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# Techniques for Real-System Characterization of Java Virtual Machine Energy and Power Behavior

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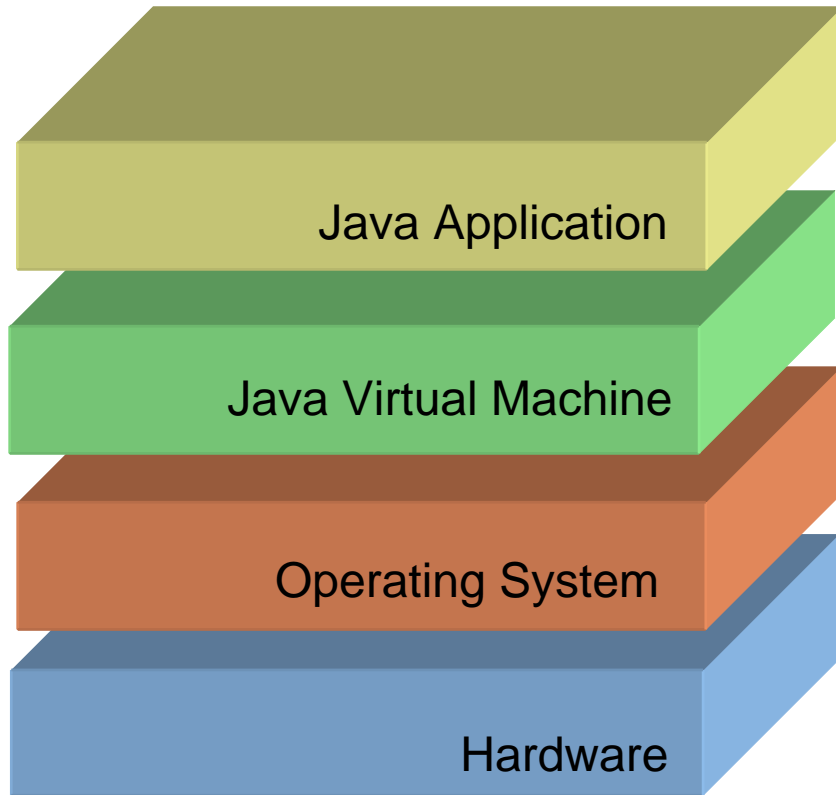
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# Why Study Power in Java Systems?

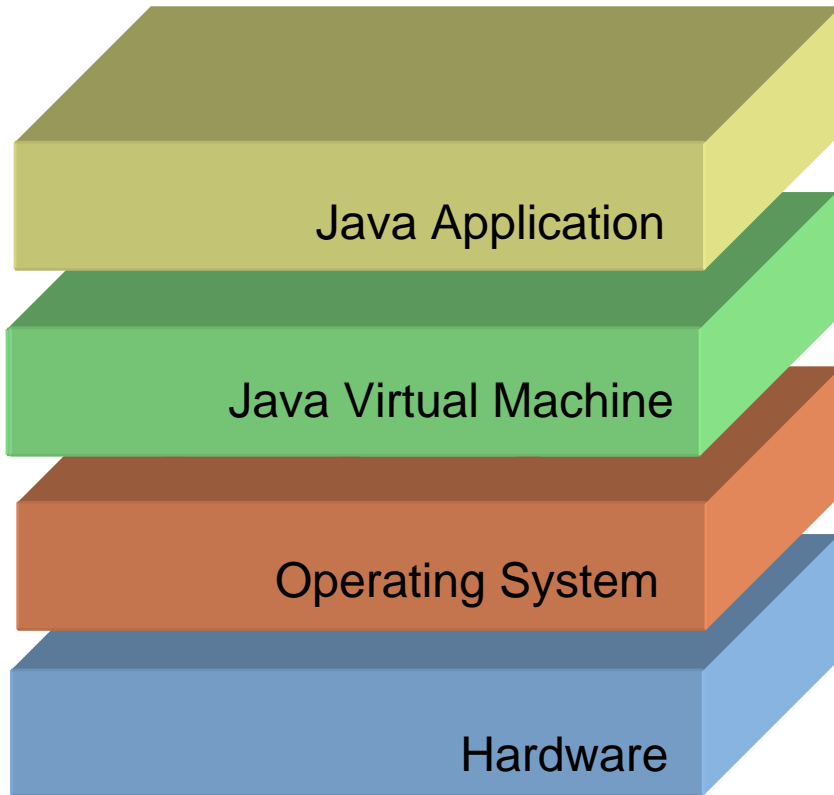
- The Java platform has been adopted in a wide variety of devices
- Java servers demand performance, embedded devices require low-power
- Performance is important, power/energy/thermal issues are equally important
- How do we study and characterize these requirements in a multi-layer platform?

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# Power/Performance Design Issues



# Power/Performance Design Issues



- How do the various software layers affect power/performance characteristics of hardware?
- Where should time be invested when designing power and/or thermally aware Java virtual Machines?

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# Outline

- Approaches for Energy/Performance Characterization of Java virtual machines
- Methodology
  - Breaking the JVM into sub-components
  - Hardware-based power/performance characterization of JVM sub-components
- Results
  - Jikes & Kaffe on Pentium M
  - Kaffe on Intel XScale
- Conclusions

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# Power & Performance Analysis of Java

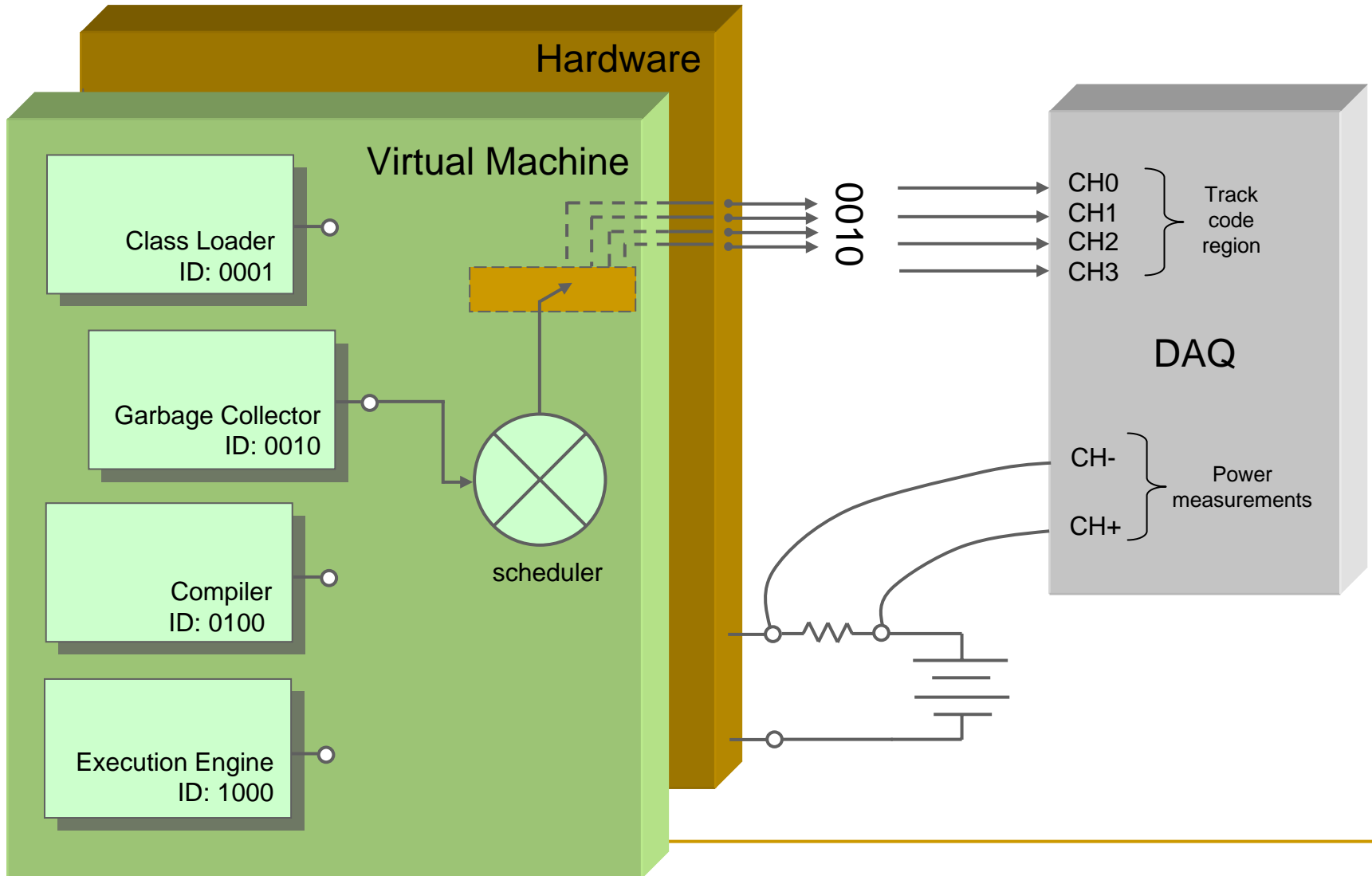
## ■ Simulation Approach

- ✓ Flexible: easy to model non-existent hardware
- ✗ Simulators may lack comprehensiveness and accuracy
- ✗ Thermal studies require tens of seconds granularity
  - Accurate simulators are too slow

## ■ Hardware Approach

- ✓ Able to capture full-system characteristics and effects
- ✓ Data gathering is comparable to hardware speeds
- ✗ Only applicable to existent hardware

# Hardware-based Characterization



# Two Virtual Machines

## Jikes RVM

## Kaffe JVM

<b>Design goal</b>	High performance	Flexibility and portability
<b>Architecture support</b>	High-end processors	High-end to embedded
<b>Garbage collection</b>	Multiple collectors	Mark-and-sweep
<b>Runtime optimizations</b>	Runtime compiler with different optimization levels	Just-in-time compiler



# Two Platforms

Pentium M (P6)

Intel XScale

<b>Platform Type</b>	High-performance mobile computers	High-end handheld devices
<b>Configuration</b>	1.6Ghz, 512MB RAM	400Mhz, 32MB RAM
<b>Theoretical Max Power</b>	31W	1.4W
<b>JVM Used</b>	Jikes RVM Kaffe	Kaffe

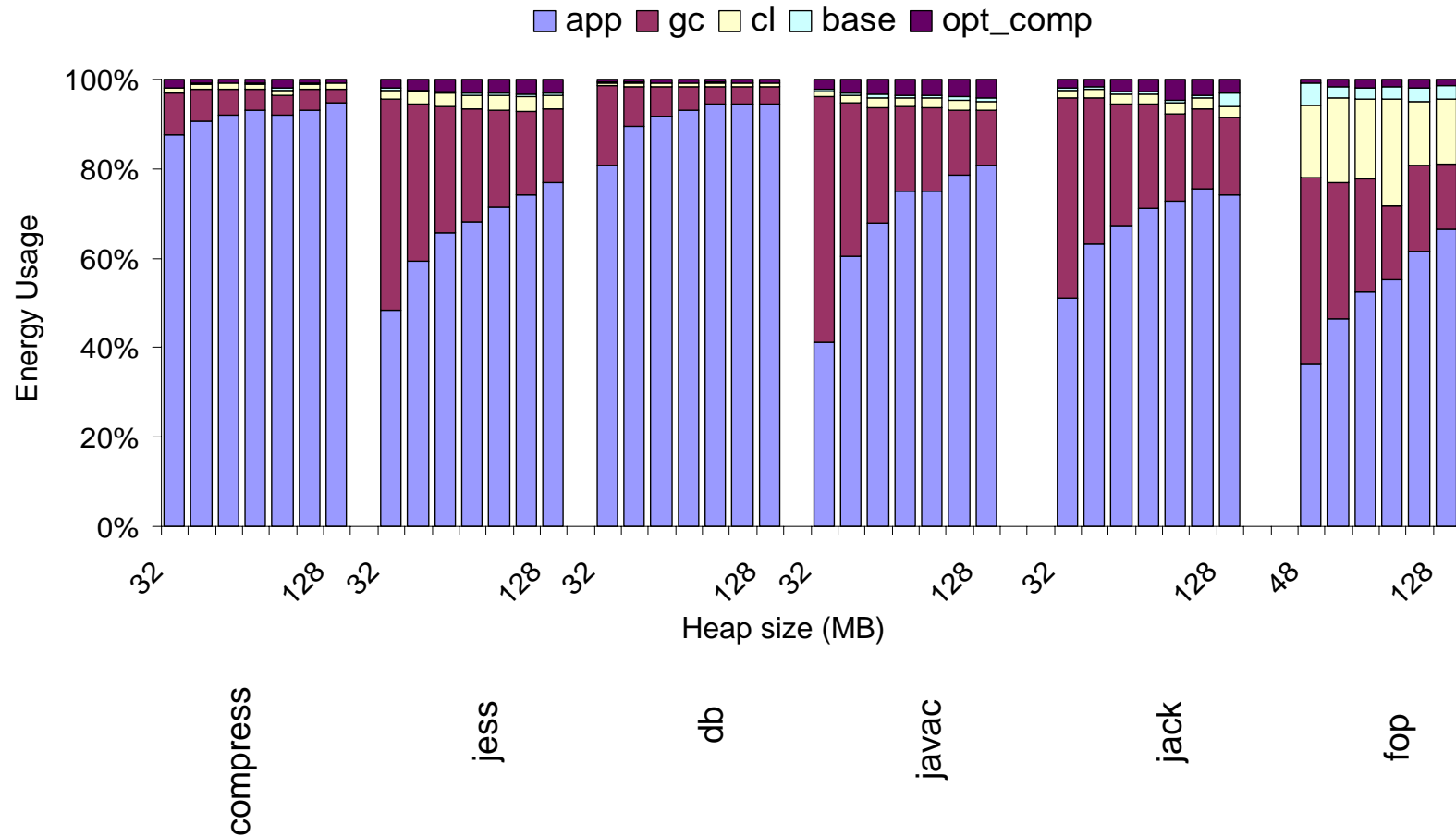
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# Outline

- Approaches for Energy/Performance Characterization of Java virtual machines
- Methodology
  - Breaking the JVM into sub-components
  - Power/performance hardware-based characterization of JVM sub-components
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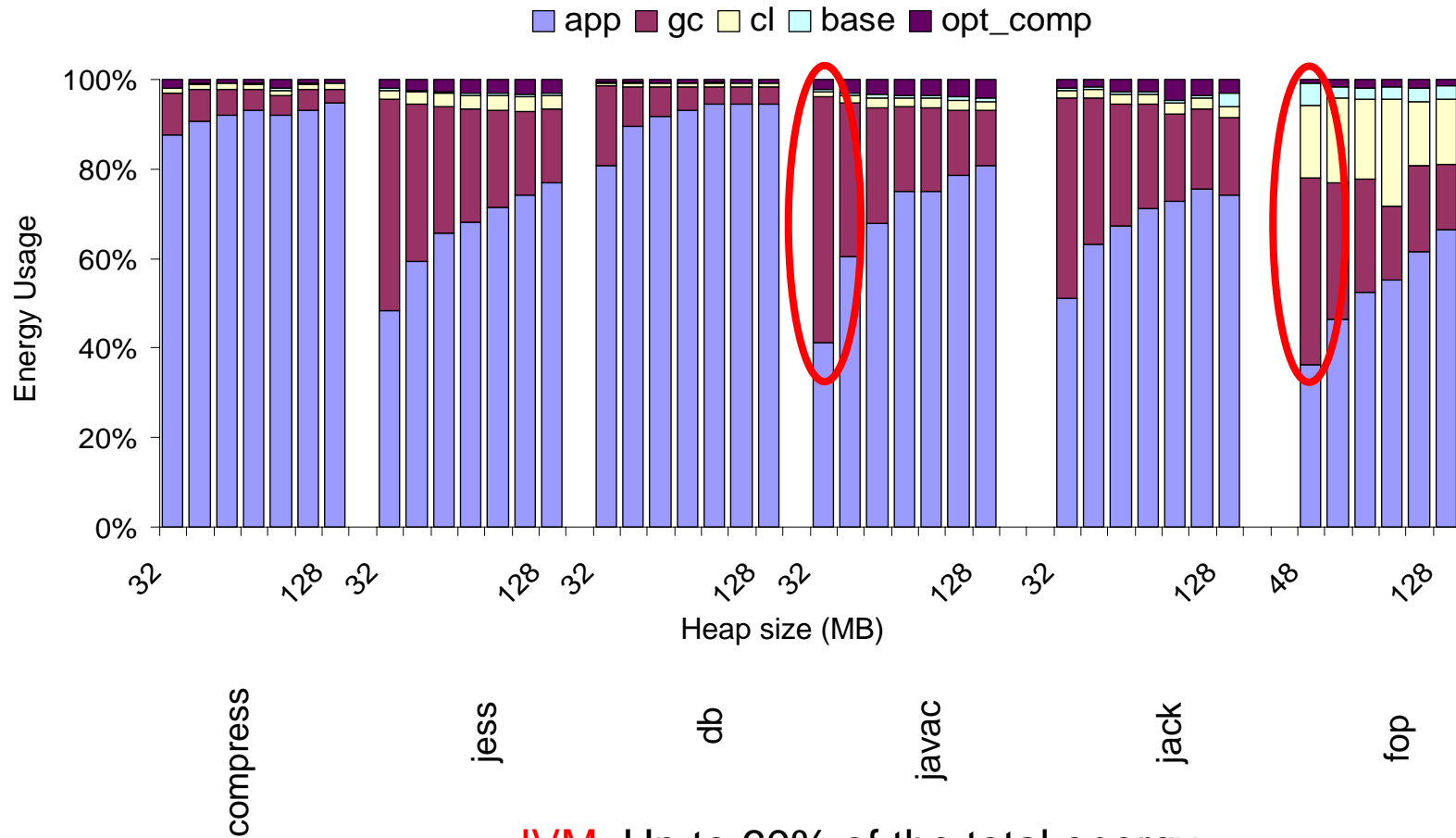
# Jikes Energy Distribution on P6

SemiSpace Garbage Collector



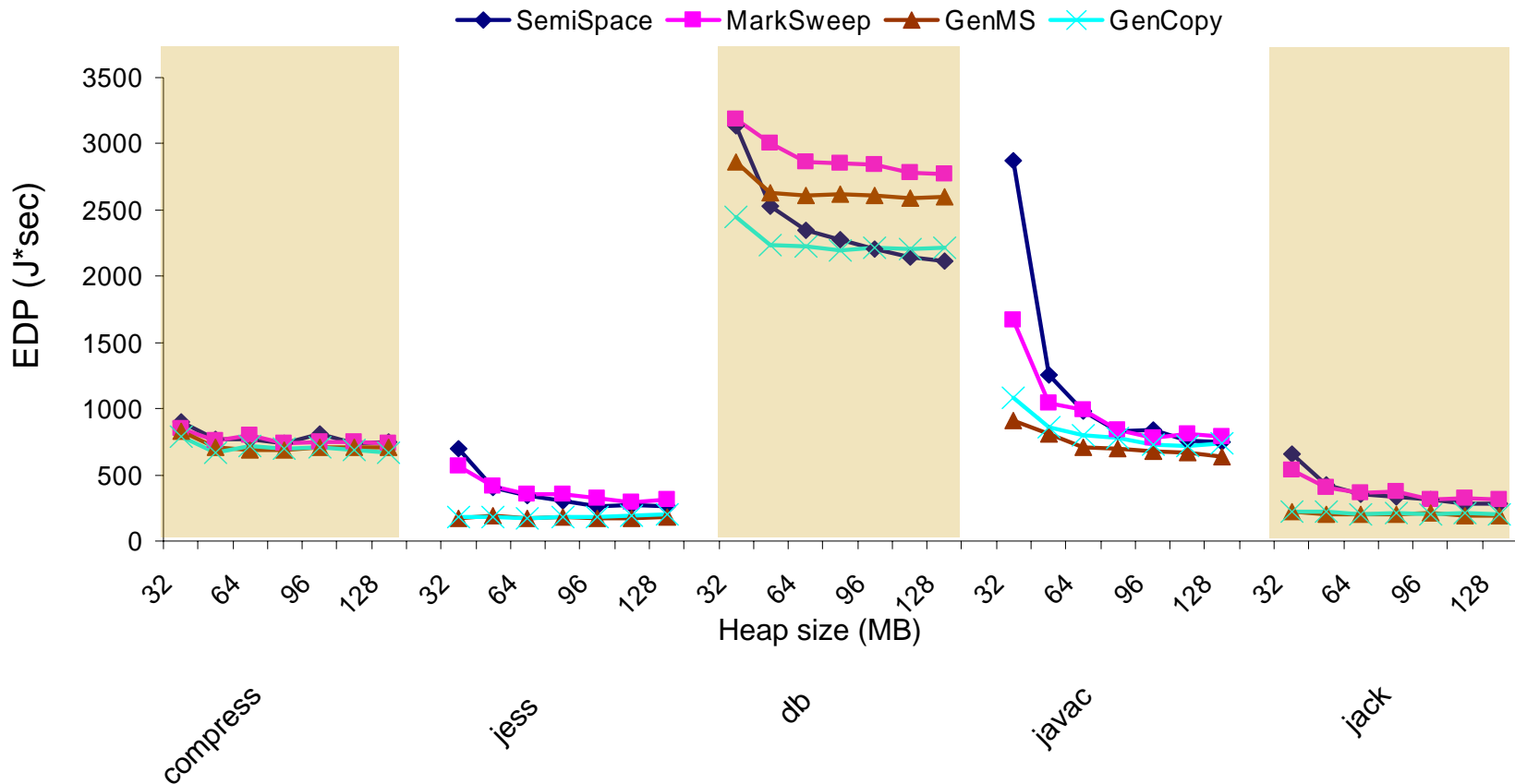
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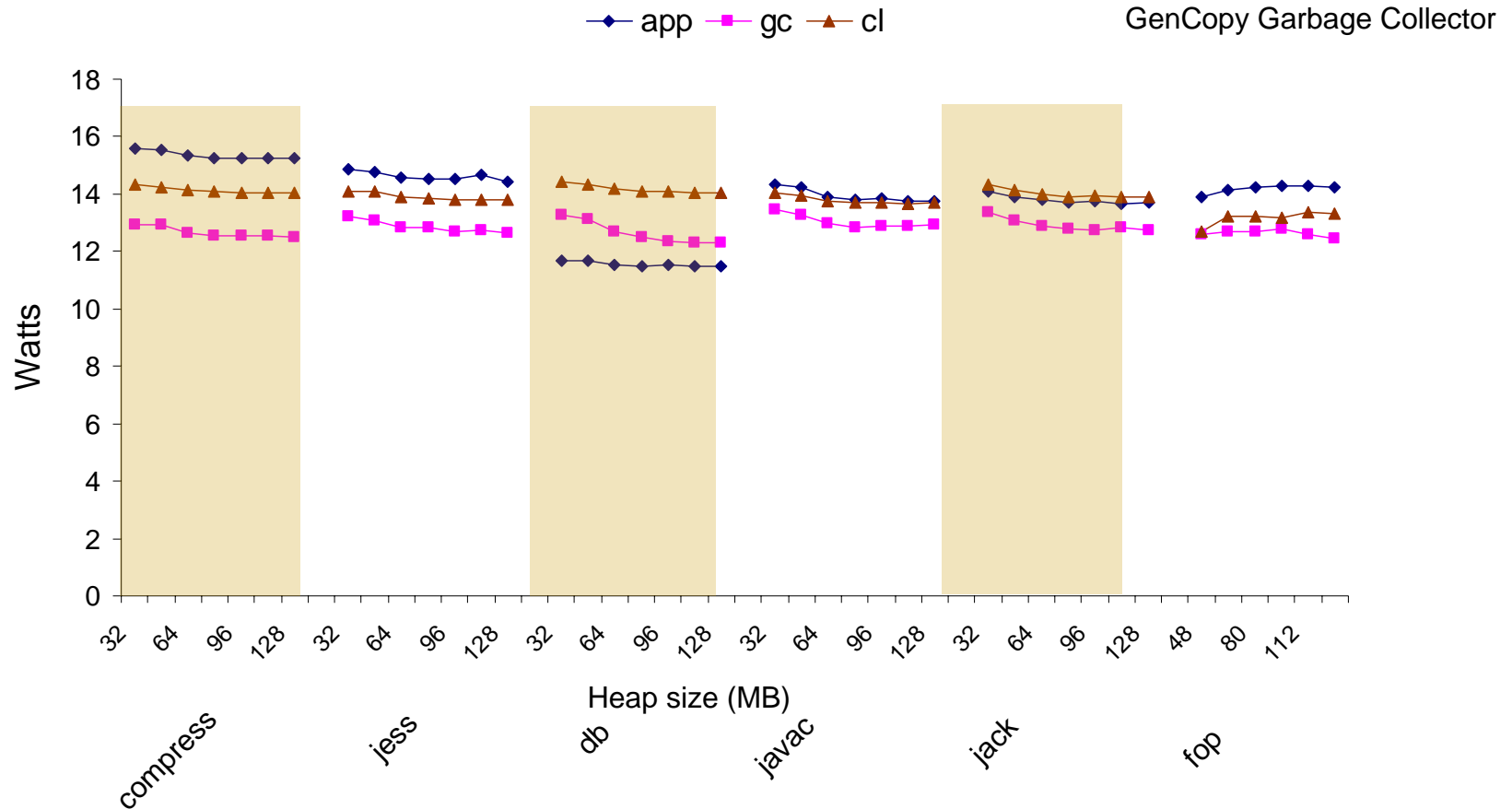
- **JVM**: Up to 60% of the total energy
- **GC**: Average 37% of the total energy of SpecJVM98

# Jikes Energy-Delay Product on P6



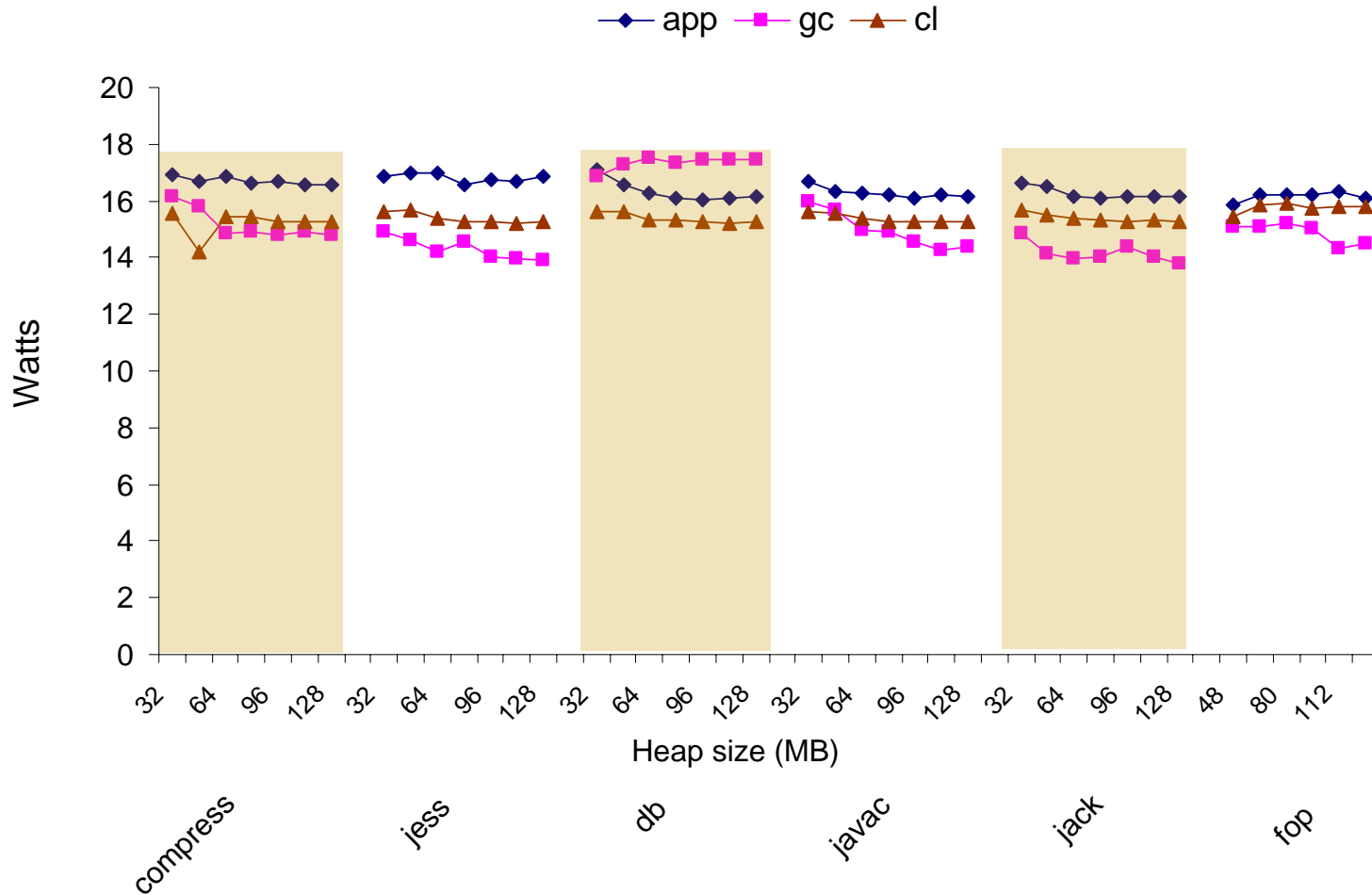
- Jikes: heap size has a significant impact on energy efficiency
- EDP decrease across heap sizes due to a decrease in application execution time

# Jikes Power Consumption on P6



- Average power for JVM varies little across heap-sizes
- Garbage collector is high energy consumer, but low power

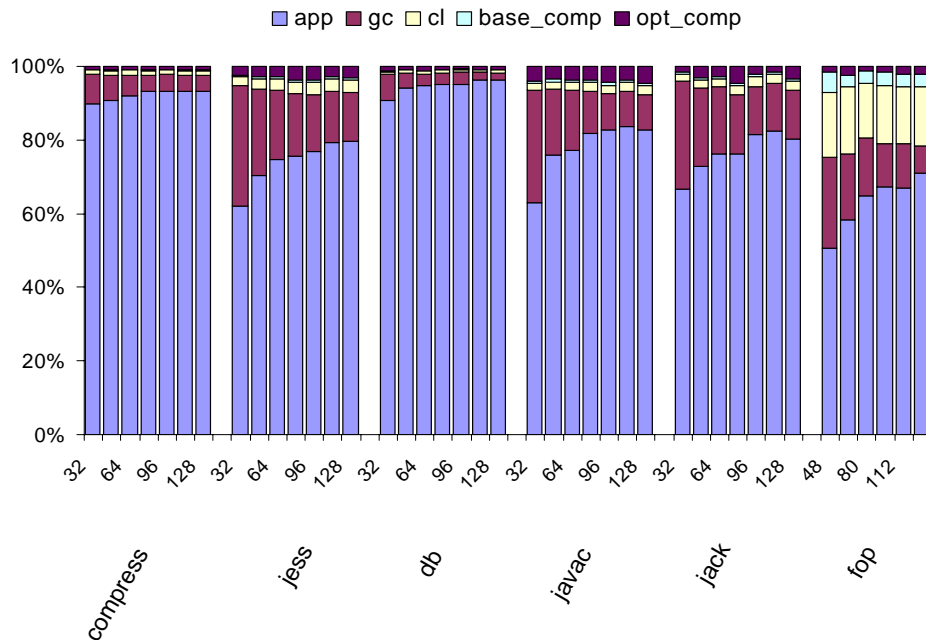
# Jikes Peak Power on P6



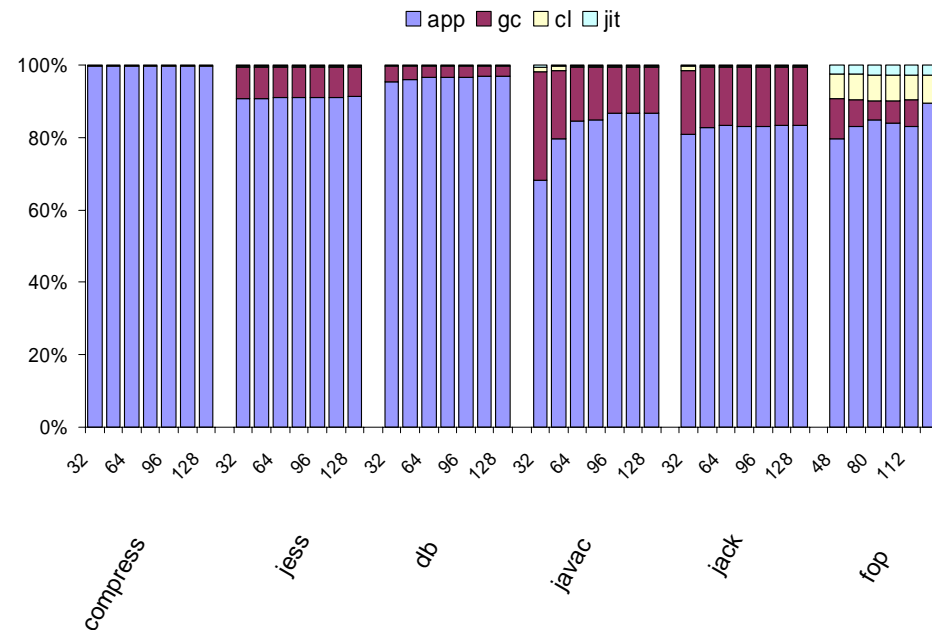
- Execution engine has the highest peak-power

# Jikes versus Kaffe: Energy Distribution on P6

## Jikes



## Kaffe

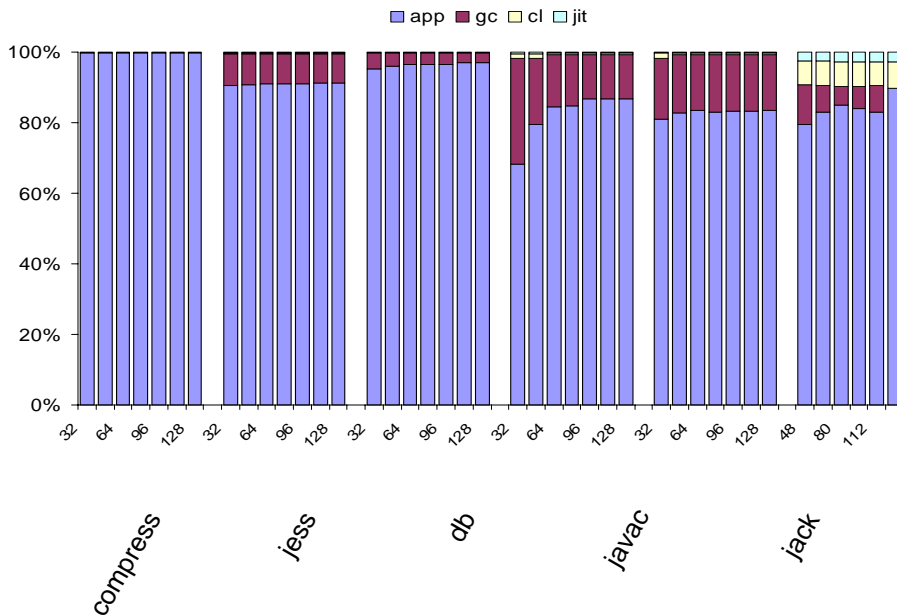


- Kaffe: high application energy caused by long execution times
- Kaffe: 8% of total average energy goes to virtual machine

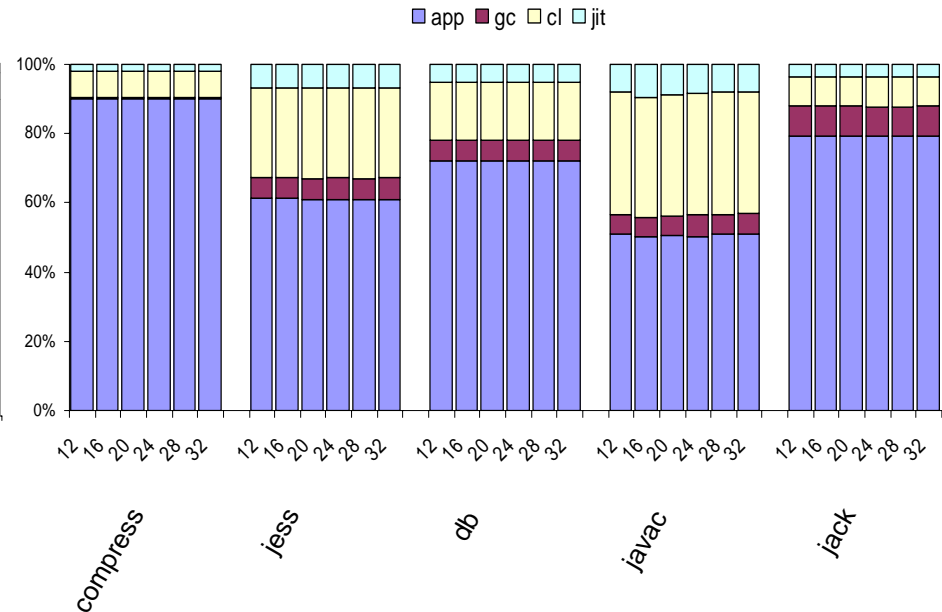


# Kaffe Across Platforms

Pentium M



Intel XScale



- XScale: no classes are included in the binary
- XScale: GC only represents 6% of the total energy consumed

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# Conclusions

## ■ Methodology

- ❑ The complexity of the Java virtual machine calls for a more in-depth power/energy analysis
- ❑ Hardware-based characterization of the virtual machine's sub-components allow long execution times and trustworthy measurements

## ■ Lessons learned

- ❑ In both platforms, JVM energy overhead is considerable
- ❑ Jikes: the GC is low power but high energy consumer (up to 37% on average)
- ❑ For Kaffe on XScale, the class loader becomes high-energy consumer (18% for measured benchmarks)

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# Thank you!

