Scheduling Algorithms

- FCFS (First Comes First Served)
  - Non-Preemptive and Simplest CPU-scheduling algorithm
  - Process requesting CPU first is allocated CPU first
- Shortest-Job-First Scheduling (Non-Preemptive)
  - Assign CPU to the process with smallest next CPU burst
  - Next CPU bursts of 2 processes same, FCFS scheduling
- Shortest-Remaining-Time-First (SRTF)
  - A preemptive version of SJF algorithm
  - If the next CPU burst of the newly arrived process is shorter than what is left of the currently executing process, it will preempt the currently executing process

1

Priority Scheduling

- A priority is associated with each process
- CPU is allocated to highest priority process
  - Equal-priority processes are scheduled in FCFS order
- Priorities are generally indicated by some fixed range of numbers, such as 0 to 7 or 0 to 1,023
- External (Static)
  - non-preemptive
- Internal (Dynamic)
  - preemptive

2

Priority Scheduling

- Static Priority-non-preemptive
  - Higher number→ Higher Priority

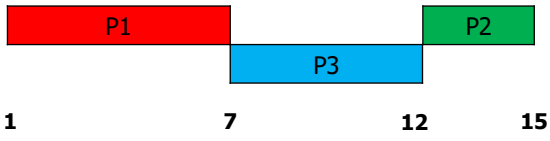
Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	2

3

Priority Scheduling

- Static Priority-non-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	2



4

Priority Scheduling

- Static Priority-non-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	2

5

Priority Scheduling

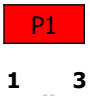
- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4

Ready	Running
P1(6)	-

➡

Ready	Running
P2(3)	P1(4)



6

Priority Scheduling

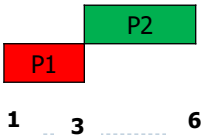
- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4

Ready	Running
P1(4)	P2(3)

➡

Ready	Running
P3(5)	-
P1(4)	



7

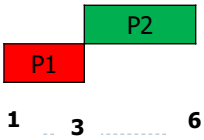
7

Priority Scheduling

- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4

Ready	Running
P1(4)	P3(5)



8

8

Priority Scheduling

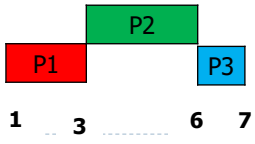
- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4

Ready	Running
P1(4)	P3(5)

➡

Ready	Running
P4(2)	P3(4)
P1(4)	



Priority Scheduling

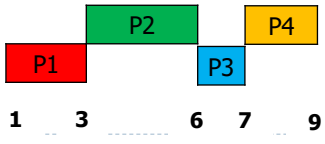
- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4

Ready	Running
P3(4)	P4(2)
P1(4)	

➡

Ready	Running
P3(4)	-
P1(4)	



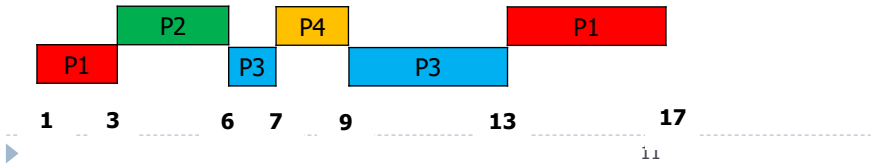
Priority Scheduling

- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Ready	Running
P1(4)	P3(4)

Ready	Running
-	P1(4)

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4



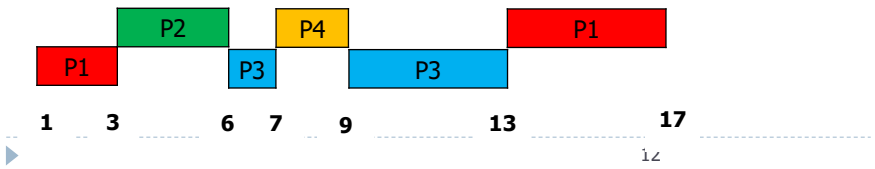
11

Priority Scheduling

- Dynamic Priority-preemptive
  - Higher number→ Higher Priority

Ready	Running
-	-

Process	Arrival	Burst	Priority
P1	1	6	1
P2	3	3	2
P3	6	5	3
P4	7	2	4



12

Round Robin Scheduling

- Designed especially for timesharing systems
- FCFS + Preemption (to context switch processes)
- Time quantum/slice defined (10 to 100 milliseconds)
- Ready queue is a circular queue
- Time slice > time required for a typical interaction

Round Robin Scheduling

Ready	Running
P1(7)	-

Ready	Running
-	P1(4)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units

P1

1 **4**

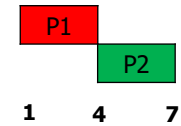
Round Robin Scheduling

Ready	Running
P2(4)	P1(4)
P3(2)	

Ready	Running
P3(2)	P2(4)
P1(4)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units



15

15

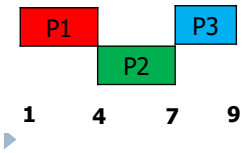
Round Robin Scheduling

Ready	Running
P3(2)	P2(1)
P1(4)	
P4(5)	

Ready	Running
P1(4)	P3(2)
P4(5)	
P2(1)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units



16

16

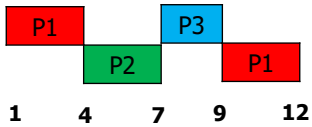
Round Robin Scheduling

Ready	Running
P4(5)	P1(4)
P2(1)	

Ready	Running
P4(5)	P1(1)
P2(1)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units



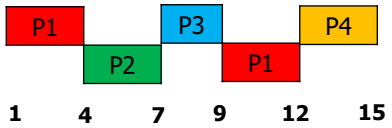
Round Robin Scheduling

Ready	Running
P2(1)	P4(5)
P1(1)	

Ready	Running
P2(1)	P4(2)
P1(1)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units



Round Robin Scheduling

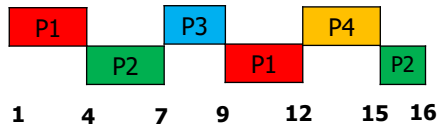
Ready	Running
P1(1)	P2(1)
P4(2)	

➡

Ready	Running
P4(2)	P1(1)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units



Round Robin Scheduling

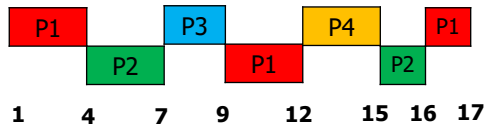
Ready	Running
P4(2)	P1(1)

➡

Ready	Running
-	P4(2)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units



Round Robin Scheduling

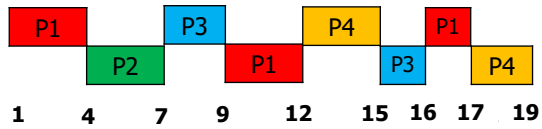
Ready	Running
-	P4(2)

➡

Ready	Running
-	-

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	2
P4	5	5

Time slot = 3 units

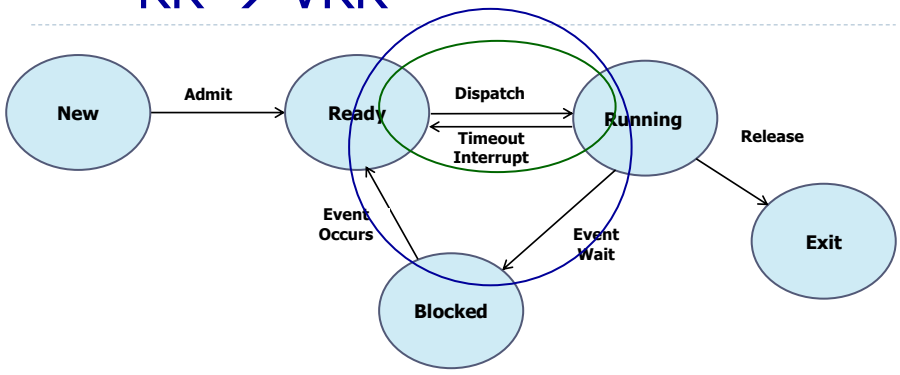


Round Robin Scheduling

- Effective in a general-purpose time-sharing system
- Unfair scheduling for I/O-bound processes
- To avoid this unfairness, refinement to Round Robin is explored

Virtual Round Robin (VRR)

RR → VRR



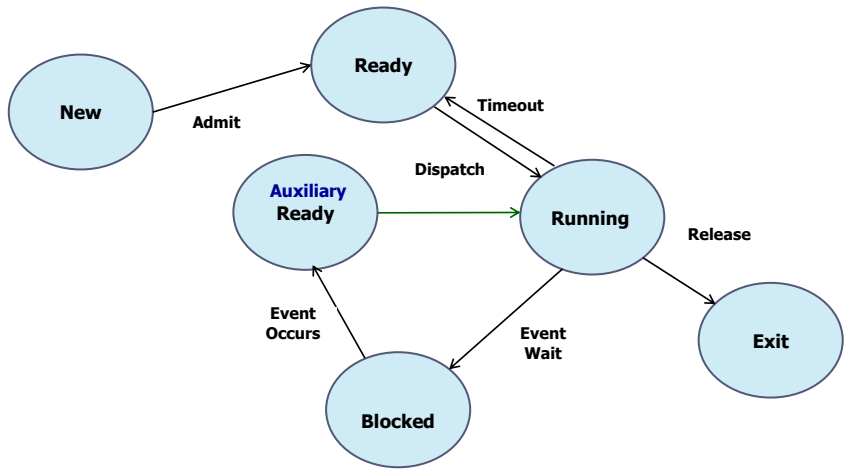
- New → Ready → Running ←→Ready
- Running → Wait (Blocked on IO)
- Compute Bound Vs IO Bound Processes
- VRR (RR + Auxiliary Ready Queue for IO bound processes

Virtual Round Robin (VRR)

Auxiliary Queue (FCFS)

- Processes moved to Auxiliary Queue after being released from an I/O block
- When a dispatching CPU decision is to be made, processes in the Auxiliary queue get preference over main ready queue
  - A process dispatched from auxiliary queue, runs its remaining time of time slice last allocated when it initiates an I/O

Process Model of VRR



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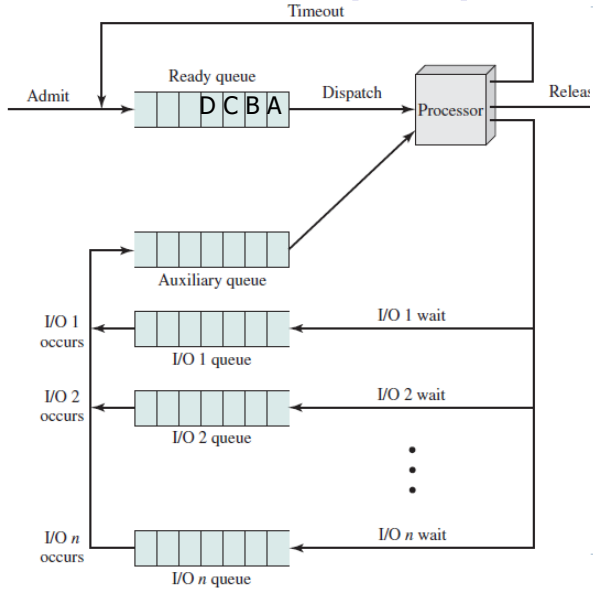
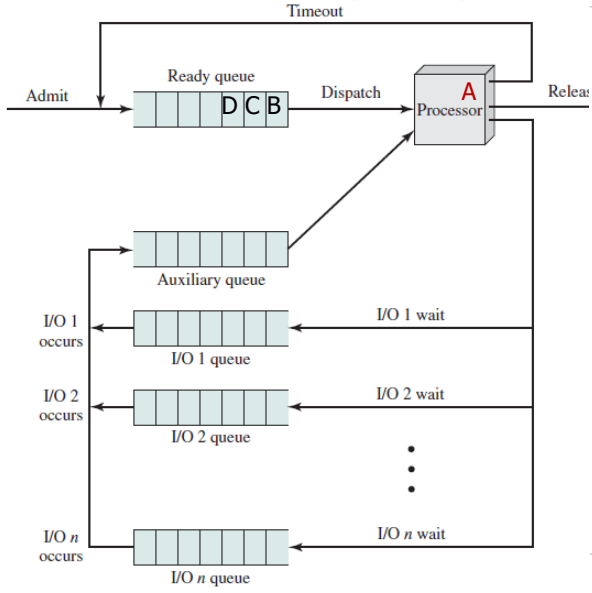
Virtual Round Robin (VRR)



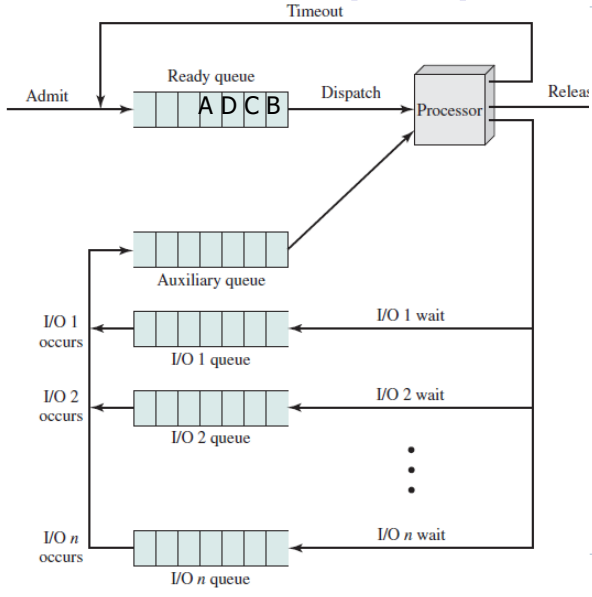
26

Virtual Round Robin (VRR)



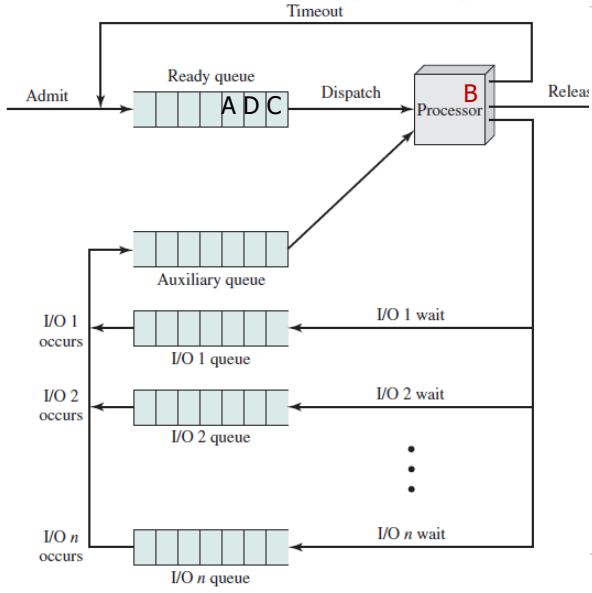
27

Virtual Round Robin (VRR)



28

Virtual Round Robin (VRR)



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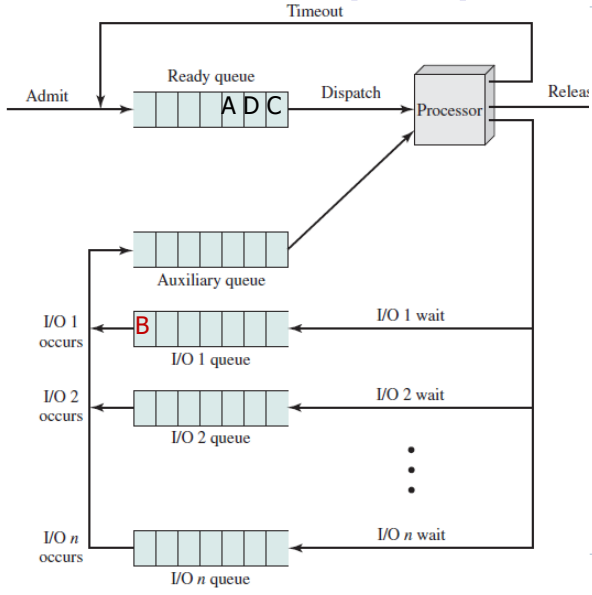
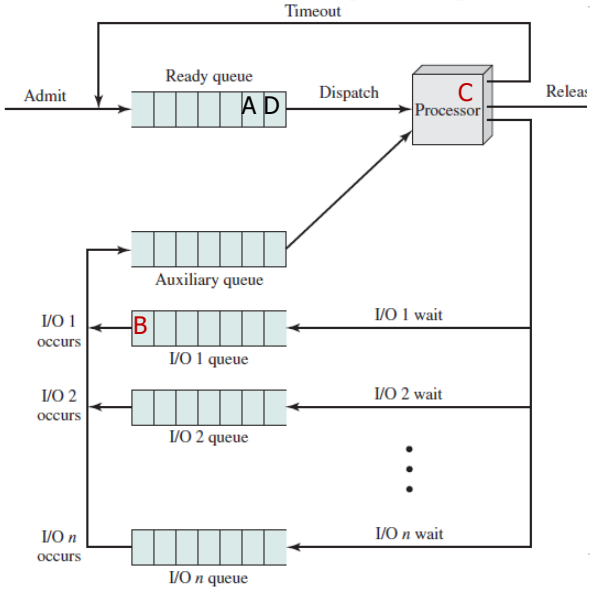
Virtual Round Robin (VRR)



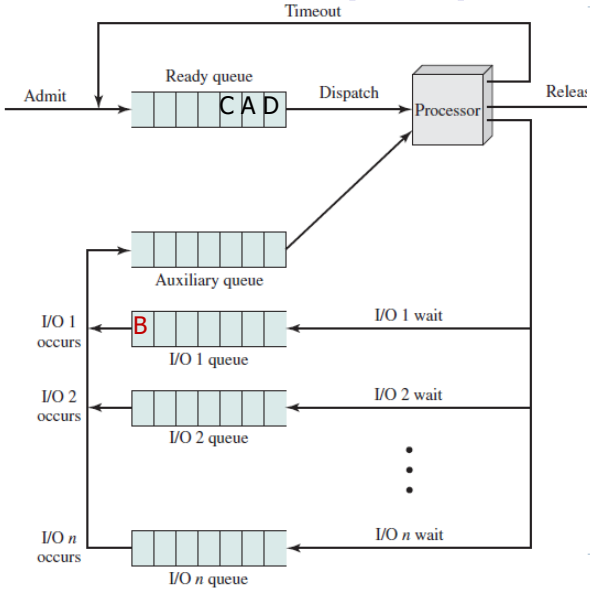
30

Virtual Round Robin (VRR)



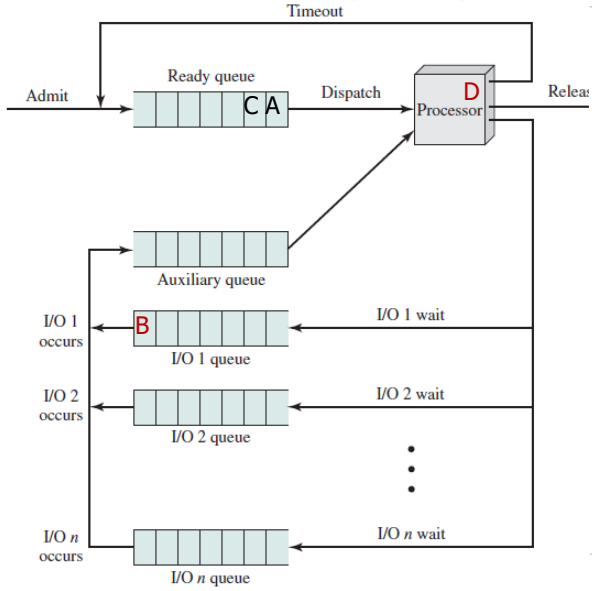
31

Virtual Round Robin (VRR)



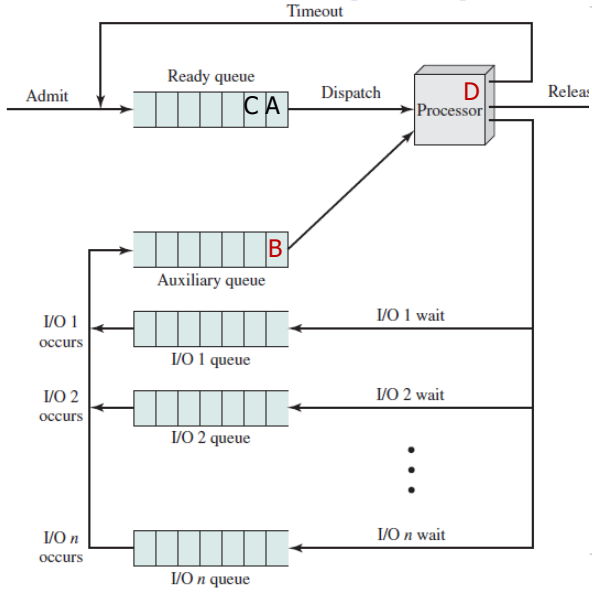
32

Virtual Round Robin (VRR)



33

Virtual Round Robin (VRR)



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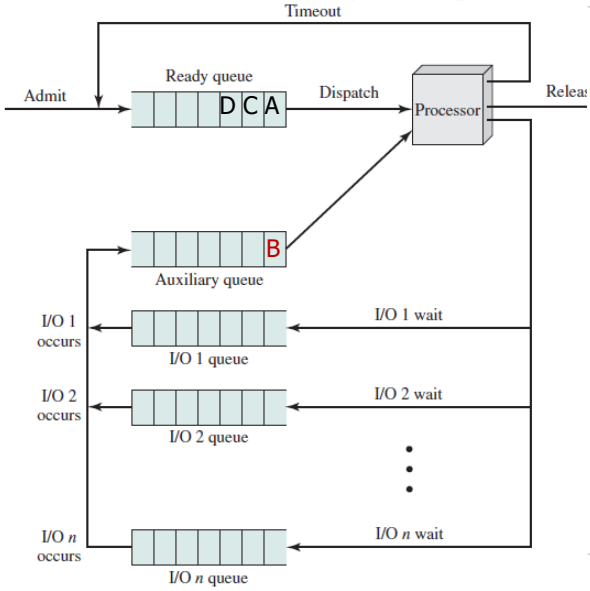
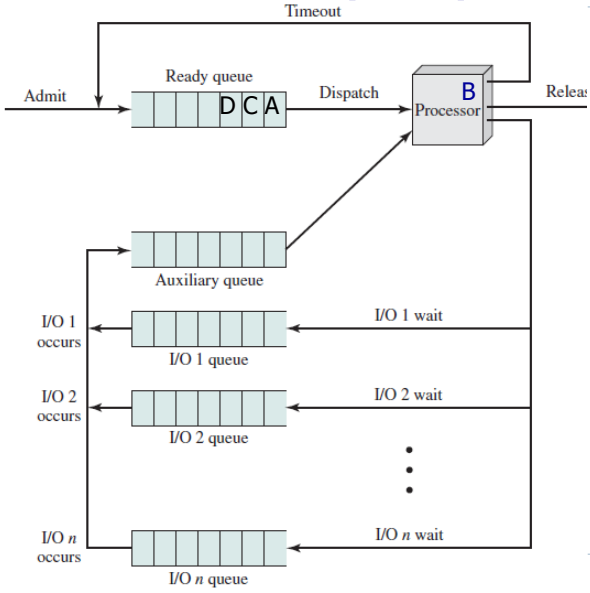
Virtual Round Robin (VRR)



35

Virtual Round Robin (VRR)



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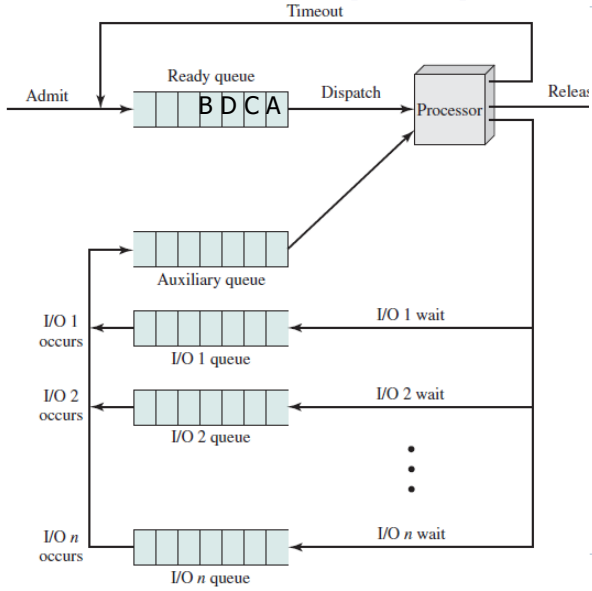
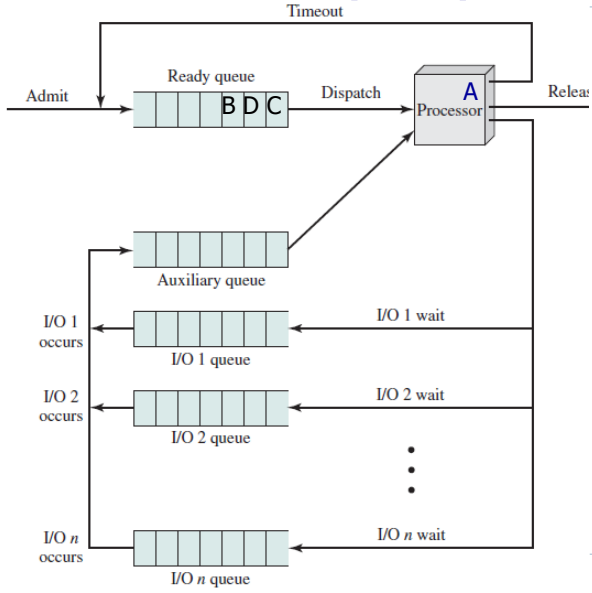
Virtual Round Robin (VRR)



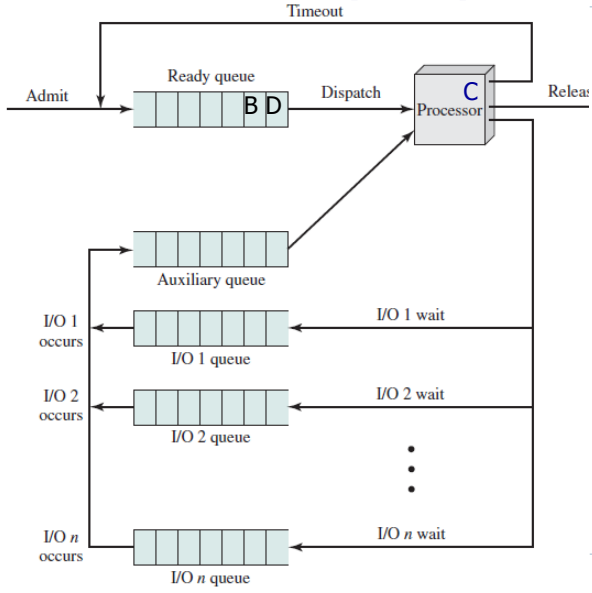
37

Virtual Round Robin (VRR)



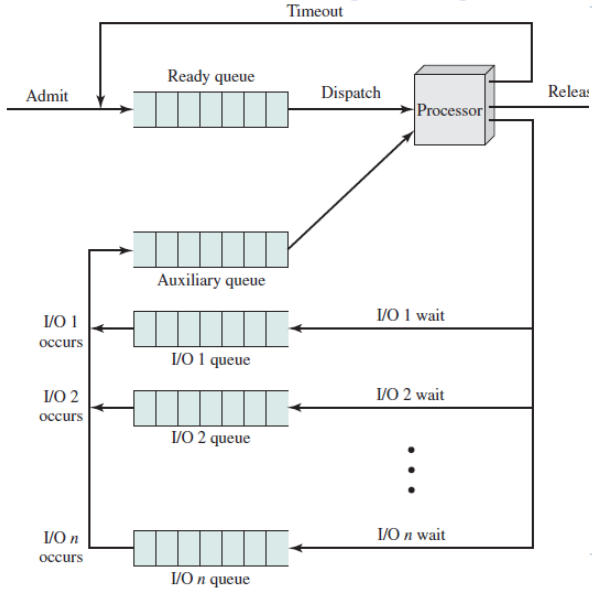
38

Virtual Round Robin (VRR)



39

Virtual Round Robin (VRR)



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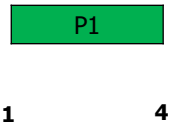
Virtual Round Robin

Ready	Running
P1(7)	-

Ready	Running
-	P1(7)
P2(4)	
P3(5)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	5

Time slot = 3 msec
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



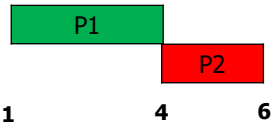
Virtual Round Robin

Ready	Running
P2(4)	-
P3(5)	
P1(4)	

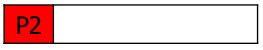
Ready	Running
P3(5)	P2(4)
P1(4)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	5

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



IO Blocked Queue



Virtual Round Robin

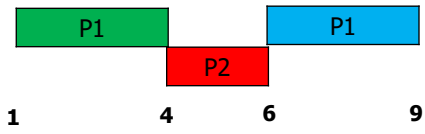
Ready	Running
P3(5)	-
P1(4)	

➡

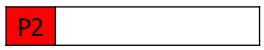
Ready	Running
P1(4)	P3(5)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	3
P3	3	5

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



IO Blocked Queue



11

43

43

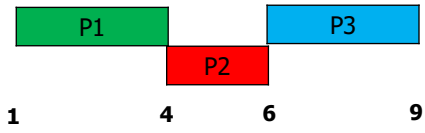
Virtual Round Robin

Ready	Running
P3(2)	P1(4)

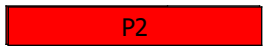
Auxiliary Ready
P2(2)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	5

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



IO Blocked Queue



11

44

44

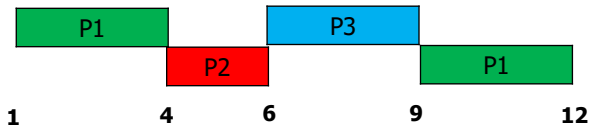
Virtual Round Robin

Ready	Running
P3(2)	P1(4)

Auxiliary Ready
P2(2)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	5

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



IO Blocked Queue

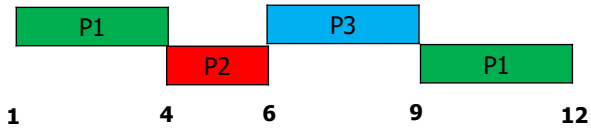
Virtual Round Robin

Ready	Running
P3(2)	-
P1(1)	

Auxiliary Ready
P2(2)

Process	Arrival Time	Burst Time
P1	1	7
P2	2	3
P3	3	5

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



IO Blocked Queue

Virtual Round Robin

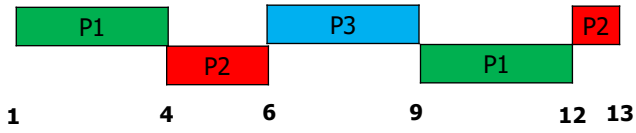
Ready	Running
P3(2)	P2(2)
P1(1)	

Ready	Running
P3(2)	-
P1(1)	
P2(1)	

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	5

Auxiliary Ready
-

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec



IO Blocked Queue

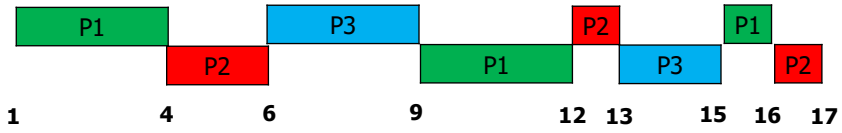
Virtual Round Robin

Ready	Running
-	-

Process	Arrival Time	Burst Time
P1	1	7
P2	2	4
P3	3	5

Auxiliary Ready
-

Time slot = 3 units
P2-IO bound
Initiates IO after 2msec CPU
IO takes 5 msec

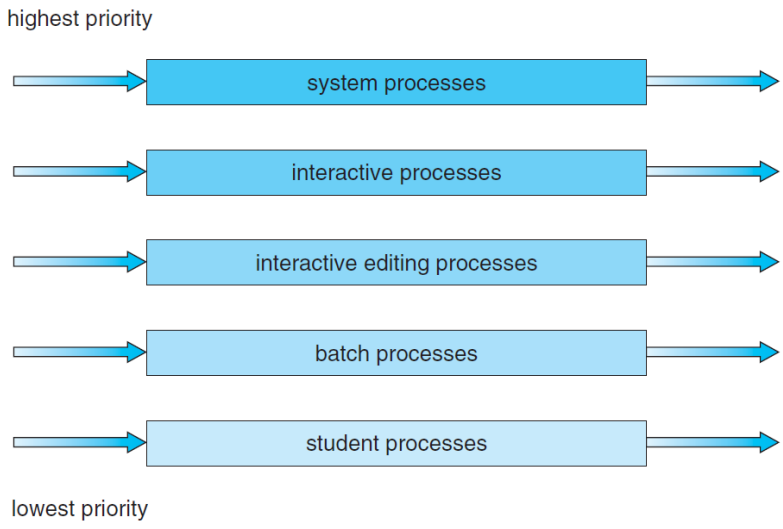


IO Blocked Queue

Multilevel Queue Scheduling

- Partitions ready queue into several separate queues
- Processes are permanently assigned to one queue
  - memory size, process priority, or process type
- Each queue has its own scheduling algorithm
  - foreground and background processes
  - foreground queue might be scheduled by RR
  - background queue is scheduled by FCFS
- Scheduling among the queues (fixed-priority preemptive scheduling)

Multilevel Queue Scheduling



Multilevel Queue Scheduling

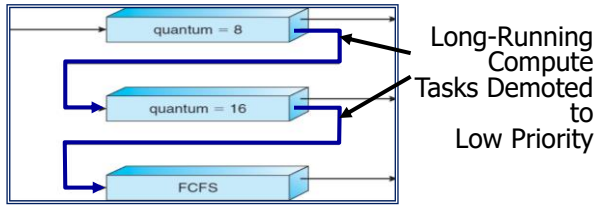
- Time-slicing among the queues
  - Each queue gets a certain portion of the CPU time
    - schedule among its various processes
  - foreground–background queue example
    - foreground queue with 80 percent of the CPU time for RR scheduling among its processes
    - background queue with 20 percent of the CPU to give to its processes on an FCFS basis

Multilevel Feedback Queue Scheduling

- Exploiting past behavior
- Multiple queues, each with different priority
- Allows a process to move between queues
- Idea is to separate processes according to the characteristics of their CPU bursts
- Each queue has its own scheduling algorithm
  - e.g. foreground – RR, background – FCFS
- Sometimes multiple RR priorities with quantum increasing exponentially (highest:4ms, next:8ms, next: 16ms, etc.)
  - A process uses too much CPU time → move to a lower-priority queue

Multilevel Feedback Queue Scheduling

- Job starts in highest priority queue
- If timeslot expires, drop one level
- If timeslot doesn't expire, push up one level (or to top)



Multilevel Feedback Queue Scheduling