OPERATING SYSTEMS

Memory Management - 9

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OPERATING SYSTEMS

Course Syllabus - Unit 3

Unit-3:Unit 3: Memory Management: Main Memory

Hardware and control structures, OS support, Address translation, Swapping, Memory Allocation (Partitioning, relocation), Fragmentation, Segmentation, Paging, TLBs context switches Virtual Memory - Demand Paging, Copy-on-Write, Page replacement policy - LRU (in comparison with FIFO & Optimal), Thrashing, design alternatives - inverted page tables, bigger pages. Case Study: Linux/Windows Memory

OPERATING SYSTEMS

Course Outline

25	Main Memory: Hardware and control structures, OS support, Address translation	8.1	64.2
26	Dynamic linking, Swapping	8.2	
27	Memory Allocation (Partitioning, relocation), Fragmentation	8.3	
28	Segmentation	8.4	
29	Paging: OS Support, TLBs, Address Translation	8.5	
30	Structure of the Page Table	8.6	
31	Design Alternatives - Inverted Page Tables, Bigger Pages	8.7-8.8	
32	Virtual Memory: Demand Paging, Copy-OnWrite	9.1-9.3	
33	Page replacement policy - LRU	9.4	
34	FIFO & Optimal	9.5	
35	Thrashing	9.6	
36	Case Study: Linux/ Windows Memory Management	9.10	

Topic Outline

- Virtual Memory - Page replacement
- What happens if there is no free Frame ?
- Basic Page Replacement
- Page and Frame Replacement Algorithms
- Graph of Page Faults versus the number of Frames

Topic Outline

- First-In-First-Out (FIFO) Algorithm
- FIFO illustrating Belady's Anomaly
- Optimal Page Replacement Algorithm
- Least Recently Used (LRU) Algorithm
- Use of a Stack to Record Most Recent Page References

Topic Outline

- LRU Approximation Algorithms
- Second-Chance (clock) Page-Replacement Algorithm
- Enhanced Second-Chance Algorithm
- Counting Algorithms
- Page-Buffering Algorithms

Topic Outline

- Applications and Page Replacement
- Allocation of Frames
- Fixed Allocation
- Priority Allocation
- Global vs. Local Allocation
- Non-Uniform Memory Access

What happens if there is no free Frame ?

- Used up by process pages
- Also in demand from the kernel, I/O buffers, etc
- How many frames to allocate to each process requesting pages to be loaded ?
- Page replacement – find some page in memory, but not really in use, page it out
    - Algorithm – terminate ? swap out ? replace the page ?
    - Performance – want an algorithm which will result in minimum number of page faults
- Same page may be brought into memory several times

Page Replacement

- Prevent over-allocation of memory by modifying page-fault service routine to include page replacement

- Use modify (**dirty**) bit to reduce overhead of page transfers => only modified pages are written to disk

- Page replacement completes separation between logical memory and physical memory => large virtual memory can be provided on a smaller physical memory

Page Replacement

1. Find the location of the desired page on disk

2. Find a free frame:

    i. If there is a free frame, use it

    ii. If there is no free frame, use a page replacement algorithm to

    iii. Select a **Victim** frame

        - Write **Victim** frame to disk if **dirty**

Page Replacement

3. Bring the desired page into the (newly) free frame; update the page and frame tables

4. Continue the process by restarting the instruction that caused the trap

Note: Potentially 2 page transfers for page fault – increasing EAT, if the page is swapped

Page and Frame Replacement Algorithms

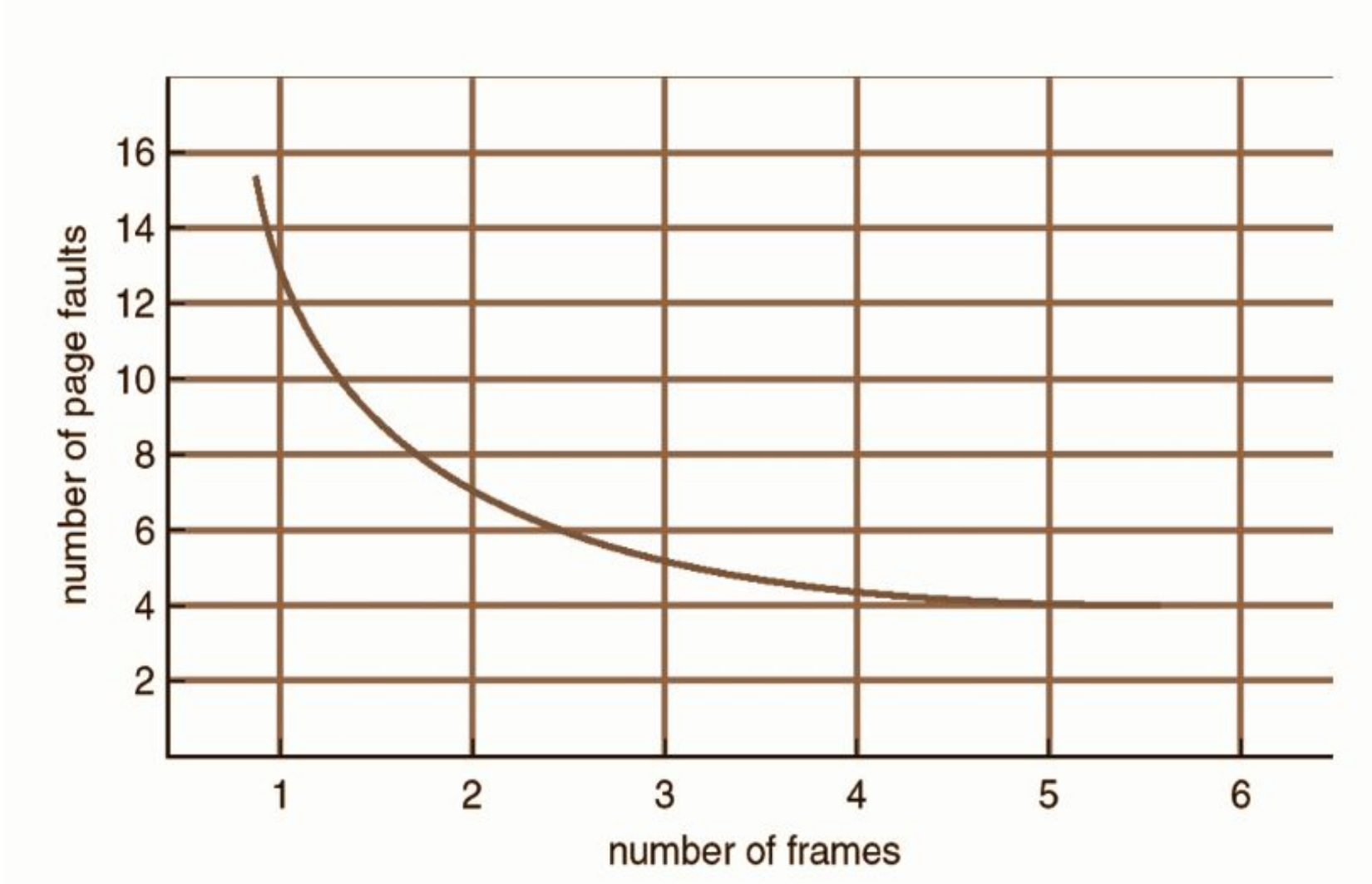
- **Frame-allocation algorithm - FRA** determines
  - How many frames to give each process ?
  - Which frames to replace ?
- **Page-replacement algorithm - PRA**
  - Want lowest page-fault rate on both first access and re-access

Page and Frame Replacement Algorithms

- Evaluate algorithm by running it on a particular string of memory references (reference string) and computing the number of page faults on that string
  - String is just page numbers, not full addresses
  - Repeated access to the same page does not cause a page fault if available in the frame
  - Results depend on number of frames available
- In all our examples, the reference string of referenced page numbers of the same process is

Req #	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
Page #	7	0	1	2	0	3	0	4	2	3	0	3	0	3	2	1	2	0	1	7	0	1

Graph of Page Faults versus the Number of Frames



PRA : First in First Out (FIFO) Algorithm

Req #	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
Page #	7	0	1	2	0	3	0	4	2	3	0	3	0	3	2	1	2	0	1	7	0	1

Fr #	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
1	7	7	7	2	2	2	2	4	4	4	0	0	0	0	0	0	0	0	0	7	7	7
2		0	0	0	0	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1	0	0
3			1	1	1	1	0	0	0	3	3	3	3	3	3	3	2	2	2	2	2	1
Flag	PF	PF	PF	PF	PH	PF	PF	PF	PF	PF	PF	PH	PH	PH	PH	PF	PF	PH	PH	PF	PF	PF

Working Set => { 7, 0, 1, 2 ,3, 4 }

Total Number of Page Requests = > 22

Total Number of Frames => 3

Total Number of Page faults => 15

% of Page Faults = > 15/22 => 68.18%

% of Page Hits => 31.81 %

Legend
Page Fault => PF

Page Hit => PH

PRA: FIFO Illustrating Belady's Anomaly

Req #	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
Page #	1	2	3	4	1	2	5	1	2	3	4	5

Fr #	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
1												
2												
3												
Flag												

- Can vary by reference string: consider 1,2,3,4,1,2,5,1,2,3,4,5
  - Adding more frames can cause more page faults!
  - Belady's Anomaly
- How to track ages of pages ?
  - Just use a FIFO queue

Working Set => { }

Total Number of Page Requests = >

Total Number of Frames =>

Total Number of Page faults =>

% of Page Faults = >

% of Page Hits =>

Legend
Page Fault => PF

Page Hit => PH

*Anomaly => Something that deviates from what is standard, normal, or expected

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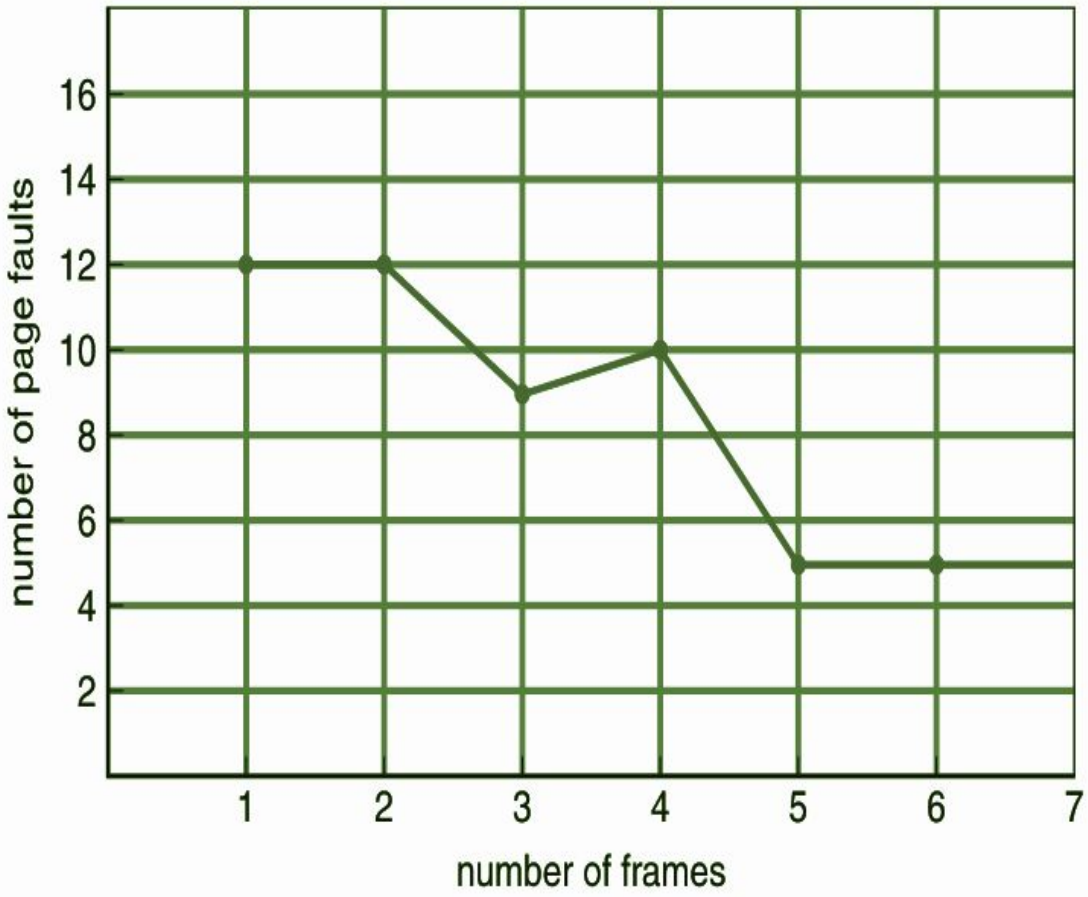

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THANK YOU

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