Lecture 2
Operating Systems

CoSc2043 – Network and System Administration

Topics

1. What is a kernel?
2. Kernel history and versions
3. Kernel source code
4. Kernel modules
5. Building a custom kernel
6. Operating System, Kernel
7. Bootstrapping

8. System processes, Startup Scripts & Run Levels
9. Boot Configuration and Troubleshooting
10. Important user: superuser, daemon
11. System Shutdown

What is an OS kernel?

Program that is always running.

- Manages resources.
- Provides services.

Layering

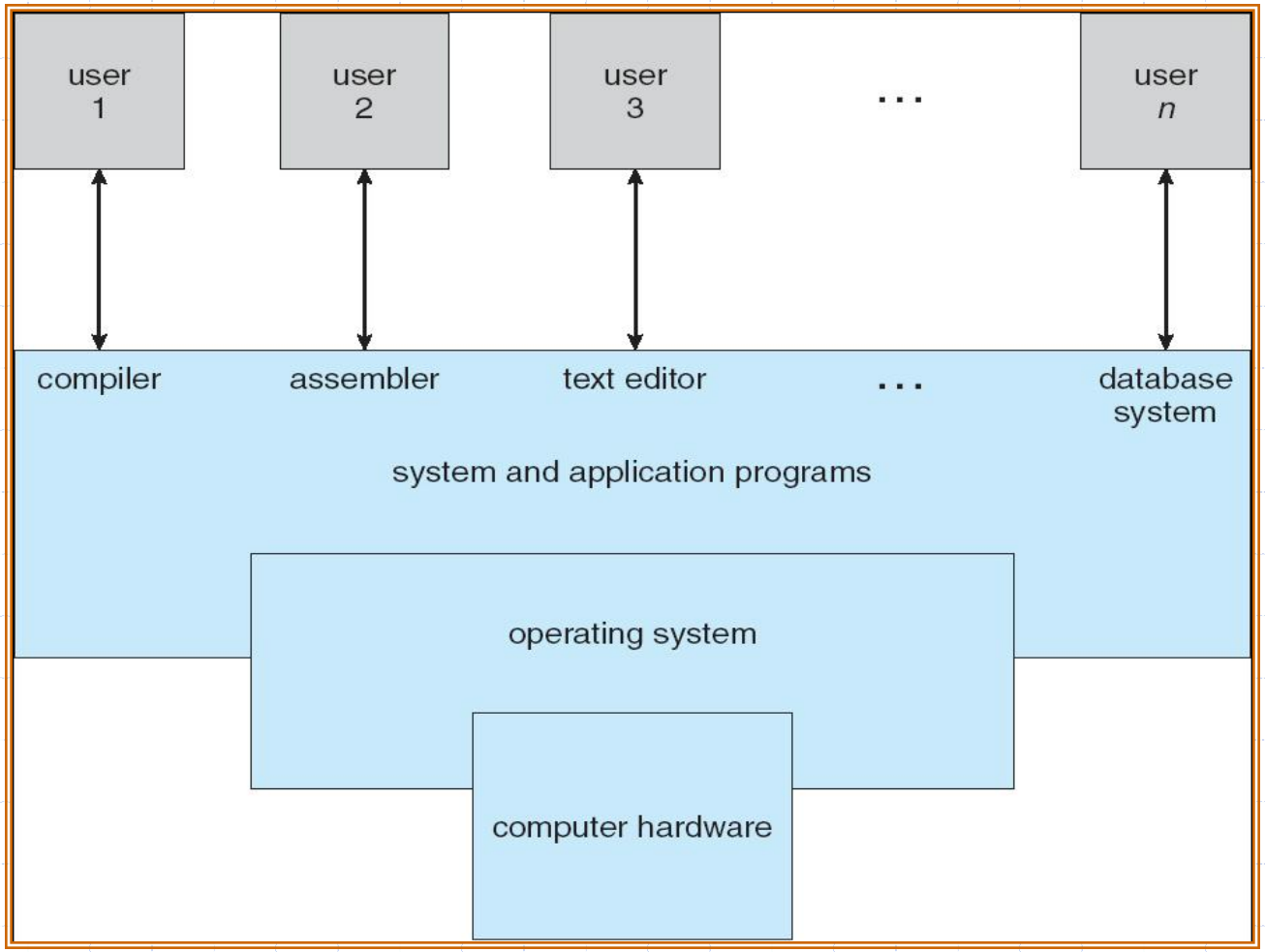
- Layer between programs and hardware.
- Layer between users (multiuser OS).
- Layer between programs (multitasking OS).

Examples of Operating Systems

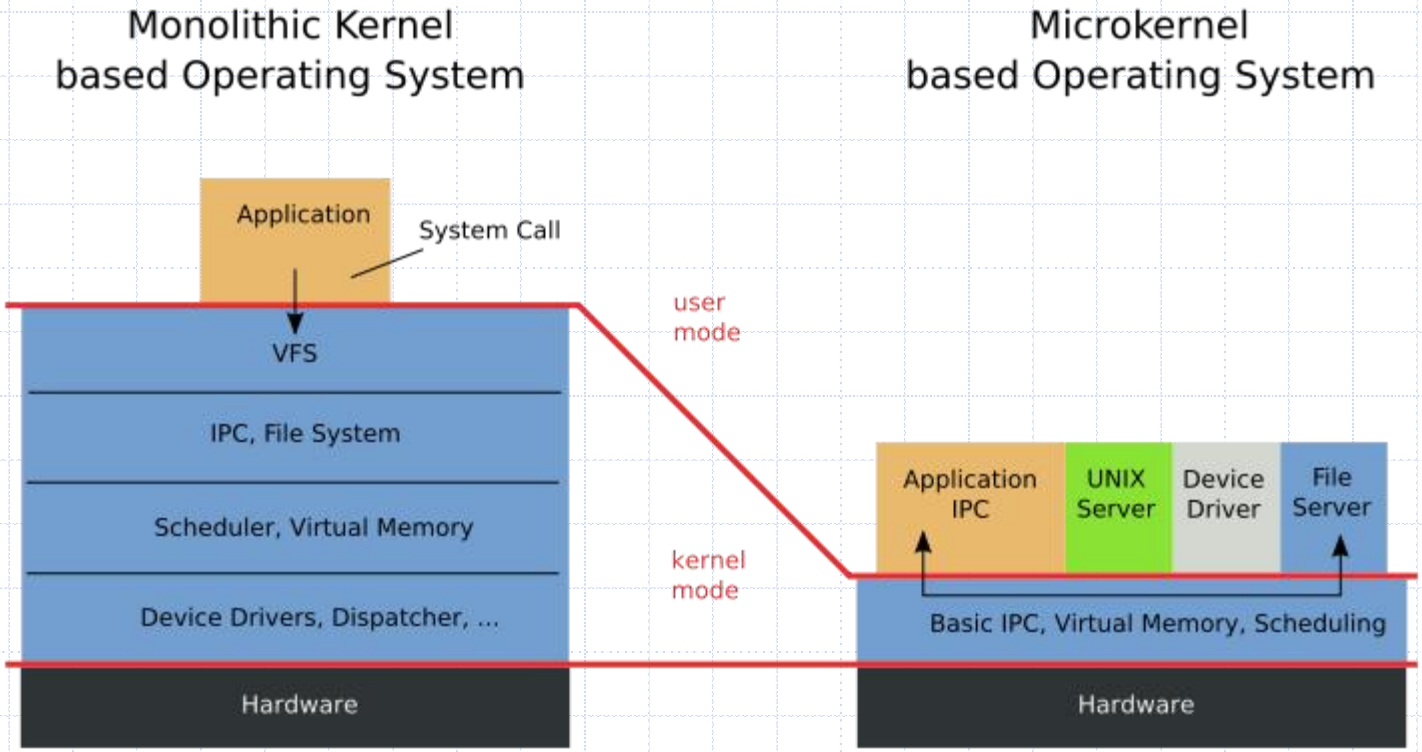
- DOS - Disk Operating System
- Windows
- MacOS
- Unix – Linux

Unix – Linux: originally created with a command-line interface, but recently have added GUI enhancements.

What is an OS kernel?



Monolithic vs. Microkernels



Source:http://en.wikipedia.org/wiki/Microkernel

Resource Management

- Allocation
  - Allocates finite resources among competing processes.
  - CPU, memory, disk, network
- Protection
  - Prevents processes from interfering with each other.
- Reclamation
  - Voluntary at runtime; automatic at termination.
- Virtualization
  - Provides illusion of private unshared resources
  - Timeshared CPU, Virtual Memory, Virtual Machines

What is the Linux kernel?

- Free open source UNIX-compatible kernel.
  - Created by Linus Torvalds.
  - Developed by thousands across the world.
  - Coordinated via linux-kernel mailing list.

Kernel History

0.01	First version released by Linus (1991).
1.0	First release (x86 only) in 1994.
1.2	Supports other CPUs (Alpha, MIPS) in 1995.
2.0	SMP support, more architectures (1996).
2.2	Efficient SMP, more hardware support (1999).
2.4	LVM, Plug-n-Play, USB, etc. (2001).
2.6	Scalability (embedded, NUMA, PAE, sched), kernel pre-emption, User-mode linux (2003).

Version Numbering: A.B.C.D

- A: Major version
  - Changed twice: 1.0 (1994), 2.0 (1996)
- B: Minor version
  - Even numbers are stable releases
  - Odd numbers are development releases
- C: Minor revision
  - Not so minor in 2.6 as development continues.
- D: Bug-fix / security patch release
  - First occurred with NFS bug in 2.6.8.1
  - Official policy as of 2.6.11

Kernel Versions

- mm: Andrew Morton tree
  - New patches, almost ready for distribution.
- ac: Alan Cox tree
- Distribution trees
  - RedHat
  - Mandrake
  - Debian
  - Gentoo, etc.

Identifying the Running Kernel

```
> uname
Linux
> uname -r
2.6.10
> cat /proc/version
Linux version 2.6.10(jw@csc660)
  (gcc version 3.3.5) #3 Sun
  Dec 25 10:22:50 EST 2005
```

Investigating the Running Kernel: /proc

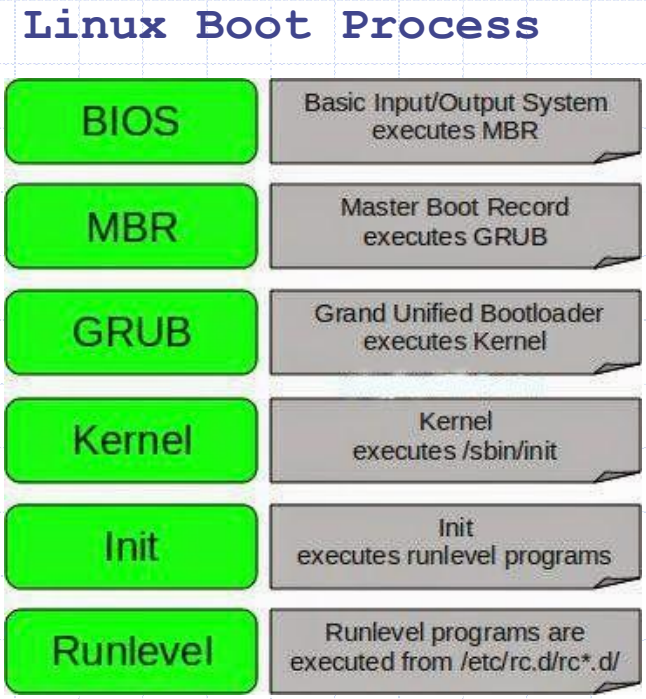
###: directory for each running process
cpuinfo: processor information
devices: supported hardware
diskstats: disk performance statistics
meminfo: memory usage information
modules: linux kernel modules
net: directory of network information
partitions: linux disk partitions
swaps: swap files/partitions in use by kernel
self: link to ### directory for current process

Bootstrapping

- Starting the system
- Process of loading kernel into memory
- Boot Modes
  - Normal
  - Single User
  - Rescue (on CD)

Boot Process

- Load & initialize kernel
- Detect & configure devices
- Fork system processes
- (Stop if Single User mode)
- Run startup scripts
- Start multiuser operations



Source: https://icssindia.in/linux-boot-process/

Boot Loader

- ROM loads boot program from disk
- Boot program finds/loads kernel
  - Checks available memory
  - Initializes kernel internal data structures
- GRand Unified Bootloader (GRUB)
  - Can boot multiple OS
  - Boot options can be edited at boot
- Linux Boot Loader (LILO)
  - Can boot multiple OS
  - Single User: **`linux single`**
  - Rescue: **`linux rescue`**

/etc/grub.conf

```
default=1
timeout=10
splashimage=(hd0,5)/boot/grub/splash.xpm.gz
title Fedora Core - N321 (2.6.11-1.1369_FC4)
        root (hd0,5)
        kernel /boot/vmlinuz-2.6.11-1.1369_FC4 ro
        root=LABEL=/1 rhgb quiet initrd
                /boot/initrd-2.6.11-1.1369_FC4.img
title Windows XP
        rootnoverify (hd0,0)
        chainloader +1
title Red Hat Enterprise WS (2.6.9-11.EL)
        rootnoverify (hd0,4)
        kernel /boot/vmlinuz-2.6.9-11.EL ro
        root=LABEL=/ rhgb quiet initrd
                /boot/initrd-2.6.9-11.EL.img
```

System Processes

- A *process* is an instance of a program in execution
- BSD Systems
  - **`swapper`** – PID 0
  - **`init`** – PID 1
  - **`pagedaemon`** – PID 2
- AT&T SVR4
  - **`sched`** – PID 0 (invisible under RedHat)
  - **`init`** – PID 1
  - **`/etc/inittab`**

Startup Scripts

- Hostname
- Timezone
- Check the hard drives
- Mount the hard drives
- Remove files from /tmp
- Configure network interfaces
- Start daemons and network services

BSD `/etc/rc*` Scripts

- `/etc/rc`
  - Master script
  - Executes supplemental scripts
- Example supplemental scripts (freeBSD)
  - `/etc/defaults/rc.conf`
  - `/etc/rc.conf`
  - `/etc/rc.conf.local`

/etc/inittab

- Initializes system for use
- Format: **`id:rl:action:process`**
  - **`id`**: uniquely identifies entry
  - **`rl`**: Run level entry applies to
  - **`action`**: How to execute process
  - **`process`**: process command line
- Ex: Setting the default Runlevel:

  `id:3:initdefault:`

Startup Run Levels

Solaris	RedHat	Mode
1 (S)	1 (S)	Single user
2	2	Multiuser (no networking)
3	3	Full Multiuser
4	4	Unused
5		Power-off shutdown
	5	X11
6	6	Reboot
0	0	Halt

Event file directives

- exec
- script
- start on <event>
- stop on <event>
- daemon
- respawn
- service

“Events”

- control-alt-delete
- power-status-changed
- startup
- runlevel <runlevel>
- started <job>
- stopped <job>

Process information

```
> ls -alF /proc/self
dr-xr-xr-x  2 jw jw 0 2005-12-29 13:46 attr/
-r--------  1 jw jw 0 2005-12-29 13:46 auxv
-r--r--r--  1 jw jw 0 2005-12-29 13:46 cmdline
lrwxrwxrwx  1 jw jw 0 2005-12-29 13:46 cwd -> /proc/20041/
-r--------  1 jw jw 0 2005-12-29 13:46 environ
lrwxrwxrwx  1 jw jw 0 2005-12-29 13:46 exe -> /bin/bash*
dr-x------  2 jw jw 0 2005-12-29 13:46 fd/
-r--r--r--  1 jw jw 0 2005-12-29 13:46 maps
-rw-------  1 jw jw 0 2005-12-29 13:46 mem
-r--r--r--  1 jw jw 0 2005-12-29 13:46 mounts
lrwxrwxrwx  1 jw jw 0 2005-12-29 13:46 root -> //
-r--r--r--  1 jw jw 0 2005-12-29 13:46 stat
-r--r--r--  1 jw jw 0 2005-12-29 13:46 statm
-r--r--r--  1 jw jw 0 2005-12-29 13:46 status
dr-xr-xr-x  3 jw jw 0 2005-12-29 13:46 task/
-r--r--r--  1 jw jw 0 2005-12-29 13:46 wchan
```

Process information

```
> cd /proc/self
> cat cmdline ; echo
-bash
> cat environ | tr '\0' '\n' | head -8
ENV_SET=1
MANPATH=/usr/local/man:/usr/man:/usr/share/man
PATH=/usr/ucb:/usr/bin:/bin:/sbin:/usr/sbin:/usr/local/bin
TERM=xterm
SHELL=/bin/bash
EDITOR=vim
VISUAL=vim
PAGER=less
> ls -l fd
total 4
lrwx------  1 jw jw 64 2005-12-29 13:50 0 -> /dev/pts/3
lrwx------  1 jw jw 64 2005-12-29 13:50 1 -> /dev/pts/3
lrwx------  1 jw jw 64 2005-12-29 13:50 2 -> /dev/pts/3
```

The Linux Kernel Archives

Welcome to the Linux Kernel Archives. This is the primary site for the Linux kernel source, but it has much more than just Linux kernels.

Protocol	Location
HTTP	http://www.kernel.org/pub/
FTP	ftp://ftp.kernel.org/pub/
RSYNC	rsync://rsync.kernel.org/pub/

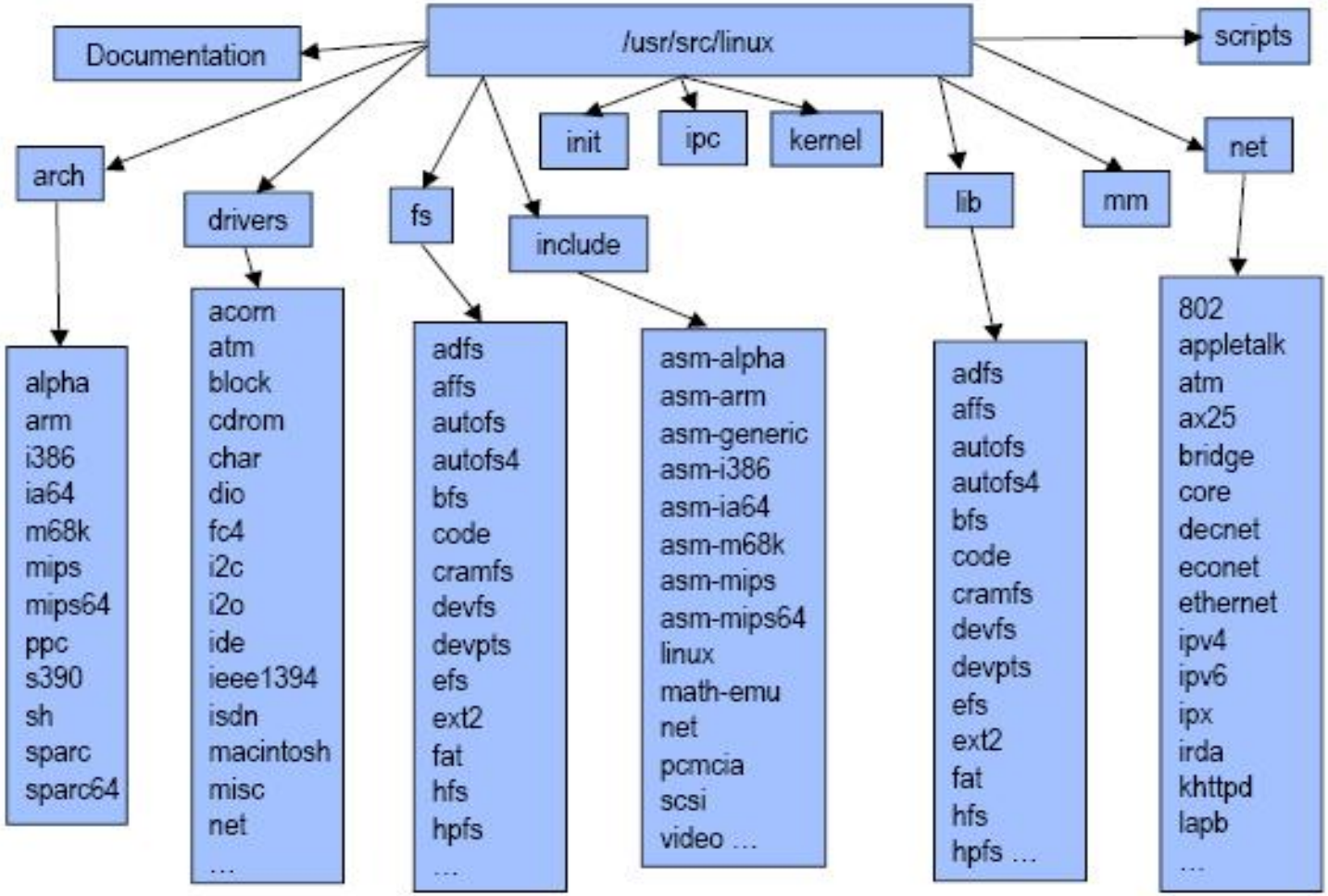
The latest stable version of the Linux kernel is:	**2.6.14.5**	2005-12-27 00:29 UTC	F	V	VI	C	Changelog
The latest prepatch for the stable Linux kernel tree is:	**2.6.15-rc7**	2005-12-25 03:39 UTC		V	VI	C	Changelog
The latest snapshot for the stable Linux kernel tree is:	**2.6.15-rc7-git3**	2005-12-29 08:01 UTC		V		C	
The latest 2.4 version of the Linux kernel is:	**2.4.32**	2005-11-16 19:13 UTC	F	V	VI	C	Changelog
The latest prepatch for the 2.4 Linux kernel tree is:	**2.4.33-pre1**	2005-12-29 16:18 UTC		V		C	Changelog
The latest 2.2 version of the Linux kernel is:	**2.2.26**	2004-02-25 00:28 UTC	F	V			Changelog
The latest prepatch for the 2.2 Linux kernel tree is:	**2.2.27-rc2**	2005-01-12 23:55 UTC		V	VI		Changelog
The latest 2.0 version of the Linux kernel is:	**2.0.40**	2004-02-08 07:13 UTC	F	V	VI		Changelog
The latest -ac patch to the stable Linux kernels is:	**2.6.11-ac7**	2005-04-11 18:36 UTC		V			
The latest -mm patch to the stable Linux kernels is:	**2.6.15-rc5-mm3**	2005-12-15 06:51 UTC		V			Changelog

F = full source, **V** = view patch, **VI** = view incremental, **C** = current changesets
Changelogs are provided by the kernel authors directly. Please don't write the webmaster about them.
Customize the patch viewer

Prepatches and Snapshots

- Prepatches
  - Alpha versions of the kernel, located in the testing/ subdirectory of kernel.org.
- Snapshots
  - Automatically created images of the kernel development tree. May not work or compile.

Linux Source Layout



Documentation

- Text files documenting various aspects of kernel
  - Can be very useful.
  - Not well organized.
  - Not always up to date.

What are Kernel Modules?

Parcels of code that can be dynamically inserted or removed from kernel at run time.

Why use Kernel Modules?

- Ease of maintenance
  - Compile kernel once.
  - Build, add, and remove modules afterwards.
- Ease of distribution
  - Compile single kernel for all machines.
  - Include drivers / options as modules.
  - Vendors can distribute drivers as modules.

Why not use kernel modules?

Performance

- There is a minor performance hit to using.
- Doesn't save RAM like dynamic user libraries, since there are no other kernels to share with.

Security

- If attacker can load module, can control kernel.
- Kernel mode rootkits control system invisibly
  - Hides attacker processes, files, network connections.
  - Runs backdoors, sniffers, etc. w/o starting processes.

What modules are loaded?

```
> lsmod | head
Module                  Size  Used by
vmnet                  31900  12
vmmon                 103584  0
proc_intf               4100  0
freq_table              4100  0
cpufreq_userspace       4572  0
cpufreq_ondemand        6172  0
cpufreq_powersave       1920  0
video                  16260  0
sony_acpi               6280  0
> head -3 /proc/modules
vmnet 31900 12 - Live 0xf8c3a000
vmmon 103584 0 - Live 0xf8c85000
proc_intf 4100 0 - Live 0xf8c2c000
```

Loading Kernel Modules

`modprobe name`

1. Lookup name

   Resolve aliases using `/etc/modprobe.conf`
2. Check dependencies

   `/lib/modules/version/modules.dep`

   Created by `depmod -a`
3. Load prerequisite modules with `insmod`
4. Load named module.

Module Licensing

- Module licenses
  - GPL
  - Dual BSD/GPL
  - Proprietary
- Why does licensing matter?
  1. So `modinfo` can tell users if kernel is free.
  2. So community can ignore bug reports including proprietary modules.
  3. So vendors can do likewise based on their own policies.

Rebuilding the Kernel

Why would you want to?

- Current kernel incompatible with your hardware.
- Current kernel has a bug on your system.
- Current kernel is missing a feature you need.
- Vendor kernel uses too much RAM/disk.

Which kernel to start with?

- Generic kernel from kernel.org.
- Vendor kernel source from your distribution.

Quick Kernel Build

1. Configure

   make xconfig

2. Build

   make –j3 bzImage

3. Build modules

   make -j3 modules && make modules_install

4. Install

   cp arch/i386/boot/bzImage /boot/bzImage-VERSION

   cp System.map /boot/System.map-VERSION

   vim /boot/grub/menu.lst

Configuring the Kernel

- kbuild: the kernel build system
- Kernel configuration

cp .config config.save	Backup old config file.
make mrproper	Clean up from prior builds.
vim .config	Make configuration changes.

- Interfaces

make config	Sequential questions on cli
make menuconfig	Ncurses-based menu interface
make xconfig	QT-based graphical interface
make gconfig	GTK-based graphical interface

.config

CONFIG_<NAME> options

y Include in kernel

n Don't include in kernel

m Build as a kernel module (not for all items)

```
# Linux kernel version: 2.6.10
CONFIG_X86=y
CONFIG_MMU=y
CONFIG_UID16=y
CONFIG_GENERIC_ISA_DMA=y
CONFIG_GENERIC_IOMAP=y
# Code maturity level options
CONFIG_EXPERIMENTAL=y
CONFIG_CLEAN_COMPILE=y
CONFIG_BROKEN_ON_SMP=y
CONFIG_LOCK_KERNEL=y
# General setup
CONFIG_LOCALVERSION=""
```

Important Options

- Code Maturity Level Options
  - Experimental: Allow alpha-quality drivers.
  - Clean compile: May not compile if set to “N”.
- Loadable Module Support
- Processor Type
  - Use `cat /proc/cpuinfo` to determine.
- Device Drivers
  - Use `lspci` to see what current kernel supports.
  - Networking configuration items located under here.
- Filesystems
- Kernel hacking
  - Stuff for us: kernel debugging features.

Building the Kernel

- Top kernel Makefile
  - Reads configuration from `.config`.
  - Updates `include/linux/version.h`
  - Sets symlink `include/asm` to our architecture.
  - Builds `include/linux/autoconf.h`
  - Builds `include/linux/config.h`
  - Invokes `make -f scripts/Makefile.build obj=subdir` for each subdirectory

Building the Kernel

- In each subdirectory, `Makefile.build` reads the `Makefile` in that subdirectory.
- Subdirectory Makefiles define
  - obj-y — Object files to build into kernel
  - obj-m — Object files to build into modules
- Example from `sched/Makefile`

```
obj-y     = sched.o fork.o panic.o
…
obj-$(CONFIG_SMP) += cpu.o spinlock.o
obj-$(CONFIG_UID16) += uid16.o
obj-$(CONFIG_MODULES) += module.o
```

Installing the Kernel

- Copy the kernel to `/boot`

```
cp arch/i386/boot/bzImage
  /boot/bzImage-VERSION
```

- Copy kernel symbols map to /boot

```
cp System.map /boot/System.map-VERSION
```

- Copy modules to `/lib/modules/VERSION`

```
make modules_install
```

- Modify the boot loader to boot new kernel.

```
vim /boot/grub/menu.lst
```

Configuring the Bootloader

- Bootloader is amall program residing on MBR.
  - BIOS loads MBR and starts program.
  - Bootloader copies rest of code from disk, then runs.
- GRUB: GRand Unified Bootloader
  - Configuration in `/boot/grub/menu.lst`
  - Example GRUB stanza:

```
title              Ubuntu, kernel 2.6.10-5-386
root               (hd1,0)
kernel             /boot/vmlinuz-2.6.10-5-386
  root=/dev/hde1 ro quiet splash
initrd             /boot/initrd.img-2.6.10-5-386
savedefault
boot
```

Important user: superuser

- superuser or root
- is a special user used for system administration purpose on Linux.
- sudo (superuser do)

Become a superuser in Linux using sudo command

Source: https://www.cyberciti.biz/faq/linux-login-as-super-user/

System Shutdown

- Turn off power – BAD!!!
- Reboot
  - `reboot`
  - `shutdown -r`
- Halting the system
  - `halt`
  - `shutdown -h`
- Changing the Run Level
  - `telinit <mode>`
  - `shutdown -i<mode>`

When to Shutdown

- Failures
- Maintenance and Upgrades
- Regularly Scheduled
  - Housecleaning
  - Window for Maintenance/Upgrades
- User Notification
  - `/etc/motd`
  - Email
  - Support web pages

References

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