Running Java Applications on the Amazon Elastic Compute Cloud

Chris Richardson  
Author of *POJOs in Action*  
Founder of Cloud Tools  
[www.chrisrichardson.net](http://www.chrisrichardson.net)
Overall presentation goal

Show how to use Amazon Elastic Compute Cloud for developing and deploying Java applications
About Chris

- Grew up in England and live in Oakland, CA
- Over twenty years of software development experience
  - Building object-oriented software since 1986
  - Using Java since 1996
  - Using J2EE since 1999
- Author of POJOs in Action
- Speaker at JavaOne, SpringOne, NFJS, JavaPolis, Spring Experience, etc.
- Chair of the eBIG Java SIG in Oakland (www.ebig.org)
- Run a consulting and training company that helps organizations build better software faster and deploy it on Amazon EC2
- Founder of Cloud Tools, an open-source project for deploying Java applications on Amazon EC2: http://code.google.com/p/cloudtools
Agenda

- Cloud computing with Amazon EC2
- Using Amazon EC2
- Overview of Cloud Tools
- Developing on Amazon EC2
- Deploying on Amazon EC2
- A few thoughts about Groovy
Computing has come a long way

Past

www.computermuseum.org.uk

Present

www.dell.com

Yet we rarely have enough
Cloud computing

A pool of highly scalable, abstracted infrastructure that hosts your application, and is billed by consumption

By James Staten of Forrester Research
Power generation

Past

Present

The Big Switch
Rewiring the World, from Edison to Google

Nicholas Carr
Author of The New Middle
Amazon-Style Cloud Computing

- Elastic Compute Cloud (EC2)
  - On-demand computing
- Elastic Block Storage (EBS)
  - "SAN on demand"
- Simple Storage Service (S3)
  - Stores blobs of data
- Simple Queue Service (SQS)
  - Hosted queue-based messaging system
- SimpleDB
  - Store data sets
  - Execute queries

Pay per use services managed by Amazon
What is Amazon EC2?

- Virtualized computing environment
- Server instances managed through a web service API
- IP addresses and host names assigned dynamically
- Pay by the hour ($0.10-0.80/hour) + external bandwidth ($0.10-0.18/Gbyte)

https://ec2.amazonaws.com/?Action=RunInstances &ImageId=ami-398438493 &MaxCount=3 &MinCount=3

<RunInstancesResponse>...
</RunInstancesResponse>

cer@arrakis ~
$ ssh ... root@ec2-67-202-41-150.compute-1.amazonaws.com
Last login: Sun Dec 30 18:54:43 2007 from 71.131.29.181
[root@domU-12-31-36-00-38-23:~]
## Instance types

<table>
<thead>
<tr>
<th></th>
<th>Virtual Cores</th>
<th>Compute Units/core*</th>
<th>32/64 Bit</th>
<th>Memory</th>
<th>Storage</th>
<th>$/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1</td>
<td>1</td>
<td>32 bit</td>
<td>1.7G</td>
<td>160G</td>
<td>0.10</td>
</tr>
<tr>
<td>High-CPU Medium</td>
<td>2</td>
<td>2.5</td>
<td>32 bit</td>
<td>1.7G</td>
<td>350G</td>
<td>0.20</td>
</tr>
<tr>
<td>Large</td>
<td>2</td>
<td>2</td>
<td>64 bit</td>
<td>7.5G</td>
<td>850G</td>
<td>0.40</td>
</tr>
<tr>
<td>Extra Large</td>
<td>4</td>
<td>2</td>
<td>64 bit</td>
<td>15G</td>
<td>1690G</td>
<td>0.80</td>
</tr>
<tr>
<td>High-CPU XL</td>
<td>8</td>
<td>2.5</td>
<td>64 bit</td>
<td>7G</td>
<td>1690G</td>
<td>0.80</td>
</tr>
</tbody>
</table>

* EC2 Compute Unit = 1.0-1.2 GHz 2007 Opteron or 2007 Xeon processor
Operating systems

- Use Amazon provided Machine Image (AMI)
  - 32-bit Fedora Core 4
  - 64-bit Fedora Core 6
- Many 3rd parties have public AMIs
  - Various Linux distributions
  - e.g. Redhat, RightScale
- Sun provides OpenSolaris
- Windows is in beta:
  - Windows Server 2003 ($0.125-$2/hour)
  - Optional SQL Server Standard ($1.10-3.20/hour)
- Build your own Linux:
  - Install applications starting with someone else's AMI and save it
  - Create an AMI from scratch
One minor thing...

Terminate your instance

⇒

your local data is lost.

Either very good or very bad
Elastic Block Storage

- Mountable storage volumes
  - "On-demand SAN"
  - Size: 1 GB to 1 TB
  - Mount on a single instance
- Create snapshots
  - Stored in S3
  - Create new volumes from the snapshot
- Cost:
  - $0.10/GByte/month
  - $0.10 per 1 million I/O requests
Elastic IP addresses

- Instance IP addresses are dynamically allocated on start-up
  - Does not work well for publicly accessible services, e.g. a website

- Elastic IP addresses:
  - Statically allocated addresses
  - Associated with your account (max. 5)
  - Attached to an instance (e.g. public facing web server)
  - You configure DNS to resolve to the elastic IP address

- Pricing:
  - Non-attached Elastic IP address - $0.01/hour
  - $0.10 per remap (if > 100 in a month)
Regions and availability zones

- By default, your database master and slave could run on the same physical host!

- Regions:
  - Geographically dispersed locations
  - Currently only one

- Availability zone:
  - Part of a region
  - Engineered to be insulated from failure in other zones

- Specify availability zone when launching instances:
  - Same zone as other instances for free data transfer
  - Different zone for higher-availability

- SLA with 99.95% region availability
  - Instances have external connectivity
  - You can launch new instances
What is the Amazon Simple Storage Service (S3)?

- Flat storage model consisting of buckets and objects
  - Bucket – has a name and contains objects
  - Object – has a key, stores 1 byte - 5G
  - Object key can look like a path 😊

- Cost:
  - $0.15/GB-Month
  - $0.10-0.18/GB of data transferred
  - $0.00001-$0.000001/Web Service call
  - Data transfers between EC2 and S3 are free of bandwidth charges

- Buckets and objects can be:
  - Public – accessible by anyone
  - Private – accessible to owner, acl member
S3 REST API

PUT / HTTP/1.1
Host: <BucketName>.s3.amazonaws.com
Authorization: AWS AWSAccessKeyId:Signature

Create a bucket

PUT /<ObjectName> HTTP/1.1
Host: <BucketName>.s3.amazonaws.com
Authorization: AWS AWSAccessKeyId:Signature
...Bytes...

Create an item in a bucket

GET /<ObjectName> HTTP/1.1
Host: <BucketName>.s3.amazonaws.com
Authorization: AWS AWSAccessKeyId:Signature
...

Download an item

DELETE /<ObjectName> HTTP/1.1
Host: <BucketName>.s3.amazonaws.com
Authorization: AWS AWSAccessKeyId:Signature
...

Delete an item
Using EC2 and S3 together

- AMIs are stored in S3
- EC2 instances use S3:
  - Use REST API
  - Store database snapshots in S3
  - Use 3rd party Linux file system that stores data in S3
  - Store EBS volume snapshots in S3
So what does this mean?

- For developers
  - Immediate access to many servers
  - Simplified setup
  - Great for testing

- For deployment
  - Eliminates capital expenses
  - Reduces risk of success catastrophe
Agenda

- Cloud computing with Amazon EC2
- **Using Amazon EC2**
- Overview of Cloud Tools
- Developing on Amazon EC2
- Deploying on Amazon EC2
- A few thoughts about Groovy
Signing up for Amazon Web Services

- AWS access identifiers:
  - Account Id
  - Access Id
  - Secret key
  - Private key and certificate
- Only takes a few minutes
EC2 API and Tools

- SOAP and Query APIs
  - Launch and manage instances etc
- Amazon provided CLI tools
  - CLI equivalents of APIs
  - AMI creation tools
- AWS CLI tools from Tim Kay
  - CLI for S3 and EC2
  - Alternatives to Amazon CLI tools
- ElasticFox
  - Awesome Firefox plugin
  - Launch and manage instances
Using the Query API

- **https://ec2.amazonaws.com/?queryparameters...**

- **Mandatory parameters:**
  - Action – what to do
  - AWSAccessKeyId – your access id
  - Version – API version
  - Timestamp – when request was made
  - Expires – when it expires
  - Signature – digest of parameters and secret key
  - SignatureVersion – set to 1

- Other parameters depend on Action
- Returns an XML document
## Example EC2 requests

<table>
<thead>
<tr>
<th>Action</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>RunInstances</td>
<td>MinCount, MaxCount, ImageId, InstanceType, ...</td>
</tr>
<tr>
<td>TerminateInstances</td>
<td>InstanceId.n</td>
</tr>
<tr>
<td>DescribeInstances</td>
<td>InstanceId.n</td>
</tr>
<tr>
<td>CreateSecurityGroup</td>
<td>GroupName, GroupDescription</td>
</tr>
<tr>
<td>AuthorizeSecurityGroupIngress</td>
<td>GroupName, SourceSecurityGroupName, IpProtocol</td>
</tr>
<tr>
<td>DeauthorizeSecurityGroupIngress</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
aws - simple access to EC2 and S3

- Easy to use CLI for EC2 and S3
- Implemented in Perl
- Authenticates using access id and secret key stored in ~/.awssecret

```bash
$ aws describe-instances
+---------------------------+---------------------------+---------------------------+
| instanceId | imageId | instanceState | launchTime |
+---------------------------+---------------------------+---------------------------+
| i-82728eeb | ami-6f2cc906 | code=48 name=terminated | -02-14T01:42:42.000Z |
| i-85728eec | ami-6f2cc906 | code=48 name=terminated | -02-14T01:42:42.000Z |

$ aws terminate-instances i-42b24c2b
+---------------------------+---------------------------+---------------------------+
| instanceId | shutdownState | previousState |
+---------------------------+---------------------------+---------------------------+
| i-42b24c2b | code=32 name=shutting-down | code=16 name=running |

$ ~
```
ElasticFox—Firefox plugin
Launching instances

TIP: launch with a key pair or else you won't have access
Creating your own image

- Easier: Modify an existing AMI
  - Launch AMI
  - Configure: e.g. yum install ...

- Harder: Build one from scratch
  - Launch AMI
  - Create a file to contain OS installation
  - Mount as a loopback file
  - Install OS: yum --installroot

- Use AMI tools to bundle and upload to S3
Agenda

- Cloud computing with Amazon EC2
- Using Amazon EC2
- Overview of Cloud Tools
- Developing on Amazon EC2
- Deploying on Amazon EC2
- A few thoughts about Groovy
Deploying a web application on EC2

Not rocket science but there are many servers to configure and multiple files to upload
What's Cloud Tools?

- Open source project
- 32 and 64 bit AMIs
  - CentOS 5.10
  - Apache/Tomcat/MySQL/JMeter/JetS3t installed
- EC2Deploy framework
  - Launches instances
  - Configures Tomcat, MySQL, Apache
  - Deploys web applications
  - Runs Jmeter tests
  - Written in Groovy
- Maven and Grails plugins
  - Quick and easy deployment to EC2
EC2Deploy framework

- Provides a DSL for describing a cluster:
  - Number of Tomcats, MySQL slaves
  - Database scripts
  - Location of web applications
- Launches EC2 instances
- Configures MySQL
- Configures Tomcat and deploys web applications
- Configures Apache to proxy the Tomcat servers
- Runs JMeter tests
Example EC2Deploy Script

def ec2 = new EC2(…)

ClusterSpec clusterSpec = new ClusterSpec()
   .tomcats(1)
   .instanceType(EC2InstanceType.SMALL)
   .slaves(1)
   .webApp('/home/cer/…/ptrack', "ptrack")
   .catalinaOptsBuilder({optsBuilder, databaseHost, slaves ->
       optsBuilder.arg("-Xmx500m")
       optsBuilder.prop("jdbc.db.server", databaseHost)})
   .schema("ptrack", ["ptrack": "ptrack"],
       ["src/test/resources/testdml1.sql",
        "src/test/resources/testdml2.sql"])

SimpleCluster cluster = new SimpleCluster(ec2, clusterSpec)

cluster.start()

cluster.loadTest("/home/cer/…/jmeter/SimpleTest.jmx", [5, 10, 15])

cluster.stop()
Domain model

- **ClusterSpec**
  - name
  - numberOfTomcats
  - numberOfMySqlSlaves
  - ...

- **EC2**
  - startPolling()
  - stopPolling()
  - newServers(n)
  -...

- **EC2RequestExecutor**
  - executeRequest(params)

- **EC2Server**
  - waitUntilRunning()
  - stop()
  - ssh(command)
  - ...

- **Ssh**
  - ssh(dns, command, ...)

- **SqlServer**
  - executeQueryAPI()
  - run, terminate and describe instances

- **TomcatServer**
  -...

- **MySqlServer**
  -...

- **Jmeter**
  - loadTest()

- **Application**
  -...
class ApacheServer extends Application {

    def configure() {
        writeFile fileName: "$apacheConfDir/cluster.conf",
            templateName: "templates/cluster.conf",
            templateArgs: [tomcats: tomcats]
        exec "$apacheBinDir/apachectl restart"
        waitForHttp port: 80, path: tomcats[0].contexts[0]
    }

    ...

class MySqlServer extends Application {

    def configureAsMaster() {
        writeFile fileName: "/etc/my.cnf", templateName: "/templates/master.my.cnf"

        restartService "mysqld"

        exec command: "mysql -u root",
            templateName: "/templates/createSchema.sql",
            templateArgs: [schemaSpec: schemaSpec]

        executeSchemaScripts()
    }

}
Efficiently uploading web applications, *etc.*

- **Non-durable disks** = upload the entire web application
  - 20+ MBs of jars, *etc.*
  - Takes a long time (over a DSL connection)
- **Web application consists of:**
  - 90% 3rd party libraries – rarely changing
  - 10% application code and content – only some of it changes
- **Use JetS3t to accelerate uploads**
  - Incremental upload of exploded web application to S3 bucket
  - Incremental download to Tomcat webapps/ directory
  - First upload is slow but subsequent uploads are fast
Maven Plugin

```xml
<plugin>
  <groupId>net.chrisrichardson</groupId>
  <artifactId>cloudtools-maven-plugin</artifactId>
  <configuration>
    <schemaName>ptrack</schemaName>
    <schemaUsers>
      <param>ptrack:ptrack</param>
    </schemaUsers>
    <catalinaOptsBuilder>
      {builder, databasePrivateDnsName ->
        builder.arg("-Xmx1000m")
        builder.prop("jdbc.db.server", databasePrivateDnsName)}
    </catalinaOptsBuilder>
  </configuration>
</plugin>
```

Goals:
- deploy
- redeploy
- stop
- dbsave
- dbrestore
- jmeter

mvn cloudtools:deploy
Grails Plugin

- Packages E2Deploy as a Grails framework plugin
- Deploys a Grails application to EC2

```
$ grails install-plugin <path to plugin>
$ grails cloud-tools-deploy
```
Agenda

- Cloud computing with Amazon EC2
- Using Amazon EC2
- Overview of Cloud Tools
- Developing on Amazon EC2
- Deploying on Amazon EC2
- A few thoughts about Groovy
Collecting performance metrics

Measure transactions/second (TPS), average response time (ART), utilization, etc.

Multiple test runs with different loads, number of servers, etc.

Requires hardware
Time consuming
Load testing with Cloud Tools

- Runs JMeter with specified number of threads
- Collects machine utilization stats
- Generates reports
- Executes multiple test runs simultaneously

```
<performanceReport>
  <cpus>1</cpus>
  <threads>10</threads>
  <host>
    <name>database</name>
    <cpuUtil>3.2757014224403784</cpuUtil>
  </host>
  <host>
    <name>tomcat0</name>
    <cpuUtil>94.32473318917411</cpuUtil>
  </host>
  <host>
    <name>apache</name>
    <cpuUtil>0.12280614752518504</cpuUtil>
  </host>
  <host>
    <name>jmeter</name>
    <cpuUtil>7.033683910704496</cpuUtil>
  </host>
  ...
  <duration>557.943</duration>
  <tps>10.753786677133686</tps>
  <art>916.6578333333</art>
</performanceReport>
```

`mvn cloudtools:jmeter -Dcloudtools.thread.count=1,4,8`
Other kinds of testing

- Testing failover
  - Launch cluster
  - Take down servers
  - Test recovery scripts, e.g. MySQL slave->master

- Testing database upgrades
  - Launch cluster
  - Install snapshot of production data
  - Apply database migration script
  - Verify that it works
Functional testing

- Tests can be slow, *e.g.*
  - Web tests
  - Database intensive tests
- Run tests in parallel on EC2
  - Multiple test drivers, app servers, DBs
  - Relatively cheap: >$75/hour developer vs. $0.10/hour machine
- Selenium Grid from Thoughtworks
  - Open Source framework
  - Runs Selenium web tests in parallel on EC2
- Stay tuned for more general solutions
Building on a fresh machine

- Debug builds that fail because of a missing dependency
  - Maven dependency
  - Manually installed 3rd party library
- Build on a fresh EC2 instance
- Great for open-source projects
Agenda

- Cloud computing with Amazon EC2
- Using Amazon EC2
- Overview of Cloud Tools
- Developing on Amazon EC2
- **Deploying on Amazon EC2**
- A few thoughts about Groovy
Deploying applications on Amazon EC2

- Great for startups (especially those without a business model)
  - Get up and running ready quickly
  - No upfront hardware costs
  - Scale up/down with load
  - Reduces the risk of a success catastrophe
- Great for enterprises
  - No need to wait for corporate IT
  - Use for short-term projects

[Cloud Computing Survey: IT Leaders See Big Promise, Have Big Security Questions](http://www.cio.com/article/455832/Cloud_Computing_Survey_IT_Leaders_See_Big_Promise_Have_Big_Security_Questions)
Issues with AWS

- **Security:**
  - Lack of PCI compliance
  - Discomfort with sending customer data to a 3rd party

- **Technology:**
  - Not yet suitable for extremely large relational databases
  - Lack of very large machines, *e.g.* 64G memory
  - Lack of multicast

- **Financials:**
  - Cost of bandwidth
  - Steady state costs > your own hardware

---

**Greatest Concerns Surrounding Cloud Adoption at Your Company**

<table>
<thead>
<tr>
<th>Concern</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security</td>
<td>45%</td>
</tr>
<tr>
<td>Integration with existing systems</td>
<td>26%</td>
</tr>
<tr>
<td>Loss of control over data</td>
<td>26%</td>
</tr>
<tr>
<td>Availability concerns</td>
<td>25%</td>
</tr>
<tr>
<td>Performance issues</td>
<td>24%</td>
</tr>
<tr>
<td>IT governance issues</td>
<td>19%</td>
</tr>
<tr>
<td>Regulatory/compliance concerns</td>
<td>19%</td>
</tr>
<tr>
<td>Dissatisfaction with vendor offerings/pricing</td>
<td>12%</td>
</tr>
<tr>
<td>Ability to bring systems back in-house</td>
<td>11%</td>
</tr>
<tr>
<td>Lack of customization opportunities</td>
<td>11%</td>
</tr>
<tr>
<td>Measuring ROI</td>
<td>11%</td>
</tr>
<tr>
<td>Not sure</td>
<td>7%</td>
</tr>
<tr>
<td>Other</td>
<td>6%</td>
</tr>
</tbody>
</table>

*Respondents selected up to three criteria.
SOURCE: CIO Research
Starter website - $
Highly available - $$

www.acme.com

Elastic IP A

Availability Zone A

Apache

Tomcat

MySQL (Master)

EBS Volume

Elastic IP B

Availability Zone B

Apache

Tomcat

MySQL (slave)
Batch processing architecture

- Inbound Queue (Simple Queuing Service)
- EC2 Instance
- EC2 Instance
- Outbound queue
- S3/SimpleDB

E.g. media transcoding
Easy upgrades

- Clone production environment
- Apply upgrades
- Terminate old instances once you are sure that everything works
Cloud bursting

- Host application on your own hardware
- Use AWS for short-term spikes
  - *e.g.* use EC2 instances with slave DBs to handle read-only requests
- Periodic batch jobs
  - *e.g.* content rendering/transformation
Using AWS in your application

- **Simple Storage Service (S3)**
  - Stores blobs of data
  - e.g. Photo sharing website
  - Store media
  - Hand out URLs to S3 objects

- **Simple Queue Service (SQS)**
  - Hosted queue-based messaging system
  - Alternative to JMS
  - Loosely coupling between systems

- **SimpleDB**
  - Store data sets
  - Execute queries
Java libraries for AWS

- JetS3t
  - Rich API for accessing S3
  - [https://jets3t.dev.java.net/](https://jets3t.dev.java.net/)

- Typica
  - API for SQS, EC2, SimpleDB
  - [http://code.google.com/p/typica](http://code.google.com/p/typica)

- SimpleJPA
  - Subset of JPA on Simple DB
  - [http://code.google.com/p/simplejpa](http://code.google.com/p/simplejpa)
Agenda

- Cloud computing with Amazon EC2
- Using Amazon EC2
- Overview of Cloud Tools
- Developing on Amazon EC2
- Deploying on Amazon EC2
- A few thoughts about Groovy
About Groovy

- Object-oriented, dynamic language
- Java compatible
- Runs on the JVM
Getting Groovy code to work can be frustrating

- Dynamic language = less information for IDE:
  - Limited compile-time checking
  - Limited refactorings
  - Limited completion
Groovy fans say "write unit tests"

BUT...

groovy.lang.MissingMethodException: No signature of method: net.chrisrichardson.ec2deployer.core.EC2RequestExecutor.executeRequest()
at org.codehaus.groovy.runtime.ScriptBytecodeAdapter.unwrap(ScriptBytecodeAdapter.java:53)
at org.codehaus.groovy.runtime.ScriptBytecodeAdapter.unwrap(ScriptBytecodeAdapter.java:53)
at org.codehaus.groovy.runtime.ScriptBytecodeAdapter.invokeMethodN(ScriptBytecodeAdapter.java:167)
at net.chrisrichardson.ec2deployer.core.EC2RequestExecutor.invokeMethod(EC2RequestExecutor.java)
at org.codehaus.groovy.runtime.Invoker.invokePogoMethod(Invoker.java:103)
at org.codehaus.groovy.runtime.Invoker.invokeMethod(Invoker.java:72)
at org.codehaus.groovy.runtime.InvokerHelper.invokeMethod(InvokerHelper.java:66)
at org.codehaus.groovy.runtime.ScriptBytecodeAdapter.invokeMethodN(ScriptBytecodeAdapter.java:166)
at net.chrisrichardson.ec2deployer.core.EC2.newServers(EC2.groovy:46)
at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:39)
at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:26)

When you have typos

public void add(Project project) {
    getHibernateTemplate().save(project);
}

public Project get(String id) {
    Project project = (Project...)

    // Change to 'save(..)'
    // Add cast to method receiver
    // Rename in file (Ctrl+2, R direct access)
Unit tests don't always catch errors

```java
class EC2RequestExecutor {
    public Node executeRequest(Map parameters) {
        ...
    }
}

public class EC2 {
    public pollStatus() {
        def params = ['Action': 'DescribeInstances']
        def p = requestor.executeRequest(params)
    }
}

public class EC2 {
    public pollStatus() {
        def params = ['Action': 'DescribeInstances']
        def p = requestor.executeRequest(params)
    }
}
```

Same typo in test and in code
Things I like: Java compatible

```java
import javax.crypto.Mac;
import javax.crypto.spec.SecretKeySpec;

class EC2RequestExecutor {
    Log logger = LogFactory.getLog(getClass())

    public String calculateRFC2104HMAC(String data, String key) {
        try {
            SecretKeySpec signingKey = new SecretKeySpec(key.getBytes("UTF8"),
            HMAC_SHA1_ALGORITHM)
            Mac mac = Mac.getInstance(HMAC_SHA1_ALGORITHM)
            mac.init(signingKey)
            byte[] rawHmac = mac.doFinal(data.getBytes())
            return new String(Base64.encodeBase64(rawHmac))
        }
        catch (Exception e) {
            throw new RuntimeException("Failed to generate HMAC : ", e)
        }
    }
}
```

Java-like syntax
Use Java libraries
Groovy is concise and expressive

def configureAsMaster() {
    writeFile fileName: "~/etc/my.cnf", templateName: "~/templates/master.my.cnf"
    
    restartService "mysqld"
    
    exec command: "mysql -u root",
    
    templateName: "~/templates/createSchema.sql",
    
    templateArgs: [schemaSpec: schemaSpec]
    
    executeSchemaScripts()
}

class TomcatServer {
    def getContexts() {
        webApps.context
    }
}

tomcatServer.contexts

No parens

Keyword parameters

No get...()
Closures

def sortServers(servers) {
    servers.sort {a, b -> a.instanceId <=> b.instanceId}
}

public EC2Server findInstance(String instanceId) {
    def server = servers.find {instanceId == it.instanceId}
    if (server)
        return server
    else
        throw new RuntimeException(....)
}
XML and GPath expressions

```java
def client = new HttpClient()
...
def responseStream =
getMethod.getResponseBodyAsStream()
def parser = new XmlParser(false, false)
def response = parser.parseText(responseStream)

def newServers = response.instancesSet.item.collect {
    new EC2Server(this, awsProperties, ssh,
    it.instanceId[0].text(),
    it.instanceState[0].children()[1].value()[0])
}
```
GStrings and templates

```groovy
def schemaScript = ""
    DROP SCHEMA IF EXISTS ${schemaSpec.name};
    CREATE SCHEMA ${schemaSpec.name};
""

String process(String templateName, Map params) {
    InputStream stream = getClass().getResourceAsStream(templateName)
    def engine = new groovy.text.SimpleTemplateEngine()
    engine.createTemplate(new InputStreamReader(stream)).make(params).toString()
}

...<% contexts.each {%>ProxyPass /$it balancer://mycluster/$it stickysession=jsessionid<%}%>
<Proxy balancer://mycluster>
<% tomcats.each {%>BalancerMember ajp://${it.hostPrivateDnsName}:8009 route=${it.jvmRoute} min=1 keepalive=On retry=5
<% }<%>
...""
def report(String path, hosts, cpuCount, threadCount) {
    def builder = new groovy.xml.MarkupBuilder(new OutputStreamWriter(new FileOutputStream(path)))
    builder.performanceReport {
        cpus cpuCount
        threads threadCount
        hosts.entrySet().each { hostEntry ->
            host {
                name hostEntry.key
                cpuUtil hostEntry.value.getAverageBusy()
            }
        }
        requests {
            timings.entrySet().sort { a, b -> a.key <=> b.key }.each { pair ->
                request {
                    name pair.key
                    art pair.value.average()
                    errors pair.value.errorPercentage()
                }
            }
        }
        def durationValue = ((float)(endTime - startTime))/1000.0
        duration durationValue
        def tpsValue = transactionCount/ durationValue
        tps tpsValue
        art averageResponseTime()
    }
}
Summary

- Cloud Computing
  - Immediate access to many servers
  - Pay as you go – no upfront investment/commitment required
  - Easily scale up/down

- Cloud Tools
  - Easy deployment and testing from Maven and Grails
  - Configure multiple clusters
  - Run JMeter tests in parallel

- Using Groovy
  - Has some nice features
  - Dynamic language features are double-edged sword
  - We need better statically typed languages
Final thoughts

- Download Cloud Tools today:
  http://code.google.com/p/cloudtools

- Buy my book 😊

- Send email:
  chris@chrisrichardson.net

- Visit my website:
  http://www.chrisrichardson.net

- Talk to me about consulting and training