Lessons learned from OS^{V}

Avi Kivity, Glauber Costa
Cloudius Systems

Agenda

Introduction to OS^V

Why C++ for systems programming?

Examples

QEMU and OS^{V} requirements

Glauber Costa

KVM, Containers, Xen

Nadav Har’EL,

Nested KVM

OS^{v}

Avi Kivity KVM originator

Pekka Enberg,

kvm, jvm, slab

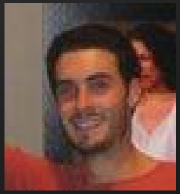
Dor Laor, Former kvm project mngr

Or Cohen

Dmitry Fleytman

Ronen Narkis

Guy Zana



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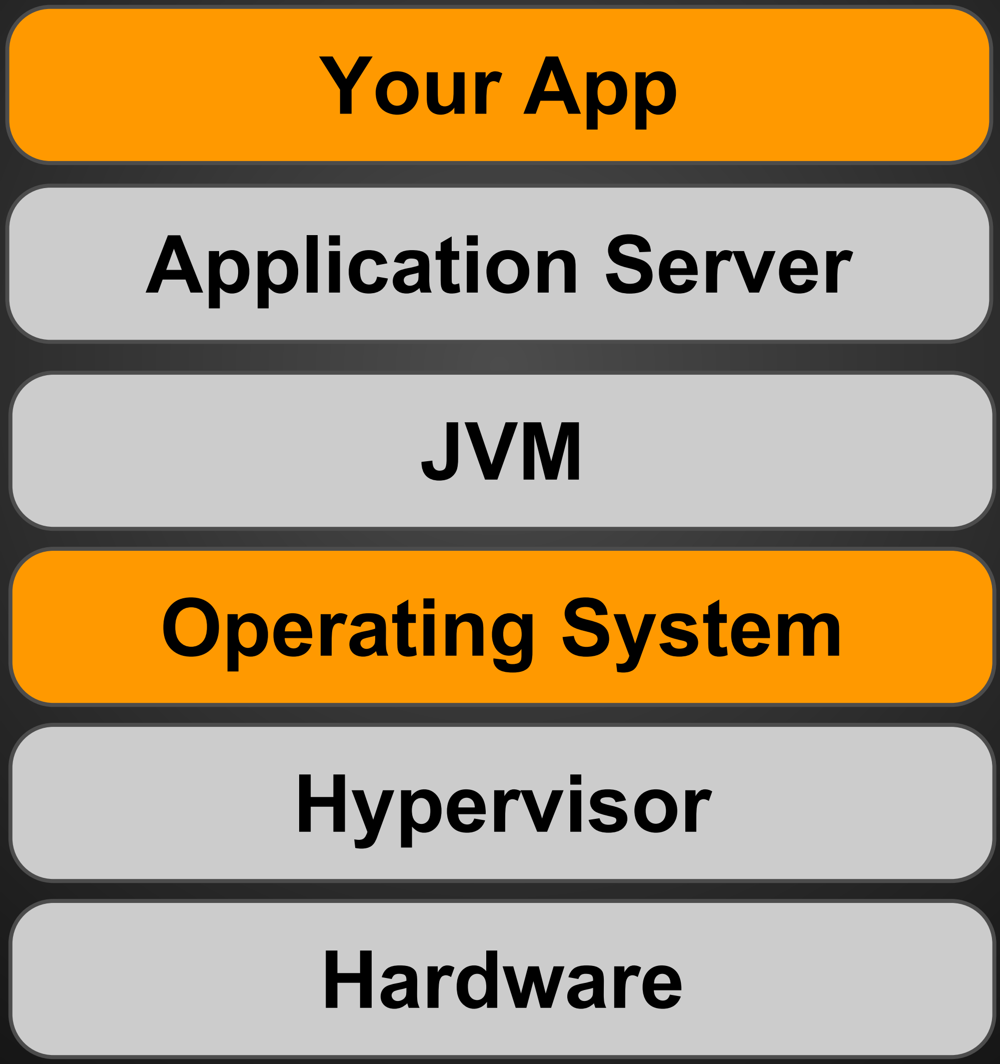
Typical Cloud Stack



Your App

Application Server

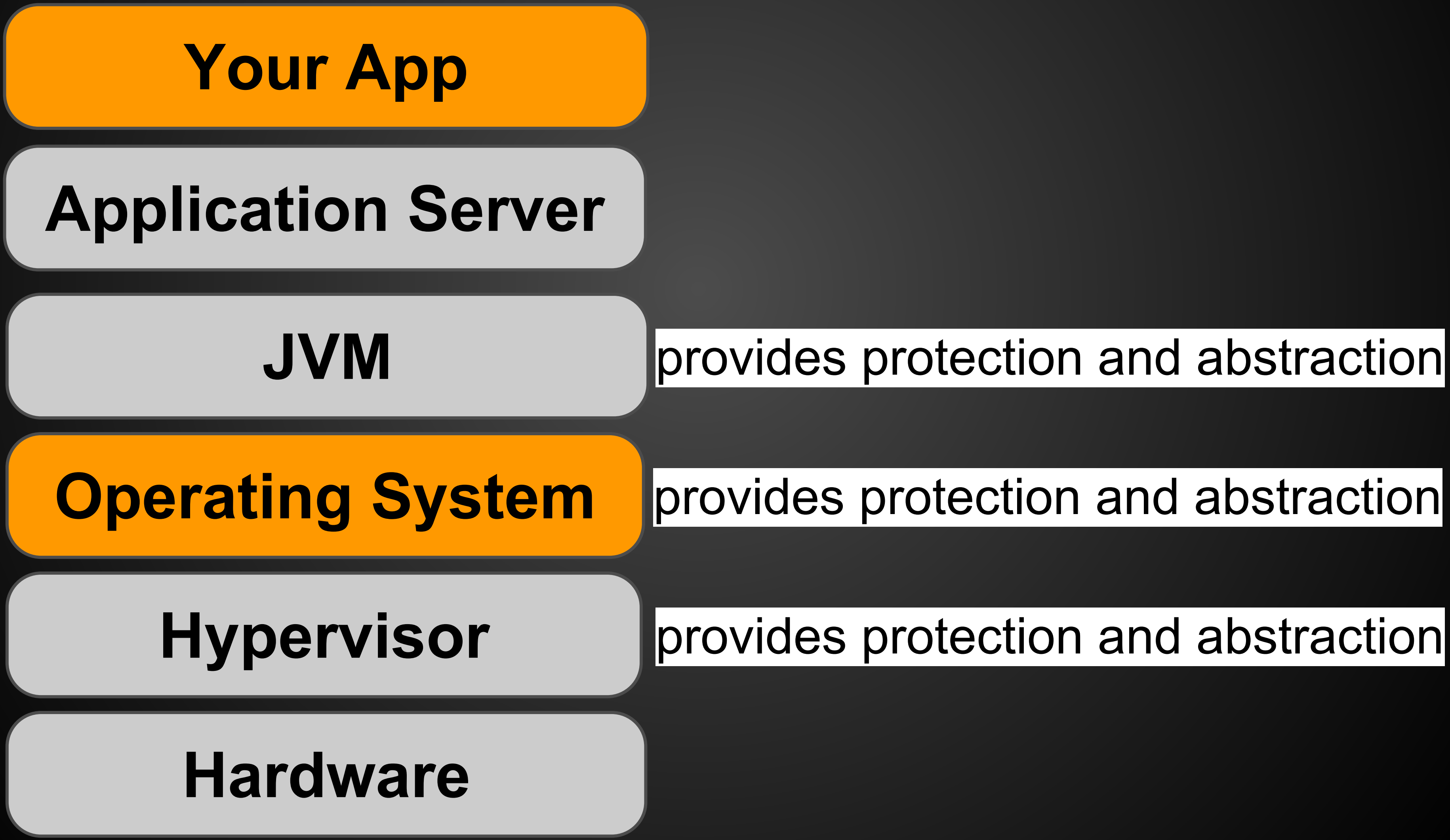
JVM

Operating System

Hypervisor

Hardware

A Historical Anomaly



Your App

Application Server

JVM — provides protection and abstraction

Operating System — provides protection and abstraction

Hypervisor — provides protection and abstraction

Hardware

Too Many Layers, Too Little Value

Property/Component	VMM	OS	runtime
Hardware abstraction	V	V	V
Isolation	V	V	V
Resource virtualization	V	V	V
Backward compatibility	V	V	V
Security	V	V	V
Memory management	V	V	V
I/O stack	V	V	
Configuration		V	

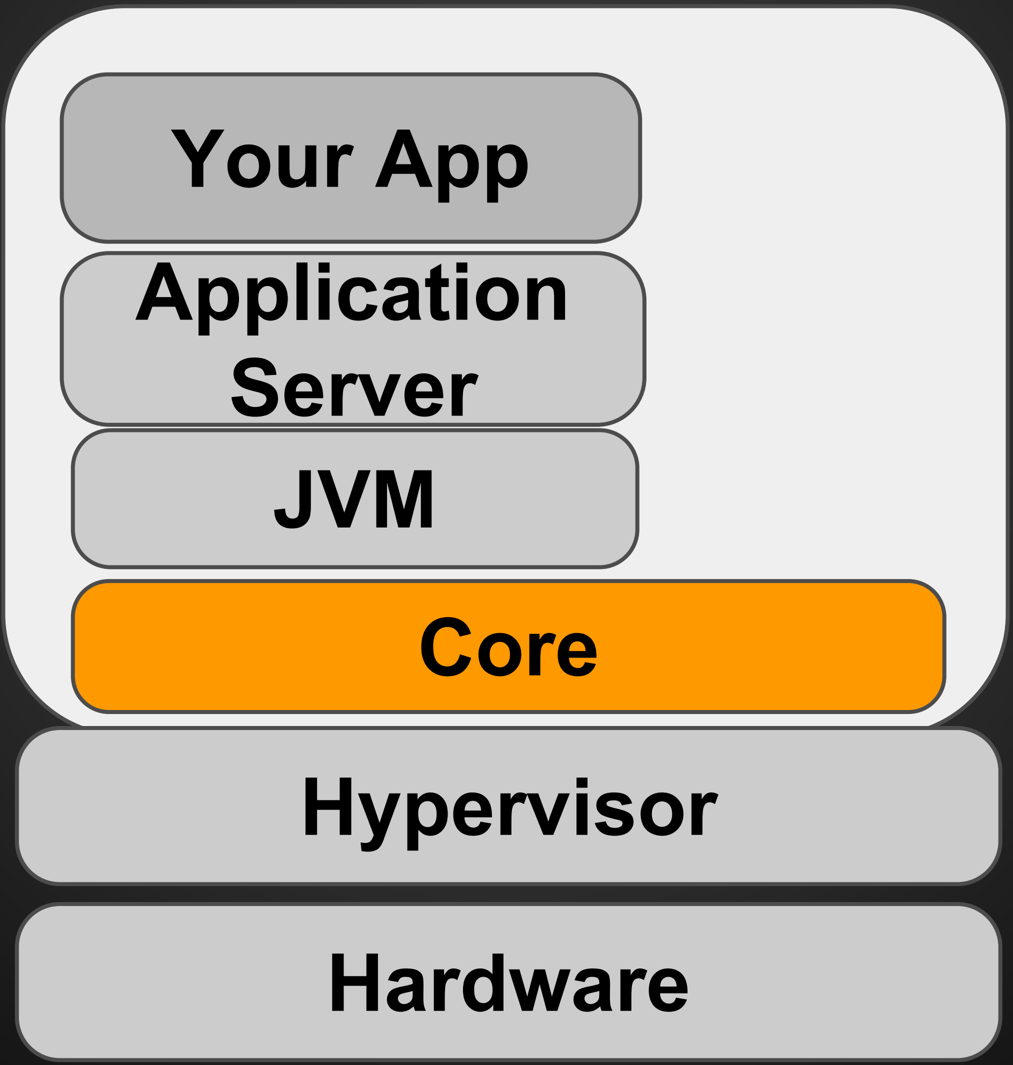
Duplication

less is more.

The new Cloud Stack - OS^v

Single Process

Kernel space only



Linked to existing JVMs

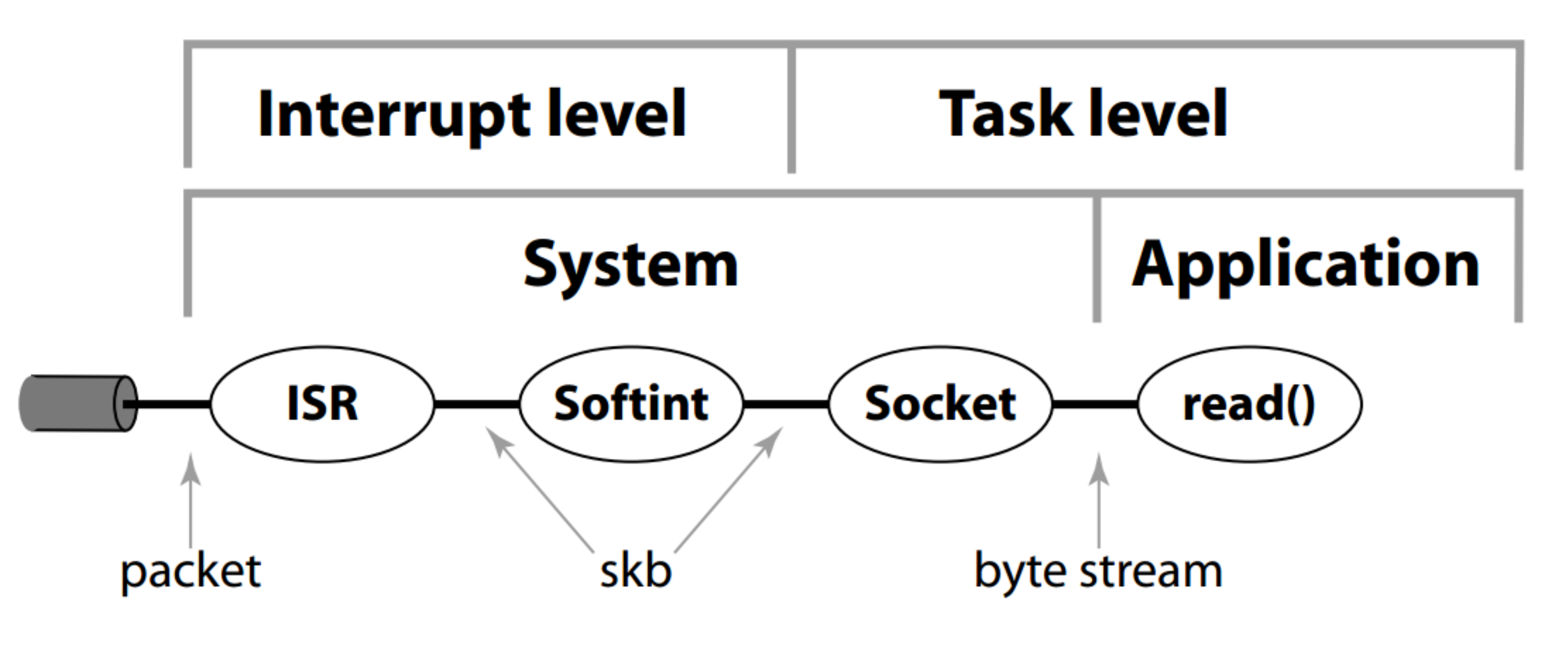
App sees no change

The new Cloud Stack - OS^v

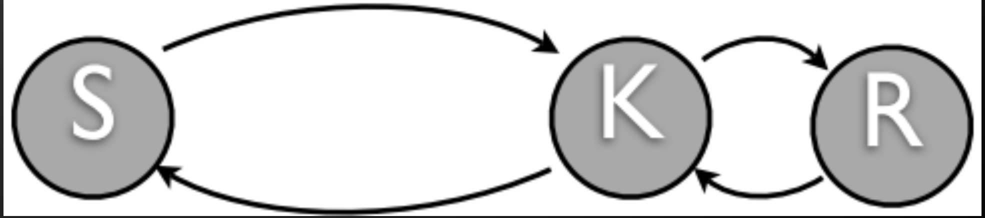
Memory	Huge pages, Heap vs Sys
I/O	Zero copy, full aio, batching
Scheduling	Lock free, low latency
Tuning	Out of the box, auto
CPU	Low cost ctx, Direct signals,..

Van Jacobson == TCP/IP

Common kernel network stack

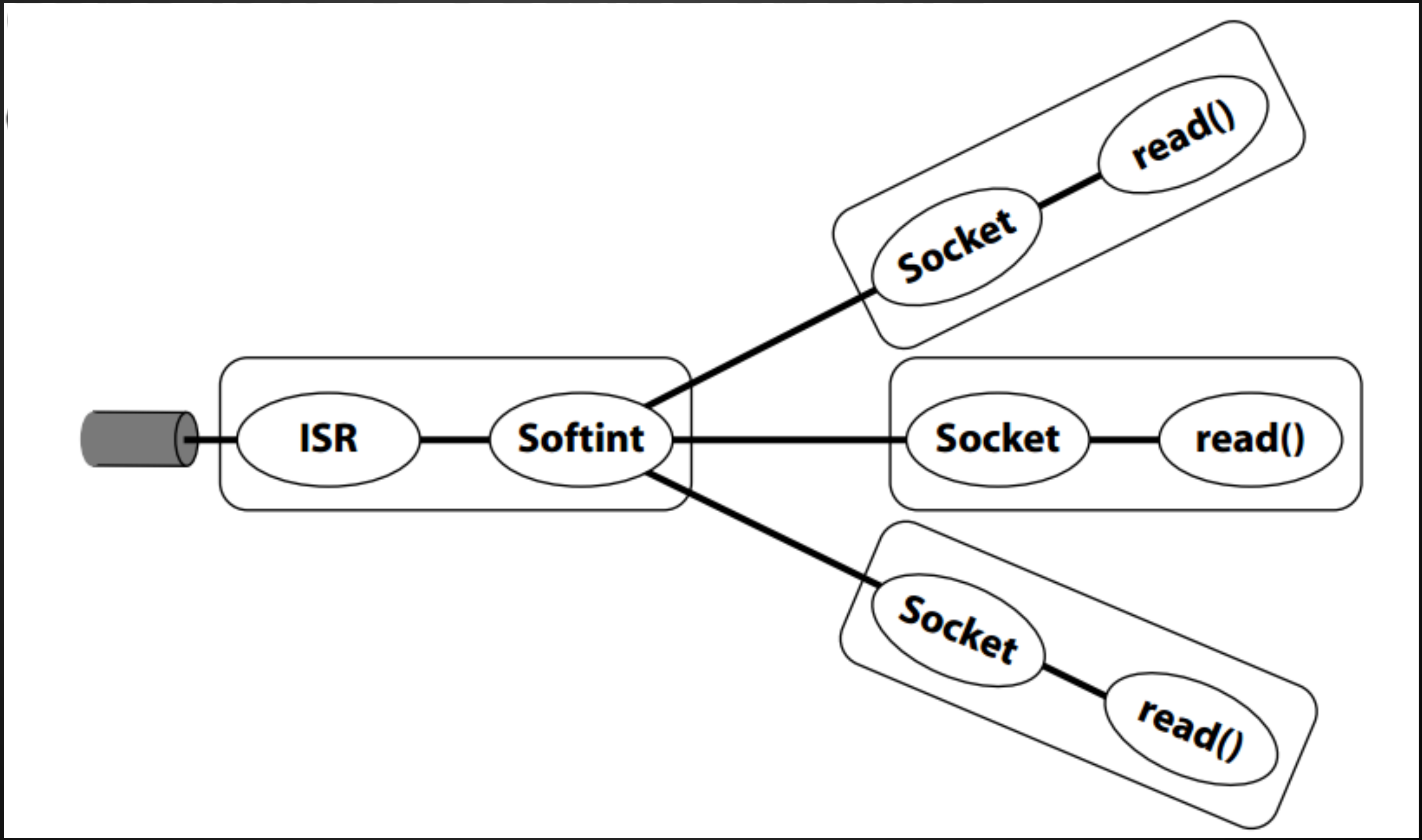


Leads to servo-loop:

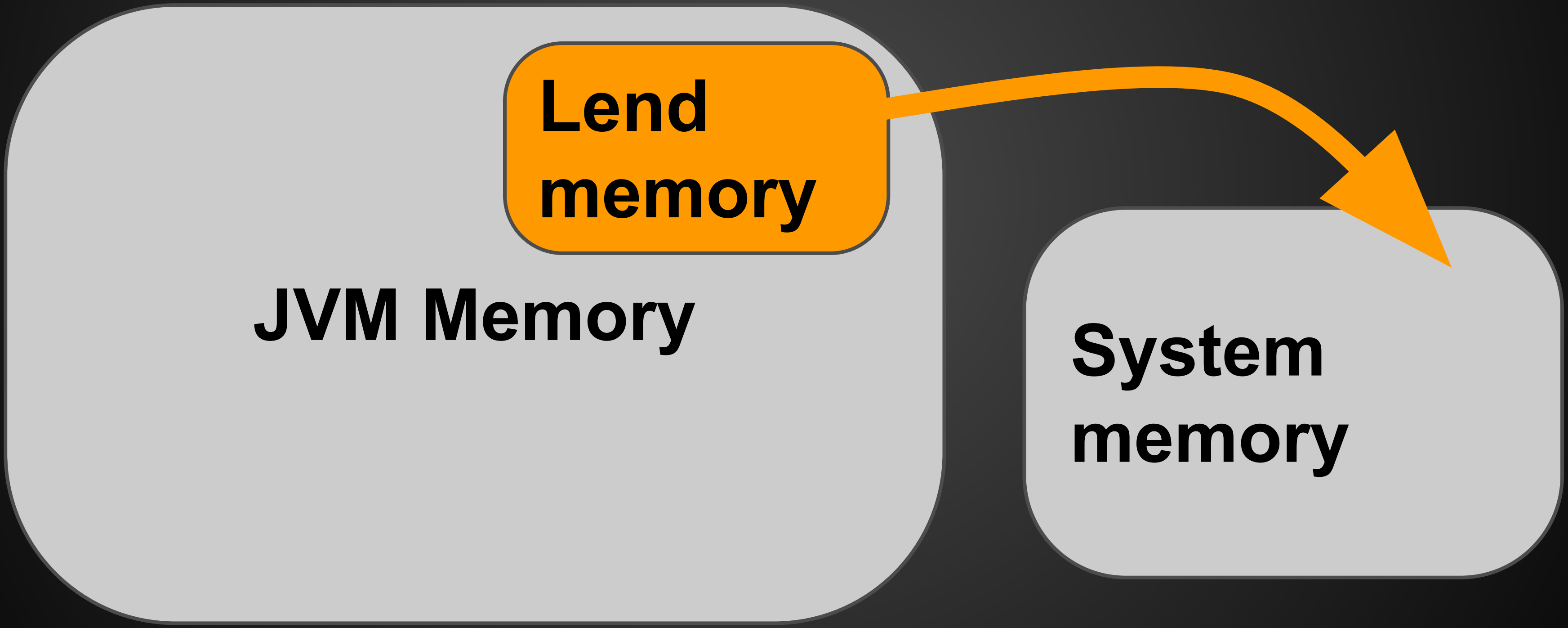


Van Jacobson == TCP/IP

Net Channel design:



Dynamic heap, sharing is good



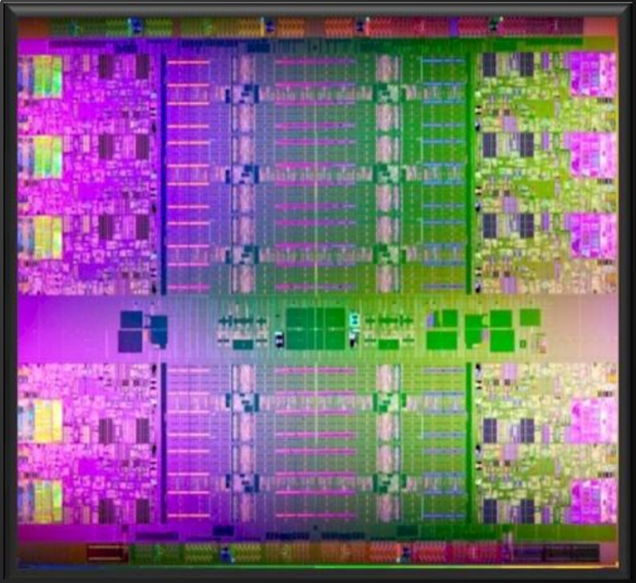
Lend memory

JVM Memory

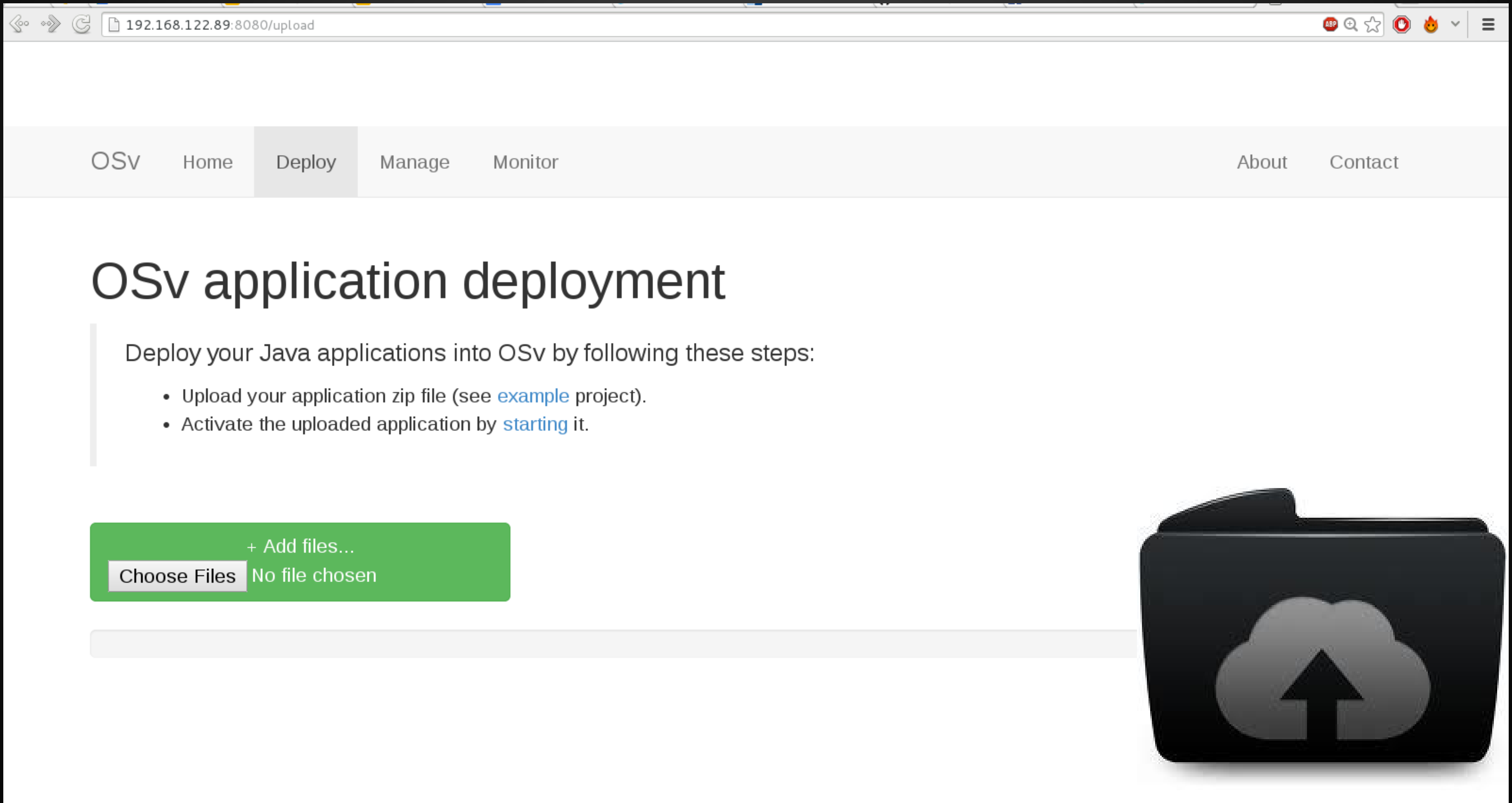
System memory

Architecture ports

- 64-bit x86
  - KVM - running like a bat out of hell
  - Xen HVM - running (still slow :-( )
  - VMware - planned in 2 months
- 64-bit ARM - planned
- Others - patches welcome



Management



OSv application deployment

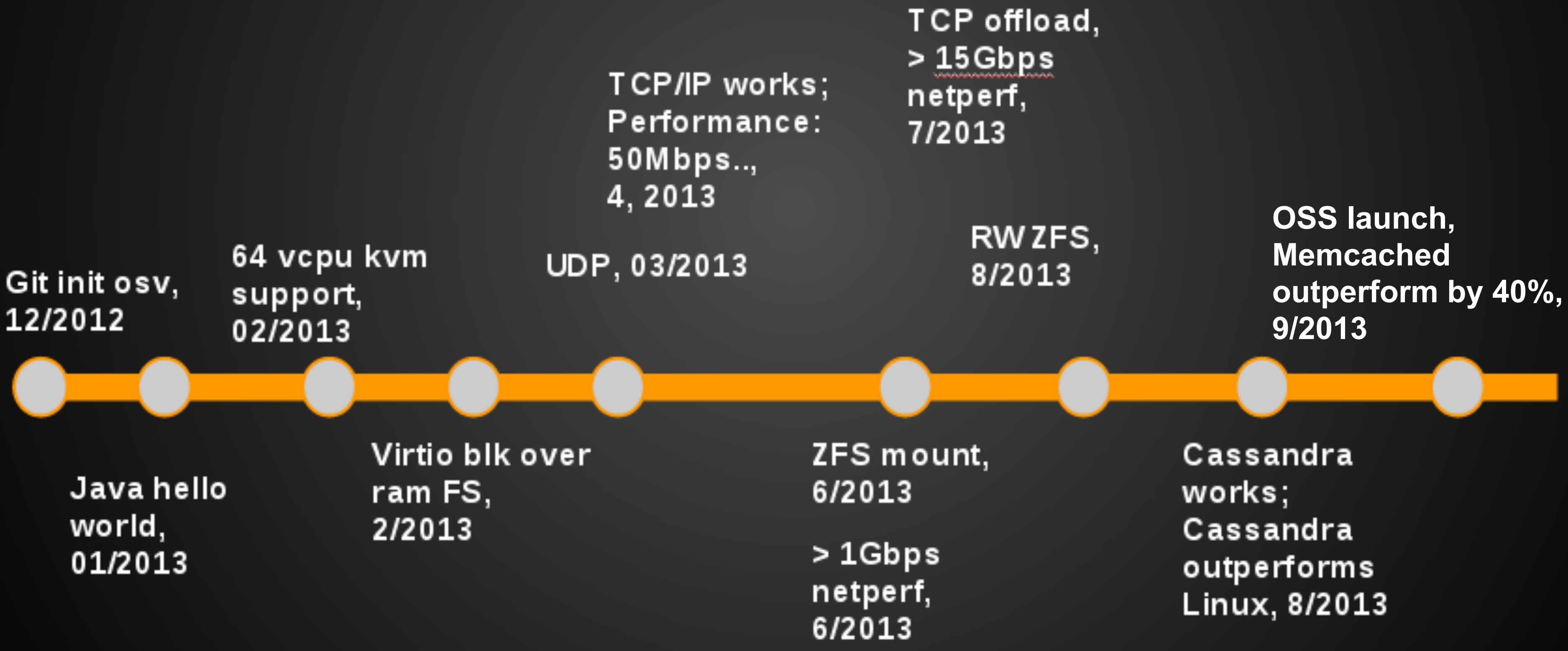
Deploy your Java applications into OSv by following these steps:

- Upload your application zip file (see example project).
- Activate the uploaded application by starting it.

Status

- Runs:
  - Java, C, JRuby, Scala, Groovy, Clojure, JavaScript
- Outperforms Linux:
  - SpecJVM, MemCacheD, Cassandra, TCP/IP
- 400% better w/ scheduler micro-benchmark
- < 1sec boot time
- ZFS filesystem
- Huge pages from the very beginning

Milestones



Git init osv, 12/2012

Java hello world, 01/2013

64 vcpu kvm support, 02/2013

Virtio blk over ram FS, 2/2013

UDP, 03/2013

TCP/IP works; Performance: 50Mbps.., 4, 2013

ZFS mount, 6/2013

> 1Gbps netperf, 6/2013

TCP offload, > 15Gbps netperf, 7/2013

RW ZFS, 8/2013

Cassandra works; Cassandra outperforms Linux, 8/2013

OSS launch, Memcached outperform by 40%, 9/2013

Two languages called C++

1. Strongly typed object oriented language specialized in leveraging synergies within business process for on demand needs of global companies in a dynamic paradigm shift

Two languages called C++

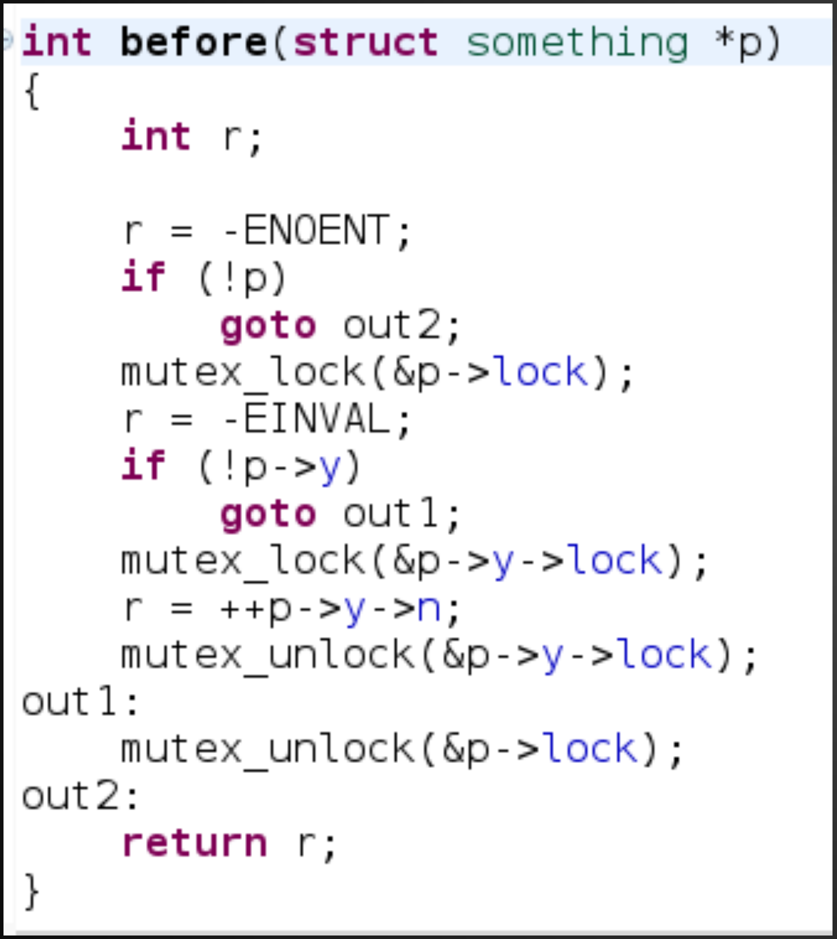
2. A macro language for generating C

Two languages called C++

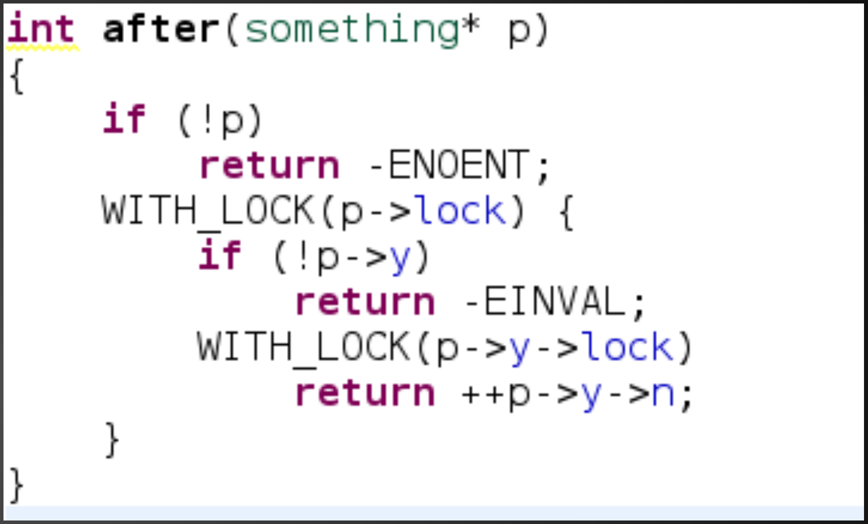
2. A macro language for generating C

- An elaborate macro language
  - Reduce boilerplate
  - Reduce C macros
  - More libraries, reuse
  - Less duplication
- Let the compiler write your C code

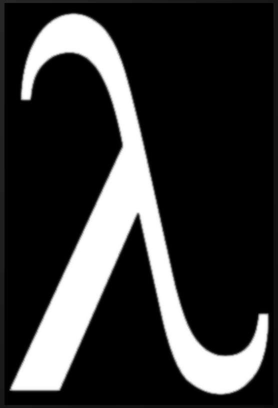
Scoped locking



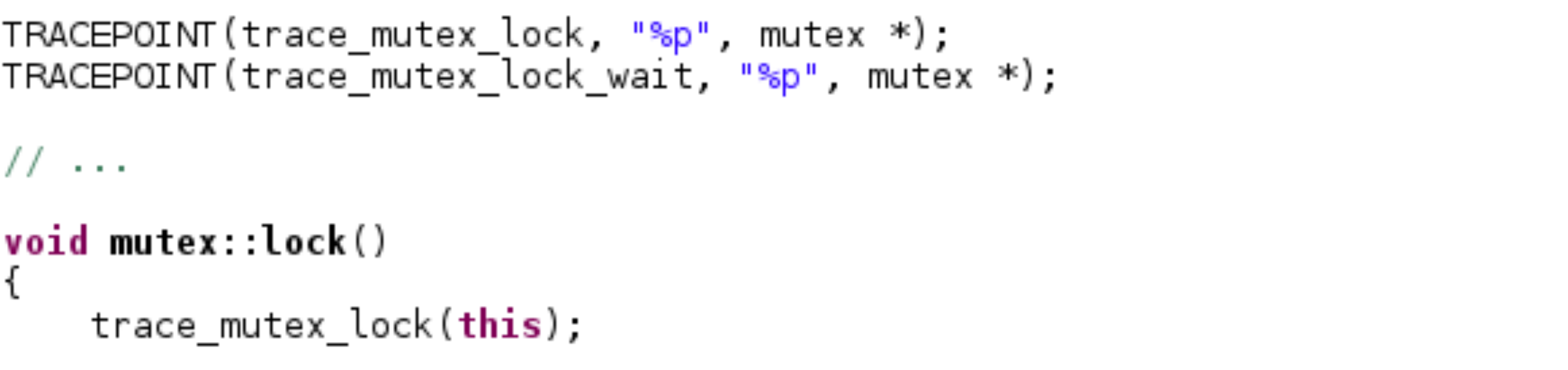
```
int before(struct something *p)
{
    int r;

    r = -ENOENT;
    if (!p)
        goto out2;
    mutex_lock(&p->lock);
    r = -EINVAL;
    if (!p->y)
        goto out1;
    mutex_lock(&p->y->lock);
    r = ++p->y->n;
    mutex_unlock(&p->y->lock);
out1:
    mutex_unlock(&p->lock);
out2:
    return r;
}
```



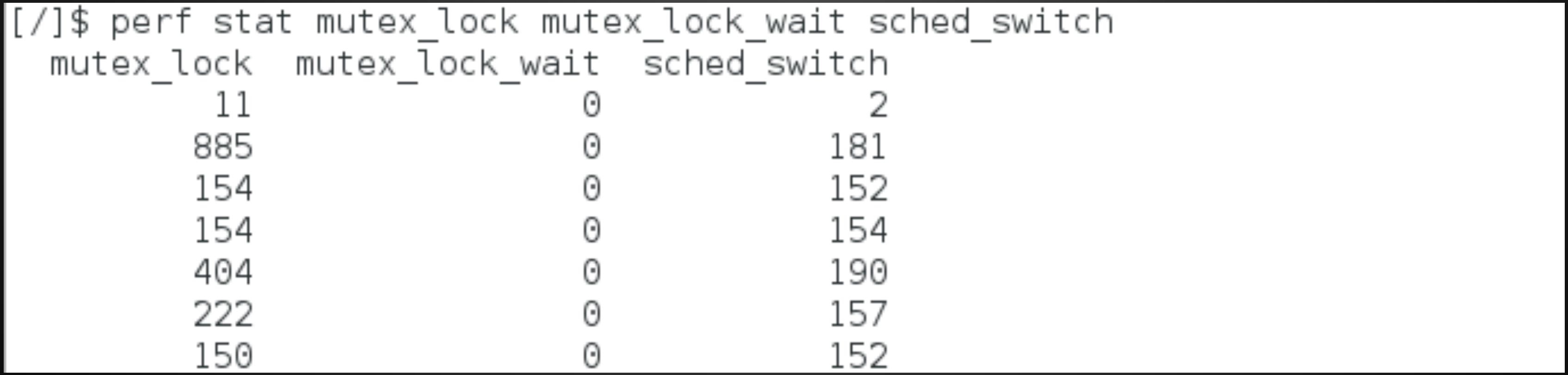
```
int after(something* p)
{
    if (!p)
        return -ENOENT;
    WITH_LOCK(p->lock) {
        if (!p->y)
            return -EINVAL;
        WITH_LOCK(p->y->lock)
            return ++p->y->n;
    }
}
```



Performance and tracing



```
TRACEPOINT(trace_mutex_lock, "%p", mutex *);
TRACEPOINT(trace_mutex_lock_wait, "%p", mutex *);

// ...

void mutex::lock()
{
    trace_mutex_lock(this);
```



```
[/]$ perf stat mutex_lock mutex_lock_wait sched_switch
  mutex_lock  mutex_lock_wait  sched_switch
          11                0             2
         885                0           181
         154                0           152
         154                0           154
         404                0           190
         222                0           157
         150                0           152
```

Atomic allocation & initialization

Allocate memory and initialize it in one step

- No need to track the size
- No error checking between steps

Containers

- vector<foo> - growable array
- unordered_map<key, value> - growable hash table
- list<bar> - doubly linked list
- set<whatever> - sorted balanced tree

Reduce the role of laziness in determining key data structures

templates - enforcing concepts at compile time

```
rcu_ptr<vector<device>> device_list;

// update:
device_list.assign(new_device_list);

// read:
auto list = device_list.read();
```

Reference counted objects

shared_ptr<device> - fully automatic reference counting

intrusive_ptr<device> - full manual control

Generic callbacks

```
function<void (int level)> irq_handler;
function<u64 (hw_addr addr, unsigned size)>
    read_callback;

irq_handler = my_irq_handler;
read_callback = bind(this, &my_device::read);
```

Generic callbacks

```
function<void (int level)> irq_handler;
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    read_callback;

irq_handler = my_irq_handler;
read_callback = bind(this, &my_device::read);
```

Signals and slots

```
signal <void ()> system_reset;


...
system_reset.connect([&] { reset_bar0(); });
…



system_reset();
```

Conclusions

- OS^V experience shows modern system programming is made easier in C++
- Boilerplate (and silly mistakes) reduced
- Easy, fast to use and build frameworks
- More fun too!
- Lessons applicable to QEMU

Resources

http://osv.io

https://github.com/cloudius-systems/osv

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osv-dev@googlegroups.com

#irc #osv on FreeNode