Memory System Behavior of Java-Based Middleware

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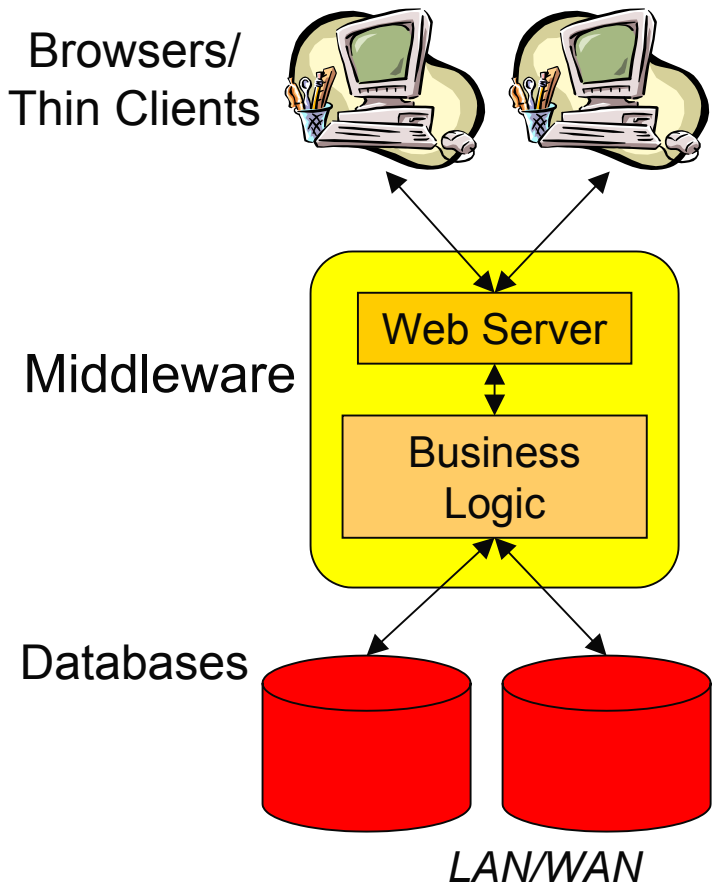
Java-Based Middleware: An Important New Workload for Multiprocessor Servers

- Java-Based middleware connects Web pages to databases
- Web-based applications are deployed in 3-tier systems
  - Clients
  - Middleware (e.g. application servers)
  - Databases
- Rapid growth
- Diverse clients will increase the role of middleware



Java Middleware Benchmarks

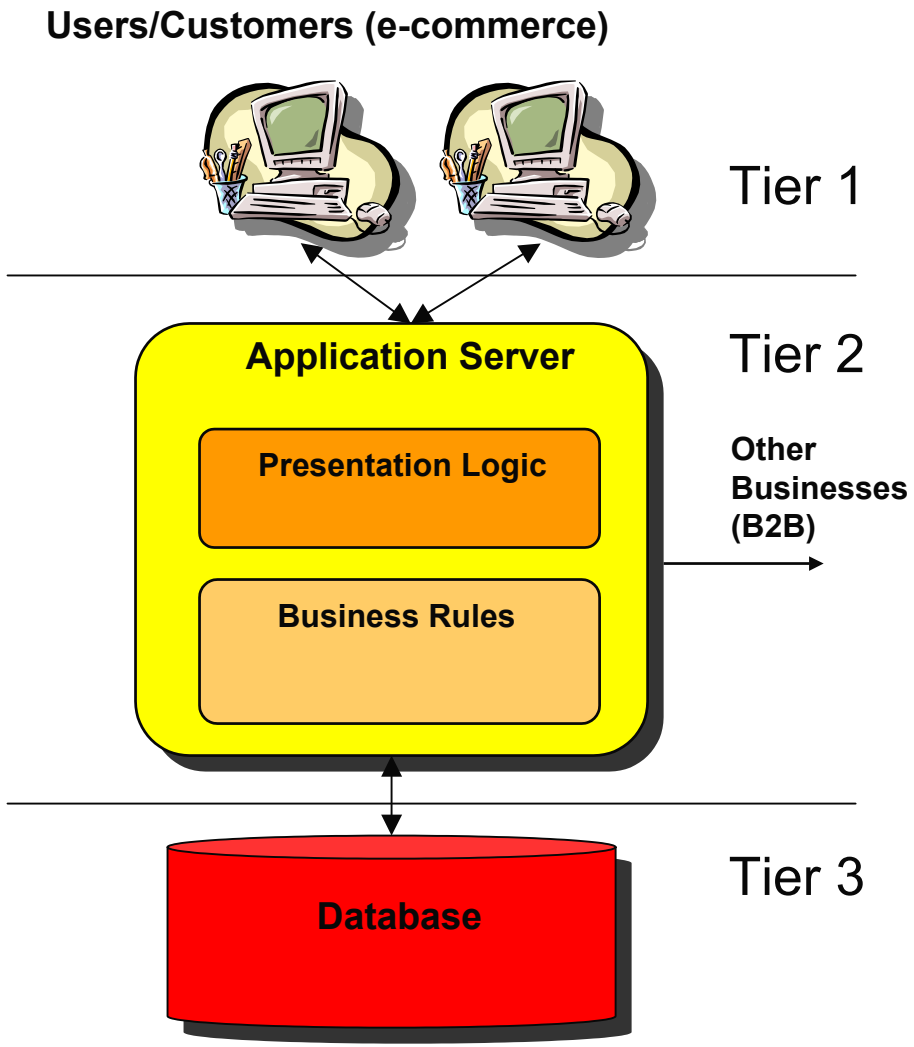
- SPECjbb2000
  - Approximates a 3-tier system in a single application
  - Will run on any JVM without any 3rd-party software
  - Easy to install, tune and run (set up time measured in hours)
- ECperf (now SPECjAppServer2001)
  - Runs on a real 3-tier system
  - Easy to isolate the behavior of individual tiers
  - Requires expensive 3rd-party software (application server and database)
  - Difficult to install, tune and run (set up time measured in weeks)

Outline

- Background
  - 3-Tiered Systems
  - ECperf and SPECjbb2000
- Hardware monitoring experiments
  - System size scaling
  - Benchmark scaling
- Simulation Experiments
  - Cache Performance
- Design decisions
  - Shared Caches

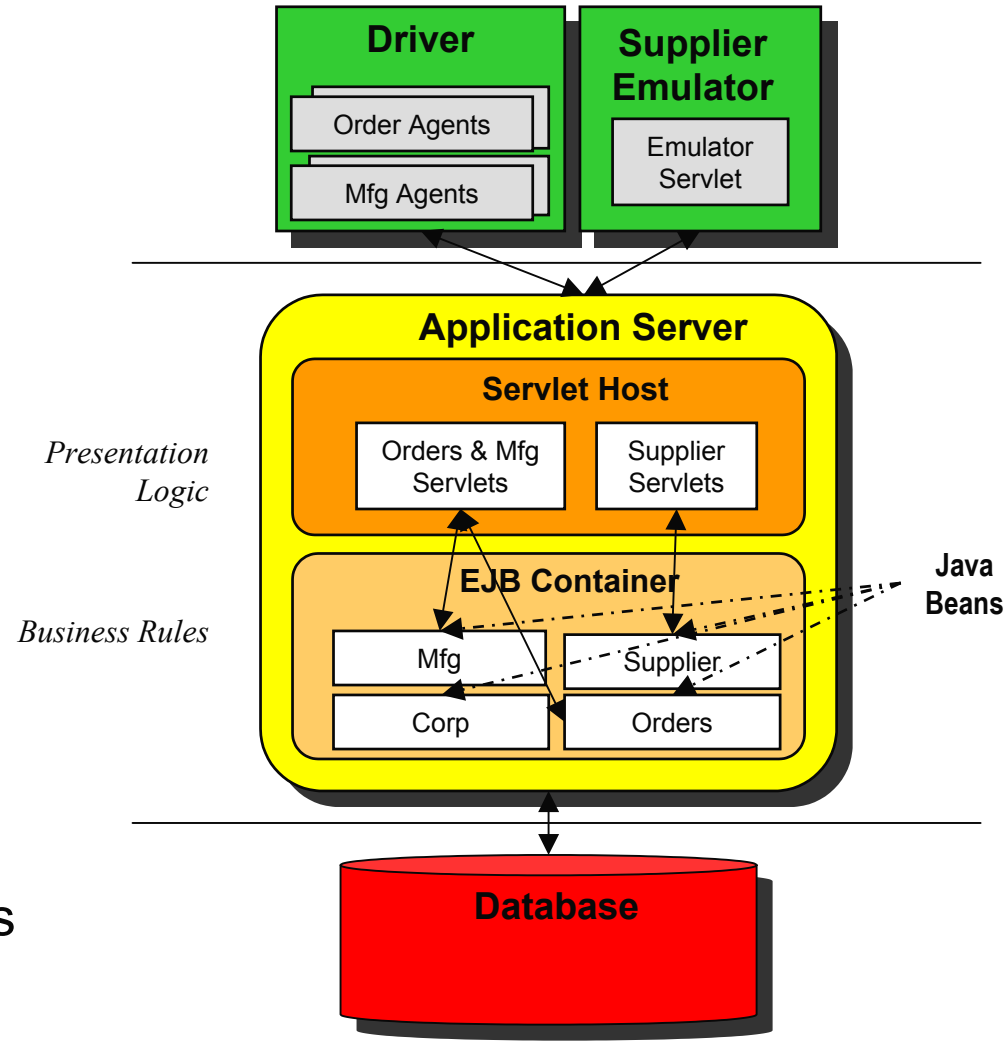
Application Servers & 3-Tiered Systems

- 3-tiered systems are common in e-commerce and B2B applications
- Application servers provide a framework for middle-tier applications
  - Presentation
  - Business Rules
- Services include
  - Database connectivity
  - Client connectivity
  - Resource management
- Application servers often implemented in Java



ECperf

- Runs on top of existing commercial applications (Database and Application Server)
  - Adds Cost, tuning effort
  - Restricted source code
- Consists of 4 networked programs
  - Application Server
  - Database
  - Supplier Emulator
  - Driver
- Runs on multiple machines
  - Easy to isolate tiers



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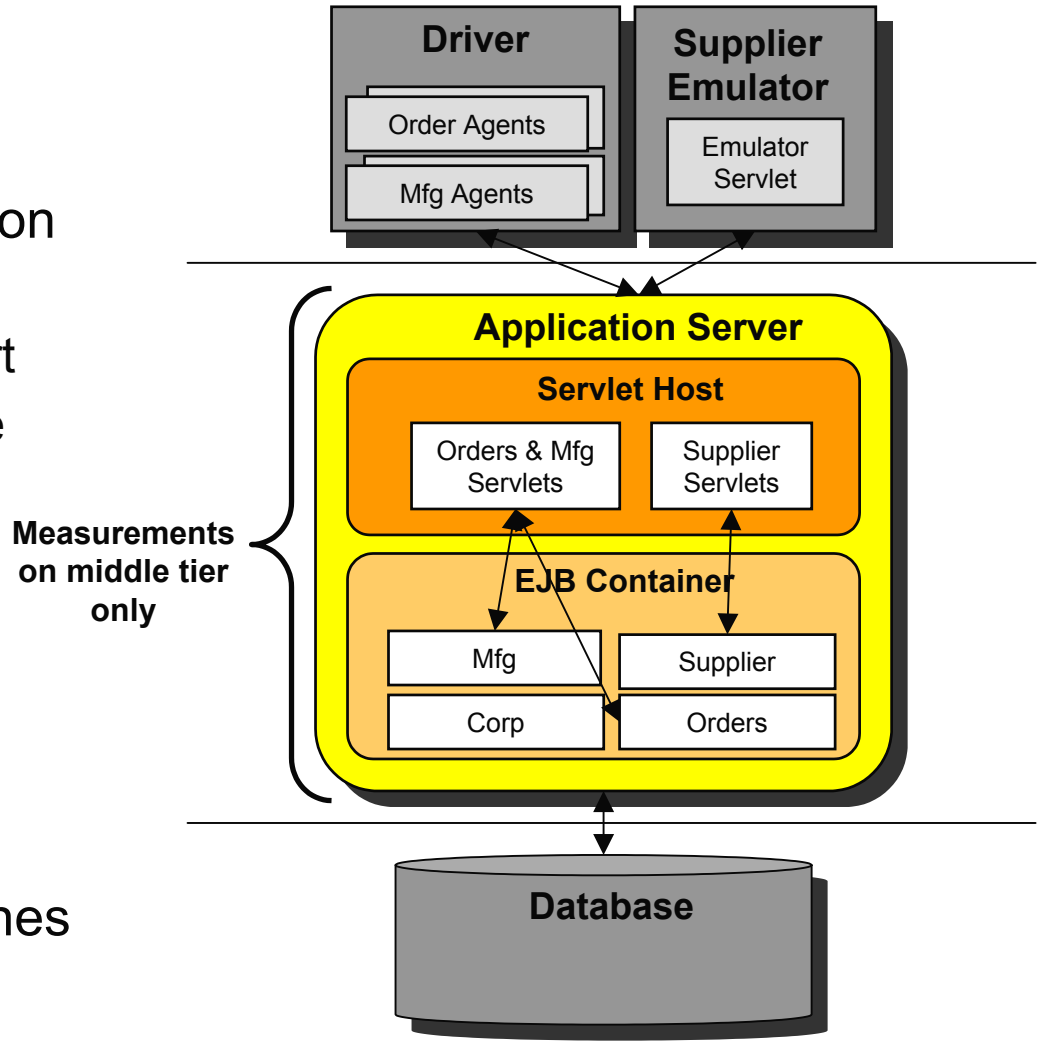
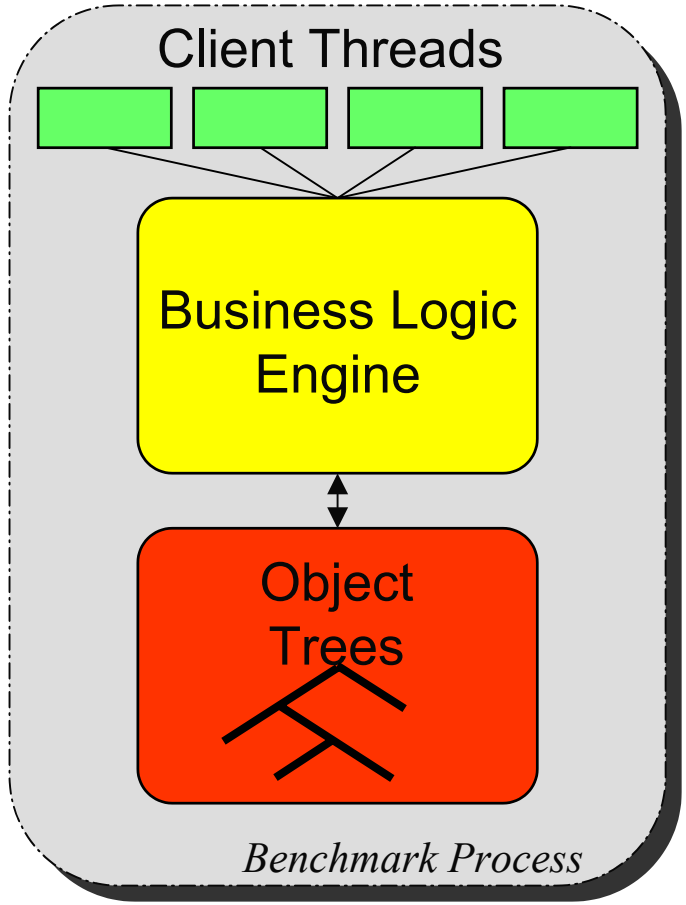


SPECjbb2000

- Single JVM
- Database emulated by trees of Java objects
- Easy to install tune and run
- Available source code
- Difficult to measure behavior of individual tiers



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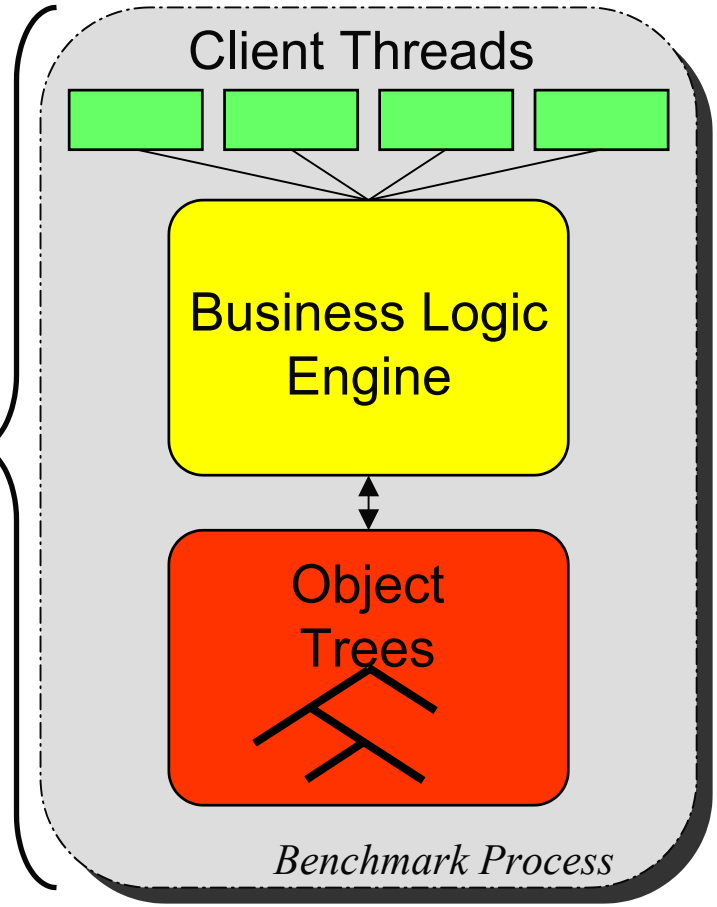
Measurements include data-base and client code



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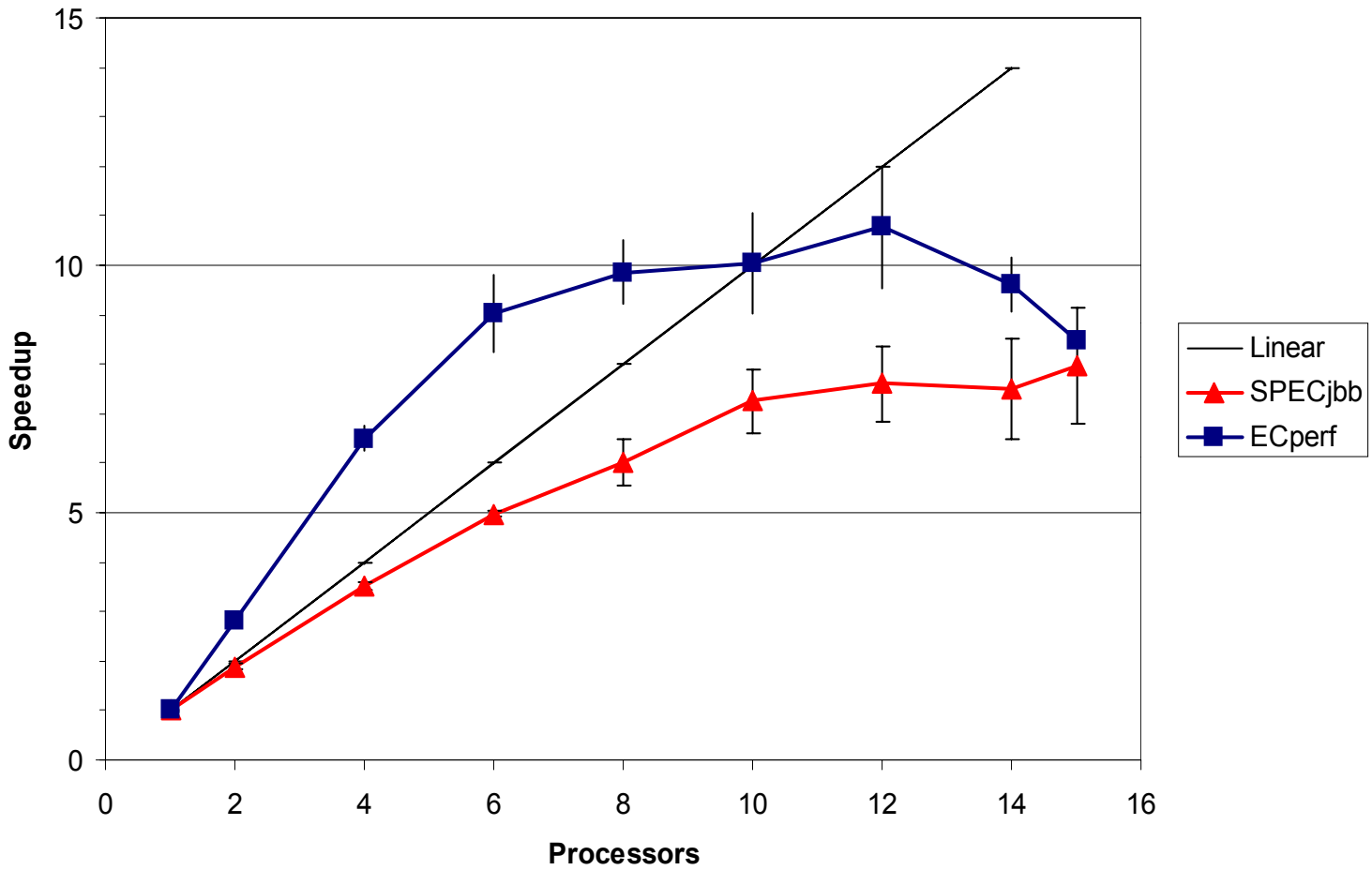
Monitoring Experiments

- Hardware
  - Sun E6000 (SPECjbb2000, Application Server, Database)
    - 16, 248 MHz UltraSparc II processors
    - 2 GB RAM
    - 1 MB unified L2 cache
  - Sun Netra (Emulator, Driver)
    - 1, 500 MHz UltraSparc IIe
- Software
  - HotSpot 1.3.1 JVM
  - Solaris 8

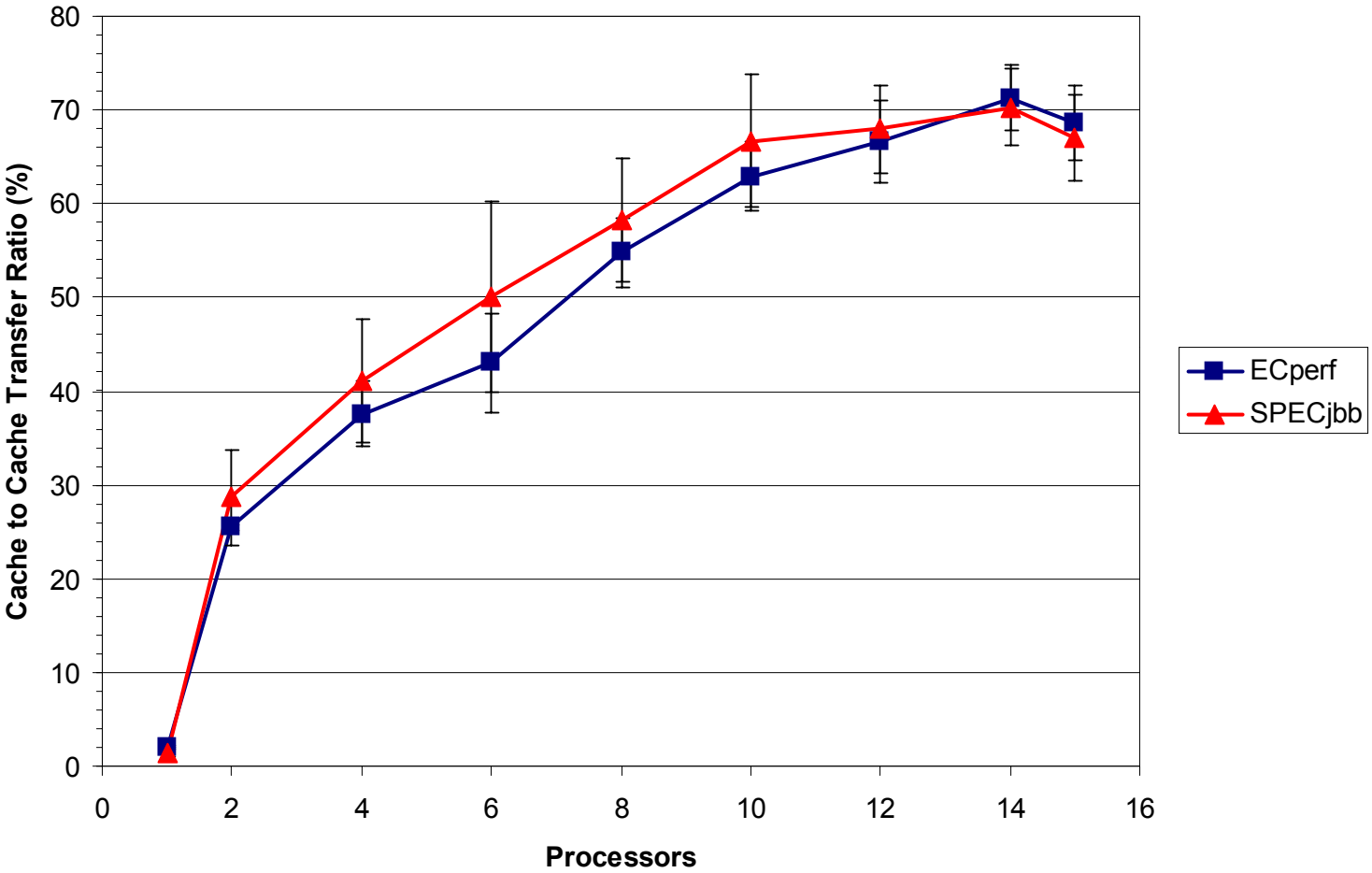
Benchmark Settings and Alterations

- SPECjbb2000
  - Increased warm-up and measurement intervals
    - 60 s warm-up and 6 min measurement
  - Picked 1 value for the number of warehouses
    - #warehouses = #processors
- ECperf
  - Relaxed response time requirements
- JVM Options
  - Heap Size = 1424 MB
  - ISM
  - New Generation = 400 MB

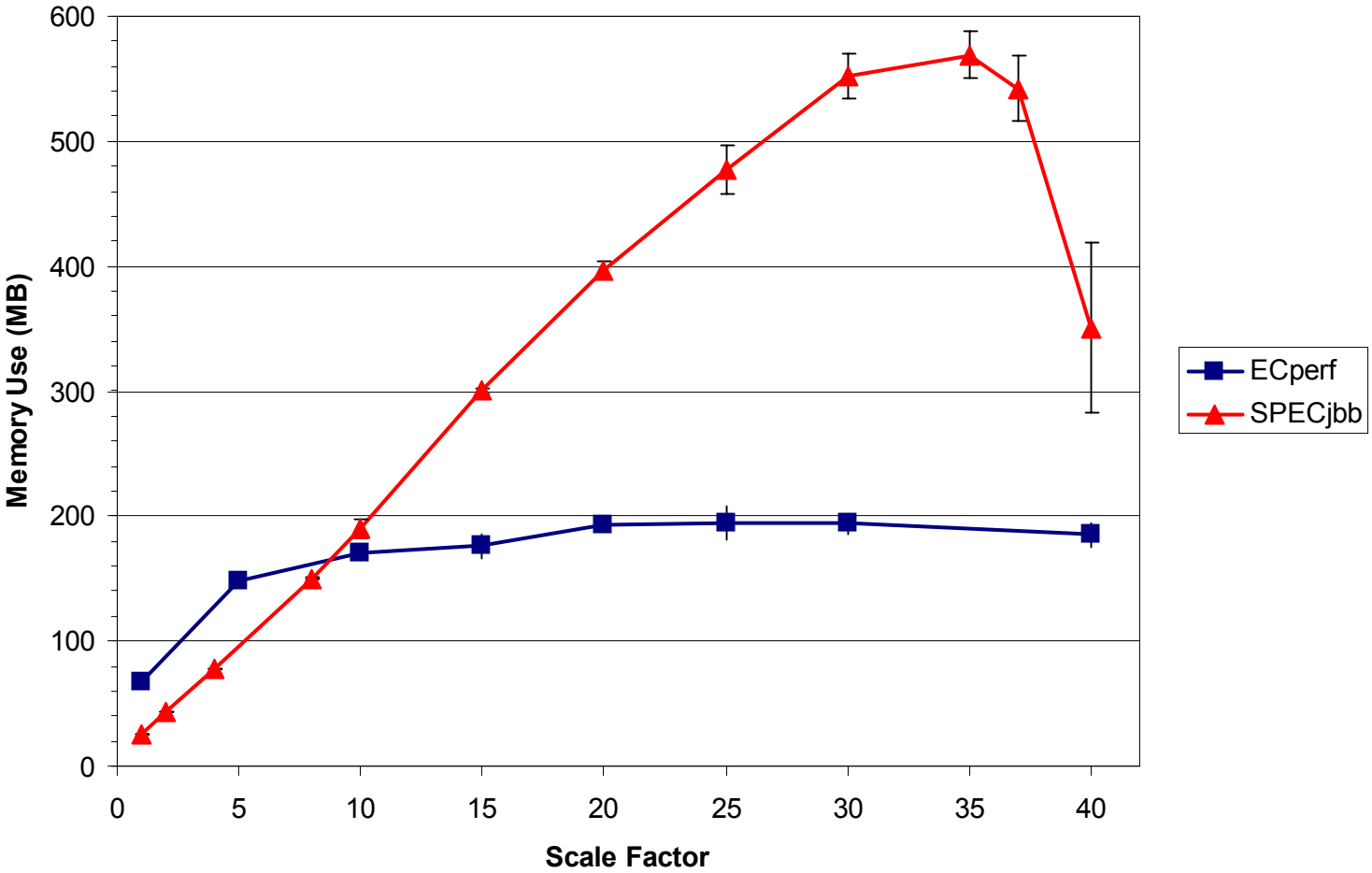
Performance Scaling



Data Sharing



Memory Use vs. Scale Factor (8 p)



Scaling Effects

- Scaling System Size
  - Increased system size from 1 to 15 processors
  - High Idle times for both benchmarks on large systems
  - Contention inside the application or JVM
  - High fraction of sharing misses on large systems
  - Very few misses to main memory despite large heap
  - CPI (ECperf 2.0-2.8, SPECjbb2000 1.8-2.3)
- Benchmark Scaling
  - Increased transaction input rate and database size
    - ECperf: Orders Input Rate
    - SPECjbb2000: Warehouses
  - Affects SPECjbb2000 more than ECperf

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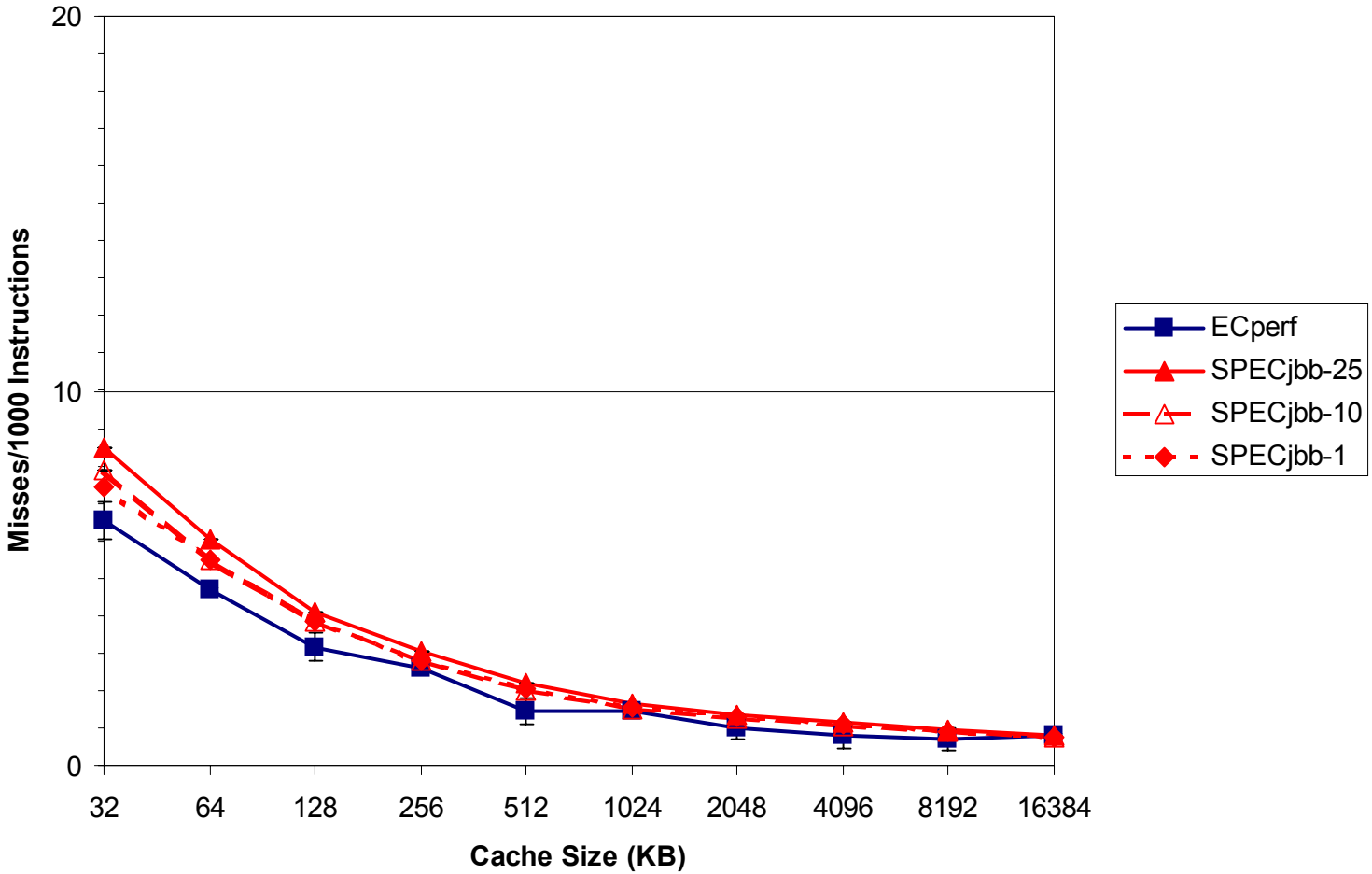
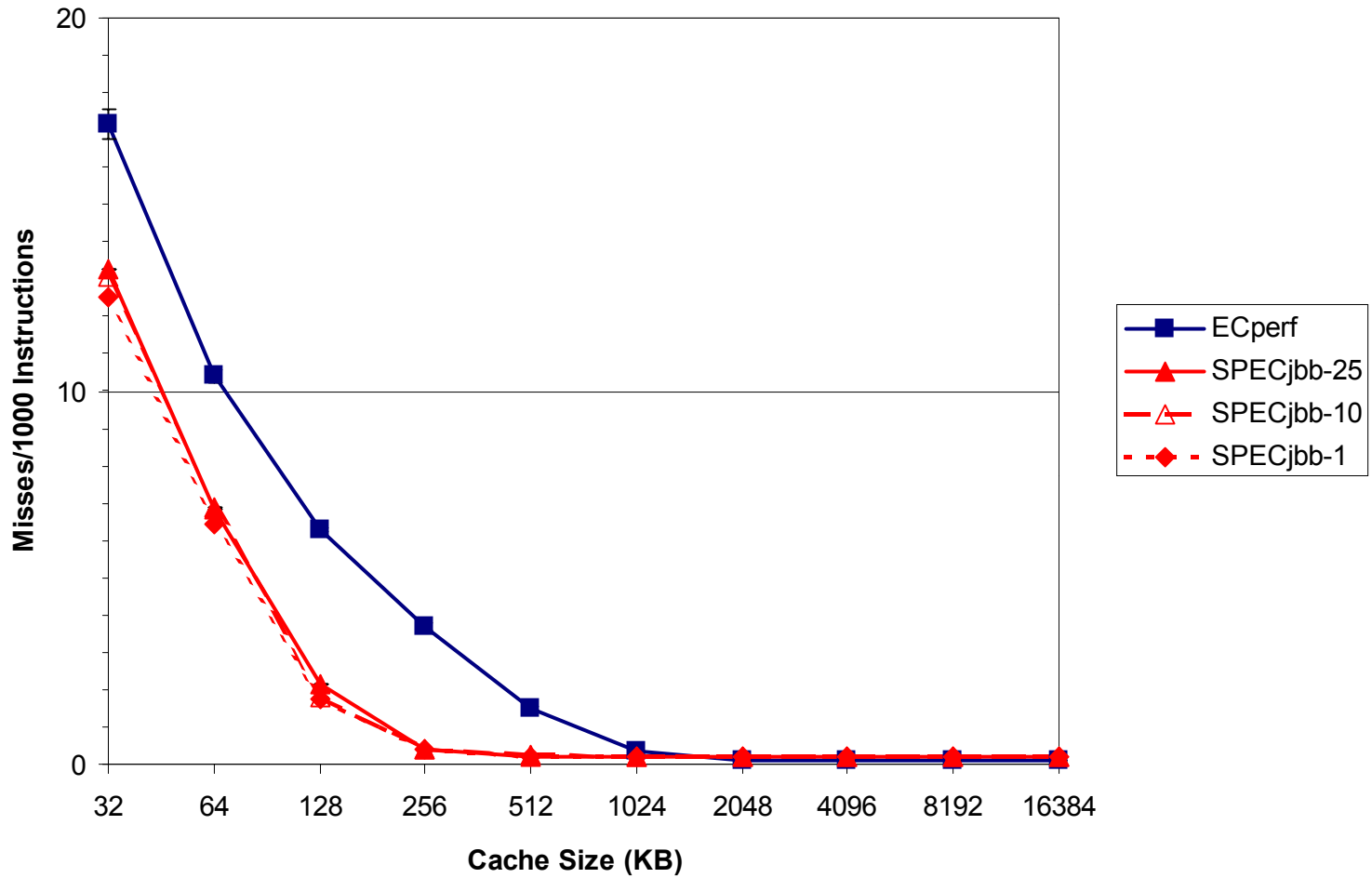
Cache Simulations

- Experiments conducted with Virtutech Simics with an extended memory system simulator
  - 4-way set associative caches
  - 64 byte cache lines
- Cache Miss Rates
  - Uniprocessor simulations
  - Split 1-level caches
- Sharing Analysis
  - 8-processor simulations
  - Unified cache

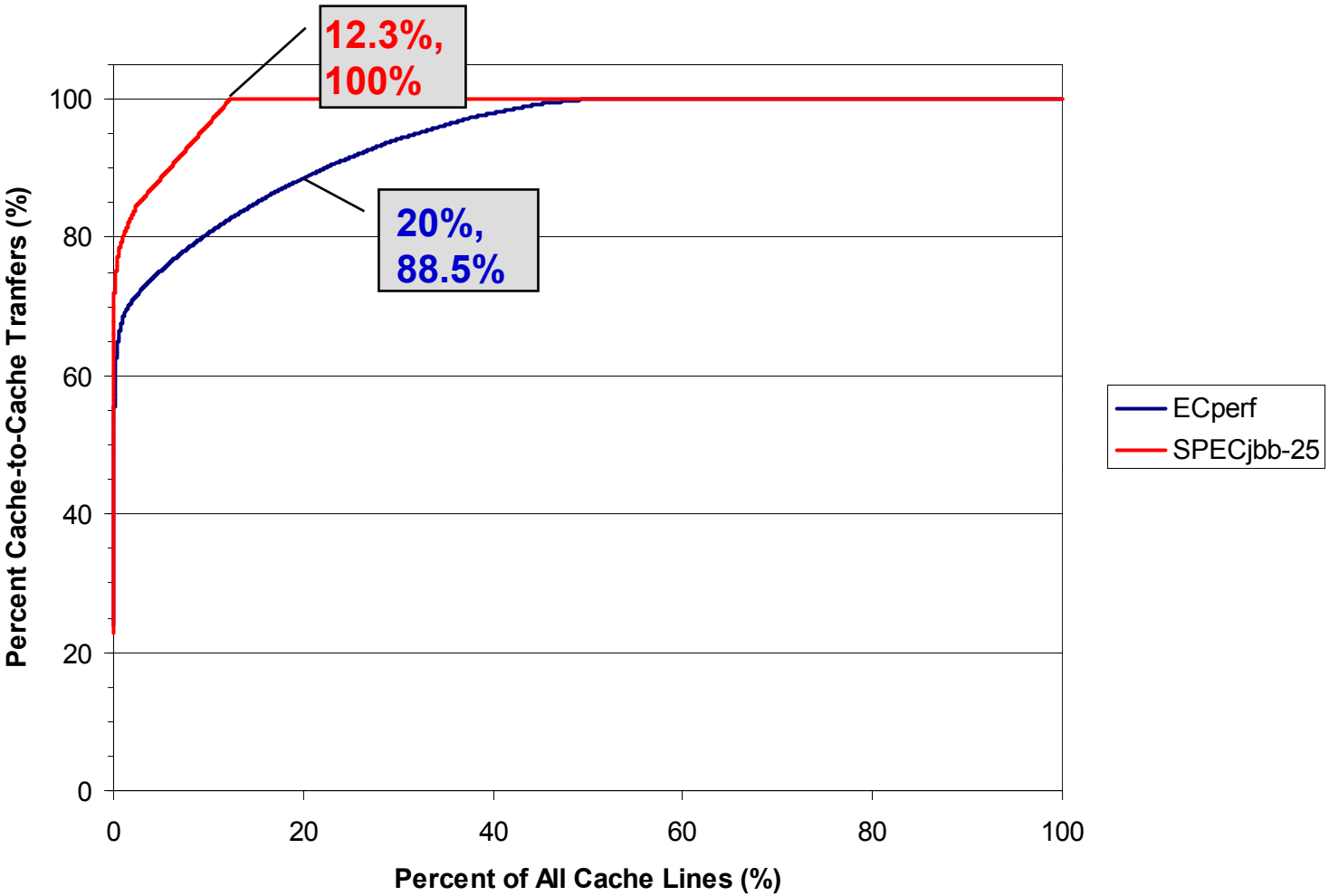
Data Cache


20
10
0
Misses/1000 Instructions
32
64
128
256
512
1024
2048
4096
8192
16384
Cache Size (KB)
ECperf
SPECjbb-25
SPECjbb-10
SPECjbb-1

Instruction Cache



Communication Distribution



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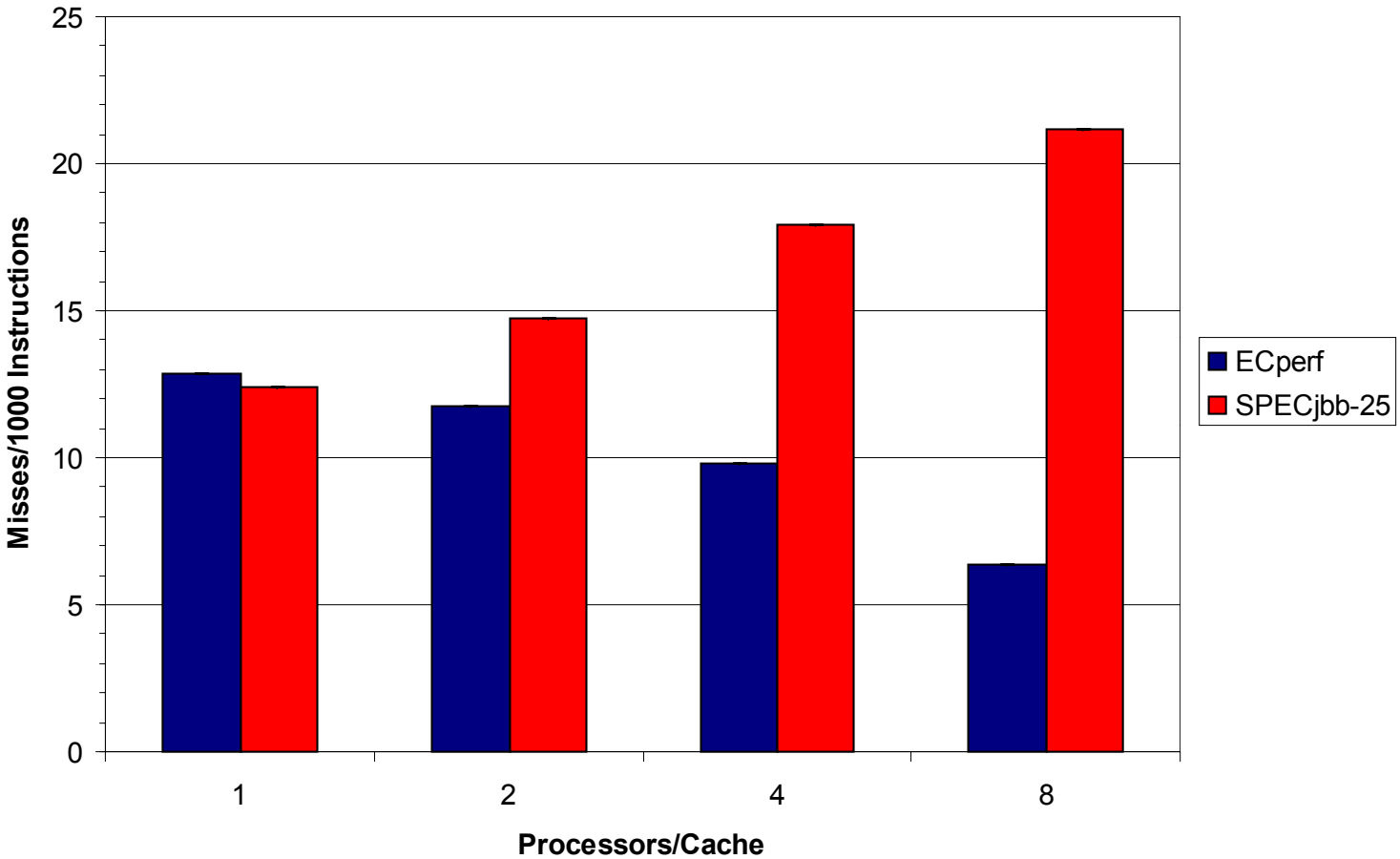
Shared Caches

- Potentially a good fit for Java-based middleware
  - High cache-to-cache transfer ratio
  - Small working sets
  - Low memory bandwidth
- Important design point for CMPs
- Experiment: Measured data miss rate for a simulated 8-processor system running each benchmark
  - All caches are 1MB
  - Varied number of caches and degree of sharing

Data Miss Rate vs. Sharing Degree



Paper Summary

- Descriptions of ECperf and SPECjbb2000
- Combination of hardware monitoring and full-system simulation
  - Scalability
  - Execution time breakdown
  - I/D Cache performance
  - Input rate scaling
- Effects of garbage collection
- Data sharing analysis and shared-cache performance
- Conclusion
  - Benchmark differences can lead to opposite design conclusions

Conclusions

- Both SPECjbb2000 and ECperf
  - Have small data sets
  - High rate of sharing misses
- SPECjbb2000 approximates ECperf well except for 2 important differences
  - ECperf has a much larger instruction footprint and a higher instruction miss rate
  - The memory footprint of SPECjbb2000 is larger than that of ECperf, especially on large systems