18-749: Fault-Tolerant Distributed Systems

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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
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

- Client
- Global JNDI
- Replication Manager
- Local JNDI
- Account & Auction Beans (Primary Replica)
- Account & Auction Beans (Secondary Replica)
- Account & Auction Beans (N-ary Replica)
- Database (MySQL)
- Fault Injector
- RPC
- JNDI Lookup
- DB Access
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)
New 4 Client Measurements
Avg. Latency for all Invocations: 47.769ms
Avg. Latency during a Fault: 1030.1ms
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