CS & IT ENGINEERING

Operating Systems

Memory Management

Lecture No. 10

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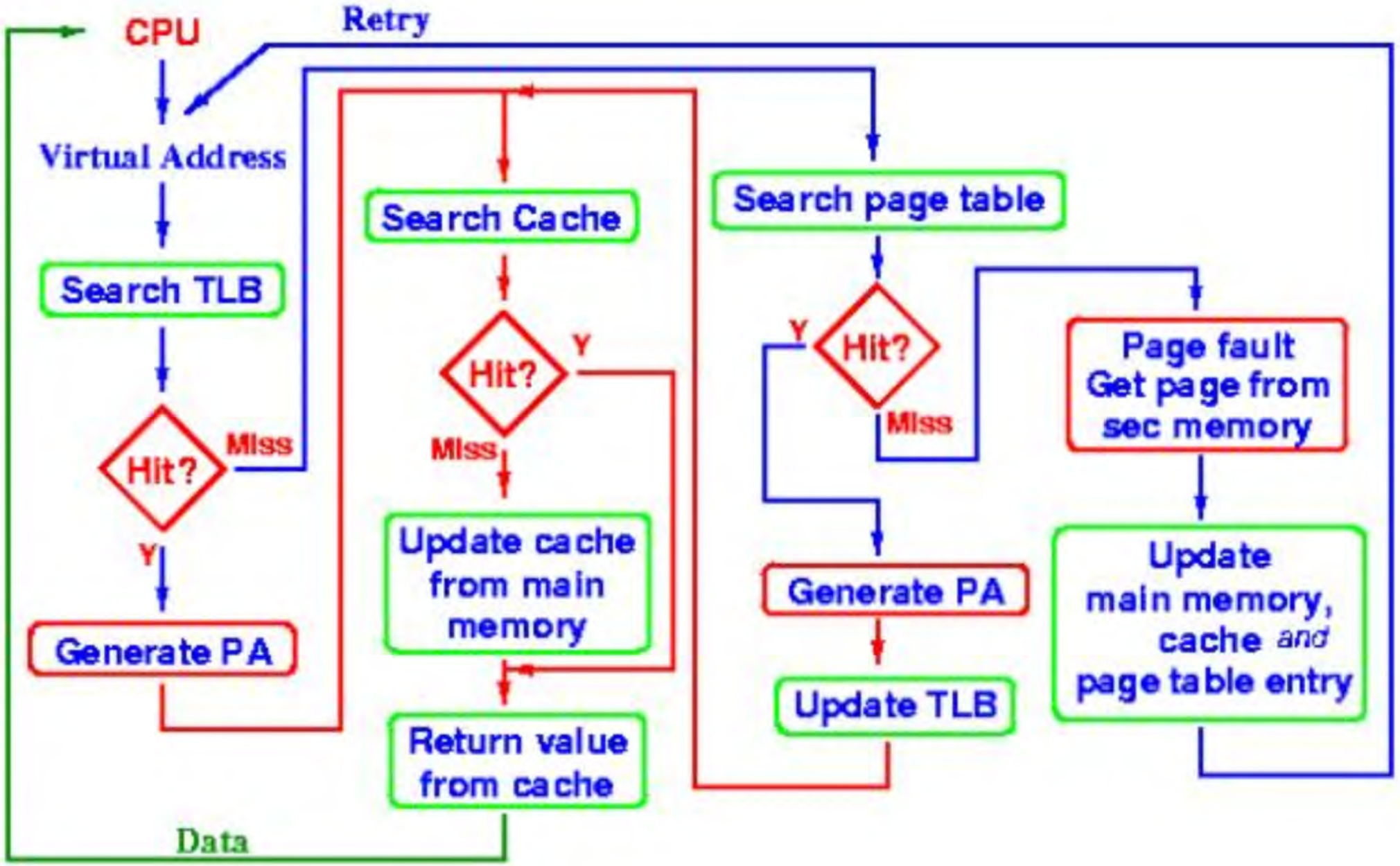
- Performance of Virtual Memory
- Page Replacement
- Problem Solving


CPU
Retry
Virtual Address
Search TLB
Hit?
Miss
Y
Generate PA
Search Cache
Hit?
Y
Miss
Update cache from main memory
Return value from cache
Search page table
Hit?
Y
Miss
Generate PA
Update TLB
Page fault Get page from sec memory
Update main memory, cache and page table entry
Data

Q. Suppose the time to service a Page fault is on the average 10 milliseconds, while a Memory Access takes 1 microsecond. Then a 99.99% Hit ratio results in Average Memory Access Time of _____.

$$EMAT = (1-P)m + P * \delta$$

a) 1.99 ms
b) 1.999 μs
c) 1.9999 μs

$MMAT = 1\ \mu s$

$PFST(\delta) = 10\ ms$

(Very High) $1-P = 99.99\%$ (0.9999)

$P = 0.01\%$ $= (0.0001)$

$1-P = 90\%$
$P = 10\%$
?

$= 0.9999 \times 1 \times 10^{-6}\ \delta + \frac{0.0001 \times 10 \times 10^{-3}\ \delta}{10^{-4} \times 10 \times 10^{-3}}$

$= 0.9999 \times 10^{-6} + 1 \times 10^{-6}$

$= \boxed{1.9999\ \mu s} \sim 2\ \mu s$

Q. If an Instruction takes 'i' microseconds and a Page Fault takes an additional 'j' microseconds, the Effective Instruction Time if on the average a page fault occurs every 'k' instructions is _____.

→ Instn time without P.F : 'i' μs

→ " " with P.F : 'i+j' μs

→ $P = 1/k$

→ $(1-P) = \left(1-\frac{1}{k}\right)$

Eff. Instn time: $\frac{1}{k}(i+j) + \left(1-\frac{1}{k}\right) i$

$= \frac{i}{k} + \frac{j}{k} + i - \frac{i}{k}$

$= \left(i + j/k\right)$ ✓

Q. (*)

Assume that we have a Demand-Paged memory. It takes 8 milliseconds to service a page fault if an empty frame is available or if the replaced page is not modified, and 20 milliseconds if the replaced page is modified. Memory-access time is 100 nanoseconds. Assume that the page to be replaced is modified 70 percent of the time. What is the acceptable page-fault rate for an effective access time of no more than 2000 nanoseconds?

8 (ms) : E.F + clean Page (30%) : 1 disk access

20 ms : Dirty Page / Modified (70%) : 2 disk access

EMAT = P * 8 + (1-P) m

m = 100 ns

P = ?

EMAT = 2000 ns

$$2000\,ns = (1-P) * 100\,ns + P * (0.7 * 20\,ms + 0.3 * 8\,ms)$$

P = ~ 0.01 %

Q.

PYQ

Consider a process executing on an operating system that uses demand paging. The average time for a memory access in the system is M units if the Corresponding memory page is available in memory, and D units if the memory Access causes a page fault. It has been experimentally measured that the average Time taken for a memory access in the process is X units. Which one of the Following is the correct expression for the page fault rate experienced by the Process?

A. (D – M)/(X – M)

B. (X – M)/(D – M) ✓

C. (D – X)/(D – M)

D. (X – M)/(D – X)

m = M

x = D

EMAT (Avg. Time) = X

P = ?

$X = (1-P)M + P*D$

P =

Q.

Consider a paging system that uses 1-level page table residing in main memory and a TLB for address translation. Each main memory access takes 100 ns and TLB lookup takes 20ns. Each page transfer to/ from the disk takes 5000 ns. Assume that the TLB hit ratio is 95%, page fault rate is 10%. Assume that for 20% of the total page faults, a dirty page has to be written back to disk before the required page is read in from disk. TLB update time is negligible. The average memory access time in ns (round off to 1 decimal places) is _____.

* NAT
VM + TLB

m → 100 ns
c → 20 ns
Disk R/W → 5000 ns
TLB Hit rate = 95%
Page fault rate = 10%
80% clean Page : $\frac{5000}{1-\text{disk}(R)}$
20% dirty Page : $\frac{}{2-\text{disk}}$

$$EMAT = 0.95\left[\frac{c}{20ns} + \frac{m}{100ns}\right] + 0.05\left[\frac{c}{20ns} + 0.9\left(100ns + 100ns\right) + 0.1\left[100ns + 0.2*\left(\overline{5000ns + 5000ns}\right) + 0.8*\left(5000ns\right)\right]\right]$$

TLB Hit

$= 154.5 \sim 155$

TLB Miss

Page hit

PTBAT

Content

Dirty

Page fault

PTBAT

clean

2) Page Replacement : one Imp. Component of V.M Implement

a) Reference String (Page-Ref String) : < Set of successively unique Pages (Page No's) referred in the given list of V.A's >

l=10; n=6

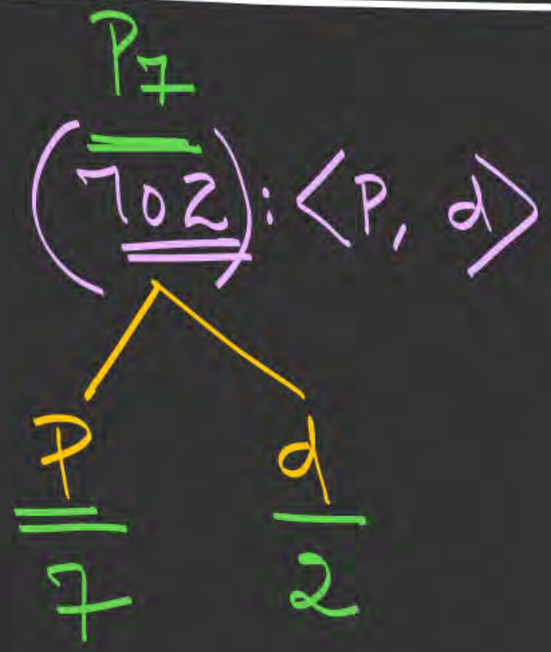
$\equiv$ <7 ; 1 ; 6 ; 4 ; 0 ; 1 ; 7 ; 9 ; 6 ; 7>

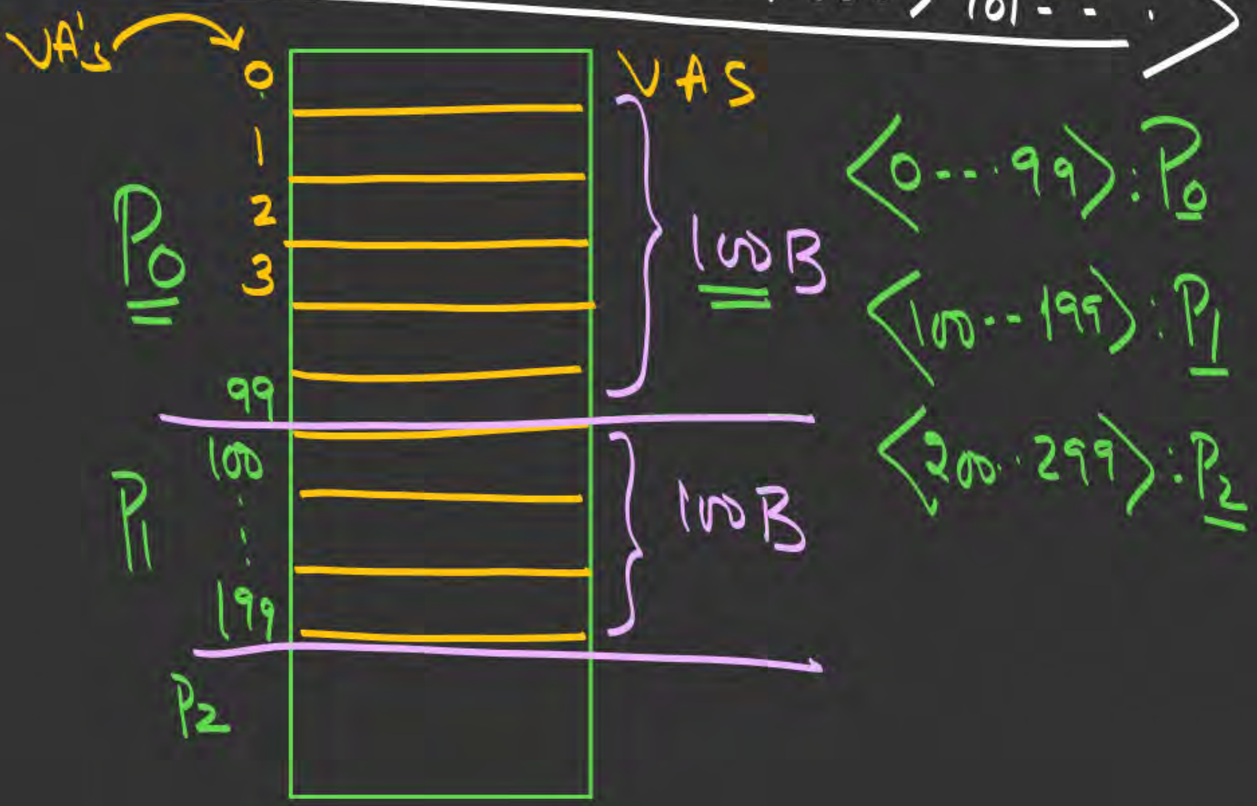
P_{ri} : <702 ; 704 ; 123 ; 654 ; 483 ; 012 ; 122 ; 124 ; 180 ; 785 ; 934 ; 655 ; 701 - - - >

Let P.S = (100B)

$$P = \frac{VA}{PS}$$

$$d = VA \% PS$$





PS = 50B

P.S = 100B

P.S = 200B

V.A's : < 654; 203; 122; 608; 706; 205; 986; 555; 486; 402; ... >

Ref. String : < 6; 2; 1; 6; 7; 2; 9; 5; 4 >

Length 'l' = 9

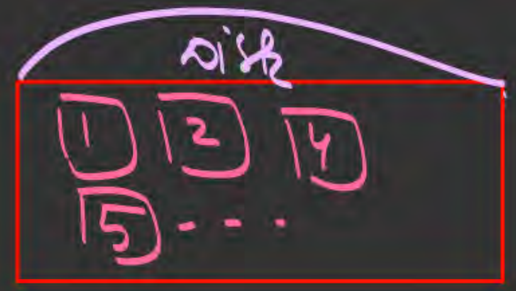
No. of unique Pages 'n' in Ref. String = 7

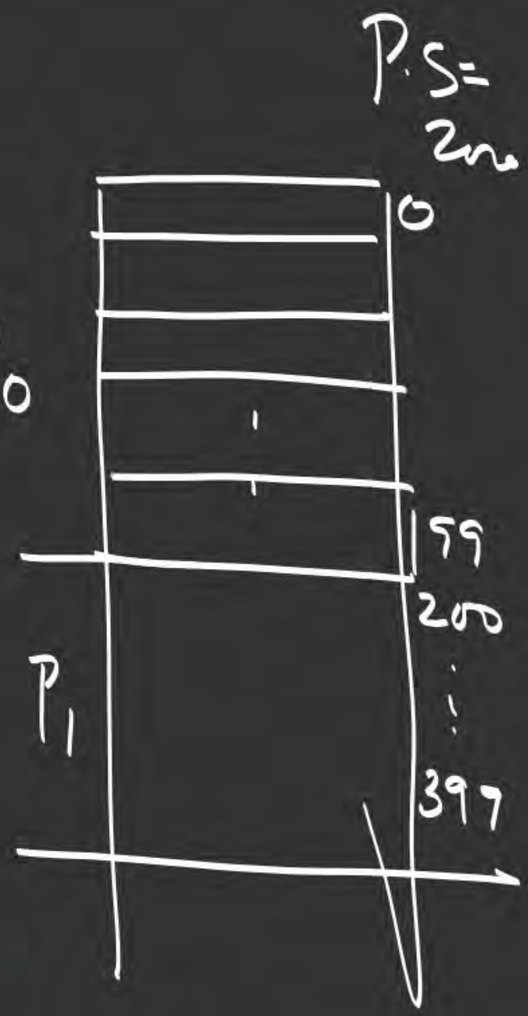
< 1, 2, 4, 5, 6, 7, 9 >

$P = \frac{654}{200} = 3$

d = 54

~ (Size of Process in No. of Pages)





b) (Frame Allocation Policies)

$a_i = \left(\frac{s_i}{D}\right) * m$

→ n : no of Processes $(P_1 \ldots P_n)$

→ s_i : demand (frames) of Proces P_i

→ D : Total demand $= \sum_{i=1}^{n} s_i$

→ M : Available frames

→ a_i : Allocated frames to P_i $[a_i \leq s_i]$

$n = 5$; $\langle P_1 \ldots P_5 \rangle$; $M = 40$

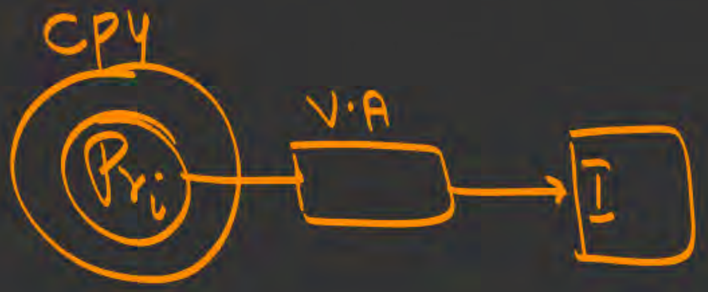
P_i	demand s_i	1) Equal Alloc $a_i = \frac{M}{n}$	2) Proportionate Alloc $a_i = (s_i/D)\,M$	3) 50% rule $a_i = s_i/2$
P_1	10	8	5	
P_2	5	8	3	
P_3	35	8	17	
P_4	18	8	9	
P_5	12	8	6	

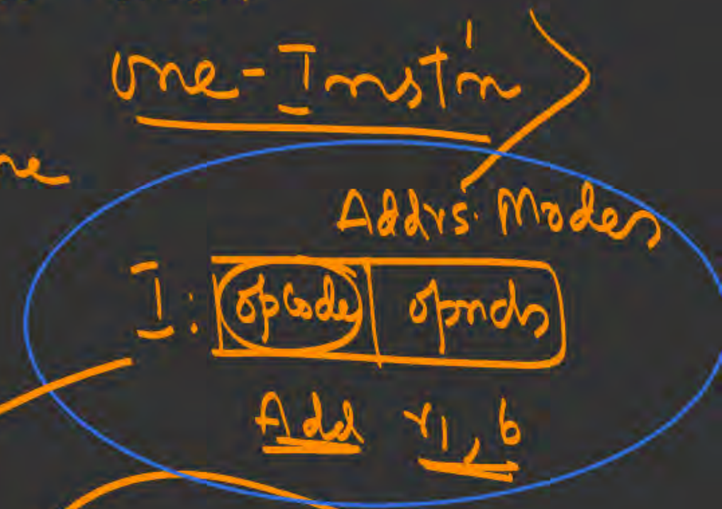
$D = 80$

Min. No. of frames to be alloc. to a Process

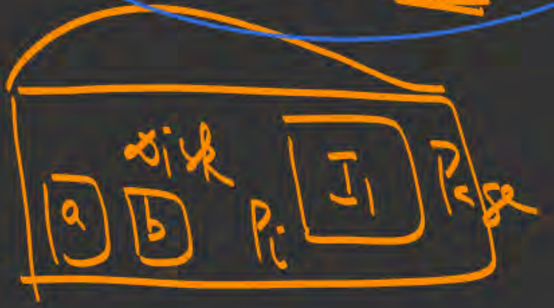
< Process cannot execute without this Min # of frames >

< Process should be able to execute min one-Instn





Instn Architecture



Q. The minimum number of page frames that must be allocated to a running process in a virtual memory environment is determined by

A. The Instruction set Architecture ✓

B. Page size ✗

C. Physical memory size ✗

D. Number of processes in memory ✗

Page Replacement Techniques

$l = 20$;
$n = 6$;

1. Ref. String: < 7 ; 0 ; 1 ; 2 ; 0 ; 3 ; 0 ; 4 ; 2 ; 3 ; 0 ; 3 ; 2 ; 1 ; 2 ; 0 ; 1 ; 7 ; 0 ; 1 >

P.D.P

(i) FIFO: → 4 Frames = ? (H/W)

Criteria: T.o.L

7	2	2	2	4	4	4	0	0	0	7	7	7
0	0	3	3	3	2	2	2	1	1	1	0	0
1	1	1	0	0	0	3	3	3	2	2	2	1

3 Frames: 15

frames

$P = \frac{15}{20} = \frac{3}{4} = 75\%$

4 frames:

THANK YOU!