WEEK 4

Memory management and virtual memory

Stallings, Chapters 7 & 8.1

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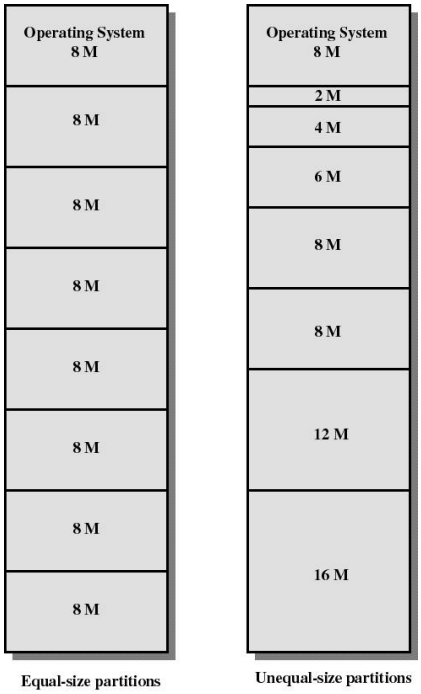
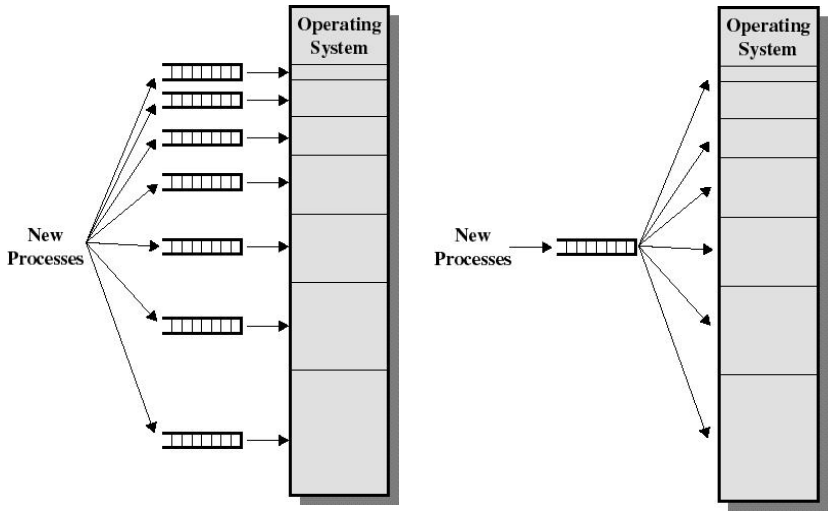
Fixed partitions

- OS splits the memory to partitions
- Whole process must fit to a partition
- Program sizes must be at most the size of the partitions
- Running larger programs required special effort from the programmer
- SWAPPING out to make place for another process
- internal fragmentation



Fixed partitions: allocation



Kuva 7.3

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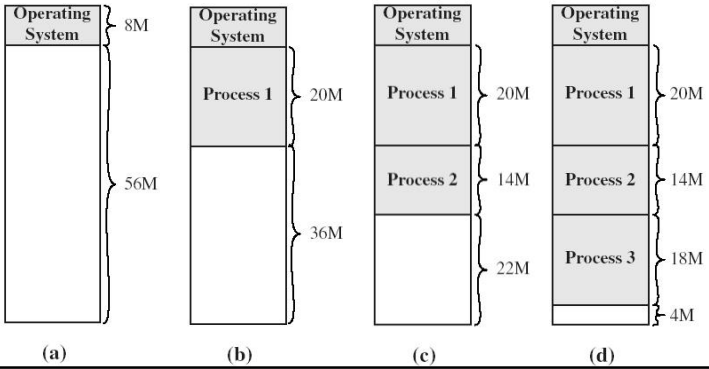
Dynamic partitioning

- No fixed predetermined partition sizes
- Each process gets only the amount of memory it needs
- **external fragmentation**
- OS must occasionally reorganize the memory **(compaction)**



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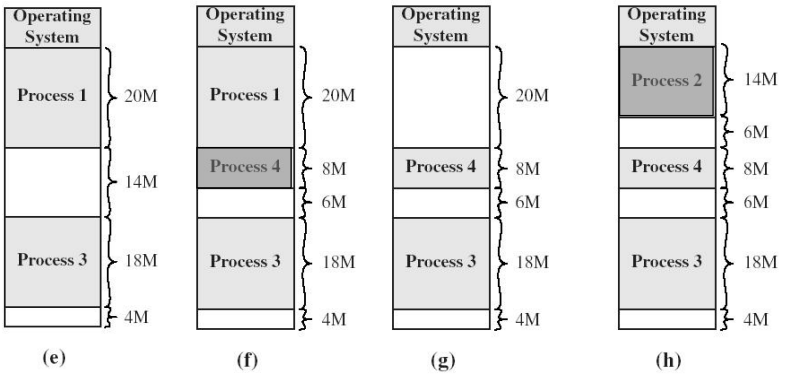
Dynaamic partitions



- Needed space for process 4 -> swap out process 2
- External fragments: 6M + 6M + 4M = 14M

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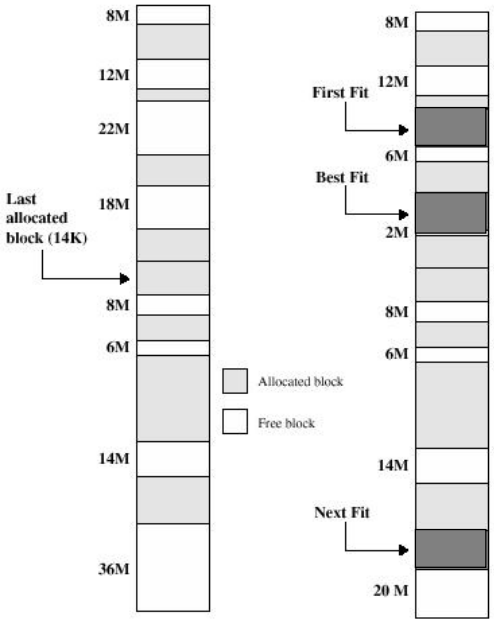
Allocation Kuva 7.5

Where to place the new process?

- Goal: avoid external fragmentation and compation
- Some alternatives:
- Best-fit
- First-fit
- Next-fit



Example Memory Configuration Before and After Allocation of 16 Mbyte Block

Buddy System

- Compromise: Fixed partition sizes, dynamic splitting
- Partition sizes are 2:n potenssissa
  - Some fixed smallest allocation size
- Allocation and combining efficient
- List for each separate size
- Allocation
  - If correct size not available, split a larger one
- Release
  - When two adjacent same sized areas free combine them

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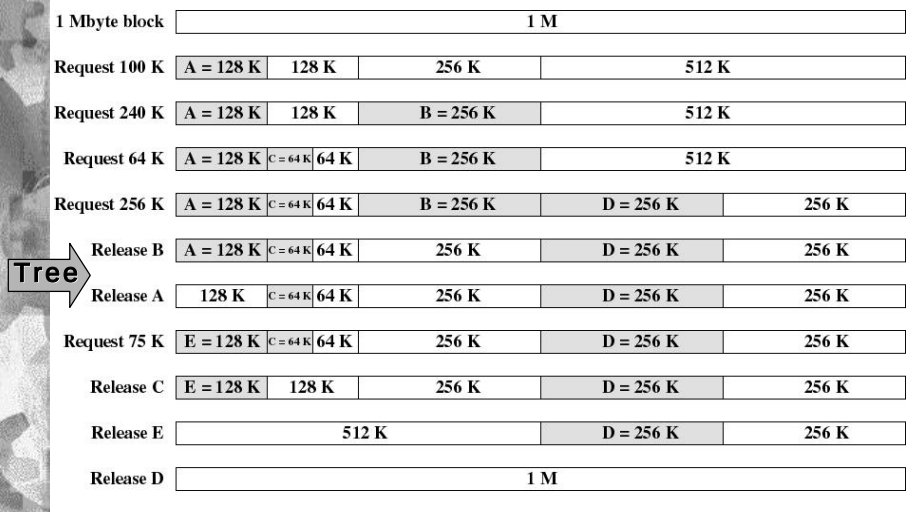
Buddy System



Kuva 7.6

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Buddy: tree representation

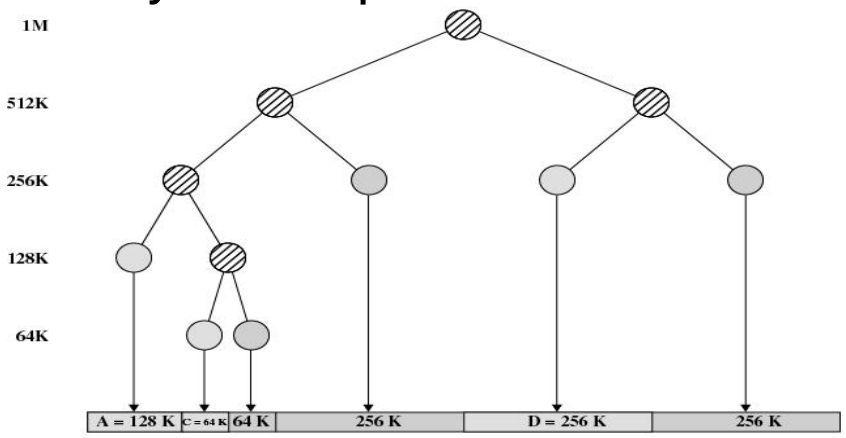

Figure 7.7 Tree Representation of Buddy System

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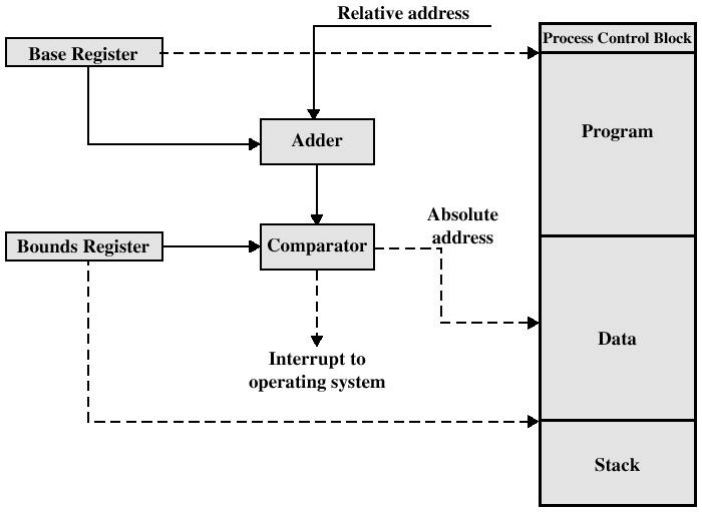
Address translations (fixed part., dynamic part. and buddy system)



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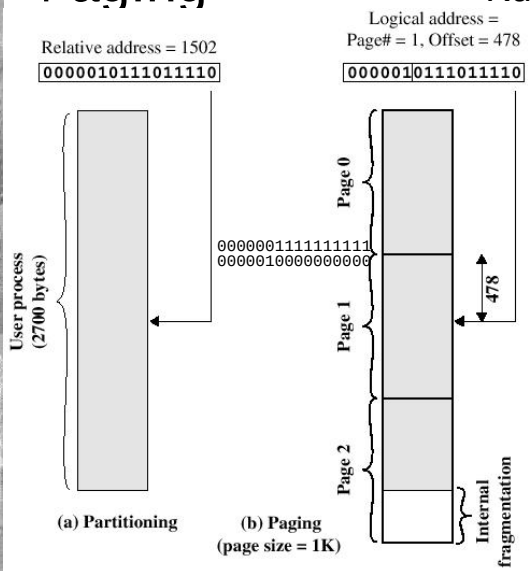
Paging

Kuva 7.11



- Each process has own page table
  - Contains the locations (frame numbers) of allocated frames
- OS maintains a table (or list) of page frames, to know which are unallocated

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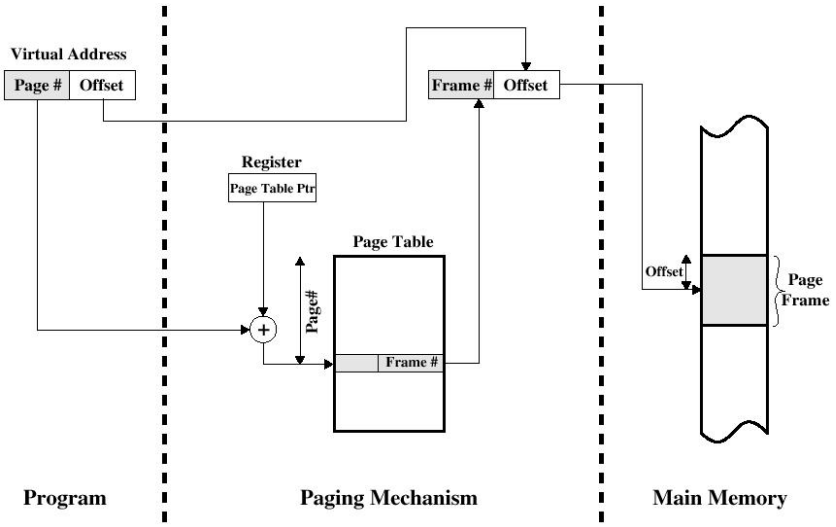
Address translation

Kuva 8.3



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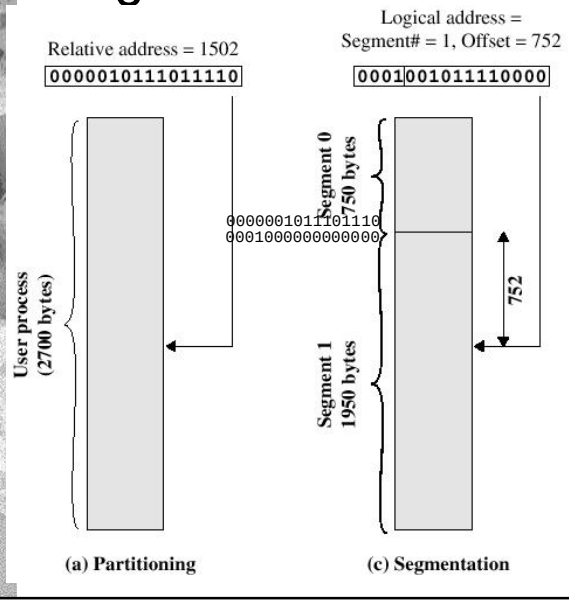
Segmentation

Kuva 7.11



- Programmer (or compiler) determines the logical, unequal-sized segments
- Still using logical addresses (segment, offset)
- Usually a maximum size for each segment given
- Segments can be freely located by OS
- OS maintains a segment table for each process

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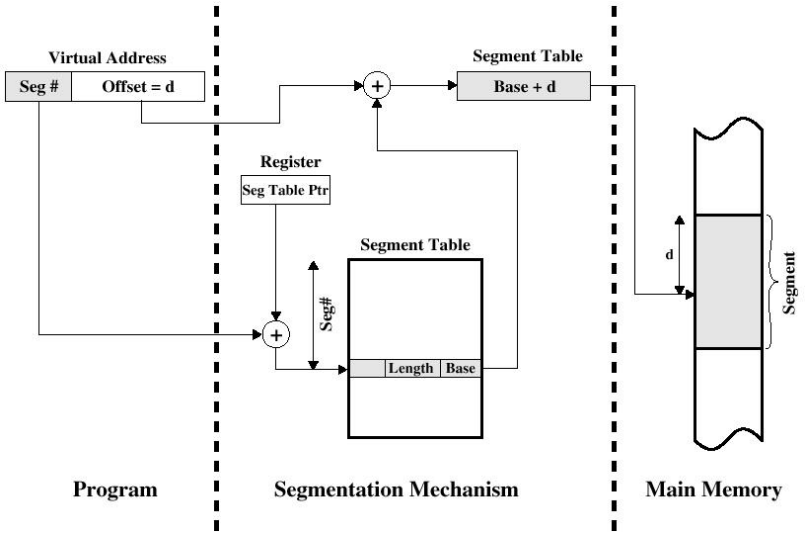
Address translation (segm.)

Kuva 8.12



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WEEK 4

Virtual memory

Stallings, Chapter 8

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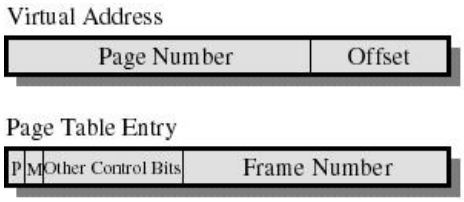
Page table

Kuva 8.2a



P= present bit
M = Modified bit

- Each process has its own page table
- Each entry has a present bit, since not all pages need to be in the memory all the time -> page faults
- Remember the locality principle
- Logical address space can be much larger than the physical

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Structure of page table

- Large virtual address space
  - Logical address could be 32- or 64-bits
- Each process has a large page table
  - Using 32-bit address and frame size 4KB (12 bit offset), means 2^{20} = 1M of page tables entries for a single process
  - Each entry requires several bytes (lets say 4 bytes), so the final size of page table could be for example 4 MB
- Thus the page table is divided to several pages also and part of it can be on the disk
  - We only need the part of the page table in the memory that covers the pages used currently in the execution of the process

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Two-level hierarchical page table

- Top most level in one page and always in the memory

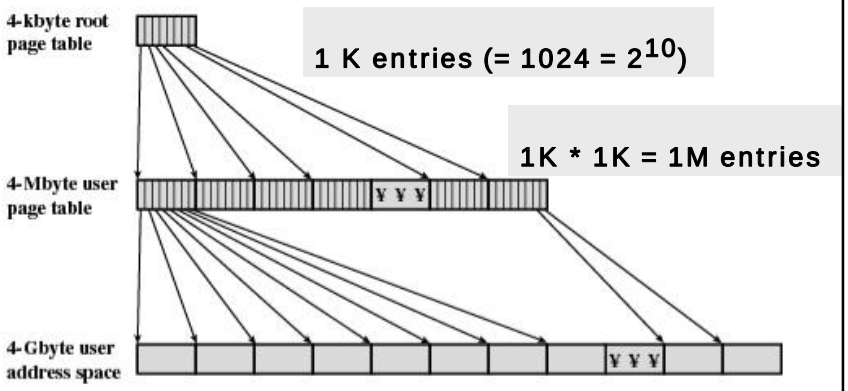

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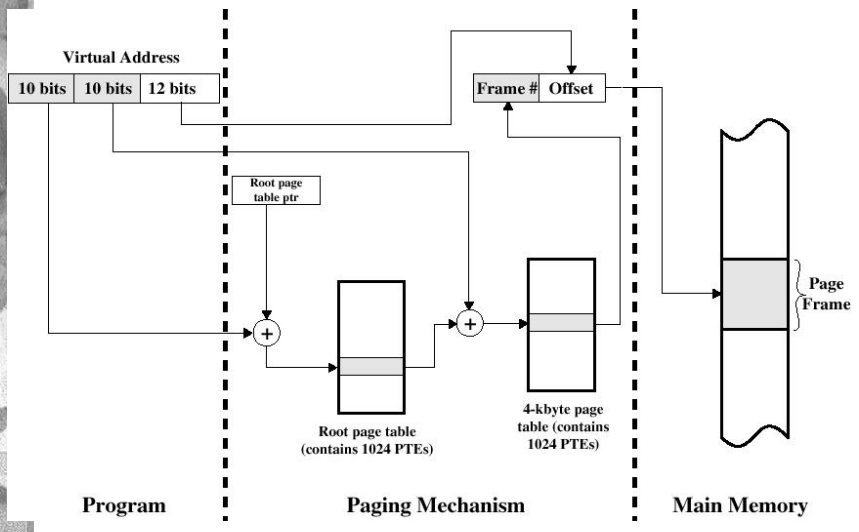
Figure 8.4 A Two-Level Hierarchical Page Table

Address translation with two levels Kuva 8.5



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Inverted page table

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Inverted page table

- Physical memory often smaller than the virtual address space of processes
- Invert booking: Store for each page frame what page (of which process) is stored there
  - Only one global table (inverted page table), one entry for each page frame.
- Seach for the page based on the content of the table
  - Ineffcient, if done sequentially,
  - Use hash to calculate the location, start search from there
- If page not found, page fault
- Useful, only if TLB is large

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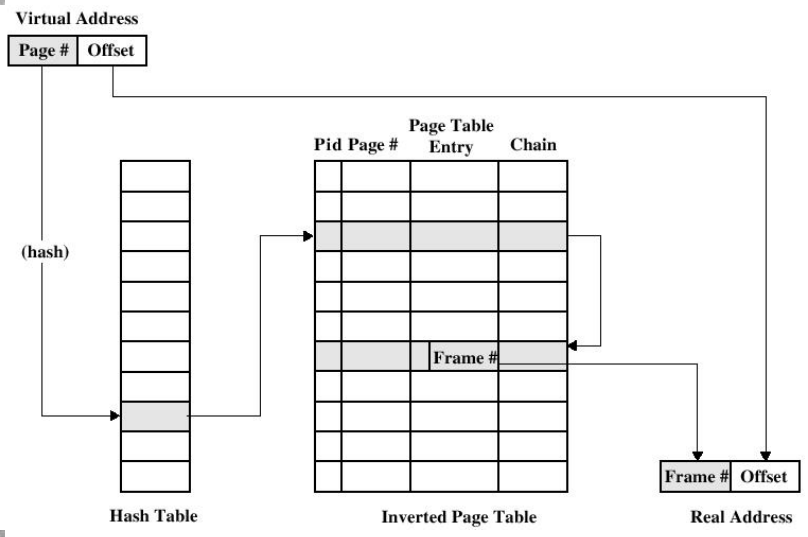
Inverted page table

4. ed

Kuva 8.6



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5. ed

Inverted page table v.2

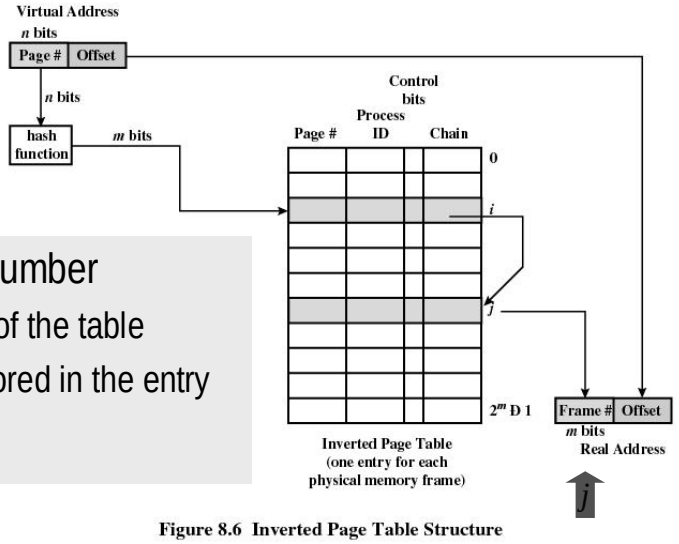

Figure 8.6 Inverted Page Table Structure

- Frame number
  - Index of the table
  - Not stored in the entry

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TLB – translation lookaside buffer

- Part of memory management unit (MMU)
  - Cache for used page table entries to avoid extra memory access during address translation
- Associative search
  - Compare with all elements at the same time (fast)
- Each TLB element contains: page number, page table entry, validity bit
- Each process uses the same page numbers 0, 1, 2, …, stored on different page frames
  - è TLB must be cleared during process switch
  - è At least clear the validity bits (this is fast)

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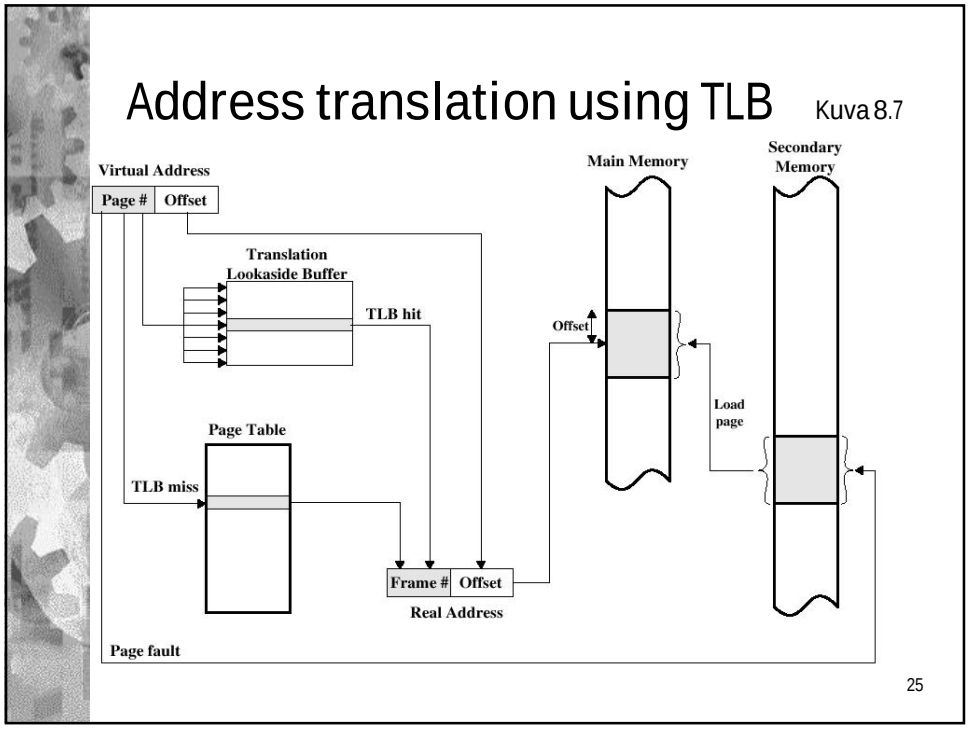
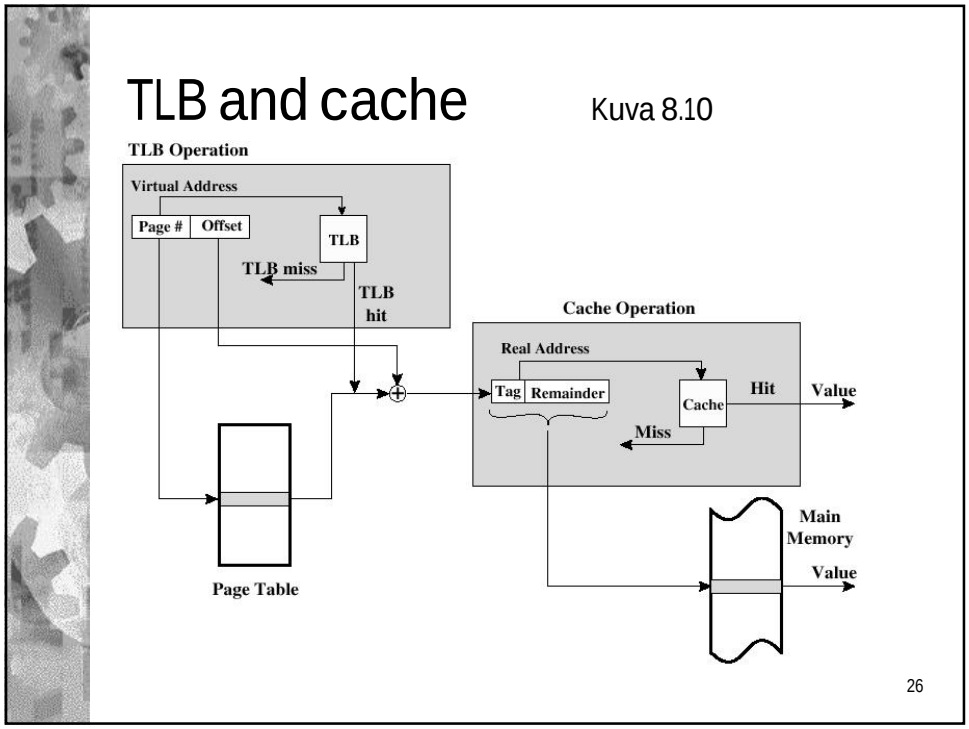

Address translation using TLB
Kuva 8.7
Virtual Address
Page #
Offset
Translation
Lookaside Buffer
TLB hit
Main Memory
Secondary
Memory
Offset
Load
page
Page Table
TLB miss
Frame #
Offset
Real Address
Page fault
25


TLB and cache
Kuva 8.10
TLB Operation
Virtual Address
Page #
Offset
TLB
TLB miss
TLB
hit
Cache Operation
Real Address
Tag
Remainder
Cache
Hit
Value
Miss
Main
Memory
Value
Page Table
26

Segmentointi ja sivutus yhdistettynä

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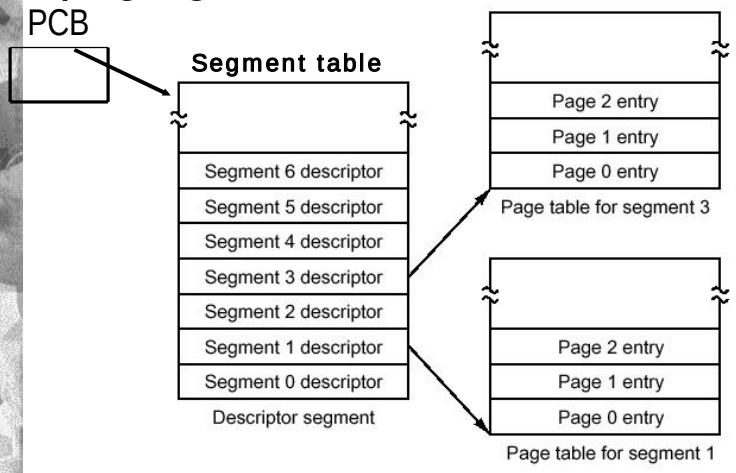
Combining segmentation and paging Tan01 4-39



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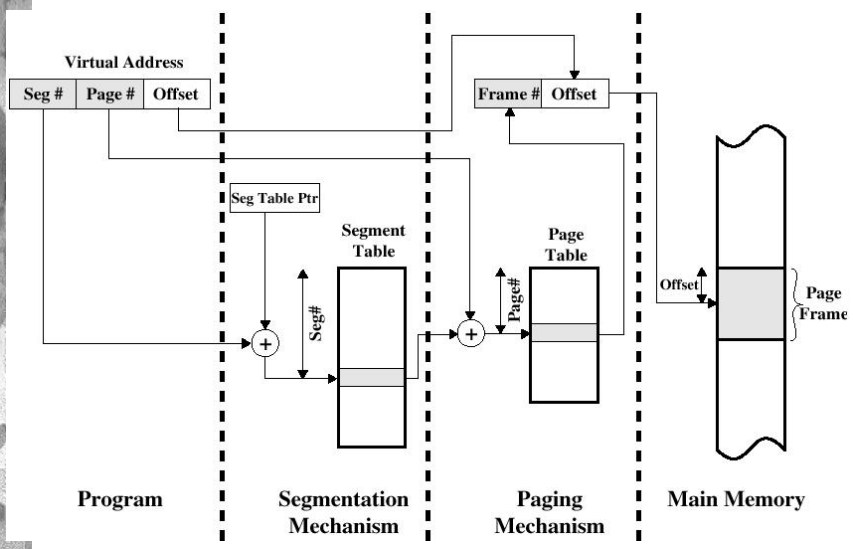
Combined segmentation and paging

Kuva 8.13



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Protection and sharing

No slides in English (sorry)

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