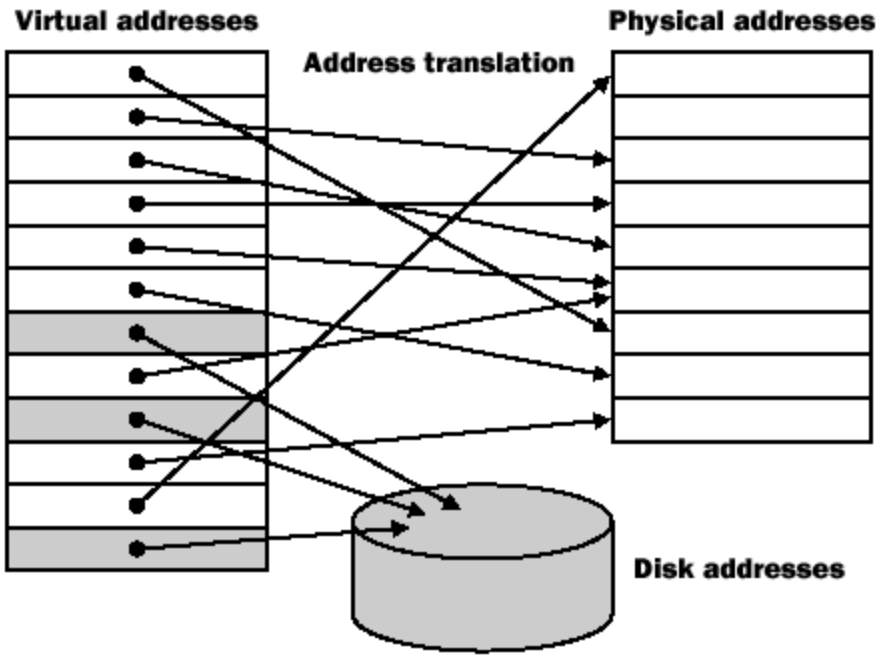
Virtual Memory

Carolina Course Evaluation Open

Today: Virtual Memory

Virtual Memory

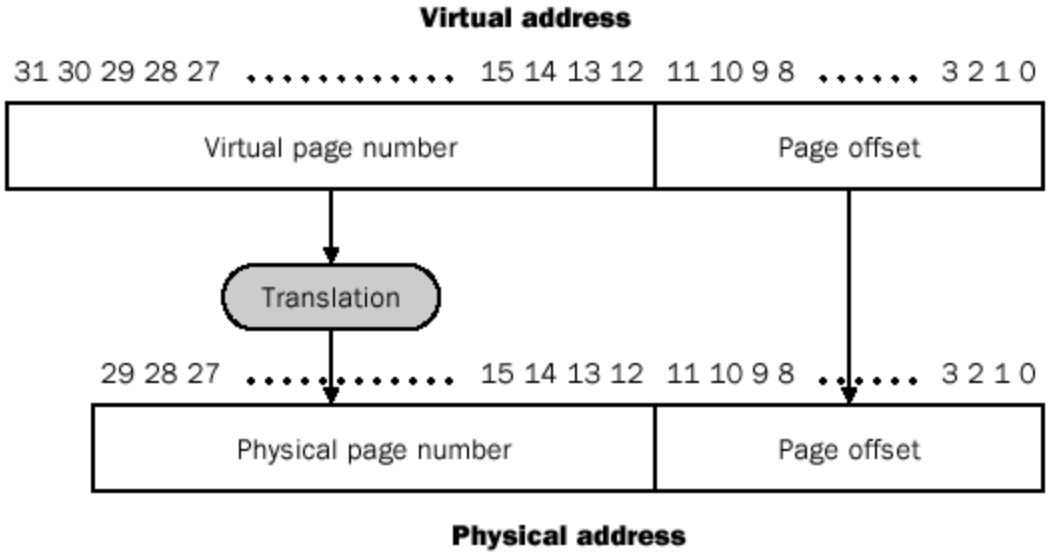


- Main memory is a CACHE for disk
- Advantages:
  - illusion of having more physical memory
  - program relocation
  - protection

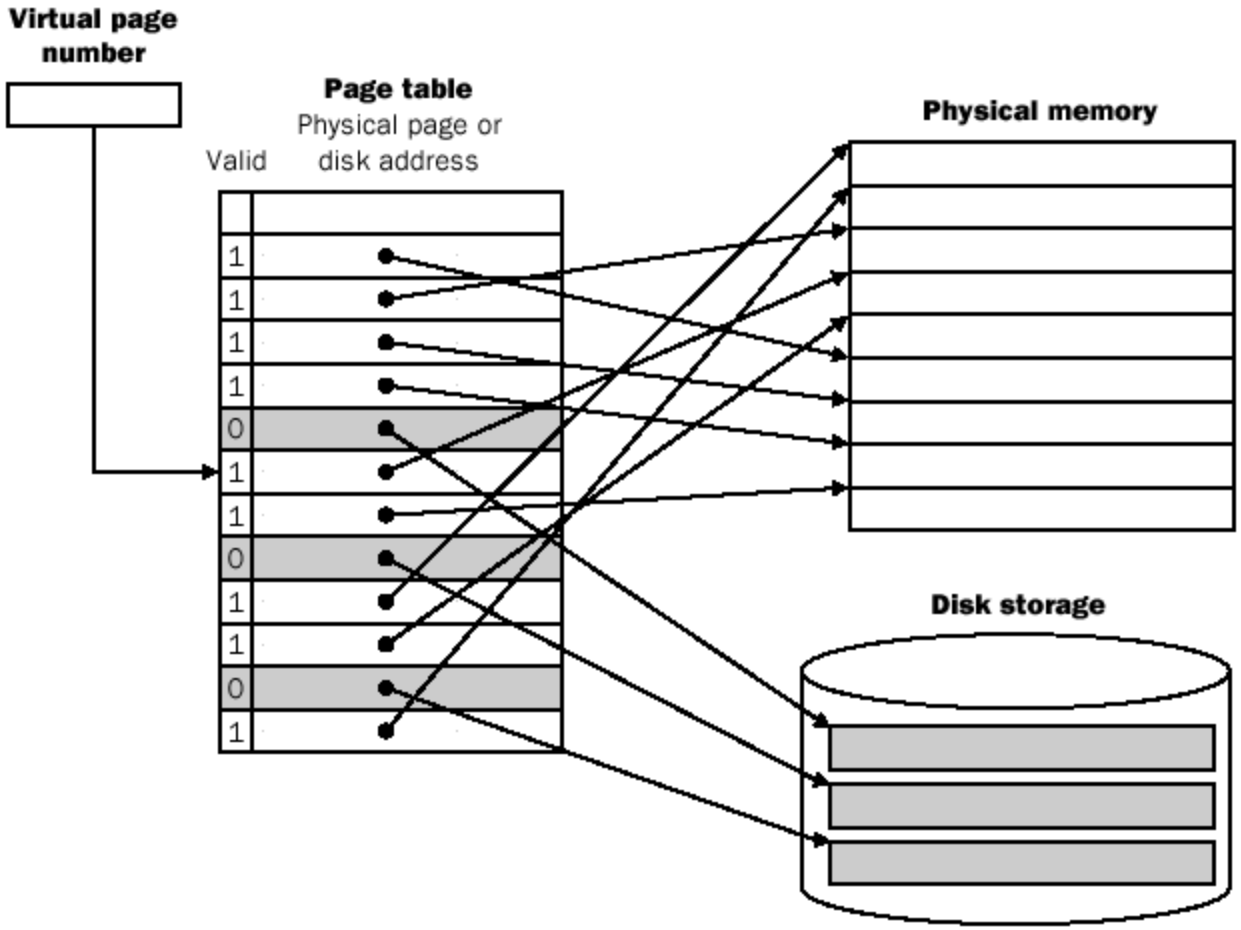
Pages: Virtual Memory Blocks

Page faults: the data is not in memory, retrieve it from disk

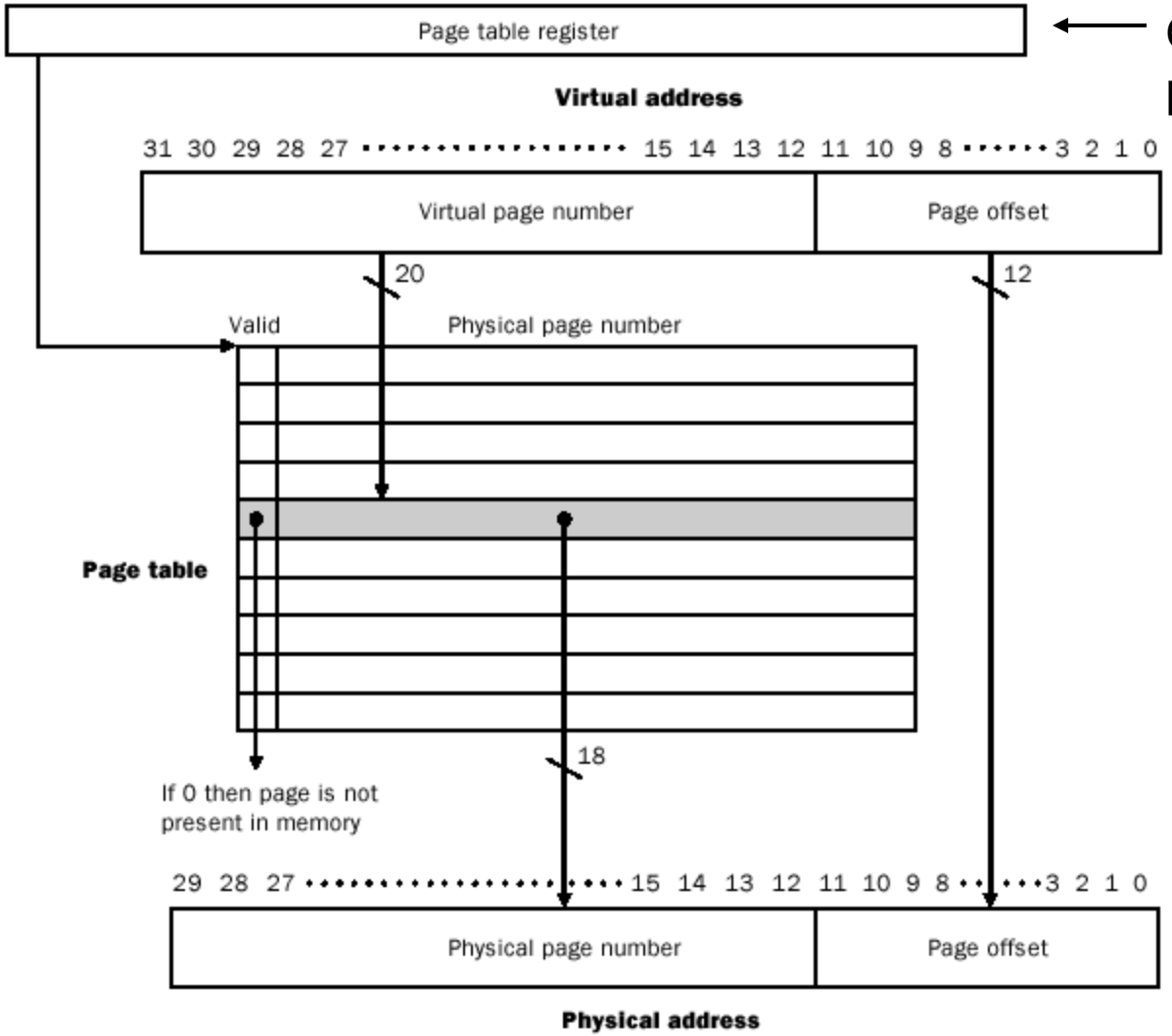
- huge miss penalty (remember **months** at human scale)
  - Pages should be fairly large (e.g., 4KB)
  - Find something else to do while waiting
- reducing page faults is important (LRU is worth the price)
- can handle the faults in software instead of hardware
- using write-through is too expensive so we use writeback



Page Tables


Virtual page number
Page table
Physical page or disk address
Valid
1
1
1
1
0
1
1
0
1
1
0
1
Physical memory
Disk storage

Page Tables

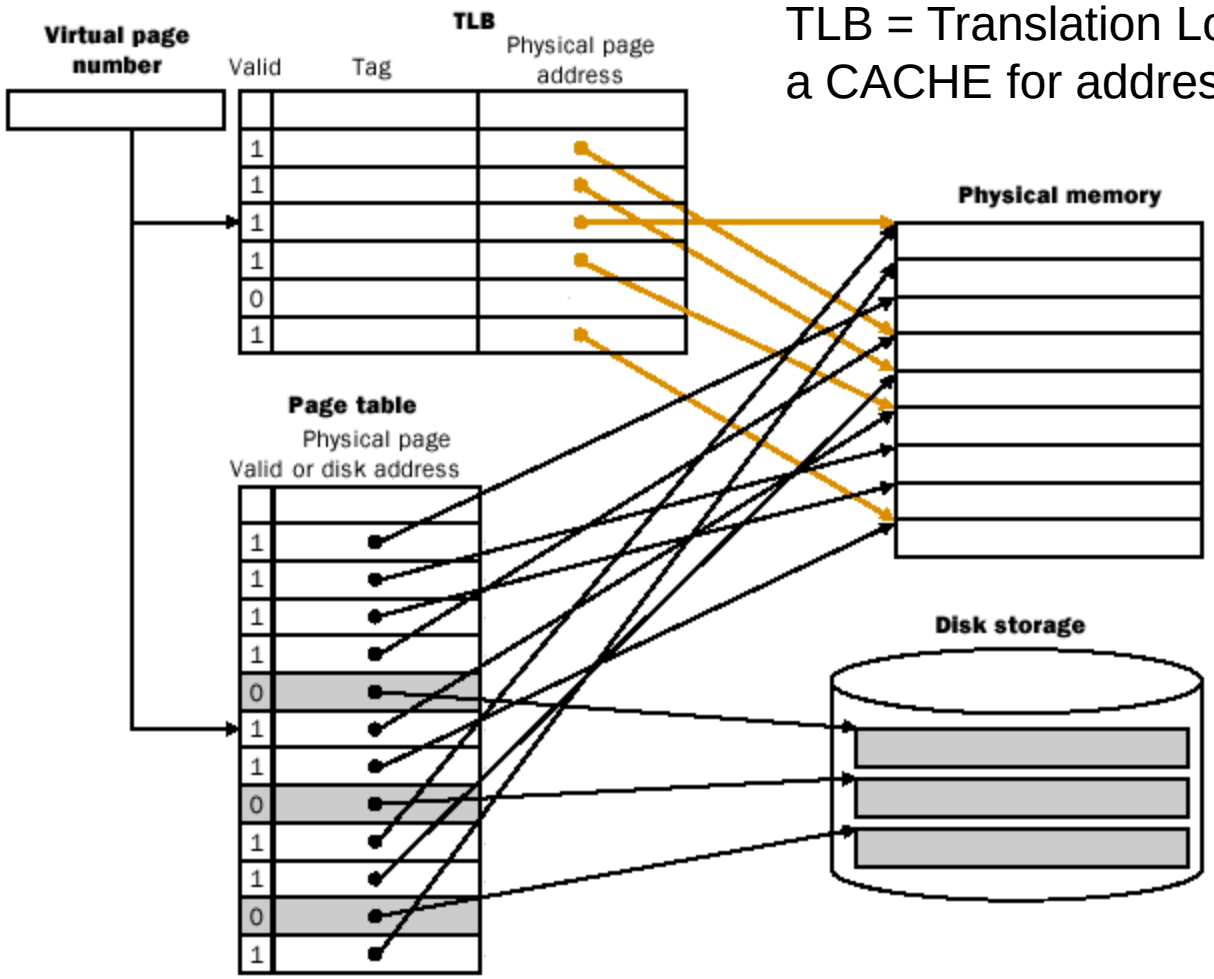


One page table per process!

Where are the page tables?

- Page tables are potentially BIG
  - 4kB page, 4MB program, 1k page table entries per program!
    - Powerpoint 18MB
    - GBMail 32MB
    - SpamFilter 48MB
    - mySQL 40MB
    - iCalMinder 5MB
    - iCal 9MB
    - Explorer 20MB
    - 40 More Processes!
  - Page the page tables!
  - Have to look up EVERY address!

Making Address Translation Fast



TLB = Translation Lookaside Buffer
a CACHE for address translation

What is in the page table?

Address = upper bits of physical memory address OR
disk address of page if not in memory

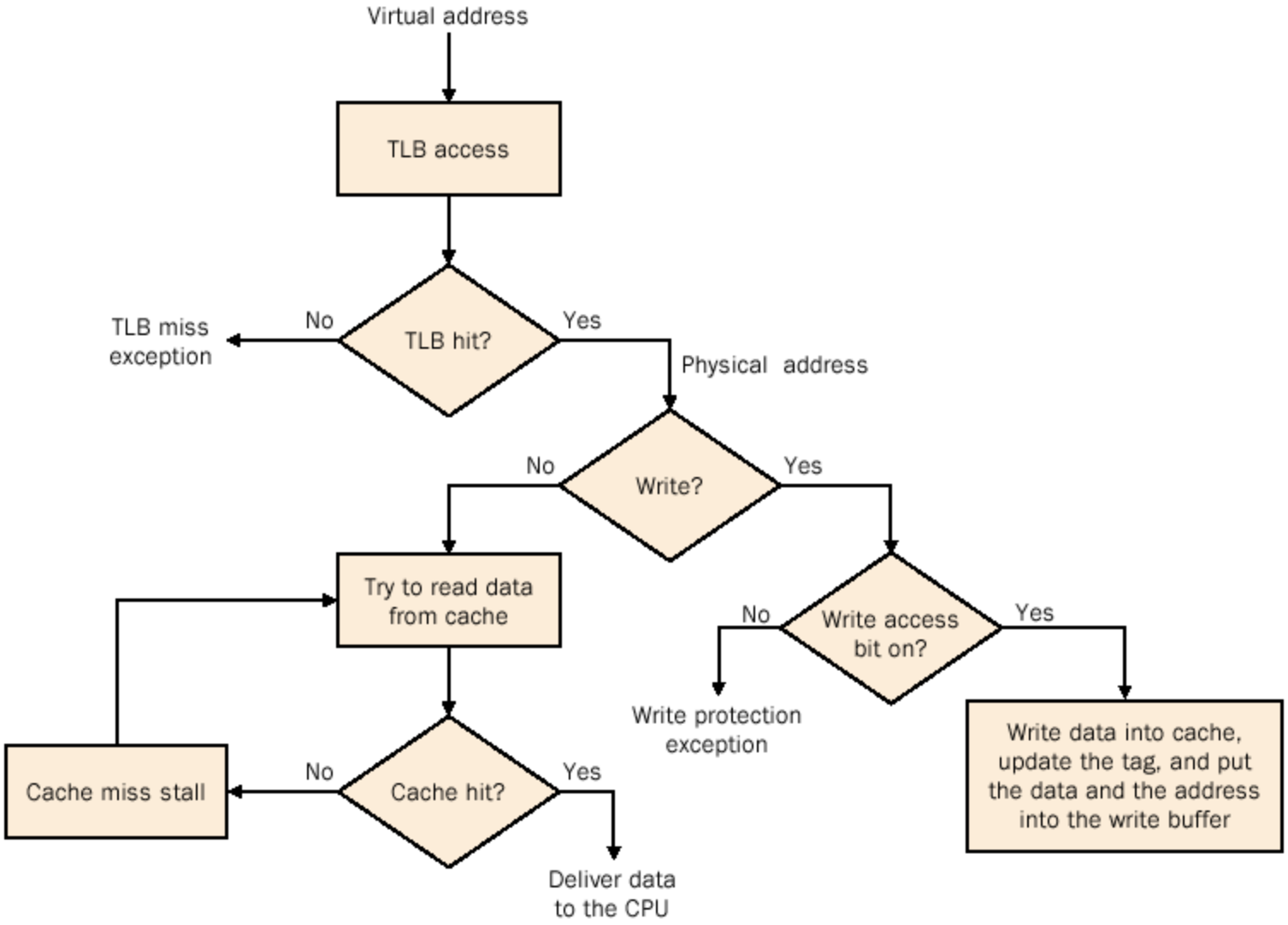
Valid = bit, set if page is in memory

Use = bit, set when page is accessed

Protection = bit (or bits) to specify access permissions

Dirty = bit, set if page has been written

Integrating TLB and Cache



Program Relocation?

We want to run multiple programs on our computer "simultaneously"

To start a new program

Without Virtual Memory:

We have to modify all the address references to correspond to the range chosen. This is "relocation".

With Virtual Memory:

EVERY program can pretend that it has ALL of memory. TEXT segment always starts at 0, STACK always resides a some huge high address (0xfffffff0)

Protection?

We'd like to protect one program from the errors of another

Without Virtual Memory (old Macs, win3-)

- One program goes bad (or the programmer makes a mistake) and kills another program or the whole system!

With Virtual Memory (new Macs, win95+)

- Every program is isolated from every other. You can't even NAME the addresses in another program.

Each page can have read, write, and execute permissions

Some Issues

Processor speeds continue to increase
— much faster than either DRAM or disk access times

Design challenge: dealing with this growing disparity

Trends:

- synchronous SRAMs (provide a burst of data)
- redesign DRAM chips to provide higher bandwidth or processing
- restructure code to increase locality
- use prefetching (make cache visible to ISA)

What cache and VM have in common

Question 1: Where can a block be placed?

Question 2: How is a block found?

Question 3: Which block should be replaced on a cache miss?

Question 4: What happens on a write?

Where can a block be placed?

Direct Mapped Cache: only 1 place for any block
(many blocks map to the same place)

2-Way Set Associative: 2 places for any block

4-Way Set Associative: 4 places for any block

Fully Associative: anywhere

Virtual Memory: anywhere

How is a block found?

Direct mapped cache: compute the index

Set associative cache: compute the index, then search

Fully associative cache: search all cache entries

Virtual memory: separate lookup table

Which block is replaced on miss?

Direct mapped cache have no choice

Others can use:

- Random replacement
- Least Recently Used (LRU)
- Other schemes

What happens on write?

Write-through: write to both the cache and the next lower level

Write-back: write only to the cache, remember that we have to write to the lower level on replacement

Misses

Compulsory misses

Capacity misses

Conflict misses