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Computer Organization and Architecture

Virtual memory part-1

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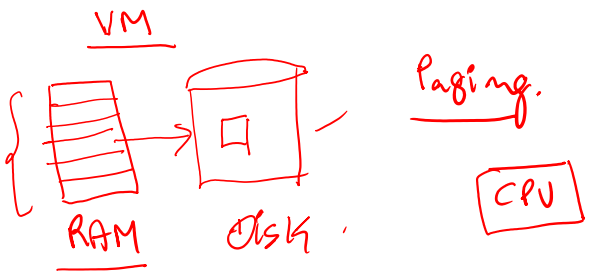
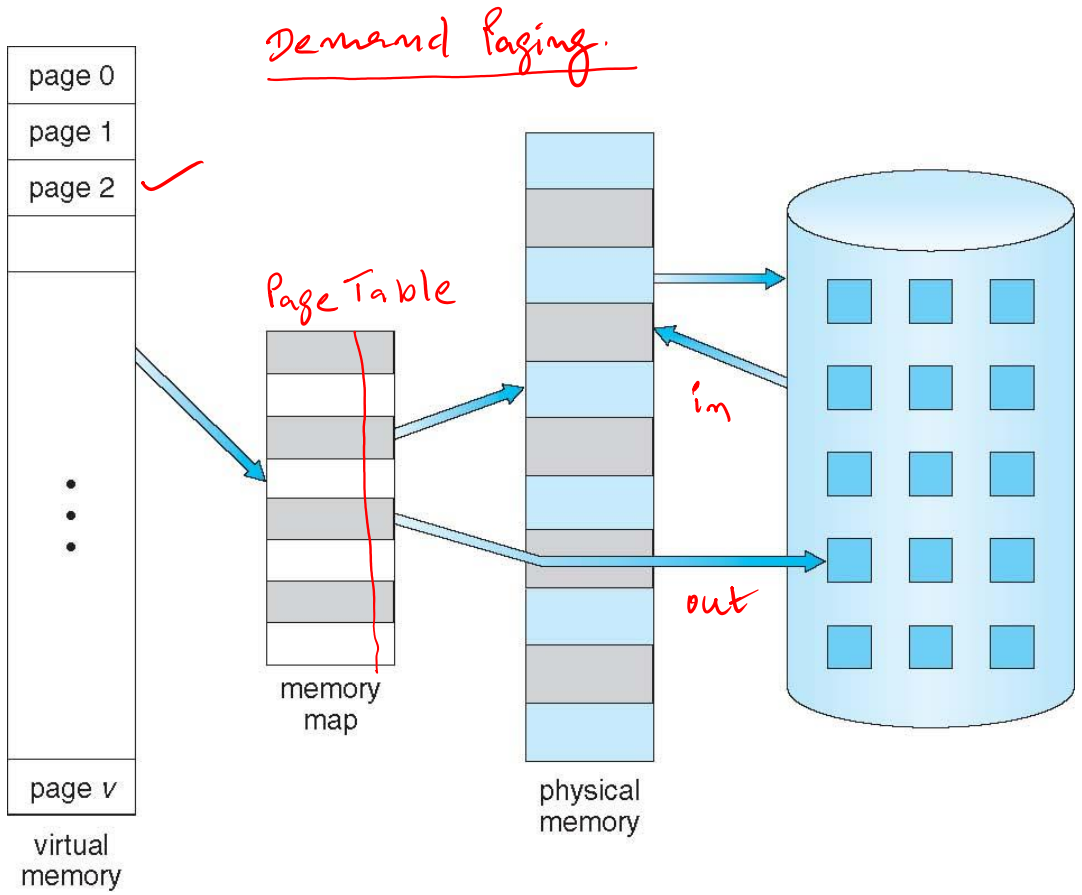
- MTech with 20 years of Experience in Teaching GATE and Engineering colleges
- IIT NPTEL Course topper in Theory of computation with 96 %
- IGIP Certified (Certification on International Engineering educator)
- GATE Qualified
- Trained more than 50 Thousand students across the country
- Area of Expertise : TOC,OS,COA,CN,DLD

Virtual memory part-1



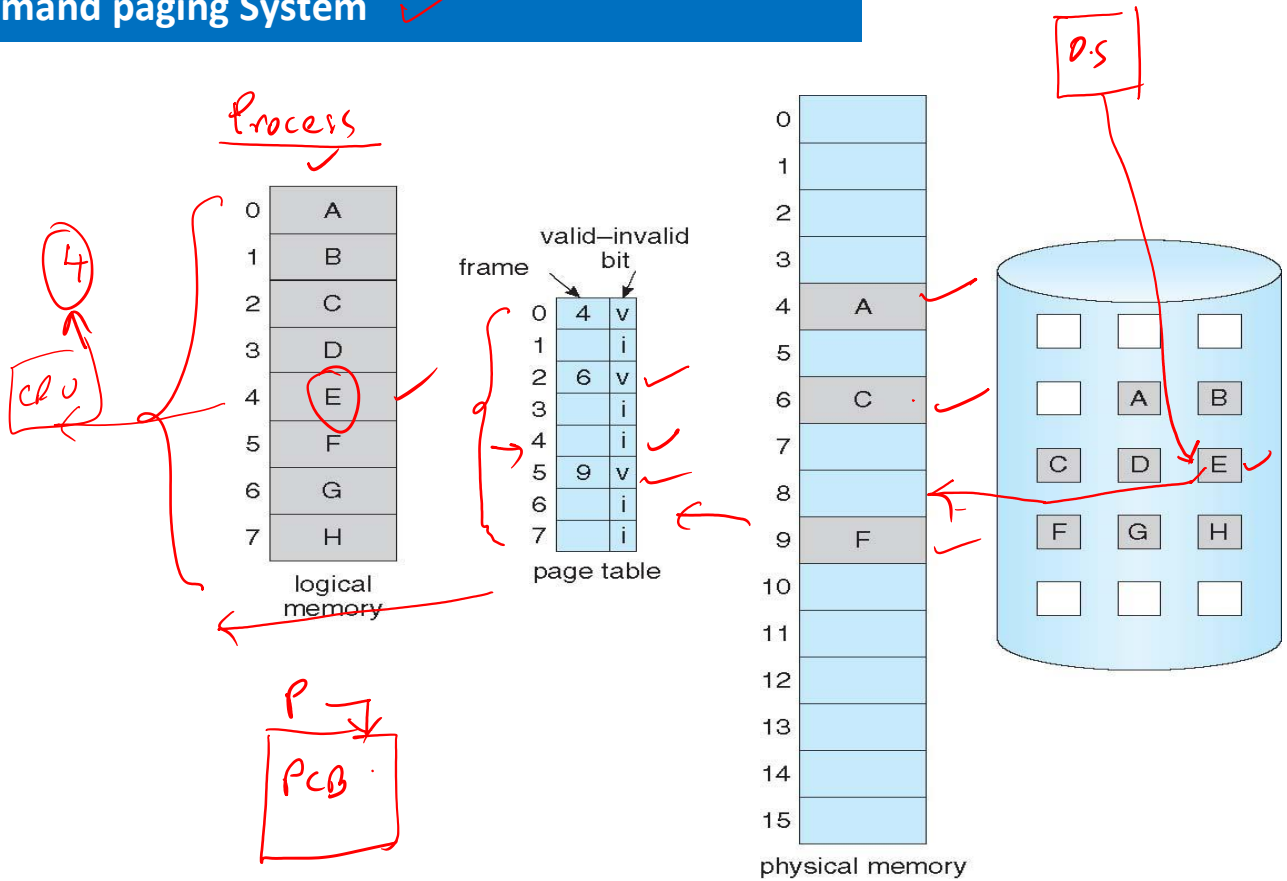


Virtual memory part-1

Demand paging System

P → (A, B ---- H)
8 Pages

Page fault Service time



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Performance of Demand Paging System

(ma) memory Access time

Effective memory Access time

$= (1-p)\,ma + p \times$ Page fault Service time

p = Probability of Page fault.

$(0 \le p \le 1)$

p = 1 Page fault for every 10^4 references

Example :— ma = 200 n.s

Page fault service takes 10 msec.

what is EMT in n.s ?

Sol :— $EMT = \left(1 - \frac{1}{10^4}\right) 200 + \frac{1}{10^4} \times 10 \times 10^6$ $\quad p = \frac{1}{10^4} = 0.0001$

$\left(1 - \frac{1}{10^4}\right) 200 + 1000$

$= 1200$ n.s

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Examples :

$p = \frac{1}{10^6}$

PST = 100 milli seconds

ma = 10 μseconds

→ memory Access takes 10 μsec. and page faults are occured 1 in every 10^6 references. If the Page fault service takes 100. miliseconds then what is the effective memory access time in Microseconds for this demand paging system?

Sol :- $EMT = \left(1 - \frac{1}{10^6}\right) 10 + \frac{1}{10^6} \times 100 \times 10^3$ μsec.

$= 10 + \frac{1}{10}$ μsec

$= 10.1$ μsec ✓

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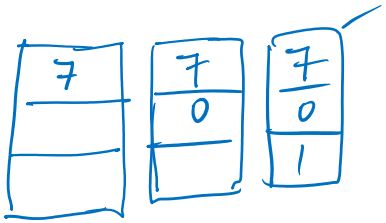
Pure Demand Paging System



→ Initially Memory will be empty.

None of the pages of the Process are loaded into memory initially.

7, 0, 1, 7, 1, 0, - - -

Process Execution starts with initial page fault only.

Normal Demand Paging

Few pages of the Process are loaded onto memory to begin with.

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Page Replacement

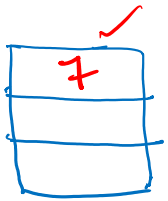
Page Replacement is needed to Provide a roomy for faulted page.
using Replacement strategy, we select a victim page for the replacement.

P[Page Table]

Algorithms

(1) FIFO :- First in First out
(2) Optimal :-
(3) LRU [Least Recently used]

FIFO : 7, 0, 1, 2, 3, 0, 1, 7, 6, 5, 1, 2, 4, 2, 7, 0, 1



7	7	2	2	2	1	1	1	5	5	5	4	4	4	1
0	0	0	3	3	3	7	7	7	1	1	2	7	7	7
	1	1	1	0	0	0	6	6	6	2	2	2	0	0

16 Faults

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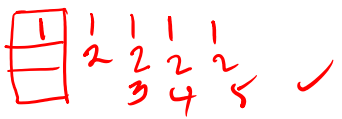
MRU

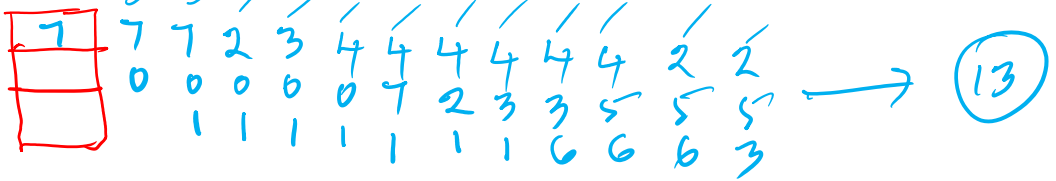
1, 2, 3, 4, 5, 1, 2



Optimal Page Replacement Algorithm

→ Replace the Page that will not be used for the longest Period of time in future.

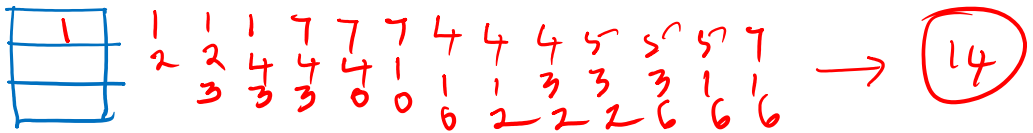
7, 0, 1, 2, 3, 4, 1, 0, 7, 2, 3, 4, 1, 6, 5, 6, 4, 2, 3



→ 13

LRU :— Replace the Page that has not been used from the longest Period of time

1, 2, 1, 3, 4, 7, 0, 1, 4, 2, 3, 5, 6, 1, 7



→ 14

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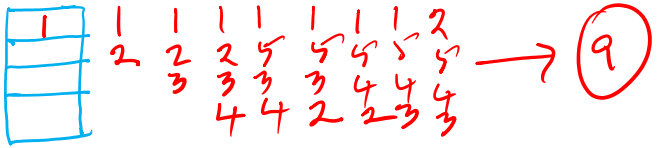
LRU, FIFO, Optimal

LRU



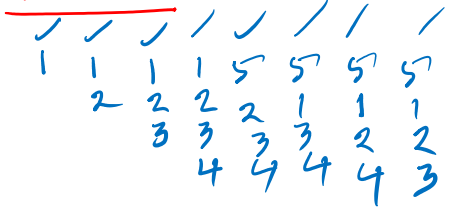
→ 9

→The following page addresses , in the given sequence , were generated by a program:

1, 2, 3, 4, 1, 3, 5, 2, 1, 5, 4, 3, 2, 3.

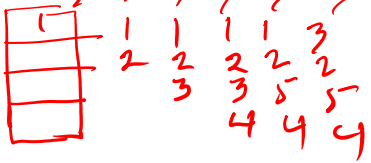
Find the number of page faults for the LRU , FIFO and OPTIMAL page replacement respectively ? (assume there were four page frames initially empty).

FIFO



→ 8 Faults

optimal



→ 6

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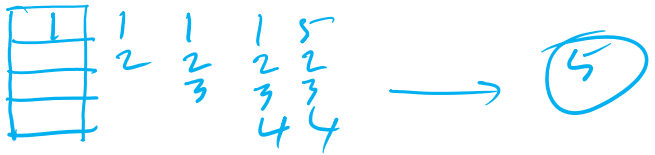
Examples:

Belady's Anamoly :— If No. of Page frames are increased, then Page faults must be reduced, But in Some Cases of FIFO Replacement, Belady found that when frames are increased, Page faults were also increased.

Example :— 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5



No Anamoly

Virtual memory part-1

4 Frames

100 distinct Pages

→A System uses FIFO policy for page replacement. It has 4 page frames with no pages loaded to begin with. The system first accesses 100 distinct pages in some order and then accesses the same 100 pages but now in reverse order. How many page faults will occur ?

A)196

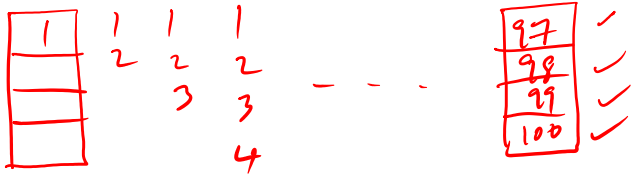
B) 192

C)197

D)195

1 2 3 4 5 ---- 97 98 99 100 , 100, 99, 98 ... 1

96 ---- 1



100 + 96 = 196

Virtual memory part-1

Avg. Mem. Access = X units

ma = M units

P.S.T = D units.

P = ?

→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 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)

$X = (1-P)M + P \times D$

$X = M - MP + PD$

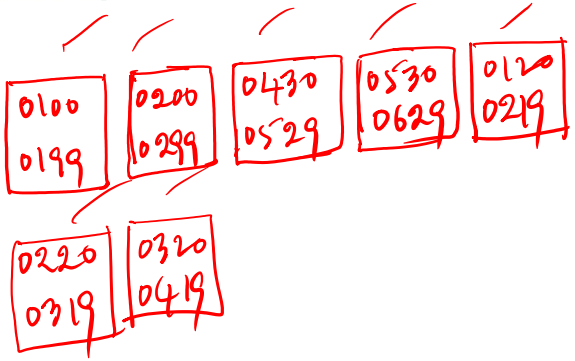
$X = M + PD - MP$

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

$X - M = P(D-M)$

$P = \frac{(X-M)}{D-M}$

Virtual memory part-1



→The address sequence generated by tracing a particular program executing in a pure demand paging system with 100 bytes per page is

0100, 0200, 0430, 0499, 0510, 0530, 0560, 0120, 0220, 0240, 0260, 0320, 0410.

Suppose that memory can store only one page and if x is the address which causes a page fault then from addresses x to x+99 are loaded on to the memory. How many page faults will occur ?

(A) 0 (B) 4 (C) 7 (D) 8

Virtual memory part-1

Logical Address
Virtual Address

(0 to 15) – 0, (16 to 31) – 1
(32-47) – 2, (48-63) – 3
(64-79) – 4, (80-95) – 5

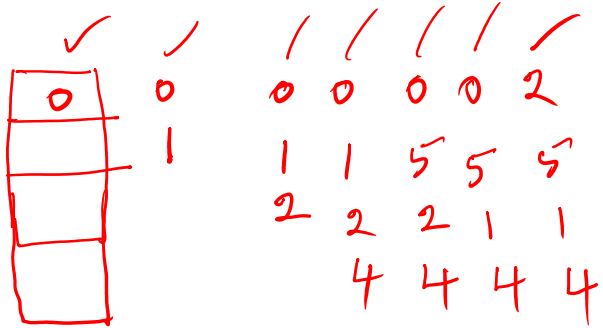
→ Assume that a main memory with only 4 pages ,each with 16 bytes is initially empty. The CPU generates the following sequence of virtual addresses and uses the Least Recently Used (LRU) page replacement policy.

0, 4, 8, 20, 24, 36, 44, 12, 68, 72, 80, 84, 28, 32, 88, 92

0 x x 1 2 0 4 5 1 2 5

How many page faults does this sequence cause ? What are the page numbers of the pages present in the main memory at the end of the sequence ?

A) 6 and 1, 2, 3, 4
B) 7 and 1, 2, 4, 5
C) 8 and 1, 2, 4, 5
D) 9 and 1, 2, 3, 5



7 (1, 2, 4, 5)

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→ Consider the following Page reference string.

1, 2, 3, 4, 1, 5, 2, 1, 2, 3, 6, 4, 1, 9, 3

Assume that memory has 3 page frames, which are initially empty. Find the no. of page faults in each of ~~the~~ following algorithms ?

(1) FIFO

(2) Optimal

(3) LRU

(4) MRU.