Escape

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MKC, 06/19/2014

Outline

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Motivation

Beginning

- Writing an OS alone? That's way too much work!
- Port of UNIX32V to ECO32 during my studies
- Started with Escape in October 2008

Goals

- Learn about operating systems and related topics
- Experiment: What works well and what doesn't?
- What problems occur and how can they be solved?

Overview

Basic Properties

- UNIX-like microkernel OS
- Open source, available on `github.com/Nils-TUD/Escape`
- Mostly written in `C++`, some parts in `C`
- Runs on x86, x86_64, ECO32 and MMIX
- Besides `libgcc` and `libsupc++`, no third party components

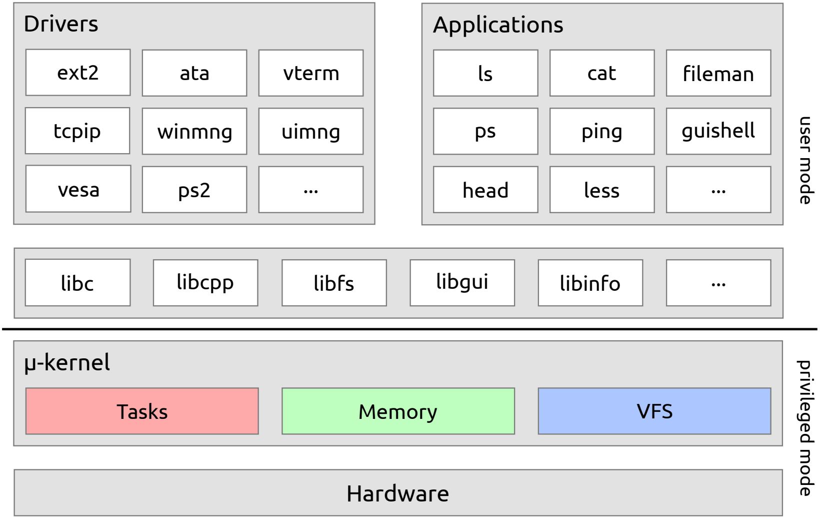
ECO32

MIPS-like, 32-bit big-endian RISC architecture, developed by Prof. Geisse for lectures and research

MMIX

64-bit big-endian RISC architecture of Donald Knuth as a successor for MIX (the abstract machine from TAOCP)

Overview


Drivers
ext2
ata
vterm
tcpip
winmng
uimng
vesa
ps2
...
Applications
ls
cat
fileman
ps
ping
guishell
head
less
...
user mode
libc
libcpp
libfs
libgui
libinfo
...
µ-kernel
Tasks
Memory
VFS
Hardware
privileged mode

Outline

Processes and Threads

Process

- Virtual address space
- File-descriptors
- Mountspace
- Threads (at least one)
- ...

Thread

- User- and kernelstack
- State (running, ready, blocked, ...)
- Scheduled by a round-robin scheduler with priorities
- Signals
- ...

Processes and Threads

Synchronization

- Process-local semaphores
- Process-local semaphores can also be created for interrupts
- Global semaphores, named by a path to a file
- Userspace builds other synchronization primitives on top
  - "User-semaphores" as a combination of atomic operations and process-local semaphores
  - Readers-writer-lock
  - ...

Priority Management

- Kernel adjusts thread priorities dynamically based on compute-intensity
- High CPU usage → downgrade, low CPU usage → upgrade

Outline

Memory Management

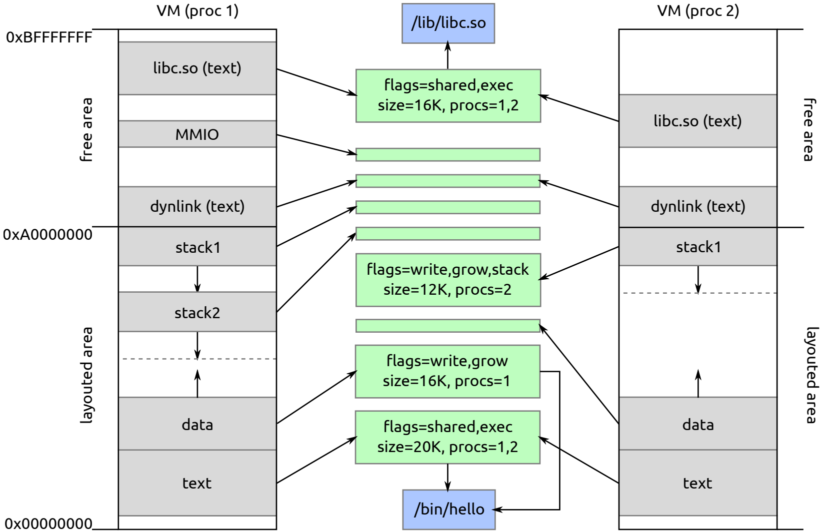
Physical Memory

- Most of the memory is managed by a stack for fast alloc/free of single frames
- A small part handled by a bitmap for contiguous phys. memory

Virtual Memory

- Kernel part is shared among all processes
- User part is managed by a region-based concept
- `mmap`-like interface for the userspace

Virtual Memory Management



Outline

1. Introduction
2. Tasks
3. Memory
4. VFS
5. IPC
6. UI
7. Demo

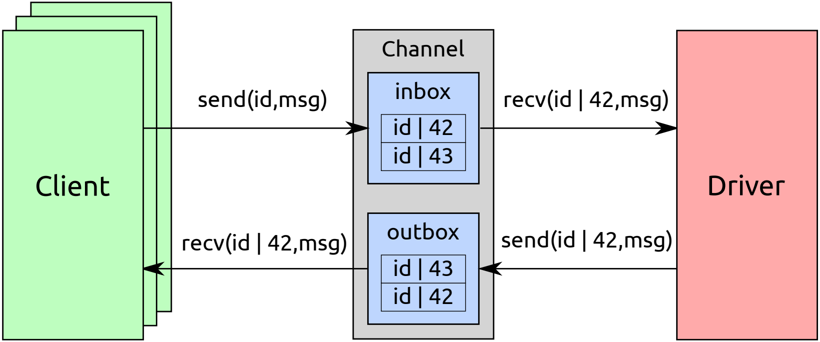
Basics

- The kernel provides the virtual file system
- System-calls: `open`, `read`, `mkdir`, `mount`, ...
- It's used for:
  1. Provide information about the state of the system
  2. Unique names for synchronization
  3. Access userspace filesystems
  4. Access devices

Drivers and Devices

- Drivers are ordinary user-programs
- They create devices via the system-call `createdev`
- These are usually put into /dev
- Devices can also be used to implement on-demand-generated files (such as /system/fs/$fs)
- The communication with devices works via asynchronous message passing

Message Passing



Devices Can Behave Like Files

- As in UNIX: Devices should be accessable like files
- Messages: `FILE_OPEN`, `FILE_READ`, `FILE_WRITE`, `FILE_CLOSE`
- Devices may support a subset of these message
- If using `open`/`read`/`write`/`close`, the kernel handles the communication
- Transparent for apps whether it is a virtual file, file in userspace fs or device

Devices Can Behave Like Filesystems

- Messages: `FS_OPEN`, `FS_READ`, `FS_WRITE`, `FS_CLOSE`, `FS_STAT`, `FS_SYNC`, `FS_LINK`, `FS_UNLINK`, `FS_RENAME`, `FS_MKDIR`, `FS_RMDIR`, `FS_CHMOD`, `FS_CHOWN`
- If using the system calls with the same names, the kernel handles the communication
- Filesystems are mounted using the `mount` system call

Mounting

Concept

- Every process has a mountspace
- Mountspace is a list of (*path*,*fs-con*) pairs
- Kernel translates fs-system-calls into messages to *fs-con*

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Example

```
// assuming that ext2 has created /dev/ext2-hda1
int fd = open("/dev/ext2-hda1", ...);
mount(fd, "/mnt/hda1");
// open("/mnt/hda1/a/b", ...) -> FS_OPEN("/a/b")
```

Achieving Higher Throughput

- Copying everything twice hurts for large amounts of data
- `sharebuf` establishes shmem between client and driver
- Easy to use: just call `sharebuf` once and use this as the buffer
- Clients don't need to care whether a driver supports it or not
- Drivers need just react on a specific message, do an `mmap` and check in `read`/`write` whether the shared memory should be used

Achieving Higher Throughput – Code Example

```
int fd = open("/dev/zero",IO_READ);
static char buf[SIZE];

while(read(fd,buf,SIZE)) > 0) {
    // ...
}

close(fd);
```

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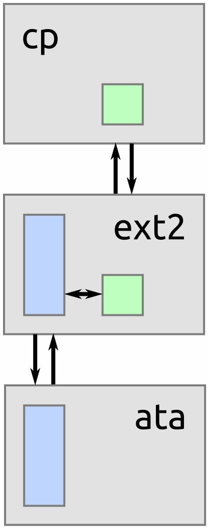
```
int fd = open("/dev/zero",IO_READ);

ulong shname;
void *buf;
if(sharebuf(fd,SIZE,&buf,&shname,0) < 0) {
    if(buf == NULL)
        error("Unable to mmap buf");
}

while(read(fd,buf,SIZE) > 0) {
    // ...
}

destroybuf(buf,shname);
close(fd);
```

Achieving Higher Throughput – Usage Example



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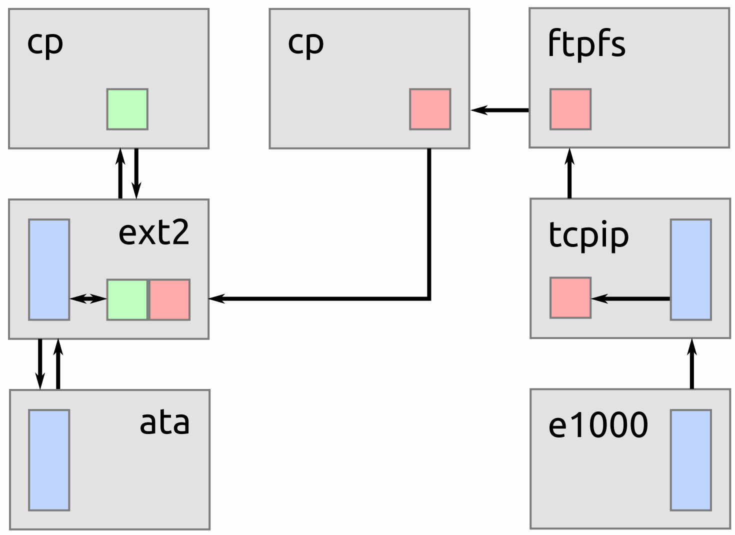

Canceling Operations

Problem

- What if we want to SIGTERM a process during a read?
- An already sent read-request can't be taken back
- Channels might be shared (shared state . . .)

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Solution

- Introduce a cancel syscall and message
- If a thread gets a signal, it wakes up and sends the cancel message to the driver
- The driver cancels the currently pending request, if necessary
- Race-condition: the driver might have already responded

Sibling Channels

Problem

- Suppose, you want to have a control channel and event channel per client
- Suppose, you want to implement socket's accept
- How do you do that?

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Solution

- Introduce a creatsibl syscall and message
- The kernel creates a new channel and sends a `DEV_CREATSIBL` message to the driver over the current channel
- The driver knows both and can then e.g. attach client-specific state to the new channel based and associate it with the old one

Integrating Networking

- Network services should be accessible like files or filesystems
- To support URLs:
  `"XYZ://foo/bar"` is translated to `"/dev/XYZ/foo/bar"`

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- To support URLs:
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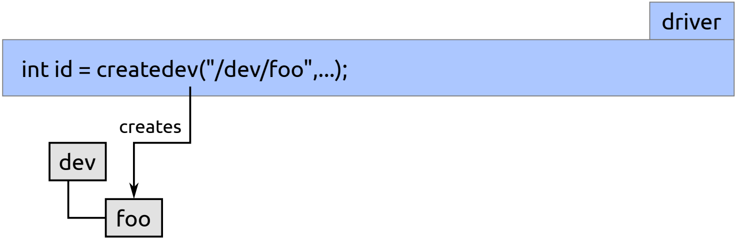
- For example:
  - `$ cat http://www.example.com`
  - `$ mount ftp://user@myhost.de/dir /mnt /sbin/ftpfs`
  - ...

Outline

IPC between Client and Driver (Low Level)



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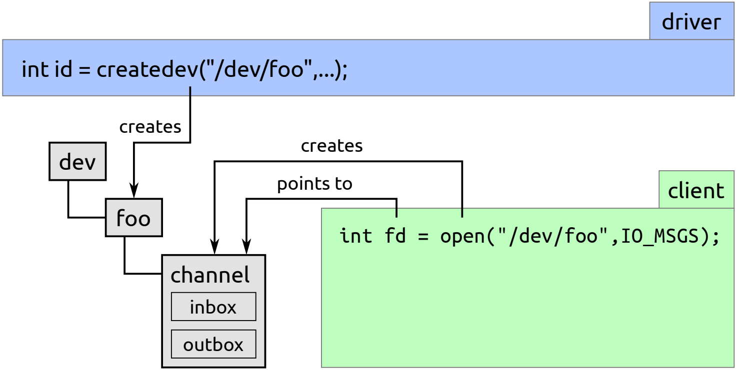

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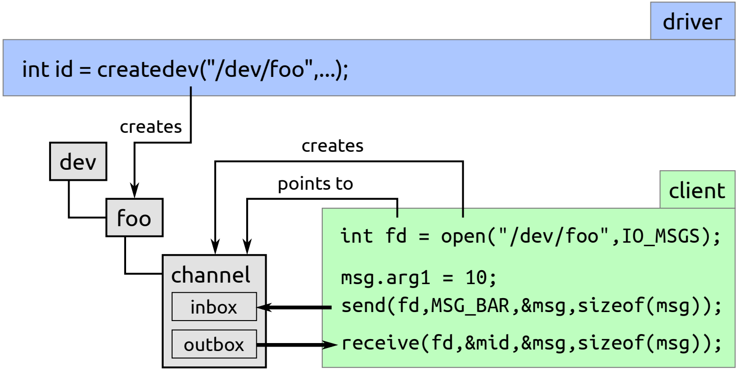

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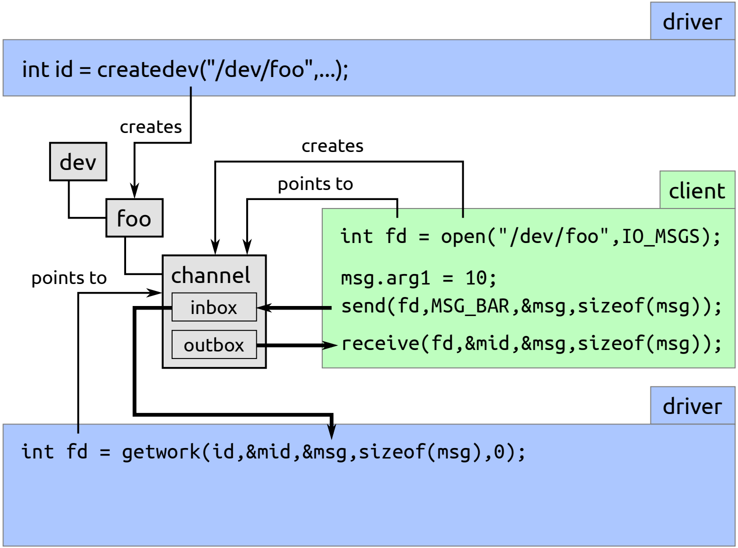

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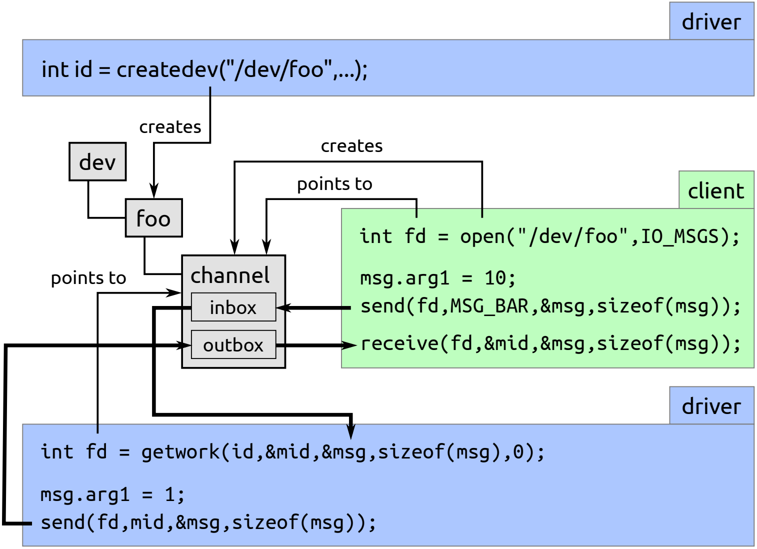

Driver Example: /dev/zero

```
struct ZeroDevice : public ClientDevice<> {
    explicit ZeroDevice(const char *name, mode_t mode)
        : ClientDevice(name, mode, DEV_TYPE_BLOCK, DEV_OPEN | DEV_SHFILE |
            DEV_READ | DEV_CLOSE) {
        set(MSG_FILE_READ, std::make_memfun(this,&ZeroDevice::read));
    }

    void read(IPCStream &is) {
        static char zeros[BUF_SIZE];
        Client *c = get(is.fd());
        FileRead::Request r;
        is >> r;

        if(r.shmemoff != -1)
            memset(c->shm() + r.shmemoff,0,r.count);
        is << FileRead::Response(r.count) << Reply();
        if(r.shmemoff == -1 && r.count)
            is << ReplyData(zeros,r.count);
    }
};

int main() {
    ZeroDevice dev("/dev/zero",0444);
    dev.loop();
    return EXIT_SUCCESS;
}
```

Client Example: vterm

```
// get console-size
ipc::VTerm vterm(std::env::get("TERM").c_str());
ipc::Screen::Mode mode = vterm.getMode();

// implementation of vterm.getMode():
Mode getMode() {
    Mode mode;
    int res;
    _is << SendReceive(MSG_SCR_GETMODE) >> res >> mode;
    if(res < 0)
        VTHROWE("getMode()", res);
    return mode;
}
```

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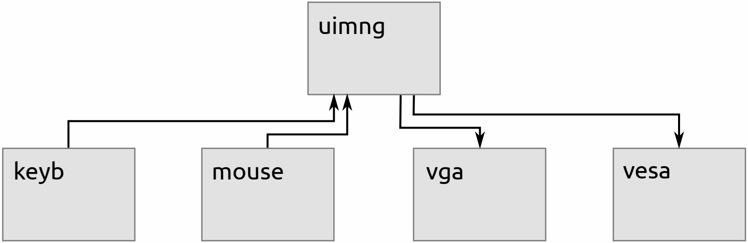
UI Concept



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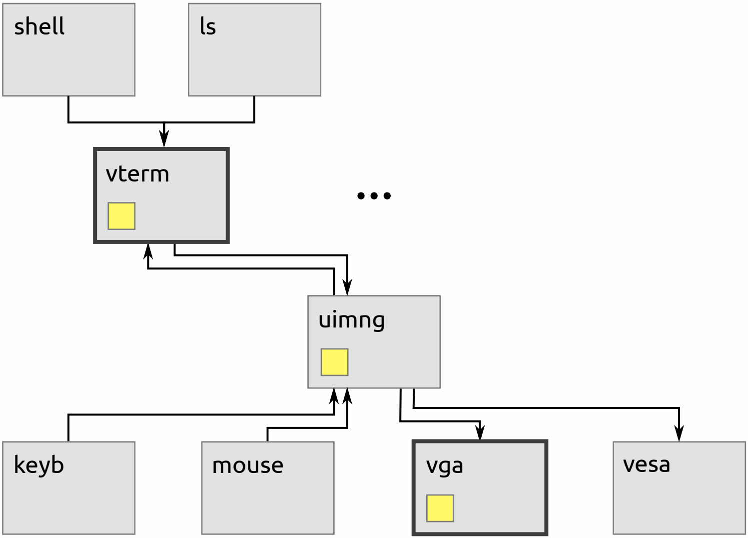

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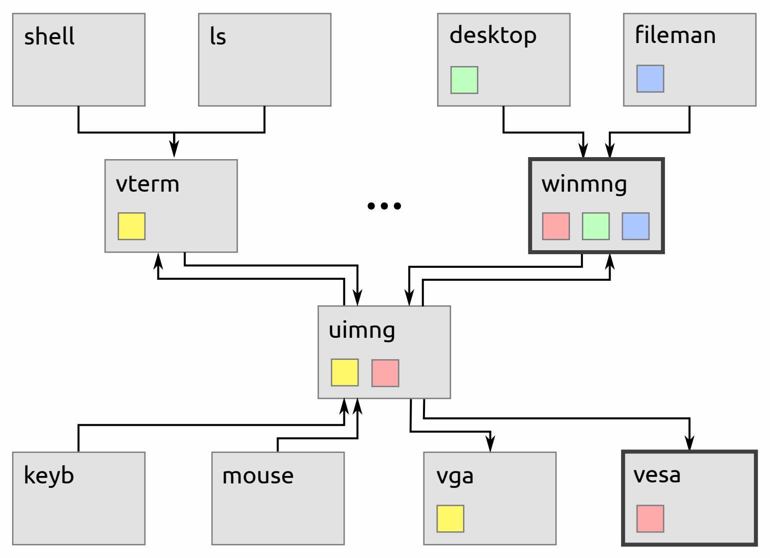
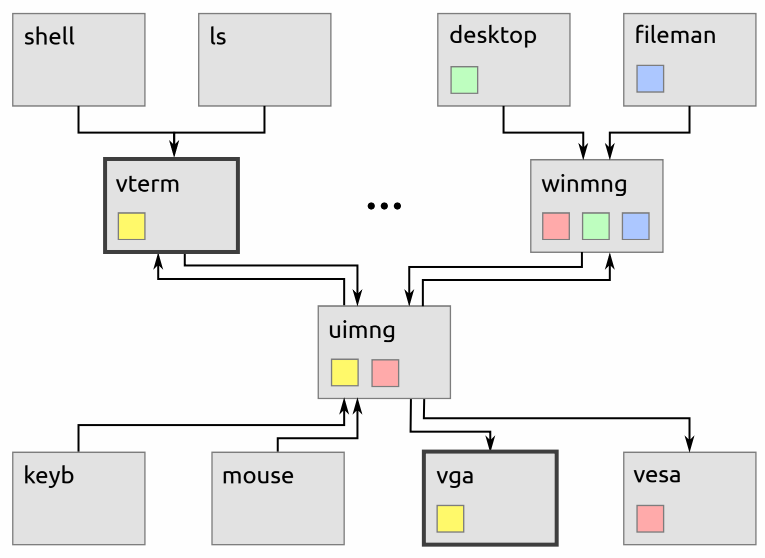

shell
ls
desktop
fileman
vterm
...
winmng
uimng
keyb
mouse
vga
vesa

UI Concept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Questions

Get the code, ISO images, etc. on:

`https://github.com/Nils-TUD/Escape`

Any questions to Escape?