Evaluating Non-deterministic Multi-threaded Commercial Workloads

Alaa R. Alameldeen, Carl J. Mauer, Min Xu, Pacia J. Harper, Milo M.K. Martin, Daniel J. Sorin, Mark D. Hill, and David A. Wood

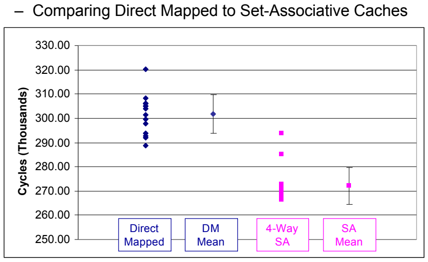
Computer Sciences Department
University of Wisconsin—Madison
http://www.cs.wisc.edu/multifacet

Introduction

- Short measurements on real machines require multiple runs
  - Uncontrolled factors
  - Want to separate random from systematic effects
- Simulation measurements use a single run
  - Simulators are deterministic
  - No uncontrolled factors
- Wrong!
  - Multi-threaded workloads can be unstable
  - Small changes in timing cause large changes in results

Introduction

- Instability may affect conclusions
  - Comparing Direct Mapped to Set-Associative Caches



Overview

- Introduction
- Methods
- Workloads
- Result I: Process scheduling
- Result II: Workload Variability
- Conclusion
- Future Work

Methods

- Real machine
  - Setup, tune, validate on a 16-processor Sun E6000
  - 8 – 16 X speed-up for each application
- Simulator
  - Simics, Full-system simulator running Solaris 8
  - Ruby, Memory timing simulator
- Experiments
  - Start from a warm checkpoint
  - Measure throughput (transactions completed / time)

Workloads

- OLTP
  - TPC-C-like benchmark using a 1 GB database
- SPECjbb
  - Server-side Java-based middleware workload
- Apache
  - Static web serving: Apache driven by SURGE
- Slashcode
  - Dynamic web serving message board, using code and data similar to `slashdot.org`

Why unstable?

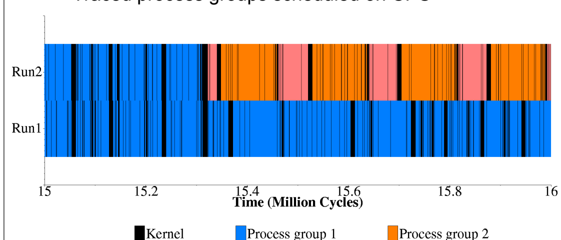
- Different paths are executed
- Hypotheses
  - Process scheduling
  - Order of lock acquisition

Result I: Process scheduling

- Deterministic simulation of OLTP on *uniprocessor*
- Artificially injected misses to I-cache
  - Run1: 0, 100, 200 …
  - Run2: 50, 150, 250 …
- Measured equivalent to 3-5 seconds in real system
- Run time difference of 9%
- Is process scheduling a factor?

Result I: Process scheduling

- Traced process groups scheduled on CPU

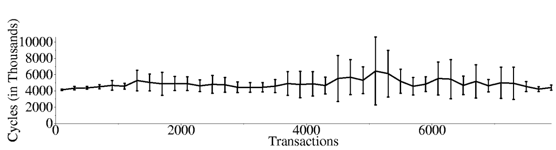


Methods, part II

- Pseudo-random perturbations
  - Run multiple runs from same checkpoint
  - All runs have same average memory latency
  - Misses to main memory perturbed by 0-4%
- Calculate mean, standard deviation

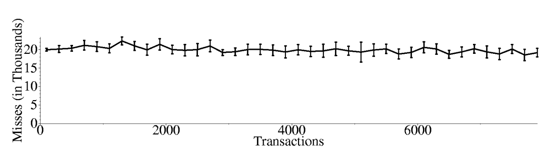
Result II: Variability

- Variability
  - 16-processor system running 8,000 OLTP transactions
  - 20 runs from same checkpoint
  - 12 – 20 seconds in real system
- 1 / Throughput (cycles per transaction)



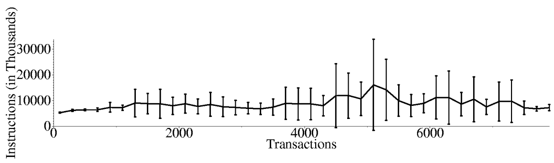
Result II: Variability

- Miss rate (misses per transaction)



Result II: Variability

- Instructions executed (per transaction)
- Hypothesis
  - “Spin-waiting” hypothesis
  - Lock-acquisition, idle loop, device activity



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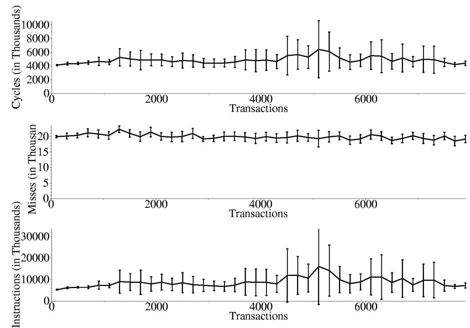
Result II: Variability



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Conclusion

- Multi-threaded commercial workloads can be unstable even on uniprocessors
- Instability can affect conclusions in short runs
- Pseudo-random methodology can help
- Even within one workload variations exist

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Future Work

- Root cause(s)?
- Methodology improvements
- Quantify instability further

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Questions

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