Virtual Memory I

CSE 351 Winter 2024

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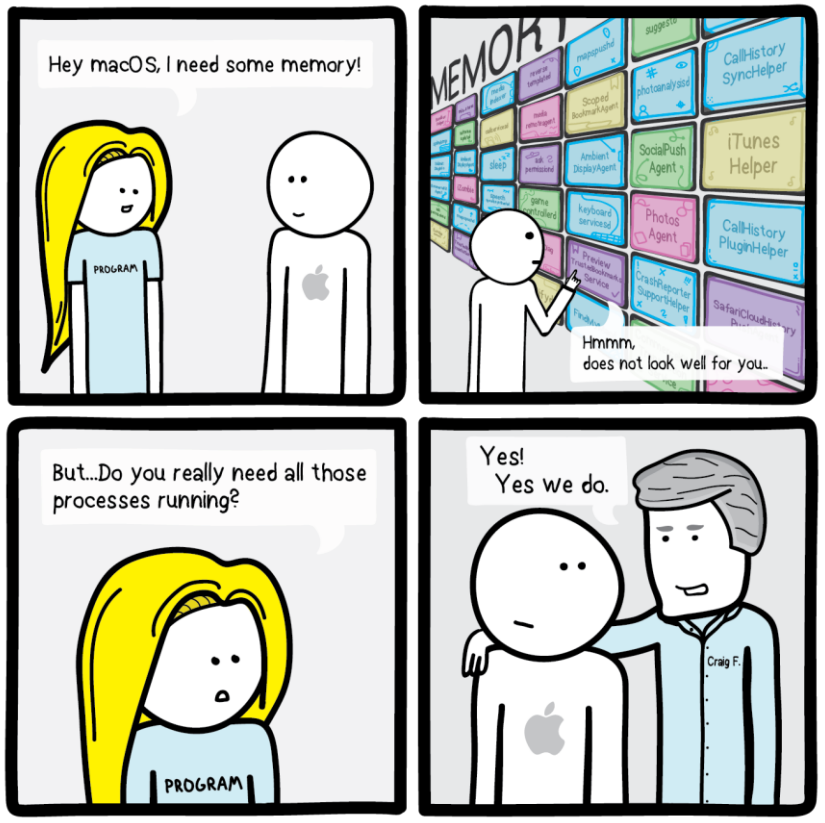


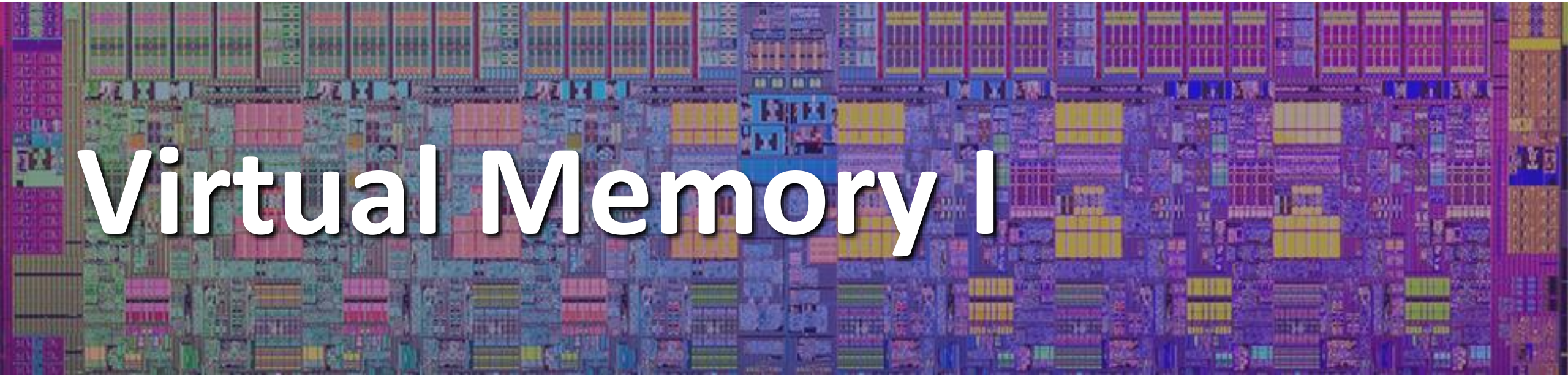
https://ptbd.jwels.berlin/comic/21/

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

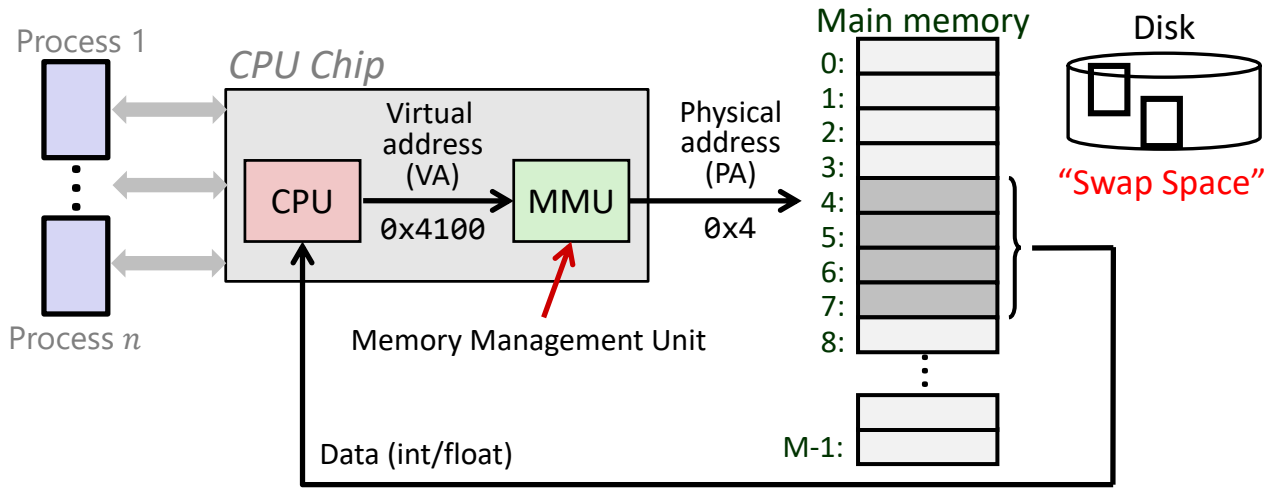


Virtual Memory I

Lesson Summary (1/2)

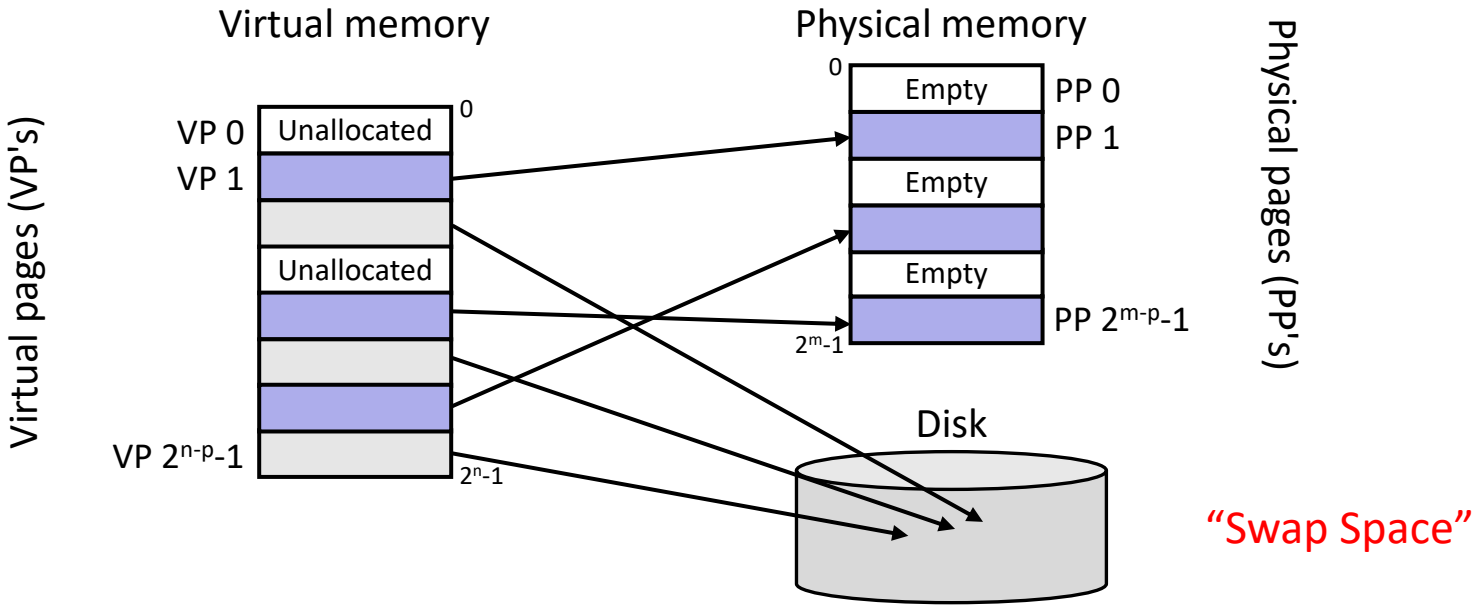
- ***Virtual memory*** is software's perspective (*e.g.*, memory layout), ***physical memory*** is hardware's perspective (*e.g.*, memory hierarchy)

- 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)

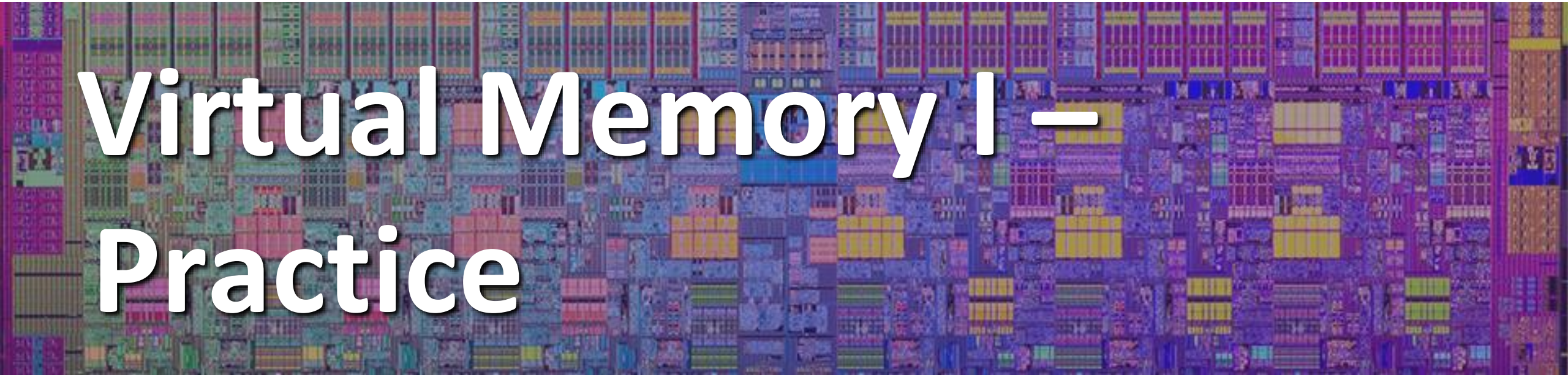
- Can think of physical memory as a cache of virtual memory
  - Data is transferred between physical memory and swap space (disk) in ***pages***
  - Physical memory has caching parameters and properties
    - Large page size, fully associative, write-back, replacement policy
  - Caveats: virtual pages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



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



Virtual Memory I – Practice

Polling Questions (1/2)

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

word size is 64 bits, so $n = 64$ and $N = 2^{64}$ bytes per process.

$2^{64} \times 8 = 2^{67}$ 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).

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

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

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 (2^{14} bytes, 2^{10} bytes) → $p = 14$ bits
  - 48-bit virtual addresses → $n = 48$ bits ⟷ 256 TiB virtual memory
  - 16 GiB physical memory (2^{34} bytes, 2^{30} bytes) → $m = 34$ bits

	VPN	PPN
(A)	34	24
(B)	32	18
(C)	30	20
(D)	34	20

VA: [VPN | PO]

VPN = n − p = 34 bits ⟷ 2^{34} pages in virtual address space

PA: [PPN | PO]

PPN = m − p = 20 bits ⟷ 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