Virtual memory & MMU I

CompSys304 – Computer Architecture

A/Prof Oliver Sinnen

Department of Electrical, Computer, and Software Engineering

Content

Virtual memory

Motivation or problems solved

1. Safe and efficient sharing of memory among multiple programs
   - Secure sharing
2. Burden of programming for small, limited memories
   - Programs can exceed size of physical memory

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- Virtual address – address used by CPU
- Physical address – address in main memory
- Address translation – *mapping* virtual to physical address

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OK, but why here, why not in OS course?

- Address translation done in CPU hardware (Memory Management Unit – MMU) and software
- Impact on CPU performance

Concepts

- Each program gets own address space (i.e. area)
  - Virtual memory exists in abundance
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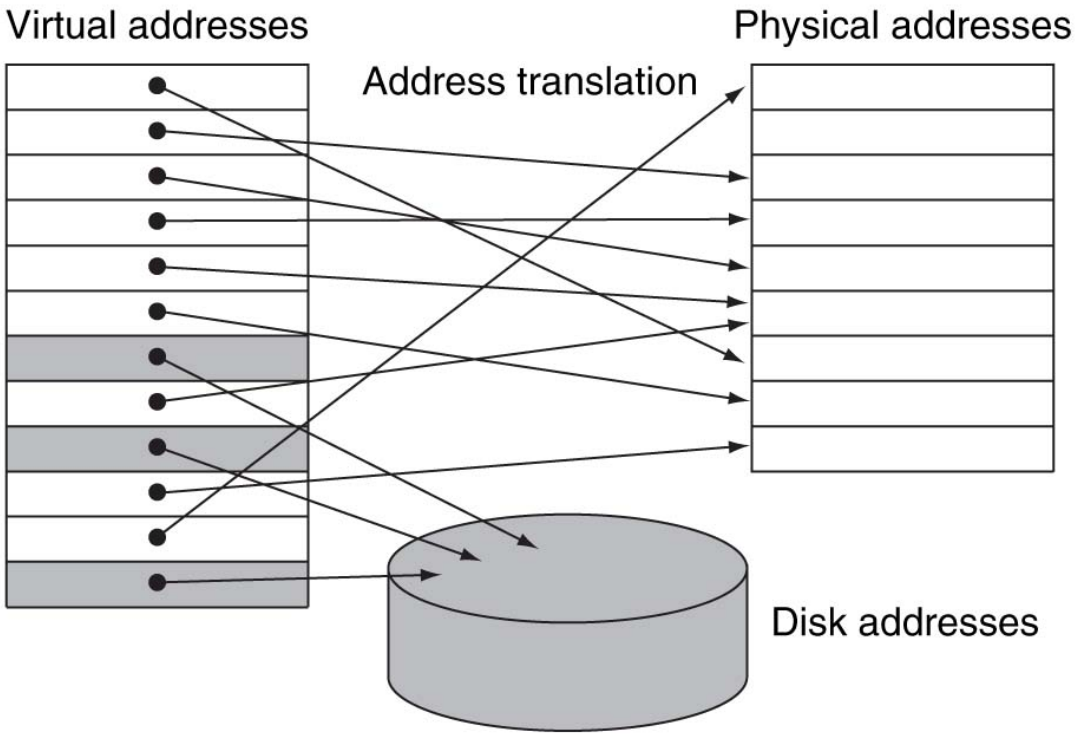
- Main memory becomes cache of secondary memory (disks)
  - Indeed very similar to cache concept
- Virtual address has usually more bits than physical address
  - Idea of concept!
  - But less is also possible (32-bit CPU with more than 4GB RAM)

Principle of address translation

- Virtual address can be mapped to any physical address or disk location
- Address translation is process of doing this



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Possible:

- 2 different virtual addresses can map to same physical address
  - To share code between programs

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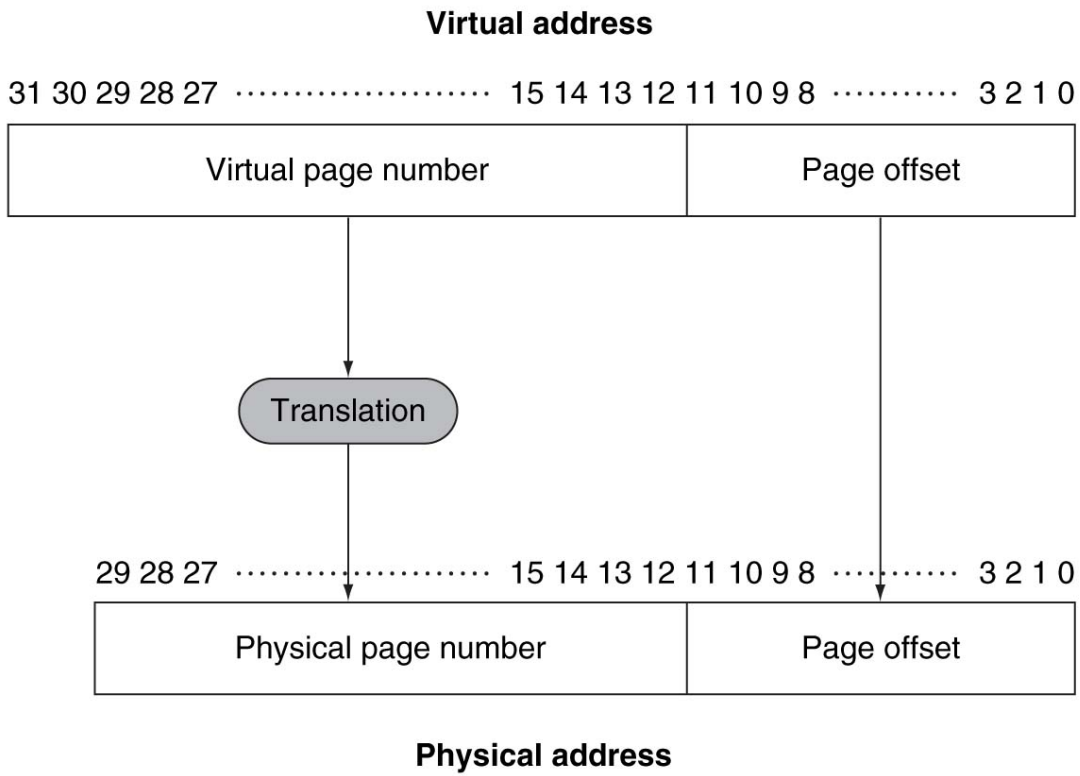
Address translation notation

- Page – smallest block handled by virtual memory
  - Corresponds to cache line
- Page offset f – 2^f is size of page (in bytes)
  - On x86 CPUs (all?) $f = 12 \rightarrow$ page size 4KByte
  - Support for 2/4MB pages on x86
- Page number – number referencing page, index of page
- Page hit – page is in main memory
  - Translation handled by MMU
- Page fault – page is not in main memory
  - Virtual memory miss
  - Corresponds to cache miss
- Page fault handler – function to handle a page miss
  - SW: part of OS kernel

Address translation

- Virtual address 32 bits, physical address 30 bits, page offset 12 bits



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- Page faults can be handled by software
  - Disk access slow anyway, hardware not necessary
  - Advantage, clever placement algorithms can reduce page fault rate

Placement and retrieval

- Reduce page fault rate
  - $\Rightarrow$ Fully associative placement of pages in memory
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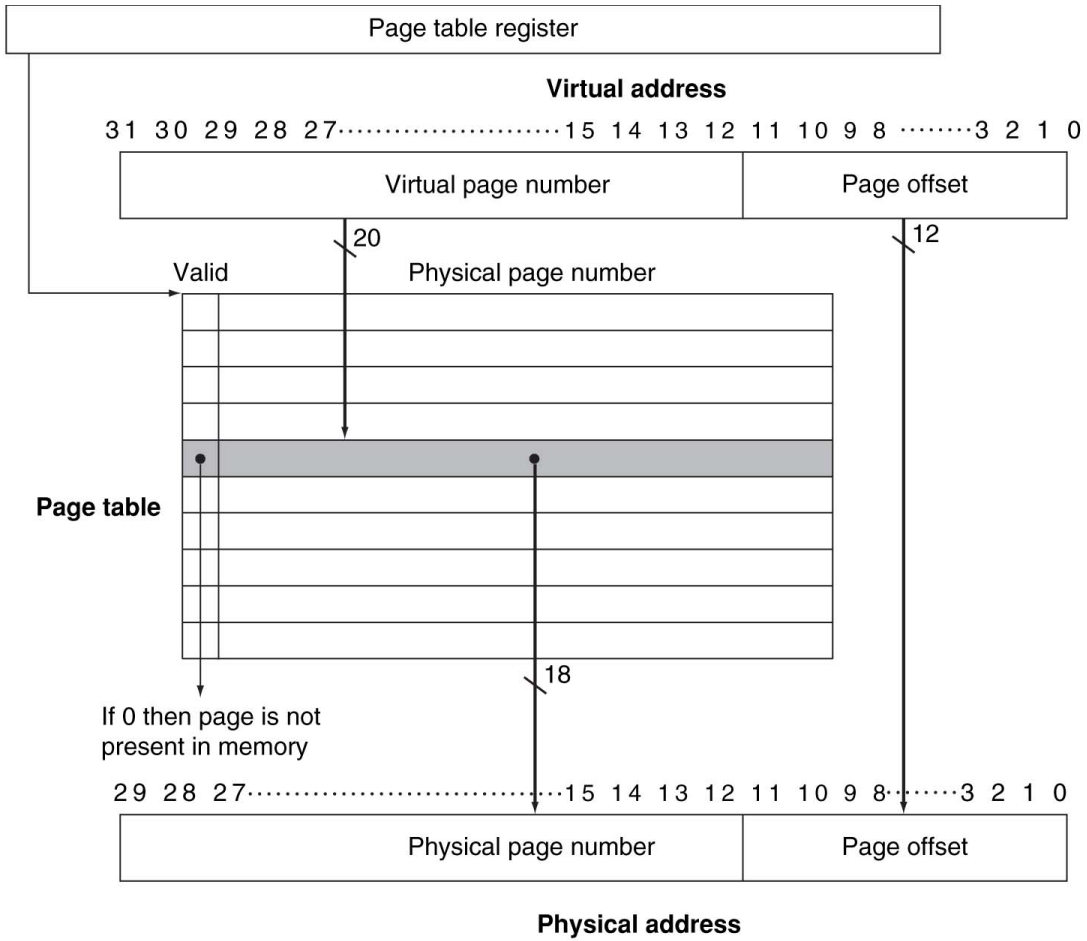
Page table

- In main memory
- Every program (process) has own page table
- Virtual-physical pairs
  - also entries for not in memory (valid bit is `false`)
- Indexed with page number of virtual address
  - No searching necessary
- Page table register
  - MMU register: points to start of page table

Page table

- Table indexed by page number
  - $2^{20} = 1$M entries, 4 bytes each $\Rightarrow$ 4MB



Memory requirement of page tables

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  - *or* ...
- Not discussed here

$\Rightarrow$ studied in Operating System design

Replacement policy

- When physical memory exhausted, evict which page?

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Approximation

- Use reference bit (ref bit)
  - Set when page is accessed
  - Periodically reset
  - Software takes snapshots before reset
    - Can build set of recently used pages
  - Evict page to swap space whose ref bit has not been set for some time