# The Fast File System

M.K. McKusick, W. Joy, S.L. Leffler, R.S. Fabry, "A Fast File System for UNIX", ACM Transactions on Computer Systems, Vol. 2, No. 3, Aug. 1984

- Recall: Limitations of Original UNIX File System
- Fast File System (FFS)
  - Increase Block Size
  - Make File System "disk-aware"
  - Some Functional Improvements

# Recall: Problems with Original Unix File System

- Original file system uses 512/1024-byte blocks.

- Inodes kept separately from data, causing long seeks to access data.
- Inodes of files in a common directory not kept together, causing low performance when searching directories.
- Data blocks of a file are not stored together.
- Free list quickly scrambles, increasing overhead of finding free blocks.

Original file system treats disk as Random Access Device!

## "Fast FS" (FFS, ca. 1984)

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Three-pronged approach:

1. Increase block size
2. Make file system disk-aware
3. Functional improvements

## FFS: Increase Block Size

Increase block size from 512 byte to at least 4096 byte.

- Block size power-of-two multiple of 4096 byte
- Defined during file system creation
- Stored as parameter in superblock

# FFS: Block Size and Fragmentation

Observation: Typical UNIX files are small compared to large blocks.

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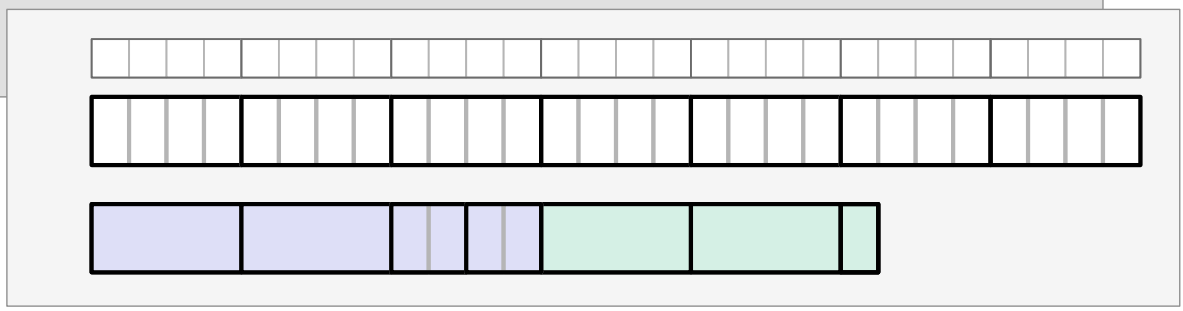
Table I. Amount of Wasted Space as a Function of Block Size

| Space used (Mbytes) | % Waste | Organization |
|---|---|---|
| 775.2 | 0.0 | Data only, no separation between files |
| 807.8 | 4.2 | Data only, each file starts on 512-byte boundary |
| 828.7 | 6.9 | Data + inodes, 512-byte block UNIX file system |
| 866.5 | 11.8 | Data + inodes, 1024-byte block UNIX file system |
| 948.5 | 22.4 | Data + inodes, 2048-byte block UNIX file system |
| 1128.3 | 45.6 | Data + inodes, 4096-byte block UNIX file system |

# Blocks vs. Fragments

Solution: Split blocks into **Fragments**

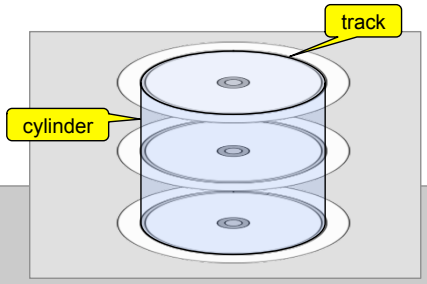
- Fragment size defined at file system creation time
- Example: 4096/1024 has 4kB blocks and 1kB fragments.



# FFS Organization: Making FS Disk-Aware

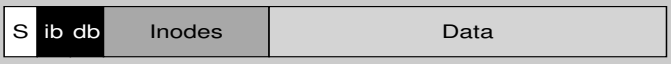
1. **Cylinder Groups**
2. File System **Parameterization**

# FFS Organization: Cylinder Groups




**Cylinder Groups**

- groups of multiple adjacent disk cylinders.
- each group maintains own copy of superblock, inode bitmap, data bitmap, inodes, and data blocks:




Allocation of directories and files:

- "keep related stuff together"
- inodes and data blocks
- blocks of same file
- files and directories

# FFS: Minimizing Rotational Latency

## File System **Parameterization**

Goal: Parameterize **processor capabilities** and **disk characteristics** so that blocks can be **allocated** in an optimal, configuration-dependent way.

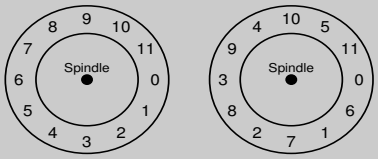
Allocate new block **rotationally well-positioned**.

Disk Parameters:

- number of blocks per **track**
- disk **spin rate**.

CPU Parameters:

- expected time to **service interrupt** and **schedule new disk transfer**




# FFS: Performance

Table IIa. Reading Rates of the Old and New UNIX File Systems

| Type of file system | Processor and bus measured | Speed (Kbytes/s) | Read bandwidth % | % CPU |
|---|---|---|---|---|
| Old 1024 | 750/UNIBUS | 29 | 29/983 3 | 11 |
| New 4096/1024 | 750/UNIBUS | 221 | 221/983 22 | 43 |
| New 8192/1024 | 750/UNIBUS | 233 | 233/983 24 | 29 |
| New 4096/1024 | 750/MASSBUS | 466 | 466/983 47 | 73 |
| New 8192/1024 | 750/MASSBUS | 466 | 466/983 47 | 54 |

Table IIb. Writing Rates of the Old and New UNIX File Systems

| Type of file system | Processor and bus measured | Speed (Kbytes/s) | Write bandwidth % | % CPU |
|---|---|---|---|---|
| Old 1024 | 750/UNIBUS | 48 | 48/983 5 | 29 |
| New 4096/1024 | 750/UNIBUS | 142 | 142/983 14 | 43 |
| New 8192/1024 | 750/UNIBUS | 215 | 215/983 22 | 46 |
| New 4096/1024 | 750/MASSBUS | 323 | 323/983 33 | 94 |
| New 8192/1024 | 750/MASSBUS | 466 | 466/983 47 | 95 |

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## FFS: Functional Enhancements

1. Arbitrary-length File Names
2. File Locking
3. Symbolic Links
4. “Rename” system call added
5. Quotas

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