Kernels and Operating Systems - Linux

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Course Code: ELEE1119

Course Name: Advanced Computer Engineering

Credits: 30

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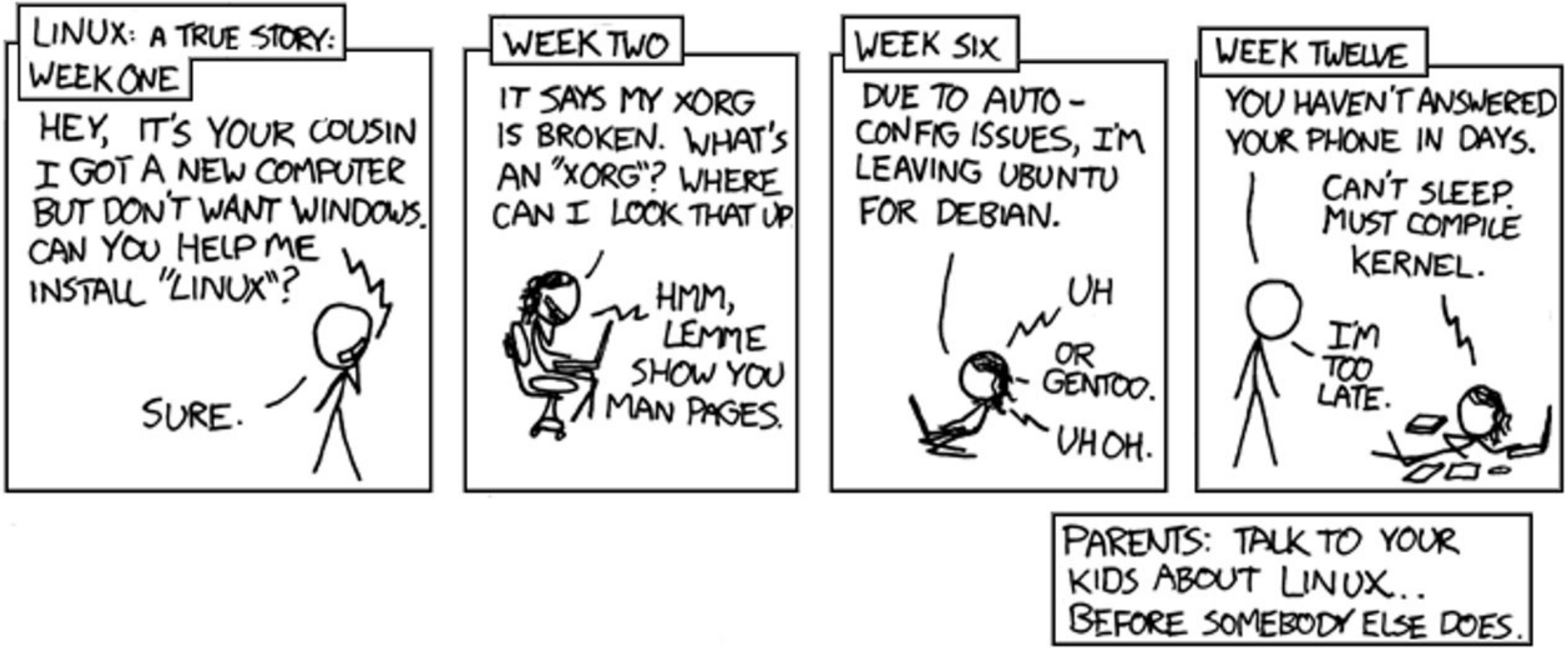
Level 3: Kernel



Kernel...

- The kernel is a busy personal assistant for a powerful executive (the **hardware**).
- It's the assistant's job to relay messages and requests (**processes**) from employees and the public (**users**) to the executive.
- To remember what is stored where (**memory**).
- To determine who has access to the executive at any given time and for how long.

Kernel is...

If implemented properly the Kernel is invisible to the user, working in its own little world known as the **Kernel Space**. Like where it allocates memory and track of where everything is stored. The **User Space** is the files or applications, what the user sees!

The Kernel is **software**

Monolithic

It has dependencies between systems components. It has huge lines of code which is complex.

Adv – It has good performance

Dis – It has dependences between system component and millions of line of code

Unix | Linux | Open VMS | XTS-400 | etc

Micro

It has virtual memory and thread scheduling. It is more stable with less services in kernel space. It puts rest in user space

Adv – It is more stable

Dis – There are lots of system calls and context switches

Mach | L4 | AmigaOS | Minix | K42 | etc

Hybrid

It has the speed and design of monolithic and modularity and stability of micro kernel

Adv – It combines both monolithic and micro kernels

Dis – It is still similar to monolithic kernel

Windows NT | Netware | BeOS | etc

Exo

Follows end-to-end principle, it allocates physical resources to applications

Adv – Fewest hardware abstractions

Dis – There is more work for application developers

Nemesis | ExOS | etc

Nano

kernel that offers hardware abstraction but without system services

Adv – Fewest hardware abstractions

Dis – It is quite same as Micro kernel hence it is less used.

EROS | etc

Linux is...

- a kernel developed by Linus Torvald in the 1994
- it's Free and Open-Source
- monolithic
- modular
- currently at version 5.19 in development

Linux Kernel

Six Major Functions	Six Layers
System	Userspace Interfaces
Processing	Virtual
Memory	Brdiges
Storage	Functional
Networking	Devices Control
Human interface	Hardware Interfaces

Kernel space and user space

Kernel and user are two terms that are often used in operating systems.

- The kernel is the part of the operating system that runs with higher privileges[1]
- while user (space) usually means by applications running with low privileges.

[1]: some processors may have even higher privileges than kernel mode, e.g. a hypervisor mode, that is only accessible to code running in a hypervisor (virtual machine monitor)

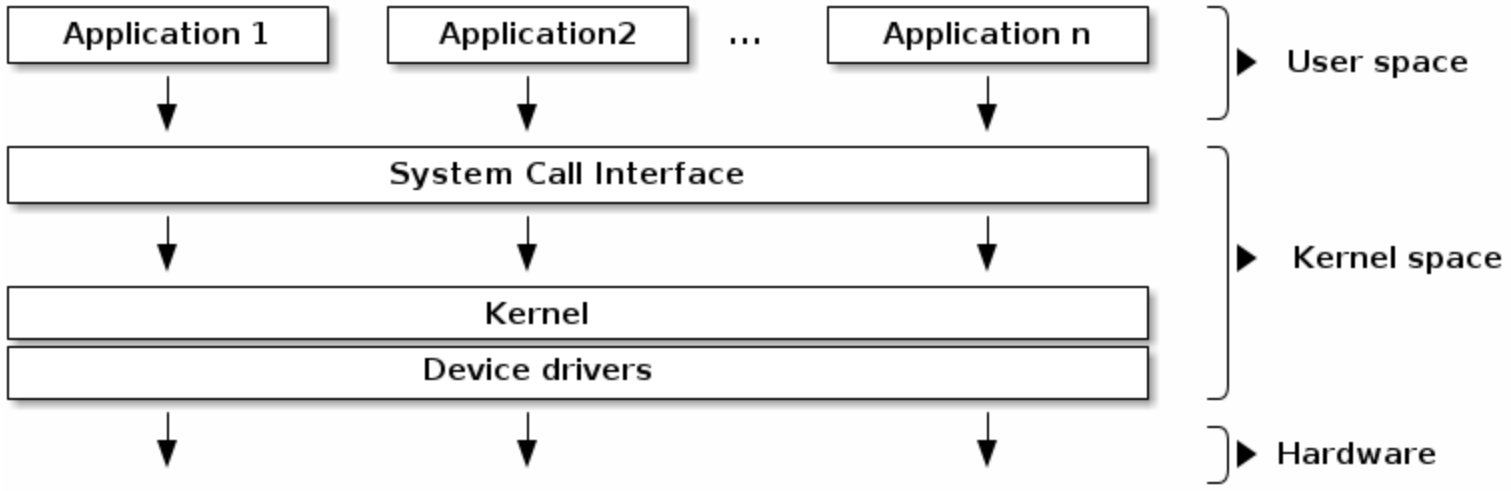
Kernel space and user space

User space and kernel space may refer specifically to **memory protection** or to **virtual address spaces** associated with either the kernel or user applications.

- The kernel space is the **memory area** that is reserved to the kernel while user space is the memory area reserved to a particular user process.
- The kernel space is access protected so that user applications can not access it directly, while user space can be directly accessed from code running in kernel mode.

Typical operating system architecture

In the typical operating system architecture (see the figure below) the operating system kernel is responsible for access and sharing the hardware in a secure and fair manner with multiple applications.



Kernel API

The kernel offers a set of ***Application Programming Interface*** (APIs) that applications issue which are generally referred to as **System Calls**. These APIs are different from regular library APIs because they are the boundary at which the execution mode **switch** from **user mode** to **kernel mode**.

In order to provide application compatibility, system calls are rarely changed. Linux particularly enforces this (as opposed to in kernel APIs that can change as needed).

Kernel Code

The kernel code itself can be logically separated in core kernel code and device drivers code.

Device drivers code is responsible of accessing particular devices while the core kernel code is generic.

The core kernel can be further divided into multiple logical subsystems (e.g. file access, networking, process management, etc.)

Linux Kernel Code

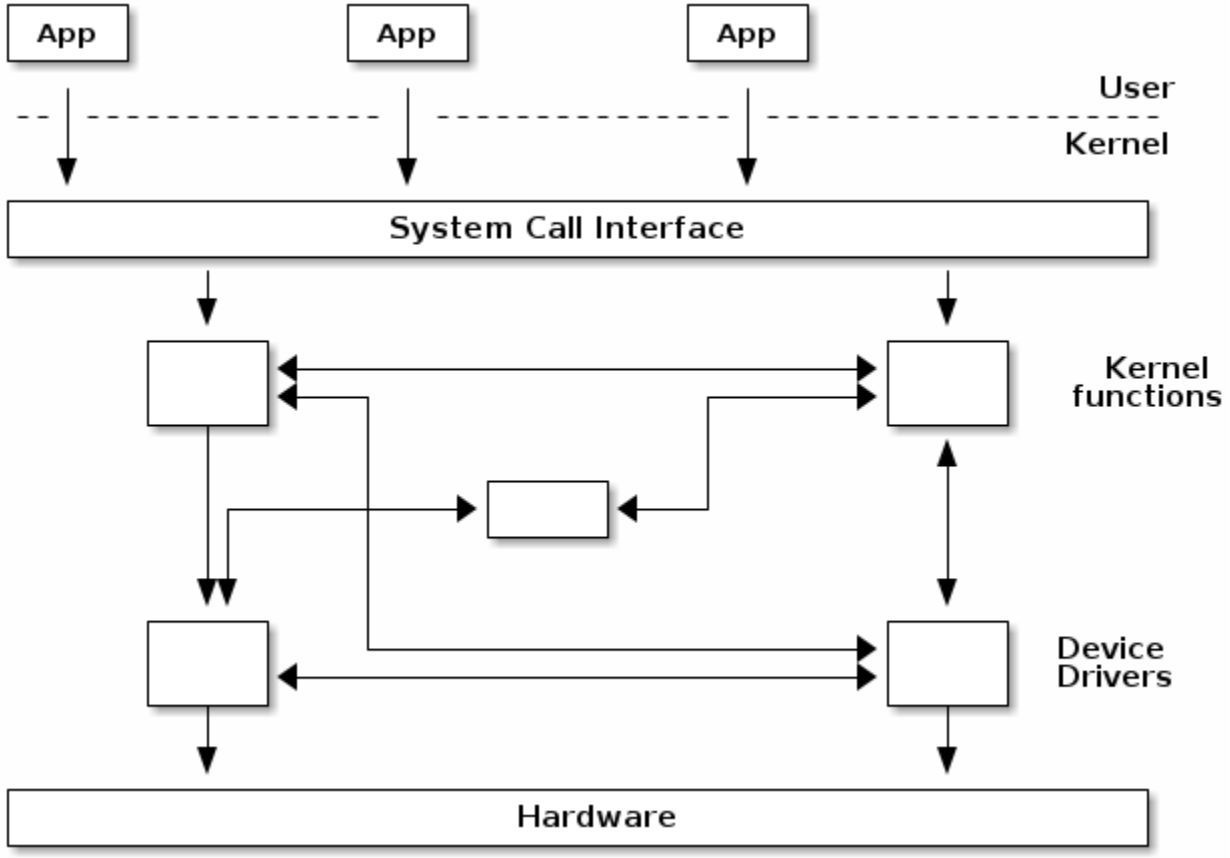
https://github.com/torvalds/linux

initramfs_data.S [assembler source file]

```
.section .init.ramfs,"a"
__irf_start:
.incbin "usr/initramfs_inc_data"
__irf_end:
.section .init.ramfs.info,"a"
.globl __initramfs_size
__initramfs_size:
#ifdef CONFIG_64BIT
        .quad __irf_end - __irf_start
#else
        .long __irf_end - __irf_start
#endif
```

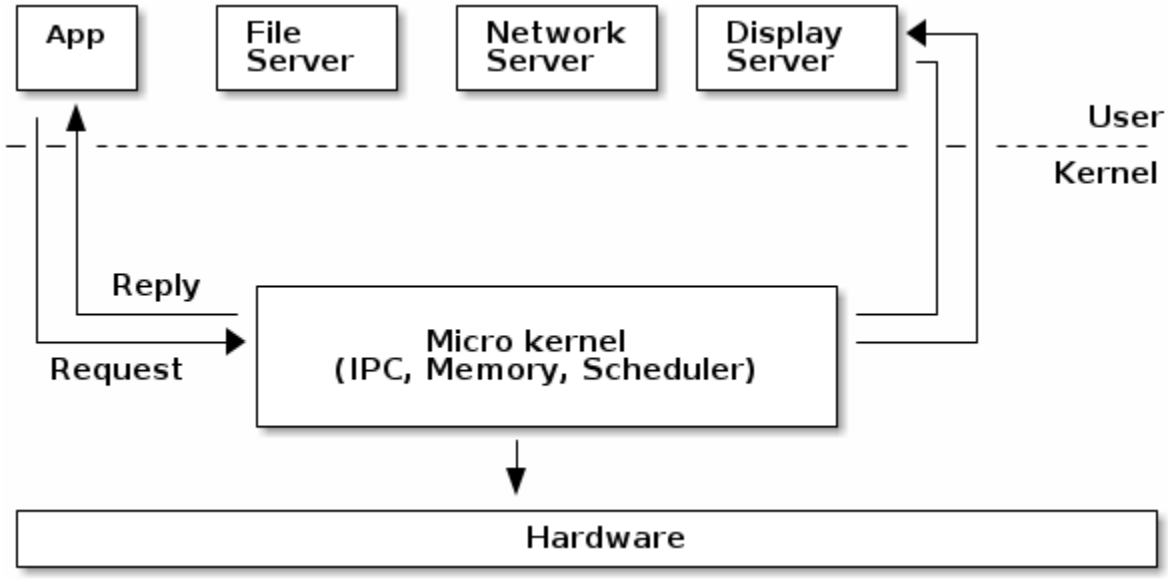
Monolithic Kernel

There is no access protection between the various kernel subsystems and where public functions can be directly called between various subsystems.



Micro-kernel

Large parts of the kernel are protected from each-other, usually running as services in user space. Because significant parts of the kernel are now running in user mode, the remaining code that runs in kernel mode is significantly smaller, hence micro-kernel term.



Micro-kernels vs monolithic kernels

Monolithic kernels can also be modular and there are several approaches that modern monolithic kernels use toward this goal:

- Components can enabled or disabled at compile time
- Support of loadable kernel modules (at runtime)
- Organize the kernel in logical, independent subsystems
- Strict interfaces but with low performance overhead: macros, inline functions, function pointers

There is a class of operating systems that (used to) claim to be hybrid kernels, in between monolithic and micro-kernels (e.g. Windows, Mac OS X). However, since all of the typical monolithic services run in kernel-mode in these operating systems, there is little merit to qualify them other than monolithic kernels.

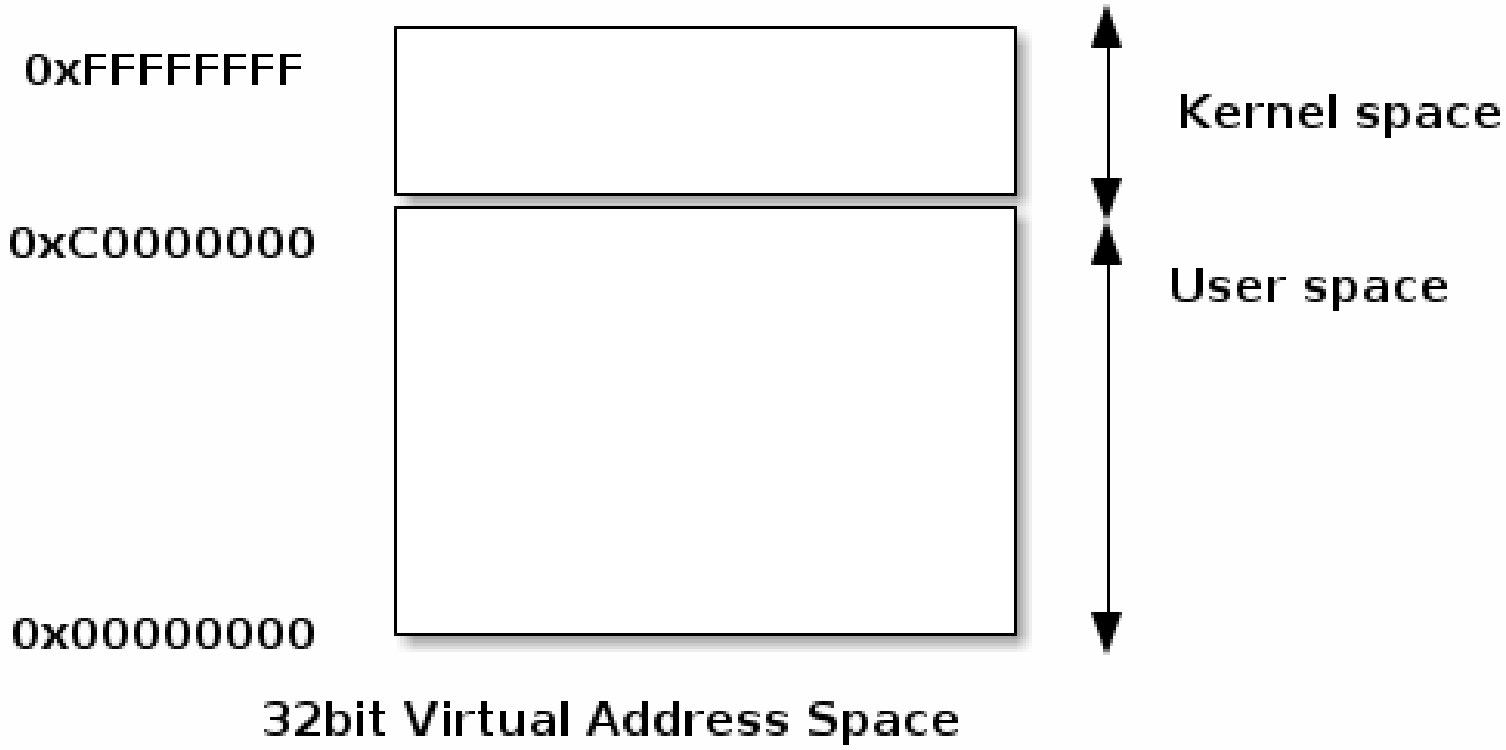
Address Space

The address space term is an overload term that can have different meanings in different contexts.

- The physical address space refers to the way the RAM and device memories are visible on the memory bus.
- The physical address space refers to the way the RAM and device memories are visible on the memory bus.
    - process (address) space [the "memory view" of processes. It is a continuous area that starts at zero]
    - kernel (address) space.

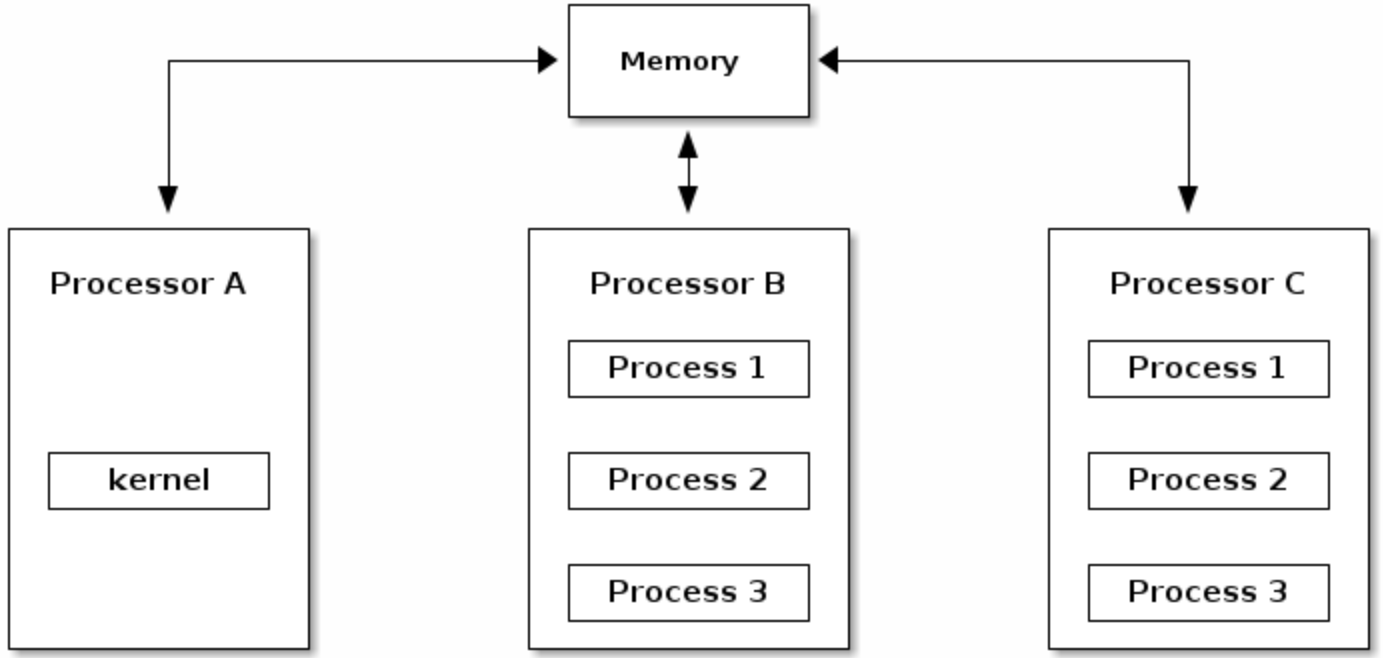
User and kernel sharing the virtual address space

A typical implementation for user and kernel spaces is one where the virtual address space is shared between user processes and the kernel.



Asymmetric MultiProcessing (ASMP)

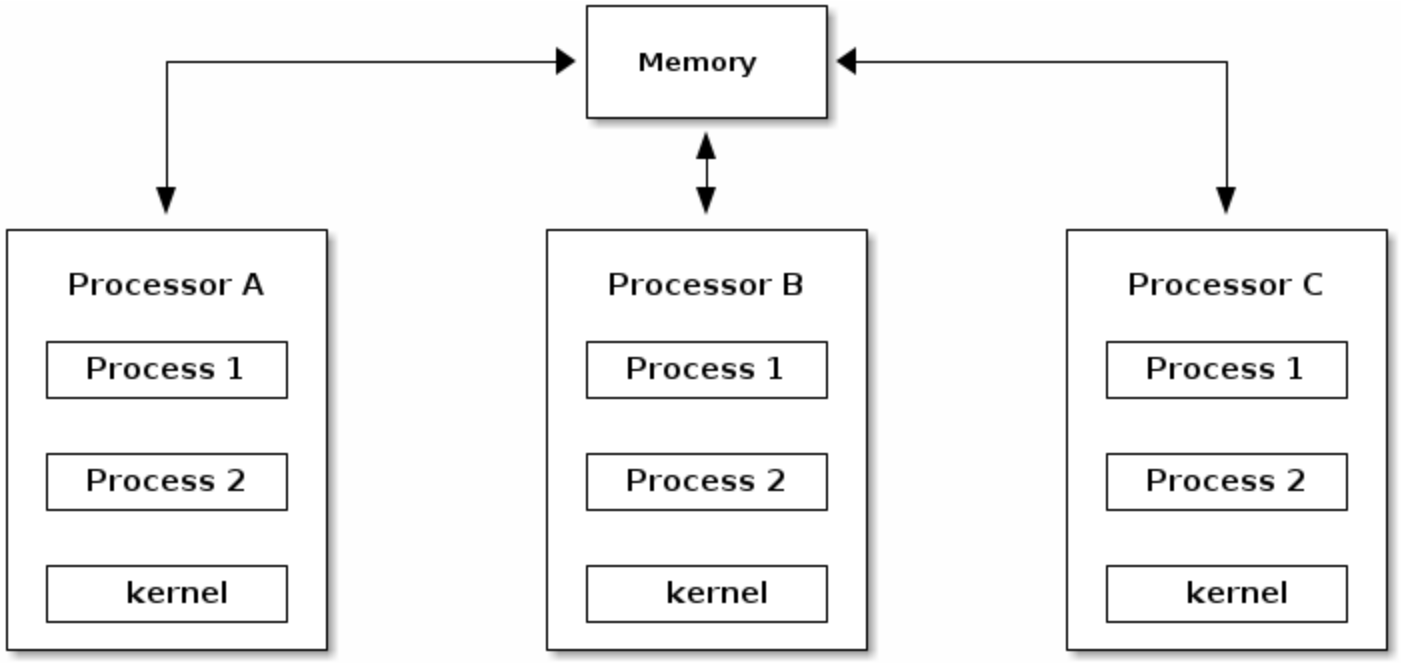
- the kernel throughput (e.g. system calls, interrupt handling, etc.) does not scale with the number of processors and hence typical processes frequently use system calls.
- The scalability of the approach is limited to very specific systems



Symmetric MultiProcessing (SMP)

Runs on any of the existing processors, just as user processes. This approach is more difficult to implement, because it creates race conditions in the kernel if two processes run kernel functions that access the same memory locations.

In order to support SMP the kernel must implement synchronization primitives (e.g. spin locks) to guarantee that only one processor is executing a critical section.



Overview of Linux Kernel

Linux Development Model

- The Linux kernel is one the largest open source projects in the world with thousands of developers contributing code and millions of lines of code changed for each release.
- It is distributed under the GPLv2 license.
- Releases at fixed intervals of time (usually 3 - 4 months)
- Merge windows two weeks

Overview of Linux Kernel

Maintainer Heirarchy

In order to scale the development process, Linux uses a hierarchical maintainership model:

- Linus Torvalds is the maintainer of the Linux kernel and merges pull requests from subsystem maintainers

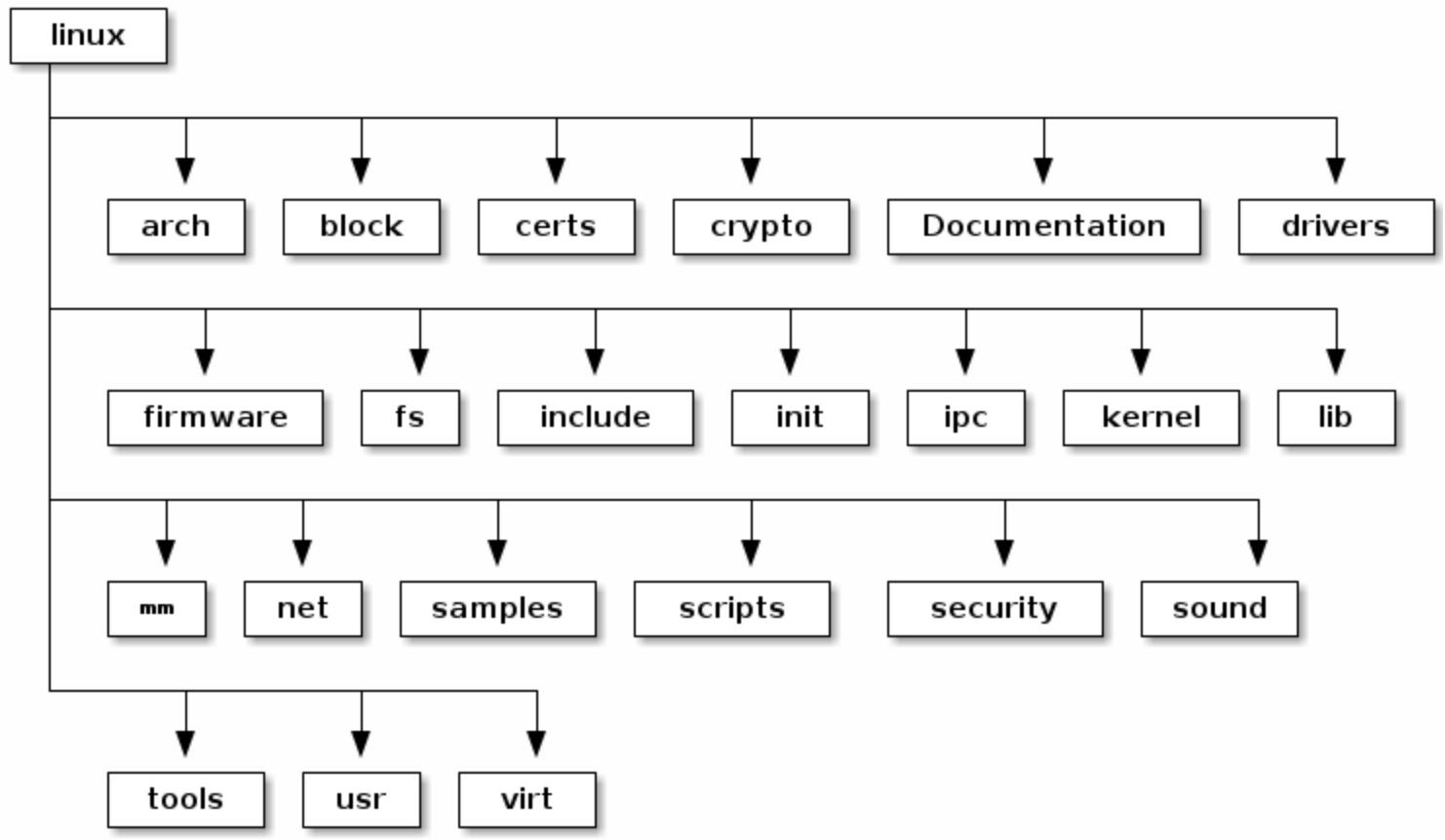
Each maintainer has its own git tree, e.g.:

- Linux Torvalds: git://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux-2.6.git
- David Miller (networking): git://git.kernel.org/pub/scm/linux/kernel/git/davem/net.git/

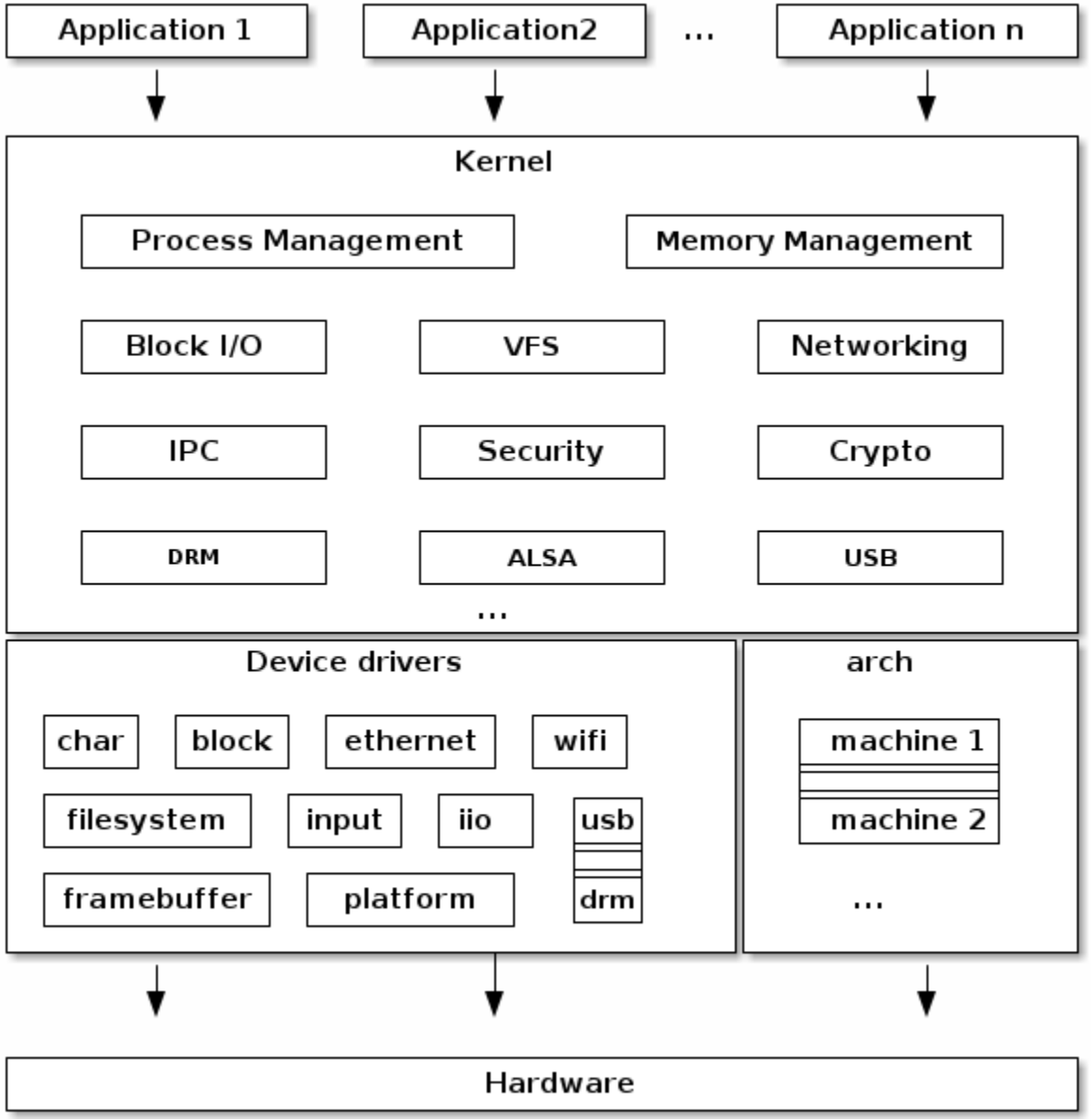
Each subsystem may maintain a -next tree where developers can submit patches for the next merge window

Overview of Linux Kernel

Linux source code layout



Linux kernel architecture



We are now going to explore a linux system.