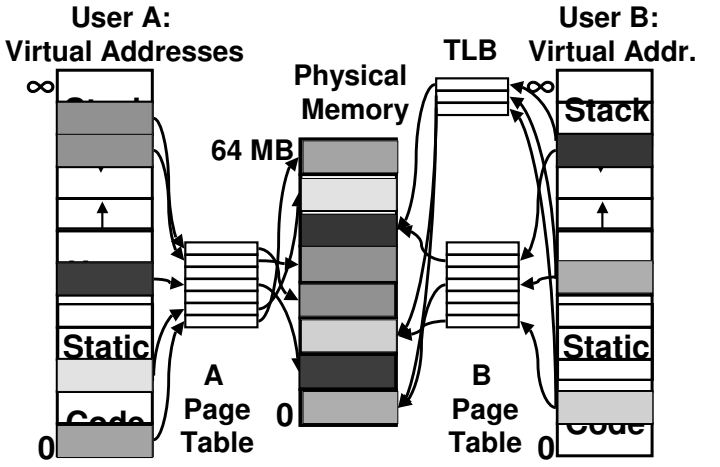
Paging/Virtual Memory Review



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Why virtual memory?

- Protection
  - regions of the address space can be read only, execute only ...
- Flexibility
  - portions of a program can be placed anywhere in physical memory, without relocation
- Expandability
  - can leave room in virtual address space for objects to grow
- Efficient use of fast storage
  - retain only most important portions of the program in memory
- Can run programs larger than size of physical memory

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Three Advantages of Virtual Memory

1) Translation:

- Program can be given consistent view of memory, even though physical memory is scrambled
- Makes multiple processes reasonable
- Only the most important part of program ("Working Set") must be in physical memory
- Contiguous structures (like stacks) use only as much physical memory as necessary yet still grow later

2) Protection:

- Different processes protected from each other
- Different pages can be given special behavior
  - (Read Only, Invisible to user programs, etc).
- Kernel data protected from User programs
- Very important for protection from malicious programs (viruses)

3) Sharing:

- Can map same physical page to multiple users ("Shared memory")

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TLB, Page Table

Memory lookup slow: TLB to reduce performance cost of VM

Need more compact representation to reduce memory size cost of simple 1-level page table, especially for 64-bit address

-64 bit address space, 4K pages => 2^52 entries in the page table

Solutions: - Multi-leveled page tables

- Inverted page tables

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Comparing the 2 levels of hierarchy

Cache Version	Virtual Memory Version
Block or Line	Page
Miss	Page Fault
Block Size: 32-64B	Page Size: 4K-8KB
Placement: Direct Mapped, N-way Set Associative	Fully Associative
Replacement: LRU or Random	Least Recently Used (LRU)
Write Thru or Back	Write Back

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Picking Page Size

- Minimize wasted storage
  - small page minimizes internal fragmentation
  - small page increases size of page table, TLB usage
- Minimize transfer time
  - large pages (multiple disk sectors) amortize disk access cost
  - sometimes transfers unnecessary info
  - sometimes prefetches useful data
- General trend toward larger pages because
  - big cheap RAM
  - increasing memory - disk performance gap
  - larger processor address spaces

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