OPERATING SYSTEMS
DESIGN AND IMPLEMENTATION

Third Edition

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Chapter 1
Introduction

The Modern Computer System

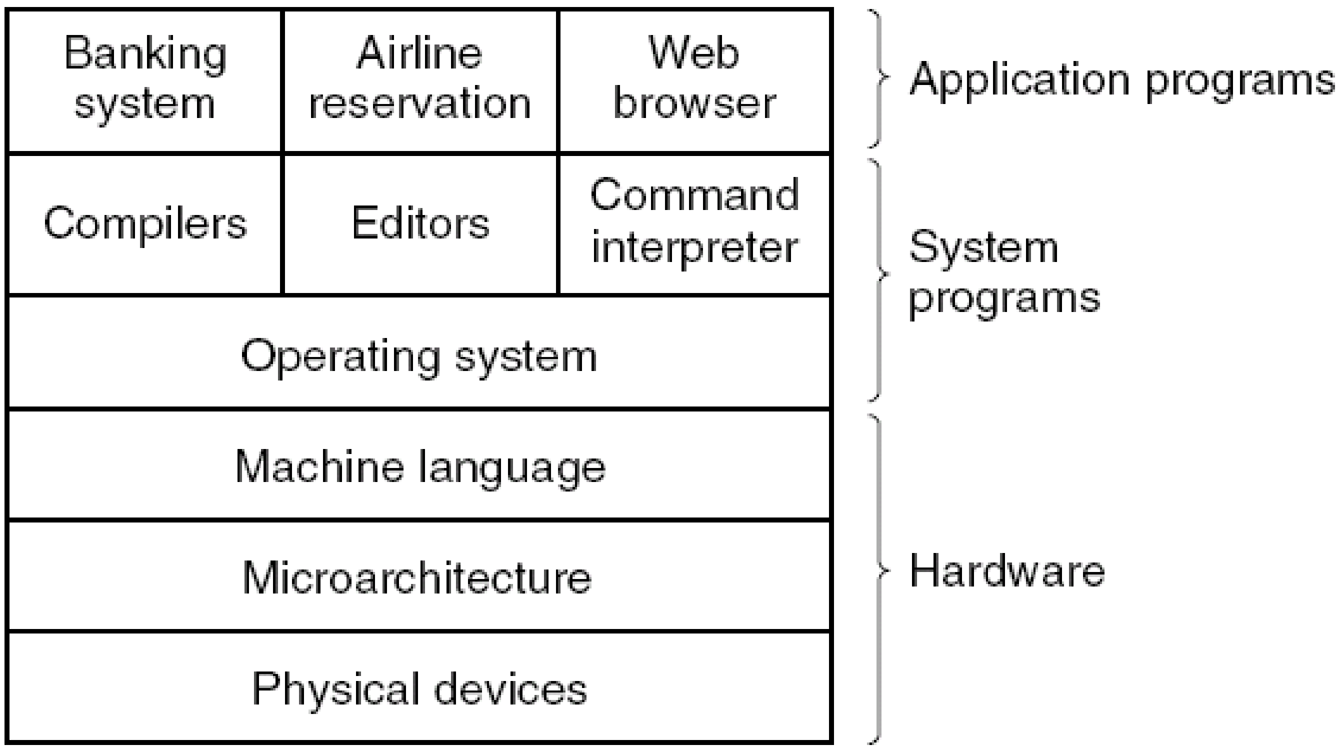


Figure 1.1 A computer system consists of hardware, system programs, and application programs.

What Is an Operating System?

The operating system has two basic functions of the operating system

- It is an extended machine or virtual machine
  - Easier to program than the underlying hardware
- It is a resource manager
  - Shares resources in time and space

Operating System Generations

- Generation 1 (1945 – 55)
  Vacuum tubes and plugboards
- Generation 2 (1955 – 65)
  Transistors and batch systems
- Generation 3 (1965 – 80)
  ICs and multiprogramming
- Generation 4 (1980 – Present)
  Personal computers

Early Batch System (1)

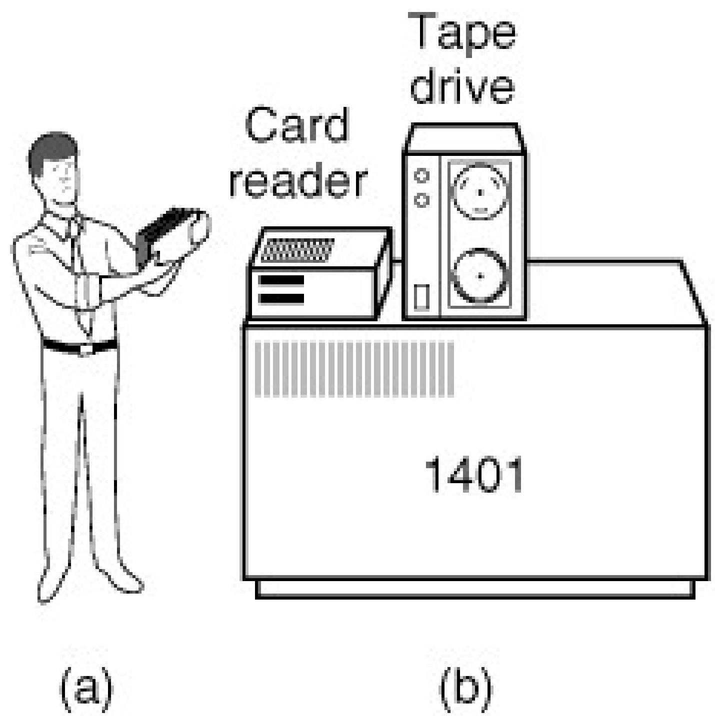


Figure 1-2. An early batch system. (a) Programmers bring cards to 1401. (b)1401 reads batch of jobs onto tape.

Early Batch System (2)

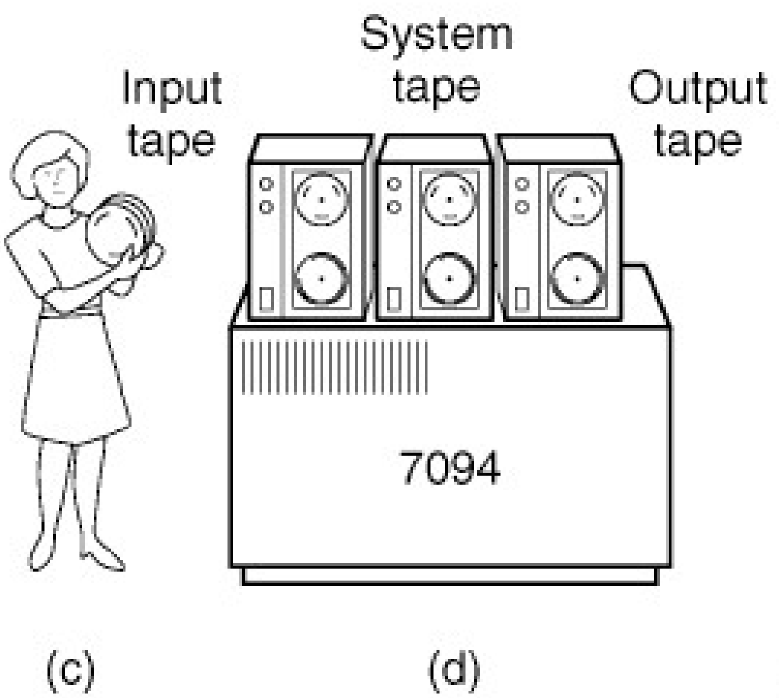


Figure 1-2. An early batch system. (c) Operator carries input tape to 7094. (d) 7094 does computing.

Early Batch System (3)

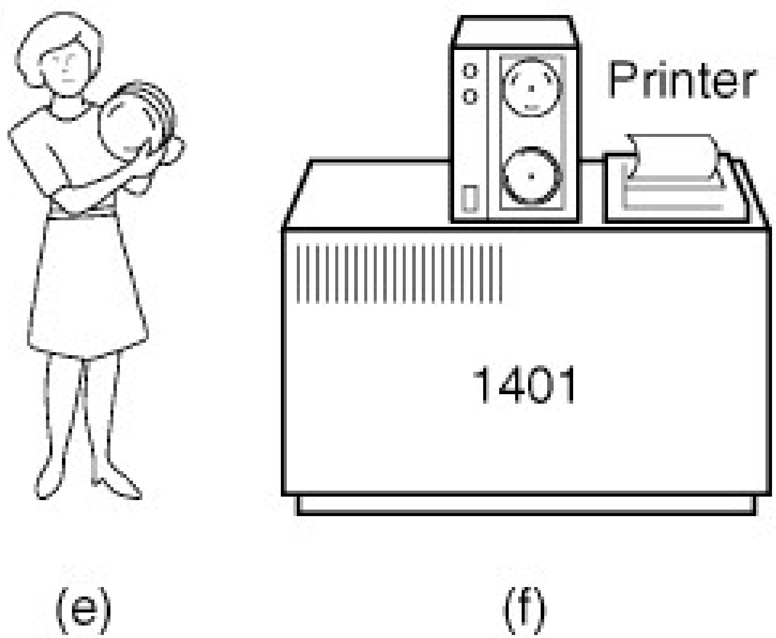


Figure 1-2. An early batch system. (e) Operator carries output tape to 1401. (f) 1401 prints output.

Early Batch System (4)

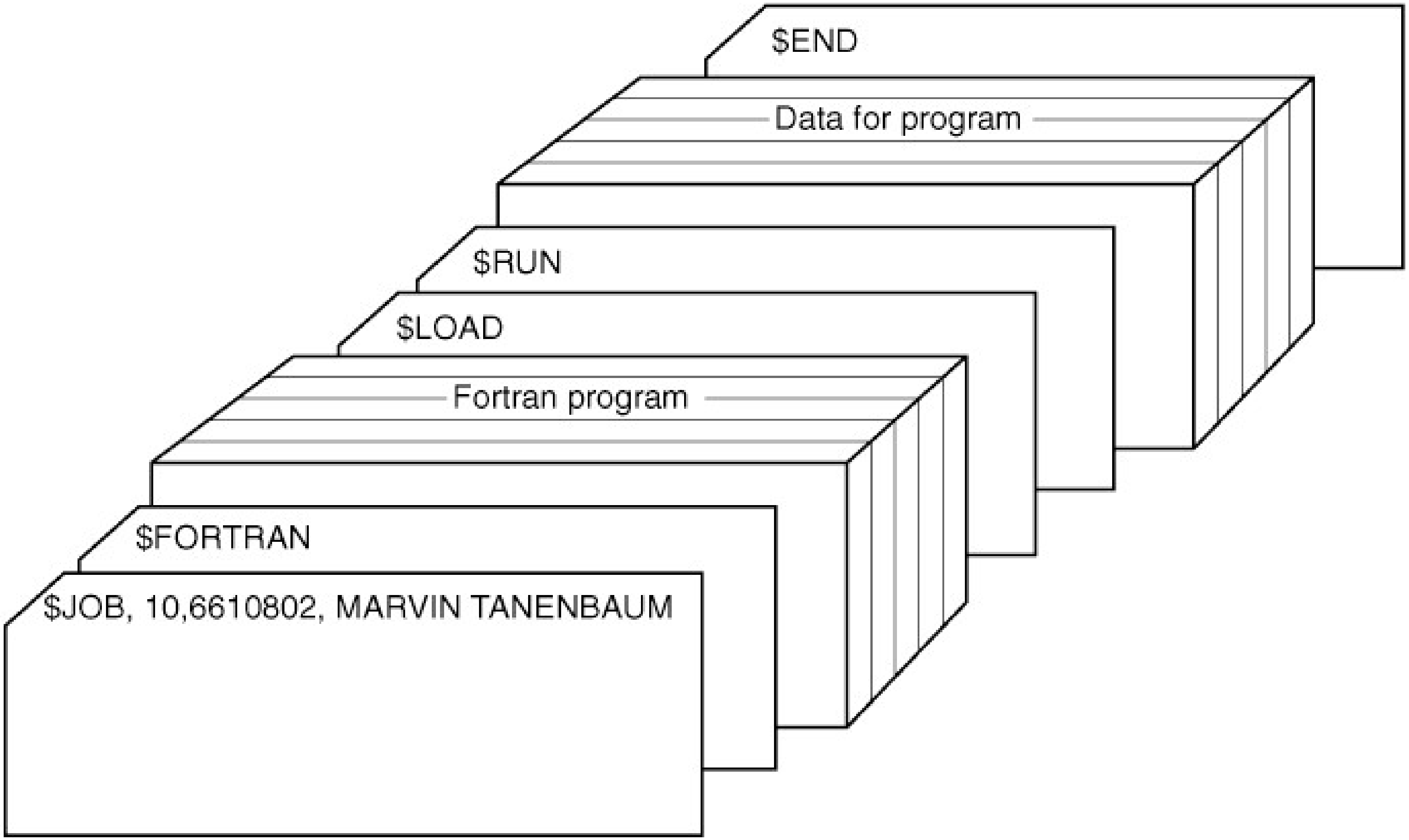


Figure 1-3. Structure of a typical FMS job.

Multiprogramming

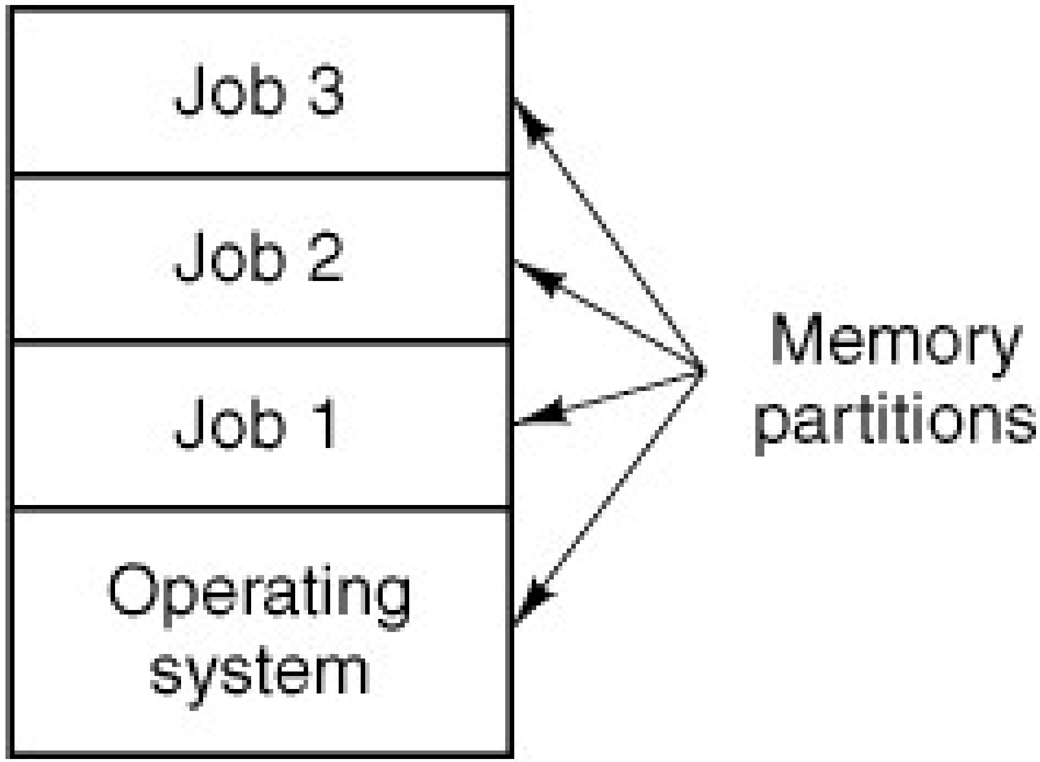


Figure 1-4. A multiprogramming system with three jobs in memory.

Processes

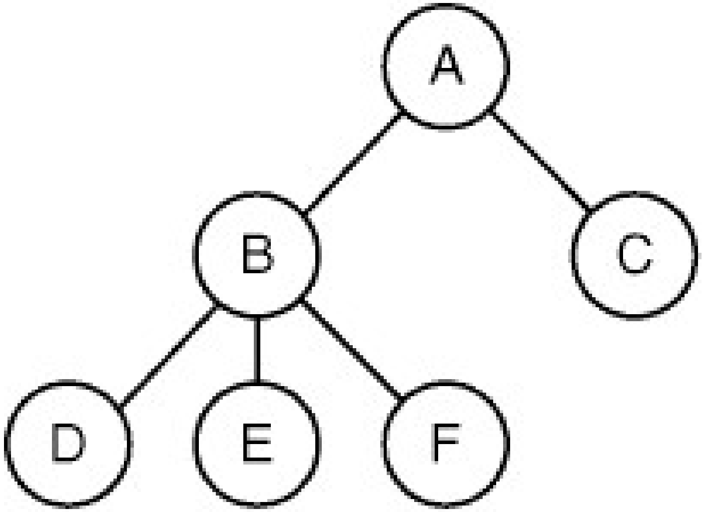


Figure 1-5. A process tree. Process A created two child processes, B and C. Process B created three child processes, D, E, and F.

File Systems (1)

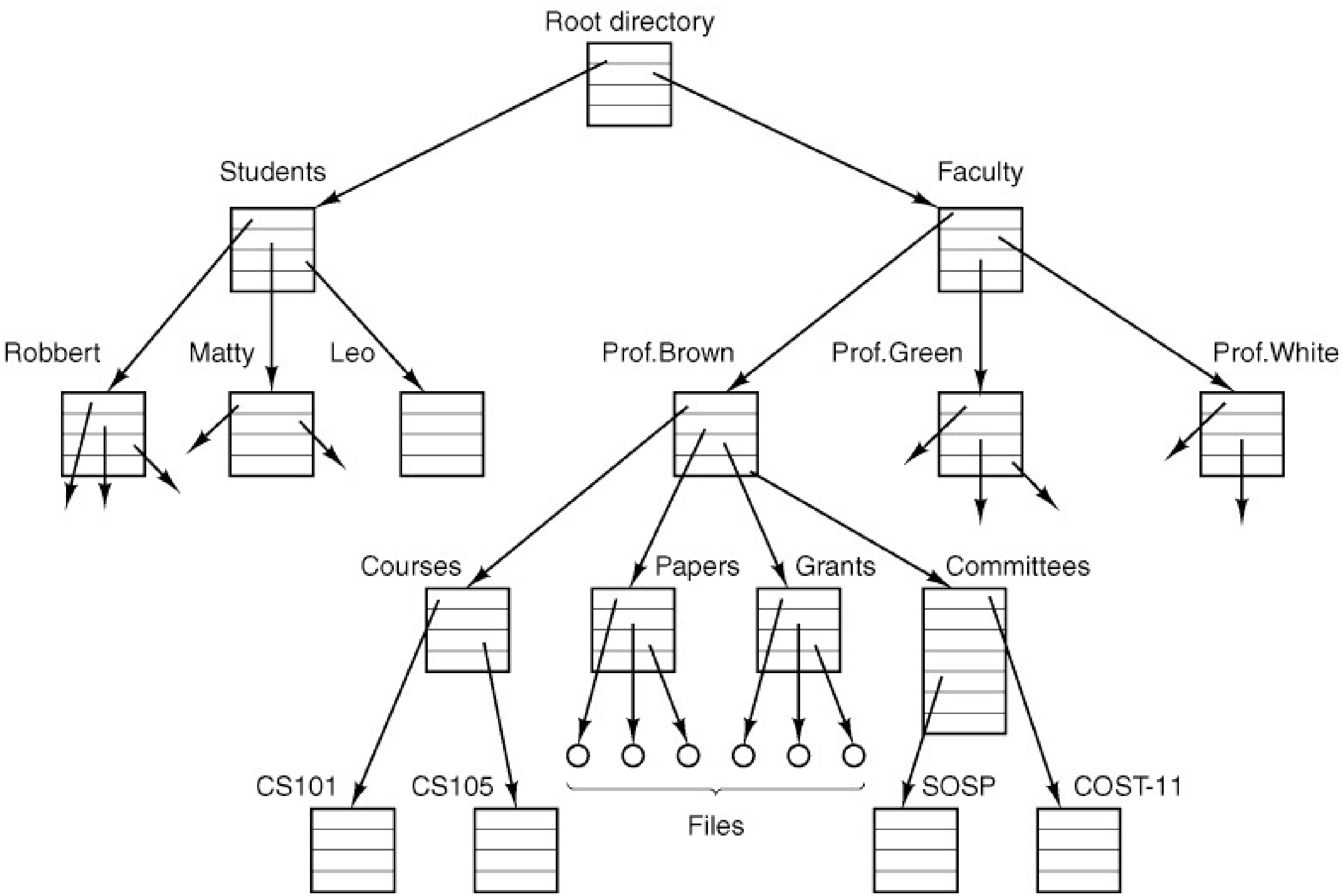


Figure 1-6. A file system for a university department.

File Systems (2)

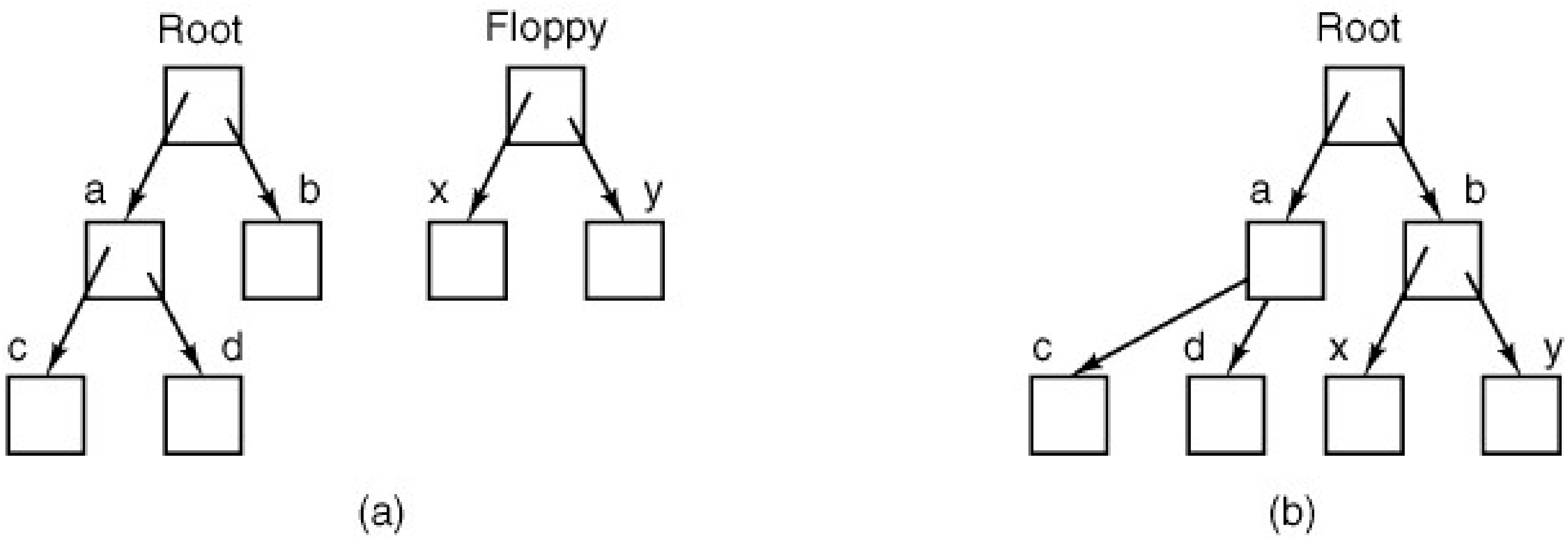


Figure 1-7. (a) Before mounting, the files on drive 0 are not accessible. (b) After mounting, they are part of the file hierarchy.

File Systems (3)

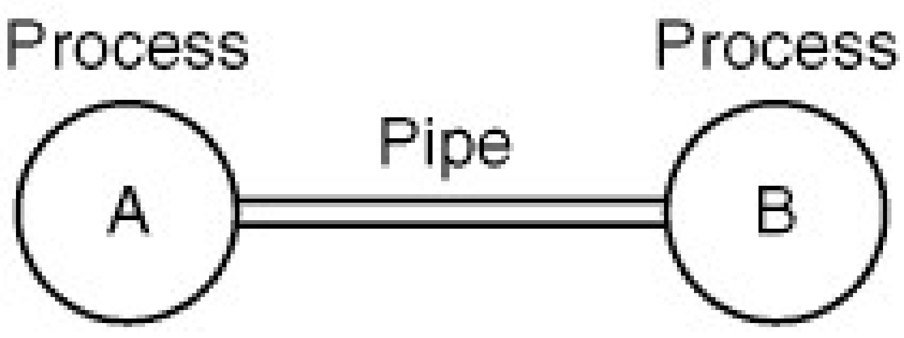


Figure 1-8. Two processes connected by a pipe.

System Calls (1)

Process Management

pid = fork()	Create a child process identical to the parent
pid = waitpid(pid, &statloc, opts)	Wait for a child to terminate
s = wait(&status)	Old version of waitpid
s = execve(name, argv, envp)	Replace a process core image
exit(status)	Terminate process execution and return status
size = brk(addr)	Set the size of the data segment
pid = getpid()	Return the caller's process id
pid = getpgrp()	Return the id of the caller's process group
pid = setsid()	Create a new session and return its process group id
l = ptrace(req, pid, addr, data)	Used for debugging

Figure 1-9. The MINIX system calls. fd is a file descriptor; and n is a byte count.

System Calls (2)

Signals

s = sigaction(sig, &act, &oldact)	Define action to take on signals
s = sigreturn(&context)	Return from a signal
s = sigprocmask(how, &set, &old)	Examine or change the signal mask
s = sigpending(set)	Get the set of blocked signals
s = sigsuspend(sigmask)	Replace the signal mask and suspend the process
s = kill(pid, sig)	Send a signal to a process
residual = alarm(seconds)	Set the alarm clock
s = pause()	Suspend the caller until the next signal

Figure 1-9. The MINIX system calls. fd is a file descriptor; and n is a byte count.

System Calls (3)

File Management

fd = creat(name, mode)	Obsolete way to create a new file
fd = mknod(name, mode, addr)	Create a regular, special, or directory i-node
fd = open(file, how, ...)	Open a file for reading, writing or both
s = close(fd)	Close an open file
n = read(fd, buffer, nbytes)	Read data from a file into a buffer
n = write(fd, buffer, nbytes)	Write data from a buffer into a file
pos = lseek(fd, offset, whence)	Move the file pointer
s = stat(name, &buf)	Get a file's status information
s = fstat(fd, &buf)	Get a file's status information
fd = dup(fd)	Allocate a new file descriptor for an open file
s = pipe(&fd[0])	Create a pipe
s = ioctl(fd, request, argp)	Perform special operations on a file
s = access(name, amode)	Check a file's accessibility
s = rename(old, new)	Give a file a new name
s = fcntl(fd, cmd, ...)	File locking and other operations

Figure 1-9. The MINIX system calls. fd is a file descriptor; and n is a byte count.

System Calls (4)

Dir. & File System Mgmt.

s = mkdir(name, mode)	Create a new directory
s = rmdir(name)	Remove an empty directory
s = link(name1, name2)	Create a new entry, name2, pointing to name1
s = unlink(name)	Remove a directory entry
s = mount(special, name, flag)	Mount a file system
s = umount(special)	Unmount a file system
s = sync()	Flush all cached blocks to the disk
s = chdir(dirname)	Change the working directory
s = chroot(dirname)	Change the root directory

Figure 1-9. The MINIX system calls. fd is a file descriptor; and n is a byte count.

System Calls (5)

Protection

s = chmod(name, mode)	Change a file's protection bits
uid = getuid()	Get the caller's uid
gid = getgid()	Get the caller's gid
s = setuid(uid)	Set the caller's uid
s = setgid(gid)	Set the caller's gid
s = chown(name, owner, group)	Change a file's owner and group
oldmask = umask(complmode)	Change the mode mask

Figure 1-9. The MINIX system calls. fd is a file descriptor; and n is a byte count.

System Calls (6)

Time Management

seconds = time(&seconds)	Get the elapsed time since Jan. 1, 1970
s = stime(tp)	Set the elapsed time since Jan. 1, 1970
s = utime(file, timep)	Set a file's "last access" time
s = times(buffer)	Get the user and system times used so far

Figure 1-9. The MINIX system calls. fd is a file descriptor; and n is a byte count.

The fork Call in the Shell

```
#define TRUE 1

while (TRUE) {                                  /* repeat forever */
     type_prompt( );                            /* display prompt on the screen */
     read_command(command, parameters);         /* read input from terminal */

     if (fork( ) != 0) {                        /* fork off child process */
         /* Parent code. */
         waitpid(–1, &status, 0);               /* wait for child to exit */
     } else {
         /* Child code. */
         execve(command, parameters, 0);        /* execute command */
     }
}
```

Figure 1-10. A stripped-down shell. Throughout this book, TRUE is assumed to be defined as 1.

Processes

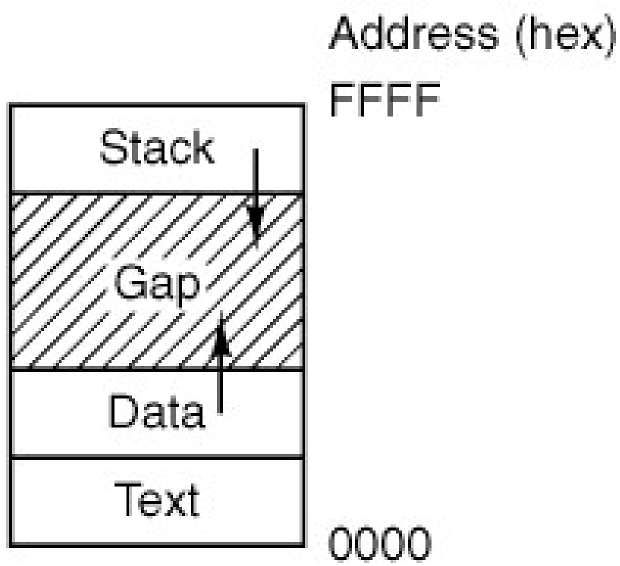


Figure 1-11. Processes have three segments: text, data, and stack. In this example, all three are in one address space, but separate instruction and data space is also supported.

System Calls for File Management (1)

```
struct stat {
    short st_dev;                      /* device where i-node belongs */
    unsigned short st_ino;             /* i-node number */
    unsigned short st_mode;            /* mode word */
    short st_nlink;                    /* number of links */
    short st_uid;                      /* user id */
    short st_gid;                      /* group id */
    short st_rdev;                     /* major/minor device for special files */
    long st_size;                      /* file size */
    long st_atime;                     /* time of last access */
    long st_mtime;                     /* time of last modification */
    long st_ctime;                     /* time of last change to i-node */
};
```

Figure 1-12. The structure used to return information for the stat and fstat system calls. In the actual code, symbolic names are used for some of the types.

System Calls for File Management (2)

```
#define STD_INPUT 0                  /* file descriptor for standard input */
#define STD_OUTPUT 1                 /* file descriptor for standard output */

pipeline(process1, process2)
char *process1, *process2;           /* pointers to program names */
{
  int fd[2];

  pipe(&fd[0]);                      /* create a pipe */
  if (fork() != 0) {
      /* The parent process executes these statements. */
      close(fd[0]);                  /* process 1 does not need to read from pipe */
      close(STD_OUTPUT);             /* prepare for new standard output */
      dup(fd[1]);                    /* set standard output to fd[1] */
      close(fd[1]);                  /* this file descriptor not needed any more */
      execl(process1, process1, 0);
  } else {   …
```

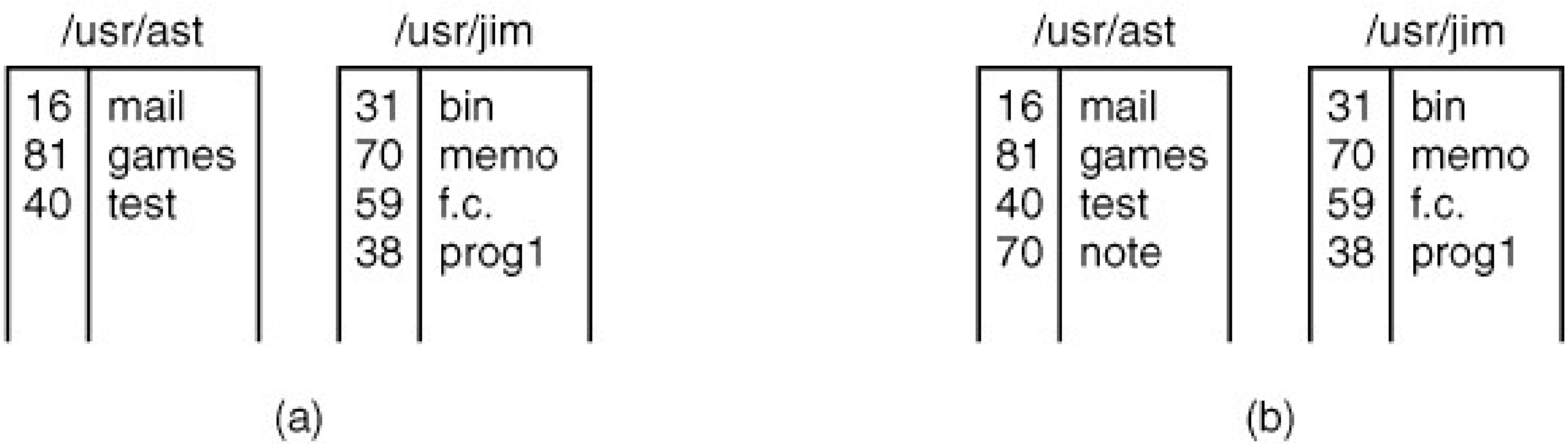
Figure 1-13. A skeleton for setting up a two-process pipeline.

System Calls for File Management (3)

```
    ...
    /* The child process executes these statements. */
    close(fd[1]);                    /* process 2 does not need to write to pipe */
    close(STD_INPUT);                /* prepare for new standard input */
    dup(fd[0]);                      /* set standard input to fd[0] */
    close(fd[0]);                    /* this file descriptor not needed any more */
    execl(process2, process2, 0);
  }
}
```

Figure 1-13. A skeleton for setting up a two-process pipeline.

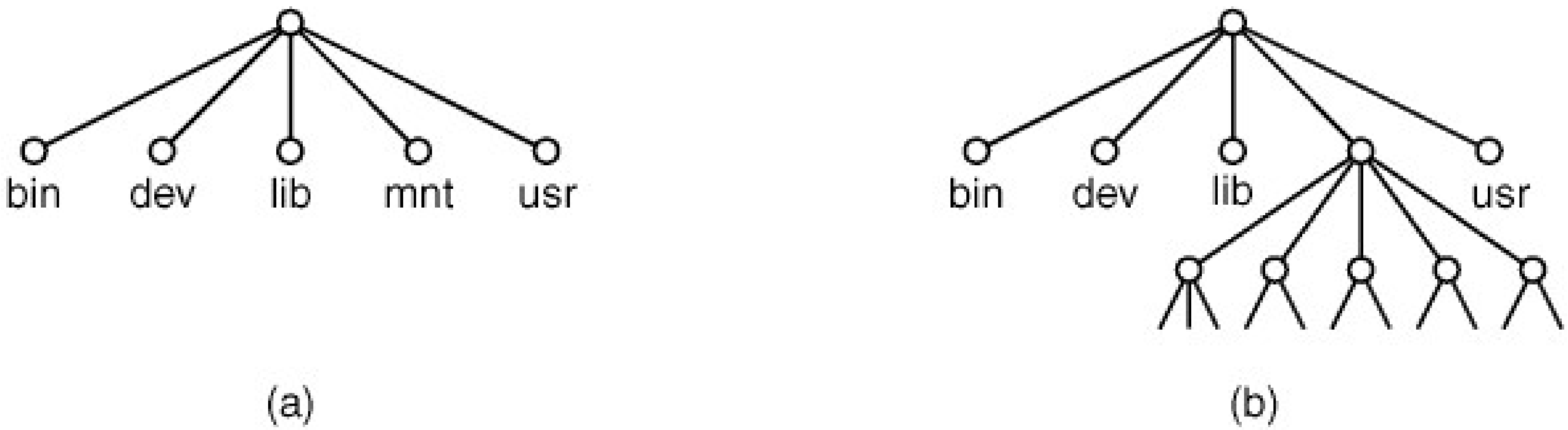
System Calls for Directory Management (1)



link("/usr/jim/memo","/usr/ast/note");

Figure 1-14. (a) Two directories before linking */usr/jim/memo* to ast's directory. (b) The same directories after linking.

System Calls for Directory Management (2)



mount("/dev/cdrom0","/mnt",0);

Figure 1-15. (a) File system before the mount.
(b) File system after the mount.

Operating System Structure

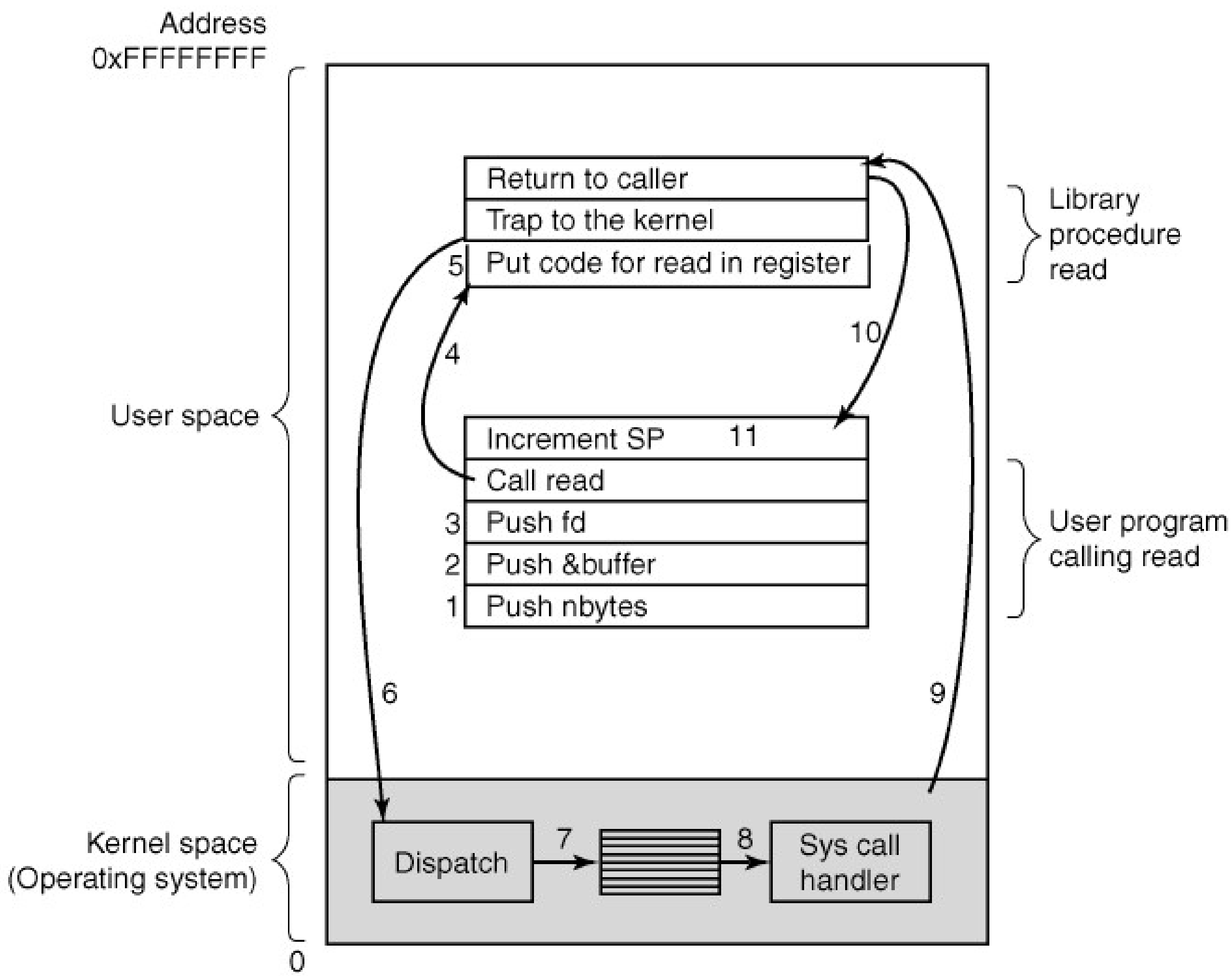


Figure 1-16. The 11 steps in making the system call read(fd, buffer, nbytes).

Basic Structure for Operating System

1. A main program that invokes the requested service procedure
2. A set of service procedures that carry out the system calls
3. A set of utility procedures that help the service procedures

Layered Systems (1)

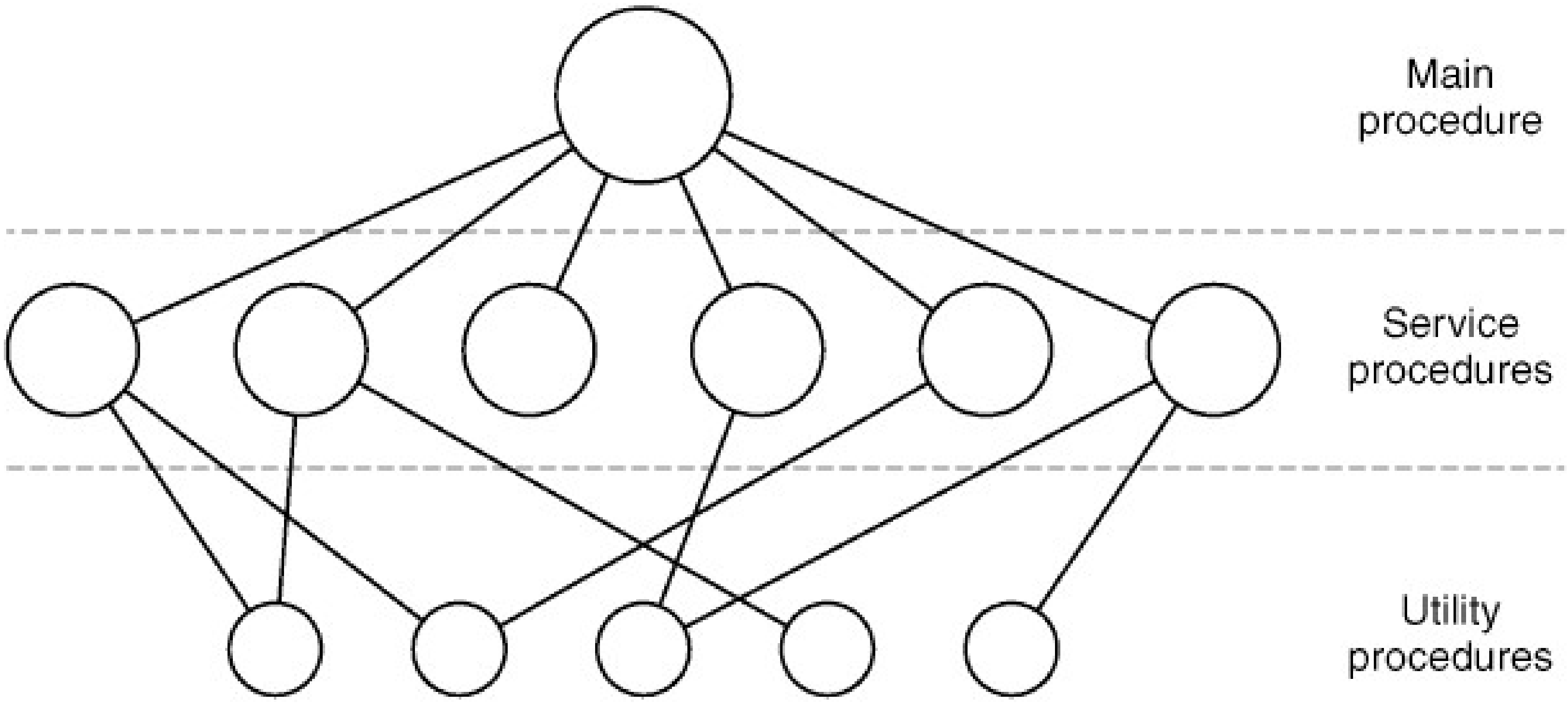


Figure 1-17. A simple structuring model for a monolithic system.

Layered Systems (2)

Layer	Function
5	The operator
4	User programs
3	Input/output management
2	Operator-process communication
1	Memory and drum management
0	Processor allocation and multiprogramming

Figure 1-18. Structure of the THE operating system.

Virtual Machines

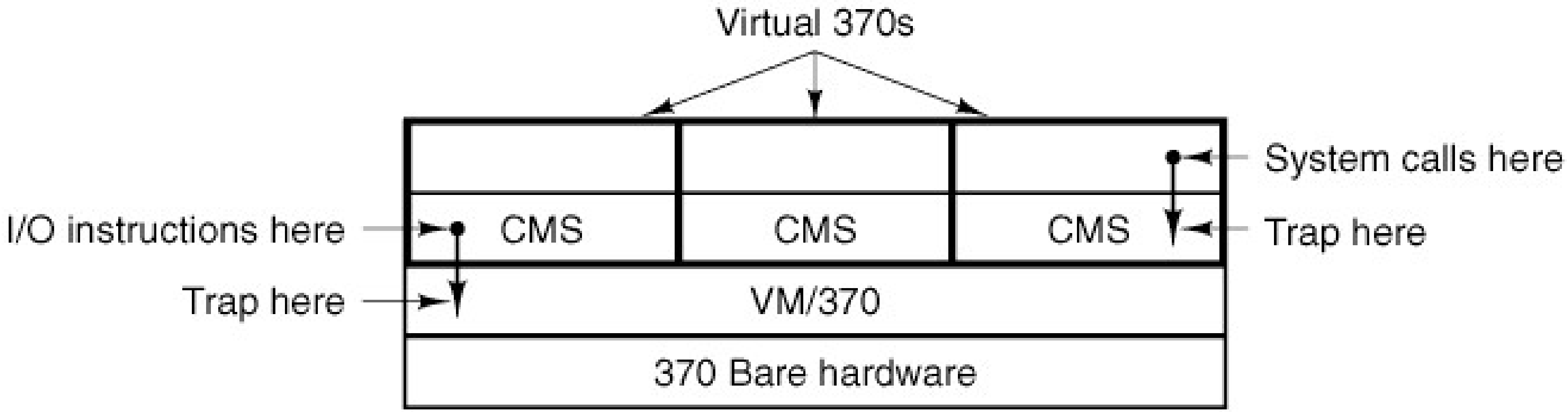


Figure 1-19. The structure of VM/370 with CMS.

Client-Server Model (1)

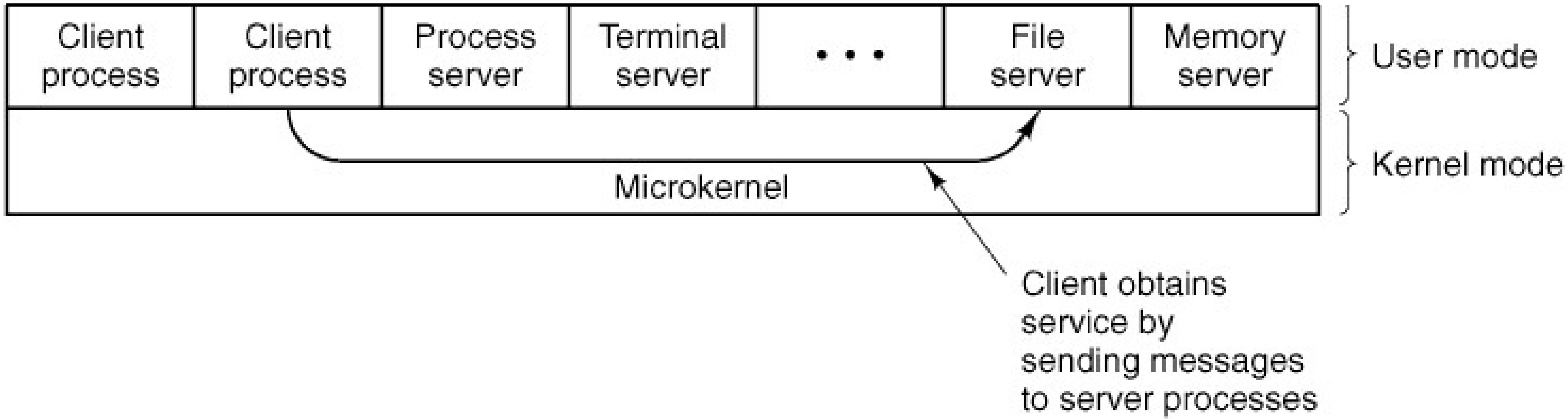


Figure 1-20. The client-server model.

Client-Server Model (2)

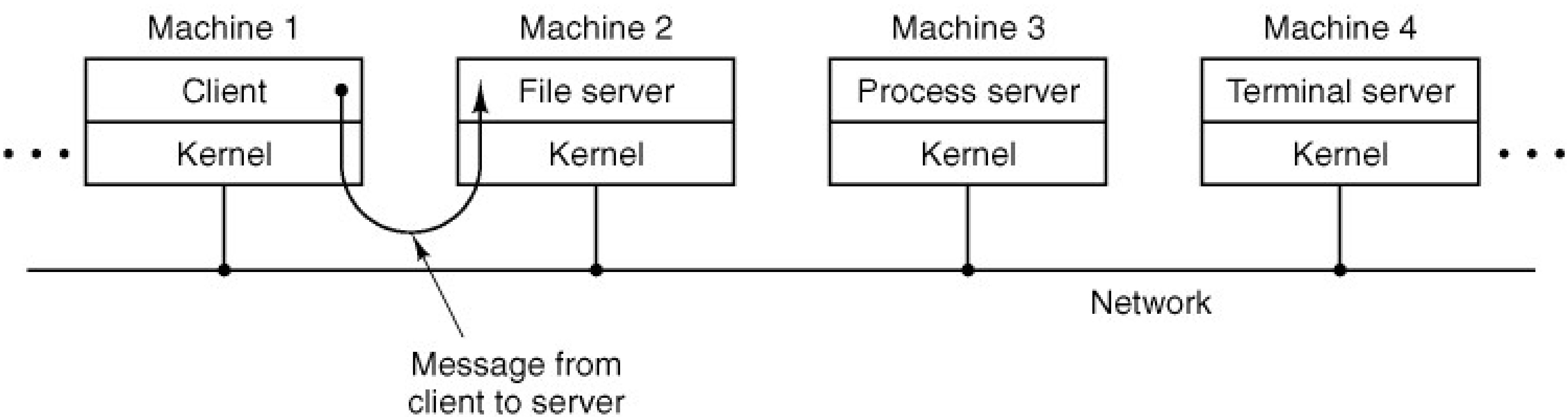


Figure 1-21. The client-server model in a distributed system.