NEXTBMS

BMS and the Cloud: Unlocking Intelligent, Decentralized, and Adaptive Battery Management Systems with NEXTBMS

AVL SFR Presentation about NEXTBMS for The BMS Alliance

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Ambition of NEXTBMS

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NEXT-generation physics and data-based BMS for optimised battery utilisation

- The rapidly growing global demand for battery-electric energy storage systems—ranging from consumer goods to electric mobility and stationary energy storage—calls for customized solutions in both battery system design and control.The NEXTBMS project is developing innovative solutions to enhance the efficiency, durability, and performance of batteries, supporting their widespread adoption in:
  - Mobile applications – Driving the transition from fossil fuels to electrification in vehicles.
  - Stationary applications – Enabling grid balancing and energy storage from variable renewable sources (e.g., wind and solar), fostering European energy independence.
- Key Focus Areas:
  - Battery lifetime – Extending both cyclic and calendar life.
  - Battery chemistry – Advancing materials and composition for better performance.
  - Challenging use cases – Addressing demanding electrical load conditions.
  - Hardware improvements – Developing enhanced sensor technologies for greater accuracy in measurements.
  - Software innovations – Refining battery models to improve the precision of state estimation and control algorithms in Battery Management Systems (BMS).

By addressing these areas, **NEXTBMS aims to optimize battery performance, extend operational lifespan, and contribute to a cleaner, more sustainable energy future**.

Technical ambition of NEXTBMS

NEXTBMS: Advancing Battery Performance and Sustainability

- The ambition of NEXTBMS is to enhance the **electrical efficiency** and **lifetime performance** of both current and future battery systems by:
  - **Innovative physics- and data-driven approaches** to optimize battery behavior and state estimation.
  - **Supporting the transition** to a more sustainable energy ecosystem by minimizing environmental footprints and maximizing battery system efficiency for both **mobile and stationary applications.**
  - This enables the following key benefits:
    - **Extended Battery Utilization & Lifetime** – Expanding the usable SoC window, increasing full equivalent cycles, and enabling faster charging.
    - **Accelerated Innovation & Time-to-Market** – Facilitating the development of new battery packs and seamless integration of novel battery chemistries.
    - **Enhanced Safety & Reliability** – Ensuring robust performance in demanding operational conditions and effective End-of-Life (EOL) management for second-life applications.
    - **Optimized BMS Performance** – Demonstrating a fully functional battery module with advanced state estimation, control algorithms, and cloud-based enhancements.

Decentralizing BMS: The NEXTBMS Approach

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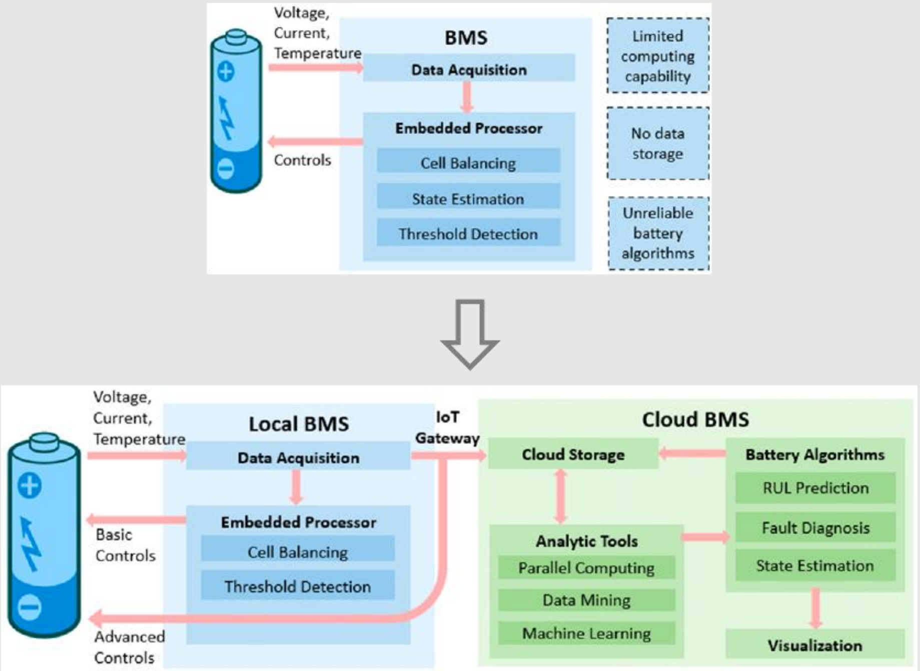
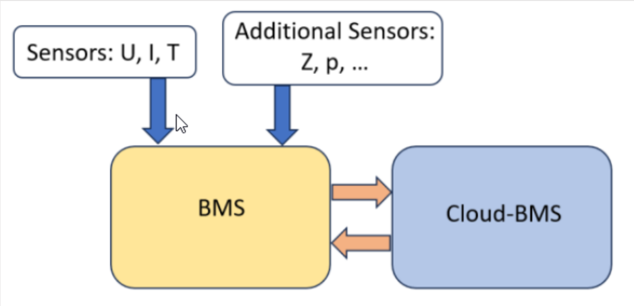
- Traditional Battery Management Systems (BMS) operate as **centralized** units, handling **data acquisition, processing, and control** within the embedded system. While effective, this approach has limitations in scalability, adaptability, and advanced analytics.
- NEXTBMS introduces a **hybrid BMS architecture**, where intelligence is distributed across:
  - **Local BMS –** Manages real-time data acquisition, safety, and control at the battery level
  - **Cloud BMS –** Enhances battery performance and lifespan through advanced analytics, machine learning, and fleet-wide optimizations
  - **IoT Gateway –** Bridges the Local and Cloud BMS, enabling bi-directional communication for real-time insights and adaptive control
- By **decentralizing BMS**, NEXTBMS **unlocks new capabilities**, including:
  - **New, scalable physics-based models** for higher accuracy in SOX estimation
  - **Predictive maintenance & safety enhancements**, including **thermal runaway risk prevention and Remaining Useful Life (RUL) estimation**
  - **BMS calibration across the battery lifecycle** (Beginning-of-Life, Mid-of-Life, End-of-Life)
  - **Data-driven functions** to optimize operational efficiency and reduce degradation
- This architecture paves the way for **next-generation battery intelligence**, ensuring **longer life, better safety, and improved efficiency** in both mobile and stationary applications.

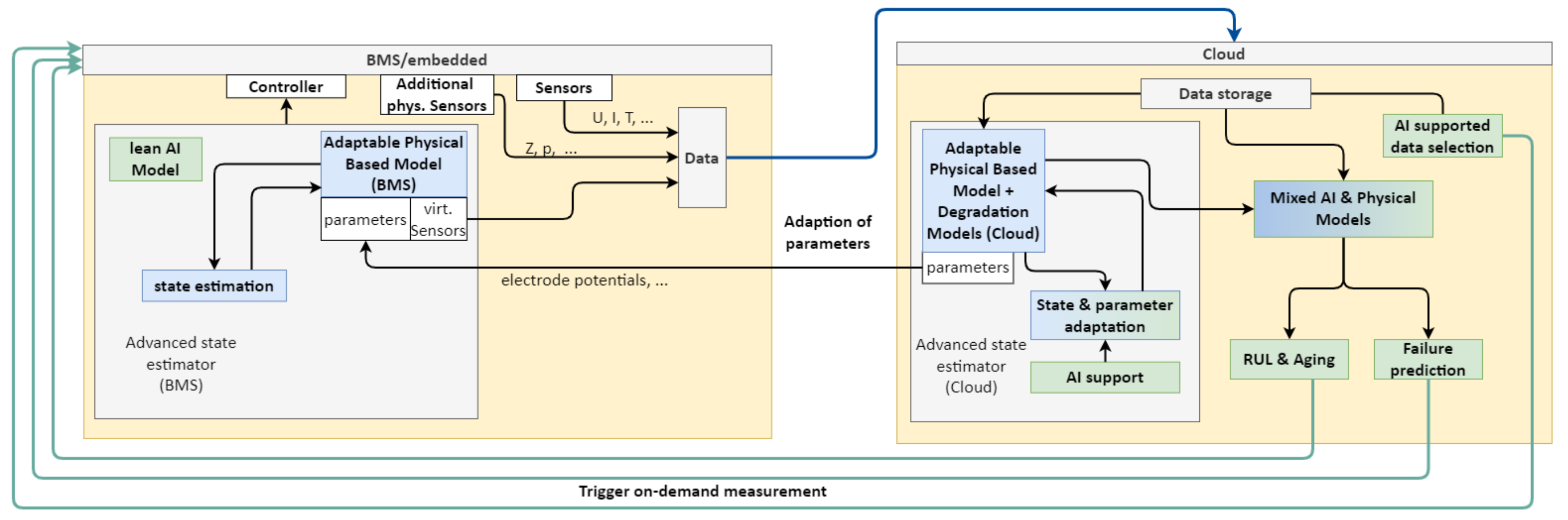


Integration of Advanced BMS Algorithms

Defining the Cloud-BMS Interface: Enabling Seamless Data Exchange

- NEXTBMS integrates **state estimators, degradation models, and predictive maintenance algorithms** in both embedded BMS hardware and the cloud to improve accuracy, safety, and efficiency.





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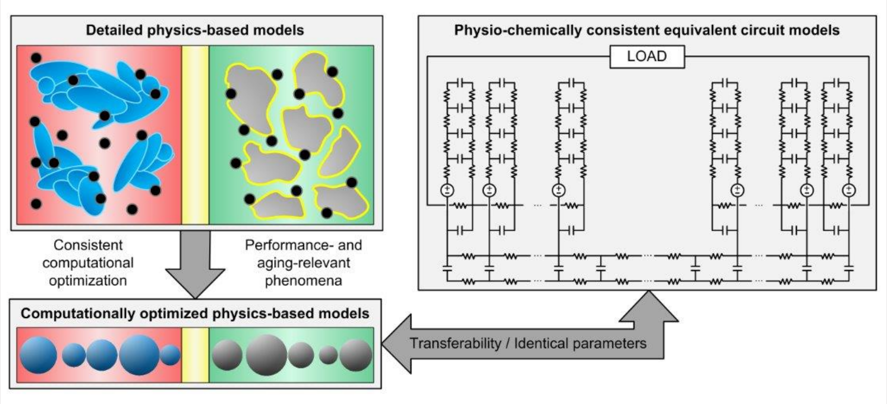
Example: Advancing Battery Intelligence with Physics-Based Models

- **Traditional Estimation Methods**
  - Techniques like Coulomb counting, lookup tables, and equivalent-circuit models are common for SoC determination. Limited by prior knowledge, leading to larger safety buffers, reduced performance, and higher TCO.
- **NEXTBMS Approach**
  - Utilizes physics-based models for enhanced precision and adaptive control. Models rely on parameters such as ionic concentrations, diffusion coefficients, and reaction kinetics.
- **Cloud-Based Enhancement**
  - AI-supported degradation and safety analysis in the cloud.
  - Data from multiple packs improves SoH/SoF estimates.
  - AI selects the most relevant data for more accurate model predictions.
- **Impact on Performance**
  - Reduces calibration/testing while improving accuracy and lifetime predictions.
  - Example: Anode Potential Modeling during fast-charging to optimize charging currents and improve battery lifespan.



Integration of Advanced BMS Algorithms

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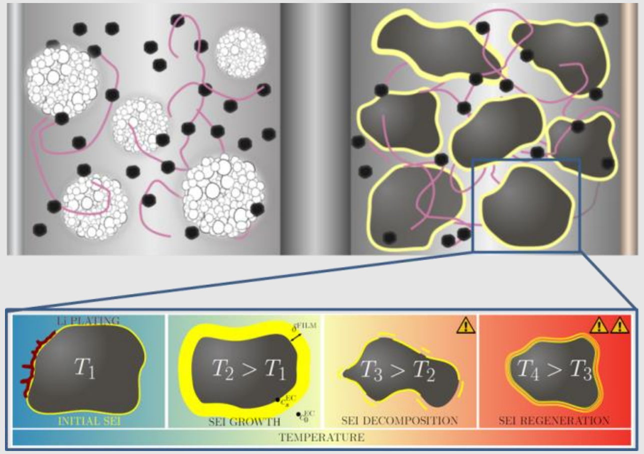
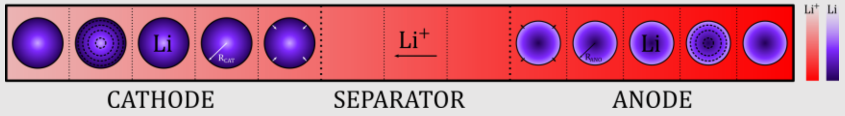
Detailed Physics based model (Cloud)



- Modelling framework for coupled simulation of performance, degradation and heat generation phenomena
- PxD approach
- Computationally demanding model
- C-code

Parameter transferability
(degradation relevant
phenomena
and safety relevant
parameters)

Computationally optimised Physics-based model (BMS)



- Modelling framework for coupled simulation of performance phenomena
- P2D approach
- Computationally optimized model
- C-code

Needs of a Connected BMS: Data Access & Harmonization

- Data Access
  - **Real-Time Data:** The IoT Gateway facilitates continuous data transmission to the cloud via a cellular network, while safety-critical decisions remain localized at the BMS level.
  - **Secure Transmission:** Employing MQTT for robust, encrypted data communication.
  - **Granular Data:** Aiming to transfer high-resolution data, with provisions for on-demand data retrieval.
  - **External Integration:** Utilizing CAN for data acquisition and bidirectional communication of parameters essential for ML model updates.
- Data Harmonization
  - **Standardized Formats:** Using consistent data formats (e.g., JSON, XML) for easier integration, storage, and exchange between different components of the BMS system.
  - **Data Synchronization:** Ensuring seamless data consistency across the decentralized system, enhanced by AI-driven analytics for superior predictive accuracy.
  - **Data Consistency**: Maintaining optimized local models at the BMS level while offloading computationally intensive tasks to the cloud for scalability and efficiency.

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