File Systems - Part II

CS 537 - Introduction to Operating Systems

Directory

- A directory maps file names to disk locations
- A single directory can contain files and other directories
- A modern file system is made up of many directories

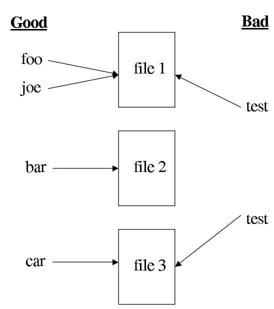
File Names

- A file name is given as a *path*
  - a road map through the directory system to the files location in the directory
- Relative path name
  - files location relative to the current directory
- Absolute path name
  - files location from beginning of directory

File Names

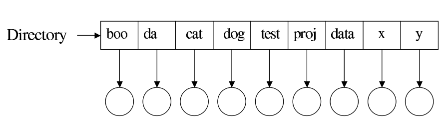
- Each file must have a unique path in the directory
- A file can have more than one path name
- The same path name cannot be used to represent multiple files

File Names



One-Level Directory

- All files are listed in the same directory



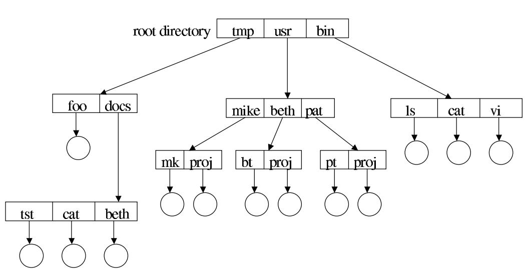
One-Level Directory

- Easy to implement
- One major problem is the unique name requirement
  - imagine 2 users both doing project 2
    - in single directory, they couldn't both name it proj2
  - even for single user system it is difficult to keep track of the names of every file

Tree Structured Directories

- Directory structure is made up of nodes and leafs
- A node is a directory
- A leaf is a file
- Each directory can contain files or sub-directories
- Each node or leaf has only 1 parent

Tree Structured Directories



Tree Structured Directories

- Allows users to have there own directories
  - users can create there own sub-directories
- Different files can now have the same name
  - as long as the absolute path is different
- A user has a *current directory*
  - directory the user is currently in

Tree Structured Directories

- Traversing the tree can be done in two ways
  - absolute path
    - begin searching from the root (/usr/beth/proj)
  - relative path
    - begin searching from current directory
    - assume in usr directory and want to access beth's project
      - beth/proj

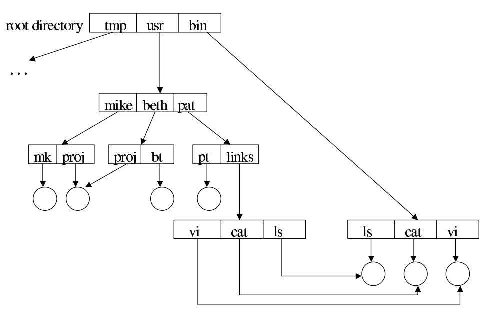
Tree Structured Directories

- Trees are fairly easy to traverse and maintain
- One major problem is the sharing of files
  - remember, only one parent per node/leaf
- Would like to be able to have multiple references to a file or directory

Acyclic Graph Directories

- Similar to a tree except each node or leaf can have more than one parent
- One requirement is that there can be no cycles
  - cycles can cause infinite search loops
- File and directory sharing now becomes easy

Acyclic Graph Directories

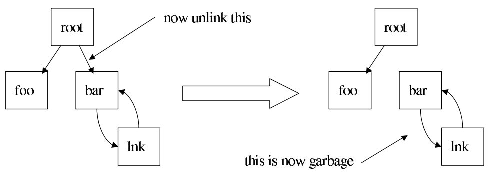


Acyclic Graph Directories

- Unix uses this structure
- Reference from one directory to another directory or file is called a *link*
- In Unix, a reference count is kept for each file (or directory)
- When no more references to a file, it is deleted
  - notice, Unix has no explicit *delete* method
  - uses *unlink* to remove a reference to a file

Cycles

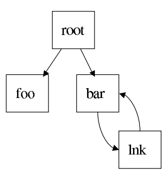
- Cycles in a graph can present a major problem



- Reference counting wouldn't work
  - would need to do garbage collection
  - garbage collection on disk is extremely time consuming

Cycles

- Cycles present other problems



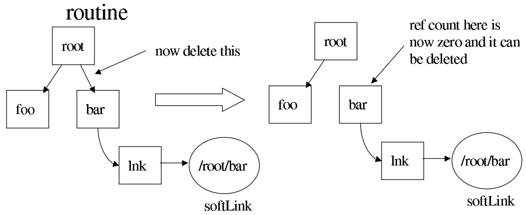
- Imagine trying to delete everything beneath bar
  - we first need to search for everything contained in bar
  - an infinite loop will develop
    - search to lnk, lnk points to bar, bar points to lnk, …

Links

- Hard links
  - actual entry in a directory
  - points directly to another directory or a file
- Symbolic links (soft links)
  - special file that contains a path name to another file or directory
  - when it is encountered, read the file and follow the path described in the file
  - does not count in reference counting scheme

Links

- To prevent cycles, do not allow more than one hard link to a directory
  - count how many times a search “loops”
  - if it loops a certain number of times, exit search routine



Directory Entry

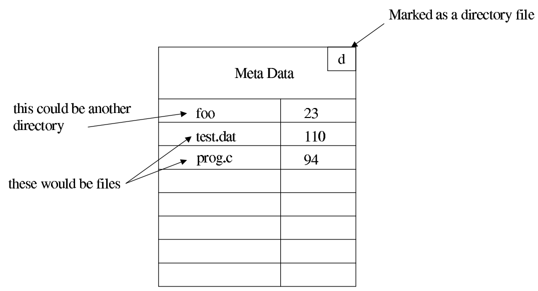
- A directory entry contains a name and a location on disk
  - the name can be a file
  - the name can be another directory
- This is a hard link to another entity

name	location

Directory

- A directory is made up entries
- In Unix, a directory is *almost* identical to a regular file
- How does Unix know it is looking at a directory and not a regular file?
  - information in meta data marks it as a directory

Directory



Searching the Directory

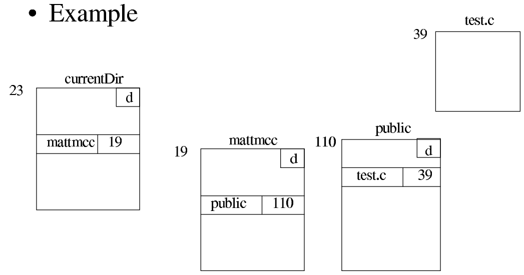
- User gives an absolute or relative path name
- A copy of the users current directory is cached memory
- If user gives relative path, use this cache
- If user gives absolute path, go to disk and find the root directory
  - continue search from there
- Unix has a function called *namei*
  - *namei* does the actual directory search

namei()

```
int namei(int startDirLoc, String [] path) {
    for(int i=0; i<path.length; i++) {
        if(startDirLoc != directoryFile)
            ERROR;
        startDirLoc = getDiskLocation(startDirLoc, path[i]);
        if(startDirLoc == 0)
            ERROR;
    }
    return startDirLoc;
}
```

namei()

- Example



namei()

- Example
  - startDirLoc = 23
  - path = {mattmcc, public, test.c}
    - test is the actual file we are looking for on disk
  - a program like emacs might do the following
    - *int fileLoc = namei(startDirLoc, path);*
  - start at currentDir and look for mattmcc -> 19
  - make 19 the current search directory and look for public -> 110
  - make 110 the current search directory and look for test.c -> 39 (this is the location we want)

Protection

- A good file system should provide a means of controlling access to files
- In early systems with only a single user, this was not an issue
- Today, almost anyone can access a computer either through a LAN or through the internet

Controlling Access

- The user that creates a file should have all rights to that file
  - that user can read, write, and delete the file
  - the user should also be able to control access rights of other users to that file
- For example
  - imagine a supervisor creates a work schedule
  - the supervisor should be able to read and modify that schedule
  - the workers should all be able to read the schedule
    - but they should not be able to modify it

Access Control List

- For each file, the author could specify every other users access rights to the file
  - this is very flexible
  - this is very tedious for a user to do
- Instead of specifying all users, system could have a default and only specify specific users to grant access to
  - still very flexible
  - much less work on the part of the file creator
  - default access may be read-only or no access at all
- Problem with both of these approaches is the amount of space needed in meta data of file
  - have to record this information and it may vary (or grow over time)

Unix Access Control

- Unix uses a much simpler strategy
  - there are three type of people in the world
    - owner of the file (usually the creator)
    - a group to which the owner belongs
    - everyone in the world
  - for each of these categories, the owner of the file specifies rights
- Directories and files have rights associated with them

Unix Access Control

- Possible rights for a file
  - read
    - can read the file, can list a directory, can copy the file
  - write
    - can write the file, can add or delete files from a directory
  - execute
    - can execute an executable file

Unix Access Control

- The rights for each type of user is specified when the file is created
- These rights can be changed by the owner of the file
- It takes 9 bits to record the access rights of the file