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Saga of Scalable Garbage Collectors

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Java Your Next (Cloud)

Program Agenda

1. Basics of Garbage Collector
2. Prerequisites …
3. Working with Z GC
4. Some benchmarking reports

Safe Harbor Statement

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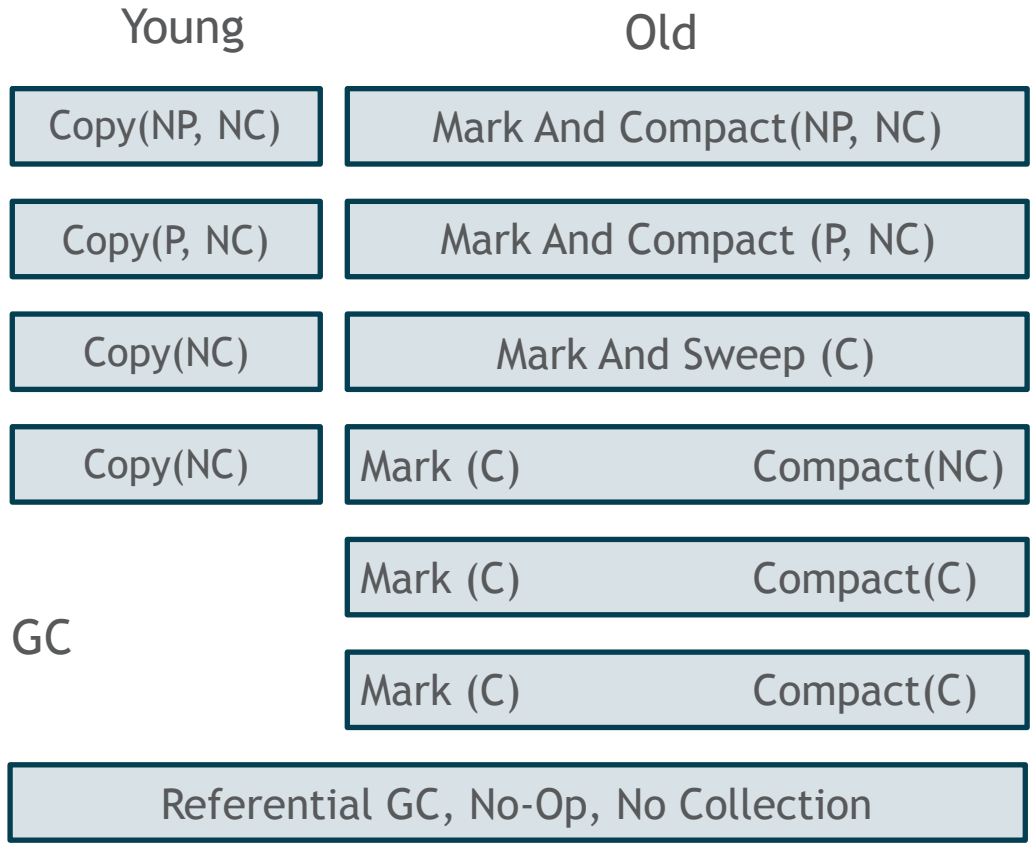
Basic of Garbage Collectors

All GC at a glance

- Serial GC
- Parallel GC
- CMS
- G1 GC
- Z GC
- Shenandoah GC
- Epsilon GC

Two generational GC

Single generational GC



Understanding Z GC

Z GC - In nutshell

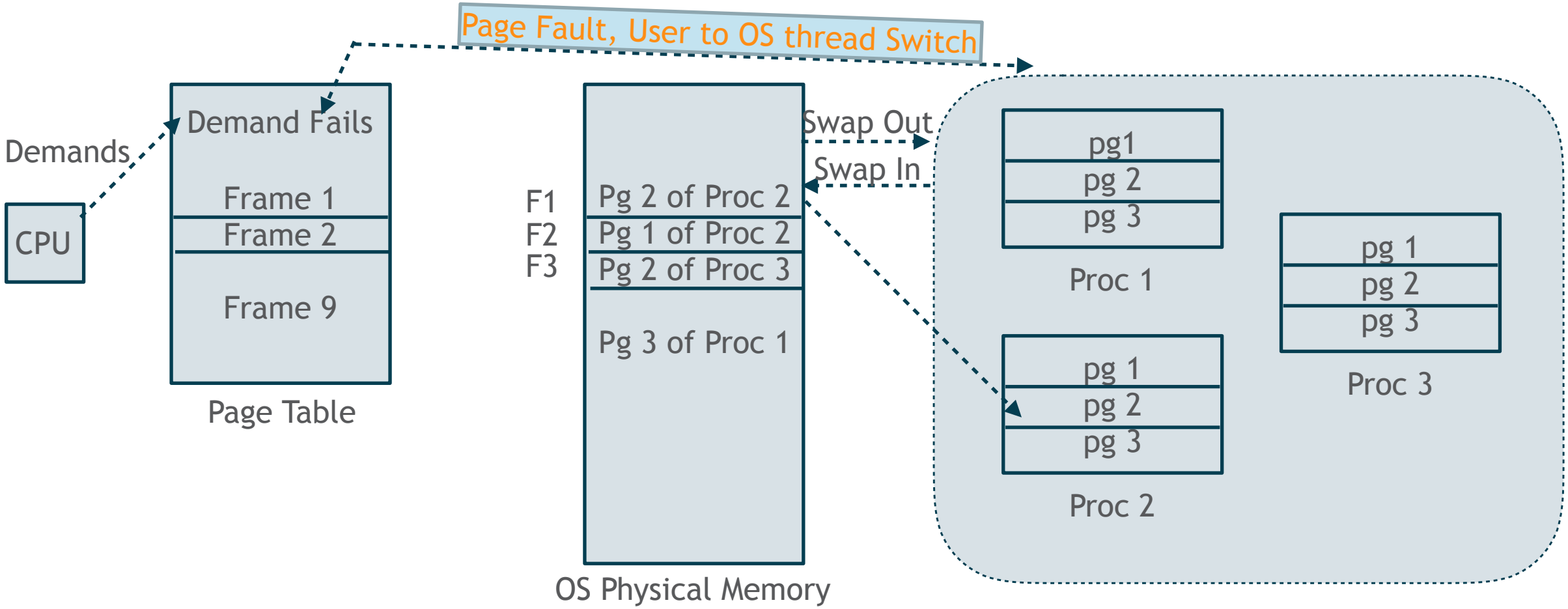
- The Z Garbage Collector, also known as ZGC, is a scalable low latency garbage collector designed to meet the following goals:
  - Pause times do not exceed 10ms
  - Pause times do not increase with the heap or live-set size
  - Handle heaps ranging from a few hundred megabytes to multi terabytes in size
- At a glance, ZGC is:
  - Concurrent
  - Region-based
  - Compacting
  - NUMA-aware
  - Using colored pointers
  - Using load barriers

Understanding of ZPages

- Z GC is a region-based Garbage Collector like G1.
- Z GC uses three different size of regions (always in multiple of 2MB for x64) unlike G1.
- The regions are :
  - ZPageTypeSmall (Size : 2 MB)
  - ZPageTypeMedium (Size : 32 MB)
  - ZPageTypeLarge (Size : n*2 MB)
- Details : http://hg.openjdk.java.net/zgc/zgc/file/59c07aef65ac/src/hotspot/share/gc/z/zPage.hpp

Understanding of Multi-mapping

- Basic understanding of virtual and physical memory



Understanding of Multi-mapping

- OS is responsible to map between virtual memory and physical memory.
- Generally done by MMU with the help of Page table and TLB.
- Z GC maps different virtual memory to same physical memory by multi-mapping
- mark0, mark1 and remap - by design only one can point to the same physical memory.

Understanding of Multi-mapping

```
//  +-----------------+-+----+-----------------------------------------------+
//  |00000000 00000000 0|0|1111|11 11111111 11111111 11111111 11111111 11111111|
//  +-----------------+-+----+-----------------------------------------------+
//  |                   | |    |
//  |                   | |    * 41-0 Object Offset (42-bits, 4TB address space)
//  |                   | |
//  |                   | * 45-42 Metadata Bits (4-bits)  0001 = Marked0      (Address view 4-8TB)
//  |                   |                                 0010 = Marked1      (Address view 8-12TB)
//  |                   |                                 0100 = Remapped     (Address view 16-20TB)
//  |                   |                                 1000 = Finalizable  (Address view N/A)
//  |                   |
//  |                   * 46-46 Unused (1-bit, always zero)
//  |
//  * 63-47 Fixed (17-bits, always zero)
```

* http://hg.openjdk.java.net/zgc/zgc/file/59c07aef65ac/src/hotspot/os_cpu/linux_x86/zGlobals_linux_x86.hpp#l61

Understanding of Colored Pointers

- Z GC works with 64-bit only.
- No CompressedOOPS
- 42 bit point to 4 TB space.
- 4 bit for mapping - finalizable, remap, mark0, mark1

Understanding of Load Barriers

- Piece of code insert by JIT when application thread loads a reference.
- C1 Barrier set - http://hg.openjdk.java.net/zgc/zgc/file/3cf81d157e9f/src/hotspot/share/gc/z/c1
- C2 Barrier set - http://hg.openjdk.java.net/zgc/zgc/file/3cf81d157e9f/src/hotspot/share/gc/z/c2
- GC need to do additional action whenever a reference gets loaded.
  - Object o = obj.field; // triggers load barrier
  - Object o1 = o; // not trigger load barrier
- ZGC need a read barrier not write barrier unlike generational GC.
- Required for concurrent compaction.

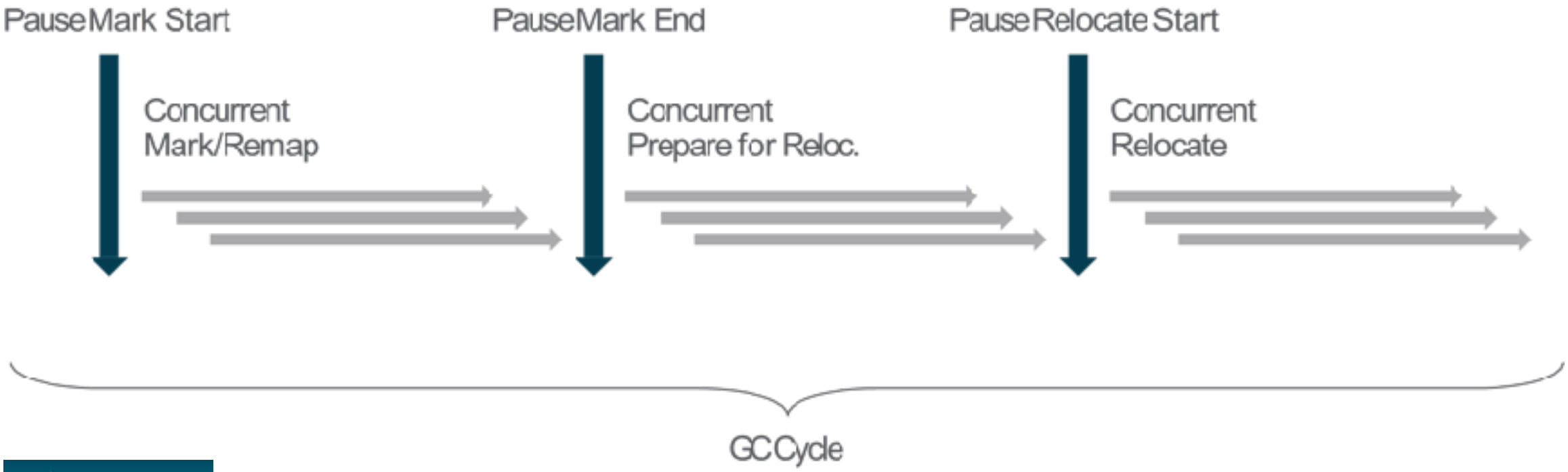
Phases of Z GC

- http://hg.openjdk.java.net/zgc/zgc/file/59c07aef65ac/src/hotspot/share/gc/z/zDriver.cpp#l304
- Phases :
  - Phase 1: Pause Mark Start (STW - very small)
  - Phase 2: Concurrent Mark
  - Phase 3: Pause Mark End (STW - very small)
  - Phase 4: Concurrent Reference Processing
  - Phase 5: Concurrent Reset Relocation Set
  - Phase 6: Concurrent Destroy Detached Pages
  - Phase 7: Concurrent Select Relocation Set
  - Phase 8: Prepare Relocation Set
  - Phase 9: Pause Relocate Start (STW - very small)
  - Phase 10: Concurrent Relocate

Z GC: A Scalable Low Latency Garbage Collector

Goals:

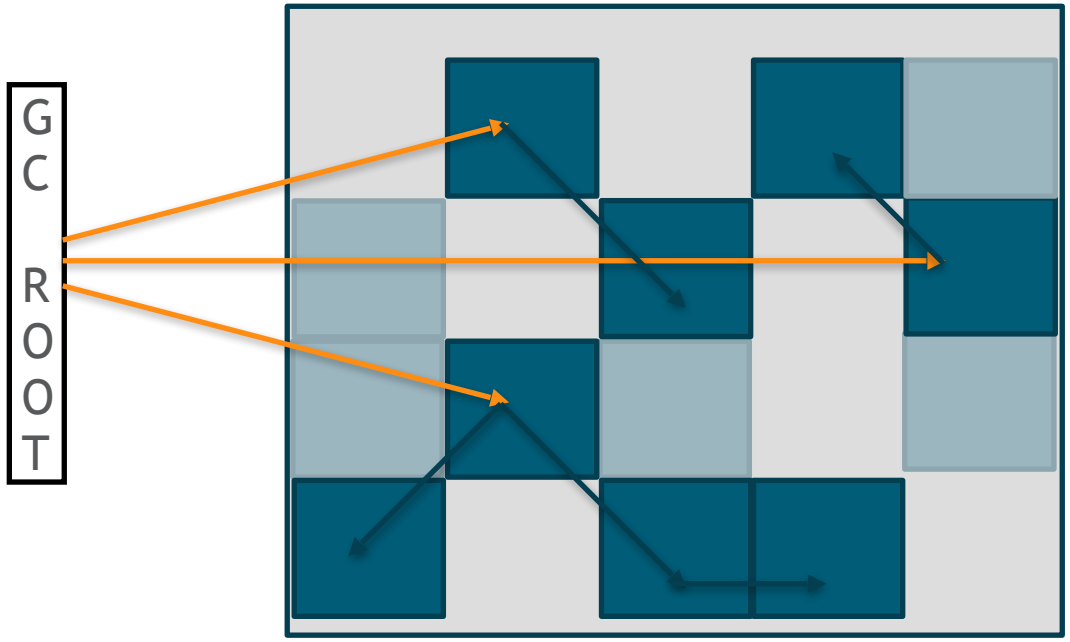
- Scales up to Multi-terabyte heaps
- 10ms as max GC pause time
- GC pause times do not increase with heap or live-set size -XX:+UseZGC



GC Root Marking and concurrent marking

* Class loaded by boot_class_loader. Object holding
    * via static field.
* Live threads.
* Stack Locals
* JNI Local and Globals
* And few more like monitors, JVM specials.

— Object not reachable from Object Graph are free be collected.

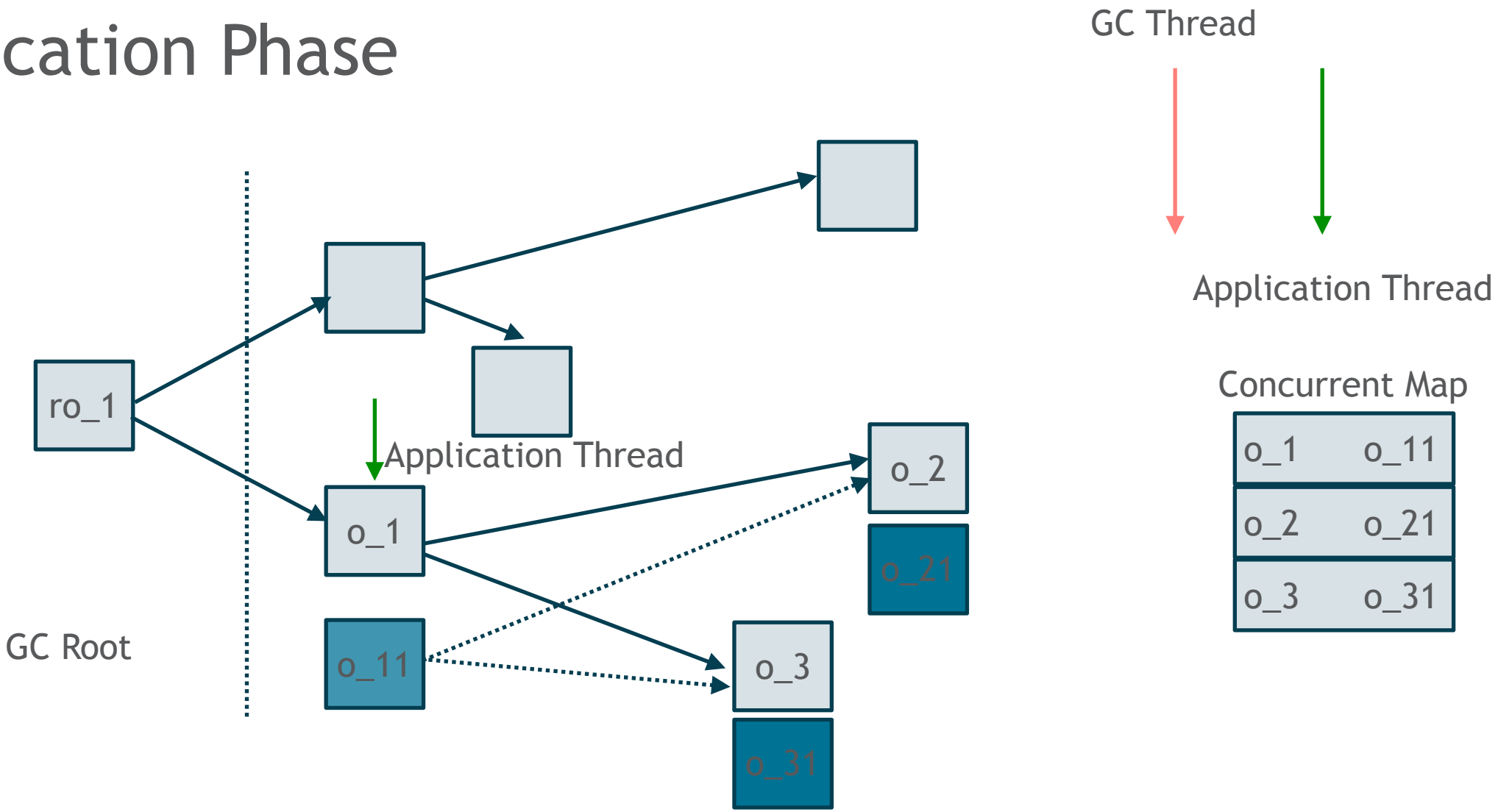


- Once GC root will be analyzed, GC will begin the next phase concurrently and mark all the objects.
- Load barrier will be tested for masking.

Relocation Phase

- Z GC divides the heap into ZPages.
- At the start, concurrently select the set of pages whose live object need to be relocated.
- A small STW to remap the root to the new reference.
- These STW don’t scale with overall heap size, because roots are little.
- Next phase is concurrent relocation and in this phase it walks to relocation set and relocate all the object in the pages it contains.
- Application thread can also relocate object [Use Load Barrier]

Relocation Phase



* http://hg.openjdk.java.net/zgc/zgc/file/59c07aef65ac/src/hotspot/share/gc/z/zRelocate.cpp#l121

Links and QA

- Z GC Main Page: https://wiki.openjdk.java.net/display/zgc/Main
- First look at Z GC : https://dinfuehr.github.io/blog/a-first-look-into-zgc/
- New Z GC is exciting : https://www.opsian.com/blog/javas-new-zgc-is-very-exciting/
- Some videos :
  - Concurrent Z GC : https://www.youtube.com/watch?v=WU_mqNBEacw&t=1776s
- Benchmarking reports : https://ionutbalosin.com/2019/12/jvm-garbage-collectors-benchmarks-report-19-12/