

- pages : split logical memory into pages of the size stored (power of two)
- Frames : split physical memory into pages of the same size

* Each page is stored in a frame.

* A process has 1 or more pages of memory.

* If we use page we don't need a contiguous memory block. we can save one by one

page table : A page table can array gives the memory address (frame) of each page of memory.

logical memory \leftarrow $\begin{matrix} \text{Page number} \\ \text{Page offset} \end{matrix}$

* technically CPU uses 2^2 times to find

CPU \rightarrow page table \rightarrow physical ~~table~~ memory
 $\xrightarrow{2^2 \text{ times}}$

So we use a Table lookup Buffer.

TLB \leftarrow implemented in hardware to use associative memory.
 \hookrightarrow mem if statements

TLB hit \rightarrow an appropriate TLB entry was found
 \Rightarrow the associated frame is returned.

TLB miss \rightarrow No TLB entry is found
 \Rightarrow the frame number is returned from the page table in memory.

TLB performance.

ϵ = TLB Look-up time.

memory access cycle : 50ns

probability of a TLB hit : α

$$\frac{\epsilon + 0.50}{\text{one access}} + \frac{(1-\alpha) \cdot 100}{\text{probability of } 1-\alpha \text{ two access}}$$

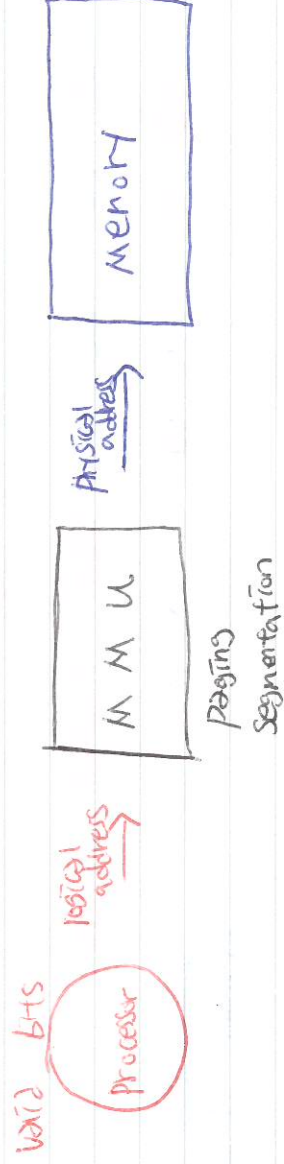
= probability of α

$$\begin{aligned} \text{ex) } & \epsilon + 0.50 + (1-\alpha) 100 \\ & = \epsilon + 0.50 + 100 - 100\alpha \\ & = \epsilon + 100 - 0.50 \end{aligned}$$

Phantom memory

more bits

dirty bits



logical address $\xrightarrow{\text{mapping}}$ physical address = binding

Deadlocking system에서는 빈 프레임에 어떤 프로세스도 적재할 수 없어 메모리를 효율적으로 사용 가능하다. 또한 외부 단편화가 생성되지 않는다.

disadvantage

- 1) 한 프로세스를 많은 페이지로 나눴을 때인 메모리에 분산 적재하면 운영체제의 페이지 관리 부담이 크다.
- 2) 또 프레임 단위로 적재 했으므로 어떤 프로세스의 공간 필요할 때까지 크기와 일치 할지 모르겠어 메모리에 할당된 프레임의 활용도가 저하 않아 내부 단편화가 생길 수도 있다.

- 3) Page 크기가 너무 작으면 page table을 유지 하는데 부담을 줄 수 있다. 페이지 테이블을 유지하는 부담은 페이지 크기를 증가 시켜서 줄일 수 있다.

page fault handling Algorithm.

- 1) First in First out
↓
number of page fault ↑
↓
number of page fault ↑
↓
I/O's problem.

* Belady's anomaly → more spaces to process but it gets more page faults.

∴ First-in-First-out is not the best

but in the general case, if number of frames ↑ then number of page faults ↓

then let's beat the Belady's anomaly.

How? → let's look at the future.
= optimal replacement.

제일 나중에 사용할 frame을 victim으로 고르고
아직 안 쓰는 것들을 위장을 고르면 된다.

= theoretical,
we can't see the future
but the lower bound that
we can know

Convoy effect = ~~slows down the whole operating system~~ because of ~~few~~ slow processes
In non-preemptive CPU scheduling if long
waiting processes has the CPU all others
process have wait for that process.

future the past working set, we can't see the least recently used, we predict from

using clock.

→ 시간당.

need to loop over a frames of memory to find the least recently used.

→ so we priority queue.

Second chance algorithm.

Instead of a clock per page, have a single bit a reference bit for page

- ① reference bit 1이면
- ② 0이면 바꾸고
- ③ 다음 page table
- ④ 그 다음 0인 것을 1로 바꾸고 victim

valid bit, reference bit.

$$P_{so} + (1-P)$$

So the best one when we can't see the future is **Least recently used**, we predict from the past working set.

using **clock**.

↳ **algorithm**.

need to loop over **n frames of memory** to find the least recently used.

↳ **use priority queue**.

Second chance algorithm.

Instead of a clock per page, have a single bit **reference bit** for page

- ① reference bit 1 slot
- ② 0 or 1 bit
- ③ **page table**
- ④ **1 bit of 32 slot in victim**

valid bit, reference bit.

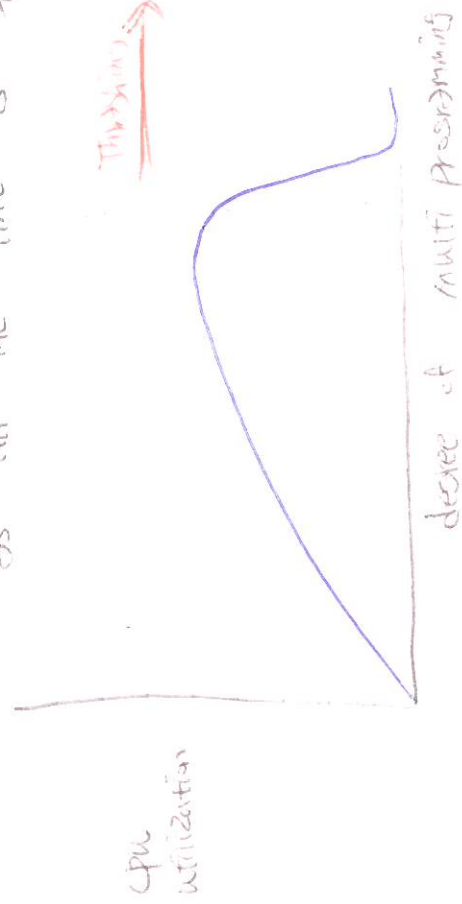
$$P_{so} + (1-P)$$

if localities (working set) > available
means pxx faults are frequent

then low cpu usage as time is spent swapping.

setting

Threshing = almost no useful work is done,
as all the time is spent swapping



pxx = thrashing : CPU usage falling rapidly to zero
we can't see the future but we can tell to the computer what is going to be happen

= Hint

Hint : what data might be accessed next

Back

Small pxx size

Large pxx size

Large localities
More Threshing

More TLB hit rate
More TLB miss rate

More TLB miss rate
Reduce

2) Page table

• Multi programming → 한정된 메모리를 여러 프로세스가 함께 사용.

• 디바이스 관리 → 프로세스들을 위한 메모리를 할당하고 제거하여 메모리를 효율

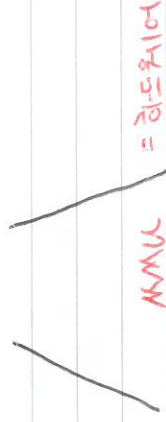
fetch policy → deciding when process starts to allocate
어떤 디바이스 사용?

Requirement
Prediction

Placement Policy → first in first allocate
디바이스 사용 순서대로
메모리를 어느 디바이스 사용 할 것인가?
Best fit
worst fit

Replacement Policy → first in first out
디바이스 사용 순서대로
가장 먼저 사용된 메모리 사용?
Least Recently used

Memory address



logical address → physical address

Address binding = logical address를 physical address
로 mapping 하는 과정.

Binding 순서

- 1) Compiler 가 프로그램 코드를 생성하여 코드 파일을 생성
- 2) Linker 가 코드 파일을 라이브러리 파일과 다는 링크 파일을 생성.
- 3) loader 가 실행 파일을 로드하여 실행.

Swapping : 두 개 스왑하기, 즉 0000이 1111이 되고 1111이 0000이 되게 하는 것. swap - out

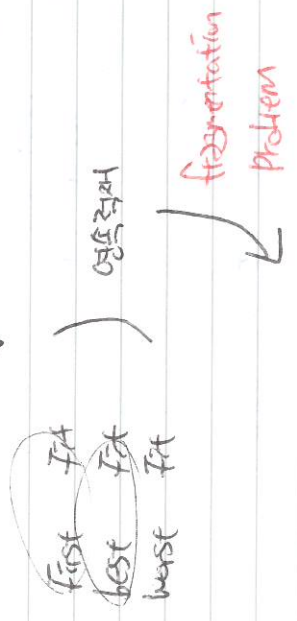
Swapping-in
swapping-out

memory allocation method

메모리 할당 방법
- 크기가 다른 프로그램이 같은 메모리 블록을 사용하려고 할 때 발생하는 문제. 프로그램이 메모리 블록을 사용할 수 없는 상황.

Fragmentation
→ Compaaction은 사용되지 않는 메모리 블록을 제거하여 사용 가능한 메모리를 늘리는 것.

문제 : memory fragmentation



Solution 1)

메모리 통합 = Coalescing → 같은 크기의 메모리 블록을 찾아서 합쳐서 사용하는 것. (First Fit, Best Fit, Worst Fit)

(First Fit, Best Fit, Worst Fit)

Solution 2)

메모리 분할 = Compaction → 메모리 블록을 이동시켜서 큰 블록을 만드는 것. (Worst Fit, Best Fit)

단점 = 사용 가능한 메모리 공간이 줄어들고, 프로그램이 실행될 수 없는 공간이 생기는 것.

Buddy System

⇒ 메모리 블록을 2의 거듭제곱 크기로 나누고, 사용 가능한 블록을 찾는 것. (2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912, 1073741824, 2147483648, 4294967296, 8589934592, 17179869184, 34359738368, 68719476736, 137438953472, 274877906944, 549755813888, 1099511627776, 2199023255552, 4398046511104, 8796093022208, 17592186044416, 35184372088832, 70368744177664, 140737488355328, 281474976710656, 562949953421312, 1125899906842624, 2251799813685248, 4503599627370496, 9007199254740992, 18014398509481984, 36028797018963968, 72057594037927936, 144115188075855872, 288230376151711744, 576460752303423488, 1152921504606846976, 2305843009213693952, 4611686018427387904, 9223372036854775808, 18446744073709551616, 36893488147419103232, 73786976294838206464, 147573952589676412928, 295147905179352825856, 590295810358705651712, 1180591620717411303424, 2361183241434822606848, 4722366482869645213696, 9444732965739290427392, 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Paging

→ 프로세스를 크기가 동일한 page로 나누고, 하나의
오래한 frame로 나뉜 page를 frame에 할당짓.

paging의 장점

→ external fragmentation X

empty frame에 어떤 frame을 적게 가능해서
나뉘어서 효율적으로 사용 가능.

→ 외부의 page를 하나씩 하나씩 여러 자리에
분산 저장하므로 page 번호 불규칙적
Internal fragmentation 현상 발생

$$\text{logical address} = \text{page index} + \text{page offset}$$

$$\text{page table} = \text{page index} \rightarrow \text{physical address of frame number를 포함해서}$$

$$\star \text{page size} = \text{Always } 2^n \text{ logical address} \rightarrow \text{page number와 offset을 쉽게 구분하기 위해서}$$

logical address

Page number	Page offset
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Page table
