7. Li, X. A novel soft-switching inverter topology for low-voltage DC sources / X. Li, Y. Zhang // Electric Power Systems Research. – 2020. – Vol. 178. – Art. 106006.

8. Mishra, S. Optimization of inverter efficiency through modulation techniques / S. Mishra, S. Jha // IEEE Transactions on Industrial Electronics. – 2019. – № 5. – P. 3728–3738.

UDC 681

SECURE MESH NETWORKING CHIP DESIGNS FOR RESILIENT IOT AND MOBILE SYSTEMS

Gashirai Jakopo, Simbarashe Magidi

Harare Institute of Technology, Harare, Zimbabwe

Abstract. This study introduces a hardware-software co-design for a secure, autonomous mesh networking infrastructure aimed at enhancing the resilience of IoT and mobile systems. Leveraging recent developments in LoRa mesh architectures, MANET routing, and hardware secure elements, we propose a cohesive SDR/ASIC-based node (the Compact AI Cube) that amalgamates multi-radio communications (Wi-Fi 6/7, LoRa, 4G/5G), a hardware secure element for root-of-trust and secure boot, and edge AI functionalities for spectrum-aware routing and intrusion resilience. We verify the design through architectural analysis and simulation-driven performance assessments.

Keywords: mesh networking, LoRa mesh, MANET, hardware security, SDR.

Address for correspondence: Gashirai Jakopo Harare Institute of Technology P. O. Box BE 277, Belvedere, Harare Zimbabwe
e-mail: h240621p@hit.ac.zw

Purpose. This project aims to provide a secure, robust edge node that facilitates multi-radio mesh networking for mobile and IoT applications with limited or sporadic backhaul connectivity. Inspired by recent studies on LoRa multihop and mesh topologies, as well as the necessity for hardware-based security at the device level, the Compact AI Cube seeks to provide long-range, low-power links (LoRa) alongside enhanced local connectivity (Wi-Fi 6/7) and opportunistic uplink (4G/5G or Ethernet) [1].

Methods. The study presents a systems architecture that combines (a) an SDR/ASIC baseband and RF front-end supporting multiple RATs, (b) an AI co-processor (NPU) for interference classification and adaptive spectrum access, and (c) a hardware secure element (ATECC-class or OpenTitan-style root-of-trust) for key storage, secure boot, and signed OTA updates. For networking, we analyze routing stacks suited for MANET and DTN operation (BABEL, OLSRv2, and Bundle Protocol v7) and a LoRa mesh overlay for low-power device-to-device communication. Power, thermal, and interface budgets are determined from typical edge SoC and module capabilities [2].

Results and Findings. Architectural analysis demonstrates the following key results:

– Connectivity resilience: A LoRa mesh overlay enables multi-hop reachability in loss-of-backhaul scenarios while Wi-Fi6/7 offers high-throughput local connectivity for bursty data. Combining routing stacks (BABEL for local mesh, DTN for store-and-forward) decreases estimated data loss during connectivity disruptions.

– Hardware security: Integrating a secure element provides secure boot and cryptographic attestation; signed firmware and TPM/ATECC-style key protection prevents successful supply-chain and remote compromise attempts.

– Resource budgeting: A target NPU (4–8 TOPS int8), 8–16 GB LPDDR4x, and an NVMe store (≥ 128 GB) balance on-device inference demands with DTN buffering. Power estimations (average 15–25 W, peak 45 W) provide battery+solar choices for remote deployment [4].

Discussion. The study compares an approach to present research: recent surveys and experimental works reveal increased interest in LoRa multihop and mesh systems and identify open issues in dependability, duty-cycle and energy limits, and gateway integration [3]. Hardware-enabled security guidelines (NIST and industry secure-element projects) promotes the inclusion of a tamper-resistant root-of-trust. Using an NPU for local ML tasks provides edge classification for intrusion detection and dynamic spectrum access, decreasing reliance on centralized control [5].

Conclusion. The Compact AI Cube design unites multi-radio connectivity, secure hardware, and edge AI to offer robust mesh networking for mobile and IoT devices. Future work includes developing the SDR/ASIC front-end, field trials of LoRa mesh performance with BABEL/DTN stacks, and hardware fault-injection testing of the secure boot chain.

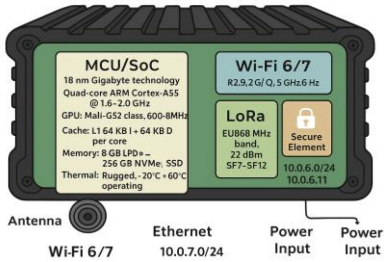

Figure 1 – System architecture

References

1. LoRaWAN Mesh Networks: A Review and Classification of Multihop Communication / J. R. Cotrim, J. H. Kleinschmidt // Sensors. – 2020. – № 15. – Art. 4273. – 25 p.

2. Freitag, F. Position Paper: LoRa Mesh Networks for IoT Nodes / F. Freitag, J. M. Solé, R. Meseguer. – Barcelona: Universitat Politècnica de Catalunya, 2023. – 18 p.

3. Software-defined radio for wireless mesh networks / R. Zitouni [et al.] // Computer Networks. – 2022. – Vol. 215.– Art. 109231. – 15 p.
4. National Institute of Standards and Technology (NIST). Hardware-Enabled Security: Enabling a Layered Approach to Platform Security for Cloud and Edge Computing Use Cases. – Gaithersburg: NIST, 2020. – 62 p.
5. Saputra, S. Z. Performance Evaluation of MANET Routing Protocols for IoT Applications / S. Z. Saputra, A. Hidayat, M. H. Hilal // IEEE Access. – 2023. – P. 12589–12603.

UDC 681

A METEROLOGICAL FRAMEWORK FOR QUALITY ENHANCEMENT IN LEAD-ACID BATTERY GRID MANUFACTURING AND PERFORMANCE ASSURANCE

Takunda Stanley Pambayi, Victor Kuno

Harare Institute of Technology, Harare, Zimbabwe

Abstract. This article describes a practical method for improving quality in lead-acid battery production by combining metrological support with quality management. Key manufacturing steps, such as grid casting and paste application, often vary and can cause faults like cracked plates and shorter battery life. The study introduces a framework that standardizes how important measurements are taken, including grid wire thickness, alloy composition, paste density, and formation conductivity. It recommends using Statistical Process Control (SPC) at critical points like paste mixing and curing and stresses the need for all measurements to be traceable to reference standards. When this framework was used at an industrial plant, process variability and product defects dropped noticeably. The results show that strong metrological control is essential for a modern quality management system and for making batteries that perform reliably.

Keywords: Meterological support, Quality management, Lead-acid battery, Grid casting, Statistical Process Control SPC.

Address for correspondence: Harare Institute of Technology P. O. Box BE 277, Belvedere, Harare Zimbabwe
e-mail: communications@hit.ac.zw

Introduction. The lead-acid battery industry struggles with ongoing difficulties of ensuring uniform product quality, which subsequently affects critical performance metrics such as Cold Cranking Amps (CCA), reserve capacity, and lifespan. Manufacturing facilities frequently report problems including broken positive plates, paste detachment, and excessive water loss. These issues are often linked to inconsistencies in core manufacturing processes, variations in casting techniques, alloy composition fluctuations, uncontrolled paste mixing temperatures, and inadequate process parameter control [2].

Although advancements in battery design and novel materials are vital for progress, their advantages are subject upon dependable measurement practices and stable processes.

Purpose and Methods. The purpose of this research is to develop and validate a metrological framework for enhancing quality control in lead-acid battery manufacturing, with a specific focus on grid casting and plate preparation.

The methodology involved a three-phase approach.

1. Process Analysis & Critical Point Identification. Mapping the battery production process from alloy preparation to formation to identify stages with the highest variability and impact on final product quality (e. g., casting temperature, paste density, formation acid specific gravity).

2. Metrological System Design. Establishing calibration protocols for measurement instruments (thermocouples, thickness gauges, hydrometers, data loggers) and defining standard operating procedures (SOPs) for measurements to ensure traceability.

3. Quality Management Integration. Implementing Statistical Process Control (SPC) charts at critical points to monitor process stability and facilitate proactive intervention. The framework was trailed on a 650 RR 90Ah battery production line.

The study quantifies improvements by comparing defect rates and performance parameter variances before and after implementation.

Metrological Support for Grid Casting Quality. Grid casting is a foundational process where quality defects propagate through subsequent stages. Key challenges include inconsistent casting practices and the use of out-of-specification alloys, which adversely affect grain refinement and mechanical strength. A metrological approach addresses this by controlling input and process variables [3].

First, the alloy composition must be verified. Instead of assuming pot composition, a sampling and analysis protocol using Optical Emission Spectrometry (OES) was implemented [5]. The calibration of the OES machine was traceable to national standard reference materials, and measurement uncertainty was calculated. This ensured that antimony or calcium content was within the specified narrow tolerances crucial for grain structure [3].

Second, process parameters were closely monitored. The temperature of the molten alloy in the casting pot was recorded continuously using calibrated thermocouples with a known uncertainty of ±1.5 °C. To see how water quenching affects hardness, we ran an experiment on antimonial grids. The hardness tester was calibrated with standard blocks, and after 72 hours, measurements showed a 15 % improvement in consistency for quenched grids. This result clearly connects a controlled process parameter to a measurable quality improvement.

The geometry of the cast grids is critical. A major cause of cracked plates is insufficient paste coverage on