CPU Scheduling

CS 447

Monday 3:30-5:00

Tuesday 2:00-3:30

Requirements of CPU Scheduling

- CPU and IO cycles
- Short vs. long tasks
- Real Time vs. non-real time tasks
- Preemption vs. no preemption
- Priorities of tasks
- Utilization of idle cycles

Performance measures

Required time

- Per process:
  - Waiting time
  - Turnaround time
  - Penalty ratio (1/Response ratio)
- System measures
  - Throughput
  - Average waiting time
  - Average Turnaround time
  - Average penalty ratio (Response ratio)

Performance measures

- Per process:
  - Required time 20 seconds
  - Waiting time 20 seconds
  - Turnaround time 40 seconds
  - Penalty ratio (1/Response ratio) 40/20 = 2
- System measures
  - Throughput k processes per min.
  - Average waiting time
  - Average Turnaround time
  - Average penalty ratio (Response ratio)

Scheduling Policies

- Non-preemptive policies
  - Once a process is scheduled, it remains scheduled till completion
- Preemptive policies
  - A scheduled process may be preempted and another may be scheduled

When is a scheduler invoked?

- Creation
- Completion
- Voluntary withdrawal
- Wait for a slower device
- Device Ready
- Policy dependent events

First come first served (FCFS)

Pid	CPU requirement
P1	25
P2	5
P3	10
P4	5

Schedule based on arrival time

Process executes till completion

FCFS Performance

Pid	Reqd. time	Waiting time	Turnaround time	Penalty Ratio = 1/Respons e ratio
P1	25	0	25	1
P2	5	25	30	6
P3	10	30	40	4
p4	5	40	45	9
averages		23.75		5

Throughput = 4/45 processes per unit time

FCFS on interactive processes

- When a process waits or blocks, it is removed from the queue and it queues up again in FCFS queue when it gets ready
- Ordering in queue may be different in second serve

Suitability and Drawbacks

- Simple to implement
- Starvation free
- Examples: printer queues, mail queues

- Response time
- Suffers from Convoy Effect

Shortest Job First (SJF)

Pid	CPU requirement
P1	25
P2	5
P3	10
P4	5

Schedule based on job size

Process executes till completion

SJF Performance

Pid	Reqd. time	Waiting time	Turnaround time	Penalty ratio
P1	25	20	45	1.8
P2	5	0	5	1
P3	10	10	20	2
p4	5	5	10	2
averages		8.75		1.7

Throughput = 4/45

Suitability and Drawbacks

- Optimal for average waiting time
- Favors shorter jobs against long jobs
- If newly arrived process are considered at every schedule point, starvation may occur
- May not be possible to know the exact size of a job before execution

Round Robin (RR)

Pid	CPU requirement
P1	25
P2	5
P3	10
P4	5

Schedule based on time slicing

RR Performance

Pid	Reqd. time	Waiting time	Turnaround time	penalty ratio
P1	25	20	45	1.8
P2	5	5	10	2
P3	10	20	30	3
p4	5	15	20	4
averages		15		2.7

Throughput =

Suitability and Drawbacks

- Somewhere between FCFS and SJF
- Guarantees response time
- But it involves context switching
  - Attempt must be made to minimize context switch time
- Process needing immediate responses have to wait for T*n-1 time units in worst case (calculate for 100 processes, 10 ms)

Preemptive Shortest Job First (SJF)

Pid	Arrival Time	CPU requirement
P1	0	10
P2	4	4
P3	8	12
P4	16	4

Schedule based on job size considering arrivals at arbitrary points

Preemptive SJF Performance

Pid	Reqd. time	Waiting time	Turnaround time	Response ratio
P1				
P2				
P3				
p4				
averages				

Throughput =

Suitability and Drawbacks

- SJF extended strictly considering arrivals at any point of time
- Optimal average waiting time in presence of dynamically arriving jobs
- The policy suffers from Starvation
- May not be possible to know the job size in advance → use prediction

Priority scheduling

Pid	Arrival Time	CPU requirement	Priority
P1	0	10	10
P2	4	4	12
P3	8	12	14
P4	12	4	12

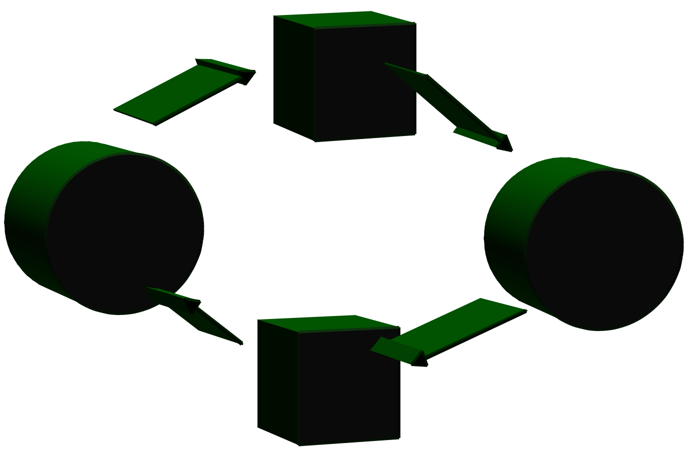
Schedule based on priority

Suitability and Drawbacks

- One can combine several parameters in one priority value
- Computing priority is a challenging task : fairness must be guaranteed to various kinds of processes
- Tunable priorities: also from user space
- Deadlocks may occur in certain situations
- Priority Inversion problem!

Construct a deadlock case?

- P1 (pri=10) arrives
- P1 executes
- P2 (pri=12) arrives
- P1 is stopped and P2 executes
- Busy wait for P1



Priority Inversion

P1 (pri=10)	P2 (pri=12)
1. Local computation 2. Wait till R is locked 3. Operations on R 4. Release R 5. Local computation	1. Local computation 2. Wait till R is locked 3. Operations on R 4. Release R 5. Local computation

Consider following case:

- P3 arrives with priority=11
- P3 does not need resource R

Point out Case of priority inversion in above example?

Solution?

Solution: Priority inheritance

- Raise the priority of P1 to that of P2 till it finishes with the resource needed by P2

Predictive SJF

- Traditional UNIX scheduler uses:
  - Priority = seed priority + (Estimate/4) + 2*nice priority
  - Lower the value, higher the priority
  - Seed priority: fixed at say 50
  - Every 10 ms: estimate of running process is incremented by 1
  - Estimate is reduced by a decay factor after every second (df of say 0.5)

For a process P1:

Real time (sec)	0	1	2	3	4	5
System clock ticks	0	100	200	300	400	500
Estimate	0	50	75	87.5	93.75	96.875
priority	50	62.5	68..	71…	73..	74..

Estimate

- Estimate = ½ (CPU usage over last 1 second+Last estimate)
- $E_n = \frac{1}{2}(U_n + E_{n-1})$
- $E_1 = \frac{1}{2}(U_1 + E_0)$
- $E_2 = \frac{1}{2}(U_2 + E_1)$
- $E_2 = \frac{1}{2} U_2 + \frac{1}{4} U_1 + \frac{1}{4} E_0$
- $E_3 = \frac{1}{2} U_3 + \frac{1}{4} U_2 + 1/8\ U_1 + 1/8\ E_0$

Predictive SJF

$T_{n+1} = x\, T_n + (1-x)\, T_{n-1}$

$0 <= x <= 1$

Multilevel feedback queues of unix

The data structure

4.4 BSD

- Decay factor = 2 * load / (2 * load +1)
- 0-127 priority levels
- 50-127 user mode
- 32 run queues
- Queue no = priority /4

4.4 BSD

- Sleeping process:
  - P_sleeptime is set to 0
  - Incremented every second
  - Estimate =
    - decay factor $^{p\_sleeptime}$ * estimate
    - Ignore nice priority

4.4 BSD

- Recompute priorities per second
- Round robin time slice 10 times per second
- Process in highest priority queue runs
- Hardclock() : 10ms