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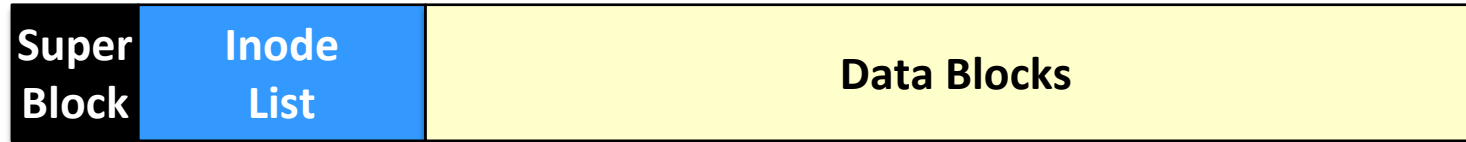
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Fast File System (FFS)



The Original Unix FS

- First Unix file system developed by Ken Thompson

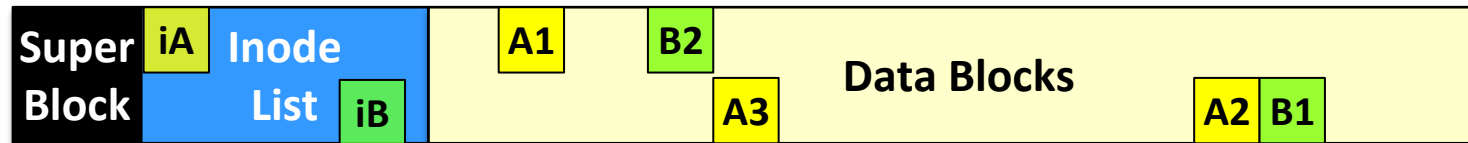


- Super block
 - Basic information of the file system
 - Head of freelists of inodes and data blocks
- Inode list
 - Referenced by index into the inode list
 - All inodes are the same size
- Data blocks
 - A data block belongs to only one file

FFS

- The original Unix file system (70's) was very simple and straightforwardly implemented
 - But, achieved only 2% of the maximum disk bandwidth
- BSD Unix folks redesigned file system called FFS
 - McKusick, Joy, Leffler, and Fabry (80's)
 - Keep the same interface, but change the internal implementation
- The basic idea is disk-awareness
 - Place related things on nearby cylinders to reduce seeks
 - Improved disk utilization, decreased response time

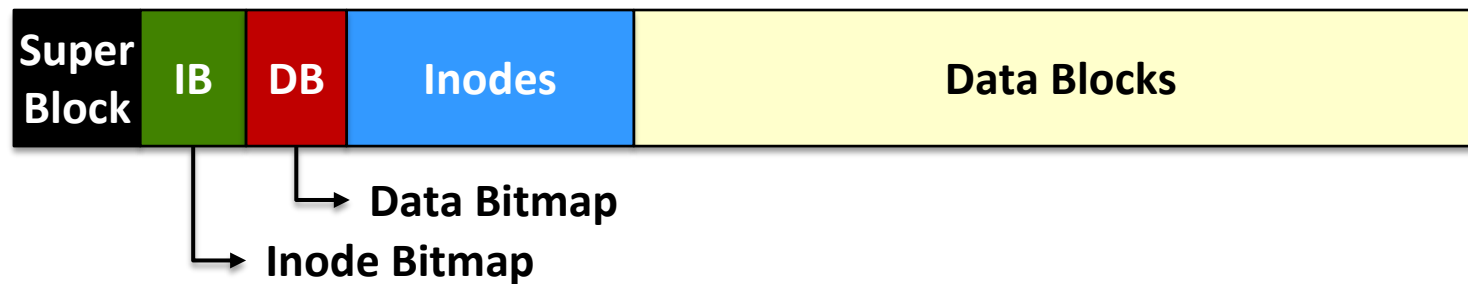
Unix FS: Problems



- Files are fragmented as the file system “_____”
 - Blocks are allocated randomly over the disk
- Inodes are allocated far from blocks
 - Traversing pathnames or manipulating files and directories requires long seeks between inodes and data blocks
- Files in a directory are typically not allocated in consecutive inode slots
- The small block size: 512 bytes

Bitmaps

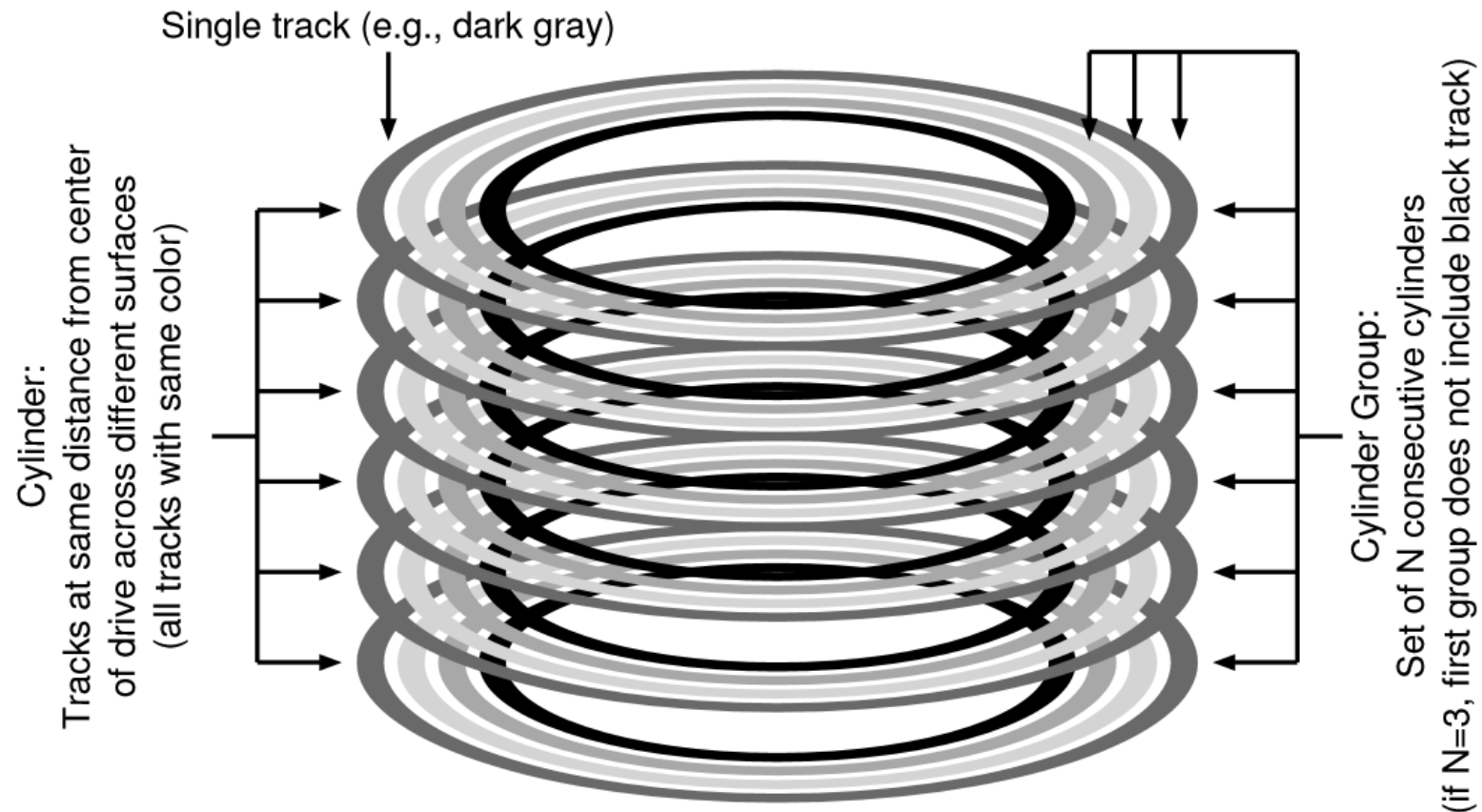
- Use bitmaps instead of free lists



- Each bit represents whether the corresponding inode (or data block) is free or in use
- Provides better speed, with more global view
- Faster to find contiguous free blocks
- Helps to reduce file fragmentation

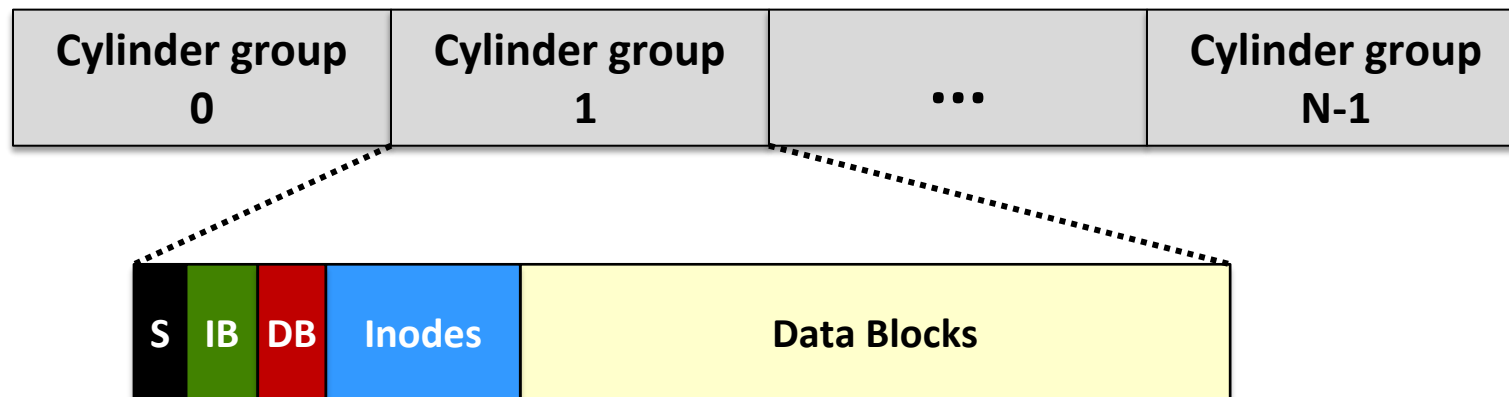
Cylinder Groups

- Divides the disk into a number of cylinder groups



On-Disk Layout

- Put all the structures within each cylinder group
 - Modern drives do not export disk geometry information
 - Modern file systems organize the drive into “block groups” (e.g., Linux Ext2/3/4)
 - Block size is increased to 4KB to improve throughput
 - Super block (S) is replicated for reliability reasons

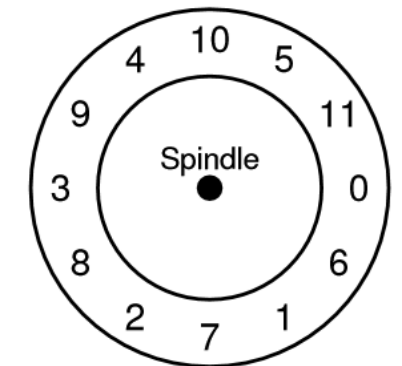
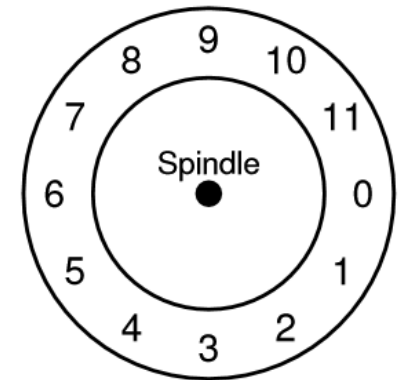


Allocation Policies

- Keep related stuff together
- Balance directories across groups
 - Allocate directory blocks and its inode in the cylinder group with a low number of allocated directories and a high number of free inodes
- Files in a directory are often accessed together
 - Place all files that are in the same directory in the cylinder group of the directory
 - Allocate data blocks of a file in the same group as its inode
 - Data blocks of a large file are partitioned into chunks and distributed over multiple cylinder groups

Other Features

- **Fragments to reduce internal fragmentation**
 - Each block can be broken optionally into 2, 4, or 8 fragments
 - The block map manages the space at the fragment level
- **File system parameterization**
 - Make the next block come into position under the disk head by skipping some blocks
- **Free space reserve**
- **Long file names**
- **Atomic rename**
- **Symbolic links**



Summary

- **First disk-aware file system**
 - Cylinder groups
 - Bitmaps
 - Replicated superblocks
 - Large blocks
 - Smart allocation policies
- **FFS achieves 14% ~ 47% of the disk bandwidth**
 - Original Unix FS: 3% ~ 5% of the disk bandwidth
 - The throughput deteriorates to about half when the file system is full
- **FFS inspired modern file systems including Ext2/3/4**