Jfokus 2020
HotSpot Handshaking

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JPG – HotSpot Runtime
February 3, 2020
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Intro

Handshakes - Latency and throughtput?

- Low latency GC's
- Runtime
- Handshake
- Effective
- Limited

HotSpot Handshaking

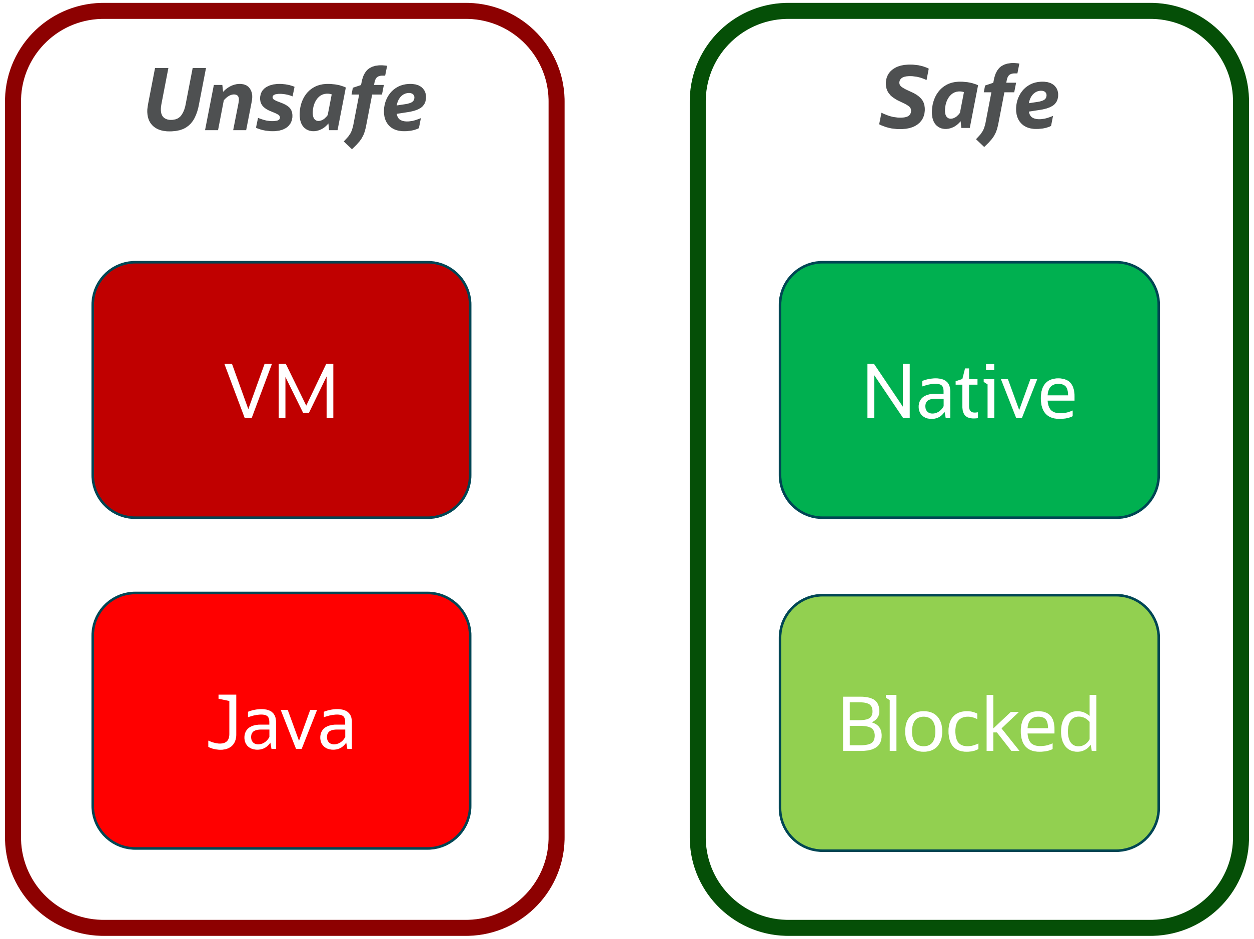
- Safepoints
- Handshakes
- Implementation
- Use cases
- Future use cases
- Additional functionality
- Real data

Safepoints

What is safe?

- Mutate virtual machine.
- Java thread (mutator) state.
- Common states:
  - Blocked
  - Native
  - Java
  - VM

Safepoints



Unsafe

VM

Java

Safe

Native

Blocked

Safepoints

States

- VM.
  - Transitions
- Java
  - Poll
  - Transitions
  - Elide into native.

- Native
  - Continue to execute
- Blocked
  - Stuck

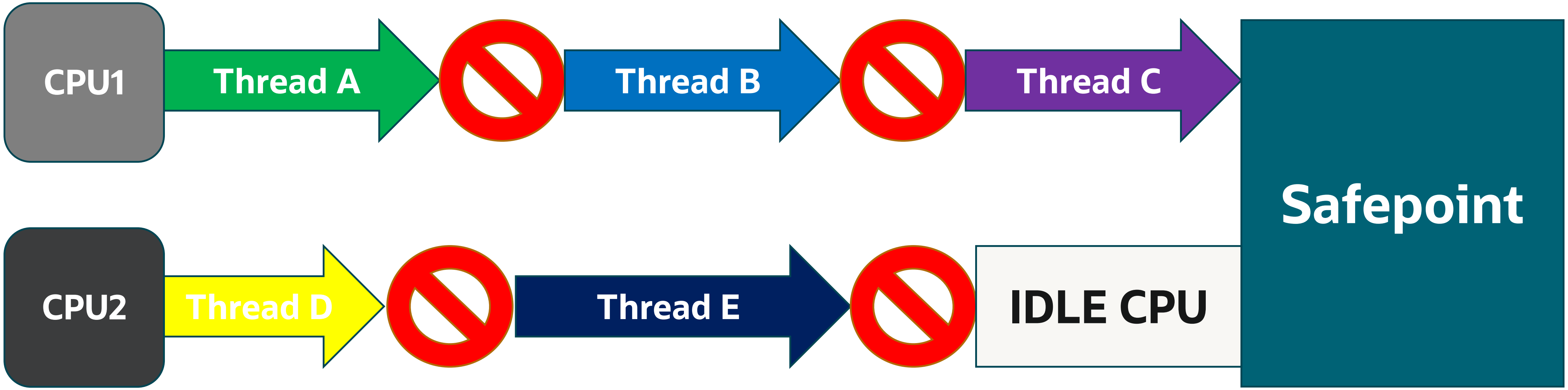
Safepoints

Basic execution

- VM Operation
- VM Queue.
- VM Thread, dispatch thread:
  - Stops
  - Accounts
  - Executes
  - Re-starts

Safepoints

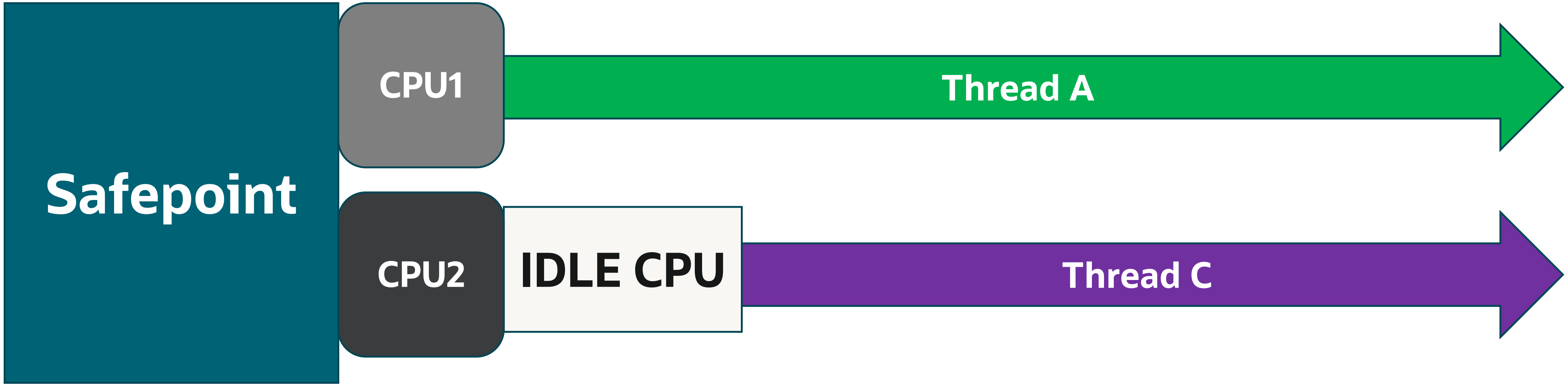
Synchronizing



🚫 = Poll

Safepoints

Restarting



Safepoints

Pros

- Simple model
- Global switch, constant time arming
- Single state
- Really safe
- Relative fast
  - ~200 us to reach a safepoint
  - ~200 us to reach full CPU utilization after safepoint

Safepoints

Cons

- Application intrusive
- Inter-thread dependency
- Unutilized CPU
- Operation without inter-thread dependency

Safepoints

Polling

```
// Generated poll in JIT
test rax, fixed-poll-adr

// Non trapping for non JIT code
bool SafepointMechanism::global_poll() {
       return (SafepointSynchronize::_state !=
               SafepointSynchronize::_not_synchronized);
}

// Arming
_state = _synchronizing;
mprotect(fixed-poll-adr, PAGE, MEM_PROT_NONE);

// Disarming
mprotect(fixed-poll-adr, PAGE, MEM_PROT_READ);
_state = _not_synchronized;
```

Handshakes

- Per thread safepoint
- Latency friendly
- Thread owned/local resources
  - Stack
  - Biased lock
  - Asynchronous exception
- Barrier
  - Un-publish
  - Handshake
  - Not visible

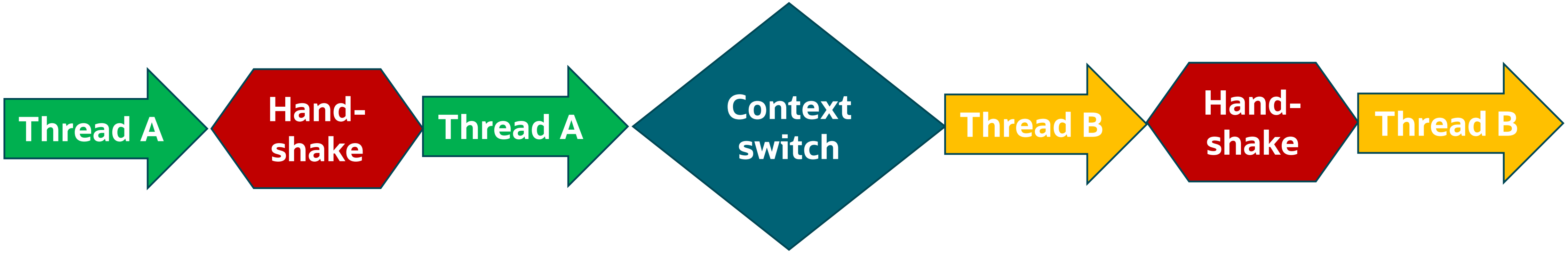
Handshakes

- VM Thread and queue
- VM Operation, non-safepoint
- Operation execution
  - Per thread installation of operation
    - Assign operation
    - Arms
  - Self (Java thread) processing
  - VM Thread processing

Handshakes

- Self processing
  - JIT poll
  - Transition
  - In slow path
    - Safepoint
    - Process handshake
- VM Thread processing
  - Safe Java threads
  - Stopped from entering unsafe state

Handshakes



- One CPU
- Serialized
- Time-slice

Handshakes

Pros

- ‘Unnoticeable’
- Individual threads
- Effectively barrier
  - Fence
- No dependencies
- CPU utilization

Handshakes

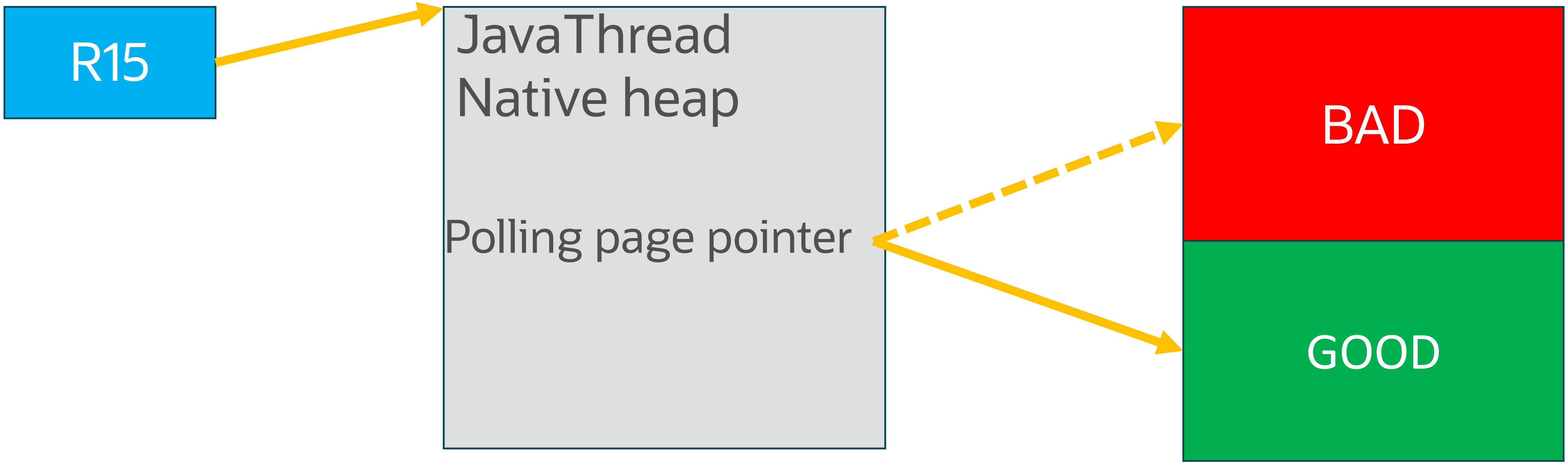
Cons

- Arming
- Complex states
- Limited use-cases
- Slow
  - ~20ms

Implementation

- Unique poll thread
- JavaThread* register
- Per thread polling page pointer
- Bad (unreadable) and good (readable)
- JIT, indirect load
- Non-JIT, branch-based

Implementation



R15

JavaThread Native heap

Polling page pointer

BAD

GOOD

Implementation

```
// Generated poll in JIT
mov  poll-offset + thread_reg, reg
test rax, reg

// Non trapping for non JIT code
bool SafepointMechanism::local_poll_armed(JavaThread* thread) {
  return thread->get_polling_word() & poll_bit();
}

// Arming one thread
thread->set_polling_page(poll_armed_value())

// Disarming one thread
thread->set_polling_page(poll_disarmed_value())

// Arming/disarming many threads
for (JavaThreadIteratorWithHandle jtiwh; JavaThread *cur = jtiwh.next(); ) {
  SafepointMechanism::arm_local_poll/disarm_local_poll(cur);
}
```

Use cases

- ZRendezvousClosure
- ShenandoahUnloadRendezvousClosure
- ZMarkFlushAndFreeStacksClosure
- InstallAsyncExceptionClosure
- RevokeOneBias
- DeoptimizeMarkedClosure
- NMethodMarkingClosure

Use cases

ZRendezvousClosure
ShenandoahUnloadRendezvousClosure

- Barrier handshake, no-op
- Stale metadata and nmethods synchronization
  - No polls while using metadata/nmethods
  1. Unpublish
  2. Handshake
  3. Free
- ZRendezvousClosure
  - Dead weak refs resurrection synchronization

Use cases

ZMarkFlushAndFreeStacksClosure

- Access thread local resource
- Flush per thread mark stacks
  - Available for concurrent GC work
- Free per thread stacks

Use cases

InstallAsyncExceptionClosure

- Access to thread local resource
- Asynchronous exception
- Thread.stop()
- ThreadDeath exception

Use cases

RevokeOneBias

- Thread owned resource
- Locked object
- Object points to a thread
- BasicLock -> Inflate -> Monitor
- Monitor handles contended locks

Use cases

DeoptimizeMarkedClosure

- Access to thread local resource
- Java stack
- nmethods marked for deoptimize
  - Classloading
  - Class redefinition
  - Invoke dynamic
- scan all stacks
- mark frames for deoptimize

Use cases

NMethodMarkingClosure

- Access to thread local resource
- Java stack
- Current nmethods on stack

Future use cases

- Suspend flag
- JVMTI
- Monitor deflation
- G1 StoreLoad barrier removal
- ZGC Concurrent stack scanning
- Safepoint via handshakes

Future use cases

Suspend flags

- Per thread
- Only checked in transition
- Overlapping functionality, but much less flexible
- Use-cases
  - Suspend/resume
  - Pending asynchronous exception (not same as installation)
  - Lazy critical native
  - JFR native sampling

Future use cases

JVMTI

- Lacking inter-thread dependencies
- Safepoint
- Suspend/resume
- Un-intrusive stack traces

Future use cases

Monitor deflation

- Contended object
- Monitor
- Address installed in markword
- Deflate
  - Remove monitor address from markword
- ABA, Monitor address resuse/free

Future use cases

G1 StoreLoad barrier removal

- StoreLoad in G1 post-write barrier
- Dirty cards
- Concurrent refinement, cleaning card(s)
- Handshaking a thread implies StoreLoad fence

Future use cases

ZGC Stack watermark barrier

- Concurrent stack scanning
- Require branch-based polling

Future use cases

Safepoints via handshakes

- Simplifies slow path
- Simplifies VM thread operation execution
- Preserve ordering

Additional functionality

- Direct handshakes, thread to thread
- Asynchronous handshakes
- Branch based polling

Additional functionality

Direct handshakes

- No VM thread hand-over
- Single handshake, no latency improvement
- Multiple handshake
  - Greatly parallelized
    - Throughput
    - Latency
  - A->B while C->D

Additional functionality

Asynchronous handshake

- Only target thread executed
- Per thread queue
  - Safepoint via handshake preserve ordering
- Suspend flag

Additional functionality

Branch based polling

- Selective polling
- Stack watermark barrier
  - Concurrent stack-scanning
- Asynchronous exception

Real data

A ZGC safepoint

```
|CPU0|CPU1|CPU2|CPU3|    Time
| J5 | ZD | J3 | J2 |    0 us
| J5 |*VT | J3 | J2 |   55 us
| J5 |*J1 | J3 | J2 |   86 us
| J5 |*.  | J3 | J2 |  110 us
| J5 | .  |*.  | J2 |  110 us
|*.  | .  | .  | J2 |  118 us
| .  | .  | .  |*.  |  129 us
| .  |*VT | .  | .  |  151 us
 SAFEPOINT, runtime/gc workers
| .  |  . |*VT | .  |  722 us
| .  |*J1 | VT | .  |  747 us
| .  |*J4 | VT | .  |  759 us
| .  |*J1 | VT | .  |  768 us
| .  | J1 | VT |*J2 |  802 us
| .  |*ZD | VT | J2 |  811 us
| .  | ZD |*J3 | J2 |  816 us
|*J5 | ZD | J3 | J2 |  827 us
```

JX = JavaThread X (green)
ZD = ZDriver (blue)
VT = VM Thread (red)

1. ZDriver initiates safepoint in CPU lane 1
2. VM Thread begins safepoint
3. VM Thread goes off-proc (for quicker stoppage)
4. Safepoint operation execution
5. VM Thread ends safepoint (starts the JavaThreads)
6. Notify ZDriver that the requested safepoint is completed

Real data

A ZGC handshake

```
|CPU0|CPU1|CPU2|CPU3|         Time
|*J2 | J4 | J1 | ZW |         0 us
|*VT | J4 | J1 | ZW |        11 us
| VT | J4 | J1 |*J3 |        14 us
|*J2 | J4 | J1 | J3 |     12970 us
|*VT | J4 | J1 | J3 |     25965 us
| VT | J4 | J1 |*ZW |     25995 us
|*J2 | J4 | J1 | ZW |     25998 us
```

JX = JavaThread X (green)
ZW = ZWorker (blue)
VT = VM Thread (red)

1. ZWorker initiates a handshake in CPU lane 3
2. VM Thread starts executing the handshake
3. Notify ZWorker, handshake is completed

Thank You

Runtime

Mutexes and TSM

- Type-Stable-Memory
- Mutexes

Runtime

Java Threads

- Linked list
- Mutex
- Array
- Hazard pointers

Runtime

Hash tables

- Fixed size
- Mutex
- Spinlock
- TSM
- Concurrent
- EBR/RCU
- Constant-time reads

Runtime

Fast safepoints

- Mutex backed
- Serialized
  - Stopping
  - Wake-up
- Futex
- Co-op semaphore