Operating Systems

Quiz

Q. An OS is a __________

A. system software

B. resource manager

C. resource allocator

D. all of the above

Q. Which of the following is a system program?

A. Compiler

B. Linker

C. loader

D. Assembler

E. all of the above

F. none of the above

Quiz

- Which of the following is a process?

A. program.i
B. program.o
C. program.s
D. program.out
E. None of the above
F. All of the above

- Which of the following is a program?

A. program.i
B. program.o
C. program.s
D. program.out
E. None of the above
F. All of the above

Quiz

Q. Which of the following program provides a graphical user interface in the Windows Operating System?

a. cmd.exe
b. explorer.exe
c. command.com
d. all of the above
e. None of the above

Q. CPU scheduling is the basis of ___________

a) multiprogramming operating systems
b) larger memory-sized systems
c) multiprocessor systems
d) none of the mentioned

Functions of an OS:

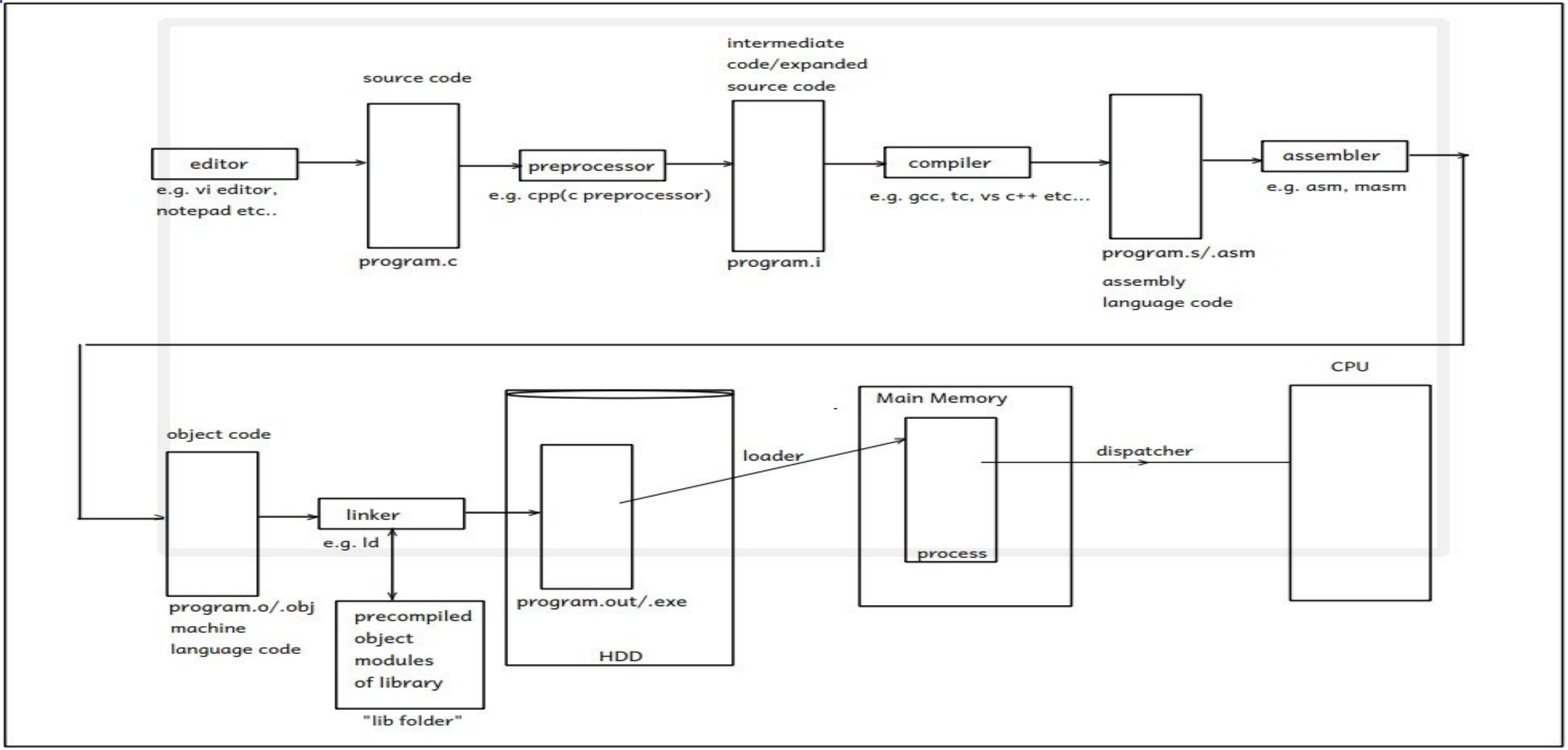
Basic minimal functionalities/Kernel functionalities:

1. Process Management
2. Memory Management
3. Hardware Abstraction
4. CPU Scheduling
5. File & IO Management

Extra utility functionalities/optional:

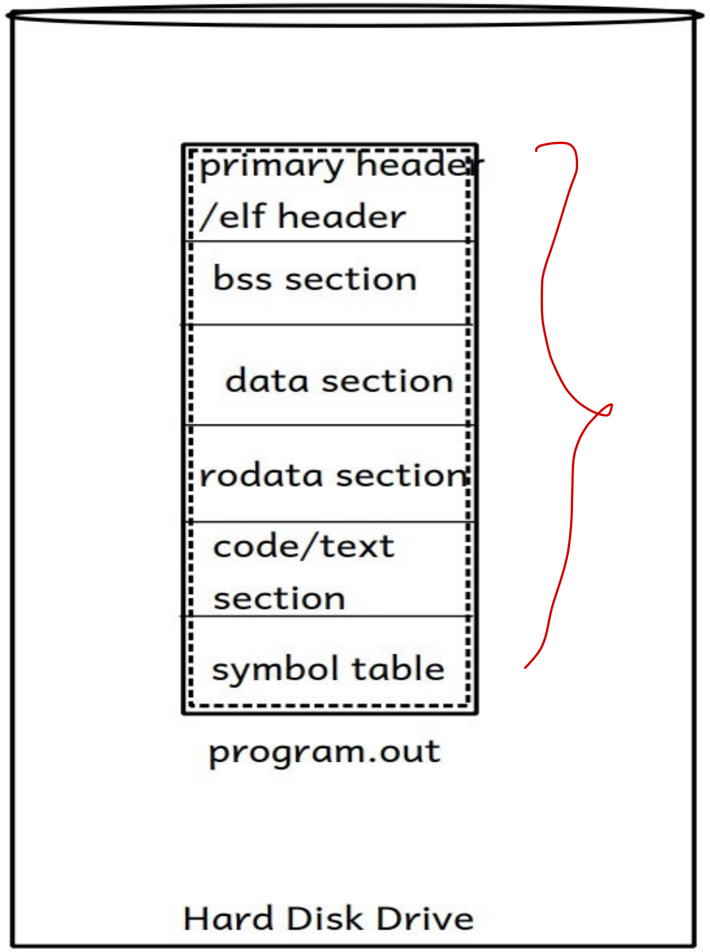
6. Protection & Security
7. User Interfacing
8. Networking

Operating System Concepts



Structure of an executable file

ELF file format in Linux



1. primary header/exe header: it contains information which is required to starts an execution of the program.

e.g. - addr of an entry point function --> main() function

- **magic number:** it is constant number generated by the compiler which is file format specific.
    - magic number in Linux starts with ELF in its eq **hexadecimal format**.
    - info about remaining sections.

2. bss(block started by symbol) section: it contains uninitialized global & static vars

3. data section: it contains initialized global & static vars

4. rodata (readonly data) section: it contains string literals and constants.

5. code/text section: it contains an executable instructions

6. symbol table: it contains info about functions and its vars in a tabular format.

Operating System Concepts

- **History of Operating System**

1. **Resident monitor**
2. **Batch System**
   - The batch/group of similar programs is loaded in the computer, from which OS loads one program in the memory and execute it. The programs are executed one after another.
   - In this case, if any process is performing IO, CPU will wait for that process and hence not utilized efficiently.
3. **Multi-programming**
   - Better utilization of CPU
   - Loading multiple Programs in memory
   - Mixed program(CPU bound + IO bound)
4. **Time-sharing/Multitasking**
   - Sharing CPU time among multiple process/task present in main memory and ready for execution
   - Any process should have response time should be less then 1sec
   - Multi-tasking is divided into two types
     - Process based multitasking
     - Thread based multitasking

- Process based multitasking: Multiple independent processes are executing concurrently. Processes running on multiple processors called as "multi-processing".
- Thread based multi-tasking OR multi-threading: Multiple parts/functions in a process are executing concurrently.

Thread is a light weight process

- When new thread is created a new stack and new TCB is created.
- Thread Share text, data, heap sections with the parent process

Process vs thread

- In modern OS, process is a container holding resources required for execution, while thread is unit of execution/scheduling.
  Process holds resources like memory, open files, IPC (e.g. signal table, shared memory, pipe, etc.). PCB contains resources information like pid, exit status, open files, signals/ipc, memory info, etc.
- CPU time is allocated to the threads. Thread is unit of execution.
- TCB contains execution information like tid, scheduling info (priority, sched algo, time left, ...), Execution context, Kernel stack, etc.
- For each process one thread is created by default it is called as main thread.

5. Multi-user system

Multiple users runs multiple programs concurrently

6. **Multi-processor/Mutli-core system**

System can run on a machine in which more than one CPU's are connected in a closed circuit.

Multiprocessing Advantage is it increased throughput (amount of work done in unit time)

- There are two types of multiprocessor systems:
- Asymmetric Multi-processing Symmetric Multi-processing

- **Asymmetric Multi-processing**

OS treats one of the processor as master processor and schedule task for it. The task is in turn divided into smaller tasks and get them done from other processors.

- **Symmetric Multi-processing**

OS considers all processors at same level and schedule tasks on each processor individually. All modern desktop systems are SMP.

Process life Cycle

- **Process States:**

To keep track on all running programs, an OS maintains few **data structures** referred as **OS data Structure**

1. **Job queue:** it contains list of all the processes(PCB).

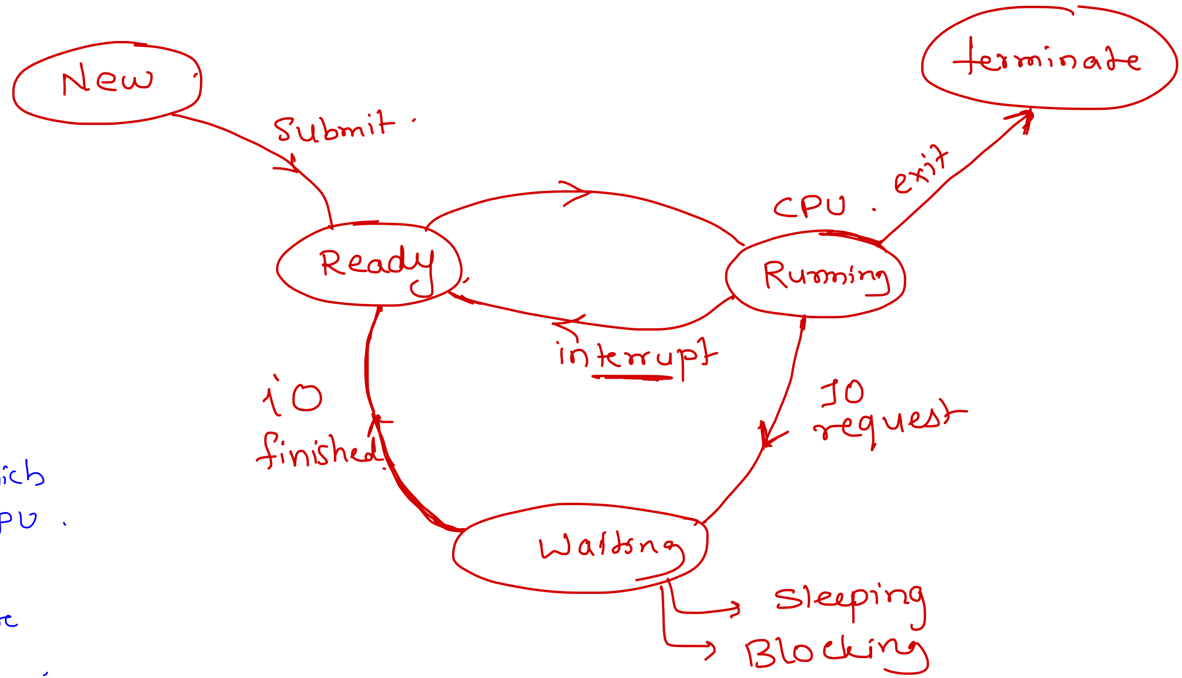
2. **Ready queue:** it contains list of PCB's of processes which are ready to run on CPU.

3. **Waiting queue:** it contains list of PCB's of processes waiting for io device or for synchronization.

Sunbeam Infotech

Process — PCB
↓
① Pid
② Sch inf
ⓐ State
ⓑ Priority
ⓒ Algorithm.

Process - State



OS data structure

① Job queue
list of all proces (PCB)

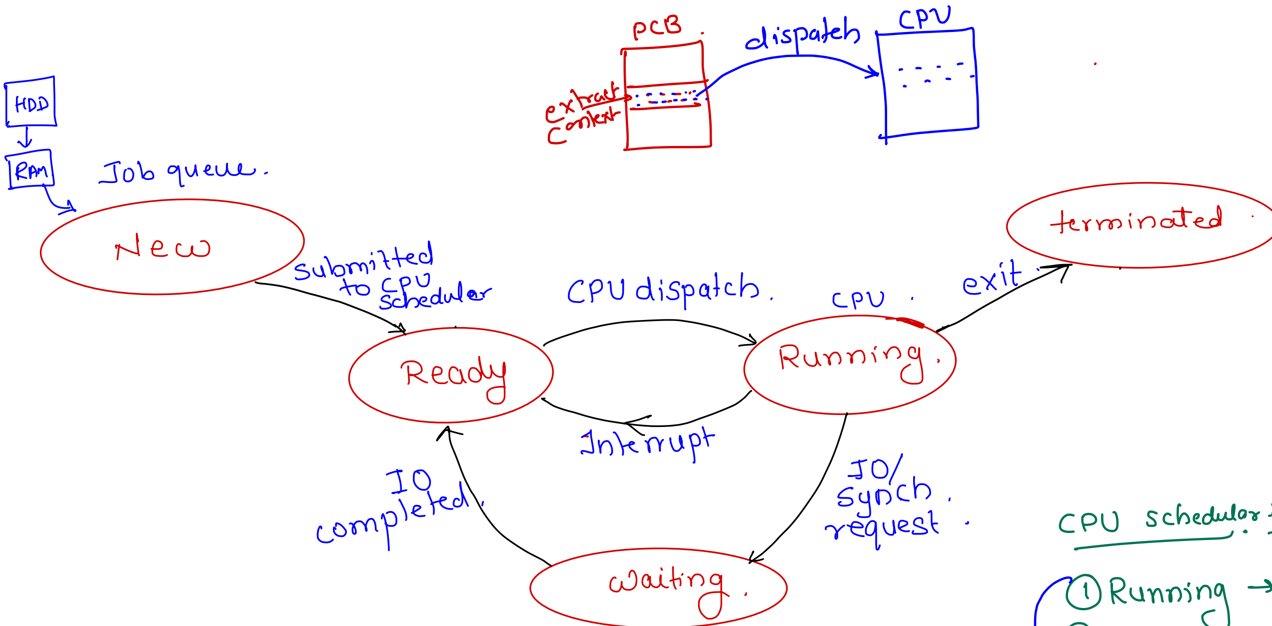
② Ready queue
list of process (PCB) which are ready to run on CPU.

③ Waiting queue
list of PCB which are ready of IO device

PCB → extract contexts.
(value of CPU reg).

CPU Schedular: decide which process to run next.

CPU dispatcher: dispatch the selected process on CPU



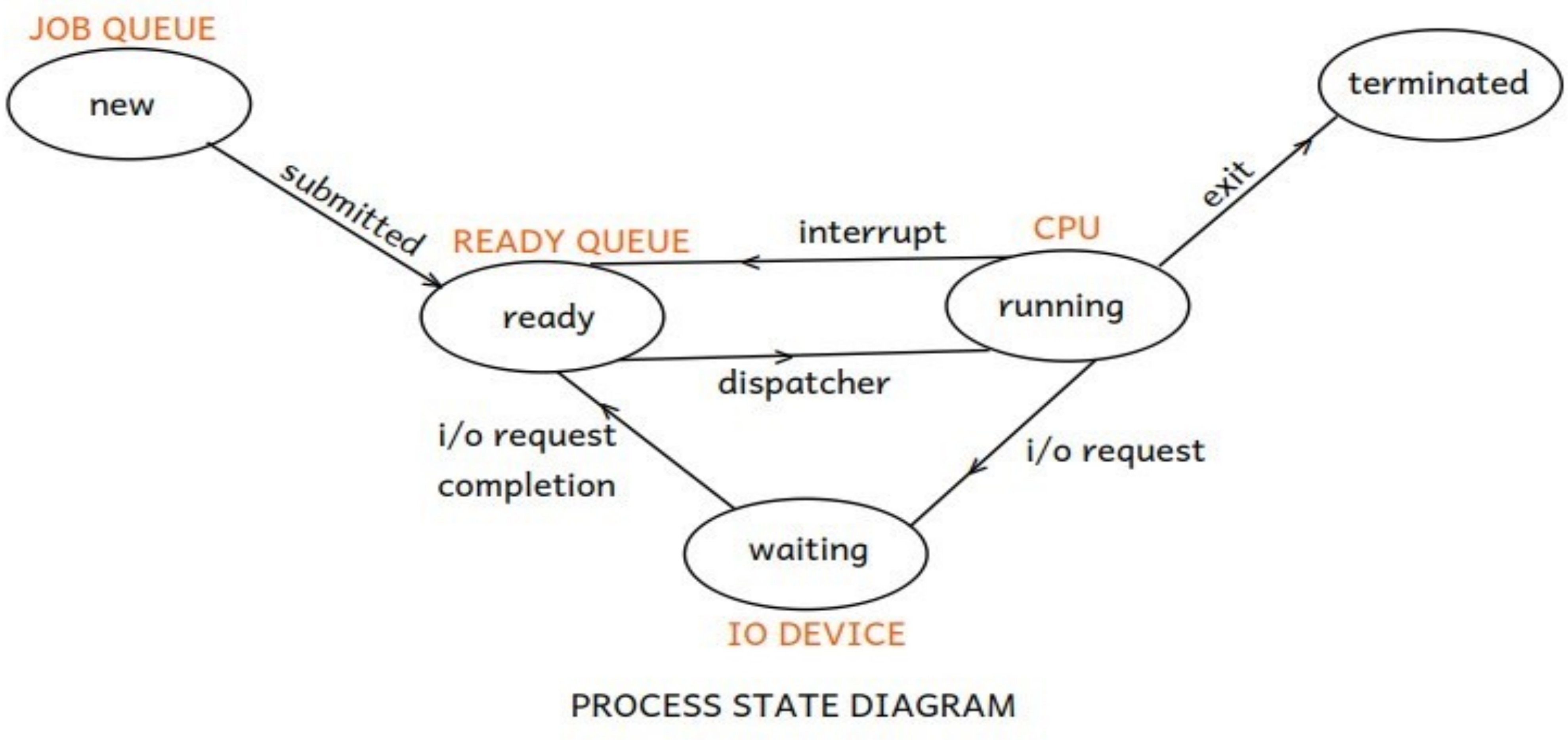
CPU scheduler invoke:

1. Running → terminated
2. Running → waiting
3. Running → Ready
4. Waiting → Ready

(1)–(2): non-preemptive scheduling ↓ co-operative sch.

(1)–(4): pre-emptive scheduling

Process State Diagram



Process States

Throughout execution, process goes through different states out of which at a time it can be only in a one state.

-States of the process:

1. **New**: New process PCB is created and added into job queue. PCB is initialized and process get ready for execution.

2. **Ready**: The ready process is added into the ready queue. Scheduler pick a process for scheduling from ready queue and dispatch it on CPU.

3. **Running**: The process runs on CPU. If process keeps running on CPU, the timer interrupt is used to forcibly put it into ready state and allocate CPU time to other process.

4. **Waiting**: If running process request for IO device, the process waits for completion of the IO. The waiting state is also called as sleeping or blocked state.

5. **Terminated**: If running process exits, it is terminated.

Sunbeam Infotech

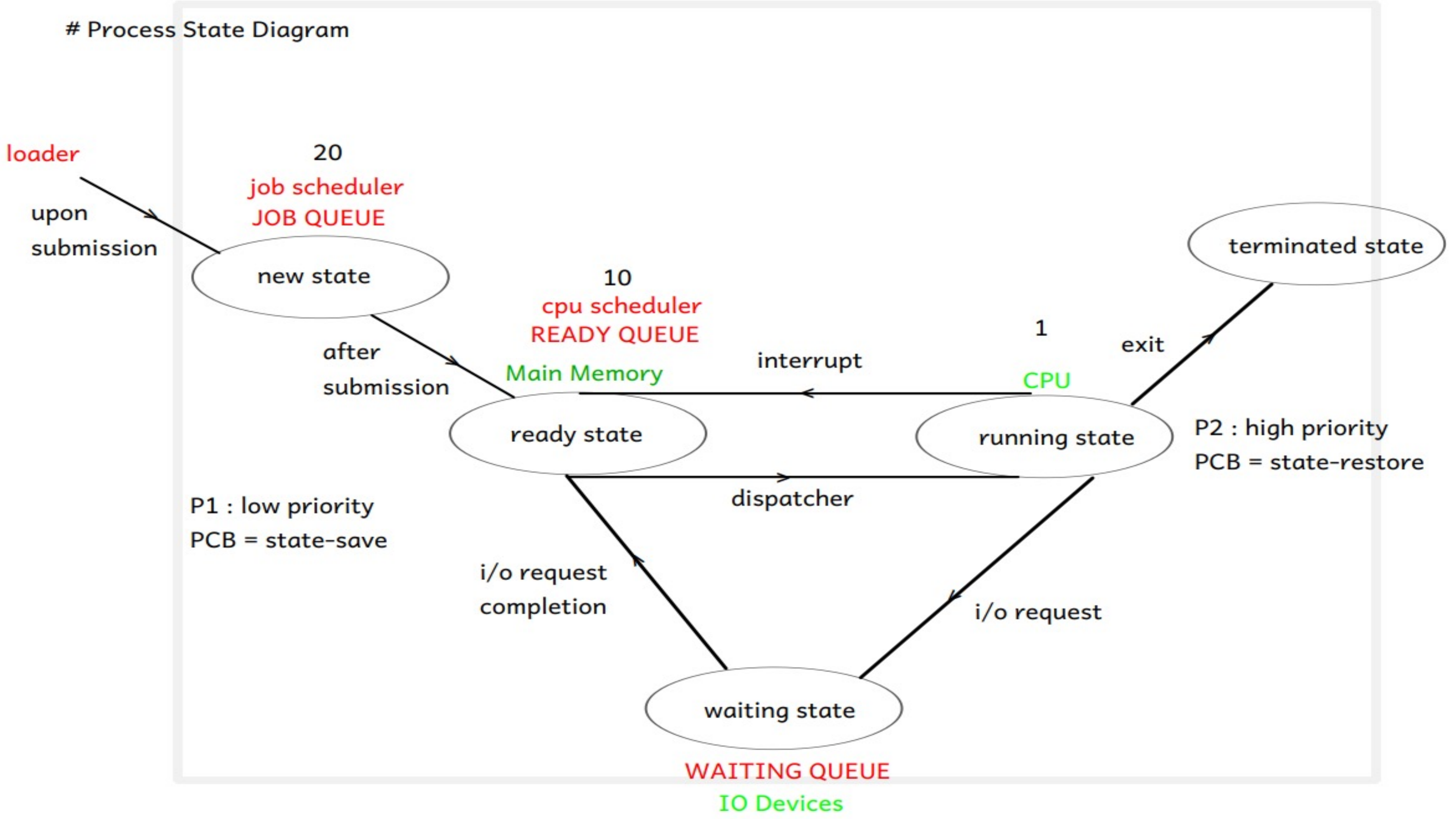
Schedulers

- **Job Scheduler/long term schedulers**
  - Job scheduler load the programs into main memory. Used in older mainframe systems.
- **CPU Scheduler/Short term schedulers**
  - CPU scheduler pick the process to be executed on CPU from ready processes.
  - selects which process should be executed next and allocates CPU
- **CPU Dispatcher**
  - It is a system program that loads a process onto the CPU that is scheduled by the CPU scheduler.
  - Time required for the dispatcher to stops execution and one process and starts execution of another process is called as **"dispatcher latency".**

Context Switch

- Execution context is values of CPU registers (while executing the process).
- Current running process execution context is saved in PCB of that process and next process's execution context is loaded from its PCB into CPU. This is called as context switch.
- The context switch needs some time (in us). Having too many context switches will reduce overall system performance.

Process State Diagram



CPU Management

- **CPU scheduler is invoked**

1. Running -> Terminated
2. Running -> Waiting
3. Running -> Ready
4. Waiting -> Ready

non-pre

pre-emptive

Types of Scheduling

- **Non-preemptive**
  - The current process gives up CPU volunteerily (for IO, terminate or yield).
  - Then CPU scheduler picks next process for the execution.
  - If each process yields CPU so that other process can get CPU for the execution, it is referred as "Co-operative scheduling". e.g. Windows 3.x, etc.

- **Pre-emptive**
  - The current process may give up CPU volunteerily or paused forcibly (for high priority process or upon completion of its time quantum)

CPU Scheduling algorithms

- Schedular decides which next process to execute depending on some Scheduling Algorithm

1. FCFS : First Come First Served
2. SJF: Shortest Job First
3. Priority Scheduling
4. Round Robin
5. Multi-level Queue
6. Multi-level Feedback Queue

CPU Scheduling Criteria

Scheduling criteria's

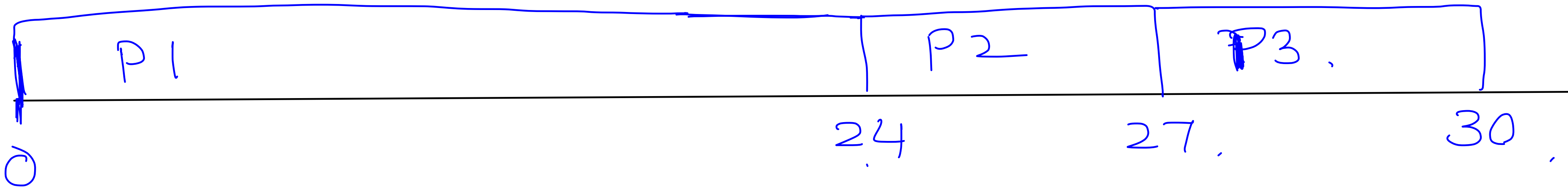
- **CPU utilization**: Ideal - max
  - On server systems, CPU utilization should be more than 90%.
  - On desktop systems, CPU utilization should around 70%.
- **Throughput**: Ideal - max
  - The amount of work done in unit time.
- **Waiting time**: Ideal - min
  - Time spent by the process in the ready queue to get scheduled on the CPU.
  - If waiting time is more (not getting CPU time for execution) -- Starvation.
- **Turn-around time**: Ideal - CPU burst + IO burst → min
  - Time from arrival of the process till completion of the process.
  - CPU burst + IO burst + (CPU) Waiting time + IO Waiting time
- **Response time**: Ideal - min
  - Time from arrival of process (in ready queue) till allocated CPU for first time.

Turn-around time → Process arrived to terminated.

Prog → CPU waiting + CPU time + IO waiting + IO time.

First-Come, First-Served (FCFS) Scheduling

Process	Arrival	CPU Burst ~~time~~	Waiting time	Turn around time	Response time
P1	0	24	0	24	0
P2	0	3	24	27	24
P3	0	3	27	30	27



Gantt's Chart

0
P1
P2
P3

$$\text{avg waiting time} = \frac{0+24+27}{3} = 17$$

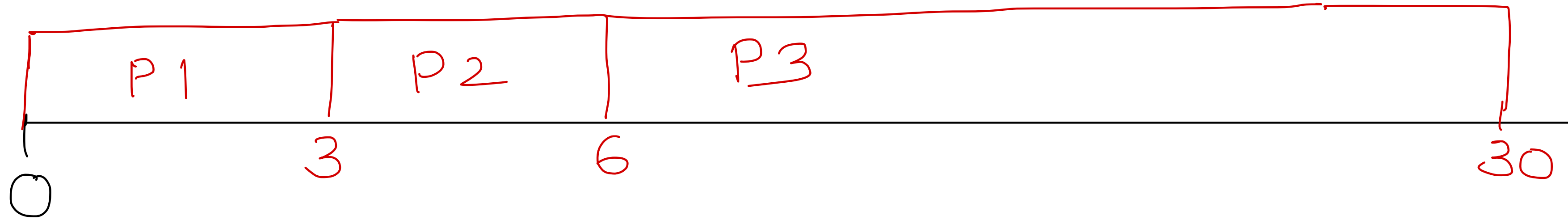
$$\text{avg turn around time} = \frac{24+27+30}{3} = 27$$

First-Come, First-Served (FCFS) Scheduling

Process	Arrival	Burst time	Waiting time
P1	0	~~24~~ 3	0
P2	0	~~3~~ 3	3
P3	0	~~3~~ 24	6

Convoy effect: If bigger processes arrives first, avg wait time increases.

non-pre-emptive



Gantt chart.

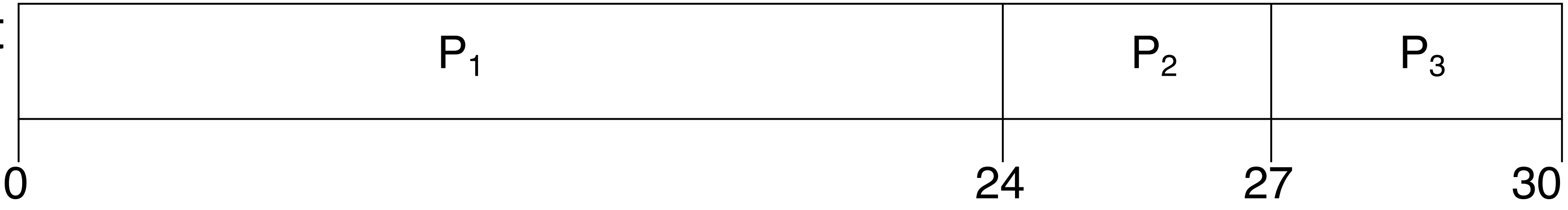
P1
P2
P3

avg waiting time = $\frac{0+3+6}{3} = 3$

First-Come, First-Served (FCFS) Scheduling

Process	Burst Time
P_1	24
P_2	3
P_3	3

- Suppose that the processes arrive in the order: P_1 , P_2 , P_3
- The Gantt Chart



Waiting time for $P_1 = 0$; $P_2 = 24$; $P_3 = 27$

- Average waiting time: (0 + 24 + 27)/3 = 17

Convoy effect -> If bigger processes arrive first, average waiting time increases

FCFS Scheduling (Cont.)

Suppose that the processes arrive in the order

P_2 , P_3 , P_1 .

The Gantt chart for the schedule is:

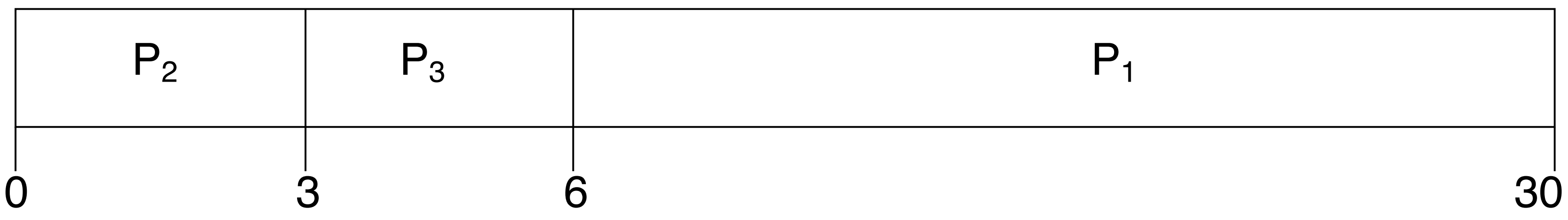
CPU burst time -> p3 = 3, p2 = 3 , p1 = 24

Waiting time for $P_1 = 6; P_2 = 0; P_3 = 3$

Average waiting time: (6 + 0 + 3)/3 = 3

Much better than previous case.

Convoy effect short process behind long process



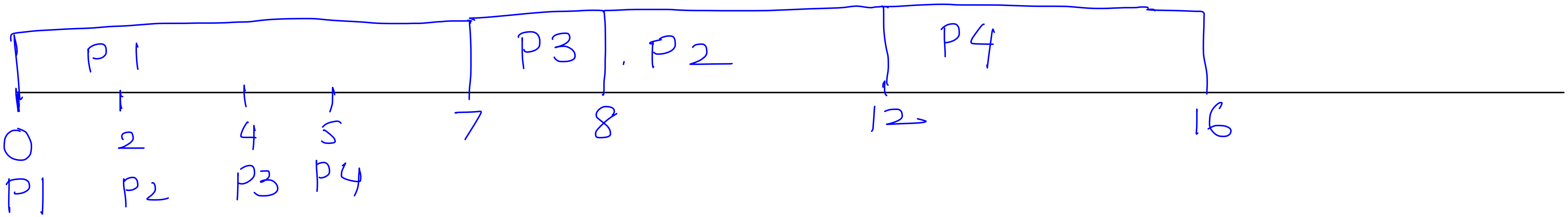
2 SJF(Shortest Job First)

min average waiting time.

Process	Arrival	Burst time	Waiting time
P1	0	7	0
P2	2	4	(8-2) = 6
P3	4	1	7 - 4 = 3
P4	5	4	12 - 5 = 7

non-preemptive.

pre-emptive

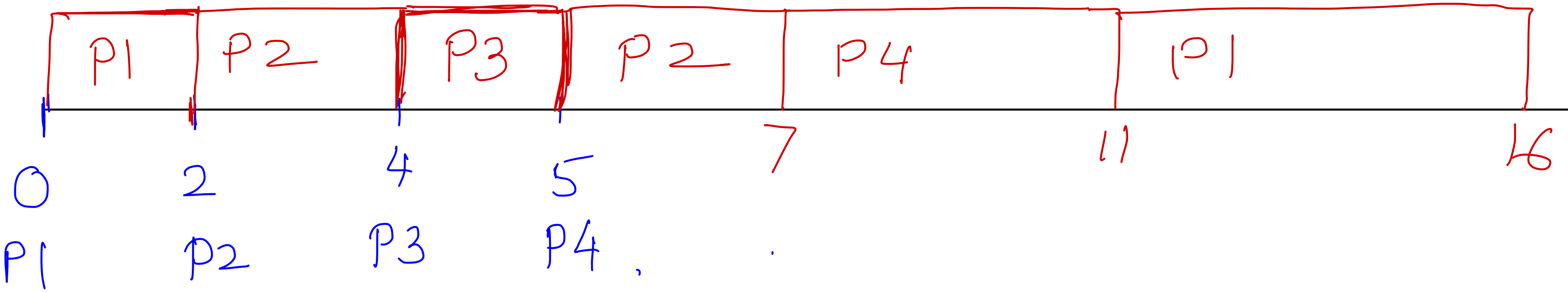


avg waiting time = $\frac{0+6+3+7}{4} = 4$

SJF(Shortest Remaining Job First)

Process	Arrival	Burst time	Remaining time	Waiting time
P1	0	7	7 - 2 = 5	11 - 2 = 9
P2	2	4	4 - 2 = 2	5 - 4 = 1
P3	4	1	1 - 1 = 0	0
P4	5	4	4	7 - 5 = 2

pre-emptive

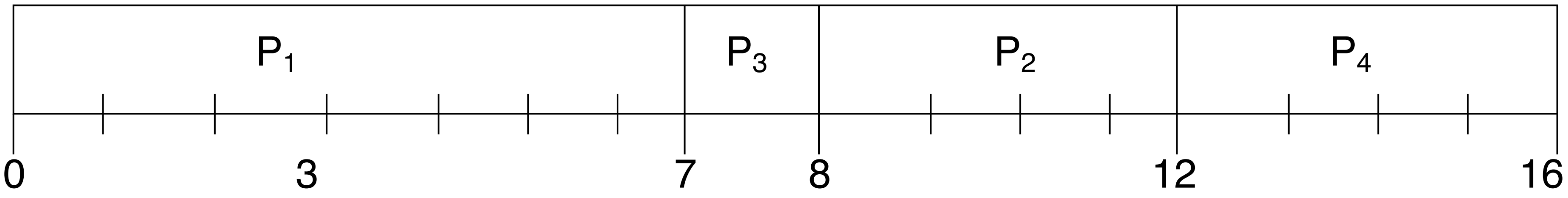


$$\text{avg waiting time} = \frac{9 + 1 + 0 + 2}{4} = 3$$

Example of SJF

Process	Arrival Time	Burst Time
P_1	0	7
P_2	2	4
P_3	4	1
P_4	5	4

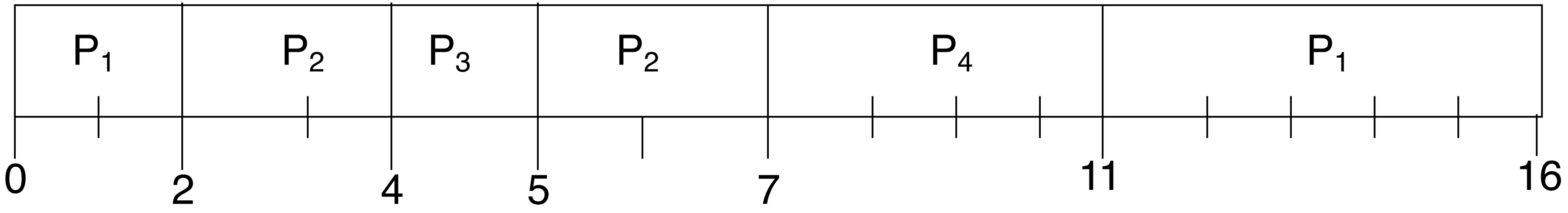
- Average waiting time = (0 + 6 + 3 + 7)/4 = 4
  - *P1 waiting time = 0*
  - *P2 waiting time = 6 (8-2)*
  - *P3 waiting time = 3(7-4)*
  - *P4 waiting time = 7(12-5)*



Example of Preemptive SJF (Shortest Remaining Time First [SRTF])

Process	Arrival Time	Burst Time
P_1	0	7
P_2	2	4
P_3	4	1
P_4	5	4

Remaining time = p1 = 5, p2 = 2, p3 =1, p4 = 4
Waiting time = p1 = 9; p2 =1 , p3=0 , p4 = 2
Average waiting time = (9 + 1 + 0 +2)/4 = 3



Priority Scheduling

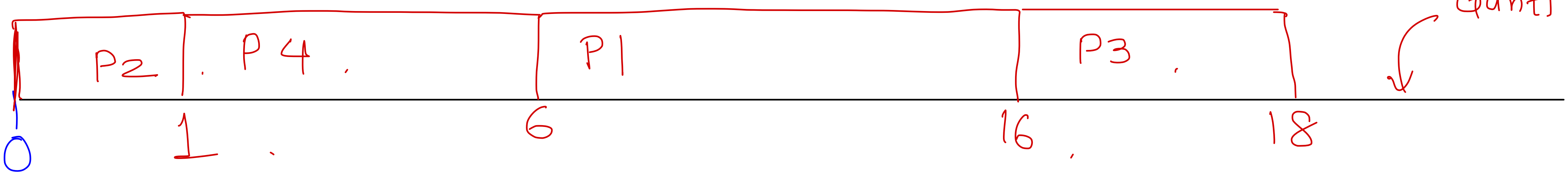
- A priority number (integer) is associated with each process
- The CPU is allocated to the process with the highest priority (smallest integer ≡ highest priority)
  - Preemptive
  - Non-preemptive
- **Starvation** – A process is not enough CPU time for its execution.(waiting in the ready queue)
- Solution of starvation is Aging – The process spending long time in ready queue, increase its priority dynamically.

Priority Scheduling

non-pre-emptive.

Process	Arrival	Burst Time	Priority	waiting time:
P1	0	10	3	6
P2	0	1	1(high priority)	0
P3	0	2	4(low priority)	16
P4	0	5	2	1

Gantt chart



P1
P2
P3
P4

$$\text{avg waiting time} = \frac{6+0+16+1}{4} =$$

Process arrival.

× ✓ → P1 (8)

→ P2 (10)

× → P3 (3)

× → P4 (5)

× → P5 (7)

× → P6 (9)

× → P7 (2).

P1.
P3.
P4
P5
P7.
P6.
P2.

Starvation :- Process is not getting enough CPU time for its execution

Pending in the ready queue.

Reason :- Low Priority

Aging :- The process spending long time in ready queue increase it's priority dynamically.

Example of Priority Scheduling

Process	Burst Time	Priority
P_1	10	3
P_2	1	1(high priority)
P_3	2	4(low priority)
P_5	5	2

P2→P5 →P1→ p3
Waiting time (p1 = 6, p2 =0 , p3=16 , p5= 1)

Average waiting time =(6 +0+ 16 + 1) /3= 5.75

Round Robin (RR)

- Each process gets a small unit of CPU time (*time quantum*), usually 10-100 milliseconds. After this time has elapsed, the process is preempted and added to the end of the ready queue.
- 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.
- Round Robin algorithm is a preemptive .

Round Robin

pre-emptive

Process	Burst Time	Remaining time	~~Waiting time~~
P1	57	57-20=37-20=17=0	
P2	17	0	
P3	68	68-20=48-20=28-20=8	
P4	24	24-20=4=0	

Time Quantum = 20

Waiting time

(77-20=57)+(121-97=24)= 81

20

37+(97-57=40)+(138-117=21)=98

57+(117-77=40)=97

P1	P2	P3	P4	P1	P3	P4	P1	P3	P3

0 20 37 57 77 97 117 121 138 158 166

P1
P2
P3
P4

Example of RR with Time Quantum = 20

Process	Burst Time
P_1	53
P_2	17
P_3	68
P_4	24

The Gantt chart is:

P_1	P_2	P_3	P_4	P_1	P_3	P_4	P_1	P_3	P_3

0 20 37 57 77 97 117 121 134 154 162

Typically, higher average turnaround than SJF, but better *response*.

CPU Scheduling

Important task → priority

Background task → SJF

GUI → RR

Other task → FCFS

Multi-level queue. CPU sch.

q1 → ← SJF

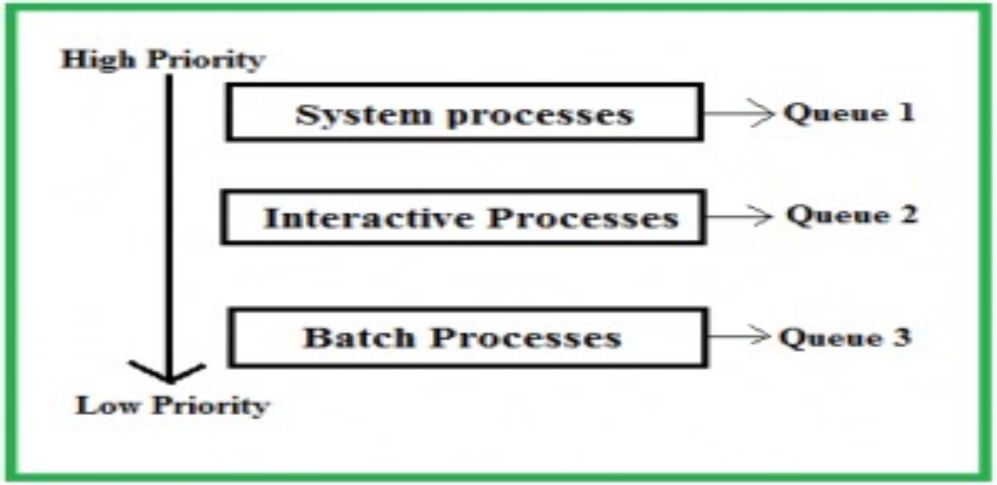
q2 → ← FCFS

q3 →

q4 →

Multi-level feeback queue

Multilevel Queue Scheduling Algorithm



- A multi-level queue scheduling algorithm partitions the ready queue into several separate queues. The processes are permanently assigned to one queue, generally based on some property of the process, such as memory size, process priority, or process type.
- processes are permanently stored in one queue in the system and **do not move between the queue.**
- separate queue for foreground or background processes
- **For example:** A common division is made between foreground(or interactive) processes and background (or batch) processes.
- These two types of processes have different response-time requirements, and so might have different scheduling needs. In addition, foreground processes may have priority over background processes

CPU Scheduling Algorithms

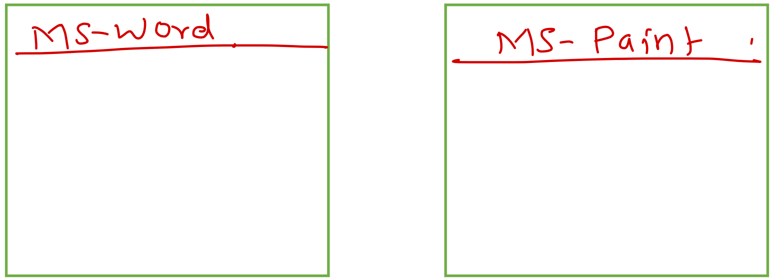
- **FCFS**
  - The process added first in the ready queue should be scheduled first.
  - Non-preemptive scheduling
  - The scheduler is invoked when the process is terminated, blocked or given up CPU is ready for execution. Convoy Effect: Larger processes slow down the 4execution of other processes.
- **SJF**
  - The process with the lowest burst time is scheduled first.
  - Non-preemptive scheduling
  - Minimum waiting time
- **SRTF -Shortest Remaining Time First**
  - Similar to SJF - but Pre-emptive scheduling
  - Minimum waiting time
- **Priority**
  - Each process is associated with some priority level. Usually lower the number, higher the priority.
  - Pre-emptive scheduling or Non-Preemptive scheduling

CPU Scheduling Algorithms

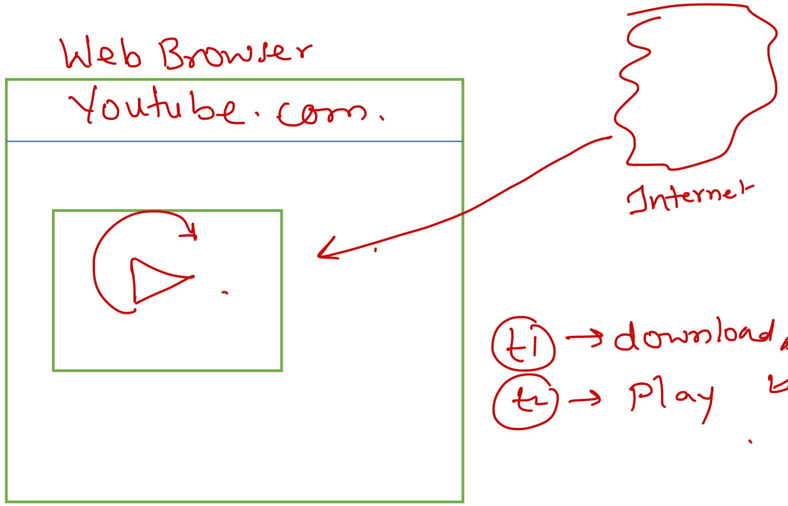
- Starvation
  - Problems may arise in priority scheduling.
  - Process not getting CPU time due to other high-priority processes.
  - The process is in a ready state (ready queue).
  - May be handled with ageing -- dynamically increasing the priority of the process.
- **Round-Robin**
  - Pre-emptive scheduling
  - The process is assigned a time quantum/slice. Once the time slice is completed/expired, then process is forcibly
  - pre-empted and another process is scheduled.
  - Min response time.
- **Multi-level queue**
  - In modern OS, the ready queue can be divided into multiple sub-queues and processes are arranged in them depending on their scheduling requirements. This structure is called a "Multi-level queue".
  - If a process is starving in some sub-queue due to a scheduling algorithm, it may be shifted into another sub-queue. This modification is referred to as" Multi-level feedback queue".
  - The division of processes into sub-queues may differ from OS to OS.

Inter process Communication (IPC)

Multitasking



Independent process



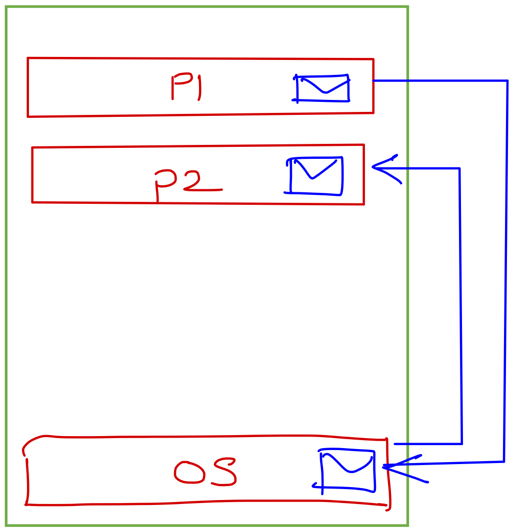
t1 → download
t2 → play
data (IPC)

Co-operative Process

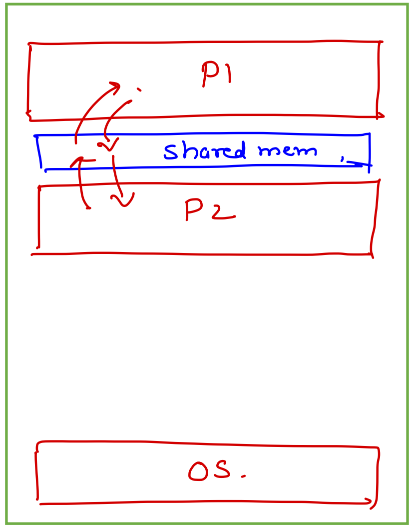
IPC techniques.

① Message Passing

RAM



② Shared Memory



Inter process Communication (IPC)

- Passing information between processes
- Used to coordinate process activity
- Processes within a system may be **independent** or **cooperating**

Independent process

- **do not get affected by the execution of another process**

Cooperating process

- **get affected by the execution of another process**

- Reasons for cooperating processes:
- Information sharing
- Computation speedup
- Modularity
- Convenience
- Cooperating processes need **inter process communication** (**IPC**)

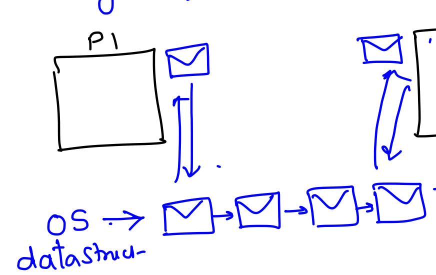
LINUX /UNIX IPC mechanism.

1. Signal
2. Message Queue
3. Pipe
4. Socket
5. Shared Memory → Shared memory.

Message passing.

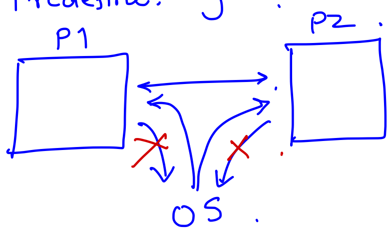
2 Message queue.

✓ Bidirectional
✓ Packet Based.



1 Signal.

– Predefine. Signal.



1. SIGINT → contl+C.
2. SIGKILL →.
3. SIGSEGV →.

3 Pipe.

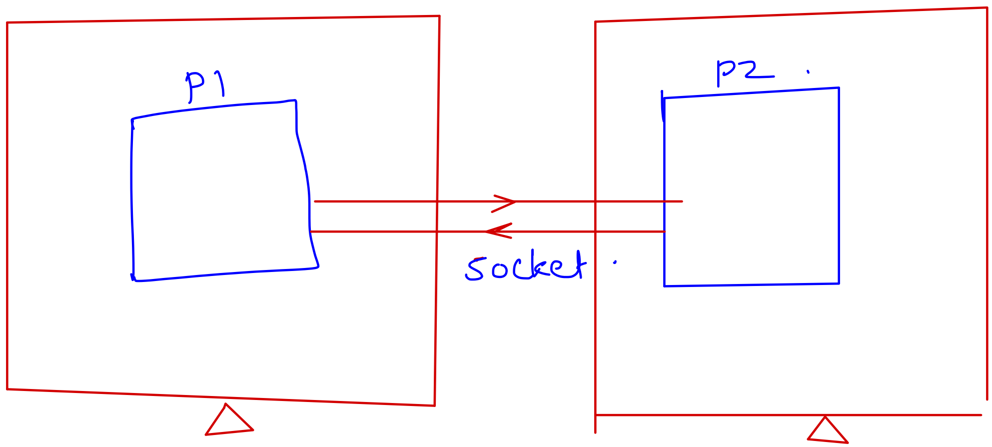
input

terminal> command1 | command2

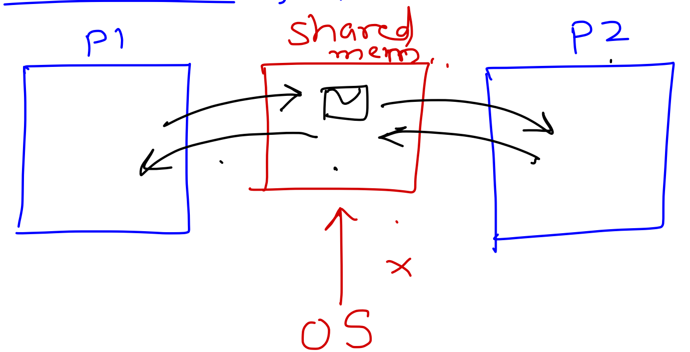
out

→ Unidirectional

→ Stream based.


P1
P2
socket

(5) Shared Memory



✓ fastest