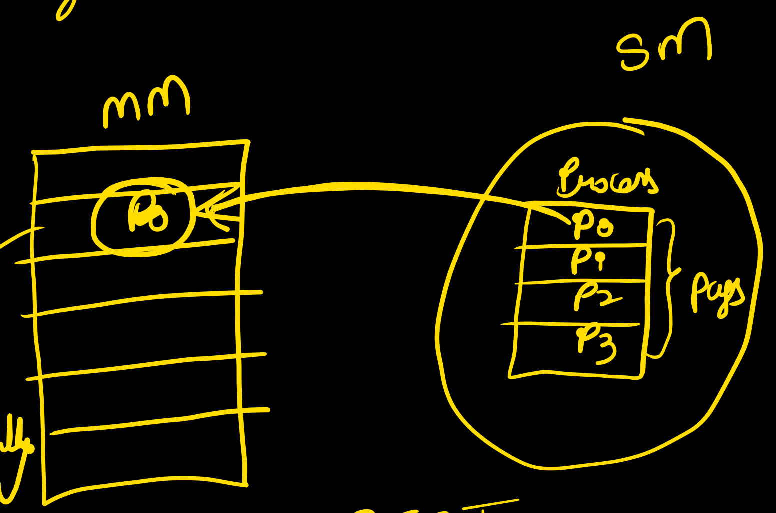
Page fault:

Demand paging: we do not load the page until it is required.

VA $\rightarrow P_0$

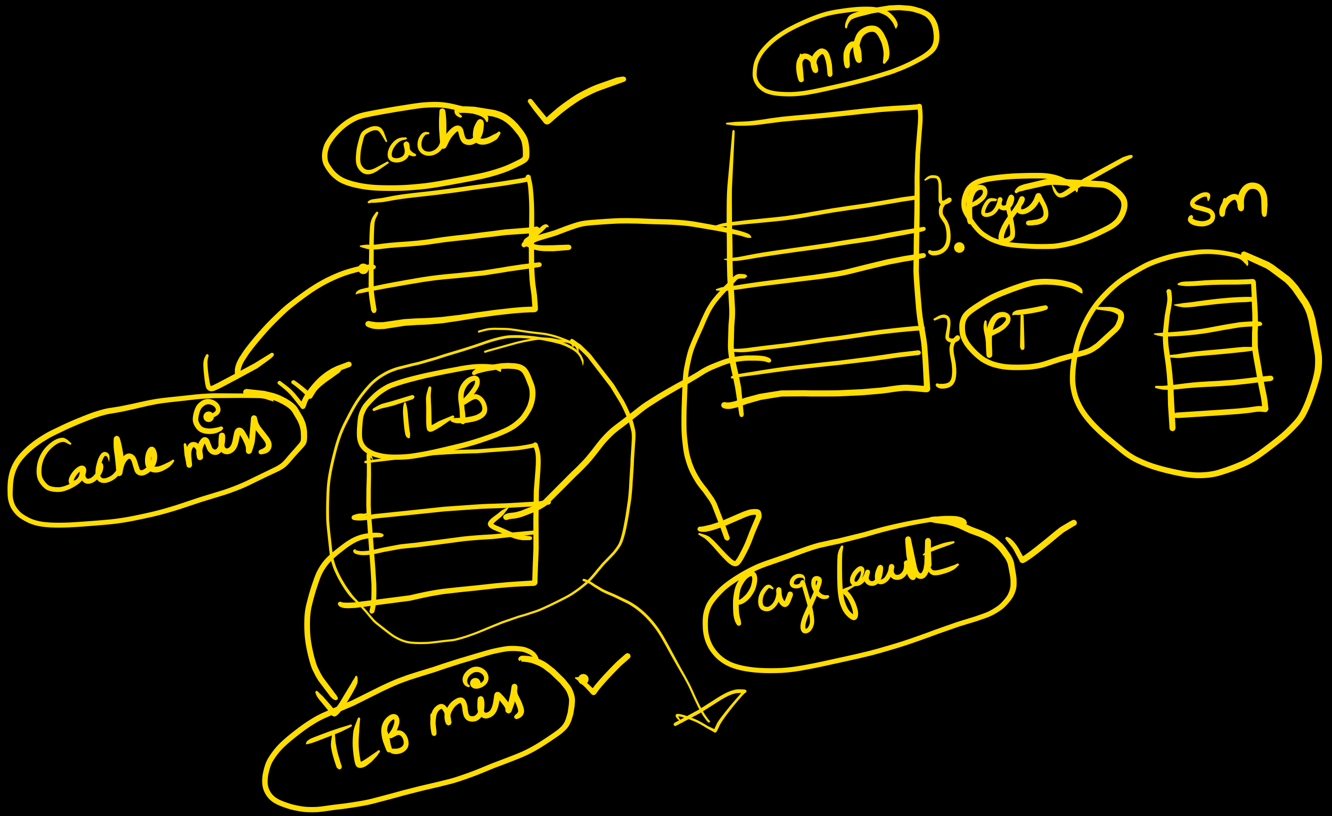


P_0 is not present initially

It is called Page fault.

PFST — Page fault service Time

$$EMAT = \underbrace{p}_{\text{page fault rate}}(\text{service time} + \underbrace{m}_{\text{main memory access time.}}) + \underbrace{(1-p)}_{\text{no page fault}}(m)$$



mm
Cache
Pages
PT
sm
TLB
Cache miss
Page fault
TLB miss

Gate'11

Let PFST be 10 ms in a computer with avg MAT being 20 ns. If one page fault is generated for every 10^6 memory accesses, what is the effective access time for memory.

$ST = 10\,ms$ $\quad MMAT = 20\,ns$ $\quad PF\ rate = \frac{1}{10^6}$

$$EMAT = \frac{1}{10^6}\left(10\times10^{-3} + 20\times10^{-9}\right) + \left(1-\frac{1}{10^6}\right)\left(20\times10^{-9}\right)$$

$= 30\,ns.$

$m + p(ST)$

$$20\times10^{-9} + \frac{1}{10^6}\left(10\times10^{-3}\right)$$

simplify the formula

$$EMAT = p(ST + m) + (1-p)(m)$$

$$= p(ST) + \cancel{pm} + m - \cancel{mp}.$$

$$\underbrace{EMAT}_{y} = \underbrace{m + p(ST)}_{c\, +\, xm}$$

Gate: If an instruction takes 'i' micro seconds and page fault takes an additional $j\ \mu s$, the effective instruction time if on the average a page fault occurs every k instructions is:

$$\boxed{i + \left(\frac{1}{k}\right)(j)}\ \mu s$$

instruction

Page fault rate

Gate: Suppose the time to service a page fault is on average 10 ms, while a memory access takes 1 μs. Then a 99.99% hit ratio results in average memory access time of:

99.99% → Hit rate

0.01% → page fault rate

→ 0.0001

$$EMAT = m + (p)(PS)$$

$$= 1\mu s + (0.0001)(10 \times 10^{-3})$$

$$= \boxed{2\mu s}$$ ✓

Gate: A demand paging system takes 100 time units to service a page fault and 300 time units to replace a dirty page. memory access time is 1 unit. The probability of a page fault is 'p'. In case of page fault the probability of page being dirty is also p. It is observed that the average access time is 3 units. Then the value of 'p' is?

$$PFST = p * 300 + (1-p)(100) = 100 + 200P$$

$$EMAT = m + p(PFST) = 1 + p(100 + 200P) = 3$$

$$200p^2 + 100p - 2 = 0 \Rightarrow 100p^2 + 50p - 1 = 0$$

$$p = \frac{-50 \pm \sqrt{2500 + 400}}{200}$$

$$= 0.019$$

Gate: A process uses 2 level paging VA = PA = 32 bits. Byte addressable.

VA = $\boxed{10 \mid 10 \mid 12}$ PTE = 4B. TLB has hit ratio of 96%. Cache has hit ratio of 90%. main memory access time is 10 ns, Cache access time is 1ns and TLB access time is 1ns. Assuming no page fault, the average time taken to access a VA is approximately?

$(VA \rightarrow PA)$ + Fetch the word from process

$$= \underbrace{t}_{TLB} + (1-\underbrace{p_t}_{TLB\ miss})(\underbrace{k}_{levels} * \underbrace{m}_{mm}) + \underbrace{c}_{cache} + \underbrace{(1-p_c)}_{cache\ miss}(m)$$

$$= 1 + (0.04)(2 * 10) + 1 + 0.1 \times 10 = 3.8\text{ ns}.$$

Gate: Consider a paging h/w with a TLB. Assume that entire page table and all pages are in physical memory. It takes 10 ms to reach the TLB and 80ms to access physical memory. If the TLB hit ratio is 0.6, the effective memory access time (in ms) is ____

$$EMAT = \underbrace{(VA \rightarrow PA)} + \text{Time to access mm}$$

$$= \underset{\text{TLB time}}{t} + \underset{\text{TLB miss}}{T_m}(\underset{\text{levels}}{K} * \underset{\text{mm access time}}{m}) + \underset{\text{mm access time}}{m}$$

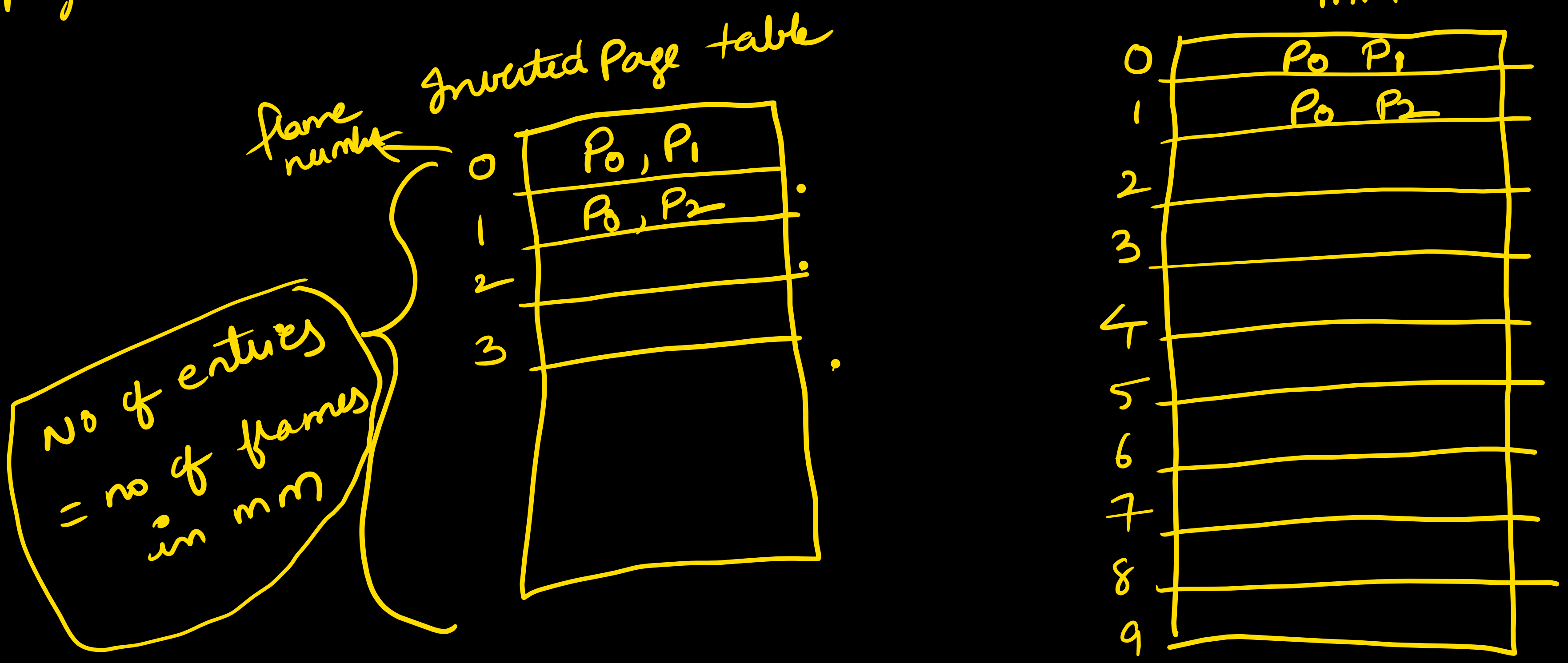
(Page fault & Cache is not given)

$$= 10 + (0.4)(80) + 80$$

$$= 122 \text{ ms.}$$

Inverted page table:

For the entire main memory, for all the processes, we maintain one page table. This is not practically used.



PA = 32 bits   Page size = 4 KB   IPTE = 4 B , size of IPT = ?

PA

f:NO	p off
20	12

32

No of frames = 2^{20}

IPTE = no of frames $\times$ IPTE

$= 2^{20} \times 4\ B = 4\ MB.$

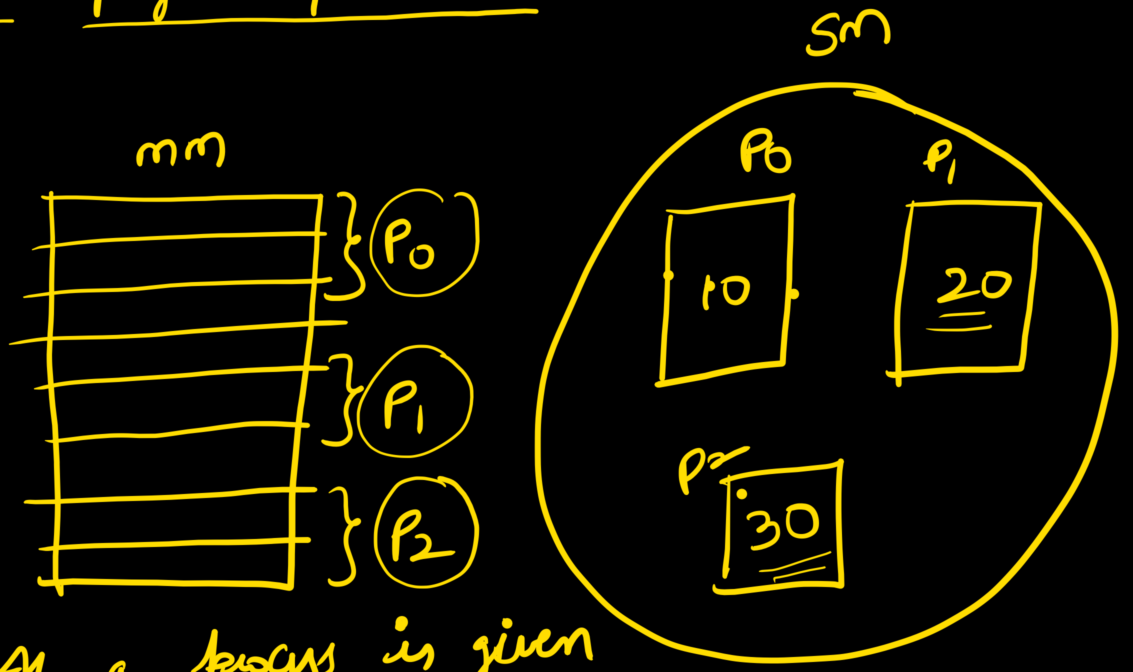
Frame allocation and page replacement:

Ex:

P_0 – 3 frame

P_1 – 4 frames

P_2 – 5 frames.



If a process is given required frames, then less number of processes can be accomodated. This reduces degree of multi programming.

Equal allocation: (static)

If 30 frames are availble.

and 3 processes are asking.

Then each process will get

$\frac{30}{3} = 10$ frames.

weighted allocation: (Static method)

If 10 frames are availble

3 process are asking

P_1 - 20 pages

P_2 - 30 pages

P_3 - 50 pages

Frame for $P_1 = \left(\frac{20}{20+30+50}\right)(10) = 2F$

" $P_2 = \left(\frac{30}{20+30+50}\right)(10) = 3F$

Frams for $P_3 = \left(\frac{50}{20+30+50}\right)(10)$

$= 5F$.

weighted: Processes will get frame according to their pages.

Dynamic allocation:

A process with higher priority will get more frame.
A process with lower priority has to sacrifice when a process with higher priority asks for frames.

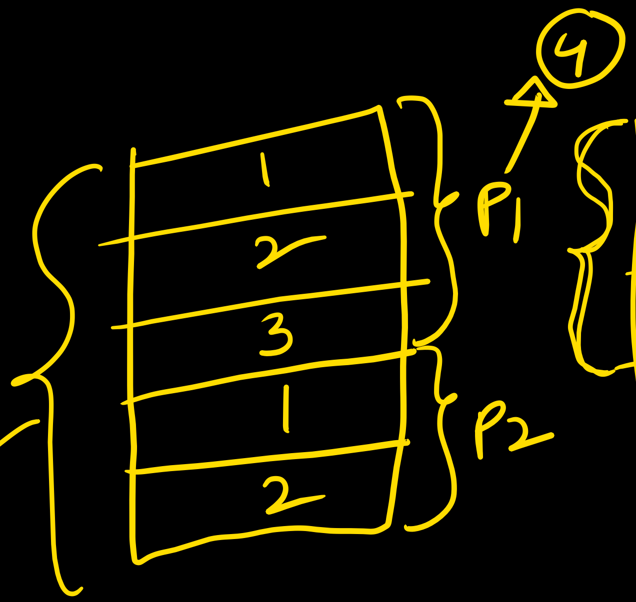
Ex:

P_1 ✓
P_1
~~P_2~~ P_1
~~P_2~~ P_1

$P_1 > P_2$

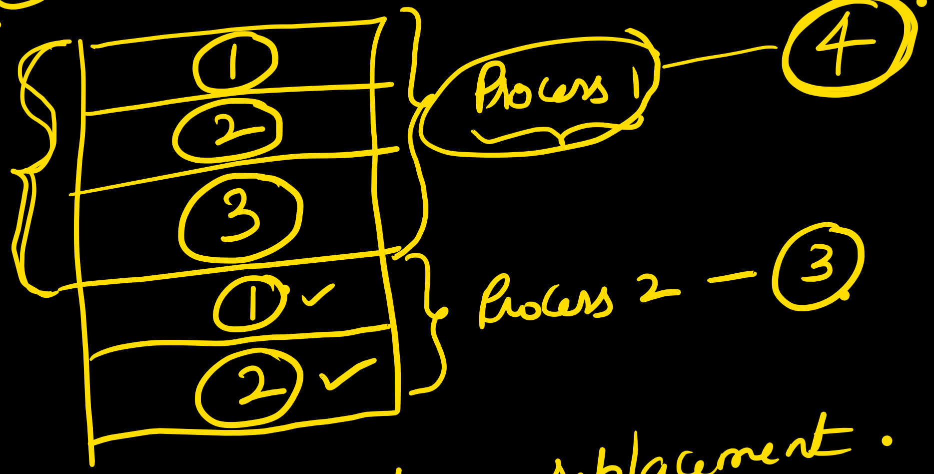
P_1 can expand.

Page replacement:

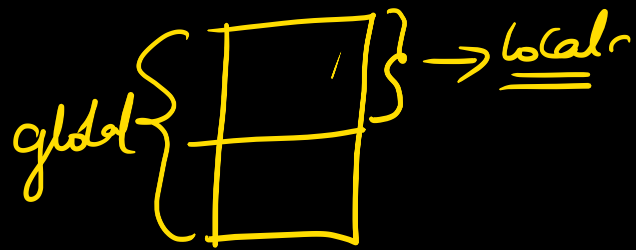


any of the pages can be

Global



Local page replacement.



Reference string: Requests of ~~a~~ pages by a process in need order.

CPU $\longrightarrow$ LA

LA: PNO | Poff

PNO: 1 2 5 6 7 4 3 1 $\longrightarrow$ reference string.

Page replacement algorithms:

→ Optimal page replacement algorithm: Replace the page which will not be referred for longest. (Not practical because future needs cannot be predicted) (used for benchmarking) In terms of performance ~~optical~~ optimal is the best

→ LRU: Replace the least recently used page (Page which has not been referred for a long time)

→ FIFO: First in First out.

Gate 14: Demand paging is used, Find the page faults, frames = 3.

optimal:

4, 7, 6, 1, 7, 6, 1, 2, 7, 2

optimal: 5.

LRU = ~~5~~ 6 ✓

~~4~~ 1 2

7

6

FIFO = 6

~~4~~ 1

~~7~~ 2

~~6~~ 7

LRU

~~4~~ 1

~~7~~ 2

6

~~4~~ ~~7~~ ~~6~~ 1 2 7

Gate: 100 records per page with 1 free main memory frame

add: 0100, 0200, 0430, 0499, 0510, 0530, 0560, 0120, 0220, 0240, 0260, 0320, 0370

Ref String: 01, 02, 04, 04, 05, 05, 05, 01, 02, 02, 02, 03, 03

$\boxed{\cancel{1}}$ $\cancel{2}$ $\cancel{4}$ $\cancel{5}$ $\cancel{1}$ $\cancel{2}$ 3

7 page faults.

whatever algo we use, we get the same PF because no of frames = 1.

Gate:

1 2 3 2 4 1 3 2 4 1

Frames = 3.

op
LRU
FIFO

optimal = 5

1
~~2~~ 4
~~3~~ 2

PFR = $\frac{5}{10}$ 50%

LRU

~~1~~ ~~4~~ 2
~~2~~ ~~3~~ 1
~~3~~ ~~1~~ 4

faults = 9

PFR = $\frac{9}{10}$ = 90%

FIFO:

~~1~~ 4.
~~2~~ 1
~~3~~ 2

faults = 6

PFR = $\frac{6}{10}$ = 60%

~~1~~ ~~2~~ ~~3~~ 4 1 2

Gate:

1 2 1 3 7 4 5 6 3 1 $F=3$

optimal:

1
~~2~~
3

~~7~~ ~~4~~ ~~5~~ 6

fault = 7

LRU

~~1~~	~~4~~ 3
~~2~~	~~7~~ 6
~~3~~	~~5~~ 1

fault = 9

FIFO:

~~1~~	~~7~~ 6
~~2~~	~~4~~ 3
~~3~~	~~5~~ 1

fault = "9"

~~1~~ ~~2~~ ~~3~~ ~~7~~ ~~4~~ ~~5~~ 6 3 1