CSE 265:
System and Network Administration

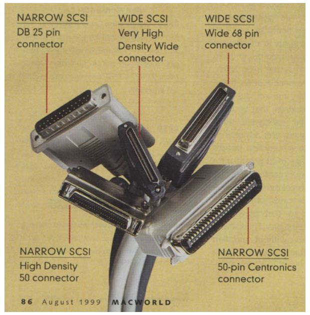
- Disks
- Partitions
- Volumes
- Filesystems
- Files

Disk interfaces

- Relatively few
  - SCSI (pronounced “scuzzy”)
    - Common, widely supported
  - IDE a.k.a. ATA or PATA, and SATA
    - Inexpensive, simple
  - Fibre Channel
    - High bandwidth, lots of simultaneous devices
    - Supports up to 16Gbit
  - Universal Serial Bus (USB)
    - Typically used for slow devices (e.g., CD-ROMs, portable, removable drives)

SCSI:
Small Computer Systems Interface

- Many versions
  - SCSI-1 (1986) 8-bits, 5MB/s
  - SCSI-2 (1990) added command queuing, DMA, more
  - Fast SCSI-2 8-bits, 10MB/s
  - Fast/wide SCSI-2 16-bits, 20MB/s
  - Ultra SCSI 8 bits, 20MB/s
  - Wide Ultra SCSI 16bits, 40MB/s
  - Wide Ultra2 SCSI 16bits, 80MB/s
  - Wide Ultra3 SCSI 16bits, 160MB/s
  - Ultra-320, Ultra-640 SCSI

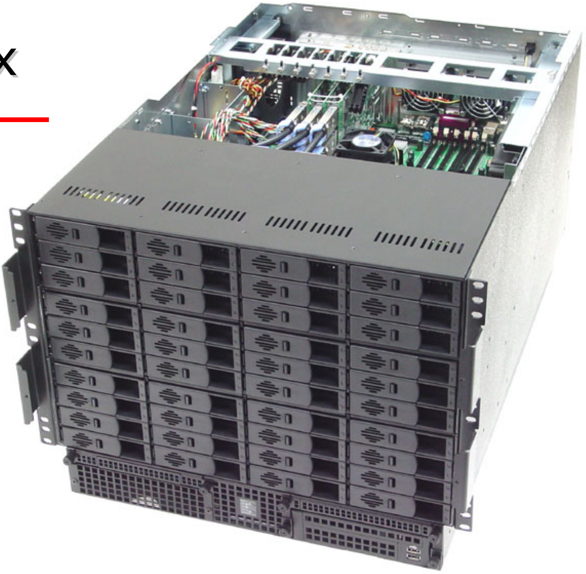


IDE a.k.a. ATA

- Integrated Drive Electronics / AT Attachment
  - Very short cable lengths (18in!)
- ATA-2 added DMA and LBA (get beyond BIOS 504MB limit)
- ATA-3 added power management, self-monitoring (16MB/s)
- Ultra-ATA added Ultra DMA/33, /66, and /133 modes (33-133MB/s)
- Hard disks with this interface were last produced in 2013
- ATAPI interface allows non-ATA devices to connect
  - E.g., CD-ROMs

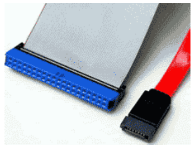
Black box

- 40+2 SATA drives
- RAID
- Dual Xeon
- 8U tall
- Up to 80TB



SATA

- Now standard equipment
  - Fast: 150-600MB/s (16GBit/s now available)
  - Software compatible with parallel ATA
  - One drive per controller
  - Thin cables



Sun X4500

- 48 SATA drives
- Software RAID or ZFS
- Dual AMD
- 4U tall
- Up to 48TB

SCSI vs. SATA

- SCSI traditionally beats SATA technically, but may not be worth the price premium
  - In single-user systems, SATA will provide 85%, cheaply
- For best possible performance, SCSI is often better
  - e.g., in servers and multi-user systems
  - handles multiple simultaneous reqs + more devices better
  - higher-end equipment (faster, better warranty, etc.)
- SATA technology is quite good
  - Usually better price/performance than SCSI
- Still subject to much debate

Disk partitions

- Drives are divided into one or more partitions that are treated independently
  - Partitions make backups easier, confine damage
- Typically have at least two or three
  - root partition (one)
    - everything needed to bring system up in single-user mode (often copied onto another disk for emergencies)
  - swap partition (at least one)
    - stores virtual memory when physical memory is insufficient
  - user partition(s)
    - home directories, data files, etc.
  - boot partition - boot loader, kernel, etc.

Adding a disk to Linux

STEP-BY-STEP (w/out LVM)

- Install new hardware
  - verify that hardware is recognized by BIOS or controller
- Boot, make certain device files already exist in /dev
  - e.g., /dev/sdc
- Use **fdisk/parted** (or similar) to partition the drive
  - Verify the system type on each partition
- Use **mke2fs** (-t ext4) on each regular partition
  - To create (an ext4) filesystem
- Use **mkswap** to initialize swap partitions
- Add entries to /etc/fstab
- Mount by hand, then reboot to verify everything

Logical Volumes

- Partitions are static, and sometimes you want to change them
- LVM (Linux Logical Volume Manager) lets you combine partitions and drives to present an aggregate volume as a regular block device (just like a disk or partition)
  - Use and allocate storage more efficiently
  - Move logical volumes among different physical devices
  - Grow and shrink logical volume sizes on the fly
  - Take “snapshots” of whole filesystems
  - Replace on-line drives without interrupting service
- Similar systems are available for other OSes

hdparm: test/set hd params

- hdparm will do simple performance tests

```
[root@wume2 ~]# /sbin/hdparm -Tt /dev/hda
/dev/hda:
 Timing cached reads:   1928 MB in  2.00 seconds = 963.26 MB/sec
 Timing buffered disk reads:  122 MB in  3.03 seconds =  40.22 MB/sec

[root@wume1 ~]# /sbin/hdparm -Tt /dev/sda
/dev/sda:
 Timing cached reads:   3440 MB in  2.00 seconds = 1720.77 MB/sec
 Timing buffered disk reads:  162 MB in  3.03 seconds =  53.41 MB/sec

[root@night ~]# /sbin/hdparm -Tt /dev/sdd
/dev/sdd:
 Timing cached reads:   10504 MB in  2.00 seconds = 5254.65 MB/sec
 Timing buffered disk reads: 1196 MB in  3.00 seconds = 398.28 MB/sec

[root@morning ~]# /sbin/hdparm -Tt /dev/hda
/dev/hda:
 Timing cached reads:   4092 MB in  2.00 seconds = 2047.82 MB/sec
 Timing buffered disk reads:   10 MB in  3.03 seconds =   3.30 MB/sec
```

ext# filesystems

- For ext2/ext3/ext4, **mke2fs** is used, which creates
  - A set of inode storage cells
    - each holds info about one file
  - A set of scattered “superblocks”
    - holds global filesystem info (multiple copies for reliability)
    - size and location of inode tables, block map and usage, etc.
  - A map of the disk blocks in the filesystem (used and free)
  - The set of data blocks

LVM

- Sample organization:

```
   hda1   hdc1      (Physical volumes on partitions
      \    /         or whole disks containing many
       \  /          physical extents)
      diskvg        (Volume group)
       /  |  \
      /   |   \
  usrlv rootlv varlv (Logical volumes)
    |       |      |
 ext3   reiserfs  xfs (filesystems)
```

Mounting a filesystem

- Filesystem must be mounted before use
  - Must be made part of root filesystem
- Can be mounted on (top of) any directory

  # **mount /dev/sda1 /usr/local**

  # **df /usr/local**
- Use /mnt for temporary mounts
- Want to set up automatic mounting

Filesystems

- Linux filesystems are created in partitions or volumes
  - ext2fs (2nd Extended File System) is old
  - ext3fs (3rd Extended File System) is common
    - Augments ext2fs to incorporate journaling
      - Journals contain filesystem updates
      - Journal log can reconstruct consistent filesystem
      - Journal speeds filesystem consistency checks
  - ext4fs (Fourth Extended File System) is modern
    - Speeds large directories
    - Compatible with ext2 and ext3
  - Other filesystems also supported
    - ReiserFS, IBM's JFS, SGI's XFS
  - Can read foreign filesystems (e.g., FAT, NTFS, ISO 9660)

fsck: check and repair filesystems

- During power failure, superblock, inodes, and data blocks may not get written to disk
- **fsck** can fix minor damage (ext3/4 systems quickly)
  - unreferenced inodes
  - inexplicably large link counts
  - unused data blocks not recorded in block maps
  - data blocks listed as free that are also used in a file
  - incorrect summary info in superblock
- More complex damage will make **fsck** ask human
  - Places unfixable files in lost+found directory
  - You should re-run **fsck** until no errors are found

/etc/fstab

- (Almost) every filesystem that the system knows about automatically is in /etc/fstab

```
[root@brian]# more /etc/fstab
# /etc/fstab
# Created by anaconda on Thu Jan 19 14:11:35 2012
#
# Accessible filesystems, by ref., are maintained under '/dev/disk'
# See man pages fstab(5), findfs(8), mount(8) and blkid(8) for more
#
/dev/mapper/vg_davison-lv_root /       ext4    defaults       1 1
UUID=52bb6031-5fda-402e-bb9f-5c0fee93ca44 /boot ext4 defaults 1 2
/dev/mapper/vg_davison-lv_home /home   ext4    defaults       1 2
/dev/mapper/vg_davison-lv_swap swap    swap    defaults       0 0
tmpfs                   /dev/shm       tmpfs   defaults       0 0
devpts                  /dev/pts       devpts  gid=5,mode=620 0 0
sysfs                   /sys           sysfs   defaults       0 0
proc                    /proc          proc    defaults       0 0
```

The Filesystem

- A filesystem incorporates:
  - A way of naming and and organizing things (namespace)
  - An API for navigating and manipulating objects
  - A security model for protecting, hiding, and sharing objects
  - An implementation to tie the model to the hardware
- Linux abstract kernel interface supports many different filesystems
  - from disk, network, memory

[u]mounting, swap

- **mount**, **umount**, **swapon** and **fsck** all read the /etc/fstab file
- enables

  # **mount /mnt/cdrom**
- fstab entries must be in the correct order
- at startup
  - **mount -a** executed, mounts all regular partitions
  - **swapon** enables swapping on all swap partitions

[u]mounting filesystems

- List of filesystems is in /etc/fstab
  - Such filesystems are checked (**fsck -A**) and mounted (**mount -a**) at boot
- umount will fail if the filesystem is busy
  - busy = any open files, processes with cwd, or copies of executing programs
  - **/sbin/fuser** will show such processes

    f – file open for reading or writing
    c – process cwd is on filesystem
    e – process is executing a file
    r – process root dir is on filesystem
    m – process has mapped file or shared lib

Pathnames

- The Linux filesystem is a single unified hierarchy, starting with / (the root directory)
- A pathname can be
  - absolute
    - /etc/passwd
  - relative
    - ./passwd
    - Always starts with current working directory
- No technical limitations on file naming other than length and /
  - some chars are more difficult to use (need quotes or escape)

File tree organization

- Not really well organized
- Many files organized by function
  - difficult to upgrade
  - /etc/ contains files that are never customized, and ones that are entirely local
- There is at least one place for everything
- Admins need to learn standard places, not move or use new ones

Mounting & unmounting filesystems

- The filesystem is made of smaller filesystems
- Most filesystems occupy disk partitions
  - but can be anything that obeys the API
- Filesystems may be added or removed using the mount and umount commands
  - The mount point is a directory
  - Ex:

```
# mount /dev/hdc1 /backup
```

File types

- Linux defines seven types of files
  - [-] - Regular files
  - [d] - Directories
  - [c] - Character device files
  - [b] - Block device files
  - [s] - Local domain sockets
  - [p] - Named pipes (FIFO)
  - [l] - Symbolic links
- **ls -ld** shows the filetype of a file

Directories

- Created with **mkdir**, deleted with **rmdir** (if empty) or **rm -r**
- Contains named references (links) to other files
- Special entries "." and ".." refer to self and parent directories respectively
- Filenames are stored within parent directory
- More than one directory entry can refer to the same file (hard links)
  - Can be created with **ln**, removed with **rm**

Filesystem hierarchy

http://www.pathname.com/fhs/

/bin : Essential user command binaries (for use by all users)
/boot : Static files of the boot loader (e.g., kernel)
/dev : Device files (terminals, disks, modems, etc.)
/etc : Host-specific system configuration
/home : User home directories (optional)
/lib : Essential shared libraries and kernel modules
/media : Filesystems on removable media
/opt : Add-on application software packages
/proc : Kernel and process information virtual filesystem
/root : Home directory for the root user (optional)
/sbin : Static system binaries for repairing, booting, & recovering OS
/tmp : Temporary files (that disappear at reboot)
/usr : (more next slide)
/var : (more next slide)

/usr, /var

/usr
- /usr/bin : Most commands and executables
- /usr/include : Header files for C programs
- /usr/lib : Libraries and support files for standard programs
- /usr/local : Local software (stuff you install)
- /usr/man : Manual pages
- /usr/sbin : Less essential sysadmin commands
- /usr/share : Content that is common to multiple systems (RO)
- /usr/src : Source code for (nonlocal) software packages

/var
- /var/adm : Various logs, system setup records
- /var/log : System log files
- /var/spool : Spooling directories for printers, mail, dns
- /var/tmp : More temporary space (preserved between reboots)

Symbolic links

- Commonly used to reorganize a subtree, or provide multiple points of access to a file
- “Soft links” -- record path information, but not actual file
- Created by **ln -s**, deleted with **rm**
- Can contain absolute or relative path
  - # **ln -s ./.. parent**
  - # **ln -s /etc/mime.types .mime.types**
- First arg is recorded, not resolved until use

Character and block device files
/dev/

- Allow programs to communicate with hardware
  - When kernel gets request that refers to device file, it is handed off to the device driver
- Character (raw) device files: drivers do i/o buffering
- Block device files: handle i/o in large chunks
- Characterized by major (which driver) and minor (which device) device numbers

```
crw-rw----  1 root   lp   6,   0 Jan 30  2003 /dev/lp0
```

- Created with **mknod** and deleted by **rm**
  - Usually managed automatically by system

File attributes

- Every file has 12 mode bits

  (four octal values of 3 bits each)
- First three bits:
  - 4000 – setuid
  - 2000 – setgid
  - 1000 – sticky bit
    - On a directory, means only the owner of the file, directory, or superuser can delete or rename files
    - Keeps /tmp more private and secure

Sockets & pipes

- Local domain sockets
  - Sockets provide connections between processes
  - Local/UNIX domain sockets are only accessible through the filesystem
  - Only used by processes involved in connection
  - Created with socket, deleted by **rm** or **unlink**
  - Used by X Windows, syslog, and printing system
- Named pipes
  - FIFO files that allow communication between processes on same host
  - Created with **mknod** and deleted with **rm**

Permission bits

- Nine permission bits
  - User:owner read, write, execute
    - 400, 200, 100
  - Group read, write, execute
    - 40, 20, 10
  - Other:world read, write execute
    - 4, 2, 1
- Ability to delete or rename is controlled by permissions on directory

Examples

```
-rwxr-xr-x  3 root  root  63555 Mar 13  2002 /bin/gzip
crw--w----  1 root  root 4,   0 Aug  4  2003 /dev/tty0
```

- **chmod** changes permissions
- **chown** changes ownership and group

  # **chown -R user.group /home/user**
- umask
  - Set shell parameters to control default permissions
  - umask 027 gives everything to owner, forbids writes to group, and gives nothing to other users
  - Usually set in /etc/profile or /etc/csh.login