How to analyze JVM application performance

Tools and Techniques

Java Meetup Thessaloniki Feb 2019

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General performance concepts(1)

➔Throughput

➔Latency

➔Capacity

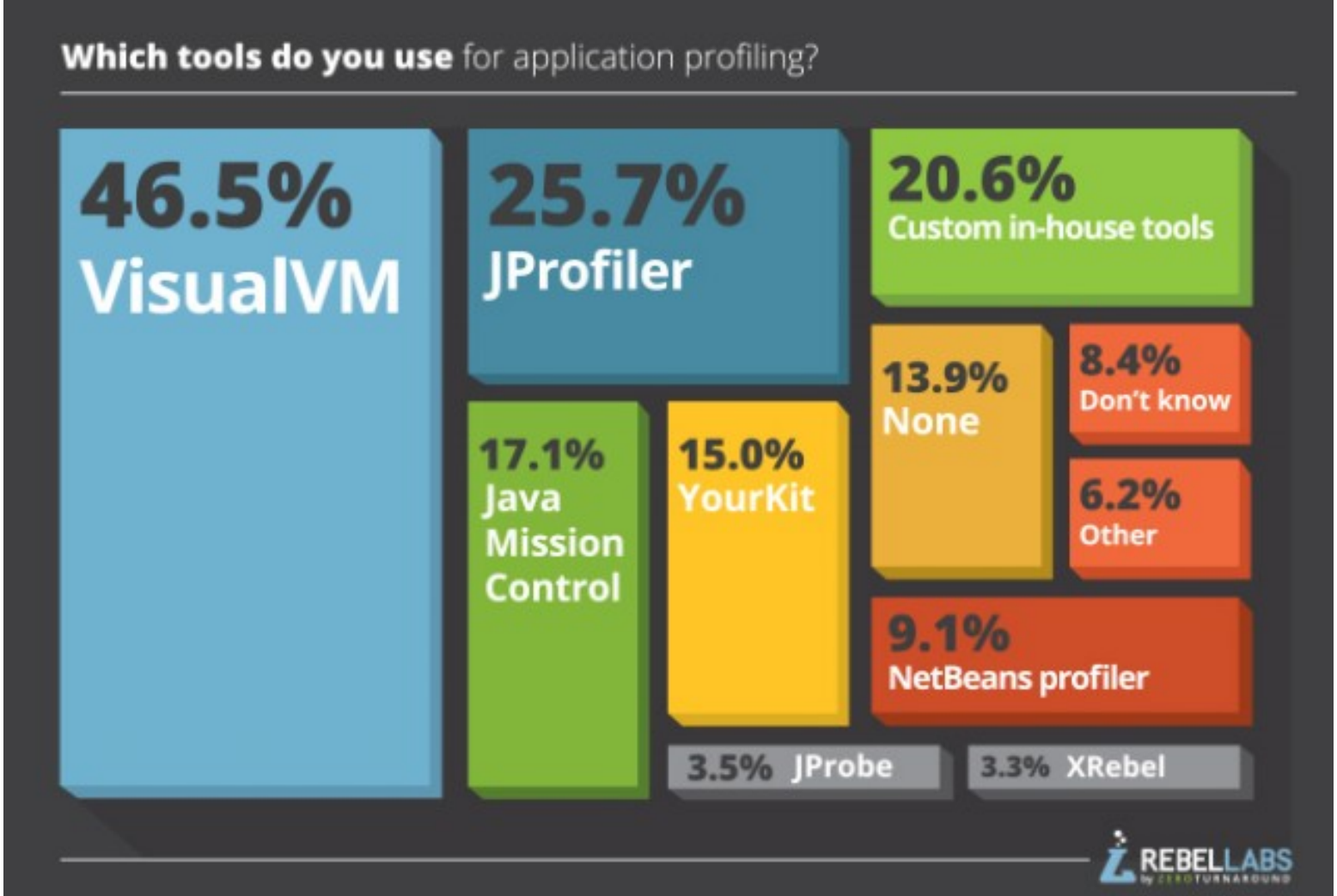
General performance concepts(2)

➔Utilization

➔Efficiency

➔Scalability

➔Degradation


Which tools do you use for application profiling?
46.5%
VisualVM
25.7%
JProfiler
20.6%
Custom in-house tools
13.9%
None
8.4%
Don't know
6.2%
Other
17.1%
Java
Mission
Control
15.0%
YourKit
9.1%
NetBeans profiler
3.5% JProbe
3.3% XRebel
REBELLABS
by ZEROTURNAROUND

How do these tools work?

- ➔JMX
- ➔Java Attach API
- ➔Java Agent (Instrumentation)
- ➔Sampling
- ➔event based (GC logs)
- ➔based on Linux commands

Visual VM

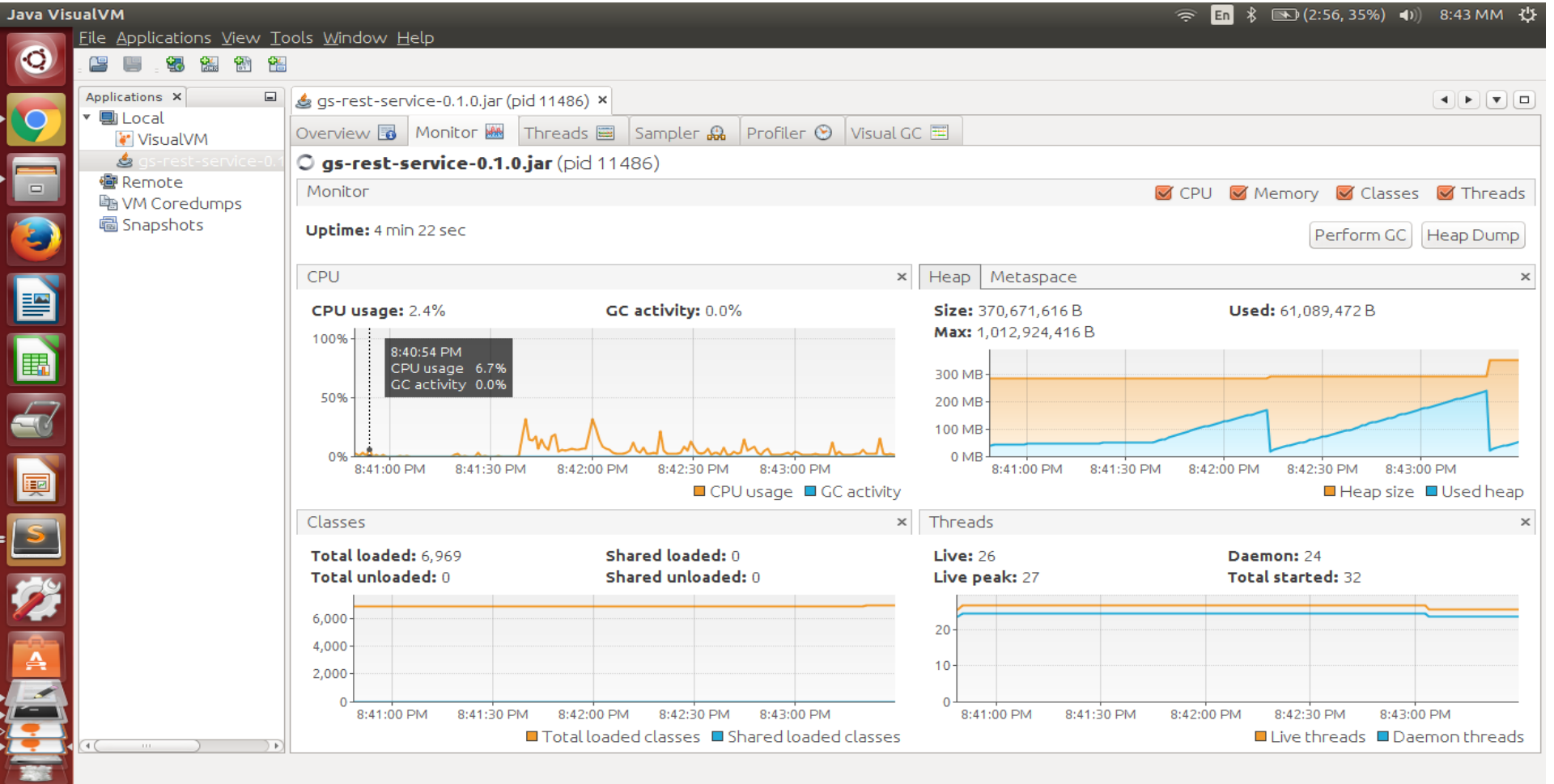
➔Based on Netbeans Profiler

➔Opensource

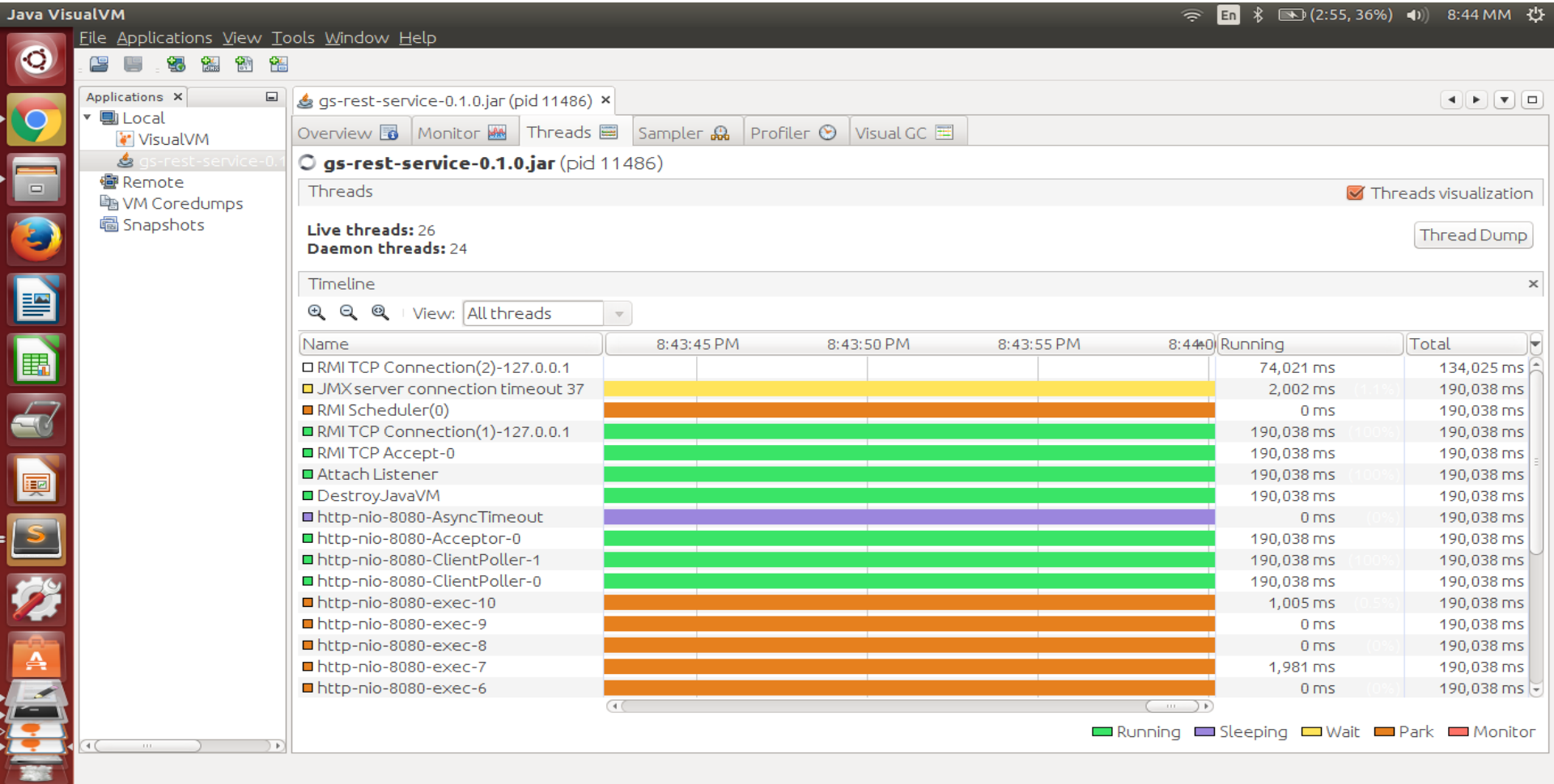
➔Popular tool for gathering metrics from jvm (real time,dumps)

➔on JDK 1.8 as jvisualvm

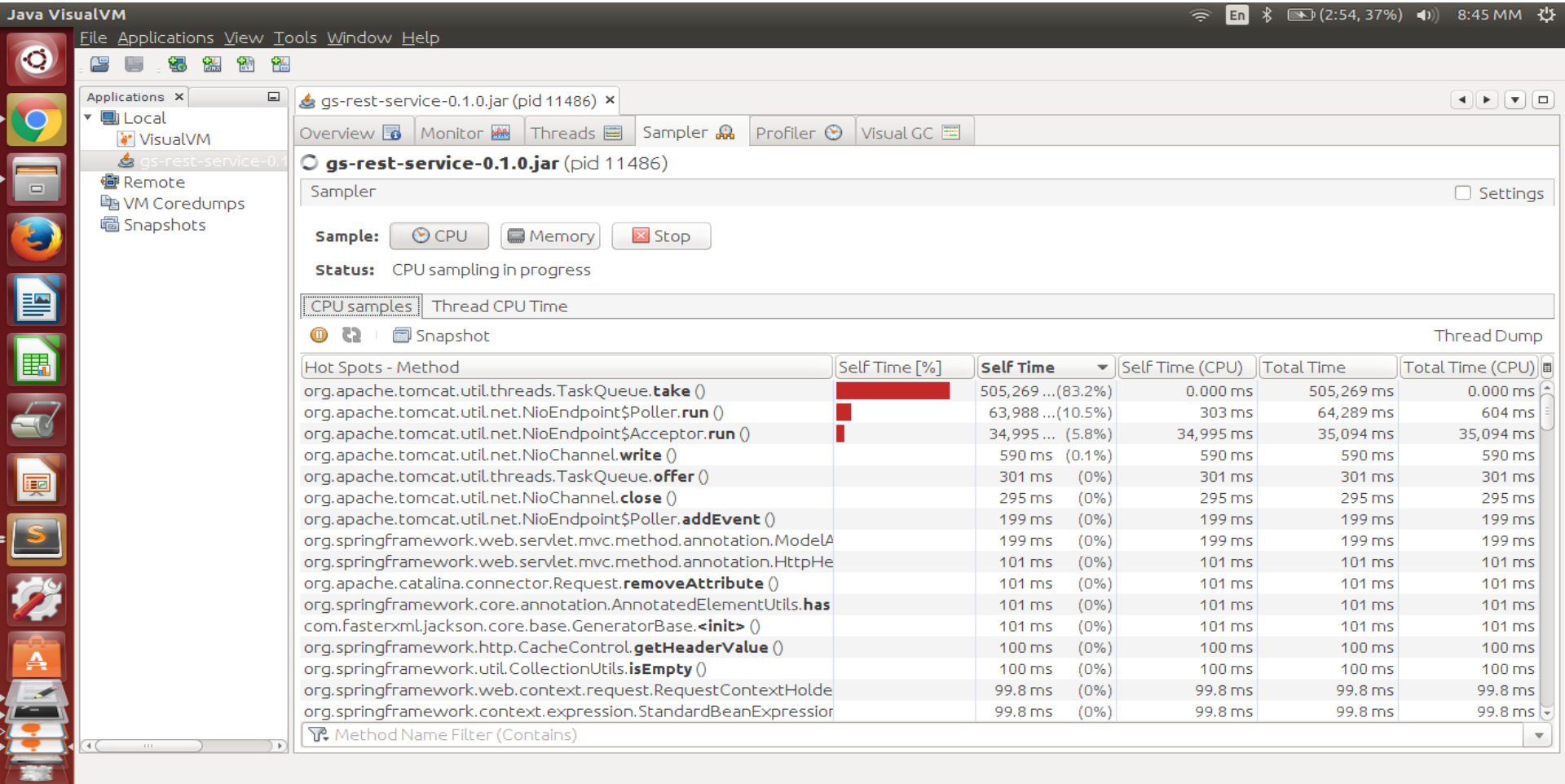
Visual VM Monitor



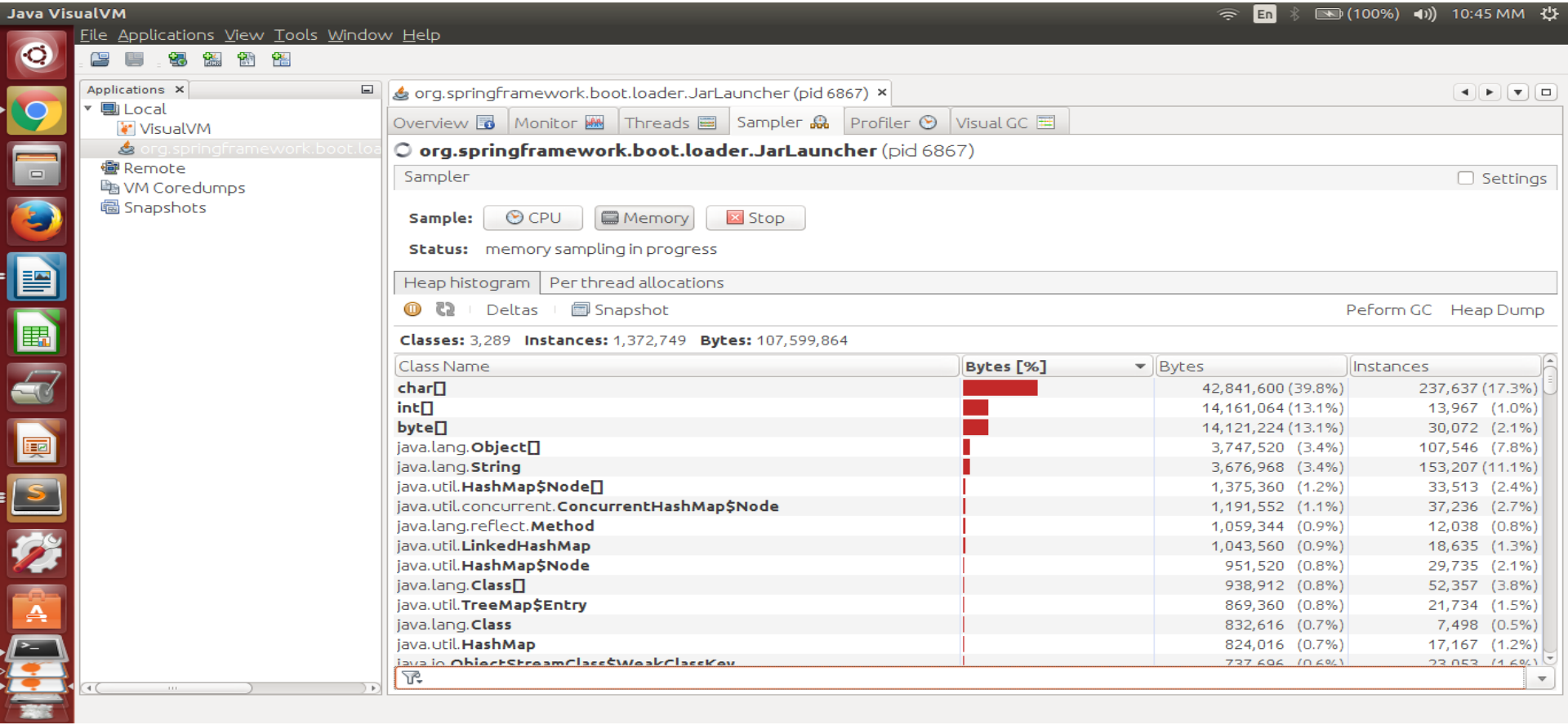
Visual VM Threads



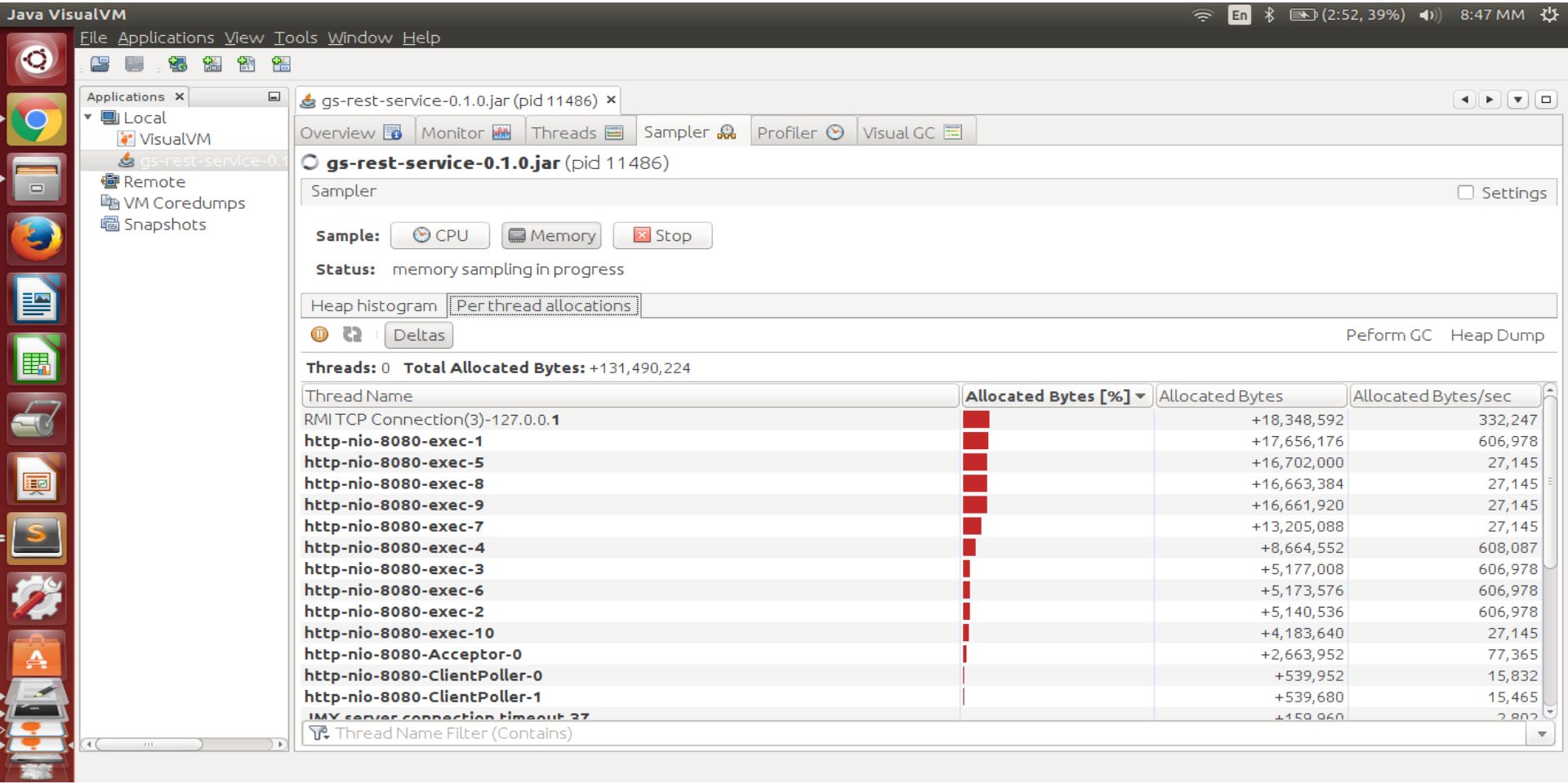
Visual VM CPU sampler



Visual VM Memory Heap Sampler



Visual VM memory Thread Sampler



Garbage Collection

➔What is GC?

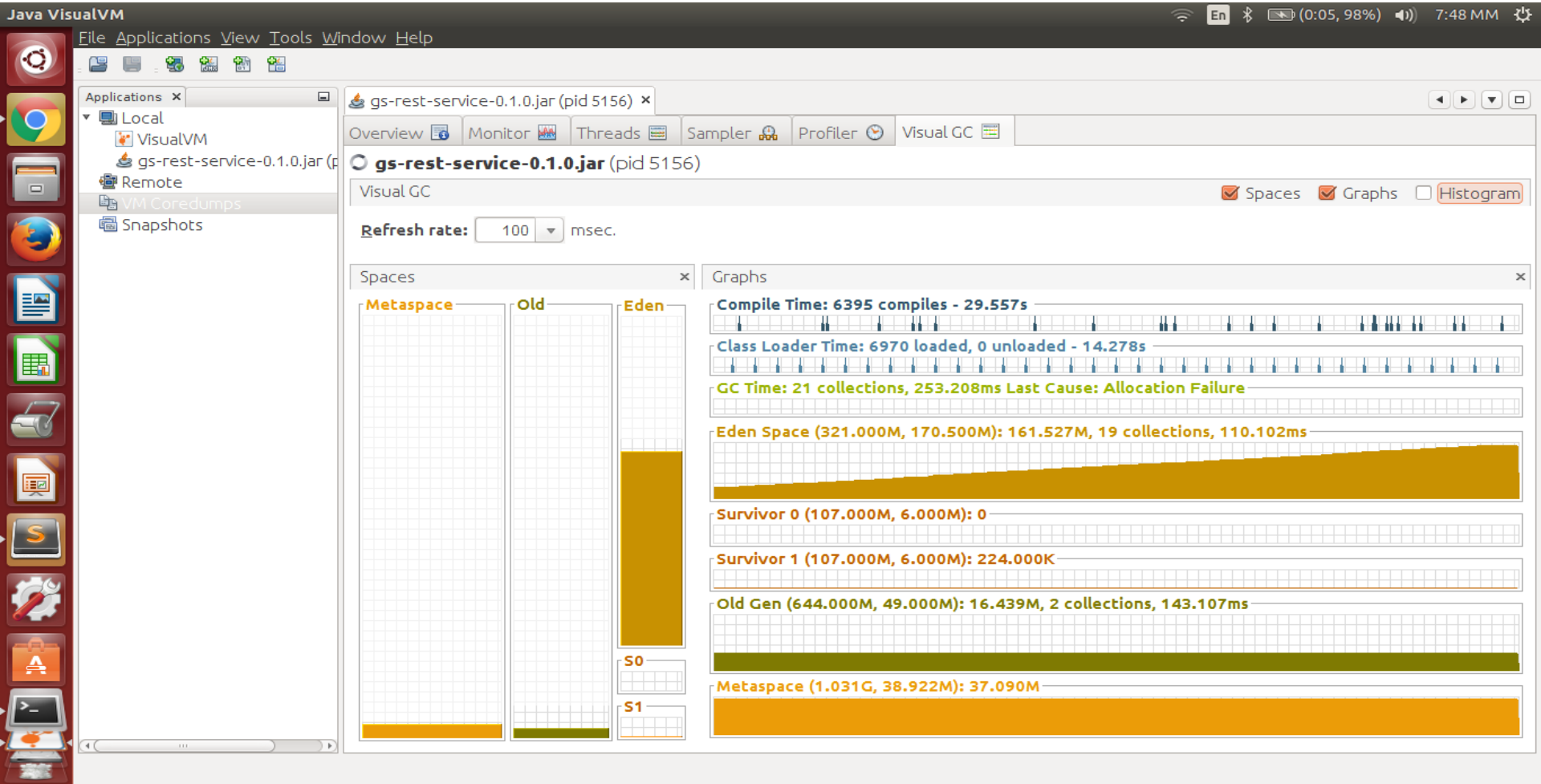
➔How often?

➔Allocation rate

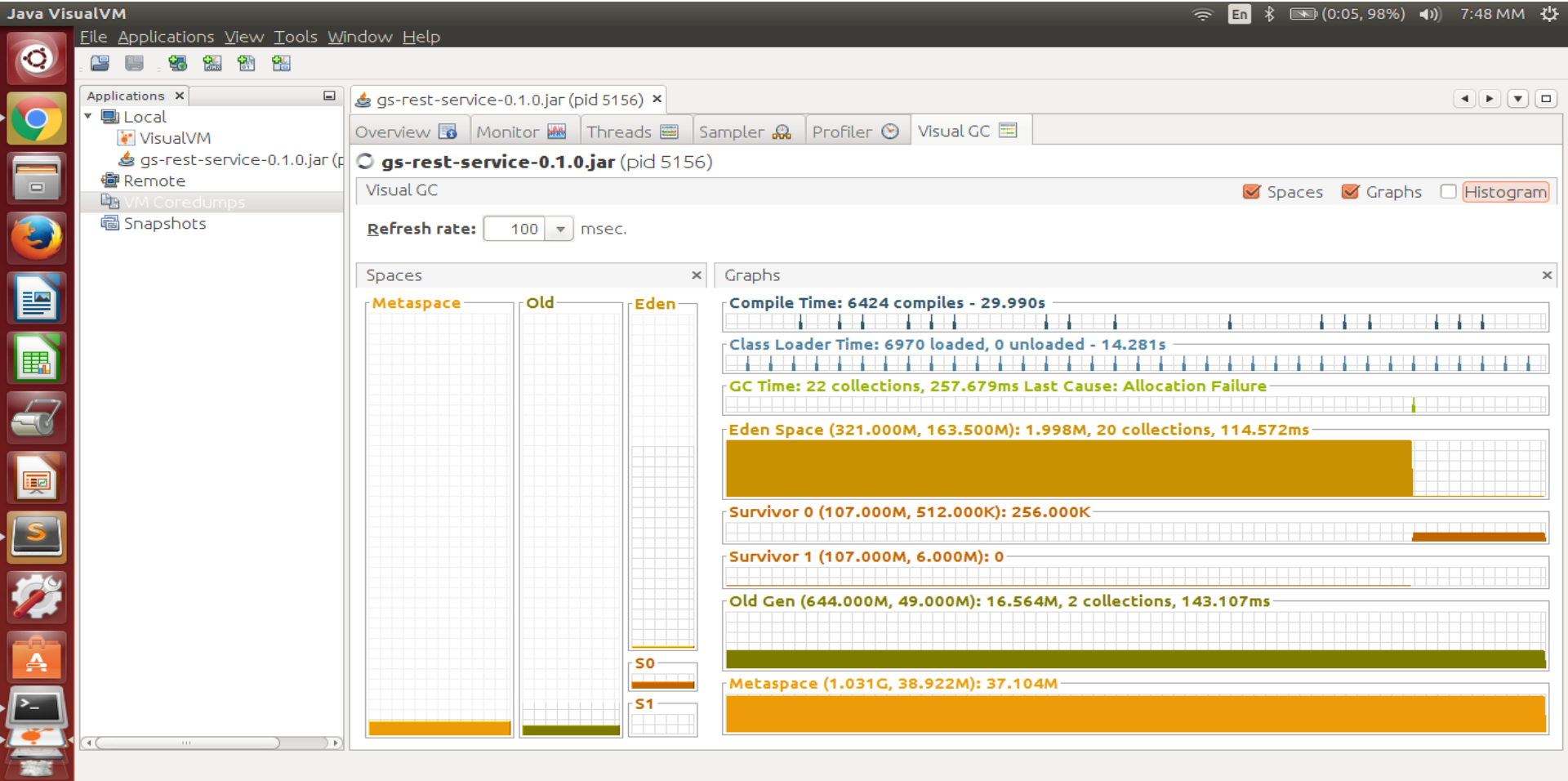
➔Object life cycle

➔Safepoints (gc pause)

Visual GC (1)


Java VisualVM
File Applications View Tools Window Help
Applications
Local
VisualVM
gs-rest-service-0.1.0.jar (p
Remote
VM Coredumps
Snapshots
gs-rest-service-0.1.0.jar (pid 5156)
Overview
Monitor
Threads
Sampler
Profiler
Visual GC
gs-rest-service-0.1.0.jar (pid 5156)
Visual GC
Spaces
Graphs
Histogram
Refresh rate: 100 msec.
Spaces
Graphs
Metaspace
Old
Eden
S0
S1
Compile Time: 6395 compiles - 29.557s
Class Loader Time: 6970 loaded, 0 unloaded - 14.278s
GC Time: 21 collections, 253.208ms Last Cause: Allocation Failure
Eden Space (321.000M, 170.500M): 161.527M, 19 collections, 110.102ms
Survivor 0 (107.000M, 6.000M): 0
Survivor 1 (107.000M, 6.000M): 224.000K
Old Gen (644.000M, 49.000M): 16.439M, 2 collections, 143.107ms
Metaspace (1.031G, 38.922M): 37.090M

Visual GC (2)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gs-rest-service-0.1.0.jar (pid 5156)
Visual GC
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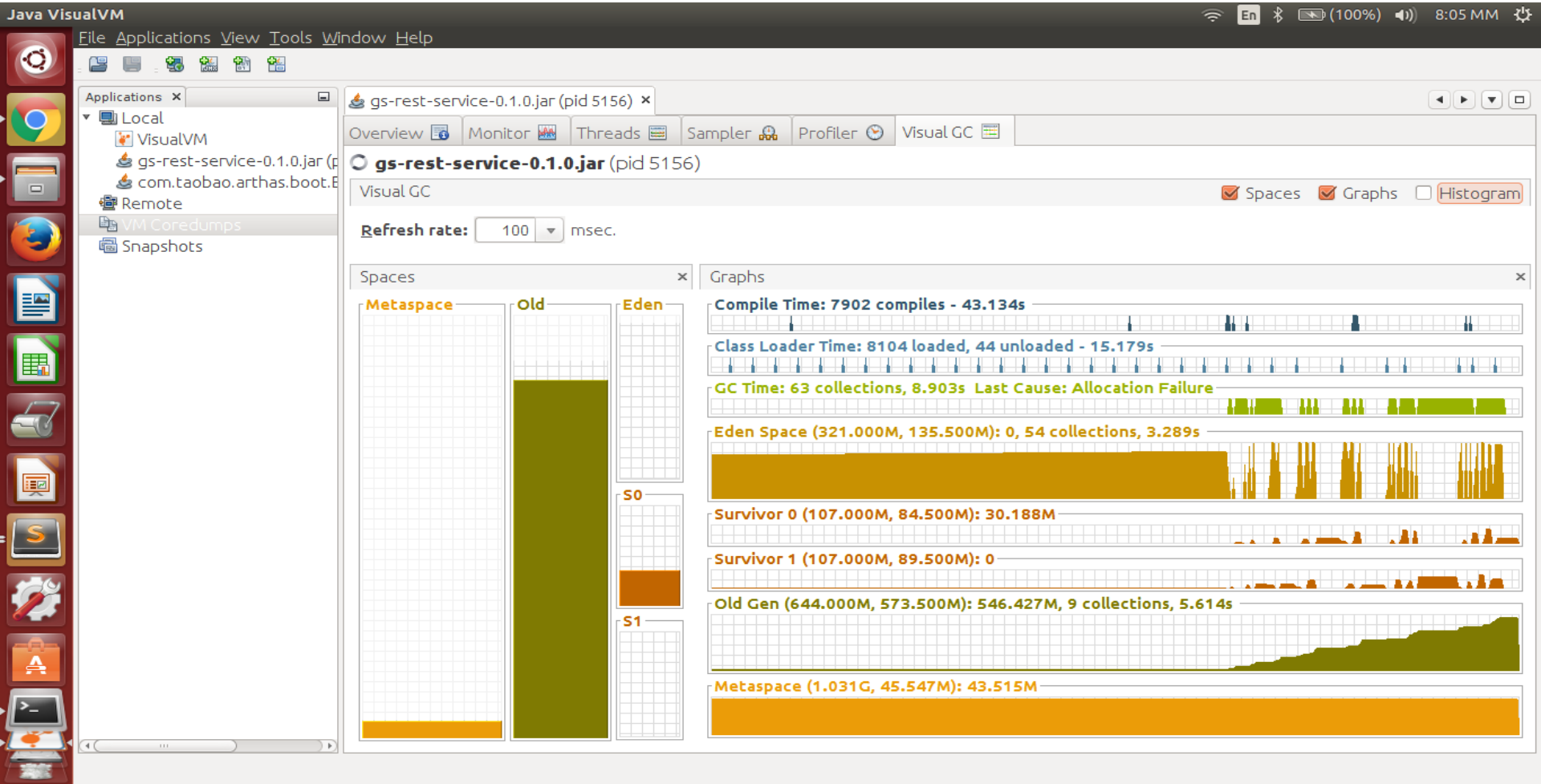
Graphs
Histogram
Refresh rate:
100
msec.
Spaces
Metaspace
Old
Eden
S0
S1
Graphs
Compile Time: 6424 compiles - 29.990s
Class Loader Time: 6970 loaded, 0 unloaded - 14.281s
GC Time: 22 collections, 257.679ms Last Cause: Allocation Failure
Eden Space (321.000M, 163.500M): 1.998M, 20 collections, 114.572ms
Survivor 0 (107.000M, 512.000K): 256.000K
Survivor 1 (107.000M, 6.000M): 0
Old Gen (644.000M, 49.000M): 16.564M, 2 collections, 143.107ms
Metaspace (1.031G, 38.922M): 37.104M

Visual GC (3)


Java VisualVM
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Applications
Local
VisualVM
gs-rest-service-0.1.0.jar (p
com.taobao.arthas.boot.E
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VM Coredumps
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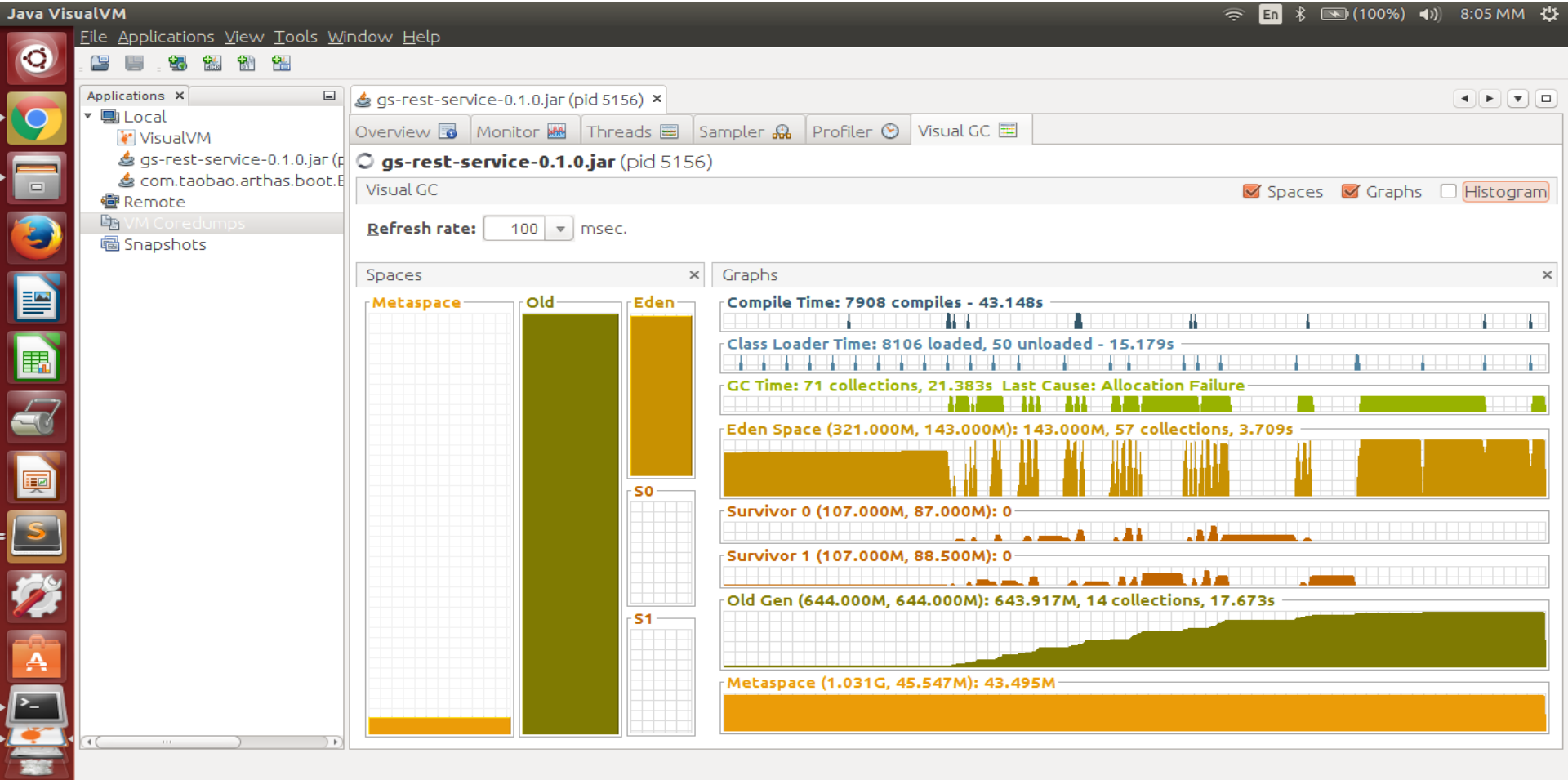
Sampler
Profiler
Visual GC
gs-rest-service-0.1.0.jar (pid 5156)
Visual GC
Spaces
Graphs
Histogram
Refresh rate: 100 msec.
Spaces
Graphs
Metaspace
Old
Eden
S0
S1
Compile Time: 7902 compiles - 43.134s
Class Loader Time: 8104 loaded, 44 unloaded - 15.179s
GC Time: 63 collections, 8.903s Last Cause: Allocation Failure
Eden Space (321.000M, 135.500M): 0, 54 collections, 3.289s
Survivor 0 (107.000M, 84.500M): 30.188M
Survivor 1 (107.000M, 89.500M): 0
Old Gen (644.000M, 573.500M): 546.427M, 9 collections, 5.614s
Metaspace (1.031G, 45.547M): 43.515M

Visual GC (4)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Applications
Local
VisualVM
gs-rest-service-0.1.0.jar (p
com.taobao.arthas.boot.E
Remote
VM Coredumps
Snapshots
gs-rest-service-0.1.0.jar (pid 5156)
Overview
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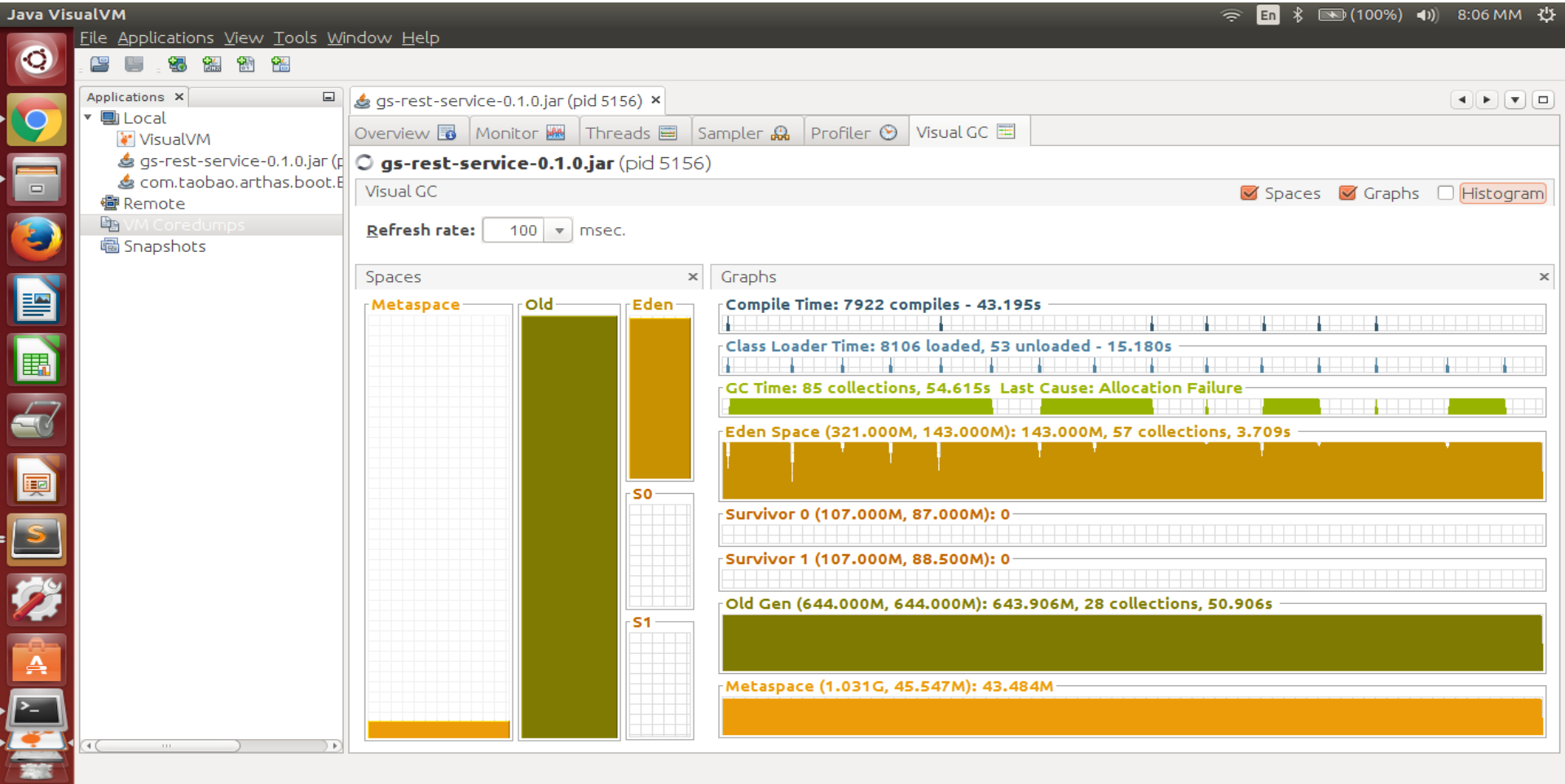
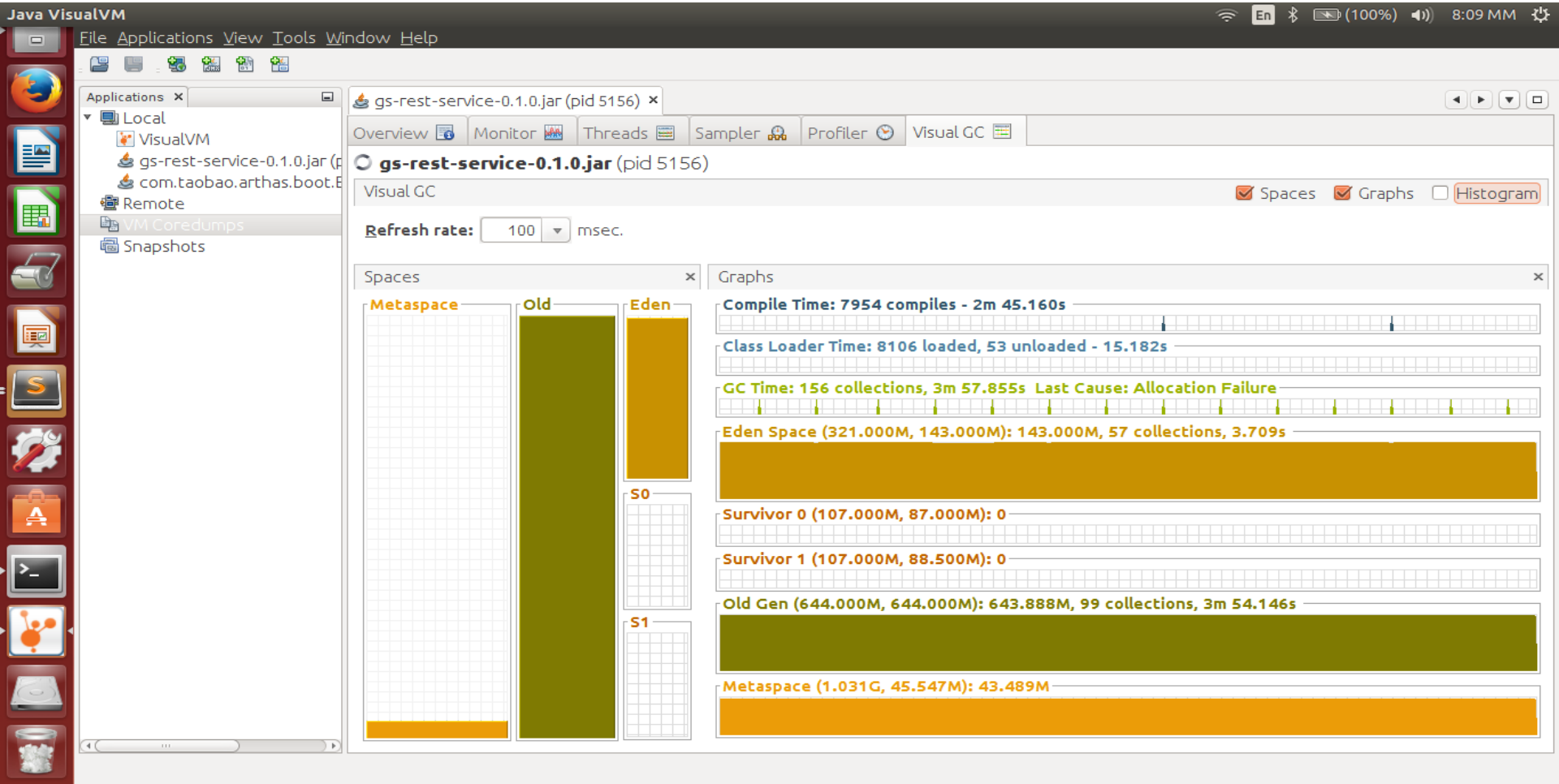
Threads
Sampler
Profiler
Visual GC
gs-rest-service-0.1.0.jar (pid 5156)
Visual GC
Spaces
Graphs
Histogram
Refresh rate:
100
msec.
Spaces
Graphs
Metaspace
Old
Eden
S0
S1
Compile Time: 7908 compiles - 43.148s
Class Loader Time: 8106 loaded, 50 unloaded - 15.179s
GC Time: 71 collections, 21.383s Last Cause: Allocation Failure
Eden Space (321.000M, 143.000M): 143.000M, 57 collections, 3.709s
Survivor 0 (107.000M, 87.000M): 0
Survivor 1 (107.000M, 88.500M): 0
Old Gen (644.000M, 644.000M): 643.917M, 14 collections, 17.673s
Metaspace (1.031G, 45.547M): 43.495M

Visual GC (5)


Java VisualVM
File Applications View Tools Window Help
Applications
Local
VisualVM
gs-rest-service-0.1.0.jar (p
com.taobao.arthas.boot.B
Remote
VM Coredumps
Snapshots
gs-rest-service-0.1.0.jar (pid 5156)
Overview
Monitor
Threads
Sampler
Profiler
Visual GC
gs-rest-service-0.1.0.jar (pid 5156)
Visual GC
Spaces
Graphs
Histogram
Refresh rate:
100
msec.
Spaces
Graphs
Metaspace
Old
Eden
S0
S1
Compile Time: 7922 compiles - 43.195s
Class Loader Time: 8106 loaded, 53 unloaded - 15.180s
GC Time: 85 collections, 54.615s Last Cause: Allocation Failure
Eden Space (321.000M, 143.000M): 143.000M, 57 collections, 3.709s
Survivor 0 (107.000M, 87.000M): 0
Survivor 1 (107.000M, 88.500M): 0
Old Gen (644.000M, 644.000M): 643.906M, 28 collections, 50.906s
Metaspace (1.031G, 45.547M): 43.484M

Visual GC (6)


Java VisualVM
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Applications
Local
VisualVM
gs-rest-service-0.1.0.jar (p
com.taobao.arthas.boot.E
Remote
VM Coredumps
Snapshots
gs-rest-service-0.1.0.jar (pid 5156)
Overview
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Threads
Sampler
Profiler
Visual GC
gs-rest-service-0.1.0.jar (pid 5156)
Visual GC
Spaces
Graphs
Histogram
Refresh rate:
100
msec.
Spaces
Graphs
Metaspace
Old
Eden
S0
S1
Compile Time: 7954 compiles - 2m 45.160s
Class Loader Time: 8106 loaded, 53 unloaded - 15.182s
GC Time: 156 collections, 3m 57.855s Last Cause: Allocation Failure
Eden Space (321.000M, 143.000M): 143.000M, 57 collections, 3.709s
Survivor 0 (107.000M, 87.000M): 0
Survivor 1 (107.000M, 88.500M): 0
Old Gen (644.000M, 644.000M): 643.888M, 99 collections, 3m 54.146s
Metaspace (1.031G, 45.547M): 43.489M

Java VisualVM
File Applications View Tools Window Help
Applications
Local
VisualVM
gs-rest-service-0.1.0.jar (p
com.taobao.arthas.boot.E
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gs-rest-service-0.1.0.jar (pid 5156)
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Sampler
Profiler
Visual GC
gs-rest-service-0.1.0.jar (pid 5156)
Monitor
CPU
Memory
Classes
Threads
Uptime: 25 min 07 sec
Perform GC
Heap Dump
CPU
CPU usage: 53.6%
GC activity: 23.4%
100%
50%
0%
7:45 PM
7:50 PM
7:55 PM
8:00 PM
8:05 PM
CPU usage
GC activity
Heap
Metaspace
Size: 1,010,827,264 B
Used: 825,063,768 B
Max: 1,012,924,416 B
1,000 MB
500 MB
0 MB
Heap size
Used heap
Classes
Total loaded: 8,053
Shared loaded: 0
Total unloaded: 53
Shared unloaded: 0
5,000
0
Total loaded classes
Shared loaded classes
Threads
Live: 38
Daemon: 31
Live peak: 38
Total started: 47
40
30
20
10
0
Live threads
Daemon threads

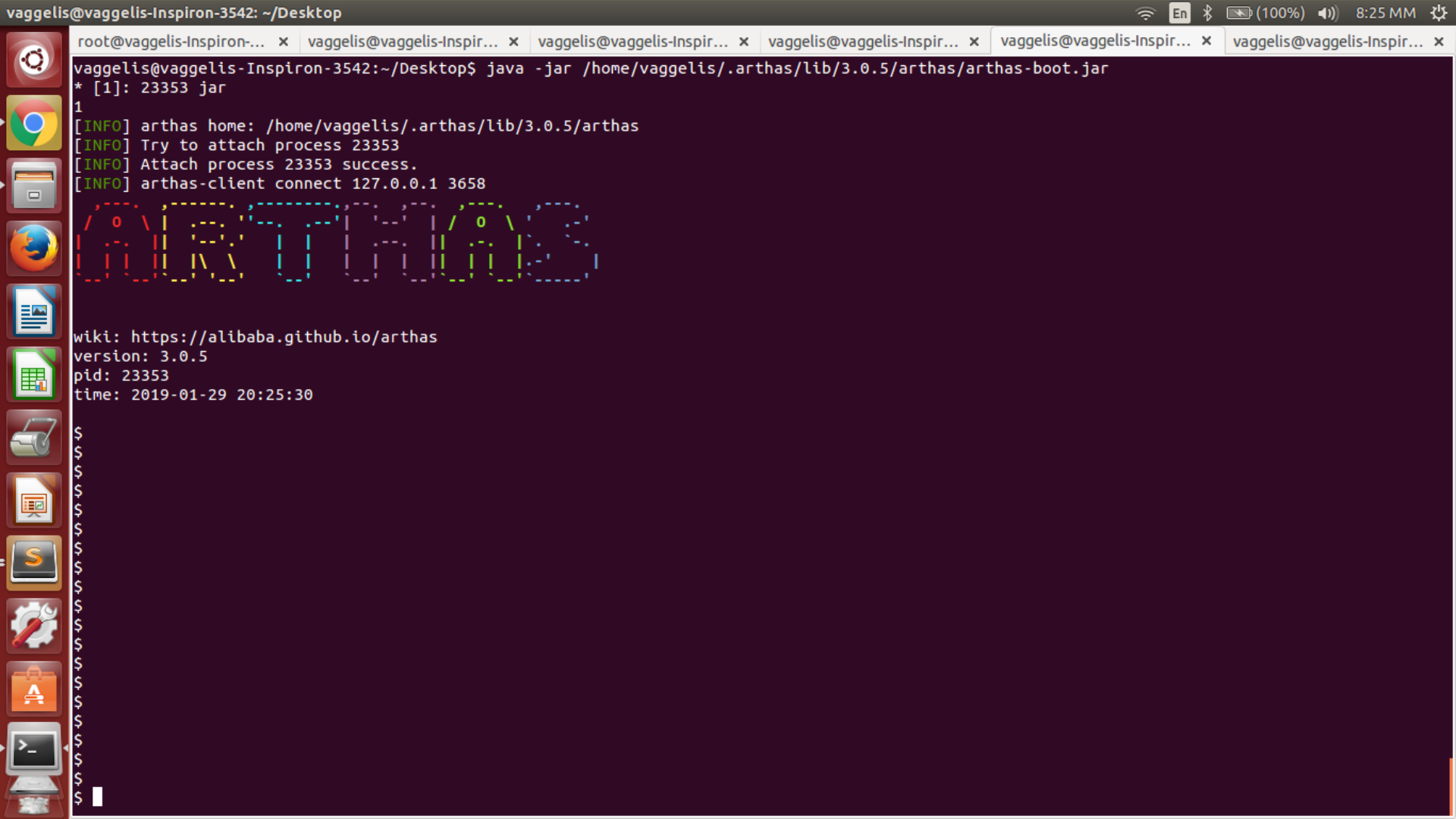
Arthas

- OSS by Alibaba

➔Diagnostic tool for jvm app in production

➔Good for remote systems

➔Console based (or web app console)


vaggelis@vaggelis-Inspiron-3542: ~/Desktop
root@vaggelis-Inspiron-...
vaggelis@vaggelis-Inspir...
vaggelis@vaggelis-Inspir...
vaggelis@vaggelis-Inspir...
vaggelis@vaggelis-Inspir...
vaggelis@vaggelis-Inspir...
vaggelis@vaggelis-Inspiron-3542:~/Desktop$ java -jar /home/vaggelis/.arthas/lib/3.0.5/arthas/arthas-boot.jar
* [1]: 23353 jar
1
[INFO] arthas home: /home/vaggelis/.arthas/lib/3.0.5/arthas
[INFO] Try to attach process 23353
[INFO] Attach process 23353 success.
[INFO] arthas-client connect 127.0.0.1 3658
wiki: https://alibaba.github.io/arthas
version: 3.0.5
pid: 23353
time: 2019-01-29 20:25:30

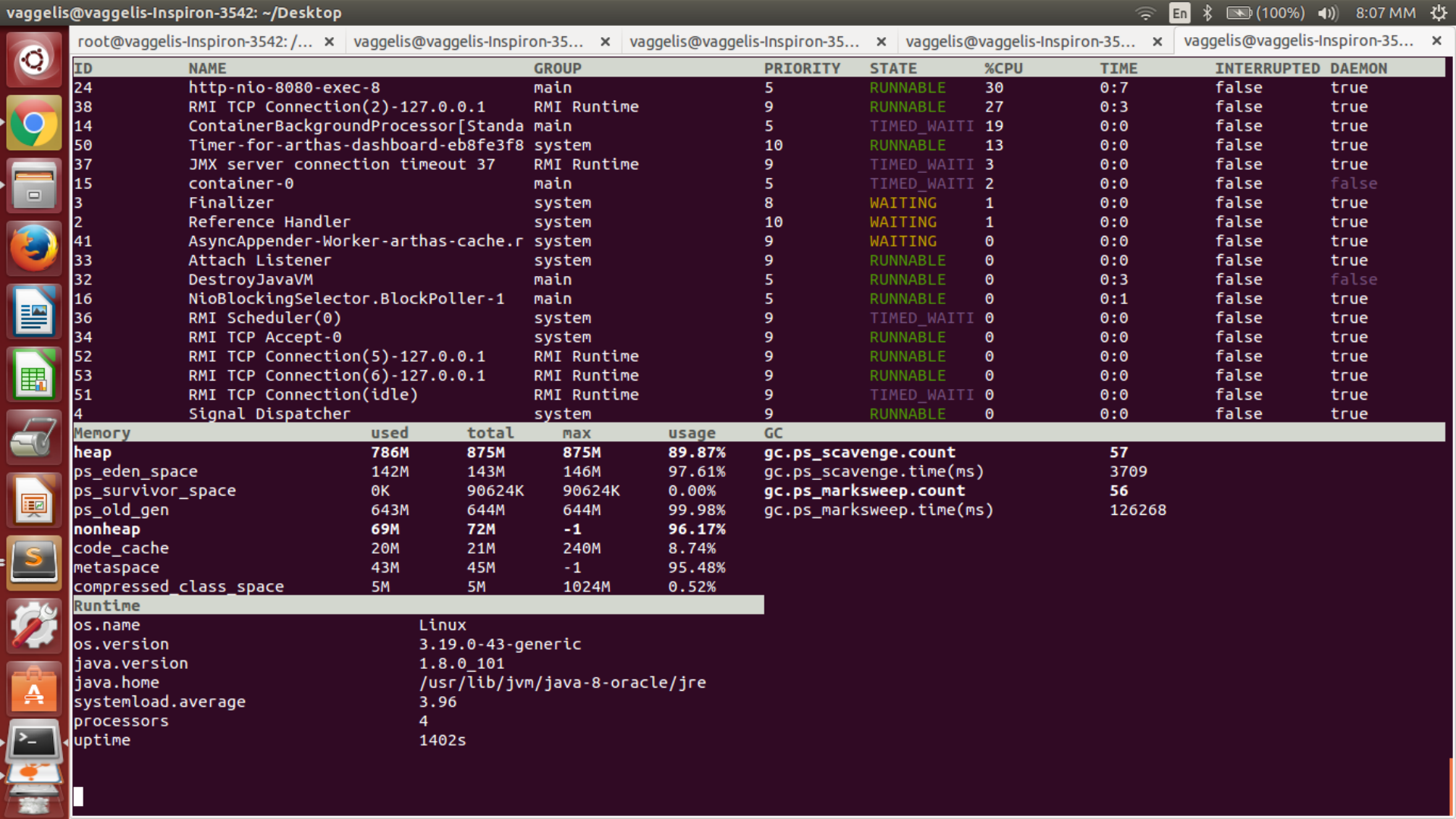

```
$
$
$
$
$
$
$
$
$
$ help
 NAME          DESCRIPTION
 help          Display Arthas Help
 keymap        Display all the available keymap for the specified connection.
 sc            Search all the classes loaded by JVM
 sm            Search the method of classes loaded by JVM
 classloader   Show classloader info
 jad           Decompile class
 getstatic     Show the static field of a class
 monitor       Monitor method execution statistics, e.g. total/success/failure count, average rt, fail rate, etc.
 stack         Display the stack trace for the specified class and method
 thread        Display thread info, thread stack
 trace         Trace the execution time of specified method invocation.
 watch         Display the input/output parameter, return object, and thrown exception of specified method invocation
 tt            Time Tunnel
 jvm           Display the target JVM information
 ognl          Execute ognl expression.
 dashboard     Overview of target jvm's thread, memory, gc, vm, tomcat info.
 dump          Dump class byte array from JVM
 options       View and change various Arthas options
 cls           Clear the screen
 reset         Reset all the enhanced classes
 version       Display Arthas version
 shutdown      Shutdown Arthas server and exit the console
 session       Display current session information
 sysprop       Display, and change the system properties.
 sysenv        Display the system env.
 redefine      Redefine classes. @see Instrumentation#redefineClasses(ClassDefinition...)
 history       Display command history
$
```


```
$ thread -n 2
"http-nio-8080-exec-9" Id=25 cpuUsage=16% WAITING on java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject@3344a0f5
    at sun.misc.Unsafe.park(Native Method)
    -  waiting on java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject@3344a0f5
    at java.util.concurrent.locks.LockSupport.park(LockSupport.java:175)
    at java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject.await(AbstractQueuedSynchronizer.java:2039)
    at java.util.concurrent.LinkedBlockingQueue.take(LinkedBlockingQueue.java:442)
    at org.apache.tomcat.util.threads.TaskQueue.take(TaskQueue.java:103)
    at org.apache.tomcat.util.threads.TaskQueue.take(TaskQueue.java:31)
    at java.util.concurrent.ThreadPoolExecutor.getTask(ThreadPoolExecutor.java:1067)
    at java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1127)
    at java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.java:617)
    at org.apache.tomcat.util.threads.TaskThread$WrappingRunnable.run(TaskThread.java:61)
    at java.lang.Thread.run(Thread.java:745)


"http-nio-8080-exec-1" Id=17 cpuUsage=14% WAITING on java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject@3344a0f5
    at sun.misc.Unsafe.park(Native Method)
    -  waiting on java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject@3344a0f5
    at java.util.concurrent.locks.LockSupport.park(LockSupport.java:175)
    at java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject.await(AbstractQueuedSynchronizer.java:2039)
    at java.util.concurrent.LinkedBlockingQueue.take(LinkedBlockingQueue.java:442)
    at org.apache.tomcat.util.threads.TaskQueue.take(TaskQueue.java:103)
    at org.apache.tomcat.util.threads.TaskQueue.take(TaskQueue.java:31)
    at java.util.concurrent.ThreadPoolExecutor.getTask(ThreadPoolExecutor.java:1067)
    at java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1127)
    at java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.java:617)
    at org.apache.tomcat.util.threads.TaskThread$WrappingRunnable.run(TaskThread.java:61)
    at java.lang.Thread.run(Thread.java:745)


Affect(row-cnt:0) cost in 147 ms.
$
```


```
$
$ thread -n 2
"http-nio-8080-exec-6" Id=22 cpuUsage=99% RUNNABLE
    at java.util.Formatter.format(Formatter.java:2455)
    at java.lang.String.format(String.java:2940)
    at hello.GreetingController.memleak(GreetingController.java:28)
    at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
    at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:62)
    at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)
    at java.lang.reflect.Method.invoke(Method.java:498)
    at org.springframework.web.method.support.InvocableHandlerMethod.doInvoke(InvocableHandlerMethod.java:209)
    at org.springframework.web.method.support.InvocableHandlerMethod.invokeForRequest(InvocableHandlerMethod.java:136)
    at org.springframework.web.servlet.mvc.method.annotation.ServletInvocableHandlerMethod.invokeAndHandle(ServletInvocableHandlerMethod.java:1
02)
    at org.springframework.web.servlet.mvc.method.annotation.RequestMappingHandlerAdapter.invokeHandlerMethod(RequestMappingHandlerAdapter.java
:891)
    at org.springframework.web.servlet.mvc.method.annotation.RequestMappingHandlerAdapter.handleInternal(RequestMappingHandlerAdapter.java:797)
    at org.springframework.web.servlet.mvc.method.AbstractHandlerMethodAdapter.handle(AbstractHandlerMethodAdapter.java:87)
    at org.springframework.web.servlet.DispatcherServlet.doDispatch(DispatcherServlet.java:991)
    at org.springframework.web.servlet.DispatcherServlet.doService(DispatcherServlet.java:925)
    at org.springframework.web.servlet.FrameworkServlet.processRequest(FrameworkServlet.java:974)
    at org.springframework.web.servlet.FrameworkServlet.doGet(FrameworkServlet.java:866)
    at javax.servlet.http.HttpServlet.service(HttpServlet.java:635)
    at org.springframework.web.servlet.FrameworkServlet.service(FrameworkServlet.java:851)
    at javax.servlet.http.HttpServlet.service(HttpServlet.java:742)
    at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:231)
    at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:166)
    at org.apache.tomcat.websocket.server.WsFilter.doFilter(WsFilter.java:52)
    at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:193)
    at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:166)
    at org.springframework.web.filter.RequestContextFilter.doFilterInternal(RequestContextFilter.java:99)
    at org.springframework.web.filter.OncePerRequestFilter.doFilter(OncePerRequestFilter.java:107)
    at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:193)
    at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:166)
    at org.springframework.web.filter.HttpPutFormContentFilter.doFilterInternal(HttpPutFormContentFilter.java:109)
    at org.springframework.web.filter.OncePerRequestFilter.doFilter(OncePerRequestFilter.java:107)
    at org.apache.catalina.core.ApplicationFilterChain.internalDoFilter(ApplicationFilterChain.java:193)
    at org.apache.catalina.core.ApplicationFilterChain.doFilter(ApplicationFilterChain.java:166)
    at org.springframework.web.filter.HiddenHttpMethodFilter.doFilterInternal(HiddenHttpMethodFilter.java:93)
```


vaggelis@vaggelis-Inspiron-3542: ~/Desktop
root@vaggelis-Inspiron-3542: /...
vaggelis@vaggelis-Inspiron-35...
vaggelis@vaggelis-Inspiron-35...
vaggelis@vaggelis-Inspiron-35...
vaggelis@vaggelis-Inspiron-35...
ID NAME GROUP PRIORITY STATE %CPU TIME INTERRUPTED DAEMON
24 http-nio-8080-exec-8 main 5 RUNNABLE 30 0:7 false true
38 RMI TCP Connection(2)-127.0.0.1 RMI Runtime 9 RUNNABLE 27 0:3 false true
14 ContainerBackgroundProcessor[Standa main 5 TIMED_WAITI 19 0:0 false true
50 Timer-for-arthas-dashboard-eb8fe3f8 system 10 RUNNABLE 13 0:0 false true
37 JMX server connection timeout 37 RMI Runtime 9 TIMED_WAITI 3 0:0 false true
15 container-0 main 5 TIMED_WAITI 2 0:0 false false
3 Finalizer system 8 WAITING 1 0:0 false true
2 Reference Handler system 10 WAITING 1 0:0 false true
41 AsyncAppender-Worker-arthas-cache.r system 9 WAITING 0 0:0 false true
33 Attach Listener system 9 RUNNABLE 0 0:0 false true
32 DestroyJavaVM main 5 RUNNABLE 0 0:3 false false
16 NioBlockingSelector.BlockPoller-1 main 5 RUNNABLE 0 0:1 false true
36 RMI Scheduler(0) system 9 TIMED_WAITI 0 0:0 false true
34 RMI TCP Accept-0 system 9 RUNNABLE 0 0:0 false true
52 RMI TCP Connection(5)-127.0.0.1 RMI Runtime 9 RUNNABLE 0 0:0 false true
53 RMI TCP Connection(6)-127.0.0.1 RMI Runtime 9 RUNNABLE 0 0:0 false true
51 RMI TCP Connection(idle) RMI Runtime 9 TIMED_WAITI 0 0:0 false true
4 Signal Dispatcher system 9 RUNNABLE 0 0:0 false true
Memory used total max usage GC
heap 786M 875M 875M 89.87% gc.ps_scavenge.count 57
ps_eden_space 142M 143M 146M 97.61% gc.ps_scavenge.time(ms) 3709
ps_survivor_space 0K 90624K 90624K 0.00% gc.ps_marksweep.count 56
ps_old_gen 643M 644M 644M 99.98% gc.ps_marksweep.time(ms) 126268
nonheap 69M 72M -1 96.17%
code_cache 20M 21M 240M 8.74%
metaspace 43M 45M -1 95.48%
compressed_class_space 5M 5M 1024M 0.52%
Runtime
os.name Linux
os.version 3.19.0-43-generic
java.version 1.8.0_101
java.home /usr/lib/jvm/java-8-oracle/jre
systemload.average 3.96
processors 4
uptime 1402s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$ trace *GreetingController greeting
Press Ctrl+C to abort.
Affect(class-cnt:1 , method-cnt:1) cost in 54 ms.
`---ts=2019-01-29 20:40:51;thread_name=http-nio-8080-exec-8;id=18;is_daemon=true;priority=5;TCCL=org.springframework.boot.web.embedded.tomcat.TomcatEmbeddedWebappClassLoader@63175cc5
    `---[0.228298ms] hello.GreetingController:greeting()
        +---[0.016104ms] java.util.concurrent.atomic.AtomicLong:incrementAndGet()
        +---[0.034782ms] java.lang.String:format()
        `---[0.004066ms] hello.Greeting:<init>()

`---ts=2019-01-29 20:40:54;thread_name=http-nio-8080-exec-3;id=13;is_daemon=true;priority=5;TCCL=org.springframework.boot.web.embedded.tomcat.TomcatEmbeddedWebappClassLoader@63175cc5
    `---[0.213307ms] hello.GreetingController:greeting()
        +---[0.007801ms] java.util.concurrent.atomic.AtomicLong:incrementAndGet()
        +---[0.039022ms] java.lang.String:format()
        `---[0.004295ms] hello.Greeting:<init>()
```

```
 jvm           Display the target JVM information
 ognl          Execute ognl expression.
 dashboard     Overview of target jvm's thread, memory, gc, vm, tomcat info.
 dump          Dump class byte array from JVM
 options       View and change various Arthas options
 cls           Clear the screen
 reset         Reset all the enhanced classes
 version       Display Arthas version
 shutdown      Shutdown Arthas server and exit the console
 session       Display current session information
 sysprop       Display, and change the system properties.
 sysenv        Display the system env.
 redefine      Redefine classes. @see Instrumentation#redefineClasses(ClassDefinition...)
 history       Display command history
$ trace *GreetingController greeting
Press Ctrl+C to abort.
Affect(class-cnt:1 , method-cnt:1) cost in 131 ms.
`---ts=2019-01-29 20:36:12;thread_name=http-nio-8080-exec-1;id=11;is_daemon=true;priority=5;TCCL=org.springframework.boot.web.embedded.tomcat.T
omcatEmbeddedWebappClassLoader@63175cc5
    `---[0.877881ms] hello.GreetingController:greeting()
        +---[0.029559ms] java.util.concurrent.atomic.AtomicLong:incrementAndGet()
        +---[0.148806ms] java.lang.String:format()
        `---[0.018996ms] hello.Greeting:<init>()


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$ monitor *GreetingController greeting
Press Ctrl+C to abort.
Affect(class-cnt:1 , method-cnt:1) cost in 83 ms.
 timestamp            class                    method    total  success  fail  avg-rt(ms)  fail-rate
-------------------------------------------------------------------------------------------------
 2019-01-29 20:38:10  hello.GreetingController  greeting  4490   4490     0     0.06        0.00%

 timestamp            class                    method    total  success  fail  avg-rt(ms)  fail-rate
-------------------------------------------------------------------------------------------------
 2019-01-29 20:39:10  hello.GreetingController  greeting  5510   5510     0     0.02        0.00%
```

FlameGraphs

➔Developed by Brendan Gregg

➔Base on linux commands (perf, dtrace)

➔Represent data in a graph

Links

➔Optimizing Java: Practical Techniques for Improving JVM Application Performance https://www.amazon.com/Optimizing-Java-Techniques-Application-Performance-ebook/dp/B07C848HQL
➔Visualvm https://visualvm.github.io/
➔How to produce gc logs https://blog.gceasy.io/2017/10/17/what-is-garbage-collection-log-how-to-enable-analyze/
➔Arthas https://github.com/alibaba/arthas
➔Flamegraphs http://www.brendangregg.com/flamegraphs.html
➔Flags for JVM http://stas-blogspot.blogspot.com/2011/07/most-complete-list-of-xx-options-for.html