Adaptive Optimization using Hardware Performance Monitors

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1. Summary

- Tasks:
  - Interface for HPM
  - Optimization of MM using HPM information
- Challenges:
  - Fast sampling & processing
  - Precise sampling
  - Runtime benefit
- Method:
  - Used kernel perfmon2 kernel patch
  - User-space library libpebsi
  - Collector-Thread in Jikes
  - Changes in Memory-Management

Overview

1. Summary / Introduction
2. Preliminaries:
   - Profiling vs. HW Sampling
   - Pentium 4 Sampling (PEBS)
   - Perfmon2 & Jikes RVM
3. Extensions
   - libpebsi
   - Jikes RVM & Collector
4. Evaluation & Benchmarks
5. Application for HW profiling (Hot/Cold GC)

2. Profiling vs. Sampling

- Modern compilers/VMs (may) use two types of information:
- Profiling: - Monitor & trace runtime events
  - Platform independent (written in Java)
  - Data is used by AOS (OptCompiler)
- HW-Sampling: - Uses low-level hardware information
  - Direct HW feedback
  - Can be used for (new) optimizations
  - Relatively new field

2. Pentium 4 Profiling (PEBS)

- Pentium 4 offers many (new) Hardware Performance Monitors
- Supports *Precise* Event Based Sampling (PEBS)
- HW takes & saves sample in memory, int generated on overflow
- Programmable over special register, runs in global context
- Many events can be sampled:
  - Cache misses (L1 & L2), DTLB misses, memory accesses, arithmetic instructions, ...

2. Perfmon2

- Fast, precise sampling is needed for effective optimizations.
- Many different kernel extensions exist, most are obsolete no longer maintained or outdated.
- Perfmon2 is a low level kernel interface and a high level user library.
- Supports virtualization, access restrictions, PEBS & randomization.

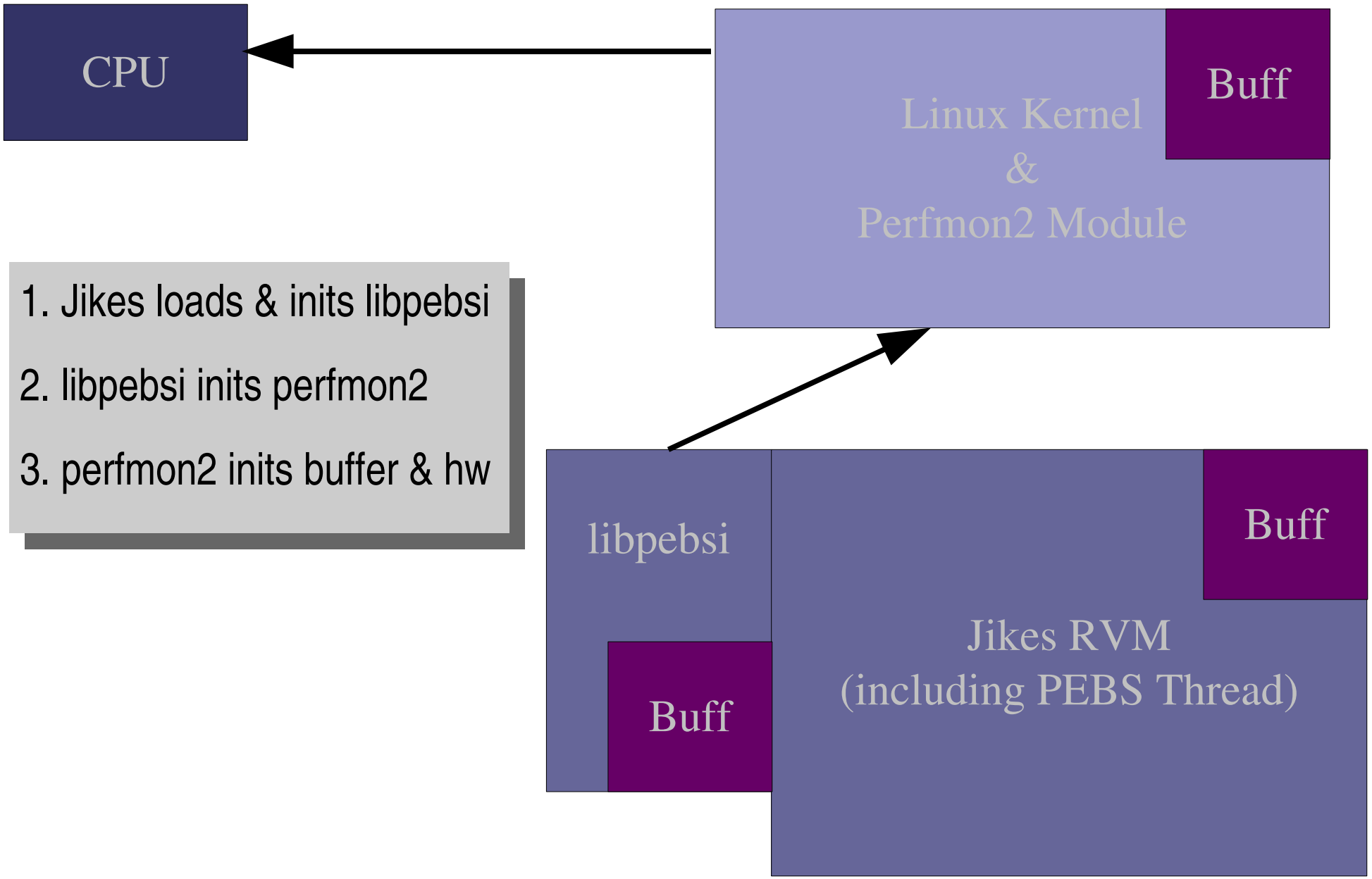
2. Jikes RVM

- The Jikes Research Virtual Machine is a complete OO Java VM.
- Used for implementations of new ideas, GCs and optimizations.
- The Adaptive Optimization System uses profiling to decide which methods need recompilation at a higher opt. level.
- HPMs are not yet used for additional information.
- A Pebsi thread runs inside Jikes to collect and process samples.

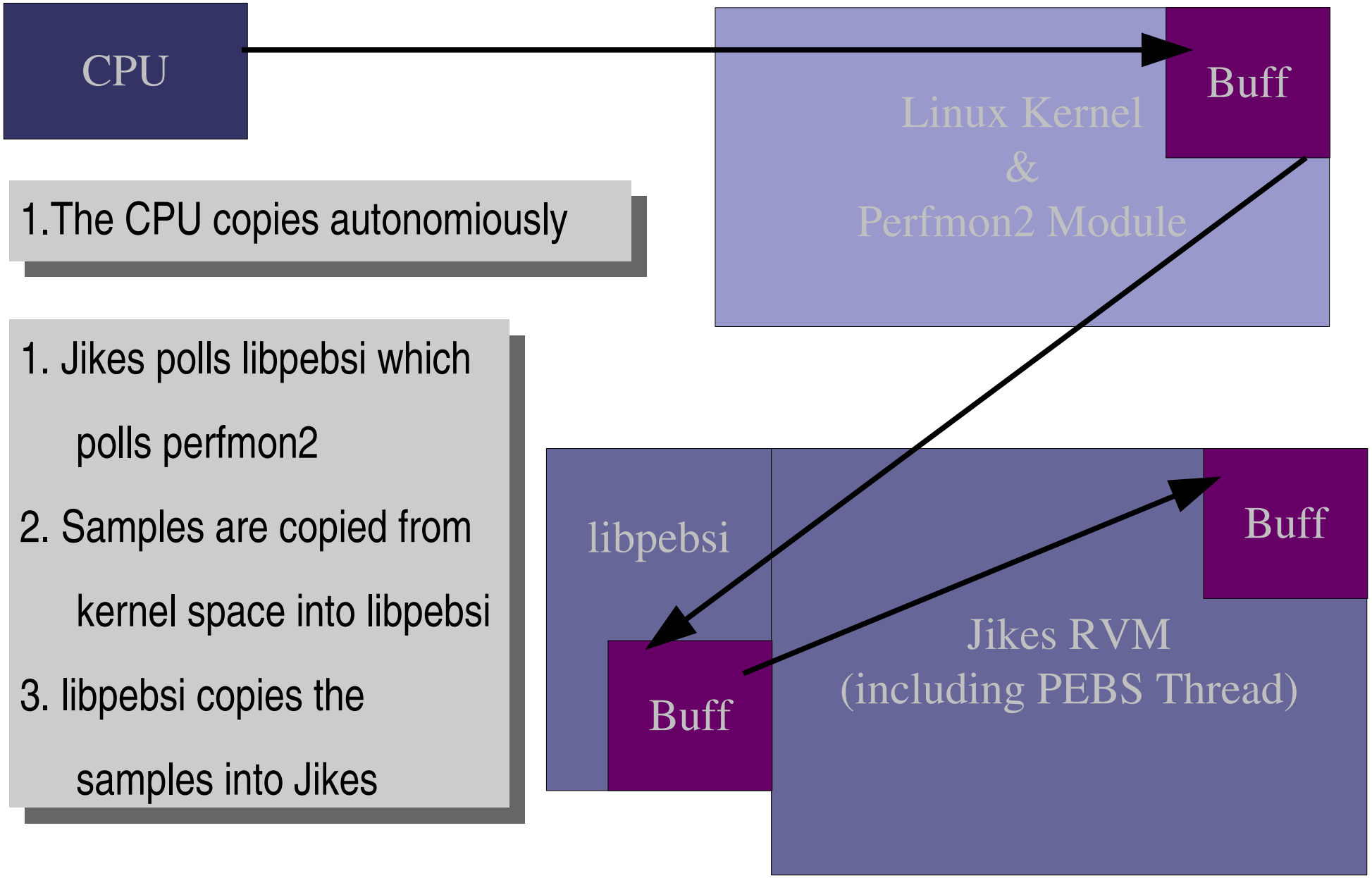
3. libpebsi

- libpebsi directly accesses the PMU (read/write to PMC & PMD)
- Offers a simple interfaec to PEBS (event, interval, buffer)
- Bindings for C, C++ and JNI available
- Written as redistributable library, independent from Jikes
  - Language independent

3. PEBS Control-Flow



3. PEBS Data-Flow



1.The CPU copies autonomiously

1. Jikes polls libpebsi which polls perfmon2
2. Samples are copied from kernel space into libpebsi
3. libpebsi copies the samples into Jikes

3. Jikes Collector Thread

- Polls libpebsi for new samples
  - EFLAGS, EIP, EAX, EBX, ECX, EDX, ESI, EDI, EBP & ESP
- Maps the IP to the corresponding compiled method
- Analyzes the bytecode instruction & gathers information
  - Saves additional statistics if selected
  - Analyzes field references
  - Analyzes method references

- Typical benchmarks with high memory and gc activity are used:
  - spec MTRT — Concurrent raytracer with two threads
  - spec JACK — Java parser generator & lexical analyzer
  - DaCapo ANT — Parser and lexer for grammer files
  - DaCapo FOP — XML to PDF transformation using XSL-FO
  - DC HSQLDB — JDBC in memory DB with transactions
  - DC JYTHON — Python interpreter in Java
  - DaCapo PS — PostScript interpreter
  - pseudo JBB — spec pseudo JBB transactional DB

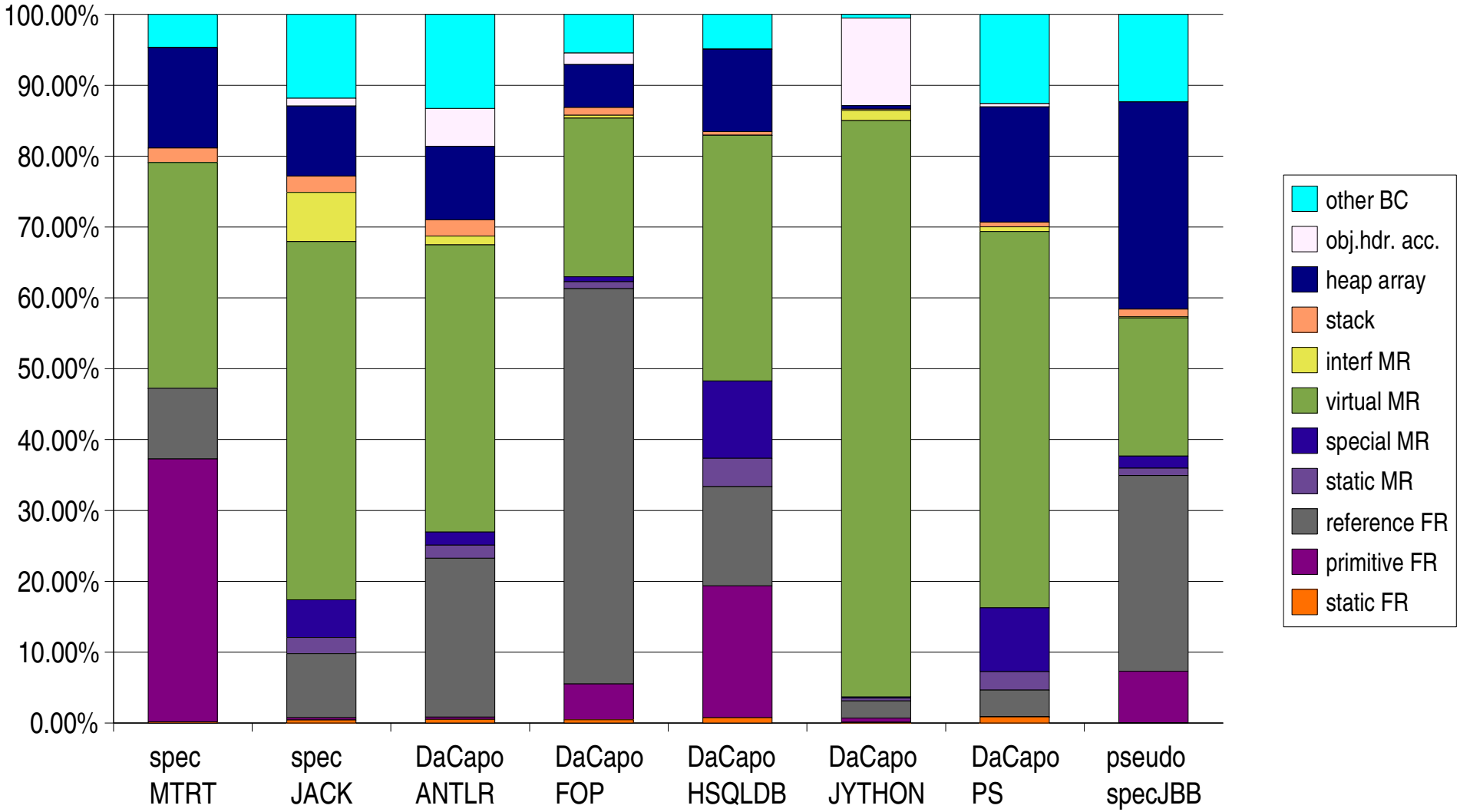
- Overhead (l2 cache miss) & # processed Samples per Second

Interval	pseudo spec JBB	
5000	2.85%	844.24
10000	1.59%	451.74
15000	1.40%	311.36
25000	0.54%	201.6
50000	0.73%	95.63
100000	0.62%	48.96

Benchmark	Overhead	Samples / Sec
spec MTRT	0.55%	103.06
spec JACK	0.39%	82.05
DaCapo ANTLR	-0.22%	132.96
DaCapo FOP	2.24%	305.19
DC HSQLDB	6.89%	139.31
DC JYTHON	0.87%	83.21
DaCapo PS	-0.05%	67.01

- In detail for pseudo spec JBB and all other benchmarks at interval 10000

- Bytecode distribution of second level cache misses:



5. Application for HW Sampling

- The HW information is used in an extended garbage collector
- Objects are handled differently if they are frequently used
  - A special memory space is reserved only for hot objects
- Hotness depends on variable threshold
  - Adjusted during runtime
- Analyzes field references and reorders hot fields

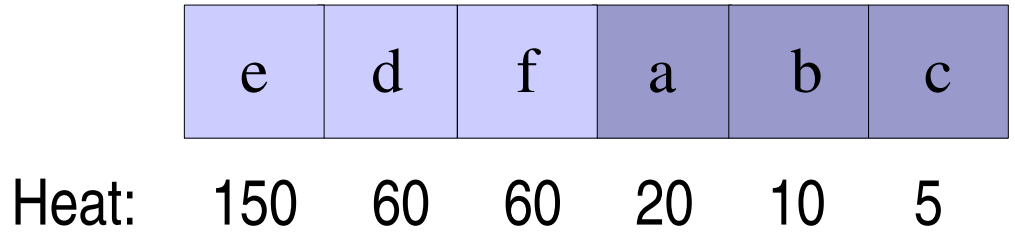
Standard generational garbage collector:

Hot Cold garbage collector with a hot copy space:

```
for (int i = 0; i < NrReferences(type); i++)
{
    Address slot = type.getSlot(object,
        type.pebsiFieldOrder[i]);
    trace.traceObjectLocation(slot);
}
```

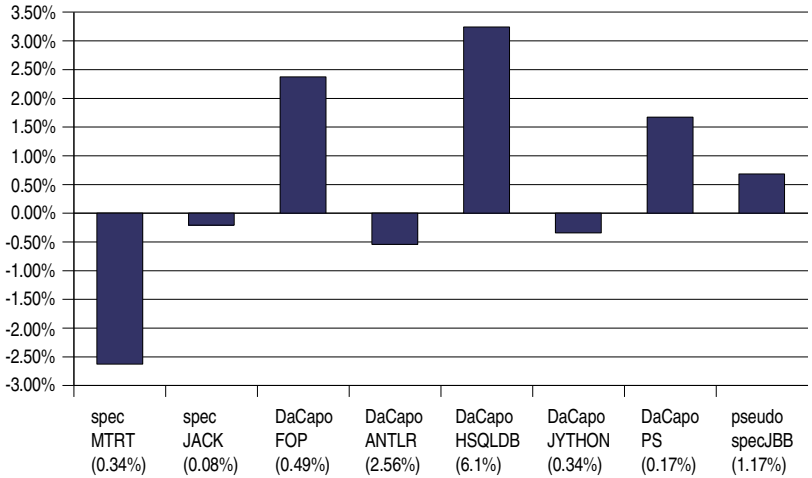
```
class Foo {
    Bar a,b;
    X d;
    X e;
    X f;
    Bar c;
}
```

pebsiFieldOrder:

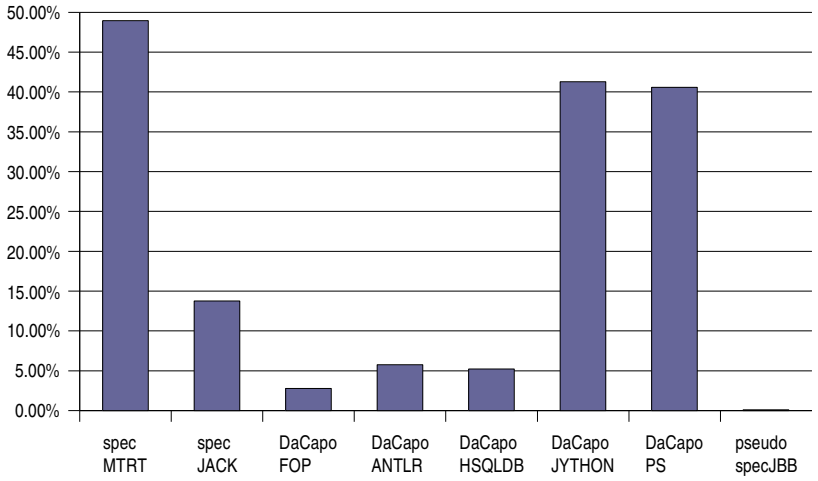


5. HC GC Benchmarks

Runtime benefit & std. deviation (HCcopyMS)



L2 miss reduction (HCcopyMS)



	Runtime [s]	Total # Samples
spec MTRT	15.9	900.5
spec JACK	21.52	627.25
DaCapo FOP	38.54	11941.75
DaCapo ANTLF	12.24	2675.25
DaCapo HSQLI	79.66	2846.25
DaCapo JYTHC	49.31	2087.75
DaCapo PS	27.04	2520.5
specJBB	200.67	63295

Conclusions

- Extendable interface for low overhead sampling
  - Useful for offline performance analysis
  - Suited for direct adaptive optimizations (avg. overhead: ~1%)
- Many events and rich statistic available inside Jikes
- Easy portable to other VM/HW-Interface

Questions