Lab 3 More

Memory Management

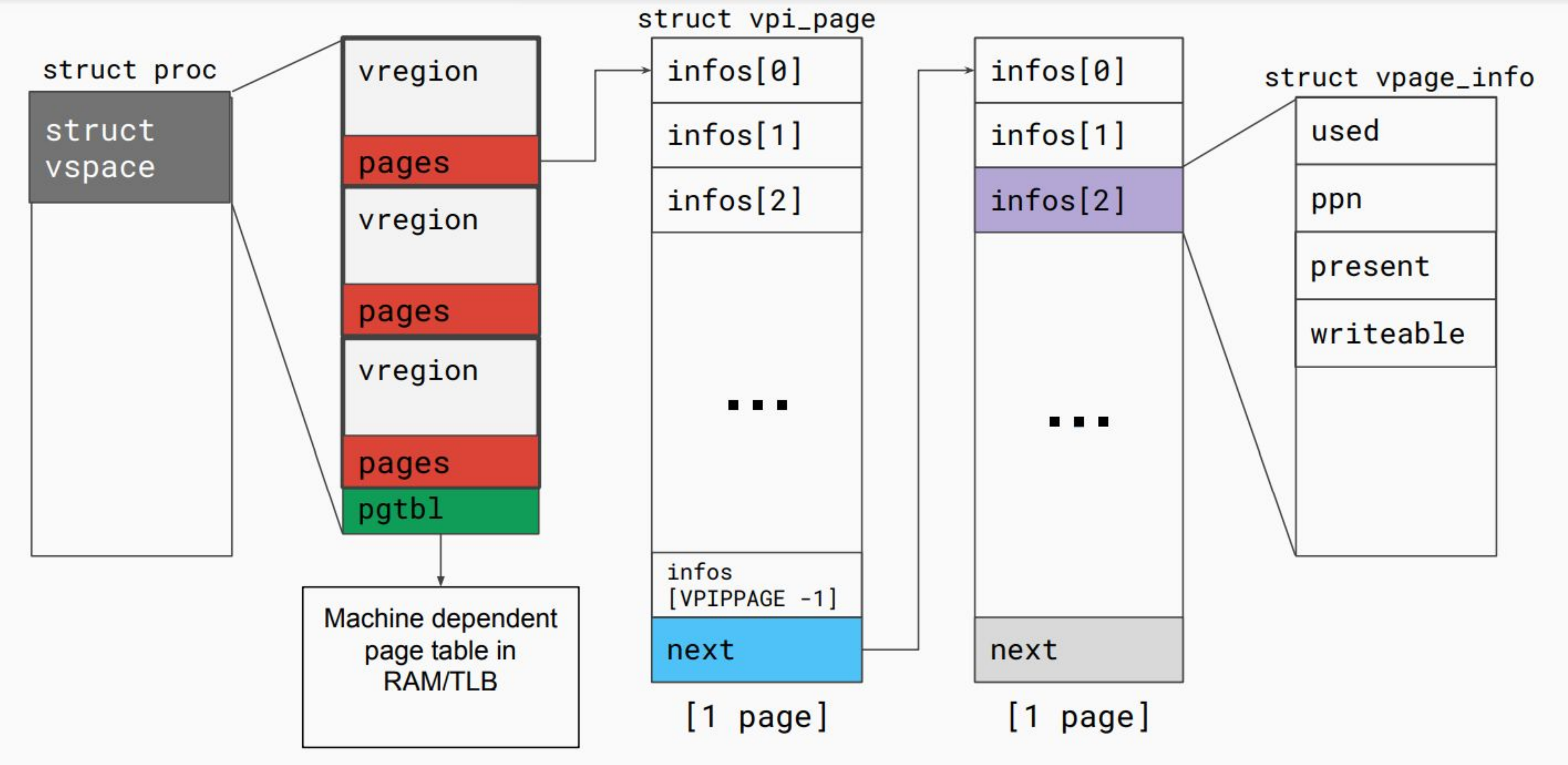
Reminder

- Lab 3 design doc is due tonight

Today’s Agenda

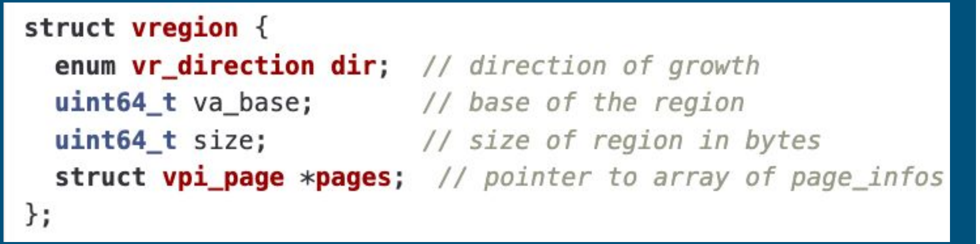
- More detail on vspace and vspace functions
- Some discussion questions on lab 3
- Q&A time

vspace Visual Diagram



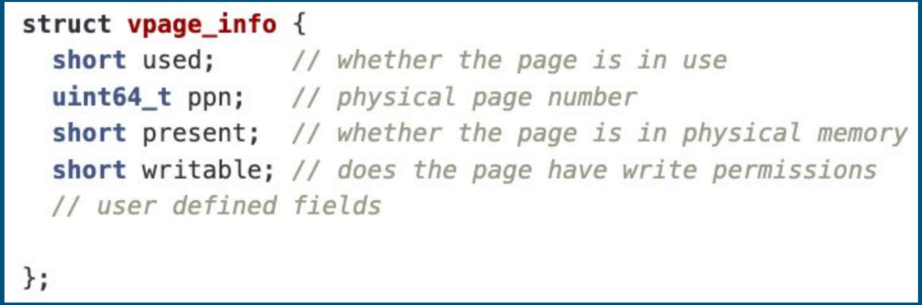
Vregions vs Page Tables

- What's the difference between vregions/vpage_infos and the page table?
- Can you make modifications to struct vpage_info?
- What happens if you make changes to vregions/vpage_info? Is it automatically reflected on the page table?



```
struct vregion {
  enum vr_direction dir;  // direction of growth
  uint64_t va_base;       // base of the region
  uint64_t size;          // size of region in bytes
  struct vpi_page *pages;  // pointer to array of page_infos
};
```

region metadata



```
struct vpage_info {
  short used;      // whether the page is in use
  uint64_t ppn;    // physical page number
  short present;   // whether the page is in physical memory
  short writable; // does the page have write permissions
  // user defined fields

};
```

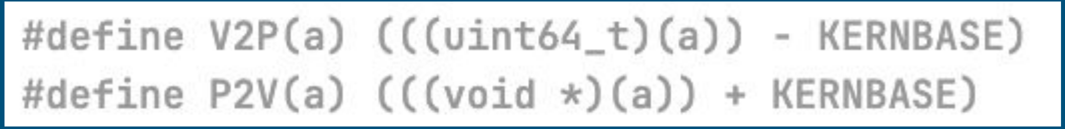
page metadata

Vspace Functions

- Given a virtual address, how do you find which vregion is belongs to?
- Given a virtual address, how do you find its metadata (vpage_info)?
- How do you add new page to frame mapping?
- How do you update the page table to reflect changes in vregion/vpage_info?
- How do you flush the TLB?
- When would you want to flush the TLB?
- Do you need to flush the TLB after a new mapping is added?

Physical Memory Management

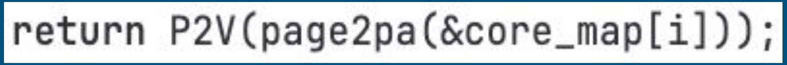
- our QEMU instance emulates 16MB of physical memory
- it is entirely mapped into the kernel virtual address range starting at KERNBASE
  - can easily find the physical address backing a kernel virtual address: subtract KERNBASE from va
  - can the same thing be done on user virtual address?



```
#define V2P(a) (((uint64_t)(a)) - KERNBASE)
#define P2V(a) (((void *)(a)) + KERNBASE)
```

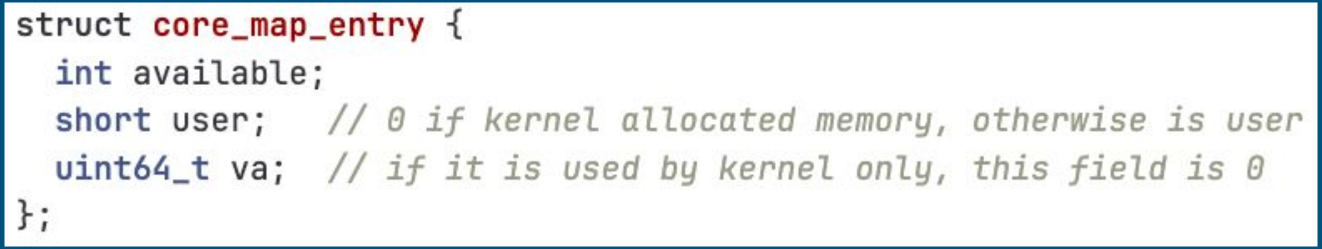
Physical Memory Allocation

- `kalloc` allocates a physical frame, it returns the kernel page mapped to the physical frame for ease of access



```
return P2V(page2pa(&core_map[i]));
```

- multiple system calls/kernel functions may call `kalloc` concurrently, what does `kalloc` do to keep these accesses safe?
- how does `kalloc` find a free frame?
  - by looking through metadata for frames (core_map)

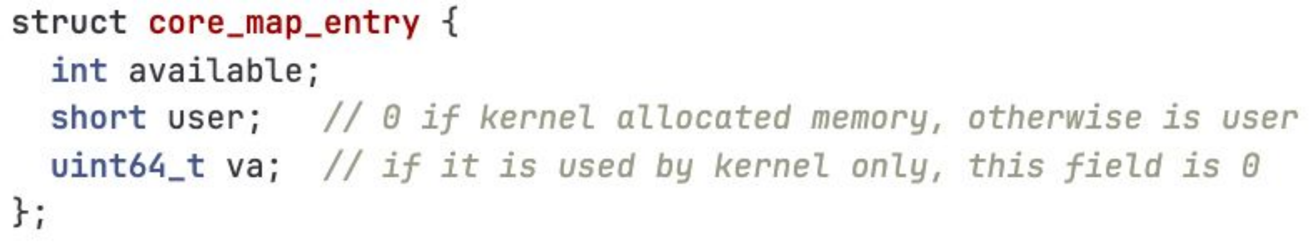


```
struct core_map_entry {
  int available;
  short user;    // 0 if kernel allocated memory, otherwise is user
  uint64_t va;   // if it is used by kernel only, this field is 0
};
```

frame metadata

Core_map_entry

- Access should be protected by the kmem.lock
- Can add to the struct to track additional information (refcounts)
  - Why do we care about refcount?
  - When will the refcount be greater than 1?



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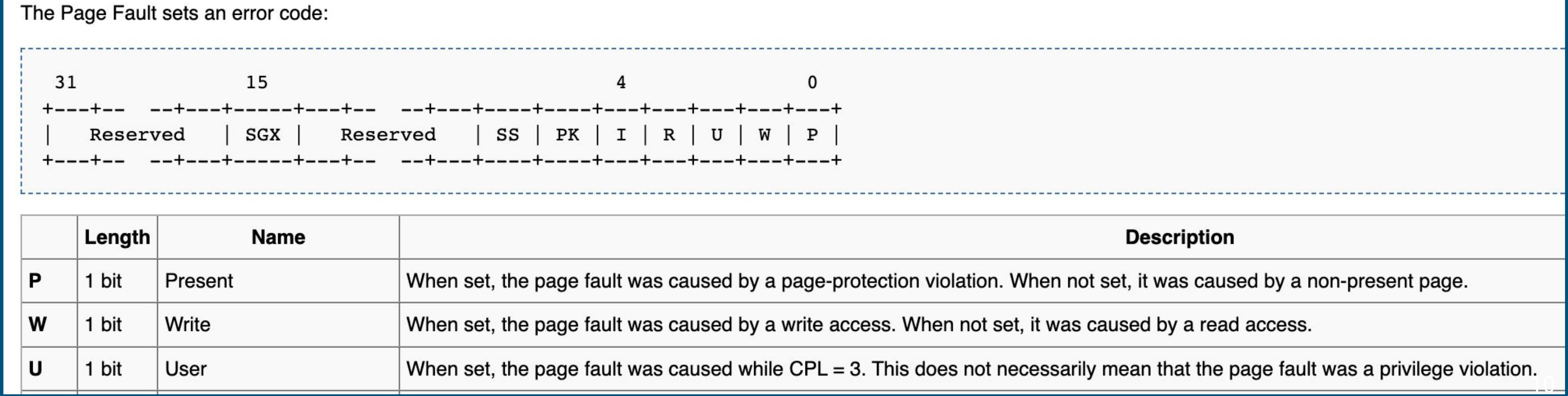
```

frame metadata

Page Faults Error Code

- Last 3 bits of tf->err
  - B2 is set if fault occurred in user mode
  - B1 is set if fault occurred on a write
  - B0 is set if the faulting page has a valid mapping to a physical frame



The Page Fault sets an error code:

```
 31              15                             4               0
+---+--  --+---+-----+---+--  --+---+----+----+---+---+---+---+---+
|   Reserved   | SGX |   Reserved   | SS | PK | I | R | U | W | P |
+---+--  --+---+-----+---+--  --+---+----+----+---+---+---+---+---+
```

	Length	Name	Description
P	1 bit	Present	When set, the page fault was caused by a page-protection violation. When not set, it was caused by a non-present page.
W	1 bit	Write	When set, the page fault was caused by a write access. When not set, it was caused by a read access.
U	1 bit	User	When set, the page fault was caused while CPL = 3. This does not necessarily mean that the page fault was a privilege violation.

Meaning of the bits

- When B0 (present bit) is set, what does this imply?
    - page fault not caused by lack of page to frame mapping!
    - must be a permission (page protection) error
    - when a stack growth (access to stack for the first time) occurs, will this bit be set?
    - when a write is done on a cow page, will this bit be set?
    - when a write is done on a mapped read only page, will this bit be set?

Meaning of the bits

- When B1 (read/write bit) is set, what does this imply?
    - access is a write
    - if we read on an unallocated stack page, will this bit be set?
    - if we write on an unallocated stack page, will this bit be set?
    - upon a cow read access, will this bit be set?
    - upon a cow write access, will this bit be set?

Meaning of the bits

- When B2 (user/supervisor bit) is set, what does this imply?
    - access is done from user mode
    - when a stack growth occurs, is this bit set? (can stack growth happen in kernel mode?)
    - when a cow fork occurs, is this bit set? (can cow happen in kernel mode?)

Copy-on-write Fork FAQ

- How do we keep track of physical pages and refcounts?
  - Everyone take a look at kalloc.c!
- What vspace function to write to support COW fork?
  - Which function do we currently use to copy? What should we replace it with? (Not a trick question, look in the spec.)
- What do the fields of a page (struct `vpage_info`) need to be after a copy-on-write fork?
    - How do you know if a given page is in use? How do you know it can be written to? How can you uniquely identify a page? How do you know which physical page the vpace maps to?
- What happens to a page that is already read-only before COW fork?

More COW

- Synchronization in modifying the **vspace** in page fault in COW fork?
  - Not needed -- current process has exclusive access to its own vspace (no multithreading)
  - **However, the ref count on the physical page could be concurrently modified**
- What can happen if a copy-on-write fork is not synchronized?

Helper Macros and Functions

P2V: physical addr to virtual addr

V2P: virtual addr to physical addr

PGNUM: physical addr to page number

va2vpage_info: virtual addr to vpi_info

Any questions?