Toward Deterministic Java Performance

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The Real-Time World

- **Responsive in “real time”**
  - Often keyed to real world events
  - Performing work on a regular basis
  - Asynchronous events
  - Graceful handling of truly exceptional conditions

- **Deterministic performance key to meet response time requirements**

- **Java performance not really responsive as-is**
  - But it’s a nice development environment
  - Motivates the Real-Time Specification for Java
Overview

- Real-Time Java
- Java performance isn’t really deterministic
- Mitigating the Chaos
- Summary
Real-Time Java

- **JSR #1: Real-Time Specification for Java**
- **Facilities to support Real-Time programming**
  - Make performance more controllable & predictable
  - Large-scale enhancements to Java
    - Threading, scheduling
    - Memory management
    - Asynchronous event handling, control transfer, termination
    - Physical memory access
Example 1: Memory Management

- SPEC assumes that managed memory (garbage collection) is incompatible with real-time needs
- New memory areas that are not collected
  - Immortal memory
  - Memory scopes
- New thread type “No Heap Realtime Thread”
  - Not permitted to even see a heap reference
  - No need to stop for any reason when GC occurs
Java performance isn’t really deterministic

- **Chaos lurks everywhere:**
  - Thread scheduling is at the whim of the operating system
  - Garbage collection occurs “whenever” for “however long”
    - JIT compilations occur “whenever” for “however long”
    - Aggressive JITs recompile methods that seem “hot”
    - JIT compilers employ many speculative optimizations
  - Class loading occurs on demand
Mitigating the JIT Chaos: stop doing “bad” stuff

- **JIT compiling delays are unacceptable**
  - Also derivative effects: profiling, sampling
  - Could run at low priority BUT risk priority inversion

- **Ahead-of-Time (AOT) compilation a better option**
  - Takes compiler out of the run-time performance equation
  - Possibly lower performance to deal with resolution order
  - Derivative effects also removed
  - BUT maybe more difficult to achieve high performance
Mitigating the JIT Chaos: stop doing “bad” stuff

- Stop doing speculative optimizations
  - No flat-word monitors
    - Also simplifies priority-inversion support
  - No monitor coarsening
  - Profiling-based optimizations
  - Not easy because JIT compilers speculate a LOT

- Devirtualization ok if all classes are pre-loaded
Mitigating the JIT Chaos: stop doing “bad” stuff

- **Class loading is a trouble spot**
  - Loading one class often requires loading other classes
  - Once class is loaded, devirtualizations may be invalid
    - Lots of call sites may need to be patched for correctness
  - Updates many VM data structures also accessed by GC
    - Particularly a problem for NoHeapRealtimeThreads

- **Application-level pre-loading is one option**
  - Collect list of loaded classes in one execution
  - “Force” class to load before application begins executing
Summary

- Java not suitable as-is for Real-Time workloads
- Real-Time Specification enhances Java for RT
- Java VMs have many sources of nondeterminism
  - GC, thread scheduling, JIT compiler
- These problems can be largely mitigated
  - Ahead-of-Time compiles, class preloading, stop doing speculative optimizations
  - Lower sustained performance but more deterministic
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Backup Slides
Example 2: Asynchronous Transfer of Control (ATC)

- RT programs need to respond to truly exceptional conditions quickly and drastically
- Thread that detects condition may need to interrupt other threads actively working
- ATC provides facilities to mark methods that can be safely interrupted
  - More draconian exception semantics in such methods
- Also mechanisms to initiate such interruptions