Escape

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MKC, 07/13/2017

Outline

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

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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
- Only third-party code: `libgcc`, `libsupc++`, x86emu, inflate

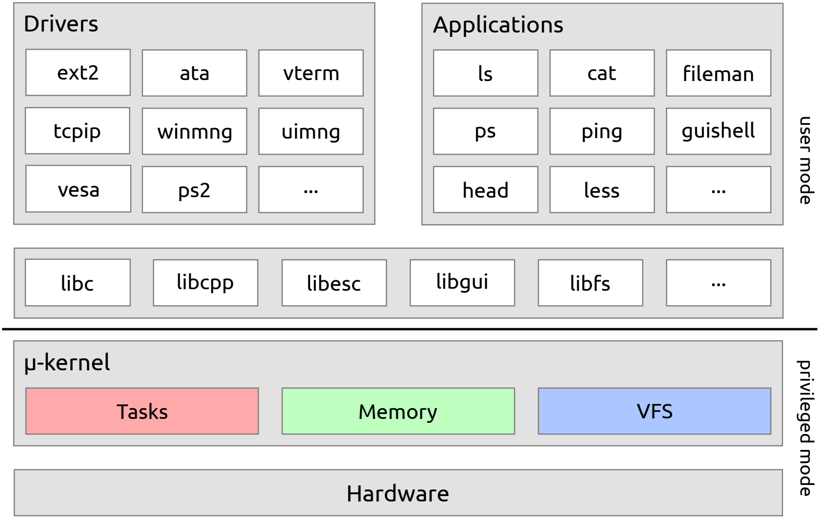
ECO32

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 ...

libc libcpp libesc libgui libfs ...

μ-kernel

Tasks Memory VFS

Hardware

user mode

privileged mode

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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
- ...

Processes and Threads

Synchronization

- 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
  - Combination of atomic ops and process-local semaphores
  - Readers-writer-lock
  - . . .

Priority Management

- Priorities are dynamically adjusted based on compute-intensity
- High CPU usage → downgrade, low CPU usage → upgrade

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Memory Management

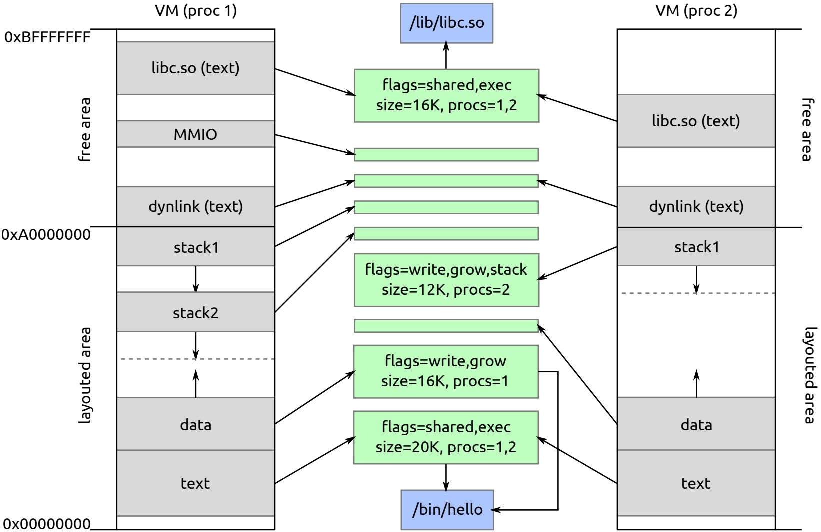
Physical Memory

- Mostly, memory is managed by a stack (fast for 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

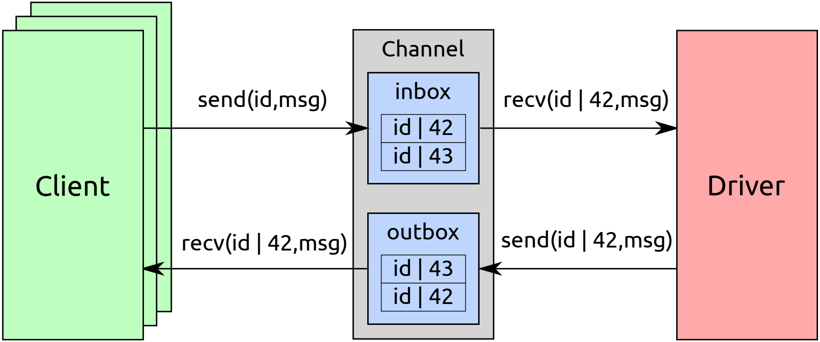
Basics

- 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. Access userspace filesystems
  3. Access devices
  4. Access interrupts

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 /sys/net/sockets)
- Communication is based on 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
- Kernel handles communication for `open`/`read`/`write`/`close`
- Type of file transparent for applications

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`
- Kernel handles communication, if syscall refers to userspace fs
- Filesystems are mounted using the `mount` system call

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 to handle `DEV_SHFILE` to support it
- In `read`/`write`, they check if SHM 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);
```

Achieving Higher Throughput – Code Example

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

static char buf[SIZE];




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


close(fd);
```

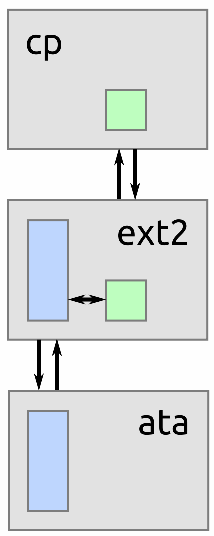
```c
int fd = open("/dev/zero",IO_READ);

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

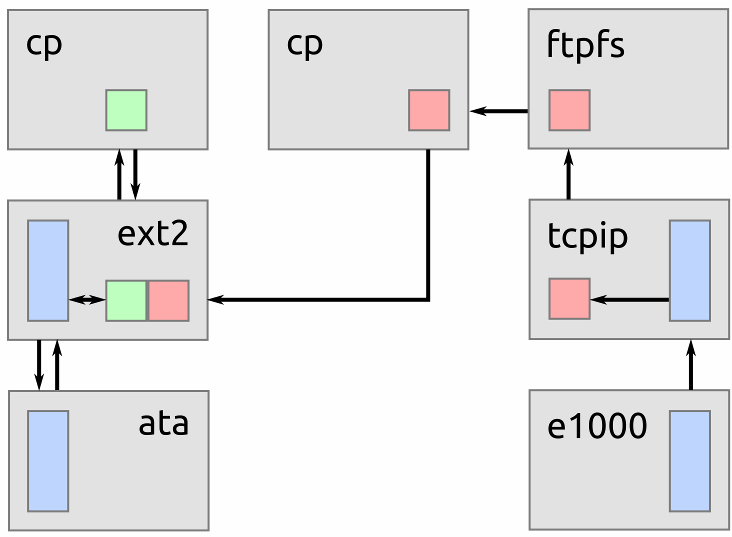
while(read(fd,buf,SIZE) > 0) {
    // ...
}

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

Achieving Higher Throughput – Usage Example



Achieving Higher Throughput – Usage Example



File Exchange

- Files (=capabilities) can be exchanged via channel
- Client can delegate/obtain files from driver:
  - `int delegate(int chan,int fd,uint perm,int arg)`
  - `int obtain(int chan,int arg)`
- Used for:
  - Establishing shared memory
  - Connecting control and event channel of uimng
  - Accepting incoming network connections (`accept`)
  - ...

File Descriptors For Everything

Interrupts

- Escape uses semaphores for interrupts
- For each interrupt, Escape creates a file /sys/irq/$irq
- Syscall `semirqcrt` expects fd for IRQ file
- On an IRQ, all semaphores in the list are up'ed

Signals

- The `kill` syscall expects fd for process directory
- Only if it has write permission, the signal can be sent

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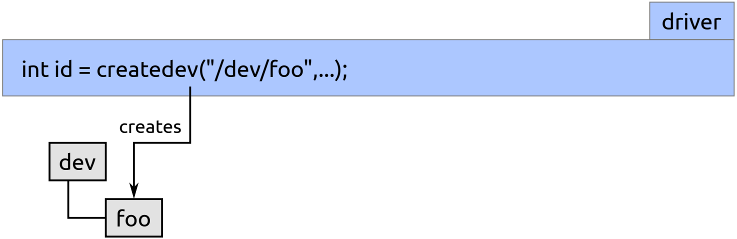
IPC between Client and Driver (Low Level)



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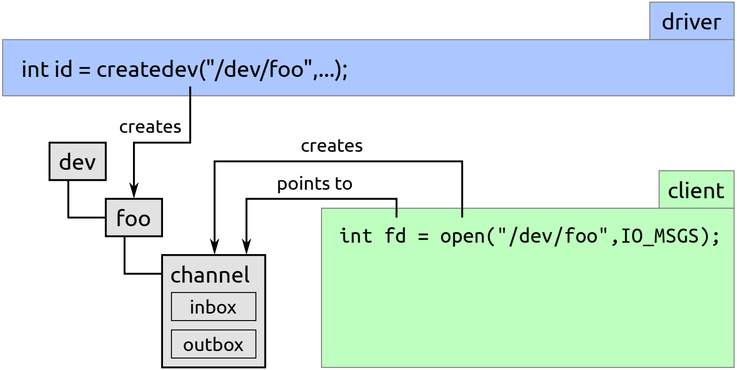

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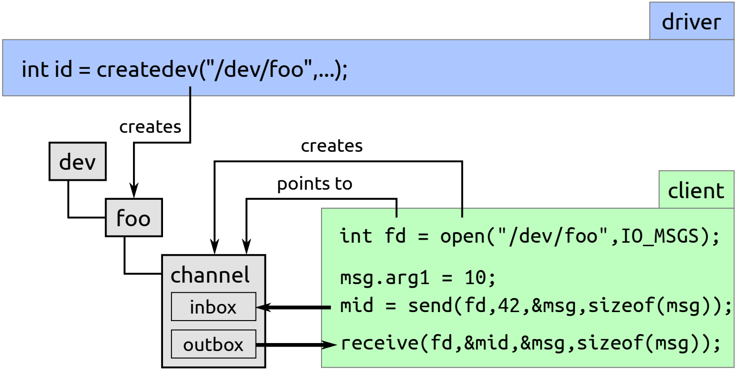


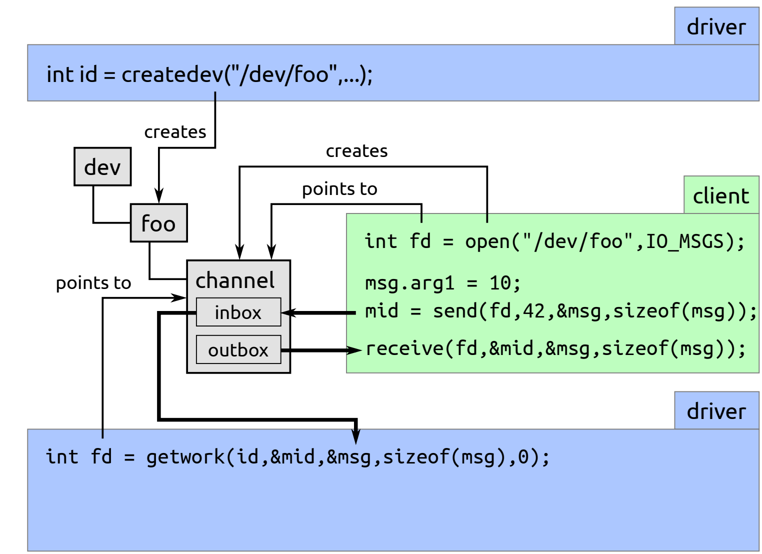
driver

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

client

```
int fd = open("/dev/foo",IO_MSGS);
msg.arg1 = 10;
mid = send(fd,42,&msg,sizeof(msg));
receive(fd,&mid,&msg,sizeof(msg));
```

IPC between Client and Driver (Low Level)



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client

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int fd = open("/dev/foo",IO_MSGS);
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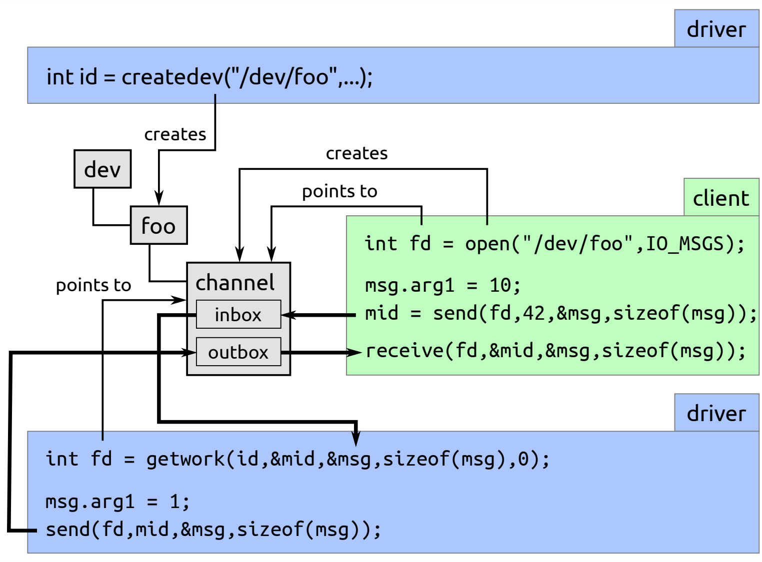
mid = send(fd,42,&msg,sizeof(msg));
receive(fd,&mid,&msg,sizeof(msg));
```

driver

```
int fd = getwork(id,&mid,&msg,sizeof(msg),0);
```

IPC between Client and Driver (Low Level)



driver

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

creates

dev

foo

points to

channel

inbox

outbox

creates

points to

client

```
int fd = open("/dev/foo",IO_MSGS);
msg.arg1 = 10;
mid = send(fd,42,&msg,sizeof(msg));
receive(fd,&mid,&msg,sizeof(msg));
```

driver

```
int fd = getwork(id,&mid,&msg,sizeof(msg),0);
msg.arg1 = 1;
send(fd,mid,&msg,sizeof(msg));
```

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_DELEGATE |
            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", 0400);
    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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General Idea

Goals

- Keep the powerful and convenient UNIX concepts
- Improve the security, reliability and maintainability

Approach

- Structure it as a microkernel-based system
- Permissions can only be downgraded (e.g., no setuid)
- Mountspace as a first layer: control entire subtrees
- ACL as a second layer: control at file-level

Mountspaces

- Every process has a mountspace, inherited to childs
- Mountspace is represented as a directory
- Child mountspaces become child directories
- Changing a mountspace requires write permission
- Mountspace translates: `path` → (`FS, perm, subpath`)
- `perm` defines upperbound for files in `subpath`
- Can be done by unprivileged users
  - Filesystems and drivers run in userspace
  - ...with the user+group of the mounter
  - Overmounting system directories is no security issue

Mounting for the User

Tools

- `mount` creates a new FS for a device and makes it visible
    - `$ mount /dev/hda1 /mnt /sbin/ext2`
- `bind` makes an existing FS visible at a different place
    - `$ bind /dev/ext2-hda1 /home/me/mnt`

What does bind do?

```
int fs = open("/dev/ext2-hda1", ...);
int ms = open("/sys/pid/self/ms", O_WRITE);
mount(ms, fs, "/home/me/mnt");
// open("/home/me/mnt/a/b", ...) -> FS_OPEN("/a/b")
```

Sandbox

Reasoning

- Some applications are not trusted
- Running them as a different user is inconvenient
- Instead: run with same user, but less permissions

The `sandbox` tool

- Allows to leave groups
- Allows to reduce permissions to entire subtrees
- Example: `sandbox -g netuser -m /home:r app`
- Sandboxes can be nested and used by unprivileged users

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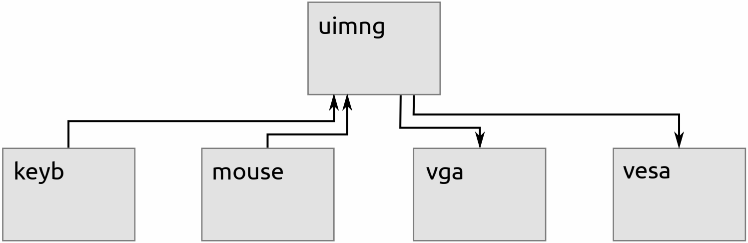
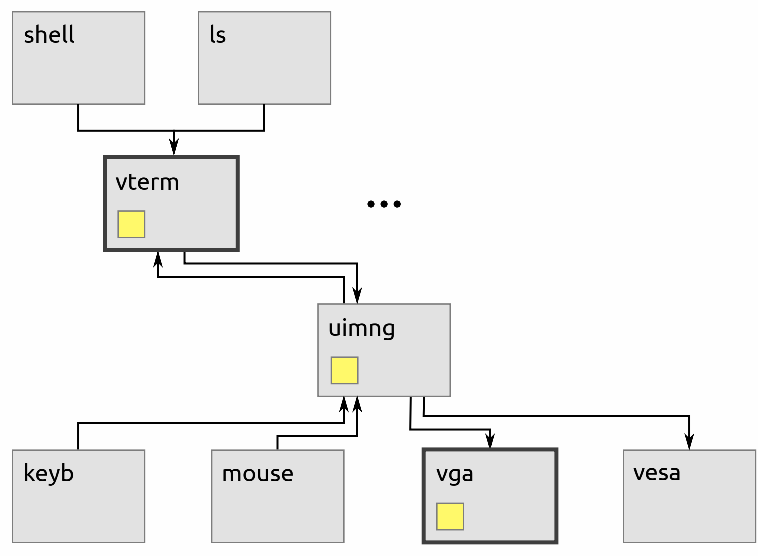
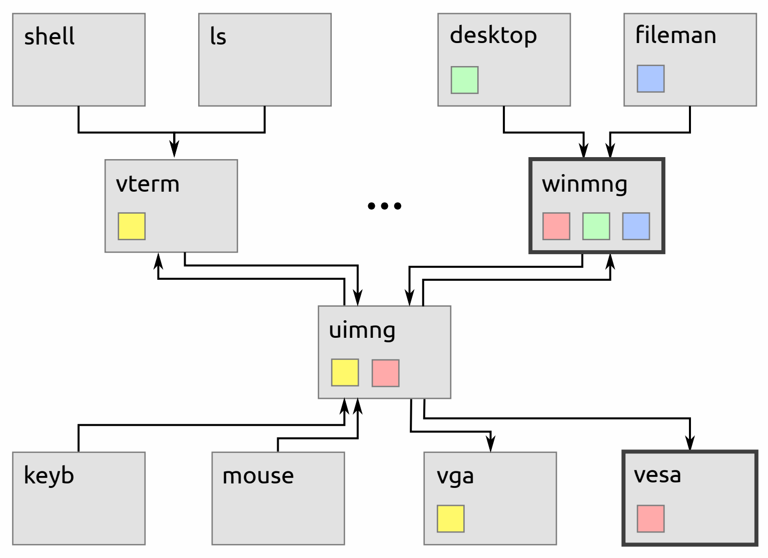
UI Concept



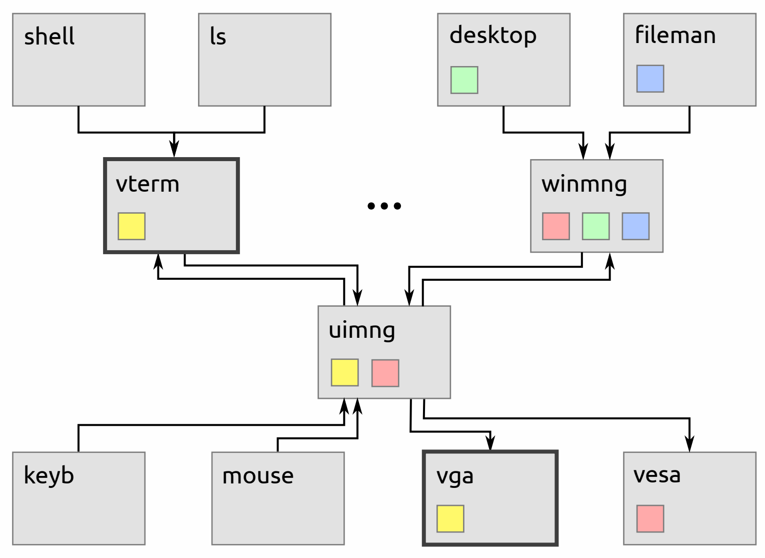
UI Concept



UI Concept


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`

Questions?