LBPerf: An Open Toolkit to Empirically Evaluate the Quality of Service of Middleware Load Balancing Services

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Distributed Systems

- Typical issues with distributed systems
  - Heterogeneous environments
  - Concurrency
  - Large bursts of client requests
  - 24/7 availability
  - Stringent QoS requirements

- Examples of distributed systems
  - E-commerce
  - Online trading systems
  - Mission critical systems
Motivation

• Development and maintenance of QoS-enabled distributed systems
  - Non-trivial
  - Requires expertise that application developers often lack

• Solution: Middleware (e.g. CORBA)
  - Can shield distributed system developers from the complexities involved with developing distributed applications
  - Can facilitate manipulation of QoS requirements and management of resources
Load Balancing

- Load balancing can improve the efficiency and scalability of a distributed system
- Load balancing service can be implemented in the following layers
  - Network layer
  - OS layer
  - Middleware layer
- Why choose middleware-layer load balancing?
  - Can take into account distributed system state
  - Can take into account the system run-time behavior
  - Application level control over load balancing policies
  - Can take into account request content
Common Deployment Scenario

- **Multiple clients making request invocations**
  - Potentially non-deterministic
  - Duration called a session

- **Members**
  - Multiple instances of the same object implementation

- **Object groups**
  - Collections of members among which loads will be distributed equitably
  - Logically a single object

- **Load balancer**
  - Transparently distributes requests to members within an object group
Common Load Balancing Tasks

• Manage multiple object groups
  - Groups may be modified at run-time

• Bind clients to servers (group members)
  - Select servers based on balancing strategy configured for given object group

• Query and analyze loads
  - Pulled
    • Loads retrieved from monitoring object
  - Pushed
    • Load pushed to load balancer from monitoring object

• Rebalance loads across group members
  - Rebind clients to other servers
Inter-task Affects

• Each of the common load balancing tasks can affect the performance of the others
  - Client binding bursts can degrade load rebalancing performance
  - High frequency load reporting can degrade client binding responsiveness
  - Costly load balancing strategies can consume resources needed to respond to object group membership changes
  - Similarly for other inter-task combinations

• Execution of some tasks may starve others
Overall Performance Evaluation Considerations

• Each of the load balancing tasks may execute non-deterministically
  – Non-determinism should be reproduced to accurately reflect true deployed run-time behavior
• Some tasks may be less critical than others
  – Give less weight to less performance critical tasks
• How do different application workloads affect load balancing performance
  – Different types of workloads incur different behavior and responsiveness from the load balancer
Evaluating Load Balancing Strategies

• Load balancing strategies can be either adaptive or non-adaptive

• Load balancing strategies can employ various run time parameters and load metrics
  – Strategies may perform differently under different parameter configurations

• Determining the appropriate load balancing strategies for different classes of distributed applications is hard without the guidance of comprehensive performance evaluation models, systematic benchmarks and empirical results
Introducing LBPerf

- LBPerf is an open source benchmarking tool suite for evaluating middleware load balancing strategies
- Supports range of adaptive and non-adaptive load balancing strategies
- Tune different configurations of middleware load balancing, including choosing different load balancing strategies and runtime parameters associated with those strategies
- Evaluate strategies using different metrics like throughput, latency, CPU utilization
Workload Characterization (1/2)

• Empirical evaluations not useful unless the workload is representative of the context in which the load balancer is deployed

• Workload model could be any of the following:
  - Closed analytical network models
  - Simulation models
  - Executable models

• Our benchmarking experiments are based on the executable workload models
Workload Characterization (2/2)

- Executable models can be classified as:
  - Resource type
    - Characterized by the type of resource being consumed
  - Service type
    - Characterized by the type of service being performed on behalf of the clients
  - Session type
    - Characterized by the type of requests initiated by a client and serviced by a server in the context of a session

- Our benchmarking experiments focused on generating session type workloads
Experiment

- Focus on load balancing behavior under different types of workloads
- Single threaded clients generating CPU intensive requests on the servers
- Experiments repeated for different strategies
  - Round Robin
  - Random
  - Load Minimum
  - Least Loaded
- Measurements
  - Throughput
    - The number of requests processed per second by the server
  - CPU utilization
    - CPU usage percentage

Diagram showing the interaction between client, load balancer, and server.
Run-time configurations

- Load reporting interval
  - The time between successive load information updates from the server location to the load balancer
- Reject threshold value of the Least Loaded strategy
  - The load at which the servers will stop receiving additional requests
- Critical threshold value of the Least Loaded strategy
  - The load at which the servers will start shedding loads
- Migration threshold value of the LoadMinimum strategy
  - The difference between the most loaded machine and the least loaded machine to trigger a migration of load from the most loaded machine to the least loaded machine
- Dampening value
  - The fraction of the newly reported load that will be considered for fresh load balancing decisions
Overhead Measurements
Single Server

Throughput (Events/Second)

Number of Clients

- No LoadBalancing
- RoundRobin Strategy
- LeastLoaded Strategy
- Random Strategy
- LoadMinimum Strategy

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Throughput Measurement

4 Servers

- RoundRobin Strategy
- LeastLoaded Strategy
- LoadMinimum Strategy
- Random Strategy

Throughput (Events / Second)

Number of Clients

0 4 8 12 16

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Throughput Comparison
4 Servers using LoadMinimum Strategy

Throughput (Events/Second)

Number of Clients

Threshold Value 40 percent
Threshold Value 80 percent

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Performance of LeastLoaded Strategy

Threshold Values

Throughput (Events/Second) vs Number of Clients

- Green diamonds: Reject Threshold 75%
- Red triangles: Reject Threshold 95%

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Results Analysis

• Adaptive load balancing strategies generally perform better than non-adaptive load balancing strategies in the presence of non-uniform loads
• Least Loaded strategy is better than the other three strategies under such loading conditions
• Reducing the number of client migrations is necessary for achieving maximum performance
  – Client session migrations are not always effective
• Need to maintain system utilization to enable more predictive behavior of the strategies
Future Work

• Extend LBPerf to evaluate other types of workloads
• Use the empirical results as a learning process to understand the nuances of the different run-time behaviors of adaptive load balancing strategies
• Use observations from the learning process to train an operational phase by developing self-adaptive load balancing strategies that can dynamically tune the run-time parameters according to the load being experienced
• Implement non-deterministic traffic generator
  - Client requests
  - Load reports
  - Membership changes
Concluding Remarks

• While load balancing can improve distributed application performance significantly, determining the optimal load balancing configuration is non-trivial
  - Different load balancing strategies may behave worse than others under different types of workloads
  - Similar behavior may be observed when utilizing different load metrics
  - Improperly tuned load balancing strategy parameters can reduce effectiveness of the strategy, thus having a negative impact on performance and overall system scalability
  - Overall load balancer scalability and responsiveness may be degraded as the different tasks performed by a load balancer are executed
References

• Ossama Othman, Jaiganesh Balasubramanian, Douglas C. Schmidt
  “The Design of an Adaptive Load Balancing and Monitoring Service”

• Jaiganesh Balasubramanian, Ossama Othman, Douglas C. Schmidt
  “Evaluating the performance of middleware load balancing strategies”

• Download Cygnus, LBPerf and TAO from
  http://deuce.doc.wustl.edu/Download.html