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NVM-Based Architecture for Intermittent Computing

Technical Brief

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Technology Summary

This technology introduces a non-volatile memory (NVM)-based system architecture tailored for intermittent computing—devices powered by unreliable or harvested energy sources. The design efficiently integrates NVM into the processor pipeline to reduce checkpointing overhead, minimize energy waste, and enable reliable execution even under frequent power failures. It provides significant improvements in execution speed, energy utilization, and reliability compared to conventional intermittent computing frameworks.

Background

Intermittent computing devices, such as batteryless IoT nodes powered by solar, RF, or vibration energy, often face abrupt power losses. Existing solutions rely on checkpoint/restore techniques to save system state into memory during power failures. However, conventional approaches store data in volatile SRAM or in slow, energy-hungry flash memory, leading to high overheads and inefficiency. This NVM-based architecture directly addresses these challenges by providing fast, low-energy, persistent storage, ensuring smooth execution cycles for energy-harvesting devices.

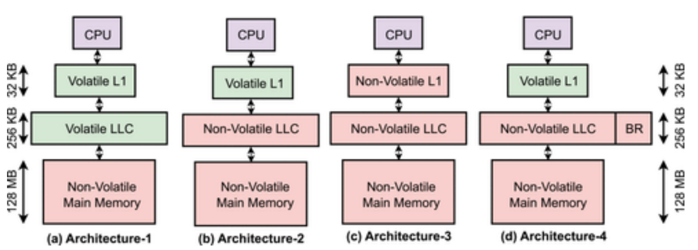
Technology Description

The proposed architecture integrates non-volatile memory elements into the system's critical path to preserve state seamlessly during power loss. Key features include:

- Efficient State Retention: Eliminates frequent checkpoints by leveraging fast-write NVM.
- Energy-Aware Execution: Dynamically adjusts memory usage and computation flow under energy constraints.
- Reduced Overhead: Cuts down energy consumption and performance penalties associated with traditional checkpoint/restore models.
- Prototype Evaluation: Implemented and tested under real-world intermittent power scenarios, showing substantial performance and energy improvements.

Market Potential / Proposed Deployment

- Global IoT Market: USD 662B (2023) → USD 1.38T (2030) | CAGR ~11%.
- Target Sectors: Low-power embedded systems, IoT sensor networks, healthcare wearables, industrial monitoring.
- Socio-Economic Impact:
- Enables long-lasting, maintenance-free IoT deployments.
- Reduces environmental impact by eliminating disposable batteries.
- Supports sustainable and scalable digital infrastructure in agriculture, healthcare, and smart cities.



Applications

- Batteryless IoT Devices: Environmental monitoring, agriculture, industrial sensing.
- Healthcare Wearables: Reliable operation with harvested energy sources.
- Smart Infrastructure: Low-maintenance nodes in smart cities and transport systems.
- Space & Remote Systems: Devices deployed in inaccessible areas where batteries are impractical.

Value Proposition

- Energy Efficiency: Optimized architecture reduces wasted energy in power cycles.
- Reliability: Maintains system integrity across frequent power interruptions.
- Performance Gains: Faster execution compared to SRAM/Flash-based checkpointing systems.
- Hardware Integration: Compatible with existing microcontroller platforms adapted for NVM.
- Sustainability: Reduces dependency on batteries, supporting eco-friendly IoT deployment.

Technology Status

- Technology Readiness Level (TRL): 4–5 (validated via hardware simulation and prototypes).
- Outcome: Published experimental results show significant execution speedup and energy reduction.
- IP Status: Research publication; patent potential exists in NVM integration techniques for IoT processors.