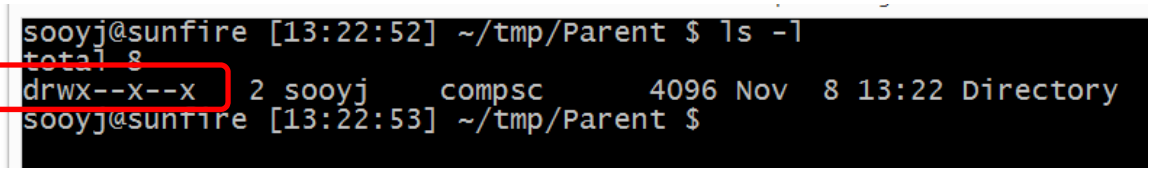
CS2106 Operating Systems
Semester 1 2020/2021

Week of 12th April 2021
Tutorial 11
File System Implementation

1. [Deferred from T10 - Understanding directory permission] In *nix system, a directory has the same set of permission settings as a file. For example:



You can see that directory **`Directory`** has the read, write, execute permission for owner, but only execution permission for group and others. It is easy to understand the permission bits for a regular file (read = can see the file content, write = can modify, execute = can execute this file). However, the same cannot be said for the directory permission bits.

Let's perform a few experiments to understand the permission bits for a directory.

Setup:
- Unzip **`DirExp.zip`** on any *nix platform (Solaris, Mac OS X included).
- Change directory to the **`DirExp/`** directory, there are 4 subdirectories with the same set of files. Let's set their permission as follows:

`chmod 700 NormDir`	`NormDir` is a normal directory with read, write and execute permissions.
`chmod 500 ReadExeDir`	`ReadExeDir` has read and execute permission.
`chmod 300 WriteExeDir`	`WriteExeDir` has write and execute permission.
`chmod 100 ExeOnlyDir`	`ExeOnlyDir` has only execute permission.

Perform the following operations on each of the directory and note down the result. Make sure you are at the **`DirExp/`** directory at the beginning. DDDD is one of the subdirectories.

a. Perform "**`ls -l DDDD`**".
b. Change into the directory using "**`cd DDDD`**".
c. Perform "**`ls -l`**".
d. Perform "**`cat file.txt`**" to read the file content.
e. Perform "**`touch file.txt`**" to modify the file.
f. Perform "**`touch newfile.txt`**" to create a new file.

Can you deduce the meaning of the permission bits for directory after the above? Can you use the "directory entry" idea to explain the behavior?

2. [Putting it together] This question is based on a "simple" file system built from the various components discussed in lecture 12.

Partition Information (Free Space Information)

- Bitmap is used, with a total of 32 file data blocks (1 = Free, 0 = Occupied):

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1
16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
1	0	1	0	1	0	1	0	1	1	1	0	0	1	0	0

Directory Structure + File Information:

- Directory structures are stored in 4 "directory" blocks. Directory entries (both files and subdirectories) of a directory are stored in a single directory block.
- Directory entry:
  - **For File:** Indicates the first and last data block number.
  - **For Subdirectory:** Indicates the directory structure block number that contains the subdirectory's directory entries.
  - The "**/**" root directory has the directory block number 0.

0	1	2	3
y |Dir | 3 f |File| 12| 2 x |Dir | 1	g |File| 0| 31 z |Dir | 2	k |File| 6| 6	i |File| 1| 3 h |File|27|28

File Data:

- Linked list allocation is used. The first value in the data block is the "next" block pointer, with "-1" to indicate the end of data block.
- Each data block is 1 KB. For simplicity, we show only a couple of letters/numbers in each block.

0	1	2	3	4	5	6	7
11 AL	9 TH	-1 S!	-1 ND	23 GS	-1 SO	-1 :)	10 TE
8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
31 RE	3 EE	28 M:	31 OH	19 SE	13 AH	4 IN	17 NO
16	**17**	**18**	**19**	**20**	**21**	**22**	**23**
30 YE	2 OU	1 ON	17 RI	26 EV	14 AT	21 DA	7 YS
24	**25**	**26**	**27**	**28**	**29**	**30**	**31**
-1 HO	18 ME	0 AL	30 OP	-1 -(	5 LO	21 ER	-1 A!

a. (Basic Info) Give:
   - The current free capacity of the disk.
   - The current user view of the directory structure.

b. (File Paths) Walkthrough the file path checking for:
   - "**`/y/i`**"
   - "**`/x/z/i`**"

c. (File access) Access the entire content for the following files:
   - "**`/x/z/k`**"
   - "**`/y/h`**"

d. (Create file) Add a new file "**`/y/n`**" with 5 blocks of content. You can assume we always use the free block with the smallest block number. Indicate **all changes required to add the file.**

3. [Disk I/O Scheduling] The example used in the disk I/O scheduling section in lecture 12 assumes that all requests arrive at the same time. Specifically, all requests are assumed to arrive at time 0.

   If possible, give an ***arrival timeline*** for the same set of requests {13, 14, 2, 18, 17, 21, 15} that results in a different schedule under i) FCFS and ii) C-SCAN algorithm. For simplicity, assume we can service one I/O request per time unit.

   Note: this means that the **order of the requests remains unchanged**, but they may now arrive at different timing. One example timeline:

Arrival Time	T0	T0	T2	T4	T7	T9	T10
Request	13	14	2	18	17	21	15

4. [AY16/17 Sem1 Exam Question] Most OSes perform some higher-level I/O scheduling on top of just trying to minimize hard disk seeking time. For example, one common hard disk I/O scheduling algorithm is described below:
    i. User processes submit file operation requests in the form of
    ***operation*(starting hard disk sector, number of bytes)**
    ii. The OS sorts the requests by hard disk sector.
    iii. The OS merges requests that are nearby into a larger request, e.g. several requests asking for tens of bytes from nearby sectors merged into a request that reads several nearby sectors.
    iv. The OS then issues the processed requests when the hard disk is ready.

    a. How should we decide whether to merge two user requests? Suggest two simple criteria.
    b. Give one advantage of the algorithm as described.
    c. Give one disadvantage of the algorithm and suggest one way to mitigate the issue.
    d. Strangely enough, the OS tends to **intentionally delay** serving user disk I/O requests. Give one reason why this is actually beneficial using the algorithm in this question for illustration.
    e. In modern hard disks, algorithms to minimise disk head seek time (e.g. SCAN variants, FCFS etc.) are **built into the** hardware controller. i.e. when multiple requests are received by the hard disk hardware controller, the requests will be reordered to minimise seek time. Briefly explain how the high-level I/O scheduling algorithm described in this question may conflict with the hard disk's built-in scheduling algorithm.

Question for your own Exploration

1. (Cluster Allocation, Adapted from [SGG]) A common modification to the file allocation scheme is to allocate **several contiguous blocks** instead of a single disk block for every allocation. This variation is known as the **disk block cluster** in FAT file systems. The design of cluster can be one of the following:

   a. Fixed cluster size, e.g. one cluster = 16 disk blocks.
   b. Variable cluster size, e.g. one cluster = 1 to 32 disk blocks.
   c. Several fixed cluster size, e.g. one cluster = 2, 4, 8 or 16 disk blocks.

   Discuss the changes to the file information in order to support cluster. Briefly state the general advantage and disadvantage of the various cluster design.

2. (File Implementations Comparison) Let us compare and contrast the various ways of implementing files in this question.

   Below are the hardware parameters:
   a. Number of disk blocks = 2^{16} = 65,536 blocks (i.e. each disk block number = 2 bytes).
   b. Disk block size = 512 bytes.

   Points of comparison:
   - **Total Number of Data Blocks:** Number of disk blocks needed to store the file data.
   - **Overhead**: Extra bookkeeping information in bytes. Focus only on information directly related to keep track of file data. You can ignore the space needed for file name and other metadata for this question.
   - **Worst Case Disk Access:** The worst case number of disk accesses needed to get to a particular block in the file. May include accessing book keeping information if they are in disk. Specify the block which causes the worst case.

   File data allocation schemes under consideration:
   A. Contiguous
   B. Linked list
   C. File allocation table
   D. Index block

   Fill in the following table for the indicated file size. State assumptions for your calculation (if any).

File size: 100 b	Total Number of Data Blocks	Overhead	Worst Case Disk Access
A			
B			
C			
D			

File size: 132,000 b	Total Number of Data Blocks	Overhead	Worst Case Disk Access
A			
B			
C			
D			

File size: 33,554,432 b	Total Number of Data Blocks	Overhead	Worst Case Disk Access
A			
B			
C			
D			