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CON2654: Java Performance: Hardware, Structures, and Algorithms

CREATE THE FUTURE

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Safe Harbor Statement

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Oracle Solaris Studio

Java One Sessions	
Mon, 5:30 – 6:30pm	**Java Performance: Hardware, Structures, and Algorithms** [CON2654], Hilton Imperial Ballroom A
Wed, 3 – 4pm	**Simplifying Development of Mixed-Language Java and C++ Applications** [CON8109], Hilton Continental Ballroom B
OOW Sessions	
Wed, 4:45 – 5:30pm	**Engineering Insights: Best Practices for Optimizing Oracle Software for Oracle Hardware** [CON8108], Intercontinental Grand Ballroom C
Thurs, 12 – 12:45pm	**Code Analysis Tools for Achieving Consistent, Secure, and Reliable Product Quality** [CON8009], Intercontinental B
Wed, 11:45 - 12:45pm	**Create Quality, Secure, High-Performing Applications on Oracle Solaris** [HOL9805], Hotel Nikko - Mendocino I/II

- http://www.oracle.com/goto/solarisstudio

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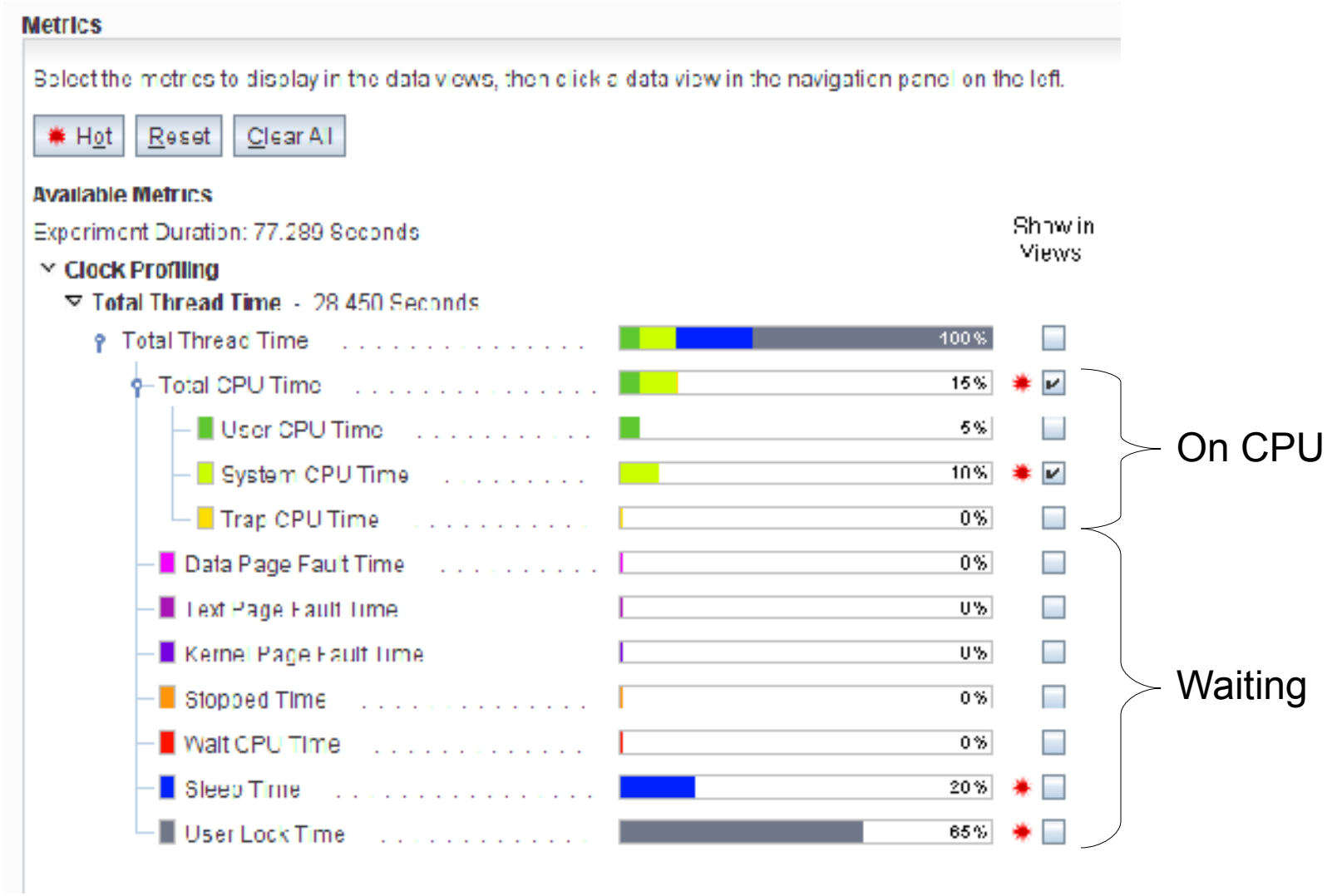
Program Agenda

1. Where to look for performance
2. The impact of hardware
3. Appropriate data structures
4. Efficient implementations
5. Concluding remarks

Where to Look for Performance

Overview



- Overview captures where the threads spend time
- Need to identify chunks of “time” to reduce.

Source Code View (High System Time)

Incl. Total CPU (sec.)	Incl. Sys. CPU (sec.)	Source File: flush.java Object File: flush.class (found as test.1.er/archives, Load Object: flush.class (found as test.1.er/archives,
0.	0.	10. for (int i=0; i<1000000; i++)
		11. {
3.402	2.362	12. out.write('a'); // one char
		13. }
0.	0.	14. out.close();
		15. }
0.	0.	16. catch (Exception e) {}

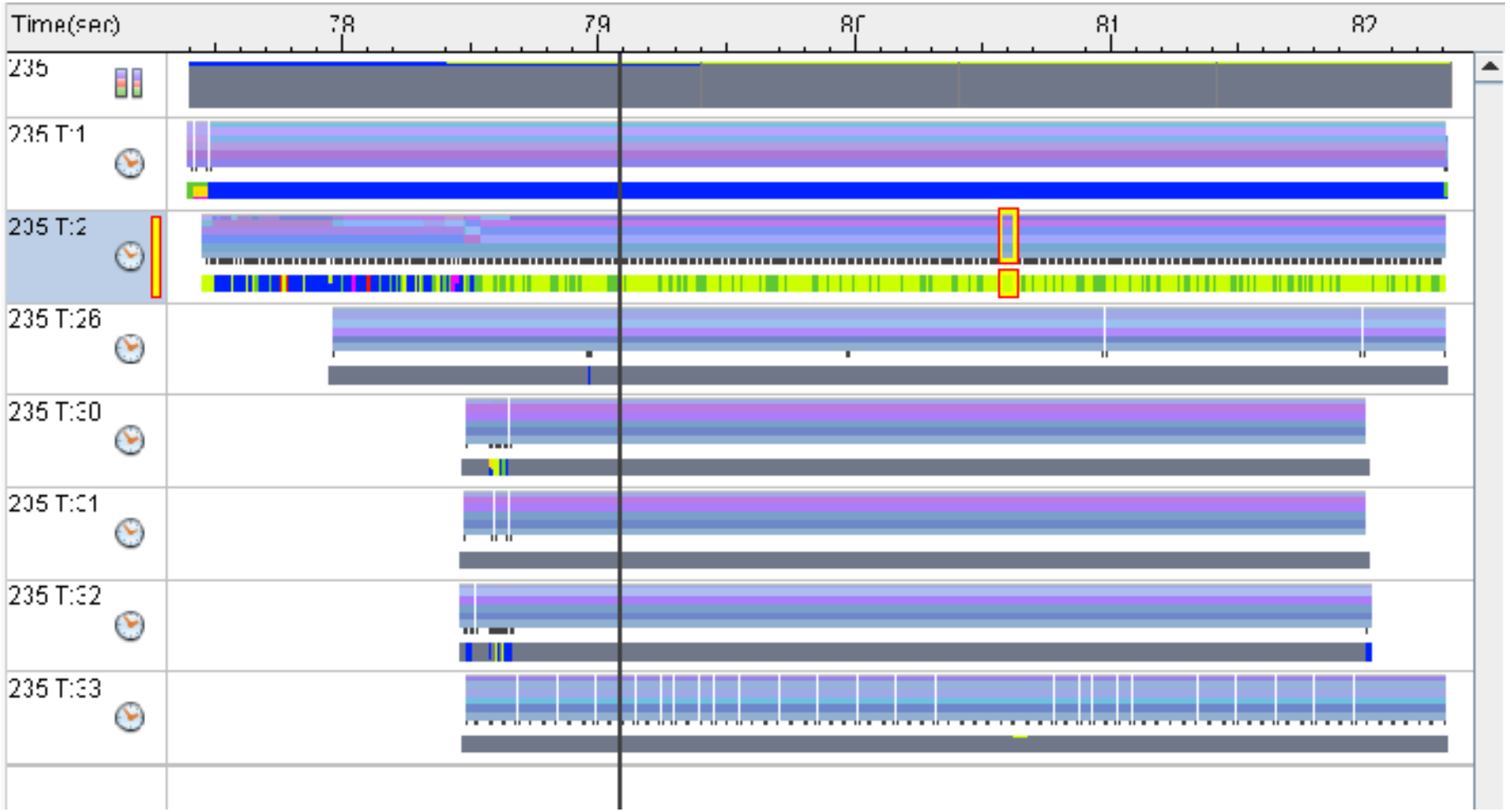
- Substantial system time spent on write of single byte

Source Code View (Reduced System Time)

Incl. Total CPU (sec.)	Incl. Sys. CPU (sec.)	Source File: flush.java Object File: flush.class (found as test.1.er/archives, Load Object: flush.class (found as test.1.er/archives,
0.	0.	20. String text = "abcdefghij";
0.	0.	21. byte data[] = text.getBytes();
0.	0.	22. for (int i=0; i<100000; i++)
		23. {
		24.
0.340	0.250	25. out.write(data,0,10); // 10 chars
		26. }
0.	0.	27. out.close();
		28. }
0.	0.	29. catch (Exception e) {}

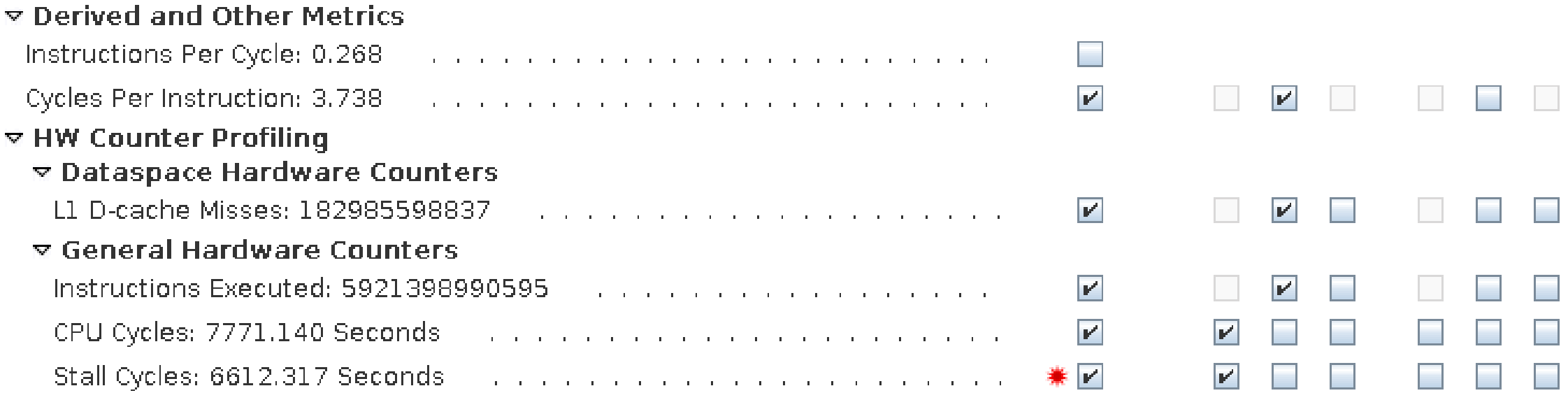
- Increasing size of writes (10x) reduces system time (10x)

Timeline View



- Sleep and User lock time often come from “idle” threads

Hardware Counters



- Hardware counters = processor events
- Can “explain” observed performance

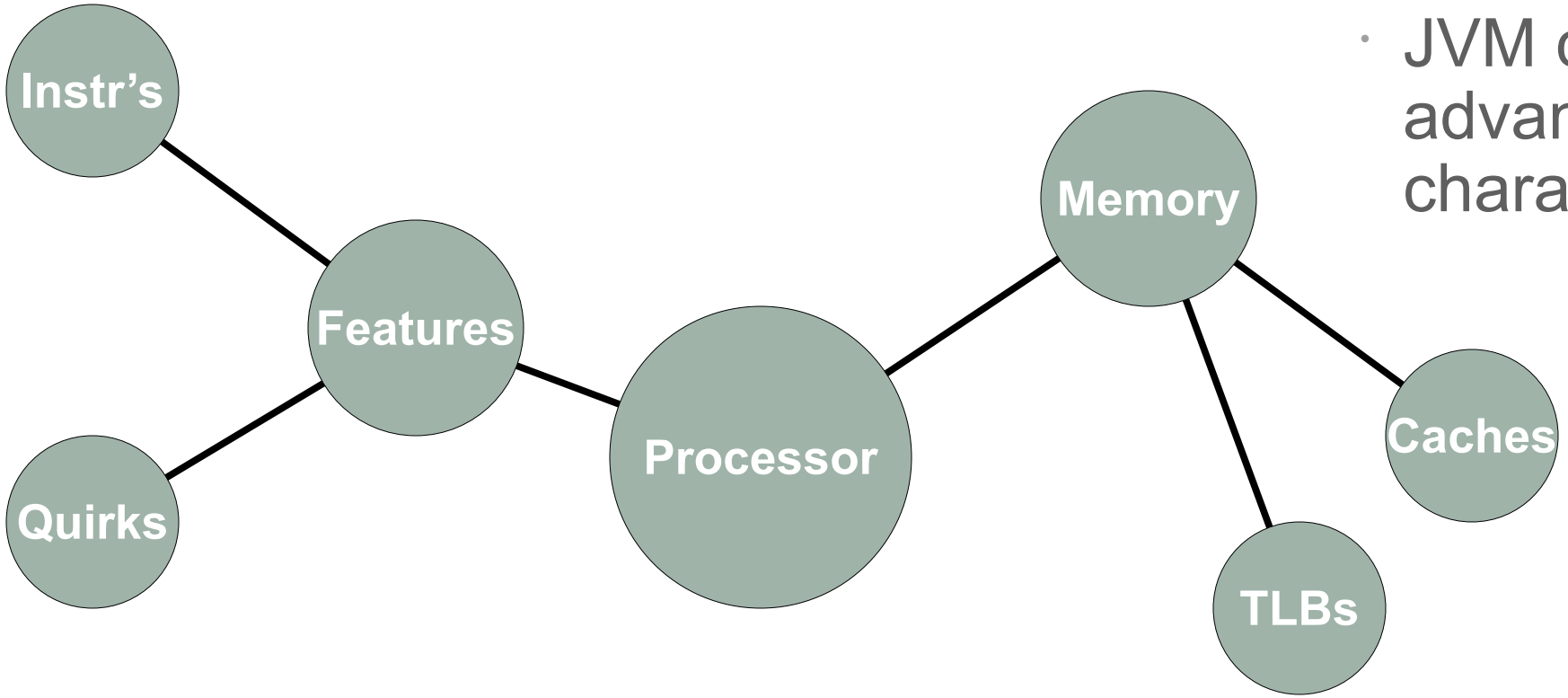
High CPI Indicates Stalls

Excl. User CPU (sec.)	Excl. CPI	Name
896.787	35.360	<Total>
27.029	143.224	java.util.TreeMap$ValueIterator
869.758	34.536	java.util.HashMap.getNode(int,

- Higher CPI indicates more stall time
- But time indicates benefit of fixing it

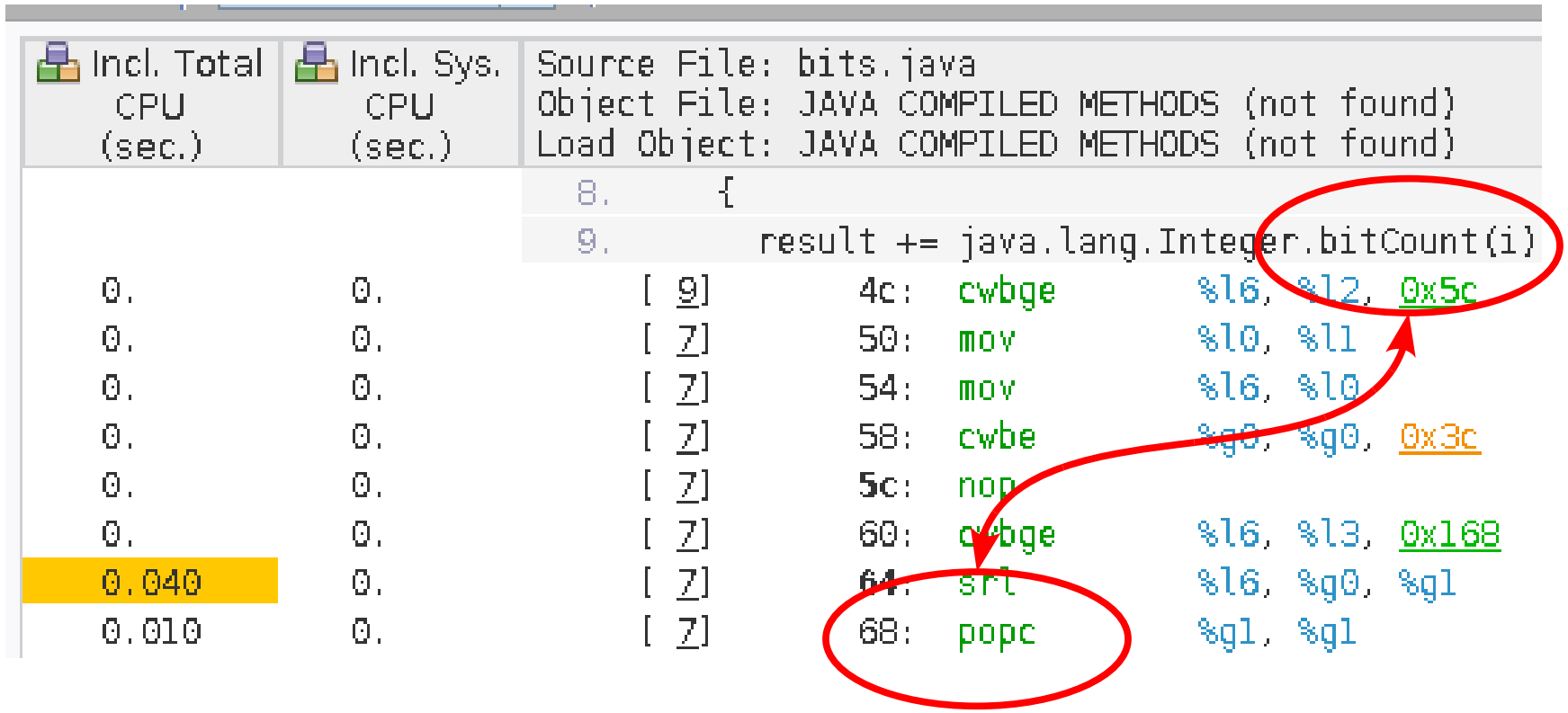
The Impact of Hardware

Hardware and the JVM



- JVM can take advantage of some characteristics

Hardware Intrinsics



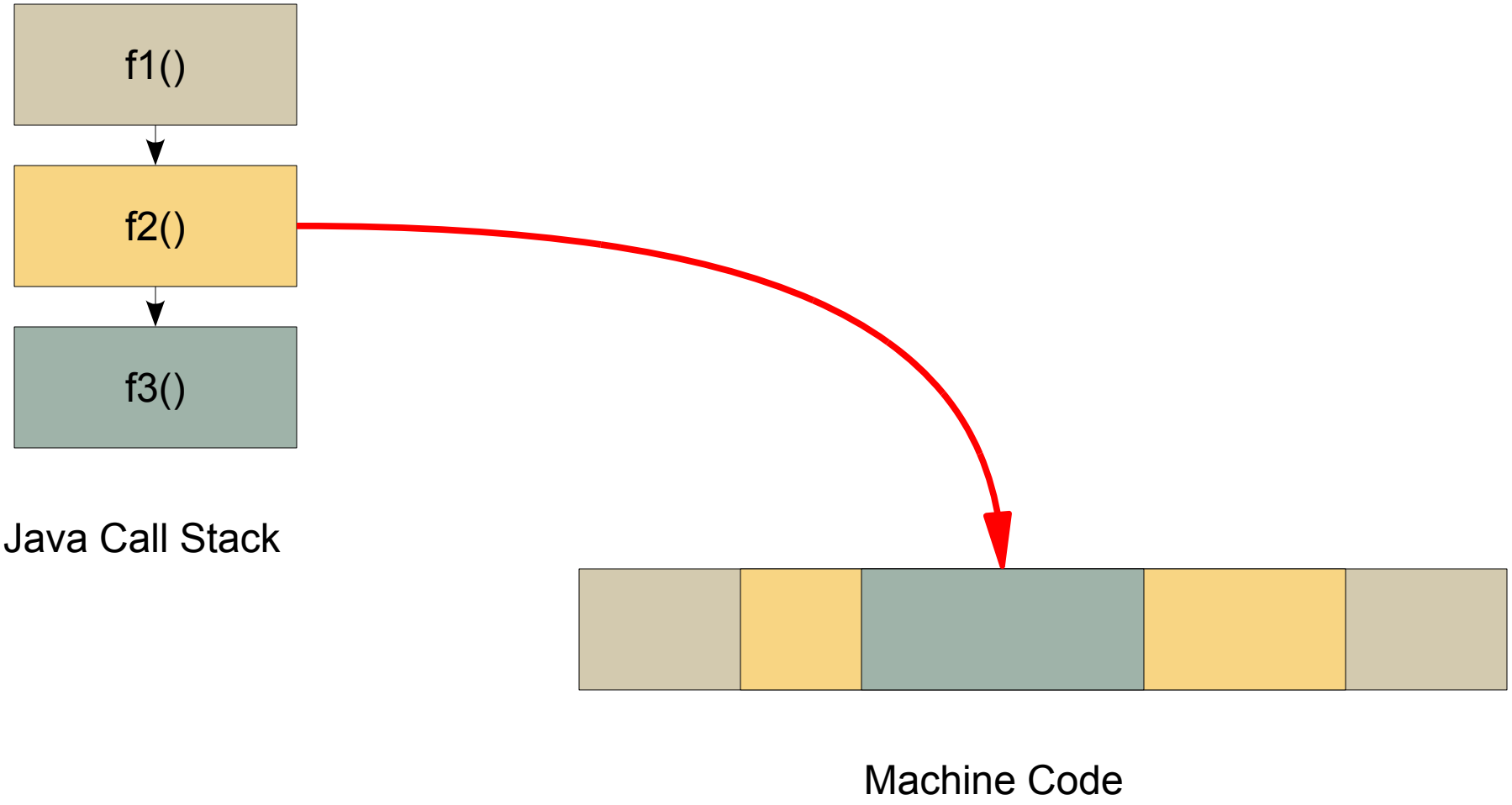
- JVM converts bitCount to popc instruction

Hardware Intrinsics in the VM

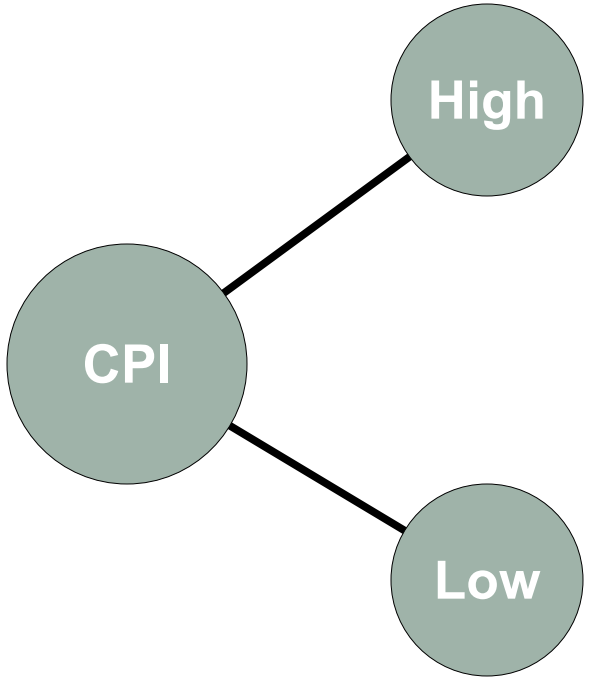
```
2341    switch (id) {
2342    case vmIntrinsics::_numberOfLeadingZeros_i:    n = new (C) CountL
2343    case vmIntrinsics::_numberOfLeadingZeros_l:    n = new (C) CountL
2344    case vmIntrinsics::_numberOfTrailingZeros_i:   n = new (C) CountT
2345    case vmIntrinsics::_numberOfTrailingZeros_l:   n = new (C) CountT
2346    case vmIntrinsics::_bitCount_i:                n = new (C) PopCou
2347    case vmIntrinsics::_bitCount_l:                n = new (C) PopCou
2348    case vmIntrinsics::_reverseBytes_c:            n = new (C) Revers
```

http://hg.openjdk.java.net/jdk8/jdk8/hotspot/file/87ee5ee27509/src/share/vm/opto/library_call.cpp

Inlining and optimisation



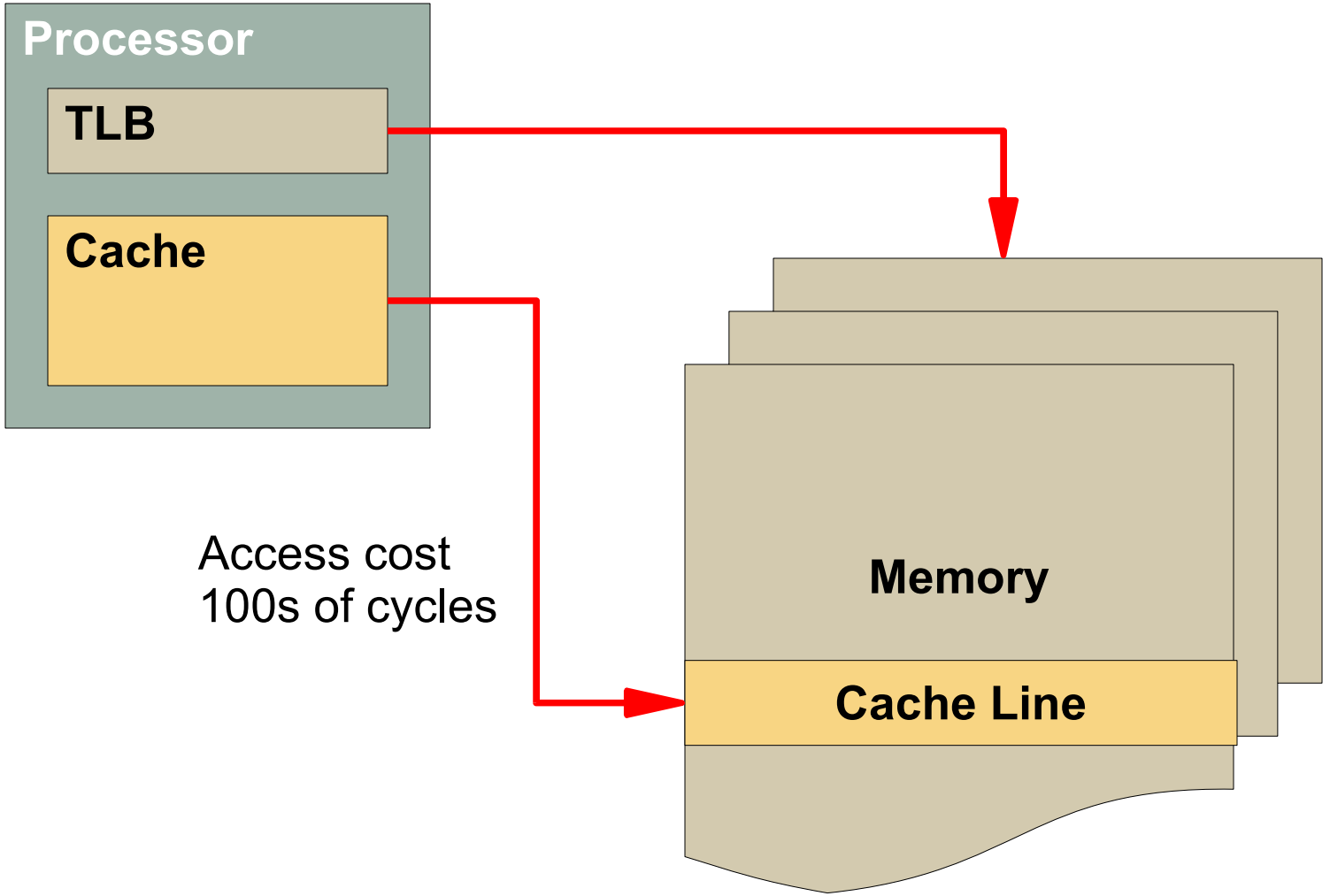
Generalisation of CPI & Performance



- High normally indicates **memory stalls**
  Suggests data structure efficiency

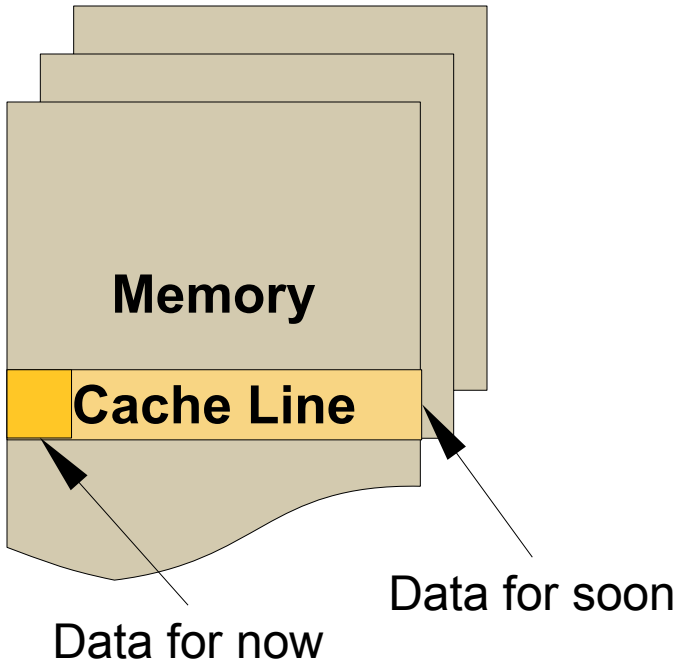
- Low CPI is **instruction issue** limited.
  Suggests algorithm efficiency

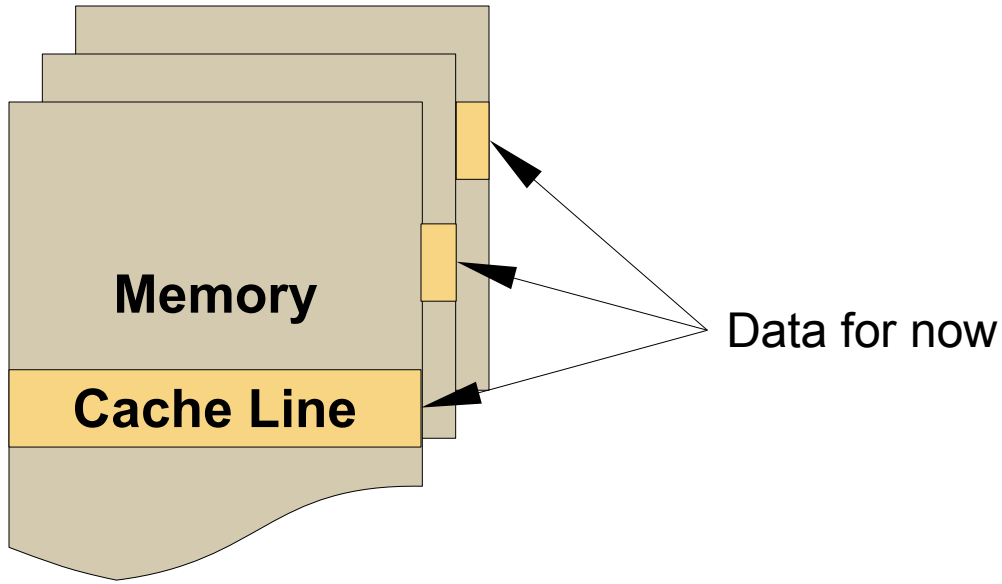
How Memory Works



- TLB maps to page in memory (KB or MB in size)
- Cache line fetched from page (often 64 bytes)

Memory Use Strategies





- Increase data density
- Increase memory level parallelism

Algorithm Cost

- Cost =

  O(operations) +

  O(cache misses) * cost/miss

- 1 cache miss ~= 100’s operations
- Worth adding operations to reduce cache misses

Appropriate data structures

Application Profile (Machine View)

Excl. User CPU (sec.)	Name
5146.620	<Total>
2031.491	spec.jbb.DeliveryTransaction.preprocess()
681.271	spec.jbb.CustomerReportTransaction.process
290.063	spec.jbb.Order.processLines(spec.jbb.Wareh
209.927	spec.jbb.Orderline.process(spec.jbb.Item,
139.638	spec.jbb.infra.Util.TransactionLogBuffer.p
130.621	spec.jbb.infra.Util.XMLTransactionLog.clea
126.969	spec.jbb.infra.Util.XMLTransactionLog.putL
126.318	spec.jbb.NewOrderTransaction.processTransa
103.452	ParallelTaskTerminator::offer_termination(
91.454	spec.jbb.StockLevelTransaction.process()

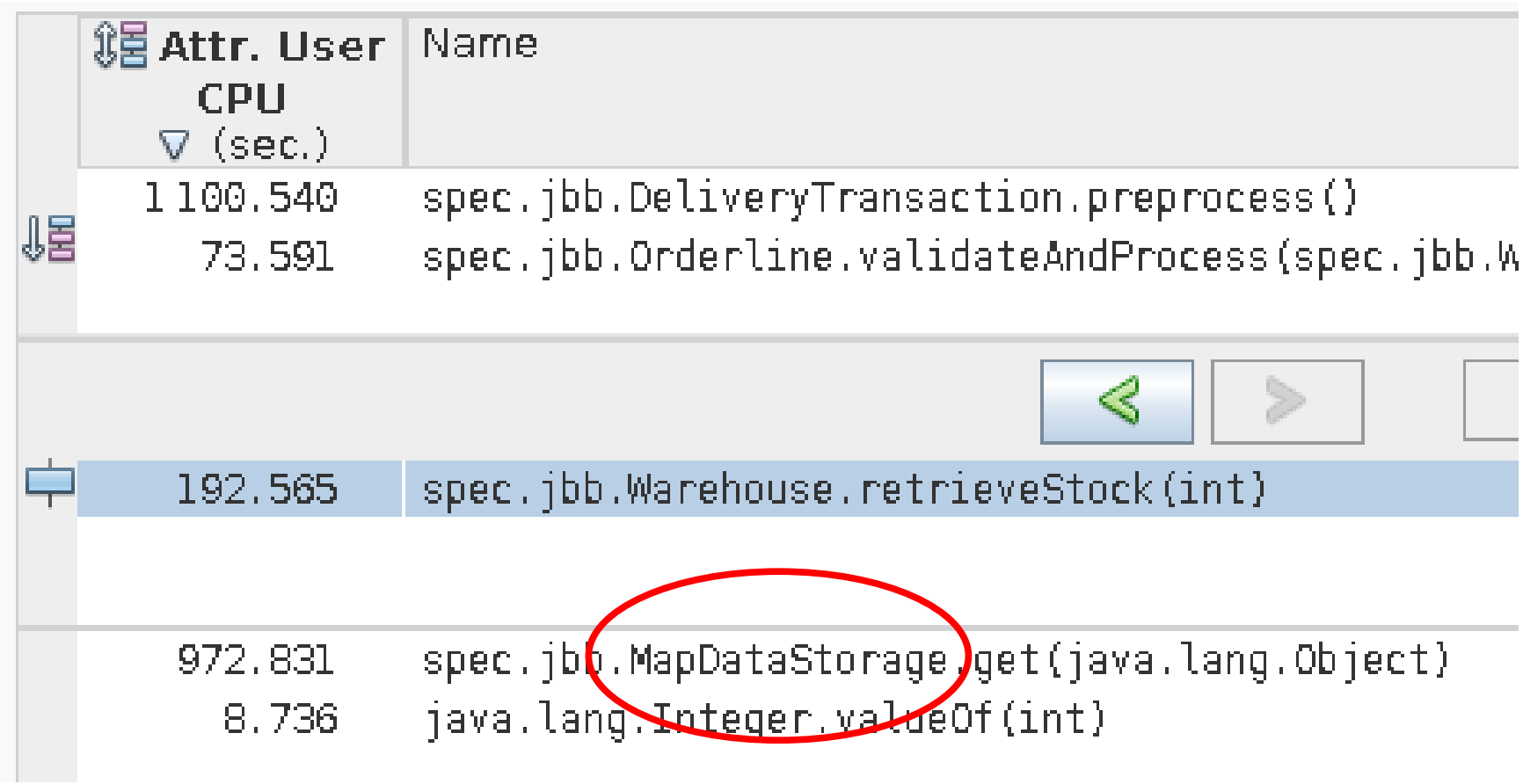
- 40% of total time

Source View of Hot Code

Incl. User CPU (sec.)	Source File: spec/jbb/DeliveryTransaction.java (not found) Object File: JAVA COMPILED METHODS (not found) Load Object: JAVA COMPILED METHODS (not found)
53.537	139. int requiredQuantity = orderline.getQuantity();
1.331	140. int itemId = orderline.getItemId();
1106.014	141. Stock stock = warehousePtr.retrieveStock(itemId);
35.035	142. int availableQuantity = stock.getQuantity();
7.936	143. if (availableQuantity >= requiredQuantity) {
1.271	144. stock.changeQuantity(-requiredQuantity);
0.	145. break;
	146. }
	147 }

- 20% of total time on code from one line

Routines Called by Hot Line



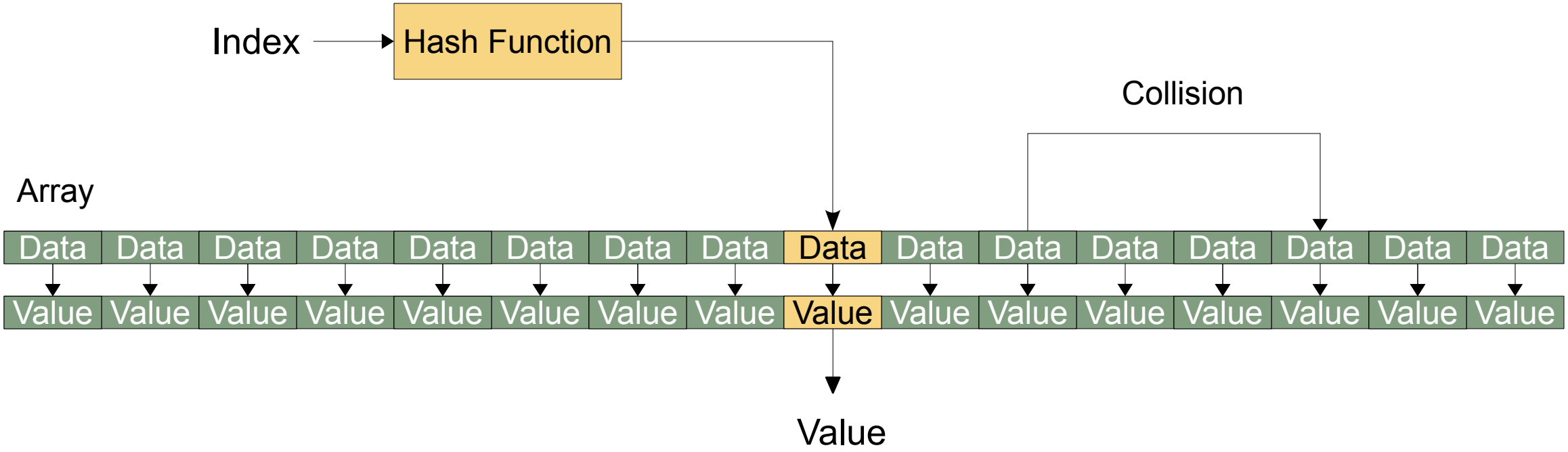
- Calls into HashTable to fetch result

Application Profile (User/Java View)

Excl. Total CPU (sec.)	Name
5,355.146	<Total>
941.699	java.util.HashMap.getNode(int, java.la
388.452	java.util.TreeMap.successor(java.util
328.560	java.util.TreeMap$Values.<init>(java.u
260.802	spec.jbb.CustomerReportTransaction.pro
230.972	java.util.TreeMap$PrivateEntryIterator
220.925	java.lang.Integer.equals(java.lang.Obj
208.576	spec.jbb.Warehouse.retrieveStock(int)

- 20% of total time

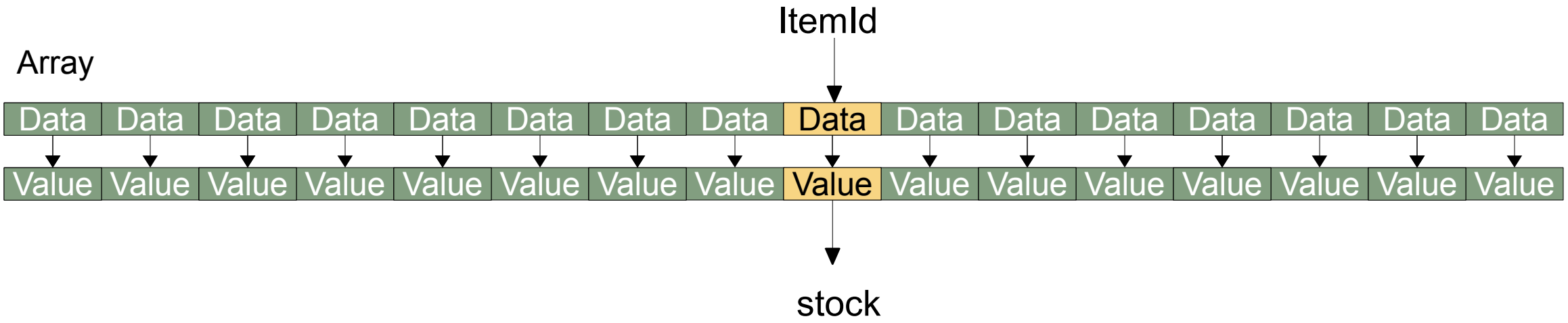
HashTable



- Look up = O(1)
- Cache misses = O(1)

ItemID is an Integer

```
    1.331    140.                    int itemId = orderline.getItemId();
1 106.014    141.                    Stock stock = warehousePtr.retrieveStock(itemId);
```



- Look up = O(1)
- Cache misses = O(1)

Application Profile with array

Excl. User CPU (sec.)	Name
5141.226	<Total>
2029.550	spec.jbb.DeliveryTransaction.preprocess()
600.480	spec.jbb.CustomerReportTransaction.process()
289.673	spec.jbb
209.677	spec.jbb
139.448	spec.jbb
130.451	spec.jbb
126.879	spec.jbb
126.098	spec.jbb
103.452	Parallel

Excl. User CPU (sec.)	Name
5145.980	<Total>
1694.395	spec.jbb.DeliveryTransaction.preprocess()
680.676	spec.jbb.CustomerReportTransaction.process()
226.108	spec.jbb.Orderline.process(spec.jbb.Item, spec

- ~300s less time, throughput increased by ~9%

Efficient implementations

Application Profile

Excl. User CPU (sec.)	Name
5141.226	<Total>
2029.550	spec.jbb.DeliveryTransaction.preprocess()
600.480	spec.jbb.CustomerReportTransaction.process()
289.673	spec.jbb.Order.processLines(spec.jbb.Warehouse, short, bool
209.677	spec.jbb.Orderline.process(spec.jbb.Item, spec.jbb.Stock)
139.448	spec.jbb.infra.Util.TransactionLogBuffer.putText(java.lang.
130.451	spec.jbb.infra.Util.XMLTransactionLog.clear()
126.879	spec.jbb.infra.Util.XMLTransactionLog.putLine(java.lang.Str
126.098	spec.jbb.NewOrderTransaction.processTransactionLog()
103.452	ParallelTaskTerminator::offer_termination(TerminatorTermina

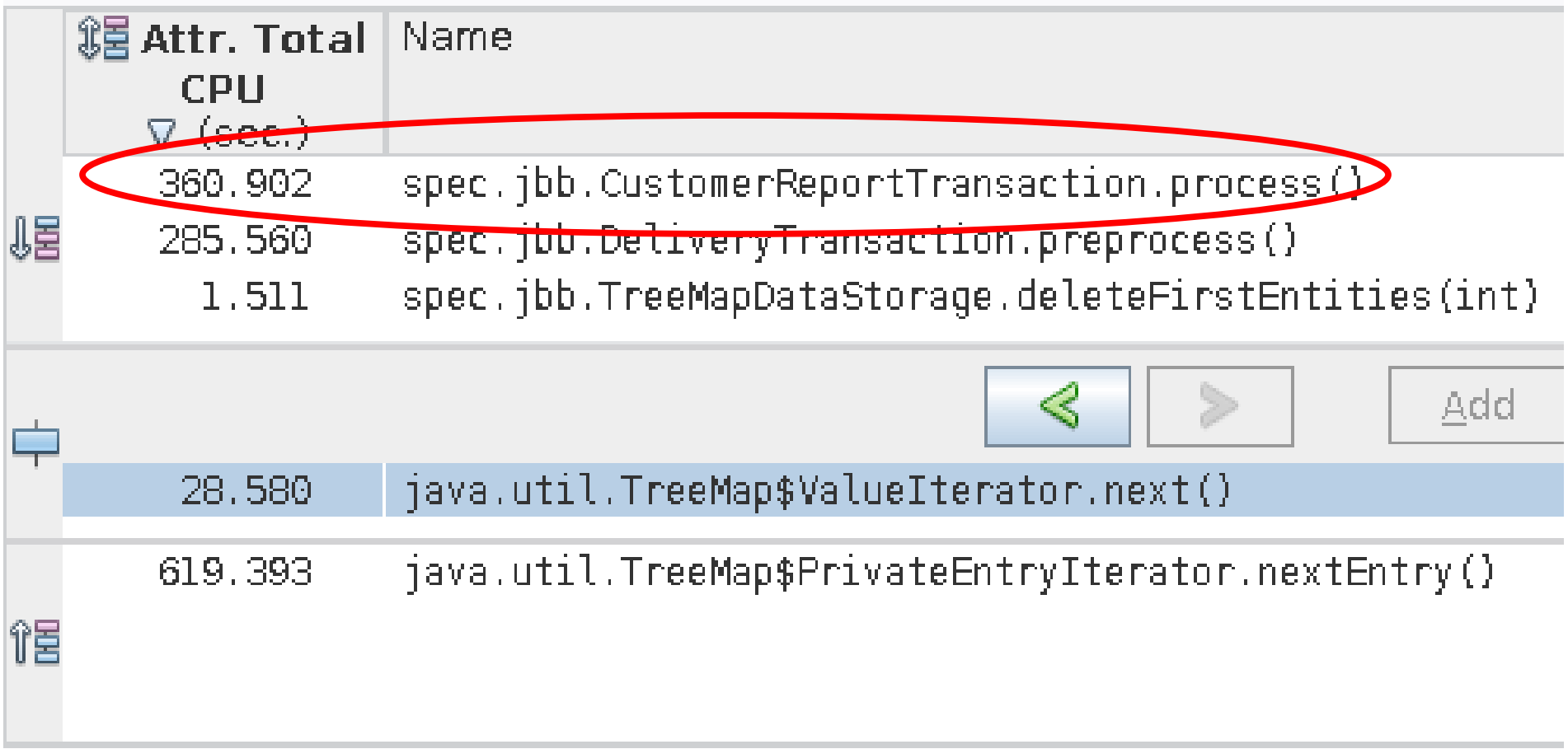
- ~12% of time

Hot Source Code

Incl. User CPU (sec.)	Source File: spec/jbb/CustomerReportTransaction.java (not found Object File: JAVA COMPILED METHODS (not found) Load Object: JAVA COMPILED METHODS (not found)
0.	235. int i = 0;
8.406	236. while (historyIter.hasNext()) {
438.337	237. history = (History) historyIter.next();
16.752	238. if (history.getCustomerId() == customerP1
1.241	239. histCount++;
0.560	240. payments[histCount] = history;
	241. }
	242. }

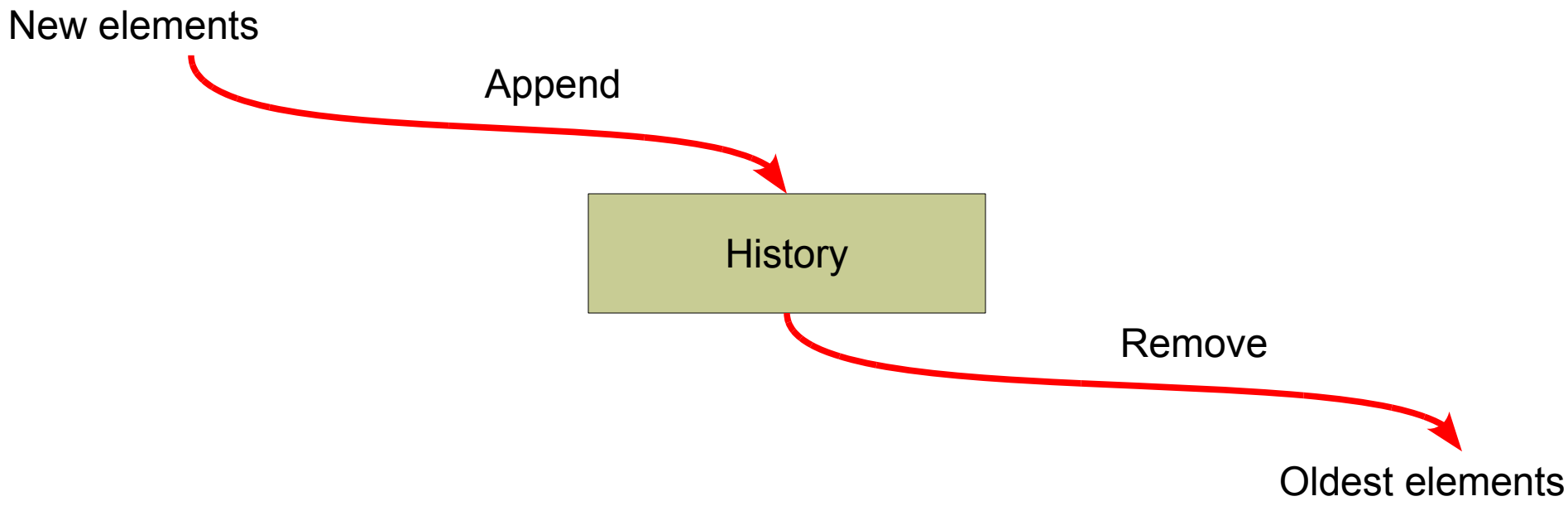
- Time spent iterating a HashMap

Hot Call Tree



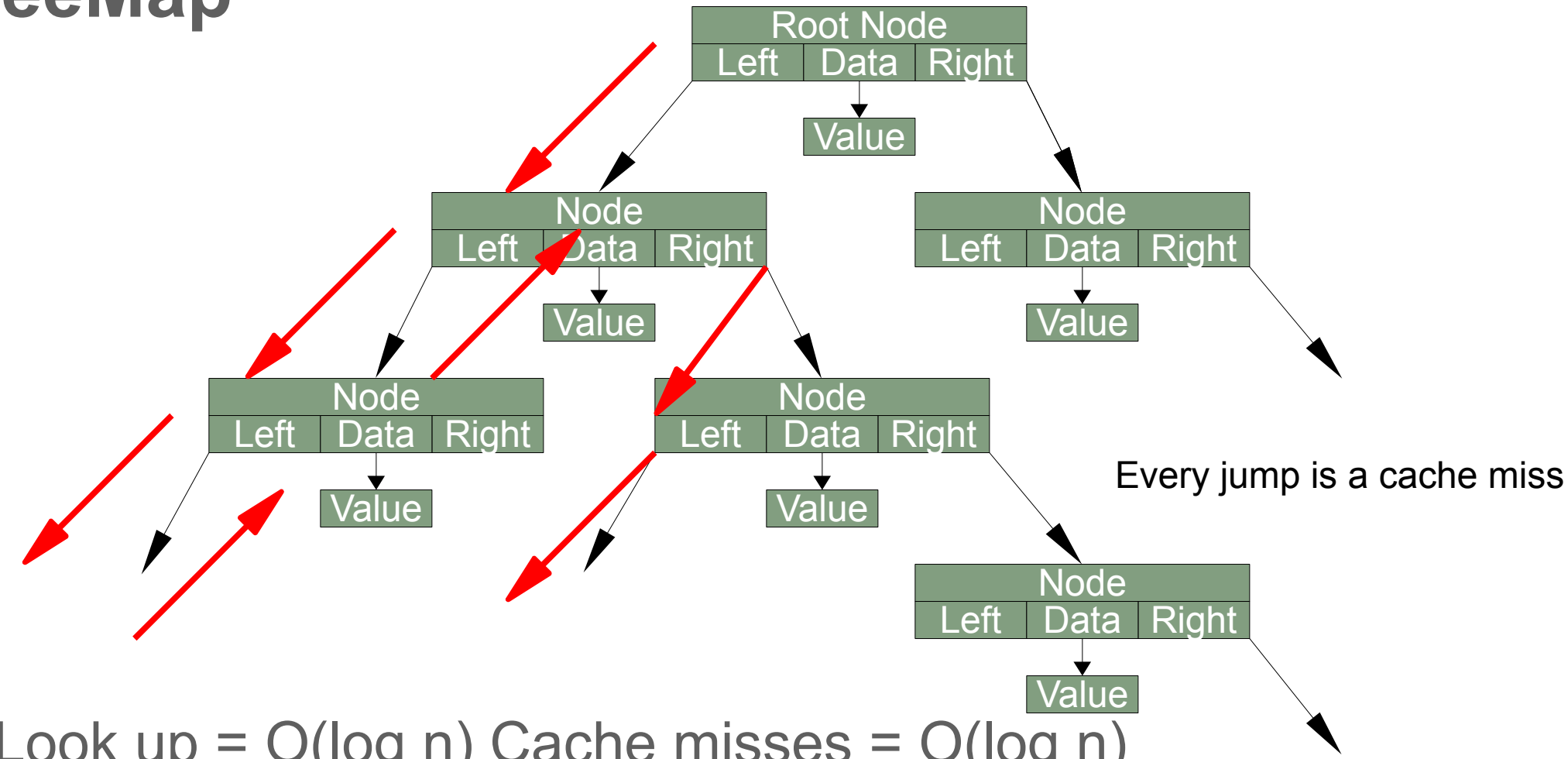
- Time spent iterating a HashMap

History



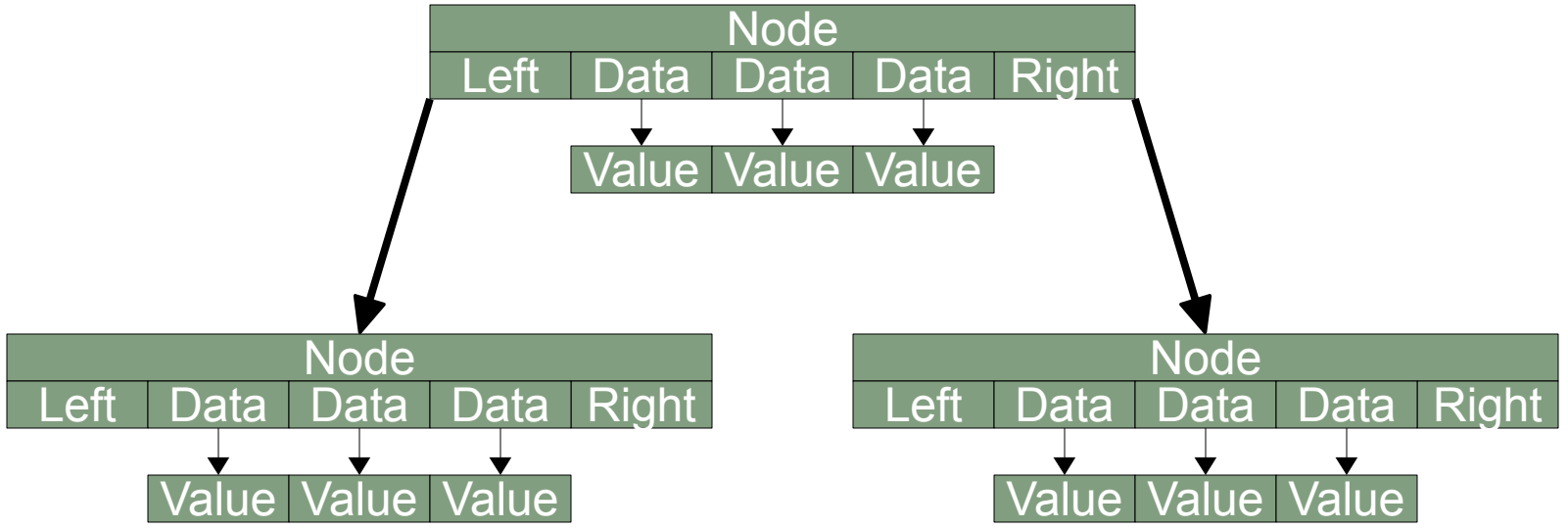
- History is constantly changing

TreeMap



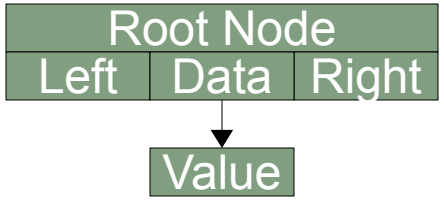
- Look up = O(log n) Cache misses = O(log n)
- Iteration = O(n) Cache misses = O(n)

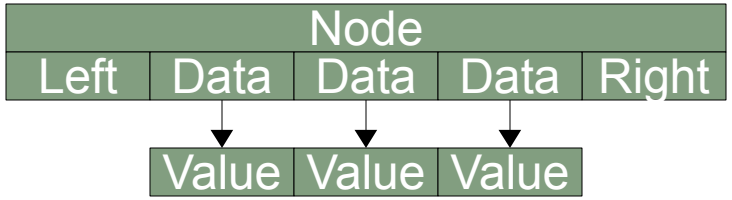
Using “Wide” Nodes

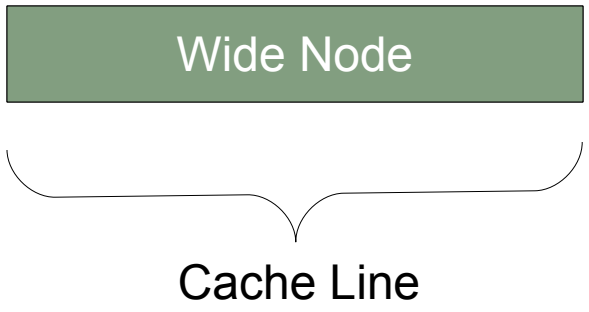


- Look up = O(log n) Cache misses = O(log n)
- Iteration = O(n), cache misses reduced by Wx (eg W=64)

Cache Line Utilisation







Application Profile with Wide Nodes

Excl. User CPU (sec.)	Name
5141.226	<Total>
2029.550	spec.jbb.DeliveryTransaction.preprocess()
600.480	spec.jbb.CustomerReportTransaction.process()
289.673	spec.jbb.O
209.677	spec.jbb.O
139.448	spec.jbb.i
130.451	spec.jbb.i
126.879	spec.jbb.i
126.098	spec.jbb.N
103.452	Parallel[Ta

Excl. User CPU (sec.)	Name
5159.009	<Total>
2117.191	spec.jbb.DeliveryTransaction.preprocess()
304.033	spec.jbb.Order.processLines(spec.jbb.Warehouse, short
277.184	spec.jbb.CustomerReportTransaction.process()

- 300s less time -> ~7% gain

Concluding Remarks

Hardware Tuning Opportunities

- Automatic JVM use of intrinsics
- Developer's knowledge of hardware
- Cache misses critical part of performance
  - Efficient use of loaded data
  - Minimise number of hops

Q&A

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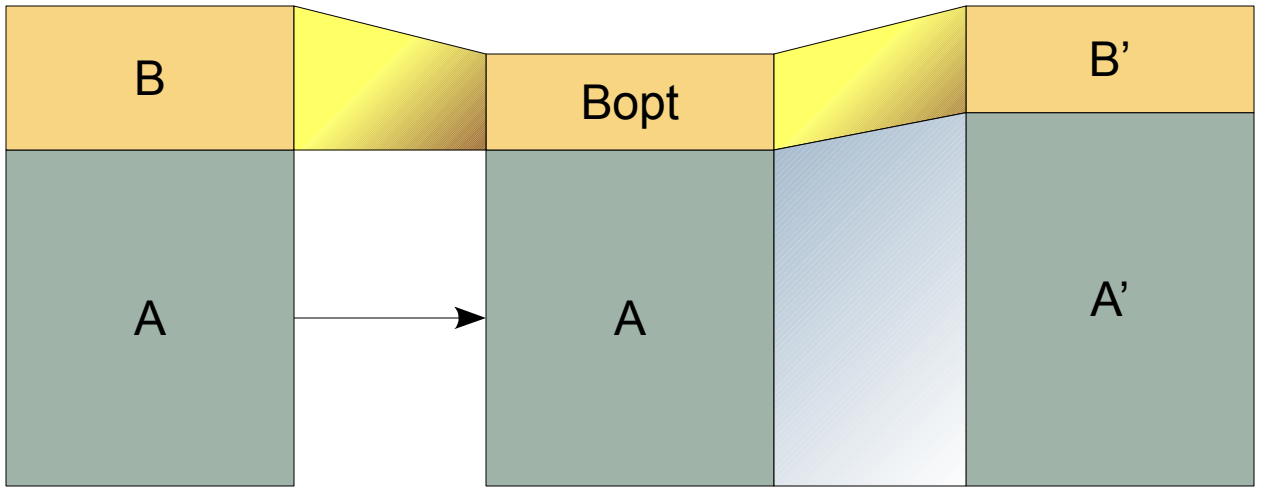
Comparing Constant Time Profiles



Original profile

Profile of optimisation and original workload

New profile

- Unmodified code scales by S
  S = A' / A