UNIX IO

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system() Function

system() - execute a shell command

- SYNOPSIS:

```
#include <stdlib.h>

int system(const char *command);
```

- The **system()** library function uses **fork()** to create a child process that executes the shell command specified in **command** using **execl()** as :**execl("/bin/sh", "sh", "-c", command, (char *) 0);**

- system() returns after the command has been completed.

- If command is NULL, then system() returns a status indicating whether a shell is available on the system.

`system()` Function Return Value

The return value of **`system()`** is one of the following:

- If command is `NULL`, then a nonzero value if a shell is available, or 0 if no shell is available.
- If a child process could not be created, or its status could not be retrieved, the return value is -1.
- If a shell could not be executed in the child process, then the return value is as though the child shell terminated by calling **`_exit()`** with the status 127.
- If all system calls succeed, then the return value is the termination status of the child shell used to execute command. (The termination status of a shell is the termination status of the last command it executes.)

read System Call

- UNIX provides sequential access to files and other devices through the **read** and **write** functions.
- The **read** function attempts to retrieve **nbyte** bytes from the file or device represented by **fildes** into the user variable **buf**.
- A large enough buffer must be provided to hold **nbyte** bytes of data.
- SYNOPSIS:

```
#include <unistd.h>

ssize_t read(int fildes, void *buf, size_t nbyte);


(1) If successful, read returns the number of bytes
    actually read.
(2) If unsuccessful, read returns -1 and sets errno.
```

- The **ssize_t** data type is a signed integer data type used for the number of bytes read, or -1 if an error occurs.
- The **size_t** is an unsigned integer data type for the number of bytes to read.

Note: `Read`

- A **`read`** operation for a regular file may return fewer bytes than requested if, for example, it reached end-of-file before completely satisfying the request.

- A **`read`** operation for a regular file returns 0 to indicate end-of-file.

- When reading from a terminal, read returns 0 when the user enters an end-of-file character(CTRL+D).

write System Call

- The **write** function attempts to output **nbyte** bytes from the user buffer **buf** to the file represented by file descriptor **fildes**.
- SYNOPSIS:

```
#include <unistd.h>

ssize_t write(int fildes, const void *buf, size_t nbyte);


(1) If successful, write returns the number of bytes
    actually written.
(2) If unsuccessful, write returns -1 and sets errno.
```

open System Call

- The open function associates a file descriptor with a file or physical device.
- SYNOPSIS:

```
#include <fcntl.h>
#include <sys/stat.h>

int open(const char *path, int oflag, ...);

(1) If successful, open returns a nonnegative integer
    representing the open file descriptor.

(2) If unsuccessful, open returns -1 and sets errno.
```

- The **path** parameter of open points to the pathname of the file or device.
- The **oflag** parameter specifies status flags and access modes for the opened file.
- A third parameter must be included to specify access permissions if a file is created.

File Descriptor

- Files are designated with in C program either by **file pointers** or by **file descriptor**.
- A file **descriptor** is an integer value that represents a file or device that is open.
- It is an index into the process file descriptor table.
- The file descriptor table is in the process user area and provides access to the system information for the associated file or device.
- File pointers and file descriptors provide logical designations called *handles* for performing device-independent input and output.

File Descriptor

- The symbolic names for the **file pointers** that represent standard input, standard output and standard error are **`stdin`**, **`stdout`** and **`stderr`**, respectively. These symbolic names are defined in **`stdio.h`**.

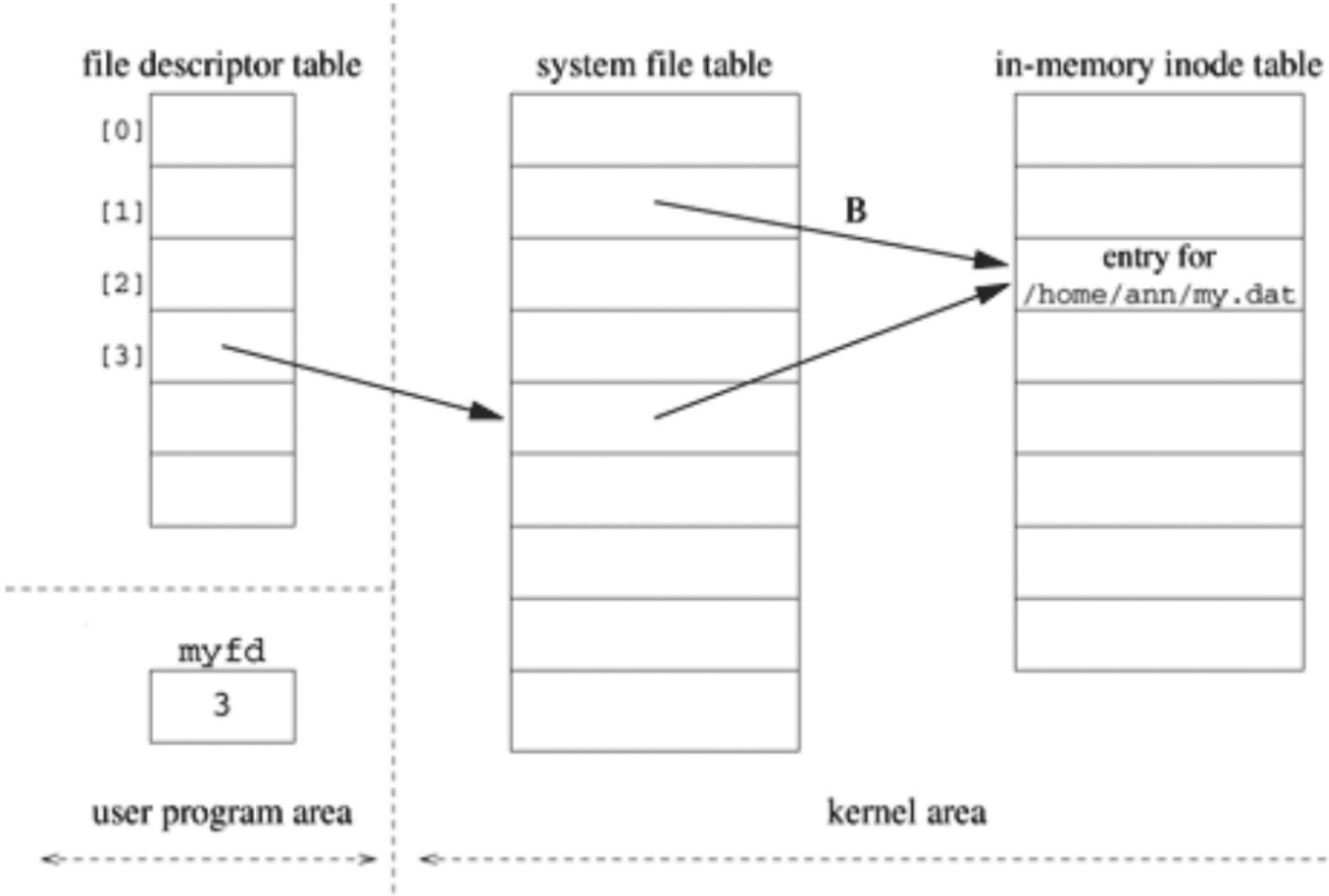
- The symbolic names for the **file descriptors** that represent standard input, standard output and standard error are **`STDIN_FILENO`**, **`STDOUT_FILENO`** and **`STDERR_FILENO`**, respectively. These symbolic names are defined in **`unistd.h`**.

- The **numeric values** that represent standard input, standard output and standard error are 0, 1, and 2 respectively.

File Descriptor

A schematic of the file descriptor table after a program executes the following.

```
myfd = open("/home/ann/my.dat", O_RDONLY);
```

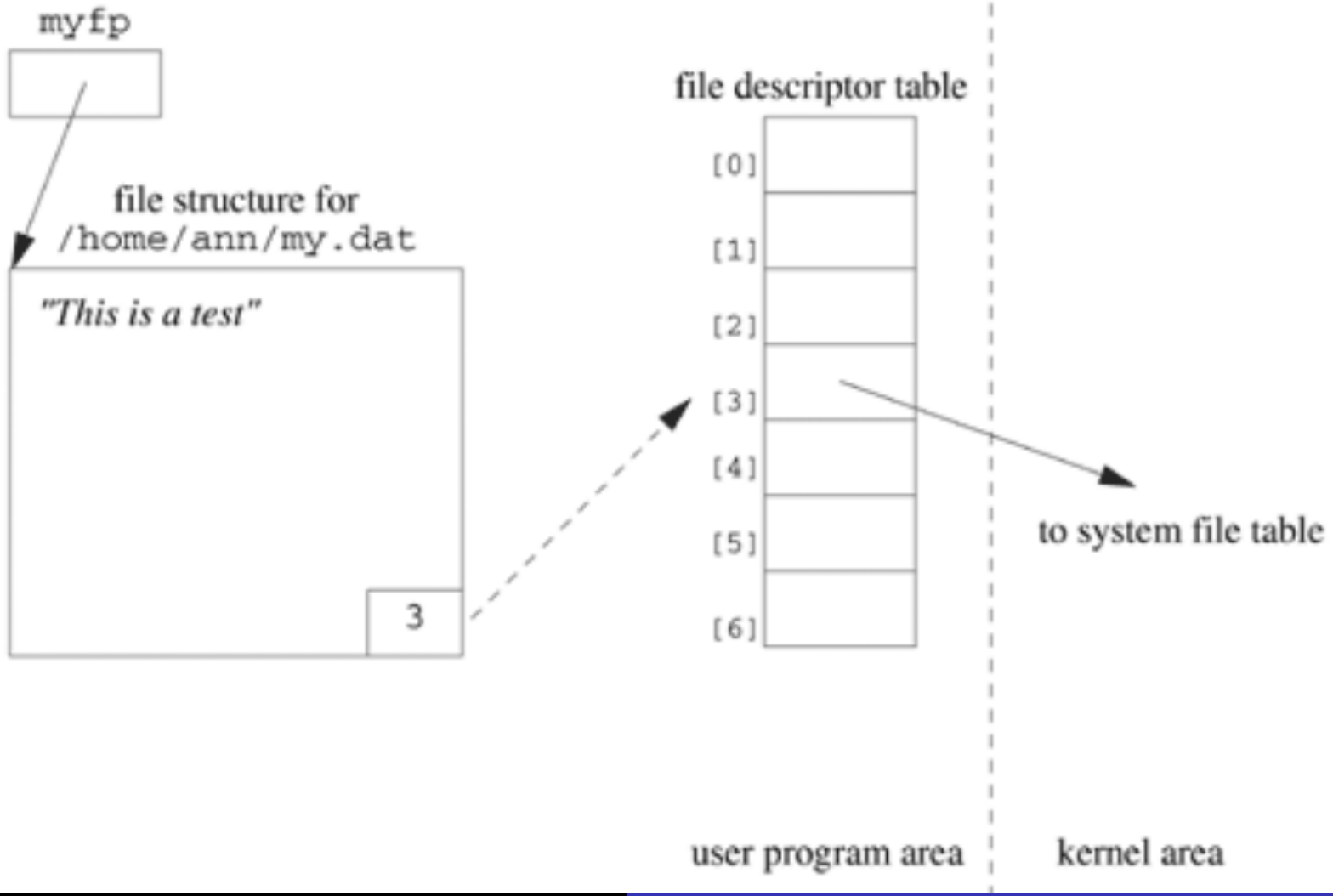


File Descriptor

- The **`open`** function creates an entry in the file descriptor table that points to an entry in the system file table.
- The **`open`** function returns the value 3, specifying that the file descriptor entry is in position three of the process file descriptor table.
- The system file table, which is shared by all the processes in the system, has an entry for each active **`open`**.

File Pointer

```
FILE *myfp;
if ((myfp = fopen("/home/ann/my.dat", "w")) == NULL)
perror("Failed to open /home/ann/my.dat");
else
fprintf(myfp, "This is a test");
```



`oflag` Argument Setting

- The POSIX values for the **access mode flags** in `oflag` argument:
  1. `O_RDONLY` : read-only access
  2. `O_WRONLY` : write-only access
  3. `O_RDWR` : read-write-only access

  Note: specify exactly one of above designating read-only, write-only or read-write access.

- The `oflag` argument is also constructed by taking the bitwise OR (|) of the desired combination of the access mode and the **additional flags**.

- The additional flags:
  1. `O_APPEND`
  2. `O_CREAT`
  3. `O_EXCL`
  4. `O_NOCTTY`
  5. `O_NONBLOCK`
  6. `O_TRUNC`

Additional Flags

O_APPEND: The O_APPEND flag causes the file offset to be moved to the end of the file before a write, allowing you to add to an existing file.

O_CREAT: The O_CREAT flag causes a file to be created if it doesn't already exist. If O_CREAT flag is included, a third argument to `open()` must be passed to designate the permissions.

O_EXCL: If you want to avoid writing over an existing file, use the combination O_CREAT | O_EXCL. This combination returns an error if the file already exists.

O_NOCTTY: The O_NOCTTY flag prevents an opened device from becoming a controlling terminal.

O_NONBLOCK: The O_NONBLOCK flag controls whether the `open()` returns immediately or blocks until the device is ready.

O_TRUNC: O_TRUNC truncates the length of a regular file opened for writing to 0.

open() Examples

The following code segment opens the file /home/students/my.dat for reading

```
#include <fcntl.h>
#include <sys/stat.h>

int myfd;
myfd = open("/home/students/my.dat", O_RDONLY);
```

How would you modify above Example to open /home/ann/my.dat for nonblocking read?

```
Perform OR the O_RDONLY and the O_NONBLOCK flags.

myfd = open("/home/students/my.dat", O_RDONLY |
    O_NONBLOCK);
```

Third argument to `open()`

- Each file has three classes associated with it: a user (or owner), a group and everybody else (others).
- The possible permissions or privileges are read(r), write(w) and execute(x). These privileges are specified separately for the user, the group and others.
- When you open a file with the O_CREAT flag, you must specify the permissions as the third argument to open in a mask of type mode_t.
- POSIX defines symbolic names for masks corresponding to the permission bits. These names are defined in **sys/ stat.h**

POSIX symbolic names for file permissions

user			group			others		
r	w	x	r	w	x	r	w	x

Symbol	meaning
S_IRUSR	read by owner
S_IWUSR	write by owner
S_IXUSR	execute by owner
S_IRWXU	read, write, execute by owner
S_IRGRP	read by group
S_IWGRP	write by group
S_IXGRP	execute by group
S_IRWXG	read, write, execute by group
S_IROTH	read by others
S_IWOTH	write by others
S_IXOTH	execute by others
S_IRWXO	read, write, execute by others
S_ISUID	set user ID on execution
S_ISGID	set group ID on execution

Example

The following code segment creates a file, info.dat, in the current directory. If the info.dat file already exists, it is overwritten. The new file can be read or written by the user and only read by everyone else.

```
int fd;

mode_t fdmode = (S_IRUSR | S_IWUSR | S_IRGRP | S_IROTH);

if ((fd = open("info.dat", O_RDWR | O_CREAT, fdmode)) ==
    -1)
    perror("Failed to open info.dat");
```

close() System Call

The close function has a single parameter, **fildes**, representing the open file whose resources are to be released.

```
#include <unistd.h>

int close(int fildes);

(1) If successful, close returns 0.
(2) If unsuccessful, close returns -1 and sets errno.
```

Filters

- A filter reads from standard input, performs a transformation, and outputs the result to standard output.
- Filters write their error messages to standard error.
- **Examples:** `head`, `tail`, `more`, `sort`, `grep`, `sed`, and `awk` etc.
- **`cat`** as a filter: The cat command takes a list of filenames as command-line arguments, reads each of the files in succession, and echoes the contents of each file to standard output. However, if no input file is specified, cat takes its input from standard input and writes its results to standard output. In this case, cat behaves like a filter.

Redirection

- A file descriptor is an index into the file descriptor table of that process.
- Each entry in the file descriptor table points to an entry in the system file table, which is created when the file is opened.
- A program can modify the file descriptor table entry so that it points to a different entry in the system file table. This action is known as **redirection**.
- Most shells interpret the greater than character (>) on the command line as redirection of standard output and the less than character (<) as redirection of standard input.
- **Example:** `$ cat > myfile.txt`, redirects standard output to `myfile.txt` with >.

dup() & dup2(): Duplicate a File Descriptor

```
#include <unistd.h>

int dup(int oldfd);
```

Return:

```
(1) dup() creates a copy of the file descriptor oldfd.
(2) dup() uses the lowest-numbered unused descriptor for
     the new descriptor returned
(3) -1 on error
```

```
#include <unistd.h>

 fd=open("read.c",O_RDONLY);
 nfd=dup(fd);        /* duplicates the file descriptor fd */
 printf("Duplicate fd=%d\n",nfd);
```

nfd is the lowest-numbered unused file descriptor. It is the duplicate of **fd**.

Example: dup()

Duplicate the standard output file descriptor to write onto a file descriptor **fd**

```
/*duplicating STDOUT_FILENO to a file descriptor fd */
int main()
{
 int fd;
 fd=open("duptest.txt",O_WRONLY|O_CREAT|O_TRUNC,S_IRUSR|
     S_IWUSR|S_IRGRP);
 printf("File descriptor: fd=%d\n",fd);
 dup(STDOUT_FILENO);/* save descriptor STDOUT_FILENO */
 close(1);          /* closing 1, creates an empty slot */
 dup(fd);           /* duplicate fd to standard output */
 close(fd);
 write(STDOUT_FILENO,"USP\n",4);
 write(STDOUT_FILENO,"DOS\n",4);
 return 0;
}
```

Run the code, then open the file: **$ cat duptest.txt**. Data is now written onto the file instead of monitor

dup2 ( ) : Duplicate a File Descriptor

```
#include <unistd.h>

int dup2(int fildes, int fildes2);
```

Return:

```
(1) On success, dup2 returns the file descriptor value
    that was duplicated.
(2) -1 on error
```

Example: dup2 ()

Duplicate the standard output file descriptor to write onto a file descriptor **fd**

```
/*duplicating STDOUT_FILENO to a file descriptor fd */

#define CREATE_FLAGS (O_WRONLY | O_CREAT | O_APPEND)
#define CREATE_MODE (S_IRUSR | S_IWUSR | S_IRGRP | S_IROTH)
int main(void) {
   int fd;
   fd = open("dup2test.txt", CREATE_FLAGS, CREATE_MODE);
   if (dup2(fd, STDOUT_FILENO) == -1) {
      perror("Failed to redirect standard output");
      return 1;
   }
   close(fd);
   write(STDOUT_FILENO, "OK", 2);
   return 0;
}
```

Run the code, then open the file: **`$ cat dup2test.txt`**. Data is now written onto the file instead of monitor

dup() vs dup2()

```
dup2(fd1,fd2);
```

Is equivalent to

```
close(fd2);
dup(fd1);
```

File Control

The **fcntl** function is a general-purpose function for retrieving and modifying the flags associated with an open file descriptor.

```
#include <fcntl.h>
#include <unistd.h>
#include <sys/types.h>

int fcntl(int fildes, int cmd, /* arg */ ...);
```

Return:

```
(1) The return value of fcntl depends on the value of the
    cmd parameter.

(2) If unsuccessful, fcntl returns -1 and sets errno.
```

Values for cmd

cmd	meaning
F_DUPFD	duplicate a file descriptor
F_GETFD	get file descriptor flags
F_SETFD	set file descriptor flags
F_GETFL	get file status flags and access modes
F_SETFL	set file status flags and access modes
F_GETOWN	if fildes is a socket, get process or group ID for out-of-band signals
F_SETOWN	if fildes is a socket, set process or group ID for out-of-band signals
F_GETLK	get first lock that blocks description specified by arg
F_SETLK	set or clear segment lock specified by arg
F_SETLKW	same as FSETLK except it blocks until request satisfied