Go: syscalls and the scheduler

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Why should you spend the next 15 minutes or so listening to me?

- Understand how high level languages function under the hood
- To become capable in understanding and debugging your program
- And if you're curious in general

What are syscalls?

```
SYSCALLS(2)              Linux Programmer's Manual            SYSCALLS(2)
NAME         top
       syscalls - Linux system calls
SYNOPSIS         top
       Linux system calls.
DESCRIPTION         top
       The system call is the fundamental interface between an
       application and the Linux kernel.
```

How do I see syscalls?

strace

```
STRACE(1)                  General Commands Manual                  STRACE(1)
NAME
       strace - trace system calls and signals
DESCRIPTION
       In the simplest case strace runs the specified command until it exits.
       It intercepts and records the system calls which are
       called by a process and the signals which are received by a process.
```

dtruss (A handy Mac replacement)

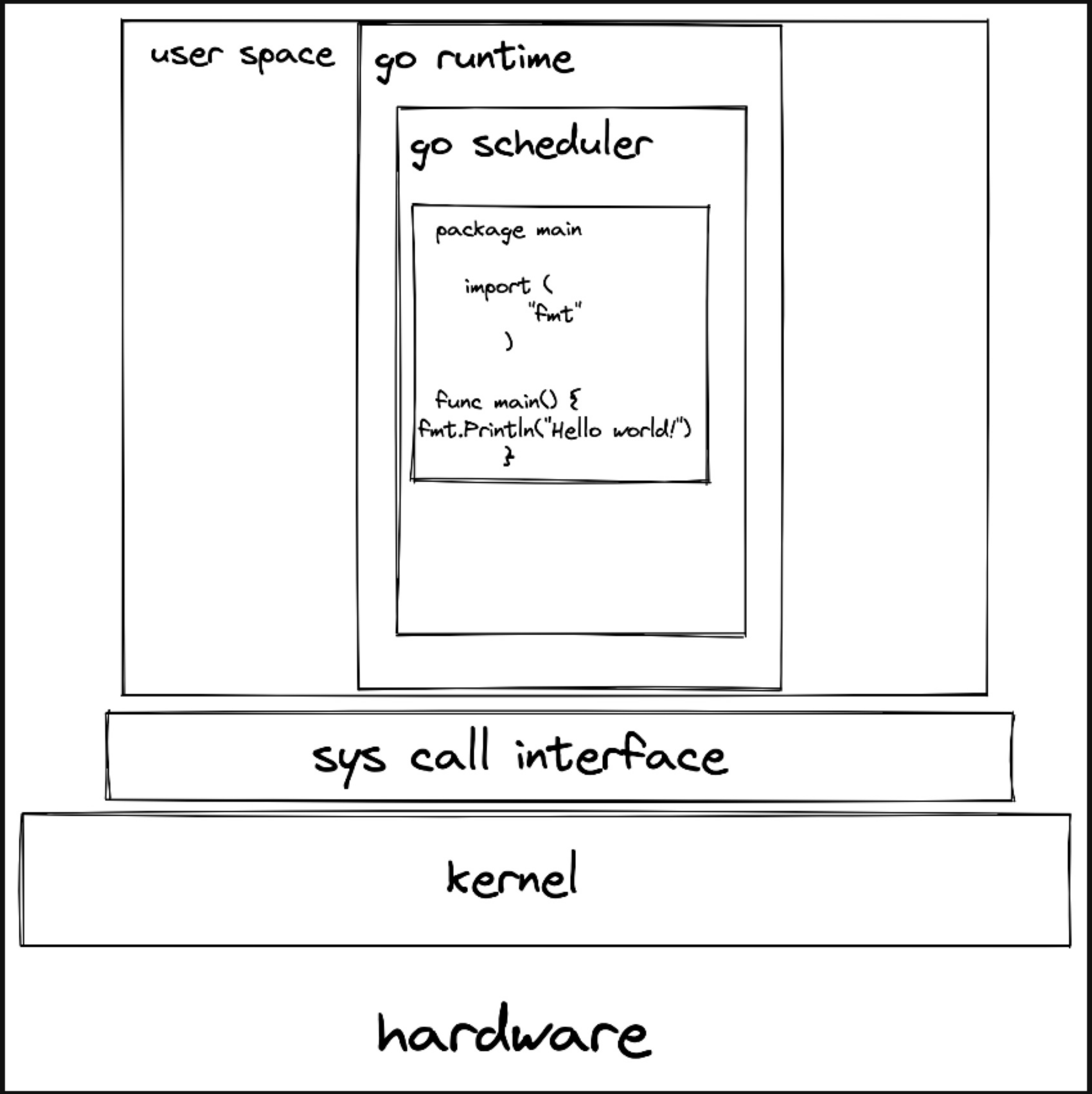
```
dtruss(1m)
NAME
       dtruss - process syscall details. Uses DTrace.
DESCRIPTION
       dtruss prints details on process system calls. It is like a DTrace
       version of truss, and has been designed to be less intrusive than truss.
```

Coming back to Go

```go
// A simple Hello world Go program
package main

import (
  "fmt"
)

func main() {
  fmt.Println("Hello world!")
}
```


user space
go runtime
go scheduler
package main
import (
"fmt"
)
func main() {
fmt.Println("Hello world!")
}
sys call interface
kernel
hardware

Tracing syscalls

```
# Output of sudo dtruss -f ./main

  PID/THRD  SYSCALL(args)       = return
Hello world!
16028/0x1d793:  fork()      = 0 0
16028/0x1d793:  access("/AppleInternal/XBS/.isChrooted\0
 ↳ ", 0x0, 0x0)     = -1 Err#2
16028/0x1d793:
 ↳   bsdthread_register(0x193D79084, 0x193D79078, 0x4000) =
 ↳ 1073742303 0
16028/0x1d793:
 ↳   bsdthread_create(0x1046644C0, 0x1400003C000, 0x16B883000) =
 ↳ 1804087296 0
16028/0x1d793:  __pthread_sigmask(0x3, 0x16B7FB6C8, 0x0) = 0 0
16028/0x1d796:  fork()      = 0 0
16028/0x1d793:
 ↳   bsdthread_create(0x1046644C0, 0x1400003C480, 0x16B90F000) =
 ↳ 1804660736 0
16028/0x1d797:  fork()      = 0 0
16028/0x1d793:  sigreturn(0x14000009C18, 0x1E, 0x97346E51C6D2C79B) =
 ↳ 0 Err#-2
16028/0x1d797:
 ↳   bsdthread_create(0x1046644C0, 0x14000080000, 0x16B99B000) =
 ↳ 1805234176 0
16028/0x1d797:  __pthread_sigmask(0x3, 0x16B90ECD8, 0x0) = 0 0
16028/0x1d793:  madvise(0x1400005C000, 0x8000, 0x8) = 0 0
16028/0x1d798:  fork()      = 0 0
16028/0x1d796:  __semwait_signal(0x903, 0x0, 0x1) = -1 Err#60
16028/0x1d793:  mlock(0x14000060000, 0x4000, 0x0) = 0 0
16028/0x1d798:  thread_selfid(0x0, 0x0, 0x0)  = 120728 0
16028/0x1d793:  __pthread_sigmask(0x3, 0x10472C1B0, 0x16B7FB588) = 0
 ↳  0
16028/0x1d798:  sigaltstack(0x0, 0x16B99AE70, 0x0) = 0 0
16028/0x1d797:  __semwait_signal(0x903, 0x0, 0x1) = -1 Err#60
16028/0x1d798:  sigaltstack(0x16B99AE30, 0x0, 0x0) = 0 0
16028/0x1d798:  __pthread_sigmask(0x3, 0x16B99AE84, 0x0) = 0 0
16028/0x1d793:
 ↳   bsdthread_create(0x1046644C0, 0x1400003C900, 0x16BA27000) =
 ↳ 1805807616 0
16028/0x1d798:  psynch_cvsignal(0x1400003C820, 0x100, 0x0) = 257 0
16028/0x1d799:  fork()      = 0 0
028/0x1d793:  write(0x1, "Hello world!\n\0", 0xD)    = 13 0
16028/0x1d796:  __semwait_signal(0x903, 0x0, 0x1) = -1 Err#60
16028/0x1d793:  kqueue(0x0, 0x0, 0x0)    = 3 0
```

Why more than one thread for just printing "Hello world!"

```
// Allow newproc to start new Ms.
mainStarted = true

if GOARCH != "wasm" { // no threads on wasm yet, so no sysmonsystemstack(func() {
newm(sysmon, nil, -1)
})
}

// Lock the main goroutine onto this, the main OS thread,
// during initialization. Iost programs won't care, but a few
// do require certain calls to be made by the main thread.
// Those can arrange for main.main to run in the main thread
// by calling runtime.LockOSThread during initialization
// to preserve the lock.
lockOSThread()
```

- sysmon starts a new thread to run the system monitor.
- Also, the main thread is blocked by the go runtime and hence the Go scheduler has to start a new thread.
- Other threads are needed for running the GC, timing etc.
- Quoting Go runtime

> *The GOMAXPROCS variable limits the number of operating system threads that can execute user-level Go code simultaneously. There is no limit to the number of threads that can be blocked in system calls on behalf of Go code; those do not count against the GOMAXPROCS limit.*

```go
package main

import (
  "fmt"
  "runtime"
  "runtime/pprof"
)

func main() {
  var threadProfile = pprof.Lookup("
 ↳ threadcreate")
  fmt.Printf("Number of logical CPUs %d\n
 ↳ ", runtime.NumCPU())
  fmt.Printf("Number of OS threads %d\n
 ↳ ", threadProfile.Count())
  fmt.Printf("Number of goroutines %d\n
 ↳ ", runtime.NumGoroutine())
  fmt.Println("Hello world!")
}
```

```
Number of logical CPUs 8
Number of OS threads 5
Number of goroutines 1
Hello world!
```

Diving into the Go scheduler

The scheduler's job is to distribute ready-to-run goroutines over worker threads.

P	M	G
processor, resource that is required to execute Go code.	worker thread, or machine.	goroutine

LRQ	GRQ
Local Run Queue, each P has its own to manage coroutines	for goroutines that have not been assigned to a P yet

Scheduling paradigms

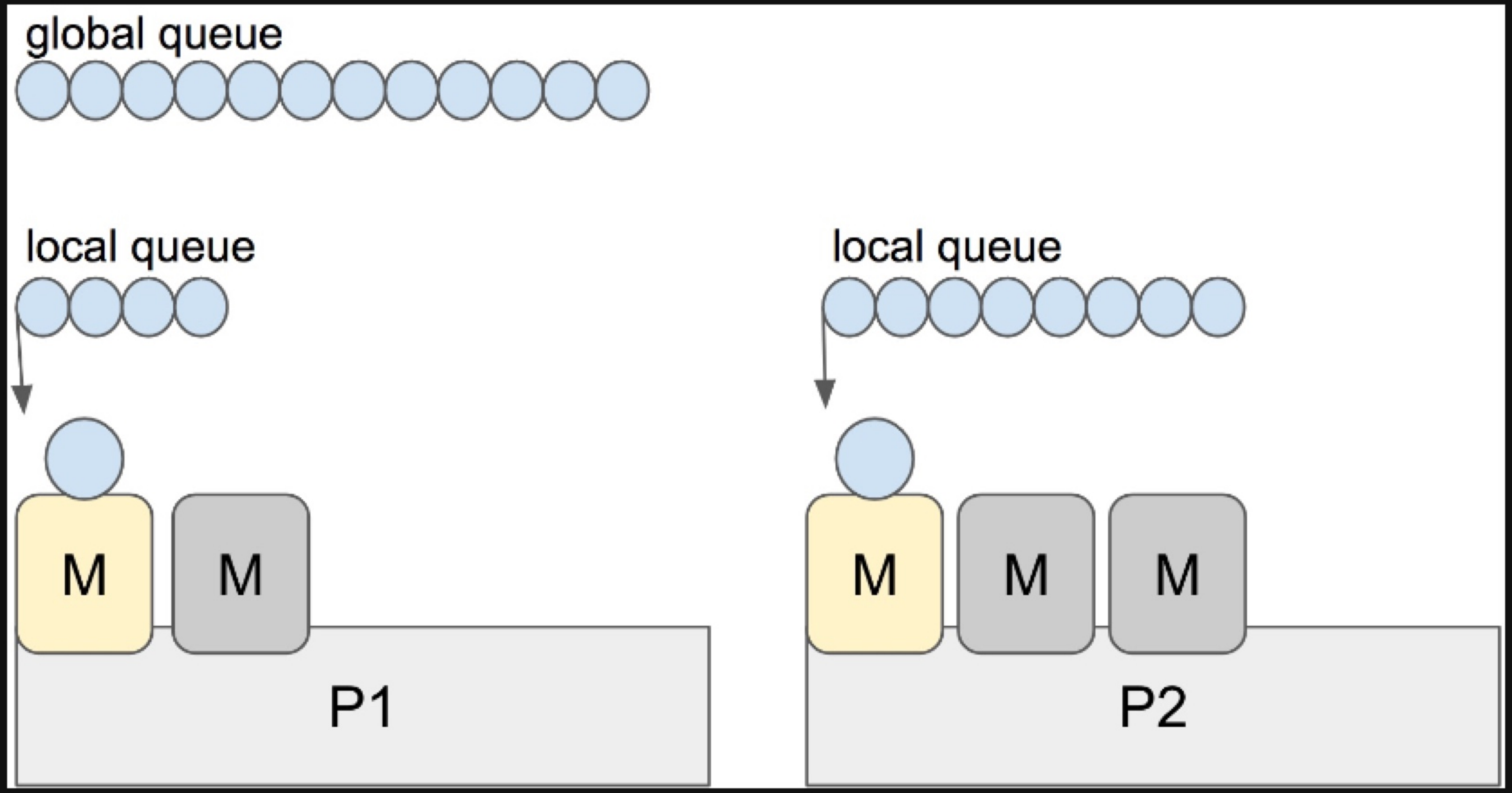
Work stealing

An underutilized processor actively looks for other processor's threads and "steal" some.

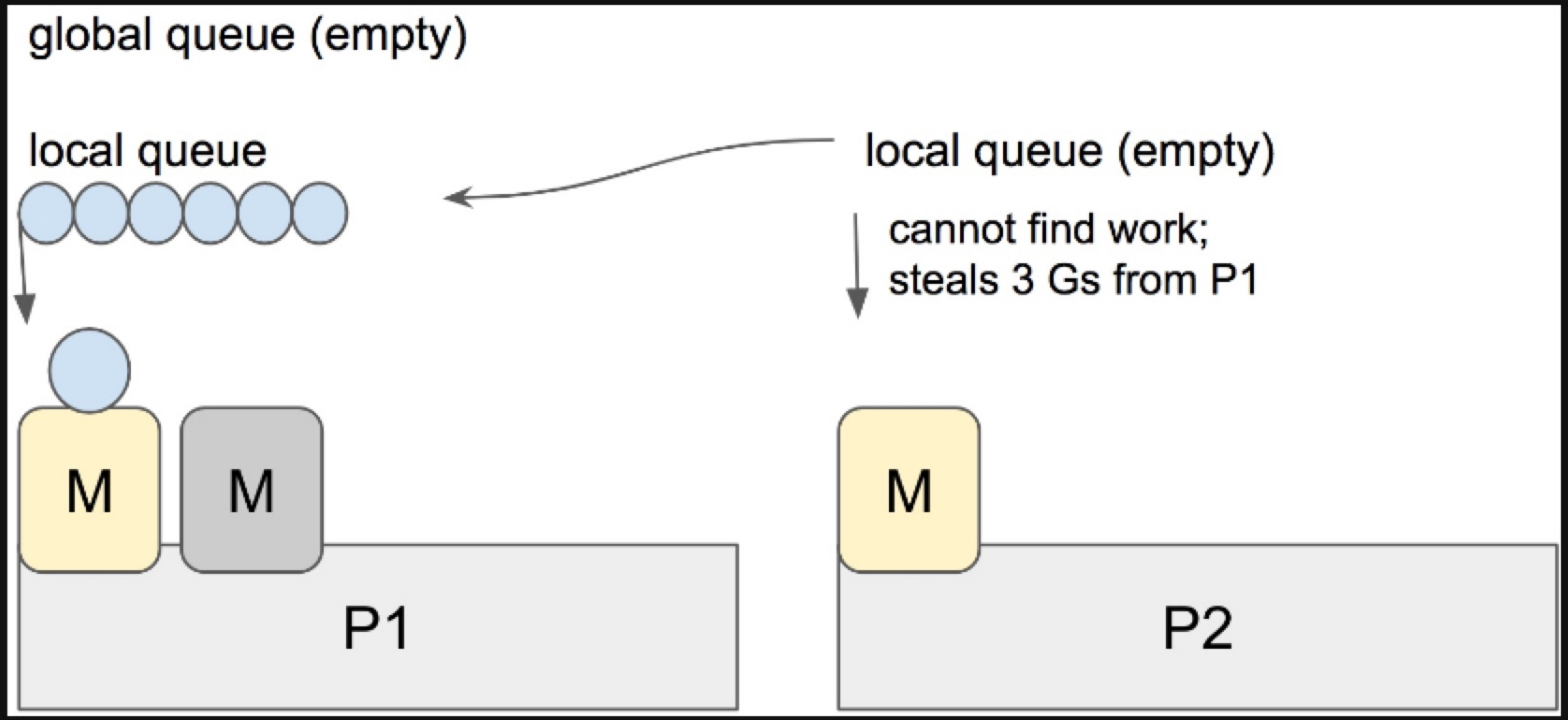
Work sharing

When a processor generates new threads, it attempts to migrate some of them to the other processors with the hopes of them being utilized by the idle/underutilized processors.

```go
↳ // One round of scheduler: find a runnable
// goroutine and execute it.
// Never returns.
func schedule() {
```



```go
// Steal half of elements from local
// runnable queue of p2 and put onto
// local runnable queue of p.
// Returns one of the stolen elements
// (or nil if failed).
func runqsteal(_p_, p2 *p, stealRunNextG
 ↳ bool) *g {
```



Does this really happen?

```
env GODEBUG=scheddetail=1,schedtrace=2 GOMAXPROCS=2 go run main.go
```

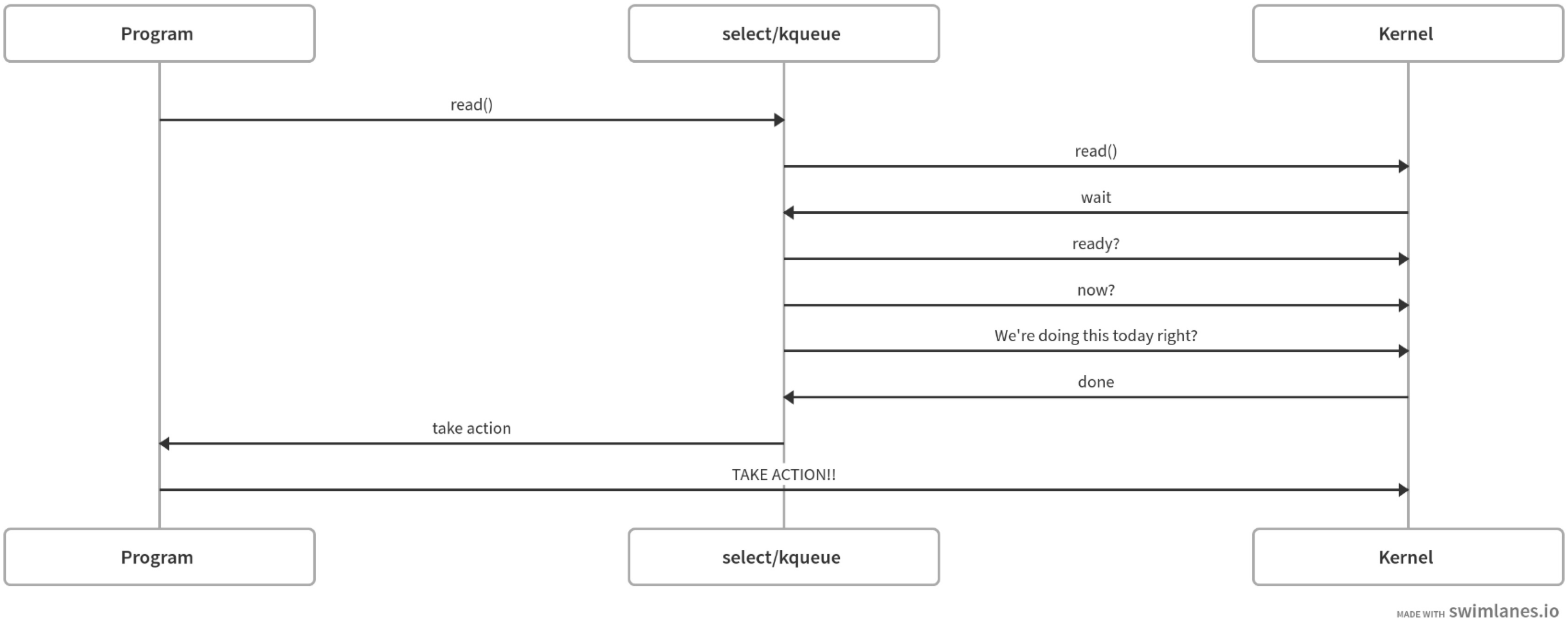
```
SCHED
 ↳ 0ms: gomaxprocs=2 idleprocs=0 threads=5 spinningthreads=0 idlethreads=0 runqueue=0 gcwaiting=0 nmidlelocke
  P0: status=1 schedtick=0 syscalltick=0 m=4 runqsize=0 gfreecnt=0 timerslen=0
  P1: status=1 schedtick=2 syscalltick=0 m=3 runqsize=0 gfreecnt=0 timerslen=0
  M4:
 ↳ p=0 curg=-1 mallocing=0 throwing=0 preemptoff= locks=1 dying=0 spinning=true blocked=false lockedg=-1
  M3:
 ↳ p=1 curg=-1 mallocing=0 throwing=0 preemptoff= locks=1 dying=0 spinning=false blocked=false lockedg=-1
  M2:
 ↳ p=-1 curg=-1 mallocing=0 throwing=0 preemptoff= locks=2 dying=0 spinning=false blocked=false lockedg=-1
M1:
 ↳ p=-1 curg=17 mallocing=0 throwing=0 preemptoff= locks=0 dying=0 spinning=false blocked=false lockedg=17
  M0:
 ↳ p=-1 curg=-1 mallocing=0 throwing=0 preemptoff= locks=1 dying=0 spinning=false blocked=false lockedg=1
  G1: status=1(chan receive) m=-1 lockedm=0
  G17: status=6() m=1 lockedm=1
  G2: status=4(force gc (idle)) m=-1 lockedm=-1
  G3: status=4(GC sweep wait) m=-1 lockedm=-1
```

What does the future of syscalls look like?

What happens right now?

- All UNIX IO syscalls are synchronous and blocking
- For example, a program calls `read()`, goes to sleep until the descriptor is ready
- `select()` and `kqueue` wake processes so that they can go and perform an action

Traditional async



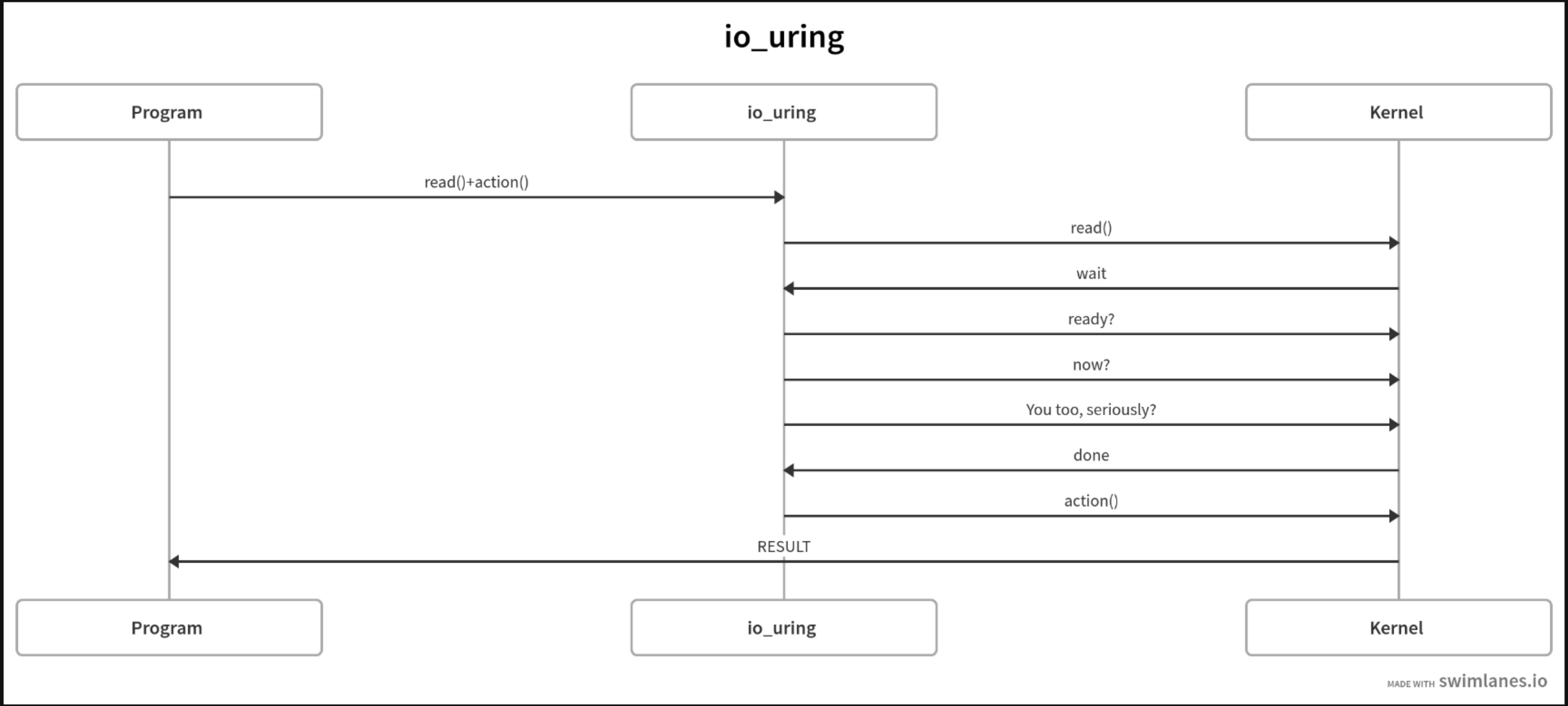
io_uring

- io_uring subsystem released in mainline kernel in 2019

- Solves for inherently synchronous Unix I/O

- Built around a ring buffer in memory shared between user space and kernel

- Allows submission of operations and collection of results asynchronously.


io_uring
Program
io_uring
Kernel
read()+action()
read()
wait
ready?
now?
You too, seriously?
done
action()
RESULT
Program
io_uring
Kernel
MADE WITH swimlanes.io

Questions?

Thank you!