Slide 2-1

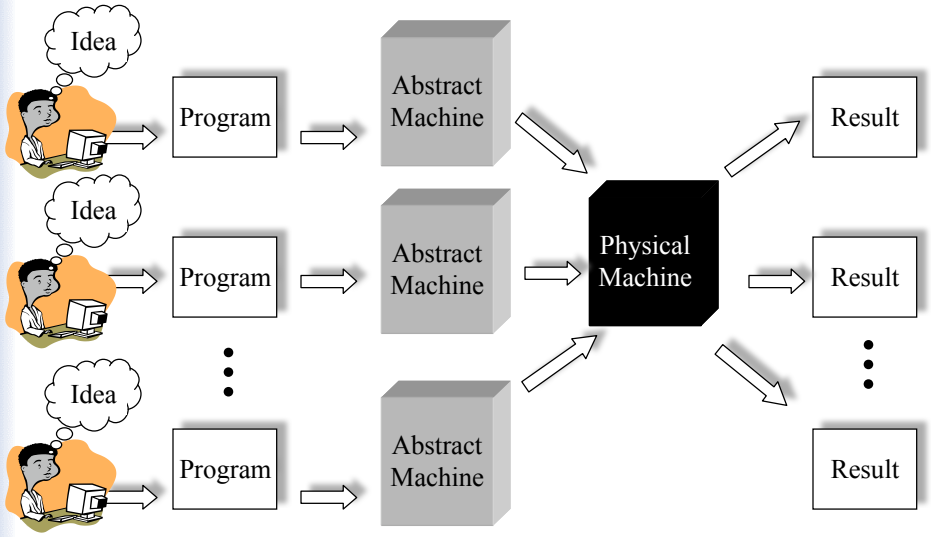
Using the Operating System

Slide 2-2

The Airplane Pilot's Abstract Machine

Slide 2-3

Basic Abstractions



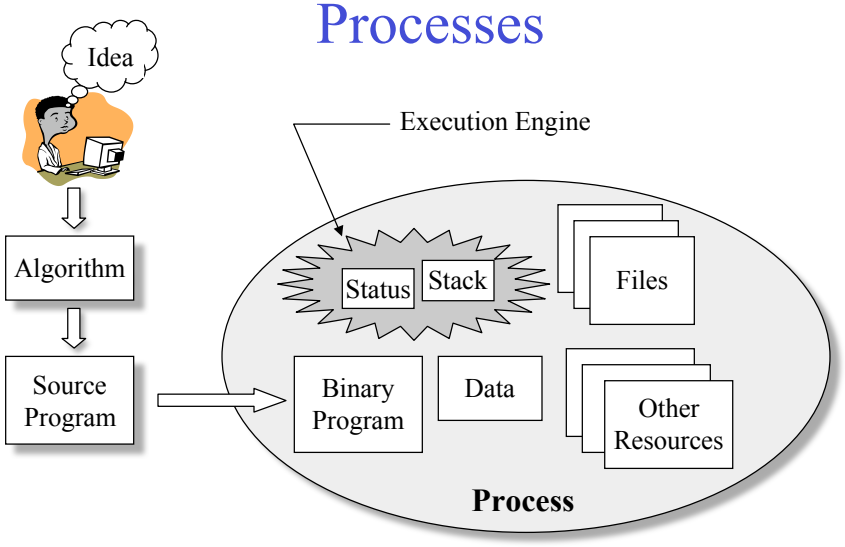
Slide 2-4

Abstract Machine Entities

- ***Process***: A sequential program in execution
- ***Resource***: Any abstract resource that a process can request, and which may can cause the process to be blocked if the resource is unavailable.
- ***File***: A special case of a resource. A linearly-addressed sequence of bytes. "A byte stream."

Algorithms, Programs, and Processes

Slide 2-5



Classic Process

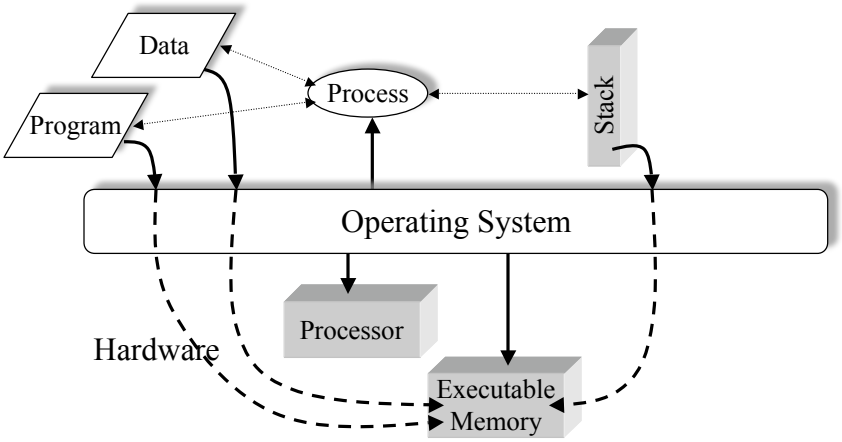
Slide 2-6

- OS implements {abstract machine} – one per task
- *Multiprogramming* enables N programs to be space-muxed in executable memory, and time-muxed across the physical machine processor.
- Result: Have an environment in which there can be multiple programs in execution *concurrently*,* each as a processes

* Concurrently: Programs appear to execute simultaneously

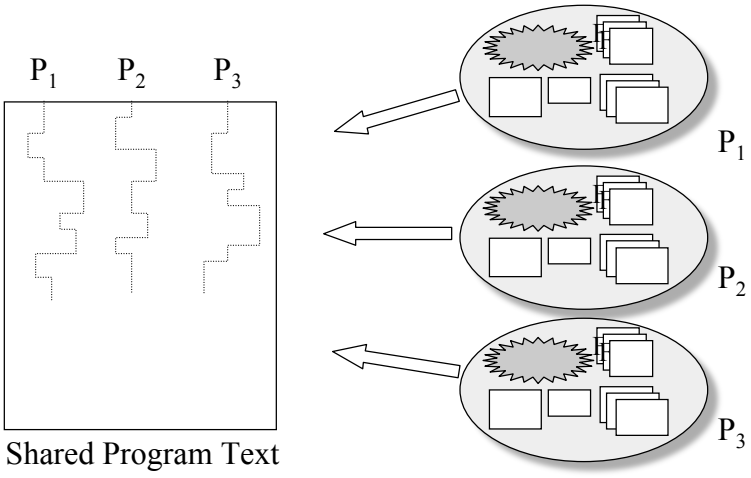
Process Abstraction

Slide 2-7



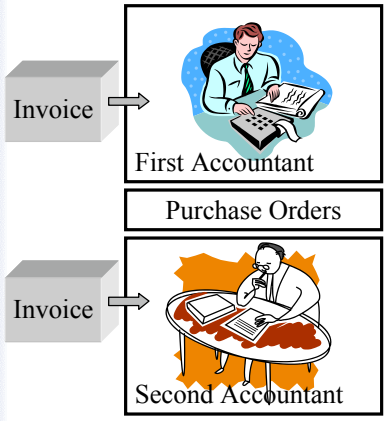
Processes Sharing a Program

Slide 2-8

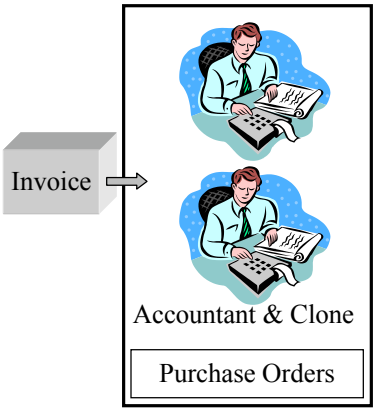


Multithreaded Accountant

Slide 2-9



(a) Separate Processes

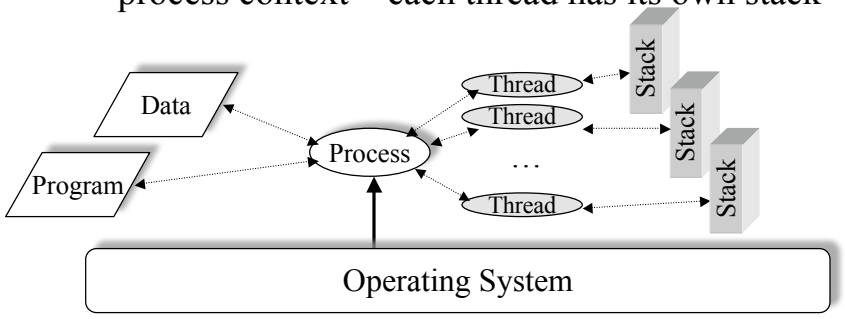


(b) Double Threaded Process

Modern Process & Thread

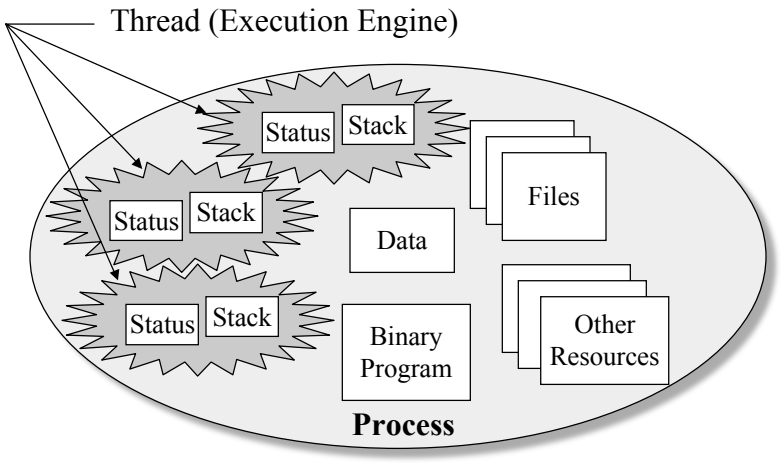
Slide 2-10

- Divide classic process:
  - *Process* is an infrastructure in which execution takes place – address space + resources
  - *Thread* is a program in execution within a process context – each thread has its own stack



A Process with Multiple Threads

Slide 2-11



More on Processes

Slide 2-12

- Abstraction of *processor* resource
  - Programmer sees an *abstract machine environment* with spectrum of resources and a set of resource addresses (most of the addresses are memory addresses)
  - User perspective is that its program is the only one in execution
  - OS perspective is that it runs one program with its resources for a while, then switches to a different process (*context switching*)
- OS maintains
  - A *process descriptor* data structure to implement the process abstraction
    - Identity, owner, things it owns/accesses, etc.
    - Tangible element of a process
  - Resource descriptors for each resource

Slide 2-13

Address Space

- Process must be able to reference every resource in its abstract machine
- Assign each unit of resource an address
  - Most addresses are for memory locations
  - Abstract device registers
  - Mechanisms to manipulate resources
- Addresses used by one process are inaccessible to other processes
- Say that each process has its own *address space*

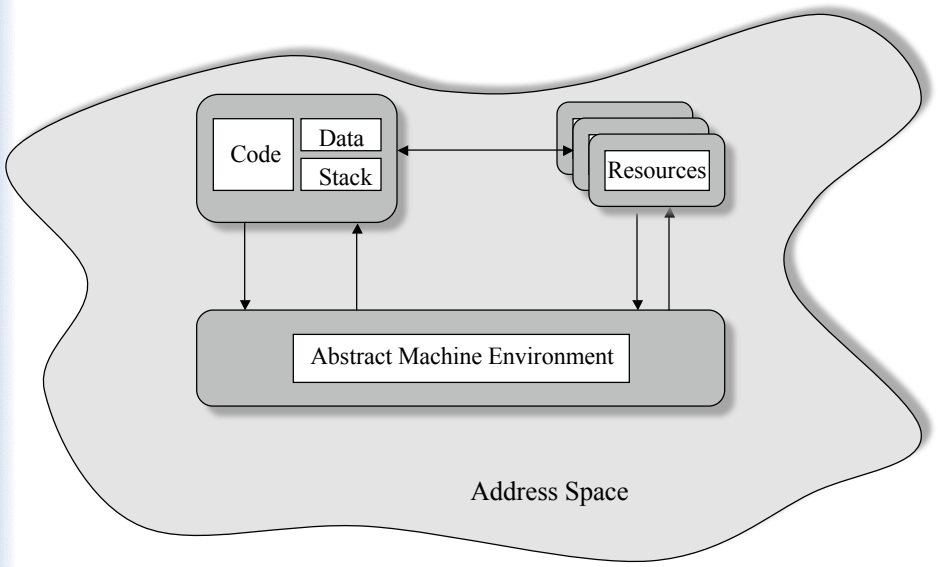
Slide 2-14

Shared Address Space

- Classic processes sharing program ⇒ shared address space support
- Thread model simplifies the problem
  - All threads in a process implicitly use that process's address space , but no "unrelated threads" have access to the address space
  - Now trivial for threads to share a program and data
    - If you want sharing, encode your work as threads in a process
    - If you do not want sharing, place threads in separate processes

Process & Address Space

Slide 2-15



Creating a Process

Slide 2-16

- Here is the classic model for creating processes:

`FORK(label)` – Create another process in the same address space beginning execution at instruction `label`
`QUIT()` – Terminate the process.
`JOIN(count)` – Merge processes into one.

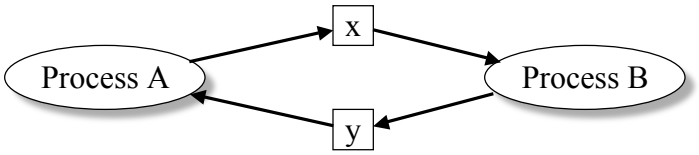
Equivalent Code:

```
disableInterrupts();
count--;
if(count > 0) QUIT();
enableInterrupts();
```

Example


```
procA() {
  while(TRUE) {
    <compute section A1>;
    update(x);
    <compute section A2>;
    retrieve(y);
  }
}
```

```
procB() {
  while(TRUE) {
    retrieve(x);
    <compute section B1>;
    update(y);
    <compute section B2>;
  }
}
```



Example (cont)


```
L0:  count = 2;
     <compute section A1>;
     update(x);
     FORK(L2);
     <compute section A2>;
L1:  JOIN(count);
     retrieve(y);
     goto L0;
L2:  retrieve(x);
     <compute section B1>;
     update(y);
     FORK(L3);
     goto L1;
L3:  <compute section B2>
     QUIT();
```

Slide 2-19

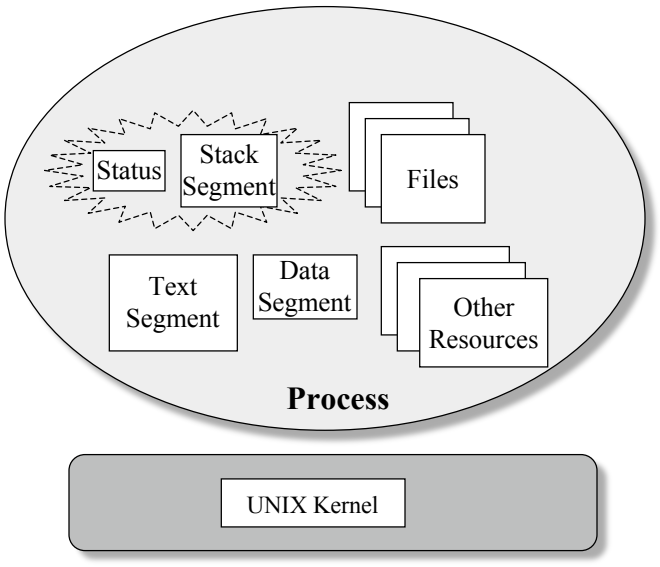
Example (cont)

```
L0:  count = 2;
     <compute section A1>;
     update(x);
     FORK(L2);
     <compute section A2>;
L1:  JOIN(count);
     retrieve(y);
     goto L0;
L2:  retrieve(x);
     <compute section B1>;
     update(y);
     FORK(L3);
     goto L1;
L3:  <compute section B2>
     QUIT();
```

```
L0:  count = 2;
     <compute section A1>;
     update(x);
     FORK(L2);
     retrieve(y);
     <compute section B1>
     update(y>;
     FORK(L3)
L1:  JOIN(count);
     retrieve(y);
     goto L0;
L2:  <compute section A2>;
     goto L1;
L3:  <compute section B2>
     QUIT();
```

Slide 2-20

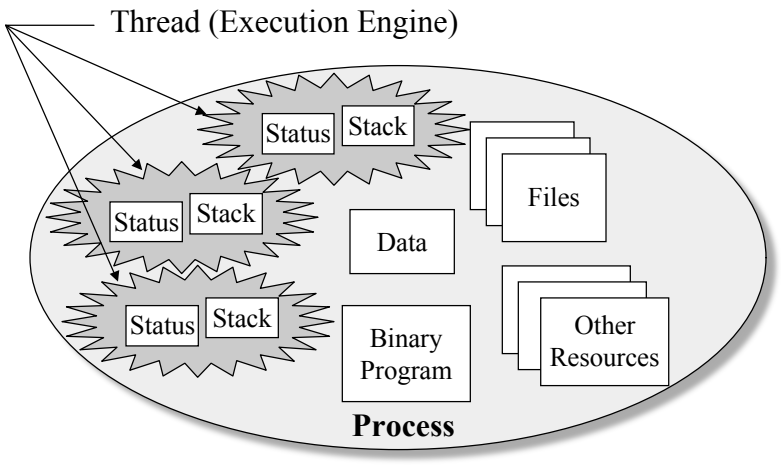
UNIX Processes



UNIX Processes

- Each process has its own address space
  - Subdivided into text, data, & stack segment
  - `a.out` file describes the address space
- OS kernel creates *descriptor* to manage process
- *Process identifier* (PID): User handle for the process (descriptor)
- Try "`ps`" and "`ps -aux`" (read man page)

A Process with Multiple Threads



Creating/Destroying Processes

- UNIX `fork()` creates a process
  - Creates a new address space
  - Copies text, data, & stack into new address space
  - Provides child with access to open files
- UNIX `wait()` allows a parent to wait for a child to terminate
- UNIX `execve()` allows a child to run a new program

Creating a UNIX Process


```
int pidValue;
 ...
pidValue = fork();       /* Creates a child process */
if(pidValue == 0) {
  /* pidValue is 0 for child, nonzero for parent */
  /* The child executes this code concurrently with parent */
    childsPlay(…);      /* A procedure linked into a.out */
    exit(0);
}
/* The parent executes this code concurrently with child */
parentsWork(..);
wait(…);
 ...
```

Child Executes a Different Program

Slide 2-25

```
int pid;
 ...
/* Set up the argv array for the child */
 ...
/* Create the child */
if((pid = fork()) == 0) {
  /* The child executes its own absolute program */
    execve(childProgram.out, argv, 0);
  /* Only return from an execve call if it fails */
    printf("Error in the exec … terminating the child …");
    exit(0);
}
 ...
wait(…);    /* Parent waits for child to terminate */
 ...
```

Example: Parent

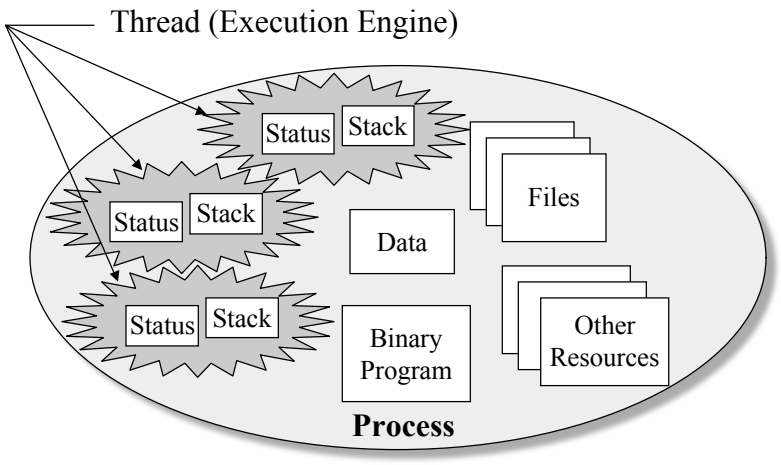
Slide 2-26

```
#include        <sys/wait.h>

#define NULL    0

int main (void)
{
    if (fork() == 0){   /* This is the child process */
        execve("child",NULL,NULL);
        exit(0);        /* Should never get here, terminate */
    }
/* Parent code here */
    printf("Process[%d]: Parent in execution ...\n", getpid());
    sleep(2);
    if(wait(NULL) > 0) /* Child terminating */
        printf("Process[%d]: Parent detects terminating child \n",
                            getpid());
    printf("Process[%d]: Parent terminating ...\n", getpid());
}
```

Example: Child


```
int main (void)
{
/* The child process's new program
   This program replaces the parent's program */

    printf("Process[%d]: child in execution ...\n", getpid());
    sleep(1);
    printf("Process[%d]: child terminating ...\n", getpid());
}
```

Threads -- The NT Model



Windows NT Process

Slide 2-29

```
#include      <cthreads.h>
 ...
int main(int argv, char *argv[]) {
          ...
          STARTUPINFO startInfo;
          PROCESS_INFORMATION processInfo;
          ...
          strcpy(lpCommandLine,
              "C:\\WINNT\\SYSTEM32\\NOTEPAD.EXE temp.txt)";
          ZeroMemory(&startInfo, sizeof(startInfo));
          startInfo.cb = sizeof(startInfo);
          if(!CreateProcess(NULL, lpCommandLine, NULL, NULL, FALSE,
                   HIGH_PRIORITY_CLASS | CREATE_NEW_CONSOLE,
                   NULL, NULL, &startInfo, &processInfo)) {
              fprintf(stderr, "CreateProcess failed on error %d\n",
                   GetLastError());
              ExitProcess(1);
          };
/* A new child process is now executing the lpCommandLine program */
     ...
          CloseHandle(&processInfo.hThread);
          CloseHandle(&processInfo.hProcess);

     t_handle = CreateProcess(…, lpCommandLine, …);
}
```

NT Threads

Slide 2-30

```
#include      <cthreads.h>
 ...
int main(int argv, char *argv[]) {
    t_handle = CreateThread(
         LPSECURITY_ATTRIBUTES lpThreadAttributes,
             // pointer to thread security attributes
                 DWORD dwStackSize,
             // initial thread stack size, in bytes
                 LPTHREAD_START_ROUTINE lpStartAddress,
                                  // pointer to thread function
                 LPVOID lpParameter,       // argument for new thread
                 DWORD dwCreationFlags,    // creation flags
                 LPDWORD lpThreadId
             // pointer to returned thread identifier
         );

/* A new child thread is now executing the tChild function */
    Sleep(100)     /* Let another thread execute */
}

DWPRD WINAPI tChild(LPVOID me) {
/* This function is executed by the child thread */
 ...
    SLEEP(100);    /* Let another thread execute */
 ...
}
```

_beginthreadex()

•Single copy of certain variables in a process
•Need a copy per thread

```
unsigned long _beginthreadex(
    void *security,
    unsigned stack_size,
    unsigned ( __stdcall *start_address )( void * ),
    void *arglist,
    unsigned initflag,
    unsigned *thrdaddr
);
```

Resources

- Anything that a process requests from an OS
  - Available ⇒ allocated
  - Not available ⇒ process is blocked
- Examples
  - Files
  - Primary memory address space (“virtual memory”)
  - Actual primary memory (“physical memory”)
  - Devices (e.g., window, mouse, kbd, serial port, …)
  - Network port
  - … many others …

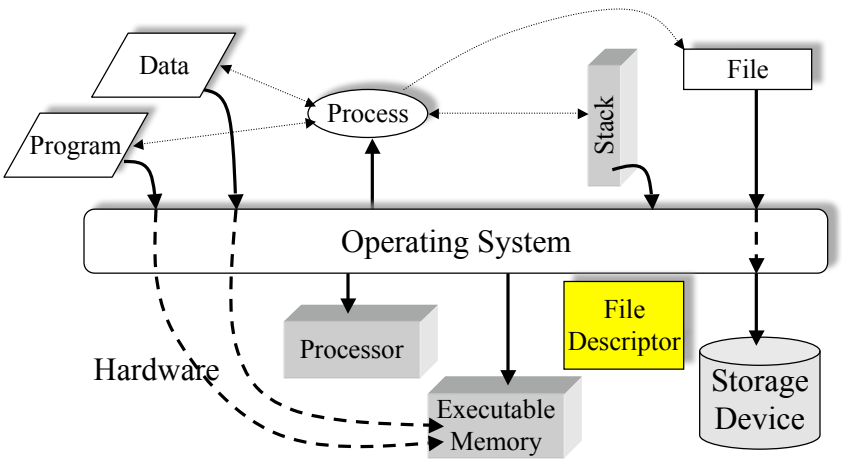
Files

Slide 2-33

- Data must be read into (and out of) the machine – I/O devices
- Storage devices provide persistent copy
- Need an abstraction to make I/O simple – the file
- A file is a linearly-addressed sequence of bytes
  - From/to an input device
  - Including a storage device

The File Abstraction

Slide 2-34



UNIX Files

- UNIX and NT try to make every resource (except CPU and RAM) look like a file
- Then can use a common interface:

`open`	Specifies file name to be used
`close`	Release file descriptor
`read`	Input a block of information
`write`	Output a block of information
`lseek`	Position file for read/write
`ioctl`	Device-specific operations

UNIX File Example


```
#include    <stdio.h>
#include    <fcntl.h>
int main() {
    int inFile, outFile;
    char *inFileName = "in_test";
    char *outFileName = "out_test";
    int len;
    char c;

    inFile = open(inFileName, O_RDONLY);
    outFile = open(outFileName, O_WRONLY);
/* Loop through the input file */
    while ((len = read(inFile, &c, 1)) > 0)
        write(outFile, &c, 1);
/* Close files and quite */
    close(inFile);
    close(outFile);
}
```

Windows File Manipulation Program

Slide 2-37

```
#include <windows.h>
#include <stdio.h>
#define BUFFER_LEN ... // # of bytes to read/write
/* The producer process reads information from the file name
   in_test then writes it to the file named out_test.
*/
int main(int argc, char *argv[]) {
// Local variables
   char buffer[BUFFER_LEN+1];
// CreateFile parameters
   DWORD dwShareMode = 0; // share mode
   LPSECURITY_ATTRIBUTES lpFileSecurityAttributes = NULL;
                // pointer to security attributes
   HANDLE hTemplateFile = NULL;
                // handle to file with attributes to copy
// ReadFile parameters
   HANDLE sourceFile; // Source of pipeline
   DWORD numberOfBytesRead; // number of bytes read
   LPOVERLAPPED lpOverlapped = NULL; // Not used here
```

Windows File Manipulation Program(2)

Slide 2-38

```
// WriteFile parameters
   HANDLE sinkFile; // Source of pipeline
   DWORD numberOfBytesWritten; // # bytes written
// Open the source file
   sourceFile = CreateFile (
         "in_test",
         GENERIC_READ,
         dwShareMode,
         lpFileSecurityAttributes,
         OPEN_ALWAYS,
         FILE_ATTRIBUTE_READONLY,
         hTemplateFile
   );
   if(sourceFile == INVALID_HANDLE_VALUE) {
         fprintf(stderr, "File open operation failed\n");
         ExitProcess(1);
   }
```

Windows File Manipulation Program(3)

Slide 2-39

```
// Open the sink file
   sinkFile = CreateFile (
         "out_test",
         GENERIC_WRITE,
         dwShareMode,
         lpSecurityAttributes,
         CREATE_ALWAYS,
         FILE_ATTRIBUTE_NORMAL,
         hTemplateFile
   );
   if(sinkFile == INVALID_HANDLE_VALUE) {
         fprintf(stderr, "File open operation failed\n");
         ExitProcess(1);
   }
```

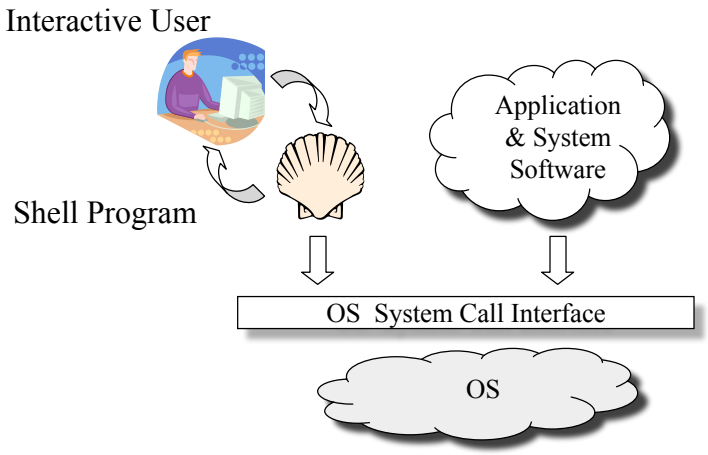
Windows File Manipulation Program(4)

Slide 2-40

```
// Main loop to copy the file
   while
   (
         ReadFile(
                  sourceFile, buffer,
                  BUFFER_LEN, &numberOfBytesRead,
                  lpOverlapped
                 )
               &&
                  numberOfBytesRead > 0
   ) {
         WriteFile(sinkFile, buffer, BUFFER_LEN,
                     &numberOfBytesWritten, lpOverlapped);
   }
// Terminating.  Close the sink and source files
   CloseHandle(sourceFile);
   CloseHandle(sinkFile);
   ExitProcess(0);
}
```

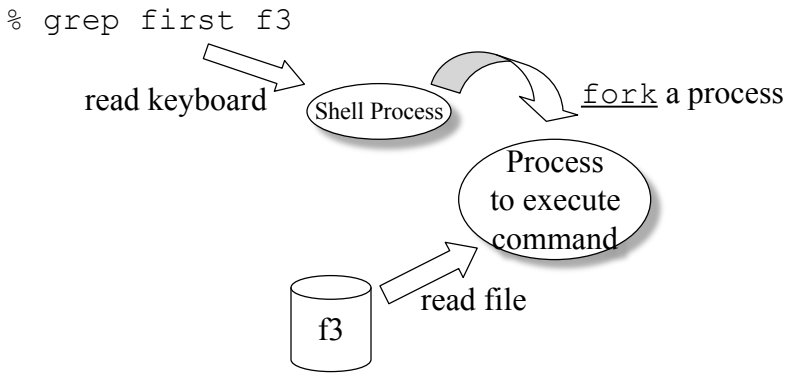
Slide 2-41

Shell Command Line Interpreter



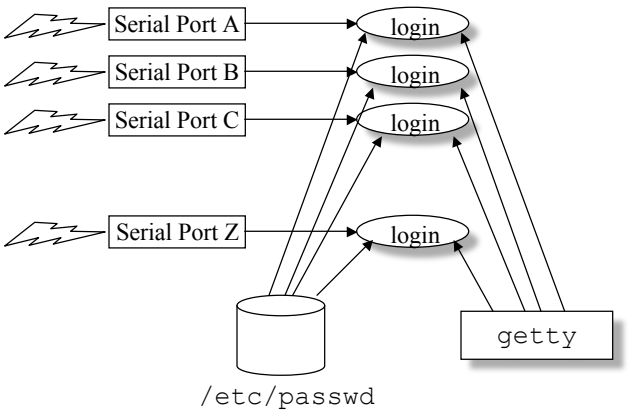
Slide 2-42

The Shell Strategy



Bootstrapping

- Computer starts, begins executing a *bootstrap program* -- *initial process*
- Loads OS from the disk (or other device)
- Initial process runs OS, creates other processes



Objects

- A recent trend is to replace processes by objects
- Objects are autonomous
- Objects communicate with one another using messages
- Popular computing paradigm
- Too early to say how important it will be ...