Virtual Memory

CS520
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Motivation

- Allow programs to exceed size of physical memory
- Support multiple programs sharing physical memory
- Efficient use of resources
- Protection
Warning

Technology is similar for virtual memory and cache

But terminology is different

Cache block $\leftrightarrow$ virtual memory page

Cache miss $\leftrightarrow$ virtual memory page fault
Page size \(2^{12} = 4\text{KB}\)

Number of physical pages \(2^{18}\)

Physical memory maximum size 16GB (30-bit address)

Virtual memory maximum size 4GB (32-bit address)
If virtual page doesn't fit in physical memory, it is stored on disk.

Large miss penalty!

So

Large page size
Misses can be handled in software
Accumulate writes — don't "write through"
Reducing page fault rate is important
to reduce page fault rate use associative mapping

allow virtual page to be placed anywhere in physical memory

use page table to implement associative mapping

→ each program has page table

page table is in memory and is pointed to by page table register
* if valid flag not set, pje is not in memory.

** when valid flag clear, then this field contains disk location of pje.
When page fault occurs, operating system is given control to get page from disk.

Key problem

If all pages in physical memory are in use, then which one should be replaced?
temporal locality \Rightarrow \text{Least Recently Used (LRU)}

Page should be chosen can be approximated via a reference bit

set when page referenced

O.S. periodically clears all the reference bits

a page with a clear bit is among those least recently used at page-fault time
"write-back" instead of "write-through"
accumulate changes
write back only at replacement time
use "dirty" bit to track whether file
has been modified
Page table in memory $\Rightarrow$

each memory reference requires two memory operations?!

once to read page table
once to read the requested memory location

to avoid this cost, systems employ a special cache to remember recent virtual-to-physical page mappings

$\Rightarrow$ Translation Lookaside Buffer (TLB)
memory protection

page table entry can contain protection information

e.g., page is read-only