淺談 Java GC 原理、調教和新發展

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文曄科技

Java™

ORACLE APPROVED EDUCATION CENTER

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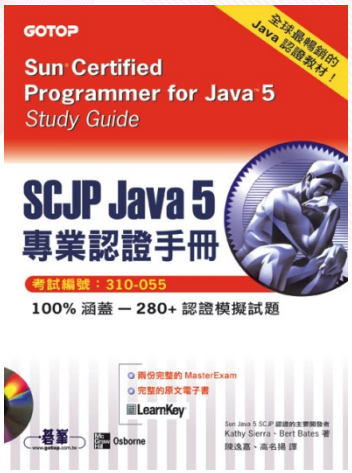
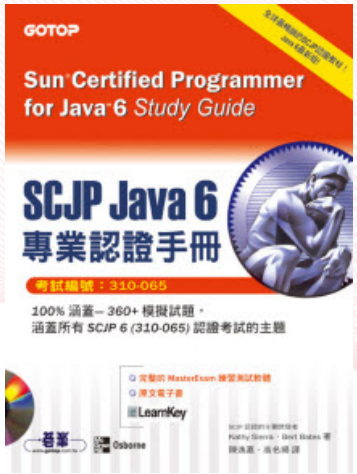
- Master of NTHU CS
- More than 15 years in Java/JEE, as programmer, architect, developer leader and consultant, in finance/telecom domain.
  - 工研院
  - 得捷
  - 新光人壽
  - Ericsson
  - Oracle
  - 文曄科技 (WT Microelectronics)

著作

- TW Patent 182927, 一種文章切割方法, 2003, 陳逸嘉, 林一中
- TW Patent 206819, 自動服務組合方法及系統, 2004, 陳逸嘉, 許維德, 洪鵬翔
- US Patent 7,617,174, Method and system for automatic service composition, 2009, Leon Chen, Wei-Tek Hsu, Peng-Hsiang Hung

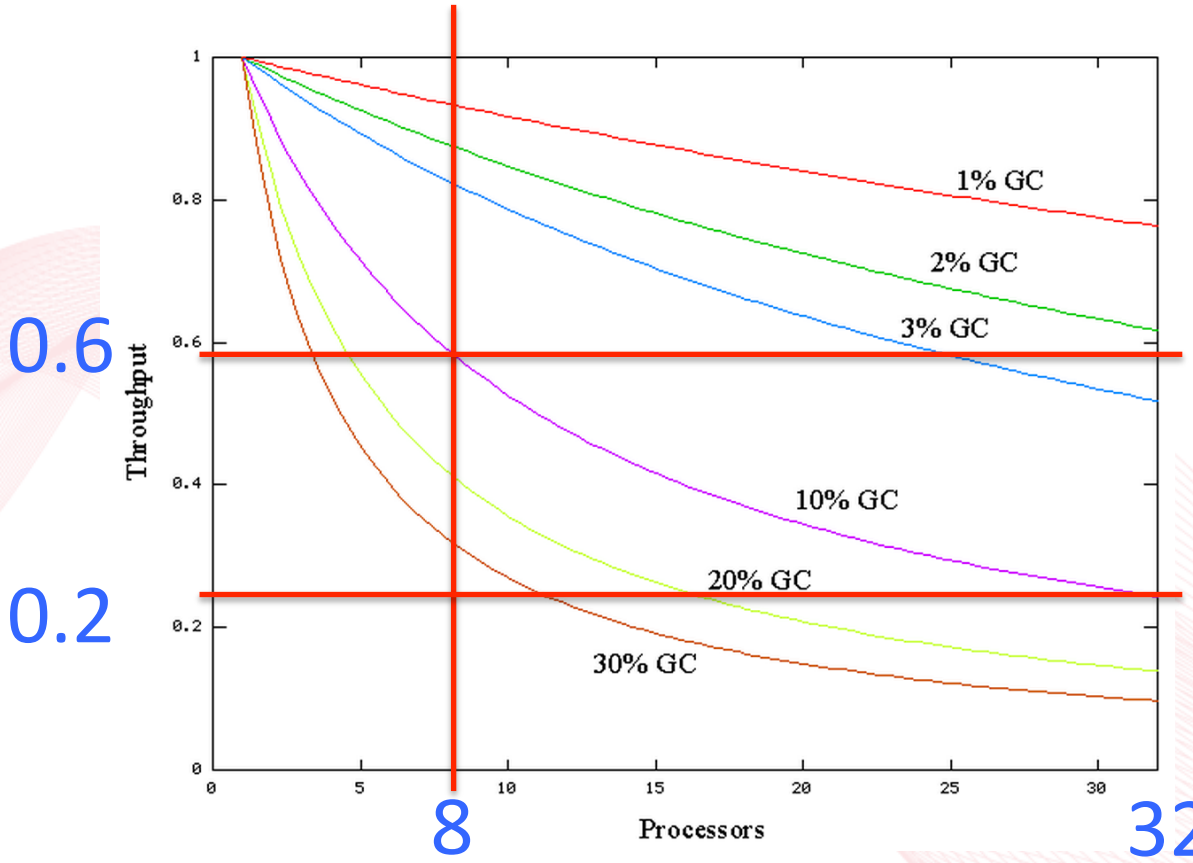




Garbage Collection

我真的需要花時間去 Tune GC 嗎?

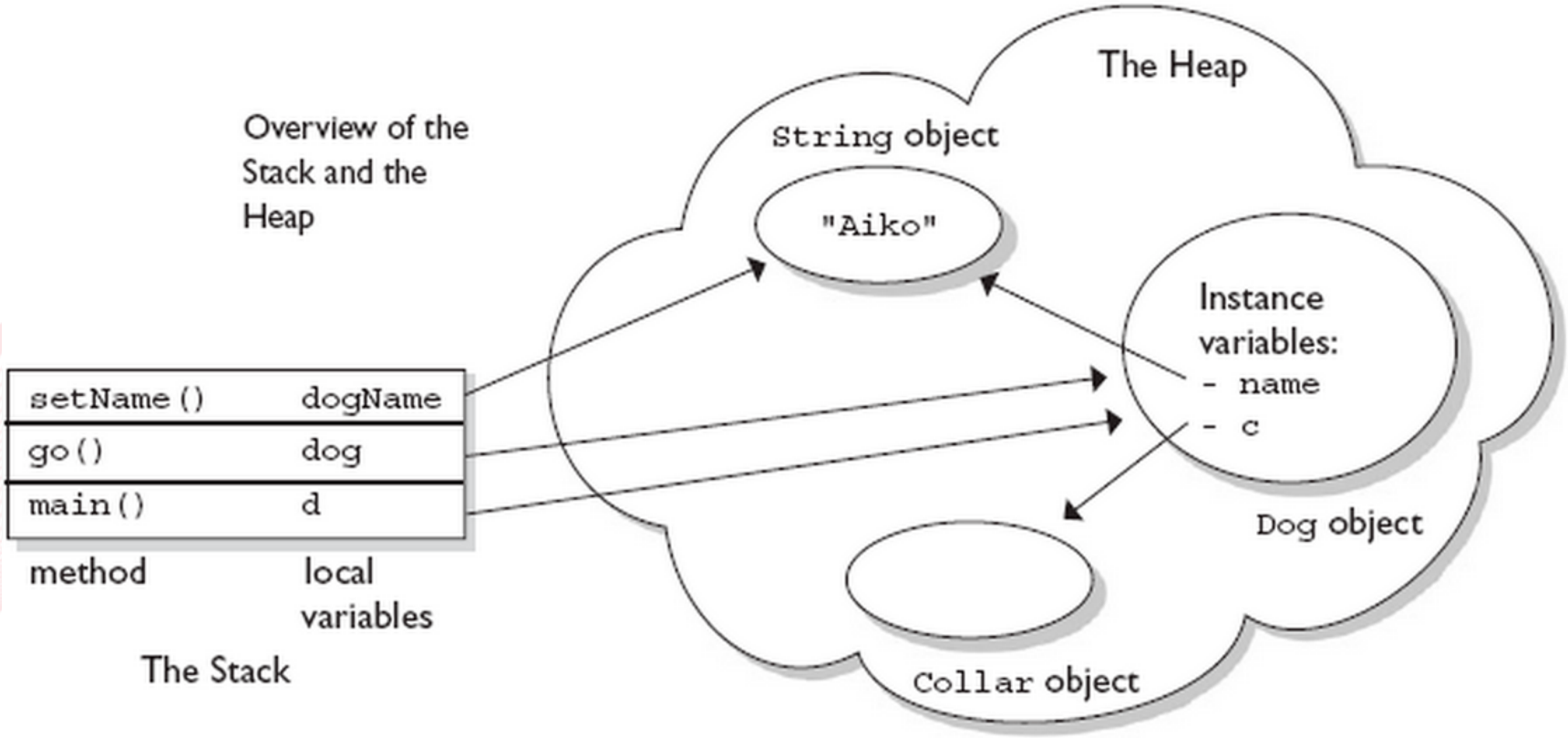
Performance Impact of GC



Java SE 6 HotSpot[tm] Virtual Machine Garbage Collection Tuning
http://www.oracle.com/technetwork/java/javase/gc-tuning-6-140523.html

有資格被回收的物件?

Java Memory Management

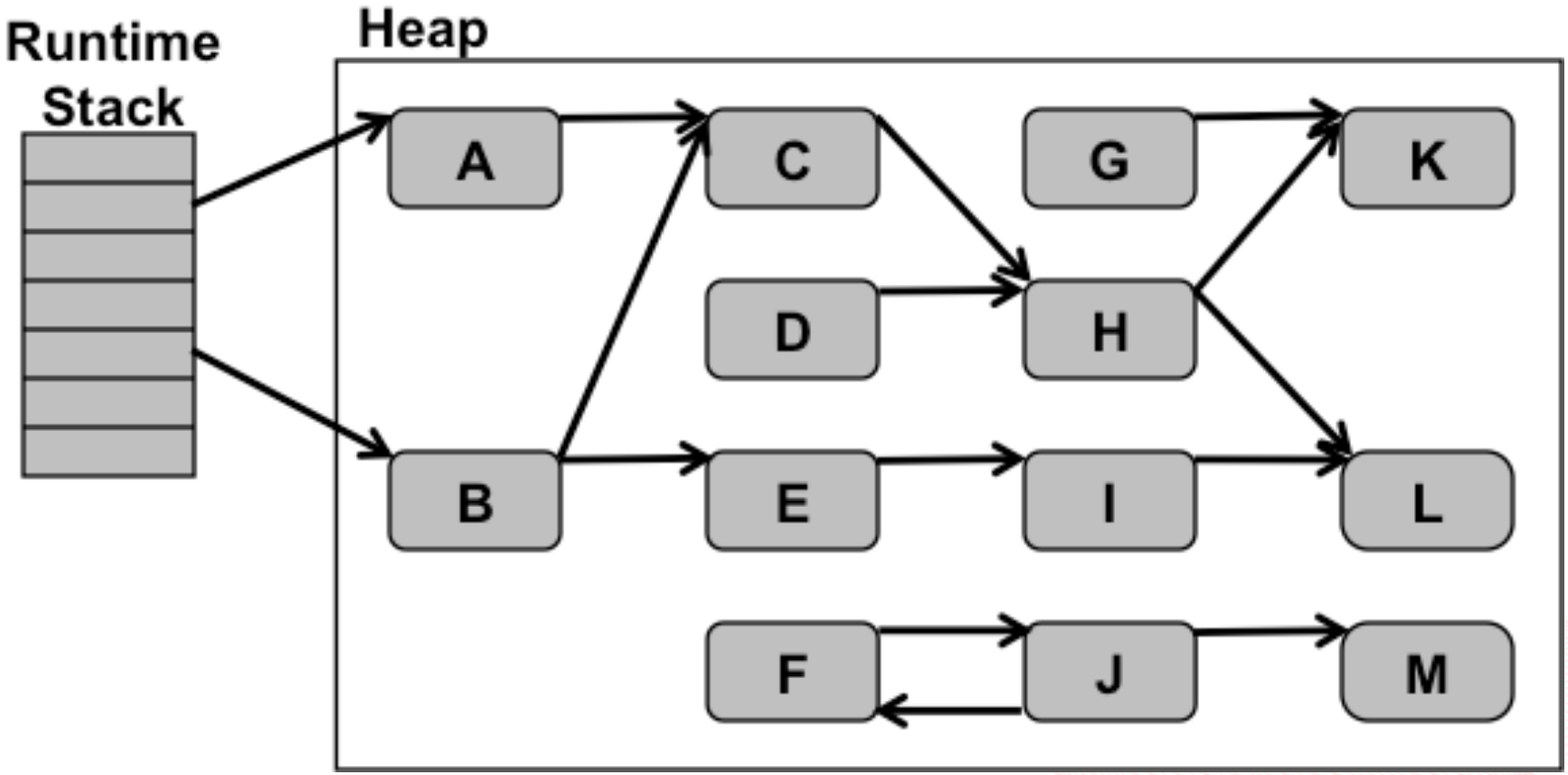


Java Memory Management

GURU99.COM

https://www.youtube.com/watch?v=450ma1zSIvA

Tracing GC Example



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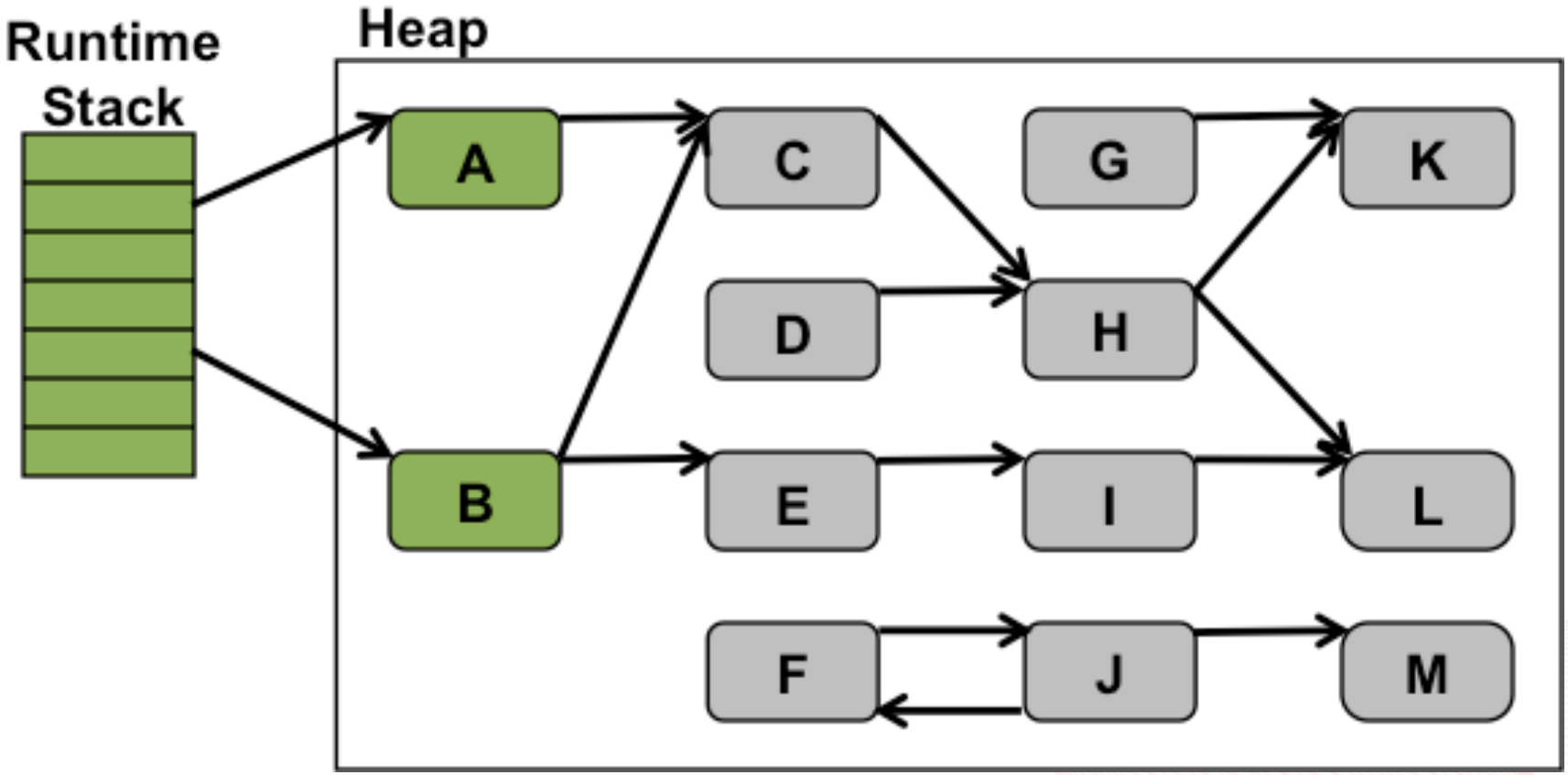

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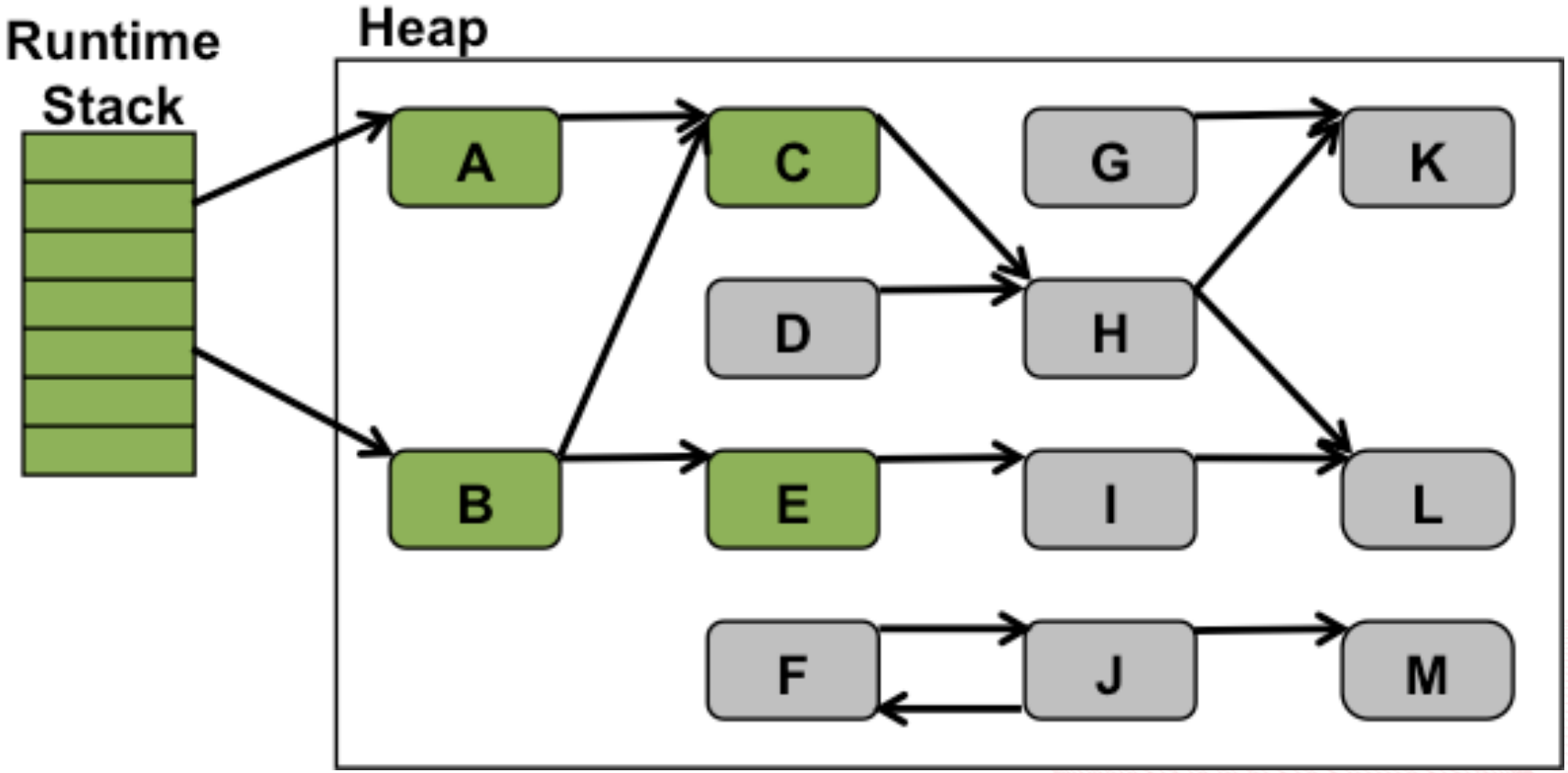

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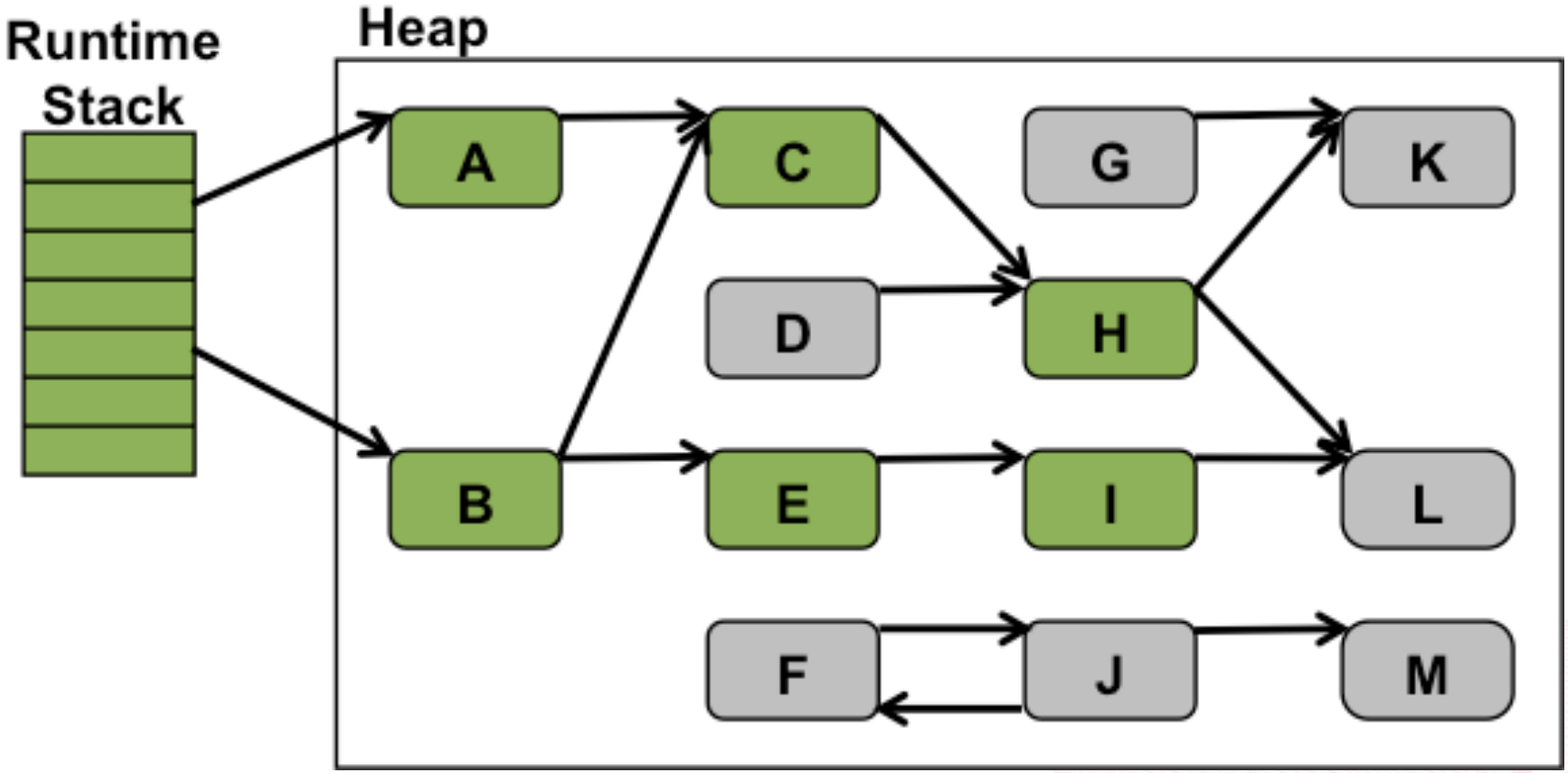

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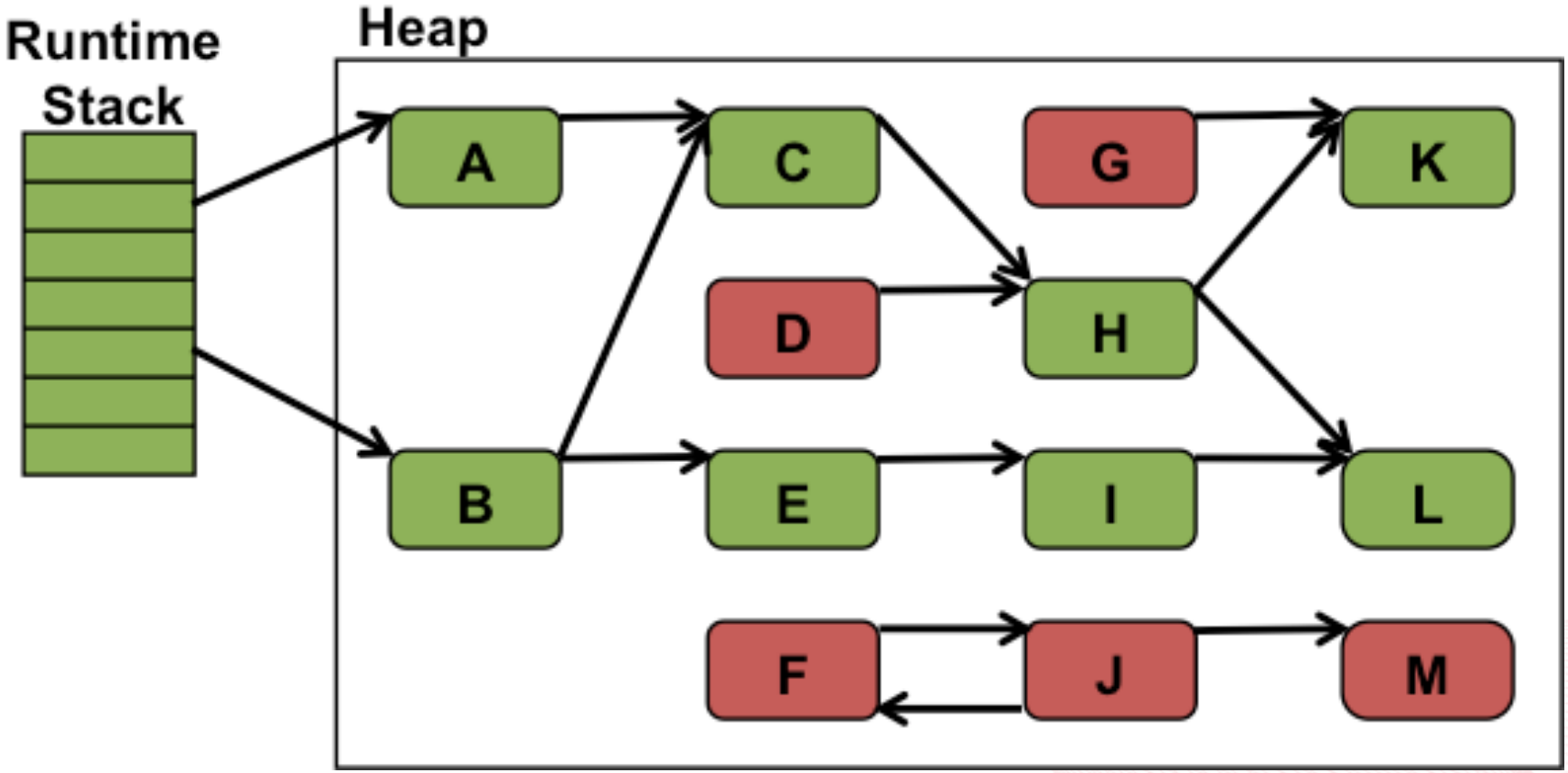

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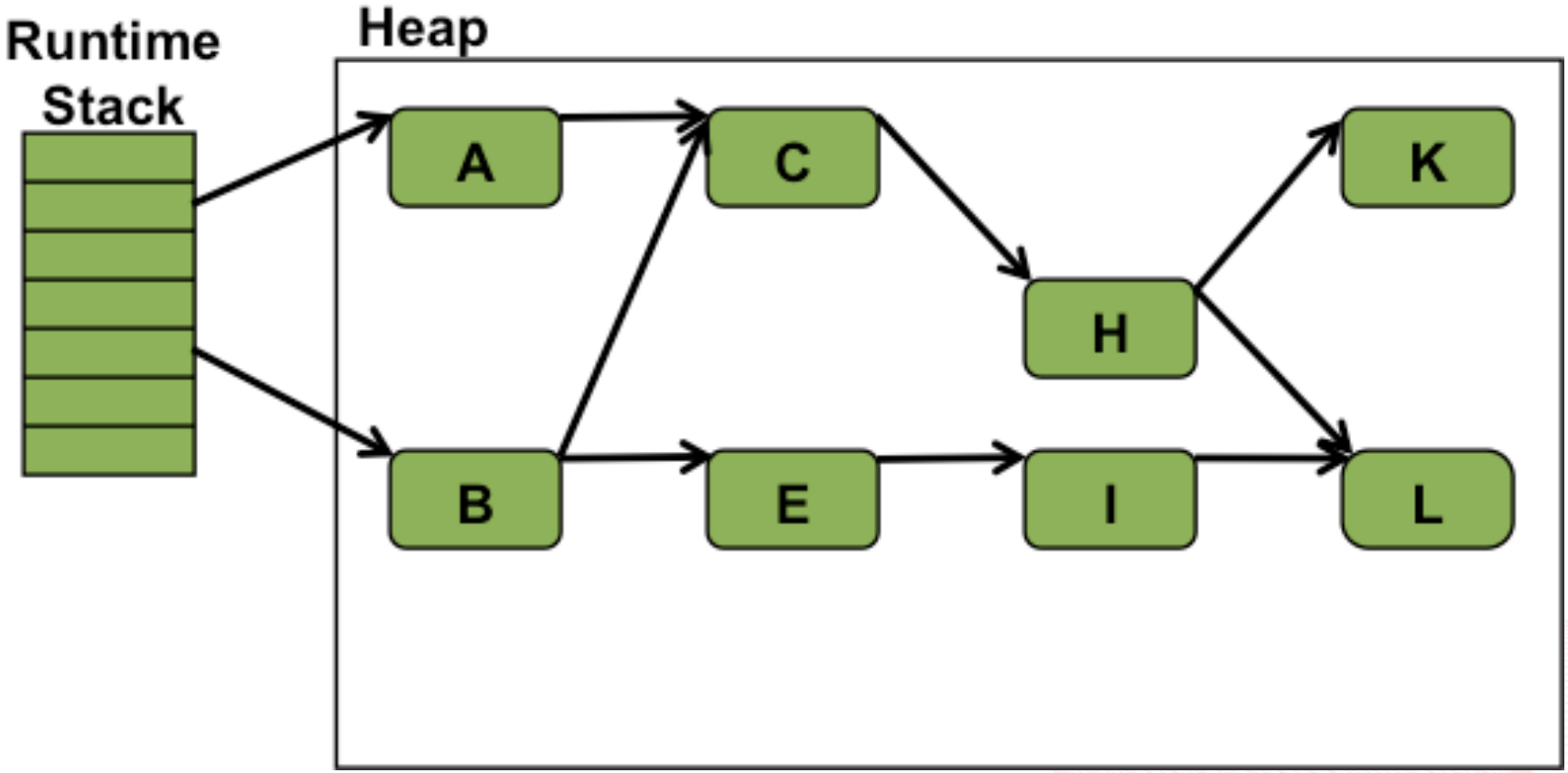
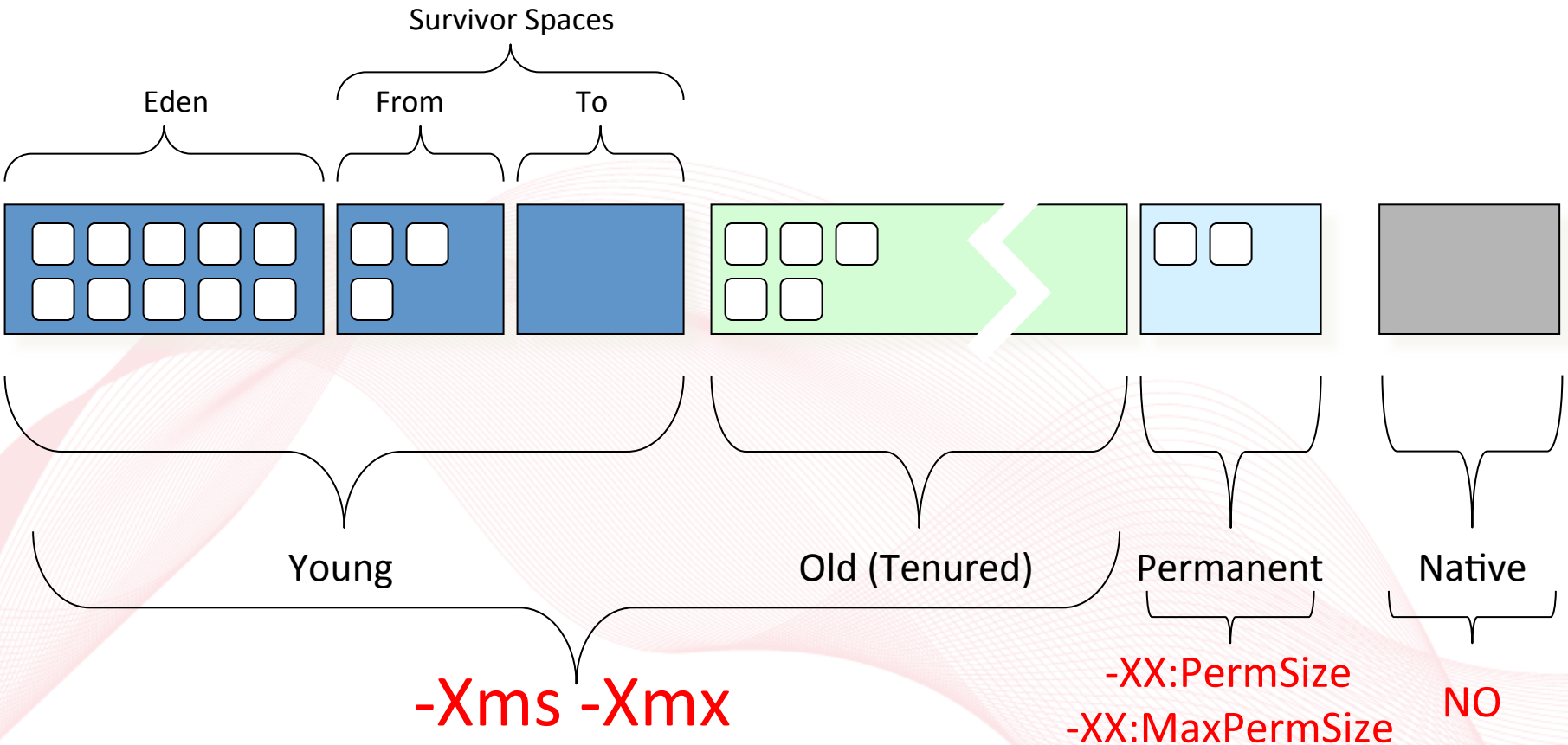


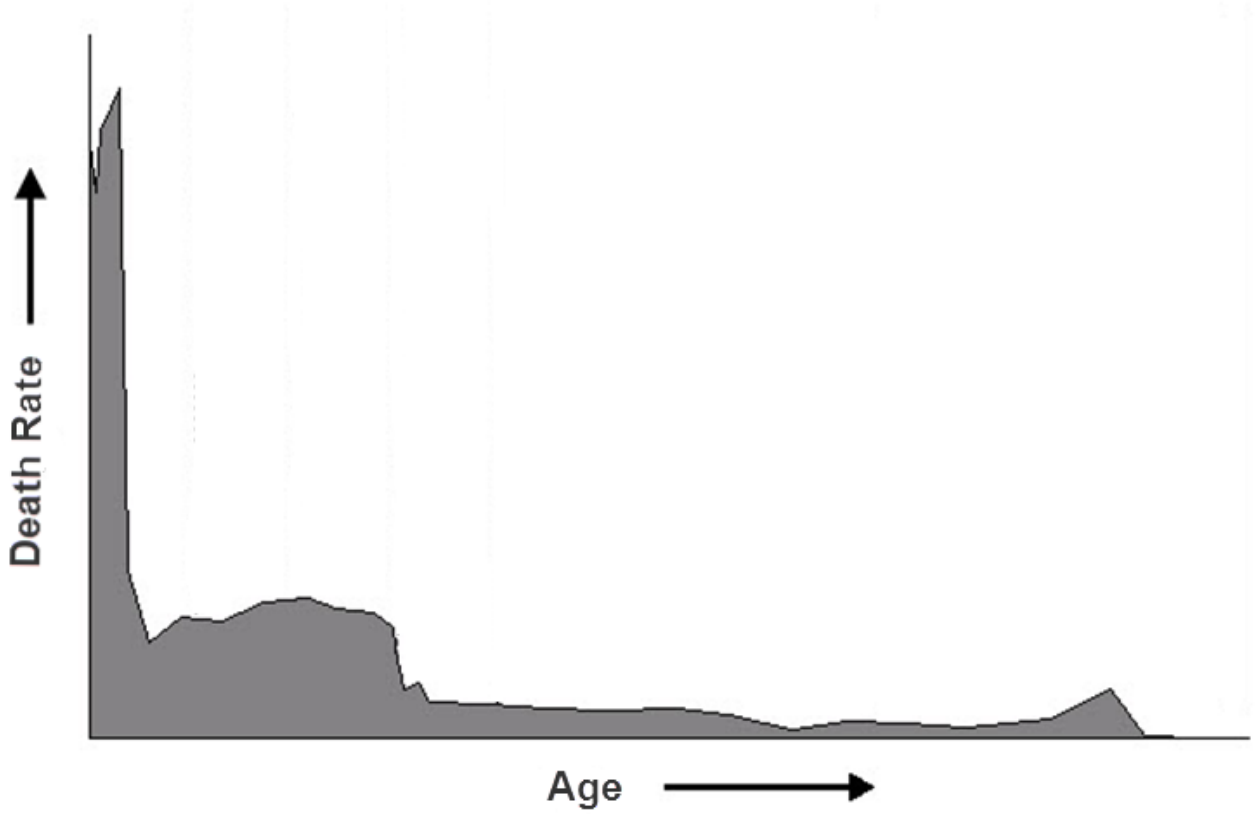
JAVA HEAP STRUCTURE AND GC

Hotspot JVM Heap Layout



GC Fundamentals

Garbage Distribution – Objects die young



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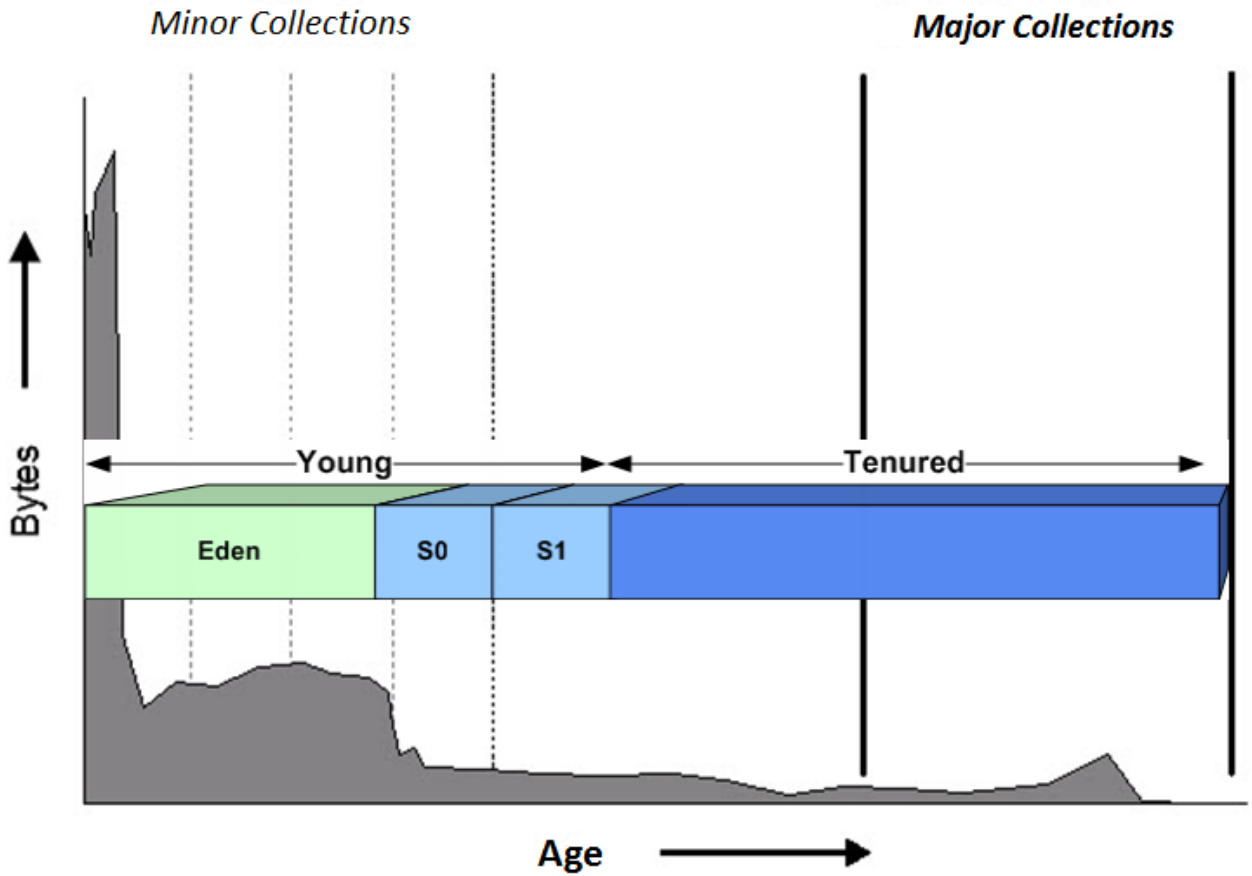
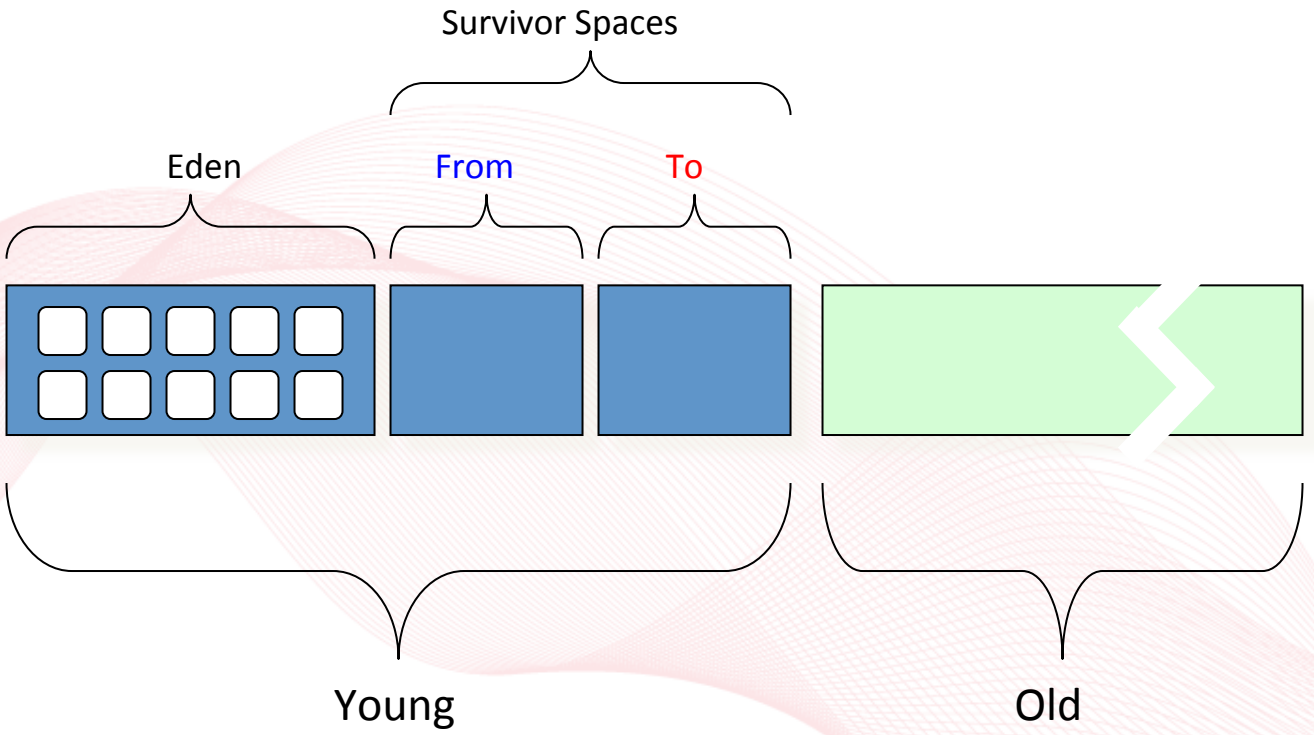


Minor GC (Young Generation GC)



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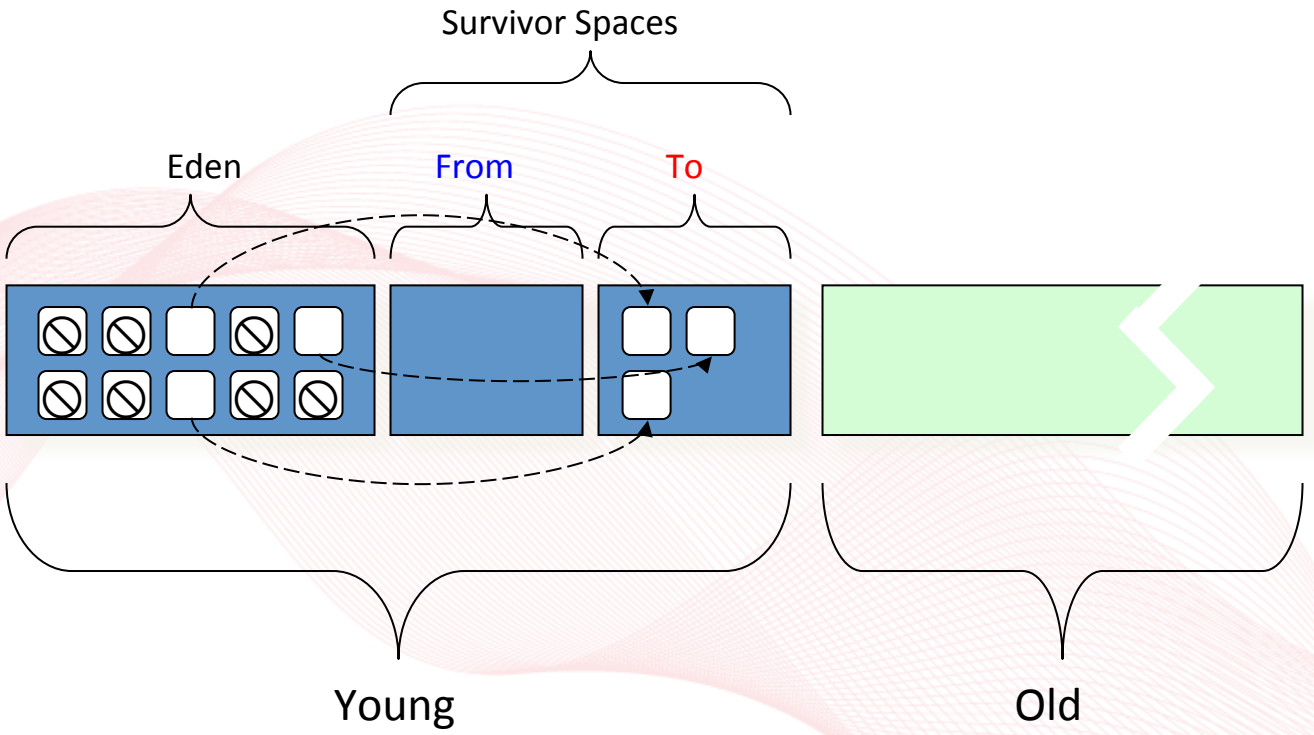

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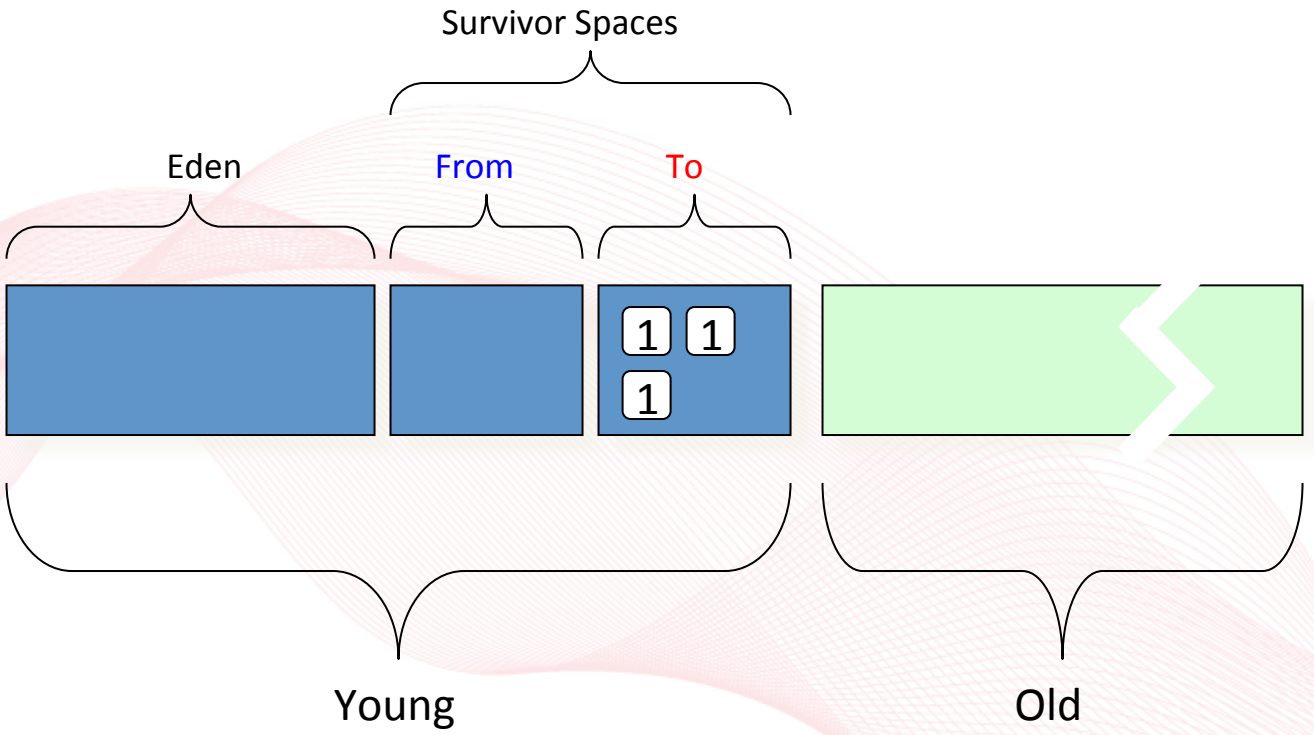

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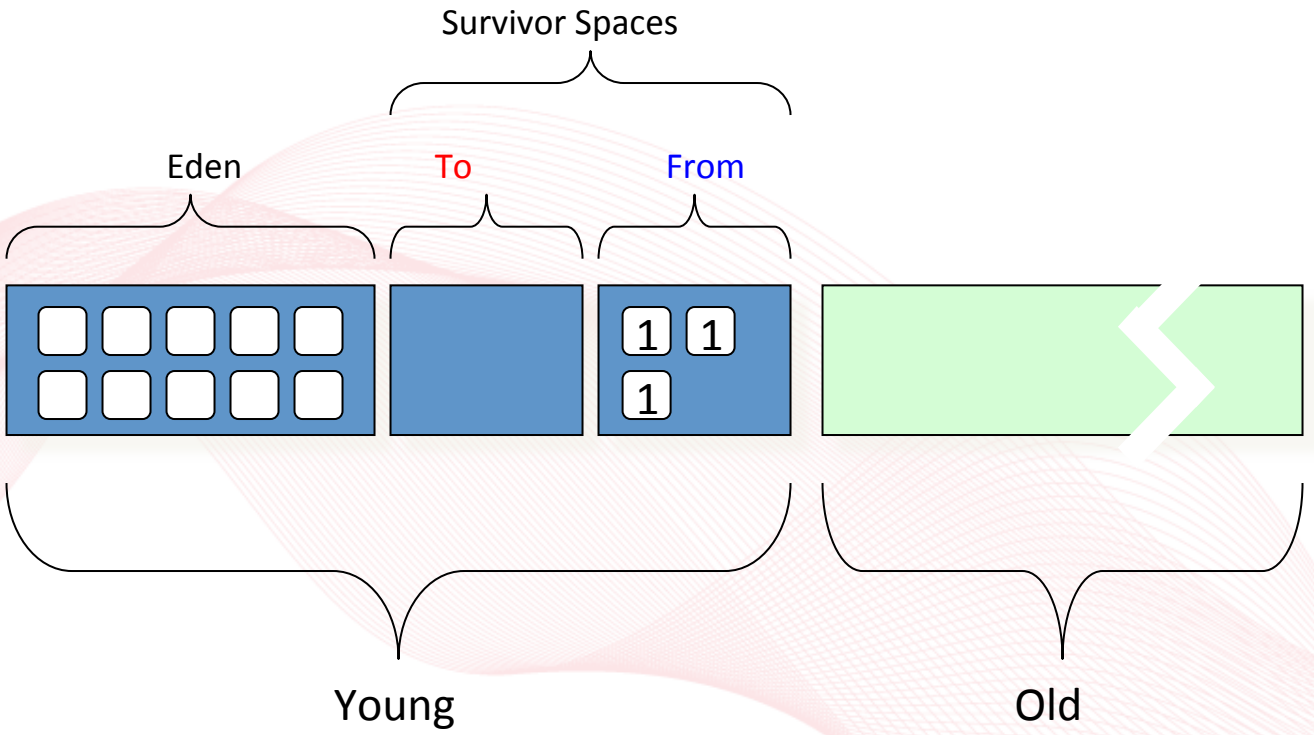

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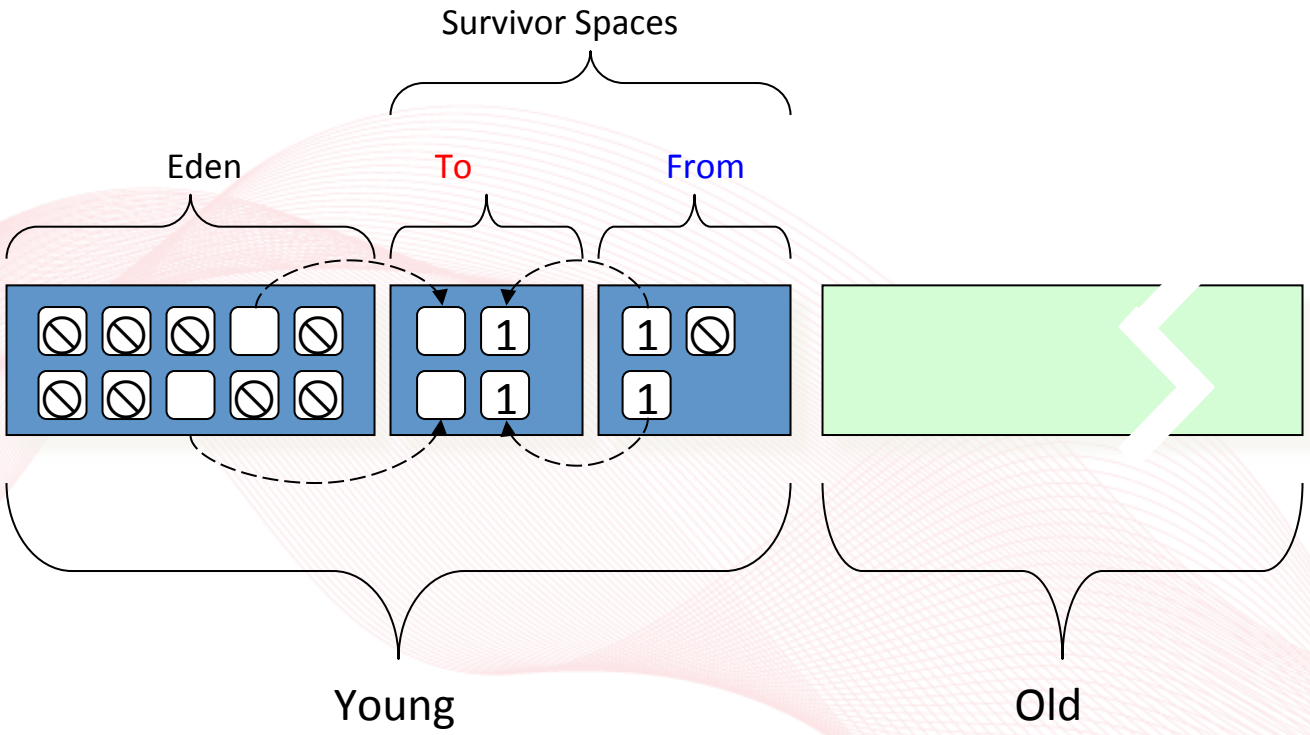

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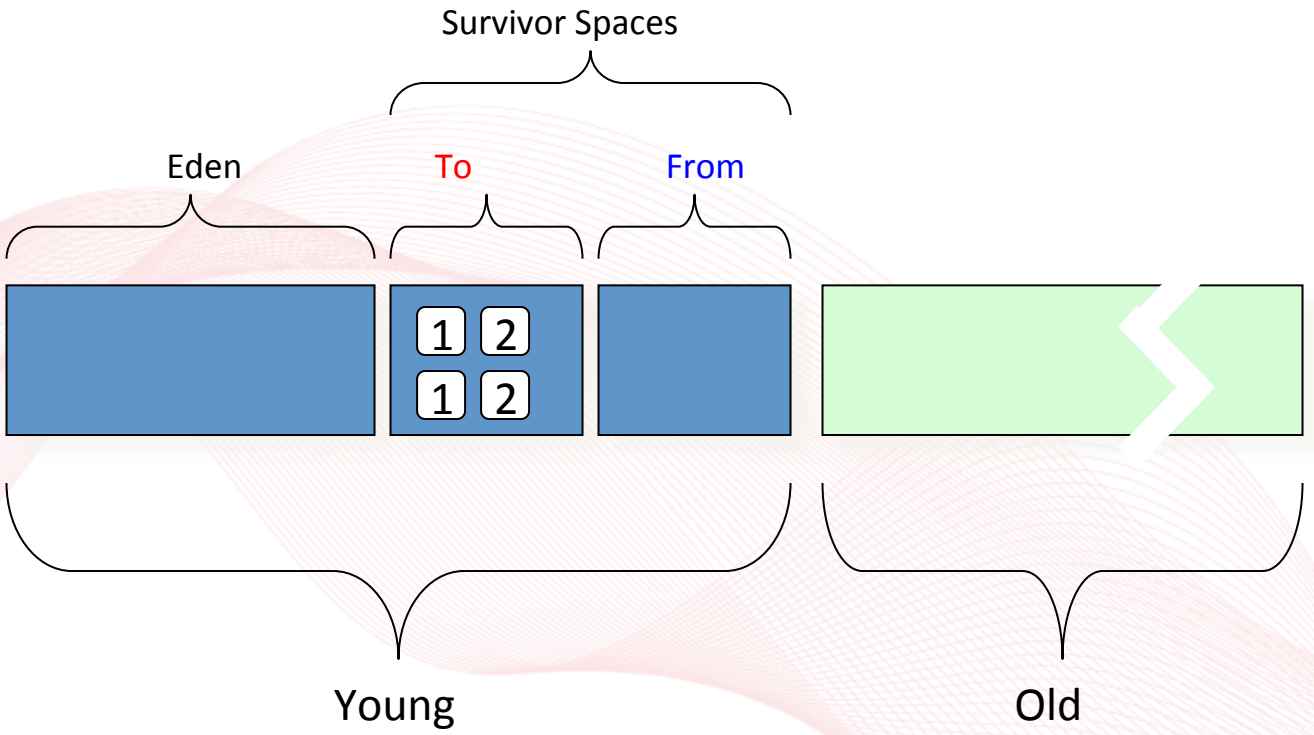

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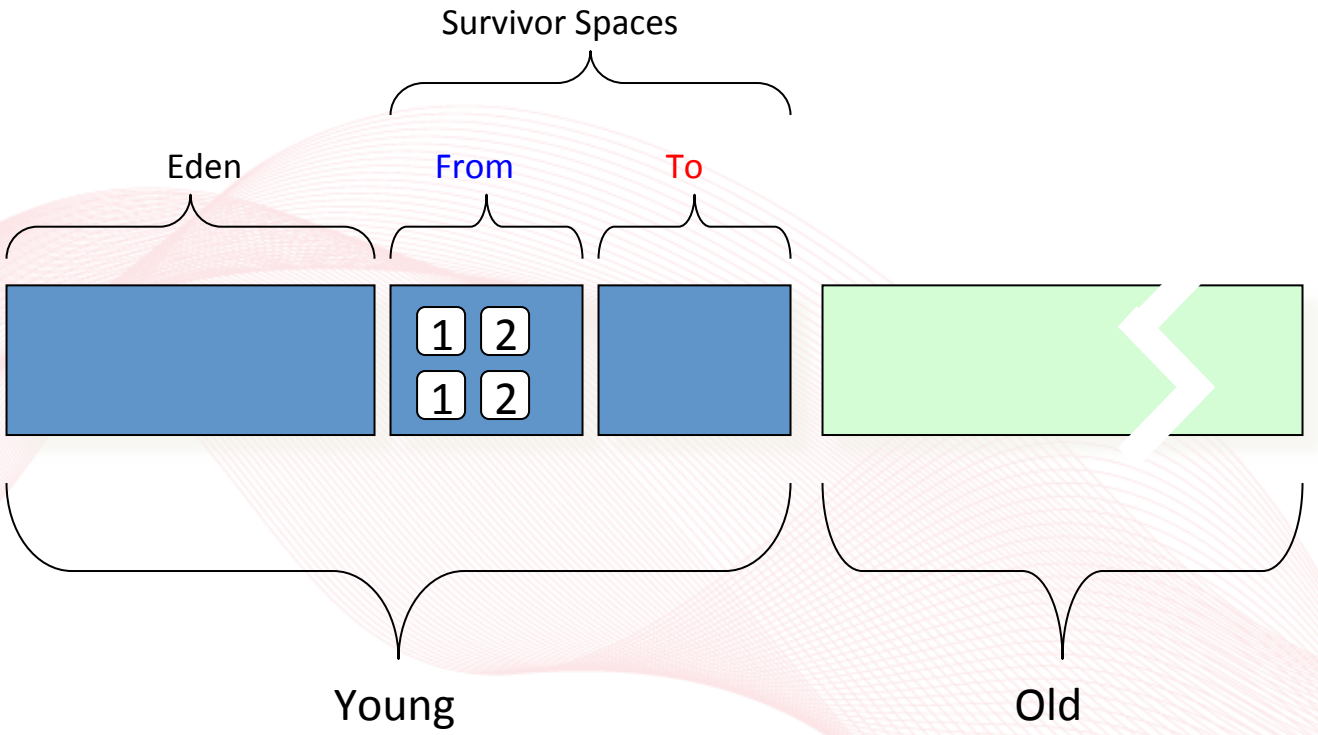

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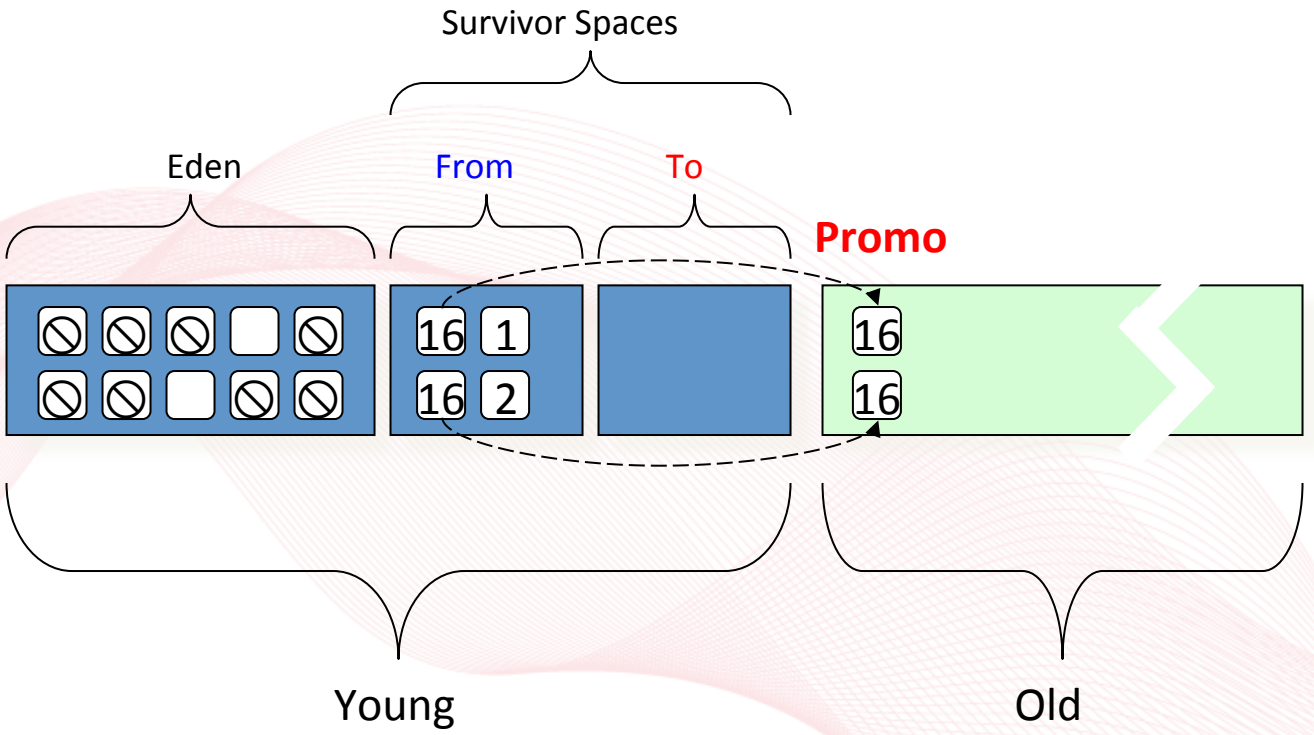

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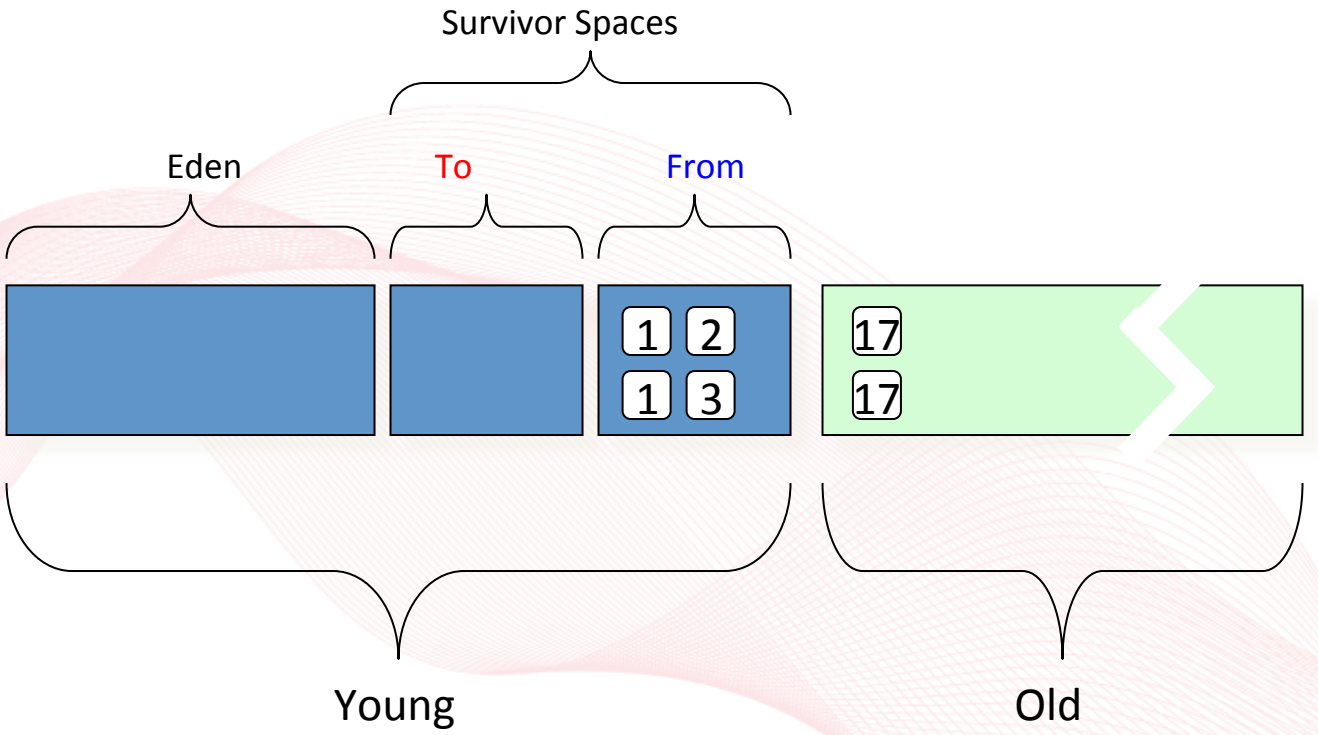
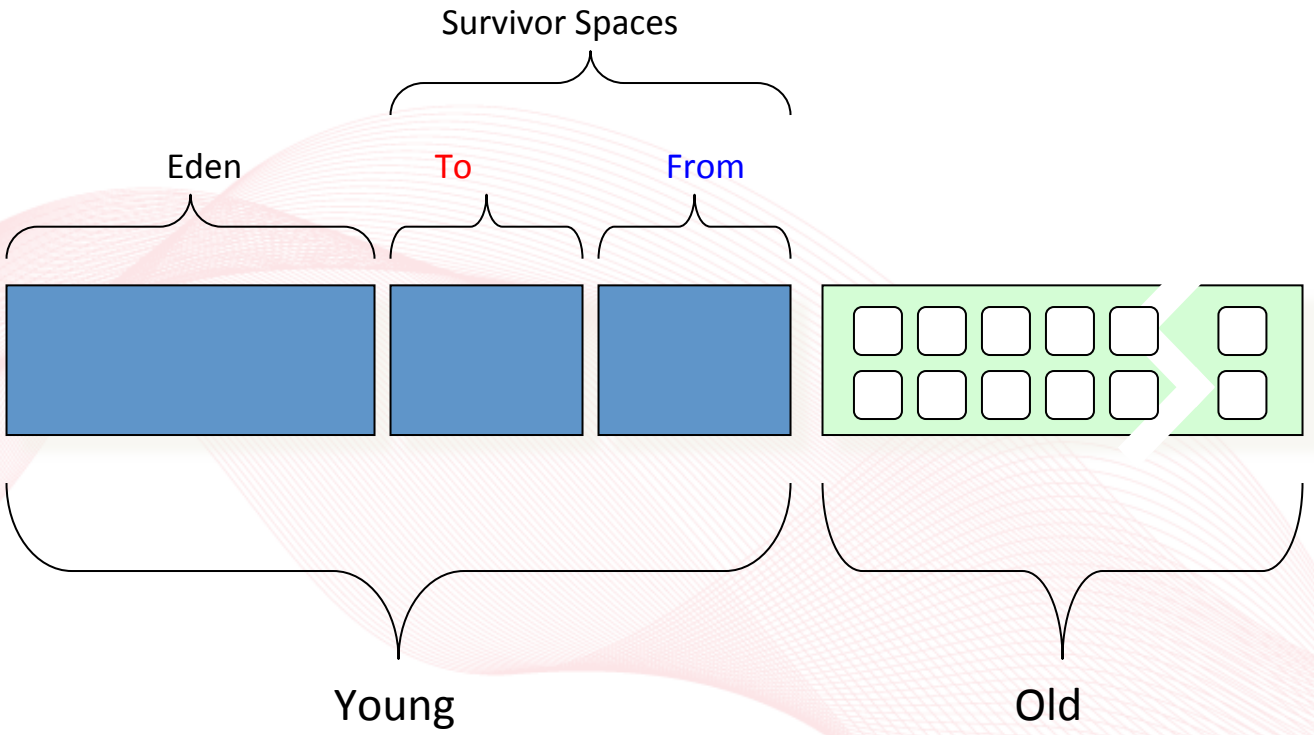


Major GC (Old Generation GC, Full GC)



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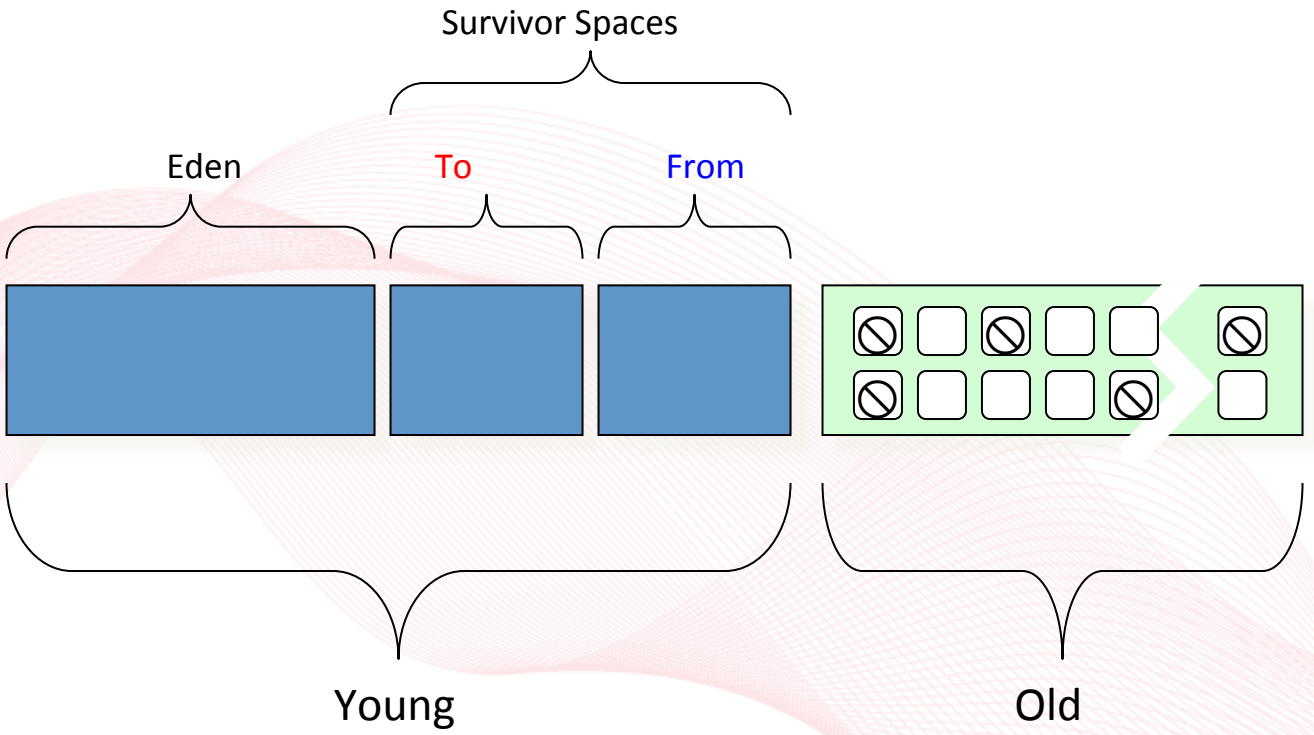

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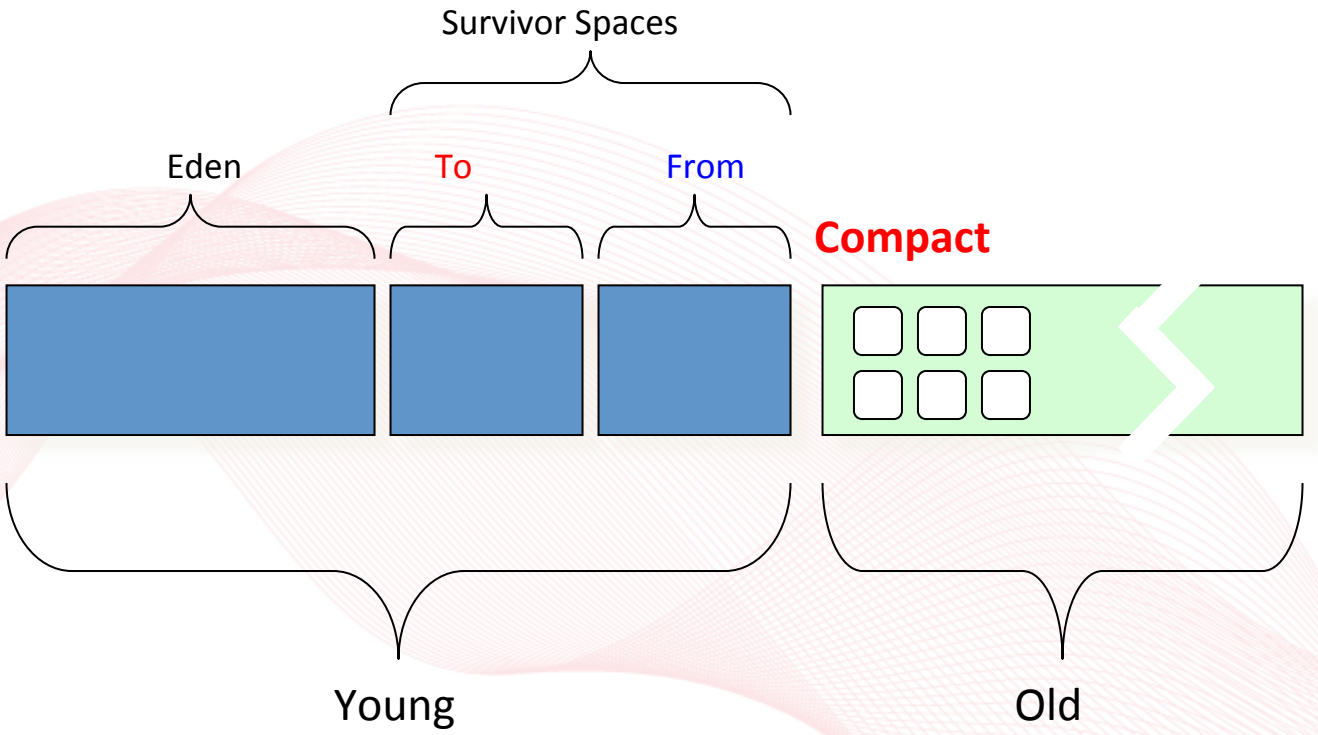


Tuning Guideline

- 讓 heap 的 size 足以容納程式的一般運作
- Major GC 通常會比 Minor GC 花更多的時間
- 盡可能減少 Major GC 的次數

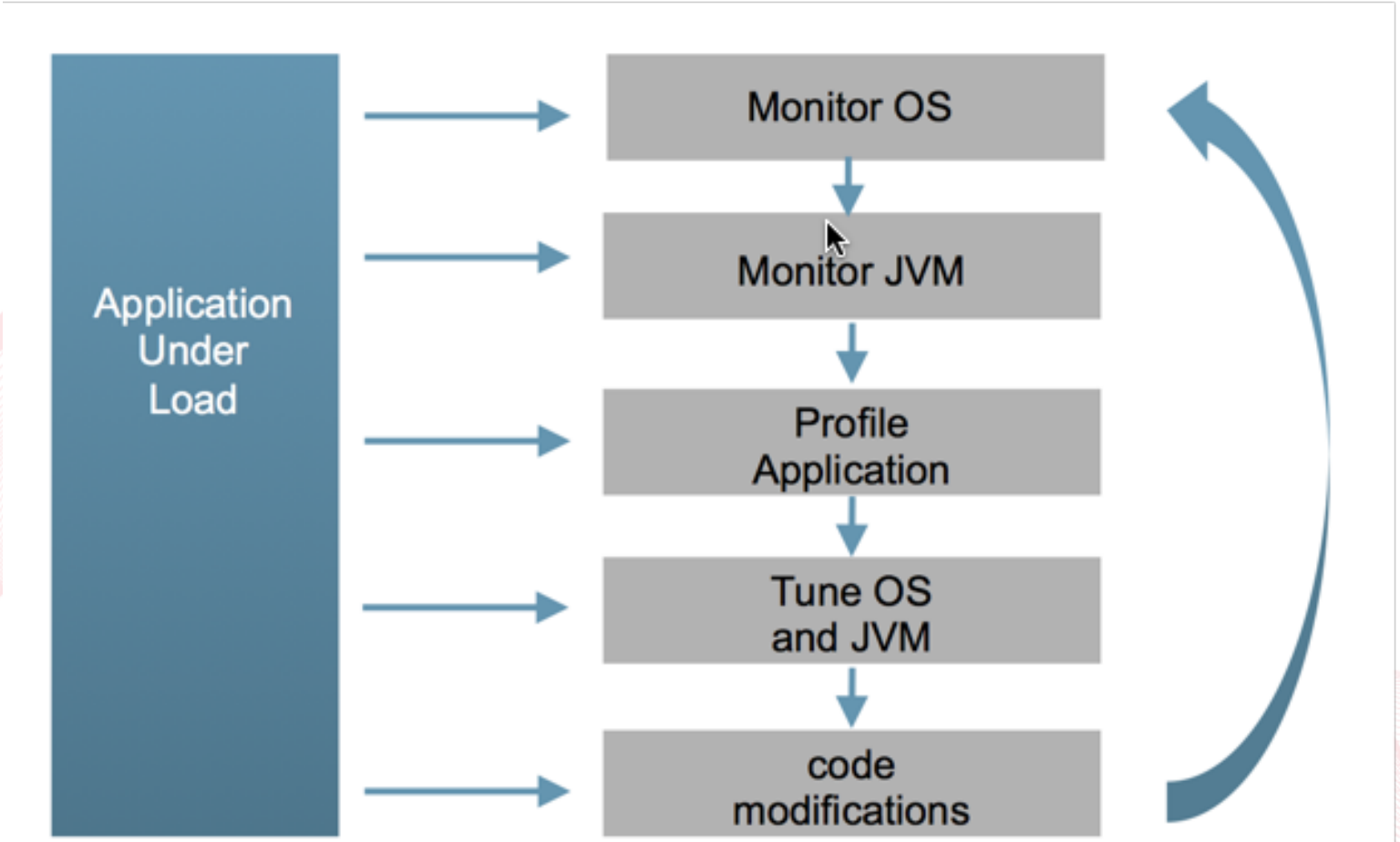
HOTSPOT GC TUNING

花太多時間做 GC → Performance變慢

Performance變慢→花太多時間做 GC

不一定!!!

Performance Tuning Methodology



Advanced JVM Tuning; Java One 2011; David Keenan, Monica Beckwith

GC Logging in Production

- Don't be afraid to enable GC logging in production
  - Very helpful when diagnosing production issues
- Extremely low / non-existent overhead
  - Maybe some large files in your file system.
  - We are surprised that customers are still afraid to enable it

If Someone doesn't enable GC logging in production

I shoot them!

Most Important GC Logging Parameters

- You need at least:
  - -XX:+PrintGCDetails
  - -XX:+PrintGCTimeStamps
    - Add -XX:+PrintGCDateStamps if you must know the time
- Also useful
  - -Xloggc:<file>
  - Rotate GC Log, After Java 1.6_34 (or 1.7_2):

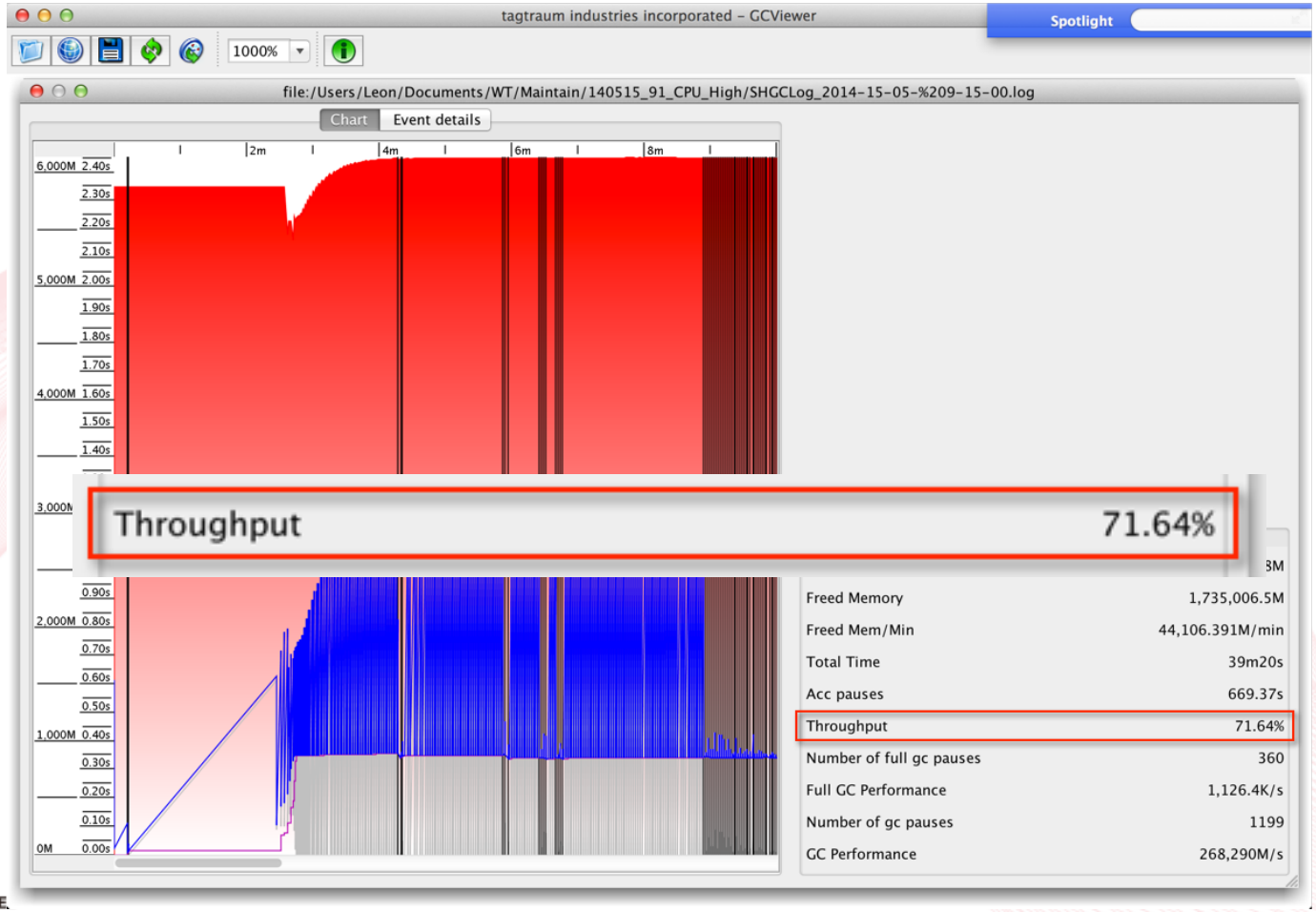
    -XX:+UseGCLogFileRotation

    -XX:NumberOfGCLogFiles=5

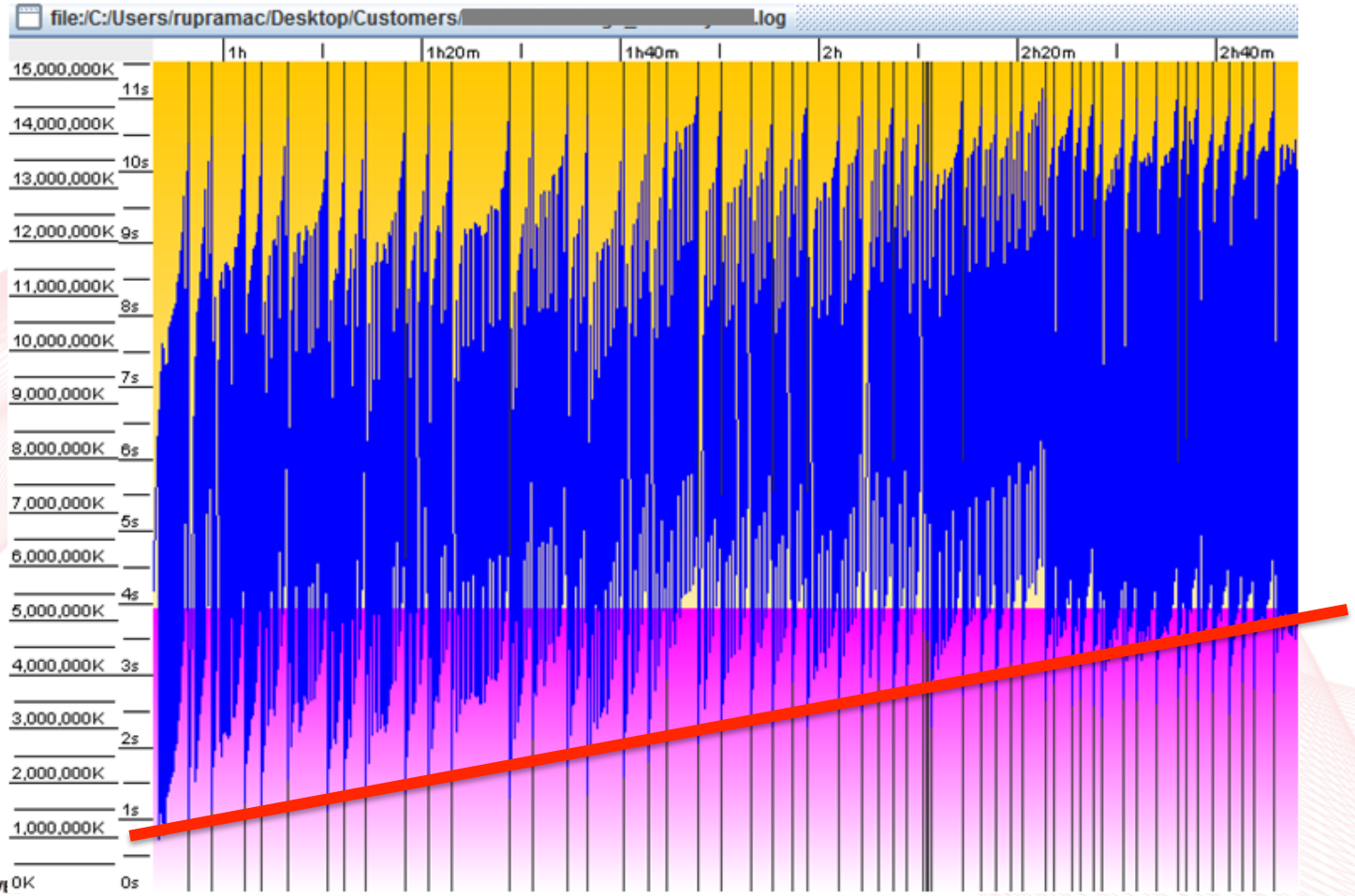
    -XX:GCLogFileSize=10M

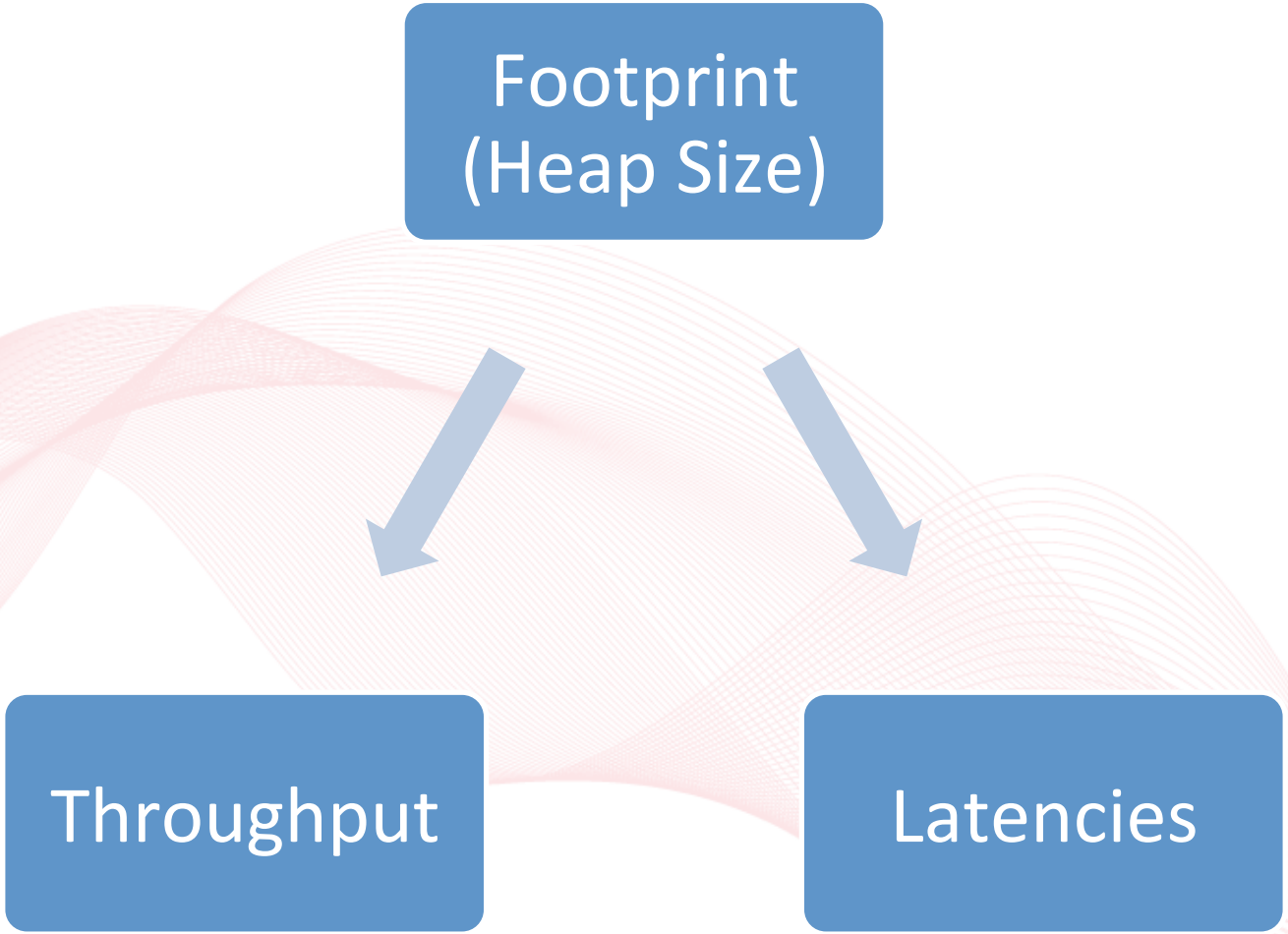
GCViewer – Offline analysis of GC logs

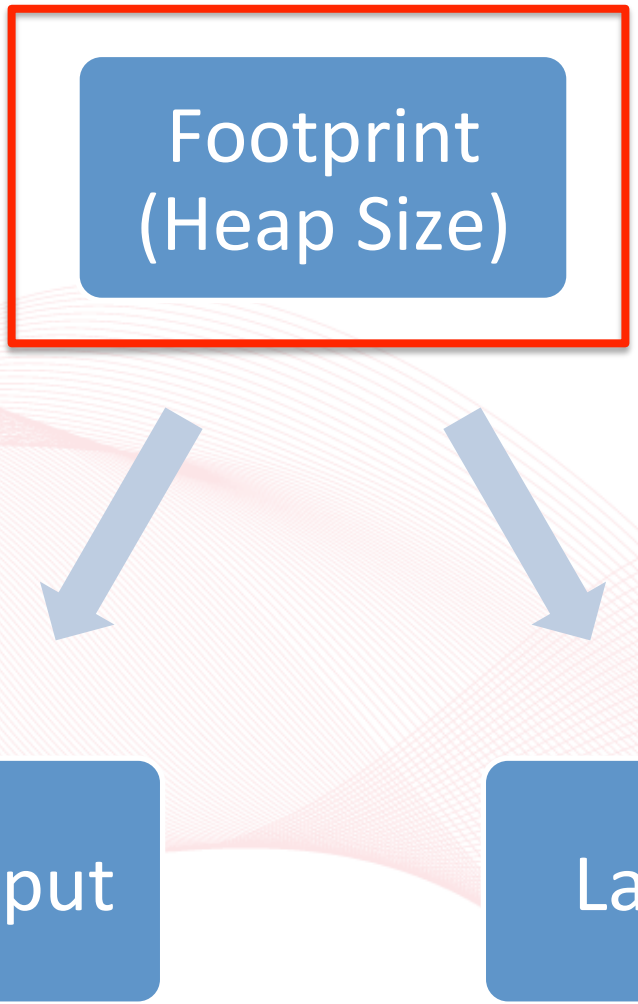
https://github.com/chewiebug/GCViewer



GCViewer – Memory Leak Pattern




Footprint
(Heap Size)
Throughput
Latencies


Footprint
(Heap Size)
Throughput
Latencies

Hotspot Tuning - Sizing Heap

- Young Generation size determines
  - ***Frequency*** of minor GC
  - ***Number of objects*** reclaimed in minor GC
- Old Generation Size
  - Should hold application's ***steady-state*** live data size
  - Try to ***minimize frequency*** of major GC's
- JVM footprint should not exceed physical memory
  - Max of 80-90% RAM (leave room for OS)
- **Thumb Rule:** Try to maximize objects reclaimed in young gen. Minimize Full GC frequency

Calculate Live Data Size (LDS)

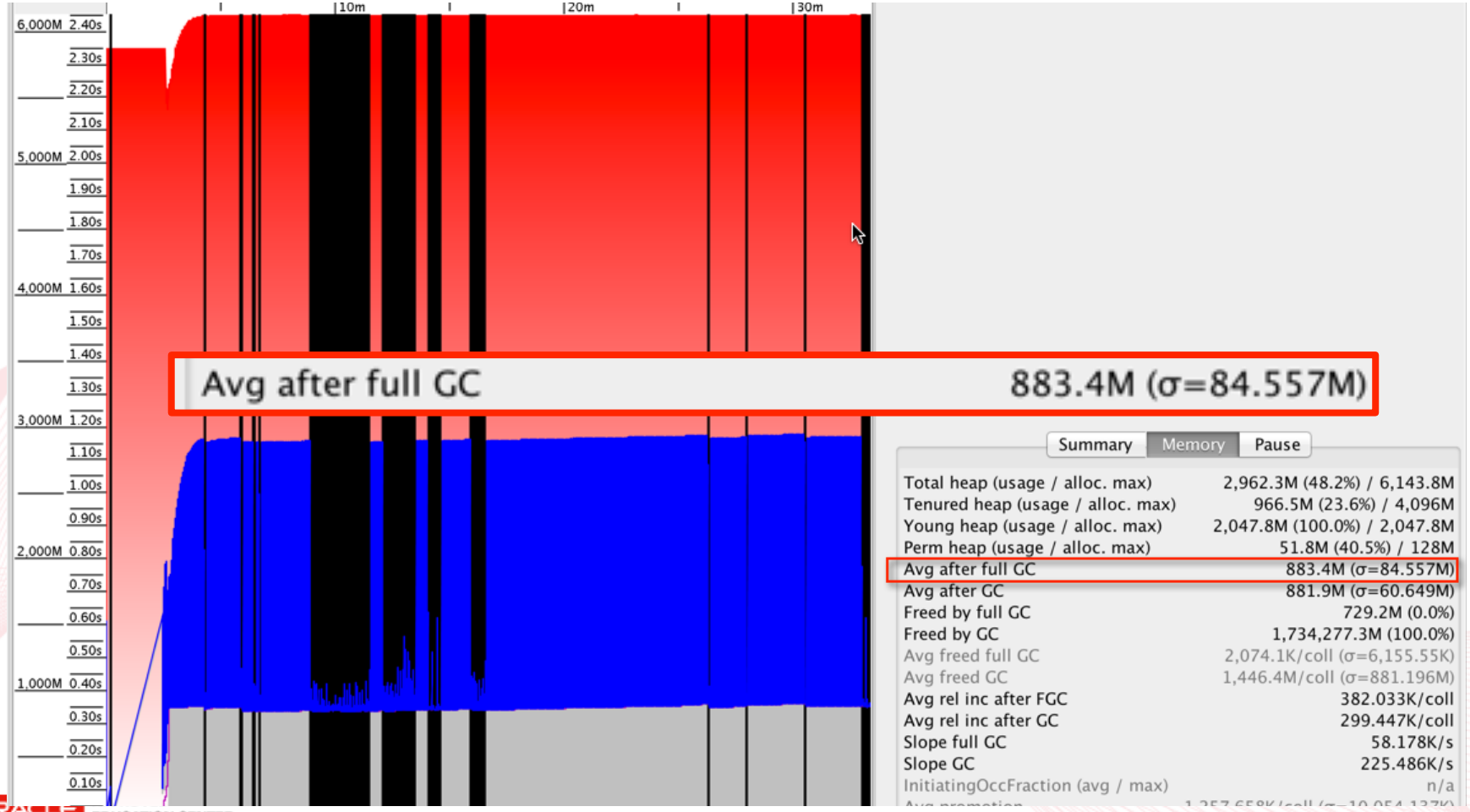
- 經過 full GC 後, 所剩下的 heap size
- Make sure you get full GCs during steady-state
- Induce a couple if necessary
  - JConsole / VisualVM
  - jmap -histo:live <pid>
  - System.gc
    - Remove it before deployment. :-)

Calculate Live Data Size

- GC log example:

```
170.517: [Full GC
          [PSYoungGen: 10128K->0K(163392K)]
          [ParOldGen: 348898K->161378K(350208K)]
                      359026K->161378K(513600K)
          [PSPermGen:   5799K->5798K(16384K)],
                                 0.3224960 secs]
```

Calculate Live Data Size by GCViewer

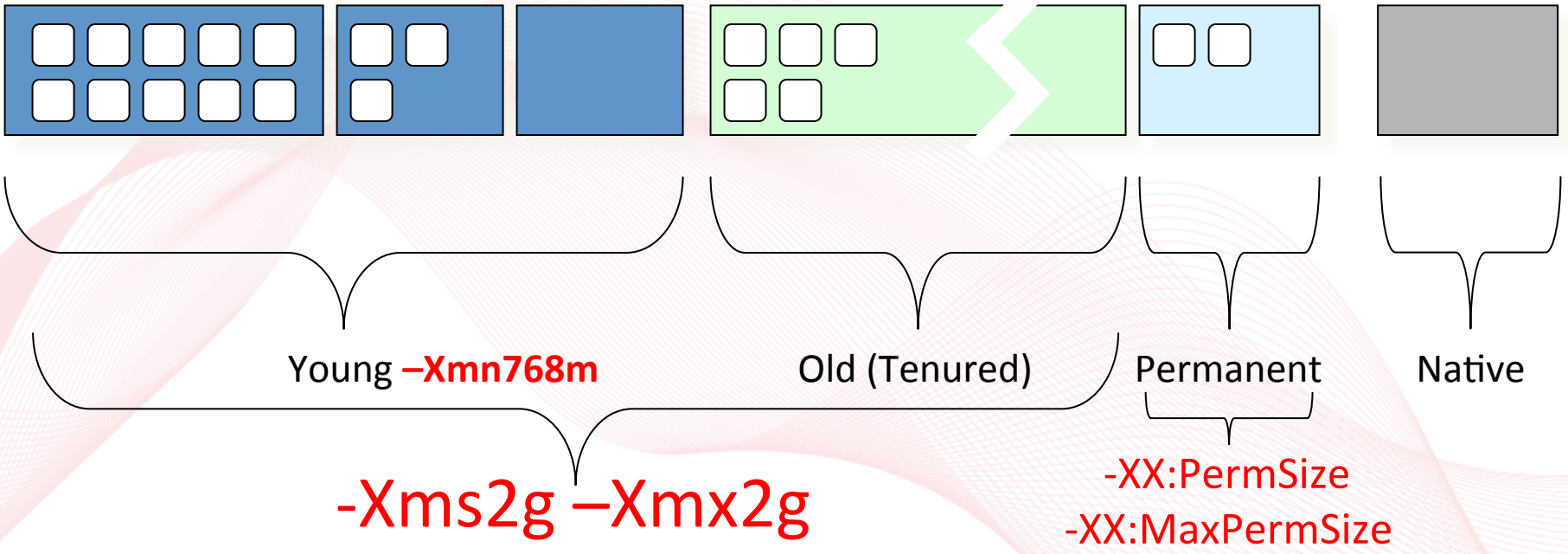


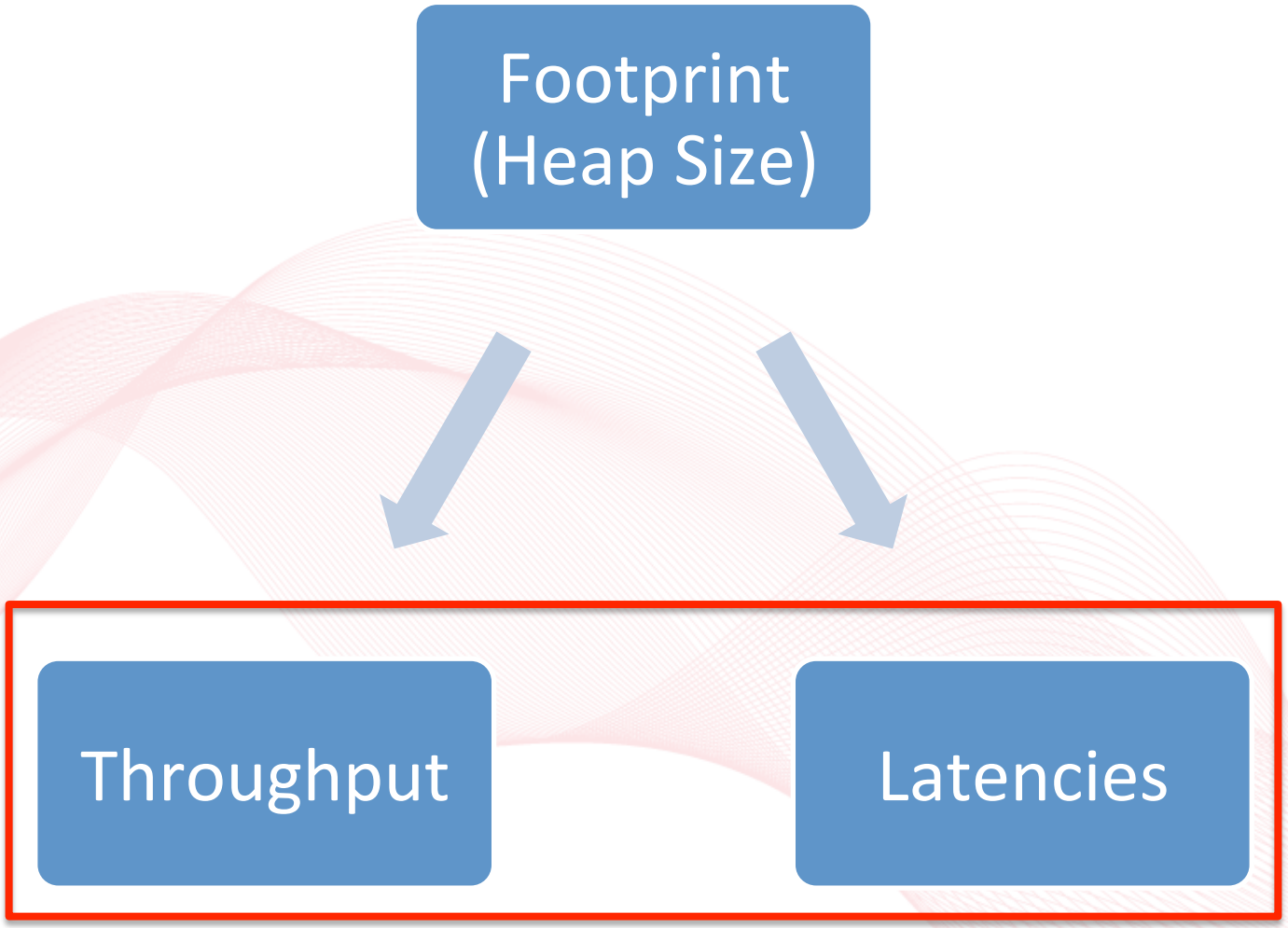
Initial Heap Configuration

- Rule of thumb
  - Set -Xms and -Xmx to 3x to 4x LDS
  - Set both -XX:PermSize and -XX:MaxPermSize to around 1.2x to 1.5x the max perm gen size
  - Set the generation sizes accordingly
    - Young gen should be around 1x to 1.5x LDS
    - Old gen should be around 2x to 3x LDS
    - e.g., young gen should be around 1/3-1/4 of the heap size

Hotspot JVM Heap Layout

For LDS of 512m : -Xmn768m -Xms2g -Xmx2g




Footprint
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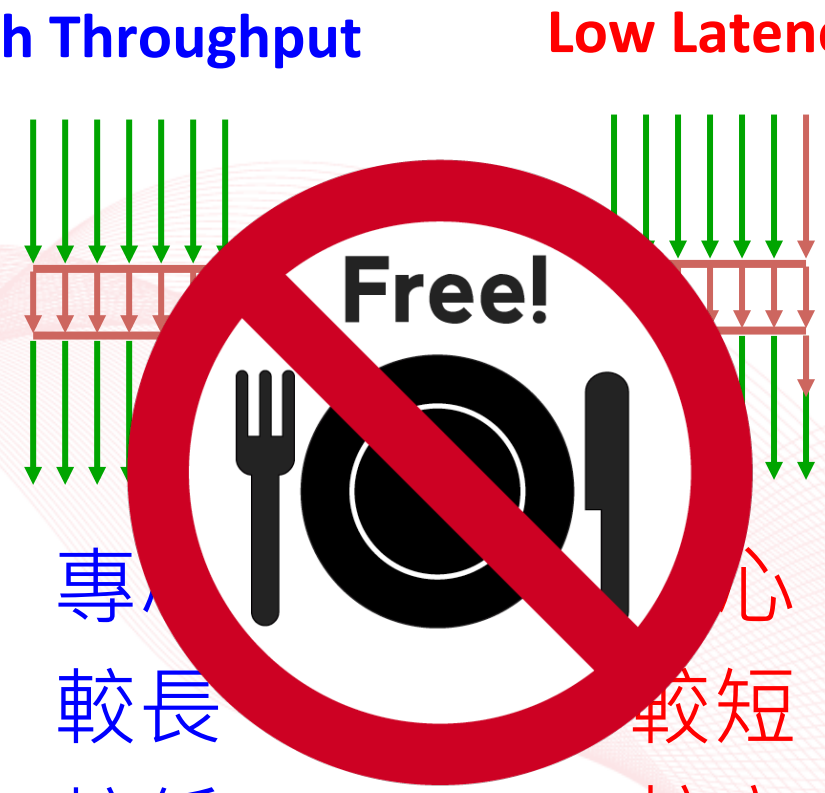
High Throughput vs. Low Latency



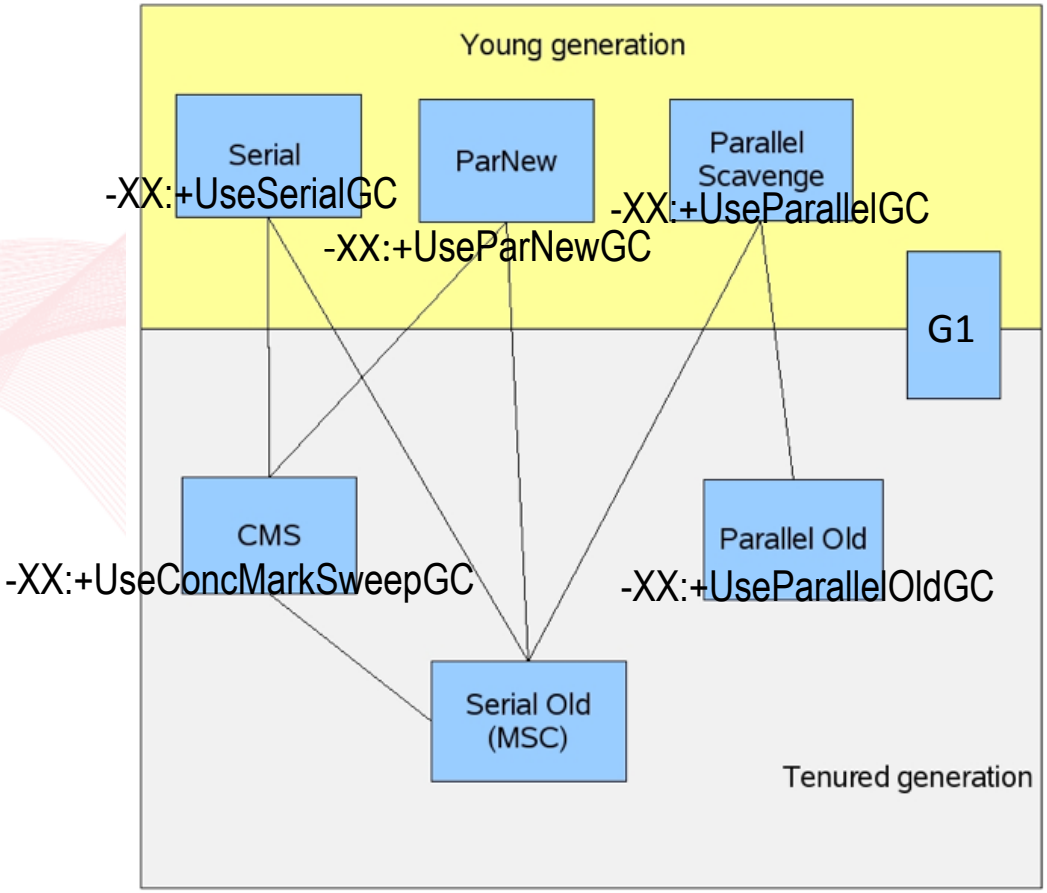
High Throughput vs. Low Latency

- For most applications, GC overhead is small
  - 2% – 5%
- High Throughput GCs
  - Move most work to GC pauses
  - Application threads do as little as possible
  - Least overall GC overhead
- Low Latency (Pause) GCs
  - Move work out of GC pauses
  - Application threads do more work
    - Bookkeeping for GC more expensive
  - More overall GC overhead

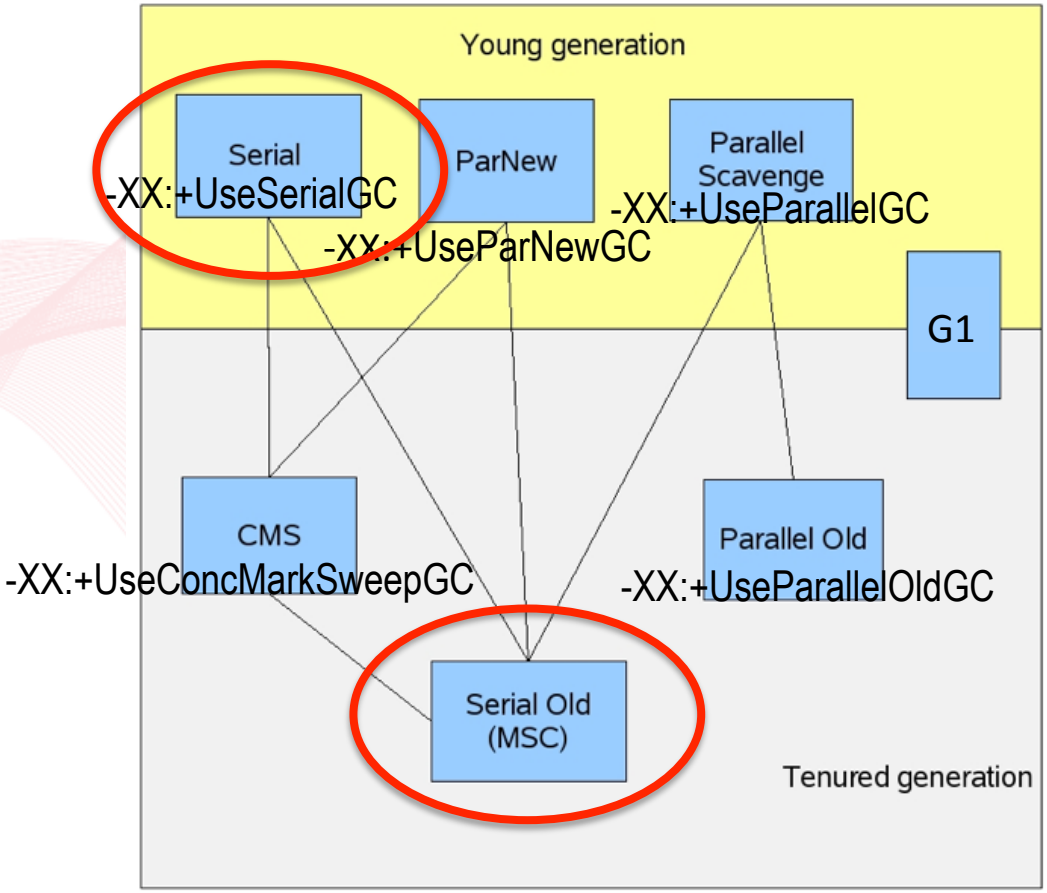
Application Requirement

- Different applications have different requirements
  - Higher Throughput:
    - Batch processing
    - Web application: pauses during garbage collection may be tolerable, or simply obscured by network latencies
  - Lower Latencies:
    - Interactive graphics application

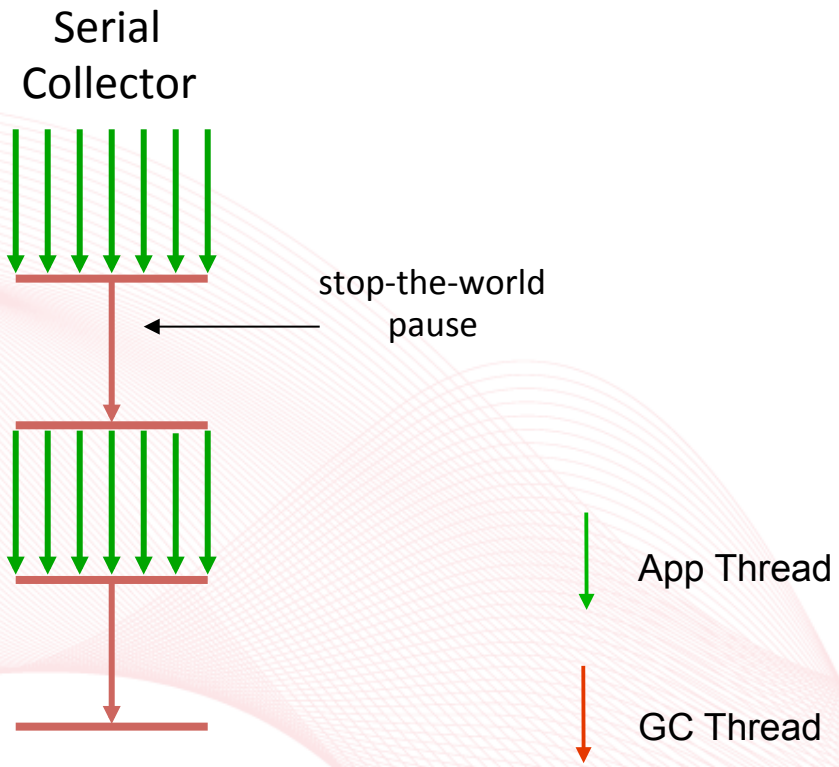
HotSpot Garbage Collectors in Java SE 6



HotSpot Garbage Collectors in Java SE 6



Serial Collector



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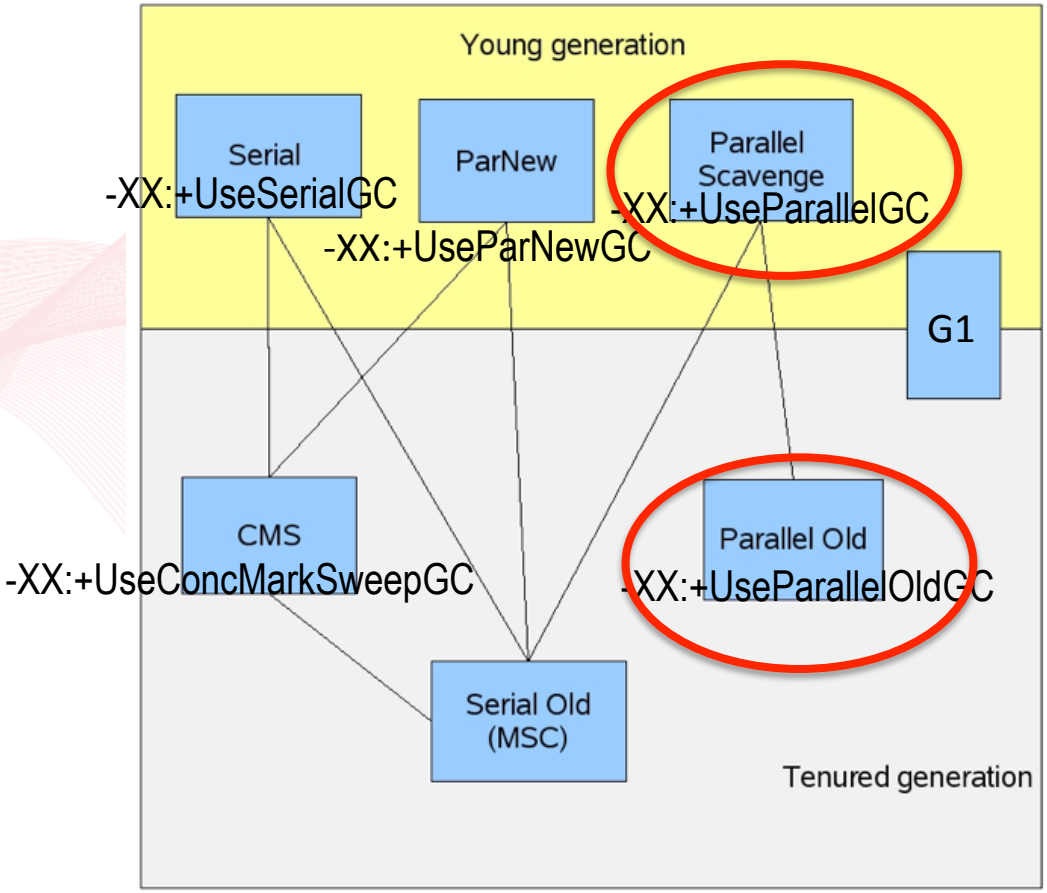
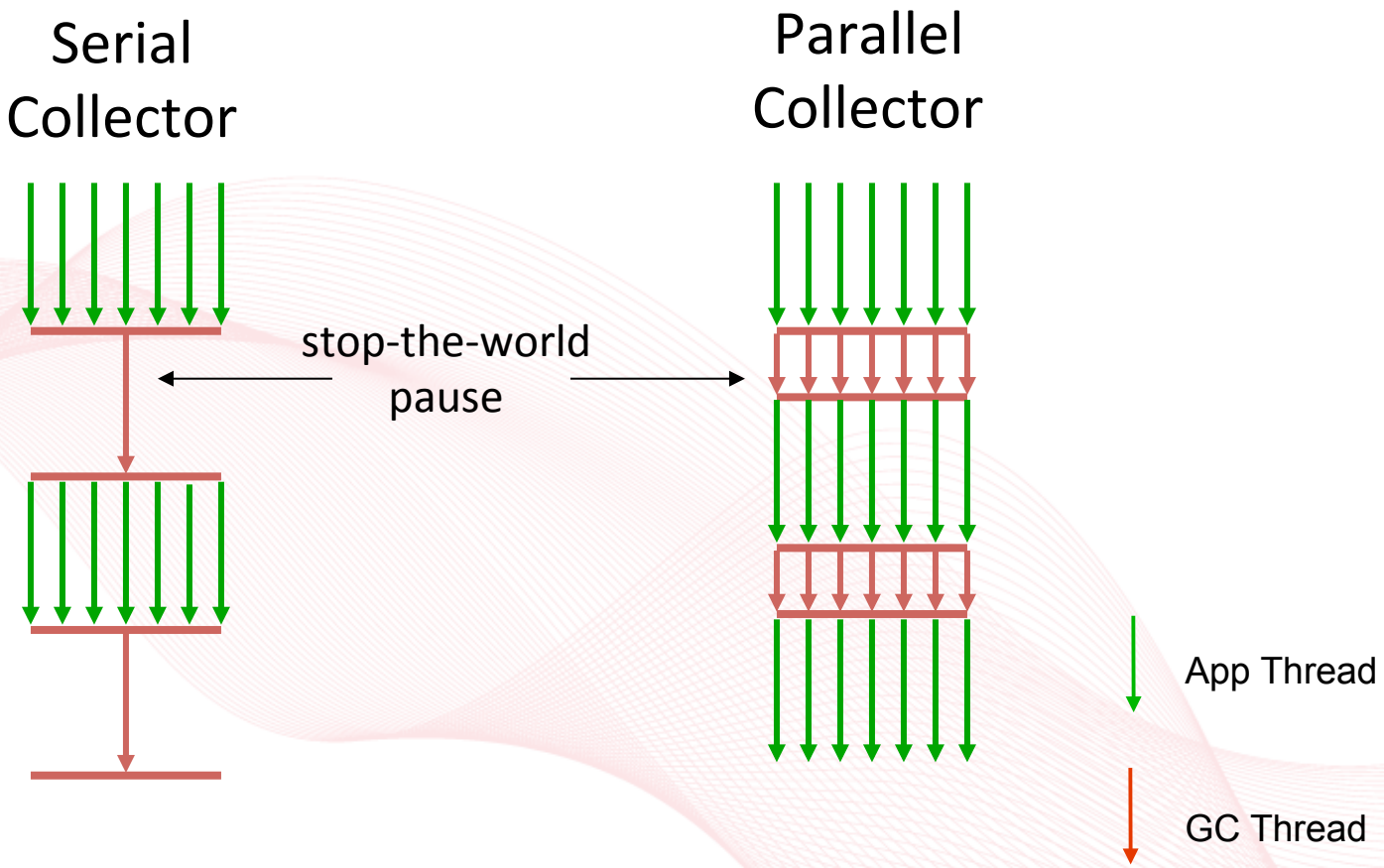


Serial VS Parallel Collector



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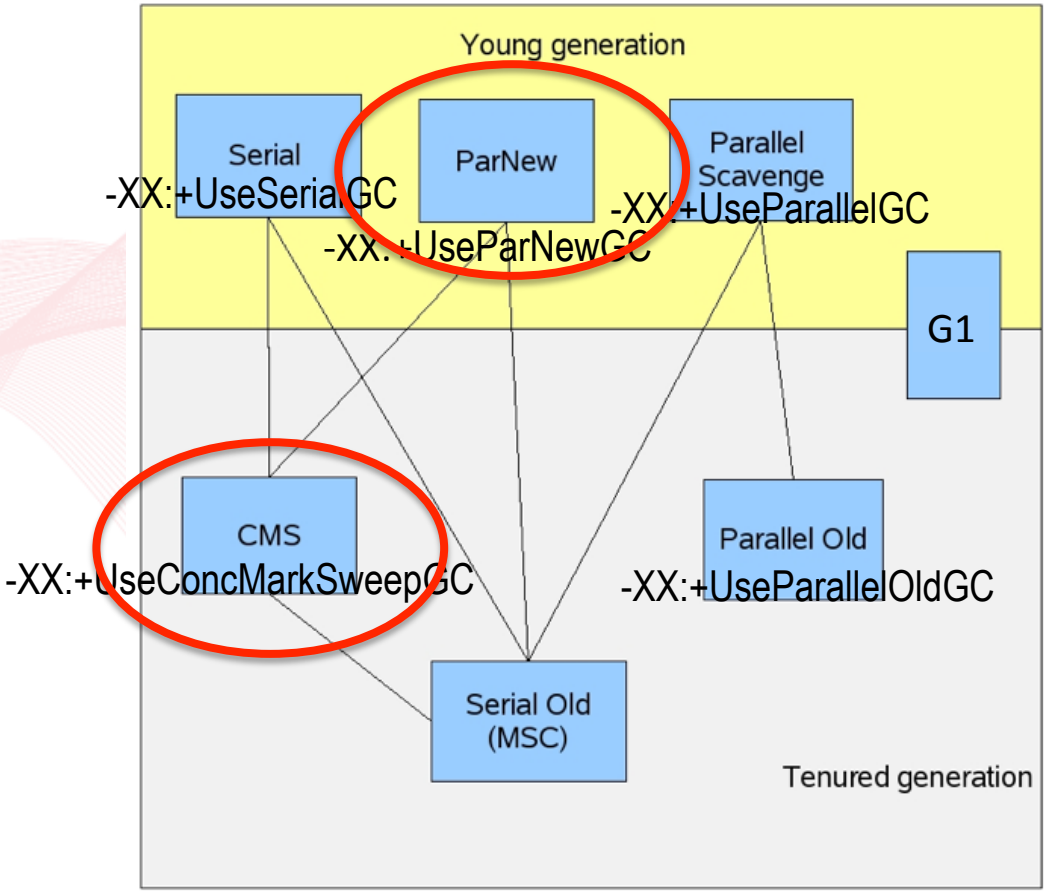
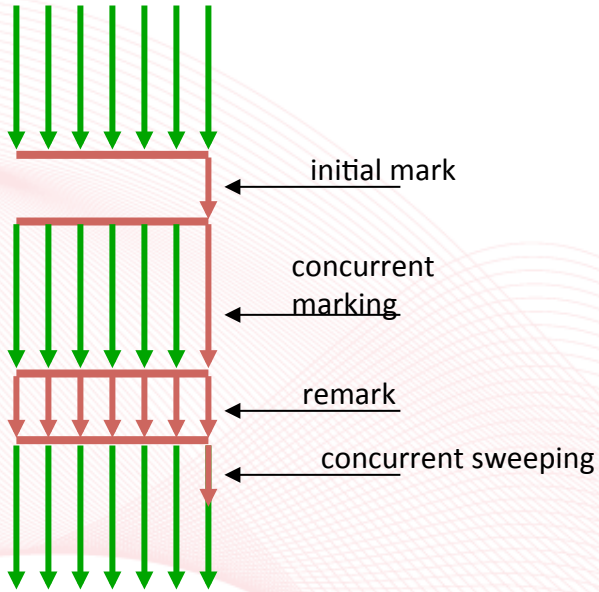


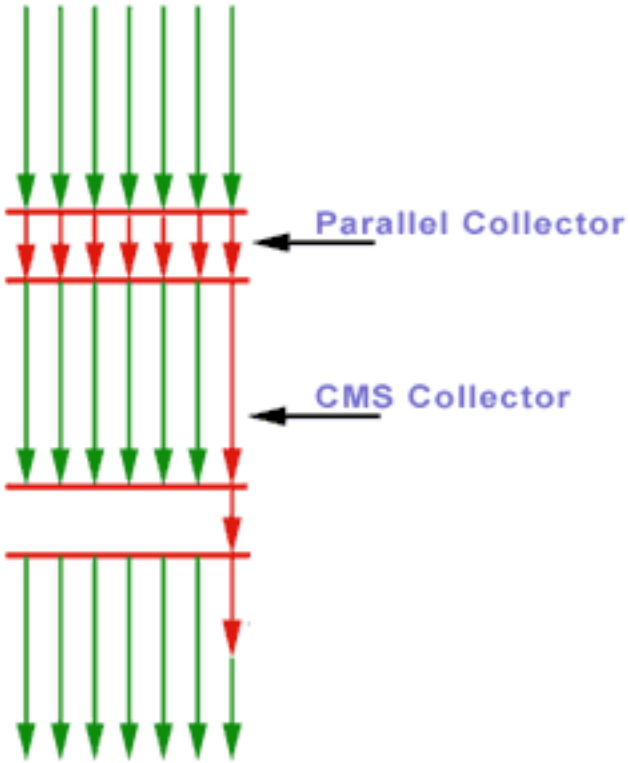
CMS Collector



App Thread

GC Thread

CMS Collector with ParNewGC



App Thread

GC Thread

GC Suggestions

Generation	Low Latency Collectors	Throughput Collectors
	2+ CPUs	2+ CPUs
Young	`-XX:+UseParNewGC`	`-XX:+UseParallelGC`
Old	`-XX:+UseConcMarkSweepGC`	`-XX:+UseParallelOldGC`

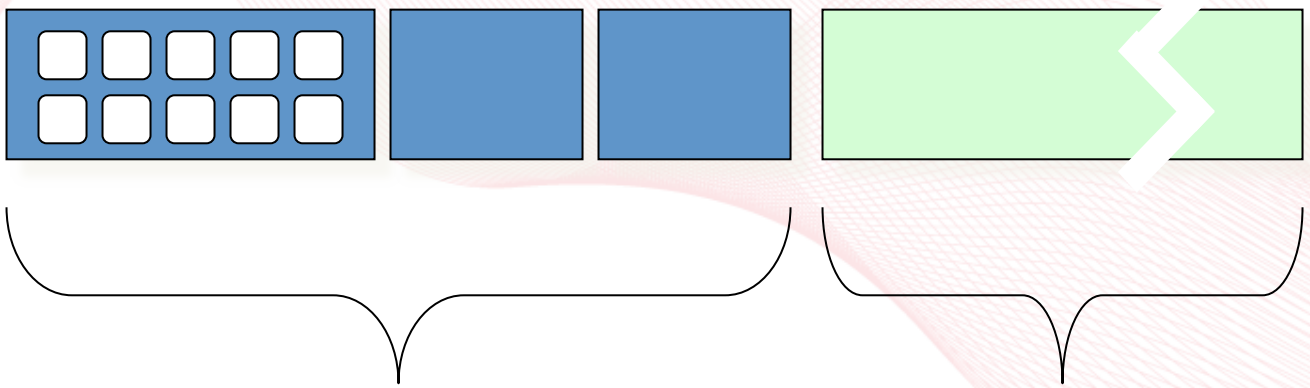
New G1 Collector as of WLS10.3.1/JDK 6 Update 14

NEXT GENERATION GC

Problems of Current GC

- Memory is cheaper and cheaper
- 64 bits JVM
- We can use very large heap!

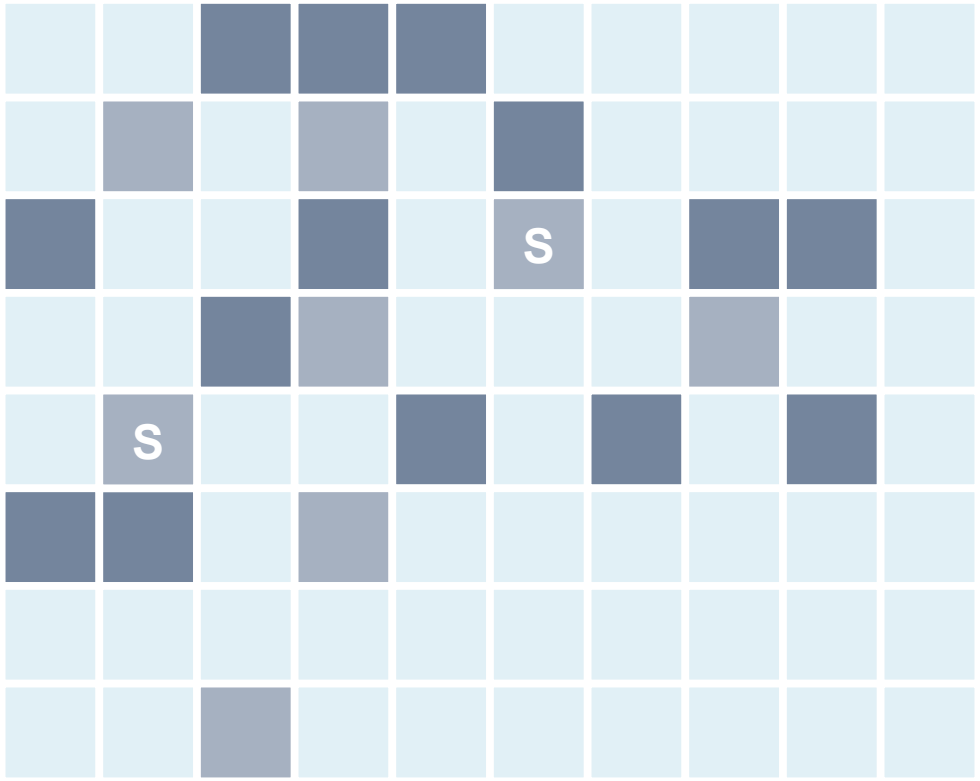
How to handle large heap size?



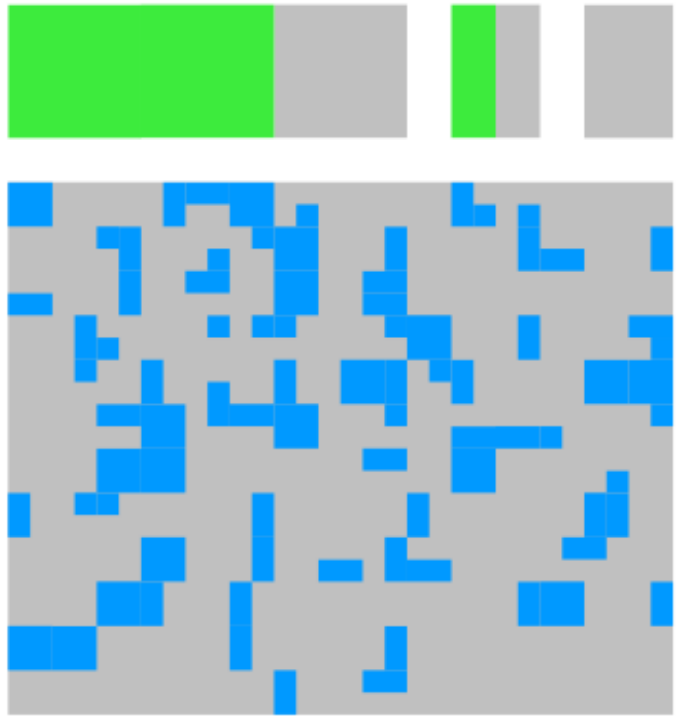
G1 Collector

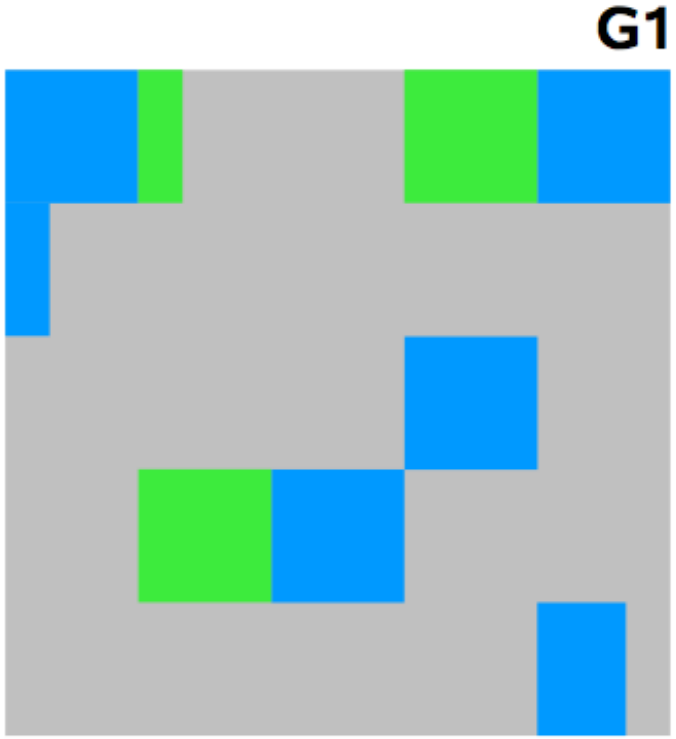
- The Garbage-First Collector
  - Since JDK 6u14, officially supported as of JDK 7u4
  - -XX:+UseG1GC
  - Future CMS Replacement
  - Server “Style” low latency collector
    - Parallel
    - Concurrent
  - Generational
  - Good Throughput
  - Compacting
  - Improved ease-of-use
  - Predictable (Soft Real-Time)

G1 – Heap Layout



CMS vs G1 Collectors





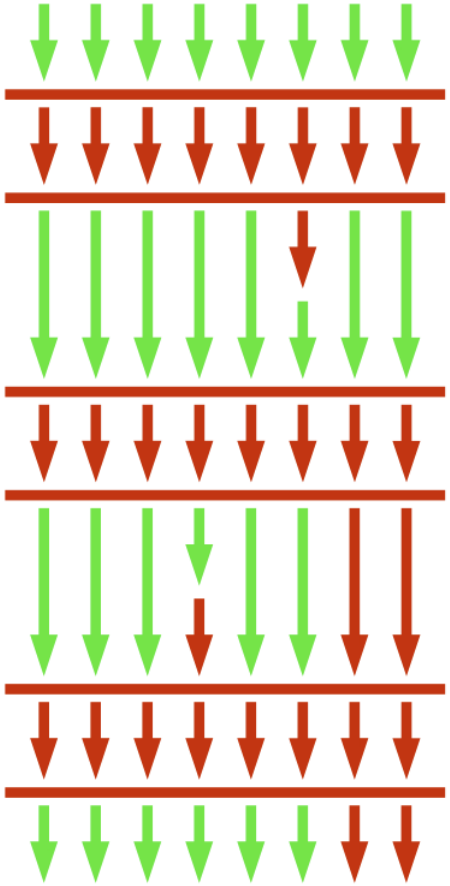
Non-Allocated Space

Young Generation

Old Generation

- Heap split into regions
- Young generation (A set of regions)
- Old generation (A set of regions)

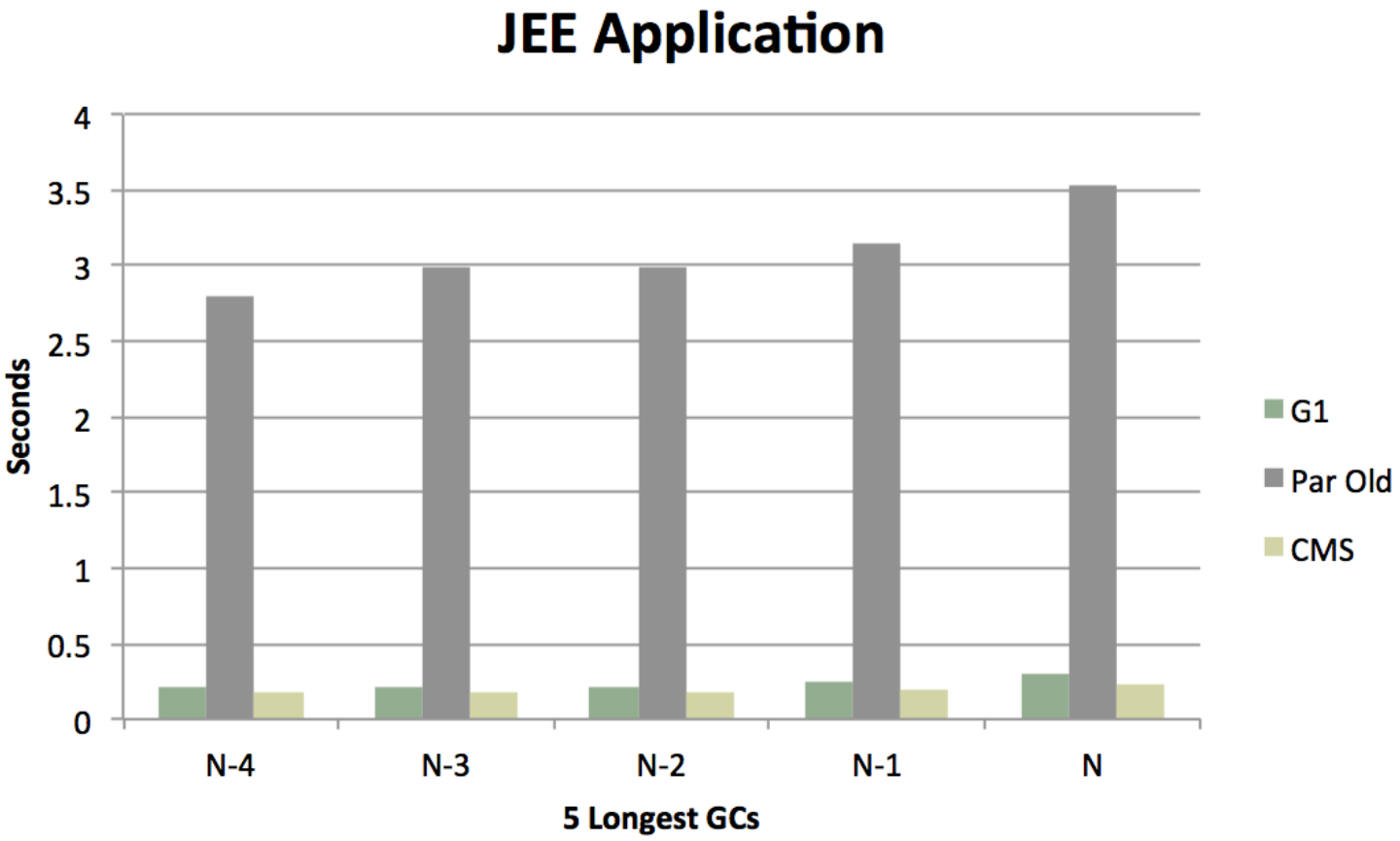
G1 Collector: Parallelism & Concurrency



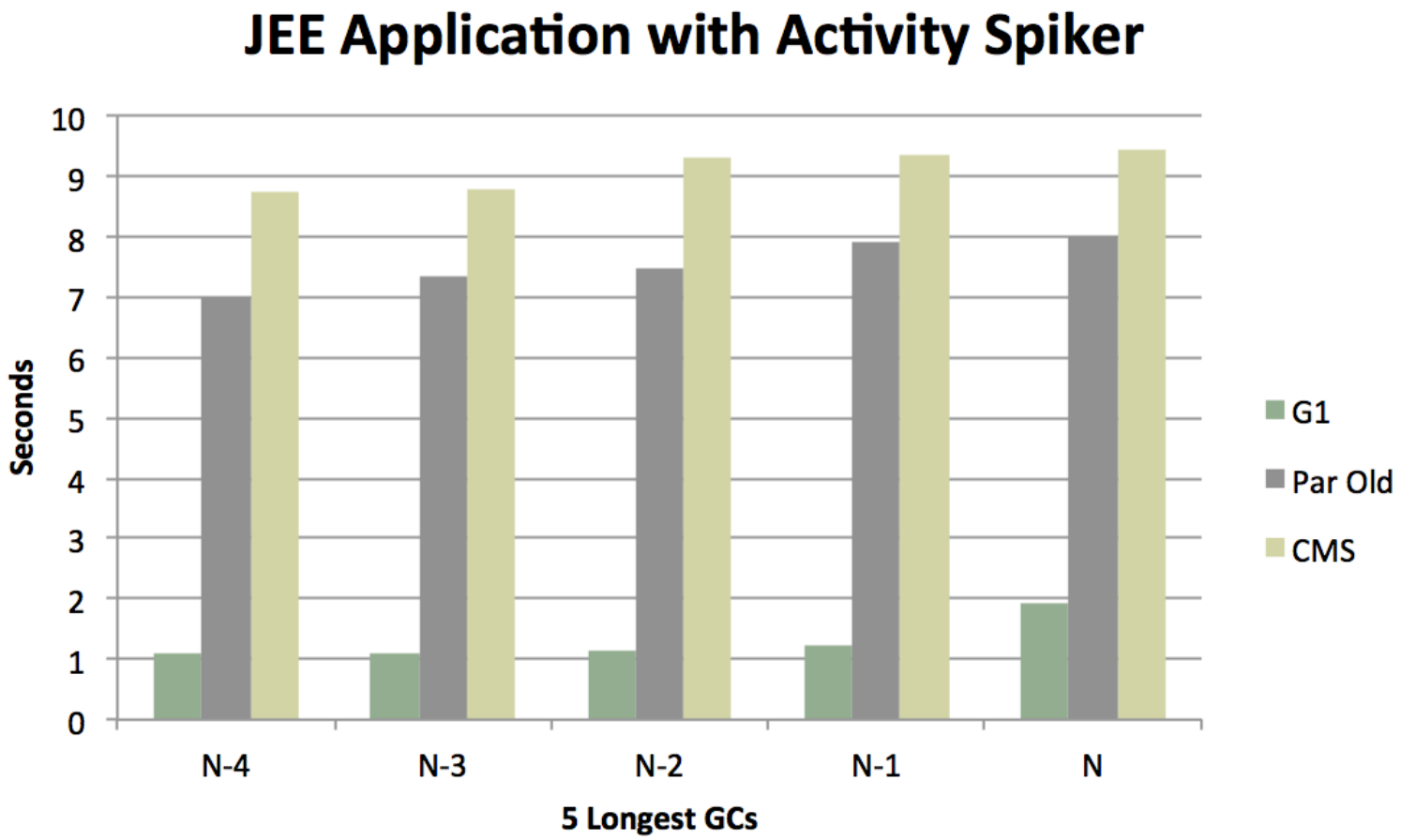
App Thread

GC Thread

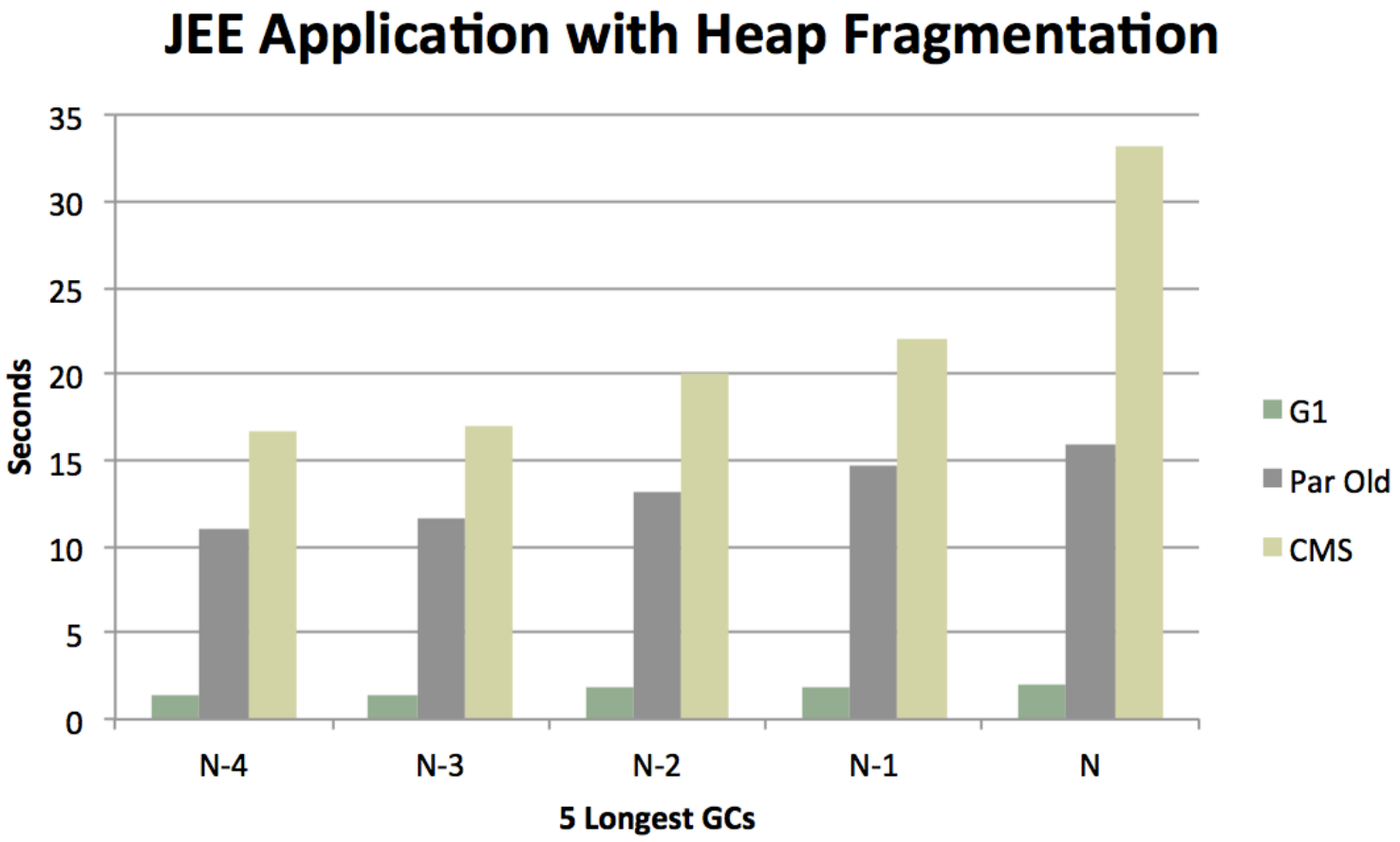
GC Comparison



GC Comparison



GC Comparison



GC Comparison

Collector	2. Garbage creation in test [MB/s]	3. Average New Gen GC Pause [ms]	4. Sigma of New Gen Pauses [ms]	5. Average Old Gen GC Pause [s]	6. Max Old Gen GC Pause [s]	7. Acc. GC Pause time [%]	8. Acc. Concurrent GC time [%]
ParallelGC	30.2	57	46	7.7	9.1	0.59	-
ParNewGC	36	62	45	6.9	7.4	0.73	-
CMS	30,9	78	69	0.65	0.97	0.81	0.06
	51.6	96	35	0.21	0.73	1.6	0.05
G1	50.1	272	41	0.28	0.67	7.0	0.78

http://blog.mgm-tp.com/2013/03/garbage-collection-tuning/

什麼時候該使用G1?

- Large heaps
  - Typically ~6GB or larger heaps
- Applications that needs low pauses

什麼時候不該使用 G1?

- G1需要更多的computing resources和 memory 來運行
- No large heaps
  - Typically smaller than 6GB
- Applications that don't need low pauses

SUMMARIZE

Summarize

- Professional developer 必須非常了解 variables, objects 的 life cycle, objects 何時有資格被會收
- GC will hurt system performance
- Must monitor GC activities
- Must enable GC logging

Tuning Procedures

- Observer LDS to decide initial size setting
- Use parallel GC first
- If the GC pause time can't be accepted, then trying to use CMS
- If heap is over 6G, and look for lower down pause time, you can consider G1
- Monitoring -> Analyzing -> Tuning -> Monitoring -> …

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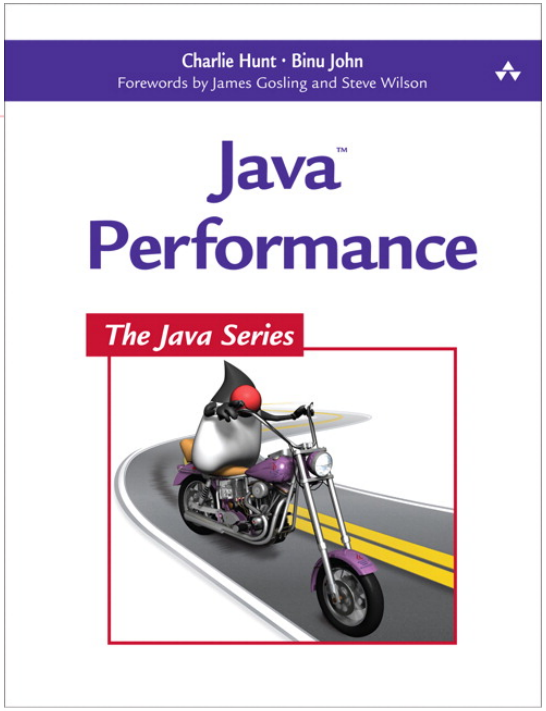
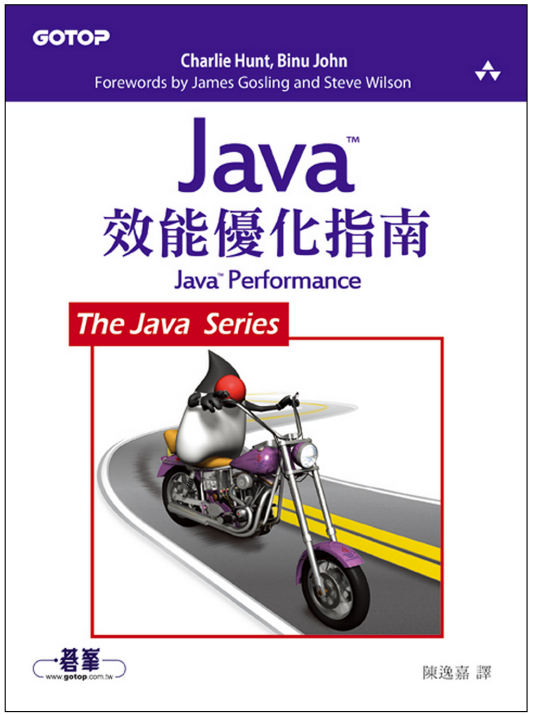
- The Garbage Collection Mythbusters – JavaOne 2010
- GC Tuning for the HotSpot JVM – JavaOne 2009
- uPortal Performance Optimization. Faizan Ahmed. Architect and Engineering Group. Enterprise Systems & Services. RUTGERS. faizan@rutgers.edu.
- http://java.sun.com/javase/technologies/hotspot/gc/gc_tuning_6.html

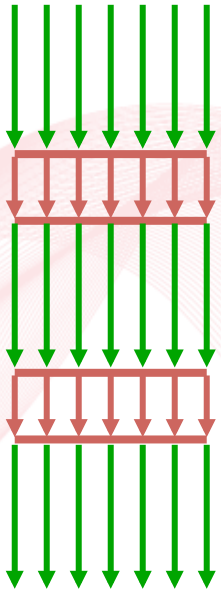




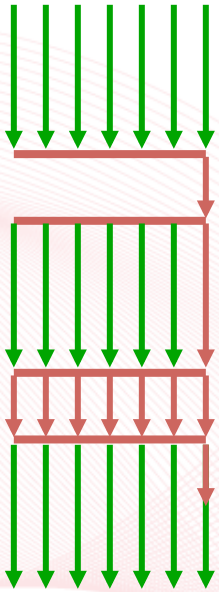
- **Java Performance –**
  Charlie Hunt, Binu John
- **HotSpot GC Tuning Guide**
  for Java SE 6
  http://www.oracle.com/technetwork/java/javase/gc-tuning-6-140523.html
- **Memory Management in the Java HotSpot VM**
  http://www.oracle.com/technetwork/java/javase/memorymanagement-whitepaper-150215.pdf
- **Java 6 Performance Whitepaper**
  http://java.sun.com/performance/reference/whitepapers/6_performance.html

Q&A

Parallel



Concurrent (CMS)



G1