APACHECON
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APRIL 7-9, 2014

Monitoring Tomcat with JMX

Presented For The Apache Foundation By
LINUX FOUNDATION

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Total Child Health, Inc.

* Slides available on the Linux Foundation / ApacheCon2014 web site and at http://people.apache.org/~schultz/ApacheCon NA 2014/Tomcat Monitoring/

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Java Management Extensions

- Protocol and API for managing and monitoring
  - Access data via JMX “Mbeans”
  - Read and write bean attributes
  - Invoke operations
  - Receive notifications
- JVM exposes certain status
- Tomcat exposes certain status

Monitoring JVM

- Heap status
- Total, free, used memory
- Garbage collection
- GC pause times

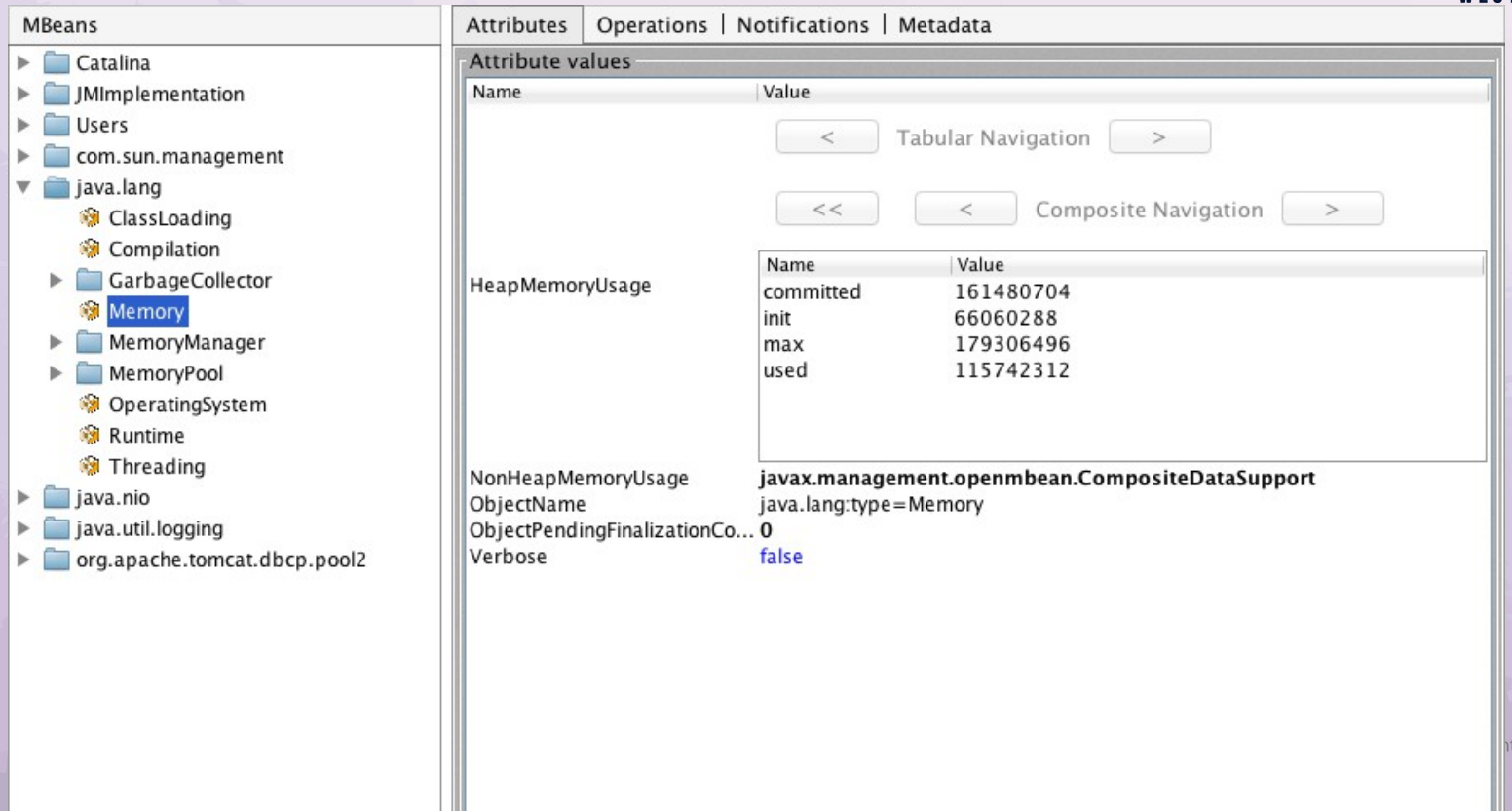
Monitoring Tomcat

- Status of connector
- Status of request-processor thread pool
- Status of data sources
- Request performance

JMX Tools

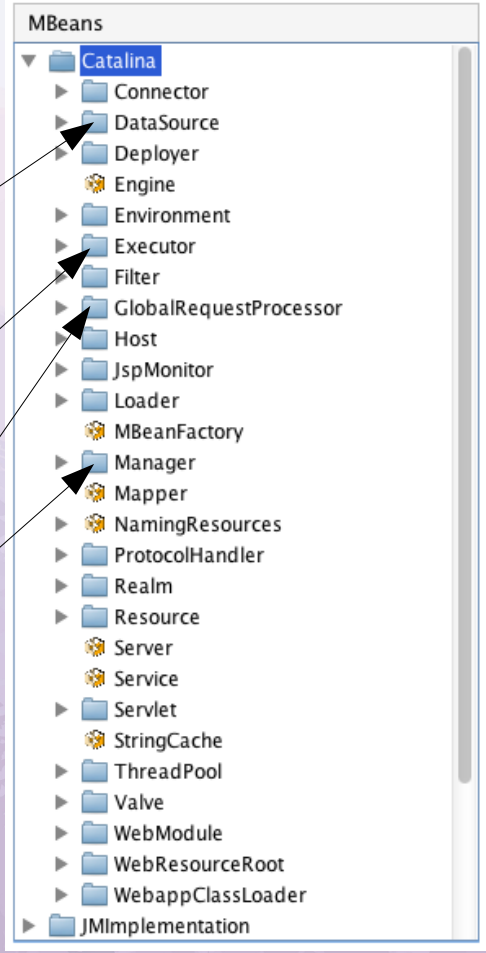
- jconsole (JDK)
- VisualVM (JDK, app bundle)
- Most profilers (e.g. YourKit, etc.)
- Custom tools using javax.management A

Monitoring JVM: Heap



Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information



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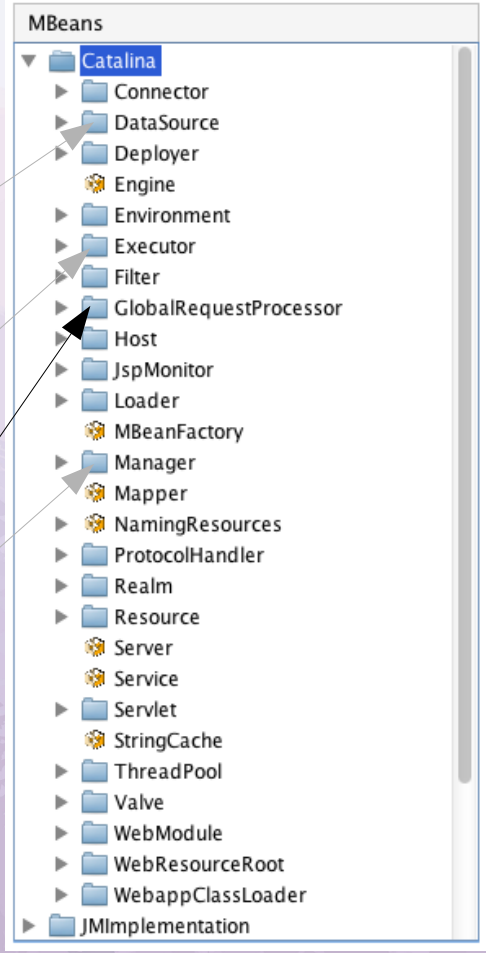


Monitoring Tomcat: Requests

MBeans

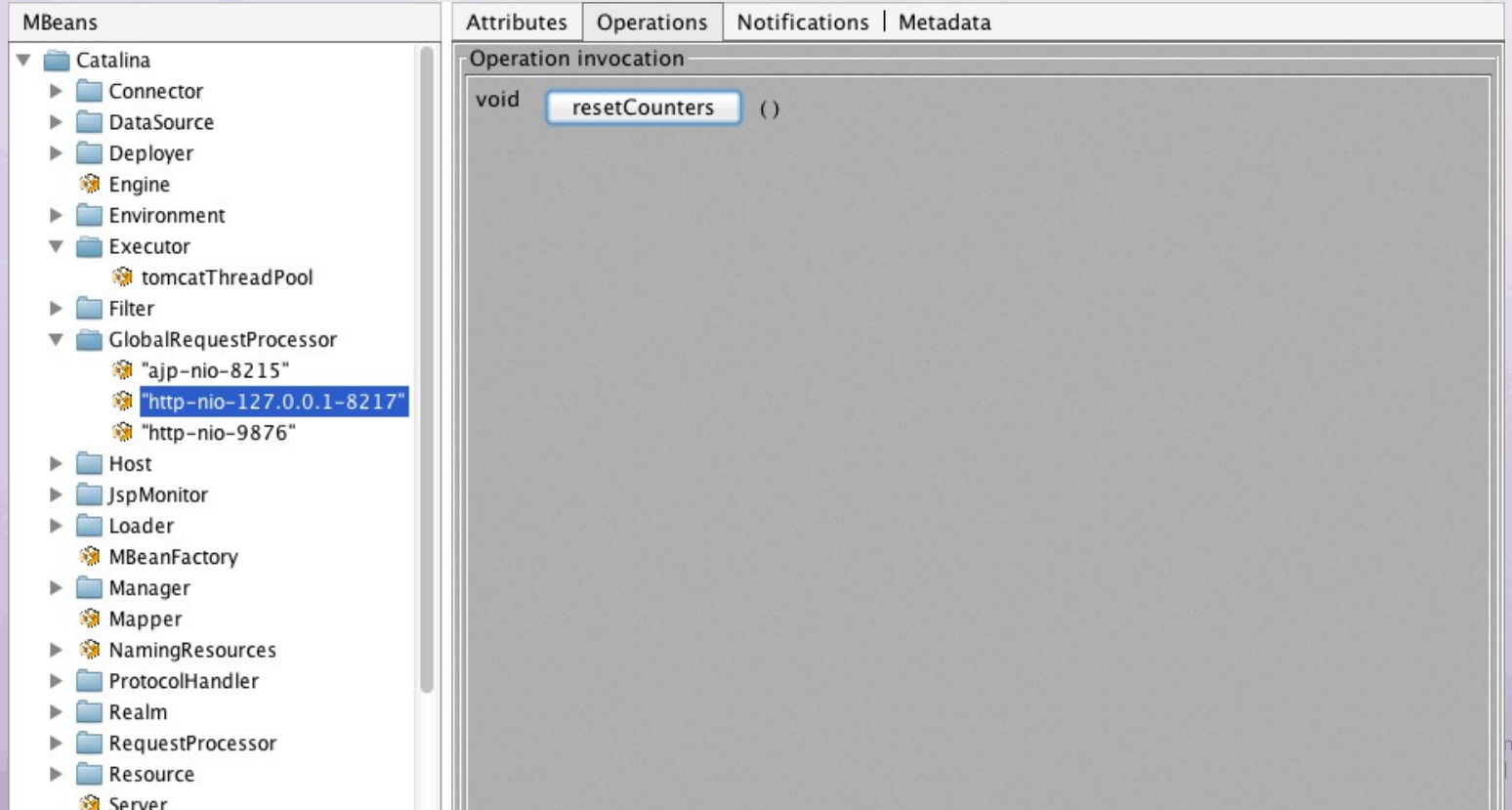
- Catalina
  - Connector
  - DataSource
  - Deployer
  - Engine
  - Environment
  - Executor
    - tomcatThreadPool
  - Filter
  - GlobalRequestProcessor
    - "ajp-nio-8215"
    - "http-nio-127.0.0.1-8217"
    - "http-nio-9876"
  - Host
  - JspMonitor
  - Loader
  - MBeanFactory
  - Manager
  - Mapper
  - NamingResources
  - ProtocolHandler
  - Realm
  - RequestProcessor
  - Resource
  - Server

Attributes | Operations | Notifications | Metadata

Attribute values

Name	Value
bytesReceived	0
bytesSent	5846954488
errorCount	0
maxTime	824
modelerType	org.apache.coyote.RequestGroupInfo
processingTime	1046463
requestCount	5192453

Monitoring Tomcat: Requests



Monitoring Tomcat: Requests

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Attributes | Operations | Notifications | Metadata

Attribute values

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bytesSent	0
errorCount	0
maxTime	0
modelerType	org.apache.coyote.RequestGroupInfo
processingTime	0
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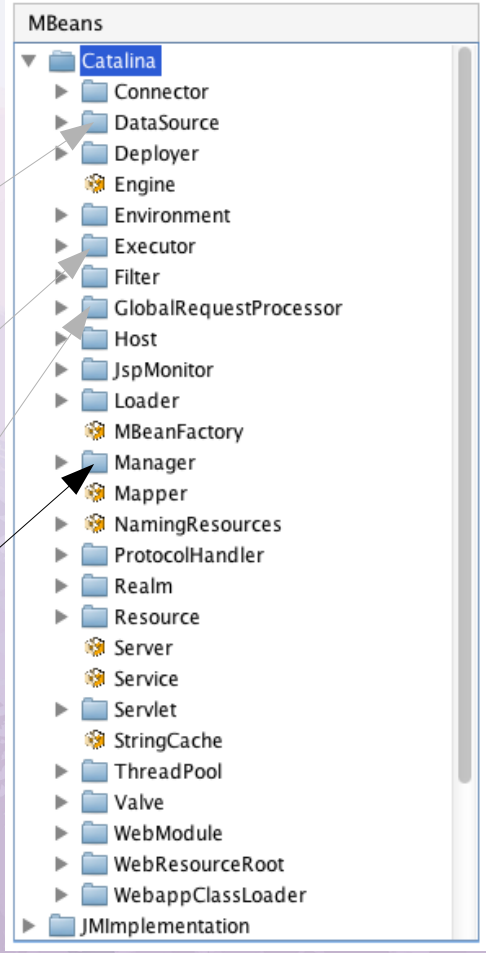
Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information



Monitoring Tomcat: Sessions

MBeans

- Catalina
  - Connector
  - Deployer
  - Engine
  - Environment
  - Executor
  - Filter
  - GlobalRequestProcessor
  - Host
  - JspMonitor
  - Loader
  - MBeanFactory
  - Manager
    - localhost
      - /
      - /examples
      - /manager
  - Mapper
  - NamingResources
  - ProtocolHandler
  - Realm
  - RequestProcessor
  - Resource
  - Server
  - Service

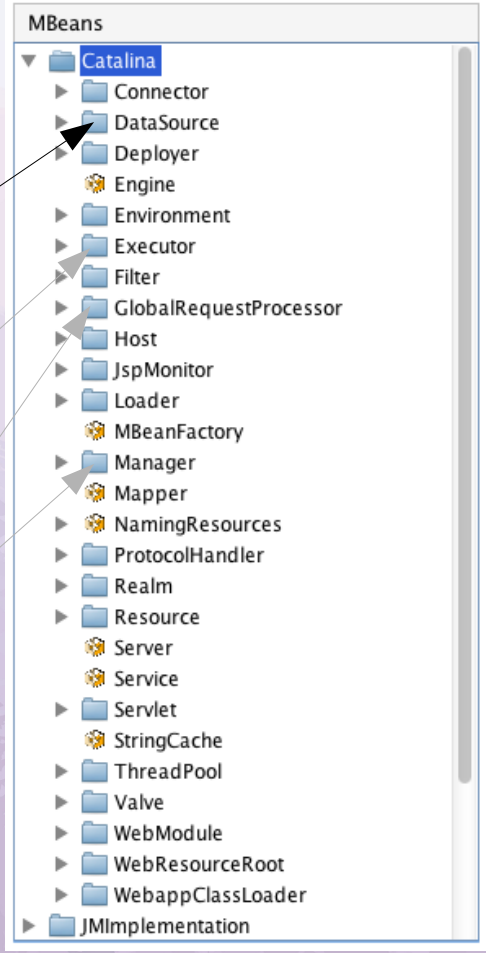
Attributes | Operations | Notifications | Metadata

Attribute values

Name	Value
activeSessions	0
className	org.apache.catalina.session.StandardManager
distributable	false
duplicates	0
expiredSessions	99
jvmRoute	
maxActive	99
maxActiveSessions	-1
maxInactiveInterval	1800
modelerType	org.apache.catalina.session.StandardManager
name	StandardManager
pathname	SESSIONS.ser
processExpiresFrequency	6
processingTime	1
rejectedSessions	0
secureRandomAlgorithm	SHA1PRNG
secureRandomClass	
secureRandomProvider	
sessionAverageAliveTime	1
sessionCounter	99
sessionCreateRate	6
sessionExpireRate	9
sessionIdLength	16
sessionMaxAliveTime	219
stateName	STARTED

Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information



Monitoring Tomcat: DataSources

MBeans

- Catalina
  - Connector
  - DataSource
    - localhost
      - /examples
        - javax.sql.DataSource
          - "jdbc/MyDataSource"
  - Deployer
  - Engine
  - Environment
  - Executor
  - Filter
  - GlobalRequestProcessor
  - Host
  - JspMonitor
  - Loader
  - MBeanFactory
  - Manager
  - Mapper
  - NamingResources
  - ProtocolHandler
  - Realm
  - Resource
  - Server
  - Service

Attributes | Operations | Notifications | Metadata

Attribute values

Name	Value
defaultTransactionIsolation	-1
driverClassName	com.mysql.jdbc.Driver
enableAutoCommitOnReturn	true
evictionPolicyClassName	org.apache.tomcat.dbcp.pool2.impl.DefaultEvicti...
initialSize	1
jmxName	Catalina:type=DataSource,host=localhost,context...
lifo	true
logAbandoned	true
loginTimeout	Unavailable
maxConnLifetimeMillis	-1
maxIdle	1
maxOpenPreparedStatements	-1
maxTotal	1
maxWaitMillis	10000
minEvictableIdleTimeMillis	1800000
minIdle	0
modelerType	org.apache.tomcat.dbcp.dbcp2.BasicDataSource
numActive	0
numIdle	1
numTestsPerEvictionRun	3
password	
poolPreparedStatements	false
removeAbandonedOnBorrow	false
removeAbandonedOnMaintenance	false
removeAbandonedTimeout	30
rollbackOnReturn	true
softMinEvictableIdleTimeMillis	-1

Monitoring Tomcat

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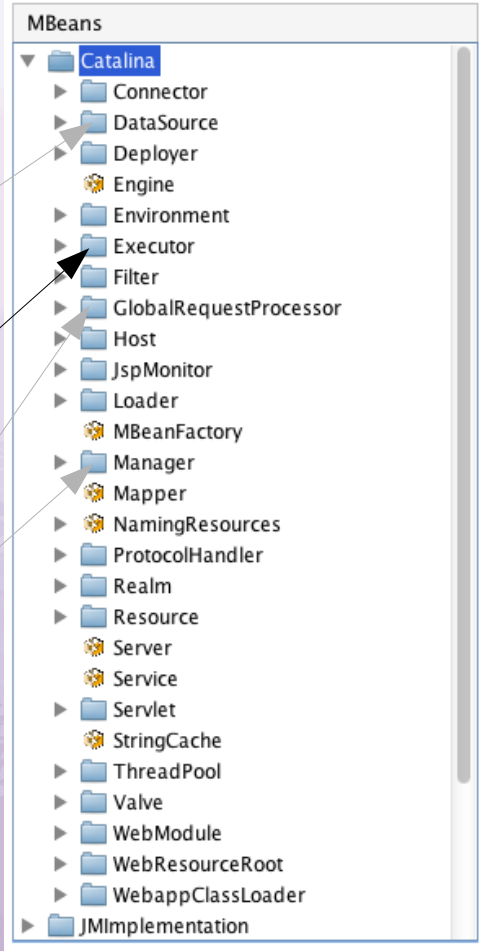
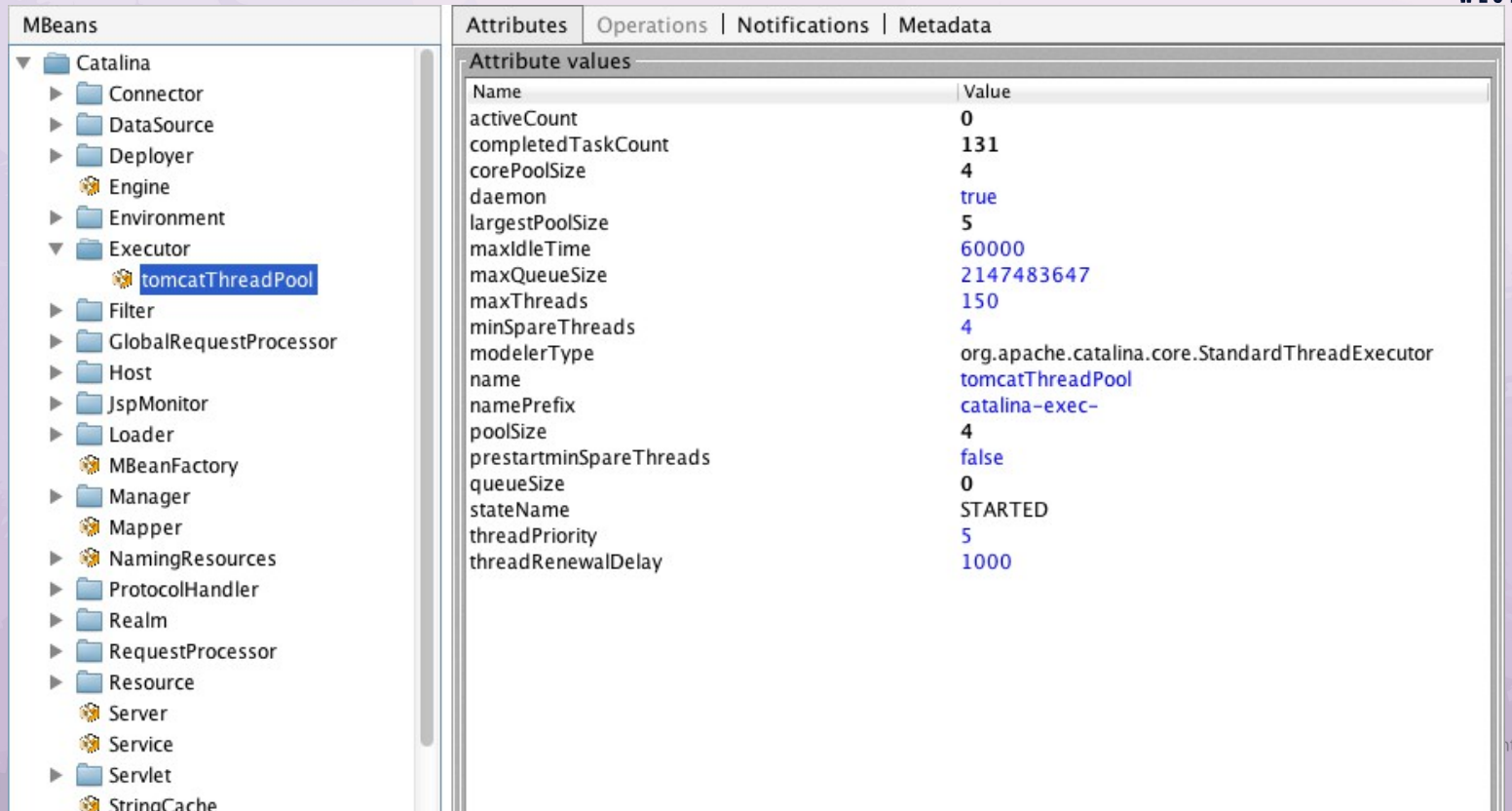
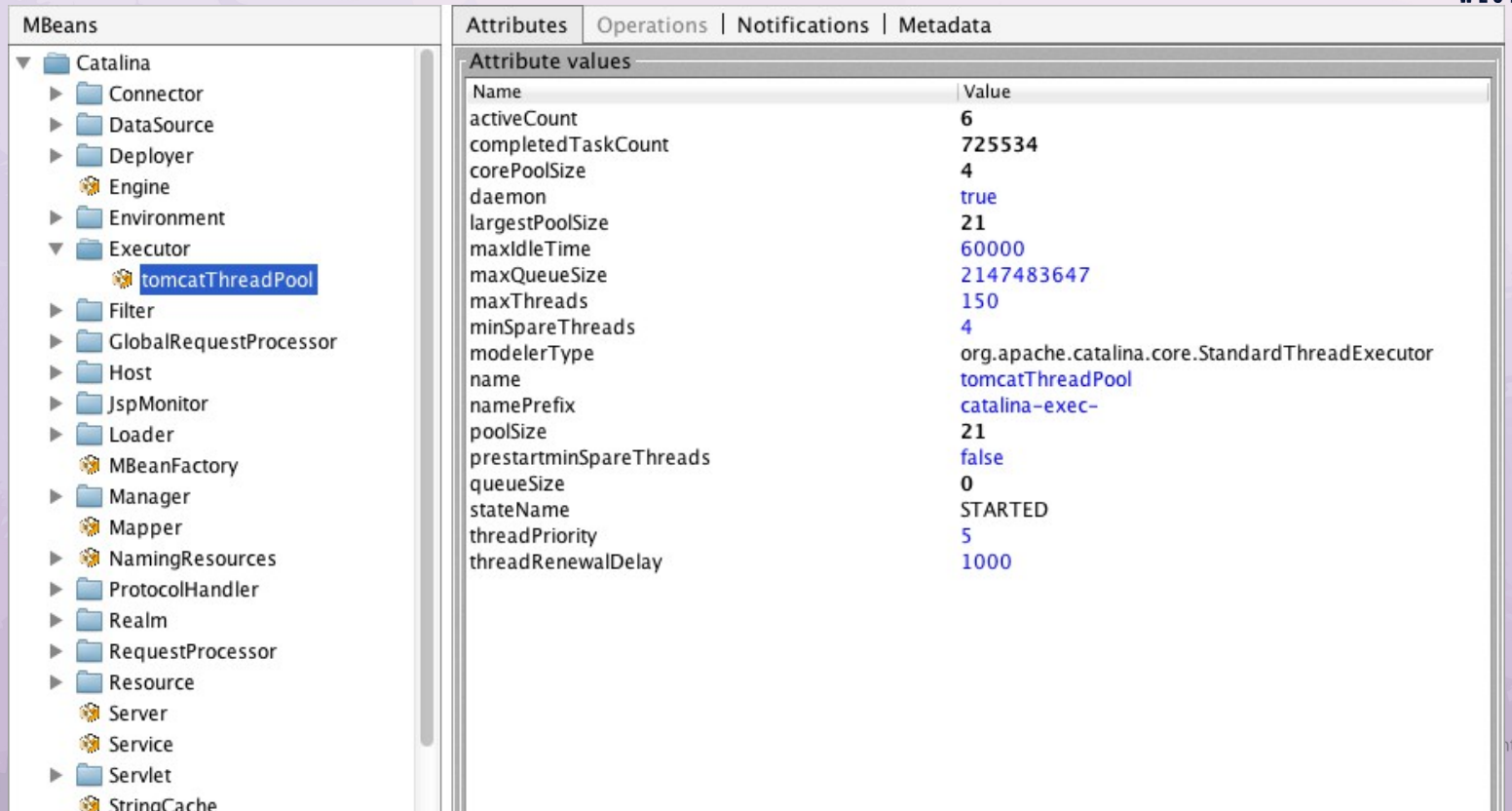


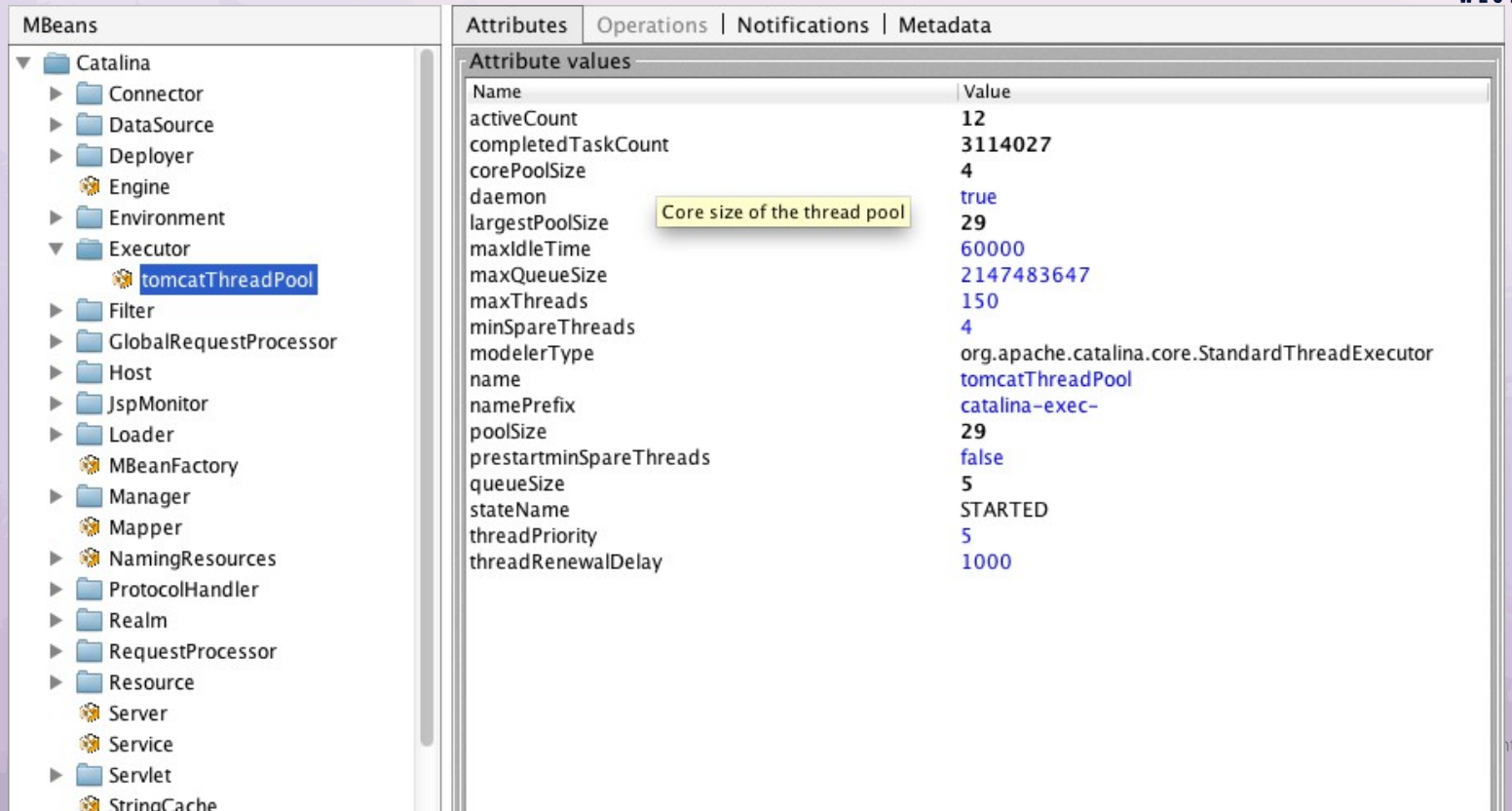
Monitoring Tomcat: Threads



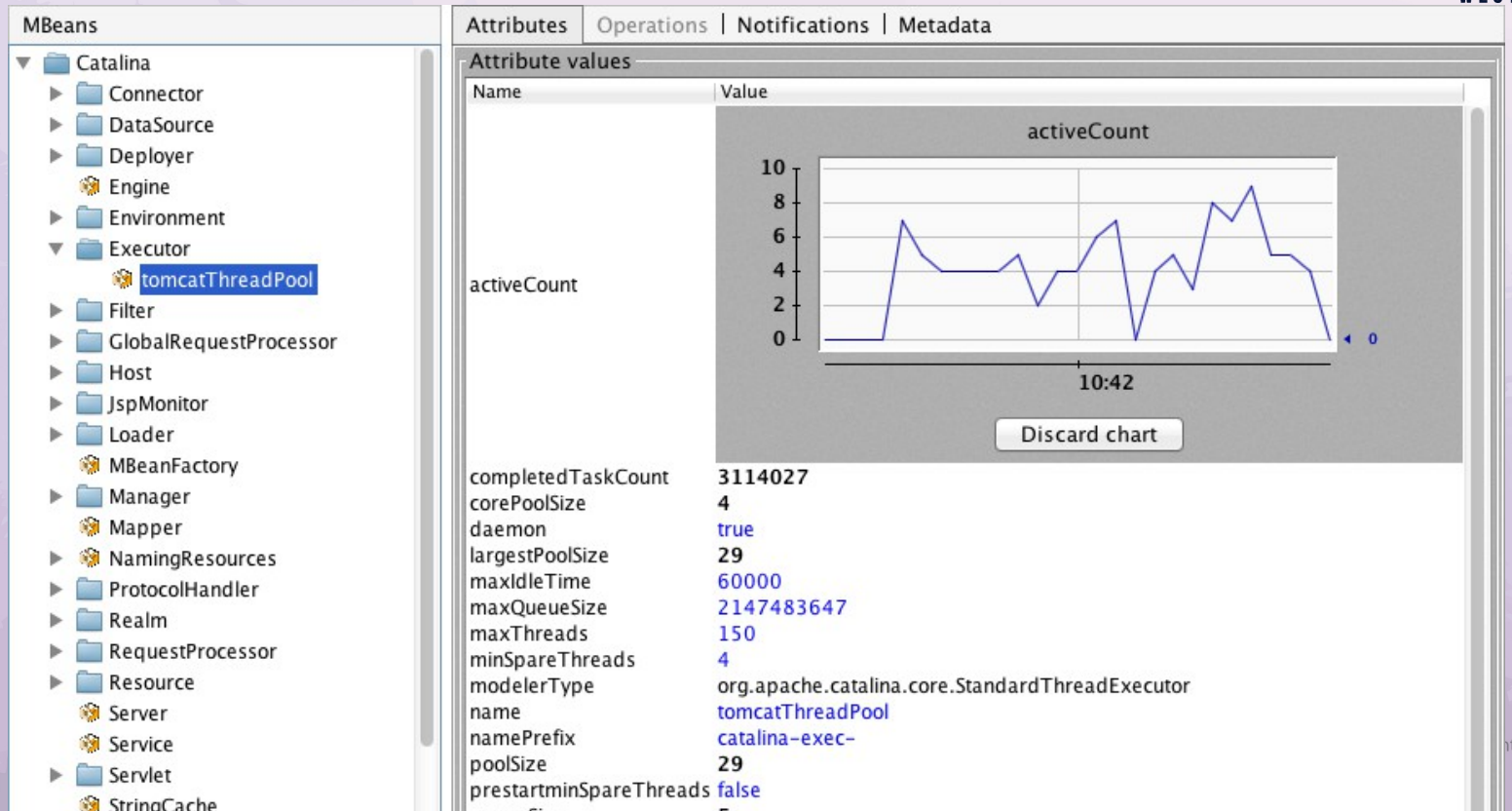
Monitoring Tomcat: Threads



Monitoring Tomcat: Threads



Monitoring Tomcat: Threads



Monitoring Your Application

- Monitor Application Processes
- Performance Metrics
- On-the-fly re-configuration

Monitoring Your Application

- Write an MBean
  - Create an Interface: FooMBean
  - Create an Implementation: Foo
  - Create an XML MBean descriptor
- Deploy package to Tomcat
  - Publish the MBean to the MBean server
- Query / invoke as necessary

* Example code will be available at
http://people.apache.org/~schultz/ApacheCon NA 2014/Tomcat Monitoring/

Example MBean

- Servlet Filter that captures total request processing time
  - Timestamp prior to request
  - Timestamp after request
  - Add the delta to a JMX-accessible counter: RequestStats

RequestStats MBean

- Write an MBean

```
public interface RequestStatsMBean {
    public long getProcessingTime();
    public long getRequestCount();
    public void resetCounters();
}
public class RequestStats
    implements RequestStatsMBean {
    [...]
    public void updateStats(long
timestamp, ServletRequest request, long
elapsed) {

_totalElapsedTime.addAndGet(elapsed);

_requestCount.incrementAndGet();
    }
```

```
 public long getProcessingTime(){
   return _totalElapsedTime.get();
 }
 public long getRequestCount() {
   return _requestCount.get();
 }
 public void resetCounters() {
   _totalElapsedTime.set(0l);
   _requestCount.set(0l);
  }
}
```

RequestStats MBean

- Write an MBean descriptor

```
<mbeans-descriptors>
  <mbean name="RequestStats" ...>
    <operation name="getProcessingTime"
        description="Gets the total number of
milliseconds spent processing requests."
             impact="INFO"
         returnType="long" />
    <operation name="getRequestCount"
        description="Gets the total number
of requests processed."
             impact="INFO"
         returnType="long" />
    <operation
          name="resetCounters"
   description="Resets all
counters."
        impact="ACTION"
    returnType="void" />
  </mbean>
</mbeans-descriptors>
```

RequestStats MBean

- Create JAR
  - Java interface
  - Java implementation
  - mbeans-descriptors.xml
- Put JAR into CATALINA_BASE/lib

RequestStats MBean

- Write the Filter

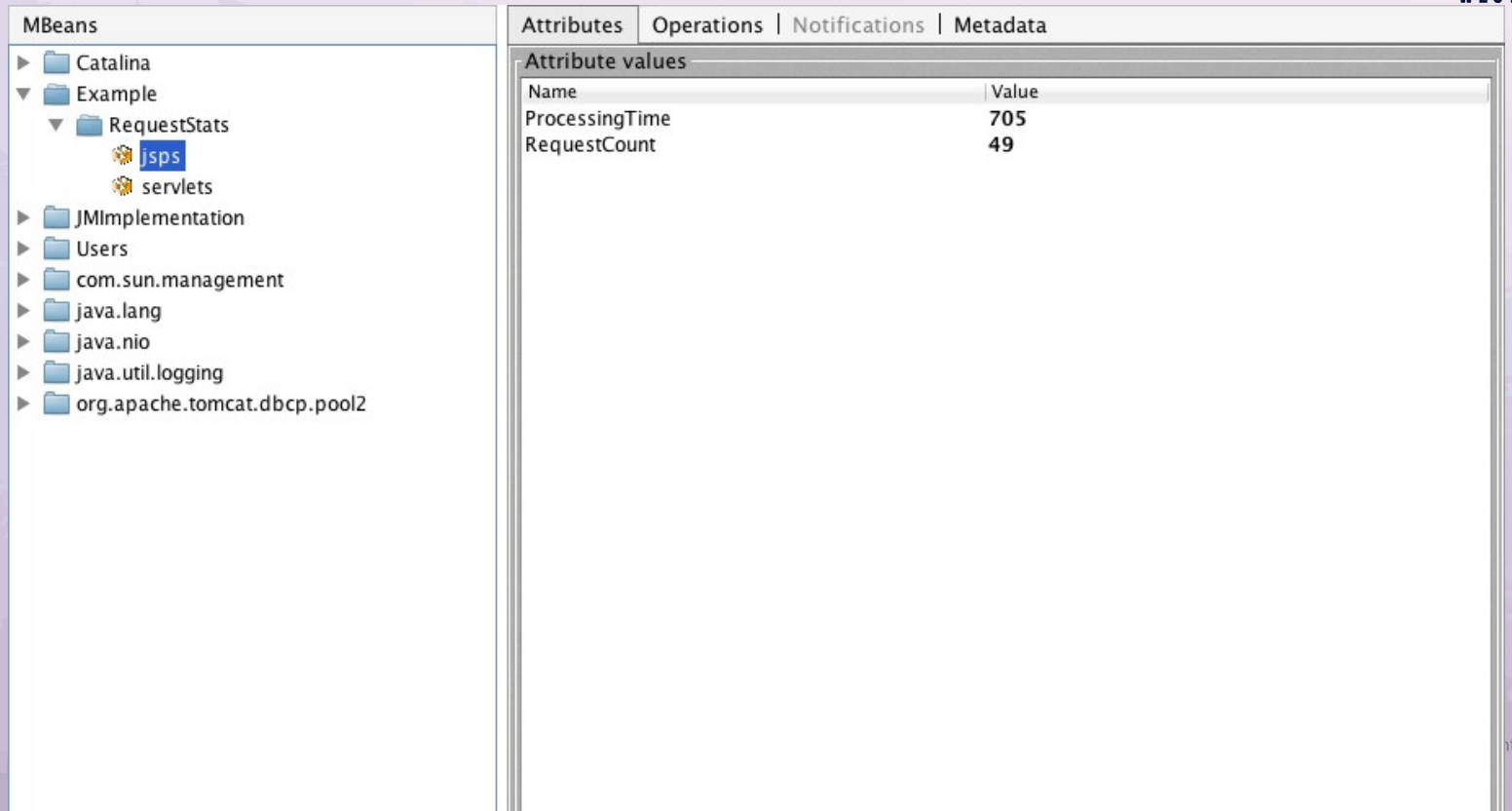
```
 public void init(FilterConfig config) {
    MBeanServer server = getServer();
    server.registerMBean(_stats, new
ObjectName("Example:RequestStats=RequestStats,name=" + filterName;));
  }
  public void doFilter(...) {
    timestamp = elapsed = System.currentTimeMillis();
    chain.doFilter(request, response);
    elapsed = System.currentTimeMillis() - elapsed;

    _stats.updateStats(timestamp, request, elapsed);
  }
```

RequestStats MBean

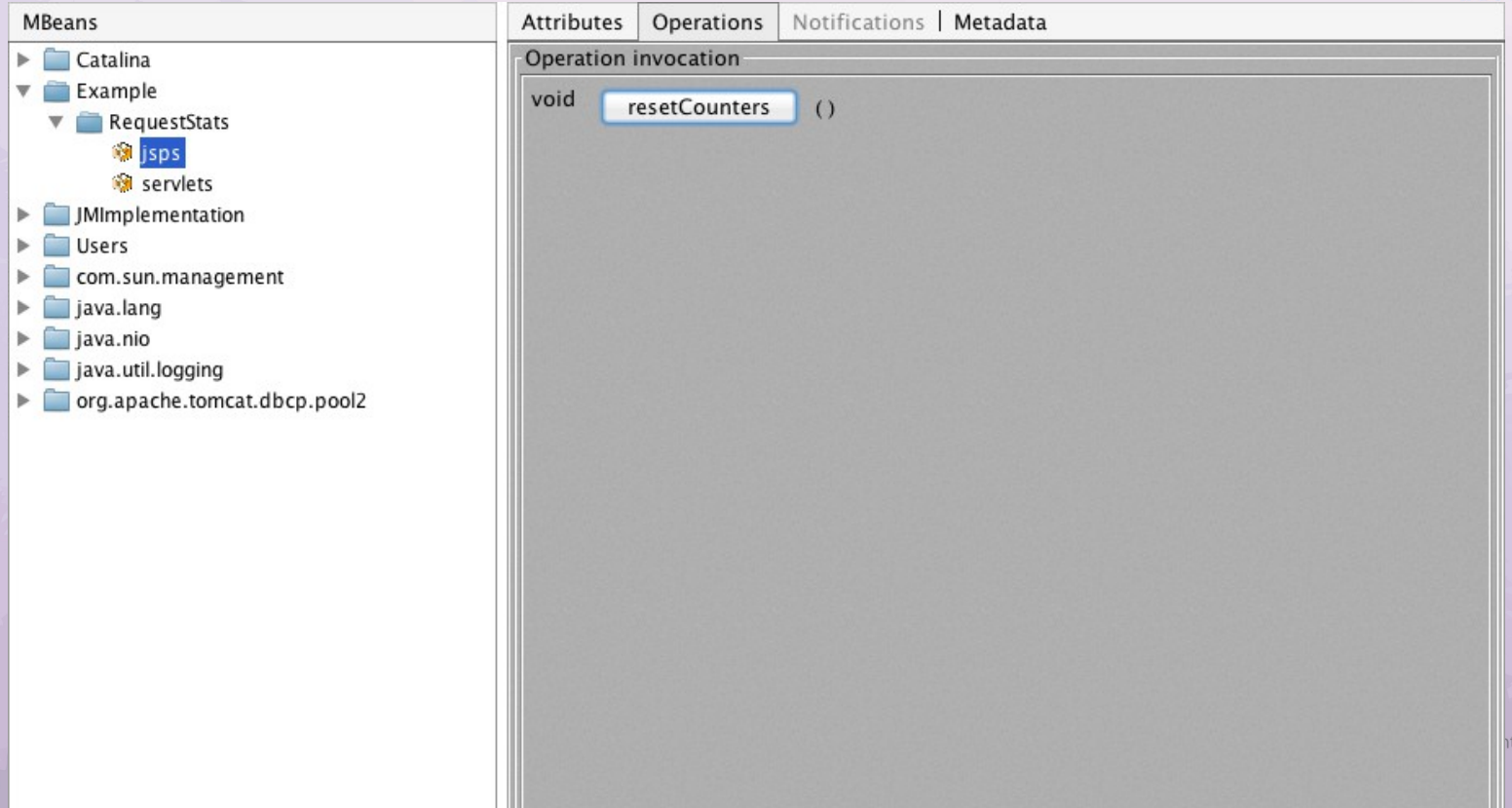
- Map the Filter

```
<filter>
  <filter-name>servlet-request-stats</filter-name>
  <filter-class>filters.RequestStatsFilter</filter-class>
  <init-param>
    <param-name>name</param-name>
    <param-value>servlets</param-value>
  </init-param>
</filter>
<filter-mapping>
  <filter-name>servlet-request-stats</filter-name>
  <url-pattern>/servlets/*</url-pattern>
</filter-mapping>
<filter><filter-name>jsp-request-stats</filter-name><filter-
class>filters.RequestStatsFilter</filter-class><init-param><param-name>name</param-
name><param-value>jsps</param-value></init-param></filter>
<filter-mapping><filter-name>jsp-request-stats</filter-name><url-pattern>/jsp/*</url-
pattern></filter-mapping>
```

RequestStats MBean



RequestStats MBean



Automated Monitoring

- Remote Access
- Large Scale
- Constant

Automated Monitoring

- Remote Access
- Large Scale
- Constant
- Need more tools!

Automated Monitoring

- Nagios
  - Simple
  - Flexible
  - Well-deployed
  - No-cost community version available

Automated Monitoring

Host	Service	Status	Last Check	Duration	Attempt	Status Information
abi.apache.org	SSH	OK	2014-03-18 15:12:04	1d 16h 22m 57s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
aegis.apache.org	HTTP - Buildbot	OK	2014-03-18 15:13:43	9d 12h 56m 18s	1/10	HTTP OK HTTP/1.1 200 OK - 22230 bytes in 0.642 seconds
	HTTPS - Jenkins	OK	2014-03-18 15:14:43	0d 23h 25m 18s	1/10	HTTP OK HTTP/1.1 200 OK - 22230 bytes in 0.830 seconds
	SSH	OK	2014-03-18 15:14:14	9d 0h 25m 47s	1/10	SSH OK - OpenSSH_5.9p1 Debian-5ubuntu1.1 (protocol 2.0)
analysis-vm.apache.org	SSH	OK	2014-03-18 15:12:43	4d 12h 32m 18s	1/10	SSH OK - OpenSSH_5.9p1 Debian-5ubuntu1.1 (protocol 2.0)
any.no-ip.com	DNS	OK	2014-03-18 15:11:42	24d 19h 28m 22s	1/10	DNS OK: 0.023 seconds response time. www.apache.org returns 140.211.11.131,192.87.106.229
arcas.apache.org	SSH	OK	2014-03-18 15:14:48	19d 7h 40m 14s	1/10	SSH OK - OpenSSH_5.9p1 Debian-20120710asf3 (protocol 2.0)
athena.apache.org	DNS	OK	2014-03-18 15:14:23	9d 0h 25m 38s	1/10	DNS OK: 0.172 seconds response time. svn.geo.apache.org returns 160.45.251.2
	GEODNS	OK	2014-03-18 15:14:14	12d 17h 10m 47s	1/10	OK DNS server 140.211.11.136 geo.apache.org is in sync with the zone file held in SVN (SERIAL in SVN: [2013101200] // SERIAL on 140.211.11.136 geo.apache.org [2013101200])
	SMTP	OK	2014-03-18 15:10:14	0d 13h 14m 47s	1/10	SMTP OK - 0.651 sec. response time
	SSH	OK	2014-03-18 15:14:23	20d 15h 50m 38s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
aurora.apache.org	HTTP - WWW EU	OK	2014-03-18 15:13:19	0d 23h 41m 42s	1/10	HTTP OK HTTP/1.1 200 OK - 40315 bytes in 0.418 seconds

Nagios Monitoring

- Plug-in architecture (i.e. arbitrary scripts)
- Freely-available JMX plug-in: check_jmx

```
$ ./check_jmx -U
service:jmx:rmi:///jndi/rmi://localhost:1100/jmxrmi\
   -O java.lang:type=Memory -A NonHeapMemoryUsage -K used\
   -w 29000000 -c 30000000
JMX WARNING NonHeapMemoryUsage.used=29050880
```

Nagios Monitoring

- Problems with check_jmx
  - Complex configuration for remote JMX
  - JVM launch for every check
  - Course-grained authentication options

Nagios Monitoring

- Alternative Option: Tomcat's JMXProxyServlet
  - JMX data available via HTTP
  - Can use Tomcat's authentication tools

```
$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' \
   -w 29000000 -c 30000000
JMX CRITICAL: OK - Attribute get 'java.lang:type=Memory' -
HeapMemoryUsage - key 'used' = 100875248
```

* check_jmxproxy can be found at http://wiki.apache.org/tomcat/tools/check_jmxproxy.pl

Nagios Monitoring

JVM:Heap	OK	03-18-2014 15:17:04	8d 9h 56m 14s	1/4	JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 126743888
JVM:Sessions	OK	03-18-2014 15:15:05	8d 9h 53m 13s	1/4	JMX OK: OK - Attribute get 'Catalina:type=Manager,context=/ ,host=localhost' - activeSessions = 0
JVM:Heap	OK	03-18-2014 15:16:08	0d 0h 42m 10s	1/4	JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 253538440
JVM:Sessions	OK	03-18-2014 15:15:08	8d 10h 13m 10s	1/4	JMX OK: OK - Attribute get 'Catalina:type=Manager,context=/ ,host=localhost' - activeSessions = 180
JVM:Heap-OOME ?	OK	03-06-2014 15:58:13	11d 23h 20m 5s	1/1	OK

JMX Command-line Tricks

- Show all logged-in usernames

```
for sessionid in `wget -O - 'http://user:pwd@host/manager/jmxproxy?
invoke=Catalina:type=Manager,context=/myapp,host=localhost&op=listSessionI
ds' \

    | sed -e "s/ /\n/g"

    | grep '^[0-9A-Za-z]\+\(\.,*\)\?$' ;\

do wget -O - "http://user:pwd@host/manager/jmxproxy?
invoke=Catalina:type=Manager,context=/myapp,host=localhost&op=getSessionAt
tribute&ps=$sessionid,user" ; done 2>/dev/null \

    | grep User
```

Tracking Values Over Time

- Some metrics are best observed as deltas
  - Session count
  - Request error count
- Requires that you have a history of data
- Requires that you consult the history of that data
- check_jmxproxy provides such capabilities

Tracking Values Over Time


```
$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' -w 33554432 -c 50331648 --write number.out
--compare number.out

JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 102278904,
delta=[...]

$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' -w 33554432 -c 50331648 --write number.out
--compare number.out

JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 113806144,
delta=11527240

$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' -w 33554432 -c 50331648 --write number.out
--compare number.out

JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 109264056,
delta=-4542088
```

Tracking Values Over Time

- Session count
  - Tomcat actually provides this already via Manager's `sessionCreateRate` attribute
- Request errors

```
$ ./check_jmxproxy  -U 'http://localhost/manager/jmxproxy?
get=Catalina:type=RequestProcessor,worker="http-nio-127.0.0.1-
8217",name=HttpRequest1&att=errorCount' -w 1 -c 10 --write errors.txt --compare
errors.txt

JMX OK: OK - Attribute get 'Catalina:type=RequestProcessor,worker="http-nio-
127.0.0.1-8217",name=HttpRequest1' - errorCount = 0, delta=0
```

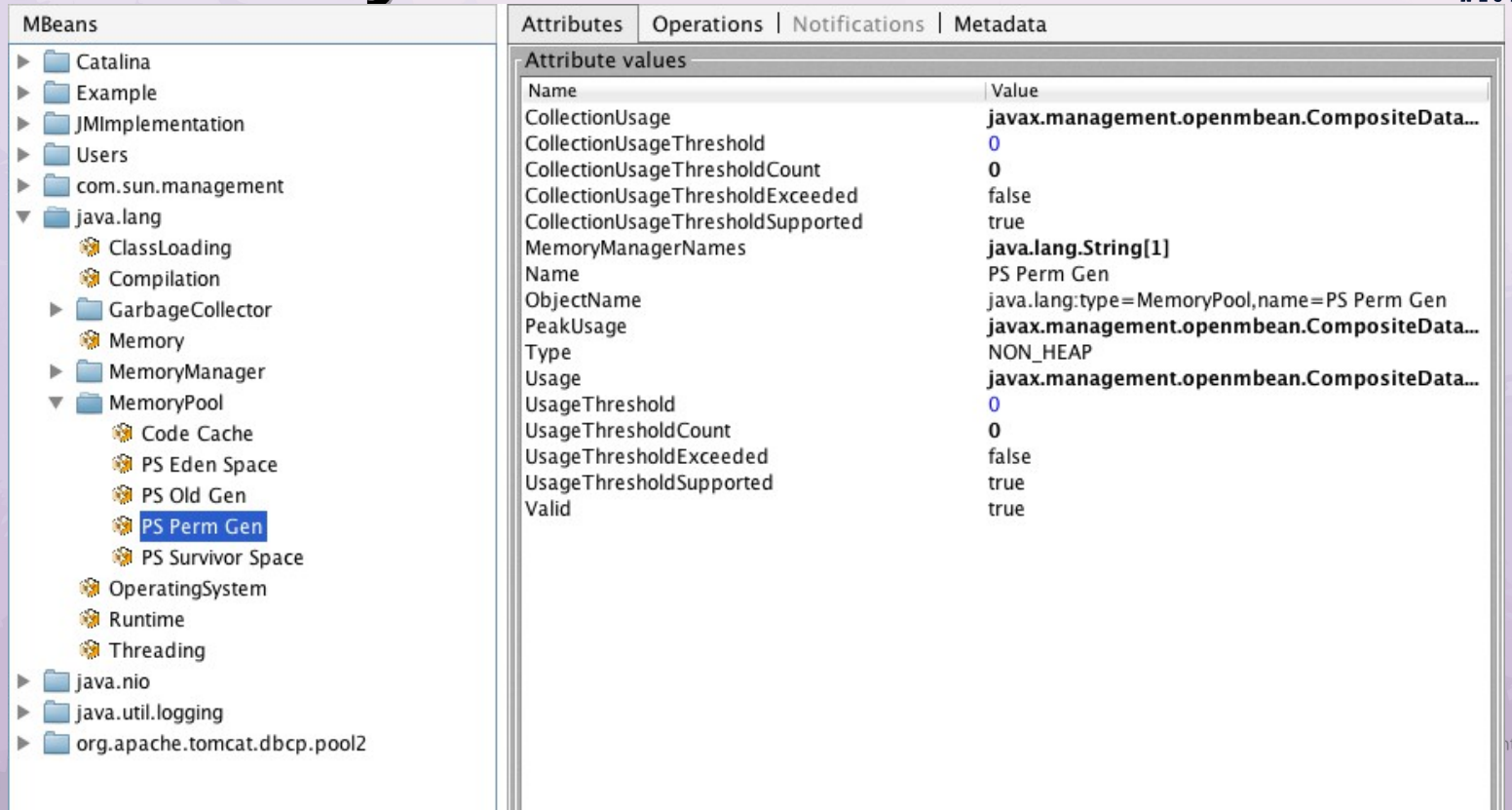
Detecting OutOfMemory

- Many sources of OOME
  - Heap exhaustion
  - PermGen exhaustion
  - Hit thread limit
  - Hit file descriptor limit

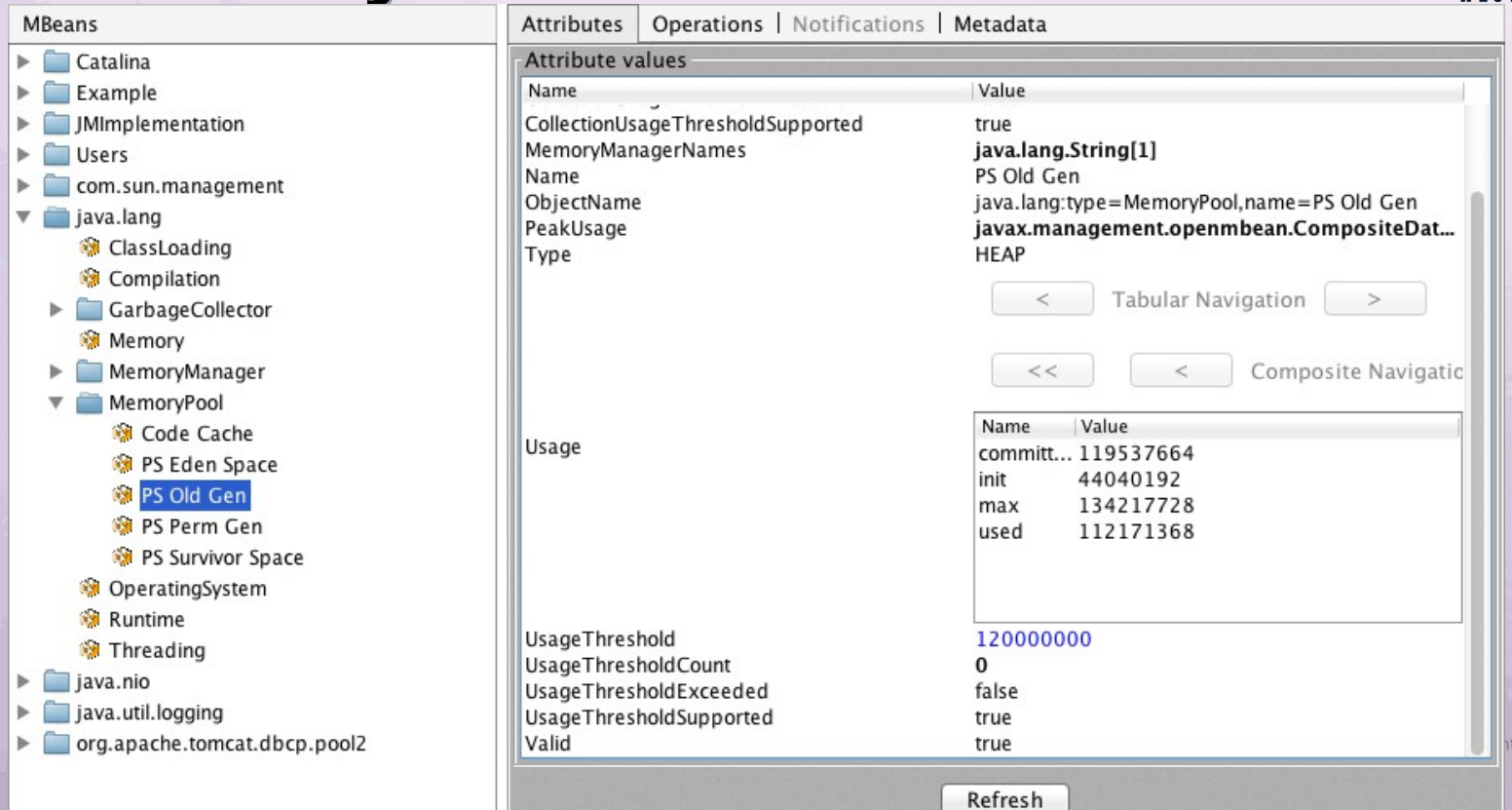
Detecting OutOfMemory

- Two types of heap OOME
  - One thread generates lots of local references
  - All threads collaborate to generate globally-reachable objects (e.g. session data)
- Former is recoverable, latter is not
- You want to be notified in any case

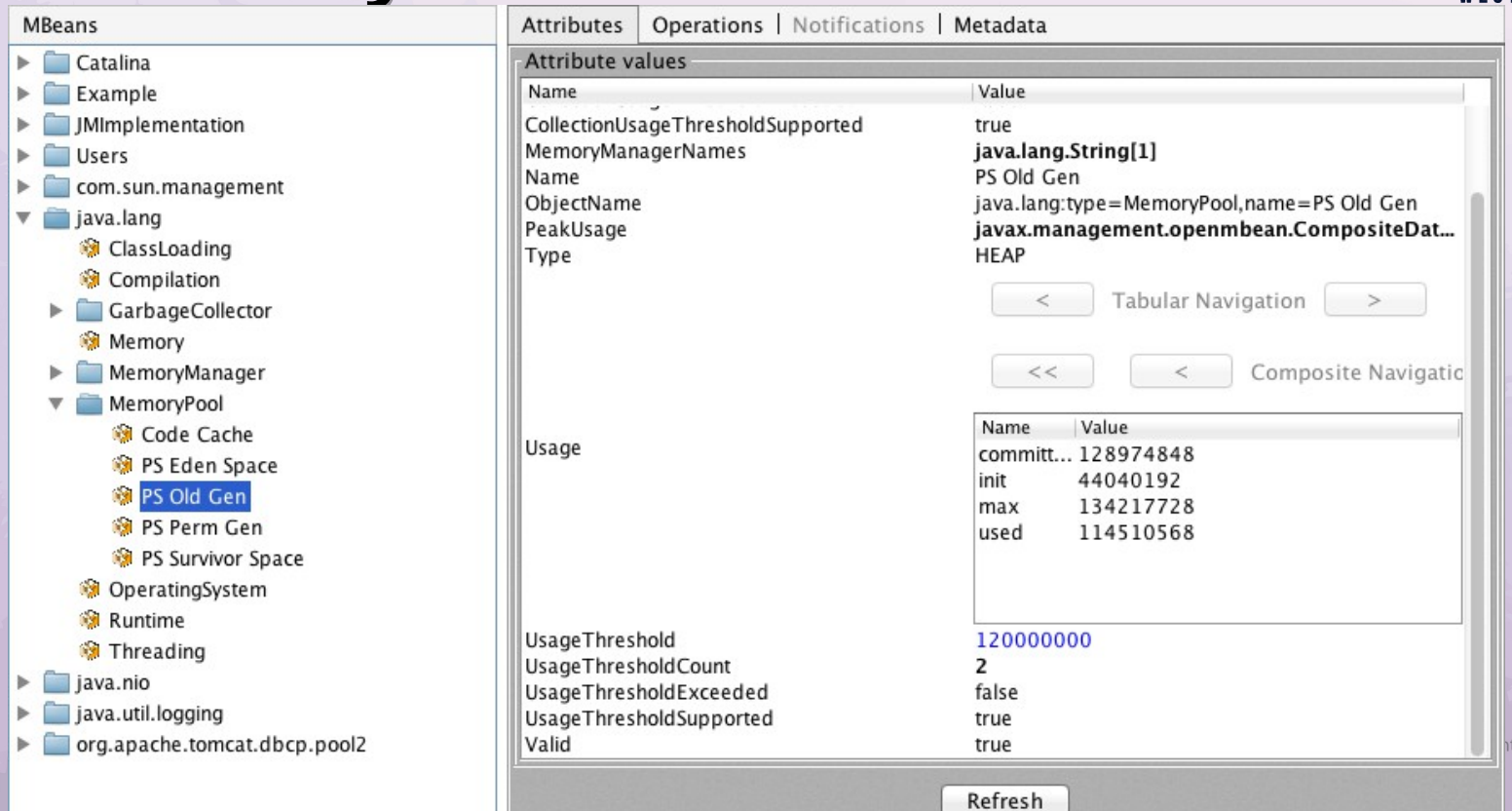
Memory Pool Thresholds



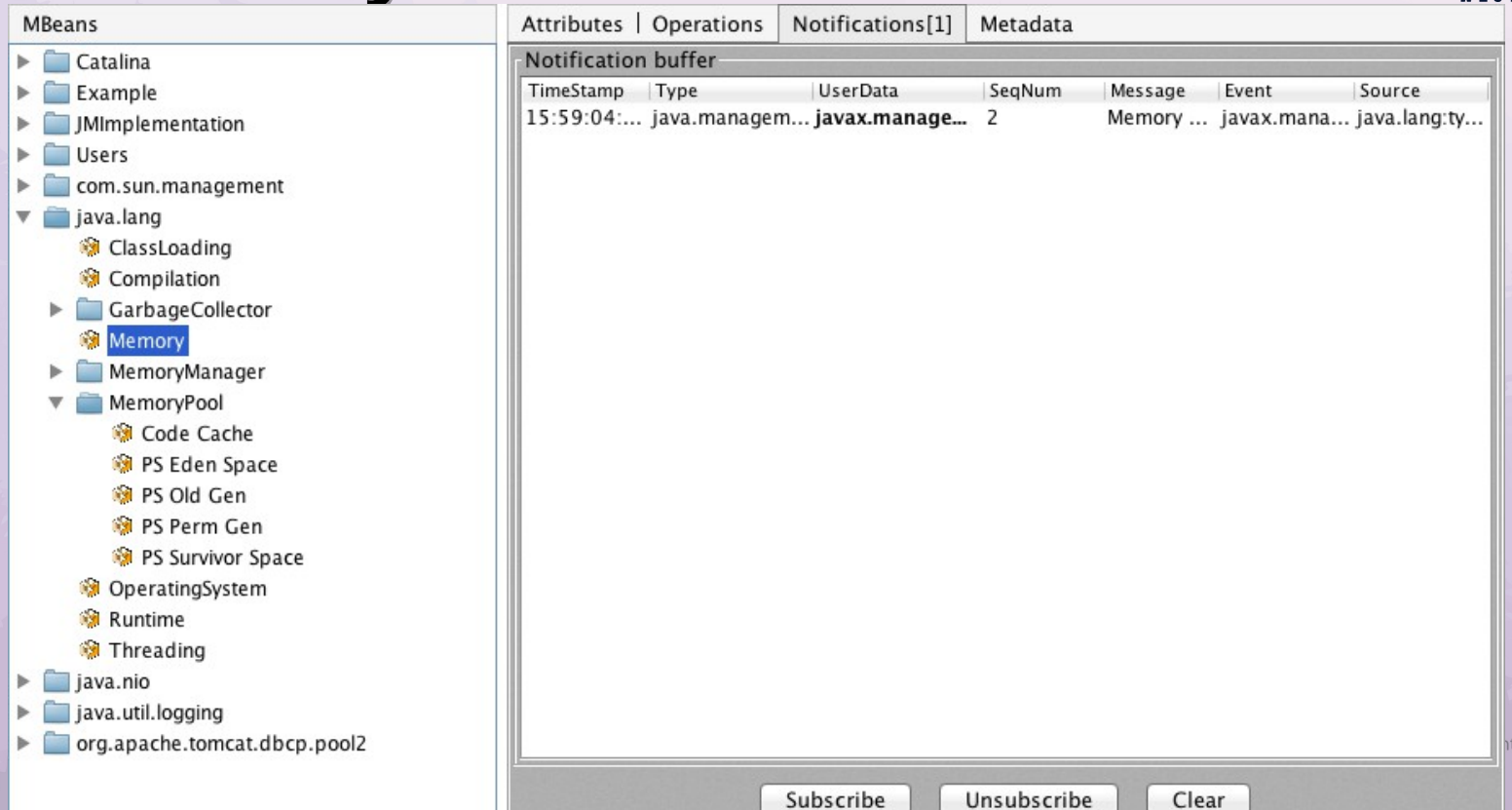
Memory Pool Thresholds



Memory Pool Thresholds



Memory Pool Thresholds



Memory Pool Thresholds

- Choice of how to detect exceeded-threshold conditions
  - Polling using check_jmxproxy
  - Register a notification listener from Java
    - Have that listener take some action

Detect OutOfMemory

- Monitoring Memory Thresholds
  - Set threshold on startup
  - Register a notification listener (callback)
  - Watch “exceeded” count (poll)
  - Report to monitoring software (Nagios)
  - Repeat for each memory pool you want to watch
  - Hope the JVM does not fail during notification
  - This is getting ridiculous

Detecting OutOfMemory

- JVM has an easier way
- Use -XX:OnOutOfMemoryError to run a command on *first* OOME detected by the JVM
- Need a command to notify Nagios

Notify Nagios on OOME

- Script that wraps curl

```
$ curl -si \
    --data-urlencode 'cmd_typ=30' \
    --data-urlencode 'cmd_mod=2' \
    --data-urlencode "host=myhost" \
    --data-urlencode "service=JVM:Heap:OOME" \
    --data-urlencode "plugin_state=2" \
    --data-urlencode "plugin_output=OOME CRITICAL" \
    'https://monitoring-host/nagios/cgi-bin/cmd.cgi'
```

Script can be found at http://wiki.apache.org/tomcat/tools/nagios-send-passive-check.sh

Monitoring Tomcat with JMX

- JMX Provides Monitoring and Management of JVMs
- Tomcat exposes a great amount of information via JMX
- Applications can expose anything to JMX via MBeans
- JRE ships with tools for light JMX interaction
- Practical use of JMX requires some additional tools

Resources

- Presentation Slides

  http://people.apache.org/~schultz/ApacheCon NA 2014/Tomcat Monitoring/

- Nagios passive-check script

  http://wiki.apache.org/tomcat/tools/nagios-send-passive-check.sh

- check_jmxproxy

  http://wiki.apache.org/tomcat/tools/check_jmxproxy.pl

- Special thanks to Christopher Blunck (MBeans info)

  http://oss.wxnet.org/mbeans.html

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APRIL 7-9, 2014

Monitoring Tomcat with JMX

Presented For The Apache Foundation By
LINUX FOUNDATION

I'm essentially a DevOps CTO, and everything I'm presenting today has been something I've had to do in my own work in that regard. My own monitoring work is very much a work in progress.

This is an introduction to monitoring Tomcat and even JVM processes in general. Nothing I'm going to present is particularly earth-shattering or difficult to understand. And that's good news!

There is really no need to consider why monitoring is necessary, so let's just jump right in.

Java Management Extensions

- Protocol and API for managing and monitoring
  - Access data via JMX “Mbeans”
  - Read and write bean attributes
  - Invoke operations
  - Receive notifications
- JVM exposes certain status
- Tomcat exposes certain status

Manage and monitor JVM processes.
Everything is MBeans
Read/write attributes
Invoke operations
Receive notifications
Both the JVM and Tomcat expose these types of things via JMX.

Monitoring JVM

- Heap status
- Total, free, used memory
- Garbage collection
- GC pause times

The JVM exposes a lot about its internal state. Here are some of the more interesting items.

Monitoring Tomcat

- Status of connector
- Status of request-processor thread pool
- Status of data sources
- Request performance

Tomcat has a great deal of information available as well. Here's a sample of what's there.

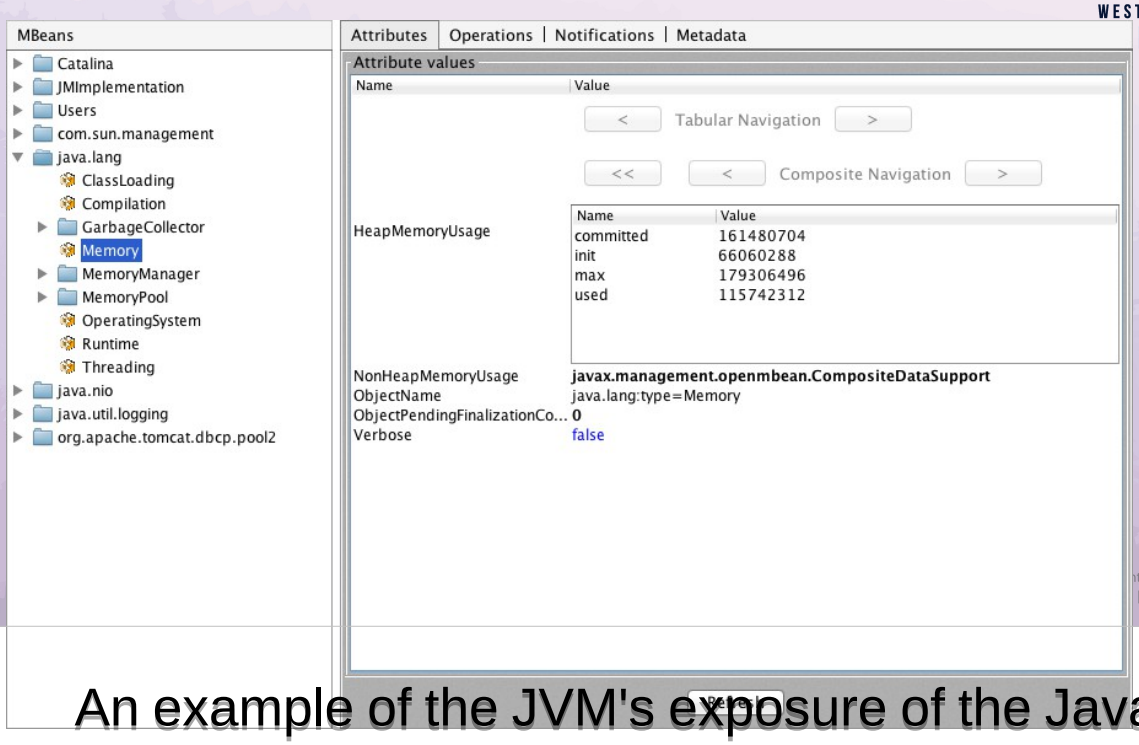
JMX Tools

- jconsole (JDK)
- VisualVM (JDK, app bundle)
- Most profilers (e.g. YourKit, etc.)
- Custom tools using javax.management API

While JMX is an API + protocol, you don't need to know or understand either of them to benefit: tools already exist.

You can always write your own if you need something special.

Monitoring JVM: Heap



An example of the JVM's exposure of the Java heap's usage: initial and maximum values are available as well as the currently-used measurement.

Notice the NonHeapMemoryUsage attribute which has not yet been “expanded” as the HeapMemoryUsage attribute has. Both of these attribute values are represented by objects that contain multiple name-value pairs. The object that stores these pairs also indicates the data type of each value and can include descriptive information for a client as well.

Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information

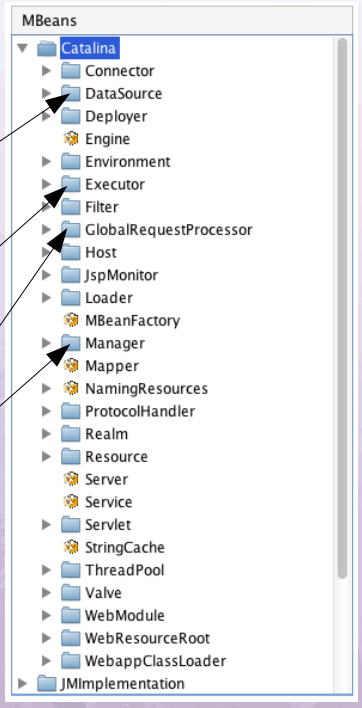


Image: sceenshot from VisualVM of Tomcat's MBean tree.

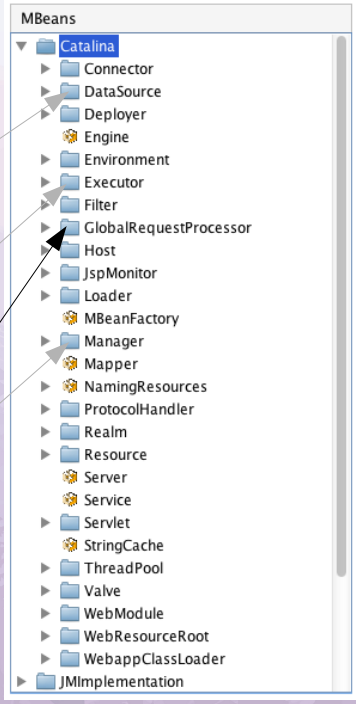
Tomcat provides a wealth of information about its internal state. Much of this information is merely configuration values that are read on startup and do not change over time.

There is, however, a great deal of real-time data available about the servlet container and its various components. I'll dive into these practical examples to demonstrate the rich data that is available.

I'm going to cover these out-of-order with respect to the top-to-bottom order shown above in order to ease-into some of the concepts.

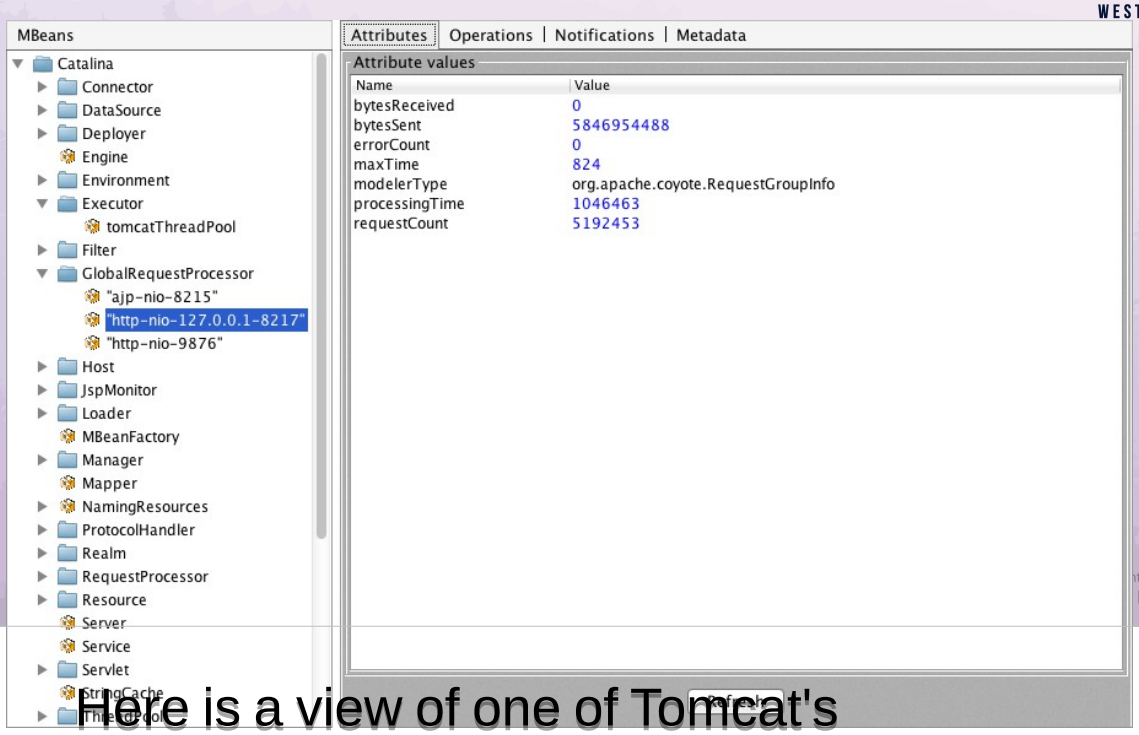
Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information



Tomcat tracks the performance of requests (in aggregate) for each connector separately. A GlobalRequestProcessor exists for each connector where you can obtain information about the performance of the requests handled by that particular connector.

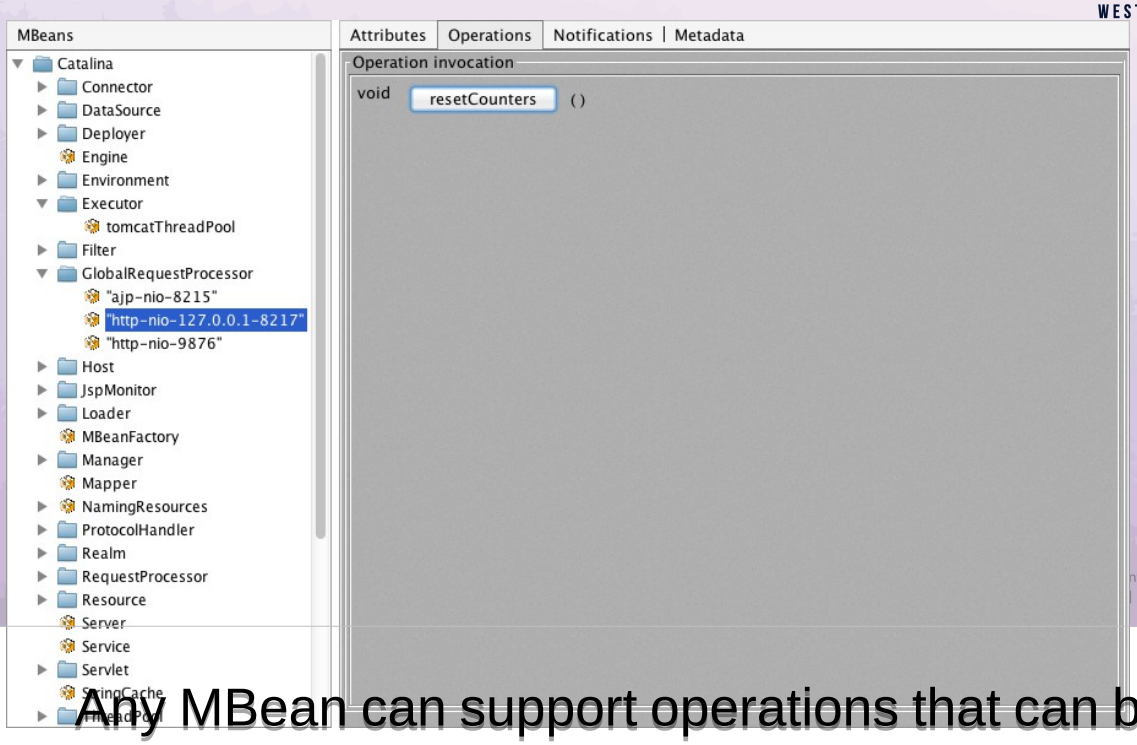
Monitoring Tomcat: Requests



Here is a view of one of Tomcat's GlobalRequestProcessors. I happen to have 3 connectors configured, and you can tell them apart by their names which also indicate a lot about them: protocol, interface address, and port number will uniquely identify any connector's GlobalRequestProcessor.

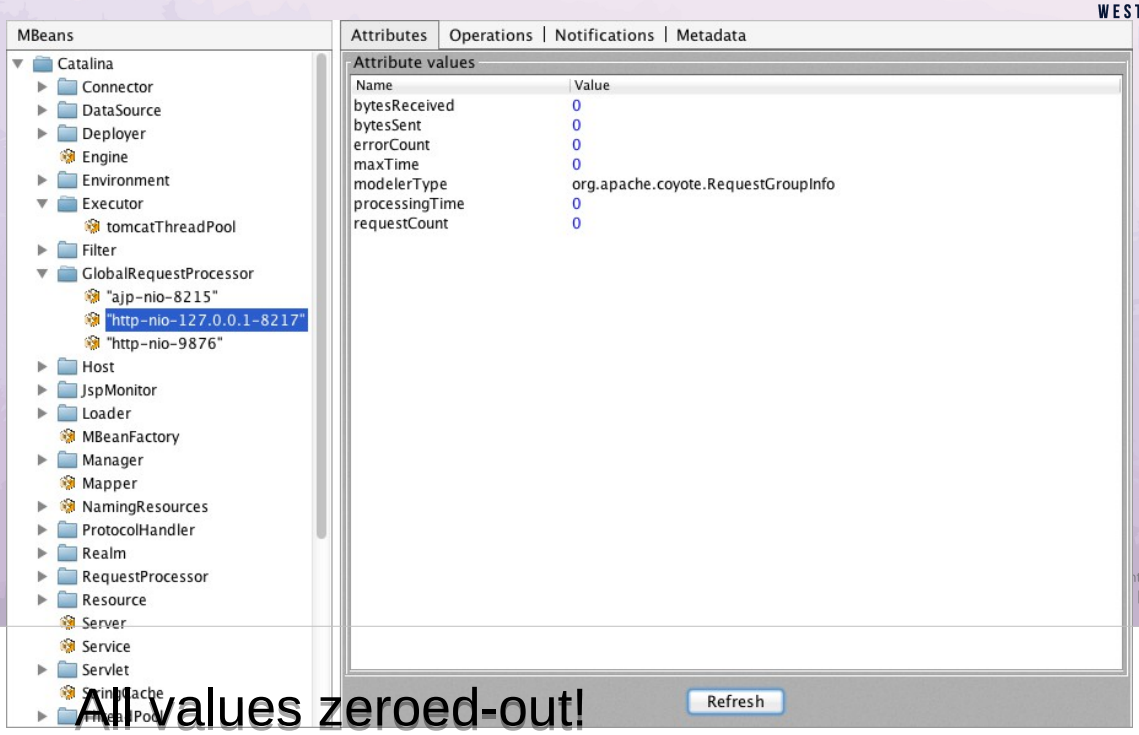
These GlobalRequestProcessors keep track of metrics about requests such as the number of requests, the cumulative processing time of those requests, and the overall volume of data processed.

Monitoring Tomcat: Requests



Any MBean can support operations that can be called via the JMX APIs. The GlobalRequestProcessor beans have a single operation: resetCounters. This operation as you might guess resets all the collected metrics for the GlobalRequestProcessor to zero.

Monitoring Tomcat: Requests

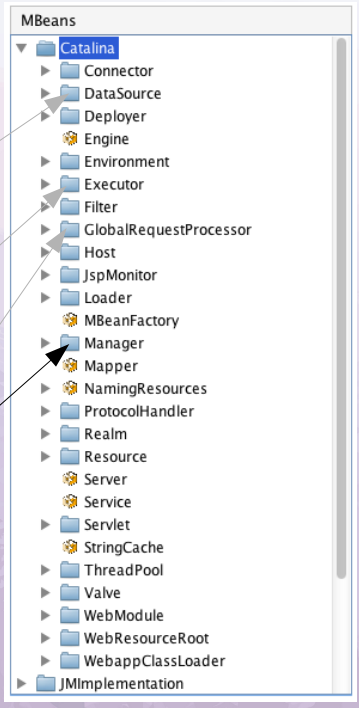


All values zeroed-out!

Resetting these counters can be useful if you want to monitor performance data over time and want to periodically reset the state of the connector's metrics.

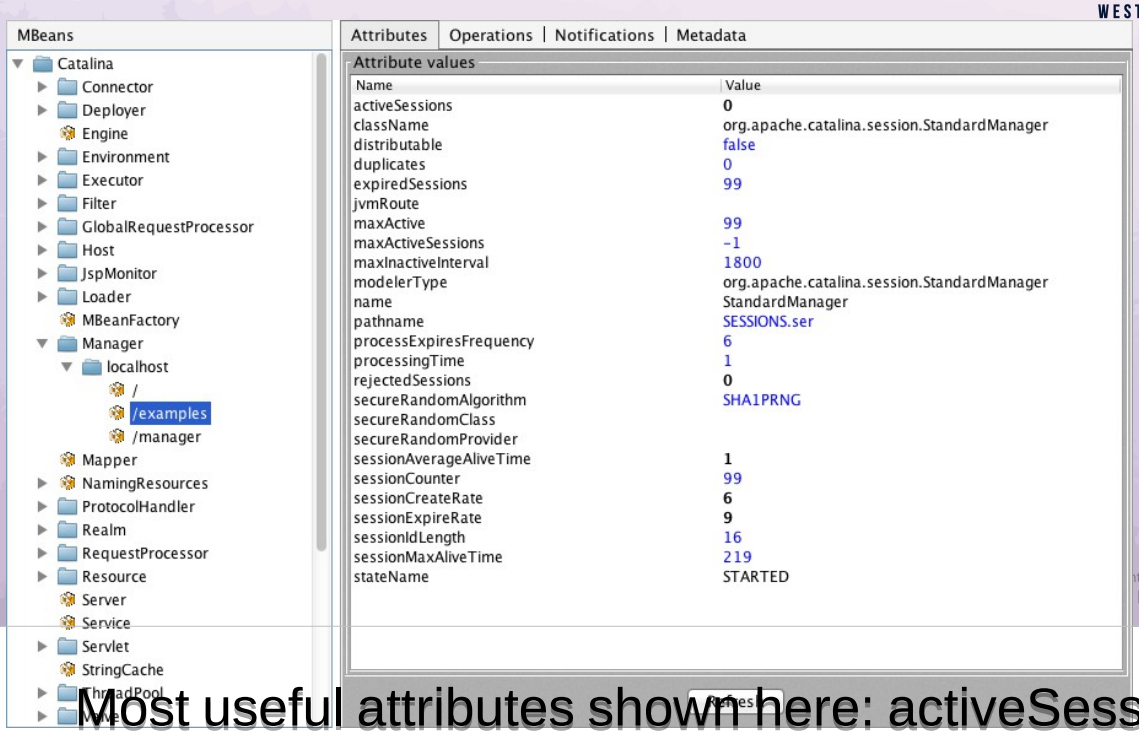
Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information



Sessions are another thing you might want to keep track of: too many sessions can bog-down a server and cause performance problems. The real problem is storing lots of data in the session, or course, but the number of sessions can be an important data point in your server monitoring strategy.

Monitoring Tomcat: Sessions

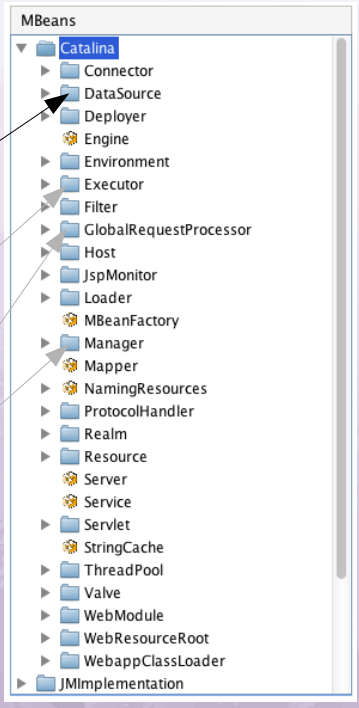


Most useful attributes shown here: activeSessions, maxActive, and expiredSessions. One attribute that is not shown is the sessionCreationRate, which gives you an idea of how fast sessions are being created.

Tomcat actually exposes every session in the container via MBean operations. You can fetch a list of all session ids, fetch attribute values from a particular session, and even expire sessions directly.

Monitoring Tomcat

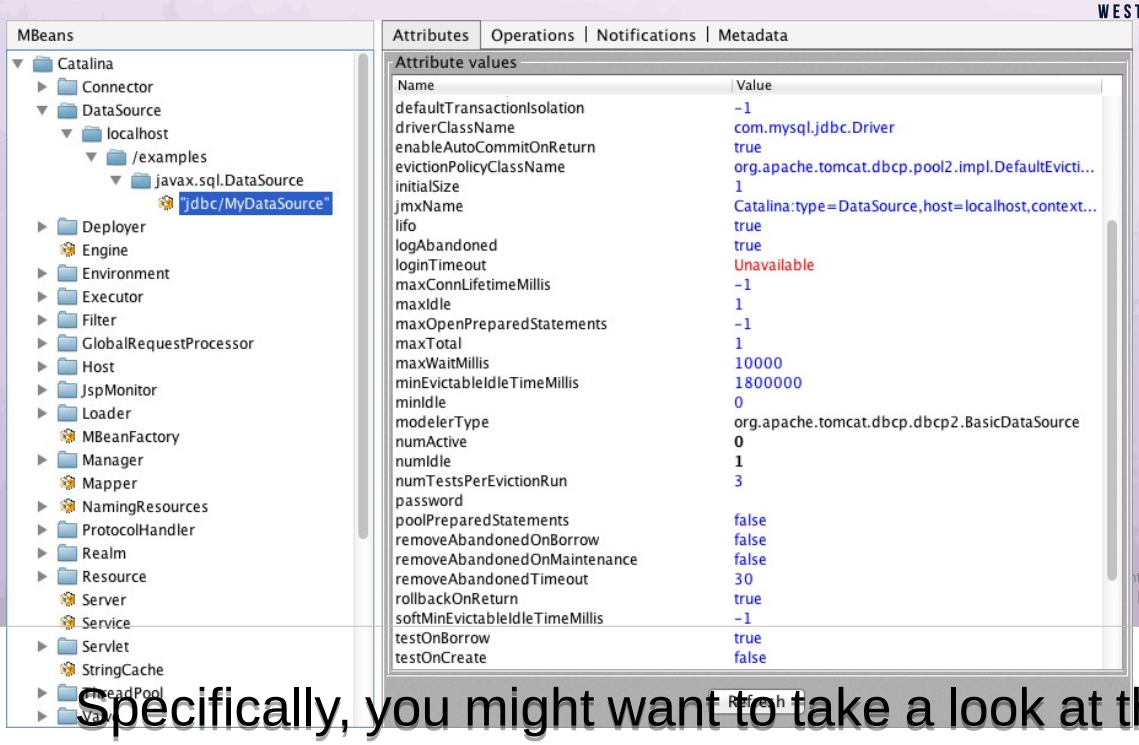
- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information



A great number of web applications use a relational database via JDBC. Those DataSources configured via Tomcat (and not directly in the application, such as those configured by Spring, Hibernate, etc.) are available for inspection.

Tomcat's DataSources have a connection pool with minimum and maximum sizes (numbers of connections), and a maxIdle setting which allows the pool to grow and shrink depending upon the demand.

Monitoring Tomcat: DataSources

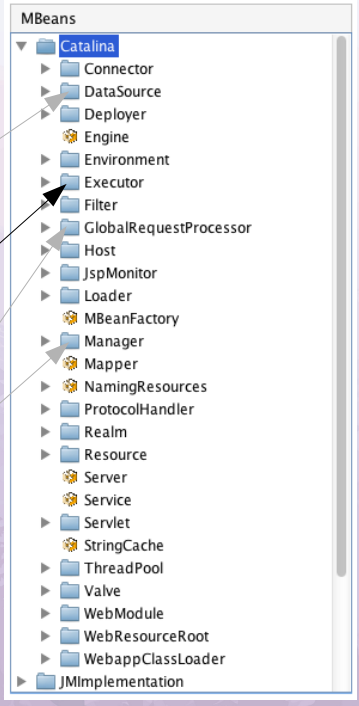


Specifically, you might want to take a look at the numActive and numIdle attributes: you can see if your JDBC connection pool is meeting the demand of your users.

Note that I have maxActive=1 since this is a test system.

Monitoring Tomcat

- Status of data sources
- Status of request-processor thread pool
- Request performance
- Session information

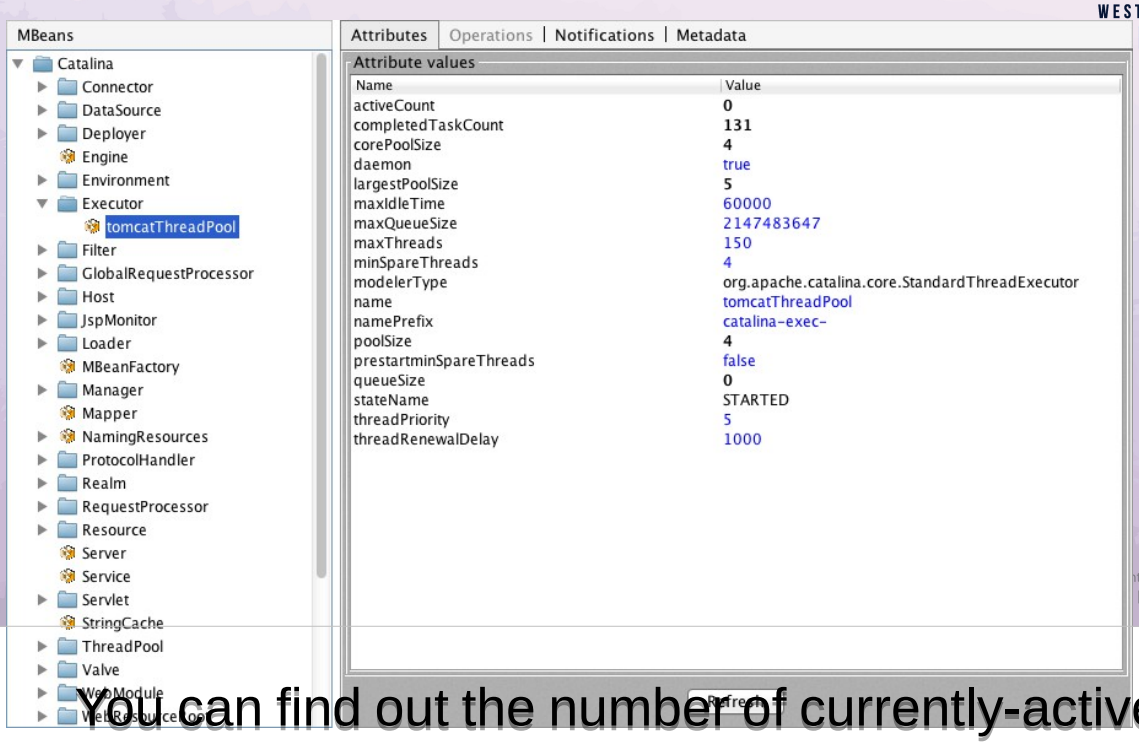


Each of Tomcat's connectors has a thread pool that is used to actually process the requests: once a request arrives, it is dispatched to a thread in the pool.

Thread pools in Tomcat are called Executors and may be shared between connectors, which is why they are treated separately from the Connectors themselves.

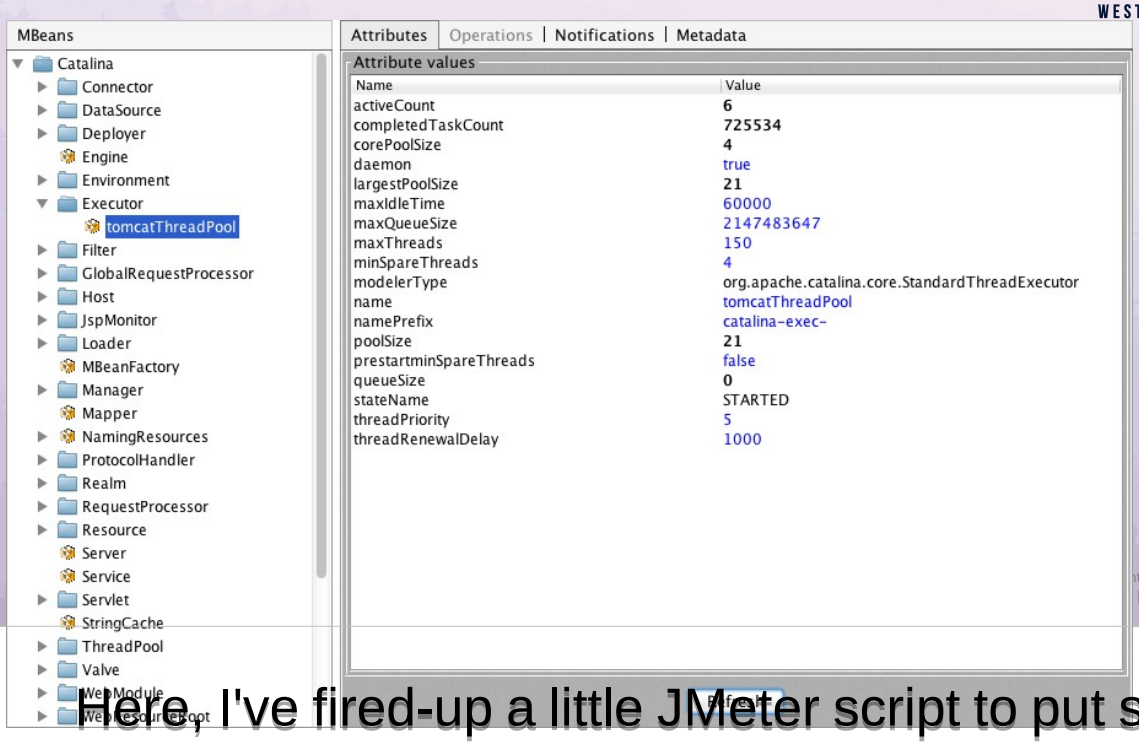
Executors are like the JDBC connection-pools from the previous example: they have minimum and maximum sizes, as well as an idle target to help match resources to user demand.

Monitoring Tomcat: Threads



You can find out the number of currently-active requests (activeCount), the total number of requests processed (by the executor, which may not be the same as the number processed by any given connector), etc.

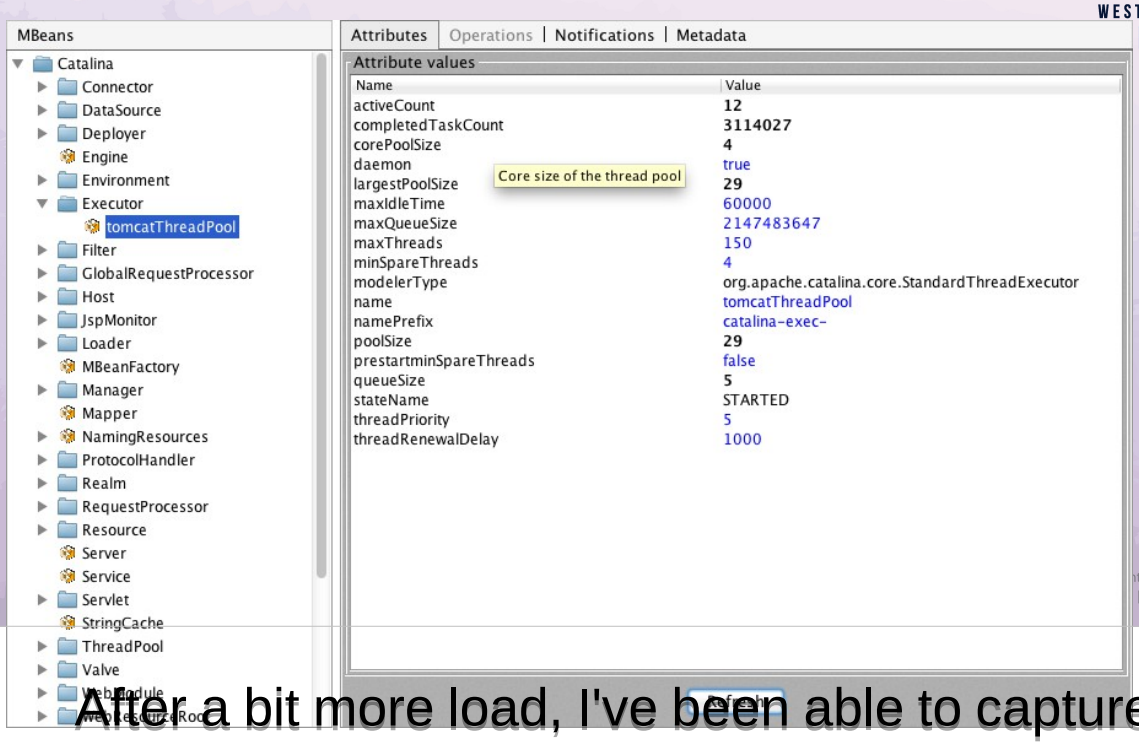
Monitoring Tomcat: Threads



Here, I've fired-up a little JMeter script to put some load on the server. You can see that there are 6 active threads and the pool size has jumped from 4 threads to 21, indicating that I've put quite a load on the pool – relatively speaking. The completedTaskCount is gong-up dramatically.

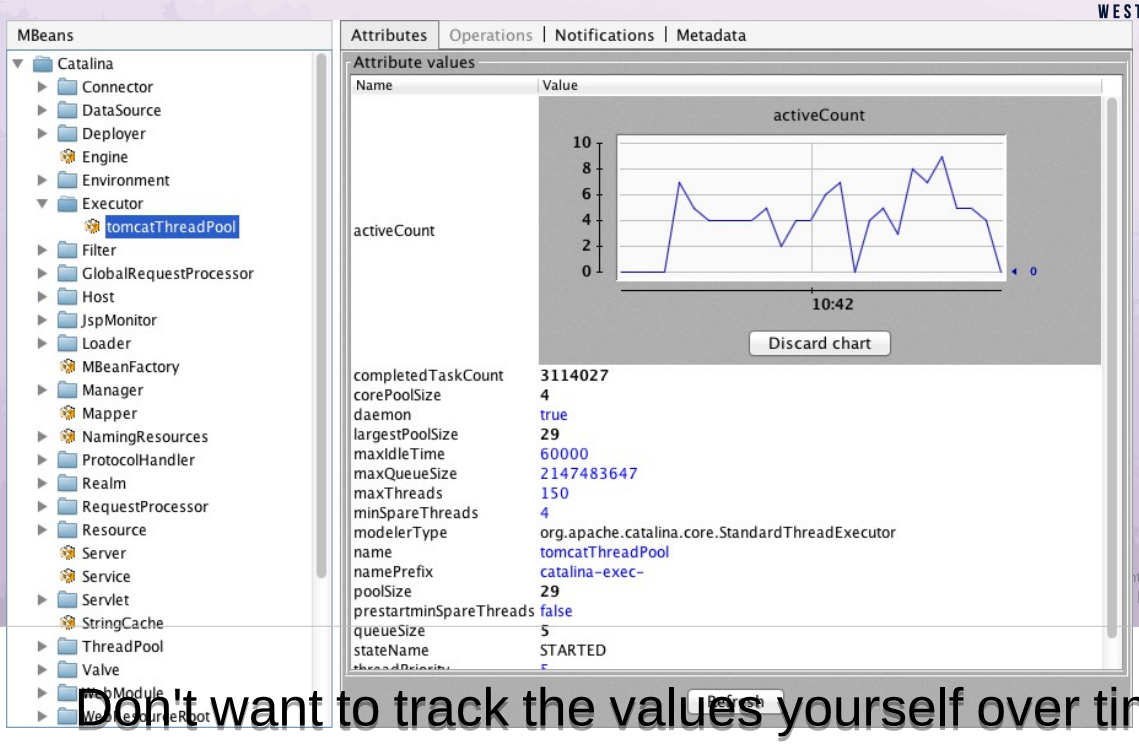
(I suspect the reason I don't have 21 threads busy--or more – right now is because my laptop only has 8 logical cores, so really only 8 threads can be active at once – that means both JMeter *and* Tomcat. The requests are also processed so quickly that it's hard to catch a large number of threads actually active.)

Monitoring Tomcat: Threads



After a bit more load, I've been able to capture the activeCount getting a bit higher.

Monitoring Tomcat: Threads



Don't want to track the values yourself over time? No problem: just double-click on any numeric value and VisualVM will graph it for you over time.

Monitoring Your Application

- Monitor Application Processes
- Performance Metrics
- On-the-fly re-configuration

So, the JVM and Tomcat expose information about themselves. That's great for monitoring the state of the JVM and the servlet container, but what about your own application's health?

You have caches, other data stores, complex objects, and a little bit of everything going on inside your own application. How can we peek under those covers?

Monitoring Your Application

- Write an MBean
  - Create an Interface: FooMBean
  - Create an Implementation: Foo
  - Create an XML MBean descriptor
- Deploy package to Tomcat
  - Publish the MBean to the MBean server
- Query / invoke as necessary

* Example code will be available at
http://people.apache.org/~schultz/ApacheCon NA 2014/Tomcat Monitoring/

A great way to do this is to write your own MBean. Then you can use all the tools described in this presentation to track arbitrary details about your application.

Remember that you can also invoke operations on MBeans, so you can even change the state and take whatever actions you feel are worthwhile from a JMX client.

It's easy to write your own MBean: just follow the steps above. I'll show a simple example in the next few slides.

Example MBean

- Servlet Filter that captures total request processing time
  - Timestamp prior to request
  - Timestamp after request
  - Add the delta to a JMX-accessible counter: RequestStats

Tomcat also provides request-processing metrics on a per-servlet basis. Want to know how the JSP servlet is performing? No problem: Tomcat already tracks that information for you.

The problem is that it's not very fine-grained: you get metrics from the simplest index.jsp mixed-in with your PerformLongTransactionAndProducePDF.jsp numbers. That's not particularly convenient.

So, I'm going to write a Filter that captures this kind of data and makes it available via JMX. You can have multiple instances of the Filter mapped to different URL patterns, and you'll get a separate set of metrics for each of them.

RequestStats MBean

- Write an MBean

```
public interface RequestStatsMBean {
    public long getProcessingTime();
    public long getRequestCount();
    public void resetCounters();
}
public class RequestStats
    implements RequestStatsMBean {
    [...]
    public void updateStats(long
timestamp, ServletRequest request, long
elapsed) {

_totalElapsedTime.addAndGet(elapsed);

_requestCount.incrementAndGet();
    }
```

```
 public long getProcessingTime(){
   return _totalElapsedTime.get();
 }
 public long getRequestCount() {
   return _requestCount.get();
 }
 public void resetCounters() {
   _totalElapsedTime.set(0l);
   _requestCount.set(0l);
  }
}
```


For Tomcat's MBean server implementation, you have to write an interface as well as a concrete class. No surprises in the code, here.

Note that I'm using AtomicLong objects (declarations not shown for brevity) because they are being used in a multi-threaded context and need to remain threadsafe.

RequestStats MBean

- Write an MBean descriptor

```
<mbeans-descriptors>
  <mbean name="RequestStats" ...>
    <operation name="getProcessingTime"
        description="Gets the total number of
milliseconds spent processing requests."
             impact="INFO"
         returnType="long" />
    <operation name="getRequestCount"
        description="Gets the total number
of requests processed."
             impact="INFO"
         returnType="long" />
    <operation
          name="resetCounters"
   description="Resets all
counters."
        impact="ACTION"
   returnType="void" />
  </mbean>
</mbeans-descriptors>
```

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Tomcat's documentation states that you must create an mbeans-descriptors.xml file and place it in the same package as your MBean interface, but I have found that it is not actually a requirement.

But, it's a good idea to write the descriptor because it documents what your attributes mean and what your and operations do. JMX clients can read this information and present it to the user. Documentation is always nice.

(I was unable to get Tomcat to read my mbeans-descriptors.xml file for some reason. Early-on in my work, I recall it working, but it stopped working at some point and I wasn't able to discover the cause.)

RequestStats MBean

- Create JAR
  - Java interface
  - Java implementation
  - mbeans-descriptors.xml
- Put JAR into CATALINA_BASE/lib

Package-up the MBean and put it into Tomcat's lib directory. Note that the bean *must* be placed-into the container's lib directory and not with your web application, otherwise you risk a pinned-ClassLoader memory leak during redeployment.

I believe Tomcat requires that your MBean be in the lib/ directory anyway, do you may not actually have a choice.

RequestStats MBean

- Write the Filter

```
 public void init(FilterConfig config) {
    MBeanServer server = getServer();
    server.registerMBean(_stats, new
ObjectName("Example:RequestStats=RequestStats,name=" + filterName;));
  }
  public void doFilter(...) {
    timestamp = elapsed = System.currentTimeMillis();
    chain.doFilter(request, response);
    elapsed = System.currentTimeMillis() - elapsed;

    _stats.updateStats(timestamp, request, elapsed);
  }
```


Now, we need to write the Filter that will actually capture the data and publish the MBean to the server.

The init method here registers the Mbean (_stats), and the doFilter method just times requests as they pass-through, then updates the stats on the bean.

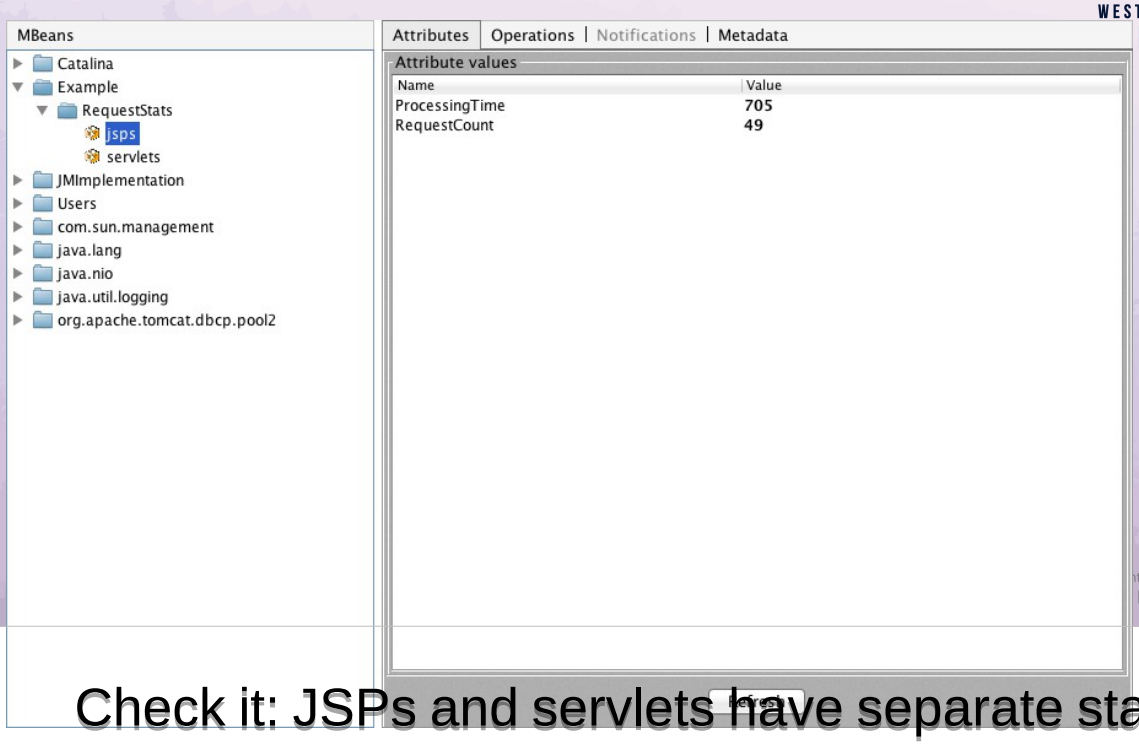
RequestStats MBean

- Map the Filter

```
<filter>
  <filter-name>servlet-request-stats</filter-name>
  <filter-class>filters.RequestStatsFilter</filter-class>
  <init-param>
    <param-name>name</param-name>
    <param-value>servlets</param-value>
  </init-param>
</filter>
<filter-mapping>
  <filter-name>servlet-request-stats</filter-name>
  <url-pattern>/servlets/*</url-pattern>
</filter-mapping>
<filter><filter-name>jsp-request-stats</filter-name><filter-
class>filters.RequestStatsFilter</filter-class><init-param><param-name>name</param-
name><param-value>jsps</param-value></init-param></filter>
<filter-mapping><filter-name>jsp-request-stats</filter-name><url-pattern>/jsp/*</url-
pattern></filter-mapping>
```

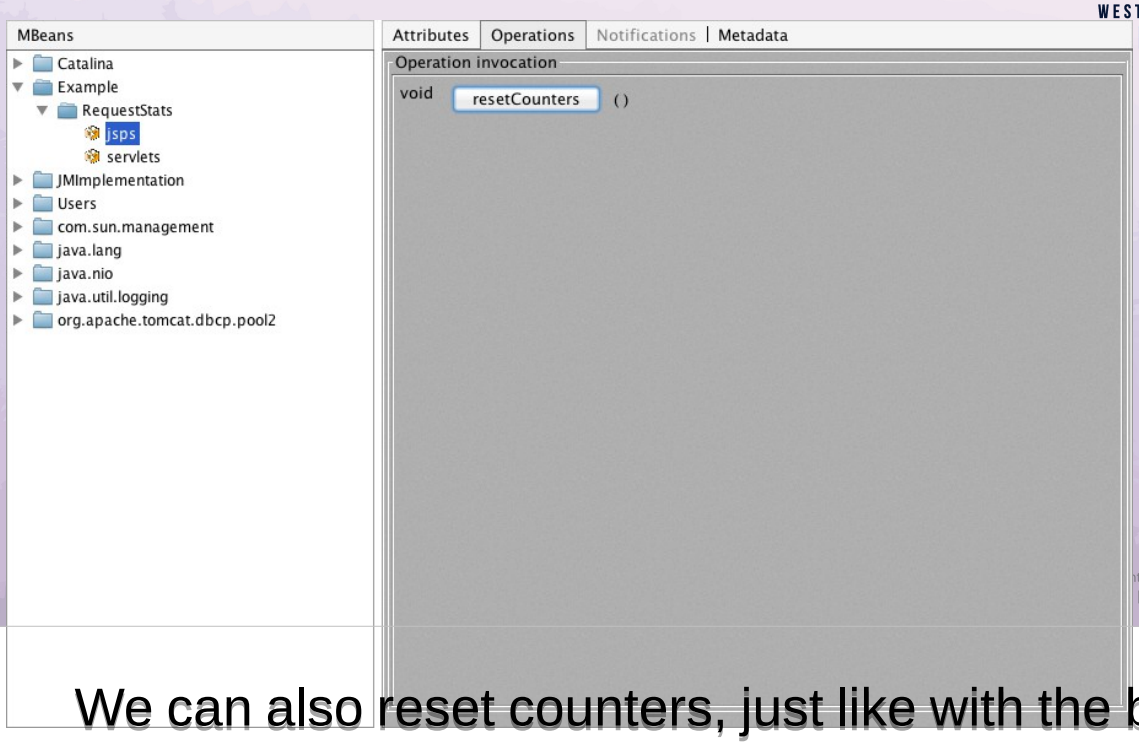

Let's map two instances of the Filter to two different URL patterns to see what things look like.

RequestStats MBean



Check it: JSPs and servlets have separate stats. I've put a bit of JMeter load on the server to get some numbers.

RequestStats MBean



We can also reset counters, just like with the built-in Tomcat MBeans.

Automated Monitoring

- Remote Access
- Large Scale
- Constant

All the examples thus far have used VisualVM which is a GUI interface. While that's fun for inspecting a single server and maybe doing some scouting for interesting data available, it's not going to work in the real world of production monitoring.

Automated Monitoring

- Remote Access
- Large Scale
- Constant
- Need more tools!

Automated Monitoring

- Nagios
  - Simple
  - Flexible
  - Well-deployed
  - No-cost community version available

Let's use Nagios: a widely-deployed monitoring system.

Automated Monitoring

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Host	Service	Status	Last Check	Duration	Attempt	Status Information
abi.apache.org	SSH	OK	2014-03-18 15:12:04	1d 16h 22m 57s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
aegis.apache.org	HTTP - Buildbot	OK	2014-03-18 15:13:43	9d 12h 56m 18s	1/10	HTTP OK HTTP/1.1 200 OK - 22230 bytes in 0.642 seconds
	HTTPS - Jenkins	OK	2014-03-18 15:14:43	0d 23h 25m 18s	1/10	HTTP OK HTTP/1.1 200 OK - 22230 bytes in 0.830 seconds
	SSH	OK	2014-03-18 15:14:14	9d 0h 25m 47s	1/10	SSH OK - OpenSSH_5.9p1 Debian-5ubuntu1.1 (protocol 2.0)
analysis-vm.apache.org	SSH	OK	2014-03-18 15:12:43	4d 12h 32m 18s	1/10	SSH OK - OpenSSH_5.9p1 Debian-5ubuntu1.1 (protocol 2.0)
any.no-ip.com	DNS	OK	2014-03-18 15:11:42	24d 19h 28m 22s	1/10	DNS OK: 0.023 seconds response time. www.apache.org returns 140.211.11.131,192.87.106.229
arcas.apache.org	SSH	OK	2014-03-18 15:14:48	19d 7h 40m 14s	1/10	SSH OK - OpenSSH_5.9p1 Debian-20120710asf3 (protocol 2.0)
athena.apache.org	DNS	OK	2014-03-18 15:14:23	9d 0h 25m 38s	1/10	DNS OK: 0.172 seconds response time. svn.geo.apache.org returns 160.45.251.2
	GEODNS	OK	2014-03-18 15:14:14	12d 17h 10m 47s	1/10	OK DNS server 140.211.11.136 geo.apache.org is in sync with the zone file held in SVN (SERIAL in SVN: [2013101200] // SERIAL on 140.211.11.136 geo.apache.org [2013101200])
	SMTP	OK	2014-03-18 15:10:14	0d 13h 14m 47s	1/10	SMTP OK - 0.651 sec. response time
	SSH	OK	2014-03-18 15:14:23	20d 15h 50m 38s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
aurora.apache.org	HTTP - WWW EU	OK	2014-03-18 15:13:19	0d 23h 41m 42s	1/10	HTTP OK HTTP/1.1 200 OK - 40315 bytes in 0.418 seconds
	HTTP - WWW EU Downloads	OK	2014-03-18 15:13:19	0d 23h 41m 42s	1/10	HTTP OK HTTP/1.1 200 OK - 26771 bytes in 0.456 seconds
	RSYNC EU	OK	2014-03-18 15:13:10	21d 21h 56m 51s	1/10	TCP OK - 0.014 second response time on port 873
	SSH	OK	[illegible]	[illegible]	1/10	[illegible]
baldr.apache.org	SSH	OK	[illegible]	[illegible]	[illegible]	[illegible]
bb-fbsd2.apache.org	SSH	OK	2014-03-18 15:14:15	9d 0h 25m 46s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
bil.zones.apache.org	SSH	OK	2014-03-18 15:14:15	14d 23h 45m 46s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
blogs.zones.apache.org	HTTP - ASF Blogs	OK	2014-03-18 15:13:56	9d 0h 26m 5s	1/10	HTTP OK HTTP/1.1 200 OK - 43275 bytes in 0.828 seconds
	SSH	OK	2014-03-18 15:11:56	17d 4h 13m 5s	1/10	SSH OK - Sun_SSH_1.1.2 (protocol 2.0)
cms.zones.apache.org	HTTPS - CMS	OK	2014-03-18 15:11:54	0d 0h 53m 7s	1/10	HTTP OK HTTP/1.1 200 OK - 8734 bytes in 3.048 seconds
	SSH	OK	2014-03-18 15:12:17	0d 13h 7m 44s	1/10	SSH OK - OpenSSH_5.8p2_hpn13v11 FreeBSD-20110503 (protocol 2.0)
continuum-vm.apache.org	SSH	OK	2014-03-18 15:10:55	12d 15h 24m 6s	1/10	SSH OK - OpenSSH_5.9p1 Debian-20120710asf3 (protocol 2.0)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The ASF uses Nagios and Tomcat exposes data via JMX. Let's see how we can marry the two.

Nagios Monitoring

- Plug-in architecture (i.e. arbitrary scripts)
- Freely-available JMX plug-in: check_jmx

```
$ ./check_jmx -U
service:jmx:rmi:///jndi/rmi://localhost:1100/jmxrmi\
   -O java.lang:type=Memory -A NonHeapMemoryUsage -K used\
   -w 29000000 -c 30000000
JMX WARNING NonHeapMemoryUsage.used=29050880
```


Nagios supports plug-ins and there's one for fetching data via JMX: check_jmx: if you know the object's name, you can get data from the command-line.

Nagios Monitoring

- Problems with check_jmx
  - Complex configuration for remote JMX
  - JVM launch for every check
  - Course-grained authentication options

There are some caveats with check_jmx. Think about how many values you might want to monitor: spinning-up 14 JVMs every minute might just be considered a waste of system resources.

Nagios Monitoring

- Alternative Option: Tomcat's JMXProxyServlet
  - JMX data available via HTTP
  - Can use Tomcat's authentication tools

```
$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' \
   -w 29000000 -c 30000000
JMX CRITICAL: OK - Attribute get 'java.lang:type=Memory' -
HeapMemoryUsage - key 'used' = 100875248
```

* check_jmxproxy can be found at http://wiki.apache.org/tomcat/tools/check_jmxproxy.pl

Tomcat has JMXProxyServlet.

check_jmxproxy is a little Perl script I wrote to fetch data from JMXProxyServlet and provide Nagios-friendly output.

Same basic features of check_jmx except that Java and the JMX protocol aren't actually used: we use Tomcat's HTTP-tp-JMX proxy instead.

Nagios Monitoring

JVM:Heap	OK	03-18-2014 15:17:04	8d 9h 56m 14s	1/4	JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 126743888
JVM:Sessions	OK	03-18-2014 15:15:05	8d 9h 53m 13s	1/4	JMX OK: OK - Attribute get 'Catalina:type=Manager,context=/ ,host=localhost' - activeSessions = 0
JVM:Heap	OK	03-18-2014 15:16:08	0d 0h 42m 10s	1/4	JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 253538440
JVM:Sessions	OK	03-18-2014 15:15:08	8d 10h 13m 10s	1/4	JMX OK: OK - Attribute get 'Catalina:type=Manager,context=/ ,host=localhost' - activeSessions = 180
JVM:Heap-OOME ?	OK	03-06-2014 15:58:13	11d 23h 20m 5s	1/1	OK

Here's a glance at some values sampled in a production setting. We'll talk about the OOME one later.

JMX Command-line Tricks

- Show all logged-in usernames

```
for sessionid in `wget -O - 'http://user:pwd@host/manager/jmxproxy?
invoke=Catalina:type=Manager,context=/myapp,host=localhost&op=listSessionI
ds' \

    | sed -e "s/ /\n/g"

    | grep '^[0-9A-Za-z]\+\(\.,*\)\?$' ;\

do wget -O - "http://user:pwd@host/manager/jmxproxy?
invoke=Catalina:type=Manager,context=/myapp,host=localhost&op=getSessionAt
tribute&ps=$sessionid,user" ; done 2>/dev/null \

    | grep User
```


We store a “user” bean in our sessions, and so we can use some command-line tricks mixed with data from check_jmxproxy to list all the currently logged-in users.

We can use similar tricks to expire all sessions that don't represent a logged-in user.

Tracking Values Over Time

- Some metrics are best observed as deltas
  - Session count
  - Request error count
- Requires that you have a history of data
- Requires that you consult the history of that data
- check_jmxproxy provides such capabilities

What about data whose rate-of-change is more important than its current value?

check_jmxproxy can store the previous value retrieved and then compare during the next invocation.

Tracking Values Over Time

```
$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' -w 33554432 -c 50331648 --write number.out
--compare number.out

JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 102278904,
delta=[...]

$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' -w 33554432 -c 50331648 --write number.out
--compare number.out

JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 113806144,
delta=11527240

$ ./check_jmxproxy -U 'http://localhost/manager/jmxproxy?
get=java.lang:type=Memory&att=HeapMemoryUsage&key=used' -w 33554432 -c 50331648 --write number.out
--compare number.out

JMX OK: OK - Attribute get 'java.lang:type=Memory' - HeapMemoryUsage - key 'used' = 109264056,
delta=-4542088
```


Let's watch heap memory usage over a few invocations.

Tracking Values Over Time

- Session count
  - Tomcat actually provides this already via Manager's `sessionCreateRate` attribute
- Request errors

```
$ ./check_jmxproxy  -U 'http://localhost/manager/jmxproxy?
get=Catalina:type=RequestProcessor,worker="http-nio-127.0.0.1-
8217",name=HttpRequest1&att=errorCount' -w 1 -c 10 --write errors.txt --compare
errors.txt
```

```
JMX OK: OK - Attribute get 'Catalina:type=RequestProcessor,worker="http-nio-
127.0.0.1-8217",name=HttpRequest1' - errorCount = 0, delta=0
```


There are lots of data whose rates of change are more important than their current values. Session count and error count are among them.

Detecting OutOfMemory

- Many sources of OOME
  - Heap exhaustion
  - PermGen exhaustion
  - Hit thread limit
  - Hit file descriptor limit

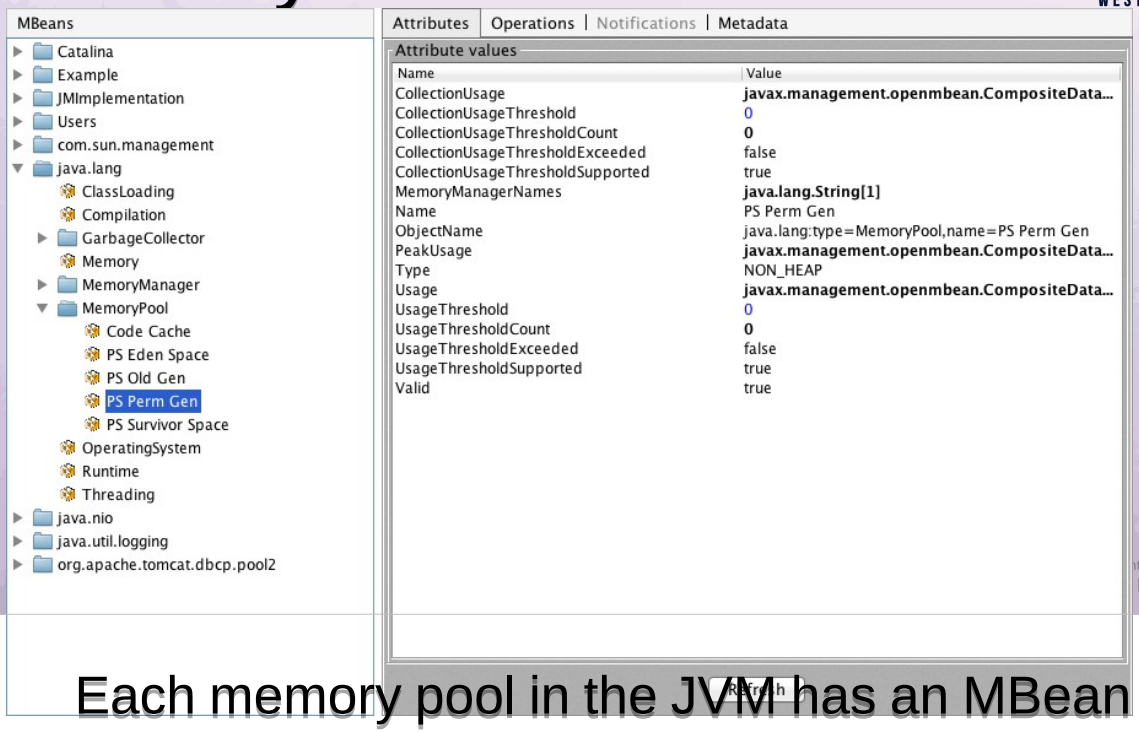
Let's talk about OutOfMemoryErrors. Of all monitoring questions I've heard about Java web applications, this one is always the first: how can I get notified about an OOME?

Detecting OutOfMemory

- Two types of heap OOME
  - One thread generates lots of local references
  - All threads collaborate to generate globally-reachable objects (e.g. session data)
- Former is recoverable, latter is not
- You want to be notified in any case

Let's focus on heap OOME for a moment.

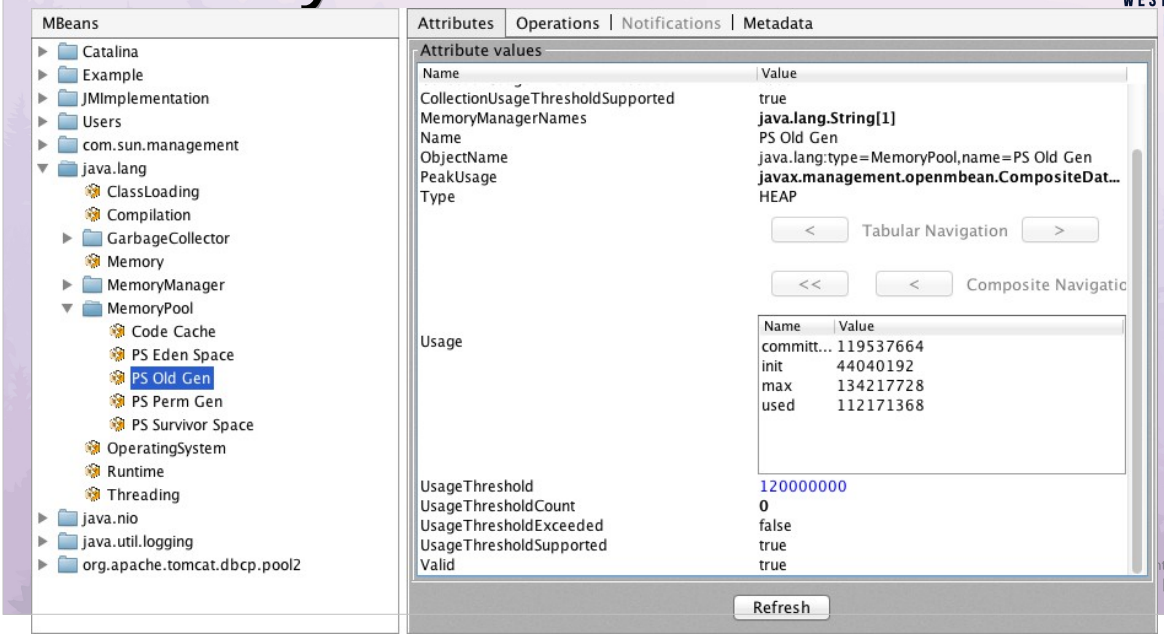
Memory Pool Thresholds



Each memory pool in the JVM has an MBean to represent it. Here's the PermGen memory pool. You can see the current usage and there are a number of “threshold” values that you can set.

Whenever the memory usage exceeds the threshold value, the JVM increments the UsageThresholdCount value and also publishes a *notification* to all interested listeners.

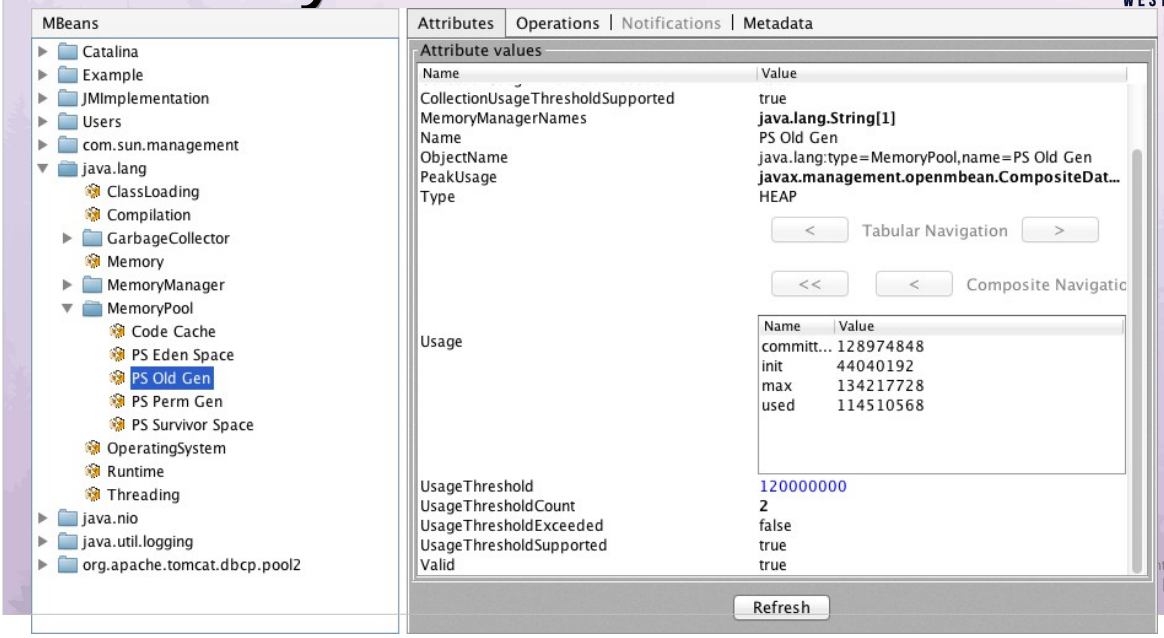
Memory Pool Thresholds



Here's the Old (tenured) Generation with its usage expanded so you can see the individual values. I've also set a threshold of roughly 115 MiB, which I know is too low of a threshold: we'll exceed this before the GC kicks-in.

Let's re-run my JMeter load test from earlier just to chew-through some heap memory and see if we can break the threshold.

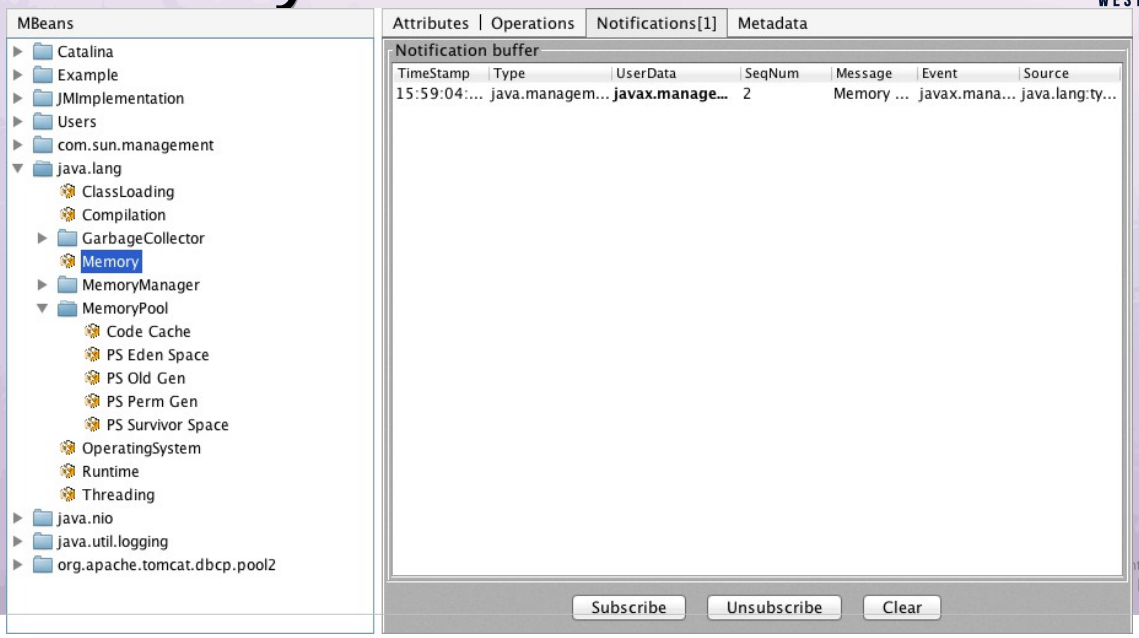
Memory Pool Thresholds



There: the UsageThresholdCount value is now 2 (up from zero). Note that the UsageThresholdExceeded value is *false* even though we have clearly broken that threshold. The “Exceeded” attribute value will only be *true* while the threshold is *still being exceeded*. It's not a one-way trip: once the memory usage falls below the threshold, that value will go back to *false*.

You can see here that the current usage is about 100MiB, less than the 115MiB threshold we set.

Memory Pool Thresholds



Hey, look at that! We can get a fairly detailed (trust me) notification about the memory threshold condition. Cool.

Memory Pool Thresholds

- Choice of how to detect exceeded-threshold conditions
  - Polling using check_jmxproxy
  - Register a notification listener from Java
    - Have that listener take some action

As usual, we have some options.

Polling doesn't seem like a great idea. What about these notifications?

Detect OutOfMemory

- Monitoring Memory Thresholds
  - Set threshold on startup
  - Register a notification listener (callback)
  - Watch “exceeded” count (poll)
  - Report to monitoring software (Nagios)
  - Repeat for each memory pool you want to watch
  - Hope the JVM does not fail during notification
  - This is getting ridiculous

Great! All you have to do is … wait. There must be a better way. One that is less fragile. This stuff is supposed to be easy.

Detecting OutOfMemory

- JVM has an easier way
- Use -XX:OnOutOfMemoryError to run a command on *first* OOME detected by the JVM
- Need a command to notify Nagios

From my field research and anecdotal evidence, -XX:OnOutOfMemoryError seems to be the most reliable way to get notifications of OOMEs.

There is one problem: you only get notified of the *first* OOME detected, so if you want to get another notification, you're going to have to bounce the JVM.

Notify Nagios on OOME

- Script that wraps curl

```
$ curl -si \
    --data-urlencode 'cmd_typ=30' \
    --data-urlencode 'cmd_mod=2' \
    --data-urlencode "host=myhost" \
    --data-urlencode "service=JVM:Heap:OOME" \
    --data-urlencode "plugin_state=2" \
    --data-urlencode "plugin_output=OOME CRITICAL" \
    'https://monitoring-host/nagios/cgi-bin/cmd.cgi'
```

Script can be found at http://wiki.apache.org/tomcat/tools/nagios-send-passive-check.sh

Here is a curl command that can be used to poke a passive-check into Nagios. To encapsulate the command, as well as to prevent the HTTP authentication information from appearing in a ps listing, we'll wrap this command in a script.

Note that you'll probably want to use a Nagios service configured for only “passive” checks since no active checks are really possible. Also, disable “flap detection” otherwise the service will immediately appear to be “flapping” when you report an OOME to Nagios – I'm not sure why – and you won't get an actual notification because Nagios thinks it's doing you a favor.

Monitoring Tomcat with JMX

- JMX Provides Monitoring and Management of JVMs
- Tomcat exposes a great amount of information via JMX
- Applications can expose anything to JMX via MBeans
- JRE ships with tools for light JMX interaction
- Practical use of JMX requires some additional tools

Summary.

Resources

- Presentation Slides

  http://people.apache.org/~schultz/ApacheCon NA 2014/Tomcat Monitoring/

- Nagios passive-check script

  http://wiki.apache.org/tomcat/tools/nagios-send-passive-check.sh

- check_jmxproxy

  http://wiki.apache.org/tomcat/tools/check_jmxproxy.pl

- Special thanks to Christopher Blunck (MBeans info)

  http://oss.wxnet.org/mbeans.html

Resources.
Questions?