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Common System Management Interface for Battery Management Systems Across Automotive OEMs: A Review

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Abstract: ***The global automotive industry is undergoing a fundamental shift toward electrification, with Battery Management Systems (BMS) serving as the critical intelligence layer governing battery safety, performance, and longevity. However, the proliferation of proprietary BMS architectures across automotive Original Equipment Manufacturers (OEMs) has created a data fragmentation problem of significant consequence. Each OEM implements unique communication protocols, data schemas, and management interfaces, making cross-OEM data consolidation a complex and resource-intensive undertaking that impedes competitive intelligence, fleet benchmarking, and supplier strategy formulation. This review paper examines the current landscape of BMS communication standards, the structural challenges of multi-OEM data consolidation, and proposes a Common System Management Interface (CSMI)- a three-layer abstraction framework comprising a Protocol Normalization Layer, a Unified Data API Gateway, and a Competitive Intelligence Engine- designed to enable standardized access to heterogeneous BMS data across multiple OEM platforms. The CSMI framework is grounded in practitioner experience consolidating BMS data across five major automotive OEMs in support of market research and competitive strategy formulation. The paper concludes that a standardized BMS management interface is a prerequisite for realizing the full potential of cross-OEM battery analytics in an industry projected to reach USD 24.92 billion by 2032.***

Keywords: Battery Management System, BMS, Common System Management Interface, CSMI, OEM interoperability, CAN bus, ISO 11898, automotive data consolidation, EV, competitive intelligence

1. Introduction

Battery Management Systems are the electronic intelligence at the heart of modern electric and hybrid vehicle powertrains. A BMS continuously monitors cell voltage, current, temperature, and state of charge across battery packs that may contain hundreds of individual cells, executing balancing, protection, and communication functions that directly determine vehicle safety, performance, and battery longevity [1]. As global electric vehicle sales exceeded 17 million units in 2024 and the automotive BMS market was valued at USD 5.52 billion in the same year, growing at a compound annual rate of 18.2% through 2032, the systems that govern battery performance have become among the most commercially and technically consequential components in the automotive supply chain [2].

The diversity of OEM BMS implementations, however, has created a structural problem that the industry has not resolved. Ford, General Motors, Toyota, Volkswagen, BMW, and their peers each implement distinct BMS hardware architectures, proprietary communication protocols, data models, and management interfaces. While individual OEM implementations may be internally consistent and technically sound, their heterogeneity makes cross-OEM comparison, benchmarking, and data consolidation an exercise in custom integration engineering rather than standardised information retrieval [3].

This fragmentation has direct operational consequences for automotive suppliers, system integrators, and engineering organisations that must understand the comparative battery performance characteristics of vehicles across multiple OEMs. A supplier developing cell chemistry for multiple OEMs, a Tier 1 electronics manufacturer optimising BMS semiconductor designs, or an engineering services firm conducting competitive battery strategy analysis must each build separate integration pipelines for each OEM platform. The multiplied cost and complexity of this approach is an industry-wide inefficiency.

This paper reviews the current BMS communication standards landscape, characterises the multi-OEM data fragmentation problem, and proposes the Common System Management Interface (CSMI)-an original three-layer framework designed to provide standardised management and data access across heterogeneous BMS platforms. The paper draws on practitioner experience consolidating BMS data from five major automotive OEMs in support of competitive strategy analysis.

2. BMS Architecture and Core Functions

A Battery Management System performs five core functional categories: measurement and monitoring, state estimation, protection, balancing, and communication [4]. Measurement and monitoring encompasses the continuous acquisition of cell voltage, module temperature, and pack current at sampling rates typically between 10 and 100 milliseconds per cell. State estimation produces the key derived parameters that both the vehicle control system and the operator depend upon: State of Charge (SoC), State of Health (SoH), State of Power (SoP), and remaining useful life projections. Protection functions implement the hardware and software interlock logic that prevents cell operation outside safe voltage, current, and temperature envelopes.

Cell balancing- the redistribution of charge among individual cells to compensate for manufacturing variation and differential aging- is implemented through either passive balancing, which dissipates excess energy as heat, or active balancing, which transfers energy between cells. The communication function interfaces the BMS with the vehicle's broader electronic control architecture, providing real-time battery state data to the powertrain control module, the charging system, the thermal management system, and, increasingly, the cloud telematics platform.

BMS topologies have evolved from purely centralised architectures- a single control unit managing the entire battery pack- toward distributed and modular configurations in which cell monitoring ICs are distributed throughout the pack and communicate over a daisy-chain or wireless link to a central controller. In 2024, centralized BMS held approximately 42% market share due to its cost simplicity, while distributed and modular architectures are gaining adoption in long-range EV applications where measurement granularity and fault isolation are paramount [2].

3. BMS Communication Interfaces and Standards

3.1. Communication protocols

The Controller Area Network (CAN), governed by ISO 11898, is the dominant in-vehicle communication protocol for BMS in automotive applications. CAN provides multi-node bus communication with strong noise immunity, real-time performance, and deterministic message arbitration appropriate for safety-critical automotive control applications [5]. CAN FD (Flexible Data-rate), an extension of the classical CAN specification, increases maximum payload from 8 to 64 bytes and data bit rate up to 8 Mbps, addressing the growing data bandwidth demands of advanced BMS diagnostic and telematics functions. Automotive Ethernet- 100BASE-T1 and 1000BASE-T1- is gaining adoption among OEMs for high-bandwidth BMS data aggregation due to its superior throughput and reduced wiring complexity [6].

In industrial and stationary energy storage applications, BMS communication relies on Modbus TCP over Ethernet or RS-485 physical layer, with CAN also present in higher-performance deployments. The coexistence of CAN, CAN FD, LIN, Automotive Ethernet, and Modbus across BMS applications reflects the absence of a single universal communication standard spanning all deployment contexts.

3.2 Standards and regulatory framework

The BMS standards landscape is fragmented across geographic and application boundaries. In the United States, UL 1973 governs stationary and vehicle battery systems, while UL 9540 addresses energy storage systems. The European Union mandates IEC 62619 for secondary lithium cells in stationary applications and IEC 62620 for industrial applications. ISO 12405 defines test procedures for lithium-ion battery packs in electrically propelled vehicles. IEEE 2686 provides recommended practice for BMS in stationary energy storage applications, with specific recommendations on interoperability including minimum measurement accuracy and standardised state-of-charge reporting [7]. The multiplication of applicable standards across geographic markets creates compliance complexity for multinational OEMs and their suppliers.

Table 1: BMS Communication Standards and Protocols

Protocol/ Standard	Primary Use	Governing Body	OEM Adoption
CAN (ISO 11898)	In-vehicle BMS comm.	ISO TC22	Universal- automotive standard
CAN FD	High-bandwidth BMS data	ISO 11898-1	BMW, VW, Ford (EV platforms)
Automotive Ethernet	Telematics, OTA updates	IEEE 802.3	Tesla, GM, Mercedes-Benz
Modbus TCP	Stationary BMS	Modbus Org.	Industrial/ESS only
ISO 12405	EV battery pack testing	ISO TC69	Compliance-all EV OEMs

4. Multi-OEM Data Fragmentation: The Core Problem

Despite the dominance of CAN at the physical and data link layers, the application-layer data models implemented by automotive OEMs above the transport protocol remain proprietary and heterogeneous. Each OEM defines its own CAN message identifiers, signal scaling factors, data types, state machine definitions, and diagnostic parameter identifiers (DIDs) for BMS data. A message transmitted on CAN ID 0x3B0 in one OEM's architecture may convey pack voltage in millivolts using a specific scale and offset; the same CAN ID in a different OEM's architecture may carry a completely different signal with a different scaling convention. Without access to the proprietary CAN database file (DBC) or OEM-specific diagnostic specification, decoding the raw bus data is not feasible.

This proprietary divergence at the application layer creates four specific barriers to multi-OEM BMS data consolidation. First, protocol heterogeneity: the absence of a common data model means that equivalent parameters- SoC, SoH, cell voltage min/max- are encoded differently across OEM platforms, requiring custom parsing logic per OEM. Second, schema fragmentation: parameter naming conventions, units, and reporting intervals vary across OEMs, preventing direct comparison without normalisation. Third, diagnostic access barriers: OEM-specific Unified Diagnostic Services (UDS) configurations and security access seed-key algorithms restrict programmatic access to extended BMS diagnostic data. Fourth, update and versioning divergence: OEM BMS software updates may alter CAN signal definitions, requiring continuous maintenance of OEM-specific decoders. The consequence is that consolidating BMS data across five OEMs- as this paper's practitioner context required- demanded the development and maintenance of five independent integration pipelines, each updated independently as OEM software versions evolved [8].

The cost of this fragmentation is not merely technical. Engineering organisations conducting competitive BMS analysis, benchmarking battery performance across OEM platforms, or formulating multi-OEM supplier strategies must invest proportionally in integration infrastructure rather than analytical capability. The analysis that should be the purpose of the exercise is delayed and diluted by the integration engineering that precedes it.

5. Common System Management Interface (CSMI) Framework

The Common System Management Interface (CSMI) proposed in this paper is a three-layer software abstraction framework designed to provide standardised management access and data normalisation across heterogeneous BMS platforms from multiple automotive OEMs. The framework does not require modification of existing OEM BMS hardware or software, nor does it depend on OEM cooperation or proprietary data access- it operates at the integration layer above existing communication infrastructure. Figure 1 illustrates the CSMI architecture.

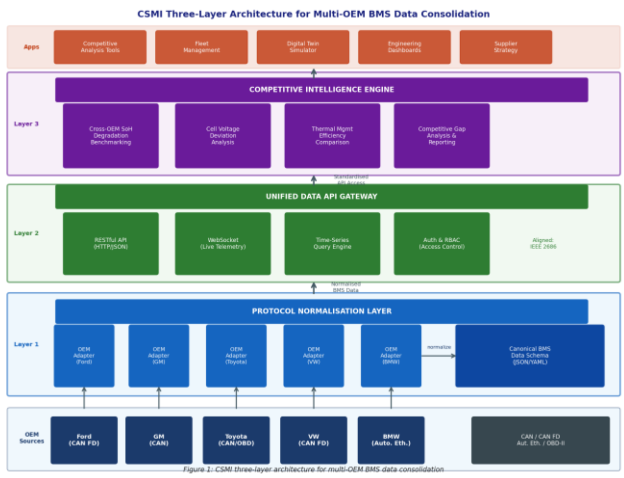

Figure 1: CSMI three-layer architecture for multi-OEM BMS data consolidation

5.1 Layer 1: Protocol Normalisation Layer

The Protocol Normalisation Layer is responsible for acquiring raw BMS data from each OEM's communication interface-CAN, CAN FD, Automotive Ethernet, or OBD-II/UDS-and translating it into a canonical internal data format. Each OEM is represented by an OEM Adapter Module: a configurable decoder that maps OEM-specific CAN signal definitions, scaling factors, and diagnostic parameter identifiers to a standardised BMS data schema. The canonical schema defines a common set of BMS parameters- SoC, SoH, SoP, cell voltage (min, max, mean, delta), module temperature (min, max), pack current, and insulation resistance- expressed in SI units with standardised naming conventions and reporting intervals.

The OEM Adapter Module configuration is maintained as a versioned, structured data file (JSON or YAML) that encodes the OEM-specific signal mappings for each BMS software version. When an OEM BMS software update alters signal definitions, only the adapter configuration requires update- the normalisation pipeline logic is unchanged. This separation of OEM-specific configuration from generic processing logic significantly reduces the maintenance burden of cross-OEM data consolidation.

5.2 Layer 2: Unified Data API Gateway

The Unified Data API Gateway exposes a standardised RESTful API through which downstream applications- competitive analysis tools, fleet management platforms, digital twin simulators, and engineering dashboards- access normalised BMS data from any connected OEM platform through a common query interface. The API provides both real-time streaming endpoints (WebSocket) for live BMS telemetry and time-series query endpoints for historical data retrieval. Authentication and authorisation are managed at the gateway layer, providing role-based access control that restricts OEM-specific raw data access while permitting normalised parameter access across all connected OEMs.

The API data model is aligned with the IEEE 2686 recommended practice for BMS interoperability, which specifies minimum measurement accuracy standards and communication data models intended to support cross-vendor BMS data exchange [7]. This alignment provides a standards basis for the CSMI data schema that facilitates eventual adoption of CSMI outputs in regulatory compliance and supply chain reporting contexts.

5.3 Layer 3: Competitive Intelligence Engine

The Competitive Intelligence Engine operates on the normalised, aggregated BMS data exposed through the Unified API Gateway to produce comparative analytics across OEM platforms. Core analytical functions include: cross-OEM SoH degradation benchmarking, which compares battery health trajectories across OEM platforms under equivalent use conditions; cell voltage deviation analysis, which identifies differences in cell balancing strategy and quality across OEMs; thermal management efficiency comparison, which assesses temperature management performance across OEM platforms under standardised drive cycle profiles; and competitive gap analysis, which quantifies performance differentials between OEM BMS implementations on standardised metrics.

In the practitioner context informing this paper, a predecessor to the CSMI framework was applied to consolidate BMS data from five major automotive OEMs, producing a market research report that provided holistic competitive analysis of battery management performance across OEM platforms for an automotive Tier 1 client. The report identified significant variation in cell voltage delta management (a key indicator of balancing strategy effectiveness) and thermal management response time across OEM platforms, providing actionable intelligence that directly informed the client's battery supply chain and BMS semiconductor investment strategy [8].

6. Implementation Challenges

The CSMI framework faces three primary implementation challenges. First, proprietary access barriers: OEM BMS diagnostic data above standard OBD-II parameters is protected by manufacturer-specific UDS security access algorithms. Full CSMI functionality for extended BMS diagnostics requires either OEM data sharing agreements or access to OEM-specific diagnostic tools. For publicly observable CAN signals- those broadcast on the standard OBD-II port- CSMI implementation is feasible without OEM cooperation. Second, version management complexity: BMS software updates from OEMs can alter CAN signal definitions, requiring continuous maintenance of adapter

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configurations. A change management process for adapter updates is a prerequisite for production CSMI deployment. Third, cybersecurity: the CSMI gateway, as an aggregation point for BMS data from multiple OEMs, represents a high-value target for adversarial data access. ISO 21434 road vehicle cybersecurity engineering requirements and IEC 62443 industrial cybersecurity standards provide the relevant framework for CSMI security architecture [9].

7. Conclusion

The proliferation of proprietary BMS architectures across automotive OEMs has created a data fragmentation problem that imposes significant engineering costs on organisations requiring cross-OEM battery system intelligence. The Common System Management Interface proposed in this paper provides a structured three-layer framework-Protocol Normalisation, Unified API Gateway, and Competitive Intelligence Engine-for addressing this fragmentation at the integration layer without requiring modification of existing OEM BMS implementations. As the automotive BMS market grows toward USD 24.92 billion by 2032 and cross-OEM battery benchmarking becomes an increasingly critical input to automotive supplier and OEM strategy, the case for a standardised BMS management interface becomes correspondingly stronger. The CSMI framework provides both the architectural specification and the practitioner validation basis for this standardisation effort.

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