Virtual Memory I
CSE 351 Winter 2024

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https://ptbd.jwels.berlin/comic/21/
Relevant Course Information

❖ HW21 due tonight, HW22 due Monday, HW23 due Wednesday
❖ Lab 4 due tonight
❖ Lab 5 due next Friday (3/8)
  ▪ The most significant amount of C programming you will do in this class – combines lots of topics from this class: pointers, bit manipulation, structs, examining memory
  ▪ Understanding the concepts first and efficient debugging will save you lots of time
  ▪ Light style grading
  ▪ Only 1 late day can be used for Lab 5

❖ No lessons for Lectures 25 and 26 – “normal” lectures
Take-Home Final Exam

- First three days of Finals Week (3/11-13)
  - Structure will be very similar to the midterm
  - Not cumulative: focused on post-midterm material
  - Hybrid final review session planned for 3/8 (room TBD)
  - Justin will hold virtual support hours on 3/12 and 3/13
  - Regrade requests Monday, 3/18
Virtual Memory I
Lesson Summary (1/2)

❖ **Virtual memory** is software’s perspective (e.g., memory layout), **physical memory** is hardware’s perspective (e.g., memory hierarchy)

❖ Virtual memory manages the memory for multiple concurrently running processes (implements **protection** and **sharing**)
  - Each process has its own virtual address space that gets mapped into parts of the physical address space
  - When run out of physical address space, put least recently used data in disk
Lesson Summary (2/2)

❖ Can think of physical memory as a cache of virtual memory
  - Data is transferred between physical memory and swap space (disk) in **pages**
  - Physical memory has caching parameters and properties
    - Large page size, fully associative, write-back, replacement policy
  - Caveats: virtual pages may not exist, data doesn’t have to exist in both physical memory and disk

![Diagram showing virtual memory and physical memory with swap space](image-url)
Lesson Q&A

❖ Learning Objectives:
  ▪ Explain the benefits behind why virtual memory is used instead of only physical memory address space.
  ▪ Describe the relationships between virtual memory parameters and policies.

❖ What lingering questions do you have from the lesson?
  ▪ Chat with your neighbors about the lesson for a few minutes to come up with questions
Polling Questions (1/2)

❖ On a 64-bit machine currently running 8 processes, how much virtual memory is currently available?

\[
\text{word size is 64 bits, so } n = 64 \text{ and } N = 2^{64} \text{ bytes per process.}
\]

\[
2^{64} \times 8 = 2^{67} \text{ bytes of virtual memory}
\]

❖ True or False: A 32-bit machine with 8 GiB of RAM installed would never use all of it (in theory).

\[
\text{word size is 32 bits, so each process has } 2^{32} \text{ bytes = } 4 \text{ GiB of virtual memory}
\]

however, we have more than 1 process, so we can easily use up all 8 GiB of physical memory

\[\text{Note: there are other limitations, (e.g., motherboard, OS) that restrict the maximum amount of usable RAM in practice.}\]
Polling Questions (2/2)

❖ How many bits wide are the following fields?

- 16 KiB pages: \( p = 14 \text{ bits} \)
- 48-bit virtual addresses: \( n = 48 \text{ bits} \) \( \iff \) 256 TiB virtual memory
- 16 GiB physical memory: \( m = 34 \text{ bits} \)

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<thead>
<tr>
<th>VPN</th>
<th>PPN</th>
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<tbody>
<tr>
<td>(A)</td>
<td>34</td>
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<tr>
<td>(B)</td>
<td>32</td>
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<td>(C)</td>
<td>30</td>
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<td>(D)</td>
<td>34</td>
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VA: \( \overline{VPN} \; \; | \; \; Po \) \nVPN = \( n - p = 34 \text{ bits} \) \( \iff \) \( 2^4 \) pages in virtual address space

PA: \( \overline{PPN} \; \; | \; \; Po \) \nPPN = \( m - p = 20 \text{ bits} \) \( \iff \) \( 2^{20} \) pages in physical address space
Group Work Time

❖ During this time, you are encouraged to work on the following:
   1) If desired, continue your discussion
   2) Work on the homework problems
   3) Work on the lab (if applicable)

❖ Resources:
   ▪ You can revisit the lesson material
   ▪ Work together in groups and help each other out
   ▪ Course staff will circle around to provide support