# CS 370: Operating Systems
## [Disk Scheduling Algorithms]

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## Frequently asked questions from the previous class survey

- ECCs: How does it impact speed?
- Would a smaller erasure block lengthen the life of flash memory?
- How do you read what is stored in the floating gate?
  - The floating gate's state of charge affects the transistor's threshold voltage for activation
    - State can be detected by applying an **intermediate voltage** to the transistor's control gate that will only be sufficient to activate the transistor if the floating gate is changed
- Does a higher RAID level mean a better system?



## Topics covered in this lecture

- Recovery in file systems
- Swap space management
- Disk scheduling algorithms



## Recovery



## Coping with system failures

- File system structures are maintained on disk and in memory
- Operations result in *structural changes* to the file system on disk
  - Changes may be interrupted by a crash
- System failures should not result in
  - **Data Loss**
  - **Inconsistencies** among data structures



## Sources of inconsistency

- OS **cache** to optimize performance
  - If cached changes do not reach disk?
    - Corruption
- **Bugs** may also corrupt a file system
  - File system implementation
  - Disk controllers
  - Applications

## Inconsistency example: File creation

- Directory structure is modified, inode is set aside, etc
- Free inode count may indicate that an inode has been allocated
  - But the directory structure may not point to it



## Consistency checking: Approaches

**(I) Scan** all metadata of file system
- Confirm or deny consistency
- Time consuming

**(II) Record** state within file system metadata
- At start of metadata change the *status bit* set
  - Metadata is in flux
- If metadata updates complete successfully
  - Clear the status bit
- If bit is set: a **consistency checker** is run



## Consistency checker compares structure with data on disk and tries to fix inconsistencies

- Allocation & free space management algorithms dictate efficiency and success
- Linked list allocation
  - Link exists from block to block
  - File can be recreated
- Indexed allocation
  - Loss of inode entry is disastrous
    - File blocks have **no knowledge** of each other



## Some issues with consistency checking

- Inconsistency may be **irreparable**
  - Inability to recover structures
  - Loss of files (possibly entire directories)
- Can require **human intervention** for conflict resolution
  - Unavailable until this is performed
- Can be very **time consuming**
  - Can take up to several hours



## LOG-STRUCTURED FILE SYSTEMS



## Applying log-based recovery techniques to file system METADATA UPDATES

- All metadata changes are written sequentially to a **log**
- Changes written to log are considered **committed**
  - System call can return
- Log entries are **replayed** across actual file system structures

## Some things about the log file

- Implemented as a circular buffer
  - When action is completed
    - Buffer entry is removed and pointer is advanced
- Log **location**
  - Separate section of the file system
  - Perhaps on a separate disk
    - Efficiency



## After a system crash the log is inspected

- Log will contain zero or more transactions
- If there are **non-zero** transactions
  - Not completed but committed by the OS
    - Must be completed
  - Aborted transaction: Not committed before crash
    - Undone
- Recovery is much more **targeted**



## Benefits of using logging for disk metadata updates

- Costly synchronous random metadata writes
  - **Become** (less expensive) synchronous, sequential writes to the logging area
- Changes in the log are **replayed asynchronously** to appropriate disk structures
  - Random writes
- Updates are **much faster** than when they are applied directly to on-disk structures



## Other approaches

- **Never overwrite** blocks with new data
- All data and metadata changes in new blocks
- When transaction completes
  - Structures **updated to point** to the new block
- Old blocks can be reused
  - If NOT, a snapshot preserves view before the update
- ZFS **checksums** all data and metadata blocks



## Swap Space Management



## Virtual memory uses the disk space as an extension of main memory

- Using swap space **decreases** system performance
- Main objective of swap space
  - Provide best possible **throughput** for the virtual memory system

## Swap space location

- Carved out of the normal file system
  - Navigating directory and allocation data structures
    - Time consuming
    - Could result in additional disk accesses
- Use a **raw** partition
  - Separate swap-space manager
  - (De)allocate blocks from the raw partition



## Using the raw partition

- Swap space *accessed more frequently* than the file system
- Algorithms are optimized for **speed** *not efficiency*
- Internal fragmentation may be higher
  - BUT swap space data have shorter life spans
    - Acceptable trade-off



## MASS STORAGE STRUCTURE



## Disk drives are attached to the computer by a set of wires called an I/O bus

- Enhanced integrated drive electronics (EIDE)
- Advanced technology attachment (ATA)
- Serial ATA (SATA)
- Universal serial bus (USB)
- Small computer systems interface (SCSI)



## Disk controllers are built into each disk drive

- Computer **places** a command using memory mapped I/O ports
- Disk controller **operates** the disk hardware to perform command



## Magnetic tape

- Early secondary-storage medium
- **Slow access** times
  - Moving to the correct spot on tape is time consuming
  - 1000 times slower than magnetic disk for random access
- Mainly for **backup**

## Disk Structure

- One dimensional **array** of blocks
  - Mapped onto sectors of the disk
- Sector **0**
  - 1st sector of 1st track on outermost cylinder
- Mapping proceeds from the outermost cylinders to the innermost one



## Sectors on a hard disk

- *{cylinder, track, sector}*
- Disks have **defective** sectors
  - Manufacturers hide this by substituting spare sectors from elsewhere on disk
- Number of sectors per track
  - Not constant in some drives



## Rotation speed and density of disks

- Density of bits is uniform
  - Outer tracks have greater length
    - More sectors = greater capacity
  - Drive increases rotation speed as it moves from inner track to outer ones
    - **Constant linear velocity**
- Disk rotation can stay constant
  - Density of bits decreases from inner tracks to outer ones



## Disk Scheduling Algorithms



## Disk scheduling: Objectives

- Fast **access times**
  - *Seek time*
    - Move disk arm to the right cylinder
  - *Rotational latency*
    - Rotate to the desired sector
- Disk **bandwidth**
  - Transfer rates



## Disk scheduling: Premise

- With many processes, there are many **pending** disk I/O requests
- Improve access time and bandwidth
  - By managing the **order** in which disk I/O requests are serviced

## Disk I/O request string

- We consider requests to I/O blocks on **cylinders**
- {98, 183, 37, 122, 14, 124, 65, 67}
  - Initial disk head position: 53
  - Number of cylinders: 200
    - 0-199

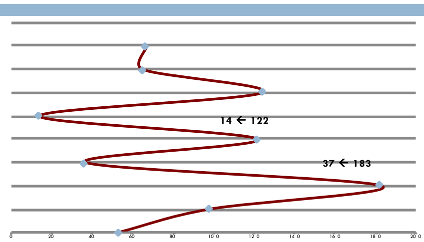


## First Come Fist Served Scheduling

- Process these requests in the order they arrive
- {98, 183, 37, 122, 14, 124, 65, 67}
- Wild swings
  - 183 → 37, 122 → 14
- Total disk-head movement is way too high
  - In our example: 640



## Plotting the disk head movement: FCFS



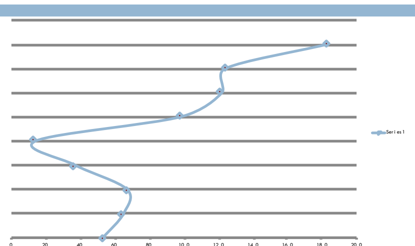



## Shortest-Seek-Time-First (SSTF) targets disk head movement

- Select request with the **lowest seek time**
  - Service requests closest to current disk head position
- {98, 183, 37, 122, 14, 124, 65, 67}
  - Initially at 53
- {65, 67, 37, 14, 98, 122, 124, 183}
  - Total head movement= 236 cylinders

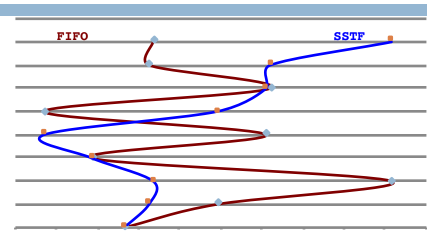


## Plotting the disk head movement: SSTF





## Contrasting disk head movements in FCFS and SSTF



## SSTF

- This is a form of shortest-job-first
- Can cause **starvation** in some requests
- Not optimal
  - SSTF: {65, 67, 37, 14, 98, 122, 124, 183}
    - Total head movement: 236 cylinders
  - We can do better
    - Could have done: {53, 37, 14, 65, 67, 98, 122, 124, 183}
    - Total head movement: 208 cylinders



## SCAN SCHEDULING AND VARIANTS



## SCAN scheduling

- Start at one end of disk & move to the other end
  - Servicing requests
- Reverse directions at the other end
- Also called **elevator** algorithm



## Before applying the algorithm to our schedule

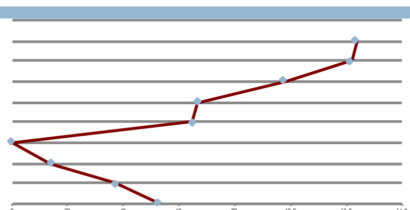
- We need to know
  - The disk head's current **position**
  - **Direction** of the head movement
- {98, 183, 37, 122, 14, 124, 65, 67}
  - Initially at 53
  - Disk arm is moving towards 0

← **53**

- {14, 37, 65, 67, 98, 122, 124, 183}



## Plot of the disk head movement in SCAN scheduling



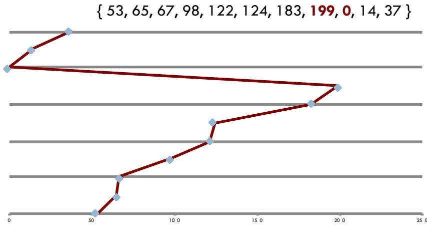



## SCAN scheduling

- When requests have been serviced
  - From one end to other
- When the disk head reaches one end
  - Heaviest **density** of requests is at the other end
  - The requests have also waited the **longest**
    - Go there first?

## Plot of the disk head movement in C-SCAN scheduling

{ 53, 65, 67, 98, 122, 124, 183, **199**, **0**, 14, 37 }





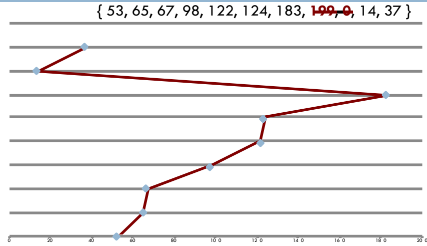
## LOOK scheduling is a variant of C-SCAN scheduling

- Arm goes only as far as the final request
- Reverse direction
  - Without going all the way to the end



## Plot of the disk head movement in LOOK scheduling

{ 53, 65, 67, 98, 122, 124, 183, ~~199, 0~~, 14, 37 }





## Selection of disk scheduling algorithms

- Depends on **number** and **types** of requests
  - If there is always *just one outstanding request*
    - All algorithms behave the same way
- Requests for disk service influenced by **file-allocation** method
  - Location of directories and index blocks



## OS has other constraints on the order in which these requests are serviced

- **Demand paging** has priority over application I/O
- If **cache is running out of free pages**
  - Writes are more important than reads
- Order a set of disk writes
  - To make file system more robust to system crashes



## The contents of this slide-set are based on the following references

- *Andrew S Tanenbaum. Modern Operating Systems. 4th Edition, 2014. Prentice Hall. ISBN: 013359162X/ 978-0133591620*
- *Avi Silberschatz, Peter Galvin, Greg Gagne. Operating Systems Concepts, 9th edition. John Wiley & Sons, Inc. ISBN-13: 978-1118063330.* [Chapter 1]
- *Kay Robbins & Steve Robbins. Unix Systems Programming, 2nd edition, Prentice Hall ISBN-13: 978-0-13-042411-2.* [Chapter 1]