Linux Basics & Internals

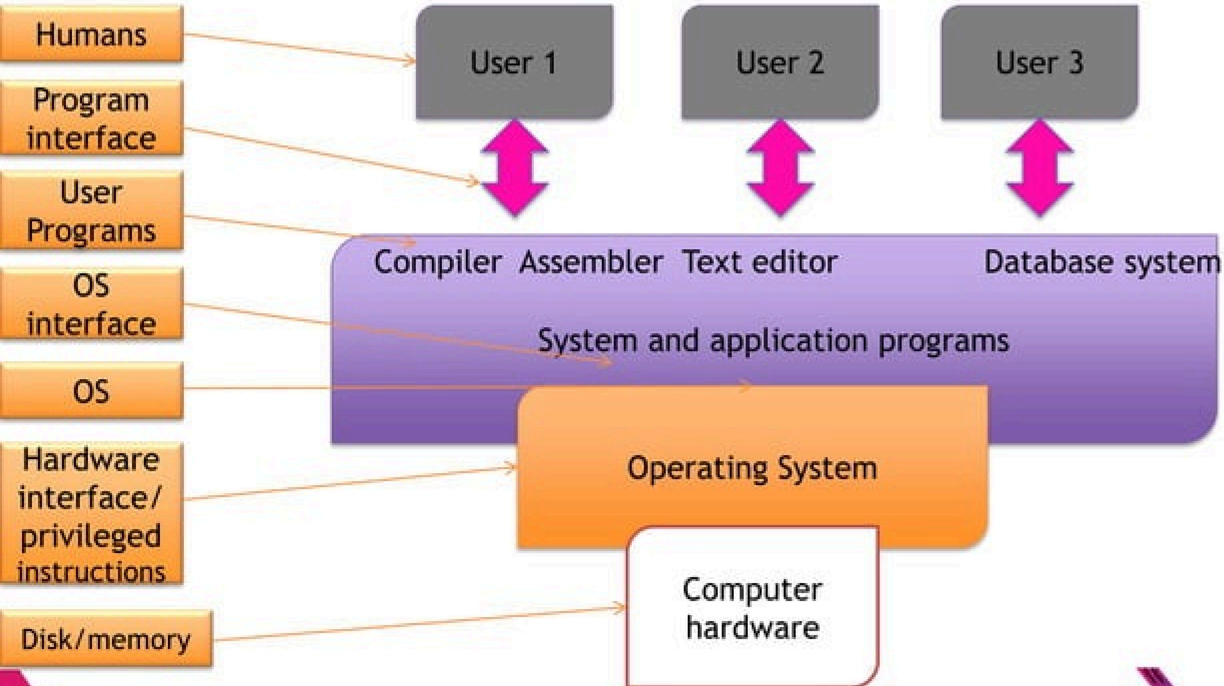
Team Emertxe
Day 1

Linux Introduction

Let us ponder...

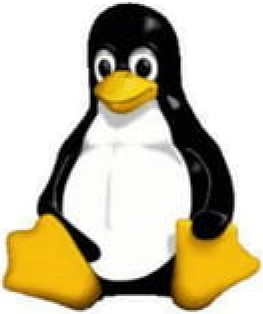
- ✓ What exactly is an Operating System (OS)?
- ✓ Why do we need OS?
- ✓ How would the OS would look like?
- ✓ Is it possible for a team of us (in the room) to create an OS of our own?
- ✓ Is it necessary to have an OS running in a Embedded System?
- ✓ Will the OS ever stop at all?

Operating System



What is Linux ?

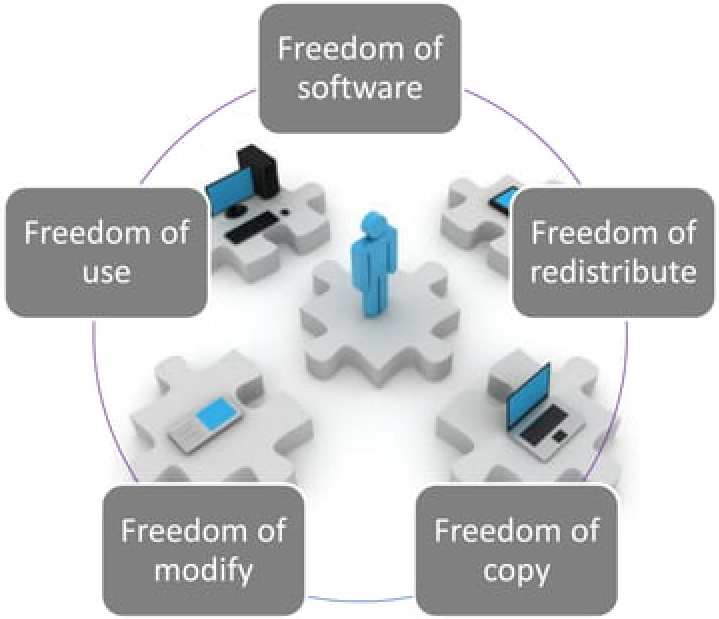
- ✓ Linux is a free and open source operating system that is causing a revolution in the computer world.
- ✓ Originally created by Linus Torvalds with the assistance of developers called community
- ✓ This operating system in only a few short years is beginning to dominate markets worldwide.



Why use Linux?

- ✓ Free & Open Source
- ✓ Reliability
- ✓ Secure
- ✓ Scalability

What is Open Source?

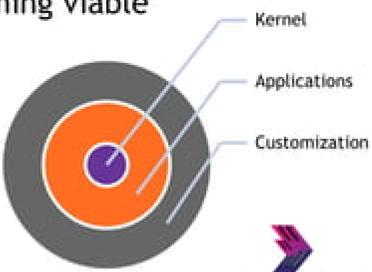


How it all started?

- ✓ With GNU (GNU is not UNIX)
- ✓ Richard Stallman made the initial announcement in 1983, Free Software Foundation (FSF) got formed during 1984
- ✓ Volunteer driven GNU started developing multiple projects, but making it as an operating system was always a challenge
- ✓ During 1991 a Finnish Engineer Linus Torvalds developed core OS functionality, called it as “Linux Kernel”
- ✓ Linux Kernel got licensed under GPL, which laid strong platform for the success of Open Source
- ✓ Rest is history!

How it evolved?

- ✓ Multiple Linux distributions started emerging around the Kernel
- ✓ Some applications became platform independent
- ✓ Community driven software development started picking up
- ✓ Initially seen as a "geek-phenomenon", eventually turned out to be an engineering marvel
- ✓ Centered around Internet
- ✓ Building a business around open source started becoming viable
- ✓ Redhat set the initial trend in the OS business



Where it stands now?

OS
redhat
android
Novell

Databases
EnterpriseDB
MySQL
Hortonworks
VoltDB

Server/Cloud
openNMS
openstack
cloudstack
OPSCODE

Enterprise
pentaho
Alfresco
SUGARCRM.
XWIKI

Consumer
Apache OpenOffice
LibreOffice

Education
canvas
docebo
moodle

CMS
Joomla!
AUTOMATTIC
MediaWiki

eCommerce
Magento
spree
opencart

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More details

Open Source SW vs. Freeware

OSS	Freeware
✓ Users have the right to access & modify the source codes ✓ In case original programmer disappeared, users & developer group of the S/W usually keep its support to the S/W. ✓ OSS usually has the strong users & developers group that manage and maintain the project	✓ Freeware is usually distributed in a form of binary at 'Free of Charge', but does not open source codes itself. ✓ Developer of freeware could abandon development at any time and then final version will be the last version of the freeware. No enhancements will be made by others. ✓ Possibility of changing its licensing policy

GPL

- ✓ Basic rights under the GPL - access to source code, right to make derivative works
- ✓ Reciprocity/Copy-left
- ✓ Purpose is to increase amount of publicly available software and ensure compatibility
- ✓ Licensees have right to modify, use or distribute software, and to access the source code

Problems with the GPL

- ✓ Linking to GPL programs
- ✓ No explicit patent grant
- ✓ Does no discuss trademark rights
- ✓ Does not discuss duration
- ✓ Silent on sub-licensing
- ✓ Relies exclusively on license law, not contract

Properties

- ✓ Multitasking
- ✓ Multi-user
- ✓ Multiprocessing
- ✓ Protected Memory
- ✓ Hierarchical File System

Components

- ✓ **Hardware Controllers:** This subsystem is comprised of all the possible physical devices in a Linux installation
- ✓ **Linux Kernel:** The kernel abstracts and mediates access to the hardware resources, including the CPU. A kernel is the core of the operating system
- ✓ **O/S Services:** These are services that are typically considered part of the operating system (e.g. shell)
- ✓ **User Applications:** The set of applications in use on a particular Linux system. (e.g. web-browser)

Directory structure

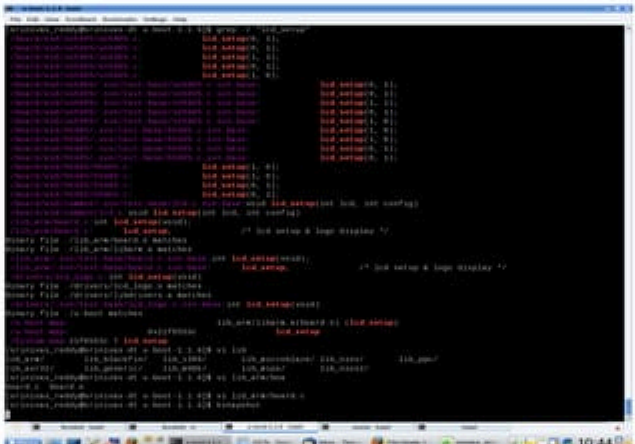
/

/boot/	Static files for boot loader
/dev/	Device files
/bin/	Essential user command binaries
/etc/	Host specific system configuration
/home/	User home directories
/lib/	Essentilal shared libraries and kernal modules
/media/	Mount point for removable media
/mnt/	Mount point for temporarily mounted file systems
/opt/	Add-on application software package
/sbin/	User specific system binaries
/tmp/	Temporary files
/usr/	Multi-user utilities and applications
/var/	Variable file (logs)
/root/	Home directory for root user
/proc/	Virtual file system documenting kernel and process status

Command Line Interface

Command Line Interface

- CLI
  - Textual mode
  - Executes requested command
- GUI
  - Mouse, keypad



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The Shell

- ✓ *What is a shell?*
- ✓ *Different types of shells*
  - *Login-shell*
  - *Non-login shell*
    - *Sh*
    - *Bash*
    - *Ksh*
    - *Csh*
- ✓ *Hands-on:*
  - *echo $0*
  - *cat /etc/shells*

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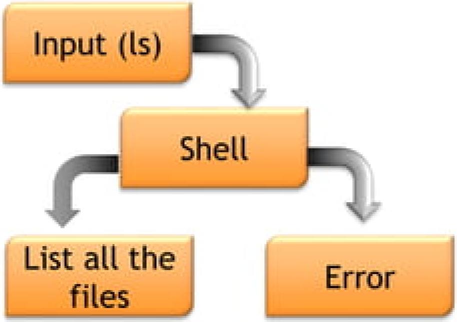
How Shell Invokes

The main task of a shell is providing a user environment



Bash Files

- ✓ Bash
  - Command interpreter
  - .bash_profile (During login)
  - .bashrc (New instance)
  - .bash_logout (Logout)
  - .bash_history (Command history)
- ✓ Hands-on:
  - *Enter ls -a in your home directory*
  - *Display contents of all files mentioned above*

Environment Variables

- ✓ Login-shell's responsibility is to set the non-login shell and it will set the environment variables
- ✓ Environment variables are set for every shell and generally at login time
- ✓ Environmental variables are set by the system.
- ✓ Environmental variables hold special values. For instance ,$ echo $SHELL
- ✓ Environmental variables are defined in /etc/profile, /etc/profile.d/ and ~/.bash_profile.
- ✓ When a login shell exits, bash reads ~/.bash_logout

The 'bash' variables & Friends

- ✓ env - lists shell environment variable/value pairs
- ✓ export [var_name] - exports/sets a shell variable

  HOME - path to user's home directory

  PATH - executable search path

  PWD - present working directory

  PS1 - command prompt

- ✓ N=10 - Assigning the variable. This a temporary variable effective only inside the current shell)
- ✓ unset N - Unset the environment variable N

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Basic Shell Commands

Basic Shell Commands

- ✓ $ ls - list's all the files
- ✓ $ pwd - gives present working directory
- ✓ $ cd - change directory
- ✓ $ man - gives information about command
- ✓ $ exit - exits from the shell
- ✓ $ which - shows full path of command

Shell: Built-in Commands

- ✓ Built-in commands are contained with in the shell itself, means shell executes the command directly, without creating a new process
- ✓ Built-in commands:
  break,cd,exit,pwd,export,return,unset,alias,echo,print f,read,logout,help,man

User Specific Command Set

- ✓ All Accesses into a Linux System are through a User
- ✓ User related Shell Command Set

$ useradd	-	create user
$ userdel	-	delete user
$ su - [username]	-	start new shell as different user
$ finger	-	user information lookup
$ passwd	-	change or create user password
$ who, w	-	to find out who is logged in
$ whoami	-	who are you

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Remote login and remote copy

- ✓ ssh is a program for logging into a remote machine and for executing commands on a remote machine.

  $ ssh (secured login)

  ssh username@ipaddress

- ✓ scp copies files between hosts on a network.

  $ scp (secured copy)

  scp filename username@ipaddress:/path/

File System Related Commands

File System related Shell Command Set

$ stat - File and Inode information

$ mount - Mounting filesystem

$ find, locate - Search for files

File Related Shell Commands

- ✓ Every thing is viewed as a file in Linux. Even a *Directory* is a file.
- ✓ Basic Shell Command Set

$ pwd	-	print working directory.
$ cd	-	change directory.
$ ls	-	list directory/file contents
$ df	-	disk free
$ du	-	disk usage
$ cp	-	copy
$ mv	-	move, rename
$ rm	-	remove

Cont...

- ✓ $ mkdir - make directory
- ✓ $ rmdir - remove directory
- ✓ $ cat, less, head, tail - used to view text files
- ✓ $ touch - create and update files
- ✓ $ wc - counts the number of lines in a file

File Detailed Listing

```
aayush@aayush-laptop:~/Documents/try$ ls -l
total 4
brw------- 1 root   root     7, 0 2010-09-12 02:02 block_file
crw------- 1 root   root   108, 0 2010-09-12 02:02 character_file
drwxr-xr-x 2 aayush aayush   4096 2011-03-17 03:56 directory_file
lrwxrwxrwx 1 aayush aayush     12 2011-03-21 21:03 link_file -> regular_file
prw-r--r-- 1 root   root        0 2011-03-17 04:51 namedpipe_file
-rw-r--r-- 1 aayush aayush      0 2011-03-17 04:36 regular_file
srwxr-xr-x 1 aayush aayush      0 2011-03-17 04:32 socket_file
```

permissions

Owner & group

File size

Created time & Date

Filename

Linux file types

1st column	Meaning
-	Plain text
d	Directory
c	Character driver
b	Block driver
l	Link file
s	Socket file
= or p	FIFO file

File permissions

- ✓ r or 4 -r--r--r-- Read
- ✓ w or 2 --w--w--w- Write
- ✓ x or 1 ---x--x--x Execute

rwx	rwx	rwx
421	421	421
user	group	others

Changing the File Permissions

$ chmod - Change file permessions

$ chown - Change file owner

$ chmod [ug+r, 746] file.txt

$ chown -R user:group [filename | dir]

Redirection

- ✓ Out put redirection (>)
- ✓ Redirecting to append (>>)
- ✓ Redirecting the error (2>)

eg : $ls > /tmp/outputfile

eg : $ls -l >> /tmp/outputfile

eg : $ls 2> /tmp/outputfile

Piping

- ✓ A pipe is a form of redirection that is used in Linux operating systems to send the output of one program to another program for further processing.
- ✓ A pipe is designated in commands by the vertical bar character

    eg: $ ls -al /bin | less

Other useful Command Set

Useful Command Set

- ✓ $ uname - print system information
- ✓ $ man <topic> - manual pages on <topic>
- ✓ $ info <topic> - information pages on <topic>
- ✓ $ stat - File and Inode information
- ✓ $ mount - Mounting filesystem
- ✓ $ find, locate - Search for files
- ✓ $ gzip filename - This will compress folder or file
- ✓ $ gunzip - This will uncompress
- ✓ $ tar - Archiving files

Filters

- ✓ Filters are the programs, which read some input, perform the transformation on it and gives the output. Some commonly used filters are as follow
  - $ tail : Print the last 10 lines of each FILE to standard output.
  - $ sort : Sort lines of text files
  - $ tr : Translate, squeeze, and/or delete characters from standard input, writing to standard output.
  - $ wc : Print newline, word, and byte counts for each file

Pattern Matching

- ✓ Grep is pattern matching tool used to search the name input file. Basically its used for lines matching a pattern
  - Command: grep

Example: `$ ls | grep *.c`

This will list the files from the current directory with .c extension

VIsual editor

VIsual editor

- ✓ vi or vim
- ✓ To open a file
  $ vi <filename> or vim <filename>

VIsual editor…

- ✓ vi opens a file in command mode to start mode.
- ✓ The power of vi comes from its 3 modes
  - Escape mode (Command mode)
    - Search mode
    - File mode
  - Editing mode
    - Insert mode
    - Append mode
    - Open mode
    - Replace mode
  - Visual mode.

Cursor Movement

- ✓ You will clearly need to move the cursor around your file. You can move the cursor in command mode.
- ✓ vi has many different cursor movement commands. The four basic keys appear below
  - k move up one line
  - h line move one character to the left
  - l line move one character to the right
  - j move down one line
- ✓ Yes! Arrow keys also do work. But these makes typing faster

Basic vi commands

- ✓ How to exit
  - :q -> Close with out saving.
  - :wq -> Close the file with saving.
  - :q! -> Close the file forcefully with out saving
- ✓ Already looks too complicated?
- ✓ Try by yourself, let us write a C program
- ✓ Try out vimtutor. Go to shell and type vimtutor

Escape mode or Command mode

- In command mode, characters you perform actions like moving the cursor, cutting or copying text, or searching for some particular text
  - Search mode
    - vi can search the entire file for a given string of text. A string is a sequence of characters. vi searches forward with the slash (/) key and string to search. To cancel the search, press ESC .You can search again by typing n (forward) or N (backward). Also, when vi reaches the end of the text, it continues searching from the beginning. This feature is called wrap scan
    - Instead of (/), you may also use question (?). That would have direction reversed
    - Now, try out. Start vi as usual and try a simple search. Type /<string> and press n and N a few times to see where the cursor goes.

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Escape mode...

- File mode
  - Changing (Replacing) Text

    :%s/first/sec - Replaces the first by second every where in the file

    :%s/fff/rrrrr/gc - For all lines in a file, find string "fff" and replace with string "rrrrr" for each instance on a line

    :q - Close with out saving

    :wq - Close the file with saving

    :q! - Close the file forcefully with out saving

    :e filename - open another file without closing the current

    :set all - display all settings of your session

    :r filename - reads file named filename in place

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Editing Modes...

- ✓ Command / Mode Name / Insertion Point

Command	Mode Name	Insertion Point
a	Append	just after the current character
A	Append	end of the current line
i	Insert	just before the current character
I	Insert	beginning of the current line
o	Open	new line below the current line
O	Open	new line above the current line

Editing Text

- ✓ Deleting Text   Sometimes you will want to delete some of the text you are editing. To do so, first move the cursor so that it covers the first character of the group you want to delete, then type the desired command from the table below.
  - dd - For deleting a line
  - ndd - For deleting a n lines
  - x - To delete a single character
  - shift + d - Delete contents of line after cursor
  - dw - Delete word's
  - ndw - Delete n words

Some Useful Shortcuts

- shift-g - Go to last line in file
- shift-j - Joining the two lines
- .   - It repeats the previous command executed
- ctrl+a - Increment number under the cursor
- ctrl+x - Decrements numbers under the cursor

Visual Mode

✓ Visual Mode

Visual mode helps to visually select some text, may be seen as a sub mode of the command mode to switch from the command mode to the visual mode type one of

- ctrl+v :- Go's to visual block mode.
- Only v for visual mode
- d or y Delete or Yank selected text
- I or A Insert or Append text in all lines (visual block only)

Linux Internals

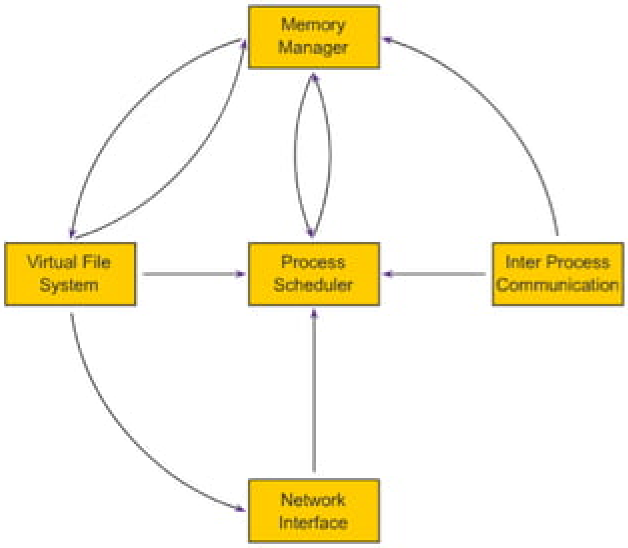
Day 2

Team Emertxe

Linux Kernel Subsystem

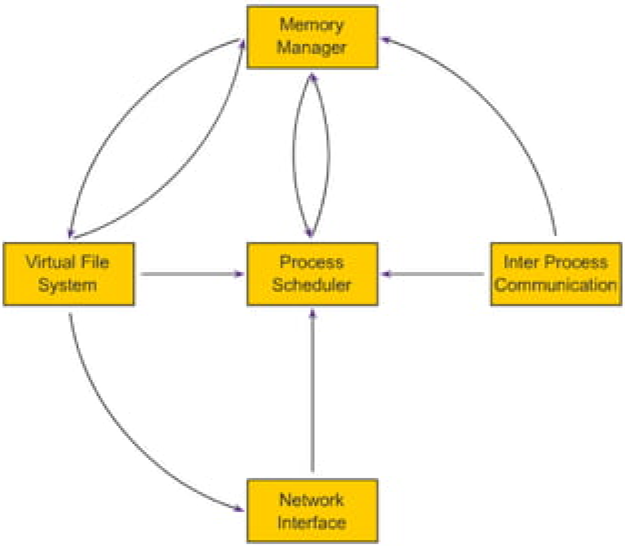
Introduction

Linux Kernel Subsystem



- Process Scheduler (SCHED):
  - To provide control, fair access of CPU to process, while interacting with HW on time
- Memory Manager (MM):
  - To access system memory securely and efficiently by multiple processes. Supports Virtual Memory in case of huge memory requirement
- Virtual File System (VFS):
  - Abstracts the details of the variety of hardware devices by presenting a common file interface to all devices

Introduction
Linux Kernel Subsystem

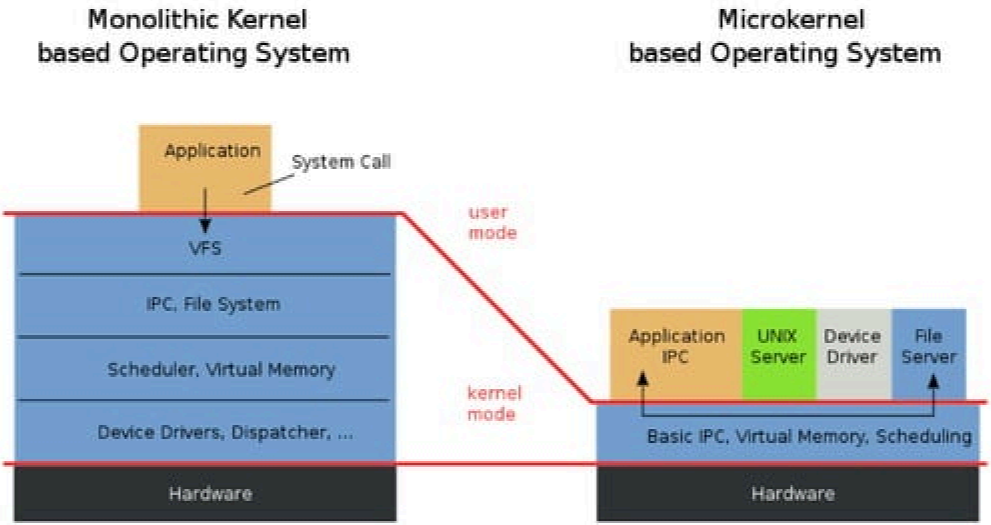


- Network Interface (NET):
  - provides access to several networking standards and a variety of network hardware
- Inter Process Communications (IPC):
  - supports several mechanisms for process-to-process communication on a single Linux system

Introduction
Linux Kernel Architecture

- Most older operating systems are monolithic, that is, the whole operating system is a single executable file that runs in 'kernel mode'
- This binary contains the process management, memory management, file system and the rest (Ex: UNIX)
- The alternative is a microkernel-based system, in which most of the OS runs as separate processes, mostly outside the kernel
- They communicate by message passing. The kernel's job is to handle the message passing, interrupt handling, low-level process management, and possibly the I/O (Ex: Mach)

Introduction
Linux Kernel Architecture



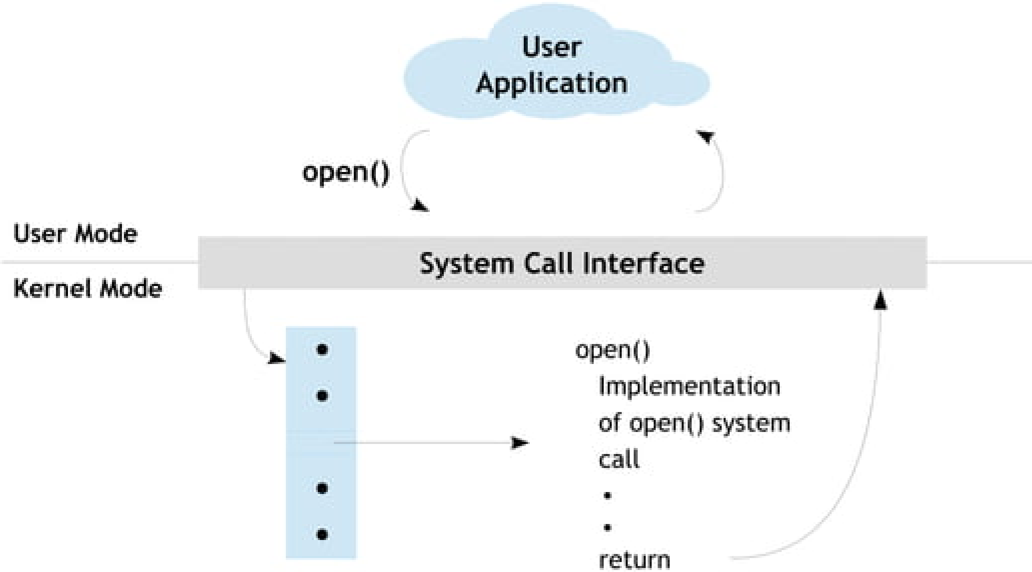
System Calls

System calls

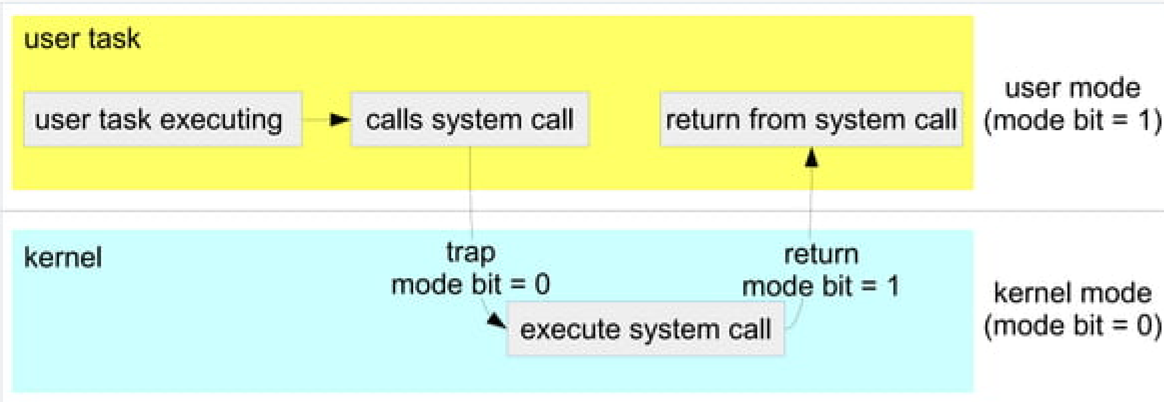
- A set of interfaces to interact with hardware devices such as the CPU, disks, and printers.
- Advantages:
  - Freeing users from studying low-level programming
  - It greatly increases system security
  - These interfaces make programs more portable

For a OS programmer, calling a system call is no different from a normal function call.
But the way system call is executed is way different.

System calls



System Call
Calling Sequence



Logically the system call and regular interrupt follow the same flow of steps. The source (I/O device v/s user program) is very different for both of them. Since system call is generated by user program they are called as 'Soft interrupts' or 'Traps'

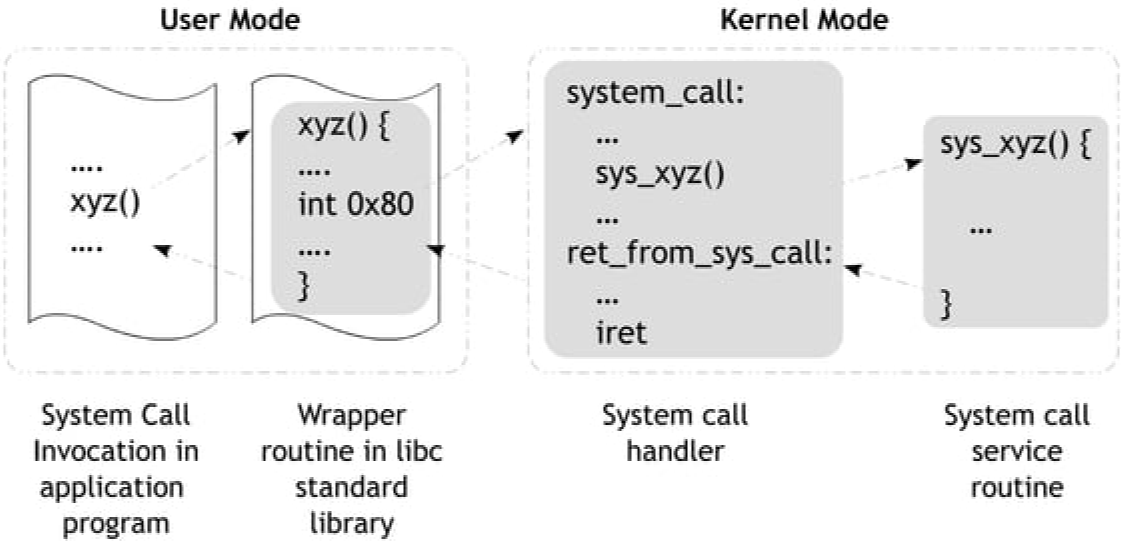
System Call
vs Library Function

- A library function is an ordinary function that resides in a library external to your program. A call to a library function is just like any other function call
- A system call is implemented in the Linux kernel and a special procedure is required in to transfer the control to the kernel
- Usually, each system call has a corresponding wrapper routine, which defines the API that application programs should employ

✓ Understand the differences between:
- Functions
- Library functions
- System calls

✓ From the programming perspective they all are nothing but simple C functions

System Call
Implementation



System Call
Information: strace

- The strace command traces the execution of another program, listing any system calls the program makes and any signals it receives

  E.g.: strace hostname

- Each line corresponds to a single system call.
- For each call, the system call's name is listed, followed by its arguments and its return value

System Call
Example: fcntl

- The fcntl system call is the access point for several advanced operations on file descriptors.
- Arguments:
  - An open file descriptor
  - Value that indicates which operation is to be performed

System Call
Example: gettimeofday()

- Gets the system's wall-clock time.
- It takes a pointer to a struct timeval variable. This structure represents a time, in seconds, split into two fields.
  - tv_sec field - integral number of seconds
  - tv_usec field - additional number of usecs

System Call
Example: nanosleep()

- A high-precision version of the standard UNIX sleep call
- Instead of sleeping an integral number of seconds, ***nanosleep*** takes as its argument a pointer to a ***struct timespec*** object, which can express time to nanosecond precision.
  - tv_sec field - integral number of seconds
  - tv_nsec field - additional number of nsecs

System Call
Example: Others

- open
- read
- write
- exit
- close
- wait
- waitpid
- getpid
- sync
- nice
- kill etc..

Process

Process

- Running instance of a program is called a PROCESS
- If you have two terminal windows showing on your screen, then you are probably running the same terminal program twice-you have two terminal processes
- Each terminal window is probably running a shell; each running shell is another process
- When you invoke a command from a shell, the corresponding program is executed in a new process
- The shell process resumes when that process complete

Process
vs Program

- A program is a passive entity, such as file containing a list of instructions stored on a disk
- Process is a active entity, with a program counter specifying the next instruction to execute and a set of associated resources.
- A program becomes a process when an executable file is loaded into main memory

Factor	Process	Program
Storage	Dynamic Memory	Secondary Memory
State	Active	Passive

Process
vs Program

Program

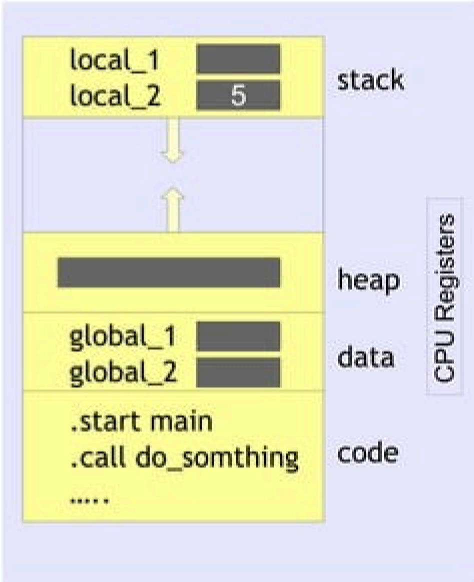
```c
int global_1 = 0;
int global_2 = 0;

void do_somthing()
{
        int local_2 = 5;
        local_2 = local_2 + 1;
}

int main()
{
        char *local_1 = malloc(100);

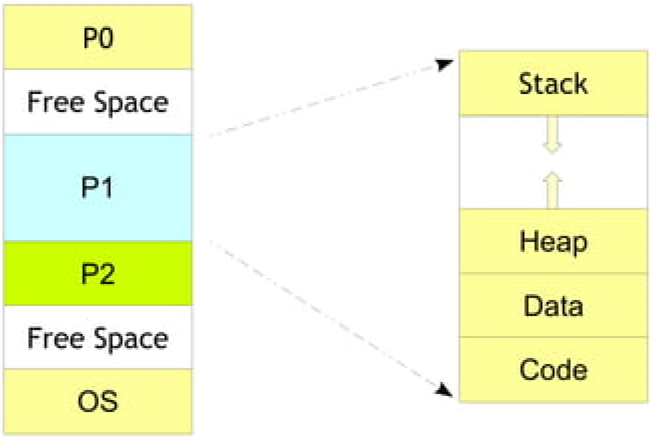
        do_somthing();
        .....
}
```

Task



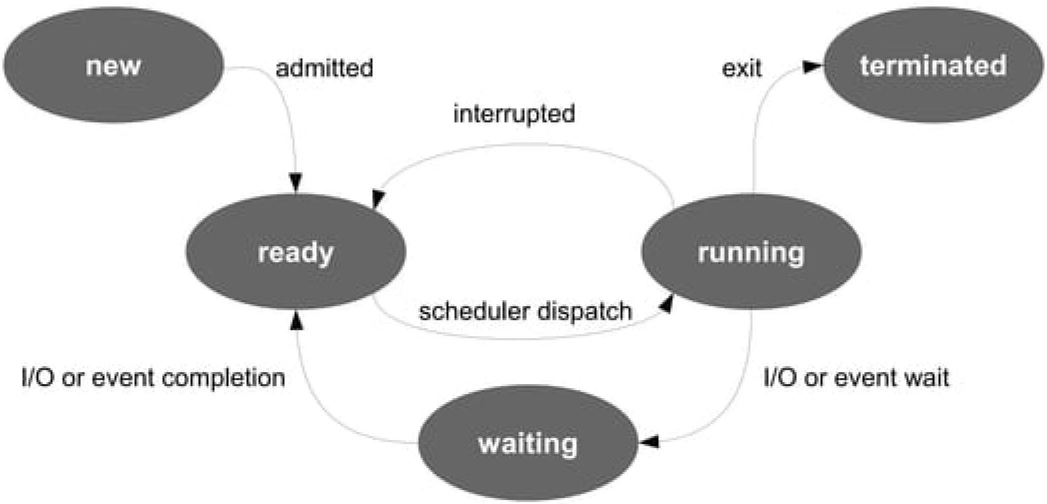
Process

More processes in memory!



Each Process will have its own Code, Data, Heap and Stack

Process
State Transition Diagram



Process
States

- A process goes through multiple states ever since it is created by the OS

State	Description
New	The process is being created
Running	Instructions are being executed
Waiting	The process is waiting for some event to occur
Ready	The process is waiting to be assigned to processor
Terminated	The process has finished execution

Process
Descriptor

- To manage tasks:
  - OS kernel must have a clear picture of what each task is doing.
  - Task's priority
  - Whether it is running on the CPU or blocked on some event
  - What address space has been assigned to it
  - Which files it is allowed to address, and so on.
- Usually the OS maintains a structure whose fields contain all the information related to a single task

Process
Descriptor

Pointer	Process State
Process ID	
Program Counter	
Registers	
Memory Limits	
List of Open Files	
. . . . . .	

- Information associated with each process.
- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- I/O status information

Process
Descriptor – State Field

- State field of the process descriptor describes the state of process.
- The possible states are:

State	Description
TASK_RUNNING	Task running or runnable
TASK_INTERRUPTIBLE	process can be interrupted while sleeping
TASK_UNINTERRUPTIBLE	process can't be interrupted while sleeping
TASK_STOPPED	process execution stopped
TASK_ZOMBIE	parent is not issuing wait()

Process

Descriptor - ID

- Each process in a Linux system is identified by its unique process ID, sometimes referred to as PID
- Process IDs are numbers that are assigned sequentially by Linux as new processes are created
- Every process also has a parent process except the special init process
- Processes in a Linux system can be thought of as arranged in a tree, with the init process at its root
- The parent process ID or PPID, is simply the process ID of the process's parent

Process
Active Processes

- The *ps* command displays the processes that are running on your system
- By default, invoking ps displays the processes controlled by the terminal or terminal window in which ps is invoked
- For example (Executed as "ps -aef"):

```
user@user:~] ps -aef
UID        PID  PPID  C STIME TTY          TIME CMD
root         1     0  0 12:17 ?        00:00:01 /sbin/init
root         2     0  0 12:17 ?        00:00:00 [kthreadd]
root         3     2  0 12:17 ?        00:00:02 [ksoftirqd/0]
root         4     2  0 12:17 ?        00:00:00 [kworker/0:0]
root         5     2  0 12:17 ?        00:00:00 [kworker/0:0H]
root         7     2  0 12:17 ?        00:00:00 [rcu_sched]
```

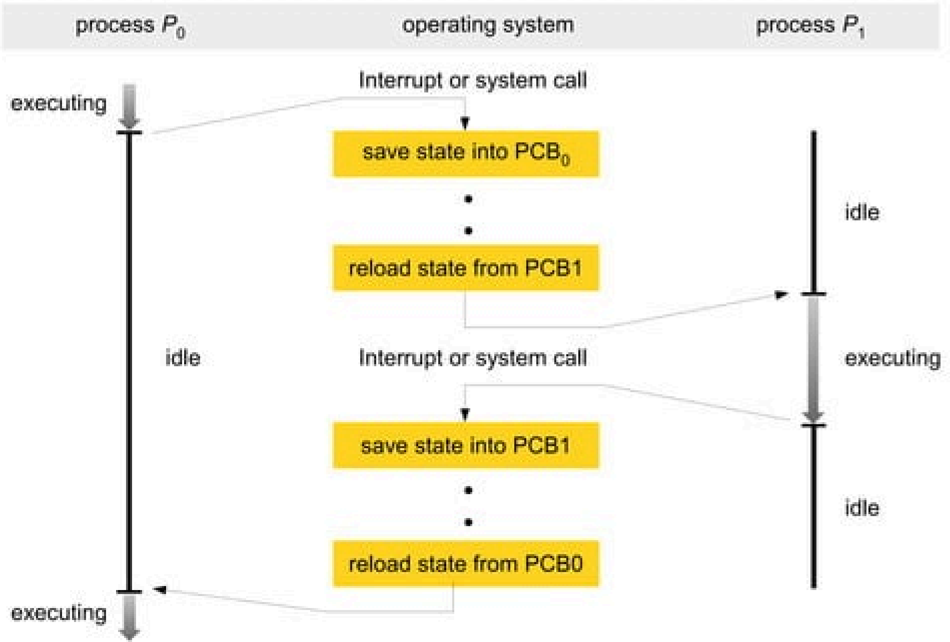
Process ID

Parent Process ID

Process
Context Switching

- Switching the CPU to another task requires saving the state of the old task and loading the saved state for the new task
- The time wasted to switch from one task to another without any disturbance is called context switch or scheduling jitter
- After scheduling the new process gets hold of the processor for its execution

Process
Context Switching



Process
Creation

- Two common methods are used for creating new process
- Using system(): Relatively simple but should be used sparingly because it is inefficient and has considerably security risks
- Using fork() and exec(): More complex but provides greater flexibility, speed, and security

Process

Creation - system()

- It creates a sub-process running the standard shell
- Hands the command to that shell for execution
- Because the system function uses a shell to invoke your command, it's subject to the features and limitations of the system shell
- The system function in the standard C library is used to execute a command from within a program
- Much as if the command has been typed into a shell

Process
Creation - fork()

- fork makes a child process that is an exact copy of its parent process
- When a program calls fork, a duplicate process, called the child process, is created
- The parent process continues executing the program from the point that fork was called
- The child process, too, executes the same program from the same place
- All the statements after the call to fork will be executed twice, once, by the parent process and once by the child process

Process

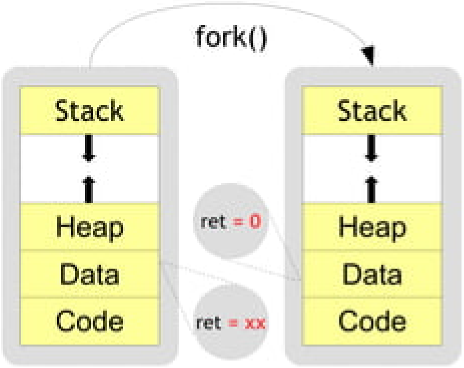
Creation - fork()

- The execution context for the child process is a copy of parent's context at the time of the call

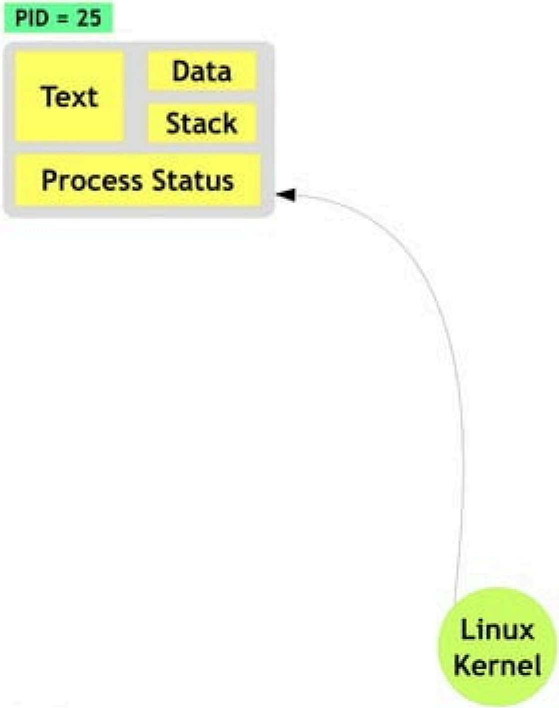
```
int child_pid;
int child_status;

int main()
{
    int ret;

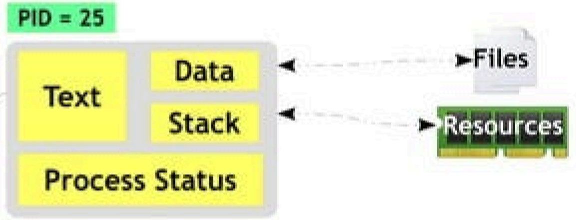
    ret = fork();
    switch (ret)
    {
        case -1:
            perror("fork");
            exit(1);
        case 0:
            <code for child process>
            exit(0);
        default:
            <code for parent process>
            wait(&child_status);
    }
}
```



Process
fork() - The Flow



Process
fork() - The Flow




```
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switch (ret)
{
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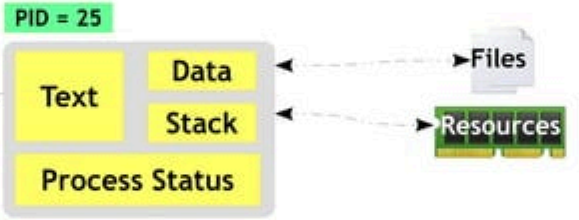
Process
fork() - The Flow

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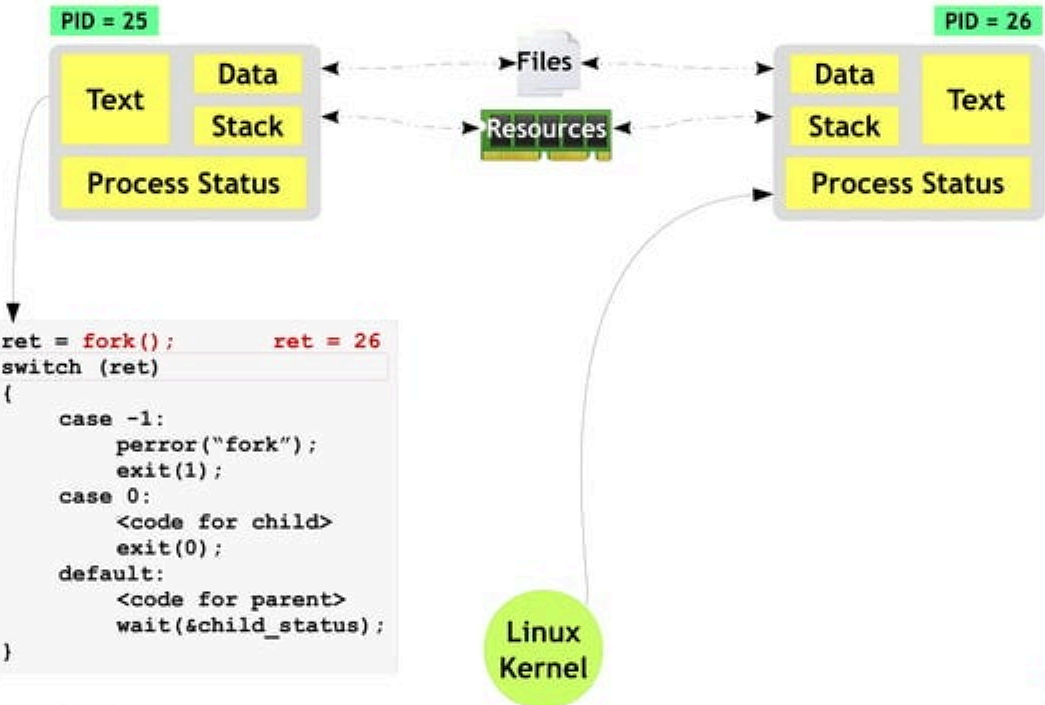
Process

fork() - The Flow




```
ret = fork();          ret = 26
switch (ret)
{
    case -1:
        perror("fork");
        exit(1);
    case 0:
        <code for child>
        exit(0);
    default:
        <code for parent>
        wait(&child_status);
}
```

Process
fork() - The Flow


```
ret = fork();        ret = 26
switch (ret)
{
    case -1:
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}
```

Linux Kernel

```
ret = fork();
switch (ret)
{
    case -1:
        perror("fork");
        exit(1);
    case 0:
        <code for child>
        exit(0);
    default:
        <code for parent>
        wait(&child_status);
}
```

Process
fork() - The Flow


```c
ret = fork();          ret = 26
switch (ret)
{
    case -1:
        perror("fork");
        exit(1);
    case 0:
        <code for child>
        exit(0);
    default:
        <code for parent>
        wait(&child_status);
}
```

```c
ret = fork();          ret = 0
switch (ret)
{
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        perror("fork");
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        exit(0);
    default:
        <code for parent>
        wait(&child_status);
}
```

Linux Kernel

Process

fork() - The Flow


```
ret = fork();          ret = 26
switch (ret)
{
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Process
fork() - The Flow


```
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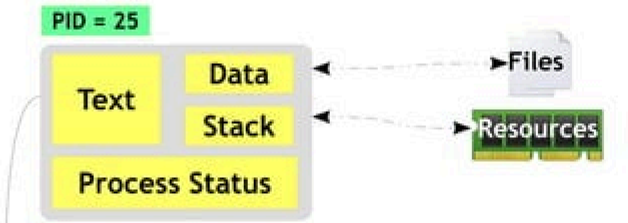
Process
fork() - The Flow

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        exit(0);
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        <code for parent>
        wait(&child_status);
}
```

EMERTXE

Process

fork() - How to Distinguish?

- First, the child process is a new process and therefore has a new process ID, distinct from its parent's process ID
- One way for a program to distinguish whether it's in the parent process or the child process is to call getpid
- The fork function provides different return values to the parent and child processes
- One process "goes in" to the fork call, and two processes "come out," with different return values
- The return value in the parent process is the process ID of the child
- The return value in the child process is zero

Process

Overlay - exec()

- The exec functions replace the program running in a process with another program
- When a program calls an exec function, that process immediately ceases executing and begins executing a new program from the beginning
- Because exec replaces the calling program with another one, it never returns unless an error occurs
- This new process has the same PID as the original process, not only the PID but also the parent process ID, current directory, and file descriptor tables (if any are open) also remain the same
- Unlike fork, exec results in still having a single process

Process
Termination

- When a parent forks a child, the two process can take any turn to finish themselves and in some cases the parent may die before the child
- In some situations, though, it is desirable for the parent process to wait until one or more child processes have completed
- This can be done with the wait() family of system calls.
- These functions allow you to wait for a process to finish executing, enable parent process to retrieve information about its child's termination

Process
Wait

- There are four different system calls in wait family
- Simplest one is wait(). It blocks the calling process until one of its child processes exits (or an error occurs).
- It returns a status code via an integer pointer argument, from which you can extract information about how the child process exited.
- The waitpid function can be used to wait for a specific child to exit, instead of any child process.
- The wait3 function returns resource usage information about the exiting child process.

Process
Zombie

- Zombie process is a process that has terminated but has not been cleaned up yet
- It is the responsibility of the parent process to clean up its zombie children
- If the parent does not clean up its children, they stay around in the system, as zombie
- When a program exits, its children are inherited by a special process, the init program, which always runs with process ID of 1 (it's the first process started when Linux boots)
- The init process automatically cleans up any zombie child processes that it inherits.

Inter Process Communications (IPC)

Inter Process Communications

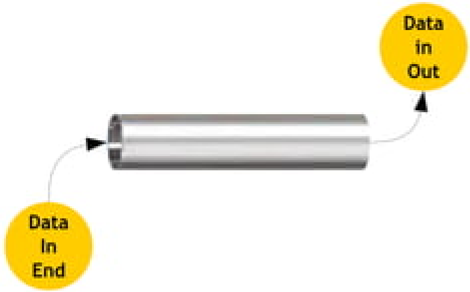
Introduction

- *Inter process communication (IPC)* is the mechanism whereby one process can communicate, that is exchange data with another processes
- Example, you may want to print the filenames in a directory using a command such as ls | lpr
- The shell creates an ls process and separate lpr process, connecting the two with a pipe, represented by the "|" symbol.

Pipes

Inter Process Communications
Pipes

- A pipe is a communication device that permits unidirectional communication
- Data written to the “write end” of the pipe is read back from the “read end”
- Pipes are serial devices; the data is always read from the pipe in the same order it was written



Inter Process Communications
Pipes - Creation

- To create a pipe, invoke the pipe system call
- Supply an integer array of size 2
- The call to pipe stores the reading file descriptor in array position 0
- Writing file descriptor in position 1

FIFO

Inter Process Communications
FIFO - Properties

- A *first-in, first-out (FIFO)* file is a pipe that has a name in the file-system
- FIFO file is a pipe that has a name in the file-system
- FIFOs are also called Named Pipes
- FIFOs is designed to let them get around one of the shortcomings of normal pipes

Inter Process Communications
FIFO vs Pipes

- Unlike pipes, FIFOs are not temporary objects, they are entities in the file-system
- Any process can open or close the FIFO
- The processes on either end of the pipe need not be related to each other
- When all I/O is done by sharing processes, the named pipe remains in the file system for later use

Inter Process Communications
FIFO - Creation

- FIFO can also be created using

  mknod("myfifo", S_IFIFO | 0644, 0);
- The FIFO file will be called "myfifo"
- Creation mode (permission of pipe)
- Finally, a device number is passed. This is ignored when creating a FIFO, so you can put anything you want in there.

Inter Process Communications
FIFO - Access

- Access a FIFO just like an ordinary file
- To communicate through a FIFO, one program must open it for writing, and another program must open it for reading
- Either low-level I/O functions (open, write, read, close and so on) or C library I/O functions (fopen, fprintf, fscanf, fclose, and so on) may be used.

Inter Process Communications
FIFO - Access Example

- For example, to write a buffer of data to a FIFO using low-level I/O routines, you could use this code:

```
int fd = open(fifo_path, O_WRONLY);
write(fd, data, data_length);
close(fd);
```

- To read a string the FIFO using C library I/O functions, you could use this code:

```
FILE* fifo = fopen(fifo_path, "r");
fscanf(fifo, "%s", buffer);
fclose(fifo);
```

Inter Process Communications
Broken Pipe

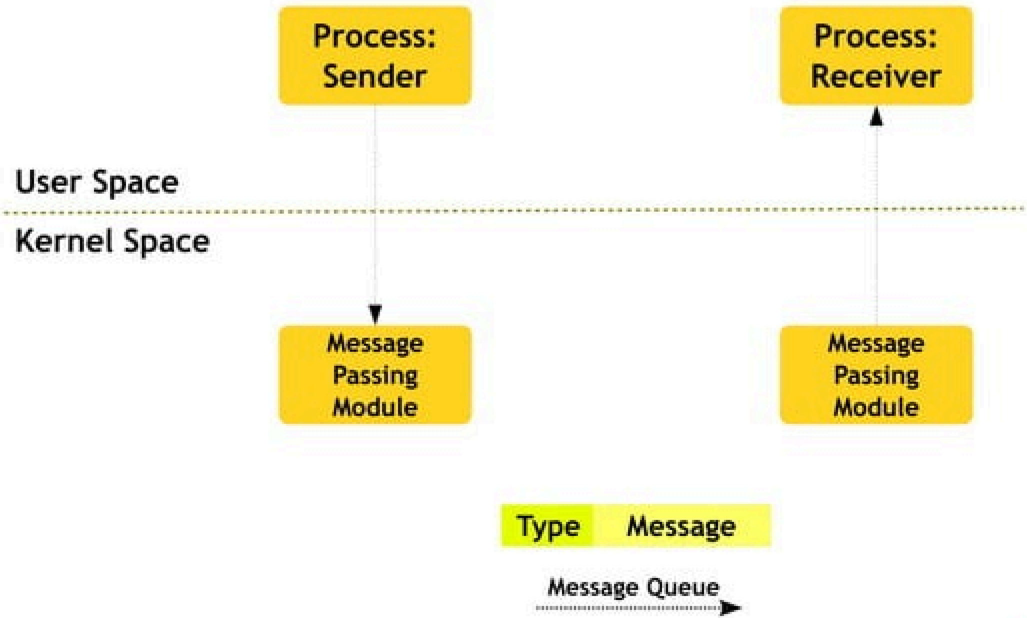
- In the previous examples, terminate read while write is still running. This creates a condition called “Broken Pipe”.
- What has happened is that when all readers for a FIFO close and the writers is still open, the write will receive the signal SIGPIPE the next time it tries to write().
- The default signal handler prints “Broken Pipe” and exits. Of couse, you can handle this more gracefully by catching SIGPIPE through the signa()l call.

Message Queues

Inter Process Communications
Message Queues

- Message queues are two way IPC mechanism for communicating structured messages
- Works well for applications like protocols where there is a meaning behind every message
- Asynchronous communication mechanism, applied in group applications
- Queue full and queue empty situations
- Automatic synchronizations

Inter Process Communications
Message Queues - Flow



Shared Memory

Inter Process Communications
Shared Memories

- Shared memory allows two or more processes to access the same memory
- When one process changes the memory, all the other processes see the modification
- Shared memory is the fastest form of Inter process communication because all processes share the same piece of memory
- It also avoids copying data unnecessarily

Inter Process Communications
Shared Memories - Procedure

- To start with one process must allocate the segment
- Each process desiring to access the segment must attach to it
- Reading or Writing with shared memory can be done only after attaching into it
- After use each process detaches the segment
- At some point, one process must de-allocate the segment

- Under Linux, each process's virtual memory is split into pages.
- Each process maintains a mapping from its memory address to these virtual memory pages, which contain the actual data.
- Even though each process has its own addresses, multiple processes mappings can point to the same page, permitting sharing of memory.

Inter Process Communications

Shared Memories – Procedure

- Allocating a new shared memory segment causes virtual memory pages to be created.
- Because all processes desire to access the same shared segment, only one process should allocate a new shared segment
- Allocating an existing segment does not create new pages, but it does return an identifier for the existing pages
- To permit a process to use the shared memory segment, a process attaches it, which adds entries mapping from its virtual memory to the segment's shared pages

Inter Process Communications

Shared Memories – Example

- This invocation of the shmget creates a new shared memory (or access to an existing one, if shm_key is already used) that;s readable and writable to the owner but not other users

```
int segment_id;

segment_id = shmget(shm_key, getpagesize(), IPC_CREAT | S_IRUSR | S_IWUSR);
```

- If the call succeeds, shmget returns a segment identifier

Socket

Sockets

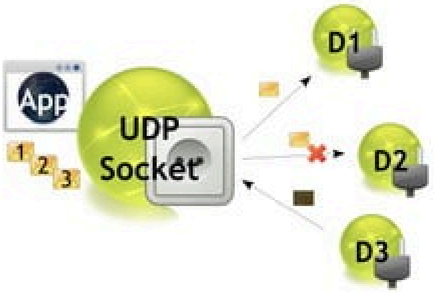
- A sockets is communication mechanism that allow client / server system to be developed either locally on a single machine or across networks.
- It is well defined method of connecting two processes locally or across networks

Sockets
The APIs

- int socket(int domain, int type, int protocol);
  - Domain
    - AF_UNIX, AF_INET, AF_INET6 etc.
  - Type
    - SOCK_STREAM, SOCK_DGRAM, SOCK_RAW
- int bind(int sockfd, const struct sockaddr *addr, socklen_t addrlen);
- int listen(int sockfd, int backlog);
- int accept(int sockfd, struct sockaddr *addr, socklen_t *addrlen);
- int connect(int sockfd, const struct sockaddr *serv_addr, socklen_t addrlen);

Sockets
Types - TCP and UDP

TCP socket (SOCK_STREAM)	UDP socket (SOCK_DGRAM)
• Connection oriented TCP • Reliable delivery • In-order guaranteed • Three way handshake • More network BW	• Connectionless UDP • Unreliable delivery • No-order guarantees • No notion of “connection” • Less network BW



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