Drivers and the Kernel

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? (?-2018)

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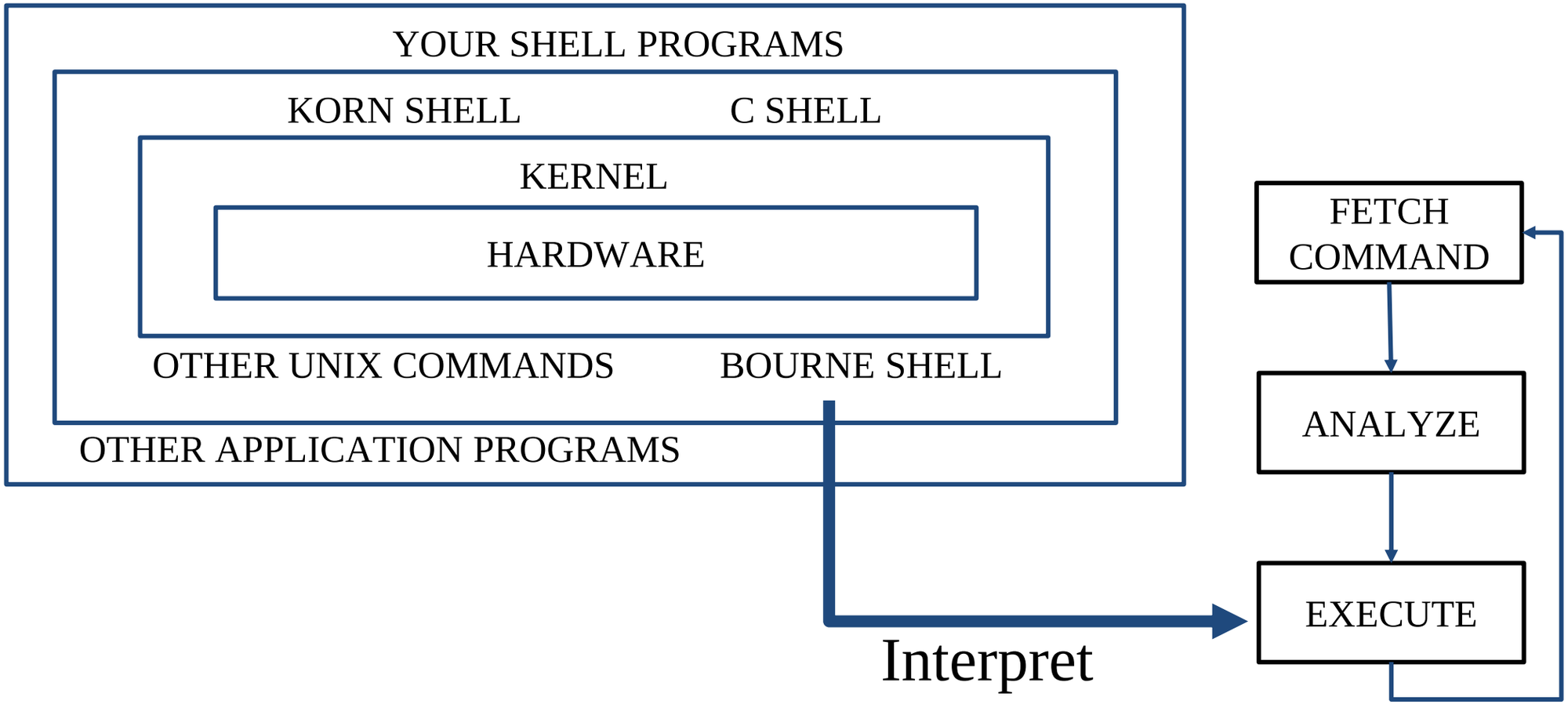
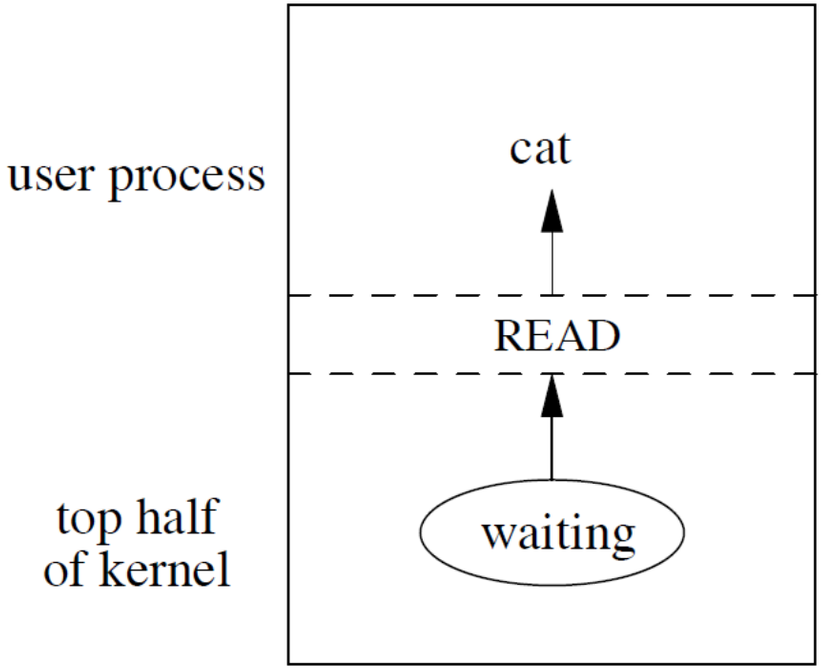
Introduction – UNIX Kernel and Shell

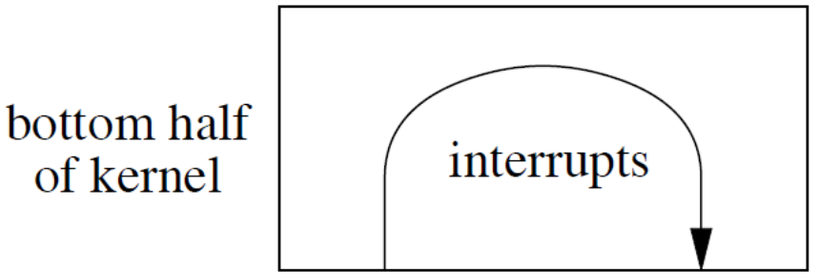


Run-time structure of the kernel



Preemptive scheduling;
cannot block;
runs on user stack in user address space.

Runs until blocked or done;
can block to await a resource;
runs on per-process kernel stack.

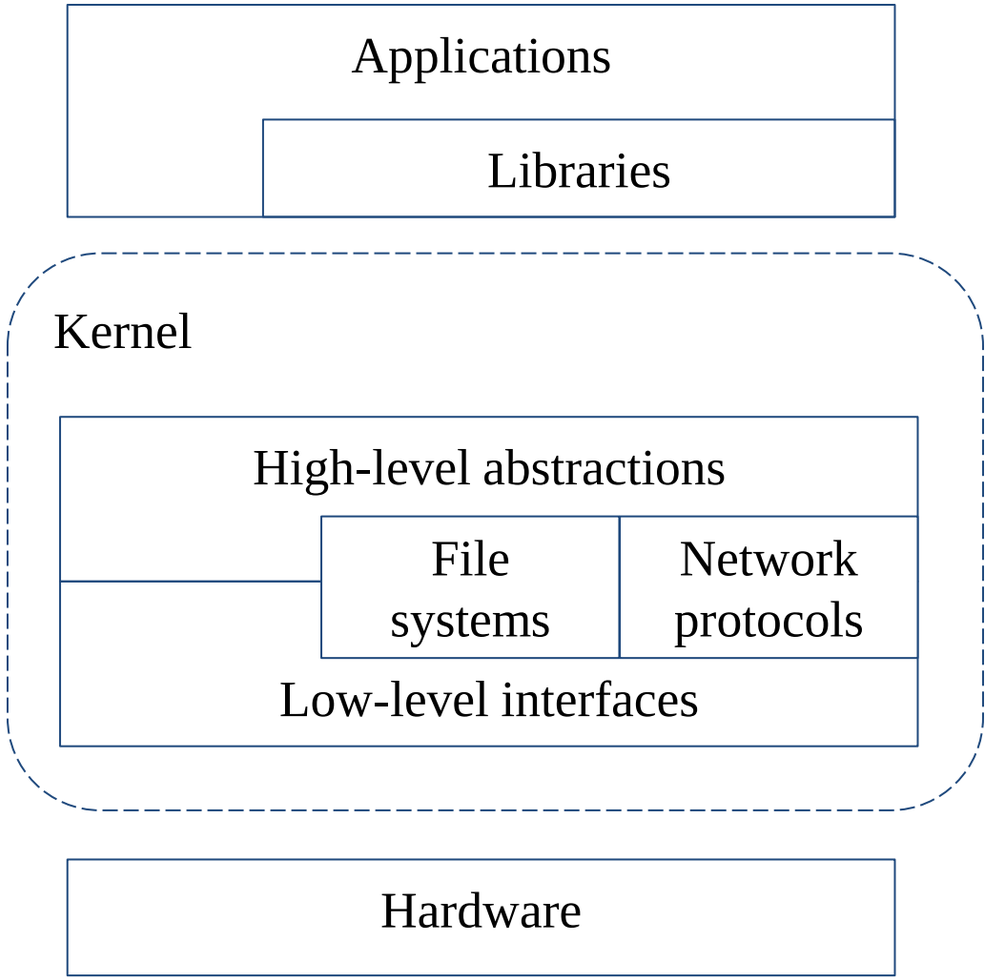


Scheduled by interrupts;
can block to await a resource;
runs on per-interrupt kernel stack.

Figure 3.1 - Design and Implementation of the FreeBSD Operating System, The, 2nd Edition

Roles of Kernel

- Components of a UNIX System
  - User-level programs
  - Kernel
  - Hardware
- Two roles of kernel (OS)
  - High-level abstractions
    - Process managements
      - Time sharing, memory protect
    - File system management
    - Memory management
    - I/O management
  - Low-level interfaces
    - drivers



Kernel I/O structure

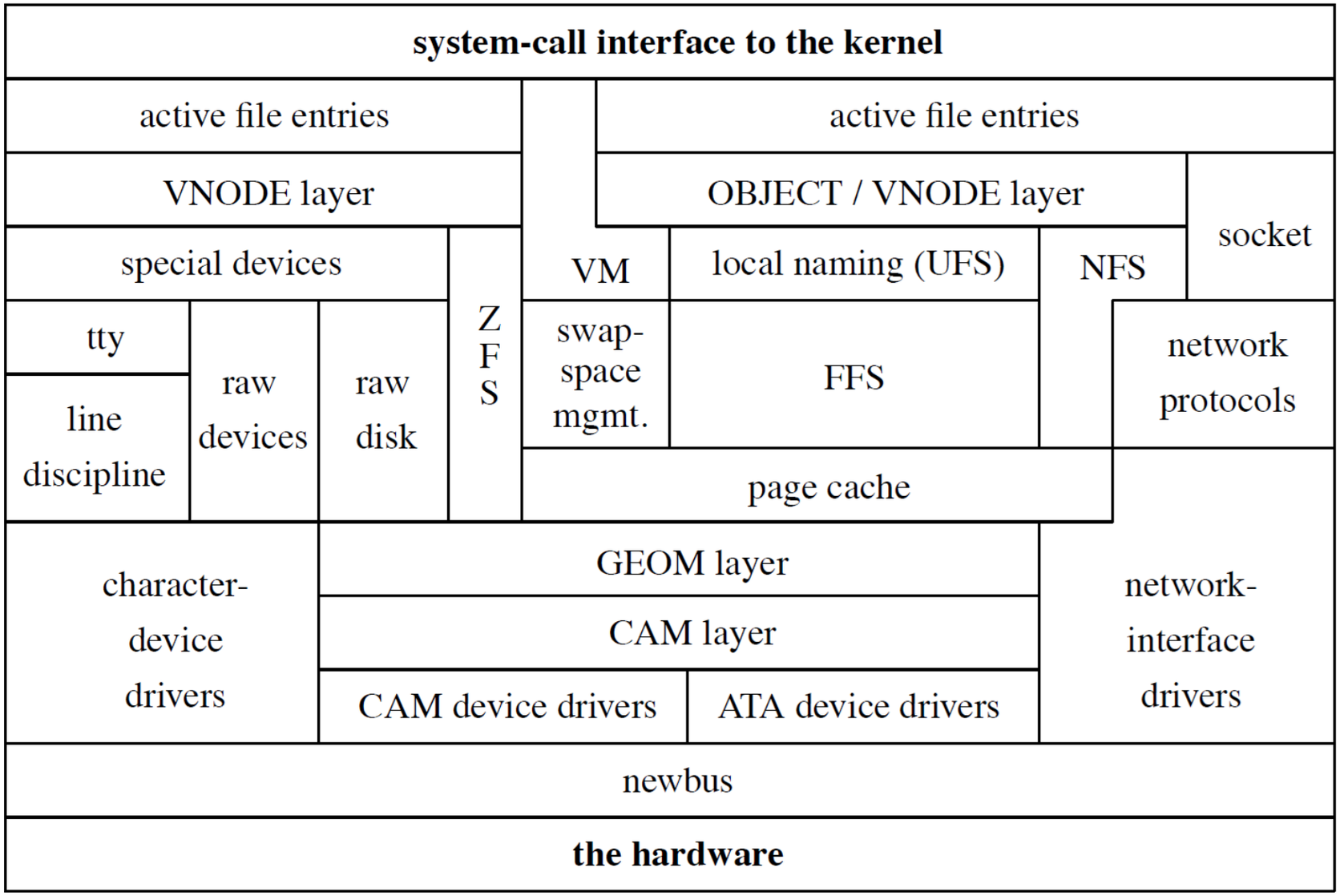
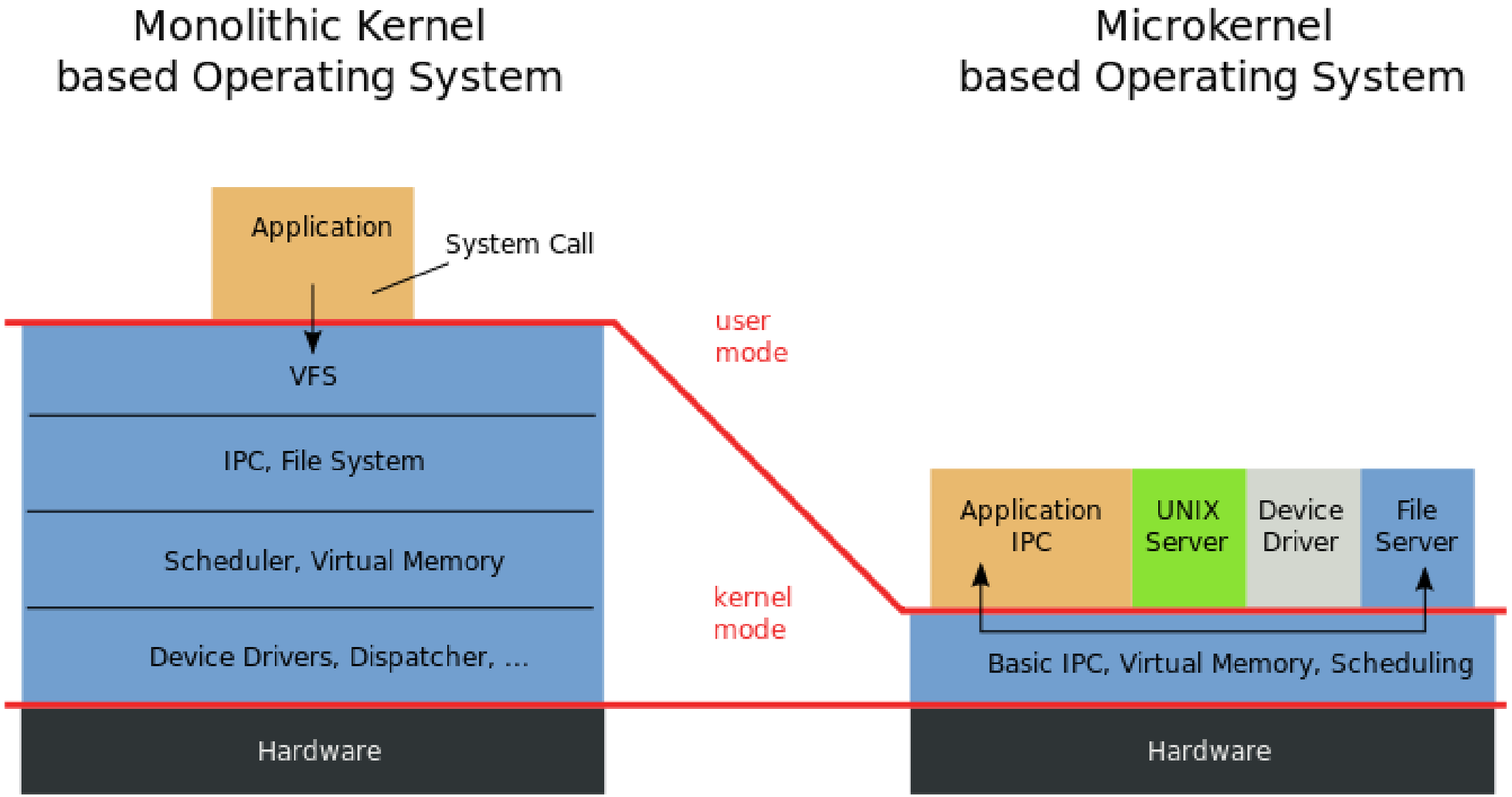


Figure 7.1 - Design and Implementation of the FreeBSD Operating System, The, 2nd Edition

Kernel Types



https://en.wikipedia.org/wiki/Microkernel

Kernel Types

Concept of being modulized …
only provides essential functionalities;
Put other sophisticated functions into user level
e.g., I/O management in the user level

- increase scalability and less difficult in maintenance
- How to communicate?
  -> Message passing – less efficient

- Two extreme types
  - **Microkernel**
    - **Provide only necessarily, compact and small functionalities**
    - **Other functions is added via well-defined interfaces**
  - **Monolithic kernel (a huge kernel - e.g., UNIX)**
    - **Whole functionalities in one kernel, tightly integrated**
- Modern OS
  - Solaris
    - **Completely modular kernel**
    - **Load necessary module when it is needed**
  - BSD/Linux-derived system
    - **Much of the kernel's functionality is contained in modules**

Monolithic kernel developing towards micro kernel (being more modulized),
but without IPC (message passing) problem

Kernel related directories

- Source directory and location

System	Source Directory	Kernel file
FreeBSD	/usr/src/sys	/kernel (< 4.x) /boot/kernel/kernel (>= 5.x)
Linux	/usr/src/linux	/vmlinuz or /boot/vmlinuz
Solaris	-	/kernel/unix
SunOS	/usr/kvm/sys	/vmunix

Why customize kernel?

GENERIC: with most common devices and feature supported

- The GENERIC kernel is for general purpose
- Tailoring kernel to match site situation
  - Purge unnecessary kernel devices and options
  - Add functionalities that you want

kernel image -> memory usage

- Patching
  - Remedy security hole of kernel implementation
- Fine-tuning system performance
  - Such as adjusting important system parameters
- Add device drivers or features
- Decrease boot time
- Lower memory usage

Build and install FreeBSD Kernel

- Kernel source
  - /usr/src/sys
- Kernel configuration file
  - /usr/src/sys/<ARCH>/conf
    - GENERIC
    - LINT (generated by `make LINT` under this directory)
    - NOTES (all options with comments)
- Steps to build a new kernel
  - Edit /usr/src/sys/<ARCH>/conf/<KERNCONF>
    - For example, save a configuration file named as SABSD
  - $ cd /usr/src ;
  - $ make –j<N> buildkernel KERNCONF=SABSD
  - $ make installkernel KERNCONF=SABSD

https://freebsdfoundation.org/updating-freebsd-from-git/
https://docs.freebsd.org/en/books/handbook/kernelconfig/#kernelconfig-building

To Build a FreeBSD Kernel…

- What to Choose?
- What to Load?
- Option Settings?
- Device Drivers?

Finding the system hardware (1)

- Before venturing into kernel configuration
  - Get an inventory list of the machine’s hardware
    - Focus on what you want to use
  - Microsoft's **Device Manager**
- dmesg
  - dmesg(8) - display the system message buffer
  - cat /var/run/dmesg.boot

```
vtnet0: <VirtIO Networking Adapter> on virtio_pci0
vtnet0: Ethernet address: xx:xx:xx:xx:xx:xx
vtnet0: netmap queues/slots: TX 8/256, RX 8/128
vtnet0: link state changed to UP
```

Finding the system hardware (2)

- pciconf & man page
  - man -k atheros
    - Find drivers from company name
  - pciconf -l & man
    - List all attached devices

```
ehci1@pci0:0:29:7:      class=0x0c0320 card=0x3a3a8086 chip=0x3a3a8086 rev=0x00 hdr=0x00
pcib10@pci0:0:30:0:     class=0x060401 card=0x244e8086 chip=0x244e8086 rev=0x90 hdr=0x01
isab0@pci0:0:31:0:      class=0x060100 card=0x3a168086 chip=0x3a168086 rev=0x00 hdr=0x00
ahci0@pci0:0:31:2:      class=0x010601 card=0x3a228086 chip=0x3a228086 rev=0x00 hdr=0x00
none8@pci0:0:31:3:      class=0x0c0500 card=0x3a308086 chip=0x3a308086 rev=0x00 hdr=0x00
em0@pci0:3:0:0:         class=0x020000 card=0x00008086 chip=0x10d38086 rev=0x00 hdr=0x00
em1@pci0:2:0:0:         class=0x020000 card=0x00008086 chip=0x10d38086 rev=0x00 hdr=0x00
```

Finding the system hardware (3)

- pciconf
  - pciconf -lv

```
none3@pci0:0:20:3:      class=0x028000 card=0x00348086 chip=0x9df08086 rev=0x30 hdr=0x00
    vendor     = 'Intel Corporation'
    device     = 'Cannon Point-LP CNVi [Wireless-AC]'
    class      = network
```

```
em0@pci0:0:31:6:        class=0x020000 card=0x20748086 chip=0x15be8086 rev=0x30 hdr=0x00
    vendor     = 'Intel Corporation'
    device     = 'Ethernet Connection (6) I219-V'
    class      = network
    subclass   = ethernet
nvme0@pci0:109:0:0:     class=0x010802 card=0x2263c0a9 chip=0x2263c0a9 rev=0x03 hdr=0x00
    vendor     = 'Micron/Crucial Technology'
    device     = 'P1 NVMe PCIe SSD'
    class      = mass storage
    subclass   = NVM
```

May not support by GENERIC because of size, license, or…

Finding the system hardware (4)

- Man page for devices
  - man [device]
  - e.g.: man em

```
NAME
     em – Intel(R) PRO/1000 Gigabit Ethernet adapter driver

SYNOPSIS
     To compile this driver into the kernel, place the following line in you
     kernel configuration file:

           device em

     Alternatively, to load the driver as a module at boot time, place the
     following line in loader.conf(5):

           if_em_load="YES"
```

Configuration file of FreeBSD Kernel

- Each line is a control phrase
  - Keyword + arguments
  - config(5), config(8)

Keyword	Function	Example
machine	Sets the machine architecture	amd64 or arm64
cpu	Sets the CPU type	HAMMER or ARM64
ident	Sets the name of the kernel	SABSD
(no)options	Sets various compile-time options	INET, INET6
device	Declares devices	em, ix
envvar	Set compiled-in env prepared for loader(8)	hint.psm.0.irq=“12"
(no)makeoptions	Set options for generated makefile	DEBUG=g

amd64/conf/GENERIC

```
cpu             HAMMER
ident           GENERIC
makeoptions     DEBUG=-g            # Build kernel with gdb(1) debug symbols
options         SCHED_ULE           # ULE scheduler
options         INET                # InterNETworking
device          em
```

https://docs.freebsd.org/en/books/handbook/kernelconfig/#kernelconfig-config

Kernel backup

- Kernel file locations
  - Put in the /boot directory
  - /boot/kernel/kernel, /boot/kernel.old/kernel

Old kernel is automatically moved to kernel.old when you're installing the new kernel

- If something goes wrong
  - ok mode !
    - unload kernel; load kernel.old/kernel
    - load kernel modules
  - mv /boot/kernel /boot/kernel.bad

https://docs.freebsd.org/en/books/handbook/kernelconfig/#kernelconfig-trouble

Ok mode


```
Type '?' for a list of commands, 'help' for more detailed help.
OK unload kernel
OK load /boot/kernel.old/kernel
/boot/kernel.old/kernel text=0x34a274 data=0x40df4+0x72d84 syms=[0x4+0x483e0+0x4
+0x64b7e]
OK _
```

Or “enable modules” in the ok mode..

Tuning the FreeBSD Kernel

- sysctl(8) command
  - Dynamically set or get kernel parameters
  - All changes made by sysctl will be lost across reboot
  - Use sysctl to tune the kernel and test it, then recompile the kernel

    The other way is to write your settings into /etc/sysctl.conf…
  - Format:
    - `% sysctl [options] name[=value] …`
  - E.g.:
    - `% sysctl -a` `# list all kernel variables`
    - `% sysctl -d vfs.zfs.arc_max` `# print the description of the variable`
    - `% sysctl vfs.zfs.arc_max` `# print the value of the variable`
    - `% sudo sysctl vfs.zfs.arc_max=4294967296 # set (only root writable) value`
- tuning(7)

Kernel modules

- Kernel module location
  - /boot/kernel/*.ko
  - /boot/modules
- kldstat

```
zfs[/boot/kernel] -chiahung- kldstat
Id Refs Address    Size     Name
 1   15 0xc0400000 4abd60   kernel
 2    1 0xc08ac000 13b0fc   zfs.ko
 3    2 0xc09e8000 3d5c     opensolaris.ko
 4    2 0xc09ec000 16b84    krpc.ko
 5    1 0xc0a03000 8c48     if_le.ko
```

- Load/unload kernel modules
  - kldload(8), kldunload(8)
    - E.g., kldload if_em
- Examples in share/examples/kld

Procedure of Loading a Device Module

- Loading a device module
  1. pciconf -l for a device
  2. man vendor name for module name in BSD
  3. find the name in /boot/kernel/*.ko
  4. kldload [module name]
  5. Setup permanently by
     - **A. Recompile the kernel** or
     - **B. Add [module name]_enable="YES" in /boot/loader.conf** or
     - **C. Put to “kld_list” in /etc/rc.conf**
- **devmatch(8)**

Building Linux Kernel

- General procedure
  - Install kernel toolchain
  - Get source code from https://kernel.org
  - Extract to /usr/src/linux
  - make menuconfig
  - make –jN
  - make modules
  - make modules_install
  - make install
  - Check /boot/{initramfs.img,System.map,vmlinuz}
- Check the distribution specified method
  - Kernel package

Reference

- https://docs.freebsd.org/en/books/handbook/kernelconfig/#kernelconfig-config
- /usr/src/sys/<ARCH>/conf
  - NOTES -> machine dependent kernel configuration with comments
  - LINT
  - GENERIC
- "building kernel" of Linux distributions documents
  - https://kernel-team.pages.debian.net/kernel-handbook/ch-common-tasks.html#s-common-official
  - https://wiki.ubuntu.com/Kernel/BuildYourOwnKernel
  - https://wiki.archlinux.org/index.php/Kernel/Arch_Build_System
  - https://wiki.centos.org/HowTos/Custom_Kernel

Backup Slides

Kernel Module (c.)

- Build & install kernel module from 3rd party
- DKMS (Dynamic Kernel Module Support)