Selective Policies for Efficient State Retention in Transiently-Powered Systems

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Energy Harvesting

- Alternative energy source to batteries to power embedded electronic devices
- Scavenge energy from the environment:
  - Light, Vibration, Motion, Temperature
- Large energy buffers to cope with source variability
- **Increased weight, size and cost**

Transient Systems

- Class of energy-driven systems
- Computation sustained despite variability
- **No need for additional energy storage**
- Figure of merit: Forward Progress
- System state (registers and main memory) saved to Non-Volatile Memory (NVM) and restored once power is available again
- Existing approaches (e.g. Hibernus [1]):
  - Save the **entire** state to NVM (Figure 1a)
    - Significant **energy/time overhead** for the saving/restoring process
    - Less energy spent on **useful computations**
  - Use a **universal policy** without regard for the characteristics of the NVM

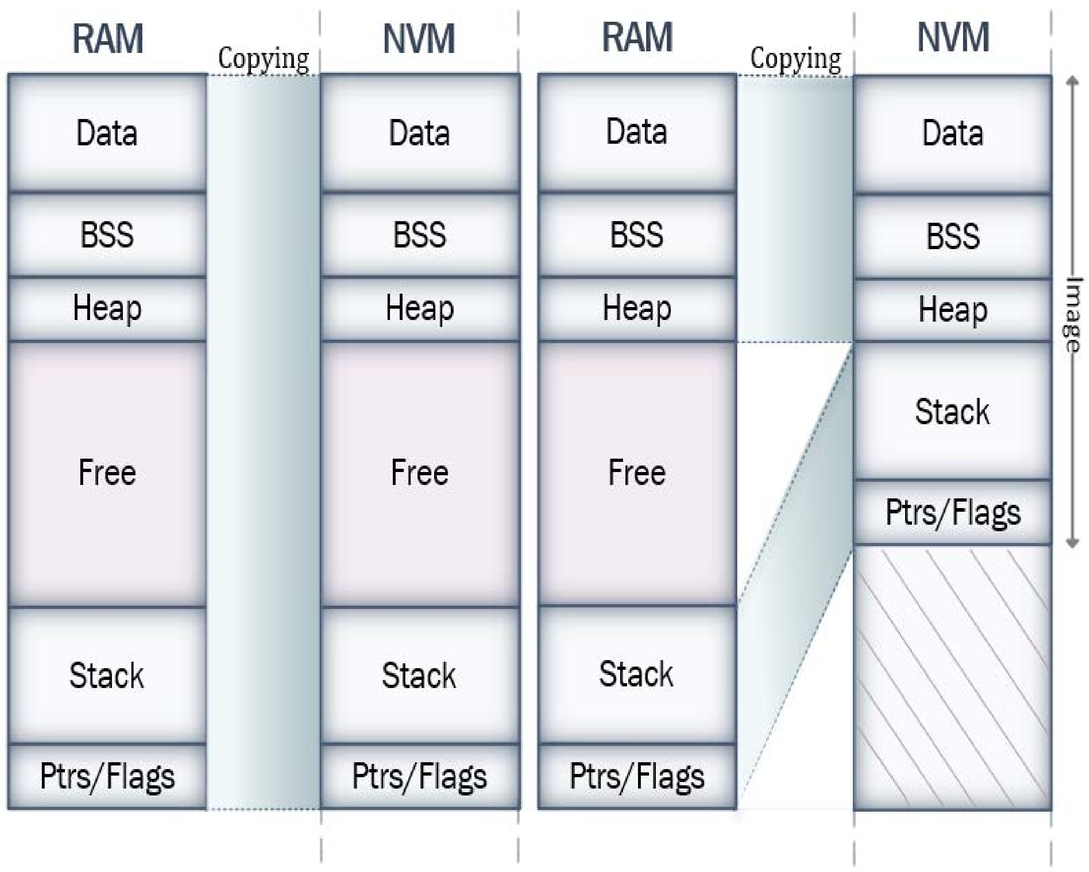
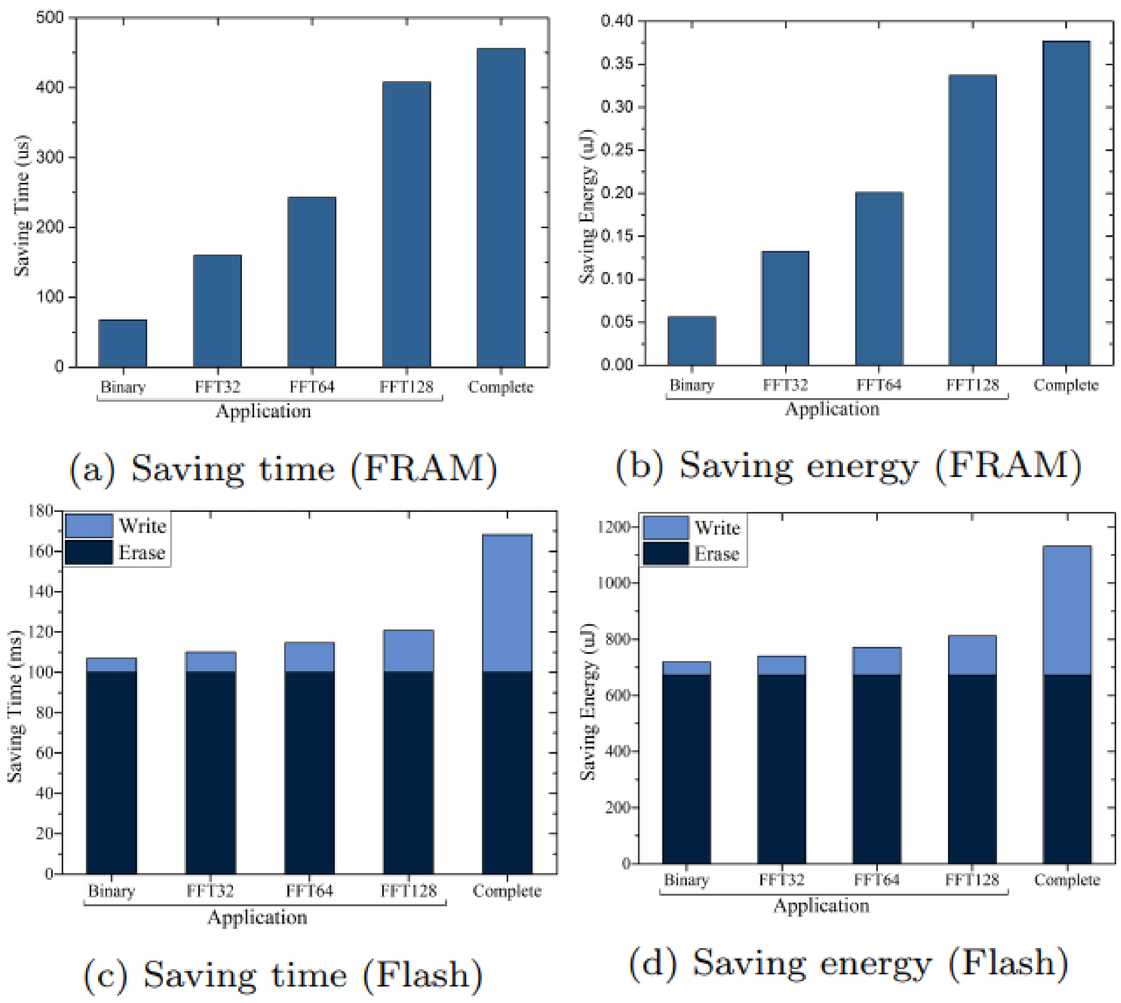


Figure 1: Complete State policy (a) [1] vs Allocated State policy (b) [2]



(a) Saving time (FRAM) (b) Saving energy (FRAM)

(c) Saving time (Flash) (d) Saving energy (Flash)

Figure 2: Allocated State policy applied on systems with FRAM and Flash

Selective Policies

- Saving only the necessary parts of memory to reduce the energy/time overhead
- Dynamic identification of **unallocated space** proposed in [2] (Fig. 1b)
- We implemented this policy on different platforms: FRAM and Flash memory.
  - Positive impact on FRAM (Fig. 2a, 2b)
    - Saving cost proportionally reduced with size of allocated memory
    - Up to **85.1%** energy/time savings when memory usage is 18%.
- **Far less effective** on Flash due to the overhead of erasing required (Fig. 2c, 2d)
  - Saving process strongly affected by the erasing process which accounts for up to **94% of the total cost for saving.**
- Need for novel **selective** policies, targeted at minimising the energy/time overhead for the saving process
- Policies need to be tailored to:
  - **Specific NVM characteristics**:
    - Need to erase before writing
    - Symmetric read/write
  - **Memory usage**

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References

[1] D. Balsamo, A. S. Weddell, G. V. Merrett, B. M. Al-Hashimi, D. Brunelli, and L. Benini. "Hibernus: Sustaining computation during intermittent supply for energy-harvesting systems"". IEEE Embedded Syst. Lett., 2015.

[2] N. A. Bhatti and L. Mottola. "Efficient state retention for transiently-powered embedded sensing", in EWSN, Graz, Austria, 2016, pp 137–148