A Cluster-Aware Distributed Java Virtual Machine written in Java

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Talk Outline

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Motivation

- **Investigate distributed Java Virtual Machine (dJVM) focusing on long running low contention server side applications.**
- **Target commodity hardware, e.g. Bunyip—a 96 node cluster of PCs.**
- **dJVM platform enables the investigation of techniques and algorithms for supporting distribution, including:**
  - **methods for determining object placement, caching and migration, and**
  - **the evaluation of runtime support algorithms, such as distributed garbage collection.**

Related Work

There are broadly three approaches to the effective implementation of distributed JVM:

1. **Provide a solution built on top of a set of standard JVMs, either by:**
   - **static transformation—ahead of time transformation, or**
   - **dynamic transformation—just in time transformation.**
2. **Building a JVM on cluster enabled infrastructure, such as a DSM.**
3. **Developing a cluster aware JVM.**

Approach—Design

- **Maintain the standard Java programming environment—Single System Image (SSI).**
- **Master-slave model of class management.**
- **Distribution model:**
  - **Execution normally based on object location.**
  - **Distribution by placement of objects (including threads) and subsequent migration.**
- **Independent memory management on nodes (so far).**

Approach—Implementation

- **Effect distribution through transformation of code:**
  - **Ideally—**$f(JVM) \mapsto dJVM$**.**
  - **Practical—combination of** f **and infrastructure changes.**
- **Use the Jikes RVM developed by IBM Research:**
  - **Written in Java.**
  - **Compiles to native code.**
  - **Integrates runtime and application code.**

Issues—Globally Visible Data

- **JVM runtime structures have global scope in a non-distributed implementation.**
- **Initialization must only occur once.**
- **Booting is a two phase process, before and after joining a cluster:**
  - **Initialization locally.**
  - **Coalesce global data.**
  - **Unify type information identity.**

Issues—Remote Objects

- **Objects are owned by a particular node, and given a global identity on demand.**
- **References to remote objects are distinguished from those to local objects by their form. Consequently, software faulting is based on the form of a reference.**
- **Type information is always locally available even for references to remote objects.**

Issues—Transformations

- **Define transformations that apply to:**
  - **the construction of the JVM image,**
  - **the transformation code, and**
  - **the application code.**
- **Transformations need to be incorporated in-between the JVM load and link sequence phases.**
- **Annotations to guide or direct transforms extend the Jikes RVM annotation model:**
  - **Implement interfaces.**
  - **Method throw lists.**
  - **Try/Catch blocks.**

Issues—Magic

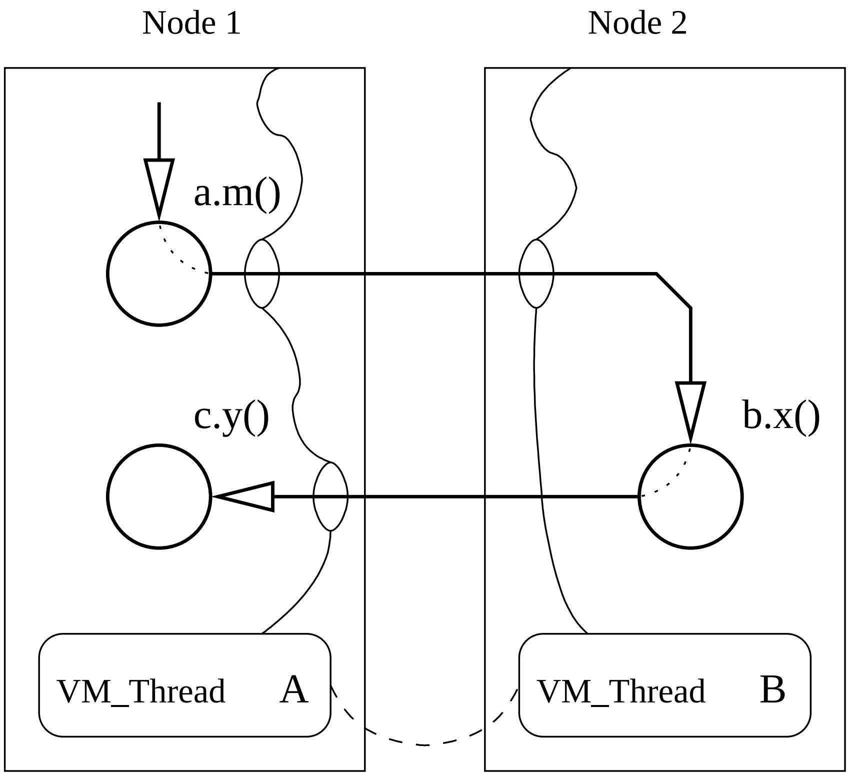
Reference faulting requires:

- **Hooks for defining the form of references to local and to remote objects.**
- **The JVM to allow dynamic type resolution through faulting references.**
- **GC must allow mechanisms to handle faulting references.**

Issues—Threading Support

- A thread resource is local to a node.
- Threads may take on the identity of a remote thread, acting as a proxy.
  - invoking a method on a remote object thus involves a *remote method call* (RMC)
  - class loading on *slave nodes* is done similarly by an RMC to the *master node*
- Local thread resources reused for correctness & performance.
- As well as threads corresponding to the application, there are threads associated with the dJVM itself
  - these include a *communication thread*, activated whenever a message is received

Issues—Thread Reuse



Performance Evaluation

- **Platform used: a 20 node Beowulf cluster (550 MHz dual PIII, 10Mb/s network)**
- **Application: numerical integration program, 1 master and p slave thread**
  - **synchronized using standard `wait()`/`notify()` methods**
  - **communication of input / results via RMC parameters / return values**

Performance Evaluation – Results

- **Overhead of an RMC 40–$80\times$ that of MPI round-trip message ($260\mu s$)**
- **Overhead of remote class loading & thread creation 5–$10\times$ greater still**
- **Overheads high even when master and slave threads were run on same node**
- **Parallel speedup at $p = 20$ of 5.2 (with 0.22s computation & 0.04s for 2 RMC's per integration)**
- **Major problem: all JVM-level threads were run on a single kernel-level thread: communication overheads were a multiple of a timeslice!**

Current Status

- Prototype based on Jikes RVM 2.0.2 using the baseline compiler running on a 20 node cluster.
- Testing the prototype revealed two serious issues:
  - Thread switching bug.
  - Adverse scheduling behaviour.
- The port to the latest version of the Jikes RVM is near completion. In conjunction with the port we are:
  - minimizing the invasiveness of the changes, raising as many alterations to the bytecode level as practical, and
  - incorporating modifications to enable the optimizing compiler to be used.

Future Work

- Expect (2nd) release based on Jikes 2.2.0 under GPL 11/03
  - preliminary tests indicate much better performance
- Investigate:
  - Placement, migration and caching policies and techniques.
  - Tuning underlying infrastructure layers.
  - Incorporating Fault-tolerance for long-running applications.
  - Distributed Garbage Collection algorithms and inter-node contracts.

and their interactions and synergies with each other.

Conclusions

- The dynamic bytecode transformation approach combined with a JVM written in Java provides a high level of flexibility, allowing transformation techniques to be applied at build and runtime.
  - does have drawbacks; more scope for very subtle bugs
- Analysis and transform techniques can be re-executed at runtime as further information comes to light.
- Identifying and addressing global data issues can be non-trivial.
- Low level mechanisms are JVM dependent.

- **We believe that:**
  - **Interoperability can be addressed with appropriate inter-node interfaces and contracts.**
  - **Portability issues can be reduced to a small number of low level JVM specific modifications.**

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