Dynamic Analyses for Understanding and Optimization of Enterprise Java Applications

Ph.D. Dissertation

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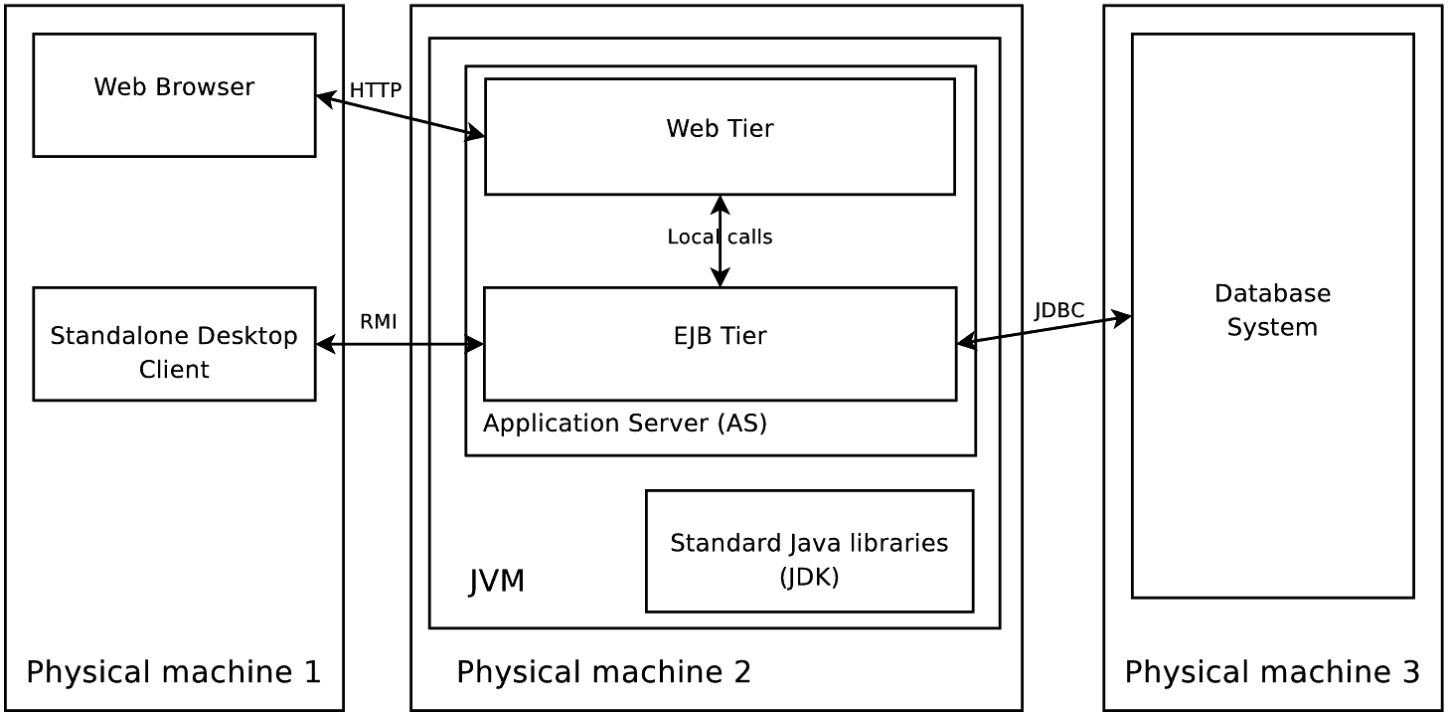
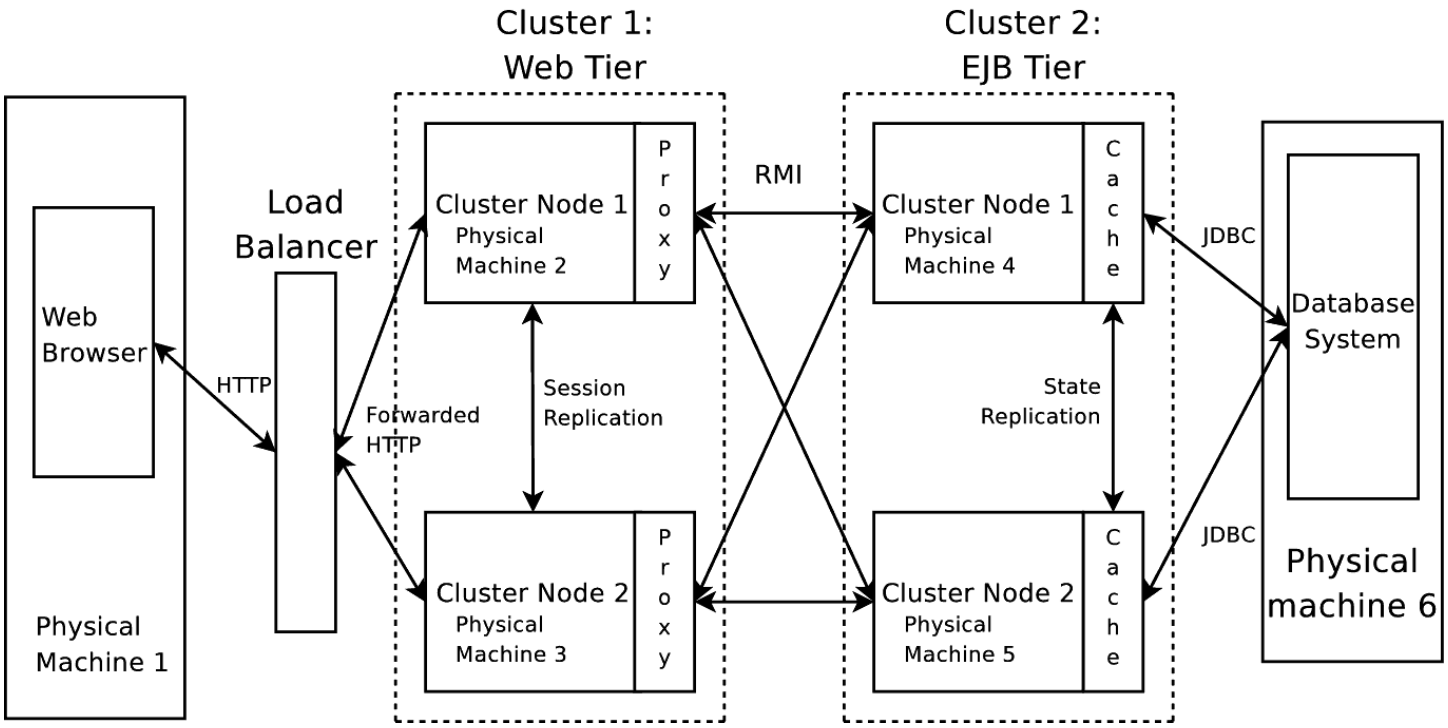
Outline

- Background and Problem Overview
  - Enterprise Java
  - Motivation and challenges
- Entity Bean ID Identification
  - Match EJB Tier inputs to Entity Bean IDs
- EJBQL Relationship Identification
  - Track query parameters and extract their function
- DTO Identification
  - Track accesses to object state in different EJB tiers

Java EE Tiers



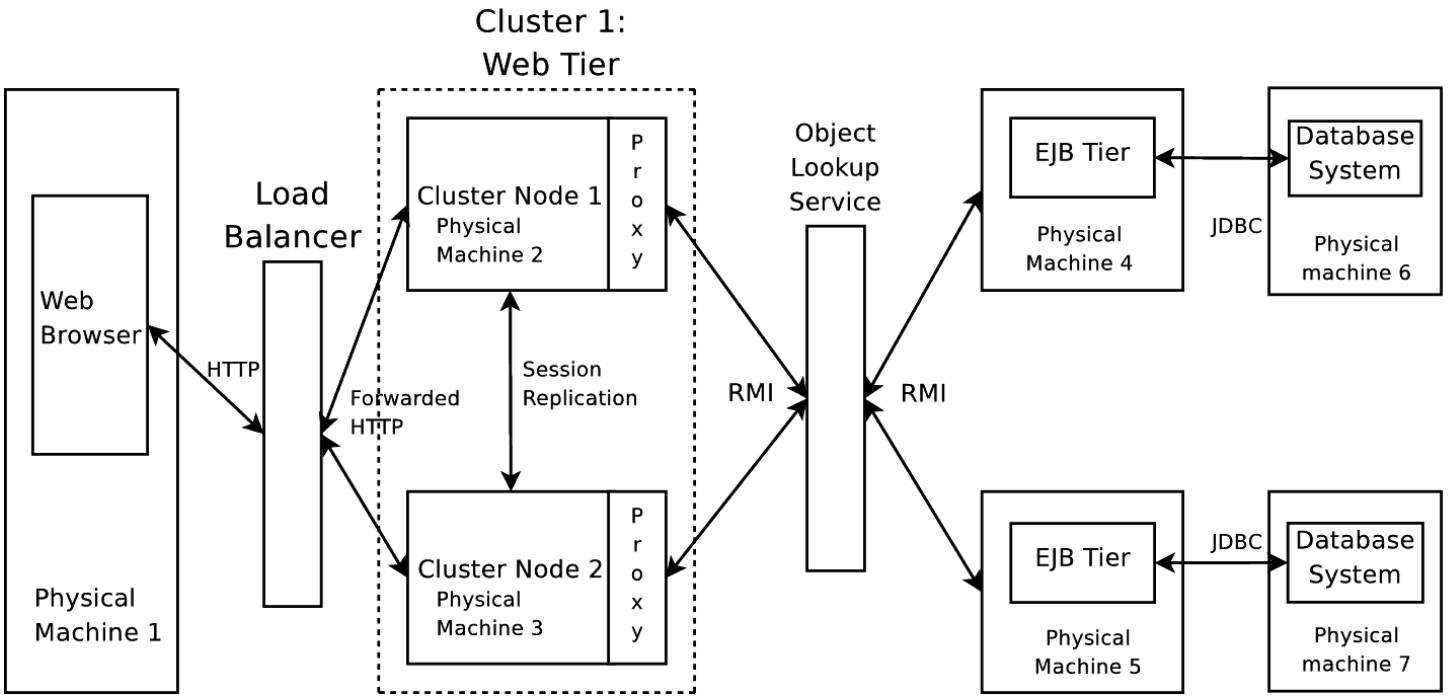
A Complex Cluster



Challenges

- Horizontal Scalability
  - implemented through clustering services
- Memory Scalability
  - state propagated everywhere
  - memory scalability is non-existent
- Network Scalability
  - maintenance RMI calls typically exceed RMI calls doing “real work”
  - network scalability is bad

Object Lookup Service



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Typical J2EE Roles

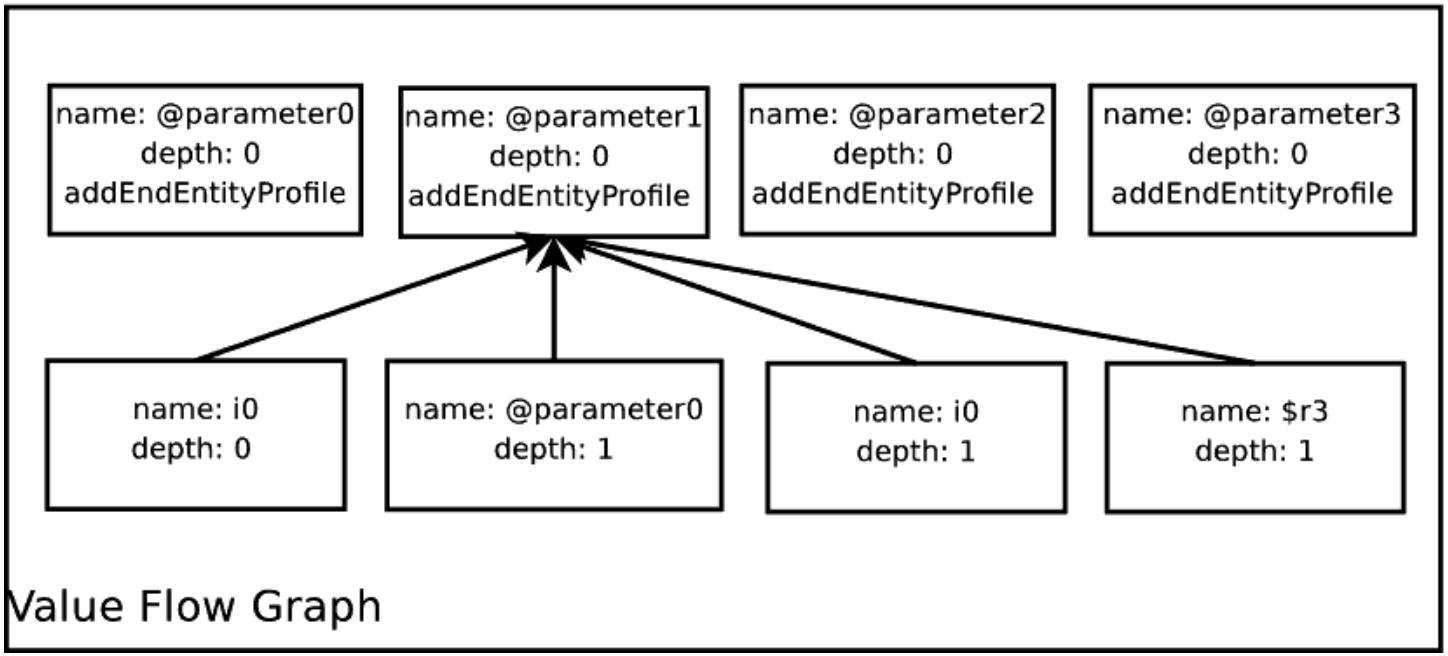
- J2EE Application Server developer
  - Concerned with *how*, not *what*
  - Application servers provide services that applications need
- J2EE application developer
  - Concerned with *what*, not *how* (ideally, not even that)
  - Enterprise culture states that app developers should be able to focus on their business needs
- J2EE administrator
  - Concerned with deploying and integrating apps into servers
  - Configures the general services to work with specific apps

Entity Bean ID Identification

- Leads to Intelligent Proxy Service
- Intelligent proxy works at the *object* level
- Entity Beans directly represent database data
- Entity Beans have unique IDs
- The proxy needs to see an Entity Bean ID in order to dispatch the request accordingly

Possible Use Cases

- Client directly passes a primitive-type id
- Client directly passes a composite primary key
- Client passes the data that comprises a composite primary key within the same remote call
- Client passes the data that comprises a composite primary key within multiple remote calls

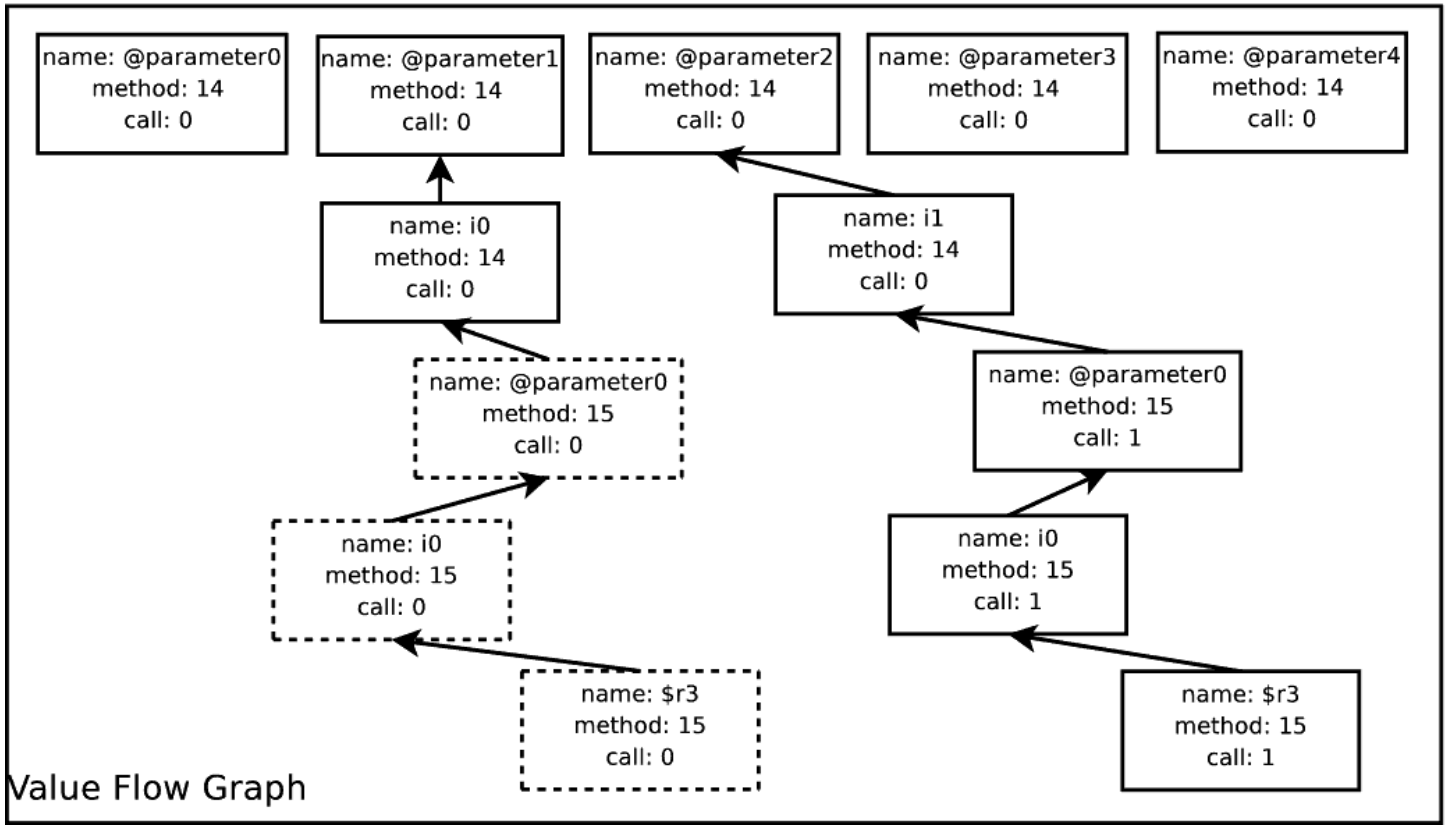



```
public void addEndEntityProfile(Admin,
    int, String, EndEntityProfile) {
   LocalRaAdminSessionBean r0;
   int i0;
   boolean $z1;
   i0 := @parameter1;
   $z1 = r0.isFreeEndEntityProfileId(i0);
}
```

```
private boolean
isFreeEndEntityProfileId(int) {
   LocalRaAdminSessionBean r0;
   int i0;
   EndEntityProfileDataLocalHome $r2;
   Integer $r3;
   r0 := @this;
   i0 := @parameter0;
   $r2 = r0.profiledatahome;
   $r3 = new Integer;
   $r3.<init>(i0);
   $r2.findByPrimaryKey($r3);
}
```

Implementation

- Code instrumentation of the Jimple representation of the enterprise application
- All direct assignments are instrumented
- Local variables are kept track of based on the stack depth and the variable name
- Static and instance fields are kept track of based on their classname, identity hashcode (if exists), and field name
- Root nodes correspond to parameters input to the EJB Tier
- All nodes except roots have references to their origin




```
public void addEndEntityProfile(Admin, int, int, String, EndEntityProfile) {
        LocalRaAdminSessionBean r0;
        int i0, i1;
        boolean $z0, $z1;
        i0 := @parameter1;
        i1 := @parameter2;
        $z0 = r0.isFreeEndEntityProfileId(i0);
        $z1 = r0.isFreeEndEntityProfileId(i1);
}
```

Experimental Study

- EJB Certificate Authority (EJBCA) application
  - Open-source, commercially deployed
  - Comes with its own test suite
  - Multiple tiers: EJB, Web, console client, GUI desktop client
  - A total of 635 classes
- Duke's Bank, Pet Store
  - Smaller applications

Experimental Results

- Analysis Precision
  - matched 141 out of 152 **find** invocations (~93%) in EJBCA
    - 3 of the 11 unmatched ones had values originating within the EJB tier
  - 100% in Duke's Bank and Pet Store
- Analysis Cost
  - online and offline version
  - EJBCA online: ~279% overhead, offline: ~150%
  - EJBCA offline trace: 183MB, 15m33s to process it
  - Smaller apps online: ~183% Duke's Bank, ~195% Pet Store

Optimizations and Enhancements

- Track PKs passed as members of a complex data structure
  - Java Collection
  - DTO
- Unwrap such a complex data structure and track its parts separately

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EJBQL Relationship Identification

- EJBQL is J2EE's query language, similar to SQL
- Object lookup service must be aware of query parameters flowing in client requests
- Ideally, it will also be aware of their relationships (to optimize query execution)
- Analysis: upgrade to previous one
  - Additional output
  - Tracking of query return values (Entity beans)

Preprocessing and VFG changes

- Parse application code to identify possible types of query parameters
  - Parsing source is easier than parsing bytecode/Jimple
- Parse queries to identify parameter relationships
  - Most common relationships extracted

- VFG nodes may have more than one origin
- A special type of node holds Entity Bean information (return values from queries)

Implementation and Experiments

- Implemented by instrumenting Jimple
- Experimental setup is the same as before
- Precision:
  - 43 out of 45 (96%) in EJBCA
  - 100% for the smaller apps (7/7 for Duke's Bank, 4/4 for Pet Store)
- Cost: ~293% overhead
- Relationship coverage: 87%

Enhancements

- Track query parameters entering the EJB tier in a larger structure (DTO, Collection)
- Unwrap an Entity bean returned from a query and track its parts separately
- Unwrap Collections of Entity beans returned from queries and track them
- Increase the relationship coverage

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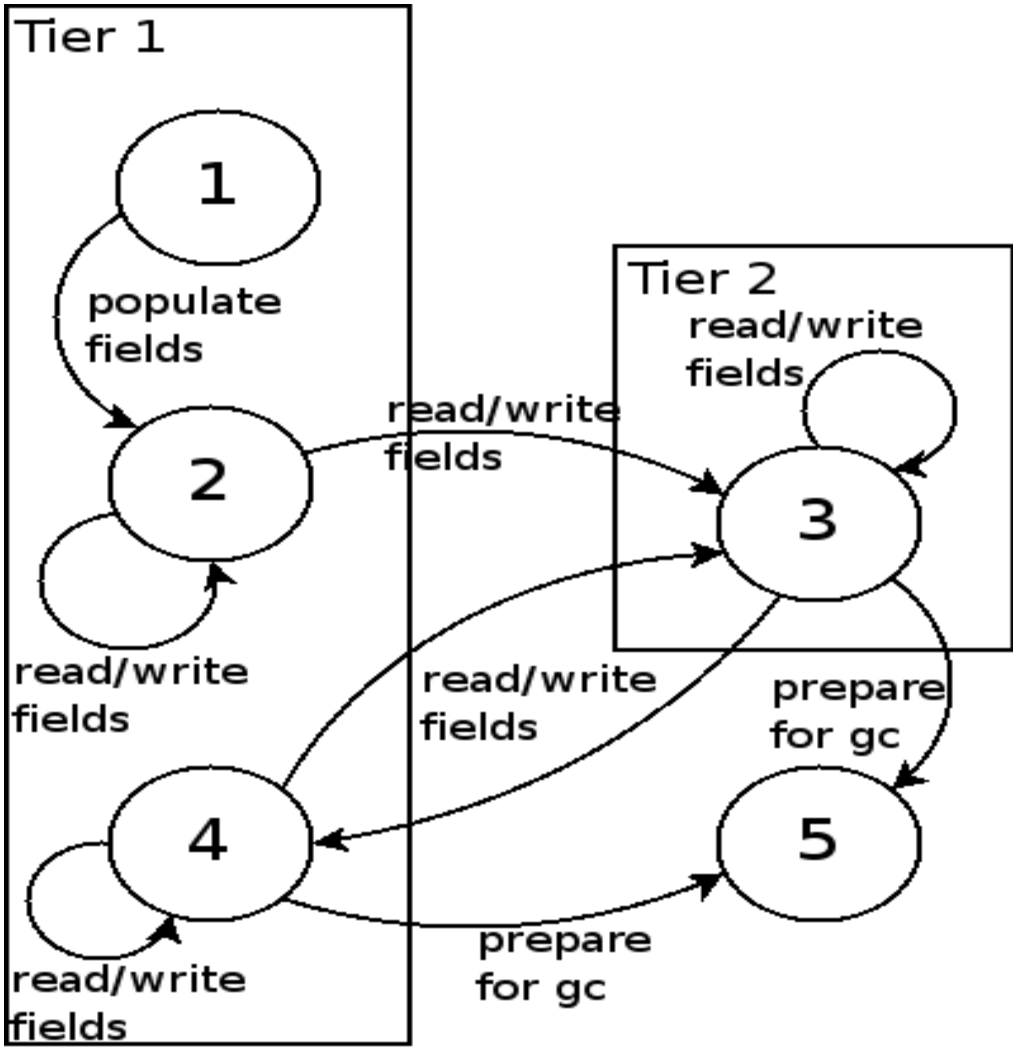
Data Transfer Objects

- DTO design pattern
  - Reduces the number of remote accesses
  - Often used in Enterprise Java software
- Goal: identify DTOs in an EJB application
  - Find classes whose instances implement the pattern
  - Approach based on dynamic analysis
- Motivation: pre-processing step for the previous analyses
- Published at the Fifth International Workshop on Dynamic Analysis (WODA'07)

DTO Lifecycle



Dynamic Analysis

- Focuses on the state of objects
  - Tracks field reads & writes as opposed to method entries & exits
  - Fields of interesting (Serializable) objects tagged when the objects are created
- Matches state transitions against the DTO lifecycle
  - Requires precise identification of the EJB tier of the initiator of a state transition:
    - Handled by traversing the call stack
- Interested only in application classes
  - Robust with respect to reflection
- JVMTI used with Java 6 JVM (agent written in C)

Experimental Study

- EJB Certificate Authority (EJBCA) application
- Experimental Results
  - 132 interesting (Serializable) clases in EJBCA code
  - 13 deemed DTOs after manual inspection
  - 11 of those 13 were utilized by the application's test suite (loaded in the JVM)
  - Analysis precision: big picture
    - One false positive
    - One false negative

False Positive and False Negative

- False positive: not really false
  - Carries state
  - Problem is, never allows direct access to its state, so technically it is not a DTO
- False negative: wrapped by another DTO
  - True DTO
  - All reads & writes of its fields carried out through the wrapper
  - Wrapper classified as DTO, but wrapped object appears to have never moved between tiers

Run-time Performance

- Start-up overhead
  - 1m32s without agent
  - 91% overhead with full agent deployed
  - 29% overhead with dummy agent (JVMTI capabilities enabled, but all agent event handlers return immediately)
- Application overhead
  - 4m53s without agent
  - 263% overhead with full agent deployed
  - 31% with dummy agent

Conclusions and Future Work

- Three dynamic analyses presented
- All of them contribute information for the use of an object-level lookup service
- In turn, such a service would alleviate the scalability issues inherent in Java EE applications

- Enhancements to the analyses as discussed
- Build the services in the proposed architecture