CS & IT ENGINEERING

Operating System

Virtual Memory

Lecture No. 01

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Recap of Previous Lecture

Topic TLB Mapping

Topic Segmentation

Topics to be Covered

Topic Virtual Memory

Topic Demand Paging

Topic Page Fault

Topic : Virtual Memory

- Feature of OS
- Enables to run larger process with smaller available memory

Topic : Virtual Memory

```
int x ;
printf("%d", x);
```

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

000	
001	
010	
011	
100	
101	
110	
111	

00	
01	
10	
11	

Topic : Virtual Memory

Process

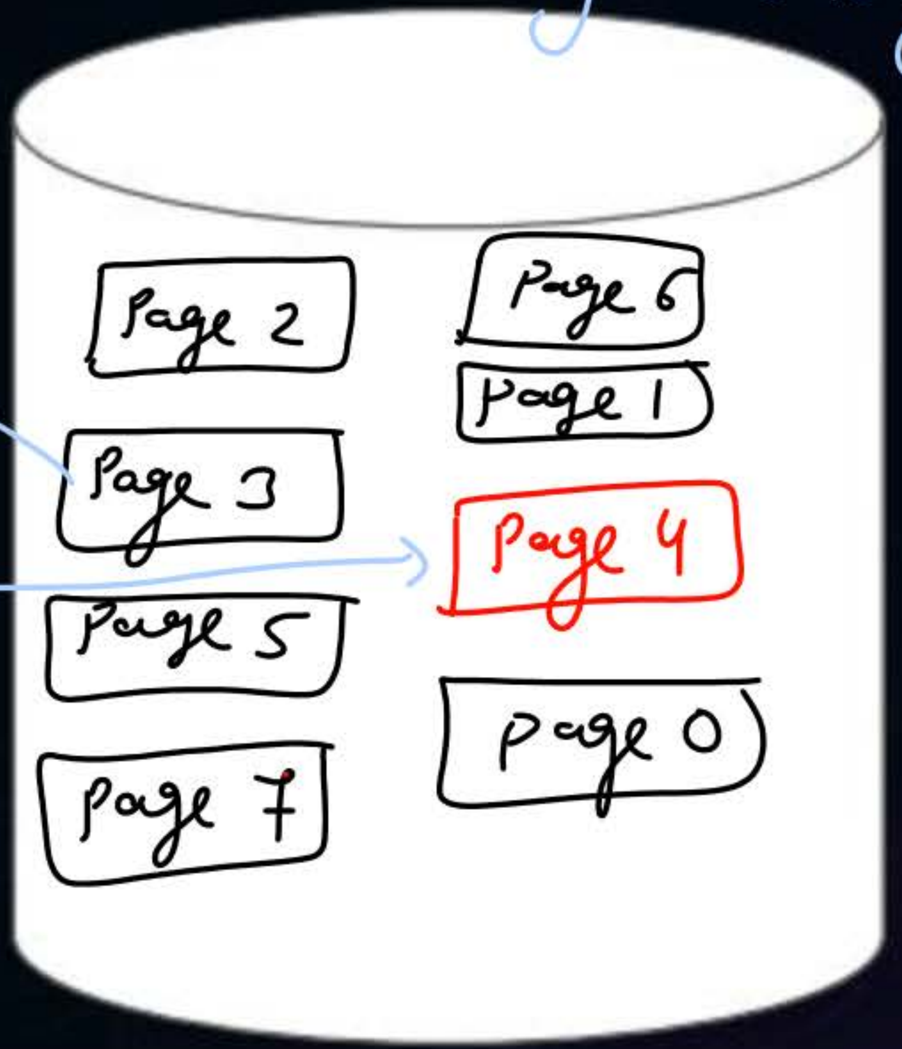
Page 0
Page 1
Page 2
Page 3
Page 4
Page 5
Page 6
Page 7

000	11
001	10
010	–
011	01
100	~~01~~
101	–
110	00
111	–

Main mem.

00	Page 6
01	Page ~~4~~ 3
10	Page 1
11	Page 0

Secondary memory



example 1 :-

CPU generates logical address (virtual add.)

p	d
1	✓

→ search in P.T. for P=1 $\Rightarrow f = 2$

Page hit

$\Downarrow$

goto

f	d

physical add.

ex 2 :-

CPU generates L.A.

P = 3	d

→ goto P.T. & search for P = 3 } ⇒ Page fault ⇒ OS does page fault service

After service, the instruction which raised page fault will restart.

⇓

Brings faulted page from secondary memory to main memory.
(A page is replaced if needed)
and update page table

Topic : Demand Paging

- **Demand Paging:**

  Bring pages in memory when CPU demands

- **Page Fault:**

  When the demanded page is not available in physical memory

- Page fault service time :-

  Time needed to service a page fault, after page fault is raised.

- Page fault rate :-

  fraction of time page fault occurs.

Pure demand paging :-

when a process arrives, none of it's pages are brought into main memory. and pages are brought into m.m. on demand.

Demand Paging :-

when a process arrives, a few initial pages are brought to main memory and rest are brought on demand.

Topic : How to Check Page Hit/Fault

using valid / invalid bit → 0 invalid
→ 1 valid

	V/I	f
000	1	11
001	1	10
010	0	
011	~~0~~ 1	01
100	~~1~~ 0	01
101	0	
110	1	00
111	0	

CPU generates L.A.

p	d
3	

goto P.T. at P = 3 & check V/I bit

⇓

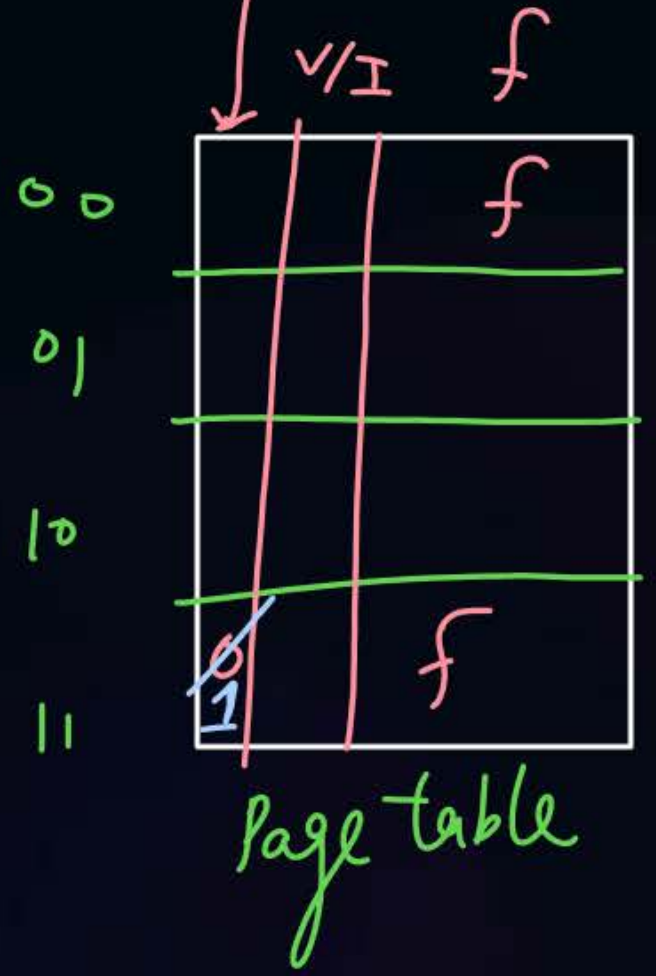
V/I bit = 0

⇓

Page fault ⇒ after service of page fault V/I bit of page 3 changed to 1 & V/I bit for replaced page 4 is made 0.

Topic : Saving Page Swap Time

Dirty or modified bit
- → 0 ⇒ only read done in page
- → 1 ⇒ write done in page (Page has become dirty)



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only dirty pages are copied back to secondary memory when replaced, hence write time of non-dirty replaced pages can be saved.

Topic : Effective Memory Access Time

Assume page fault rate = p

E.M.A.T. = (1 − p) * time needed for mem. access when page hit + p * time needed for mem access when page fault

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$$E.M.A.T. = (1-p) * \underbrace{2t_{mm}}_{\substack{\text{one for P.T.} \\ \text{one for content}}} + p * (\underbrace{t_{mm}}_{\text{for P.T. check}} + \text{p.f. service time})$$

$$= t_{mm} + (1-p)\,t_{mm} + p * \text{p.f. service time}$$

ex:-

$p = 2\%$

page hit time = 500ns

page fault time = 15000 ns

$$E.M.A.T. = 0.98 * 500 + 0.02 * 15000$$

$$= 790 \text{ ns}$$

ex:-

$t_{mm} = 200\,ns$

$p = 1\,\%$

p.f. service time $= 100\,\mu sec = 100000\,ns$

$$E.M.A.T. = 0.99 * (2 * 200) + 0.01\,(200 + 100000)\,ns$$

$$= 1398\,ns$$

TLB with virtual memory

CPU generates L.A.

⇓

search in TLB

TLB hit → P.A. ⇓ access content from mm

$= t_{TLB} + t_{mm}$

TLB miss → search P.T.

page hit → P.A. ⇓ access content from mm

$= t_{TLB} + 2t_{mm}$

fault → Page fault service

$= t_{TLB} + t_{mm}$
$+ \text{P.f. service time}$

$$\text{E.M.A.T.} = H\left(t_{TLB} + t_{mm}\right)$$

$$+ (1-H)\left[(1-p)\left(t_{TLB} + 2t_m\right) + p * \left(t_{TLB} + t_{mm} + \begin{array}{c}\text{p.f.}\\ \text{service}\\ \text{time}\end{array}\right)\right]$$

Topic : Effective Memory Access Time with TLB

TLB & Virtual memory :

$$EMAT = H(t_{TLB} + t_{mm}) + (1 - H)\,[(1-p) * (t_{TLB} + t_{mm} + t_{mm})$$
$$+\, p * (t_{TLB} + t_{mm} + \text{p. f. Service time})$$

$$= t_{TLB} + t_{mm} + (1 - H)\,[(1 - p) * t_{mm} + p * \text{p. f. Service Time}\,]$$

Topic : Question

TLB hit = 90%

TLB access time = 10 nsec

mm access time = 200 n sec

Page fault rate = 1 %

p.f. service time = 100 m sec

E. M. A. T. = __________ n sec.

E.M.A.T.

$$= 0.9 * (10 + 200)$$
$$+ 0.1 * \left[0.99 * (10 + 2 * 200) + 0.01 * (10 + 200 + 100 * 10^6 \text{ ns}) \right]$$
$$= 100229.8 \text{ ns}$$

2 mins Summary

Topic Virtual Memory

Topic Demand Paging

Topic Page Fault

Happy Learning

THANK - YOU