



The Squawk Java™ Virtual Machine: Java on the Bare Metal

Doug Simon and Cristina Cifuentes, Sun Labs
(doug.simon@sun.com, cristina.cifuentes@sun.com)

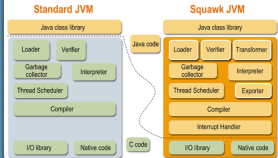
The Squawk JVM

J2ME + OS Functionality

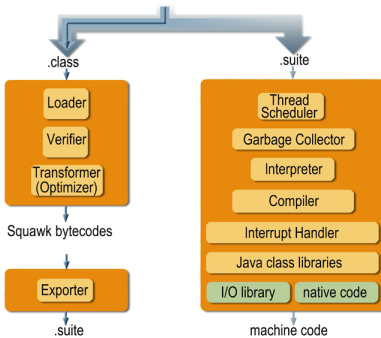
- Small JVM written in Java => Portable
- Runs on bare ARM hardware (without an OS)
- Runs on Solaris, Linux, MacOS and Windows (within standard J2SE VM)
- Designed for small devices
- Runs multiple applications (isolates) in one VM
- Allows migration of running applications (isolates) between VMs



Standard JVM vs. Squawk JVM



Squawk's Split VM Architecture



Allows Migration of Running Applications

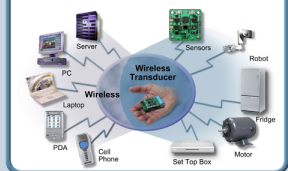
Isolate (Application) Migration

- Move running application with its state to another machine with the same resources
- Limitations with respect to external state
- Uses:
 - > Load balancing
 - > Field replacement of hardware
 - > Simple client-server applications
 - > Local debugging of remote application

Load Balancing Example



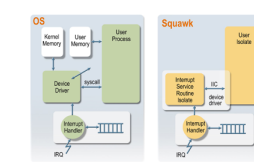
A Platform for Cooperating Devices



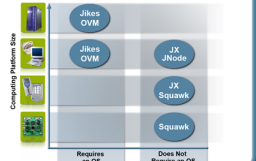
Runs Without an OS on Bare ARM

Squawk's Interrupt Handler

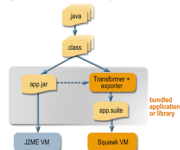
- Interrupt handlers in Java
- Support hardware interrupts
- Support device drivers written in Java
- Version 1 – one heap, interrupt-driven
- Version 2 – isolate-based, two heaps, interrupt-driven
- Effects of GC on interrupt handling latency



Comparison to Other Work



Suites: An Execute-in-Place (Position Independent Code) File Format



Optimized for Small Devices

Uncompressed JAR vs. Suite File Size Comparison

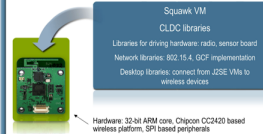
Application	JAR	Suite	Save/Load
CLDC	49,271	149,542	0.33
cubex	38,904	16,667	0.42
hand	1,905	825	0.48
delta blue	10,823	8,144	0.27
map	100,917	54,088	0.54
matrixballs	12,017	6,190	0.51
pong	17,262	7,567	0.42
spacewaders	50,854	25,983	0.51
stepsize	18,576	7,428	0.40
wordgame	23,945	8,131	0.38
Total	751,955	286,255	0.38

Squawk Bytecodes vs. Java Bytecodes

Squawk Bytecode Property	Benefit
Commonly used bytecodes are 2 bytes instead of 3 bytes	• More compact
References to fields and methods resolve into physical offsets	• More efficient for interpretation
Local variables are typed	• More efficient for compilation
One OOP map per method, nothing on the operand stack at GC points	• Simplifies garbage collection

Case Study: Squawk on the Sun SPOT Platform

The Sun SPOT System



Sample Application Code

```

// Open a network socket (like radio)
// Read data from the socket
// Write data to the socket
// Close the socket
// ...

```

Acknowledgments

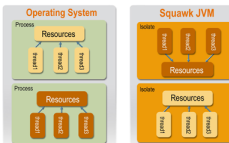
- VM: Nik Shaylor, Interns, Andrew Crouch
- Alex Garhwala, David Liu
- John Daniels, Sanyo, UK, Gary Yee
- Dave Cleal, Sanyo, UK, Edward Carter
- Poster Presentation: Olaf Manzcak
- Randy Smith
- Graphic Design: Nancy Snyder

Isolate Mechanism

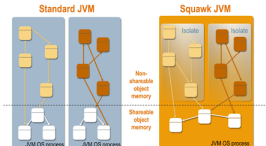
- An implementation of JSR 121
- Similar to operating system processes
 - > Provides isolation of applications within one VM
 - > Each isolate can have multiple threads
 - > System-level resources are shared without contention
- Allows reification of applications
 - > Can pause, resume, ask things about the application

Runs Multiple Applications in One VM

JVM Isolates and OS Processes Analogy



A Research Implementation of JSR 121



Squawk on Sun SPOT Facts

- Interpreter based (at present)
- Memory sizes:
 - > 80K RAM for VM
 - > Libraries 270K flash
- Suites
 - > ~3% the size of jar'd class files
- Performance
 - > Comparable to KVM (J2ME C-based, interpreted JVM)
 - Device drivers written in Java (no C)
 - 802.15.4 MAC layer in Java (no C)

Experimental Results

Benchmark	Class	Suite	Sampling	(samples/sec)
Richards (Gibbons)	11,716	4,584	ARM PIO lines	11,786
Richards (Deutsch)	19,655	6,766	Sensor board input lines	300-900
Delta Blue	27,520	9,724		
Game of Life	7,390	3,396	Radio range:	90 ms

Benchmark	LOC	ms on ARM7 EB40 board
Richards (Gibbons)	410	5.277
Richards (Deutsch)	456	8.362
Delta Blue	684	4.766
Game of Life	354	4.032

Bibliography

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<http://jikesvm.sourceforge.net>
- JX
<http://www.jxos.org>
- OVM
<http://www.ovm.org>
- Squawk
<http://research.sun.com/projects/squawk>