Team eBay

18-749: Fault-Tolerant Distributed Systems

Bryan Murawski
Meg Hyland
Jon Gray
Joseph Trapasso
Prameet Shah
Michael Mishkin

Electrical & Computer
ENGINEERING

Team Members

BrYan Murawski
bmurawsk@andrew.cmu.edu

Meg Hyland
mhyland@andrew.cmu.edu

Jonathan Gray
jongray@cmu.edu

Michael Mishkin
mmishkin@andrew.cmu.edu

Joe Trapasso
jtrapass@andrew.cmu.edu

Prameet Shah
phs@andrew.cmu.edu

http://www.ece.cmu.edu/~ece749/teams-06/team4/

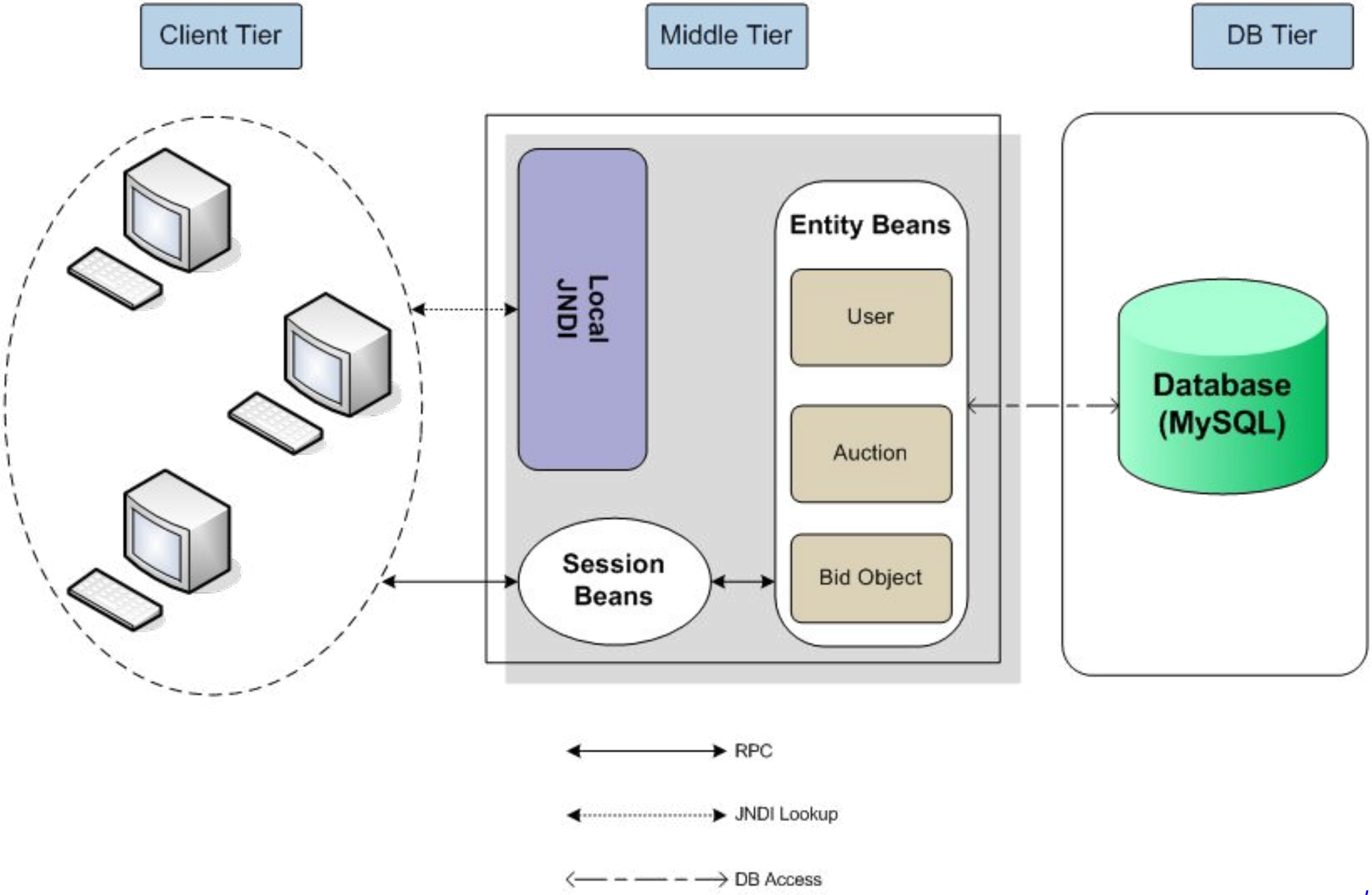
Baseline Application

- System Description
  - EJBay is a distributed auctioning system that allows users to buy and sell items in an auction plaza
- Baseline Applications
  - A user can create, login, update, logout, view other users' account information.
  - A user can post, view, search, post a bid, view bid history of auctions.
  - Application Exceptions: DuplicateAccount, InvalidAuction, InvalidBid, InvalidUserInfo, InvalidUserPass, UserNotLoggedIn
- Why is it Interesting?
  - A service used by many commercial vendors.
- Configuration
  - Operating System
    - Server & Client: Linux
  - Language
    - Java SDK 1.4.2
  - Middleware
    - Enterprise Java Beans
  - Third-party Software
    - Database: MySQL
    - Application Server: JBoss
    - IDE: XEmacs, Netbeans

Baseline Application – Configuration Selection Criteria

- **Operating System: Linux**
  - Easier to use, since ECE clusters are configured.
  - System is managed and backed up nightly by Computing Services.
- **Enterprise Java Beans (EJB)**
  - Popular technology in the industry.
  - Every members’ preference.
- **MySQL**
  - World’s most popular open source database.
  - Easy to install and use.
  - Couple of group members knew it well.
- **JBoss**
  - Easily available on the servers.
  - Environment that was used in previous projects.
- **XEmacs**
  - Most commonly learned text editor.
  - Members were familiar with syntax.
- **Netbeans**
  - Easy to install and incorporates tab completion.
  - Allows you to see available functions within a class.

Baseline Architecture



Experimental Evaluation – Architecture

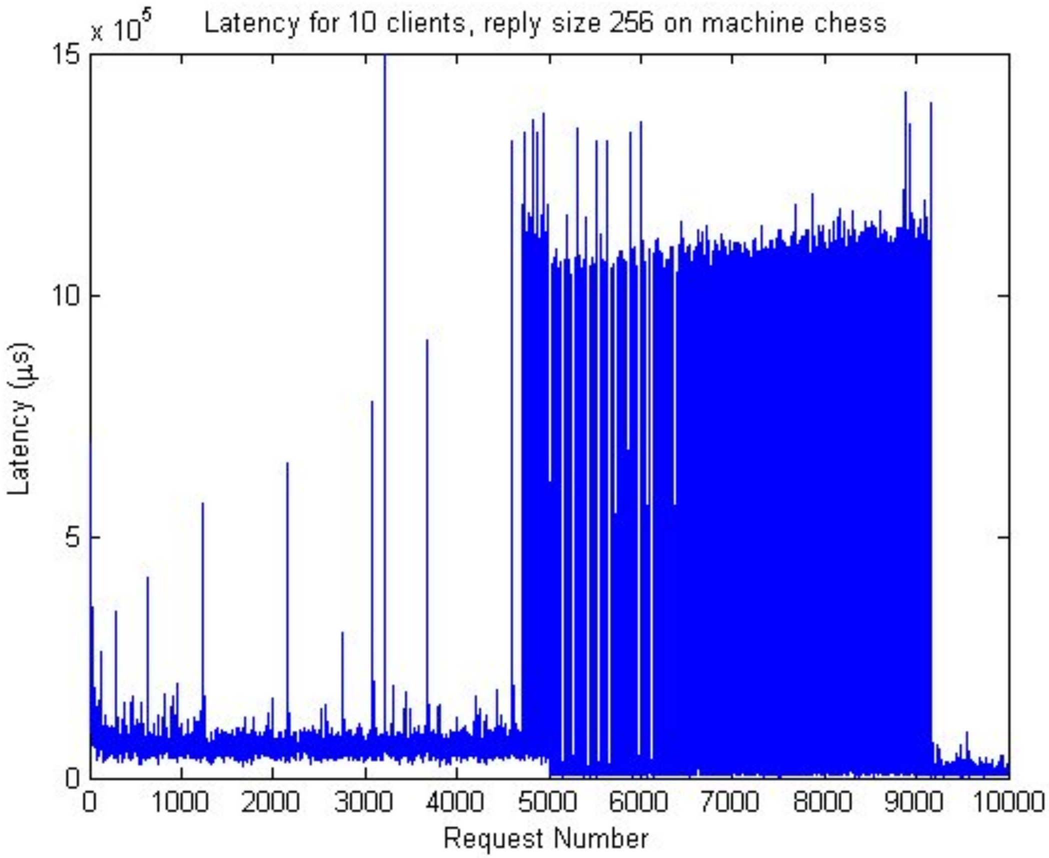
- Unmodified Server Application
- New Automated Client
  - Experimental variables taken as command-line inputs
  - Performs specified number of invocations and dies
- Central Library of MATLAB scripts
  - One script to read in data from all probes
  - Others scripts each responsible for a specific graph

Experimental Evaluation – Results

- Expected results
  - Increasing clients yield increasing latency
  - Most time spent in Middleware
  - “Magical 1%”
  - Slightly longer latencies in non-standard reply size cases

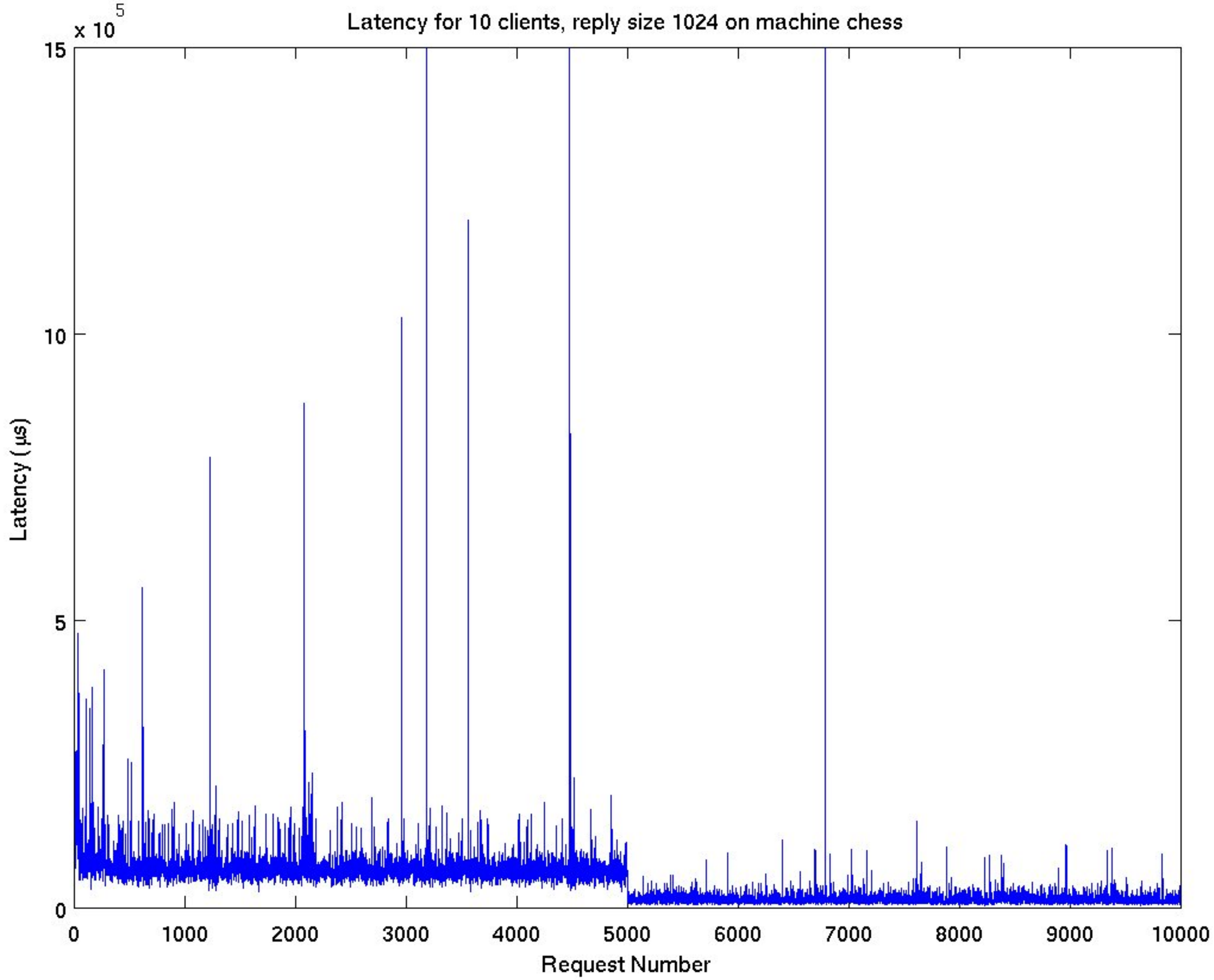
- Actual results
  - Memory / Heap problems
  - Java optimizations changing behavior of code
    - Shorter latency in non-standard reply size cases
  - Database INSERTs take much longer than SELECTs
  - Only exhibited “Magical 1%” to some extent
  - Very high variability and some unusual/unexpected results
    - During test runs close to deadline; very high server/database loads

Experimental Evaluation – Original Latency



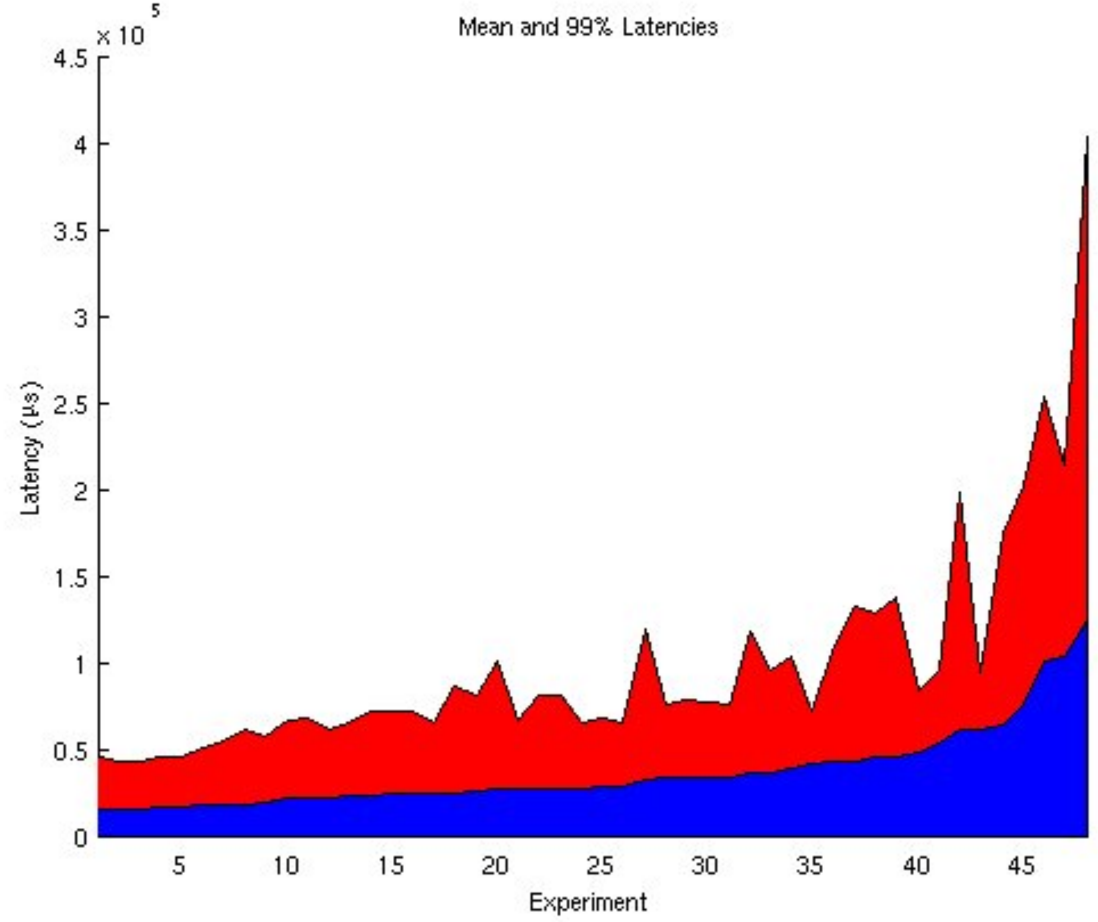
- First set of experiments revealed unusual characteristics at high load
- Default Java heap-size was not large enough
- Garbage collector ran constantly after ~4500 requests w/ 10 clients

Experimental Evaluation – Improved Latency



- Increased heap from default to 300MB

Experimental Evaluation – Improved Latency

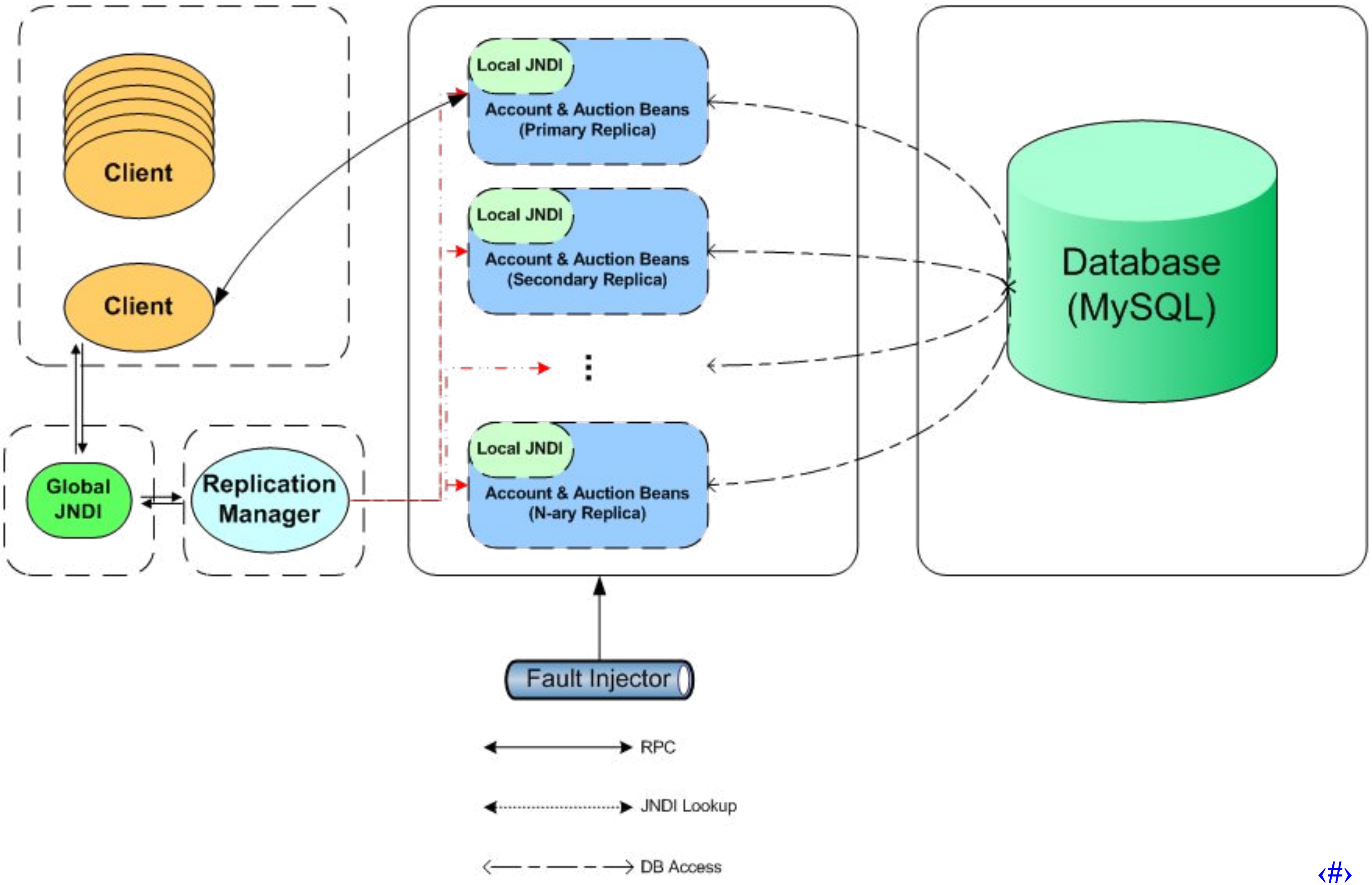


– Mean and 99% Latency area graph only loosely exhibited the *"Magic 1%"* behavior

Fault-Tolerance Framework

- Replicate servers
  - Passive replication
  - Stateless servers
  - Allow for up to 14 replicas
    - One for each machine in the Games cluster (minus ASL and Mahjongg)
- Sacred Machines
  - Clients
  - Replication Manager
  - Naming Service
  - Fault Injector
  - Database
- Elements of Fault-tolerance Framework
  - Replication Manager
    - Heartbeat
    - Fault detector
    - Automatic recovery (maintenance of number of replicas)
  - Fault Injector

FT-Baseline Architecture



Replication Manager

- Responsible for launching and maintaining servers
- Heartbeats replicas periodically
  - 500ms period
- Differentiates between crash faults and process faults
  - Crash fault: Server is removed from the active list
  - Process fault: Process is killed and restarted
- Catches port binding exceptions
  - A server is already running on the current machine □remove from active list
- Maintains global JNDI
  - Updating server references for clients
  - Indicates which server is primary/secondary
  - Keeps a count of the number of times any primary has failed
- Advanced Features
  - Allows the user to see the current status of all replicas
  - Allows the user to see the bindings in the JNDI

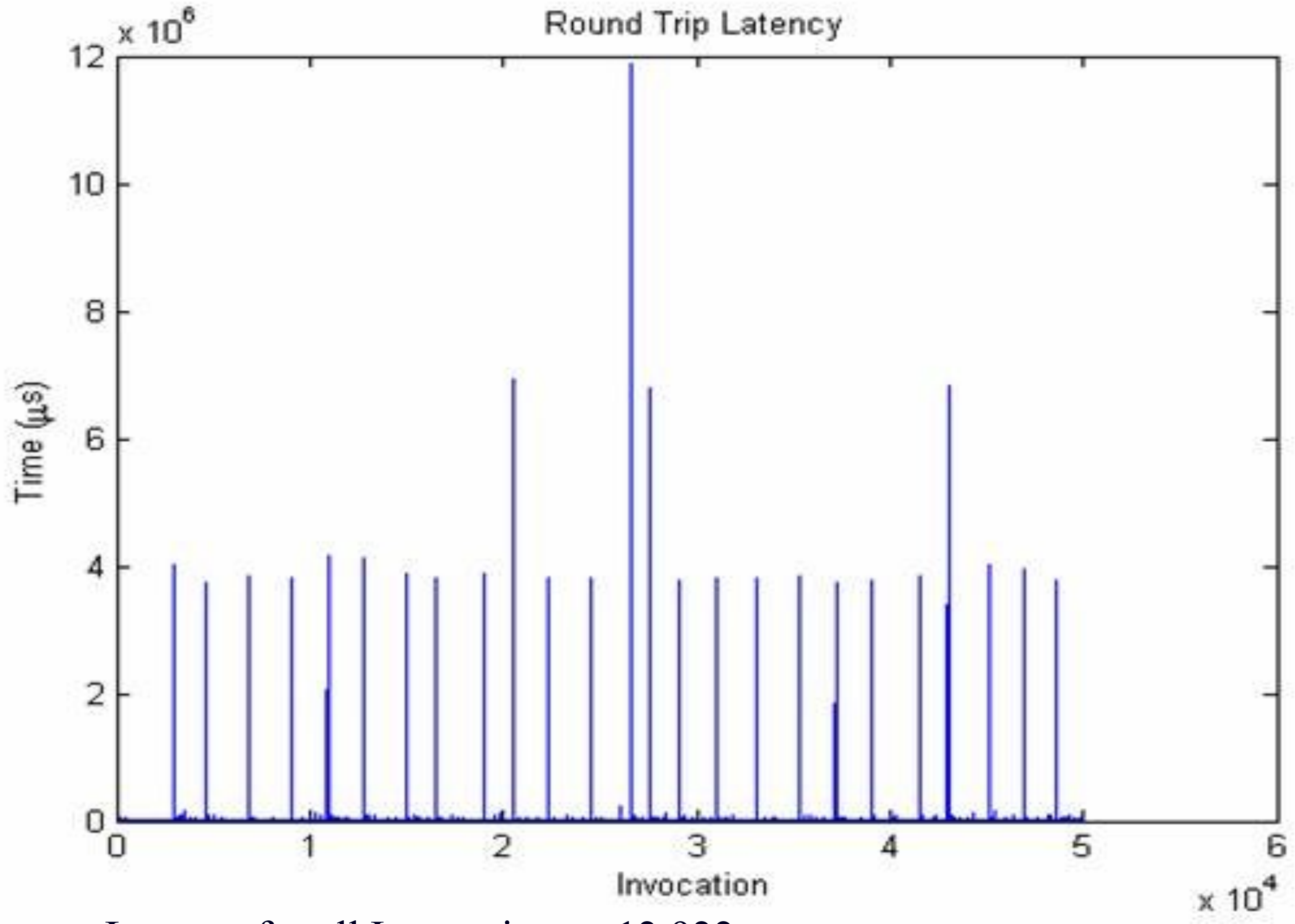
Fault Injector

- 2 Modes
- Manual Fault Injection
  - Runs a “kill -9” on a user specified server
- Periodic Fault Injection
  - Prompts user to set up a kill timer
    - Base period
    - Max jitter about the base period
    - Option to only kill primary replica, or a random replica

Mechanisms for Fail-Over

- Replication Manager detected fail-over
  - Detects that a heartbeat thread failed
  - Kills the associated server
  - Checks cause of death
  - Launches new replica
  - If no active servers are free, the replication manager will print a message, kill all servers and exit
- Client detected fail-over
  - Receives a RemoteException
  - Queries naming service for a new primary
    - Previously accessed JNDI directly
      - Required a pause for JNDI to be corrected
    - Sometimes this resulted in multiple failover attempts
      - When JNDI was not ready after predetermined wait time

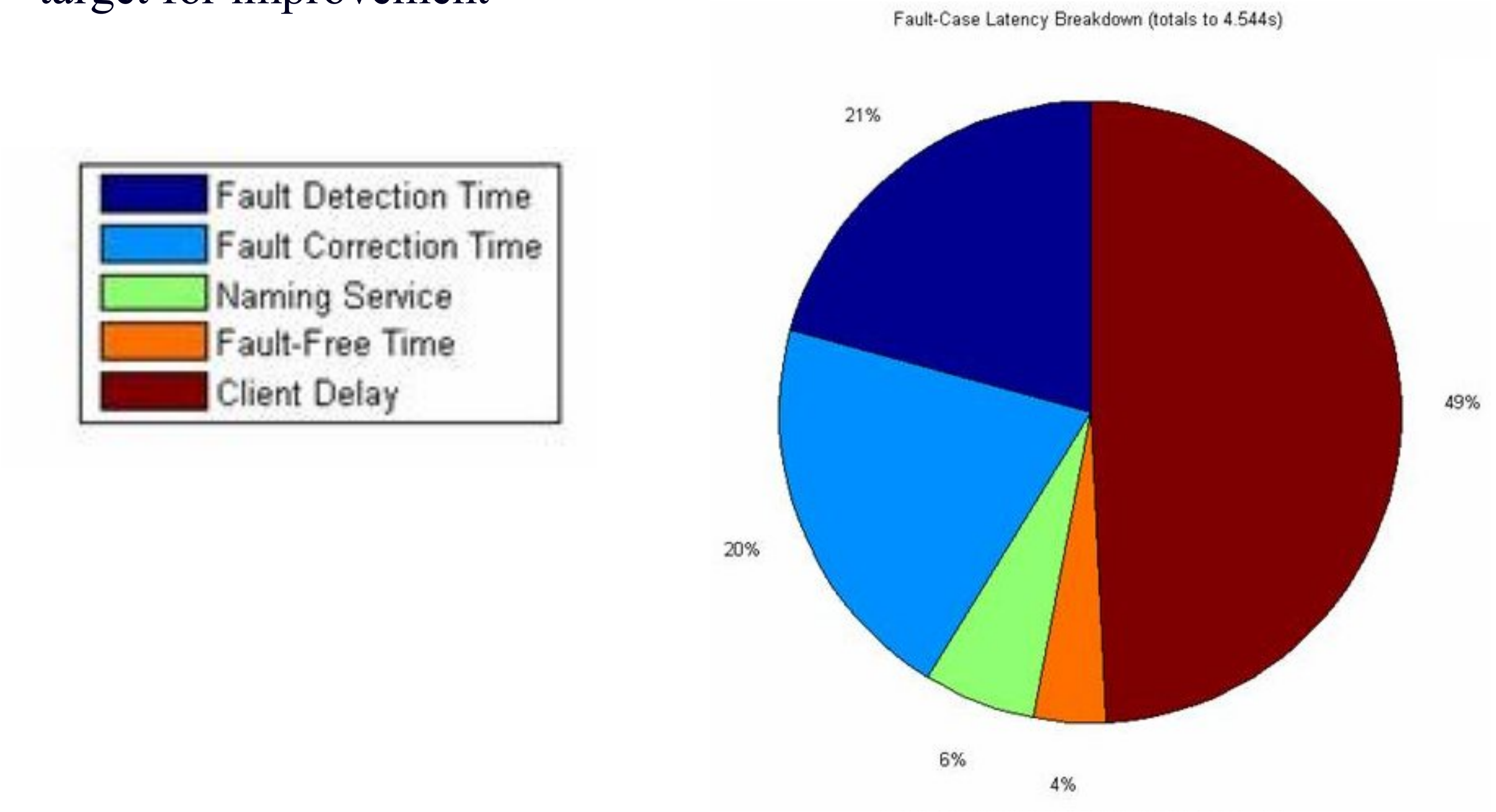
Round Trip Client Latency w/Faults



Average Latency for all Invocations – 12.922 ms

Fail-Over Measurements

- Half fault time is client delay waiting for JNDI to be updated
- Rest of time spent between detection and correction in Rep Manager
- This discrepancy between delay-time and correction time is the major target for improvement

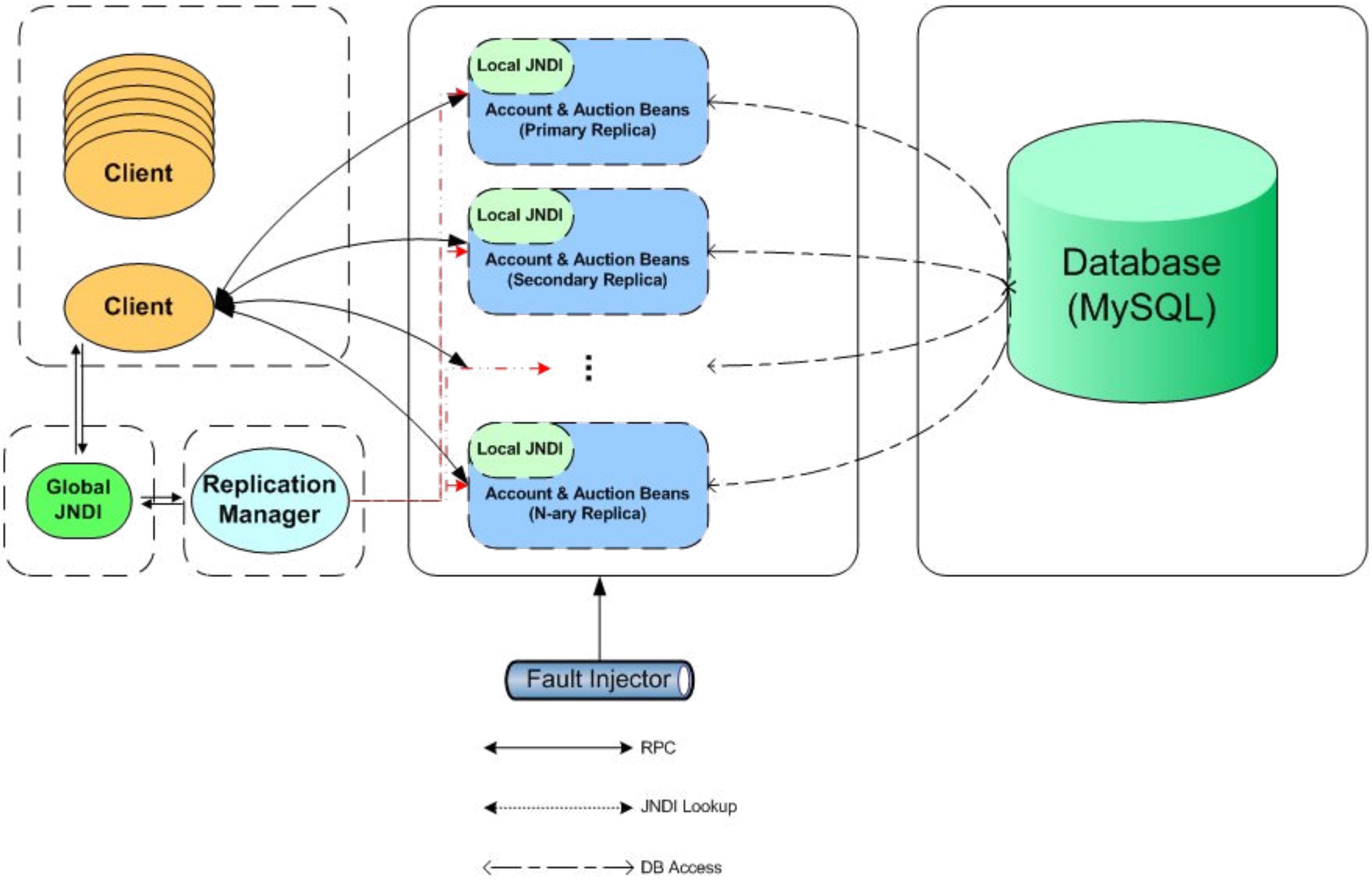


RT-FT-Baseline Architecture Improvements

- Target fault-detection and correction time in Replication Manager
  - Tweaking heartbeat frequency and heartbeat monitor frequency
  - Improvements in interactions with JNDI
    - Additional parameters to specify primary server
    - Update JNDI by modifying entries rather than rebuilding each time

- Target fail-over time in client
  - Client pre-establishes connections to all active servers
  - Background thread queries JNDI and maintains updated list
  - On fail-over, client immediately fails-over to next active server
    - **No delay waiting for Replication Manager to update JNDI**
    - Background thread will synchronize client’s server list once it has been updated by the Replication Manager

RT-FT-Baseline Architecture



RT-FT- Post-Improvement Performance

Old 1 Client Measurements

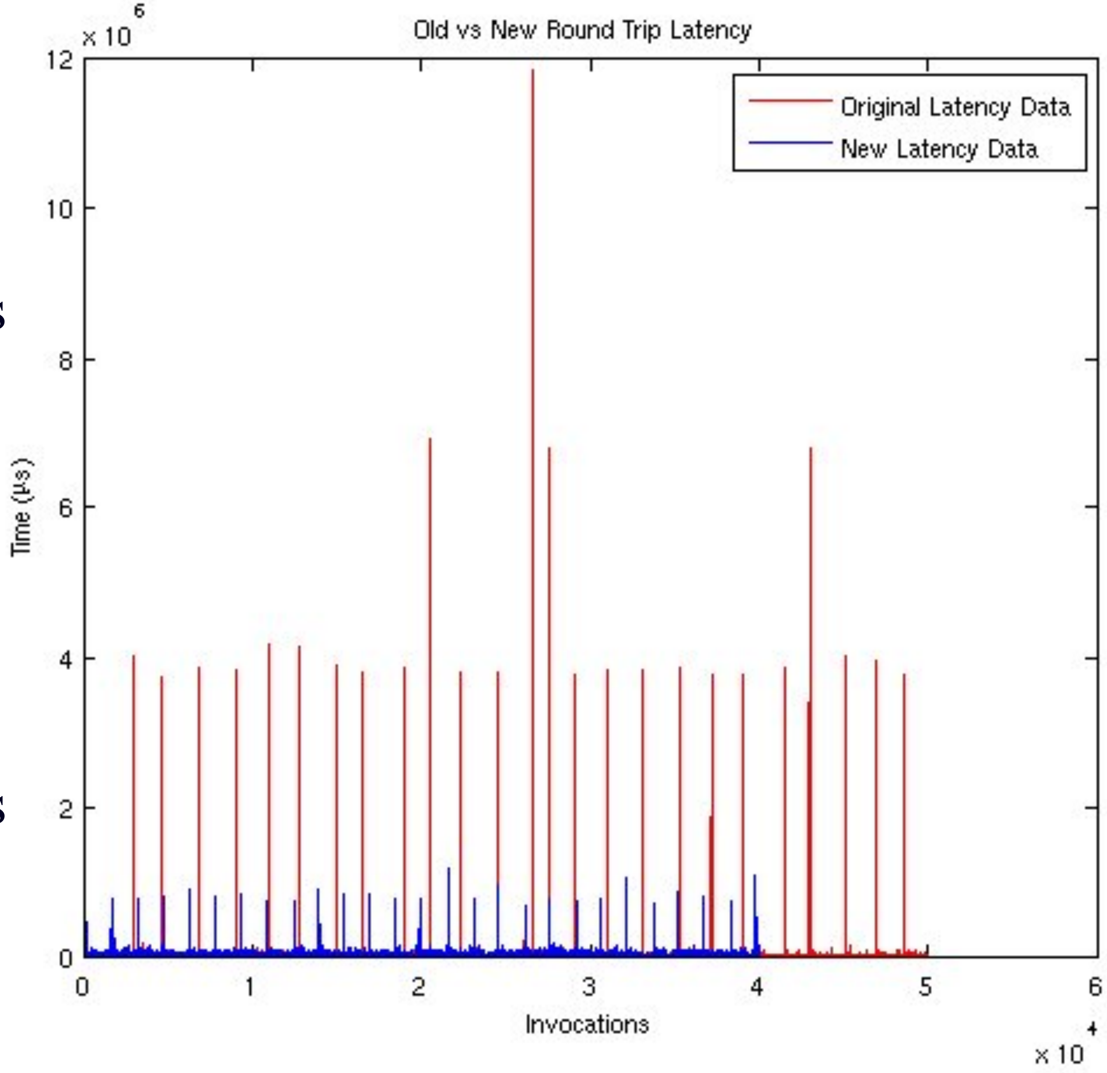
Avg. Latency for all Invocations: 12.922ms

Avg. Latency during a Fault: 4544ms

New 1 Client Measurements

Avg. Latency for all Invocations: 16.421ms

Avg. Latency during a Fault: 806.96ms (82.2% Improvement)

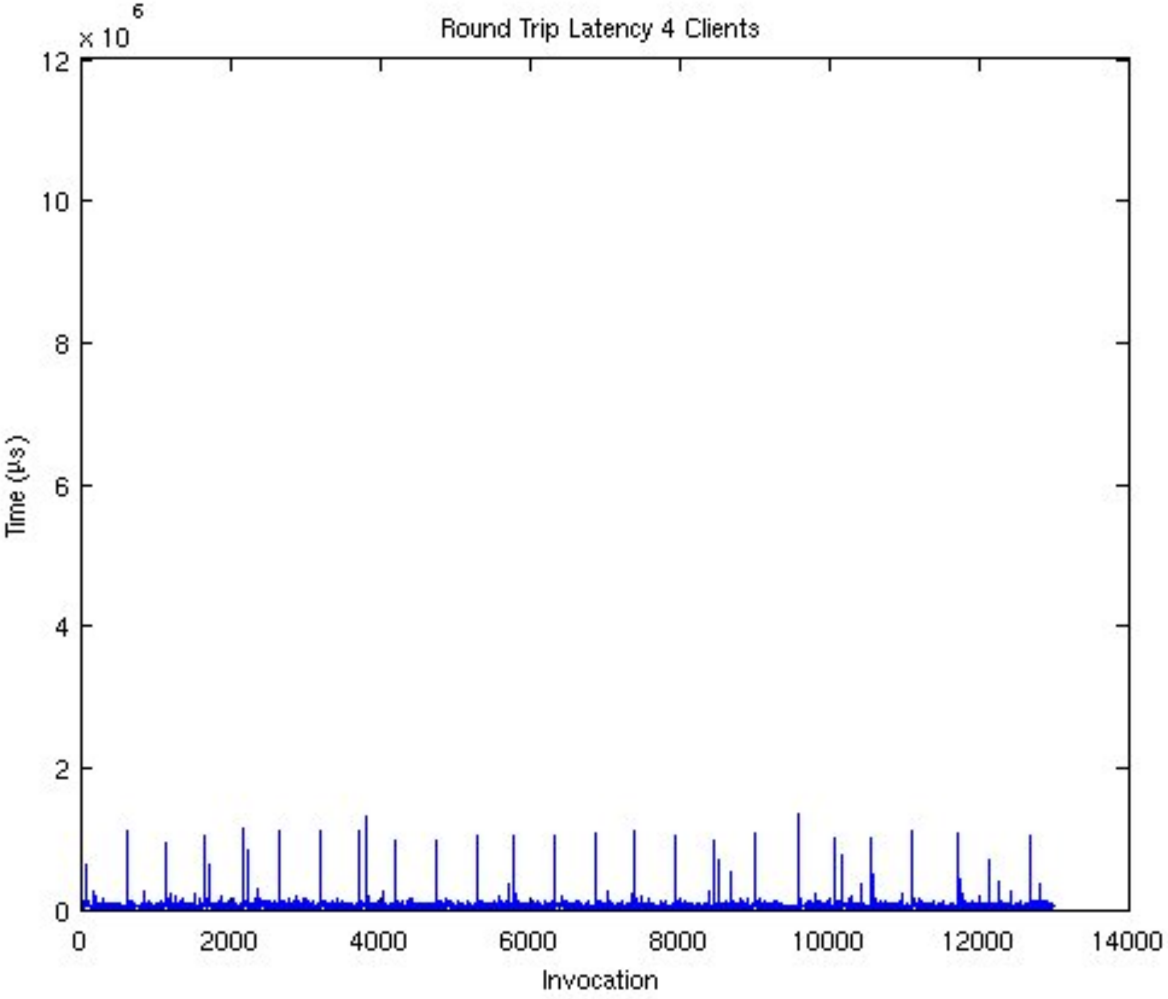


RT-FT- Post-Improvement Performance – 4 Clients

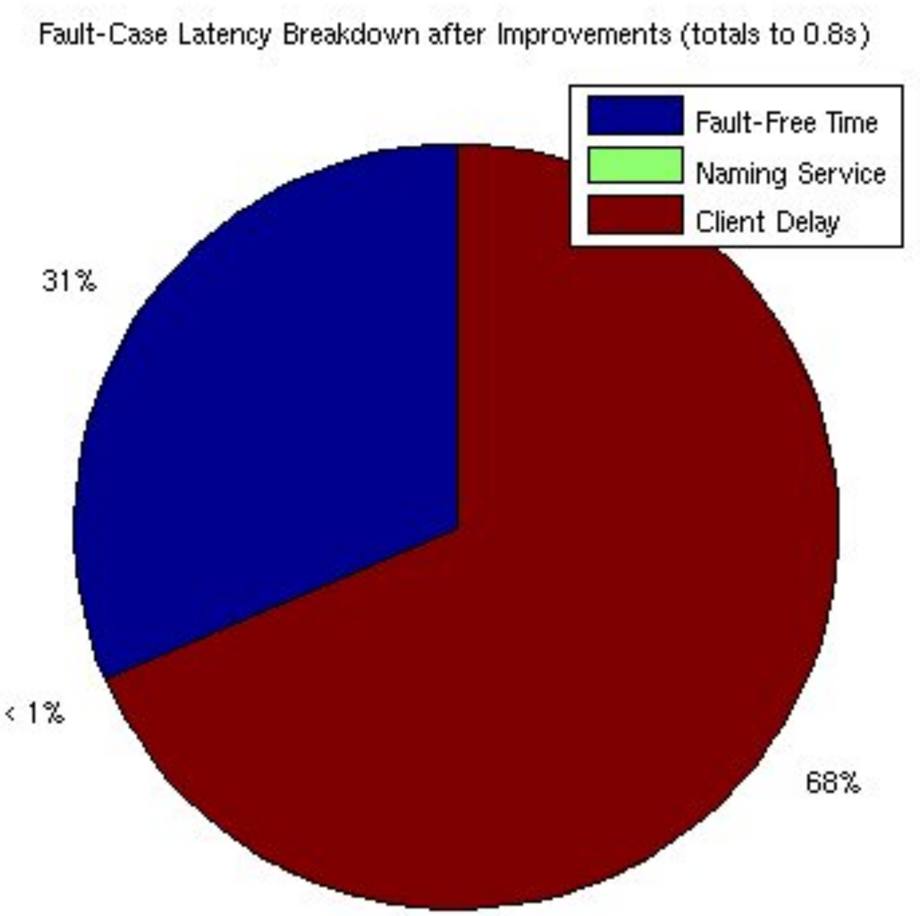
New 4 Client Measurements

Avg. Latency for all Invocations: 47.769ms

Avg. Latency during a Fault: 1030.1ms



RT-FT- Post-Improvement Performance



- More even distribution of time
- Client reconnect time still dominates, but is a much smaller number

Special Features

- Experimental Evaluation
  - Utilized JNI for microsecond precision timers
  - Maintained a central library of MATLAB processing scripts
  - Perl and shell scripts to automate entire process
- Fault-Tolerant Baseline
  - Powerful Replication Manager that starts, restarts, and kills servers
  - Integrated command-line interface for additional automation
  - Fault-Injector with dual-modes
- Fault-Case Performance
  - New client functionality to pre-establish all connections
  - Contents of JNDI directly correlated to actual status of servers
    - Online, offline, booting

Open Issues

- Problems launching multiple servers concurrently from Rep Manager
  - Many attempts to address/debug this issue with only some success
  - If multiple faults occur within short period of time, some servers may die unexpectedly

- Improved Client Interface
  - GUI or Web-Based

- Additional Application Features
  - Allow deletion of accounts, auctions, and bids
  - Security!
  - Improved search functionality

Conclusions

- What we have learned
  - Stateless middle tier requires less overhead
  - XML has poor documentation. XDoclet would have been a good tool to use.
  - Running experiments takes an extremely long time. Automating test scripts increases throughput.
- What we accomplished
  - A robust fault-tolerant system with a fully automated Replication Manager
  - Fully automated testing and evaluation platform
- What we would do differently
  - Spending more time with XDoclet to reduce debugging
  - Use one session bean instead of separating functionality into two