Computer Organization and Architecture

12 Virtual Memory

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Nov. 12, 2019



Summary

- RAID 0
- RAID 1
- RAID 2
- RAID 3
- RAID 4
- RAID 5
- RAID 6



Memory Management

- In the past, only OS and one program are in memory
- Currently, OS and multiple programs are in memory
 - To avoid the idle of processor when the programs wait for I/O, it requires to load more programs in memory
- Memory management
 - In multiprogramming system, the "user part" of memory should be further partitioned to fit multiple programs, which is dynamically carried out by OS
 - Don't consider "process" in this slide



Solution to Load More Programs

- Enlarge memory
- Using exchange and overlap techniques
 - When no program is ready, OS loads other programs in
 - · Partitioning and paging
- Virtual memory
 - Demand paging
 - Virtual address



Partitioning

- Fixed-size partition
 - OS: fixed size
 - User program: fixed size with different lengths
 - When load a program, put it in the smallest partition which has enough length
 - Drawback: waste of memory

OS
64K
128K
256K



Partitioning (cont.)

Variable-length partition

OS: fixed size

User program: as requirement

Drawback: the number of fragments increases

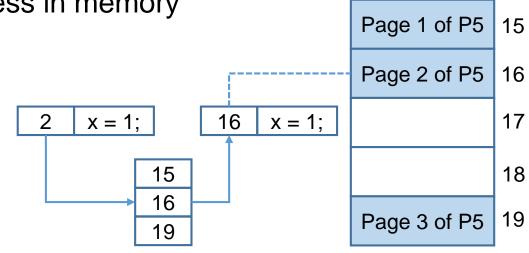
os	OS	os	os	OS
Program 1		Program 4	Program 4	Program 4
Program 2				
Program 3	Program 3	Program 3		Program 5



Paging

- Basic idea
 - Divide the memory into fixed-size blocks, named page frame, and divide the program into fixed size blocks, named page
 - Load the pages into page frames
- Logical address: address in instruction

Physical address: address in memory





Virtual Memory

Problem

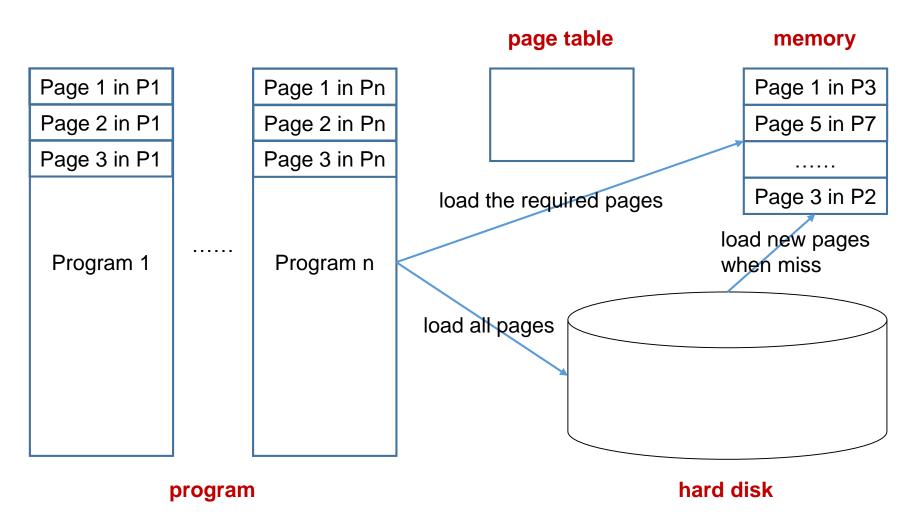
 The size of memory is limited, but the requirement of memory keeps increasing

Basic idea

- Demand paging: only load the active pages in paging
- Essence
 - Programming in a logical address space larger than memory
 - Only load the required programs and data in memory
 - Transfer the logical address to physical address by hardware
 - Exchange information between memory and hard disk when miss



Virtual Memory (cont.)





Virtual Memory (cont.)

- Some problems
 - Size of page
 - 4KB, 8KB, ...
 - Mapping function
 - Associative mapping
 - Types
 - Page based virtual memory
 - Segment based virtual memory
 - Segment and page based virtual memory
 - Write policy
 - Write back



Memory is 100000 times faster than hard disk

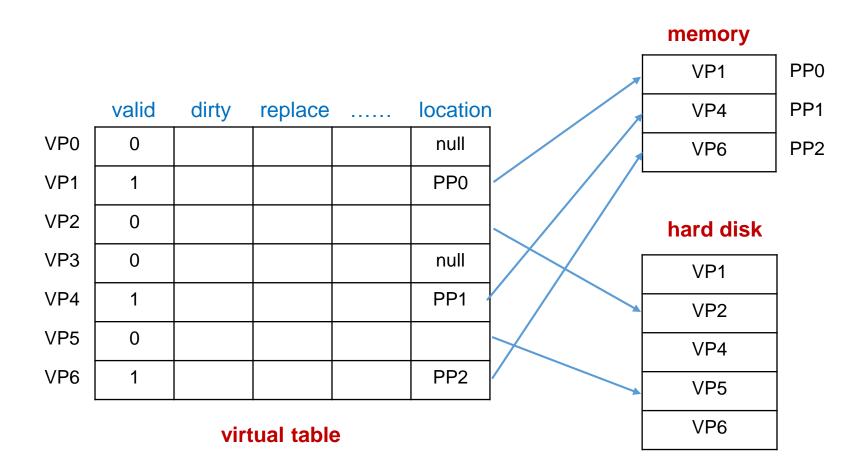


Page based Virtual Memory

- Divide the main memory and virtual memory into pages with the same size
 - Virtual page (VP) / logical page: page in virtual memory
 - Physical page (PP) / page frame: page in main memory
- Page table
 - A table contains the information of all VPs, including location, valid bit, dirty bit, r/w right et al.
 - Store in main memory
 - Virtual address
 - Virtual page number + offset in page



Page based Virtual Memory (cont.)



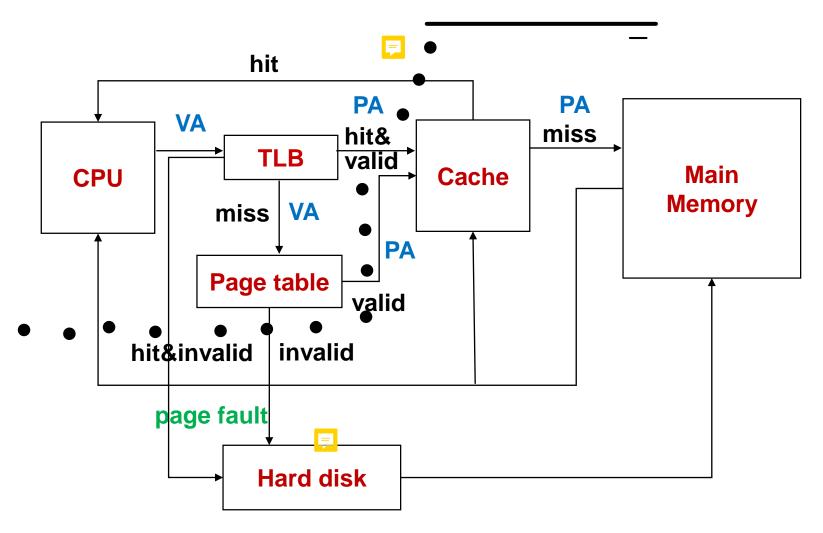


Translation Lookaside Buffer

- The usage of page table increases the access of main memory
- To reduce memory access, load the frequently used items in page table to cache
- TLB: the page table items loaded in cache
 - Associative mapping, set associative mapping
 - Random replacement



Translation Lookaside Buffer (cont.)





Translation Lookaside Buffer (cont.)

No.	TLB		page table	cache	possibility
1	hit	valid		hit	possible, in cache
2	hit	invalid		hit	impossible
3	hit	valid		miss	possible, in memory but not cache
4	hit	invalid		miss	possible, not in memory
5	miss		valid	hit	possible, in cache
6	miss		invalid	hit	impossible
7	miss		valid	miss	possible, in memory but not cache
8	miss		invalid	miss	possible, not in memory

Best 1 no memory access

Good 3, 5 once memory access

Moderate 7 twice memory access

Bad once memory access and hard disk access

Worst 8 twice memory access and hard disk access



Segment based Virtual Memory

- Divide the program and data into segments with different lengths, and load the required segments into memory
- Virtual address
 - Segment number + offset in segment
- Compared to page base virtual memory
 - Page base virtual memory
 - Advantage: simple, low cost
 - Disadvantage: instruction and data may cross pages
 - Segment based virtual memory
 - Advantage: naturally divide program and data
 - Disadvantage: not fixed length



Segment and Page based Virtual Memory

- Divide the program and data into segments, and further divide the segments into pages
 - Each segment has its page table
- Virtual address
 - Segment number + page number + offset in page
- Advantage
 - Program is shared and protected in segment
- Disadvantage
 - Required multiple times table search



Summary

- Memory management
- Exchange and overlap technique
 - Partitioning and paging
- Virtual memory
 - Page based VM, segment based VM, segment and page based VM



Thank You

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