TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute for System Architecture, Operating Systems Group

MKC – Exercise 1

Nils Asmussen

2020-06-25

Virtual Mode

- This is the first virtual exercise in MKC
- If you have a question, are stuck, …
  - raise your hand (BBB has this feature)
  - write in chat
- If we cannot solve the problem, I might ask you to share your screen
- **REMEMBER:** I don’t see your progress; you have to **ask** for help

Roadmap

- Brief intro/review on kernel bootstrapping

- Start within minimal kernel
- Leave kernel to userland via iret
- Reenter via sysenter
- Do very basic syscalls (nop, add, ...)

Get the Code

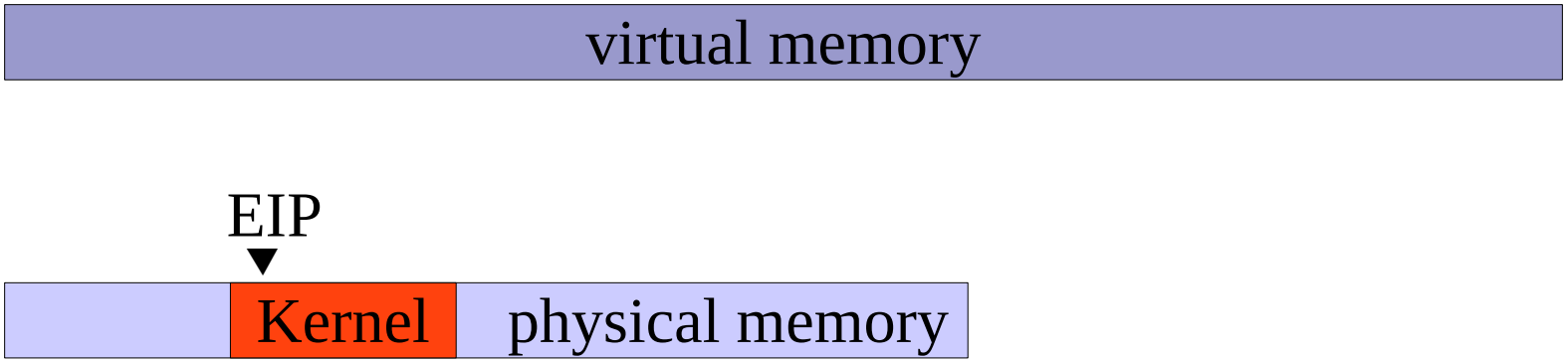
```
$ git clone
https://os.inf.tu-dresden.de/repo/git/mkc.git
$ git checkout exercise1

# build it
$ make

# run it
$ make run
```

... very first few instructions

- Open src/start.S
- Hard-coded segment descriptor table
- Execution starts at symbol **__start**
- Setup boot page table
- Enable paging
- Load segment selectors
- Call init()

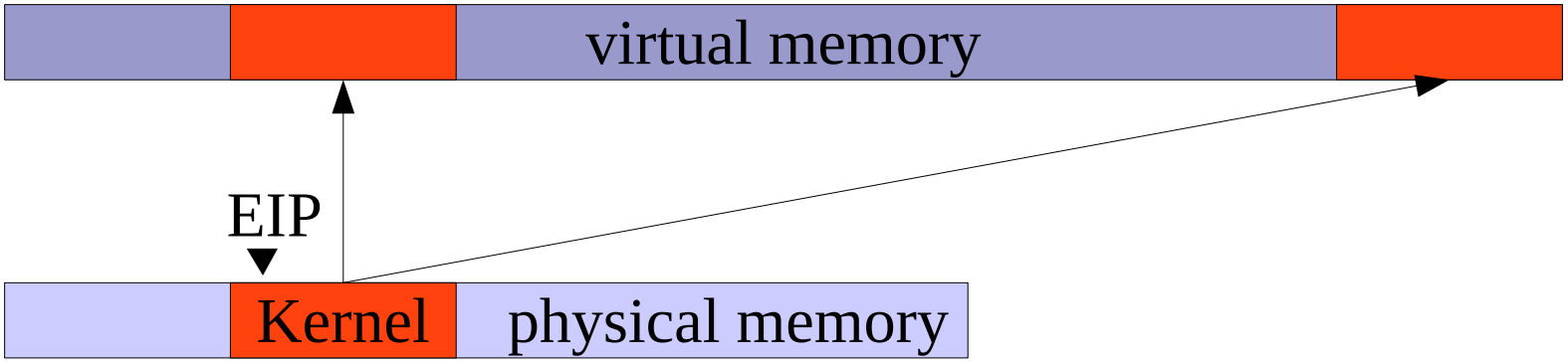
Initial Machine State

- Protected mode, no paging, but segmentation
- All segments: base 0, limit 0xFFFF FFFF
- CS: 32bit r+x code segment
- DS,ES,FS,GS,SS: 32bit r+w data segment
- Exact values are undefined
- See Multiboot Specification for details



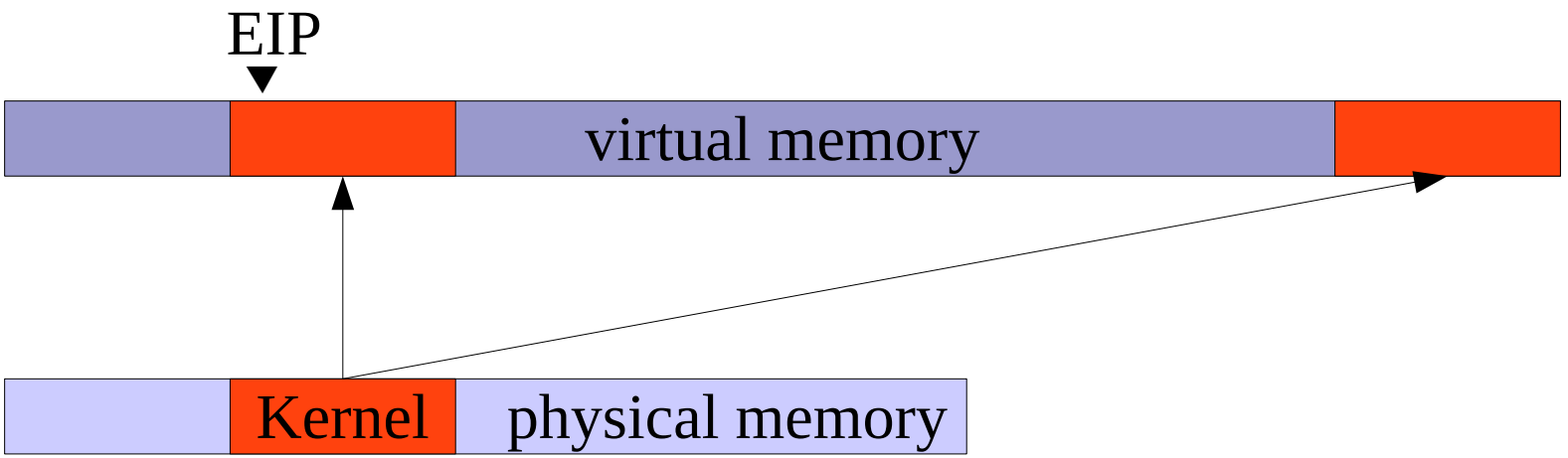
Setup Memory

- Setup boot page table



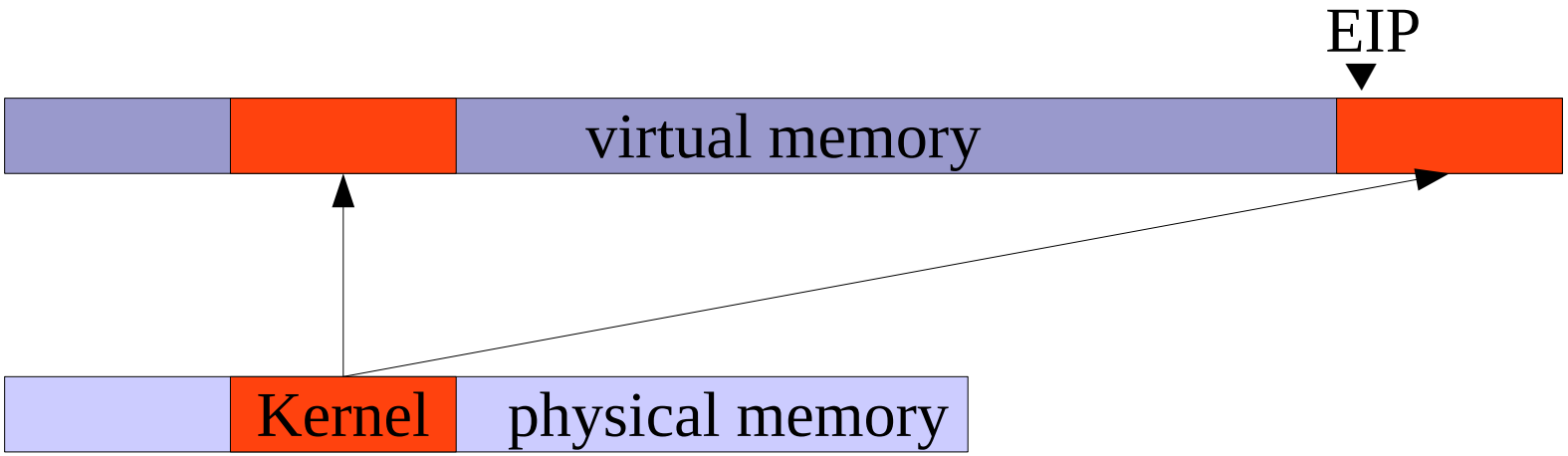
Setup Memory

- Setup boot page table
- Enable paging, thus use page tables to fetch next instruction (therefore need 1:1 mapping)



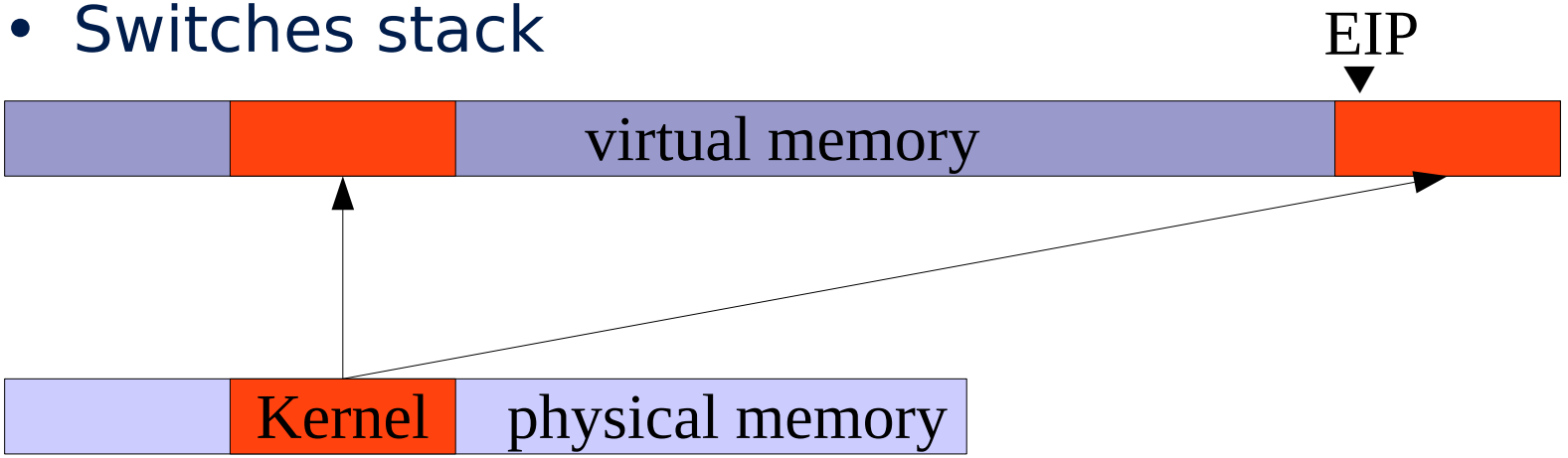
Setup Memory

- Setup boot page table
- Enable paging, thus use page tables to fetch next instruction (therefore need 1:1 mapping)
- Jump to high memory
  - This changes the EIP, but the 'old' stack from 1:1 mapping is still in use, need to switch later



Init() ...ialization

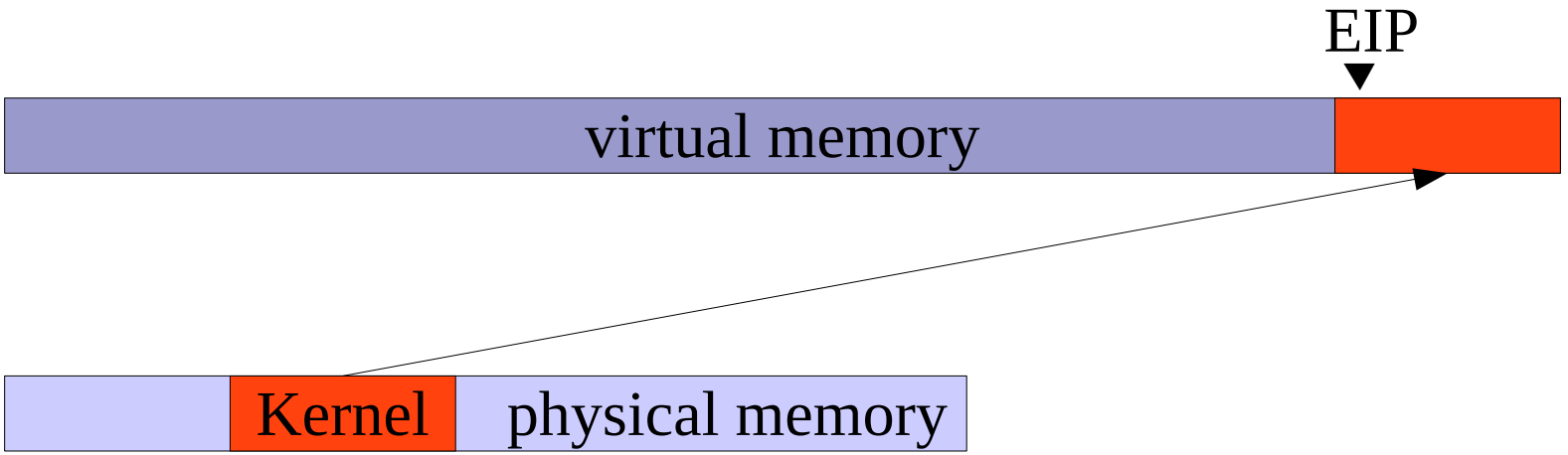
- Open src/init.cc
- Setup serial port for early debug output
- Map new kernel stack
- Setup GDT, IDT, GSI, and TSS
- Init PIC, mask all IRQs or install handlers
- Prepare Sysenter (CS,EIP,ESP)
- Switches stack



Init() ...ialization

- Again, src/init.cc, bootstrap

- Removes 1:1 mapping
- Flushes TLB
- Creates new EC (thread) for our user-code
- Switches to that EC

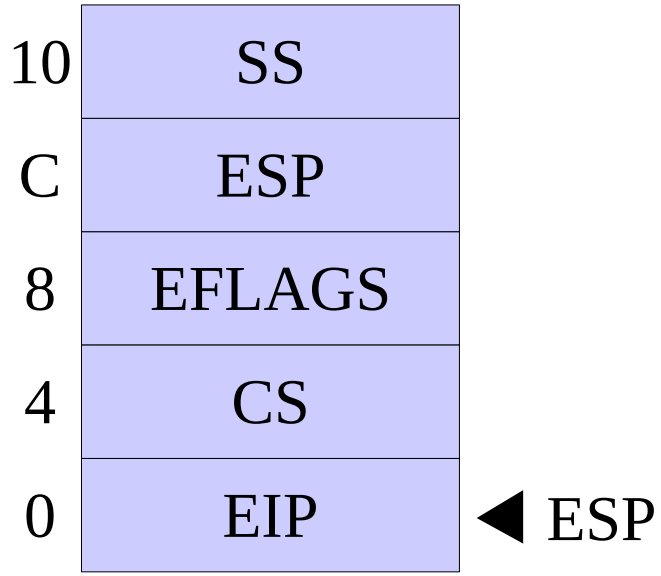


Getting out of the kernel ...

- Open src/ec.cc : **`root_invoke()`**

- Prepare address space
  - Map 1 page user stack (at address 0x1000)
  - Map 1 page user code (at address 0x2000)
- Prepare stack frame to be used with **`iret`**
  - User code segment + instr. pointer (**`CS`**, **`EIP`**)
  - User stack segment + stack pointer (**`SS`**, **`ESP`**)
  - No Data segment for now
- IRET: loads CS:EIP, SS:ESP and EFLAGS

IRET stack layout



- (kernel) ESP points to array with ES:EIP, EFLAGS and SS:ESP
- IRET (atomically) loads registers and switches from privilege level 0 to 3
- Fetches and starts executing first instruction from new instruction pointer

Getting out of the kernel ...

- User code starts in function usercode, thus
  `mword code = reinterpret_cast<mword>(&usercode);`
- Adjust new EIP to point within page at 0x2000
  `code = (code & PAGE_MASK) + 2 * PAGE_SIZE;`
- Handcraft stack frame and **IRET**

Inline assembly in a nutshell

```
asm volatile (
   “nop;”
   : <out> : <in> : <clobber> );

mword i=2, j=3;
asm volatile (
   “add %%ebx, %%eax;”
   : “+a” (i) : “b” (j) );
printf (“%d %d\n”,i,j);
```

- Load esp with addr of stack frame and do 'iret'

And.... ACTION!

- Prepare array with 5 elements and **`iret`**
  - Code : user instruction pointer to exit to
  - SEL_USER_CODE : new CS (include/selectors.h)
  - 0x200 : EFLAGS, just set interrupt enabled flag
  - 2 * PAGE_SIZE : new stack pointer
  - SEL_USER_DATA : new SS stack segment
- Open src/usercode.cc : usercode()
  - 1st Fault immediately
  - 2nd reenter kernel via **`sysenter`**
  - 3rd prepare **`sysexit`** by loading ecx and edx with proper values (ESP and EIP **after** returning)
  - 4th do simple system calls, like add 2 numbers

Hello user

- Open src/usercode.cc, function usercode()
- To check if everything is ok, fault immediately
  - asm (“ud2”); → exception #6
  - Ec::handle_exc 0x6 (eip=0x2016 cr2=0x0)
  - Force a page fault by reading or writing to an address somewhere below 0x1000
  - Ec::handle_exc 0xe (eip=0x2016 cr2=0x23)