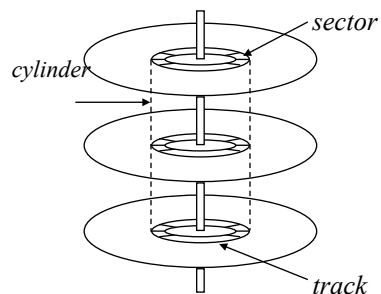


CPSC 410/611: Disk Management

- Disk Structure
 - Disk Scheduling
 - RAID
 - Disk Block Management
-
- *Reading: Silberschatz Chapter 12*

Disk Structure



Disk speed:

- **seek time** : head moves to correct track
- **rotational delay** : wait until sector is under head
- **transfer time** : transfer data between disk and memory

Disk Performance

- **Seek Time** : T_s

n = number of tracks traversed
 m = "track traversal time"
 s = startup time

$$T_s = m \times n + s$$

 - **Rotational Delay (Latency Time)**: T_R

r = # revolutions per time unit

$$T_R = \frac{1}{2r}$$

 - **Transfer Time**: T_T

b = # bytes to be transferred
 N = number of bytes on track

$$T_T = \frac{b}{rN}$$

 - **Disk Access Time**:

$$T = T_s + T_R + T_T$$
-

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-

Disk Scheduling

- Question: Does it pay off to think about scheduling policy in disk queue?
- Evaluation: Compare time for service for given request sequence, distinguish only by cylinder.

FCFS Scheduling

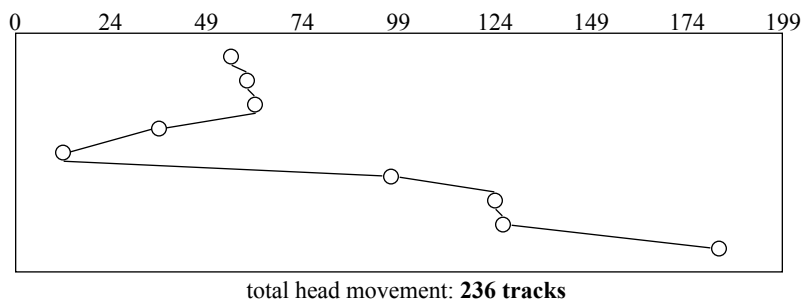
- Advantages:
 - simple
 - fair
- Disadvantages
 - poor average service time
- Example:

98, 183, 37, 122, 14, 124, 65, 67

total head movement: **640 tracks**

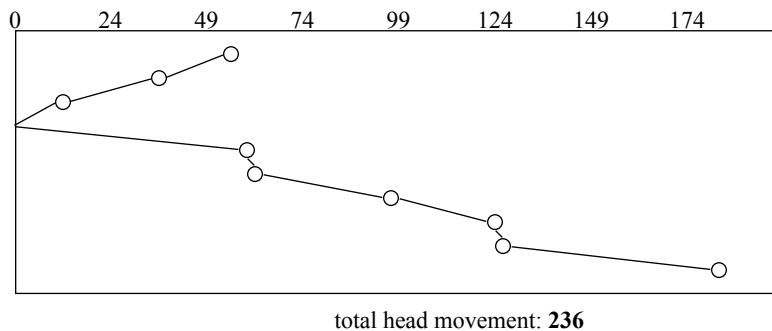
Shortest-Seek-Time-First (SSTF)

- Always service closest request.
- Problem:
 - Starvation



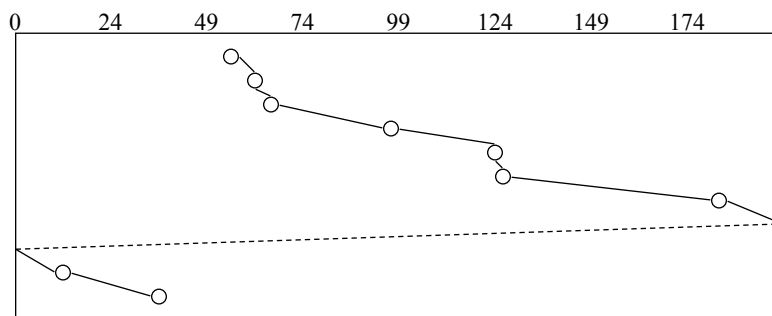
SCAN (Elevator Algorithm)

- Continuously scan disk from one end to the other.
- When scanning, few requests after us, since just past through.
- Problem: When we change direction at end, requests there are very new.

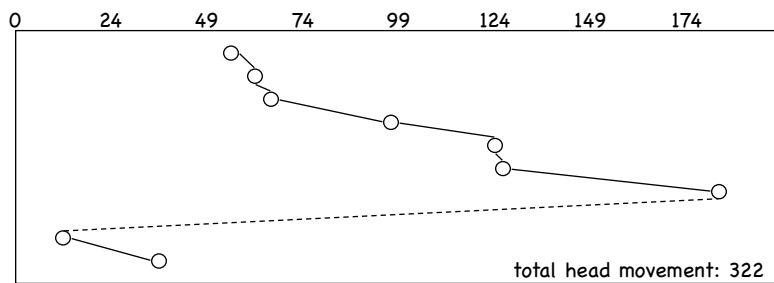
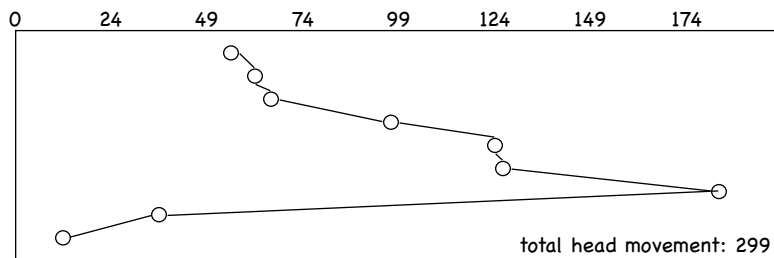


C-SCAN (circular SCAN)

- Reduce variance in service time by always starting at the beginning of the disk.



LOOK, C-LOOK



CPSC 410/611: Disk Management

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 - Disk Scheduling
 - **RAID**
 - Disk Block Management
-
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-

RAID

- Secondary storage devices are slow!
 - Improve their performance by using multiple devices in parallel: arrays of disks.
 - **RAID**
 - **Redundant Arrays of Independent Disks**
 - **Redundant Arrays of Inexpensive Disks** (Berkeley)
 - Common characteristics:
 - Array of physical disks that are **visible as single device** to OS.
 - Data is distributed across physical drives of array.
 - Redundant disk capacity is used for error detection/correction.
-

RAID (cont)

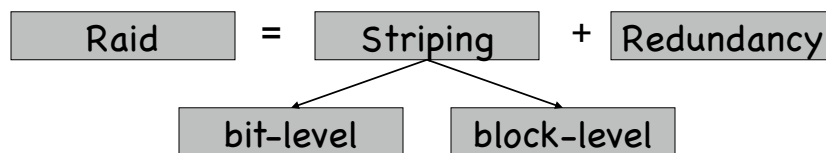
- Replace **single large-capacity** disk with **array of smaller-capacity** disks.
- Benefits:
 - Improved I/O performance
 - Enables incremental upgrade
- Problems:
 - **Reliability**: more devices **increase** the probability of failure.

$$R(t) = P[t_F > t] \quad \text{e.g.} \quad R(t) = e^{-\lambda t}$$

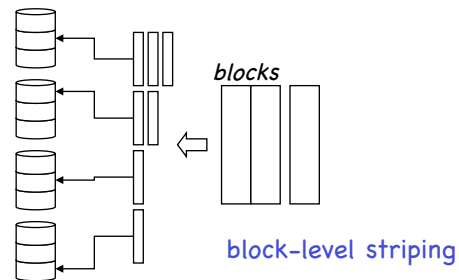
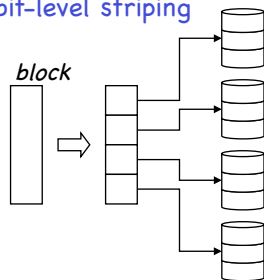
$$MTTF = E[t_F] = \int_0^{\infty} R(t) dt$$

- Solution: **redundancy**

Raid (cont 2)

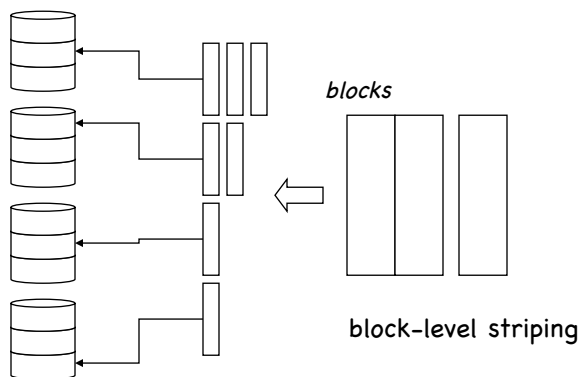


bit-level striping



RAID Level 0

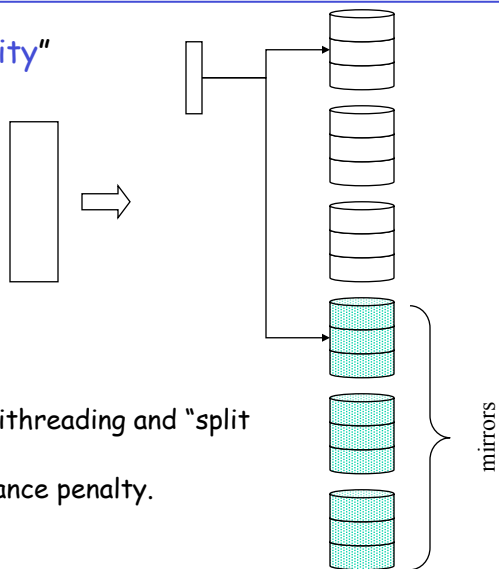
"Block-level Striped Set without Parity"



RAID Level 1

"Mirrored Set without Parity"

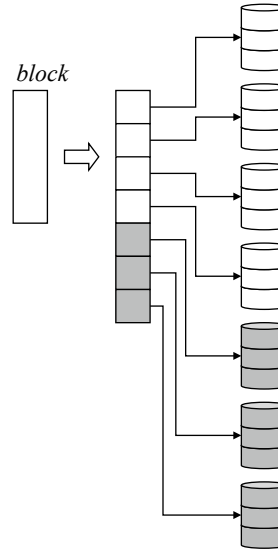
- Problem:
 - cost (100% redundancy)
- Performance
 - READS : good (with multithreading and "split reads")
 - WRITES: small performance penalty.



RAID Level 2

"Memory-Style Error-Correcting Parity"

- Head and spindles synchronized
- Small strips
- Error correction code calculated over bits of data disks.
(Hamming Code)
- Appropriate for systems with many failures.
- Typically not implemented.



RAID Level 3

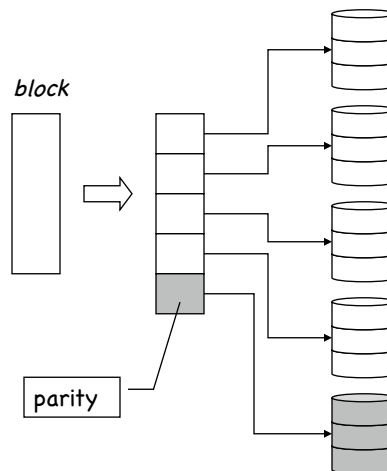
"Bit-Interleaved Parity"

- Heads and spindles synchronized.
- Small strips.
- Simple parity bits instead of ECC.

e.g. $P(S) = S_4 = S_3 \oplus S_2 \oplus S_1 \oplus S_0$

Disk 1 fails:

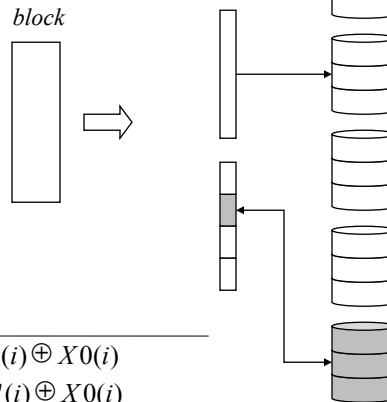
$$S_1 = S_4 \oplus S_3 \oplus S_2 \oplus S_0$$



RAID Level 4

"Block level Parity"

- Same as RAID 3, but with block-level striping.
- No synchronization across disks.
- Large strips.
- Each strip on parity disk contains parity information for all corresponding strips.
- Parity computation upon READ:

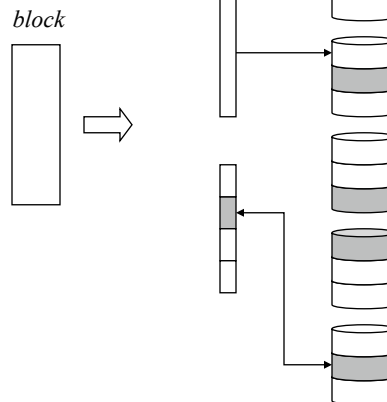


$$\begin{aligned}
 X4(i) &= X3(i) \oplus X2(i) \oplus X1(i) \oplus X0(i) \\
 X4'(i) &= X3(i) \oplus X2(i) \oplus X1'(i) \oplus X0(i) \\
 &= X3(i) \oplus X2(i) \oplus X1'(i) \oplus X0(i) \oplus X1(i) \oplus X1(i) \\
 &= X4(i) \oplus X1(i) \oplus X1'(i)
 \end{aligned}$$

RAID Level 5

"Striped Set with Interleaved Parity"

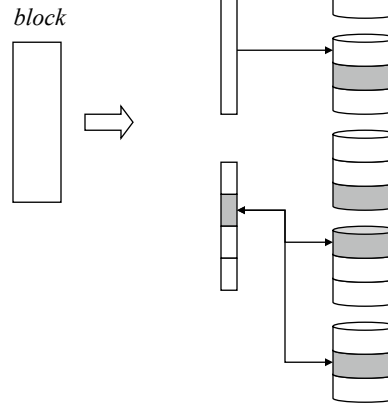
- Same as RAID 4, but parity spread across all disks.
- No synchronization across disks.
- Large strips.



RAID Level 6

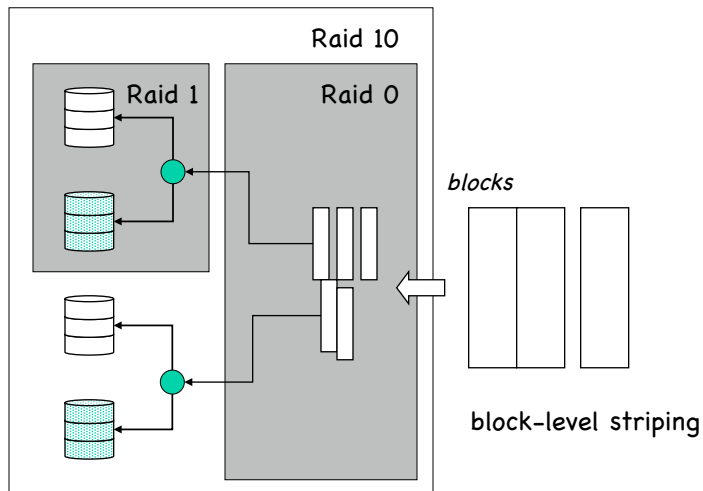
"Striped Set with **Dual Interleaved Parity**"

- Same as RAID 5, but uses 2 bits to store "parity".
- No synchronization across disks.
- **Large strips.**
- Uses ECC instead of parity.
- Tolerates two failures.
- In practice, a second drive can fail during recovery from first drive failure.



Nested Levels: RAID Level 1+0 = RAID 10

"Mirrored Set in a Striped Set"

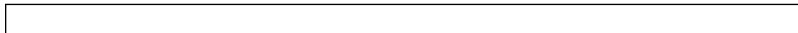


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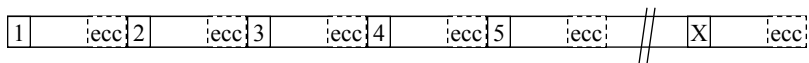
Disk Formatting

- **Bare disk:**



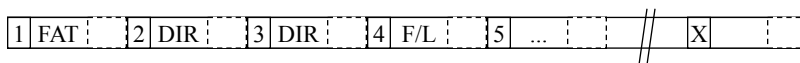
- **Physical formatting:**

- "cut" into sectors
- identify sectors
- add space for error detection/correction

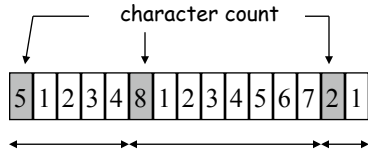
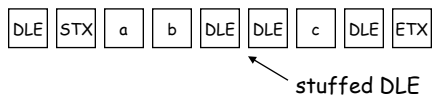
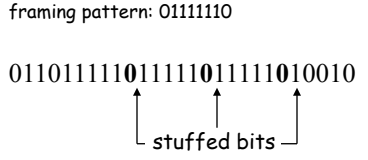
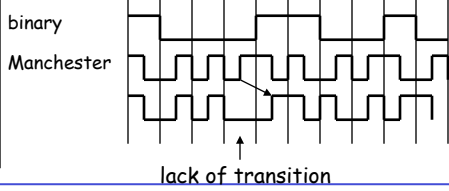


- **Logical formatting:**

- add blank directory, FAT, free space list, ...



Framing

<ul style="list-style-type: none"> Character count 	<ul style="list-style-type: none"> Starting and ending chars, with character stuffing 
<ul style="list-style-type: none"> Starting and ending flags, with bit stuffing <p>framing pattern: 01111110</p> <p>011011111011111011111010010</p> 	<ul style="list-style-type: none"> Physical layer coding violations 

Bad Block Management

- One or more blocks become unreadable/unwritable: **bad blocks**
- Off-line management of bad blocks:
 - Run bad-block detection program and put bad blocks on **bad-block list**. (Either remove them from free list or mark entry in FAT.)
 - May have to run file recovery utility.
- On-line management:
 - Have the device driver map the bad block onto a good block
 - Block *X* goes bad. Whenever OS requests block *X*, the disk transparently accesses a replacement block *Y*.
 - Problem: interferes with scheduling!