CSE 451: Operating Systems
Autumn 2001

Lecture 13
File Systems

File Systems

- The concept of a file system is simple
  - the implementation of the abstraction for secondary storage
    - abstraction = files
  - logical organization of files into directories
    - the directory hierarchy
  - sharing of data between processes, people and machines
    - access control, consistency, …

Files

- A file is a collection of data with some properties
  - contents, size, owner, last read/write time, protection …
- Files may also have types
  - understood by file system
    - device, directory, symbolic link
  - understood by other parts of OS or by runtime libraries
    - executable, dll, source code, object code, text file, …
- Type can be encoded in the file's name or contents
  - windows encodes type in name
    - .com, .exe, .bat, .dll, .jpg, .mov, .mp3, …
  - unix has a smattering of both
    - in content via magic numbers or initial characters (e.g., #!)

Basic operations

Unix

- create(name)
- open(name, mode)
- read(fd, buf, len)
- write(fd, buf, len)
- sync(fd)
- seek(fd, pos)
- close(fd)
- unlink(name)
- rename(old, new)

NT

- CreateFile(name, CREATE)
- CreateFile(name, OPEN)
- ReadFile(handle, …)
- WriteFile(handle, …)
- FlushFileBuffers(handle, …)
- SetFilePointer(handle, …)
- CloseHandle(handle, …)
- DeleteFile(name)
- CopyFile(name)
- MoveFile(name)

File Access Methods

- Some file systems provide different access methods that specify ways the application will access data
  - sequential access
    - read bytes one at a time, in order
  - direct access
    - random access given a block/byte #
  - record access
    - file is array of fixed- or variable-sized records
  - indexed access
    - FS contains an index to a particular field of each record in a file
    - apps can find a file based on value in that record (similar to DB)
- Why do we care about distinguishing sequential from direct access?
  - what might the FS do differently in these cases?

Directories

- Directories provide:
  - a way for users to organize their files
  - a convenient file name space for both users and FS's
- Most file systems support multi-level directories
  - naming hierarchies (/, /usr, /usr/local, /usr/local/bin, …)
- Most file systems support the notion of current directory
  - absolute names: fully-qualified starting from root of FS

```
bash$ cd /usr/local
```

  - relative names: specified with respect to current directory

```
bash$ cd /usr/local   (absolute)
bash$ cd bin          (relative, equivalent to cd /usr/local/bin)
```

Directory Internals

- A directory is typically just a file that happens to contain special metadata
  - directory = list of (name of file, file attributes)
  - attributes include such things as:
    - size, protection, location on disk, creation time, access time, …
  - the directory list is usually unordered (effectively random)
    - when you type “ls”, the “ls” command sorts the results for you

Path Name Translation

- Let’s say you want to open “/one/two/three”

```
fd = open(“/one/two/three”, O_RDWR);
```

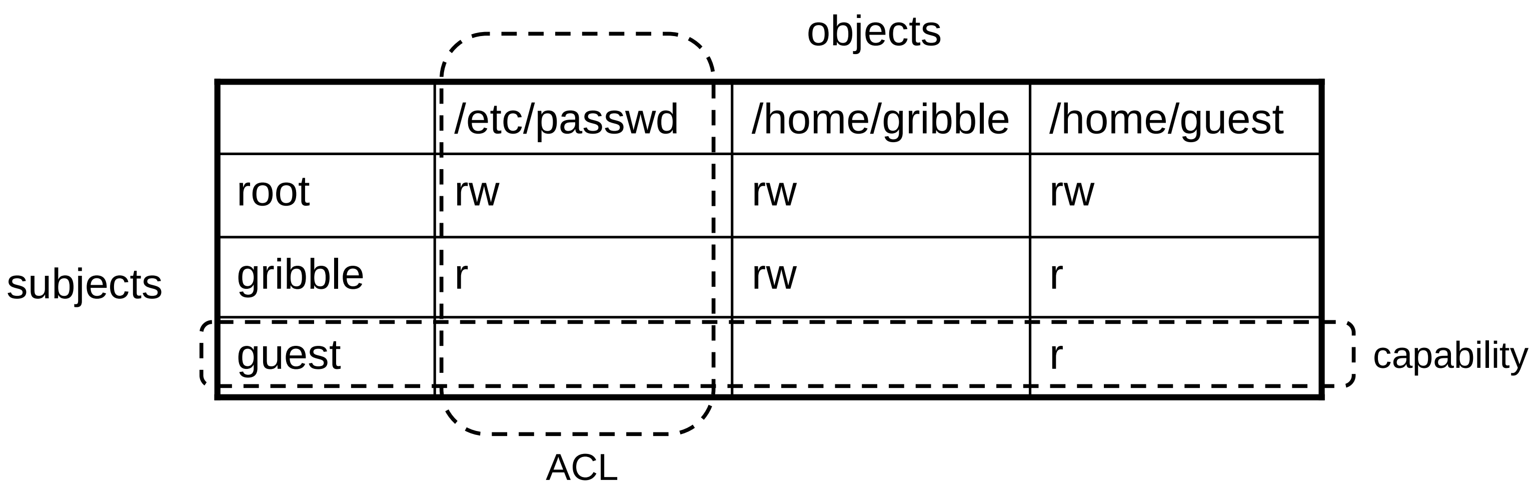
- What goes on inside the file system?
  - open directory “/” (well known, can always find)
  - search the directory for “one”, get location of “one”
  - open directory “one”, search for “two”, get location of “two”
  - open directory “two”, search for “three”, get loc. of “three”
  - open file “three”
  - (of course, permissions are checked at each step)
- FS spends lots of time walking down directory paths
  - this is why open is separate from read/write (session state)
  - OS will cache prefix lookups to enhance performance
    - /a/b, /a/bb, /a/bbb all share the “/a” prefix

Protection Systems

- FS must implement some kind of protection system
  - to control who can access a file (user)
  - to control how they can access it (e.g., read, write, or exec)
- More generally:
  - generalize files to objects (the “what”)
  - generalize users to principles (the “who”, user or program)
  - generalize read/write to actions (the “how”, or operations)
- A protection system dictates whether a given action performed by a given subject on a given object should be allowed
  - e.g., you can read or write your files, but others cannot
  - e.g., your can read `/etc/motd` but you cannot write to it

Model for Representing Protection

- Two different ways of thinking about it:
  - access control lists (ACLs)
    - for each object, keep list of subjects and subj's allowed actions
  - capabilities
    - for each subject, keep list of objects and subj's allowed actions
- Both can be represented with the following matrix:



	/etc/passwd	/home/gribble	/home/guest
root	rw	rw	rw
gribble	r	rw	r
guest			r

ACLs vs. Capabilities

- Capabilities are easy to transfer
  - they are like keys: can hand them off
  - they make sharing easy
- ACLs are easier to manage
  - object-centric, easy to grant and revoke
    - to revoke capability, need to keep track of subjects that have it
    - hard to do, given that subjects can hand off capabilities
- ACLs grow large when object is heavily shared
  - can simplify by using “groups”
    - put users in groups, put groups in ACLs
    - you are all in the “VMware powerusers” group on Win2K
  - additional benefit
    - change group membership, affects ALL objects that have this group in its ACL