The microkernel OS Escape

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FOSDEM’14
Outline

1. Introduction
2. Tasks
3. Memory
4. VFS
5. Demo
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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
- The kernel and the GUI are written in C++, the rest in C
- Runs on x86, 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
- iso9660
- ata
- vesa
- winmng
- keyb
- ... 

Applications
- ls
- cat
- fileman
- ps
- top
- guishell
- head
- less
- ...

µ-kernel
- Tasks
- Memory
- VFS

Hardware
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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
- ...

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Processes and Threads

Synchronization
- Process-local semaphores
- 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
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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
- Upper part is for the kernel and shared among all processes
- Lower part is managed by a region-based concept
- mmap-like interface for the userspace
Virtual Memory Management

VM (proc 1)
- libc.so (text)
- MMIO
- dynlink (text)
- stack1
- stack2
- data
- text

Flag: flags=shared,exec
Size: 16K, procs=1,2

VM (proc 2)
- libc.so (text)
- dynlink (text)
- stack1
- data
- text

Flag: flags=write,grow,stack
Size: 12K, procs=2

Flag: flags=write,grow
Size: 16K, procs=1

Flag: flags=shared,exec
Size: 20K, procs=1,2

/0x00000000
/0xA0000000
/0xBFFFFFFF
/0x00000000
/bin/hello
/lib/libc.so
/dynlink (text)
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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 and shared memory
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
IPC between Client and Driver

```c
int id = createdev("/dev/foo",...);
```
IPC between Client and Driver

```c
int id = createdev("/dev/foo",...);

int fd = open("/dev/foo",IO_MSGS);
```

Diagram:
- **Driver**
- **Client**
- **Channel**
  - **Inbox**
  - **Outbox**
- **Device**
- **Device**
- **Driver**

Interactions:
- Device creates
- Channel points to
- Client reads writes
IPC between Client and Driver

int id = createdev("/dev/foo",...);

int fd = open("/dev/foo", IO_MSGS);

msg.arg1 = 10;
send(fd, MSG_BAR, &msg, sizeof(msg));
receive(fd, &mid, &msg, sizeof(msg));
**IPC between Client and Driver**

```
int id = createdev("/dev/foo",...);

// Client
int fd = open("/dev/foo",IO_MSGS);
msg.arg1 = 10;
send(fd,MSG_BAR,&msg,sizeof(msg));
receive(fd,&mid,&msg,sizeof(msg));

// Driver
int fd = getwork(id,&mid,&msg,sizeof(msg),0);
```
IPC between Client and Driver

- **dev**
  - int id = createdev("/dev/foo",...);
  - creates
  - foo

- **client**
  - channel
    - inbox
    - outbox
  - points to
  - fd = open("/dev/foo",IO_MSGS);
  - msg.arg1 = 10;
  - send(fd,MSG_BAR,&msg,sizeof(msg));
  - receive(fd,&mid,&msg,sizeof(msg));

- **driver**
  - int fd = getwork(id,&mid,&msg,sizeof(msg),0);
  - msg.arg1 = 1;
  - send(fd,MSG_RESP,&msg,sizeof(msg));
Integrating devices into the read-write-pattern

- As in UNIX: Devices should be accessable like files
- Messages: DEV_OPEN, DEV_READ, DEV_WRITE, DEV_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
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
Tasks

Memory

VFS

Demo

Mounting

Concept

- Every process has a mountspace, that is inherited to childs
- `clonemaps` gives your process its own copy
- Mountspace is a list of `(path, fs-con)` pairs
- Kernel translates fs-system-calls into messages to `fs-con`
Mounting

Concept

- Every process has a mountspace, that is inherited to childs
- clonems gives your process its own copy
- Mountspace is a list of \((\text{path}, \text{fs-con})\) pairs
- Kernel translates fs-system-calls into messages to \(\text{fs-con}\)

Example

```c
// assuming that an ext2-instance has been started
// to create /dev/ext2-hda1
int fd = open("/dev/ext2-hda1", ...);
mount(fd, "/mnt/hda1");
```
Get the code, ISO images, etc. on:
https://github.com/Nils-TUD/Escape

Thanks for your attention!