विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF SCIENCE & TECHNOLOGY

AWaDH
IIT Ropar-TIF

Mapi-Pro: Energy-Efficient Memory Mapping for Intermittent Computing

Technical Brief

Ref No: TechBrief/2025/17

Technology Summary

Mapi-Pro is an Integer Linear Programming (ILP)-based memory mapping technique designed to optimize energy efficiency in intermittently powered IoT devices. The method strategically allocates different segments of an application (code, data, stack) between limited SRAM and larger non-volatile memory (FRAM) to minimize the Energy-Delay Product (EDP), thus enhancing performance in both stable and unstable power conditions.

Background

IoT devices operating without batteries—often harvesting energy from the environment—face frequent power interruptions. Traditional designs that either use only SRAM or only FRAM fall short: SRAM loses state upon power failure, while FRAM-only configurations incur high energy overheads. Prior approaches have not comprehensively addressed the trade-offs or simultaneous application segmentation. Mapi-Pro fills this gap by formulating the memory placement problem as an ILP to support intermittent computing with optimal energy-delay trade-offs.

Technology Description

Mapi-Pro analyzes an application's structure (global variables, functions, stacks) and decides, via ILP optimization, which parts should reside in SRAM versus FRAM. The framework also reserves a small FRAM-based backup region to preserve volatile state during power loss. It was evaluated using MSP430FR6989 (SRAM + FRAM) and compared to MSP430F5529 (flash-based) boards. Experimental results demonstrate reductions in EDP by up to 38.1% (versus SRAM-only baseline) and 21.99% (versus existing hybrid mappings) under unstable power—and similar gains under stable conditions.

Market Potential / Proposed Deployment

- Market Outlook: Growing demand for batteryless IoT solutions across sectors like agriculture, infrastructure, and smart environments.
- Target Segments: Energy-efficient embedded systems, intermittent computing applications, and environmental IoT.
- Socio-Economic Impact:
- Reduces reliance on batteries, lowering maintenance costs and environmental pollution.
- Enables robust operation in inaccessible or hazardous contexts (e.g., deep mines, outer space).
- Advances sustainable and reliable IoT deployments.

Applications

- Battery-Free IoT Devices: Enhances energy efficiency for sensors and embedded systems in remote or extreme environments.
- Energy-Harvesting Systems: Ensures reliable performance across frequent power cycles, useful in environmental monitoring, space tech, and industrial IoT.
- Low-Power Embedded Platforms: Applicable to any system where hybrid memory configurations (SRAM + FRAM) are used to balance energy and reliability.

Value Proposition

- Optimized Energy Efficiency: Significant reduction in energy-delay product using ILP-driven allocation.
- Resilience to Power Interruptions: Maintains operational continuity via FRAM backup strategy.
- Hardware Agnostic Strategy: Demonstrated on commodity TI MSP430 platforms—extensible to similar hybrid-memory microcontrollers.
- Quantifiable Gains: Achieves 10–38% EDP reduction under stable power and up to 22% under unstable conditions compared to baselines.

Technology Status

- TRL Level: 4–5 (validated through prototype development on TI boards).
- Outcome: ILP-based model formulated and tested; real hardware results confirm efficiency gains.
- IP Status: Research publication; no patent mentioned—potential for IP development remains open.