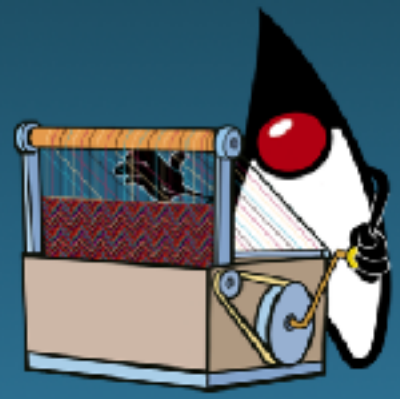
Project Loom

Fibers and Continuations



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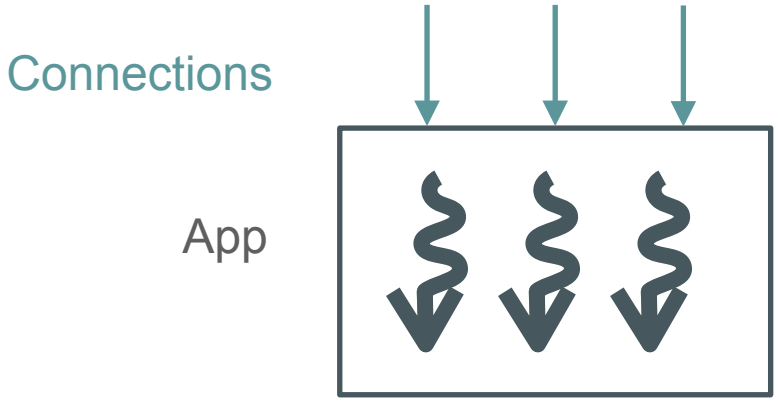
Project Loom

- Continuations
- Fibers
- Tail-calls

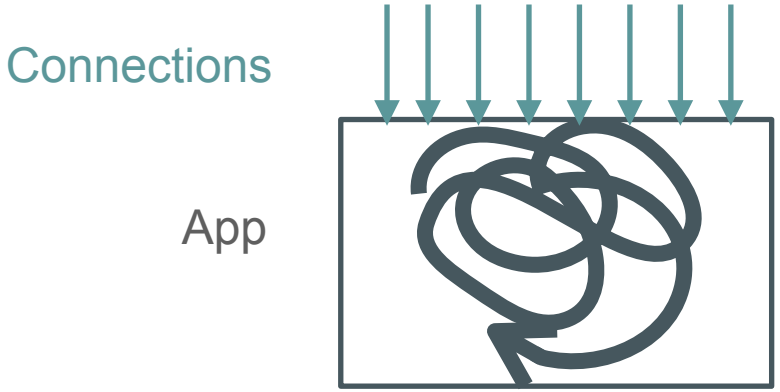
Why Fibers

Today, developers choose between



simple (blocking / synchronous),
but less scalable code (with threads)

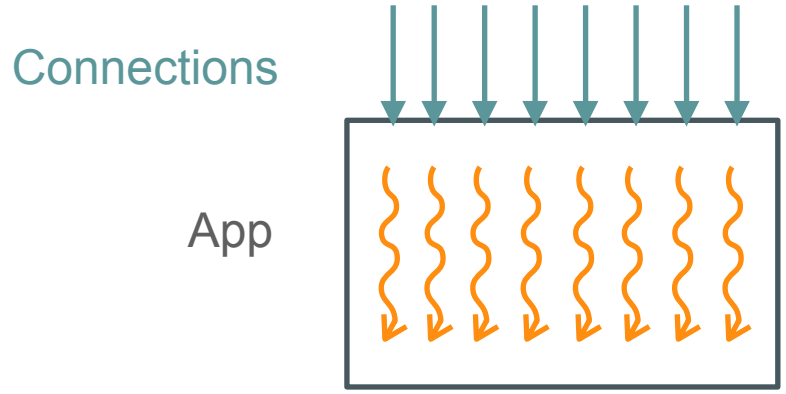
and



complex, non-legacy-interoperable,
but scalable code (asynchronous)

Why Fibers

With fibers, devs have *both*: simple, familiar, maintainable, interoperable code, that is also scalable



Fibers make even existing server applications consume fewer machines (by increasing utilization), significantly reducing costs

Continuations

A continuation (precisely: delimited continuation) is a program object representing a computation that may be suspended and resumed (also, possibly, cloned or even serialized).

Prototype Continuation API

```
package java.lang;

public class Continuation implements Runnable {

    public Continuation(ContinuationScope scope, Runnable target)

    public final void run()

    public static void yield(ContinuationScope scope)

    public boolean isDone()

    :

}
```

Fibers

A Fiber *light weight* or *user mode thread*, scheduled by the Java virtual machine, not the operating system

Fibers are low footprint and have negilgible task-switching overhead. You can have millions of them!

Why fibers?

- The runtime is well positioned to manage and schedule application threads, esp. if they interleave computation and I/O and interact very often (exactly how server threads behave)

- Make concurrency simple again

fiber = continuation + scheduler

fiber = continuation + scheduler

- A fiber wraps a task in a continuation
  - The continuation yields when the task needs to block
  - The continuation is continued when the task is ready to continue
- Scheduler executes tasks on a pool of *carrier* threads
  - java.util.concurrent.Executor in the current prototype
  - Default/built-in scheduler is a ForkJoinPool

Fiber prototype

- Focus to date has been on the control flow and concepts, not the API
- Minimal `java.lang.Fiber` in current prototype that supports scheduling, park/unpark, and waiting for a fiber to terminate
- java.util.concurrent APIs can park/unpark fibers
- Socket and pipe APIs park fiber rather than block threads in syscalls

How much existing code can fibers run?

- A big question, lots of trade-offs
  - Do we completely re-imagine threads?
  - Can we run all existing code in the context of a fiber?
- Likely to wrestle with these questions for a long time
- Current prototype can run existing code but with some limitations

Example using existing code/libraries

- Example uses Jetty and Jersey

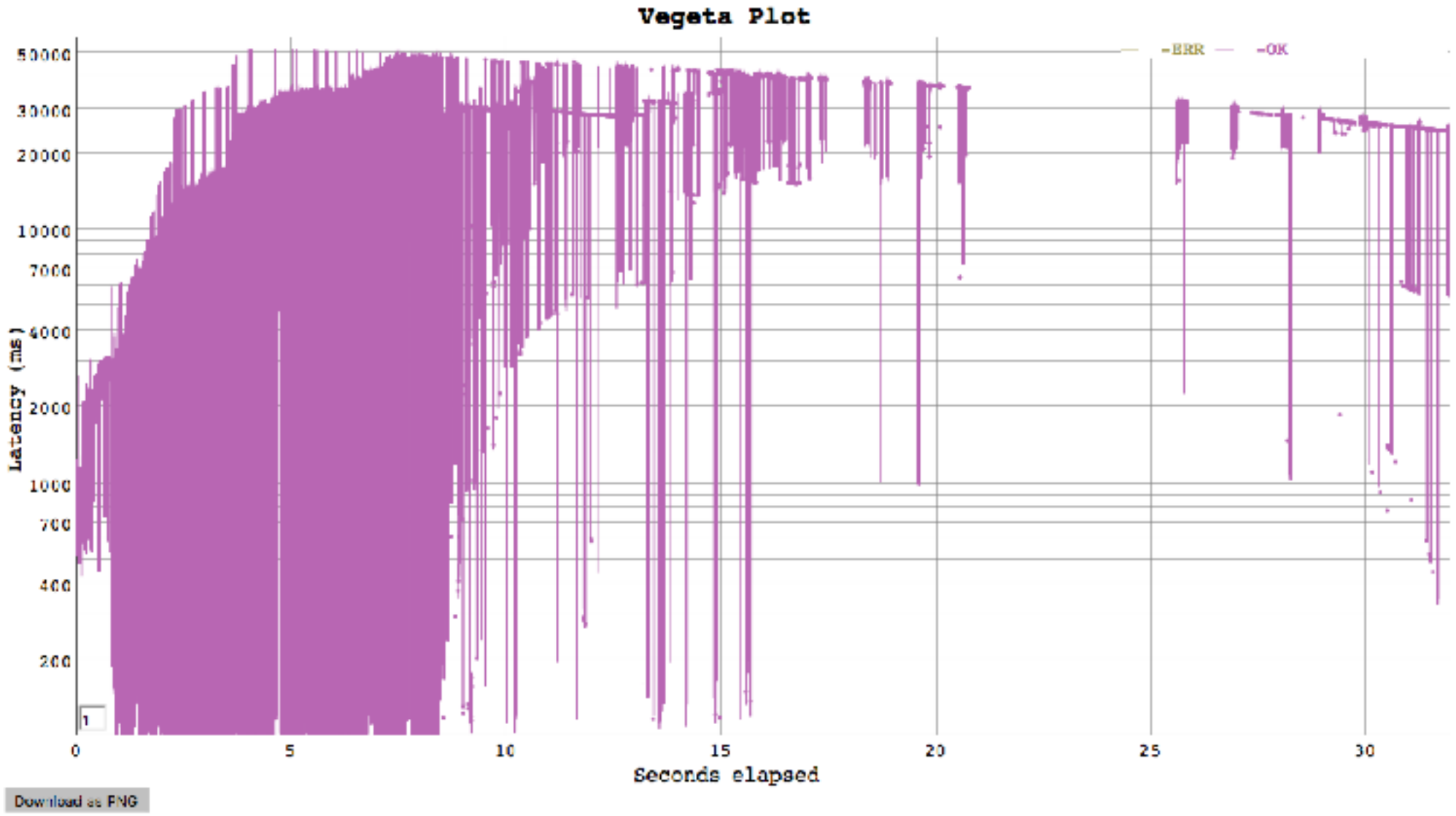
Example with existing code/libraries

- Assume servlet or REST service that spends a long time waiting

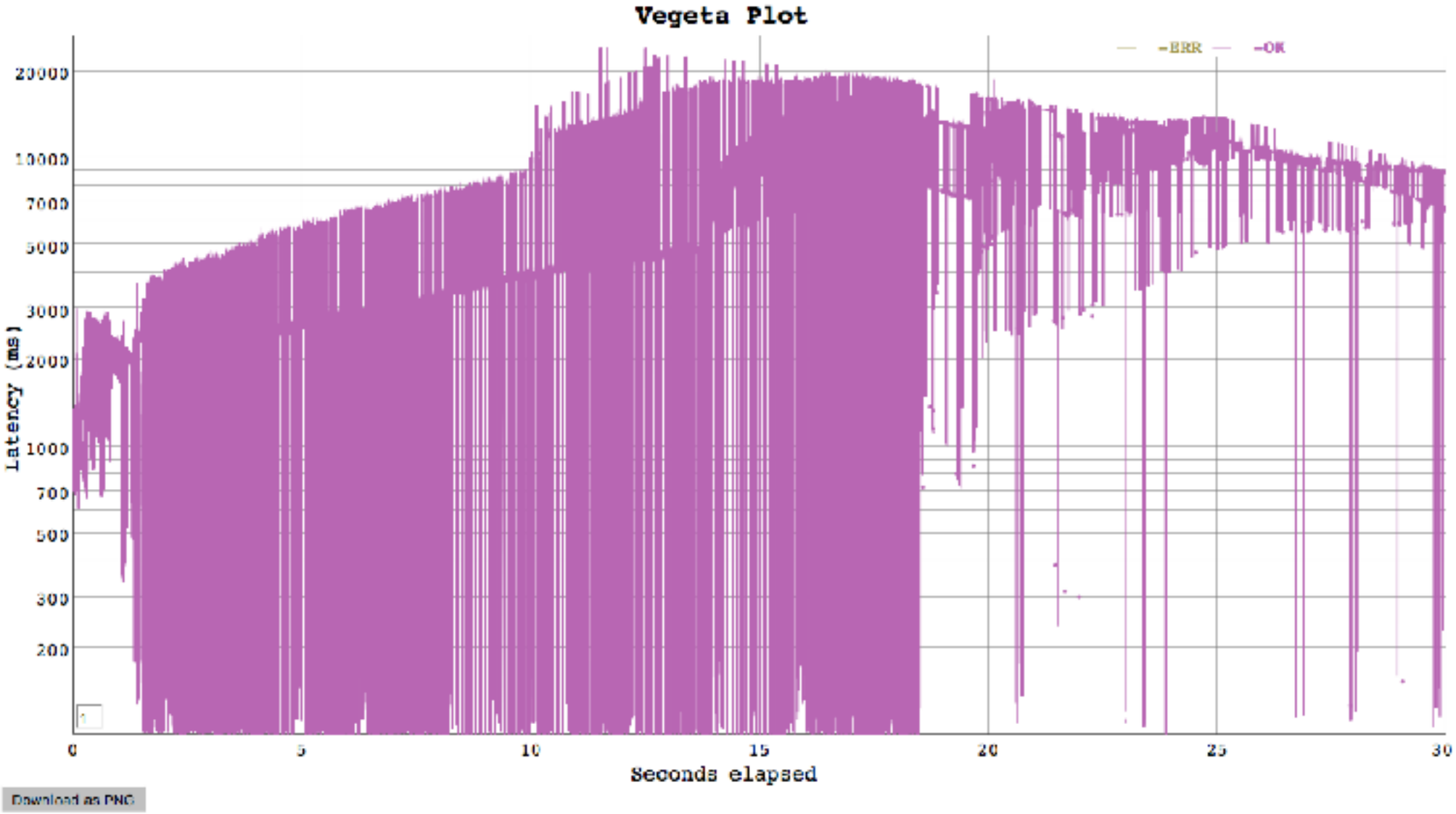
```
@GET
@Path("greeting")
@Produces(MediaType.APPLICATION_JSON)
public String greeting() {
    return "{ \"message\": \"" + computeValue() + "\" }";
}
```

assume this takes 100ms

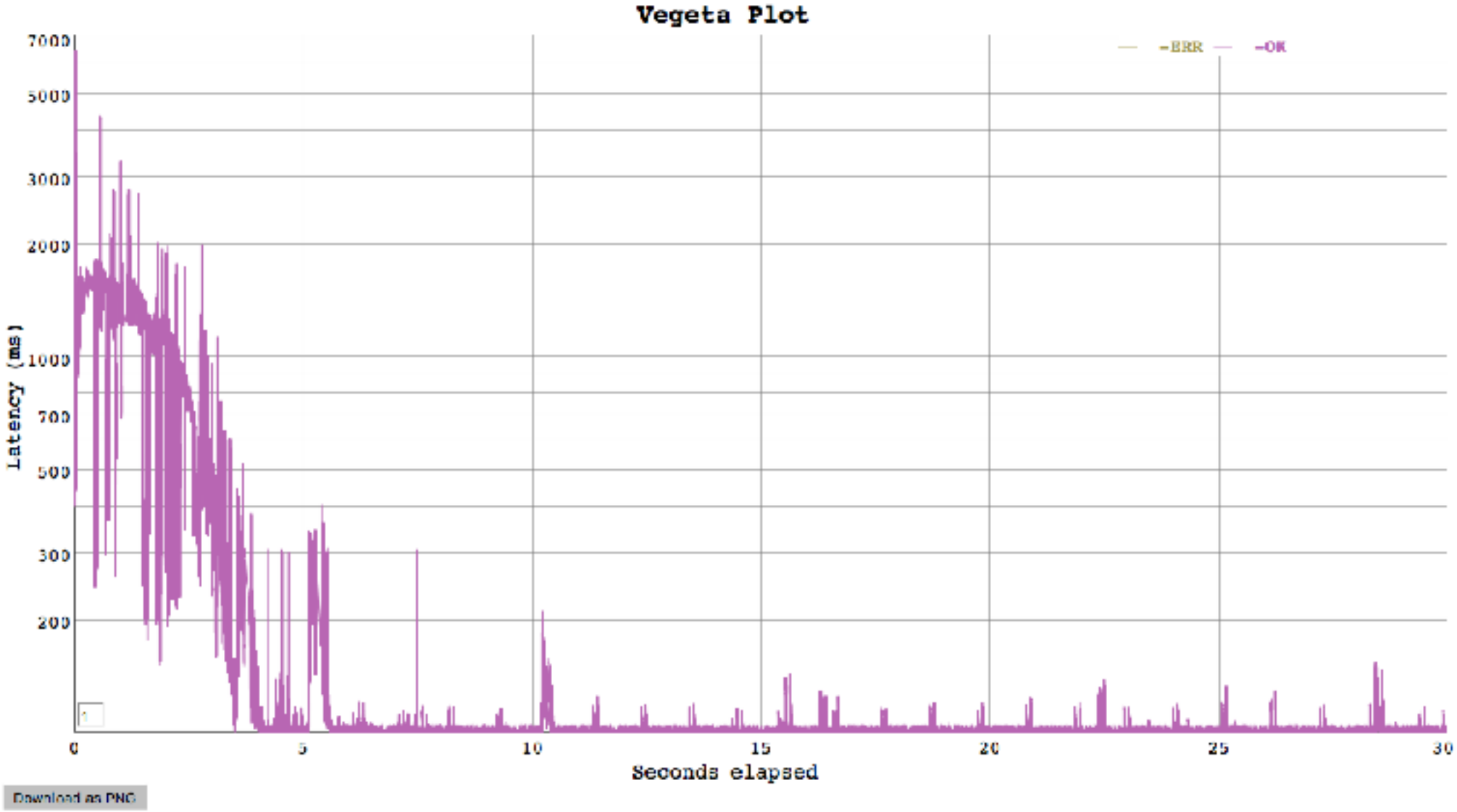
Default configuration (maxThreads = 200), load = 5000 HTTP request/s



maxThreads = 400, load = 5000 HTTP request/s



fiber per request, load = 5000 HTTP request/s



Current limitations

- Can’t yield with native frames on continuation stack
- Can’t yield while holding a monitor
- In both cases, parking pins the carrier thread
- monitorenter/Object.wait may park carrier thread

Back to the big questions

- Will fibers be able to run *all existing code*?
- Should we completely re-imagine threads?

Thread.currentThread() and Thread API

- A lot of existing code uses the Thread API and `Thread.currentThread()` (maybe indirectly)
- For now, current prototype can run in a *mode* that emulates `Thread.currentThread()` and most of the Thread API. That allows fibers to run existing code.
- Project Loom is the opportunity to re-imagine threads

What is wrong with java.lang.Thread

- ThreadGroup
- Context ClassLoader
- Inheritance: TCCL, ACC, InheritedThreadLocals
- suspend/resume, deprecated for 20+ years
- Thread interrupt problematic with threads pools
- Thread locals …

Thread locals

- e.g. container managed cache of connection or credentials context
- Long-standing source of memory leaks in thread pools
- Often used because because isn’t anything better
  - Sometimes used to make context available to callees
  - Sometimes used as approximation to “processor locals”

Locals (exploring)

- Frame/scope locals
  - Locals that are accessible to callees
    e.g. Clojure dynamic binding, special variables in Lisp
  - Semantics TDB
  - Maybe tied with S*tructured Concurrency*
- Processor locals
  - Locals keyed on cpu ID rather than Thread
  - Potential users are Striped64/LongAddr to avoid needing fields in Thread

Structured Concurrency (exploring)

- Core idea
  "*every time that control splits into multiple concurrent paths, we want to make sure that they join up again*".
- Background reading and motivations:
  - Nathaniel J Smith blogs:
    - Notes on structured concurrency, or: Go statement considered harmful
    - Timeouts and cancellation for humans
  - Also Martin Sustrik blogs on state machines and structured concurrency in high-level languages
- Implemented as *Nurseries* in Python Trio library

Structured Concurrency

- Early prototype, but not in loom/loom yet

```
Instant deadline = Instant.now().plusSeconds(1);
FiberScope.withDeadline(deadline).run(() -> {

    Fiber<?> fiber1 = …
    Fiber<?> fiber2 = …

});
```

fiber1 and fiber2 guaranteed to have terminated

Communication between fibers

- Current prototype executes tasks as Runnable or Callables
- j.u.concurrent *just works* so can share objects or share by communicating
- Not an explicit goal at this time to introduce Channels or other concurrency APIs but new APIs may emerge

Current status

- Initial prototype with Continuation and Fiber support
- Current focused on
    - Performance
    - Fiber API
    - Debugger support
- Several other topics under exploration

APIs that potentially park in current prototype

- Thread sleep, join
- java.util.concurrent and LockSupport.park
- Networking socket read/write/connect/accept
- Pipe read/write

Footprint

- Thread
  - Typically 1MB reserved for stack + 16KB of kernel data structures
  - ~2300 bytes per started Thread, includes VM meta data
- Fiber
  - Continuation stack: hundreds of bytes to KBs
  - 200-240 bytes per fiber in current prototype

Debugging and serviceability

- Basic support in JVM TI to track fiber scheduling, mount and unmount
- Hope to have some basic debugger support soon
- No investigation yet on JMX/java.lang.management and other tool APIs

Other topics to explore

- Tail calls
- Forced preemption
- Serialization and cloning

More information

- Project Loom page: http://openjdk.java.net/projects/loom/
- Mailing list: loom-dev@openjdk.java.net
- Repo: http://hg.openjdk.java/net/loom/loom (fibers branch)

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