بسم الله الرحمن الرحیم

«سیستم عامل»

۱

جلسه ۲۶: کارآیی فایل‌ها

Improving file system performance

- **Memory mapped files**
  - Avoid system call overhead
- **Buffer cache**
  - Avoid disk I/O overhead
- **Careful data placement on disk**
  - Avoid seek overhead
- **Log structured file systems**
  - Avoid seek overhead for disk writes (reads hit in buffer cache)

Memory-mapped files

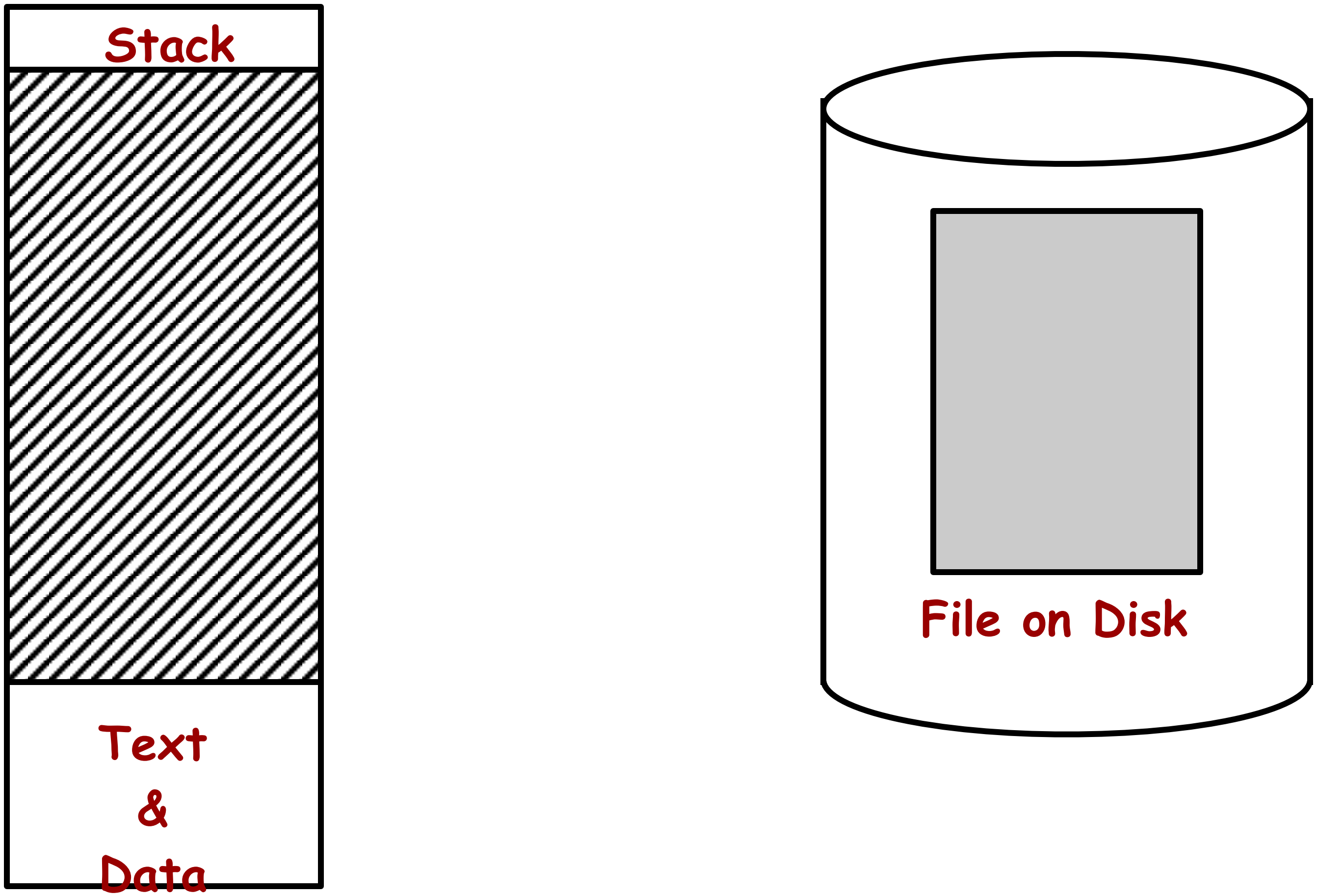
- **Conventional file I/O**
  - Use system calls (e.g., open, read, write, ...) to move data from disk to memory
- **Observation**
  - Data gets moved between disk and memory all the time without system calls
    - **Pages moved to/from PAGEFILE by VM system**
  - Do we really need to incur system call overhead for file I/O?

Memory-mapped files

- **Why not "map" files into the virtual address space**
  - Place the file in the "virtual" address space
  - Each byte in a file has a virtual address
- **To read the value of a byte in the file:**
  - Just load that byte's virtual address
    - **Calculated from the starting virtual address of the file and the offset of the byte in the file**
  - Kernel will fault in pages from disk when needed
- **To write values to the file:**
  - Just store bytes to the right memory locations
- **Open & Close syscalls → Map & Unmap syscalls**

Memory-mapped files

- Virtual Address Space



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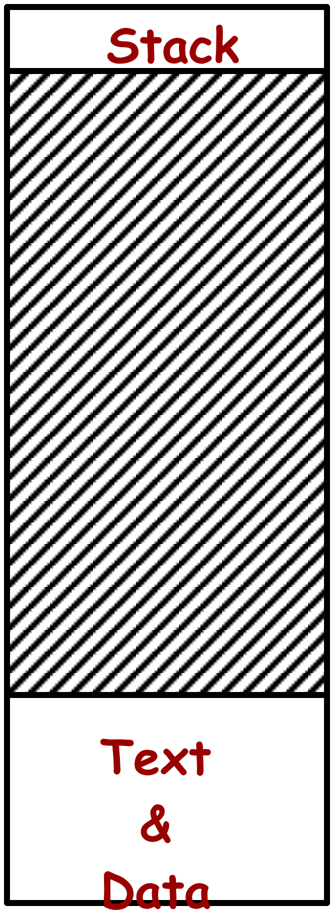

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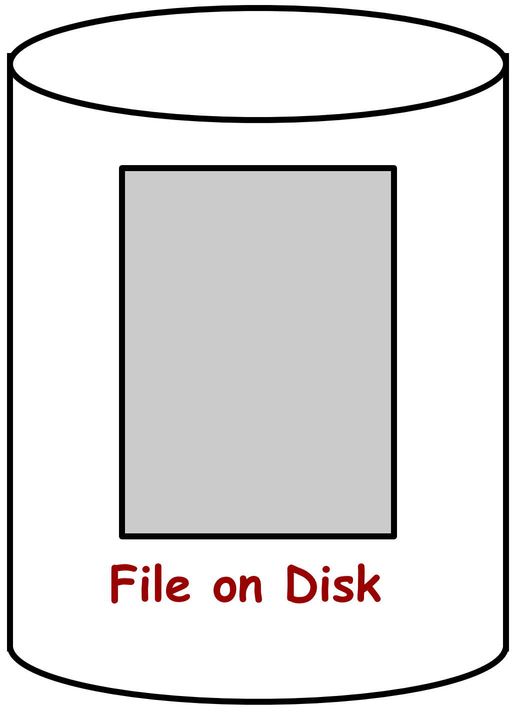

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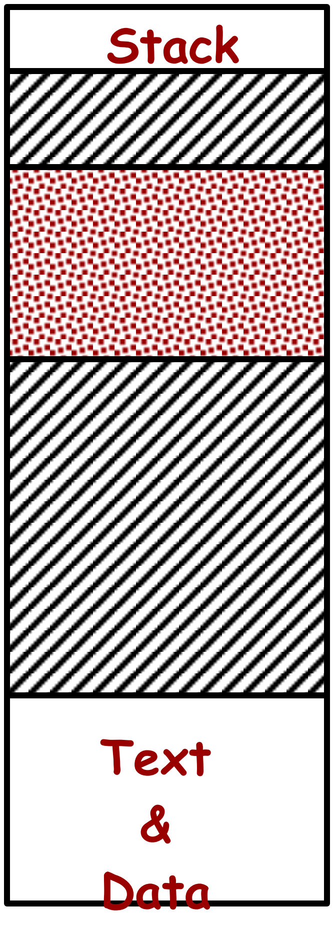

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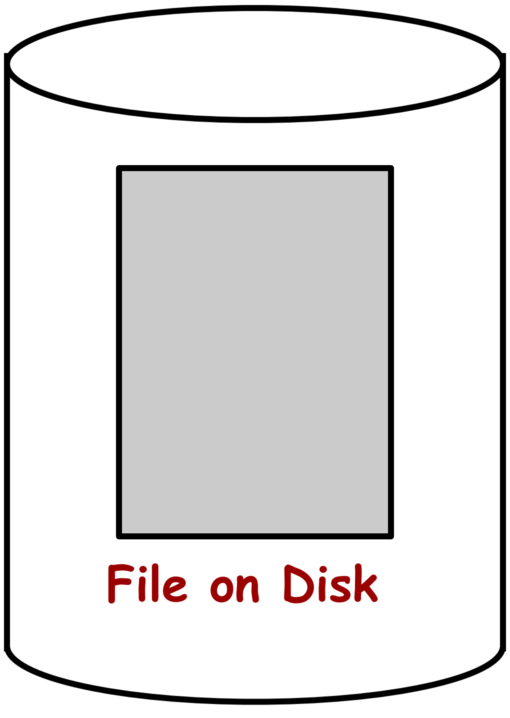

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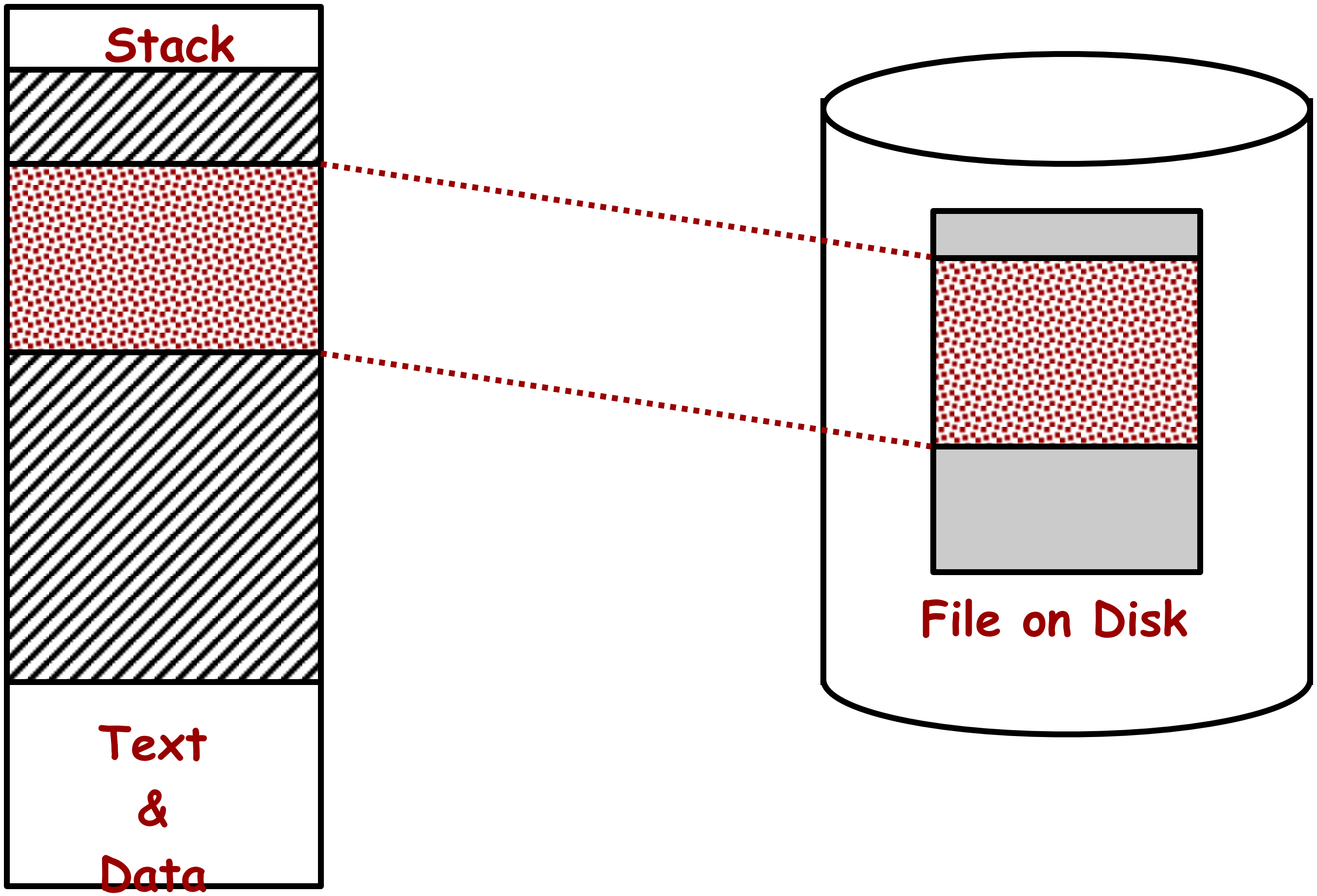

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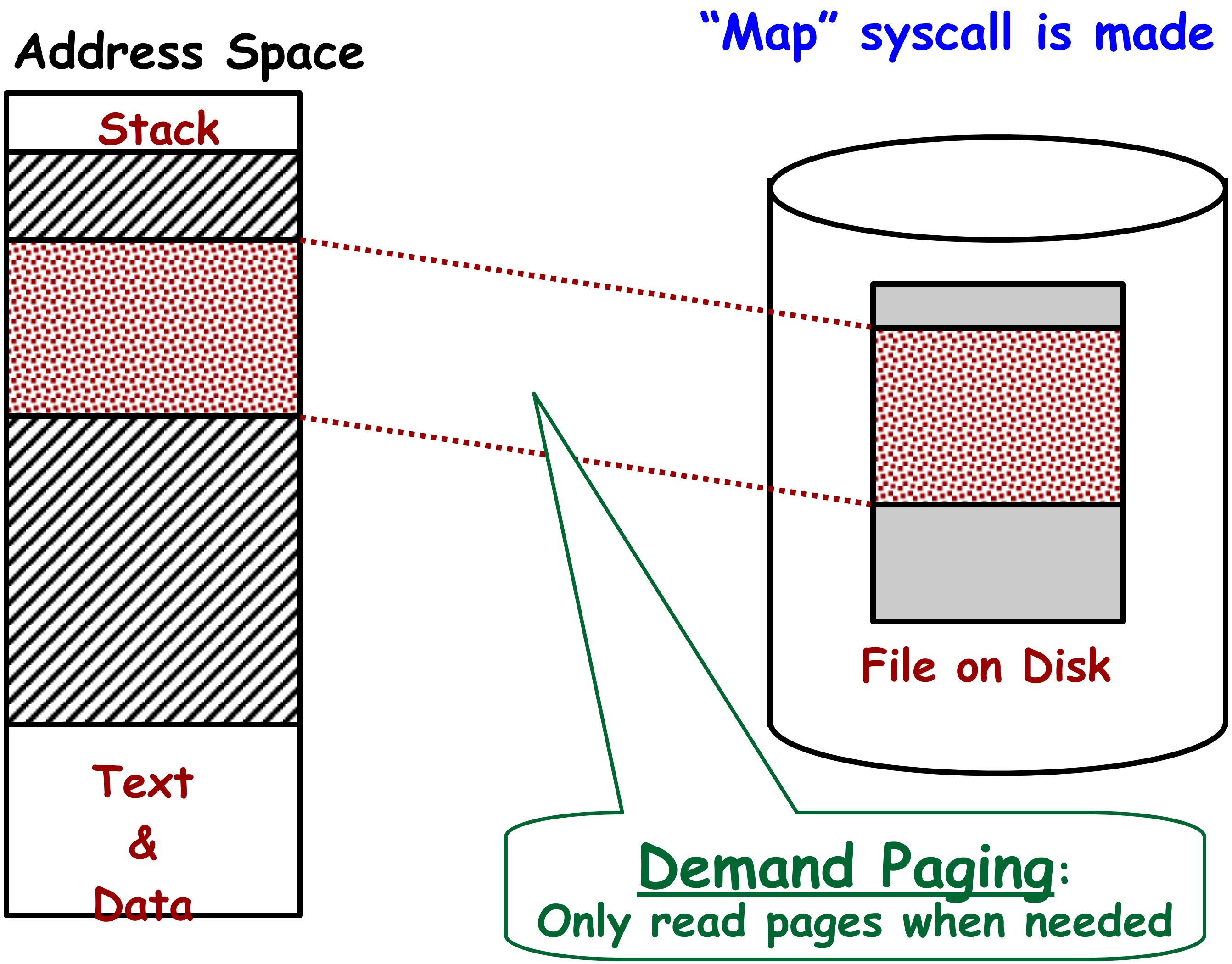


File system performance

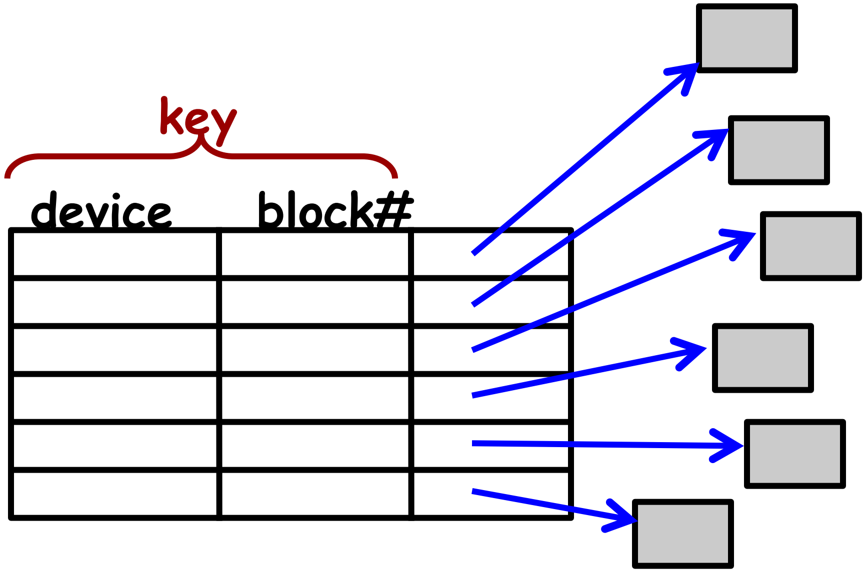
- So how does memory mapping a file affect performance?

Buffer cache

- **Observations:**
  - Once a block has been read into memory it can be used to service subsequent read/write requests without going to disk
  - Multiple file operations from one process may hit the same file block
  - File operations of multiple processes may hit the same file block
- **Idea: maintain a "block cache" (or "buffer cache") in memory**
  - When a process tries to read a block check the cache first

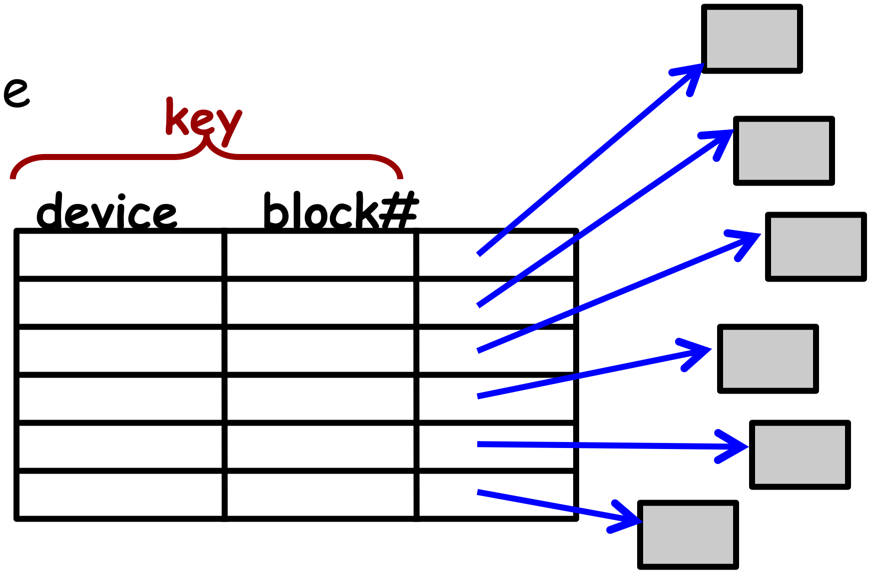
Buffer cache

- <u>Cache organization:</u>
  - Many blocks (e.g., 1000s)
  - Indexed on block number

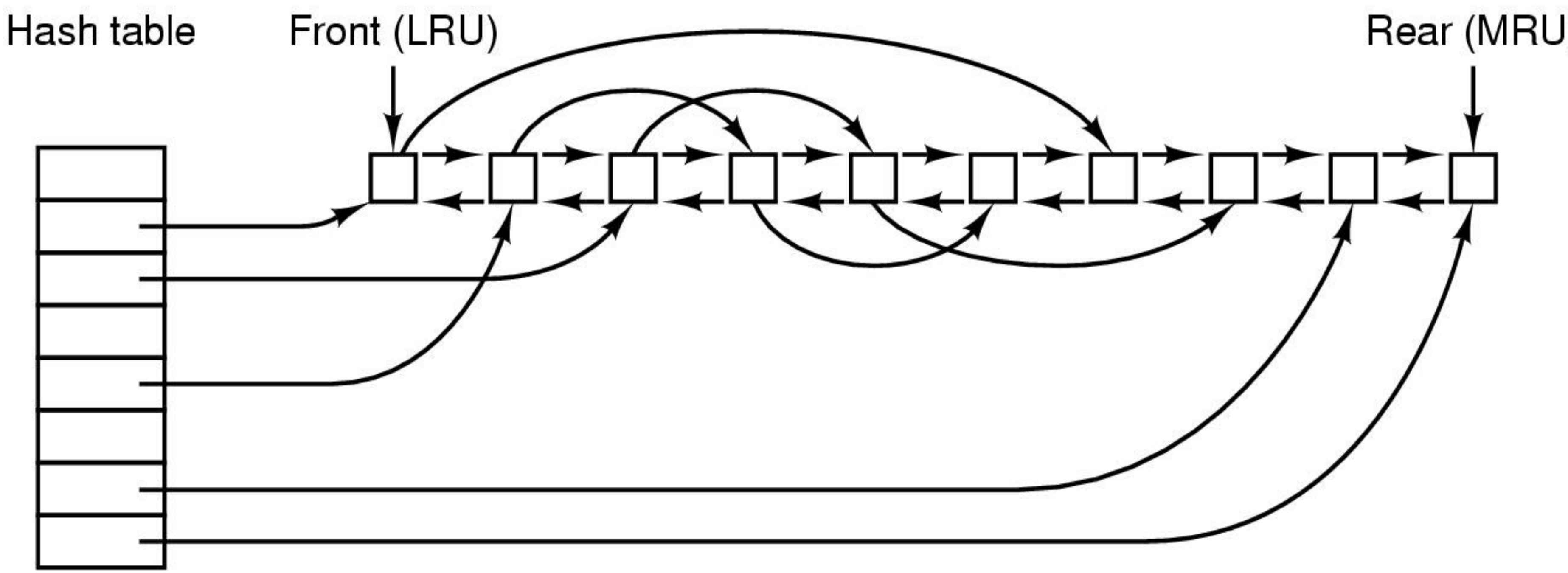


Buffer cache

- **Cache organization:**
  - Many blocks (e.g., 1000s)
  - Indexed on block number
- **For efficiency,**
  - use a hash table



Buffer Cache



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  - Modify the version in the block cache

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- **What if the system crashes?**
- **Can the file system become inconsistent?**

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- **What if system crashes?**
- **Can the file system become inconsistent?**
  - Write directory and i-node info immediately
  - Okay to delay writes to files
    - **Background process to write dirty blocks**

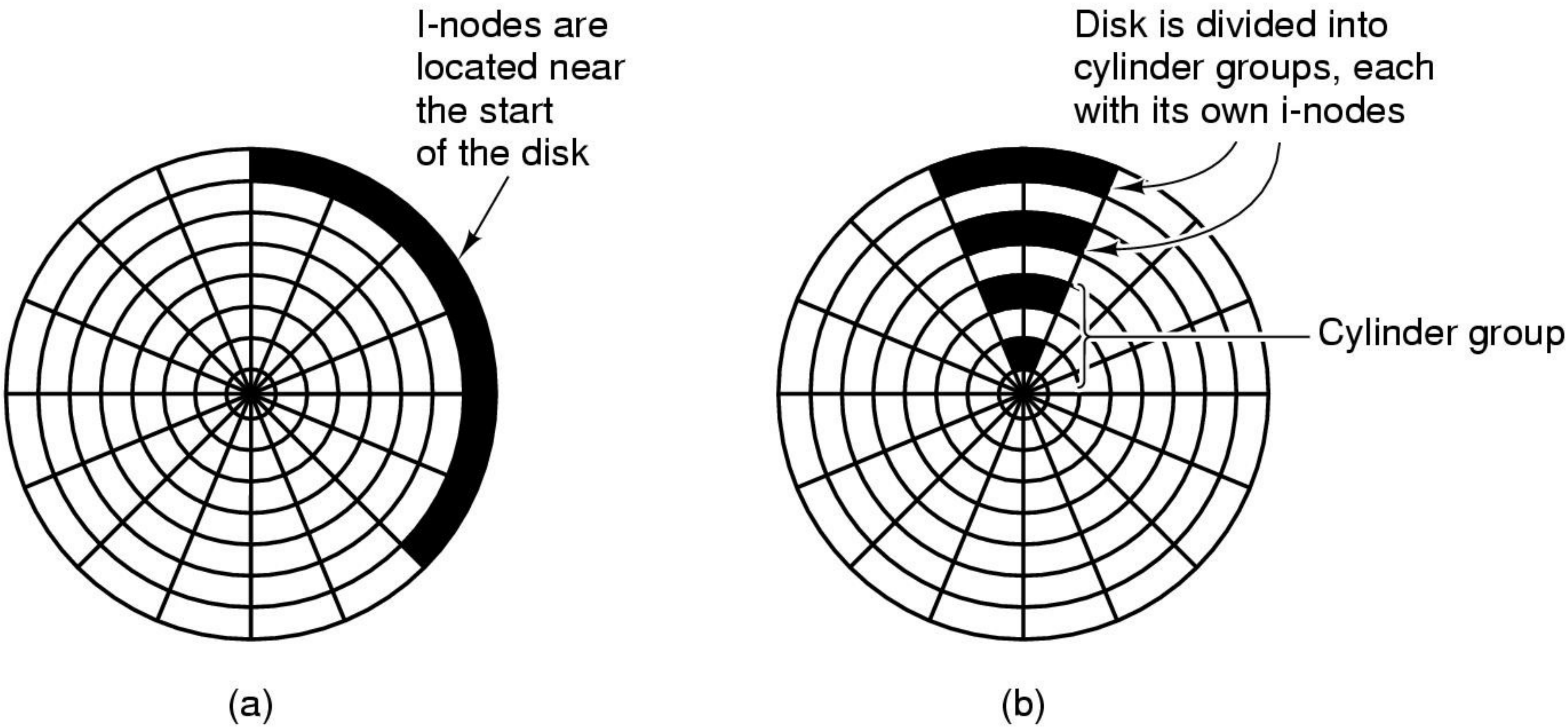
File system performance

- How does a buffer cache improve file system performance?

Careful data placement

- **Idea**
  - Break disk into regions
    - **"Cylinder Groups"**
  - Put blocks that are "close together" in the same cylinder group
    - **Try to allocate i-node and blocks in the file within the same cylinder group**

Cylinder groups (old vs new approach)



File system performance

- How does disk space allocation based on cylinder groups affect file system performance?

Log-structured file systems

- **Observation**
  - Buffer caches are getting larger
  - For a "read"
    - **Increasing probability the block is in the cache**
  - The buffer cache effectively filters out most reads
- **Conclusion:**
  - Most disk I/O is "write" operations!
- **So how well do our file systems perform for a write-dominated workload**
  - Is strategy for data placement on disk appropriate?

Log-structured file systems

- **Problem:**
  - The need to update disk blocks "in place" forces writes to seek to the location of the block
- **Idea:**
  - Why not just write a new version of the block and modify the inode to point to that one instead
  - This way we can write the block wherever the read/write head happens to be located, and avoid a seek!
- **But ...**
  - Wouldn't we have to seek to update the inode?
  - Maybe we could make a new version of that too?

Log-structured file systems

- **What is a "log"?**
  - A log of all actions

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Log-structured file systems

- **What is a "log"?**
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- **The entire disk becomes a log of disk writes**
- **Approach**
  - All writes are buffered in memory
  - Periodically all dirty blocks are written ... to the end of the log
    - **The i-node is modified ... to point to the new position of the updated blocks**

Log-structured file systems

- All the disk is a log.
- What happens when the disk fills up???

Log-structured file systems

- **All the disk is a log**
  - What happens when the disk fills up?
  - How do we reclaim space for old versions of blocks?
  - How do we ensure that the disk's free space doesn't become fragmented?
    - **If it did, we would have to seek to a free block every time we wanted to write anything!**
  - How do we ensure that the disk always has large expanses of contiguous free blocks
    - **If it does we can write out the log to contiguous blocks with no seek or rotational delay overhead**
    - **Optimal disk throughput for writes**

Log-structured file systems

- **A “cleaner” process**
  - Reads blocks in from the beginning of the log.
    - **Most of them will be free at this point.**
  - Adds non-free blocks to the buffer cache.
  - These get written out to the log later.

- **Log data is written in units of an entire track.**
- **The “cleaner” process reads an entire track at a time.**
  - Efficient

File system performance

- How do log structured file systems improve file system performance?

Disk space management

- **Must choose a disk block size...**
  - = Page Size?
  - = Sector Size?
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  - Last block has (on average) 1/2 wasted space
  - Lots of very small files; waste is greater.

Disk space management

- **Must choose a disk block size...**
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  - = Track size?
- **Large block sizes:**
  - Internal fragmentation
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- **Small block sizes:**
  - More seeks; file access will be slower.

Block size tradeoff

- Smaller block size?
  - Better disk utilization
  - Poor performance
- Larger block size?
  - Lower disk space utilization
  - Better performance

Example

- A Unix System
  - 1000 users, 1M files
  - Median file size = 1,680 bytes
  - Mean file size = 10,845 bytes
  - Many small files, a few really large files

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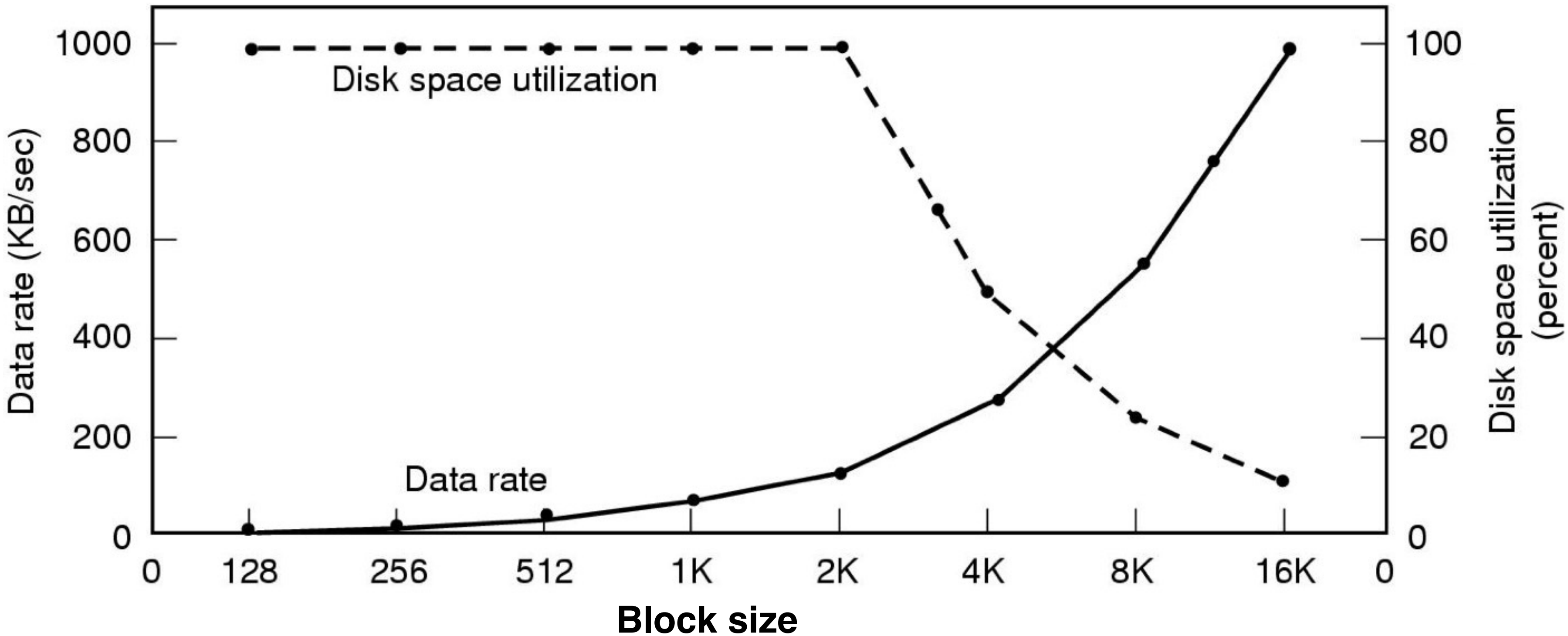
- A Unix System
  - 1000 users, 1M files
  - Median file size = 1,680 bytes
  - Mean file size = 10,845 bytes
  - Many small files, a few really large files
- **Let's assume all files are 2 KB...**
  - What happens with different block sizes?
  - (The tradeoff will depend on details of disk performance.)

Block size tradeoff



Assumption: All files are 2K bytes

Given: Physical disk properties

Seek time=10 msec

Transfer rate=15 Mbytes/sec

Rotational Delay=8.33 msec * 1/2

Managing free blocks

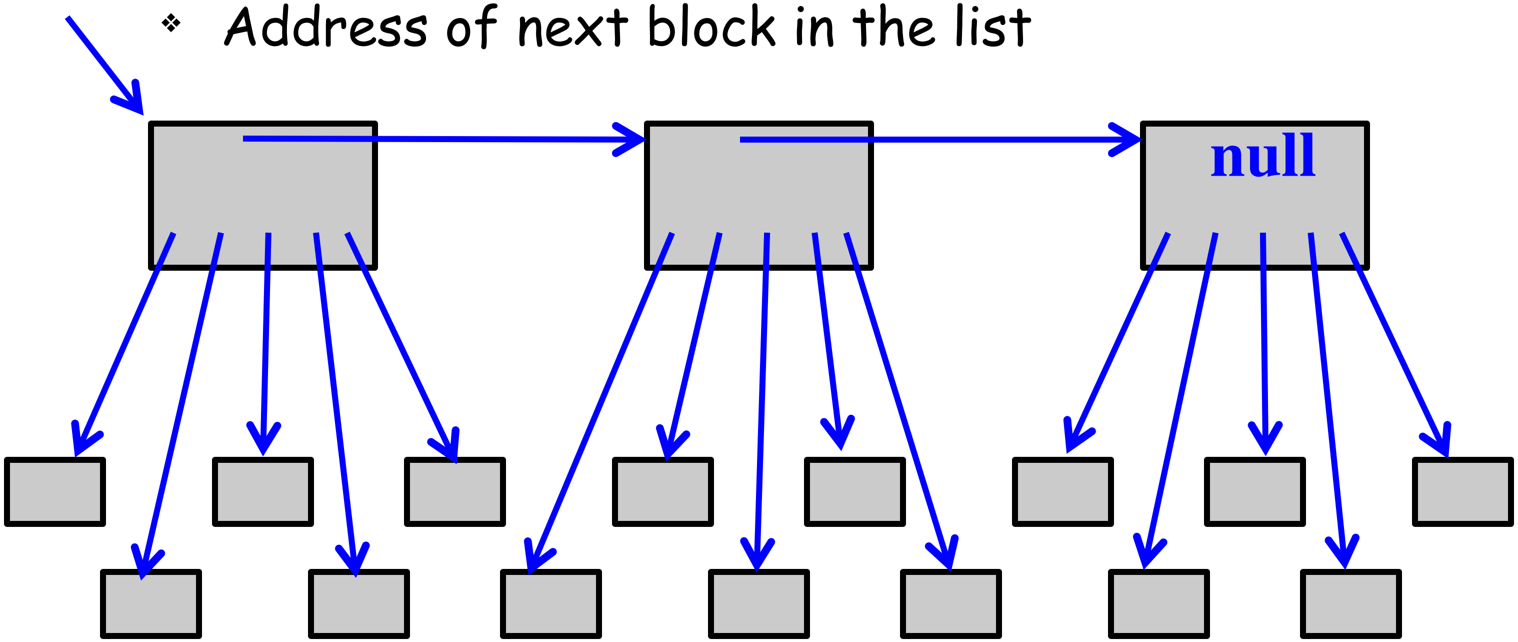
- **Approach #1:**
  - Keep a bitmap
  - 1 bit per disk block
-
- **Approach #2**
  - Keep a free list

Managing free blocks

- Approach #1:
  - Keep a bitmap
  - 1 bit per disk block
    - Example:
      - 1 KB block size
      - 16 GB Disk ⇒ 16M blocks = 2^{24} blocks
    - Bitmap size = 2^{24} bits ⇒ 2K blocks
      - 1/8192 space lost to bitmap
-
- Approach #2
  - Keep a free list

Free list of disk blocks

- Linked List of Free Blocks
- Each block on disk holds
  - A bunch of addresses of free blocks
  - Address of next block in the list



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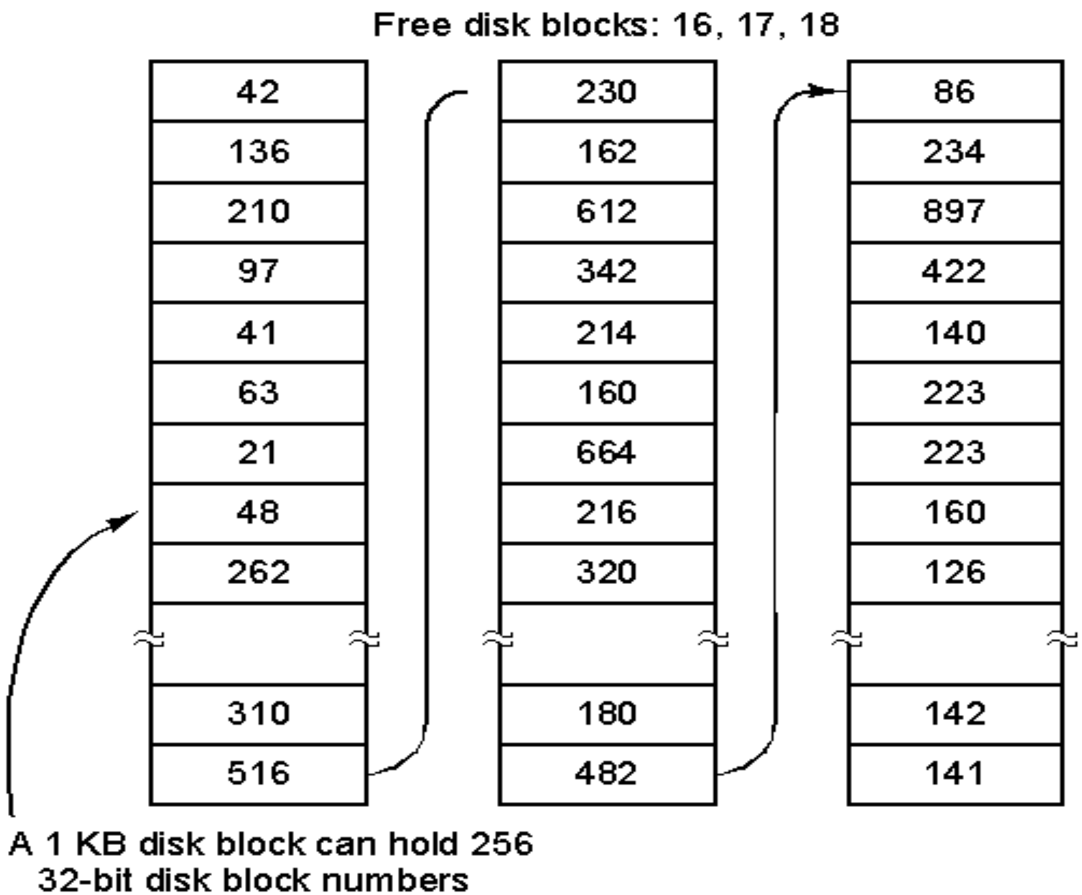

Assumptions:

Block size = 1K

Each block addr = 4bytes

Each block holds

- 255 ptrs to free blocks
- 1 ptr to the next block

This approach takes more space...

But "free" blocks are used, so no real loss!

Free list of disk blocks

- **Two kinds of blocks:**
  - Free Blocks
  - Block containing pointers to free blocks
- **Always keep one block of pointers in memory.**
- **This block may be partially full.**
- **Need a free block?**
  - This block gives access to 255 free blocks.
  - Need more?
    - **Look at the block's "next" pointer**
    - **Use the pointer block itself**
    - **Read in the next block of pointers into memory**

Free list of disk blocks

- **To return a block (X) to the free list...**
  - If the block of pointers (in memory) is not full:
    - **Add X to it**

Free list of disk blocks

- **To return a block (X) to the free list…**
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  - If the block of pointers (in memory) is full:
    - **Write it to out to the disk**
    - **Start a new block in memory**
    - **Use block X itself for a pointer block**
      - **All empty pointers**
      - **Except the next pointer**

Free list of disk blocks

- **Scenario:**
  - Assume the block of pointers in memory is almost empty.
  - A few free blocks are needed.

Free list of disk blocks

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  - Now the block in memory is almost full.

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- **Problem:**
  - Numerous small allocates and frees, when block of pointers is right at boundary
  - Lots of disk I/O associated with free block mgmt!

Free list of disk blocks

- **Solution (in text):**
  - Try to keep the block in memory about 1/2 full
  - When the block in memory fills up...
    - **Break it into 2 blocks (each 1/2 full)**
    - **Write one out to disk**
- **Similar Algorithm:**
  - Keep 2 blocks of pointers in memory at all times.
  - When both fill up
    - **Write out one.**
  - When both become empty
  - Read in one new block of pointers.

Comparison: free list vs bitmap

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  - Keep all the blocks in one file close together.

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- **Desirable:**
  - Keep all the blocks in one file close together.
- **Free Lists:**
  - Free blocks are all over the disk.
  - Allocation comes from (almost) random location.
- **Bitmap:**
  - Much easier to find a free block "close to" a given position
  - Bitmap implementation:
    - **Keep 2 MByte bitmap in memory**
    - **Keep only one block of bitmap in memory at a time**

Quotas

- **For each user...**
  - OS will maintain a record.
  - Example:
    - **Amount of disk space used (in blocks)**
      - **Current**
      - **Maximum allowable**
    - **Number of files**
      - **Current**
      - **Maximum allowable**
- **Soft Limits:**
  - When exceeded, print a warning
- **Hard Limits:**
  - May not be exceeded

Backing up a file system

- **"Incremental" Dumps**
  - Example:
    - Once a month, back up the entire file system
    - Once a day, make a copy of all files that have changed
- **Why?**
  - Faster!
- **To restore entire file system...**
  1. Restore from complete dump
  2. Process each incremental dump in order

Backing up

- **"Physical Dump"**
  - Start a block 0 on the disk
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- **Blocks on the free list?**
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- **Bad sectors on disk?**
  - Controller remaps bad sectors:
  - Backup utility need not do anything special!
    - **OS handles bad sectors:**
    - **Backup utility must avoid copying them!**

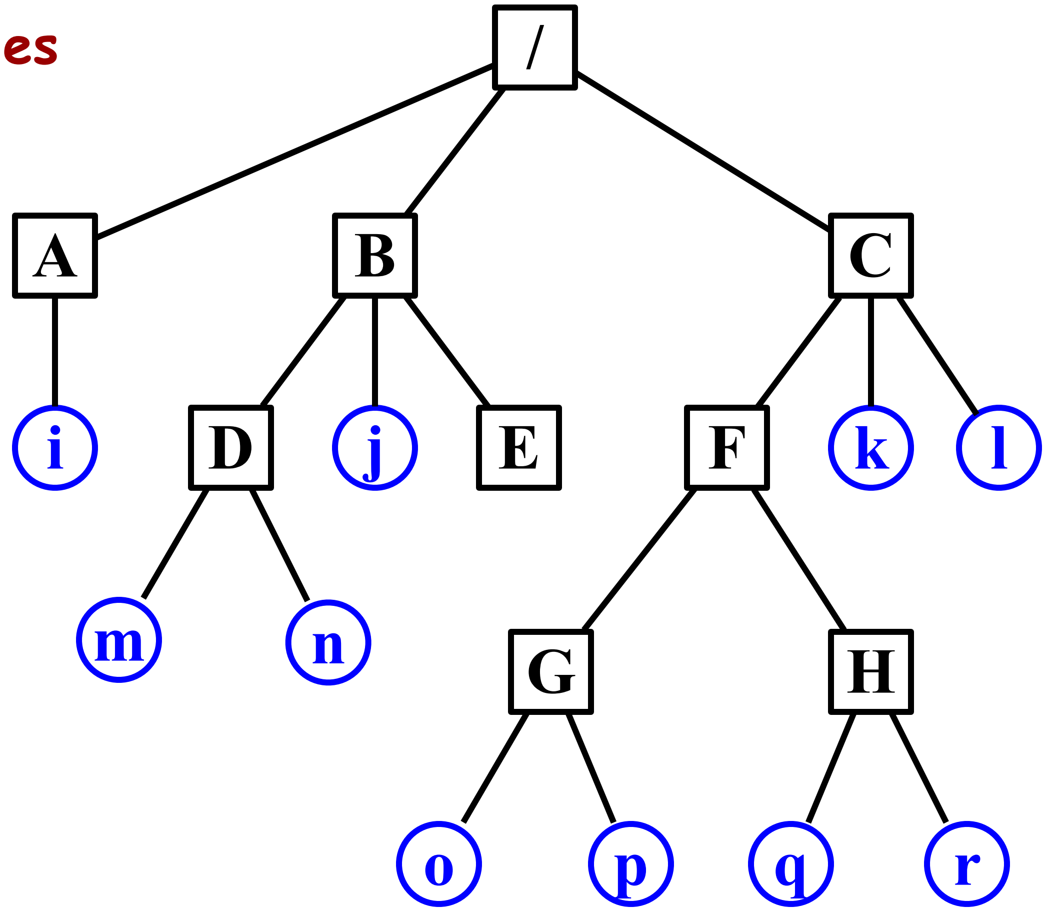
Backing up

- **"Logical Dump"**
  - Dump files and directories
  - (Most common form)

- **Incremental dumping of files and directories:**
  - Will copy only files that have been modified since last incremental backup.
  - Must also copy the directories containing any modified files.

Incremental backup of files

Determine which files have been modified



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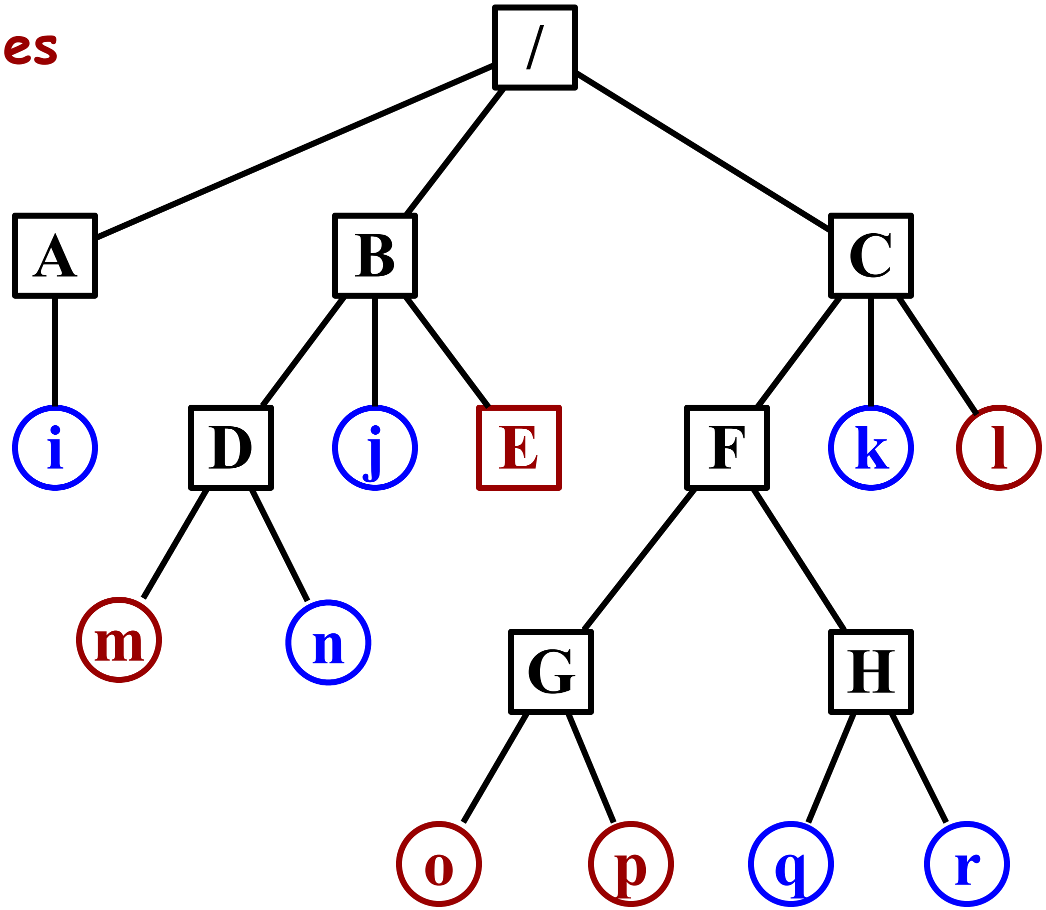

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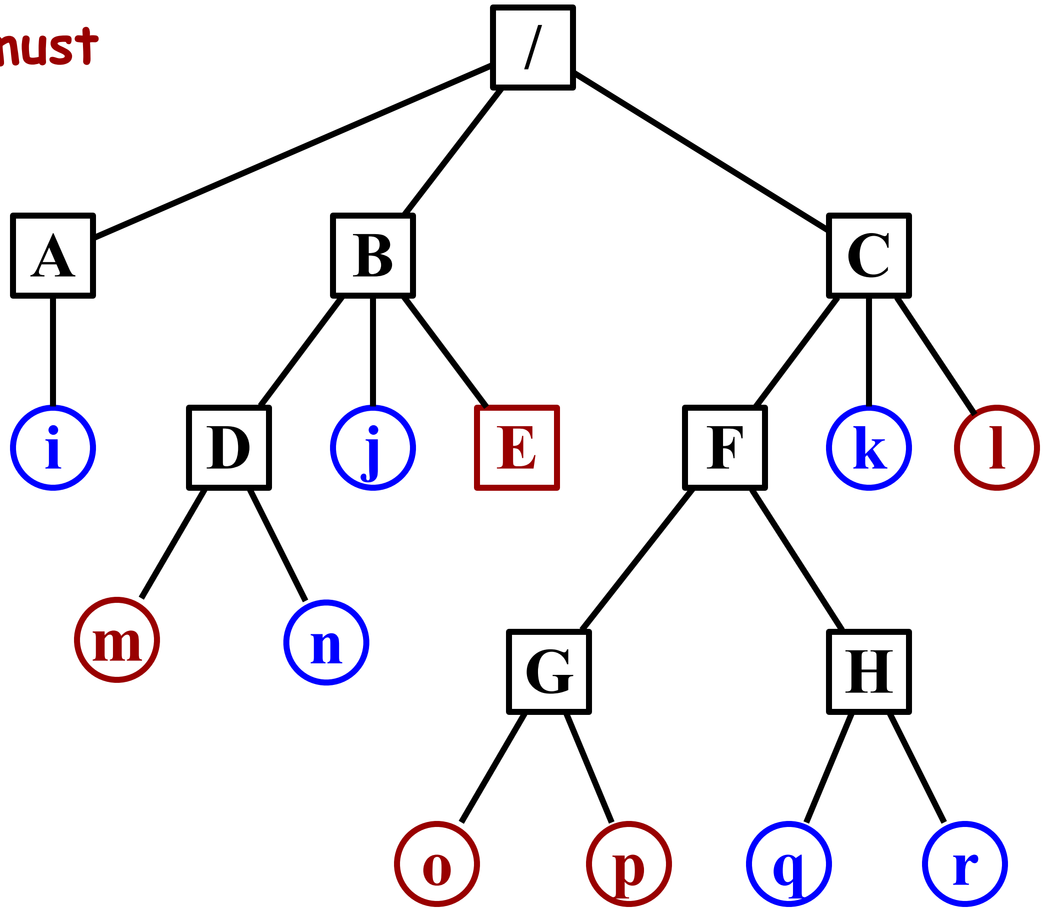

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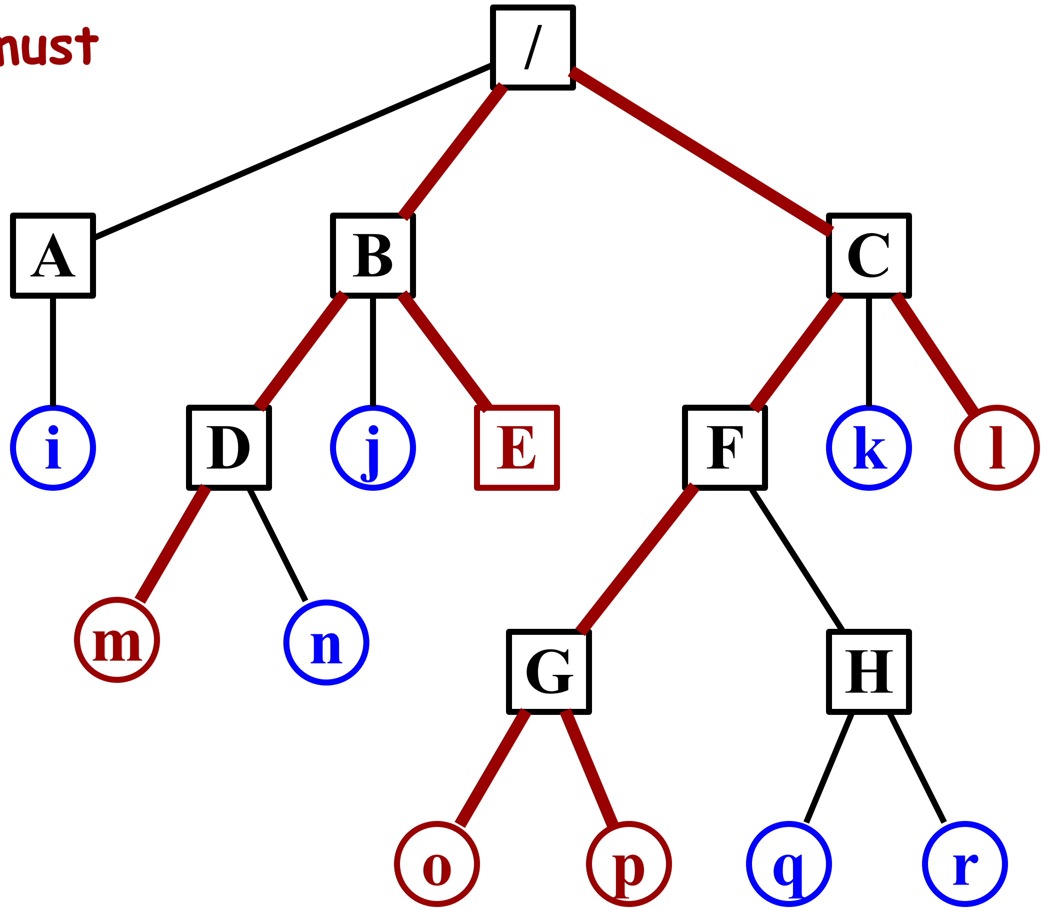

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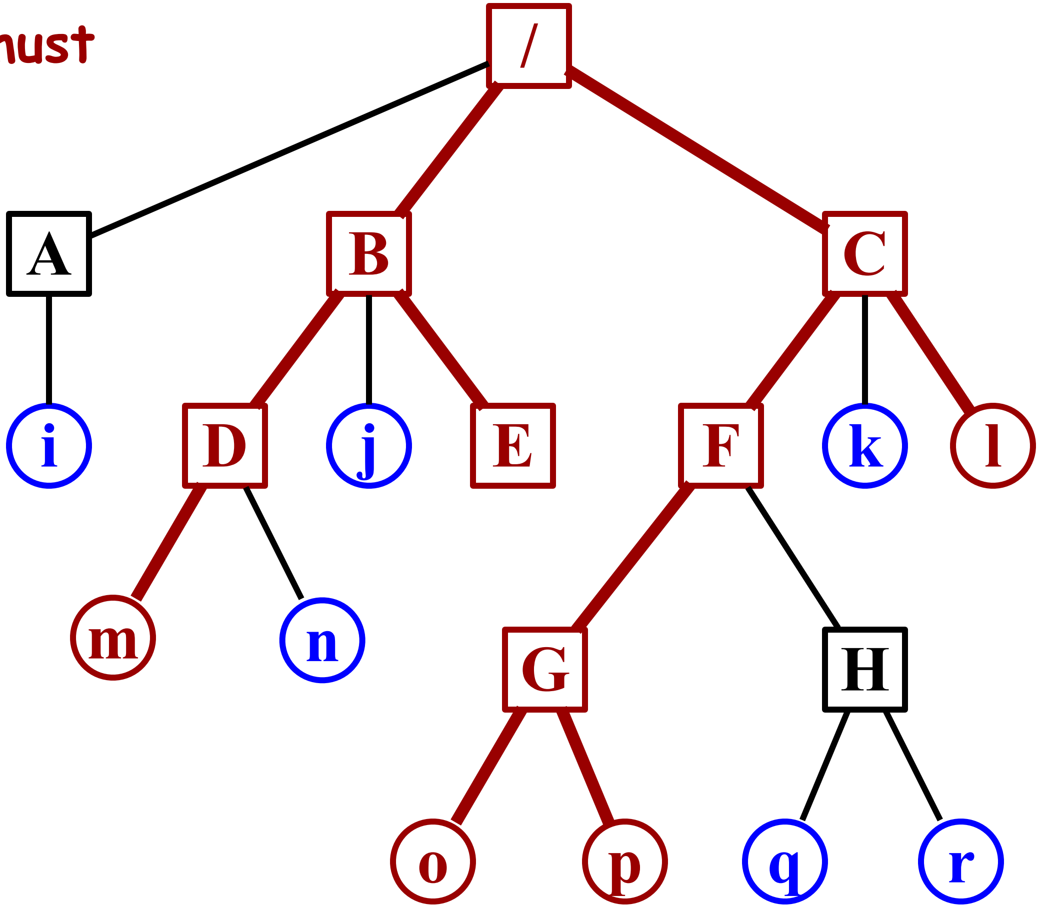

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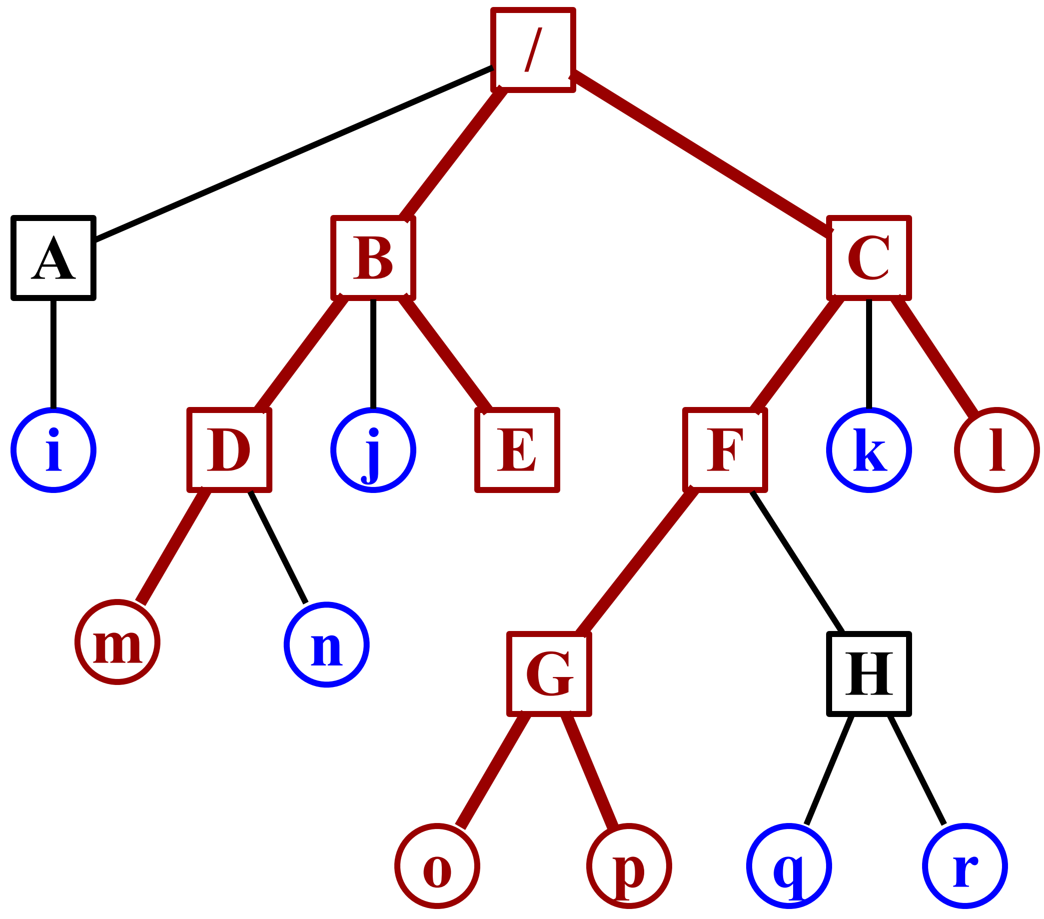

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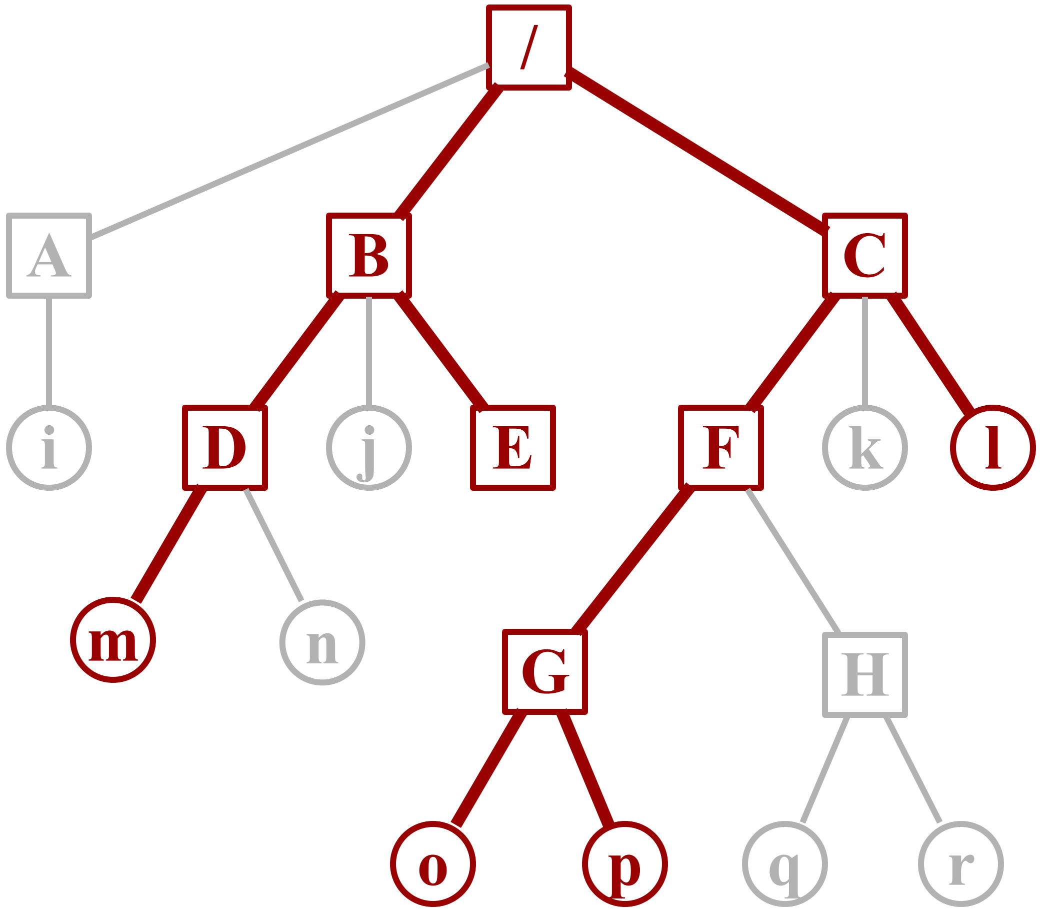

Recycle bins

- **Goal:**
  - Help the user to avoid losing data.
- **Common Problem:**
  - User deletes a file and then regrets it.
- **Solution:**
  - Move all deleted files to a "garbage" directory.
  - User must "empty the garbage" explicitly.
- **This is only a partial solution;**
  - May still need recourse to backup tapes.

File system consistency

- **Invariant:**
  - Each disk block must be
    - **in a file (or directory), or**
    - **on the free list**

File system consistency

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    - **(Can’t happen when using a bitmap for free blocks.)**
    - **Fix the free list so the block appears only once.**
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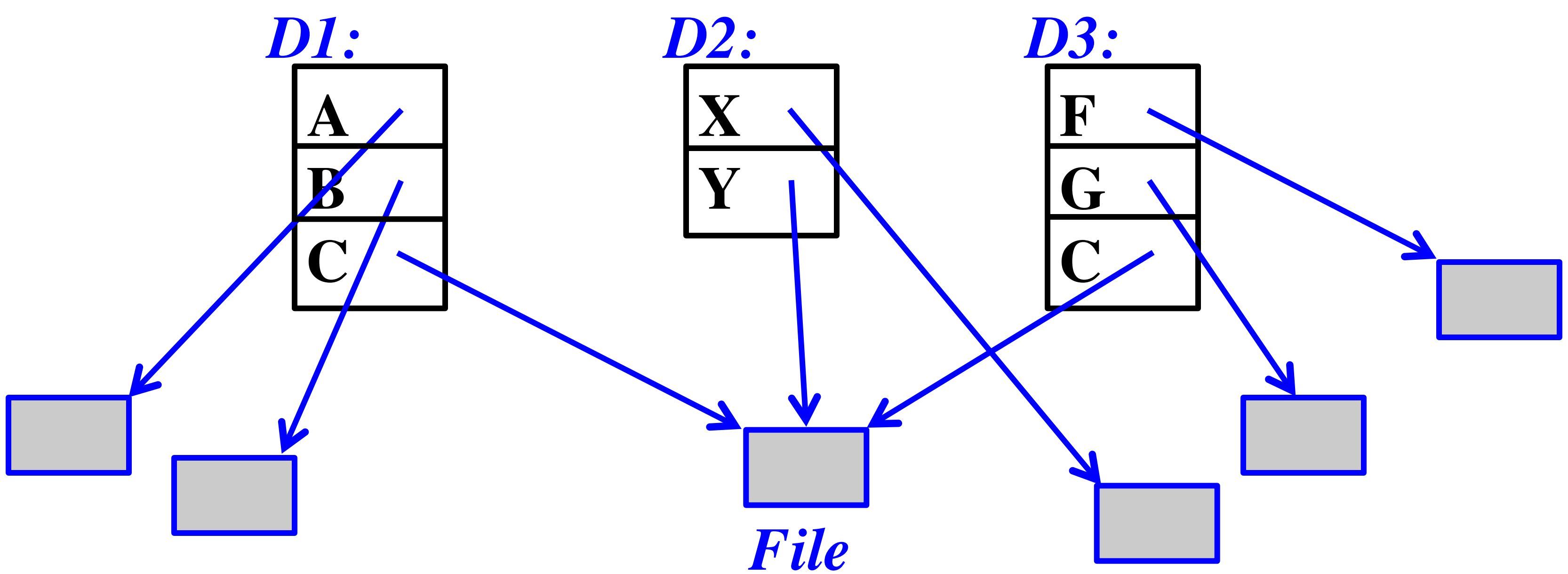
  - Some block is in more than one file
    - **Allocate another block.**
    - **Copy the block.**
    - **Put each block in each file.**
    - **Notify the user that one file may contain data from another file.**

File system consistency - reference counts

- Invariant (for Unix):
- "The reference count in each i-node must be equal to the number of hard links to the file."



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- **Solution:**
  - Correct the reference count.