

Cloud-aided battery management strengthened with cybersecurity and Artificial Intelligence

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Abstract

This paper presents a secure cloud-based Battery Management System (BMS) architecture that leverages AWS infrastructure, advanced communication modules, and AI-driven analytics. The design, as illustrated, integrates temperature, current, and voltage sensing, as well as high-side and/or low-side measurement and protection channels. This integration enables real-time protection, diagnostics, and SoX (SoC, SoH, SoF) calculations. Secure connectivity is facilitated by GSM modules, where the requisite certificates ensure data integrity and confidentiality. The system also employs GPS/GNSS modules to obtain location data, which is then visualized in the cloud interface for advanced asset tracking. The battery pack is safeguarded against overvoltage, overcurrent, and temperature deviations by onboard chargers, power path controllers, and advanced sensing algorithms. The architecture is further fortified by HSM-based encryption for secure data transmission and AI-based cybersecurity features hosted in the cloud. This integrated approach optimizes battery performance, facilitates predictive maintenance, and provides powerful remote monitoring capabilities. [1].

charging infrastructure is securely transmitted via secure IoT or CAN gateways (at the edge, i.e., vehicles or grid) to the cloud, where it undergoes pre-processing, machine learning, and AI modeling. Cloud services include cybersecurity and AI backends, supported by a Hardware Security Module (HSM) and encryption services. AI is used for predictive maintenance, which enhances EV battery health monitoring (State-of-Health) through XGBoost [2] and Transformer-based models [3]. XGBoost achieves superior accuracy (RMSE: 0.02, MAE: 0.0154, R^2 : 0.9913) with low power consumption (233.78 W), making it ideal for real-time, edge-based BMS applications. Transformer models, though less accurate (RMSE: 0.0762, R^2 : 0.8537), excel in predicting degradation direction (MDA: 0.9967) and use less memory (1136 MB vs. 1306 MB), but require 34,569.08 W—147× more power. These findings reveal key trade-offs between accuracy, range prediction, and computational efficiency, guiding deployment based on system constraints and analytics needs.

References

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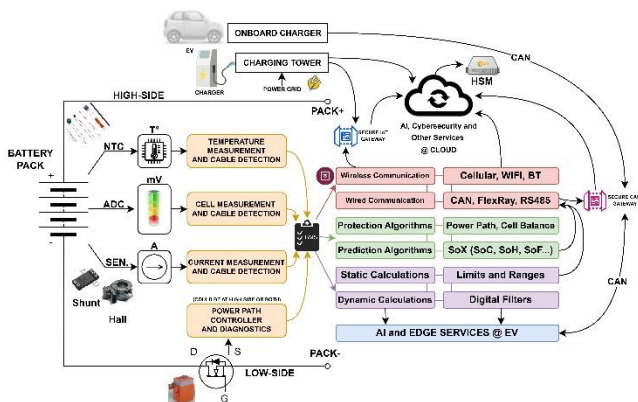


Fig 1 System Design Architecture

This architecture illustrates a multi-layered system integrating edge, cloud, and application components. Data from EVs and

Description

We present a **secure cloud-based BMS architecture** utilizing **AWS infrastructure**, **AI-driven analytics**, and **advanced GSM and GPS/GNSS communication**. It integrates temperature, voltage, and current sensing with both **high-side and low-side protections**, enabling real-time diagnostics and **State-of-X (SoX)** calculations. Cybersecurity is fortified using **Hardware Security Modules (HSMs)** and AI-based threat modeling.

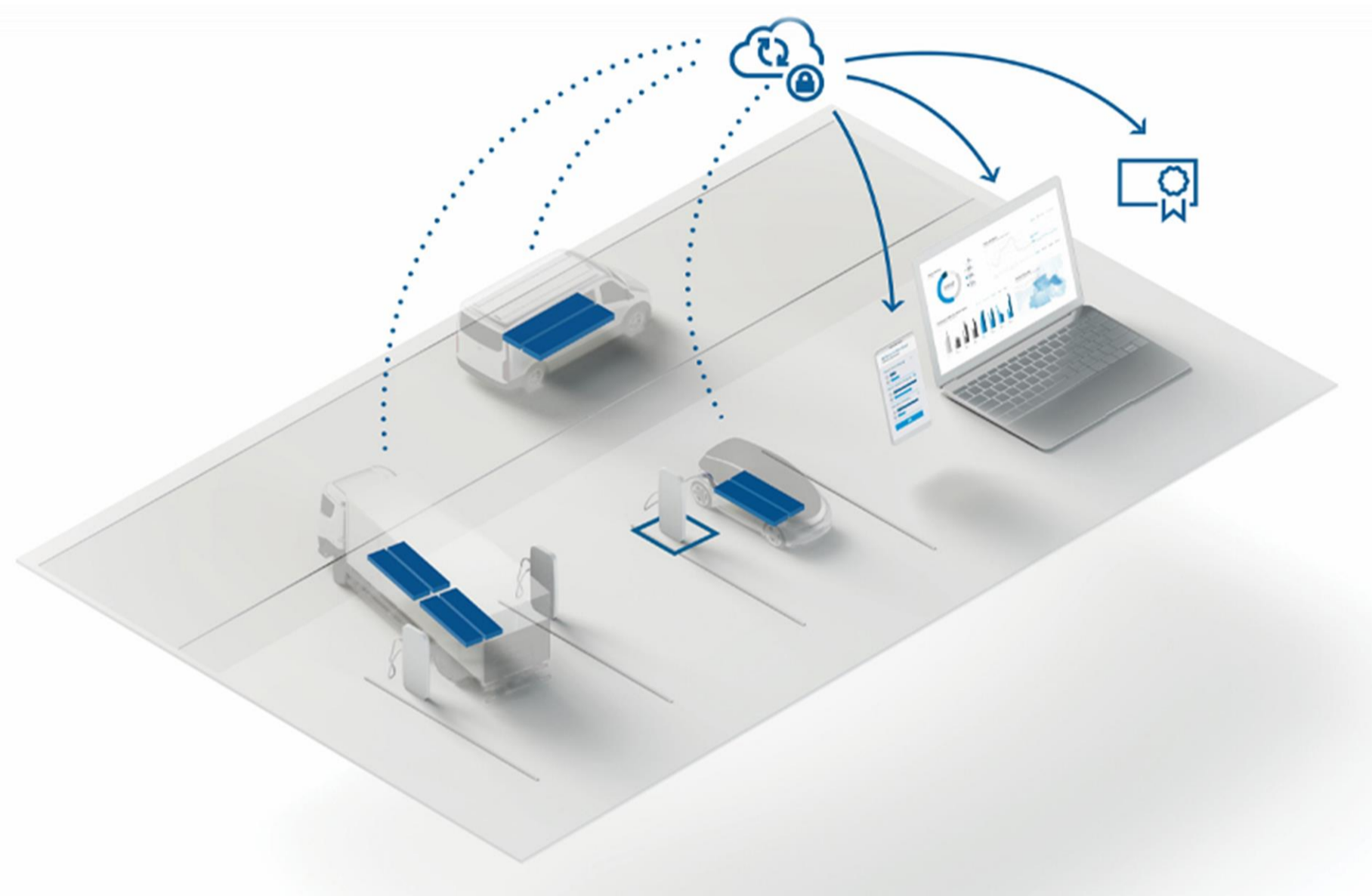
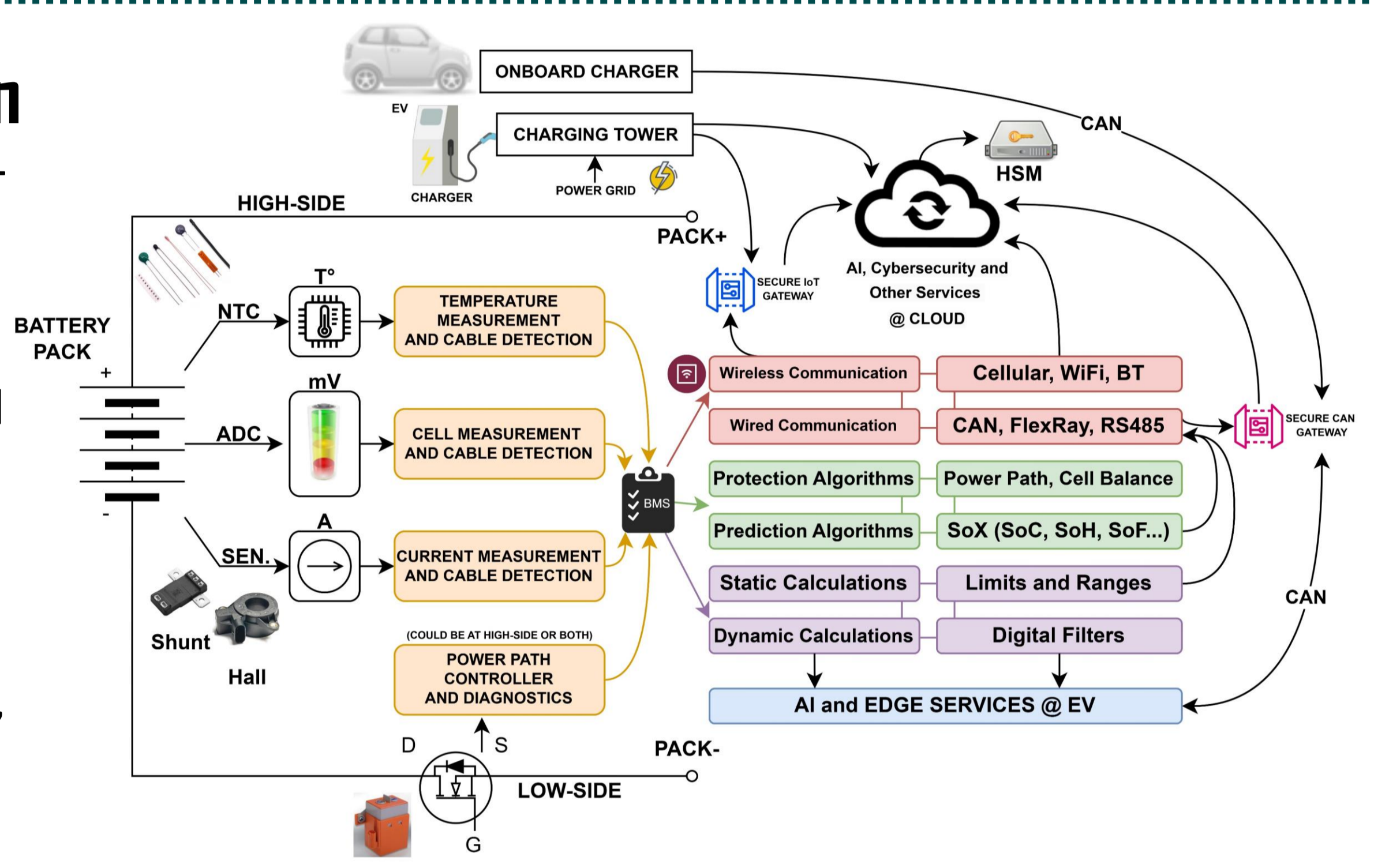


Figure Source: <https://www.bosch-mobility.com/en/solutions/software-and-services/battery-in-the-cloud/battery-in-the-cloud/>

Methodology : Multi Layered Design

- Edge Layer:** Data acquisition from EVs, CAN/IoT Gateway, Battery Management System
- Cloud Layer:**
 - Preprocessing, XGBoost & Transformer AI models
 - Encrypted transmission & storage
 - Cybersecurity AI backend
- Application Layer:** Remote visualization, diagnostics, and asset tracking



ML/AI Performance

Model	RMSE	MAE	MAPE	R ²	Normalized Energy Consumption	Memory Usage (MB)
XGBoost	0.02	0.0154	%0.21	0.9913	0.0066	1306
Transformer	0.0762	0.0622	%0.39	0.8537	1	1136

R² : Variance
 RMSE : Root Mean Square Error
 MAE : Mean Absolute Error
 MAPE : Mean Absolute Percentage Error
 Data : <https://github.com/wang-fujin/XJTU-Battery-Dataset-Papers-Summary>

Objectives

- ✓ Real-time Health and SoX Monitoring
- ✓ Predictive Maintenance
- ✓ Robust Cybersecurity
- ✓ Cloud Visualization
- ✓ Location-based Tracking

Technology & Innovations

- **XGBoost** → Accurate, efficient for real-time
- **Transformer** → Better degradation prediction (MDA: 0.9967), but higher energy and time cost

Partners:

