Kernel programming

Kernel has access to all resources

Kernel programs not subject to any constraints for memory acces or hardware access

$\Rightarrow$ faulty kernel programs can cause system crash

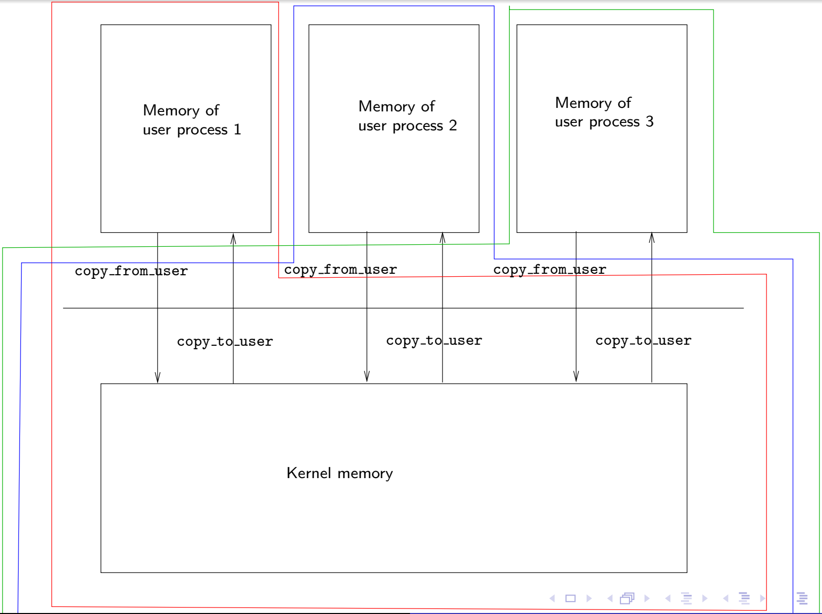
Interaction between kernel and user programs

Kernel provides its functions only via special functions, called system calls

standard C-library provides them

Have strict separation of kernel data and data for user programs

$\Rightarrow$ need explicit copying between user program and kernel


Memory of
user process 1
Memory of
user process 2
Memory of
user process 3
copy_from_user
copy_from_user
copy_from_user
copy_to_user
copy_to_user
copy_to_user
Kernel memory

Structure of kernel

Simplified structure of kernel:

```
initialise data structures at boot time;
while (true) {
   while (timer not gone off) {
      assign CPU to suitable process;
      execute process;
   }
   select next suitable process;
}
```

In addition, have interrupts:
kernel asks HW to perform certain action
HW sends interrupt to kernel which performs desired action
interrupts must be processed quickly
$\Rightarrow$ any code called from interrupts must not sleep

Linux kernel modes

Structure of kernel gives rise to two main modes for kernel code:

- process context: kernel code working for user programs by executing a system call
- interrupt context: kernel code handling an interrupt (eg by a device)

have access to user data only in process context
Any code running in process context may be pre-empted at any time by an interrupt
Interrupts have priority levels
Interrupt of lower priority are pre-empted by interrupts of higher priority

Kernel modules

- can add code to running kernel
- useful for providing device drivers which are required only if hardware present
- `modprobe` inserts module into running kernel
- `rmmod` removes module from running kernel (if unused)
- `lsmod` lists currently running modules

Concurrency issues in the kernel

Correct handling concurrency in the kernel important:
Manipulation of data structures which are shared between

- code running in process mode and code running in interrupt mode
- code running in interrupt mode

must happen only within critical regions
In multi-processor system even manipulation of data structures shared between code running in process context must happen only within critical sections

Achieving mutual exclusion

Two ways:

- Semaphores: when entering critical section fails, current process is put to sleep until critical region is available
  $\Rightarrow$ only usable if all critical regions are in process context
- Spinlocks: processor tries repeatedly to enter critical section
  Usable anywhere
  Disadvantage: Have busy waiting

Programming data transfer between userspace and kernel

- Linux maintains a directory called `proc` as interface between user space and kernel
- Files in this directory do not exist on disk
- Read-and write-operations on these files translated into kernel operations, together with data transfer between user space and kernel
- Useful mechanism for information exchange between kernel and user space

A tour of the Linux kernel

Major parts of the kernel:

- Device drivers: in the subdirectory `drivers`, sorted according to category
- file systems: in the subdirectory `fs`
- scheduling and process management: in the subdirectory `kernel`
- memory management: in the subdirectory `mm`
- networking code: in the subdirectory `net`
- architecture specific low-level code (including assembly code): in the subdirectory `arch`
- include-files: in the subdirectory `include`