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Draft Indian Standard

ELECTRIC VEHICLE BATTERY SWAP SYSTEM – PART 4 LIGHT ELECTRIC VEHICLES – SECTION 3 COMMUNICATION PROTOCOL

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Electrotechnology in Mobility Sectional Committee, ETD 51

NATIONAL FOREWORD

(*Formal clauses will be added later***)**

The Indian Standards for an interoperable Battery as a Service (BaaS) System for Light Electric Vehicles consist of following series of standards:

Part 1 General Guidelines
Part 2 Safety Guidelines
Part 3 Central Management System
Part 4/Sec 1 Light Electric Vehicle- Guidelines and Pack Dimensions
Part 4/Sec 2 Light Electric Vehicle- Connection System
Part 4/Sec 3 Light Electric Vehicle- Communication protocol

In order to increase the pace of transformation of mobility, the Government of India is promoting Battery as a Service (BaaS) wherein the electric vehicles batteries can be replaced at the Battery Swap Station. BaaS is designed as an interoperable system for consumer convenience, faster adoption (scalability), and asset utilisation wherein within the light electric vehicle categories, any vehicle can use these battery packs inter-changeably. This standard covers communication protocol requirements.

The composition of the committee responsible for formulation of this standard is given at Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2: 1960 ‘Rules for rounding of numerical values (revised)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft Indian Standard

ELECTRIC VEHICLE BATTERY SWAP SYSTEM
PART 4 LIGHT ELECTRIC VEHICLES
SECTION 3 COMMUNICATION PROTOCOL

1 SCOPE

1.1 This standard is applicable to Battery Swap System(BSS) connected to supply, with rated input supply voltage upto 415 V a.c, 50 Hz or up to 400 V d.c. and swappable battery system(SBS) with a nominal voltage of 48 V d.c. and a maximum working voltage of less than or equal to 60 V d.c.

1.2 The aspects covered in this standard include:

a) Requirements for communication protocol for Swappable battery system (SBS);
b) Requirements for communication protocol for Battery Swap System(BSS); and
c) Requirements for communication protocol for vehicle.

1.3 The standard does not cover the detailed requirements for Battery swap systems located in hazardous areas where flammable gas or vapor and/or combustible materials, fuels or other combustible or explosive materials are present. Additional requirements as per CEA , PESO regulations may apply for such locations.

2 REFERENCES

The standards listed below contain provisions, which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below:

IS No	*Title*
IS 17896(Part 1):2022/ IEC TS 62840-1:2016	Electric vehicle battery swap system - Part 1 General and Guidance
IS 17896(Part 1):2022/ IEC 62840-2:2016	Electric vehicle battery swap system - Part 2 Safety requirements
IS 17896 (Part 3)	Electric Vehicle Battery Swap System – Part 3 Central Management System for Interoperable Battery Packs (*under development*)
IS-17896 (Part 4/Section 1)	Electric Vehicle Battery Swap System – Part 4 Light Electric Vehicles – Section 1 Guidelines and Pack Dimensions (*under development*)
IS 17896 (Part 4/Sec 2)	Electric Vehicle Battery Swap System – Part 4 Light Electric Vehicle-Sec 2 Connection System (*under development*)
ISO 11898-1:2015	Road vehicles — Controller area network (CAN) — Part 1: Data link layer and physical signaling
AIS 065	Statutory Plates and Inscriptions for Motor Vehicles, their Location and Method of attachment – Vehicle Identification Numbering System
AIS 007	Information on Technical Specifications to be submitted by the Vehicle Manufacturer
SAE J1939	Recommended practice for a serial control and communications vehicle network
SAE J1939 / 14_201612	Physical layer, 500 Kbps
SAE J1939 / 21_200612	Data link layer

3 TERMINOLOGY

For the purpose of this standard, the following definitions in addition to those given in IS 17896 (Part 4/Sec 1) shall apply.

3.1 Parameter

A single piece of information relevant to charging/discharging control, and that is exchanged between a battery and a charger/vehicle using a form of digital communication.

4 SYSTEM CONFIGURATION

The system configuration shall be in accordance with **5.4.2** of IS-17018 Part 4 /Section 1.

5 DIGITAL COMMUNICATION ARCHITECTURE

In this standard, digital communication architectures based on CAN using a dedicated data communication circuit is used. CAN protocol is given in ISO 11898-1; refer to Annexure A for specific implementation details.

6 CHARGING/DISCHARGING CONTROL PROCESS

The charging / discharging control process shall be in accordance with **6.4.4** of IS-17018 Part-4 /Section 1.

7 OVERVIEW OF CHARGING/DISCHARGING CONTROL

The digital communication of charging / discharging control covered by this standard is as shown in Figure 1. This standard does not cover the control protocol inside the device, such as battery management control of the battery (SBS) , charge control function of the charger (BSS) , or motor control protocol of the vehicle.

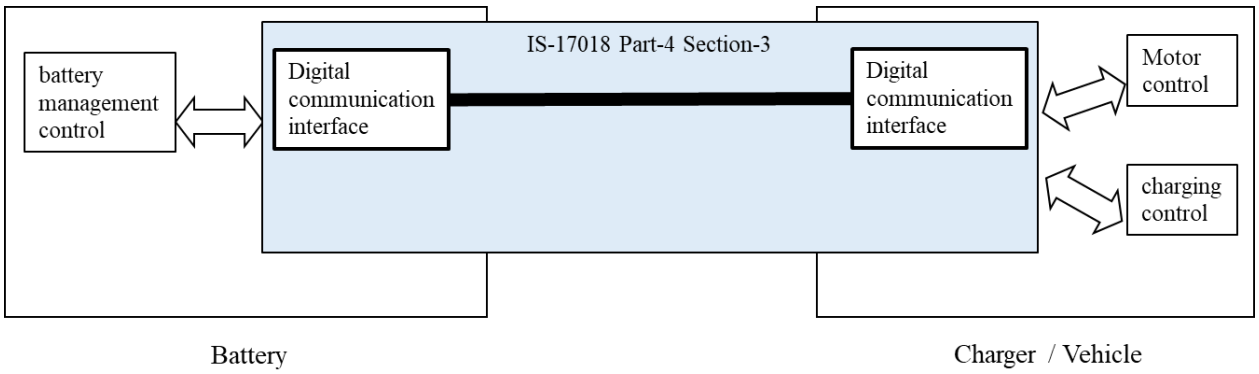


Figure 1 – Digital communication between Battery (SBS) and Charger (BSS) / Vehicle for control of charging/discharging

ANNEXURE A

A.1 Introduction

This annexure specifies the communication protocols for battery swapping architecture. Figure. 2 shows the battery swapping architecture and the various entities involved on a broad perspective.

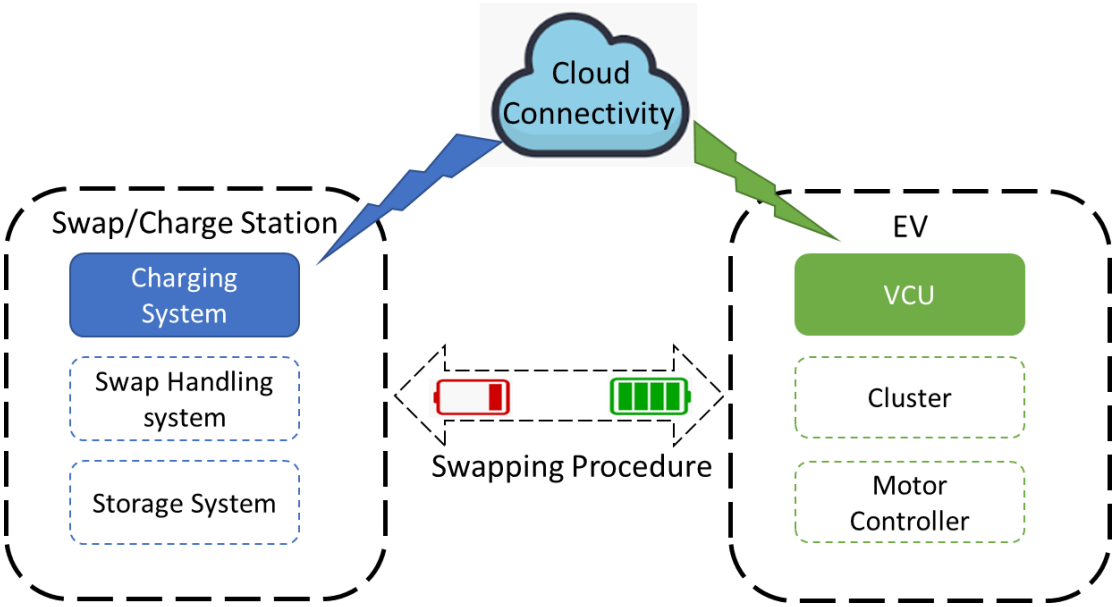


Figure 2: Battery Swapping Architecture

The Swap/Charge station comprises of Charging System, Swap handling system and storage system as major modules along with other sub systems. Similarly, Electric Vehicle (EV) comprises of Vehicle Control Unit (VCU) , Cluster and Motor controller as major modules along with other sub systems. This annexure presents the specifications of the communication between swap/charge station and EV detailing the following protocols:

a) **Charging Protocol**: Communication protocol between battery swap/charger (BSS) system and battery management system (BMS) of the swappable battery system (SBS) /removable rechargeable energy storage system (REESS) battery pack.
b) **Driving Protocol**: Communication protocol between light electric vehicle (EV) and BMS of swappable battery system (SBS) -REESS battery pack.

Note 1: Communication protocols pertaining to quick start of EV may potentially be considered in later versions/revisions of this standard.

Note 2: Communication protocols pertaining to non-EV usage of the battery (For example, for driving a household lighting using these battery packs) may potentially be considered in later versions/revisions of this standards.

A.2 CAN Communication Protocol

The communication protocol shall be based on CAN (Controller Area Network) 2.0B. The definitions of physical layer, data link layer and application layer shall be common for both charging and driving protocol.

A.2.1 Physical Layer

Physical layer shall follow following standards

a) Standards: ISO 11898-1:2003 and SAE J1939-14: 201612
b) Baud rate: 500kbps

A.2.2 Data Link Layer

A.2.2.1 Frame Format

The swappable battery system shall use 29-bit identifier of CAN extended frame, and the corresponding definition of each specific bit allocation shall meet the requirements as given in SAE J1939-21:2006.

A.2.2.2 Protocol Data Unit (PDU)

Each CAN data frame contains a single protocol data unit (PDU) . The protocol data unit is composed of seven parts which respectively are priority, reserved bit, data page, PDU format, specific PDU, source address and data field. Figure. 3 shows the PDU format

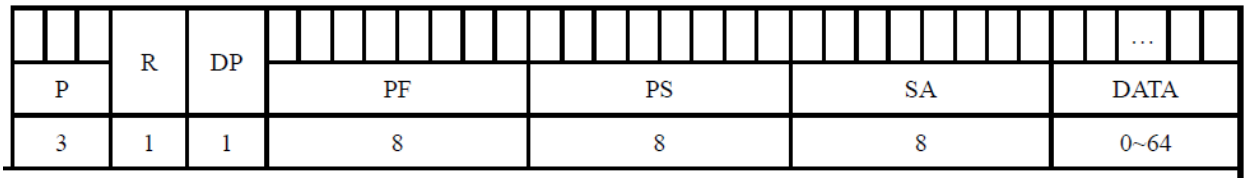


Figure 3. PDU Format

a) P – Priority set from highest 0 to lowest 7
b) R – Reserved bit is set as zero in this specification
c) DP -Data Page is set as zero in this specification
d) PF – PDU Format. IN this standard, PDU1 format as defined in SAE J1939-21:2006 is used
e) PS – PDU Specific. With PDU1, PS value will be destination address
f) SA – Source Address
g) DATA – Up to 8 bytes of data can be transmitted. For data size beyond 8 bytes, the communication shall be established using multiple packets of parameter groups.

A.2.2.3 Functions of transport protocol

The transport of 9~1785-byte data between BMS and battery swapping station (BSS) charger shall use the transport protocol function. The specific connection initialization, data transport and connection closing shall comply with the provisions on message transport as given in 5.4.7 and 5.10 of SAE J1939-21:2006. As for the multi-frame message, the message period refers to the transport period for the whole data package.

A.2.2.4 Address allocation

Network address shall ensure the uniqueness of the message identifier and the message source. The battery swapping station (BSS) charger address shall be 128 (Dec) or 80H and swappable

battery system address shall be assigned by the battery swapping station (BSS) charger as a part of the protocol.

A.2.3 Application Layer

a) The application layer is defined as set of parameters and parameter groups.
b) Parameter group is numbered by Parameter Group Number (PGN) , and each node identifies the content of data packet according to PGN.
c) The second byte of PGN is PDU format (PF) value, and both high byte and low bytes of PF shall be 00H
d) Data shall be transported in the form of periodic messages or event-driven messages.
e) The message options may be either mandatory or optional. If all the contents in the same frame of message are optional, such message shall not be transported; if some contents in the same frame of message are optional, all the optional bits shall be transported in the format as specified in this standard. Optional bits or fields not specified in this standard may be filled with 1.
f) The length and content of message shall be transported in the format as specified in this standard.

A.2.3.1 Time-out

In each stage, if SBS BMS (or charger (BSS) /vehicle) does not receive message from the charger (BSS) /vehicle (or SBS BMS) or does not receive correct message within the stipulated time limit, the waiting entity will timeout. Unless otherwise specified, the timeout is 5 Seconds for all the messages. After timeout, the SBS BMS (or charger (BSS) /vehicle) expecting the message shall send the time-out message.

A.2.3.2 Suspension

The following three types of suspension shall be addressed:

a) **Error Suspension:**
The flow shall stop after occurrence of an error and shall start after resolution of the error. Some errors like Battery Identification Number (BIN) –Vehicle Identification Number (VIN) mismatch or BIN-Battery Charging Station Number (BCSN) mismatch are non-recoverable, while others like battery or component over-temperature can be overcome with some idle time.

b) **Warning Suspension:**
These alerts shall warn the user of impending potential problems that could automatically stop the flow.
Note: It is advisable for the user to stop the vehicle so that the warning condition does not become an error. For e.g., if there is a battery over-temperature warning, stopping the vehicle and waiting for some-time for the temperature to come down will prevent an abrupt stopping.

c) **Other Suspension:** There shall be provision for sending other suspensions as a part of protocol. For example, manufacturer specific suspension codes shall also be supported.

A.2.3.3 Cloud Connectivity

The timeout for CAN communication is 5 Seconds. In case of network delay in obtaining response from server when the charger (BSS) /vehicle tries to communicate with the cloud

during the communication flow, there could be a possibility of network delay in getting the response from the server. In such cases, a 10 Seconds timeout shall be considered.

Note: The mechanism and parameters to be communicated to cloud for diagnostic and safety related alerts are out of scope of this standard.

A.3 Verification Procedure

Verification stage is a part of both charging and driving protocol. This verification shall be performed to ensure that only the authorized batteries are used with the charger (BSS) /EV. Further, the batteries shall charge/discharge only in authorized chargers (BSS) and vehicles. The verification of battery (SBS) shall be performed through a verification message sent by the battery (SBS) to the charger (BSS) /vehicle. This verification message shall be communicated by the charger (BSS) /vehicle to the Central Management System (CMS) to verify the identity of the battery (SBS) .

The actual mechanism for verification can be left to each energy operator (EO) . However, the response message from the charger (BSS) /vehicle to the verification message from the battery (SBS) shall contain the number of verification messages to be exchanged in both the directions. Post successful verification of the battery identity (BIN) by the charger (BSS) /vehicle the flow shall proceed to the next stage.

The verification of vehicle/charger (BSS) by battery (SBS) are optional in this standard as it requires independent Internet connectivity for the battery (SBS) . The place holders for carrying this procedure is elaborated in clause A.4.2.3. and clause A.5.3.3. The authentication library will be provided by Energy Operator (EO) .

A.4 Charging Protocol

A.4.1 Overall Charging Procedure

The Communication protocol between a Battery Swapping Station (BSS) and Battery Management System (BMS) of SBS comprises of multiple stages.

After establishment of physical connection, protocol starts with

a) Address Assignment Stage,
b) Handshake Stage,
c) Identity Verification/Authenticity check Stage,
d) Parameter Exchange Stage,
e) Charging Stage, and
f) End-of-charging stage.

Suspension and message time-outs are handled throughout the protocol stages. Figure. 4 shows the charging protocol stages.

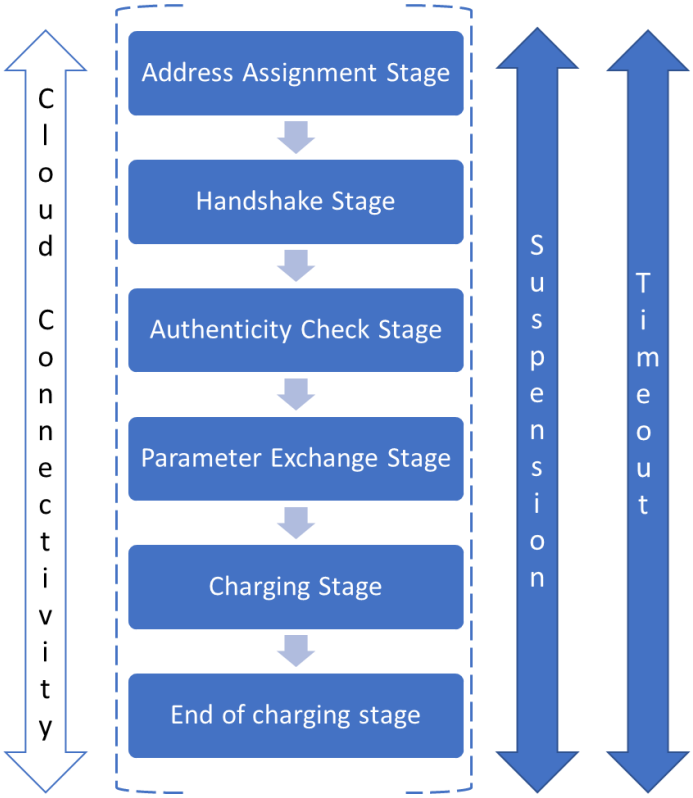


Figure 4: Charging Protocol Stages

A.4.2 Charging Protocol Stages

The BSS shall be capable of charging multiple batteries simultaneously. The BSS shall assign the address automatically to each BMS of SBS as it gets plugged in. For all the parameters, the order of Suspect Parameter Numbers (SPNs) in the CAN communication shall be as per the order specified in this standard. For any suspension during the protocol flow, the state machine shall reset and start from the beginning of the protocol.

A.4.2.1 Address assignment stage

The BMS of SBS is assumed to start charging as it gets connected to the Charger (BSS) . The BMS mode switching, for example from Driving or Sleep state to charging state is out of scope of this definition and to be handled by BMS based on message sequence or decision made based on some internal mechanism.

Charger (BSS) keeps broadcasting a message to initiate the protocol flow in the beginning of the auto-address assignment stage. When battery (SBS) is connected to the charger (BSS) , the charging protocol shall be initiated in the battery (SBS) by listening for and responding to the charger broadcast message (CBM) from charger (BSS) .

The SBS BMS address will not be hard coded in them, instead when SBS are connected to BSS, BSS shall assign address to each SBS. BSS should reserve the address in the range of 0x95 - 0xD0 for SBS-BMS addressing. BSS's source address (SA) is defined as 128 (80H) . By default, SBS-BMS should have default address as 254 (0xFE) , i.e., Null address when it gets connected to the BSS.

A.4.2.1.1 Assignment Process

a) **MESSAGE 1: Request for address claim from SBS-BMS**

SBS-BMS will send a request for address claim to BSS by generating a random number (RN1- e.g 2E2614D0) of 4 bytes in the data field.

Bytes 1 to 4 will be used for this. Unused bytes in the data field will be filled with 0x00.

SA	**DA**	**DATA Byte: 01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
FE (Null Address)	80 (BSS Address)	2E2614D0	00	00	00	00

b) **MESSAGE 2: Broadcast response for address claim from BSS**

In case BSS received the **MESSAGE 1** successfully it broadcasts to CAN bus with the same random number (RN1- 2E2614D0) and allotted address (e.g 0x95) . The allotted address will be available in the 5th byte of data field.

SA	**DA**	**DATA Byte:01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
80 (BSS Address)	FF (Broadcast Address)	2E2614D0	95	00	00	00

c) **MESSAGE 3: SBS-BMS confirmation request for allotted address from SBS-BMS**

Once the SBS-BMS receives **MESSAGE 2** it shall request BSS to confirm the usage of the allotted address by generating and sending another random number (RN2 – e.g 33AB7F30) and allotted address (0x95) to BSS.

SA	**DA**	**DATA Byte:01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
FE (Null Address)	80 (BSS Address)	33AB7F30	95	00	00	00

d) **MESSAGE 4: BSS confirmation response for allotted address from BSS**

On receiving the **MESSAGE 3**, the BSS shall broadcast to CAN bus with the random number (RN2) , allotted address (0x95) and address status (0xAA: Success; 0xFF: Failure) .

The address status shall be available in the 6th byte of data field. If the status from BSS is a failure, i.e., the address being allotted to some other SBS-BMS, then SBS-BMS must repeat and start from **MESSAGE 1**.

SA	**DA**	**DATA Byte: 01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
80 (BSS Address)	FF (Broadcast Address)	33AB7F30	95	AA	00	00

e) **MESSAGE 5: SBS-BMS confirmation on allotted address**

On receiving the **MESSAGE 4**, the SBS-BMS confirms to BSS on the allotted address by sending the random number 2, allotted address and the confirmation status (0xAA: Success; 0XFF: Failure) using the allocated address.

SA	DA	DATA Byte:01-04	DATA Byte:05	DATA Byte:06	DATA Byte:07	DATA Byte:08
95 (Allocated SBS-BMS Address)	80 (BSS Address)	33AB7F30	95	AA	00	00

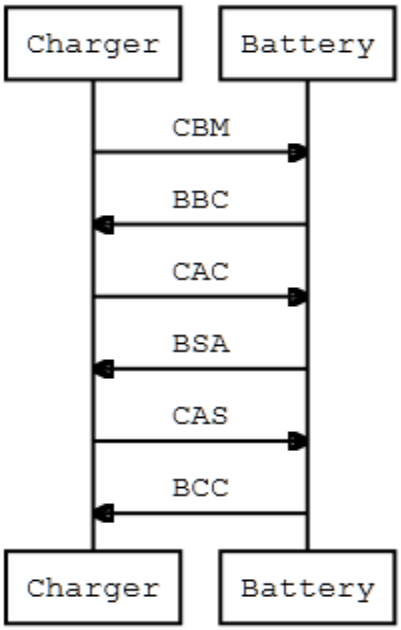
If the status from BSS is failure at any stage the SBS-BMS shall repeat and start from **MESSAGE 1** to get an address assigned. When BSS sees a success status (receives **MESSAGE 5** successfully) , it ensures that this address is not given to any other SBS-BMS.

The address assignment for other SBS-BMS shall happen in parallel in the same manner. The following use case is presented to elaborate on address assigning procedure under few conditions:

Use Case: BSS receives the same random number from two SBS-BMS (in **MESSAGE 1**)

1) BSS will broadcast RN1+allotted address as defined in **MESSAGE 2**.
2) Both the SBS-BMS will receive this response and will send a confirmation request for allotted address with random number 2 (RN2) in **MESSAGE 3**.
3) BSS will receive the messages and by looking at the allotted address being common in the packets, it will send (**MESSAGE 4** with AA in byte 06) success to first SBS-BMS and failure (**MESSAGE 4** with FF in byte 06) to other SBS-BMS.
4) SBS-BMS receiving success status will continue with **MESSAGE 5** onwards and SBS-BMS receiving failure status will start from **MESSAGE 1.**
5) Probability of occurrence of random number 2 being same for two SBS-BMS is less. However, in case the random number 2 is same for the two SBS-BMS, the failure (**MESSAGE 4** with FF in byte 06) is sent to both the SBS-BMS. Both SBS-BMS start from **MESSAGE 1** in this case.

A.4.2.1.2 Message Flow



A.4.2.1.3 Messages

Message Code	Message Description	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
CBM	Charger broadcast message	Charger (BSS) to SBS-BMS; Broadcast	001800H	7	1	500
BBC	Battery (SBS) address claim request message	SBS-BMS to Charger (BSS)	001000H	4	4	250
CAC	Charger broadcasts response for address claim message	Charger (BSS) to SBS-BMS; Broadcast	002600H	4	5	250
BSA	SBS-BMS confirmation address request Message	SBS-BMS to Charger (BSS)	002700H	4	5	250
CAS	Charger confirmation address response	Charger (BSS) to SBS-BMS	002800H	4	6	250
BCC	SBS-BMS confirmation response on allotted address	SBS-BMS to Charger (BSS)	001100H	4	6	250

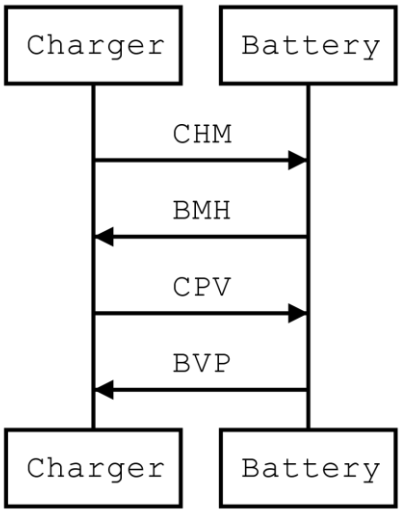
A.4.2.1.4 Parameters

Message Code	Parameter Name	Description	SPN in (Decimal)	Size in Bytes	Delivery Option
CBM	Battery (SBS) wakeup = 0xAA	Charger broadcasting message for battery (SBS) to start charging	2599	1	Mandatory
BBC	Random Number 1	Random number 1 generated by SBS-BMS. Till Charger (BSS) confirms or rejects or time out, this random number 1 to be re-used.	346	4	Mandatory
CAC	Random Number 1	Random number received in BBC	289	4	Mandatory
	Allotted address	Address allotted by charger (BSS)	290	1	Mandatory
BSA	Random Number 2	Random number 2 generated by SBS-BMS. Till charger (BSS) confirms or rejects or time out, this random number 1 to be re-used.	291	4	Mandatory
	Allotted address	Allotted address in CAC	292	1	Mandatory
CAS	Random number 2	Random number 2 received in BSA message	347	4	Mandatory
	Allotted address	Allotted address by charger (BSS) in CAC message	348	1	Mandatory
	Allotted status Success=0xAA; Failure=0xFF	Allotted address status. Charger (BSS) confirming the address status as success or failure	349	1	Mandatory
BCC	Random Number 2	Random number 2 generated in BSA message	350	4	Mandatory
	Allotted address	Allotted address in CAC messages	351	1	Mandatory
	Acceptance status Success=0xAA; Failure=0xFF;	SBS-BMS acceptance status for allotted address	352	1	Mandatory

A.4.2.2 Handshake stage

In this stage, both charger (BSS) and SBS-BMS communicates the Identification numbers, protocol version and checks for any incompatibility in the values shared.

A.4.2.2.1 Message Flow



A.4.2.2.2 Messages

Message Code	Message Description	Source – Destination	PGN (HEX)	Priority	Data Length in Bytes	Message Period (ms)
CHM	Charger Handshake Message	Charger (BSS) to SBS-BMS	002A00H	6	6	250
BMH	Battery Handshake Message	SBS-BMS to Charger (BSS)	002900H	6	26	250
CPV	Charger Protocol Version Acknowledgment Message	Charger (BSS) to SBS-BMS	002C00H	6	1	250
BVP	Battery Protocol Version Confirmation Message	SBS-BMS to Charger (BSS)	002B00H	6	3	250

A.4.2.2.3 Parameters

Message Code	Parameter Name	Description	SPN (Decimal)	Size in Bytes	Delivery Option
CHM	Bulk Charger (BSS) communication protocol version	Communication protocol version number of charger (BSS)	295	3	Mandatory
	Charger (BSS) firmware version	Firmware version of charger (BSS)	2567	3	Mandatory
BMH	BIN	Unique battery identification number	293	20	Mandatory
	SBS-BMS communication protocol version	Communication protocol version number of SBS-BMS	294	3	Mandatory
	SBS-BMS Firmware version	Firmware version of SBS-BMS	2565	3	Mandatory
CPV	Protocol version acknowledgement	Acknowledgement on protocol version from SBS-BMS. Success:0xAA; Failure:0XFF	297	1	Mandatory
BVP	Confirmed version of SBS-BMS communication protocol	Based on charger (BSS) 's protocol version, SBS-BMS will confirm the version number	296	3	Mandatory

A.4.2.3 Verification check stage

Identity verification check is done in two stages:

Verification Stage 1: Verification check initiated by BSS (Charger)

In this stage, a verification message shall be sent by the charger (BSS) . The SBS-BMS shall respond with battery identification number (BIN) verification message. This verification message shall be used by the charger (BSS) to confirm the identity of the battery (SBS) via CMS. For any mismatch, charger (BSS) shall reattempt the verification process. After 3 BIN verification failures the charger (BSS) shall suspend the flow for 5 sec.

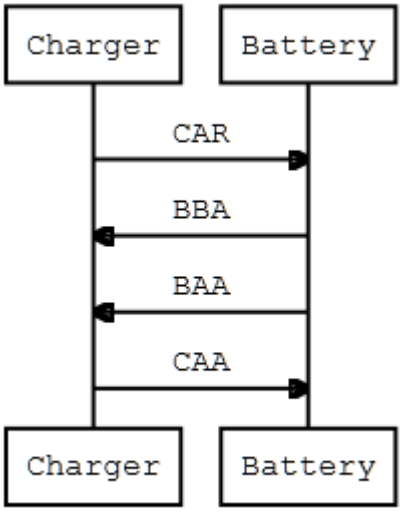
To ensure inter-operability, the BSS shall check if the received BIN belongs to this energy operator (EO) by communicating with the CMS. In case the BIN belongs to another energy operator (home operator) , the verification message shall be communicated to the CMS of the home operator for BIN verification. Once the BIN verification is successful, the regular communication continues between the battery swapping station (BSS) and the SBS-BMS. In case of failure of authentication by home operator, the process shall be reattempted. In case of 3 consecutive BIN verification failures, the process flow shall be suspended for 5 secs for this SBS-BMS.

Verification Stage 2: Verification check initiated by Battery (SBS) (optional)

In this stage, a verification message shall be sent by the SBS-BMS. The charger (BSS) shall respond by sharing a BCSN verification message. The verification message is used by the SBS-BMS to confirm the identity of the charger (BSS) via CMS.

Note: Since this step requires Internet/CMS connectivity for each SBS-BMS it is kept as optional for this standard. More details can be considered in future versions/revisions of this standard. For any mismatch, SBS-BMS shall suspends the flow.

A.4.2.3.1 Message Flow



A.4.2.3.2 Messages

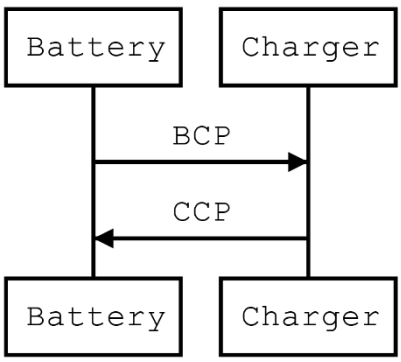
Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
CAR	Verification Request Message initiated by charger (BSS)	Charger (BSS) to SBS-BMS	002D00H	6	4	250
BBA	SBS-BMS verification Response Message for request initiated by charger (BSS)	SBS-BMS to Charger (BSS)	002E00H	6	4	250
BAA	Verification request message initiated by battery (SBS)	SBS-BMS to Charger (BSS)	001F00H	6	4	250
CAA	Charger (BSS) verification response message for request initiated by battery (SBS)	Charger (BSS) to SBS-BMS	001E00H	6	4	250

A.4.2.3.3 Parameters

Message Code	Parameter Name	Description	SPN (DEC)	Size in Bytes	Delivery Option
CAR	Based on the BIN received in handshake share the number of message exchanges, operator specific data, and protocol for verification	Verification request initiated by Charger (BSS)	298	4	Mandatory
BBA	SBS-BMS Response for Given CAR	Battery (SBS) authenticity response	299	4	Mandatory
BAA	Based on the BCS received in handshake share the number of message exchanges, operator specific data, and protocol for verification	Authenticity request initiated by battery (SBS)	2568	4	Optional
CAA	Charger (BSS) response for given BAA	Authenticity response by charger (BSS) for battery (SBS) -initiated request	2569	4	Optional

A.4.2.4 Parameter Exchange stage

In this stage, charger (BSS) and the SBS-BMS exchanges required parameter for charging.



A.4.2.4.1 Message Flow

A.4.2.4.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BCP	Battery Charging Parameters Message	SBS-BMS to Charger (BSS)	004000H	6	10	250
CCP	Charger Charging Parameter Set Message	Charger (BSS) to SBS-BMS	003F00H	6	4	250

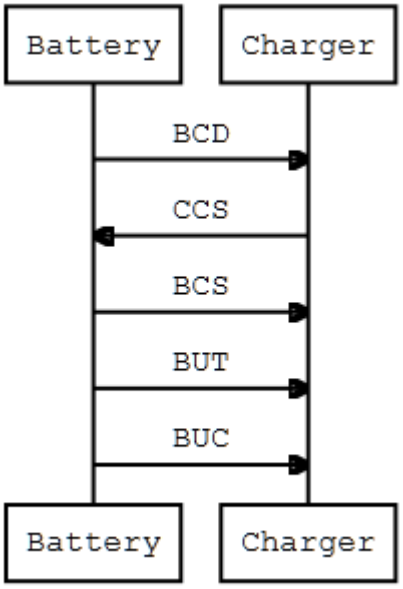
A.4.2.4.3 Parameters

Message Code	Parameter Name	Description	SPN (DECIMAL)	Size in Bytes	Delivery Option
BCP	Maximum charging voltage of battery (SBS) pack	Battery (SBS) pack charging voltage in Centi Volt	317	2	Mandatory
	Maximum charging current of battery (SBS) pack	Battery (SBS) maximum acceptable charging current in Centi Amperes	318	2	Mandatory
	Battery (SBS) rated capacity	Battery (SBS) rated capacity in W-Hr	319	2	Mandatory
	SoC	State of Charge in percentage	320	2	Mandatory
	Available energy	Available energy in W-Hr	378	2	Mandatory
CCP	Charger (BSS) max. rated voltage	Maximum rated voltage of charger (BSS)	316	2	Mandatory
	Charger (BSS) max. rated current	Maximum rated current of charger (BSS)	371	2	Mandatory

A.4.2.5 Charging stage

Throughout the charging stage, SBS-BMS will periodically send demand voltage and current to the charger (BSS) and the charger (BSS) will regulate the charging voltage and charging current according to battery (SBS) requirements.

A.4.2.5.1 Message Flow



A.4.2.5.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BCD	Battery charging demand Message (BCD)	SBS-BMS to Charger (BSS)	004200 H	4	4	1000
CCS	Charger Charging state message	Charger (BSS) to SBS-BMS	004300 H	4	4	1000
BCS	Battery Charging State Message	SBS-BMS to Charger (BSS)	004400 H	4	7	1000
BUT	Battery update message on temperature values	SBS-BMS to Charger (BSS)	002200 H	4	4	1000
BUC	Battery update message on cell voltage values	SBS-BMS to Charger (BSS)	002300 H	4	6	1000

A.4.2.5.3 Parameters

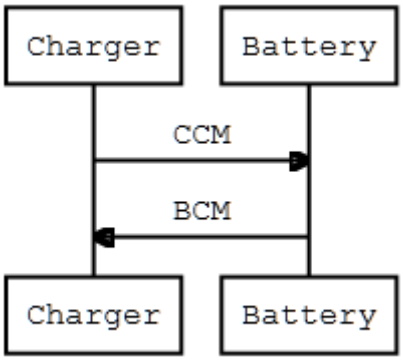
Message Code	Parameter Name	Description	SPN (DECIMAL)	Size in Bytes	Delivery Option
BCD	Battery current demand	Current requested by battery (SBS) in Centi Amperes	322	2	Mandatory
	Battery voltage demand	Voltage requested by battery (SBS) in Centi Volts	303	2	Mandatory
CCS	Charger (BSS) output voltage	Charger (BSS) output voltage in Centi Volts	324	2	Mandatory
	Charger (BSS) output current	Charger (BSS) output current in Centi Amperes	325	2	Mandatory
BCS	Current SOC	Battery (SBS) pack instantaneous SOC in percent (%) with a rounded value	327	1	Mandatory
	Measured battery current	Measured battery current in Centi-Amperes	2570	2	Mandatory
	Measured battery voltage	Measured battery voltage in Centi-volts	2571	2	Mandatory
	Available Energy	Available energy in W-hr	379	2	Mandatory
BUT	Min. cell temp no	Cell no with minimum temperature	2607	1	Mandatory
	Min. cell temp value	Minimum temperature of cell in 0.1°C	2608	1	Mandatory
	Max. cell temp no	Cell no with maximum temperature	2609	1	Mandatory
	Max. cell temp value	Maximum temperature of cell in 0.1°C	2610	1	Mandatory
BUC	Max.Cell voltage no	Cell no with maximum voltage	2612	1	Mandatory
	Max. Cell Voltage	Maximum cell voltage in centi-volts	2613	2	Mandatory

	Min. Cell Voltage no.	Cell no with minimum voltage	2614	1	Mandatory
	Min. Cell Voltage	Minimum cell voltage in centi-volts	2615	2	Mandatory

A.4.2.6 End-of-Charging Stage

This stage is to indicate to the battery (SBS) that charging is completed successfully, and battery (SBS) can change to driving mode, awaiting to be placed in the vehicle.

A.4.2.6.1 Message Flow



A.4.2.6.2 Messages

Message Code	Message Description	Source – Destination	PGN (HEX)	Priority	Data Length in Bytes	Message Period (ms)
CCM	Charger (BSS) Battery mode change message	Charger (BSS) to SBS-BMS	004F00 H	6	1	250
BCM	Battery mode change acknowledge Message	SBS-BMS to Charger (BSS)	005000 H	6	1	250

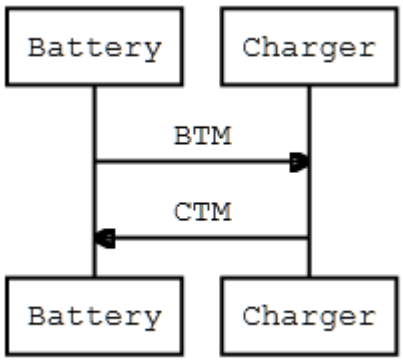
A.4.2.6.3 Parameters

Message Code	Parameter Name	Description	SPN (DEC)	Size in Bytes	Delivery Option
CCM	Battery mode: 0x01	Charger (BSS) requesting battery (SBS) to change mode from charge to drive mode	342	1	Mandatory
BCM	Battery mode acknowledge	Battery (SBS) acknowledging mode change. Success: 0xAA; Failure: 0XFF.	343	1	Mandatory

A.4.2.7 Time-out Messages

When there is failure of message from the other node, time-out message indicating the PGN of the expected message is sent after 5 Seconds. The second byte of PGN is used in the data byte of time-out message.

A.4.2.7.1 Message Flow



A.4.2.7.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BTM	SBS-BMS time-out Message	Battery (SBS) to Charger (BSS)	005100H	2	1	250
CTM	Charger time-out message	Charger (BSS) to Battery (SBS)	005200H	2	1	250

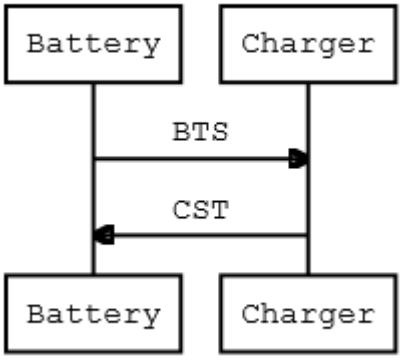
A.4.2.7.3 Parameters

Message Code	Parameter Name	Description	SPN (DECIMAL)	Size in Bytes	Delivery Option
BTM	Second Byte of PGN Value of timed-out message	Battery Messages time-out	344	1	Mandatory
CTM	Second Byte of PGN Value of timed-out message	Charger (BSS) Messages time-out	345	1	Mandatory

A.4.2.8 Suspension Messages

The Suspension messages are sent based on the suspension reason. Each suspension is given a hex code. The hex code along with the breach and threshold value is sent to the other node.

A.4.2.8.1 Message Flow



A.4.2.8.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BTS	SBS-BMS Suspension Message	Battery (SBS) to Charger (BSS)	005100 H	2	1	250
CST	Charger (BSS) Suspension message	Charger (BSS) to Battery (SBS)	005200 H	2	1	250

A.4.2.8.3 Parameters

Message Code	Parameter Name	Description	SPN (HEX)	Size in Bytes	Delivery Option
BTS	Battery Suspending Message	SBS-BMS to Charger (BSS)	004500 H	2	10
CST	Charger (BSS) Suspending Message	Charger (BSS) to SBS-BMS	004600 H	2	10

A.4.2.8.4 SBS-BMS Suspending Reasons (BTS)

With two bytes, the error values could be from 1-65534 (0x1 – 0x FFFF) . While error codes 0x1 – 0x7FFF are reserved for protocol specific, 0x8000 – 0xFFFF are available for manufacturer specific code. The table below summarizes the suspending / alert code range and allocated ranges.

#	Suspending /Alert code specific to	Range	Range Split
1	Overall range	0x0001-0xFFFF	NA
2	Protocol specific	0x001 – 0x7FFF	Battery (SBS) Specific: 0x0001-0x3FFF
			Charger (BSS) Specific: 0x4000 – 0x7FFF
3	Manufacturer specific	0x8000 – 0xFFFF	Battery (SBS) Specific:0x8000 – 0xBFFF Charger (BSS) Specific:0xC000 - 0xFFFF

While suspending, SBS-BMS will give error code and threshold with breach value corresponding to that error code, if available. If there are no appropriate values could be sent on threshold and breach values, it must be filled as FFFFH.

Suspension Type	Reason	Hexa decimal Code	BTS Threshold Value	BTS Breach Value
Normal Suspension	Reached the required SOC target value	0001H	FFFFH	FFFFH
Error Suspension	Charger (BSS) Authentication failed	0003H	SBS-BMS random number challenge response	Charger (BSS) random number challenge
	Charging current is over or greater than the battery demand current	0004H	Demand current	Charging current
	Charging voltage mismatch with battery (SBS) demand voltage	0005H	Demand voltage	charging voltage
	Battery cell over-temperature	0006H	Threshold temp.	Excess temp.
	Battery cell over-voltage	0007H	Threshold value	Breach value
	Battery pack over-voltage	0008H	Threshold value	Breach value
	Battery cell under-voltage	0009H	Threshold value	Breach value
	Battery pack under-voltage	000AH	Threshold value	Breach value
	Time-out suspension	000BH	PGN of time-out message	FFFFH
Warning Suspension	Battery pack over temperature	0007H	Threshold temp.	Excess temp.
	Battery cell over-temperature	0009H	Cell number + Threshold temp.	Cell number + Excess temp.
Other Suspensions	Other suspensions	3FFEH	Threshold value	Breach value

A.4.2.8.4 Charger Suspending Reasons (CST)

The suspending/alert code for charger (BSS) will be in the range of 0x4000-0x7FFF
While suspending, charger (BSS) will give error/alert code and threshold with breach value for that code, if available. If there are no appropriate values could be sent on threshold and breach values, it must be filled as FFFFH.

Suspension Type	**Reason**	**Hexadecimal Code**	**CST Threshold Value**	**CST Breach Value**
Normal Suspension	Suspending due to reaching target SoC set by the charger (BSS)	4001H	SoC	FFH
Error Suspension	BIN acknowledgement failure Result	4002H	FFH	FFH
	Battery authentication failed	4003H	Charger (BSS) Random number	Random number response
	Protocol version acknowledgment error	4004H	Charger (BSS) protocol version	SBS-BMS Protocol version
	Battery parameters compatibility failure	4005H	FFFFH	FFFFH
	Battery demand parameters compatibility failure	4006H	FFFFH	FFFFH
	Time-out suspension	400AH	PGN of time-out message	FFFFH
Warning Suspension	Internal temperature of charger (BSS) is excessive	4009H	Threshold temp.	Excess temp.
Other Suspension	Other Suspension	7FFFH	Threshold value	Breach Value

A.5 Driving Protocol

The communication protocol between Vehicle and SBS-BMS shall be referred as "Driving Protocol". It is assumed that vehicle controller Unit (VCU) in the Electric Vehicle will execute the protocol.

The whole driving process comprises of five stages:

i. Address assignment stage,
ii. Handshake stage,
iii. verification check stage,
iv. Parameter exchange stage and
v. driving stage.

In each stage, if the vehicle or SBS-BMS does not receive message from the other party or does not receive correct message within the stipulated time limit, the waiting entity will timeout; unless otherwise specified, the timeout is 5 s. After timeout, vehicle or SBS-BMS will send suspending message. Figure. 5 shows the driving protocol stages.

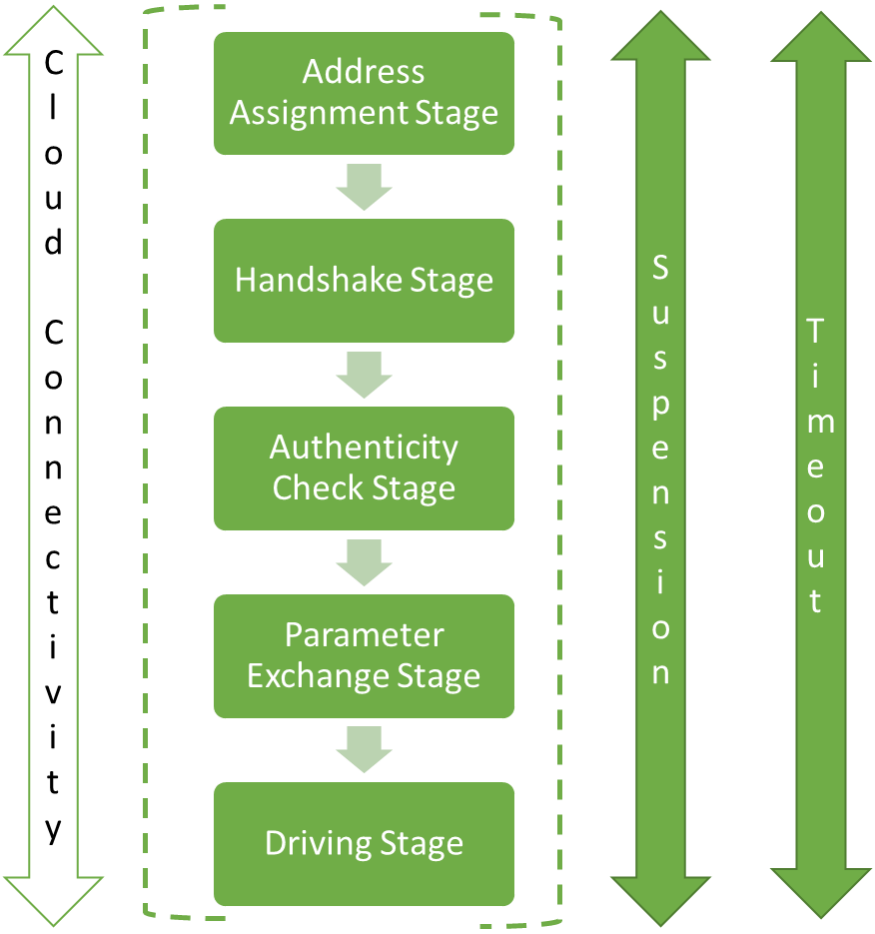


Figure 5. Driving Protocol Stages

A.5.1 Overall Driving Procedure

When the batteries (SBS) get placed inside the vehicle, the module address shall be assigned by the vehicle controller automatically. VCU would reserve addresses in the range of 0x90 to 0x94 for addressing SBS-BMS modules. This address assignment should happen only once when the battery (SBS) gets placed and not on every start of the vehicle and is taken care of by SBS-BMS. By default, SBS-BMS address would be 254 (0xFE) , Whenever a vehicle is started, a vehicle start message is broadcasted to all SBS-BMS. When SBS-BMS receives this message, it checks its address and if it is other than 254 (0xFE) , then it checks for its mode (Master/Slave) with vehicle and starts reacting based on the mode assigned by the VCU

When the Vehicle is again started, SBS-BMS will have its address assigned so it will initiate the mode (Master/Slave) confirmation message to VCU. By sensing only two requests and with the source address, VCU will identify the failure of Master SBS-BMS and will re-assign the next slave as Master.

A.5.2 Multi-battery (SBS) Handling

The protocol is defined to handle multiple batteries (up to 5 batteries) . When multiple batteries are placed in the vehicle, one will act as Master and all the other batteries will act as Slaves.

By default, the battery (SBS) module with least address 0x90 shall act as master and take care of the communication with vehicle controller. If there is a failure in Master SBS-BMS, then vehicle would time-out for some message, suspend and stop as there would not be any communication with Master SBS-BMS.

While assigning the Master SBS-BMS, VCU will inform the other module address as well as its role to all the SBS-BMS. This way all the SBS-BMS are informed about the master SBS-BMS ID to which they must communicate with. The Slave batteries continuously updates their energy to Master battery (SBS) which Master battery (SBS) does the summation and presents the total energy to the VCU. Similarly, Master battery (SBS) keeps communicating to Slave batteries. When this communication packet fails, slave batteries understands that there is a failure in Master battery (SBS) and hence stops discharging.

When there is a Master SBS-BMS failure, the protocol flow suspends and in the next start, the slave with least address gets assigned as Master.

A.5.3 Driving Protocol Stages

A.5.3.1 Address assignment stage

VCU shall assigns addresses for all SBS-BMS's. VCU must reserve the address in the range of 0x90 -0x94 for SBS-BMS addressing irrespective of the number of batteries to be placed in the vehicle. VCU's source address (SA) is defined as 129 (81H) as per Driving Protocol version: 0.0.1.

Whenever Vehicle is started, vehicle broadcasts vehicle start message to SBS-BMS. SBS-BMS checks if its address is assigned, if yes then SBS-BMS confirms its role (Master/Slave) with vehicle and proceeds with handshake stage. If address is not assigned, then SBS-BMS requests for an assignment

a) **MESSAGE 1: Indication of vehicle started from VCU**

VCU broadcasts vehicle started message to SBS-BMS. SBS-BMS checks for address assignment and if not sends **MESSAGE 2** requesting for address claim else sends SBS-BMS will send a role (Master/Slave) confirmation request to VCU.

SA	**DA**	**DATA Byte:01**	**DATA Byte:02**	**DATA Byte:03**	**DATA Byte:04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
81 (VCU Address)	FF Global Address)	AA				00	00	00	00

b) **MESSAGE 2: Request for address claim from SBS-BMS**

SBS-BMS will send a request for address claim by generating a random number (RN1- e.g. 2E2614D0) of 4 bytes in the data field. Bytes 1 to 4 will be used for this. Unused bytes in the data field will be filled with 0x00.

SA	**DA**	**DATA Byte:01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
FE (Null Address)	81 (VCU Address)	2E2614D0	00	00	00	00

c) **MESSAGE 3: Broadcast response for address claim from VCU**

VCU broadcasts to CAN bus with the same random number (RN1- 2E2614D0) and allotted address (e.g 0x90) . The allotted address will be available in the 5th byte of data field.

SA	**DA**	**DATA Byte:01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
81 (VCU Address)	FF (Broadcast Address)	2E2614D0	90	00	00	00

d) **MESSAGE 4: SBS-BMS confirmation request for allotted address from SBS-BMS**

SBS-BMS requests VCU to confirm the usage of the allotted address by generating and sending another random number (RN2 – e.g 33AB7F30) and allotted address (0x90) to VCU.

SA	**DA**	**DATA Byte:01-04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
FE (Null Address)	81 (VCU Address)	33AB7F30	90	00	00	00

e) **MESSAGE 5: VCU confirmation response for allotted address from VCU**

VCU broadcasts to CAN bus with the random number (RN2) , allotted address (0x90) and address status (0xAA: Success; 0xFF: Failure) . The address status will be available in the 6th byte of data field. If the status from VCU is a failure i.e. the address being allotted to some other SBS-BMS, then SBS-BMS must repeat and start from **MESSAGE 1**.

When VCU broadcasts with random number, allotted address and address status in the CAN bus. Each SBS-BMS should keep a track on this message to identify the number of batteries present.

SA	DA	DATA Byte:01-04	DATA Byte:05	DATA Byte:06	DATA Byte:07	DATA Byte:08
81 (VCU Address)	FF (Broadcast Address)	33AB7F30	90	AA	00	00

f) **MESSAGE 6: SBS-BMS confirmation on allotted address**

SBS-BMS confirms to VCU on the allotted address by sending the random number 2, allotted address and the confirmation status (0xAA: Success; 0XFF: Failure)

SA	DA	DATA Byte:01-04	DATA Byte:05	DATA Byte:06	DATA Byte:07	DATA Byte:08
FE (Null Address)	81 (VCU Address)	33AB7F30	90	AA	00	00

The failure status would occur, if SBS-BMS is unable to assign the allotted address for some reasons. In this case, the SBS-BMS must repeat and start from **MESSAGE 2** to get an address assigned.
When VCU sees a success status, it ensures that this address is not given to any other SBS-BMS

g) **MESSAGE 7: VCU assigning master SBS-BMS**

VCU will assign SBS-BMS with least address as Master SBS-BMS. For e.g. it the batteries gets 0x90, 0x91 and 0x92 as their assigned addresses, then VCU assigns SBS-BMS with 0x90 as Master SBS-BMS. The other SBS-BMS will act as Slaves.

i. **For Master SBS-BMS**

SA	DA	DATA Byte:01	DATA Byte:02	DATA Byte:03	DATA Byte:04	DATA Byte:05	DATA Byte:06	DATA Byte:07	DATA Byte:08
81 (VCU Address)	90 (Master SBS-BMS)	AA (Master)	90 (Self Address)	90 (Master Address)	0	00	00	00	00

ii. **For Slave SBS-BMS1**

SA	DA	DATA Byte:01	DATA Byte:02	DATA Byte:03	DATA Byte:04	DATA Byte:05	DATA Byte:06	DATA Byte:07	DATA Byte:08
81 (VCU Address)	91 (Slave SBS-BMS1)	FF (Slave)	91 (Self Address)	90 (Master Address)	00	0	00	00	00

iii. **For Slave SBS-BMS2**

SA	**DA**	**DATA Byte:01**	**DATA Byte:02**	**DATA Byte:03**	**DATA Byte:04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
81 (VCU Address)	92 (Slave SBS-BMS1)	FF (Slave)	92 (Self Address)	90 (Master Address)	00	00	00	00	00

The address assignment for other SBS-BMS shall happen in parallel in the same manner. In order to reduce the probability of multiple trials, each SBS-BMS shall start with aforementioned **MESSAGE 2** after a random delay for a duration between 50 to 200 ms. The following use cases are defined to elaborate on address assigning procedure under few conditions:

Case 1: Probability of VCU receiving the same random number from two SBS-BMS (MESSAGE 2)

a) VCU will broadcast RN1+allotted address as defined in **MESSAGE 3**.
b) Both the SBS-BMS will receive this response and will send a confirmation request for allotted address with random number 2.
c) VCU will receive the response and will send (**MESSAGE 5** with 0xAA in byte 06) success to first SBS-BMS and failure (**MESSAGE 5** with 0x00 in byte 06) to other SBS-BMS.
d) SBS-BMS receiving success status will continue with **MESSAGE 6** onwards and SBS-BMS receiving failure status will start from **MESSAGE 2**
e) Probability of occurrence of random number 2 being same for two SBS-BMS is less. However, in case this happens, both the SBS-BMS receive failure status and start from the beginning.

Case 2: Failure in Master SBS-BMS

Assuming there is a failure in Master SBS-BMS, VCU will time-out and suspend the drive. When the vehicle is again started, Master SBS-BMS is down without any communication, each SBS-BMS will confirm its role with VCU by sending a battery (SBS) mode re-iteration message.

VCU will detect only two batteries are present and issue a warning to the driver and will continue with assigning the Slave with address 0x91 as Master and start with the protocol. When master SBS-BMS had failed, VCU assigns SLAVE SBS-BMS 1 as Master:

SA	**DA**	**DATA Byte:01**	**DATA Byte:02**	**DATA Byte:03**	**DATA Byte:04**	**DATA Byte:05**	**DATA Byte:06**	**DATA Byte:07**	**DATA Byte:08**
81 (VCU Address)	91 (Slave SBS-BMS1)	AA (Master)	91 (Self Address)	91 (Master Address)		0	00	00	00

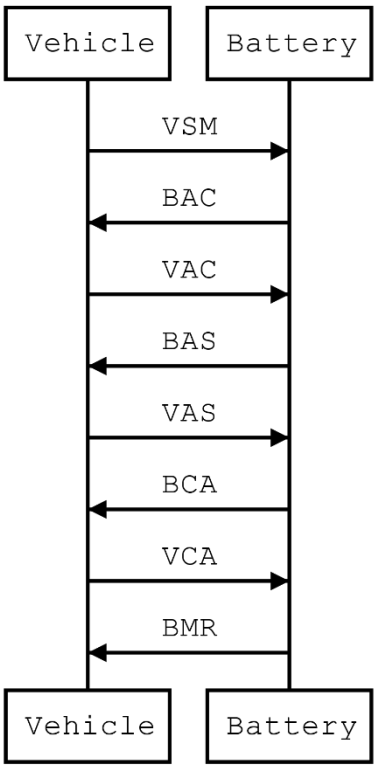
The same message will be issued to Slave SBS-BMS2 also. During the run of the vehicle, when Master resumes from its failure mode, it will initiate the battery (SBS) mode re-iteration message to VCU to check whether it is Master and VCU confirms its status by sending **MESSAGE 6**. Through **MESSAGE 6**, Master SBS-BMS will realize that it is not currently master and will start acting as slave. When Master SBS-BMS resumes and requests to confirms its status, VCU would send

SA	DA	DATA Byte:01	DATA Byte:02	DATA Byte:03	DATA Byte:04	DATA Byte:05	DATA Byte:06	DATA Byte:07	DATA Byte:08
81 (VCU Address)	90 (Master SBS-BMS)	FF (Slave)	90 (Self Address)	91 (Master Address)	0	0	00	00	00

Case 3: When SBS-BMS resumes after a failure

When any SBS-BMS fails due to some reason, then immediately after recovery, it must check if its address is assigned and if not, it would claim by using address assignment procedure. Next it would check whether it was acting as Master SBS-BMS, if yes then it would send BMR message requesting the status of its role as Master SBS-BMS. Master SBS-BMS will send **MESSAGE 6** to confirm whether it must act as Master or slave.

A.5.3.1.1 Message Flow



A.5.3.1.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
VSM	Vehicle start message	Vehicle to SBS-BMS	000F00H	4	1	250
BAC	Battery address claim request message	SBS-BMS to Vehicle	001200H	4	4	250
VAC	Vehicle broadcast response for address claim message	Vehicle to SBS-BMS	005700H	4	5	250
BAS	SBS-BMS confirmation address request Message	SBS-BMS to Vehicle	005800H	4	5	250
VAS	VCU confirmation address response. VAS message shall be used by SBS-BMS to identify the number of batteries present in the vehicle. VCU broadcasts VAS with random number, allotted address and address status in the CAN bus. Each SBS-BMS should keep track of this message and the unique allotted address to decipher the number of batteries present.	Vehicle to SBS-BMS	005900H	4	6	250
BCA	SBS-BMS confirmation request on allotted address	SBS-BMS to Vehicle	005A00H	4	6	250
VCA	Vehicle Assigning Master SBS-BMS Message	Vehicle to SBS-BMS	001300H	4	3	250
BMR	SBS-BMS mode re-iteration Message.	SBS-BMS to Vehicle	001400H	4	1	250

SBS-BMS Mode Re-Iteration Message: This message will be used in two scenarios:

Scenario 1: Start of vehicle:

Whenever a vehicle is started, it will send VSM message to indicate the start of vehicle to SBS-BMS. SBS-BMS checks if its address is assigned and if not, it would claim by using address assignment procedure by sending “BAC” message. If address is assigned, then SBS-BMS sends BMR message to check if it is Master or Slave. VCU will give the confirmation through VCA message. This would be repeated for each SBS-BMS in the vehicle

Scenario 2: Master SBS-BMS failure

Due to some reasons, when Master SBS-BMS fails to provide the required details to VCU, VCU will send Time-out message and suspend the drive.

As driver won’t be aware of this, when he starts the vehicle again, VCU will receive BMR only from other SBS-BMS. As this count will be less than the expected count based on number of batteries in vehicle, vehicle will indicate this as warning to the driver.

As it had received only two requests from the SBS-BMS, by checking the source address, VCU identifies that Master SBS-BMS had failed and assigns next Slave SBS-BMS (e.g. 91H) as Master and continues with the protocol. The VCU waiting time for BMR request from batteries could be 3 seconds. After receiving first BMR, if VCU doesn't receive other BMR within 3 seconds, then VCU will proceed with mode confirmation message. The same steps are applicable when any SBS-BMS fails.

A.5.3.1.3 Parameters

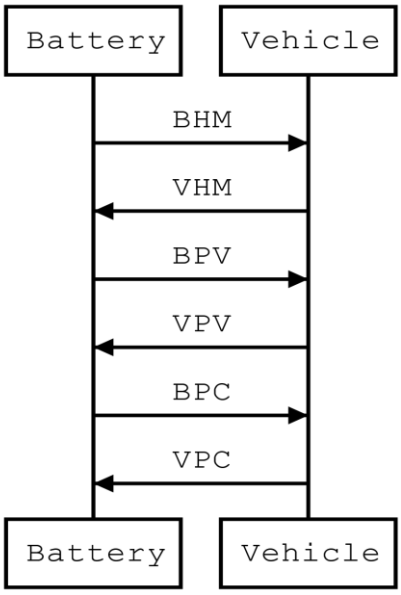
Message Code	Parameter Name	Description	SPN (Decimal)	Size in Bytes	Delivery Option
VSM	Vehicle start; Value=0xAA	Vehicle start parameter to SBS-BMS to indicate the ignition of vehicle	370	1	Mandatory
BAC	Random Number 1	Random number 1 generated by SBS-BMS. Till VCU confirms or rejects or time out, this random number 1 to be re-used.	356	4	Mandatory
VAC	Random Number 1	Random number received in BAC	260	4	Mandatory
	Allotted address	Address allotted by VCU	261	1	Mandatory
BAS	Random Number 2	Random number 2 generated by SBS-BMS. Till VCU confirms or rejects or time out, this random number 1 to be re-used.	262	4	Mandatory
	Allotted address	Allotted address in VAC	263	1	Mandatory
VAS	Random number 2	Random number 2 received in BAS message	357	4	Mandatory
	Allotted address	Allotted address by VCU in VAC message	358	1	Mandatory
	Allotted status Success=0xAA; Failure=0xFF	Allotted address status. VCU confirming the address status as success or failure	359	1	Mandatory
BCA	Random Number 2	Random number 2 generated in BAS message	360	4	Mandatory
	Allotted address	Allotted address in VAC messages	361	1	Mandatory

	Acceptance status Success=0xAA; Failure=0xFF;	SBS-BMS acceptance status for allotted address	362	1	Mandatory
VCA	Master SBS-BMS Assignment with Master: 0xAA; Slave :0xFF;	VCA assigning the SBS-BMS with least address as Master SBS-BMS. By default, it would be 90H and incase of Master SBS-BMS failure, the next least address would be 91H	363	3	Mandatory
BMR	BMR assignment request, Value=0xAA;	SBS-BMS requesting Master status	364	1	Mandatory

A.5.3.2 Handshake Stage

In this stage, the BIN-VIN matching check is done to make sure that the VIN is programmed in Swapping outlet to work with this BIN is indeed the VIN in which the SBS-BMS is placed. This is followed by battery (SBS) verification check by VCU and driving protocol version – compatibility check.

A.5.3.2.1 Message flow



A.5.3.2.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BHM	Battery Handshake Message (BHM)	SBS-BMS to Vehicle	005C00H	6	24	250
VHM	Vehicle Handshake Message (VHM)	Vehicle to SBS-BMS	005B00H	6	20	250
BPV	SBS-BMS protocol version Message	SBS-BMS to Vehicle	005F00H	6	3	250
VPV	Vehicle Protocol Version Message	Vehicle to SBS-BMS	006000H	6	3	250
BPC	Battery Protocol Version Confirmation Message	SBS-BMS to Vehicle	006100H	6	3	250
VPC	Vehicle Protocol Version Acknowledgment Message	Vehicle to SBS-BMS	006200H	6	1	250

A.5.3.2.3 Parameters

Message Code	Parameter Name	Description	SPN in Decimal	Size in Bytes	Delivery Option
BHM	BIN	BIN	265	20	Mandatory
	SBS-BMS firmware version	Firmware version of SBS-BMS	337	3	Mandatory
	VIN Acknowledgment Result	Acknowledgment result by SBS-BMS on receiving VIN. This step is to confirm that the battery (SBS) modules are configured for the same VIN during swapping procedure. Success = 0xAA; Failure=0XFF	266	1	Mandatory
VHM	VIN	VIN - Vehicle Identification Number	264	17	Mandatory
	VCU firmware version	Firmware version of VCU	336	3	Mandatory
BPV	SBS-BMS driving protocol version	Driving protocol version number of SBS-BMS e.g. 00H01H00H for version 1.0	269	3	Mandatory
VPV	Vehicle driving protocol version	Driving protocol version number of the vehicle	270	3	Mandatory
BPC	Confirmed version of SBS-BMS communication protocol	Based on vehicle's protocol version, SBS-BMS will confirm the version number	271	3	Mandatory
VPC	Protocol version acknowledgement	Acknowledgement on protocol version from SBS-BMS. Success = 0xAA; Failure=0XFF	272	1	Mandatory

A.5.3.3 Verification Check Stage

Identity verification check is done in two stages:

Verification Stage 1: Verification check initiated by VCU

In this stage, a verification message shall be sent by the VCU. The SBS-BMS shall respond with battery identification number (BIN) verification message. This verification message shall be used by the VCU to confirm the identity of the battery via CMS. For any mismatch, VCU shall

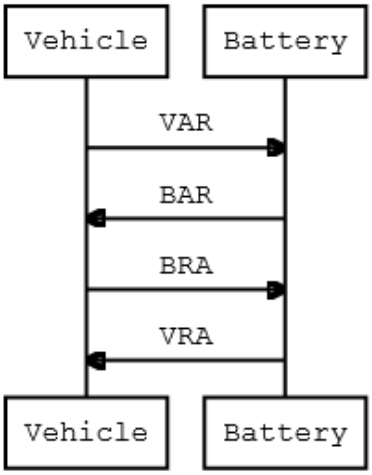
reattempt the verification process. After 3 BIN verification failures the VCU may suspend the flow for 5 sec.

Verification Stage 2: Verification check initiated by Battery (optional)

In this stage, a verification message shall be sent by the SBS-BMS. The VCU shall respond by sharing a VIN verification message. The verification message shall be used by the SBS-BMS to confirm the identity of the Vehicle via CMS.

Note: Since this step requires Internet/CMS connectivity for each SBS-BMS it is kept as optional for this standard. More details can be considered in future versions/revisions of this standard. For any mismatch, SBS-BMS may suspends the flow.

A.5.3.3.1 Message flow



A.5.3.3.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
VAR	Verification Request Message initiated by Vehicle	Vehicle to SBS-BMS	005D00H	6	4	250
BAR	Verification Response Message by battery for vehicle-initiated request	SBS-BMS to Vehicle	005E00H	6	4	250
BRA	Verification Request Message initiated by Battery	SBS-BMS to Vehicle	000E00H	6	4	250
VRA	Verification Response Message by Vehicle for battery-initiated request	Vehicle to SBS-BMS	001D00H	6	4	250

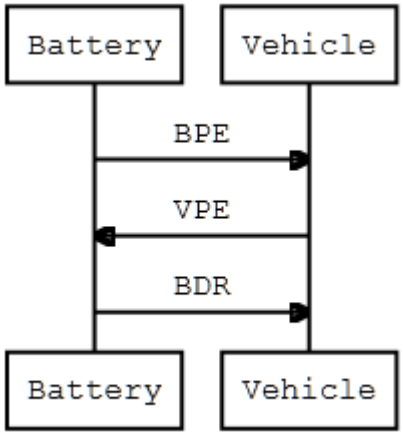
A.5.3.3.3 Parameters

Message Code	Parameter Name	Description	SPN in Decimal	Size in Bytes	Delivery Option
VAR	Based on the BIN received in handshake share the number of message exchanges, operator specific data, and protocol for verification	Verification request initiated by VCU	267	4	Mandatory
BAR	SBS-BMS Response for Given VAR	Battery authenticity response	268	4	Mandatory
BRA	Based on the VIN received in handshake share the number of message exchanges, operator specific data, and protocol for verification	Authenticity request initiated by battery	310	4	Optional
VRA	VCU response for given BRA	Authenticity response by VCU for battery-initiated request	311	4	Optional

A.5.3.4 Parameter Exchange Stage

During this stage, the parameters required for driving are exchanged between SBS-BMS and vehicle VCU. The available energy shall be provided by Master SBS-BMS. Master SBS-BMS will do all mathematical calculation and provide the required detail to vehicle VCU.

A.5.3.4.1 Message Flow



A.5.3.4.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BPE	Battery Parameter Exchange Message. During parameter exchange stage, once a SBS-BMS is assigned as slave, it would keep sending the SoC*SoH value to Master SBS-BMS. Master SBS-BMS will do the summation of all the SoC*SoH and present it as “available energy” to the vehicle.	Master SBS-BMS to VCU and Slave SBS-BMS to Master SBS-BMS	006300 H	6	4	250
VPE	Vehicle Parameter Exchange Message	Vehicle to SBS-BMS	006400 H	6	2	250
BDR	Battery discharge ready message	SBS-BMS to Vehicle	001500 H	6	1	250

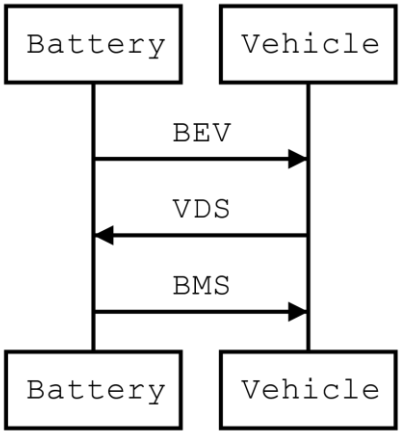
A.5.3.4.3 Parameters

Message Code	Parameter Name	Description	SPN in Decimal	Size in Bytes	Delivery Option
BPE	Available energy in watt-hour	Summation of available energy of battery modules is sent by the master module to the VCU. Slave battery modules should send their available energy to master module	273	2	Mandatory
	SoC	Summation of SoC of battery modules is sent by the master module to the VCU. Slave battery modules should send their SoC to master module	275	2	Mandatory
VPE	Motor rated capacity	Rated capacity if motor	274	2	Mandatory
BDR	Battery discharge ready signal. Value- 0xAA	Master SBS-BMS giving the discharge ready signal to vehicle	365	1	Mandatory

A.5.3.5 Driving Stage

Throughout the driving stage, the SBS-BMS and VCU communicates periodically using the defined messages. The SBS-BMS must send the available energy by maintaining some level of threshold to ensure that battery doesn't get drained to the end. This threshold value can be a proprietary parameter of battery manufacturer.

A.5.3.5.1 Message Flow



A.5.3.5.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BEV*	Battery Status Message	Master SBS-BMS to Vehicle & Slave SBS-BMS to Master SBS-BMS	006500 H	4	8	500
VDS	Vehicle Status Message	Vehicle to SBS-BMS	006600 H	4	4	1000
BMS	Master to Slave battery update	Master SBS-BMS to Slave SBS-BMSes	002500 H	4	2	1000

NOTE: *During driving stage, Slave SBS-BMS should keep sending the available energy value to Master SBS-BMS every 50 ms. Master SBS-BMS will do the summation of all the available energy and present it as “available energy” to the vehicle.

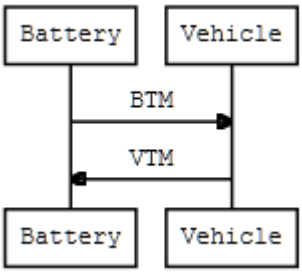
A.5.3.5.3 Parameters

Message Code	Parameter Name	Description	SPN in Dec	Size in Bytes	Delivery Option
BEV	Available energy	Summation of available energy from slave batteries by Master battery.	278	2	Mandatory
	SoC	State of Charge in percentage	276	2	Mandatory
VDS	Vehicle controller Voltage	Vehicle controller voltage in Centi volts	279	2	Mandatory
	Vehicle controller current	Vehicle controller current in centi-amperes	354	2	Mandatory
BMS	Master Battery update value = 0xAAH	Master SBS-BMS broadcasting value 0xAAH to slave batteries.	2589	1	Mandatory

A.5.3.6 Time-out Messages

The time-out of messages during the whole driving process is communicated using these messages. This message will carry the second byte of PGN to indicate the timed-out message.

A.5.3.6.1 Message Flow



A.5.3.6.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BTM	Battery time-out Message	SBS-BMS to VCU	006900H	2	1	250
VTM	Vehicle Time-out Message	Vehicle to SBS-BMS	006A00H	2	1	250

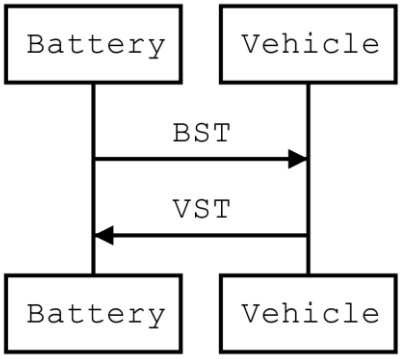
A.5.3.6.3 Parameters

Message Code	Parameter Name	Description	SPN (Dec)	Size in Bytes	Delivery Option
BTM	Second Byte of PGN Value of timed-out message	Battery time-out messages	287	1	Mandatory
VTM	Second Byte of PGN Value of timed-out message	Vehicle time-out messages	288	1	Mandatory

A.5.3.7 Suspension Messages

The Suspension messages are sent based on the suspension reason. Each suspension is given a hex code. The hex code along with the breach and threshold value is sent to the other node.

A.5.3.7.1 Message Flow



A.5.3.7.2 Messages

Message Code	Messages	Direction	PGN (HEX)	Priority	Size in Bytes	Time Period (ms)
BST	Battery Suspending /Alert Message	Master SBS-BMS to Vehicle & Slave SBS-BMS to Master SBS-BMS	006700 H	2	10	500
VST	Vehicle Suspending / Alert Message	Vehicle to SBS-BMS	006800 H	2	10	500

A.5.3.7.3 Parameters

Message Code	Parameter Name	Description	SPN (DEC)	Size in Bytes	Delivery Option
BST	SBS-BMS Stops Discharging (BST)	SBS-BMS stops discharging with detailing normal, fault or error cause.	281	2	Mandatory
	BST Threshold Value	Parameter to carry the data related to Battery suspension reason with threshold value	282	4	Mandatory
	BST Breach Value	Parameter to carry the data related to Battery suspension reason with breach value	283	4	Mandatory
VST	Vehicle Stops (VST)	Vehicle stops with detailing normal, warning or error cause. This would be broadcasted over CAN bus to indicate that the vehicle is stopping	284	2	Mandatory
	VST Threshold Value	Parameter to carry the data related to vehicle suspension reason with threshold value	285	4	Mandatory
	VST Breach Value	Parameter to carry the data related to vehicle suspension reason with breach value	286	4	Mandatory

A.5.3.7.4 Battery Suspending/ Alert Reasons (BST)

With two bytes, the error values could be from 1-65534 (0x1 – 0x FFFF) . While error codes 0x1 – 0x7FFF are reserved for protocol specific, 0x8000 – 0xFFFF are available for manufacturer specific code. The table below summarizes the suspending / alert code range and allocated ranges.

#	**Suspending /Alert code specific to**	**Range**	**Details**
1	Overall range	0x0001-0xFFFF	
2	Protocol specific	0x001 – 0x7FFF	Battery (SBS) Specific: 0x0001- 0x3FFF
			Vehicle Specific: 0x4000 – 0x7FFF
3	Manufacturer specific	0x8000 – 0xFFFF	Battery (SBS) Specific:0x8000 – 0xBFFF Charger (BSS) Specific:0xC000 - 0xFFFF

While suspending, SBS-BMS will give error code and threshold with breach value for that particular error code, if available. If there is no appropriate values could be sent on threshold and breach values, it has to be filled as FFH.

Suspension Type	**Reason**	**Hexa-decimal Code**	**BST Threshold Value**	**BST Breach Value**
Error Suspension	Discharging current is excess*	0002H	Threshold discharging current	Discharging current above threshold
	Battery cell over temperature	0004H	Cell number + Threshold cell temp.	Cell number + Excess cell temp.
	Vehicle authenticity check failure	0006H	SBS-BMS Random number challenge	VCU Random number challenge response
	Battery lock state (Not allowed to discharge)	0007H	FFFFH	FFFFH
	Battery cell over-voltage*	0009H	Threshold value	Breach value
	Battery pack over-voltage*	000AH	Threshold value	Breach value
	Battery cell under-voltage	000BH	Threshold value	Breach value
	Battery pack under-voltage	000CH	Threshold value	Breach value
	Time-out Suspension	000DH	PGN of time-out message	FFFFH
Warning /Alerts	SBS-BMS component over temperature	1001H	Threshold component temp.	Excess component temp.
	Battery cell over temperature	1002H	Threshold cell temp.	Excess cell temp.
	Battery over temperature	1003H	Threshold battery temp.	Excess battery temp.
Other Suspension	Other suspension	3FFEH	Threshold Value (if available)	Breach value (if available)

A.5.3.7.5 Vehicle Suspending Reasons (VST)

The suspending/alert code for vehicle will be in the range of 0x4000-0x7FFF. While suspending, vehicle will give error/alert code and threshold with breach value for that particular code, if available. If there are no appropriate values could be sent on threshold and breach values, it must be filled as FFFFH.

Suspension Type	**Reason**	**Hexa-decimal Code**	**VST Threshold Value**	**VST Breach Value**
Normal Suspension	Vehicle stopped by user	4001H	FFFFH	FFFFH
Error Suspension	Battery Authenticity Failure	4002H	Vehicle random number challenge	SBS-BMS random number challenge response
	Protocol version acknowledgment error	4003H	Protocol version	Protocol version
	Available energy of battery less than threshold value set by vehicle	4004H	Threshold energy	Available energy
	Time-out Suspension	4007H	PGN of time-out message	FFFFH
	Motor controller communication failure	4008H	FFFFH	FFFFH
Warning Suspension	Internal temperature of Vehicle controller is excessive	4005H	Threshold internal temp.	Excess internal temp.
	Vehicle component temperature is excess	4006H	Threshold component temp.	Excess component temp.
Other Suspension	Other suspension	7FFFH	Threshold value (If available)	Breach value (if available)

Annexure B: Identifiers

B.1 Vehicle Identification Number – VIN (Existing Definition as per AIS 065 & Table 11 of AIS 007 of Central Motor Vehicle Rules (CMVR))

a) VIN - 17-digit code and does not include alphabets I, O, Q to avoid confusion with numerals 1 and 0

Standard	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ISO 3779	World manufacturer identifier			VDS						VIS							

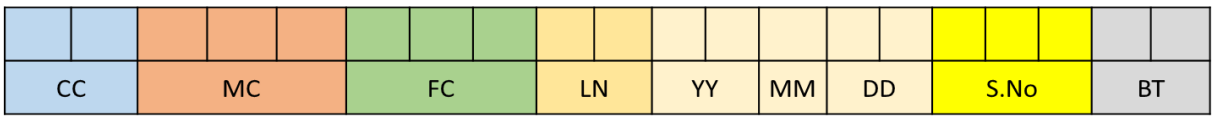
b) **WMI - World Manufacturer Identifier [Digits 1-3]**
   i. Assigned by SAE (Society of Automotive Engineers) in US to countries and manufacturers
   ii. First two digit indicates country code: India country code: MA- ME
   iii. Third digit indicates manufacturer E.g. J- Ford India, L – Hyundai, 1 – Mahindra etc. E.g. WMI – MAL: India Hyundai, MB1: India Ashok Leyland etc.

c) **VDS - Vehicle Descriptor Section [Digits 4-9]**
   i. Carries manufacturer specific information like engine type, vehicle model, body type, transmission etc.
   ii. Besides letter I, O, Q not being used in VIN, letters U and Z are not used in VDS
   iii. Used according to local regulations to identify vehicle type and each manufacturer has unique system for using this field to identify the vehicle

d) **VIS - Vehicle Identifier Section [Digits 10-17]**
   i. Digit 10 – Model year of the vehicle
   ii. Digit 11 – Plant code of the manufacturer
   iii. Digit 12-17 – 6-digit Serial number of the vehicle

B.2 Battery Identification Number – BIN

a) BIN Components – 20 Digits

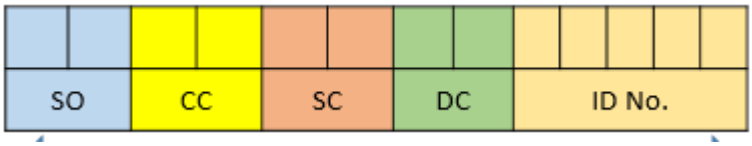


#	Components	Abbreviation	Description	Reference	Digits
1	Country code	CC	To identify the country	ISD country codes can be used Ref: https://countrycode.org/	2
2	Manufacturer Code	MC	To identify the manufacturer	To be assigned by some regulatory authority to identify different manufacturers. E.g. EXI – Exide, AMR-Amara raja	3
3	Factory code of the manufacturer	FC	To identify the factory code where the battery (SBS) manufacturing is done	This could be manufacturer specific data to identify the factory	3
4	Line Number in the factory	LN	To identify the line number in the factory	This could be manufacturer specific data to identify the factory	2
5	Production Date	YYMMDD	Year, Month and date of production	Year: Offset to be 2017. E.g. 1 indicates 2017, 2 indicates 2018 and so on up to 99 Month: A-Jan, B-Feb, C-Mar…. J-Nov, K-Dec Date: 01, 02, 03… 30, 31.	2+1+2= 5
6	Serial Number	S. No	Serial number of the battery	Three-digit serial number of the battery ranging from 1 to 4095 (0X01H to 0xFFFH)	3

7	Battery Type	BT	Battery chemistry type	01H: lead acid battery; 02H: nickel hydrogen battery; 03H: lithium iron phosphate battery; 04H: lithium manganite battery; 05H: cobalt based lithium battery; 06H: ternary material battery; 07H: polymer lithium-ion battery; 08H: lithium ion battery; 09H: NMC (Lithium Nickel Manganese Cobalt Oxide) 0AH: NCA (Lithium Nickel Cobalt Aluminum Oxide) 0BH: Lithium titanate oxide (LTO) 0CH: Lithium Nickel cobalt manganese FFH: other batteries	2

B.3 BaaS Outlet Number (BON)

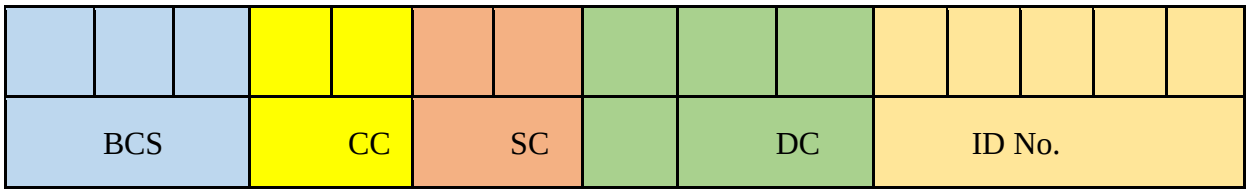
- SOID Components – 13 Digits



#	Components	Abbreviation	Description	Reference	Digits /Bytes
1	Entity Name: Swapping Outlet/Operator	SO	To identify the entity name in the infrastructure	Taken from the first letters from each word of entity name	2
2	Country Code	CC	To identify the country	ISD country codes can be used Ref: https://countrycode.org/	2
3	State code	SC	To identify the state in which the SO is present. State codes used in vehicle number plate can be taken as reference. CMS will have list of state code. This would be captured during registration of SO with CMS and generated based on user's selection of location	Ref:https://en.wikipedia.org/wiki/Vehicle_registration_plates_of_India#Current_codes	2
4	District Code	DC	To identify the district of respective state in which the SO is present. CMS will have list of state-wise district code. This would be captured during registration of SO with CMS and generated based on user's selection of location	Ref: https://en.wikipedia.org/wiki/List_of_districts_in_India	2
5	ID Number	ID No.	5-digit number to identify the SO	Auto-generated 5-digit ID from CMS upon successful registration	5

B.4 Battery Swapping Charging Station Number (BCSN)

- BCSN– 14 Digits



#	Components	Abbreviation	Description	Reference	Digits /Bytes
1	Entity Name: Bulk Charging Station or Battery Swap Station (BSS) /supplier	BCS	To identify the entity name in the infrastructure	Taken from the first letters from each word of entity name	3
2	Country Code	CC	To identify the country	ISD country codes can be used. Ref: https://countrycode.org/	2
3	State code	SC	To identify the state in which the BCS is present. State codes used in vehicle number plate can be taken as reference. CMS will have list of state code. This would be captured during registration of SO with CMS and generated based on user's selection of location	Ref:https://en.wikipedia.org/wiki/Vehicle_registration_plates_of_India#Current_codes	2
4	District Code	DC	To identify the district of respective state in which the BCS is present. CMS will have list of state-wise district code. This would be captured during registration of SO with CMS and generated based on user's selection of location	Ref:https://en.wikipedia.org/wiki/List_of_districts_in_India	2

5	ID Number	ID No.	5-digit number to identify the BCS	Auto-generated 5-digit ID from CMS upon successful registration	5