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Unified JVM Logging in JDK 9

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Java Your Next (Cloud)

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Agenda

1. Logging History
2. Unified Logging Concepts
3. Additional Configuration
4. Usage and Recommendations

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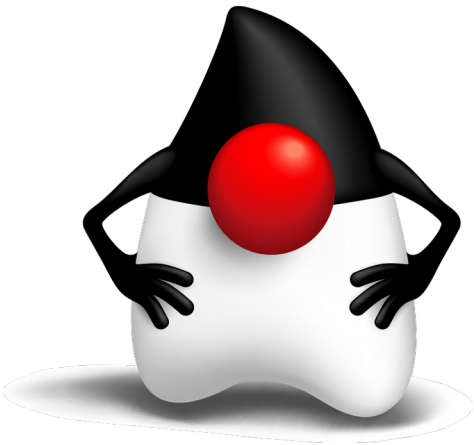
Note

- This presentation is **not** about logging in Java
  - Unrelated to java.util.logging
- Only handles logging for the Java Virtual Machine (JVM)



History of Logging in the JVM

- Simple printouts to terminal guarded by flags
  - E.g. `-XX:+PrintGC -XX:+PrintGCDetails, -XX:+Print…, -XX:+Trace…`
- Features tied to certain types of logging
  - GC logging to file (`-Xloggc:…`)
    - Optional log file rotation (`-XX:+UseGCLogFileRotation`)
  - Also supports decorating messages with timestamps
    - E.g. `-XX:+PrintGCTimeStamps`, `-XX:+PrintGCDateStamps`

Problems With Previous Solution

- Difficult to configure
  - Requires numerous command line arguments
  - Hard to discover what logging is available
    - Requires knowledge about each logging flag
  - Not always re-configurable during runtime
- Only supports logging to file for a fixed set of messages
  - Single file logging
- No consistent use of log message decorations

Logging Flags

-XX:+TraceClassResolution

-XX:+TraceExceptions

-XX:+TraceClassUnloading

-XX:+PrintGCDetails

-XX:+PrintGC

-XX:+PrintVtables

-XX:+TraceMonitorInflation

-XX:+TraceClassLoaderData

-XX:+TraceVMOperation

-XX:+PrintGCCause

-XX:+TraceClassInitialization

-XX:+TraceMonitorMismatch

-XX:+TraceDynamicGCThreads

-XX:+TraceSafepoint

-XX:+TraceRedefineClasses

-XX:+VerboseVerification

-XX:+TraceStartupTime

-XX:+PrintCMSStatistics

-XX:+TraceDefaultMethods

-XX:+PrintTaskQueue

-XX:+TraceBiasedLocking

-XX:+PrintCompressedOopsMode

-XX:+PrintJNIGCStalls

-XX:+PrintTLAB

-XX:+TraceReferenceGC

-XX:+PrintPLAB

-XX:+TraceClassResolution

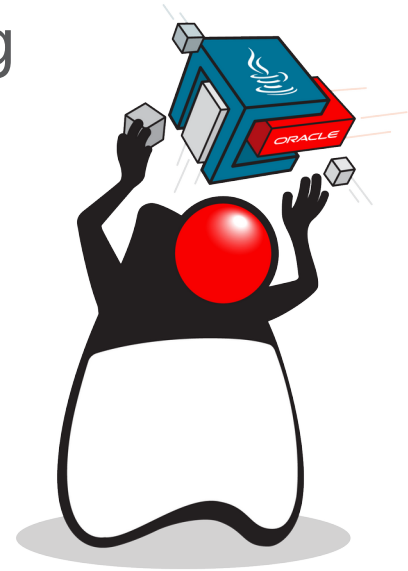
-XX:+TraceMonitorInflation

Sample Logging from JDK 8

```
$ java -XX:+TraceClassLoading -XX:+TraceMonitorInflation -XX:+PrintGCDetails ...

...

[GC (Allocation Failure) [PSYoungGen: 559296K->49792K(575488K)] 675307K->184715K(746496K),
0,0983604 secs] [Times: user=0,25 sys=0,03, real=0,10 secs]

[Full GC (Ergonomics) [PSYoungGen: 49792K->8772K(575488K)] [ParOldGen: 134923K-
>170112K(309248K)] 184715K->178884K(884736K), [Metaspace: 7744K->7744K(1056768K)],
1,6429547 secs] [Times: user=3,80 sys=0,01, real=1,64 secs]

[Loaded java.math.BigDecimal$StringBuilderHelper from /usr/lib/jvm/java-8-
jdk/jre/lib/rt.jar]

Deflating object 0x00000006cb4519c0 , mark 0x00007f6cb8004c1a , type org.h2.engine.Database

[GC (Allocation Failure) [PSYoungGen: 506948K->35616K(649728K)] 677060K->207952K(958976K),
0,1414756 secs] [Times: user=0,30 sys=0,01, real=0,14 secs]

...
```

The Unified JVM Logging Project

- Introduce a framework for all logging in the JVM
  - Use the concept of log levels
  - Categorize messages
  - Allow fine-grained control of what, where and how to log
  - Make it easier to use
- Adds the `-Xlog` java command line argument



Command Line Usage

- JVM configured for warnings and errors to *stdout*
- `-Xlog` enables info level logging
  - Customize with additional arguments (`-Xlog:<options>`)
- `-Xlog:help` for reference
  - Syntax, available options, examples
- `-Xlog:disable` to silence

Usage Example

```
$ java -Xlog -version
[0.003s][info][os] SafePoint Polling address: 0x00007fd18e125000
[0.003s][info][os] Memory Serialize Page address: 0x00007fd18e124000
[0.003s][info][os] HotSpot is running with glibc 2.24, NPTL 2.24
[0.003s][info][biasedlocking] Aligned thread 0x00007fd184012f70 to 0x00007fd184013000
[0.003s][info][os,thread    ] Thread attached (tid: 25659, pthread id: 140538008258304).
[0.003s][info][class,path   ] bootstrap loader class path=/home/mlarsson/jdk-9/lib/modules
[0.003s][info][class,path   ] classpath:
[0.003s][info][class,path   ] opened: /home/mlarsson/jdk-9/lib/modules
[0.003s][info][class,load   ] opened: /home/mlarsson/jdk-9/lib/modules
[0.003s][info][pagesize     ] CodeHeap 'non-nmethods':  min=2496K max=5696K
base=0x00007fd16bcb2000 page_size=4K size=5696K
[0.003s][info][pagesize     ] CodeHeap 'profiled nmethods':  min=2496K max=120032K
base=0x00007fd16c242000 page_size=4K size=120032K
[0.003s][info][pagesize     ] CodeHeap 'non-profiled nmethods':  min=2496K max=120032K
base=0x00007fd17377a000 page_size=4K size=120032K
...
```

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Logging

- Free text messages
- Line oriented
  - Typically one message – one line
- Not a low overhead profiling and instrumentation tool
  - Use Java Flight Recorder instead

Log Message Classification

- Classify messages according to content
  - Not all messages fit in a single category
    - Some messages span multiple categories
- Use a message tagging scheme
  - Each message is associated with a set of tags (its **tag set**)
    - A tag set is one or more tags identifying a category of messages
    - Maximum of 5 tags in a tag set
  - Selecting what to log is a matter of listing tags of interest

Log Tags

- A tag might describe a particular JVM subsystem
  - GC, interpreter, JIT compiler, OS interaction, etc.
- Or an action
  - Update, load, cleanup
- Can also distinguish messages of interest
  - For example, the **start** tag signifying start of some event

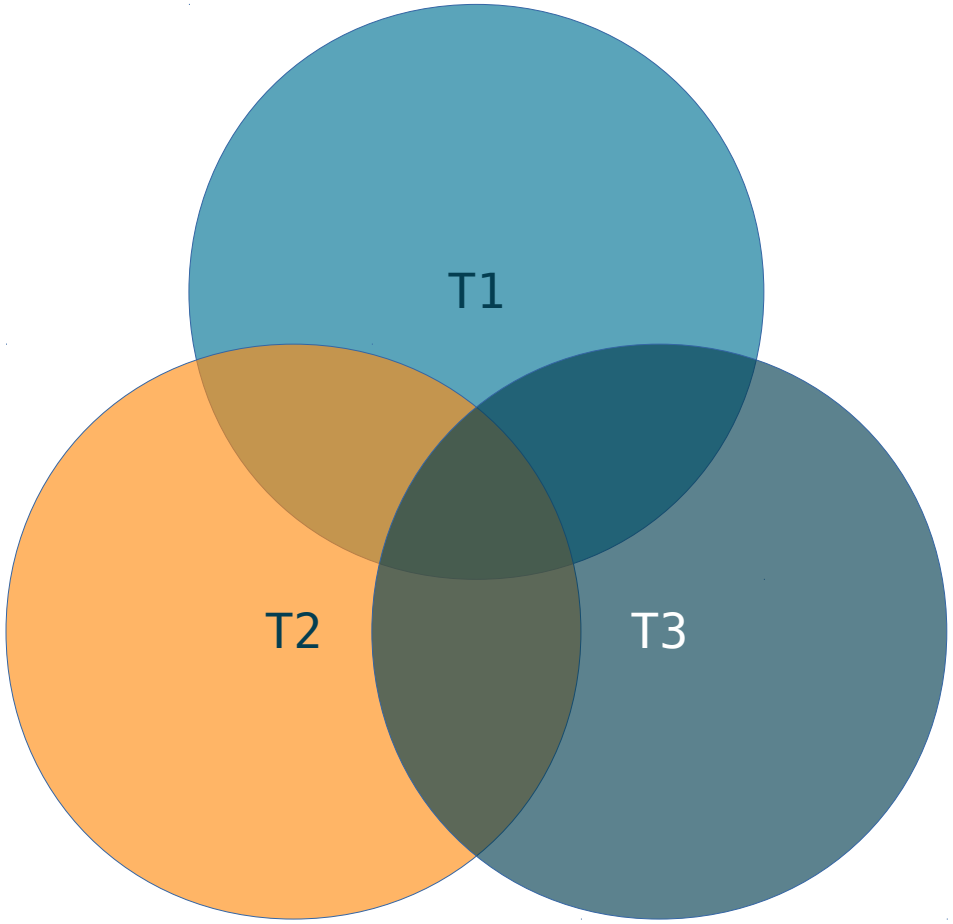
Selecting Log Tags

- First parameter to `-Xlog` describes what to log
  - E.g. -Xlog:gc enables all ‘gc’ tagged logging
  - Multiple selections comma separated: `-Xlog:gc,os`
  - Combine tags to form tag sets using ‘+’
    - E.g. -Xlog:gc+heap
  - Add ‘*’ to select **at least** the given tags
    - E.g. `-Xlog:gc*` selects all tag sets containing the ‘gc’ tag
- Syntax reference: `-Xlog:[<selection>]`
  - Where `<selection> = t1[+t2…][*][,…]`
    `‘all’`

Usage Example With Selection

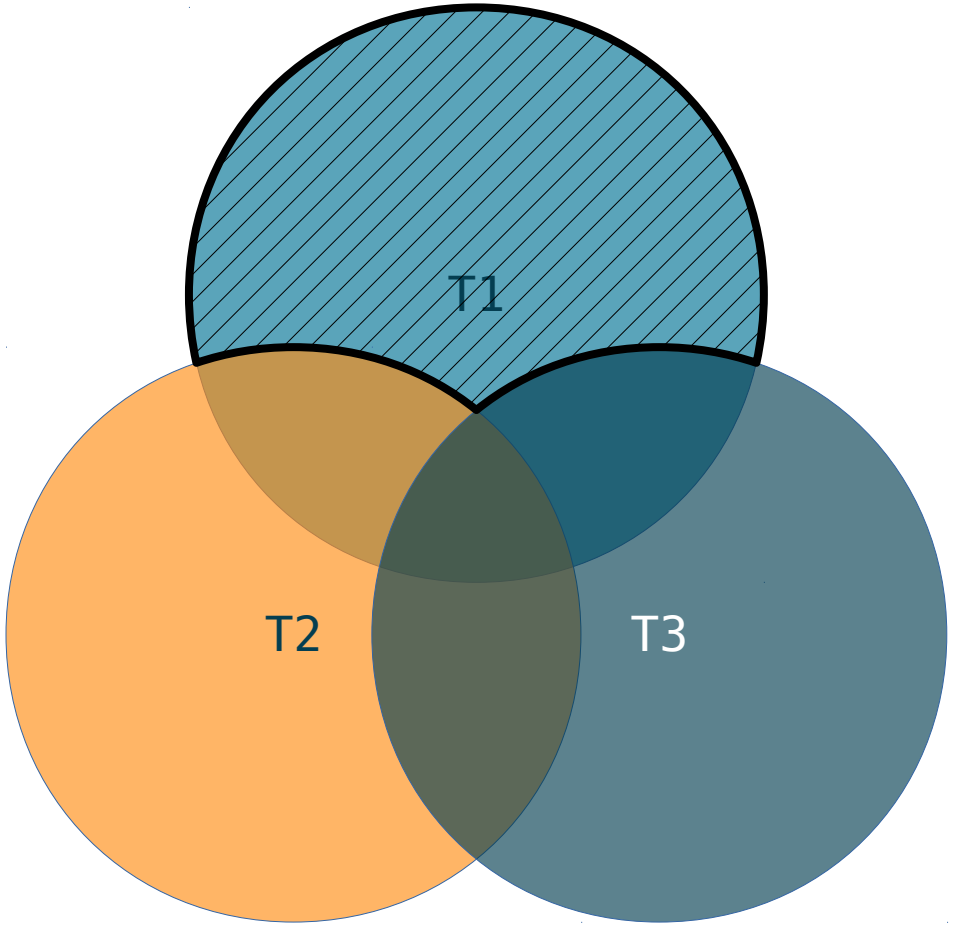
```
$ java -Xlog:gc* -version
[0.007s][info][gc,heap] Heap region size: 1M
[0.010s][info][gc     ] Using G1
[0.010s][info][gc,heap,coops] Heap address: 0x00000006c6c00000, size: 3988 MB, Compressed
Oops mode: Zero based, Oop shift amount: 3
java version "9-ea"
Java(TM) SE Runtime Environment (build 9-ea+135)
Java HotSpot(TM) 64-Bit Server VM (build 9-ea+135, mixed mode)
[0,100s][info][gc,heap,exit ] Heap
[0,100s][info][gc,heap,exit ]  garbage-first heap   total 256000K, used 2048K
[0x00000006c6c00000, 0x00000006c6d007d0, 0x00000007c0000000)
[0,100s][info][gc,heap,exit ]   region size 1024K, 3 young (3072K), 0 survivors (0K)
[0,100s][info][gc,heap,exit ]  Metaspace       used 3532K, capacity 4486K, committed 4864K,
reserved 1056768K
[0,100s][info][gc,heap,exit ]   class space    used 337K, capacity 386K, committed 512K,
reserved 1048576K
```

Log Tag Selection Visualized



- Log tags T1, T2, T3
- Example selections:
  - Only T1 `-Xlog:T1`
  - T1 `-Xlog:T1*`
  - Only T1 and T2 `-Xlog:T1+T2`
  - T1 and T2 `-Xlog:T1+T2*`
  - Only T1, T2, T3 `-Xlog:T1+T2+T3`
  - All `-Xlog:all`

Log Tag Selection Visualized



- Log tags T1, T2, T3
- Example selections:
  - **Only T1** **`-Xlog:T1`**
  - T1 `-Xlog:T1*`
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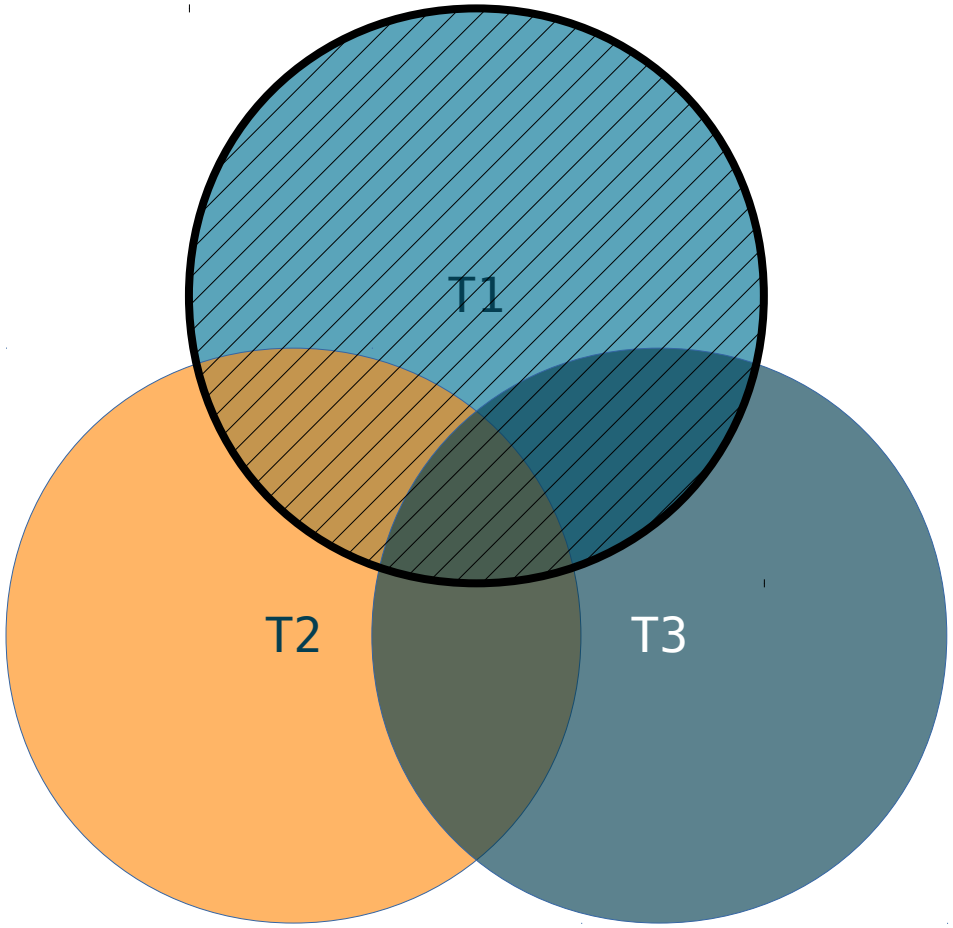
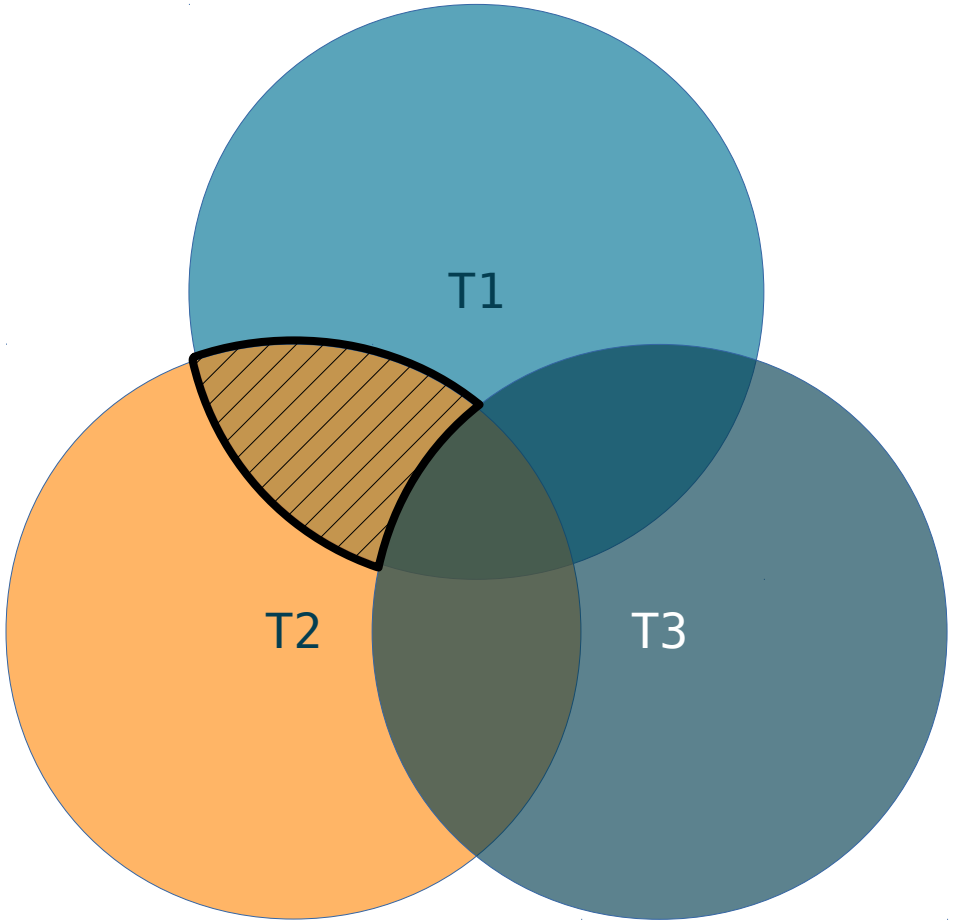


- Log tags T1, T2, T3
- Example selections:
  - Only T1 `-Xlog:T1`
  - **T1** **`-Xlog:T1*`**
  - Only T1 and T2 `-Xlog:T1+T2`
  - T1 and T2 `-Xlog:T1+T2*`
  - Only T1, T2, T3 `-Xlog:T1+T2+T3`
  - All `-Xlog:all`

Log Tag Selection Visualized



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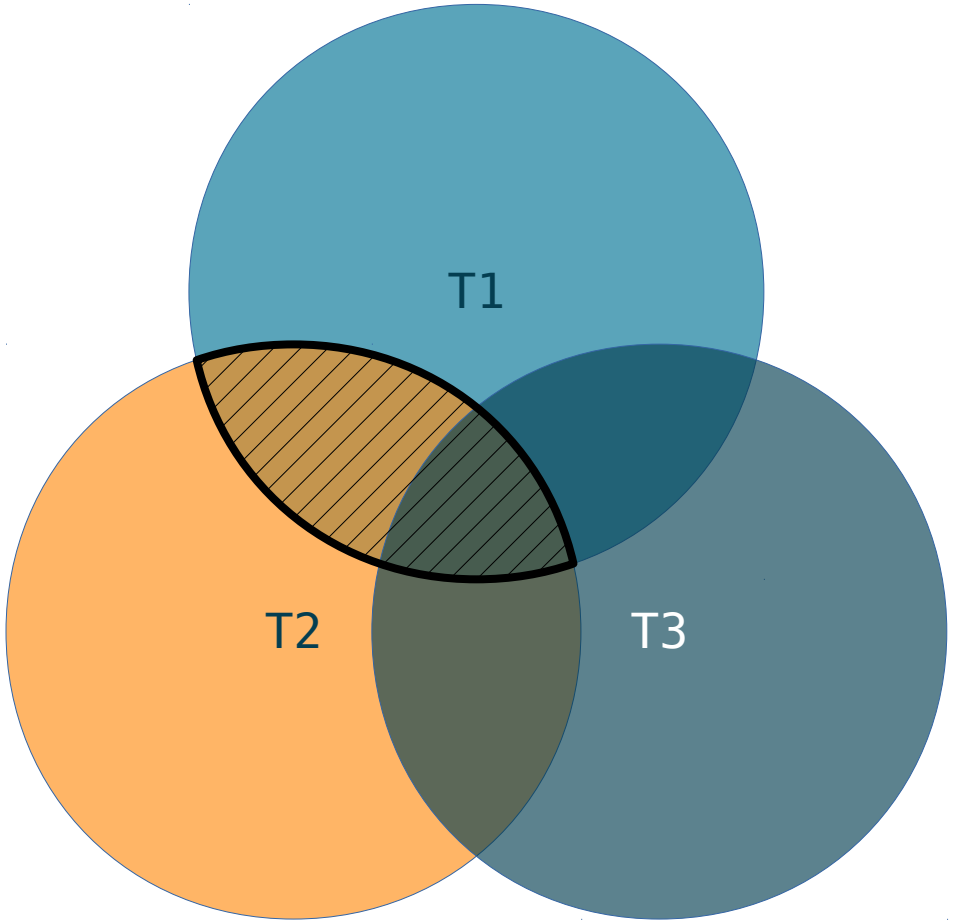
- Example selections:
  - Only T1 `-Xlog:T1`
  - T1 `-Xlog:T1*`
  - **Only T1 and T2** **`-Xlog:T1+T2`**
  - T1 and T2 `-Xlog:T1+T2*`
  - Only T1, T2, T3 `-Xlog:T1+T2+T3`
  - All `-Xlog:all`

Log Tag Selection Visualized



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- Example selections:
  - Only T1 `-Xlog:T1`
  - T1 `-Xlog:T1*`
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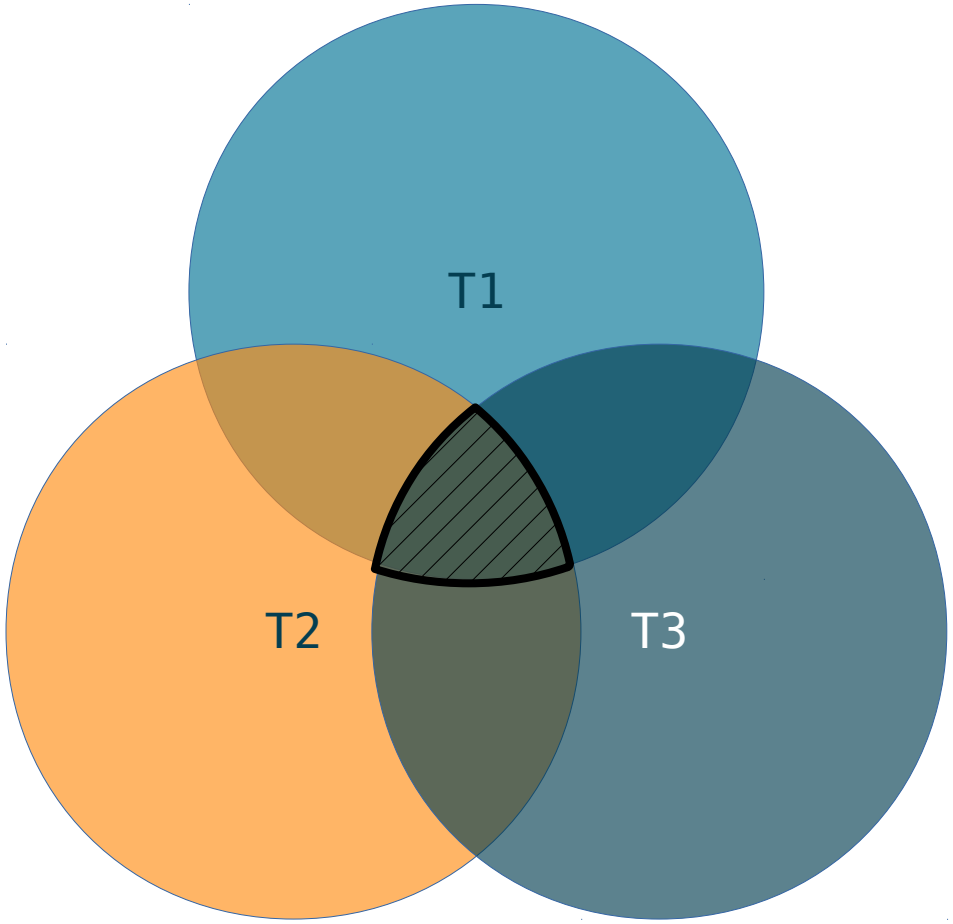
  - **T1 and T2** **`-Xlog:T1+T2*`**
  - Only T1, T2, T3 `-Xlog:T1+T2+T3`
  - All `-Xlog:all`

Log Tag Selection Visualized



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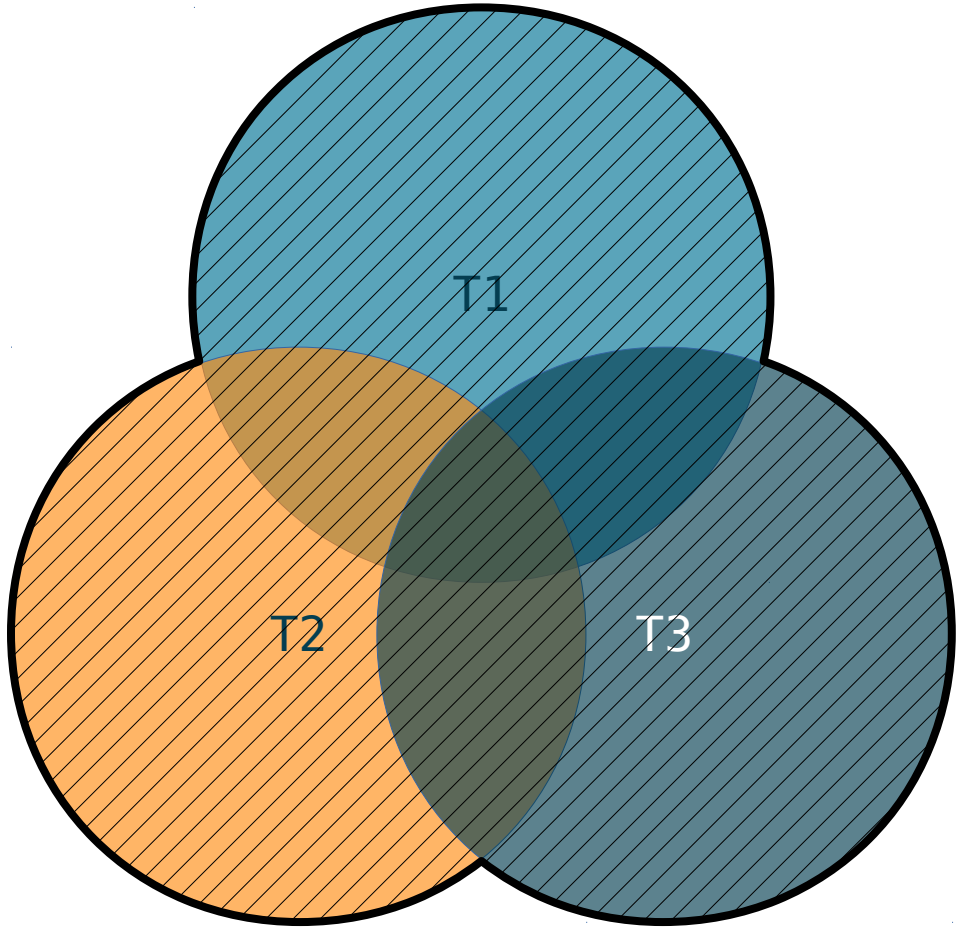
  - T1 `-Xlog:T1*`
  - Only T1 and T2 `-Xlog:T1+T2`
  - T1 and T2 `-Xlog:T1+T2*`
  - **Only T1, T2, T3** **`-Xlog:T1+T2+T3`**
  - All `-Xlog:all`

Log Tag Selection Visualized



- Log tags T1, T2, T3
- Example selections:
  - Only T1 `-Xlog:T1`
  - T1 `-Xlog:T1*`
  - Only T1 and T2 `-Xlog:T1+T2`
  - T1 and T2 `-Xlog:T1+T2*`
  - Only T1, T2, T3 `-Xlog:T1+T2+T3`
  - **All** **`-Xlog:all`**

Log Levels

- Common set of levels
  - Separate messages according to verbosity and importance
  - In increasing verbosity: `error, warning, info, debug, trace`
  - Aggregated
    - `info` implies `warning` and `error`
- Log level selection can be done per tag selection
  - Enables fine grained control over what to log
    - E.g. log GC on debug level but class loading on info level

Selecting Log Level

- Level is a part of the selection syntax
  - Each tag selection may have a '`=<level>`' suffix
    - E.g. `-Xlog:gc=debug` or `-Xlog:gc*=debug,os=info`
    - Assume `info` level unless specified
- Can use '`off`' to selectively disable logging
  - E.g. `-Xlog:gc*,gc+heap=off`
- Amended -Xlog selection syntax:
  - `<selection> = t1[+t2…][*][=<level>][,…]`

Usage Example With Selection Including Level

```
$ java -Xlog:gc+heap*=debug -version
[0.007s][info][gc,heap] Heap region size: 1M
[0.007s][debug][gc,heap] Minimum heap 8388608  Initial heap 262144000  Maximum heap
4181721088
[0.008s][debug][gc,ergo,heap] Expand the heap. requested expansion amount:262144000B
expansion amount:262144000B
[0.009s][info ][gc,heap,coops] Heap address: 0x00000006c6c00000, size: 3988 MB, Compressed
Oops mode: Zero based, Oop shift amount: 3
java version "9-ea"
Java(TM) SE Runtime Environment (build 9-ea+135)
Java HotSpot(TM) 64-Bit Server VM (build 9-ea+135, mixed mode)
[0,093s][info ][gc,heap,exit ] Heap
[0,093s][info ][gc,heap,exit ]  garbage-first heap   total 256000K, used 1024K
[0x00000006c6c00000, 0x00000006c6d007d0, 0x00000007c0000000)
[0,093s][info ][gc,heap,exit ]   region size 1024K, 2 young (2048K), 0 survivors (0K)
[0,093s][info ][gc,heap,exit ]  Metaspace       used 3530K, capacity 4486K, committed
4864K, reserved 1056768K
[0,093s][info ][gc,heap,exit ]   class space    used 337K, capacity 386K, committed 512K,
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```
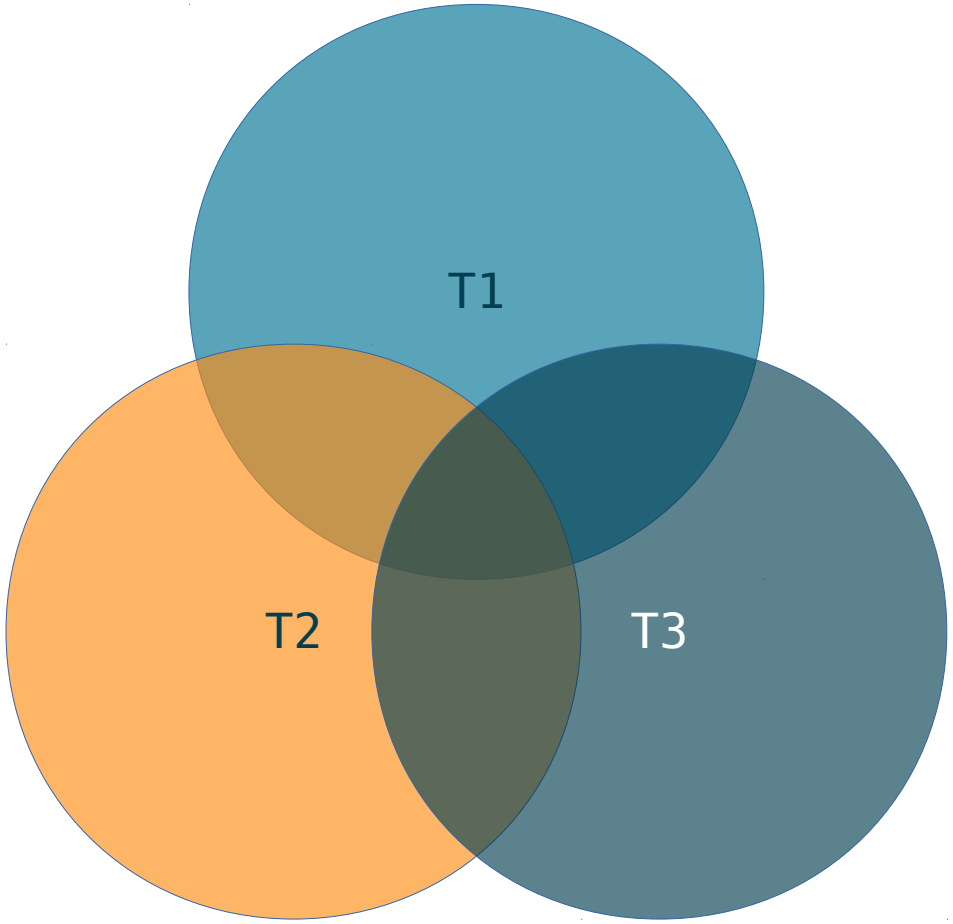

Log Tag Selection Revisited



- Can deselect just as well
- Examples:
  - T1 except with T3

    ```
    -Xlog:T1*,T3*=off
    ```

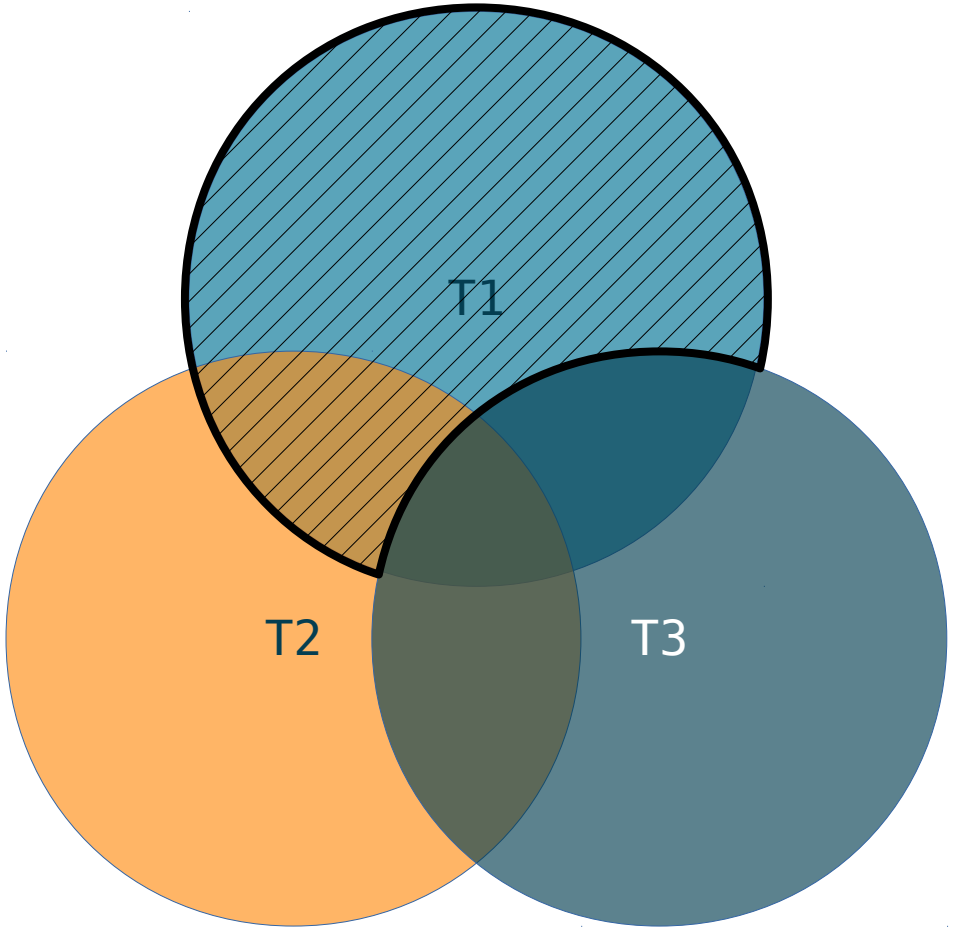
  - T1 except with T1+T3

    ```
    -Xlog:T1*,T1+T3=off
    ```

- Use `warning` to preserve default settings

  ```
  -Xlog:T1*,T3*=warning
  ```

Log Tag Selection Revisited



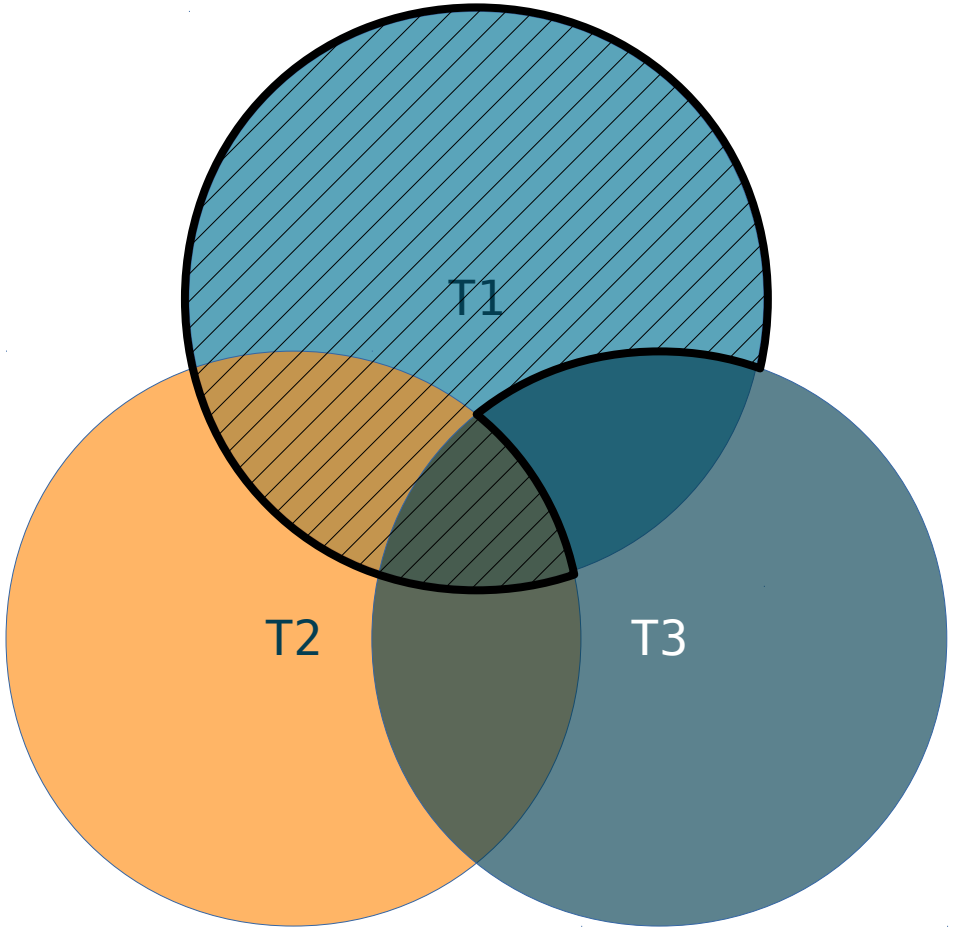
- Can deselect just as well
- Examples:
  - **T1 except with T3**

    `-Xlog:T1*,T3*=off`
  - T1 except with T1+T3

    `-Xlog:T1*,T1+T3=off`
- Use `warning` to preserve default settings

  `-Xlog:T1*,T3*=warning`

Log Tag Selection Revisited



- Can deselect just as well
- Examples:
  - T1 except with T3

    `-Xlog:T1*,T3*=off`
  - **T1 except with T1+T3**

    `-Xlog:T1*,T1+T3=off`
- Use `warning` to preserve default settings

  `-Xlog:T1*,T3*=warning`

Tracking Log Tag Selection

- Use `-Xlog:logging=trace`
  - Lists all available tag sets
  - Logs initial configuration
    - All configured outputs
    - Explicitly lists all tag sets with configured levels
      - Can view and verify the configuration
- Unmatched selections cause warnings

```
$ java -Xlog:logging+gc
[0.003s][warning][logging] No tag set matches selection(s): logging+gc
```

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Log Outputs

- Allow logging both to terminal and file(s)
  - Valid outputs are *stdout*, *stderr*, and any number of log files
    - Support for log file rotation
      - Based on target file size
- Log configuration is tied to the output
  - Can have different logging selections for different files
    - E.g. log GC messages on trace level to `gctrace.log`, while at the same time logging info level messages to the terminal

Selecting Log Output

- Second `-Xlog` option specifies output
  - E.g. `-Xlog:all=debug:debug.log` logs to file ‘debug.log’
  - Valid options are stdout, stderr, file=<filename>
    - ‘`file=`’ prefix is default
  - Omitting the output defaults to `stdout`
    - I.e. `-Xlog:all` is short for `-Xlog:all:stdout`
- New syntax: `-Xlog:[<selection>]:[<output>]`
  - Where `<output> =` ‘`stdout`’
‘`stderr`’
`[file=]<filename>`

Selecting Log Output

- Can include JVM PID and timestamp in filename
  - %t expands to timestamp for JVM start
    - E.g. ‘foo.log.%t’ → ‘foo.log.2016-09-21_09-05-17’
  - %p expands to the JVM process ID
    - E.g. ‘`foo.%p.log`’ → ‘`foo.4711.log`’

Usage Example With a Different Log Output

```
$ java -Xlog:gc*=debug:gc-debug.log -version
java version "9-ea"
Java(TM) SE Runtime Environment (build 9-ea+135)
Java HotSpot(TM) 64-Bit Server VM (build 9-ea+135, mixed mode)
$ cat gc-debug.log
[0.010s][info][gc,heap] Heap region size: 1M
[0.010s][debug][gc,heap] Minimum heap 8388608  Initial heap 262144000  Maximum heap
4181721088
[0.010s][debug][gc,ergo,refine] Initial Refinement Zones: green: 4, yellow: 12, red: 20,
min yellow size: 8
[0.011s][debug][gc,marking,start] Initialize Card Live Data (0.011s)
[0.011s][debug][gc,marking      ] Initialize Card Live Data (0.011s, 0.011s) 0.019ms
[0.011s][debug][gc              ] ConcGCThreads: 1
[0.011s][debug][gc              ] ParallelGCThreads: 4
[0.011s][debug][gc,ergo,heap    ] Expand the heap. requested expansion amount:262144000B
expansion amount:262144000B
[0.013s][debug][gc,ihop         ] Target occupancy update: old: 0B, new: 262144000B
[0.013s][info ][gc              ] Using G1
...
```

Log Message Decorations

Log Message Decorations

- Decorate log messages with additional information
  - Uptime, level and tag set by default
    - E.g. `[0.014s][info][gc] <message>`
  - Supports a set of predetermined decorations:
    - Date and time in ISO 8601
    - JVM uptime
    - Log tags
    - Log level
    - Epoch seconds
    - System.currentMillis()
    - System.nanoTime()
    - Thread ID
    - Process ID
    - Hostname
- Configured per log output

Selecting Log Decorations

- Third `-Xlog` option specifies which decorators to use
  - Comma separated list of desired decorators
    - E.g. `-Xlog:all=debug:debug.log:uptime,tags,level,tid`
  - See -Xlog:help for the list of decorators
  - Can be set to ‘none’ for no decoration
- New syntax: `-Xlog:[<selection>]:[<output>]:[<decorators>]`
  - Where `<decorators> = <decorator>[,…]`
    `‘none’`

Log File Rotation

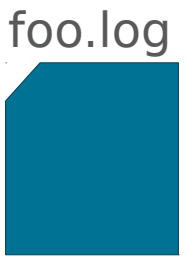
Log File Rotation

- Rotation based on target size with set number of files
- By default, files rotated using 5 files at 20MB each
- Target size and number of files configurable
  - Setting target size to 0 disables automatic rotation
    - Can still trigger rotations manually
  - Setting number of files to 0 disables rotation
    - Existing log files overwritten

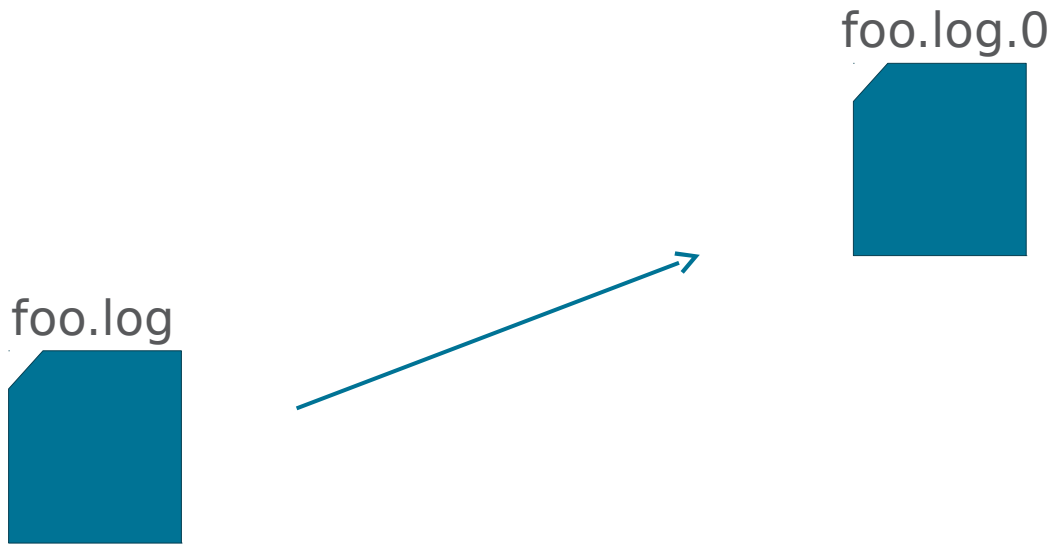
Rotation Mechanics

- Active log file uses given filename
  - E.g. `-Xlog:all:foo.log` logs to ‘foo.log’
- Rotated files are suffixed with archive number
  - E.g. ‘foo.log’ → ‘foo.log.0’
  - Round robin number assignment
    - First rotation adds `.0`, next rotation `.1`, etc
- Replaces oldest file when `filecount` reached
    - E.g. with `filecount=5`, sixth rotation will replace ‘foo.log.0’

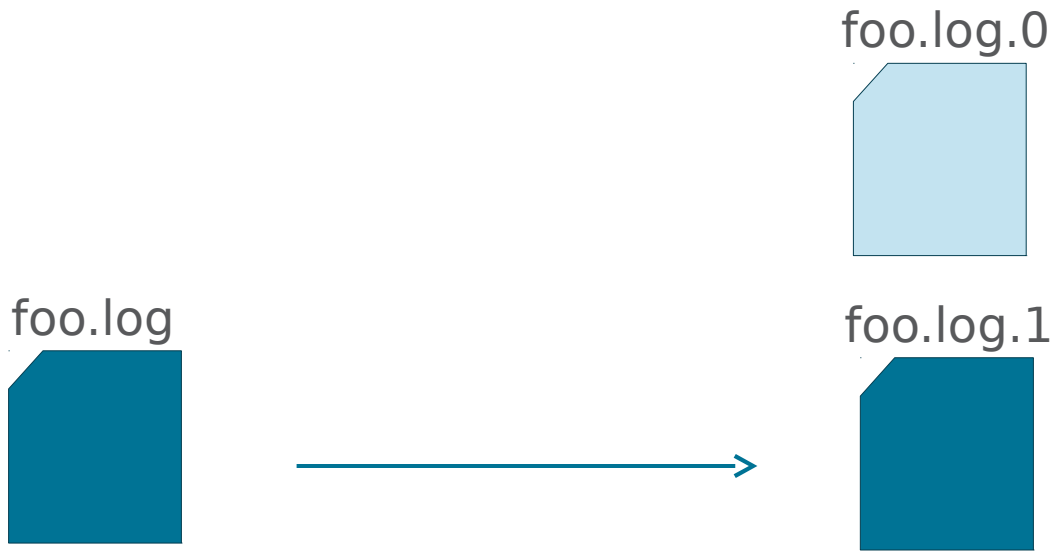
Rotation Mechanics Example



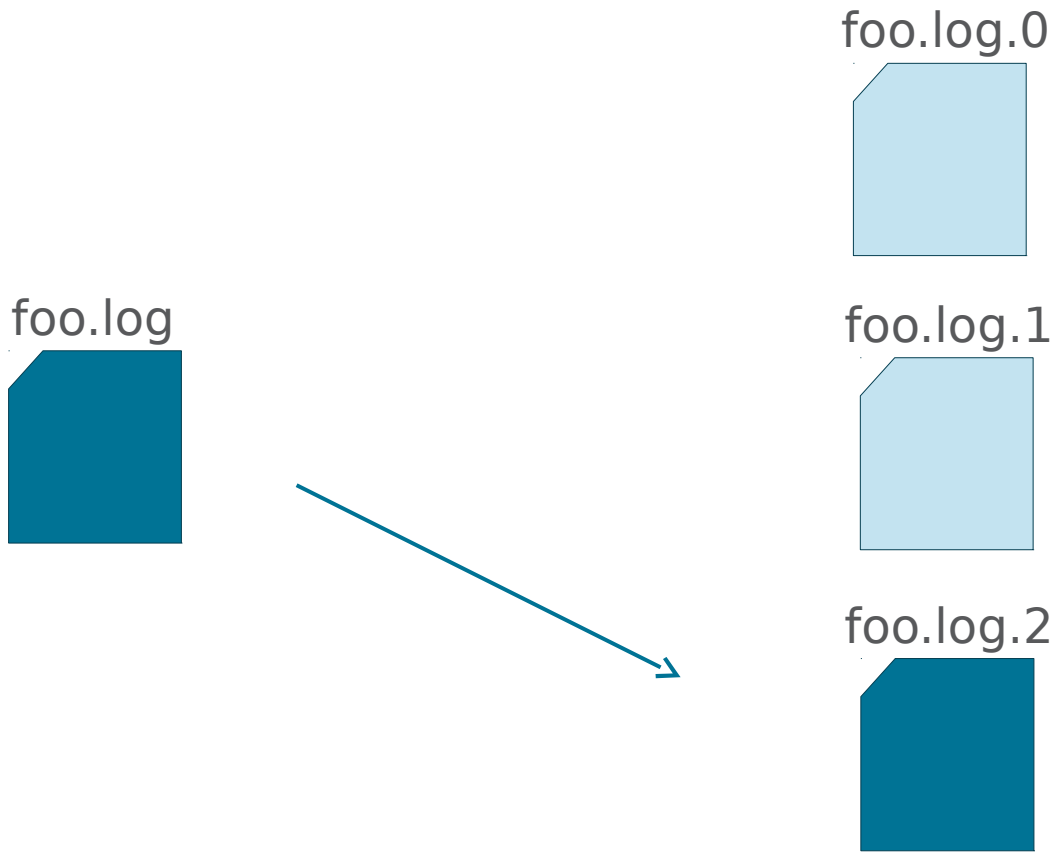
Rotation Mechanics Example



Rotation Mechanics Example

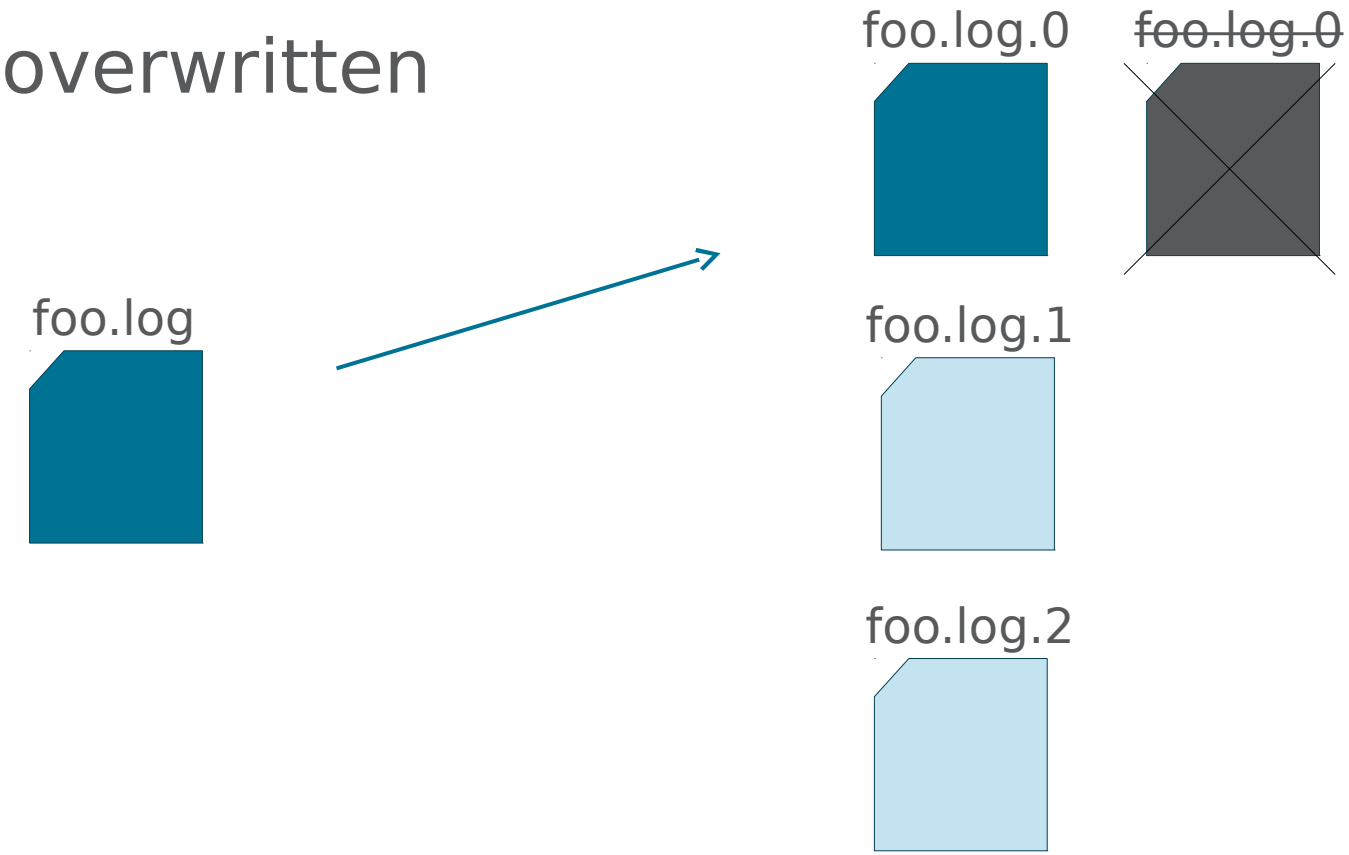


Rotation Mechanics Example



Rotation Mechanics Example

- Previous ‘foo.log.0’ overwritten



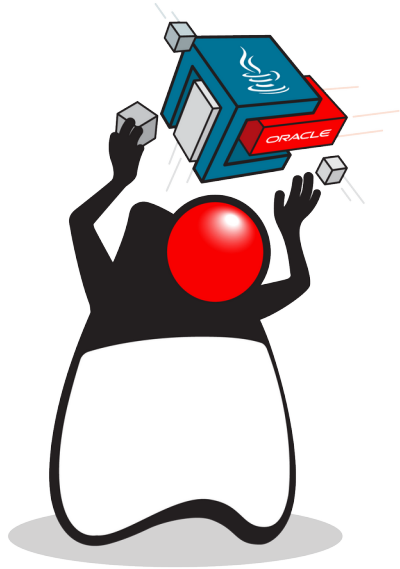
Configuring File Rotation

- Last option for `-Xlog` specifies output options
- Comma separated key=value pairs
- File outputs have `filecount` and `filesize`
  - Filesize specified in bytes (supports K, M, G suffix)
  - E.g. `-Xlog:gc:gc.log::filecount=10,filesize=200M`

Dynamic Reconfiguration

Reconfiguration During Runtime

- Log configuration can be changed at runtime
  - No need to restart the VM
  - Implemented using the diagnostic command **VM.log**
    - CLI using the **jcmd** utility
    - Exposed as MBean
      - Allows reconfiguration through JMX



VM.log Diagnostic Command

- Works similar to `-Xlog`
  - Named options
    - E.g ‘`jcmd <pid> VM.log what=gc output=stdout decorators=uptime`’
      - Equivalent to `-Xlog:gc:stdout:uptime`
- Supports listing current configuration
  - `VM.log list`
- Can trigger file rotations manually
  - `VM.log rotate`

VM.log Usage Example

```
$ jcmd <pid> VM.log list
Available log levels: off, trace, debug, info, warning, error
Available log decorators: time (t), uptime (u), timemillis (tm), uptimemillis (um), ...
Available log tags: add, age, alloc, annotation, ...
Described tag combinations:
 logging: Logging for the log framework itself
 ...
Log output configuration:
#0: stdout all=warning    uptime,level,tags
#1: stderr all=off        uptime,level,tags

$ jcmd <pid> VM.log output=#0 what=all=off list
...
Log output configuration:
#0: stdout all=off    uptime,level,tags
#1: stderr all=off    uptime,level,tags
```

Agenda

1. Logging History
2. Unified Logging Concepts
3. Additional Configuration
4. Usage and Recommendations

Unified Logging Adoption

- Not all logging converted
  - Ongoing effort
- Some flags removed
  - Others aliased and deprecated
- GC logging converted in full
  - The two most significant flags aliased
    - `-XX:+PrintGC` → `-Xlog:gc`
    - `-XX:+PrintGCDetails` → `-Xlog:gc*`

Deprecated and Aliased Flags

```
$ java -XX:+PrintGC -XX:+TraceClassLoading ...
[0.000s][warning][arguments] -XX:+TraceClassLoading is deprecated. Will use
-Xlog:class+load=info instead.
[0.000s][warning][gc       ] -XX:+PrintGC is deprecated. Will use -Xlog:gc instead.
[0.003s][info   ][class,load] opened: /home/mlarsson/jdk-9/lib/modules
[0.010s][info   ][gc        ] Using G1
...
```

Aliased Flags Example

Old Flag	Tag Set	Level
TraceClassLoading	`class+load`	`info`
TraceClassUnloading	`class+unload`	`info`
TraceClassResolution	class+resolve	debug
TraceExceptions	redefine+class	`info`
TraceMonitorInflation	monitorinflation	debug
TraceJVMTIObjectTagging	jvmti+objecttagging*	debug

Default and Implicit Configuration

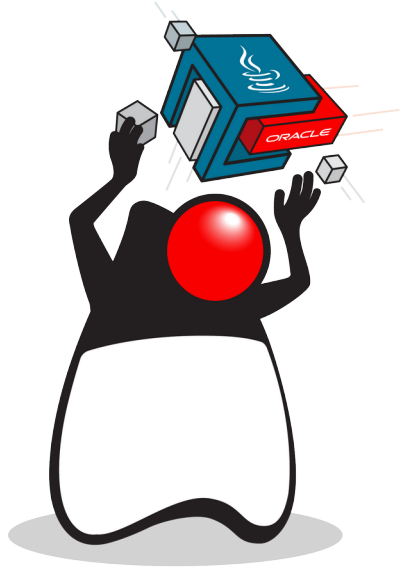
- Default configuration

  `-Xlog:all=warning:stdout:uptime,level,tags`

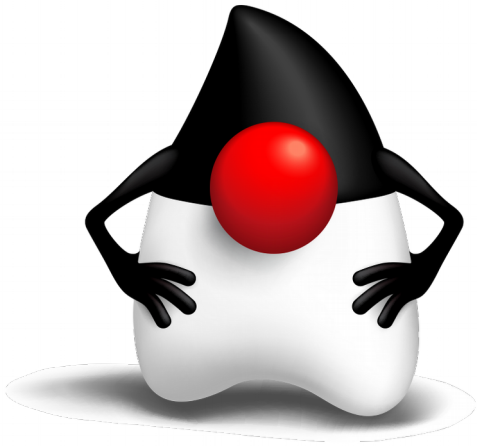
- Implicit configuration
  - When `-Xlog` is specified but options are omitted
    - `-Xlog:all=info:stdout:uptime,level,tags`
      - E.g. `-Xlog::stderr` → `-Xlog:all=info:stderr:uptime,level,tags`
    - File outputs add implicit `filecount=5,filesize=20M`

Recommendations

- Start out with broad selection
- Identify tags of interest
  - Narrow the selection
    - Optionally increase level of detail
- Use wildcard selections (*)
  - Makes configuration more robust



Questions?



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