

Systems 3

Memory Management II

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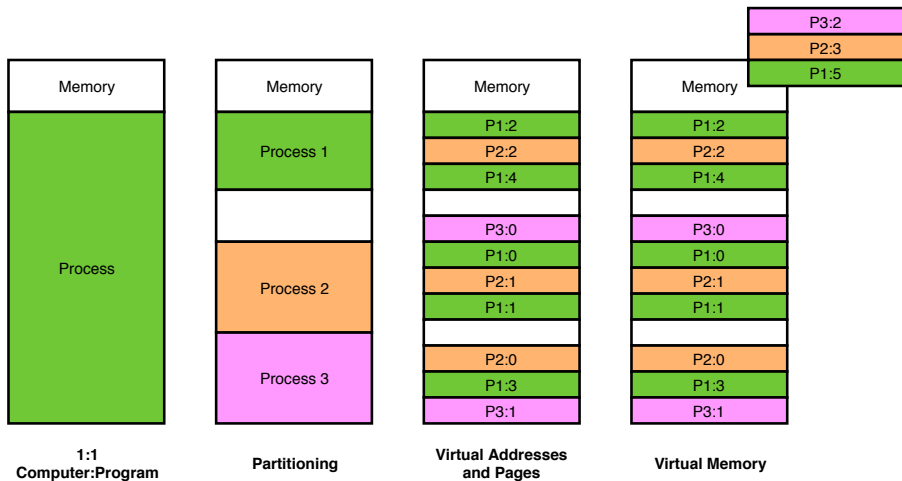
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Chapter Goals

- Going beyond physical memory
- How to simplify memory management for the kernel?
- How can this be represented with the existing page table structure?
- How to select which pages to replace on memory pressure?
- What are the (logical) segments of a program?

Memory development



Evolution

Present Bit

Index	Present	Modified	Frame / Info
0	1	1	1234
1	1	0	2600
2	0	-	File #123, block 883
3	0	-	File #123, block 884
4	1	0	1536
5	0	-	Really invalid
...

Overcoming Memory Limits

Approach	Mechanism
Layout	Increase
Static	Swapping
Paged (virtual memory)	Paging

Which page should be replaced?

The three most simple replacement algorithms are:

- Optimal replacement
- Not recently used (NRU) replacement
- First-in, first-out (FIFO) replacement

But there are more algorithms. See next slides.

Second Chance Replacement

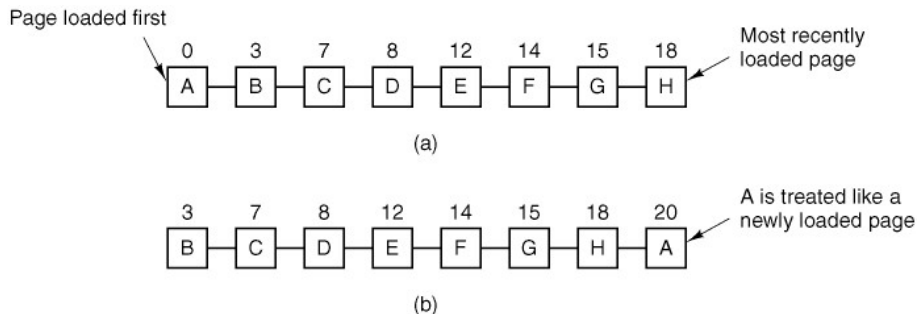
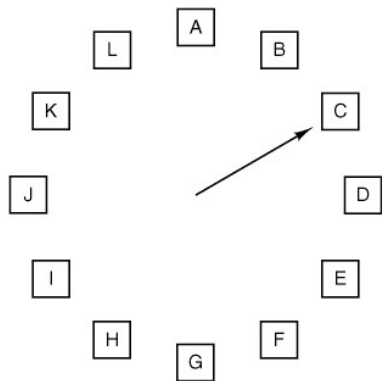


Figure: Operation of second chance. (a) Pages sorted in FIFO order. (b) Page list if a page fault occurs at time 20 and A has its R bit set. The numbers above the pages are their loading times. (Tannenbaum fig. 4-14)

Clock Page Replacement



When a page fault occurs,
the page the hand is
pointing to is inspected.
The action taken depends
on the R bit:
R = 0: Evict the page
R = 1: Clear R and advance hand

Figure: The clock page replacement algorithm. (Tannenbaum fig. 4-15)

What is the difference between Second Chance and Clock Page Replacement?

Least Recently Used

Assumption: Pages that have not been used for ages will probably remain unused for a long time.

Can be implemented in

- Hardware
- Software

Advantages? Disadvantages?

Simulating LRU

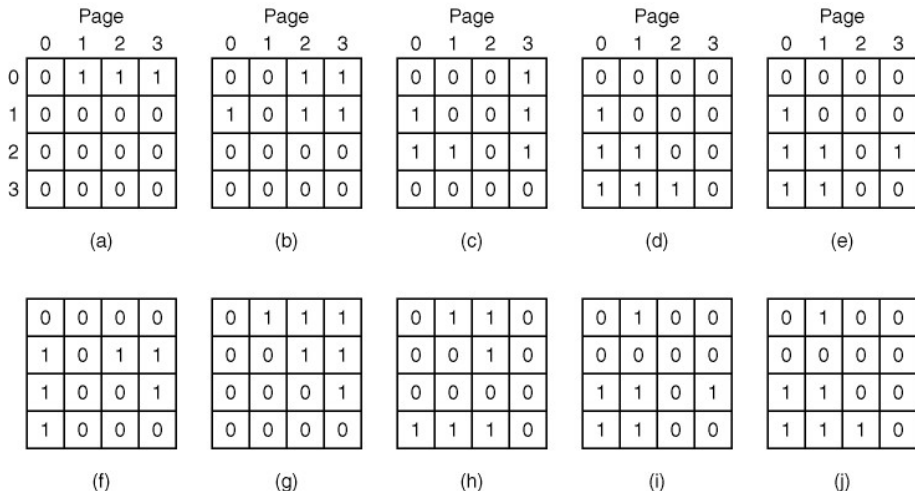
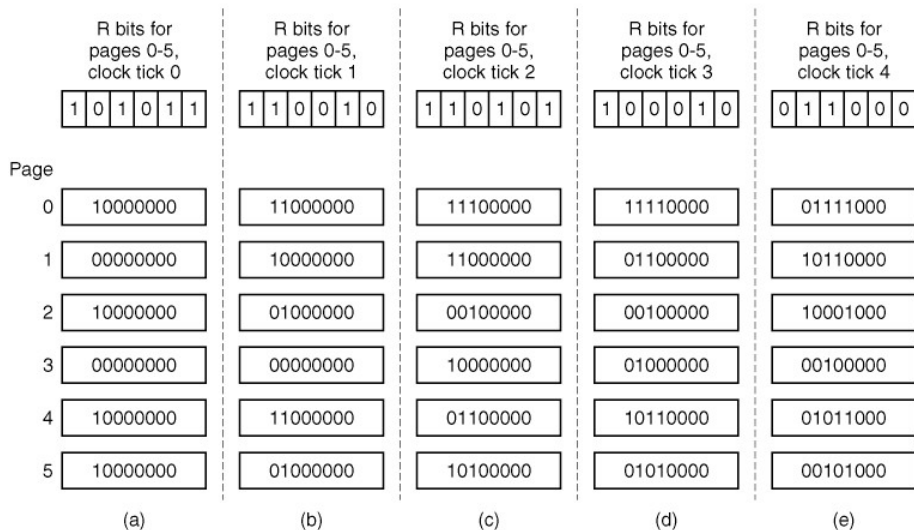
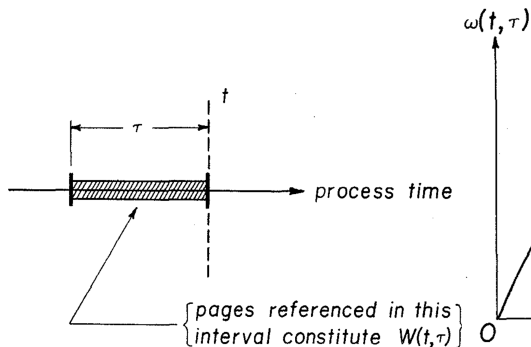
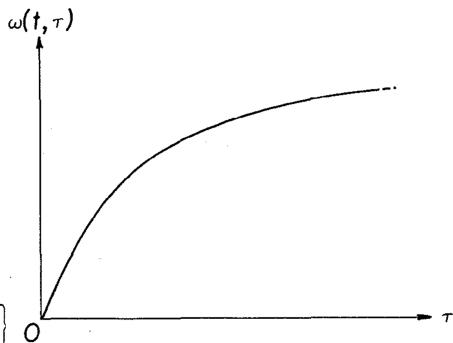


Figure: LRU using a matrix when pages are referenced in order 0, 1, 2, 3, 2, 1, 0, 3, 2, 3. (Tannenbaum fig. 4-16)

Simulating LRU



Working set¹

FIG. 2. Definition of $W(t, \tau)$ FIG. 3. Behavior of $\omega(t, \tau)$

This locality results in a (slowly) growing working set. Memory areas, which have not been recently used are less likely to be accessed again soon and could be moved to slower memory.

¹Denning, Peter J. (1968). "The working set model for program behavior". Communications of the ACM. 11(5):323–333

Local vs. Global

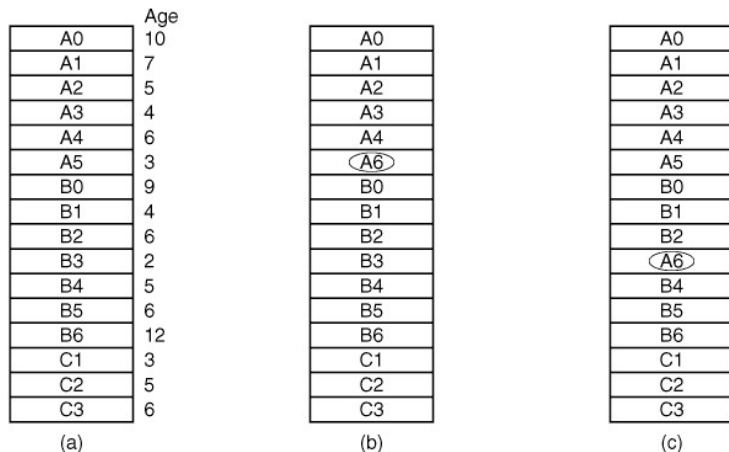


Figure: Local vs. global page replacement. (a) Original configuration. (b) Local page replacement. (c) Global page replacement. (Tannenbaum fig. 4-19)

Page Fault Frequency

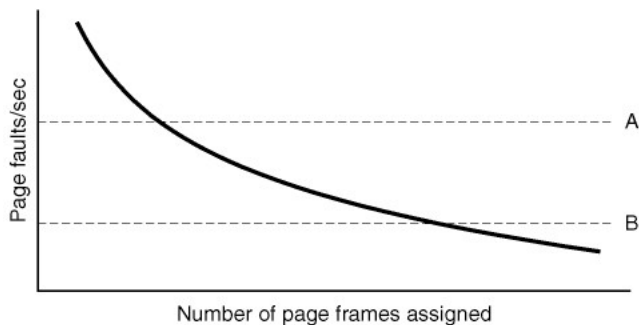


Figure: Page fault rate as a function of the number of page frames assigned.
(Tannenbaum fig. 4-20)

Page size

Page size criteria

- What are arguments for large pages?
- What are arguments for small pages?
- What is a useful range?
- Are there applications with different criteria?

Memory Layout of C Programs

