File Systems

Goal

To learn how files are represented both in memory and on the secondary storage devices.

File Systems

A file is a collection of data. There are two aspects of it:

- *virtual*: this is how the user (process) sees the file
- *physical*: this is how the file is represented to the hardware and operating system.

A file's name often reflects something about the file.
example: in TOPS-20, file names are *name*.*ext*, where *ext* is a three-character extension describing the file; “bas” for BASIC, “for” for FORTRAN, “bli” for BLISS, “obj” for object, “exe” for executable, “txt” for text, and so forth. On UNIX™ and MINIX, the last letter may designate something; for example, C source files end in “.c” and PASCAL source files in “.p”.

Directories

Files can be organized into *directories* ("folders" to the Mac) to make organizing them easier. A directory contains pairs of

(name, location)

The location may be a physical location (disk address) or an index into an array containing those locations or any other datum used to locate files. There are several main types of directory organizations; in historical order, they are:

- a one-level (flat) directory in which all files are in the same, single directory.
  - no two files can have the same name (so to keep users having to worry about collisions, the system could make the user name a component of each file name)
  - to find a file, one must search the whole directory
- hierarchical directories impose a tree structure on directories; typically there is a master directory, and then user directories for each user.
  - do absolute and relative path names, current working name.
- graph-structured directory systems are basically hierarchical systems, but with the ability to *alias* files.
  - *direct* aliasing occurs when one (file) location appears twice (or more) in directories, often with different names.
  - *indirect*aliasing occurs when a special type of file containing a path name is created; it is said to be an indirect alias for the file it names. When you refer to the indirect alias, the operating system interpolates the name of the file being aliased.

    issues:
    - naming: there is no such thing as a "true" name now
    - deletion: If a file is deleted under one alias, is it inaccessible using the other aliases?

      yes: must find all other aliases and delete them; expensive

      no: don't delete file until all aliases deleted; use a *link count* to track how many aliases a file has.
    - accounting: usually, the owner of a file pays for storage (and other related charges), but if another user aliases to the file, the owner might no longer be able to delete all references to it!

      solution: have each person owning a link to the file (*ie*., owning a directory containing a link to the file) pay a percentage of the cost of the file.

Information kept in a directory (or indicated by it) is the name, file type, *etc*.
example: UNIX handout; note the difference between in-core representation and representation of information on disk.

Access Control

Typical protection modes are: *read*, *write*, *append*, *delete*, *privilege* (allows modification of others' rights), *owner* (indicates owner of file), and *search* (grants permission to search directory).
example: UNIX; note difference in meaning of execute for files and directories.
implementation: describe access lists, abbreviation
association of rights: are privileges associated with a *name* or a *file*? That is, if *x* is an alias for *y*, can a user have read permission on *x* but not
on *y*?

Process View of File

Processes operate on files using the following commands:

- *create*: find space for the file, allocate it, and make an entry in the directory
- *open*: begin operations on a file
- *close*: end operations on a file
- *read*: transfer information from the file
- *write*: transfer information to the file
- *rewind*: move to the beginning (or a random point) in the file
- *delete*: remove the file

Access Methods

How can processes access files?

- *sequential*: one block after the other. The process keeps track of a *read/write pointer* (part of the PCB) indicating where the next action is to be done; the pointer always advances.
- *direct*: the read/write pointer can move freely.
- *mapped*: map the file into a virtual segment, and return the segment number rather than the file descriptor; then treat thr file as part of the process' virtual store. On closing, just release the storage.
  example: TOPS-20, MULTICS
- *structured*: the file consists of a sequence of records; often the operating system knows about the file type.
  example: ISAM (Indexed Sequential Access Method). In this, a small master index points to blocks in a secondary index, which in turn point to real file blocks. Thus, it takes at most 2 reads to locate any record

Information in disk directory file

A *disk directory* is like a directory for a disk; it describes what blocks are in use and which are free. This means it must keep track of what blocks are not in use; such a list is a *free list*. Several representations:

- a bit map, with 1 bit per block
- a linked list of blocks
- like linked list, but in each block of size *n* on the free list, store *n*-1 numbers of free blocks; the *n*-th is the address of the next block making up the list
- pairs of (block number, number of free blocks from that block on); if there is more than one contiguous block free, this usually saves same space

The latter three are often called *file maps* because each free block is represented by 1 word (pointer).

Allocation of Disk Blocks to Files

This is done in one of three ways:

- *contiguous allocation*: here, blocks are allocated sequentially (contiguously)
  advantages:
  - minimal head motion for sequential reading of file

  problems
  - need to find space for it (using the usual algorithms: first-fit, best-fit, ...). Compaction is possible but usually requires copying almost everything on the disk
  - how much space should be allocated for the file? It might grow beyond its initial allocation.
    - there may be room to increase the allocation;
    - the program may be terminated; in this case, people tend to ask for as much room as possible (wasting space)
    - the file may be moved elsewhere (very slow)

    Note that files may grow for years, so even if you know the maximum size a file will ever get, you may waste lots of space for a long time.
- *linked allocation*: the directory contains pointers to the first and last blocks of the file, and the last *n* bytes of each block in the file point to the next block in the file.
  advantages:
  - this scheme eliminates the need to know the size of files in advance
  - again, it is great for files accessed sequentially

  disadvantages:
  - it is poor for direct access files as the operating system must follow links to get to the desired block.
  - it wastes *n* bytes of disk space per block
  - it is unreliable: if 1 pointer is deleted or changed, the file is garbled; a doubly-linked list, which would ameliorate this, uses more memory.
- *indexed allocation*: this scheme brings all pointers together into one block.
  advantages:
  - compact and easy to reference blocks

  disadvantages:
  - wastes more space as an entire block is pointers rather than just 1 word per block (so a 511 block file and a 2 block file use the same number of pointers)

implementation issue If you need more than 1 index block, link them together. Or, use indirection: if you can have 256 pointers/block, 2 levels of indirection allows 256^2 = 65,536 blocks.

example: UNIX scheme: the first 12 blocks of a file are data, the 13th is an index block, the 14th is a doubly-indexed block (*ie*, it contains pointers to index blocks), and the 15th is a triply-indexed block (*ie*, it contains pointers to doubly-indexed blocks)