41. Locality and The Fast File System

Operating System: Three Easy Pieces

Unix operating system

Data structures

- The Good Thing
  - Simple and supports the basic abstractions.
  - Easy to use file system.
- The Problem
  - Terrible performance

Problem of Unix operating system

- Unix file system treated the disk as a **random-access memory.**
  - Example of random-access blocks with Four files.
    - Data blocks for each file can accessed by going back and forth the disk, because they are are **contiguous.**

A1	A2	B1	B2	C1	C2	D1	D2

    - File b and d is deleted.

A1	A2			C1	C2		

    - File E is created with free blocks. (**spread across** the block)

A1	A2	E1	E2	C1	C2	E3	E4

- Other Problem is the original block size was too small(512 bytes)

FFS: Disk Awareness is the solution

- FFS is **Fast File system** designed by a group at Berkeley.
- The design of FFS is that file system structures and allocation polices to be "disk aware" and improve performance.
  - Keep same API with file system. (`open()`, `read()`, `write()`, etc)
  - Changing the internal implementation.

Organizing Structure: The Cylinder Group

- FFS divides the disk into a bunch of groups. **(Cylinder Group)**
  - Modern file system call cylinder group as block group.

G0	G1	G2	G3	G4	G5	G6	G7	G8	G9

- These groups are uses to improve seek performance.
  - By placing two files within the same group.
  - Accessing one after the other **will not be long seeks** across the disk.
  - FFS needs to allocate files and directories within each of these groups.

Organizing Structure: The Cylinder Group (Cont.)

- Data structure for each cylinder group.
  - A copy of the **super block(S)** for reliability reason.
  - **inode bitmap(ib)** and **data bitmap(db)** to track free inode and data block.
  - **inodes** and **data block** are same to the previous very-simple file system(VSFS).

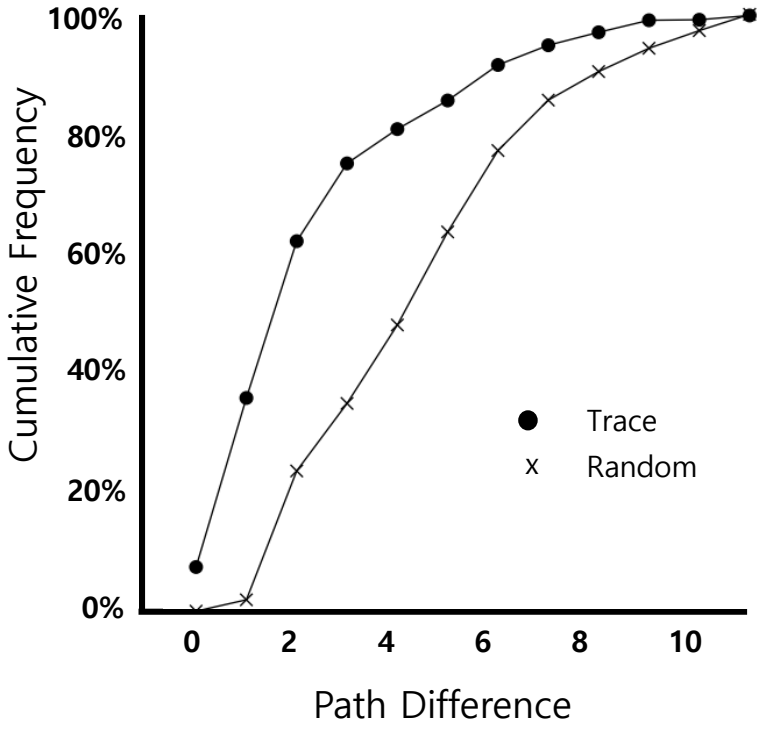
How To Allocate Files and Directories?

- Policy is "**keep related stuff together**"
- The placement of directories
  - Find the cylinder group with a low number of allocated directories and a high number of free inodes.
  - Put the directory data and inode in that group.
- The placement of files.
  - Allocate data blocks of a file in the same group as its inode
  - It places all files in the same group as their directory

FFS Locality for SEER Traces.

- How "**far away**" file accesses were from one another in the directory tree.

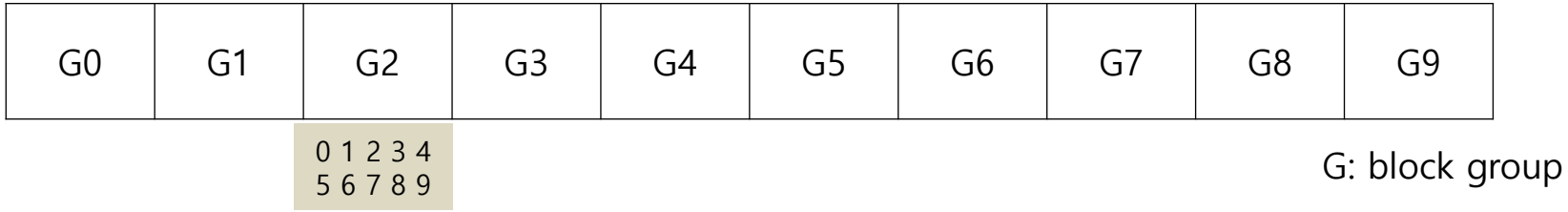
```
proc/src/foo.c
proc/src/bar.c
the distance of two file access is 1

proc/src/foo.c
proc/obj/foo.o
the distance of two file access is 2
```



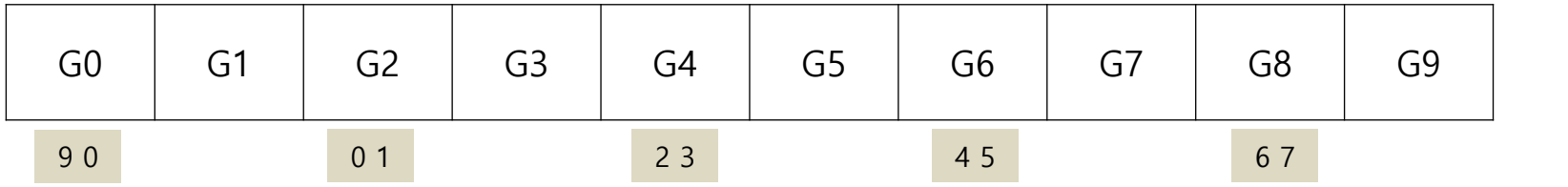
- 7% of file accesses to the same file
- Nearly 40% of file accesses in the same directory
- 25% of file accesses were two distances

The Large-File Exception

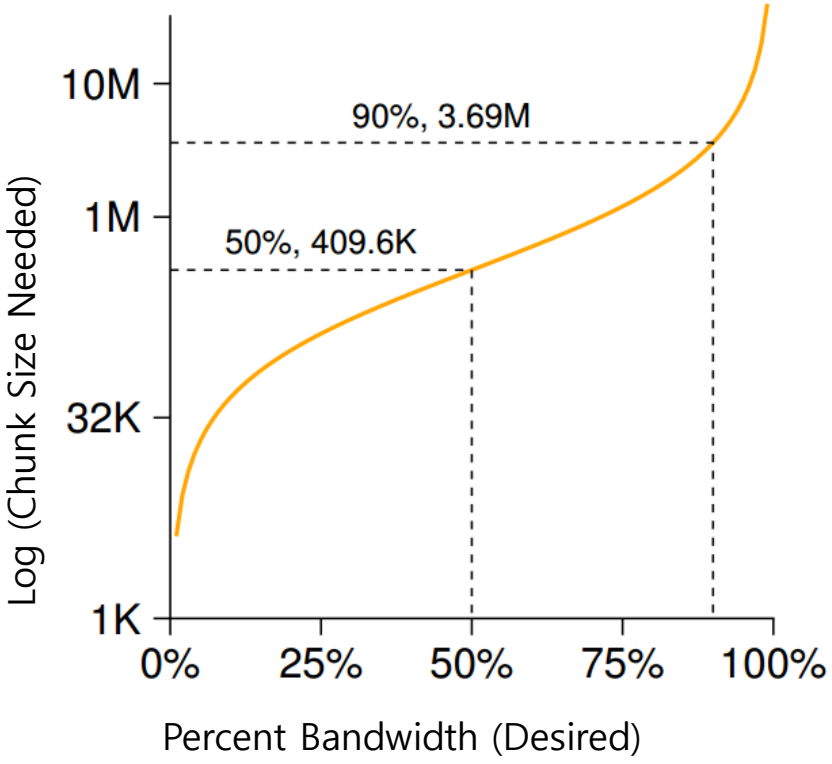
- General policy of file placement
  - Entierly fill the block group it is first place within
  - Hurt file-access locality from "related" file being placed



- For large files, chunks are spread across the disk
  - Hurt performance, but it can be addressed by choosing chunk size
  - **Amortization**: reducing overhead by doing more work



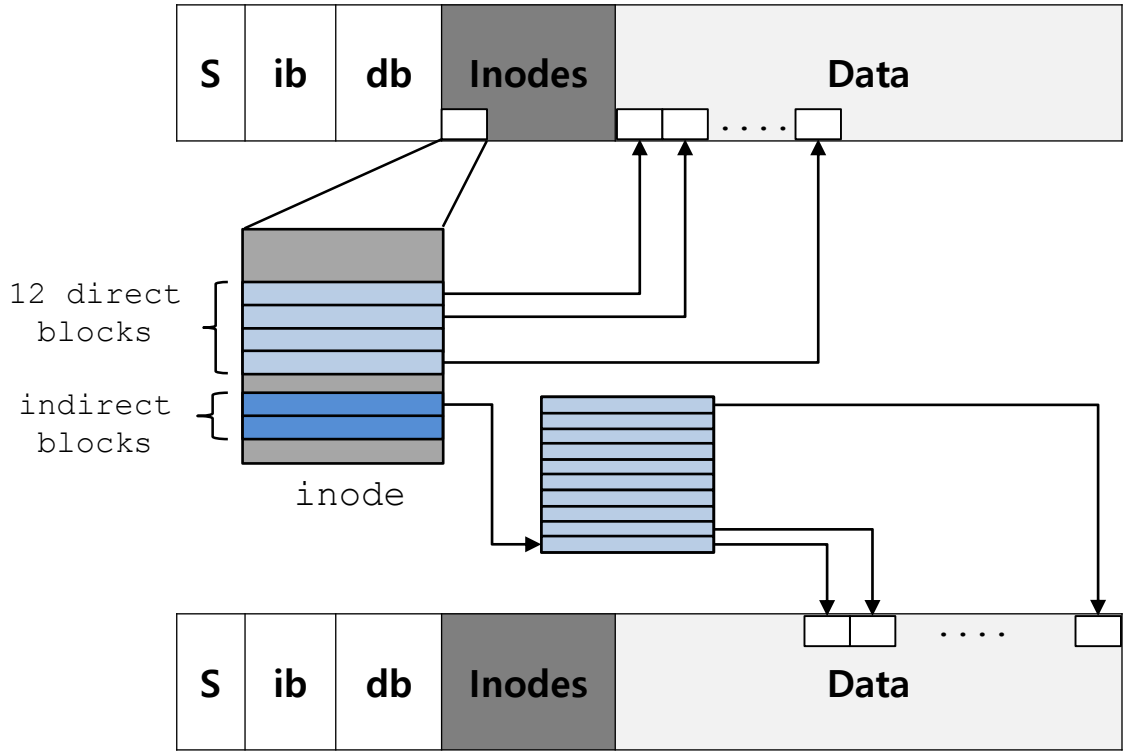
Amortization: How Big Do Chunks Have To Be?



- Computation of the size of chunk
  - Desire 50% of peak disk performance
    - half of time seeking and half of time trasferring
  - Disk bandwidth: 40 MB/s
  - Positioning time: 10ms
  - $\frac{40\ \cancel{MB}}{\cancel{sec}} \cdot \frac{1024\ KB}{1\ \cancel{MB}} \cdot \frac{1\ \cancel{sec}}{1000\ \cancel{ms}} \cdot 10\ \cancel{ms} = 409.6\ KB$
    - Transfer only 409.6 KB every time seeking
  - 99% of peak performance on 3.69MB chunk size

The Large-File Exception in FSS

- A simple approach based on the structure of inode
  - Each subsequent **indirect blocks**, and all the **blocks it pointed to**, placed in **a different block group.**
  - Every **1024 blocks (4MB)** of the **file in a separate group**



A few other Things about FFS

- Internal fragmentation
- Sub-blocks
  - Ex) Create a file with 1 KB : use two sub-blocks, not an entire 4-KB blocks
- Parameterization
- Track buffer
- Long file names
  - Enabling more expressive names in the file system
- Symbolic link