Project OSv

Shang Wu
Bite Ye
Xinyu Han

2021-04-22
George Washington University

Content

- Overview of OSv
- Components of OSv
  - Memory & Thread
  - Filesystem
  - Network
- General answer to questions
  - System performance
  - Security
- Thoughts about the system
- Q&A

Overview of OSv

- It’s a unikernel
  - Single address space
  - No system call overhead, simple function call
  - Small context switch overhead
- It’s dedicated to virtual machine
  - No need to support kinds of hardware drivers
  - Isolation in hardware level
  - Small size
- It’s for cloud
  - Easy to deploy
  - Small size + High performance == Cheap

Components of OSv Memory

- Implementation follows the POSIX-like APIs

```
struct page_allocator {
    virtual bool map(uintptr_t offset, hw_ptep<0> ptep, pt_element<0> pte, bool write) = 0;
    virtual bool map(uintptr_t offset, hw_ptep<1> ptep, pt_element<1> pte, bool write) = 0;
    virtual bool unmap(void *addr, uintptr_t offset, hw_ptep<0> ptep) = 0;
    virtual bool unmap(void *addr, uintptr_t offset, hw_ptep<1> ptep) = 0;
    virtual ~page_allocator() {}
};
```

Components of OSv Memory

- OSv uses single memory space
  - Both user and kernel shares the same memory space
  - Improve efficiency of the context switch
  - Does not need to switch the page table and flush TLB

Components of OSv Thread

- Six main characteristic for OSv
  - Lock-free
  - Preemptive
  - Tick-less
  - Fair
  - Scalable
  - Efficient

Components of OSv Filesystem

- “For its filesystem support, OSv follows a traditional UNIX-like VFS (virtual filesystem) design and adopts ZFS as its major filesystem.”
  - Also provides other options likes ramfs and some other pseudo filesystems

```
int     sys_open(char *path, int flags, mode_t mode, struct file **fp);
int     sys_read(struct file *fp, const struct iovec *iov, size_t niov,
                 off_t offset, size_t *count);
int     sys_write(struct file *fp, const struct iovec *iov, size_t niov,
                 off_t offset, size_t *count);
int     sys_lseek(struct file *fp, off_t off, int type, off_t * cur_off);
```

Components of OSv Filesystem

- By utilizing function pointers, OSv adopts polymorphism to the filesystem part and make it extensible.

```
#define VOP_CREATE(DVP, N, M) ((DVP)->v_op->vop_create)(DVP, N, M)
#define VOP_MKDIR(DVP, N, M) ((DVP)->v_op->vop_mkdir)(DVP, N, M)
```

Components of OSv Filesystem

- Previous things mentioned are existed in any Unix-like operating system. In addition to those, OSv implemented a virtiofs based on virtio lib and FUSE (Filesystem in Userspace) to provide faster data exchange between host and guest.

✓ **virtio-fs: initial implementation of read-only subset**

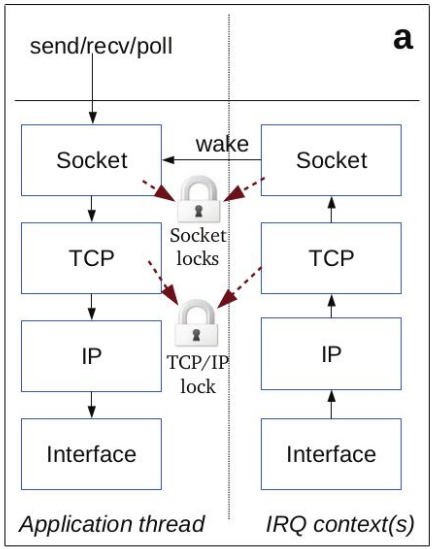
This patch provides initial implementation of read-only subset
of new virtio-fs filesystem. One of the main two parts is new virtio
driver - virtio-fs - that handles interactions with virtio device
as specified in the new 1.2 virtio spec -
https://stefanha.github.io/virtio/virtio-fs.html#x1-41500011. The second
part implements VFS sublayer that provides virtio-fs filesystem in OSv and in essence
serves as a passthrough between VFS abstract layer and virtio-fs device and host filesystem.

Components of OSv Network

- Problems of traditional network stack
  - Many layers in sending & receiving directions
  - Data copy from packet to skb to user
  - Lock contention
  - Inefficient data structure

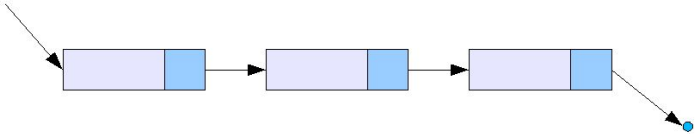
Components of OSv Network

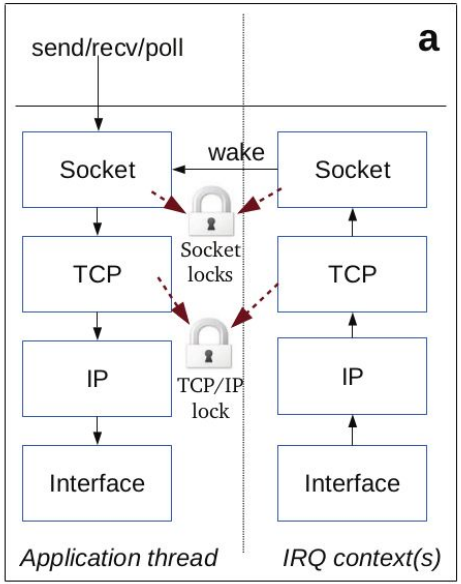
- Problems of traditional network stack
  - Many layers in sending & receiving directions
    - They are in different process/threads (context switches), or in different cores probably, thus bad CPU locality
    - System call overhead



Components of OSv Network

- Problems of traditional network stack
  - Data copy from packet to skb to user
  - Lock contention
    - Atomic operation freezes cache
  - Inefficient data structure
    - Linked list is bad for cache





Components of OSv Network

- OSv solution - network channel by Van Jacobson in 2006

Components of OSv Network

- Context switches (different cores) problem is solved by the single address model, where all system calls are converted into simple function calls.
- OSv also removes layers in receiver side in kernel, instead replacing it with a simple classifier.

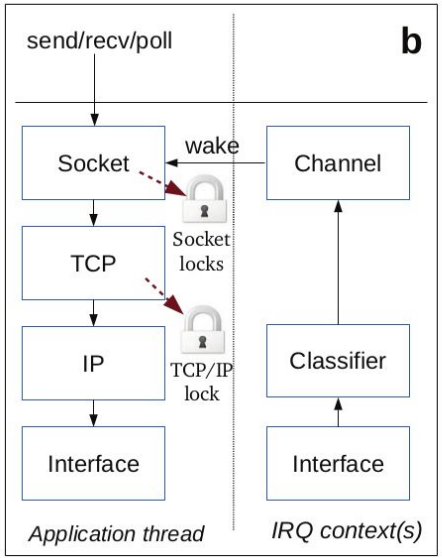
Components of OSv Network

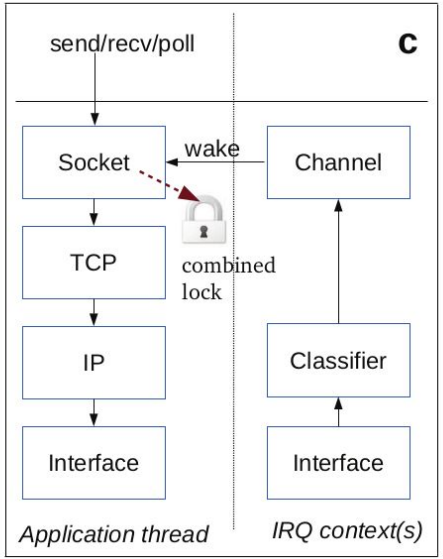
```
class classifier {
public
    ...
    void add(ipv4_tcp_conn_id id, net_channel* channel);
    void remove(ipv4_tcp_conn_id id)
    ...
    bool post_packet(mbuf* m);
    ...
    ipv4_tcp_channels _ipv4_tcp_channels;
};


struct ipv4_tcp_conn_id {
    ...
    in_addr src_addr;
    in_addr dst_addr;
    in_port_t src_port;
    in_port_t dst_port;

    size_t hash() const {
        // FIXME: protection against hash attacks?
        return src_addr.s_addr ^ dst_addr.s_addr ^ src_port ^ dst_port;
    }
    bool operator==(const ipv4_tcp_conn_id& x) const {
        return src_addr == x.src_addr
            && dst_addr == x.dst_addr
            && src_port == x.src_port
            && dst_port == x.dst_port;
    }
};
```

- Hash different flows (different channels), thus sending different packets into different threads (improve CPU locality)
- One core per flow

Components of OSv Network

- Lock contention can be largely avoided because kernel now does not process heavy logic
- Only one thread is processing packets (socket sending & receiving buffers), thus locks can be merged.
- TCP layer lock can be combined since TCP processing is part of socket processing context





Components of OSv Network

- Linked list problem is replaced with channels.
- A channel is just a fixed-sized ring buffer queue, thus cache friendly

```
class net_channel {
private:
    std::function<void (mbuf*)> _process_packet;
    ring_spsc<mbuf*, 256> _queue;
    sched::thread_handle _waiting_thread CACHELINE_ALIGNED;
    // extra list of threads to wake
    osv::rcu_ptr<std::vector<pollreq*>> _pollers;
    osv::rcu_hashtable<epoll_ptr> _epollers;
    mutex _pollers_mutex;
    ...
    // producer: try to push a packet
    bool push(mbuf* m) { return _queue.push(m); }
    // consumer: wake the consumer (best used after multiple push()s)
    void wake() {
        _waiting_thread.wake();
        if (_pollers || !_epollers.empty()) {
            wake_pollers();
        }
    }
    // consumer: consume all available packets using process_packet()
    void process_queue();
    ...
}
```

General answer to questions

- Performance
  - Good when dealing tasks that has frequent Linux syscalls & heavy network loading
    - Remove system call & single address model
    - Network channel strategy
  - Memcached benchmark shows a 20% more requests per second capability compared with Linux

General answer to questions

- Performance
  - Not good when dealing with heavy disk I/O operations application
    - Coarse-grained locking in VFS could lock vnode for a long time
    - Not good for application like MySQL

General answer to questions

- Security
  - OSv relies on the security provided by the underlying facilities, strong isolation.
  - Least Common Mechanism: each application is in a separate protection domain(VM), they nealy does not share services, except things like hypervisor.
  - Least Privilege: each application will focus on its job within VM, this application has no choice but to live with VM, thus in a limited scope, cannot do anything bad outside of that
  - The single address model & VM actually put 100% trust on the underlying facilities, which means the system does not need to put too much effort into security.

Thoughts about OSv

- Linux is everywhere, thus practical & useful
- Applications can be adopted quickly
- SaaS (software as a service) becoming much more popular than before.Along with the trend, thanks to hardware acceleration, virtualization and cloud based services became the dominant type of services provided on the internet.

Thank you