# Disks

# Outline

❑ Interfaces

❑ Geometry

❑ Add new disks

- Installation procedure
- Filesystem check
- Add a disk

❑ RAID

- GEOM

# Disk Interfaces

- SCSI
  - Small Computer Systems Interface
  - High performance and reliability

Expensive!

SCSI Card ~ 10k

- IDE (or ATA)
  - Integrated Device Electronics (or Advanced Technology Attachment)
  - Low cost
  - Become acceptable for enterprise with the help of RAID technology

Low Price!

- SATA
  - Serial ATA

Enhancement

- SAS
  - Serial Attached SCSI

Speeds up!

- USB
  - Universal Serial Bus
  - Convenient to use

# Disk Interfaces – ATA & SATA

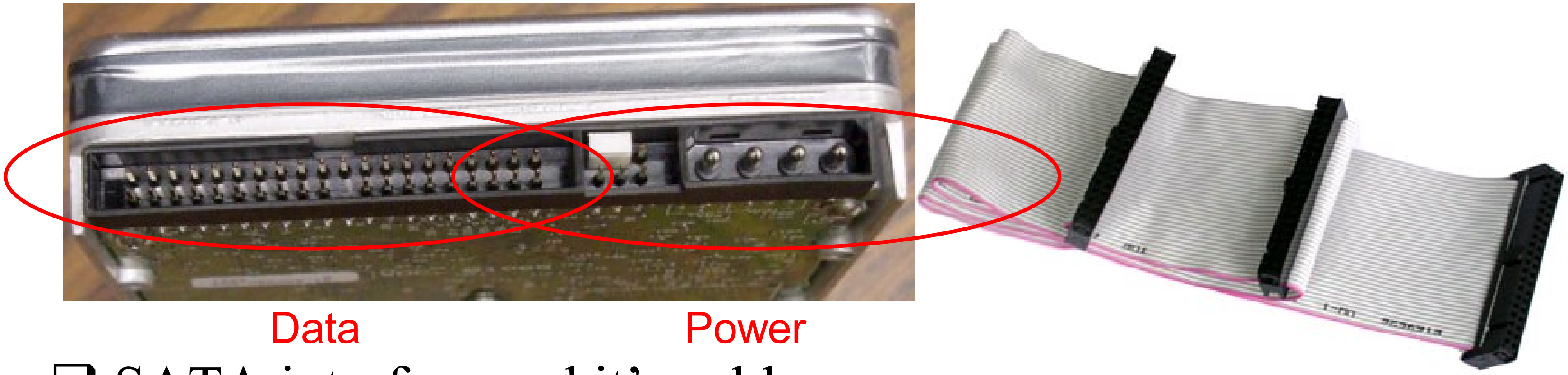
- ❑ ATA (AT Attachment)
  - ATA2
    - ➢ PIO, DMA
    - ➢ LBA (Logical Block Addressing)
  - ATA3, Ultra DMA/33/66/100/133
  - ATAPI (ATA Packet Interface)
    - ➢ CDROM, TAPE
  - Only one device can be active at a time
    - ➢ **SCSI support overlapping commands, command queuing, scatter-gather I/O**
  - Master-Slave
  - 40-pin ribbon cable

Primary Master (0)/Slave(1)
Secondary Master(2)/Slave(3)

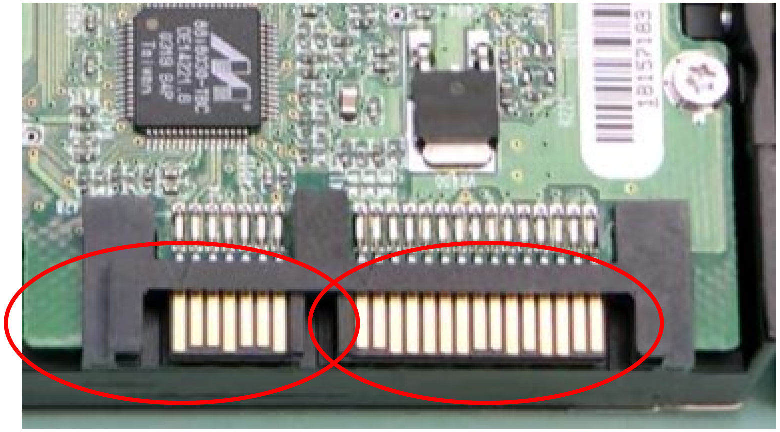
- ❑ SATA
  - Serial ATA
  - SATA-1 1.5Gbit/s, SATA-2 3Gbit/s, SATA-3 6GBit/s
  - SATA 3.1, SATA 3.2 16Gbit/s, SATA 3.3, eSATA, mSATA

# Disk Interfaces – ATA & SATA Interfaces

- ❑ ATA interface and it’s cable



- ❑ SATA interface and it’s cable



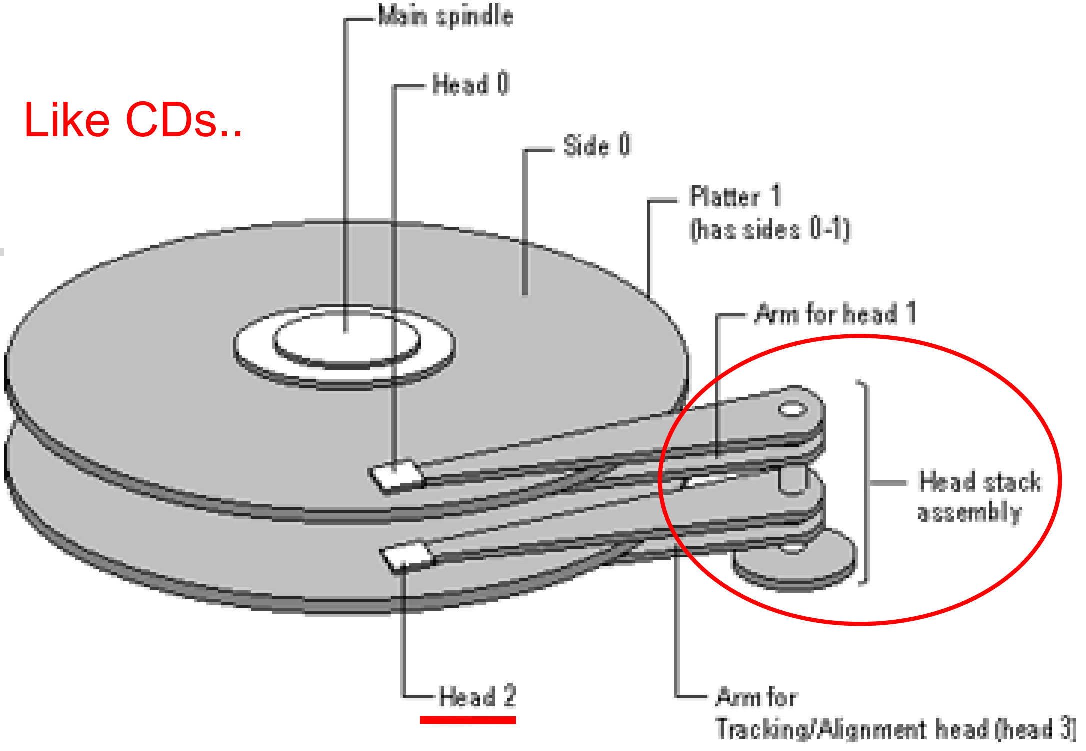
# Disk Interfaces – USB

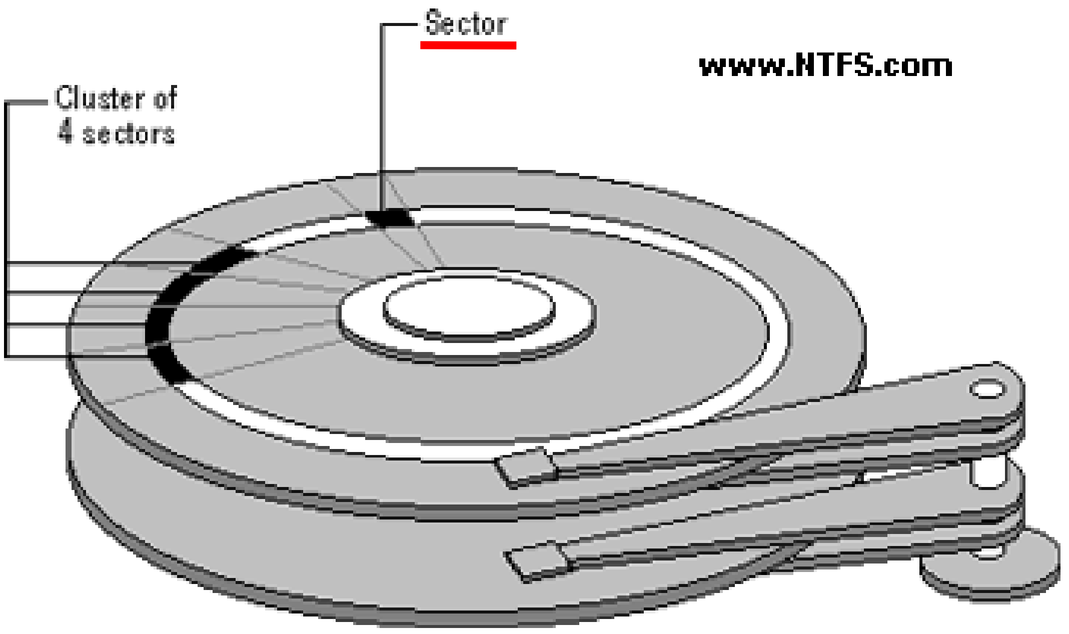
- ❑ IDE/SATA to USB Converters

# Disk Geometry (1)

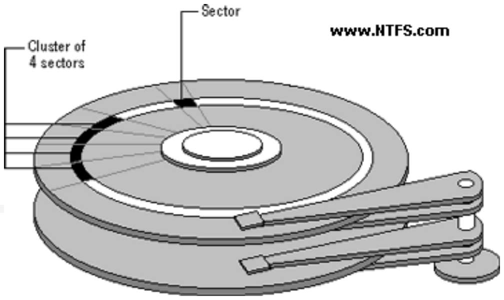
Like CDs..

- ❑ sector
  - Individual data block
- ❑ track
  - circle
- ❑ cylinder
  - circle on all platters
- ❑ Position
  - CHS:
    Cylinder,
    Head (0, 1, …),
    Sector





# Disk Geometry (2)



- ❑ 40G HD
  - 4866 cylinders, 255 heads
  - 63 sectors per track, 512 bytes per sector
  - 512 * 63 * 4866 * 255 = $40,\underbrace{024}_{G},\underbrace{212}_{M},\underbrace{480}_{K}$ bytes
  - 1KB = 1024 bytes
  - 1MB = 1024 KB = 1,048,576 bytes
  - 1GB = 1024 MB = 1,073,741,824 bytes
  - 40,024,212,480 / 1,073,741,824 ≒ $\underline{37.275\text{ GB}}$

Why?

10^3 vs. 2^10…

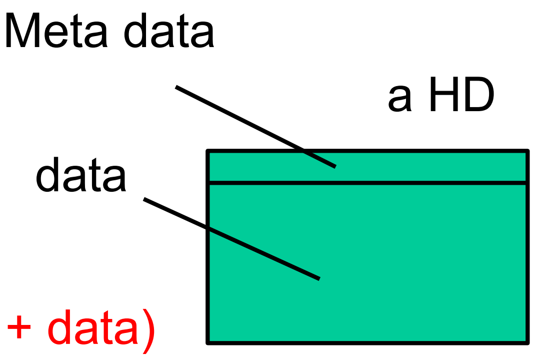
# Disk Installation Procedure (in BSD…)

# Disk Installation Procedure (1)

❑ The procedure involves the following steps:

- Connecting the disk to the computer
  - ➢ IDE: master/slave
  - ➢ SATA
  - ➢ SCSI: ID, terminator
  - ➢ power
- Creating device files
  - ➢ Auto created by devfs
- Formatting the disk
  - ➢ Low-level format
    - – Manufacturer diagnostic utility
    - – **Kill all** address information and timing marks on platters
    - – Repair bad sectors → mark the bad sectors and don't use them!

Please do it offline…



Format (metadata + data) vs. fast format (data only)

# Disk Installation Procedure (2)

- **Partitioning (and Labeling) the disk)**
  - **Allow the disk to be treated as a group of independent data area**
  - **e.g. root, home, swap partitions**
  - **Former Suggestions:**
    - **/var, /tmp ➔ separate partition (for backup issue)**
    - Make a copy of root filesystem for emergency
- **Establishing logical volumes**
  - **Combine multiple partitions into a logical volume**
  - **Related to RAID**
  - **Software RAID technology**
    - **GEOM: geom(4) 、geom(8)**
    - **ZFS: zpool(8) 、zfs(8) 、zdb(8)**

# Disk Installation Procedure (3)

- Creating UNIX filesystems within disk partitions
  - Use "newfs" to install a filesystem for a partition
  - Establish all filesystem components
    - A set of inode storage cells
    - A set of data blocks
    - A set of superblocks
    - A map of the disk blocks in the filesystem
    - A block usage summary

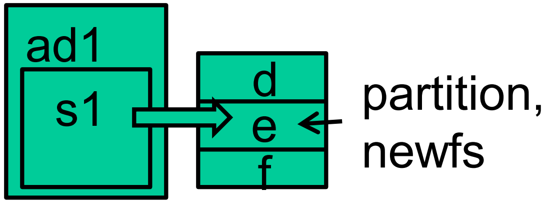
# Disk Installation Procedure (4)

- Superblock contents
  - The length of a disk block
  - Inode table's size and location
  - Disk block map
  - Usage information
  - Other filesystem's parameters

- sync
  - The ***sync() system call*** forces a write of dirty (modified) buffers in the block buffer cache out to disk.
  - The ***sync utility*** can be called to ensure that all disk writes have been completed before the processor is halted in a way not suitably done by reboot(8) or halt(8).

# Disk Installation Procedure (5)

- **mount**
  - **Bring the new partition to the filesystem tree**
  - **mount point can be any directory (empty)**
  - **# mount /dev/ad1s1e /home2**
- **Setting up automatic mounting**
  - **Automount at boot time**
    - **/etc/fstab**
    - **% mount -t ufs /dev/ad2s1a /backup**
    - **% mount -t cd9600 -o ro,noauto /dev/acd0c /cdrom**



Mount CD
Also for ISO image file

```
liuyh@NASA:/etc> cat fstab
# Device          Mountpoint      Fstype   Options       Dump   Pass#
/dev/ad0s1b       none            swap     sw            0      0
/dev/ad2s1b       none            swap     sw            0      0
/dev/ad0s1a       /               ufs      rw            1      1
/dev/acd0         /cdrom          cd9660   ro,noauto     0      0
/dev/ad2s1a       /backup         ufs      rw,noauto     2      2
csduty:/bsdhome   /bsdhome        nfs      rw,noauto     0      0
```

Mount from the network; talk about it in "NFS"…

Usually: 2, 1 for root;
No write = 0

# Disk Installation Procedure (6)

- **Setting up swapping on swap partitions**
  - swapon, swapoff, swapctl
    - **# swapon –a**
      - mount all partitions for swap usage
  - swapinfo, pstat

```
nctucs [~] -wangth- swapinfo
Device          1K-blocks     Used    Avail Capacity
/dev/da0p2        2097152    42772  2054380     2%
```

# fsck –
# check and repair filesystem (1)

- ❑ System crash will cause
  - Inconsistency between memory image and disk contents
- ❑ fsck
  - Examine all local filesystem listed in /etc/fstab at boot time. (fsck -p)
  - Automatically correct the following damages:
    - ➢ Unreferenced inodes
    - ➢ Inexplicably large link counts
    - ➢ Unused data blocks not recorded in block maps
    - ➢ Data blocks listed as free but used in file
    - ➢ Incorrect summary information in the superblock
    - ➢ fsck(8)、fsck_ffs(8)
    - ➢ ffsinfo(8): dump metadata

Check if filesystem is clean…
1: clean (ro)
0: dirty (rw)

# fsck – check and repair filesystem (2)

No guarantee on fully recover you HD…

- ❑ Run fsck in manual to fix serious damages
  - Blocks claimed by more than one file
  - Blocks claimed outside the range of the filesystem
  - Link counts that are too small
  - Blocks that are not accounted for
  - Directories that refer to unallocated inodes
  - Other errors
- ❑ fsck will suggest you the action to perform
  - Delete, repair, …

# Adding a disk to FreeBSD (1)

1. Check disk connection
    - Look system boot message

```
ada3: 238475MB <Hitachi HDS722525VLAT80 V36OA6MA> at ata1-slave UDMA100
```

Line, speed

2. Use gpart(8) to create a partition on the new HD
    - # gpart create -s GPT ada3
    - # gpart add -t freebsd-ufs -a 1M ada3
3. Use newfs(8) to construct new UFS file system
    - # newfs -U /dev/ada3p1
4. Make mount point and mount it
    - # mkdir /home2
    - # mount -t ufs /dev/ada3p1 /home2
    - # df
4. Edit /etc/fstab

- https://www.freebsd.org/doc/handbook/disks-adding.html

# Adding a disk to FreeBSD (2)

❑ If you forget to enable soft-update when you add the disk

- % umount /home2
- % tunefs -n enable /dev/ada3p1
- % mount -t ufs /dev/ada3p1 /home2
- % mount

```
/dev/ada0p2 on / (ufs, local, soft-updates)
/dev/ada1p1 on /home (ufs, local, soft-updates)
procfs on /proc (procfs, local)
/dev/ada3p1 on /home2 (ufs, local, soft-updates)
```

- https://www.freebsd.org/doc/handbook/configtuning-disk.html

# GEOM

Modular Disk Transformation Framework

# GEOM – (1)

- ❑ Support
  - ELI – geli(8): cryptographic GEOM class
  - JOURNAL – gjournal(8): journaled devices
  - LABEL – glabel(8): disk labelization
  - MIRROR – gmirror(8): mirrored devices
  - STRIPE – gstripe(8): striped devices
  - …

Journalize (logs) before write

Software RAID1

Software RAID0

- http://www.freebsd.org/doc/handbook/geom.html

# GEOM – (2)

## ❑ GEOM framework in FreeBSD

- Major RAID control utilities
- Kernel modules (/boot/kernel/geom_*)
- Name and Prodivers ← devices
  - ➢ "manual" or "automatic"
  - ➢ Metadata in the last sector of the providers

Logical volumes

## ❑ Kernel support

- {glabel,gmirror,gstripe,g*} load/unload
  - ➢ device GEOM_* in kernel config
  - ➢ geom_*_enable="YES" in /boot/loader.conf

(1) On demand load/unload kernel modules

- load automatically at booting

(2) Build-in kernel and recompile

# GEOM – (3)

## ❑ LABEL

Why use it? → bundle by name instead of bundle by provider

- Used for GEOM provider labelization
- Kernel
  - device GEOM_LABEL
  - geom_label_load="YES"

e.g. ad0s1d → usr

- glabel (for new storage)
  - # glabel label -v usr da2
  - # newfs /dev/label/usr
  - # mount /dev/label/usr /usr
  - # glabel stop usr
  - # glabel clear da2

glabel label … → Create permanent labels
glabel create … → Create transient labels

/dev/label/usr

Stop using the name

Clear metadata on provider

- UFS label (for an using storage)
  - # tunefs -L data /dev/da4s1a
  - # mount /dev/ufs/data /mnt/data

“data” is a name

# GEOM – (4)

## ❑ MIRROR

- Kernel
  - ➢ device GEOM_MIRROR
  - ➢ geom_mirror_load="YES"
- gmirror

```
➢ # gmirror label -v -b round-robin data da0
➢ # newfs /dev/mirror/data
➢ # mount /dev/mirror/data /mnt
➢ # gmirror insert data da1
➢ # gmirror forget data
➢ # gmirror insert data da1
➢ # gmirror stop data
➢ # gmirror clear da0
```

logical volume called “data”, using HD: da0, …

Add in HD

Kill inexist HDs

# GEOM – (5)

## ❑ STRIPE

- Kernel
  - device GEOM_STRIPE
  - geom_stripe_load="YES"
- gstripe
  - # gstripe label -v -s 131072 data da0 da1 da2 da3
  - # newfs /dev/stripe/data
  - # mount /dev/stripe/data /mnt
  - # gstripe stop data
  - # gstripe clear da0

Create logical volume “data”, which stripe da0~da3 HDs

# RAID

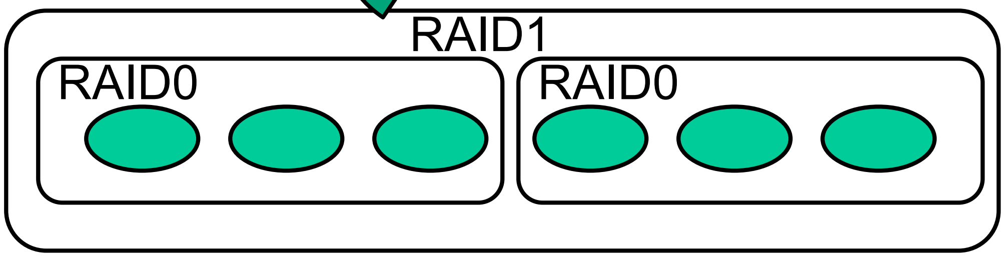
# RAID – (1)

- ❑ Redundant Array of Inexpensive Disks
  - A method to combine several physical hard drives into one logical unit

e.g. HD1, HD2 → D:\ in windows

- ❑ Depending on the type of RAID, it has the following benefits:
  - Fault tolerance
  - Higher throughput
  - Real-time data recovery
- ❑ RAID Level
  - RAID 0, 1, 0+1, 2, 3, 4, 5, 6
  - Hierarchical RAID

RAID1
- RAID0
  - HD
  - HD
  - HD
- RAID0
  - HD
  - HD
  - HD

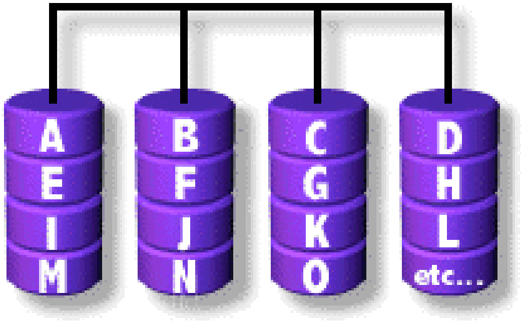


# RAID – (2)

- ❑ Hardware RAID
  - There is a dedicate controller to take over the whole business
  - RAID Configuration Utility after BIOS
    - Create RAID array, build Array
- ❑ Software RAID
  - **GEOM**
    - **CACHE、CONCAT、ELI、JOURNAL、LABEL、MIRROR、MULTIPATH、NOP、PART、RAID3、SHSEC、STRIPE、VIRSTOR**
  - **ZFS**
    - **JBOD、STRIPE**
    - **MIRROR**
    - **RAID-Z、RAID-Z2、RAID-Z3**

# RAID 0 (normally used)

(500GB+500GB=1TB)



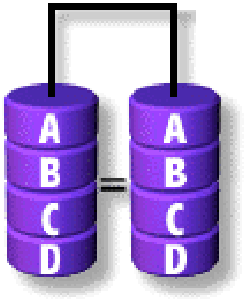
- ❑ Stripped data intro several disks
- ❑ Minimum number of drives: 2
- ❑ Advantage
  - Performance increase in proportional to n **theoretically**
  - Simple to implement
- ❑ Disadvantage
  - No fault tolerance
- ❑ Recommended applications
  - Non-critical data storage
  - Application requiring high bandwidth (such as video editing)

e.g. HD1 (500GB), HD2 (500GB)
→ D:\ in windows (1TB)

parallel file io from/to different HDs

# RAID 1
# (normally used)

(500GB+500GB=500B)



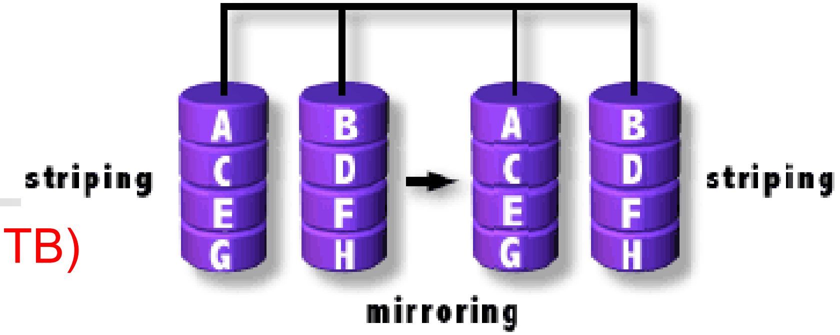
- □ Mirror data into several disks
- □ Minimum number of drives: 2
- □ Advantage
  - 100% redundancy of data
- □ Disadvantage
  - 100% storage overage
  - Moderately slower write performance

Cause by double check mechanisms on data…

- □ Recommended application
  - Application requiring very high availability (such as home)

# RAID 0+1 (normally used)

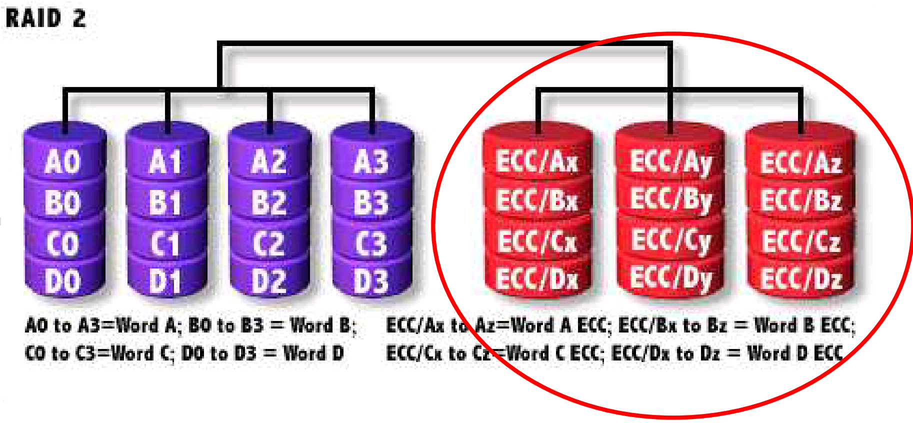
[(500GB+500GB)+(500GB+500GB)]=1TB)



- ❑ Combine RAID 0 and RAID 1
- ❑ Minimum number of drives: 4

RAID1, RAID1
Them RAID0 above it

# RAID 2



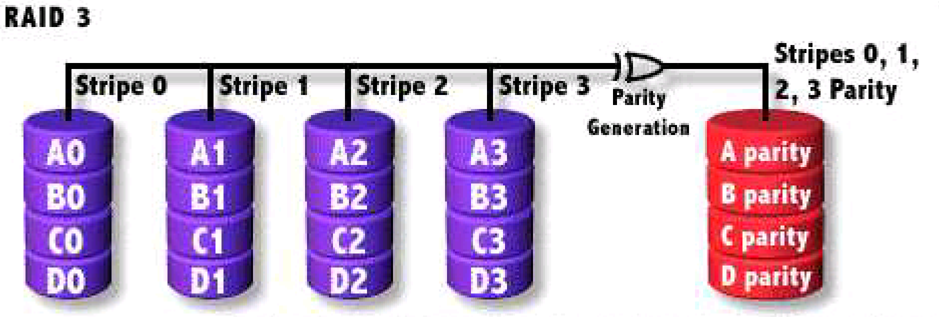
A0 to A3=Word A; B0 to B3 = Word B; C0 to C3=Word C; D0 to D3 = Word D

ECC/Ax to Az=Word A ECC; ECC/Bx to Bz = Word B ECC; ECC/Cx to Cz=Word C ECC; ECC/Dx to Dz = Word D ECC

- Hamming Code ECC Each bit of data word
- Advantages:
  - "On the fly" data error correction
- Disadvantages:
  - Inefficient
  - Very high ratio of ECC disks to data disks
- Recommended Application
  - No commercial implementations exist / not commercially viable

Read, check if correct, then read

# RAID 3

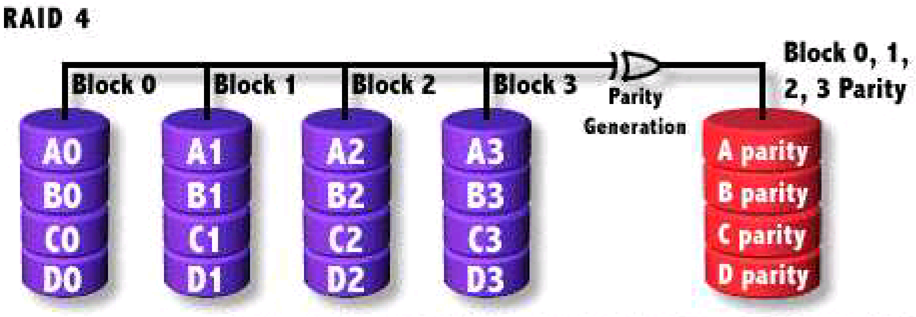


RAID1 if two HDs

Save parity

- ❑ Parallel transfer with Parity
- ❑ Minimum number of drives: 3
- ❑ Advantages:
  - Very high data transfer rate
- ❑ Disadvantages:
  - Transaction rate equal to that of a single disk drive at best
- ❑ Recommended Application
  - Any application requiring high throughput

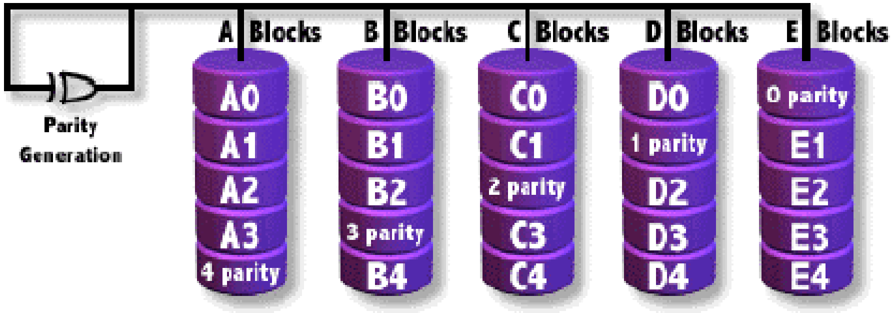
# RAID 4



- ❑ Similar to RAID3
- ❑ RAID 3 V.S RAID 4
  - Byte Level V.S Block Level
  - Block interleaving
    - ➢ Small files (e.g. 4k)

Block normally 512bytes (4k for WD HDs)

# RAID 5 (normally used)



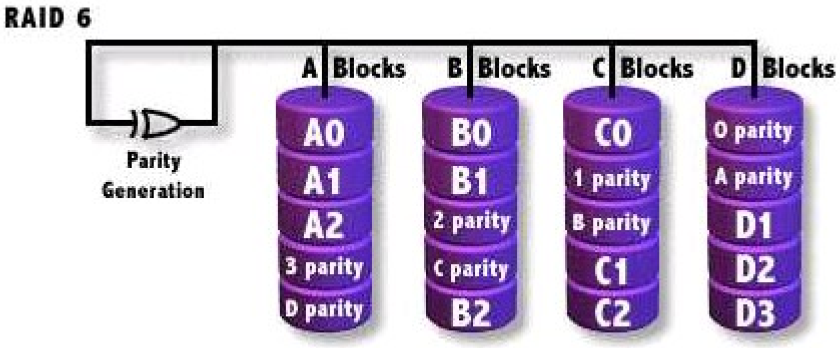
- ❑ Independent Disk with distributed parity blocks
- ❑ Minimum number of drives: 3

Origin from RAID3

- ❑ Advantage Parallel file I/O
  - Highest read data rate
  - Medium write data rate
- ❑ Disadvantage
  - Disk failure has a medium impact on throughput
  - Complex controller design
  - When one disk failed, you have to rebuild the RAID array

Can tolerate only 1 HD failure

# RAID 6 (normally used)



- ❑ Similar to RAID5
- ❑ Minimum number of drives: 4
- ❑ 2 parity checks, 2 disk failures tolerable.

Slower than RAID5 because of storing 2 parities…