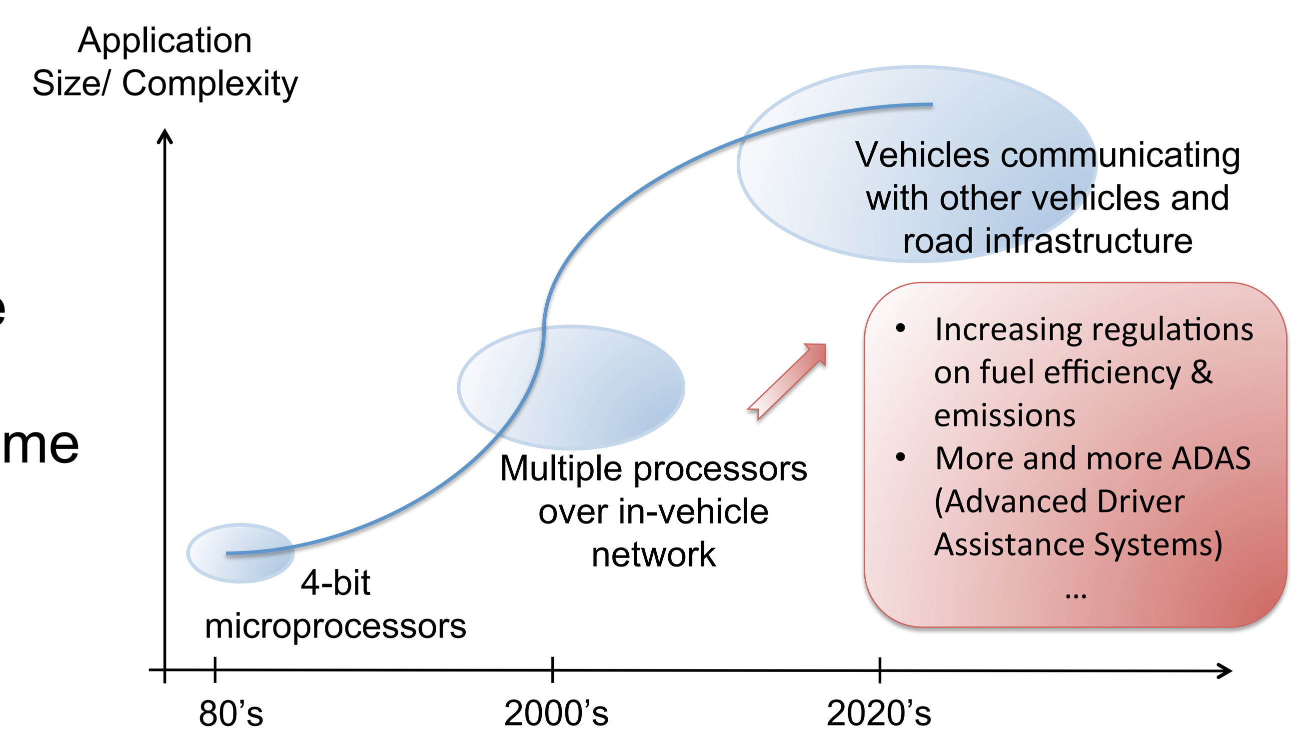
Scaling the Real-time Capabilities of Powertrain Controllers in Automotive Systems

PI: Aviral Shrivastava, Compiler Microarchitecture Lab, Arizona State University

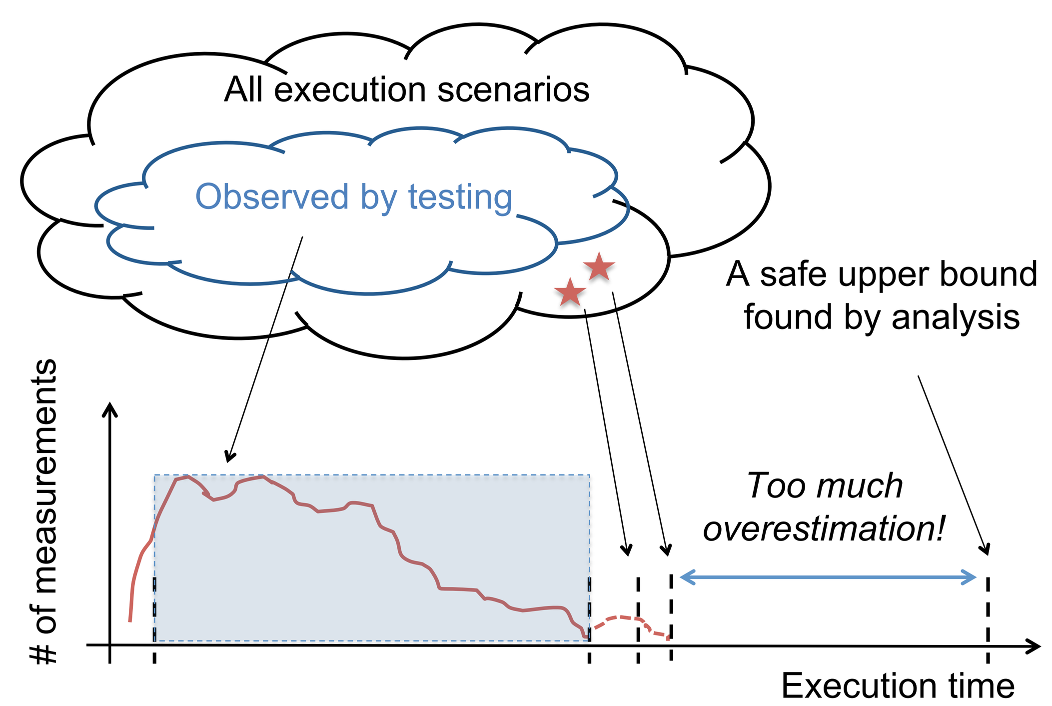
Background

- The complexity and the size of automotive control systems are increasing.
- Such systems have hard real-time constraints, thus high-performance-yet-predictable control systems are needed.



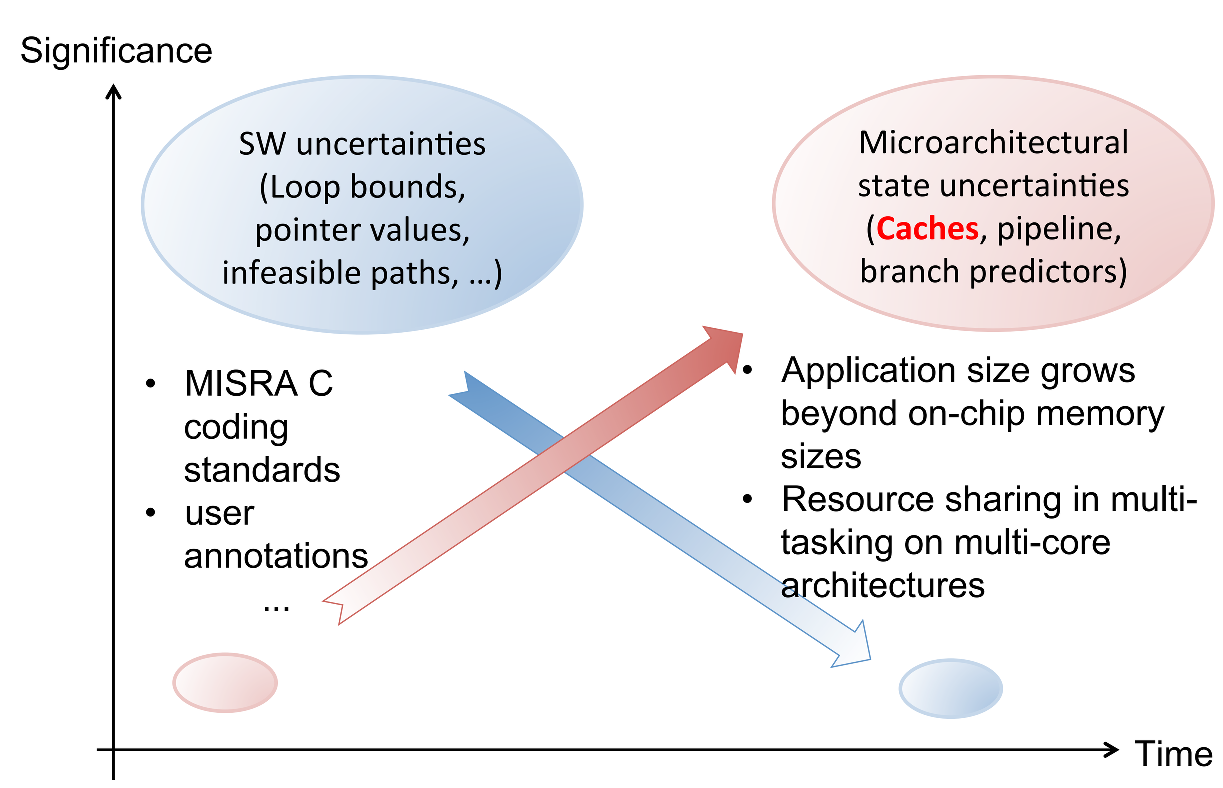
Problem

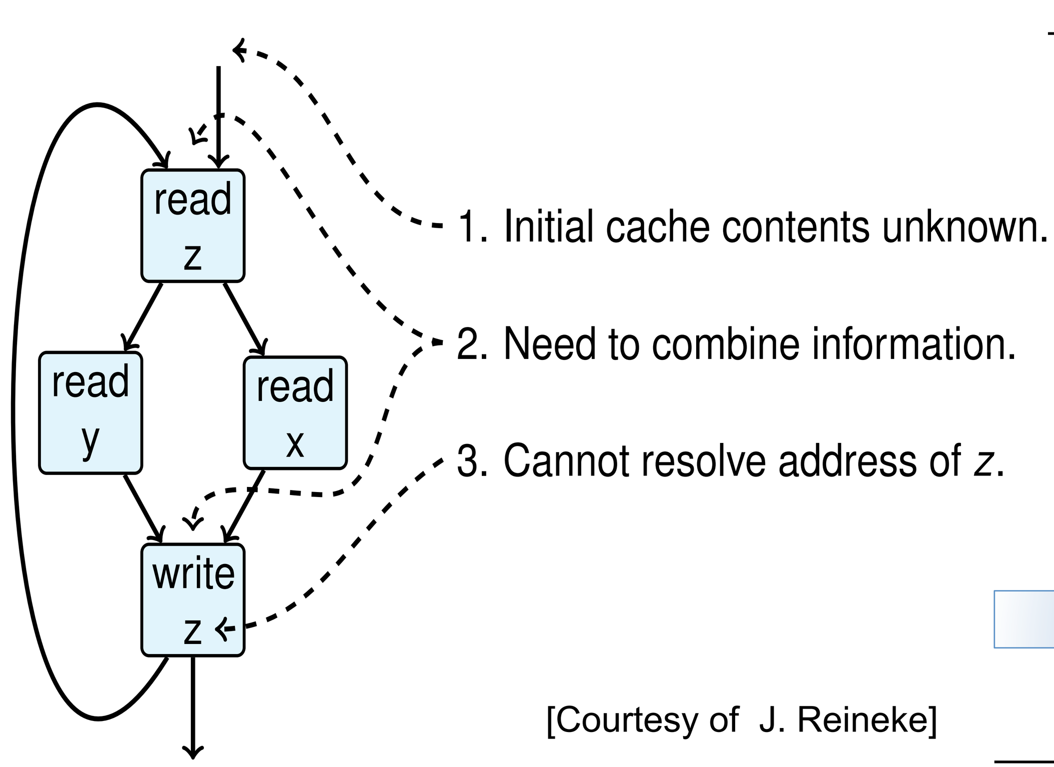
- Current control system design in practice relies on testing, even though the correctness can only be guaranteed by static analysis at design time, not by testing.
- This is because of the unacceptable amount of pessimism in the analysis results.



Caches: The main culprit

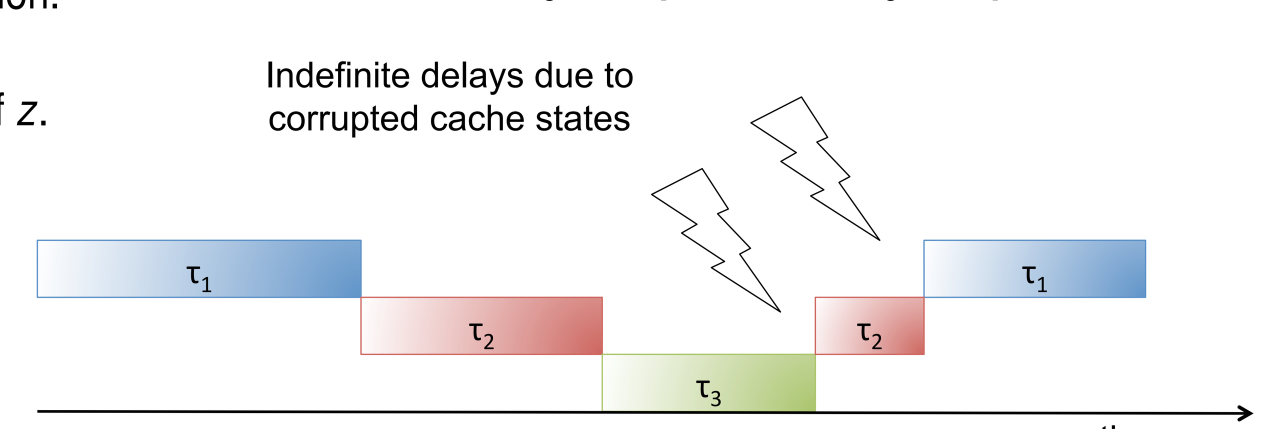
- HW uncertainties are becoming more significant due to ever-increasing application sizes and system complexity.
- Caches are the main source that increases the uncertainties.





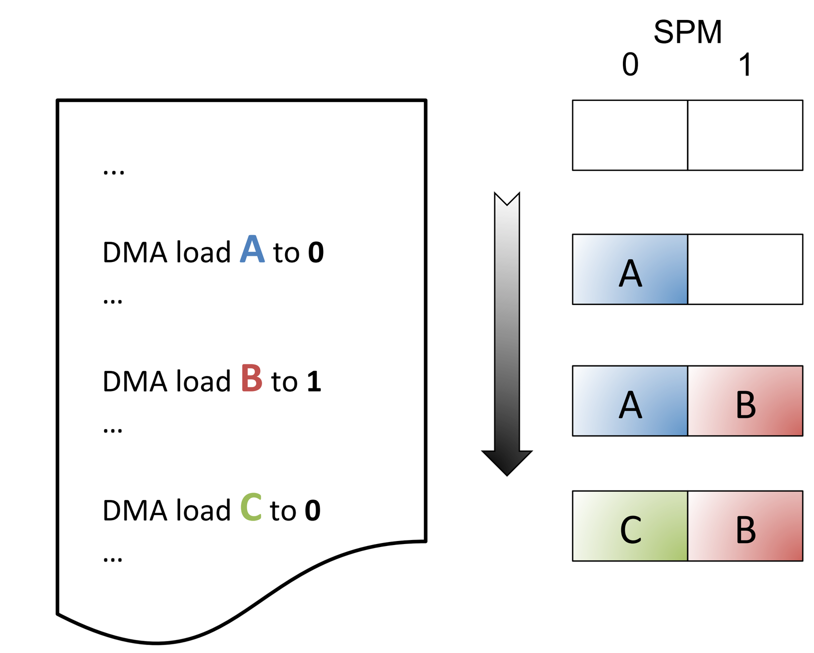
[Courtesy of J. Reineke]

Caches make:
- WCET analysis difficult and pessimistic
- WCRT analysis practically impossible



Solution: Using scratchpad memories (SPMs)

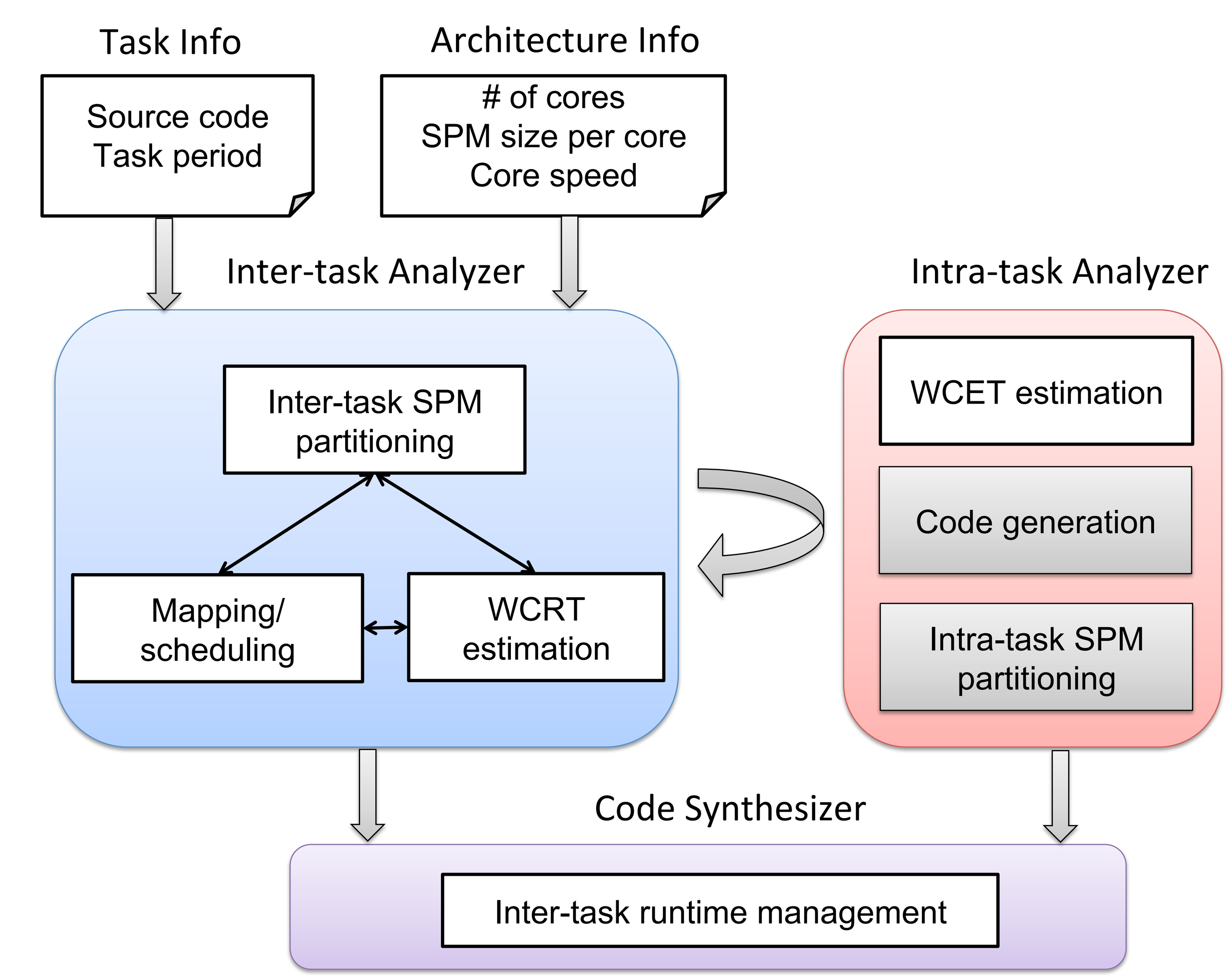
- Replace caches with scratchpad memories (SPMs)
- SPMs have the following benefits:
  - Tight WCET estimation thanks to explicit management
  - Better performance than caches
    - [DAC 2013] SSDM: Smart Stack Data Management for Software Managed Multicores (SMMs)
    - [CODES+ISSS 2013] CMSM: An Efficient and Effective Code Management for Software Managed Multicores

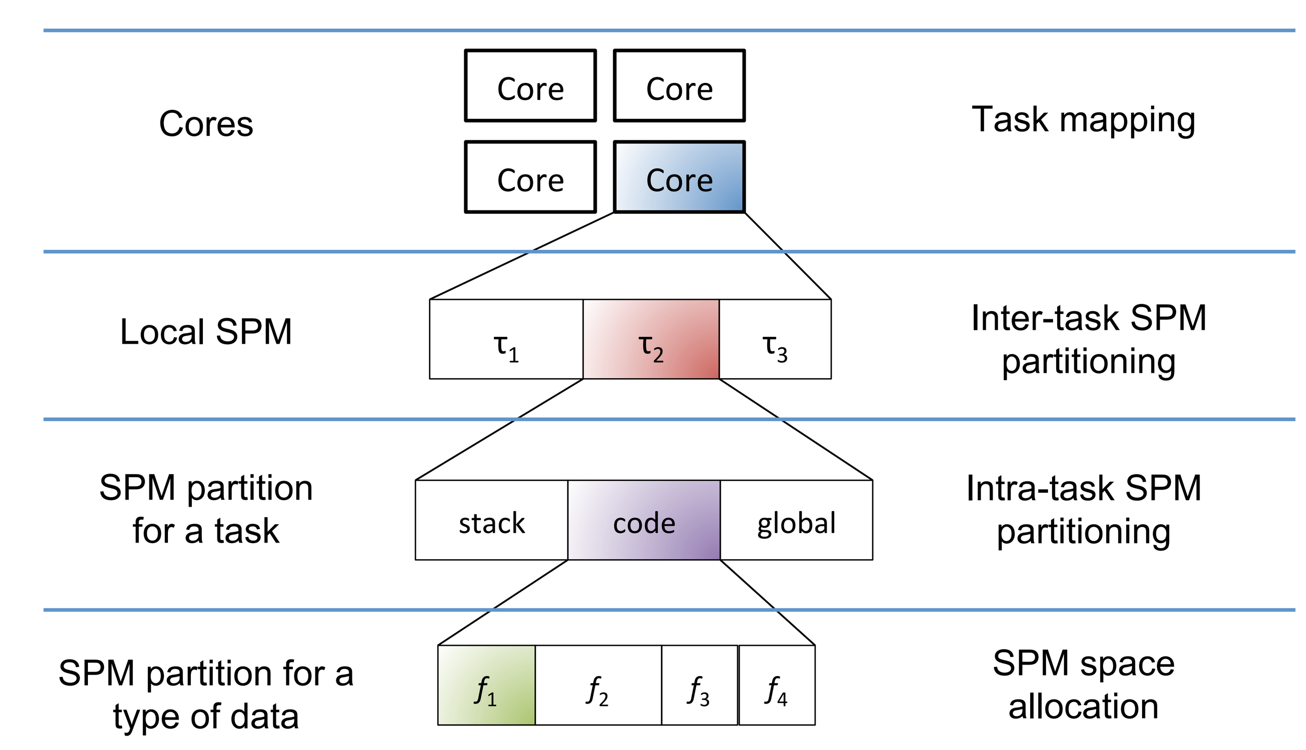


Predictable memory behavior

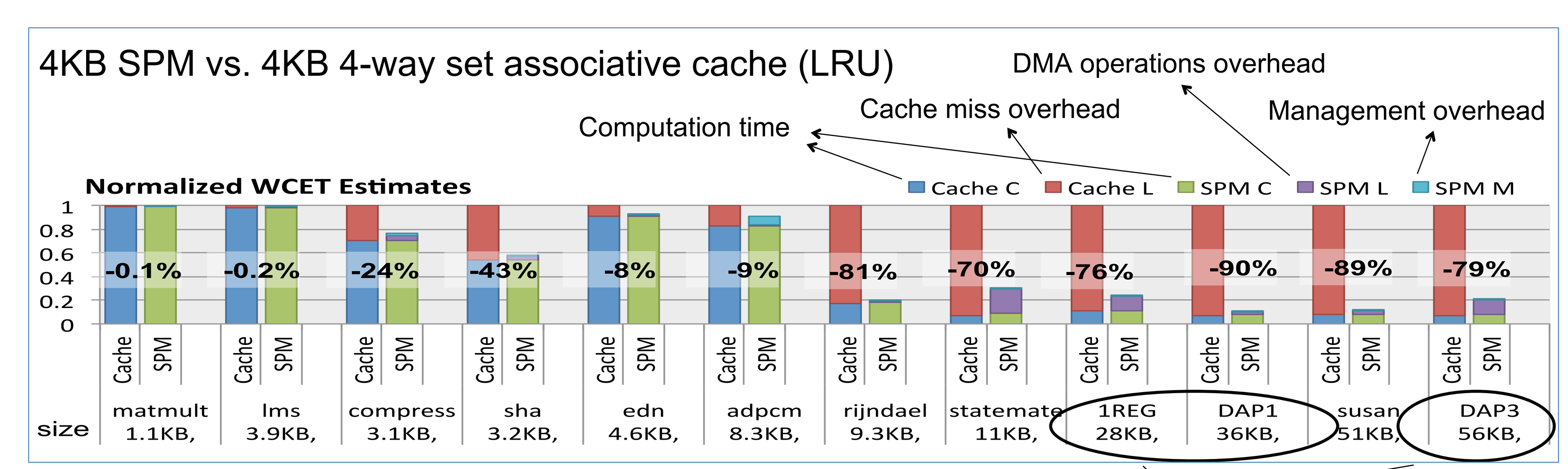
SPM Management Framework

- Using SPMs enables various optimizations in compiler and scheduler to improve real-time capabilities, tailored to each application (no hardwired logic).
- SPM space is partitioned for each task, and each type of data to privatize memory accesses.
- SPM space is allocated to minimize memory interference in the worst-case execution path.





Results with Code Management



Toyota proprietary powertrain controller models

Acknowledgement

This work was supported in part by the Center for Hybrid and Embedded Software Systems (CHESS) at UC Berkeley, Toyota Motors and the National Science Foundation grant **CNS 1525855**

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of any of the sponsors.