central system
5	Firmware Status Notification	To inform about progress of the firmware update
6	Heartbeat	To inform the central system at particular interval that the charge box that it is still alive
7	Meter Values	To provide information about the meter values to the central system at some defined interval
8	Status Notification	To notify about a status or error condition to central system
9	Start Transaction	To inform the start of a charging transaction
10	Stop Transaction	To inform the stop of a charging transaction

TABLE VI. CMS INITIATED OPERATIONS

#	Operation	Description
1	Cancel Reservation	To cancel a reservation based on the reservation ID
2	Change Availability	To request the charge box to change the availability to available or unavailable
3	Change Configuration	To request charge box to change its configuration parameters
4	Clear Cache	To request a charge box to clear its cache
5	Data Transfer	To send vendor specific information to the charge box
6	Get Configuration	To retrieve the value of configuration settings of the charge box
7	Get Diagnostics	To request a charge box for diagnostics information
8	Get Local List Version	To request the version number of the local list at the charge box
9	Remote Start Transaction	To request a charge box to start a transaction by sending a remote start transaction
10	Remote Stop Transaction	To request a charge box to stop a transaction by sending a remote stop transaction
11	Reserve Now	To reserve a specific connector at the charge box for use by a specific ID-Tag
12	Reset	To request a charge box to reset itself
13	Send Local List	To send a local authorization list to charge box for authorization of ID-Tags
14	Unlock Connector	To request the charge box to unlock one of its connector
15	Update Firmware	To notify the charge box to update its firmware

C. *CMS – Mobile Application Protocol*

The Communication between CMS – Mobile application is based on JSON using web services. The application has the following important features. EV User Registration / Profile Update, Charge point description with average user rating, user reviews listing, report a complaint about a Charging Station , Map interface with markers for Charging Stations with indications for operative/inoperative CPs, reservation availability status, Search option to locate nearby (compatible) stations, Driving directions, FAQs, Reservation history with cancel reservation option, Charging history with consumed units & cost, Detailed ToD metering update, Notifications about reservation , new charge point addition and meter values update at the end of a charging session.

IV. DEVELOPMENT RESULTS

With the integrated CIMS implementation, the complete communication cycle starting from the reservation of a charge point from mobile application by the EV user followed by the charging session at EVSE for the reserved slot and the updated charging session details at CMS like meter values, duration of charging, cost for the charging session and finally passing of meter values and consumed cost being sent to the EV User, are developed and tested

A. *EV - EVSE*

Boards with CAN support (for EV & EVSE) and with HTTP support (for EVSE) are used for the implementation of the protocols using FreeRTOS.

On EV side, the GB/T 27930 protocol implementation on CAN to communicate with EVSE is developed and tested.

On EVSE side, the GB/T 27930 protocol implementation on CAN to communicate with EV.

B. EVSE - CMS

For EVSE, the implementation of OCPP1.5 protocol communicating over web services is developed and tested.

For CMS, a web based application with OCPP implementation along with other features like, admin panel for Charging Point (CP) user Management, Charging stations & charge points management, interface for EV user from mobile app, Time of Day metering management – for profile creation, assignment to a charge point and calculation of cost for consumed units based on the ToD slots, is built. A CP user panel is also built to aid the owner of a charging station to add/update/delete charge points and to view the transaction details that has taken place in her charging points.

Fig 2 shows snapshot of CMS on the log of CP initiated operations with the status of the response from respective charge points and Fig 3 shows ToD profile creation for normal day, special day and profile assignment to charge points.

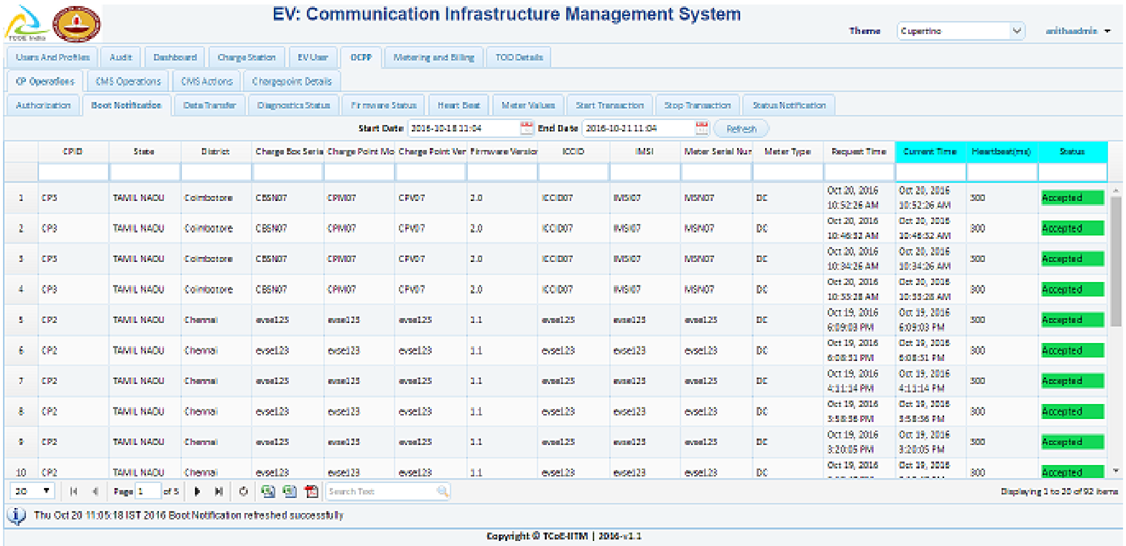

Fig.2 CMS Snapshot – CP Initiated operations log

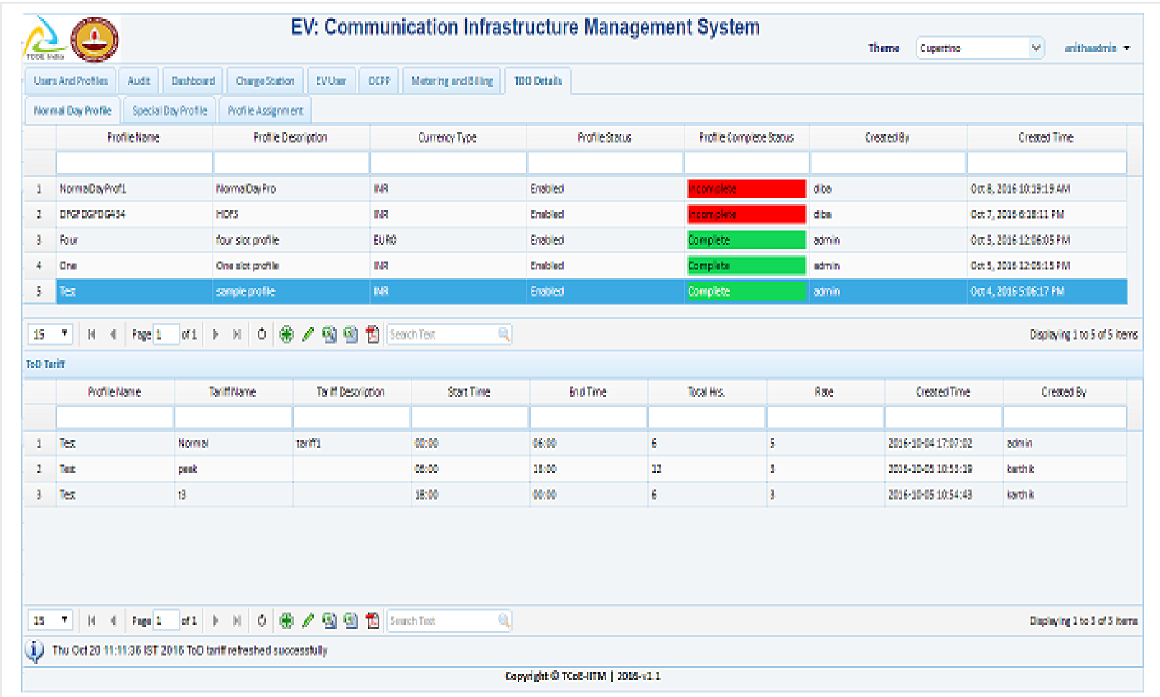

Fig 3: CMS Snapshot on TOD details

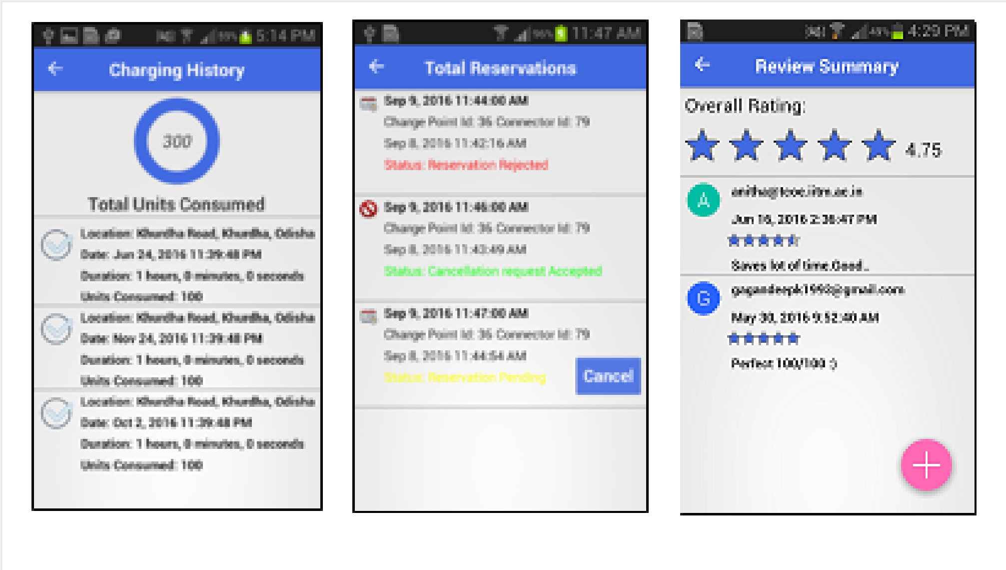

Fig 4. Android App snapshots

C. CMS – Mobile Application

The mobile application is based on Android and communicates over web services to render the listed features in CMS – Mobile Application Protocol. Fig. 4 shows the mobile application's snapshots of charging history, Reservation history and Review page

V. CONCLUSIONS & FUTURE WORK

With the emphasis on green technologies that the world is now witnessing, EVs are one of the major areas that is poised to grow and contribute towards that goal. This paper has presented the details of the implemented CIMS, with EVSE communicating with EV on GB/T 27930 protocol on one side and communicating with CMS using OCPP 1.5 protocol on the other side. In addition, the EV user mobile app implementation, where EV user communicates with CMS for the required information and services is also elaborated.

This integrated CIMS model is an important technology milestone that provides an end-to-end solution in the charging infrastructure for the EV eco system. This is an important cog in the wheel for EV proliferation in India.

We are moving to work on the other two EV-EVSE communication protocols: CHAdeMO and ISO 15118-2, in the same order with the other communication models remaining the same.

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