Unit-1

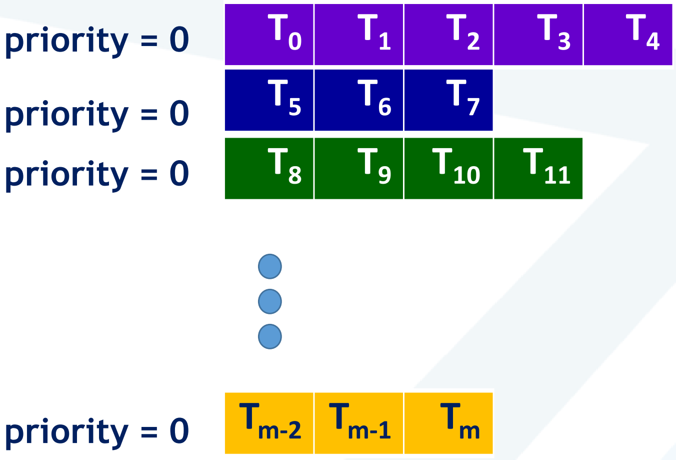
Multilevel Queue Scheduling

Multi-Processor Scheduling

Based on: Operating-system-concepts-Abraham Silberschatz- 10th edition

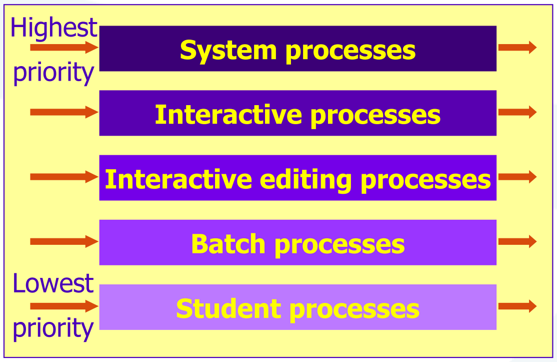
Multilevel Queue Scheduling

Multilevel queue



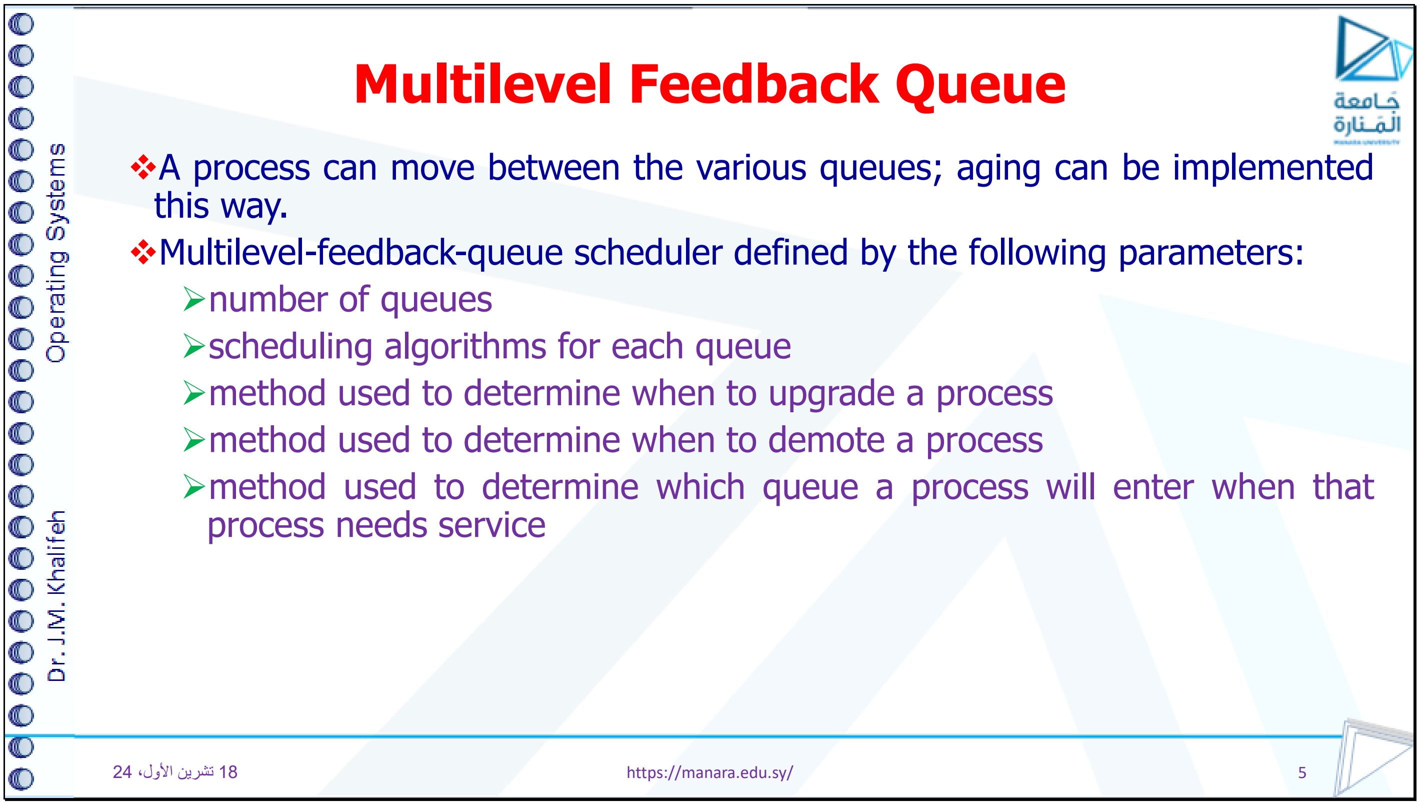
- ❖Separate queue for each distinct priority, and priority scheduling simply schedules the process in the highest-priority queue.
- ❖It works well when priority scheduling is combined with round-robin: if there are multiple processes in the highest-priority queue, they are executed in round-robin order.
- ❖A process remains in the same queue for the duration of its runtime.

Multilevel Queue Scheduling



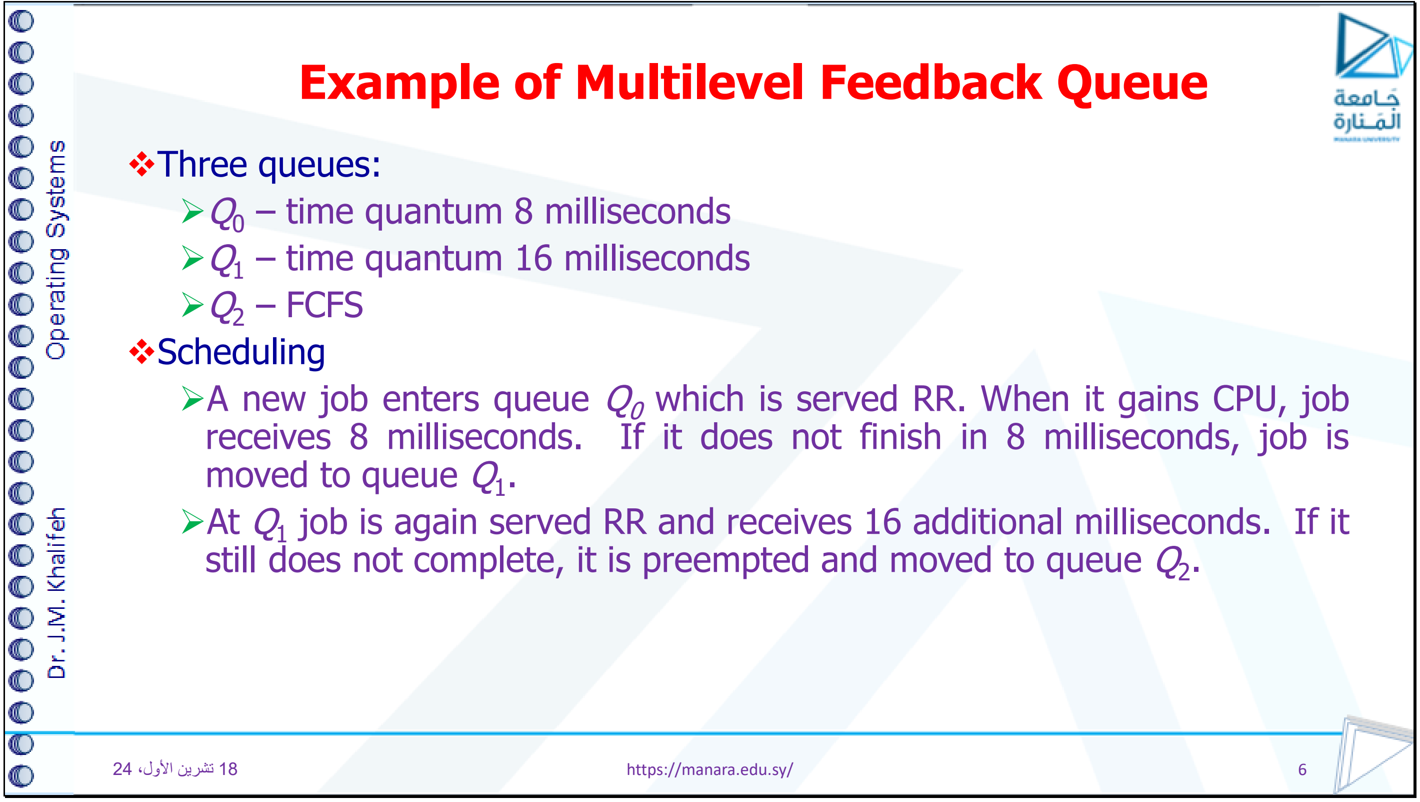
- **Ready queue is partitioned into separate queues:**
  - ❖ foreground (interactive) background (batch)
- **Each queue has its own scheduling algorithm**
  - ❖ foreground – RR background – FCFS

- **Scheduling must be done between the queues.**
  - ❖ Fixed priority scheduling; (i.e., serve all from foreground then from background). Possibility of starvation.
  - ❖ Time slice – each queue gets a certain amount of CPU time which it can schedule amongst its processes; i.e., 80% to foreground in RR
  - ❖ 20% to background in FCFS
- **Processes are permanently assigned to a queue on entry to the system. Processes do not move between queues**



Multilevel Feedback Queue

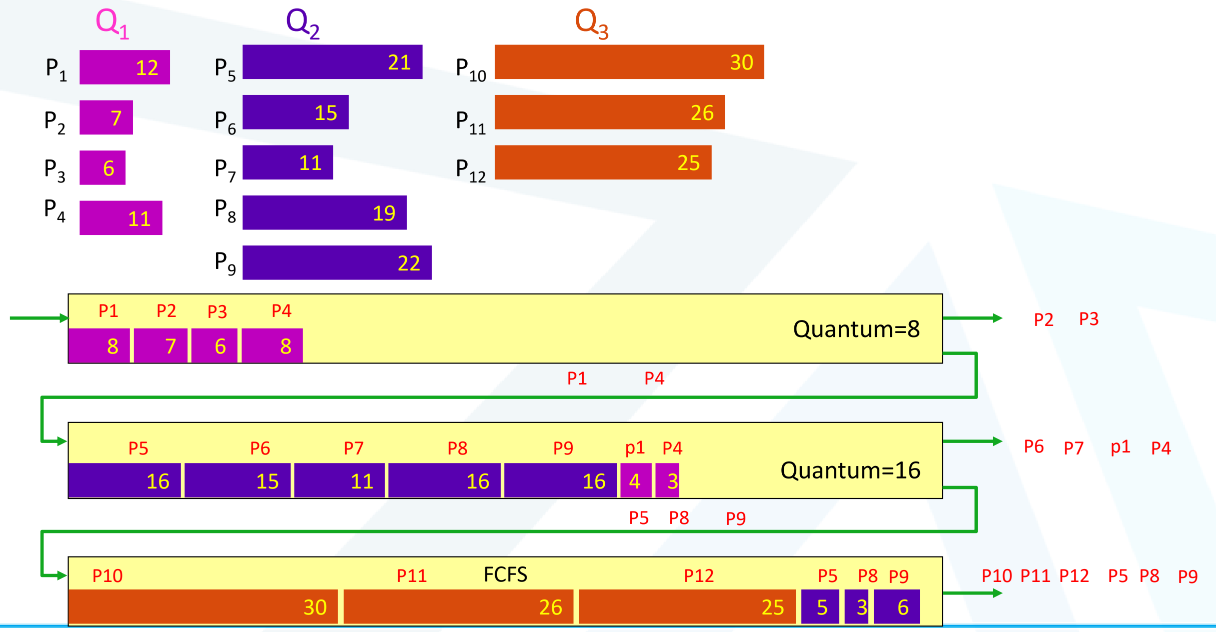
- A process can move between the various queues; aging can be implemented this way.
- Multilevel-feedback-queue scheduler defined by the following parameters:
  - number of queues
  - scheduling algorithms for each queue
  - method used to determine when to upgrade a process
  - method used to determine when to demote a process
  - method used to determine which queue a process will enter when that process needs service



Example of Multilevel Feedback Queue

- Three queues:
  - Q_0 – time quantum 8 milliseconds
  - Q_1 – time quantum 16 milliseconds
  - Q_2 – FCFS
- Scheduling
  - A new job enters queue Q_0 which is served RR. When it gains CPU, job receives 8 milliseconds. If it does not finish in 8 milliseconds, job is moved to queue Q_1.
  - At Q_1 job is again served RR and receives 16 additional milliseconds. If it still does not complete, it is preempted and moved to queue Q_2.

Example of Multilevel Feedback Queue



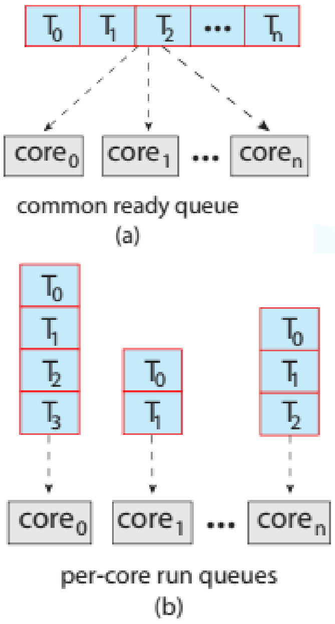
- ❖CPU scheduling more complex when multiple CPUs are available
- ❖Multiprocess may be any one of the following architectures:
  - ➢Multicore CPUs
  - ➢Multithreaded cores
  - ➢(non-uniform memory access)NUMA systems
  - ➢Heterogeneous multiprocessing

Approaches to Multiple-Processor Scheduling

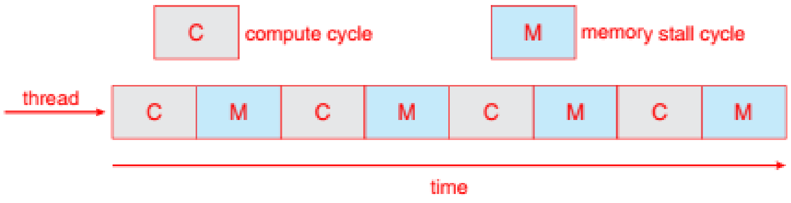
❖Symmetric multiprocessing (SMP) is where each processor is self scheduling.

❖All threads may be in a common ready queue (a)

❖Each processor may have its own private queue of threads (b)



Multicore Processors



❖Memory stall can occur because of a cache miss (accessing data that are not in cache memory. In this scenario, the processor can spend up to 50 percent of its time waiting for data to become available from memory

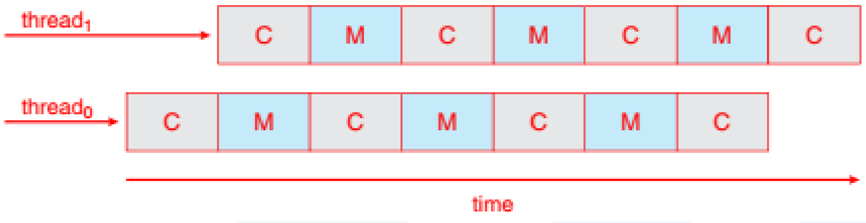
❖Multiple threads per core also growing

- ➢Takes advantage of memory stall to make progress on another thread while memory retrieve happens

Multithreaded Multicore System

Each core has > 1 hardware threads.

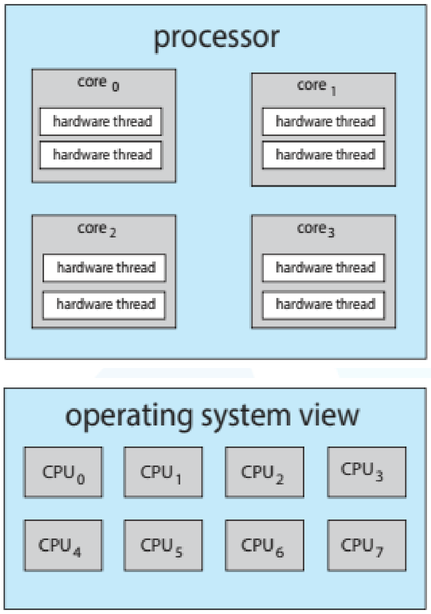
If one thread has a memory stall, switch to another thread!



Multithreaded Multicore System

- **Chip-multithreading** (CMT) assigns each core multiple hardware threads. (Intel refers to this as **hyperthreading**.)

- On a quad-core system with 2 hardware threads per core, the operating system sees 8 logical processors.

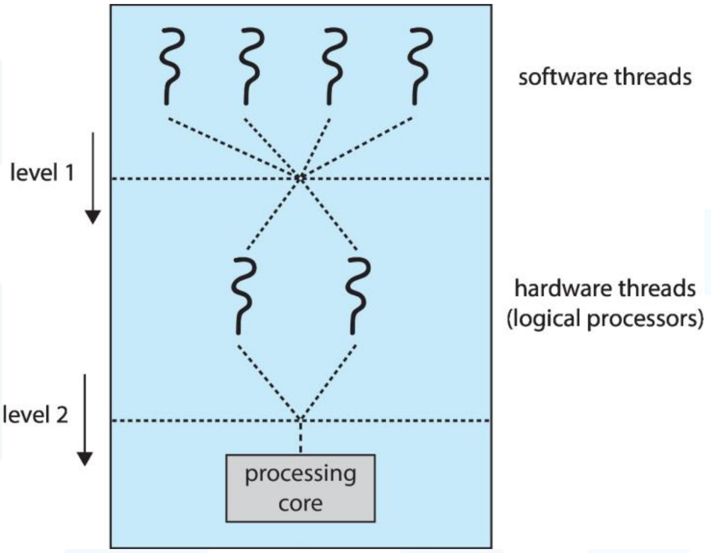


Multithreaded Multicore System

❖Two levels of scheduling:

1. The operating system deciding which software thread to run on a logical CPU

2. How each core decides which hardware thread to run on the physical core.



Multiple-Processor Scheduling – Load Balancing

❖If SMP, need to keep all CPUs loaded for efficiency

❖**Load balancing** attempts to keep workload evenly distributed

❖**Push migration** – periodic task checks load on each processor, and if found pushes task from overloaded CPU to other CPUs

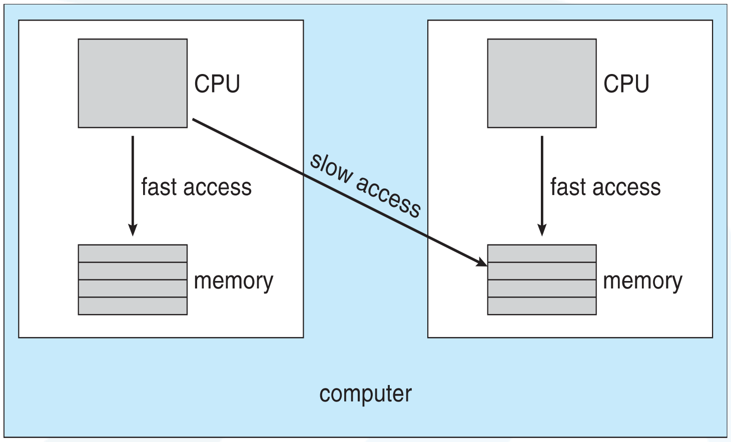
❖**Pull migration** – idle processors pulls waiting task from busy processor

Multiple-Processor Scheduling – Processor Affinity

- When a thread has been running on one processor, the cache contents of that processor stores the memory accesses by that thread.
- We refer to this as a thread having affinity for a processor (i.e. “processor affinity”)
- Load balancing may affect processor affinity as a thread may be moved from one processor to another to balance loads, yet that thread loses the contents of what it had in the cache of the processor it was moved off of.
- **Soft affinity** – the operating system attempts to keep a thread running on the same processor, but no guarantees.
- **Hard affinity** – allows a process to specify a set of processors it may run on.

NUMA and CPU Scheduling

If the operating system is **NUMA-aware**, it will assign memory closes to the CPU the thread is running on.



Heterogeneous Multiprocessing (HMP)

❖In some systems (Mobile), cores run the same instruction set, yet vary in terms of their clock speed and power management, including the ability to adjust the power consumption of a core to the point of idling the core.

❖The intention behind HMP is to better manage power consumption by assigning tasks to certain cores based upon the specific demands of the task (Mobile).

❖For ARM (Advanced RISC Machine) processors that support it, this type of architecture is known as **big.LITTLE** (Mobile, Windows 10)

❖***Big*** cores consume greater energy and therefore should only be used for short periods of time.

❖Likewise, ***little*** cores use less energy and can therefore be used for longer periods.

Real-Time CPU Scheduling

❖The most important feature of a real-time operating system is to respond immediately to a real-time process as soon as that process requires the CPU.

❖In general, we can distinguish between

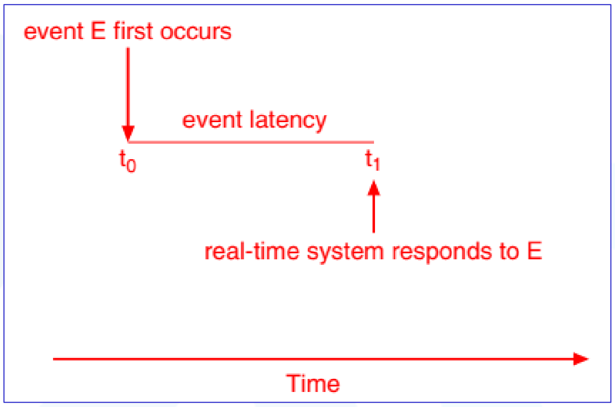
- ➢**Soft real-time systems** – Critical real-time tasks have the highest priority, but no guarantee as to when tasks will be scheduled
- ➢**Hard real-time systems** – task must be serviced by its deadline

❖ Usually, different events have different latency requirements. Two types of latencies affect performance

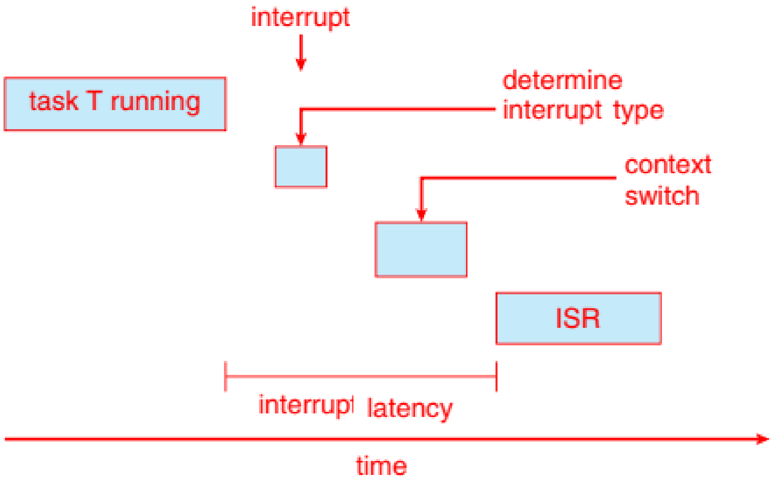
1. **Interrupt latency**
2. **Dispatch latency**

Real-Time CPU Scheduling - Minimizing Latency

- ❖The system is typically waiting for an event in real time to occur.
- ❖Events may arise either in software or in hardware.
- ❖When an event occurs, the system must respond to and service it as quickly as possible.
- ❖**Event latency:** the amount of time that elapses from when an event occurs to when it is serviced.

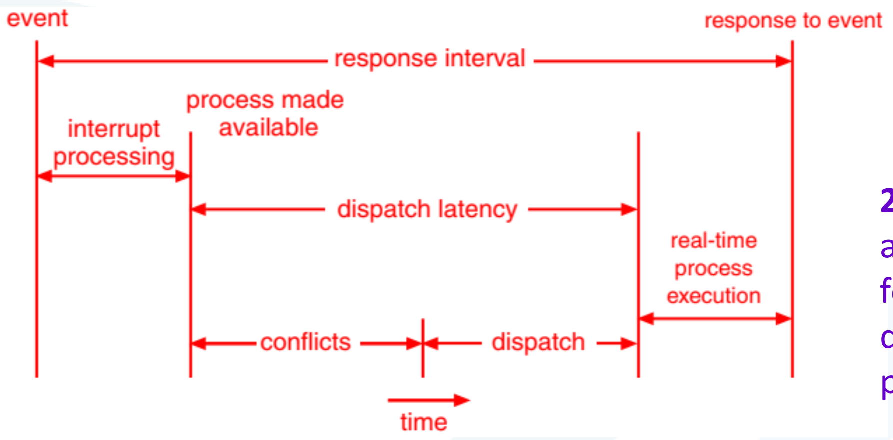


Interrupt Latency



1.Interrupt latency – time from arrival of interrupt to start of routine that services interrupt

Dispatch Latency



2- Dispatch latency: The amount of time required for the scheduling dispatcher to stop one process and start another.

❖Conflict phase of dispatch latency:

1. Preemption of any process running in kernel mode
2. Release by low-priority process of resources needed by high-priority processes

Priority-based Scheduling

❖The scheduler for a real-time operating system must support a priority based algorithm with preemption.

❖Priority-based scheduling algorithms assign each process a priority based on its importance; more important tasks are assigned higher priorities than those deemed less important.

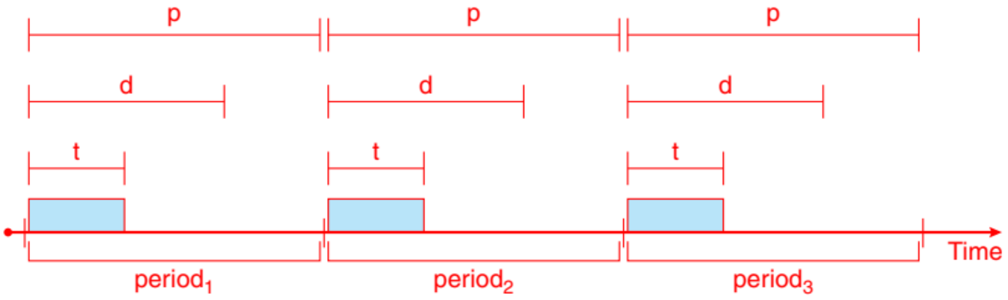
❖If the scheduler also supports preemption, a process currently running on the CPU will be preempted if a higher-priority process becomes available to run.

Priority-based Scheduling- Notes

- Note that providing a preemptive, priority-based scheduler only guarantees soft real-time functionality.
- Hard real-time systems must further guarantee that real-time tasks will be serviced in accord with their deadline requirements, and making such guarantees requires additional scheduling features.

Priority-based Scheduling = define certain characteristics of the processes

- **Periodic process:**
  - ones require CPU at constant intervals
  - Has processing time *t*, deadline *d,* period *p*
  - $0 \le t \le d \le p$
  - **Rate** of periodic task is $1/p$



Priority-based Scheduling = define certain characteristics of the processes

- ❖Schedulers can assign priorities according to a process’s deadline or rate requirements.
- ❖A process may have to announce its deadline requirements to the scheduler. Then, using a technique known as an **admission-control** algorithm.
- ❖The scheduler does one of two things:
  - ➢It either admits the process, guaranteeing that the process will complete on time,
  - ➢or rejects the request as impossible if it cannot guarantee that the task will be serviced by its deadline.

Rate Monotonic Scheduling

- ❖A priority is assigned based on the inverse of its period
- ❖Shorter periods = higher priority;
- ❖Longer periods = lower priority
- ❖P_1 is assigned a higher priority than P_2.

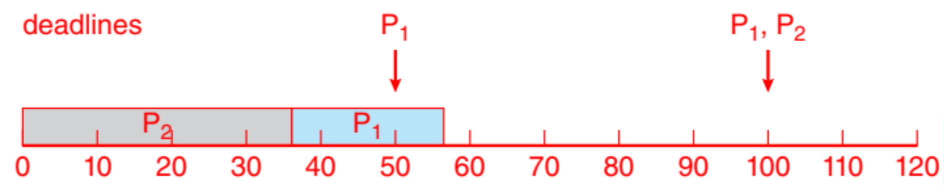
Rate Monotonic Scheduling

- p1 = 50 and p2 = 100.
- *t*1 = 20 for *P*1 and *t*2 = 35 for *P*2
- If we measure the CPU utilization of a process **Pi** as the ratio of its burst to its period—**ti⁄pi** —the CPU utilization of **P**1 is 20⁄50 = 0.40 and that of **P**2 is 35⁄100 = 0.35, for a total CPU utilization of 75 percent.
- Therefore, it seems we can schedule these tasks in such a way that both meet their deadlines and still leave the CPU with available cycles.
- The worst-case CPU utilization for scheduling *N* processes is

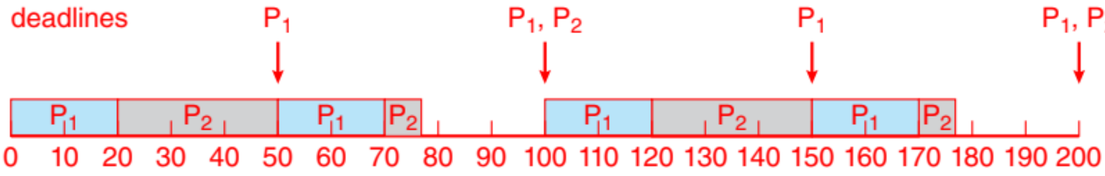
$$N(2^{1/N} - 1).$$

Rate Montonic Scheduling

- When we assign **P**2 a higher priority than **P**1.



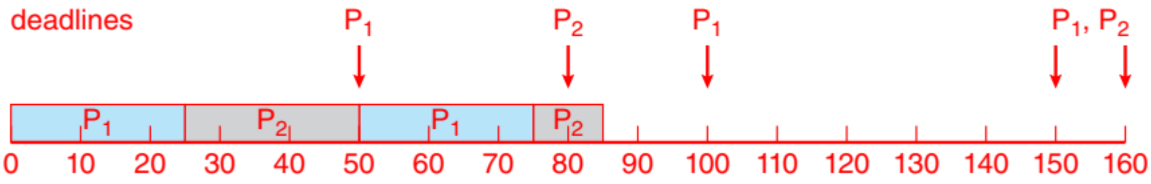
- When we assign **P**1 a higher priority than **P**2.



- if a set of processes cannot be scheduled by this algorithm, it cannot be scheduled by any other algorithm that assigns static priorities.

Missed Deadlines with Rate Monotonic Scheduling

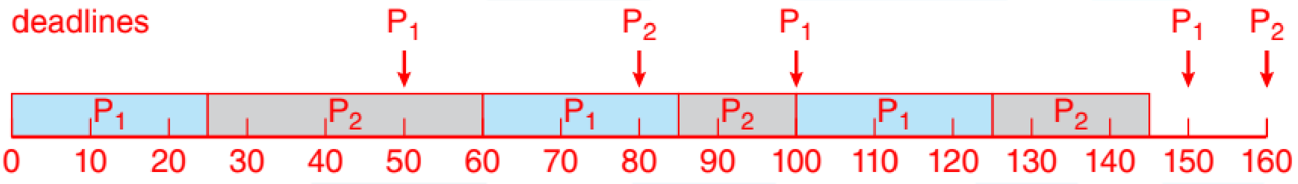
- p1 = 50 and p2 = 80.
- *t*1 = 25 for *P*1 and *t*2 = 35 for *P*2
- The total CPU utilization of the two processes is (25⁄50) + (35⁄80) =0.94, and it therefore seems logical that the two processes could be scheduled and still leave the CPU with 6 percent available time.



Process P2 misses finishing its deadline at time 80

Earliest Deadline First Scheduling (EDF)

- Priorities are assigned dynamically according to deadlines:
  - the earlier the deadline, the higher the priority;
  - the later the deadline, the lower the priority
- p1 = 50 and p2 = 80.
- *t*1 = 25 for *P*1 and *t*2 = 35 for *P*2
- Rate-monotonic scheduling allows P1 to preempt P2 at the beginning of its next period at time 50, EDF scheduling allows process P2 to continue running. P2 now has a higher priority than P1 because its next deadline (at time 80) is earlier than that of P1 (at time 100).



Proportional Share Scheduling

- ❖*T* shares are allocated among all processes in the system
- ❖An application receives *N* shares where *N* < *T*
- ❖This ensures each application will receive ***N*** / *T* of the total processor time
- ❖assume that a total of *T* = 100 shares is to be divided among three processes, *A*, *B*, and *C*. *A* is assigned 50 shares, *B* is assigned 15 shares, and *C* is assigned 20 shares. *A* will have 50 percent of total processor time, *B* will have 15 percent, and *C* will have 20 percent.
- ❖An admission-control policy will admit a client requesting a particular number of shares only if sufficient shares are available. In our current example, if a new process *D* requested 30 shares, the admission controller would deny *D* entry into the system.