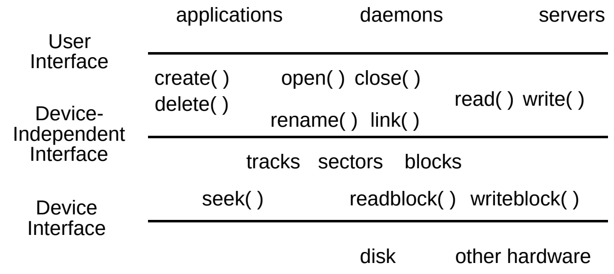
File System Abstraction

- Levels of abstraction:



applications daemons servers

User Interface

create( ) delete( ) open( ) close( ) rename( ) link( ) read( ) write( )

Device-Independent Interface

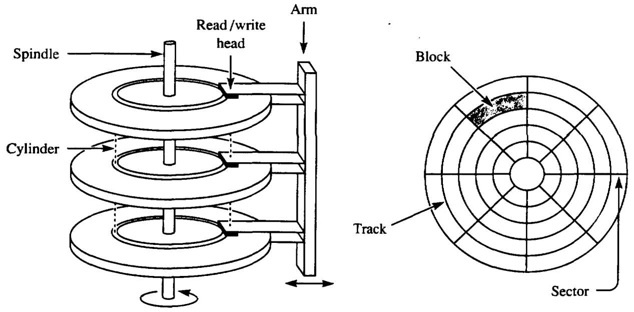
tracks sectors blocks

seek( ) readblock( ) writeblock( )

Device Interface

disk other hardware

- The hardware underneath:



(a) A hard disk drive. (b) A single disk.

Diagram from *Computer Science*, Volume 2, J. Stanley Warford, Heath, 1991.

File System Issues

- Important to the user:
  - Persistence — data stays around between power cycles and crashes
  - Ease of use — can easily find, examine, modify, etc. data
  - Efficiency — uses disk space well
  - Speed — can get to data quickly
  - Protection — others can't corrupt (or sometimes even see) my data
- OS provides:
  - File system with directories and naming — allows user to specify directories and names instead of location on disk
  - Disk management — keeps track of where files are located on the disk, accesses those files quickly
  - Protection — no unauthorized access

User Interface to the File System

- A *file* is a logical unit of storage:
  - A series of records (IBM mainframes)
  - A series of bytes (UNIX, most PCs)
  - A resource fork and data fork (Macintosh)
    - Resource fork — labels, messages, etc.
    - Data fork — code and data
- What is stored in a file?
  - C++ source code, object files, executable files, shell scripts, PostScript…
  - Macintosh OS explicitly supports file types — TEXT, PICT, etc.
  - Windows uses file naming conventions — ".exe" and ".com" for executables, etc.
  - UNIX looks at contents to determine type:
    - Shell scripts — start with "#"
    - PostScript — starts with "%!PS-Adobe…"
    - Executables — starts with *magic number*

File Operations

- **Create**(*name*)
  - Constructs a *file descriptor* on disk to represent the newly created file
    - Adds an entry to the *directory* to associate *name* with that file descriptor
  - Allocates disk space for the file
    - Adds disk location to file descriptor
- *fileId* = **Open**(*name*, *mode*)
  - Allocates a unique identifier called the *file ID* (identifier) (returned to the user)
  - Sets the mode (r, w, rw) to control concurrent access to the file
- **Close**(*fileId*)
- **Delete**(*fileId*)
  - Deletes the file's file descriptor from the disk, and removes it from the directory

Common File Access Patterns

- Sequential access
  - Data is processed in order, one byte at a time, always going forward
  - Most accesses are of this form
  - Example: compiler reading a source file
- Direct / random access
  - Can access any byte in the file directly, without accessing any of its predecessors
  - Example: accessing database record 12
- Keyed access
  - Can access a byte based on a *key* value
  - Example: database search, dictionary
  - OS does not support keyed access
    - User program must determine the address from the key, then use random access (provided by the OS) into the file

File Operations (cont.)

- **Read**(*fileId*, *from*, *size*, *bufAddress*)
  - Random access read
  - Reads *size* bytes from file *fileId*, starting at position *from*, into the buffer specified by *bufAddress*

    ```
    for (pos=from, i=0 ; i < size ; i++)
      *bufAddress[i] = file[pos++];
    ```
- **Read**(*fileId*, *size*, *bufAddress*)
  - Sequential access read
  - Reads *size* bytes from file *fileId*, starting at the current file position *fp*, into the buffer specified by *bufAddress*, and then increments *fp* by *size*

    ```
     for (pos=fp, i=0 ; i < size ; i++)
      *bufAddress[i] = file[pos++];
    fp += size;
    ```
- **Write** — similar to **Read**

Directories and Naming

- Directories of named files
  - User and OS must have some way to refer to files stored on the disk
  - OS wants to use numbers (index into an array of file descriptors) (efficient, etc.)
  - User wants to use textual names (readable, mnemonic, etc.)
  - OS uses a *directory* to keep track of names and corresponding file indices
- Simple naming
  - One name space for the entire disk
    - Every name must be unique
  - Implementation:
    - Store directory on disk
    - Directory contains <name, index> pairs
  - Used by early mainframes, early Macintosh OS, and MS DOS

Directories and Naming (cont.)

- User-based naming
  - One name space for each user
    - Every name in that user's directory must be unique, but two different users can use the same name for a file in their directory
  - Used by TOPS-10 (DEC mainframe from the early 1980s)
- Multilevel naming
  - Tree-structured name space
  - Implementation:
    - Store directories on disk, just like files
    - Each directory contains <name, index> pairs in no particular order
      - – The file pointed to by a directory can be another directory
        - » Names have "/" separating levels
      - – Resulting structure is a tree of directories
  - Used by UNIX
    - More on UNIX disk structures next time…