----------Linux kernel and Booting process----------

Operating System: An operating system is a "resource allocator" and a "controlling of operations" program.

Multicore system:

A processor that has more than one core is called Multicore Processor while one with single core is called Unicore Processor or Uniprocessor. Nowadays, most of systems have four cores (Quad-core) or eight cores (Octa-core). These cores can individually read and execute program instructions, giving feel like computer system has several processors but, they are cores and not processors. cores are integrated into single chip and will require less time.

Multiprocessor system:

Systems which have more than one processor are called multiprocessor system. These systems are also known as parallel systems or tightly coupled systems.

Multiprocessor systems have the following advantages.

- **Increased Throughput:** Multiprocessor systems have better performance than single processor systems. It has shorter response time and higher throughput. User gets more work in less time.
- **Reduced Cost:** Multiprocessor systems can cost less than equivalent multiple single processor systems. They can share resources such as memory, peripherals etc.
- **Increased reliability:** Multiprocessor systems have more than one processor, so if one processor fails, complete system will not stop. In these systems, functions are divided among the different processors.

Differences b/w multiprocessor and multicore system:

Only common thing between Multicores and Multiprocessor is to increase processing speed.

Cost of Multicore system is lesser compared to cost of multiprocessor system because of use of more physical processors in multiprocessor system.

If you want to run single program, then multicore system will be faster. But if you are running multiple programs then multiprocessor system will be faster.

Advantages of distributed system (loosely coupled) are:

- Resources get shared
- Load gets shared
- Reliability is improved
- Provide a support for inter-process communication

SMP:

- It is called as symmetric multiprocessing which is multiprocessor system.
- In it each processor runs an identical copy of the operating system.
- These copies communicate with one another as needed.
- These processor systems lead to increased throughput.
- These systems are also called parallel systems or tightly coupled systems.

Kernel has two components: core component (physical memory manager, virtual memory
manager, file manager, Interrupt handler, process manager etc.), non-core component (compiler, libs etc.)

Monolithic: All the parts of a kernel components like the Scheduler, File System, Memory Management, Networking Stacks, Device Drivers, etc., are maintained in one unit within the kernel in Monolithic Kernel. Faster processing.

Microkernel: Only the very important parts like IPC (Inter process Communication), basic scheduler, basic memory handling, basic I/O primitives etc., are put into the kernel. Communication happen via message passing. Others are maintained as server processes in User Space. Slower Processing due to additional Message Passing.

An Introduction to Linux: When installing Linux, the source code is usually stored in /usr/src/linux.

Kernel: kernel performs below main tasks:

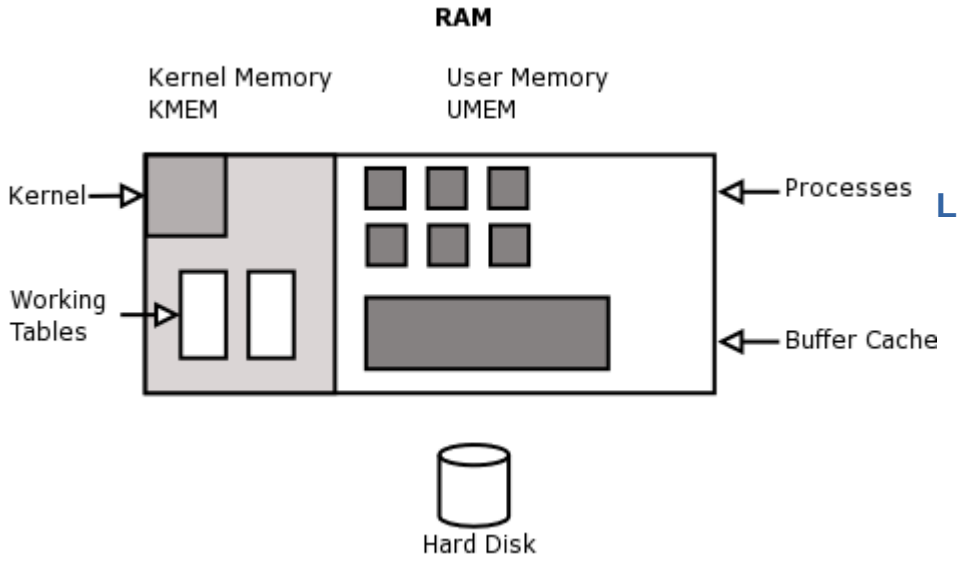
Process management
- Device management
- Memory management
- Interrupt handling
- I/O communication
- File system management

The kernel exists as a physical file on the file system in Linux it is /boot directory and is usually called vmlinux.
/boot/vmlinuz-2.4.18-22

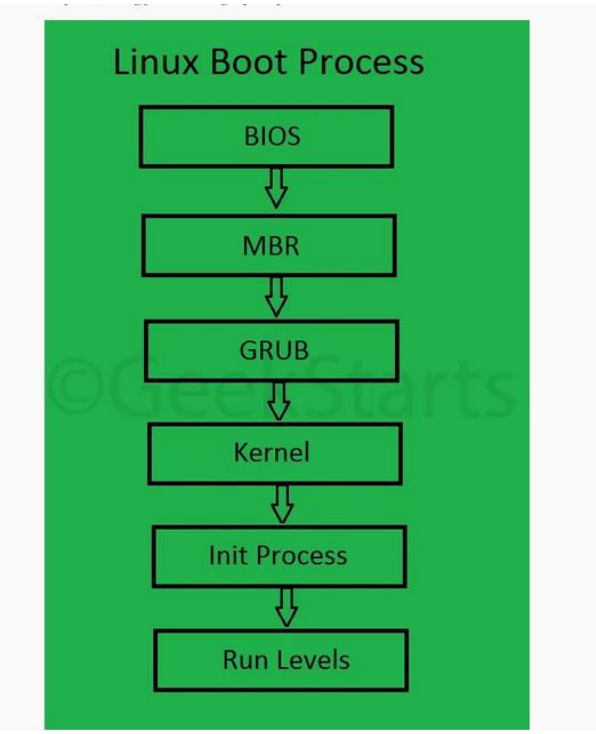
- At system boot time RAM only contains the boot loader, consuming a few kilobytes at the beginning of memory.
- The boot loader loads the kernel binary into memory from the hard disk, and places
- it at the beginning of memory.
- Once the kernel has been read in the boot loader tells the CPU to execute it by
- issuing a JMP (Jump) instruction.

Memory is divided into two areas, kernel memory and user memory.

Kernel memory is also known as kmem, kernel space and kernel land.
This contains the kernel binary itself, working tables to keep track of status on the system and buffers.
Examples of working tables that the kernel keeps in kernel memory for the operation of the system are the Global Open File Table, the Process Table and the Mount Table.



Linux Booting



steps:

1. BIOS.

• BIOS performs a POST (Power On Self Test) to check and scan if all the hardware devices
are properly connected.
• Then it scans the first sector of Hard-drive partition to find the boot loader (GRUB LILO for
Linux).
• BIOS loads the MBR into memory.
• Gives the control to MBR

2. MBR.

• MBR or Master Boot Record holds information of your current Boot-loader of your
Operating System.
• MBR is less than 512 bytes in size and holds various information like boot loader
information, validation check and the partition table present in your hard-drive.
• It is always stored in the first sector of your hard-drive.
• MBR loads the first stage loader (stage1).
• The first stage boot loader (stage 1), loads the rest of boot loader prompting you an option to
select multiple OS (if you have installed multiple OS) or loads the Operating System on
hard-drive.

• MBR loads the GRUB (boot loader for mostly all Linux OS) and gives the control over to
GRUB.

3. GRUB.

• GRUB, also known as Grand Unified Bootloader is the most common boot loader for
various Linux distributions.
• GRUB gives you an option to select multiple OS, if you have them in your hard-drive
partitions.
• The second stage loader (stage2) is loaded, giving you the GRUB screen where you can
select multiple OS or change the default settings or edit start-up parameters.
• GRUB has the kernel and intrid images, which it loads and executes.

4. Kernel.

• Kernelis loaded in two steps:
1. Kernel is loaded in Memory and decompressed and sets up the crucial functions.
2. Kernel then runs the init process (in /sbin/init). It also sets up user space and essential
processes needed for environment and for user login.
• To initialize the scheduler which has Process ID (PID 0) of 0, run the init process (PID 1)
and then mount the system in rw mode are the responsibilities of kernel.
• The init process in the second step loads the critical daemons, checks the fstab file and loads
the partitions accordingly.

5. Init Process.

• This process checks the '*/etc/inittab*' file to choose the run level.
• It reads the file to check default init level and executes it.
• Various init levels are:
• 0 = Halt, 1 = Single user mode, 2 = Multiuser mode w/o NFS, 3 = Full multiuser mode.
• 4 = Reserved (for future use), 5 = X11, 6 = Reboot.

6. Run level programs.

• If you press any key when you see the GUI and system is loading up, you go into the text
mode, where you can see the kernel starting and testing all the daemons. Eg: Starting DHCP
server…. Ok.

---------The Kernel versus Process Management----------

Process:
A process is a program that is running and under execution. On batch systems, it is called as a "job" while on time sharing systems, it is called as a "task".

Important functions of process management are:
- Creation and deletion of system processes.
- Creation and deletion of users.
- CPU scheduling.
- Process communication and synchronization.

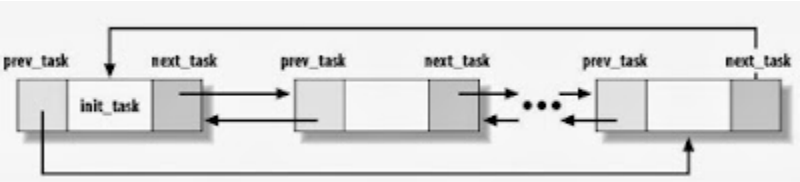
Context switching:
- It is the process of switching the CPU from one process to another.
- This requires to save the state of the old process and loading the saved state for the new process.
- The context of the process is represented in the process control block.
- During switching the system does no useful work.
- How the address space is preserved and what amount of work is needed depends on the memory management.

PCB contains:

- **Program counter:** It indicates the address of the next instruction to be executed for this process.
- **CPU Registers:** They include index registers, stack pointer and general-purpose registers. It is used to save process state when an interrupt occurs, so that it can resume from that state.
- **CPU-scheduling information:** it includes process priority, pointer to scheduling queue.
- **Memory management information:** value of the base and limit registers, page tables depending on the memory system.
- **Accounting information:** it contains an amount of CPU and real time used, time limits process number and so on.
- **I/O status information:** It includes a list of I/O devices allocated to the process, a list of open files and so on.

Process Descriptor and the Task Structure:
The kernel stores the list of processes in a circular doubly linked list called the task list. Process descriptor is nothing but each element of this task list of the

type **struct task_struct** , which is defined in <linux/sched.h> . The process descriptor contains all the information about a specific process. The task_struct is a relatively large data structure, at around 1.7 kilobytes on a 32-bit machine.



Each thread has its own thread_info. There are two basic reasons why **there are two such structures.**

Process state: It represents status of the process. It may be new, ready, running or waiting.

Process State:

Running or Runnable State (R): When a new process is started, it'll be placed into the running or runnable state. In the running state, the process takes up a CPU core to execute its code and logic.

Sleeping State: Interruptible (S) and Uninterruptible (D):

The uninterruptible sleeping state will only wait for the resources to be available before it transits into a runnable state, and it doesn't react to any signals**. On the other hand,** the interruptible sleeping state (s) will react to signals and the availability of resources.

Stopped State (T): From a running or runnable state, we could put a process into the stopped state (T) using the ***SIGSTOP*** or ***SIGTSTP*** signals.

Zombie State (Z): When a process has completed its execution or is terminated, it'll send the *SIGCHLD* signal to the parent process and go into the zombie state**.** The zombie process, also known as a defunct process, will remain in this state until the parent process clears it off from the process table

---

Process Context vs Interrupt Context:

The process and interrupt context is with reference to the kernel execution, when kernel is working on behalf of a process or it is running some kernel threads it is said to be executing in process context whereas when the kernel is handling some interrupt handler then it is said to be working in interrupt context.

When program stops execution, it saves the current contents of several processor registers in the process descriptor:
The program counter (PC) and stack pointer (SP) registers
The general-purpose registers
The floating point registers
The processor control registers (Processor Status Word) containing information about the CPU state
The memory management registers used to keep track of the RAM accessed by the process
When the kernel decides to resume executing a process, it uses the proper process descriptor fields to load the CPU registers. Since the stored value of the program counter points to the instruction following the last instruction executed, the process resumes execution from where it was stopped.

Daemon process: Disk and execution monitor, is a process that runs in the background without user's interaction. They usually start at the booting time and terminate when the system is shut down. The name of daemons usually end with 'd' at the end in Unix.
Ex: httpd, named, lpd.

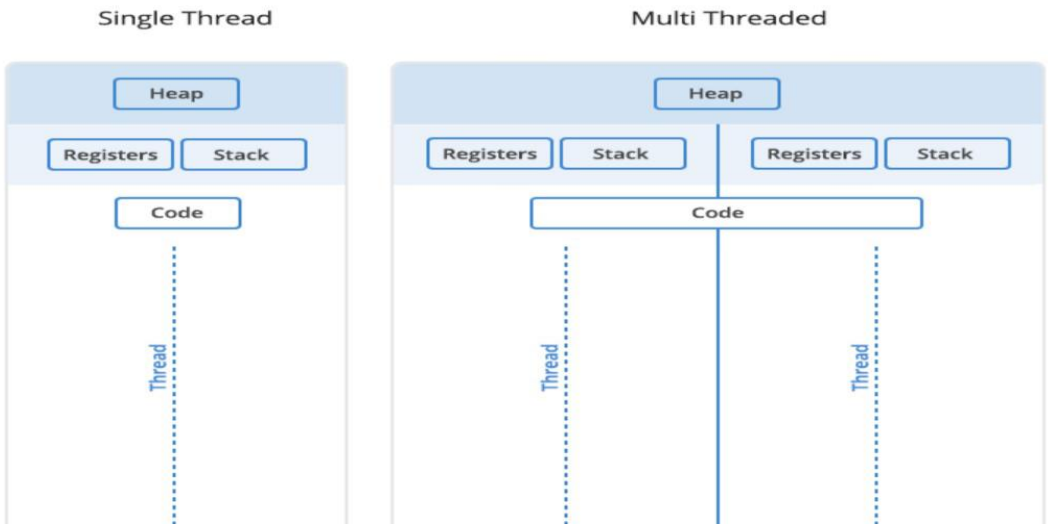
Orphan process: is a computer process whose parent process has finished or terminated, though it (child process) remains running itself.

Zombie process: is a process that has completed execution but still has an entry in the process table as its parent process didn't invoke an wait() system call.

Threads: the units of execution within a program.
Each thread within a process has a
1. unique program counter
2. process stack,
3. set of processor registers.

Threads are light weight. They don't have their own memory spaces and other resources unlike processes. All processes start with a single thread. So they behave like lightweight processes but are always tied to a parent "thick" process. So, creating a new process is a slightly heavy task and involves allocating all these resources while cresting a thread does not. Killing a process also involves releasing all these resources while a thread does not. However, killing a thread's parent process releases all resources of the thread.

A process is suspended by itself and resumed by itself. Same with a thread but if a thread's parent process is suspended then the threads are all suspended.



Multi-threading:
Threads are popular way to improve application through parallelism. For example, in a browser, multiple tabs can be different threads. MS word uses multiple threads, one thread to format the text, other thread to process inputs, etc.
Threads operate faster than processes due to following reasons:
1) Thread creation is much faster.
2) Context switching between threads is much faster.
3) Threads can be terminated easily
4) Communication between threads is faster.

Fork: The fork system call is used to create a new process. The newly created process is the child process. The process which calls fork and creates a new process is the parent process. The child and parent processes are executed concurrently. Fork returns 0 for child process and positive value for parent process and -1 for error.
//child process does not inherit parent's memory locks and timers. child process inherits mutex, condition variables, open file descriptor, message queue descriptor. page tables are copied and page frames are shared.

Exec:

The exec call is a way to basically replace the entire current process with a new program. It loads the program into the current process space and runs it from the entry point. As a new process is not created, the process identifier (PID) does not change, but the machine code , data , heap , and stack of the process are replaced by those of the new program. Exec() replaces the current process with a the executable pointed by the function.

Vfork: The basic difference between vfork and fork is that when a new process is created with vfork(), the parent process is temporarily suspended, and the child process might borrow the parent's address space. This strange state of affairs continues until the child process either exits, or calls execve(), at which point the parent process continues.

Clone : Clone, as fork, creates a new process. Unlike fork, these calls allow the child process to share parts of its execution context with the calling process, such as the memory space, the table of file descriptors, and the table of signal handlers.

Scheduler:
The scheduler is invoked: when there is change in process state, new process is created, software
interrupt, hardware interrupt etc.
Why we use scheduler:
Max CPU utilization
Max throughput
Min waiting time

Scheduling Algorithms:
Preemptive algorithms
Round Robin Scheduling
Shortest Job First Scheduling (can be both)
Priority Scheduling (can be both)
Non-preemptive algorithms
First Come First Served Scheduling

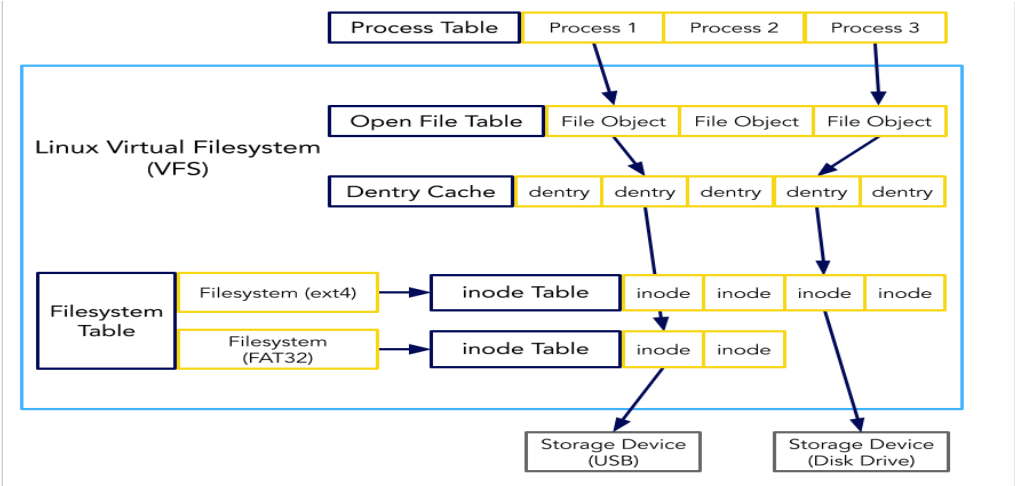
First Come First Serve (FCFS): Simplest scheduling algorithm that schedules according to arrival times of processes. First come first serve scheduling algorithm states that the process that requests the CPU first is allocated the CPU first. It is implemented by using the FIFO queue.
Round robin: Each process is assigned a fixed time(Time Quantum/Time Slice) in cyclic way. It is designed especially for the time-sharing system. The ready queue is treated as a circular queue. The CPU scheduler goes around the ready

queue, allocating the CPU to each process for a time interval of up to 1-time quantum.

Thread: we use clone () to create thread, thread is different from process. Thread uses process
address space and threads communicate through shared memory. In linux, we call ptheread_create for creating the thread.

---------- VFS: ----------

The VFS is sandwiched between two layers: the upper and the lower. The upper layer is the system call layer where a user space process traps into the kernel to request a service (which is usually accomplished via libc wrapper functions) -- thus catalyzing the VFS's processes. The lower layer is a set of function pointers, one set per filesystem implementation, which the VFS calls when it needs an action performed that requires information specific to a particular filesystem.



There are four important VFS objects:

1) **Superblock object**: represents a specific mounted filesystem.
2) **Inode object:** represents a specific file.
3) **Dentry object**: represents a directory entry, a single component of a path.
4) **File object:** represents an open file as associated with a process.

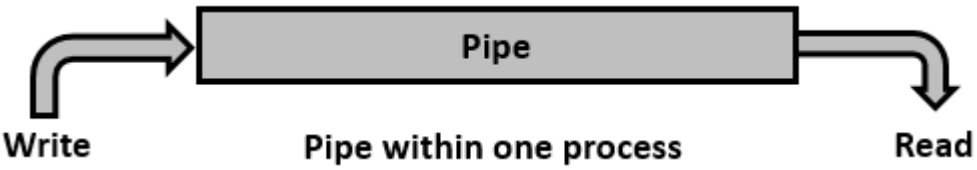
----------IPCS ----------

Signals: One process can raise the signal and can deliver to others. When signal is sent to process: Every process has process descriptor and process descriptor has three fields:

1) Signal pending field
2) Signal masking/unmasking field
3) Signal handler table.

Let's assume process is trying to access invalid logical virtual address and memory exception will be generated. Exception handler will generate SIGSEGV to current process, when system scans for pending signal, this pending signal will be addressed, and appropriate action will be taken.

Unnamed pipe: It is used for related process (within process) unidirectional byte stream which connects o/p of one process into i/p of other process. Pipes are implemented using file descriptor.



#include<unistd.h>

int pipe(int pipedes[2]);

This system call would create a pipe for one-way communication i.e., it creates two descriptors, first one is connected to read from the pipe and other one is connected to write into the pipe.

Named/fifo pipes: we can use single named pipe that can be used for two-way communication (communication between the server and the client, plus the client and the server at the same time) as Named Pipe supports bi-directional communication.

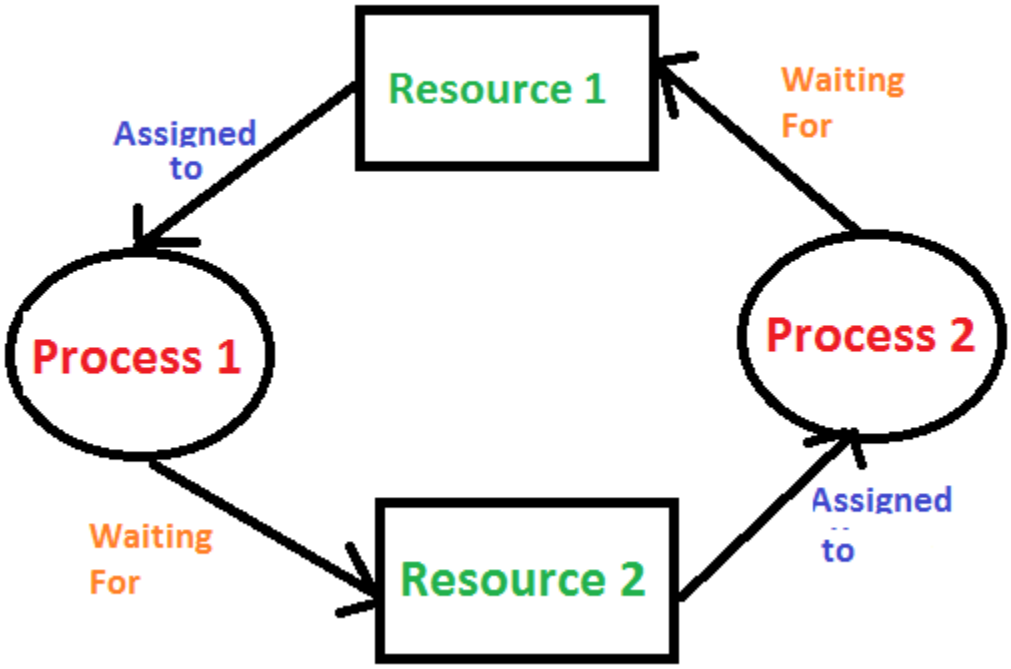
```
/* Filename: fifoserver.c */
#include <stdio.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <fcntl.h>
#include <unistd.h>
#include <string.h>
```

```
#define FIFO_FILE "MYFIFO"
int main() {
   int fd;
   char readbuf[80];
   char end[10];
   int to_end;
   int read_bytes;

   /* Create the FIFO if it does not exist */
   mknod(FIFO_FILE, S_IFIFO|0640, 0);
   strcpy(end, "end");
   while(1) {
      fd = open(FIFO_FILE, O_RDONLY);
      read_bytes = read(fd, readbuf, sizeof(readbuf));
      readbuf[read_bytes] = '\0';
      printf("Received string: \"%s\" and length is %d\n", readbuf,
          (int)strlen(readbuf));
      to_end = strcmp(readbuf, end);
      if (to_end == 0) {
         close(fd);
         break;
      }
   }
   return 0;
}
```

Deadlock: A deadlock happens in operating system when two or more processes need some resource to complete their execution that is held by the other process.

Is it



possible to have a deadlock involving only one process: No
A deadlock situation can arise if the following four conditions hold simultaneously in a system.
- **Mutual Exclusion:** The resources available are not sharable. This implies that the resources used must be mutually exclusive.

- **Hold and Wait:** Any process requires some resources in order to be executed. In case of insufficient availability of resources, a process can take the available resources, hold them and wait for more resources to be available.

- **No Preemption:** The resources that a process has on hold can only be released by the process itself voluntarily. This resource cannot be preempted by the system.

- **Circular Waiting:** A special type of waiting in which one process is waiting for the resources held by a second process. The second process is in turn waiting for the resources held by the first process.

Methods for handling deadlock:

There are three ways to handle deadlock
1) **Deadlock prevention or avoidance**: The idea is to not let the system into a

deadlock state.
One can zoom into each category individually; Prevention is done by negating one of above-mentioned necessary conditions for deadlock.
Avoidance is kind of futuristic in nature. By using strategy of “Avoidance”, we must assume. We need to ensure that all information about resources which process will need are known to us prior to execution of the process. We use Banker’s algorithm (Which is in-turn a gift from Dijkstra) to avoid deadlock.

2) Deadlock detection and recovery: Let deadlock occur, then do preemption to handle it once occurred. (**Killing the process a**nd **Preemption of resource**)

3) Ignore the problem altogether: If deadlock is very rare, then let it happen and reboot the system. This is the approach that both Windows and UNIX take.

Critical section: is a code segment where the shared variables can be accessed. An atomic action is required in a critical section i.e., only one process can execute in its critical section at a time. All the other processes must wait to execute in their critical sections.

---

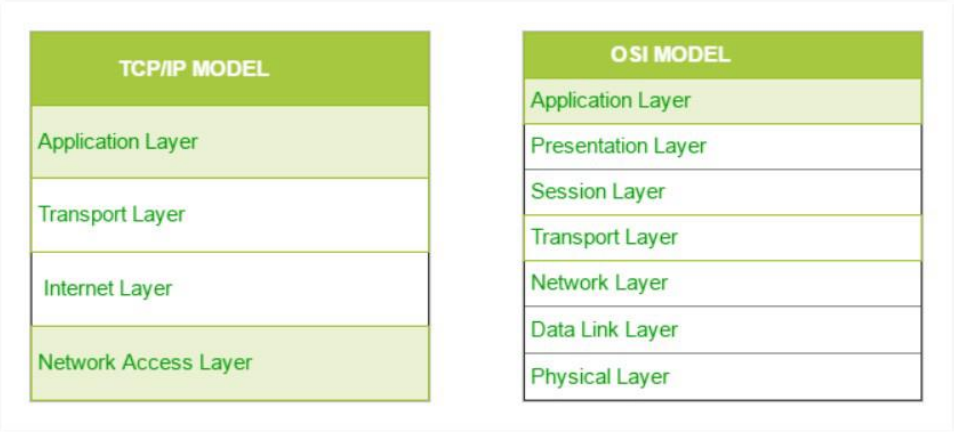
shared memory: Two or more process can access the common memory and communication is done via this shared memory where changes made by one process can be viewed by another process. The problem with pipes, fifo and message queue – is that for two processes to exchange information. The information goes through the kernel. To reiterate, each process has its own address space, if any process wants to communicate with some information from its own address space to other processes, then it is only possible with IPC (inter process communication) techniques.
//Create the shared memory segment or use an already created shared memory segment (shmget())
//Attach the process to the already created shared memory segment (shmat())
//Detach the process from the already attached shared memory segment (shmdt())
//Control operations on the shared memory segment (shmctl())

Message Queue: A message queue is a linked list of messages stored within the kernel and identified by a message queue identifier. A new queue is created or an existing queue opened by msgget(). New messages are added to the end of a queue by msgsnd().
//Create a message queue or connect to an already existing message queue (msgget())
//Write into message queue (msgsnd())
//Read from the message queue (msgrcv())

//Perform control operations on the message queue (msgctl())

//**Shared_memory vs message queues**: As understood, once the message is received by a process it would be no longer available for any other process. Whereas in shared memory, the data is available for multiple processes to access. Shared memory data need to be protected with synchronization when multiple processes communicating at the same time.

//**Socket programming:** Socket is used in a client-server application framework.
//Socket types: Stream Sockets (TCP/IP): It's reliable protocol and also data integrity is maintained. It's connection oriented. (Transmission control protocol)
//dataGram socket: UDP:It's not reliable.It's connection less.
//**How to make a Server**
//Create a socket with the socket() system call.
//Bind the socket to an address using the bind() system call. For a server socket on the Internet, an
address consists of a port number on the host machine.
//Listen for connections with the listen() system call.
//Accept a connection with the accept() system call. This call typically blocks the connection until a
client connects with the server.
//Send and receive data using the read () and write() system calls.
//**Make client**:
//Create a socket with the socket () system call.
//Connect the socket to the address of the server using the connect () system call.
//Send and receive data. There are a number of ways to do this, but the simplest way is to use the
read() and write() system calls.
//Blocking and Non-Blocking Socket I/O:TCP sockets are placed in a blocking mode. This means that the control is not returned to your program until some specific operation is complete. For example, if you call the connect () method, the connection blocks your program until the operation is complete.
//we should make non-blocking calls and can be done by calling socket. setblocking(0)
//TCP/IP nad OSI model:



BASIS FOR COMPARISON	SEMAPHORE	MUTEX
Basic	Semaphore is a signalling mechanism.	Mutex is a locking mechanism.
Existence	Semaphore is an integer variable.	Mutex is an object.
Function	Semaphore allow multiple program threads to access a finite instance of resources.	Mutex allow multiple program thread to access a single resource but not simultaneously.
Ownership	Semaphore value can be changed by any process acquiring or releasing the resource.	Mutex object lock is released only by the process that has acquired the lock on it.
Categorize	Semaphore can be categorized into counting semaphore and binary semaphore.	Mutex is not categorized further.

****

Semaphore: A semaphore is a hardware or a software tag variable whose value indicates the status of a common resource.
- Its purpose is to lock the common resource being used. A process which needs the resource will check the semaphore to determine the status of the resource followed by the decision for proceeding.
- In multitasking operating systems, the activities are synchronized by using the semaphore techniques is a better option in case there are multiple instances of resources available. In the case of single shared resource mutex is a better choice.

ldd: load dynamic dependency--> ldd executable name will listout dynamic

library dependencies for that executable.

The main advantage of a preemptive kernel is that sys-calls do not block the entire system. If a syscall takes a long time to finish then it doesn't mean the kernel can't do anything else in this time.

----------Interrupt, exception and system calls----------

Ldconfig:ldconfig is used to create, udpate and remove symbolic links for the current shared libraries based on the lib directories present in the /etc/ld.so.conf

**********OS Concepts**********
Real mode: This is the only mode which was supported by the 8086 (the very first processor of the
x86 series). The 8086 had 20 address lines, so it was capable of addressing "2 raised to the power
20" i.e. 1 MB of memory. No multi tasking – no protection is there to keep one program from
overwriting another program.
Protected mode: Multitasking and There is no 1 MB limit in protected mode. Support for virtual memory, which allows the system to use the hard disk to emulate additional system memory when needed.

Interrupts and Exceptions:
Interrupt: Interrupt can be understood as a signal from a device causing context switch. To handle the interrupts, interrupt handlers or service routines are required. The address of each Interrupt service routine is provided in a list which is maintained in interrupt vector. Interrupts are often divided into synchronous and asynchronous interrupts:
Synchronous interrupts: are produced by the CPU control unit while executing instructions and are called synchronous because the control unit issues them only after terminating the execution of an instruction.
Asynchronous interrupts: are generated by other hardware devices at arbitrary times with respect to the CPU clock signals.

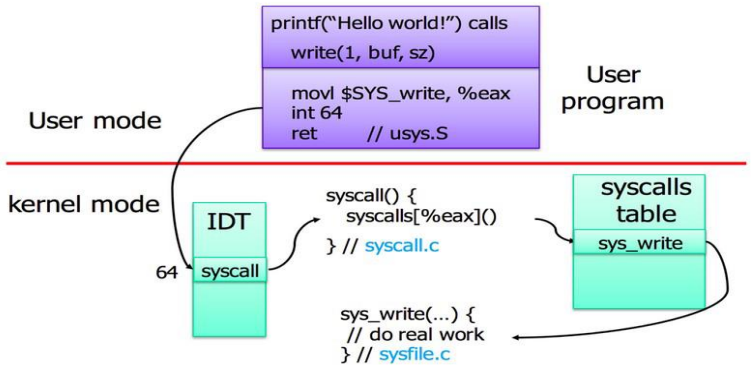
system call: **Types of System Call**

System calls can be grouped roughly into five major categories:

Sr No.	Example

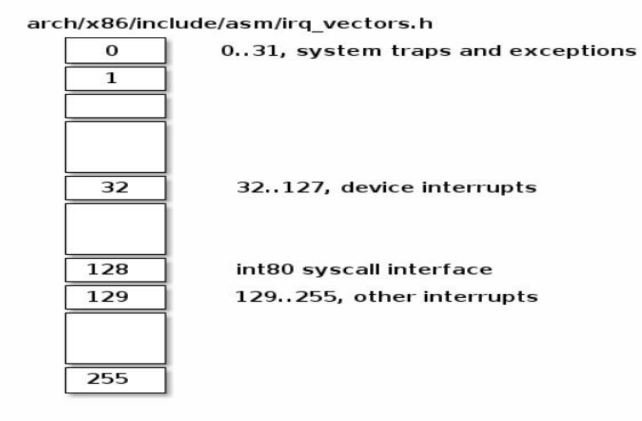
1	Process control	Create process, terminate process, end, allocate and free memory etc
2	File manipulation	Create file, delete file, open file, close file, read, write.
3	Device manipulation	request device, release device, read, write, reposition, get device attributes, set device attributes etc.
4	Information maintenance	get or set process, file, or device attributes
5	Communications	Send, receive messages, transfer status information

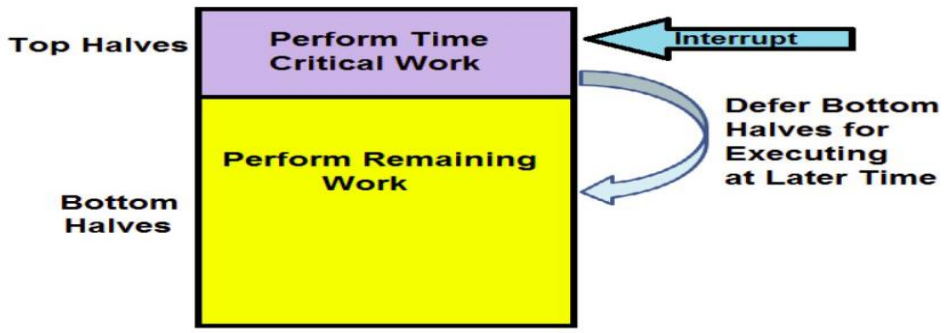
open/read/write/fork. read(c program in user space)--> printf calls write and write assign interrupt no. To sys_write. Now interrupt no. Is mached in IDT to call sysem call table and
then from there correct system call is called.



Maskable and non-maskable interrupt:
Non-maskable interrupt cannot be ignored by CPU(chipset errors, memory corruption problems, parity errors and high-level errors needing immediate attention)
Maskable interrupt can be ignored by CPU
Hardware Interrupt handling:

- Device raises an interrupt on the corresponding IRQ pin.
- PIC (Programmable Interrupt Controller) converts the IRQ into a vector number and writes it to a port for CPU to read PIC raises an interrupt on CPU INTR pin
- PIC waits for CPU to acknowledge an interrupt CPU handles the interrupt





Top Halves and Bottom Halves

Limitations On interrupt handler:-

1) It runs asynchronously by interrupting the other code.
2)All interrupt on the current processor disabled.
3)Interrupts are often time critical as they deal with hardware.
4) We cannot block interrupt handler as they run in interrupt context.

Interrupt handling is divided into two parts:

1) Top Halves:- It is executed as immediate response to interrupt.
2)Bottom Halves:- It is executed some time later when CPU get free time.

Top Halves:- Top halves executes as soon as CPU receives the interrupt . Following work are
generally performed in top halves
1) Acknowledgement of receiving the interrupt
2) copy if some data is received
3) if the work is sensitive needs to perform in top halves.
4)If the work is related to hardware needs to perform in top halves.
5)If the work needs to be ensure that another interrupt does not interrupt it , should be perform in
interrupt handler.

Softirqs vs Tasklet:

Sofirqs are re-entrant , that is the different CPU can take the same softirq and execute it while the Tasklets are serialized that is the same CPU which is running the tasklet has the right to complete it.

Difference between Hard link and Soft link:

Hard Link :

A hard link acts as a copy (mirrored) of the selected file. It accesses the data available in the original file. If the earlier selected file is deleted, the hard link to the file will still contain the data of that file.

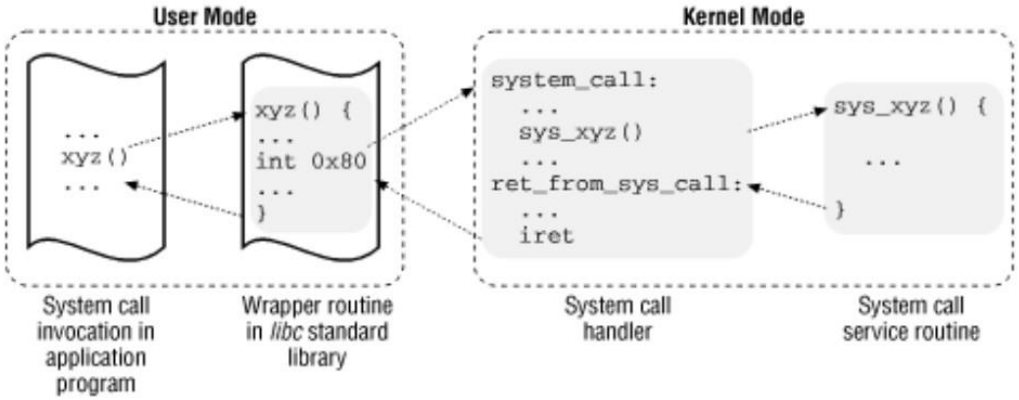
Soft Link :

A soft link (also known as Symbolic link) acts as a pointer or a reference to the file name. It does not access the data available in the original file. If the earlier file is deleted, the soft link will be pointing to a file that does not exist anymore.

CPU switches from User mode to Kernel mode in following cases:

1) User process triggers system calls (software interrupts)
2) Device sends interrupt (hardware interrupt)
3) CPU raises exception.(Exception)

Figure 8-1. Invoking a system call

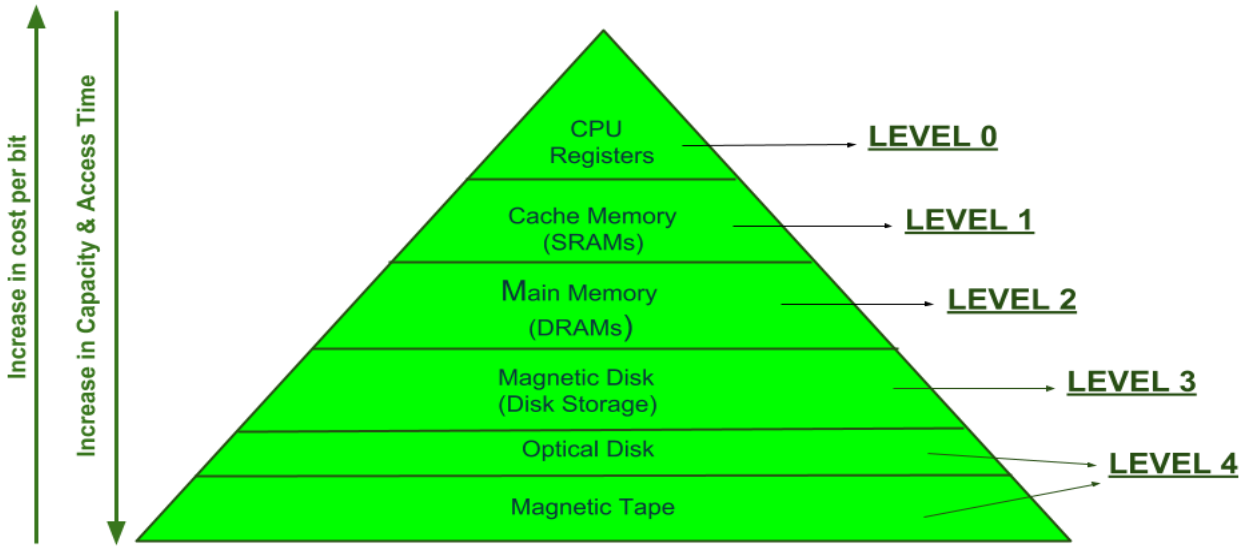


When user space process calls system calls, corresponding wrapper function will be available in libc library. This wrapper function will set vector no. 0X80. CPU will save the current process context in sytem stack and also will change processor state. In Kernel space, this will be checked in Interrupt vector table and system call table will be called and corresponding system call routine will be called.

----------Memory Management----------

Name the functions constituting the OS's memory management.

- Memory allocation and de-allocation
- Integrity maintenance
- Swapping
- Virtual memory



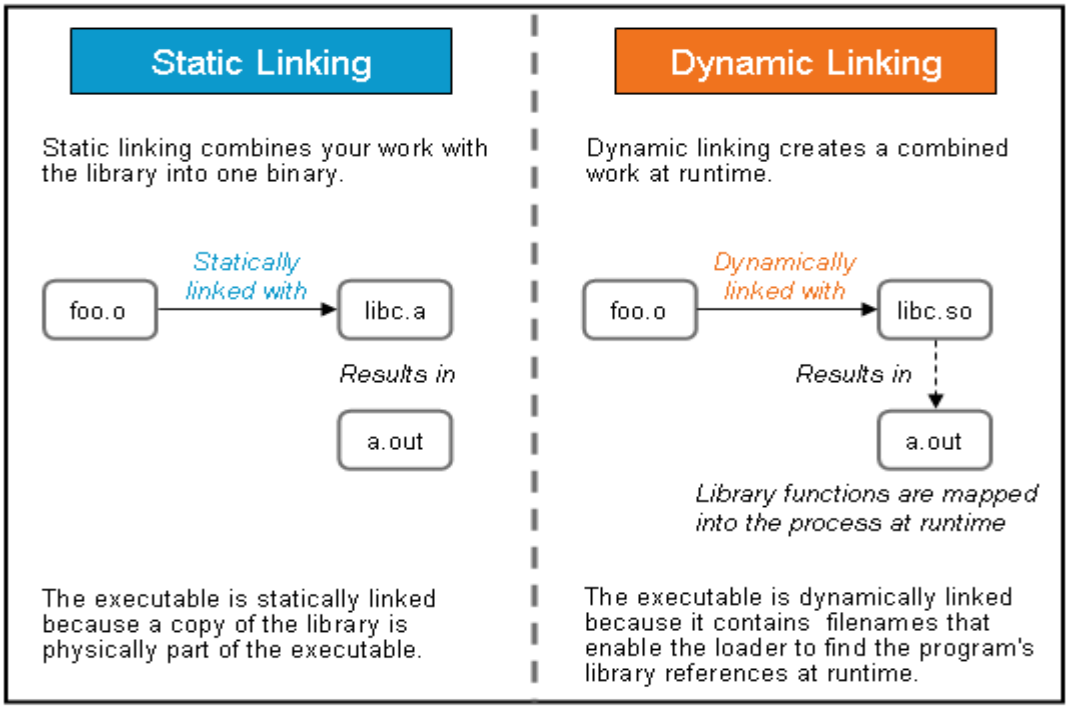
MEMORY HIERARCHY DESIGN

Cache Memory: is a special very high-speed memory. It is used to speed up and synchronizing with high-speed CPU. Cache memory is costlier than main memory or disk memory but economical than CPU registers. Cache memory is an extremely fast memory type that acts as a buffer between RAM and the CPU.

Translation Lookaside Buffer (i.e. TLB): is required only if Virtual Memory is used by a processor. In short, TLB speeds up the translation of virtual addresses to a physical address by storing page-table in faster memory. In fact, TLB also sits between CPU and Main memory.

Reentrant Kernels:
All Unix kernels are reentrant: this means that several processes may be executing in Kernel Mode at the same time.

Process Address Space: Each process runs in its private address space. A process running in User Mode refers to private stack, data, and code areas. Linux supports the mmap( ) system call, which allows part of a file or the memory residing on a device to be mapped into a part of a process address space.



Whenever there is change in static lib, code must be recompiled as well but it is secured no other app can corrupt it. While dynamic lib is not part of executable but only one copy can be shared by multiple apps.
To create a dynamic library, write the following command:

```
gcc -g -fPIC -Wall -Werror -Wextra -pedantic *.c -shared -o liball.so
```

The **-fPIC** flag allows the following code to be referenced at any virtual address at runtime. It stands for Position Independent Code.

```
export LD_LIBRARY_PATH=.:$LD_LIBRARY_PATH
```

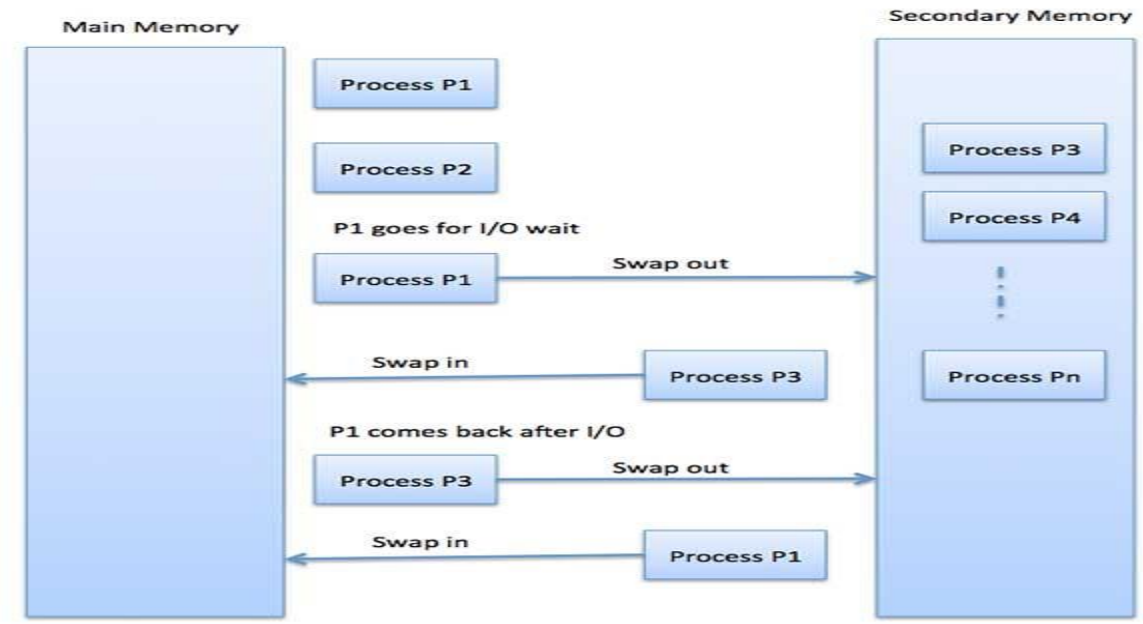
Static library creation:

```
ar rc liball.a dog.o cat.o bird.o
```

ar is for archieving and -rc is for replace and create….

Swapping:

Swapping is a mechanism in which a process can be swapped temporarily out of main memory (or move) to secondary storage (disk) and make that memory available to other processes. At some later time, the system swaps back the process from the secondary storage to main memory.



Memory Allocation
Main memory usually has two partitions −

- Low Memory − Operating system resides in this memory.
- High Memory − User processes are held in high memory.

Fragmentation: As processes are loaded and removed from memory, the free memory space is broken into little pieces. It happens after sometimes that processes cannot be allocated to memory blocks considering their small size and memory blocks remains unused. This problem is known as Fragmentation.

External fragmentation: Total memory space is enough to satisfy a request or to reside a process in it, but it is not contiguous, so it cannot be used.

Internal fragmentation: Memory block assigned to process is bigger. Some portion of memory is left unused, as it cannot be used by another process.

Paging:
A computer can address more memory than the amount physically installed on the system. This extra memory is actually called virtual memory and it is a section of a hard that's set up to emulate the computer's RAM. Paging technique plays an important role in implementing virtual memory.

Paging is a memory management technique in which process address space is broken into blocks of the same size called **pages** (size is power of 2, between 512 bytes and 8192 bytes). The size of the process is measured in the number of pages.

When does page fault error occur?
- It occurs when a page that has not been brought into main memory is accessed.

Thrashing:
- In virtual memory system, thrashing is a high page fault scenario. It occurs due to under-allocation of pages required by a process.
- The system becomes extremely slow due to thrashing leading to poor performance.

Belady's anomaly occur?
The Belady's anomaly is a situation in which the number of page faults increases when additional physical memory is added to a system.

Address Translation
Page address is called **logical address** and represented by **page number** and the **offset**.

Logical Address = Page number + page offset

Frame address is called **physical address** and represented by a **frame number** and the **offset**.

Physical Address = Frame number + page offset

Ex:

process size = 4kb

process size = logical address space = 4kb(given)

page size = page offset = 2kb(given)

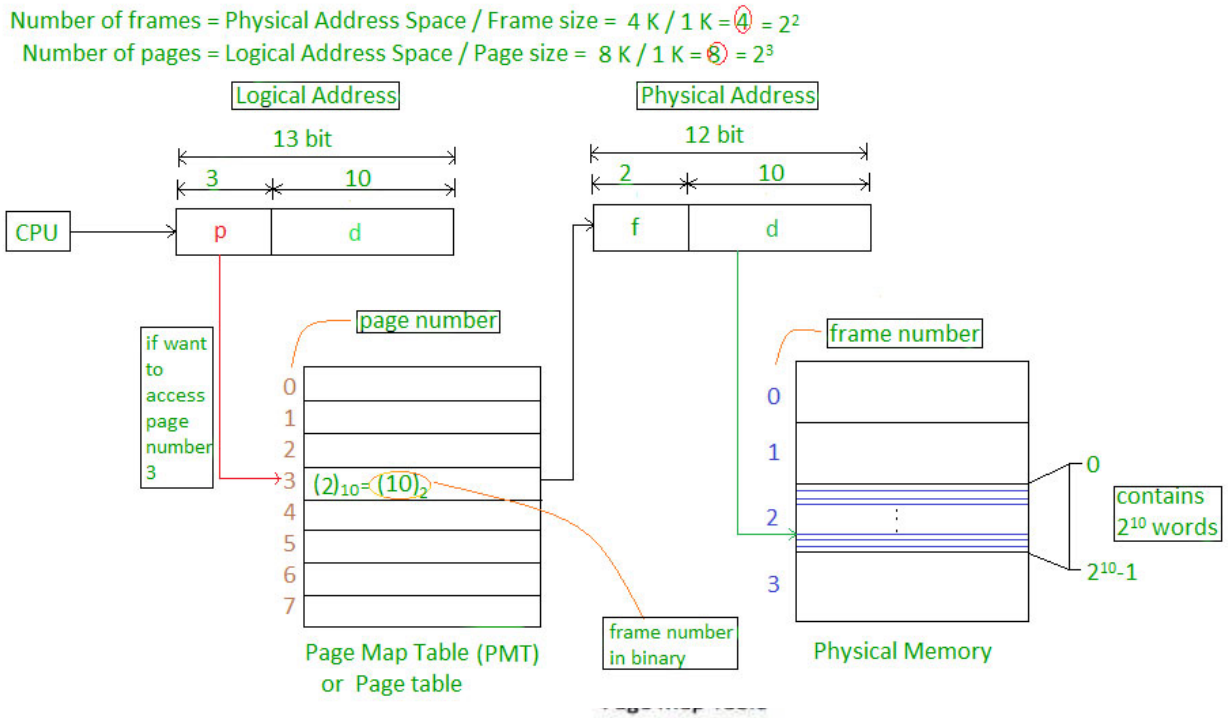
No. of page table entries/Page table size = process size/page size =

4/2 = 2 pages in page tables.

Physical memory size = 16 kb

frame offset = page offset = 2 kb

no. of page frames = 16/2 = 8



Advantages and Disadvantages of Paging

Here is a list of advantages and disadvantages of paging −

- Paging reduces external fragmentation, but still suffer from internal fragmentation.
- Paging is simple to implement and assumed as an efficient memory management technique.
- Due to equal size of the pages and frames, swapping becomes very easy.
- Page table requires extra memory space, so may not be good for a system having small RAM.

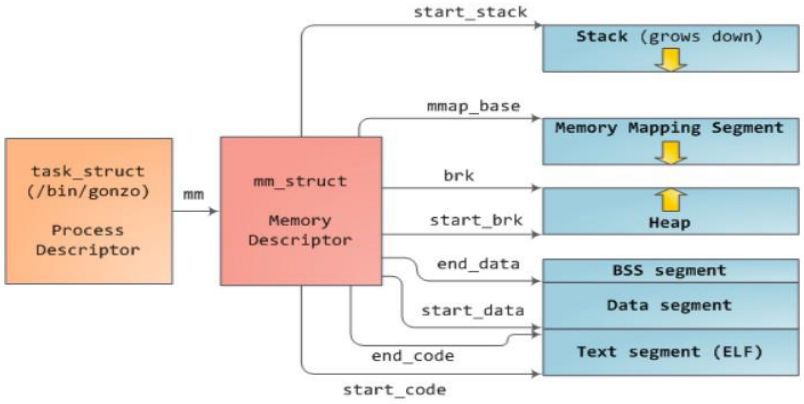
Segmentation: is a memory management technique in which each job is divided into several segments of different sizes, one for each module that contains pieces that perform related functions. Each segment is actually a different logical address space of the program.
When a process is to be executed, its corresponding segmentation are loaded into non-contiguous memory though every segment is loaded into a contiguous block of available memory.

Virtual memory:
A computer can address more memory than the amount physically installed on the system. This extra memory is called **virtual memory** and it is a section of a hard disk that's set up to emulate the computer's RAM.
Virtual memory advantages:
The main visible advantage of this scheme is that programs can be larger than physical memory. Virtual memory serves two purposes. First, it allows us to extend the use of physical memory by using disk. Second, it allows us to have memory protection, because each virtual address is translated to a physical address.
Virtual memory is commonly implemented by demand paging. It can also be implemented in a segmentation system. Demand segmentation can also be used to provide virtual memory.

Demand Paging:
A demand paging system is quite similar to a paging system with swapping where processes reside in secondary memory and pages are loaded only on demand, not in advance. When a context switch occurs, the operating system does not copy any of the old program’s pages out to the disk or any of the new program’s pages into the main memory Instead, it just begins executing the new program after loading the first page and fetches that program’s pages as they are referenced.

Direct Memory Access (DMA):
Slow devices like keyboards will generate an interrupt to the main CPU after each byte is transferred. If a fast device such as a disk generated an interrupt for each byte, the operating system would spend most of its time handling these interrupts. So a typical computer uses direct memory access (DMA) hardware to reduce this overhead. Direct Memory Access (DMA) means CPU grants I/O

module authority to read from or write to memory without involvement. DMA module itself controls exchange of data between main memory and the I/O device. CPU is only involved at the beginning and end of the transferand interrupted only after entire block has been transferred.



Each process is represented by process descriptor(instance of task_struct),Taks_struct contains mm_struct, mm_struct has primary table and primary table has secondary table and this is finally mapped to Page frames(physical memory).
Process's logical address space(256kb)-->1 page size(4kb)-> primary table will
contain 256/4 = 64 entries.

A 32-bit system can access 232 memory addresses, i.e 4 GB of RAM or physical memory. A 64-bit system can access 264 memory addresses, i.e 18-Quintillion bytes of RAM.

Preemptive kernel:
A preemptive kernel is one that can be interrupted in the middle of executing code - for instance in response for a system call - to do other things and run other threads, possibly those that are not in the kernel.

Priority inversion is a operating system scenario in which a higher **priority** process is preempted by a lower **priority** process.
Scenario: Three process p1(High), p2(medium), p3(low). P1 & p3 have to execute in critical section. P3 has locked mutex and excuting in cs, in betwen, p2 preempts p3 and p1 preempts p2.. so p1 can not excute cs since it has been locked by p3. This becomes priority inversion.

Priority inheritance: The basic idea of the **priority inheritance** protocol is that when a job blocks one or more high-**priority** jobs, it ignores its original **priority** assignment and executes its critical section at an elevated **priority** level.

mknod is a command which used create the device file (or) node in Linux file system. In unix or linux we will represent everything as a file .

----------Device Drivers----------

The kernel interacts with I/O devices by means of device drivers. Device drivers are
included in the kernel and consist of data structures and functions that control one or more
devices

--**Installing kernel:**

1) Download and extract kernel code.
2) copy current kernel's configuration.
3) Make menuconfig
4) make --> compiles and links the kernel image. This is a single file named vmlinuz.
5) make modules_install --> **installs your kernel modules to /lib/modules or /lib/modules/<version>**
6) make install--> installs your built kernel to /vmlinuz

Writing my kernel module and loading dynamically:

Modprobe Vs insmod:

modprobe is the intelligent version of insmod. insmod simply adds a module where
modprobe looks for any dependency (if that particular module is dependent on any other module)
and loads them.

Module will be loaded into *proc*/modules/

Rmmod: remove modules from module list

Type of Devices:

character devices(serial ports, parallel ports, sounds cards)
Block devices(hard disk, floppy disk)
Network devices(switches, bridge,router)

Majors and minors

Char devices are accessed through names in the filesystem.
Major no is of 12bits and Minor no. Is of 20bits. Major no. Is for driver and minor no. is for device.
Device file can be created using mknod: **mknod /dev/mycdev c 42 0**

Steps performed for device driver:

load driver->open device->read device/write to device->close device->unload driver

Reading from device-> uses copy_to_user
Write to device-> copy_from_user

Driver code sample:

```
static int dev_open(struct inode *inod, struct file *fil);
static ssize_t dev_read(struct file *filep,char *buf,size_t len,loff_t *off);
static ssize_t dev_write(struct file *flip,const char *buff,size_t len,loff_t *off);
static int dev_release(struct inode *inod,struct file *fil);
//structure containing device operation
static struct file_operations fops=
{
.read=dev_read, //pointer to device read funtion
.write=dev_write, //pointer to device write function
.open=dev_open, //pointer to device open function
.release=dev_release, //pointer to device realese function
};
static int hello_init(void) //init function to be called at the time of insmod
{
int t=register_chrdev(90,”mydev”,&fops);
if(t<0)
printk(KERN_ALERT “device registration failed.”);
else
printk(KERN_ALERT “device registred\n”);
return 0;
}
static void hello_exit(void) //exit function to be called at the time of rmmod
{
unregister_chrdev(90,”mydev”);
printk(KERN_ALERT “exit”);
}
static int dev_open(struct inode *inod, struct file *fil)
{
printk(“KERN_ALERT device opened”);
return 0;
}
static ssize_t dev_read(struct file *filep,char *buf,size_t len,loff_t *off)
{
copy_to_user(buf,ker_buf,len);
return len;
}
static ssize_t dev_write(struct file *flip,const char *buf,size_t len,loff_t *off)
{
copy_from_user(ker_buf,buf,len);
ker_buf[len]=0;
return len;
}
static int dev_release(struct inode *inod,struct file *fil)
```

{
printk(“KERN_ALERT device closed\n”);
return 0;
}
module_init(hello_init);
module_exit(hello_exit);
****

ioctl: The system call ioctl() is provided for device-specific custom commands (such as format,
reset and shutdown) that are notprovided by standard system calls such as read(), write and
mmap(). To invoke ioctl commands of a device, the user-space program would open the device first,
then send the appropriate ioctl() andany necessary arguments

**********GDB**********

compile with -g to load debug symbols.
Gdb executable name(**gdb b main/ gdb b file.c:233)**
b/break fun_name/line no.
Run(r)
s(step into)
n(next line)
c(continue)
****

mknod /dev/rama c 12 5

To deploy a module inside kernel, what are the possible methods.? Mention actual difference
among them.

insmod requires you to pass it the full pathname and to insert the modules in the right order,
while **modprobe** just takes the name, without any extension, and figures out all it needs to
know by parsing /lib/modules/version/modules.dep.

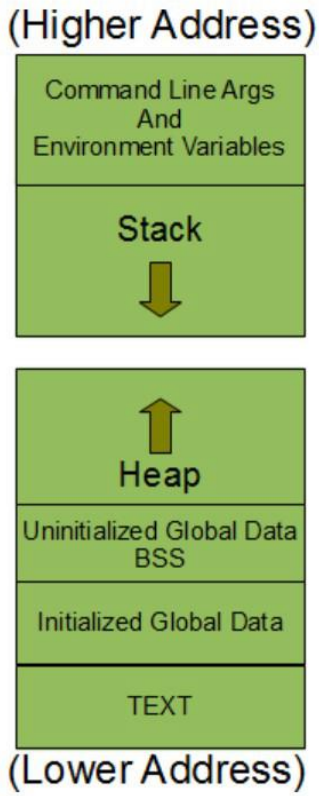
Explain about about ksets, kobjects and ktypes. How are they related?

Kobjects have a name and a reference count.
- A ktype is the type of object that embeds a kobject. Every structure that embeds a kobject needs a corresponding ktype. The ktype controls what happens to the kobject when it is created and destroyed.
- A kset is a group of kobjects. These kobjects can be of the same ktype or belong to different ktypes. The kset is the basic container type for collections of kobjects. Ksets contain their own kobjects, but you can safely ignore that implementation detail as the kset core code handles this kobject automatically.

1. As kernel can access user space memory, why should copy_from_user is needed?
Disables SMAP (Supervisor Mode Access Prevention) while copying from user space
2. how many ways we can assign a major minor number to any device?
There are two ways of a driver assigning major and minor number.
1. Static Assignment-> **Static Assignment:**
register_chrdev_region is the function to allocate device number statically.
2. Dynamic Assignment-> alloc_chrdev_region is the kernel function to allocate device
numbers dynamically
3. How is container_of( ) macro implemented?
4. Main Advantages and disadvantages of having separate user space and kernel space?
system calls might be **faster** (i.e. **lower latencies**), as the CPU doesn't have to switch from
application mode into kernel. you might get **direct access to the system's hardware** via
memory and I/O ports.
5. What is re entrant function: It can be reentered by another thread.
6. How will you insert a module statically in to linux kernel:
you just need to do a bit of hacking to move the external module into the kernel source tree,
tweak the Makefiles/Kconfig a bit so that the code is built-in, and then build your kernel image.
7. how the device files are created in Linux:
They're called **device** nodes, and are **created** either manually with mknod or automatically by
udev
8. How can a static driver runs? Without doing any insmod?
9. **What is the path of your driver inside kernel?/lib/modules/$(uname -r)**
10. Diff SLAB and Vmalloc
Kmalloc is similar to malloc function, we use in our C program to allocate memory in user space.
kmalloc allocates memory in kernel space. kmalloc allocates contiguous memory in physical
memory as well as virtual memory. vmalloc is the other call to allocate memory in kernel space as
like kmalloc.
vmalloc allocates contiguous memory in virtual memory but it doesn’t guarantee that memory
allocated in physical memory will be contiguous.
11. How do you pass a value to a module as a parameter?->**module_param()**

12. What is the functionality of PROBE function
The purpose of the probe routine is to detect devices residing on the bus and to create device
nodes corresponding to these device
13. How do you get the list of currently available drivers ?
14. What is the use of file->private_data in a device driver structure ?
Private data to driver.
15. What is a device number ?
16. What are the two types of devices drivers from VFS point of view ?
17. How to find a child process in linux/unix.?
using the -P option of pgrep(pgrep -P pid)
18. What is the difference between fork( ) and vfork( )?
The primary **difference between** the **fork**() and **vfork**() system call is that the child process
created using **fork** has separate address space as that of the parent process. On the other hand,
child process created using **vfork** has to share the address space of its parent process
19. **What are the processes with PID 0 is Sched and PID 1 is init(**process primarily responsible
for starting and shutting down the system**)**
20. What is the difference between interruptible and uninterruptible task states?
21. How processes and threads are created? (from user level till kernel level)

22. How to determine if some high prio task is hogging CPU: top
23. Priority inversion, priority inheritance, priority ceiling

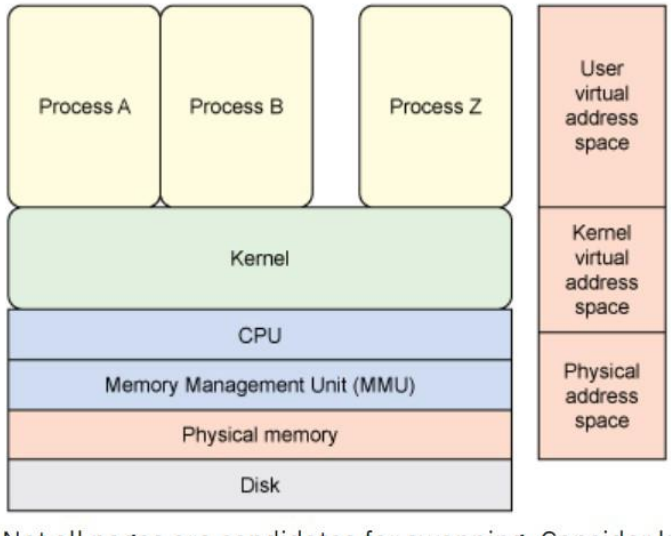


24. Process Memory Layout
25. how much memory is occupied by process address spcae.
4 GB
26. When a same executable is excuted in two terminals like terminal 1 execute ./a.out and terminal
2 executed ./a.out what will the programe address space look like on RAM
27. what is diff b/w process and threads?
A **process is** a program under execution i.e an active program. A **thread is** a lightweight **process** that can be managed independently by a scheduler. **Processes** require
more time for context switching as they are more heavy. **Threads** require less time for
context switching as they are lighter than **processes**
28. Will threads have their own stack space?
Yes
29. can one thread access the address space of another thread?
In general, each *thread* has its own registers (including its own program counter), its
own stack pointer, and its own stack. Everything else is shared between the threads
sharing a process.
In particular a *process* is generally considered to consist of a set of threads sharing

an address space, heap, static data, and code segments, and file descriptors*.

30. What is task_struct and how are task states maintained ?

Task_struct is structure used to instantiate for each and every process.
Task_states are: Running, uninterruptible sleep(D), interruptible sleep(S), Zombies



Virtual address space to Physical address space.

Mutex: When want to provide atomic access to critical section. A mutex provides mutual exclusion, either producer or consumer can have the key (mutex) and proceed with their work. As long as the buffer is filled by producer, the consumer needs to wait, and vice versa.

Semaphore: we can split the 4 KB buffer into four 1 KB buffers (identical resources). A
semaphore can be associated with these four buffers. The consumer and producer can
work on different buffers at the same time.

Spinlock: Use a spinlock when you really want to use a mutex, but your thread is not allowed
to sleep. e.g.: An interrupt handler within OS kernel must never sleep.

Deadlock: If a thread which had already locked a mutex, tries to lock the mutex again, it
will enter the waiting list of that mutex, which results in deadlock.

Scheduling methods such as First Come First Serve, Round Robin, Priority-based
scheduling

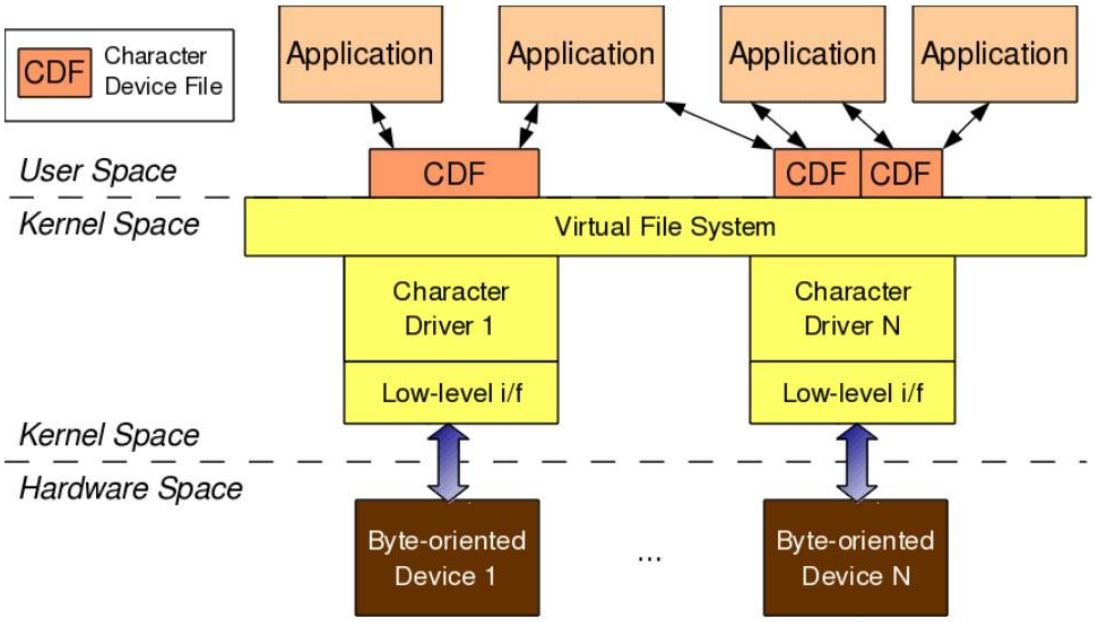
Steps to invoke device driver:

1) User space process tries to write to character device.

2)**Device file:** All data will be communicated through device file will be in *dev*.

3) **Device driver:** This is the software interface for the device and resides in the kernel space.
4) Device: This can be the actual device present at the hardware level, or a pseudo device.

fact, all device drivers that are neither storage nor network device drivers are some type of a character driver. Let's look into the commonalities of these character drivers, and how Shweta wrote one of them.



inode
The inode (index node) keeps information about a file in the general sense (abstraction): regular
file, directory, special file (pipe, fifo), block device, character device, link, or anything that can be
abstracted as a file.