Malloc & VM

By sseshadr

Agenda

- Administration
  - Process lab code will be inked by Thursday (pick up in ECE hub)
  - Malloc due soon (Thursday, November 4th)
  - Exam 2 in a week (Tuesday, November 9th)
  - Proxy Lab out in a week (Tuesday, November 9th)
- Plan for today
  - Finish malloc questions
  - mm_checkheap
  - VM

Malloc

Questions?

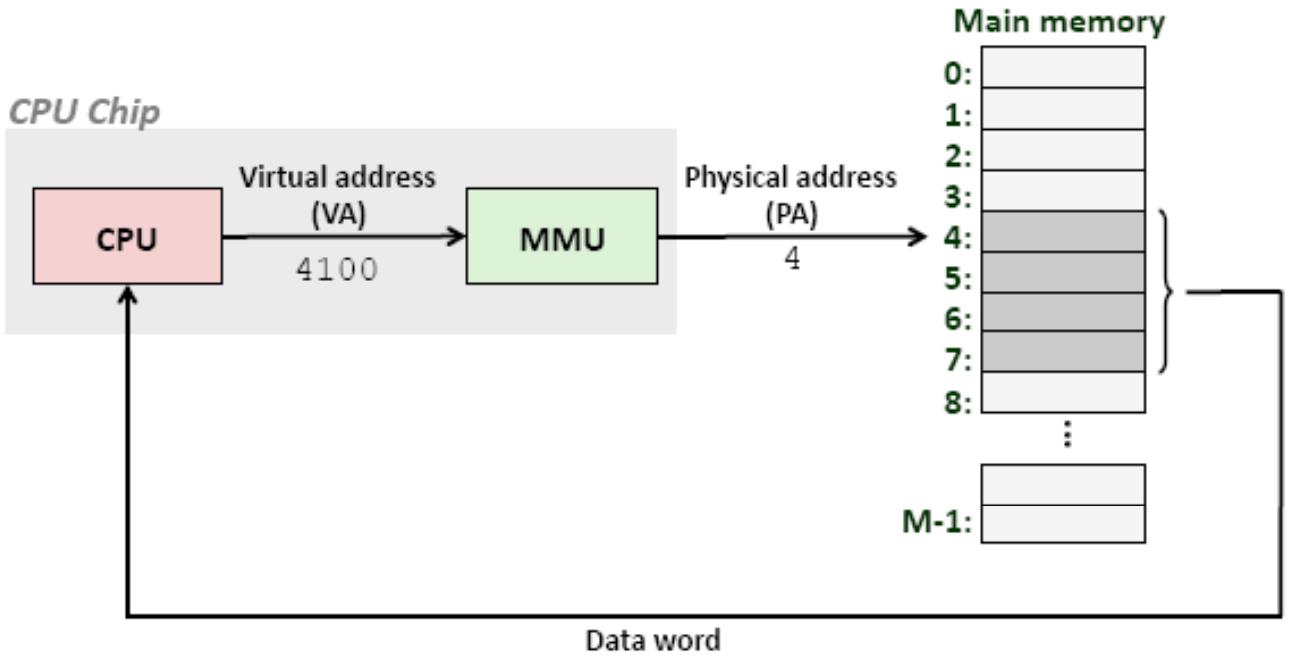
mm_checkheap

- More for YOU than for US.
  - But we'll grade it.
- Checks consistency of data structure
  - (Doubly) linked lists are pointed correctly?
  - Headers and footers match up?
  - No allocated blocks in your explicit list?
  - No free blocks NOT in your explicit list?
  - Any of YOUR OWN invariants! (address-ordering?)
  - Seg lists: no big chunks in small lists / vice versa?

Virtual Memory

Basic Concepts

A System Using Virtual Addressing



- Used in all modern servers, desktops, and laptops
- One of the great ideas in computer science

Basic Concepts

Review of Symbols

- **Basic Parameters**
  - **N = 2^n** : Number of addresses in virtual address space
  - **M = 2^m** : Number of addresses in physical address space
  - **P = 2^p** : Page size (bytes)
- **Components of the virtual address (VA)**
  - **TLBI**: TLB index
  - **TLBT**: TLB tag
  - **VPO**: Virtual page offset
  - **VPN**: Virtual page number
- **Components of the physical address (PA)**
  - **PPO**: Physical page offset (same as VPO)
  - **PPN:** Physical page number
  - **CO**: Byte offset within cache line
  - **CI:** Cache index
  - **CT**: Cache tag

Basic Concepts

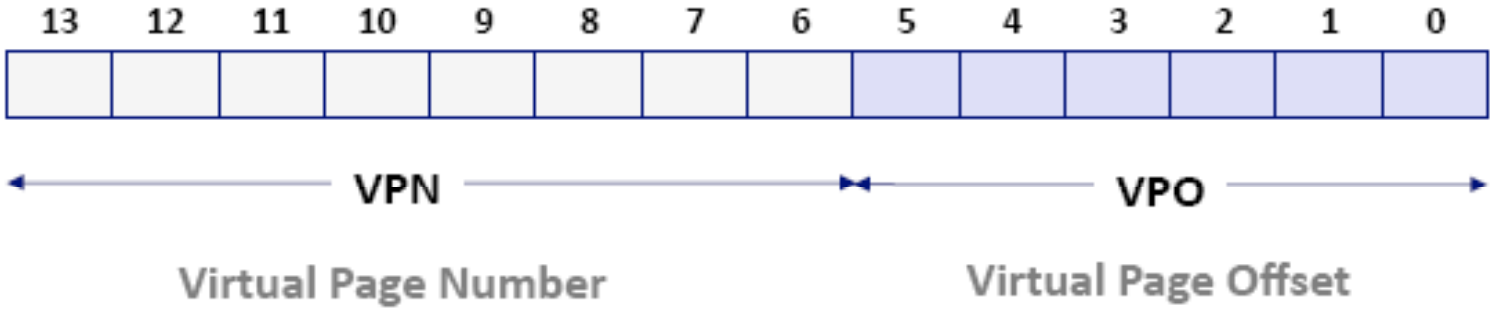
- Assumptions
  - n-bit virtual address
  - m-bit physical address
  - $P = 2^p$ = Page size
- How big is…
  - The **virtual page number**?
  - The **physical page number**?
  - The **virtual page offset**?
  - The **physical page offset**?

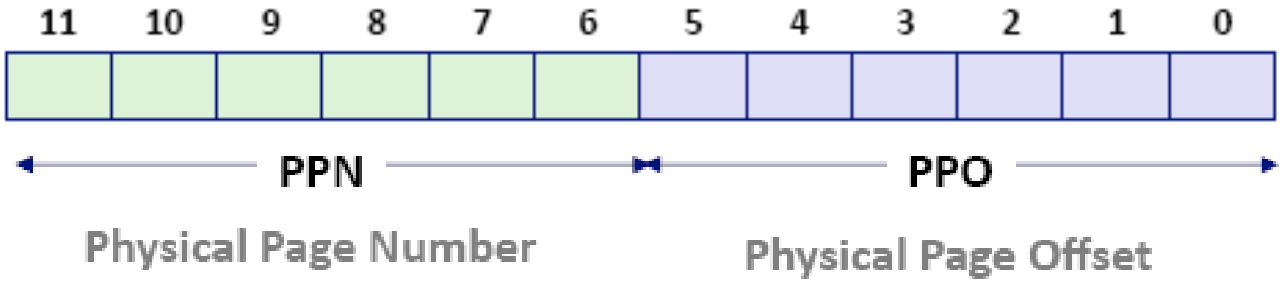
Basic Concepts

- Assumptions
  - n-bit virtual address
  - m-bit physical address
  - $P = 2^p$ = Page size
- How big is…
  - The **virtual page number**? **(n-p) bits**
  - The **physical page number**? **(m-p) bits**
  - The **virtual page offset**? **p bits**
  - The **physical page offset**? **p bits**

Basic Concepts

- Anatomy of addresses (using 14-bit VA, 12-bit PA, 64 byte page size)
  - The VPN needs to have enough information so that the TLB can look up a PPN for it.
  - The PPN needs to have enough information so that the cache can look up the DATA at the given address.





Basic Concepts

- These addresses are stored as **Page Table Entries** in a **Page Table**.
  - Just a listing of conversions from VPN -> PPN
    - And whether it's valid

- Since memory translations happen very often, modern architectures speed this up with a TLB.

Basic Concepts

- Translation Lookaside Buffer
  - **Hardware!**
  - Is like a cache from VPNs to PPNs
  - During a translation, ask the TLB first by giving it an INDEX and TAG
- How big is…
  - The index?
  - The tag?

TLB

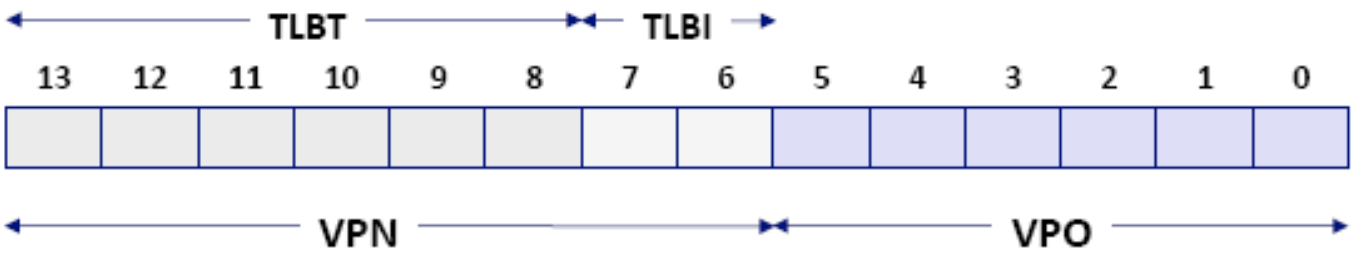
- Translation Lookaside Buffer
  - Hardware!
  - Is like a cache from VPNs to PPNs
  - During a translation, ask the TLB first by giving it an INDEX and TAG
- How big is…
  - The index? **$\log_2$ (# of sets)**
  - The tag? **(n - p - index_size)**

TLB

- TLB Hit
  - Got away with the shortcut!
- TLB Miss
  - **Not necessarily a page fault!**
  - Go check the page table, and then come back and fill in the missing spot in TLB.
- TLB Miss and not in the page table
  - Page fault. What does the OS do?
    - Make some mappings?
    - Throw a SIGSEGV?
    - Kill the process?

Virtual Address Anatomy

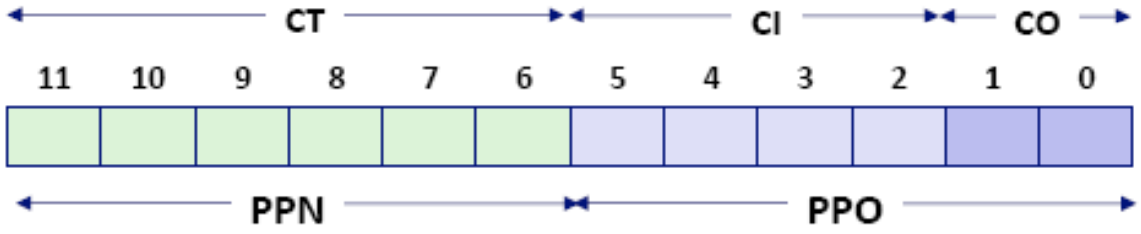
- TLB has 4 sets, 14-bit VA, 64 byte pages



Set	Tag	PPN	Valid	Tag	PPN	Valid	Tag	PPN	Valid	Tag	PPN	Valid
0	03	–	0	09	0D	1	00	–	0	07	02	1
1	03	2D	1	02	–	0	04	–	0	0A	–	0
2	02	–	0	08	–	0	06	–	0	03	–	0
3	07	–	0	03	0D	1	0A	34	1	02	–	0

Physical Address Anatomy

- Direct-mapped cache has 16 lines, each block has 4-bytes. 12-bit PA, 64 byte pages



Idx	Tag	Valid	B0	B1	B2	B3
0	19	1	99	11	23	11
1	15	0	–	–	–	–
2	1B	1	00	02	04	08
3	36	0	–	–	–	–
4	32	1	43	6D	8F	09
5	0D	1	36	72	F0	1D
6	31	0	–	–	–	–
7	16	1	11	C2	DF	03

Idx	Tag	Valid	B0	B1	B2	B3
8	24	1	3A	00	51	89
9	2D	0	–	–	–	–
A	2D	1	93	15	DA	3B
B	0B	0	–	–	–	–
C	12	0	–	–	–	–
D	16	1	04	96	34	15
E	13	1	83	77	1B	D3
F	14	0	–	–	–	–

Translation!

- End-to-end translation in the book from pages 794 to 798

Practice!

- Lots of VM questions in past Exam 2s
  - Means you're likely to see one on this test!