CS 3502
Operating Systems

Project 3 Lab

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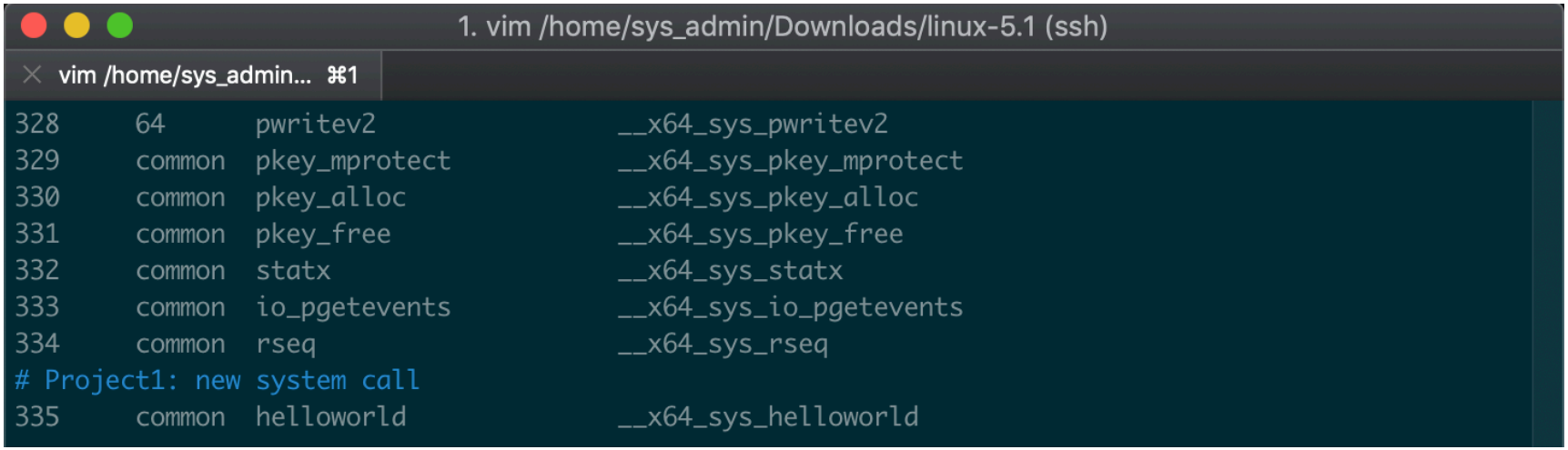
https://kevinsuo.github.io/

Review how to add system calls

- Step 1: register your system call
- Step 2: declare your system call in the header file
- Step 3: implement your system call
- Step 4: write user level app to call it

Step 1: register your system call

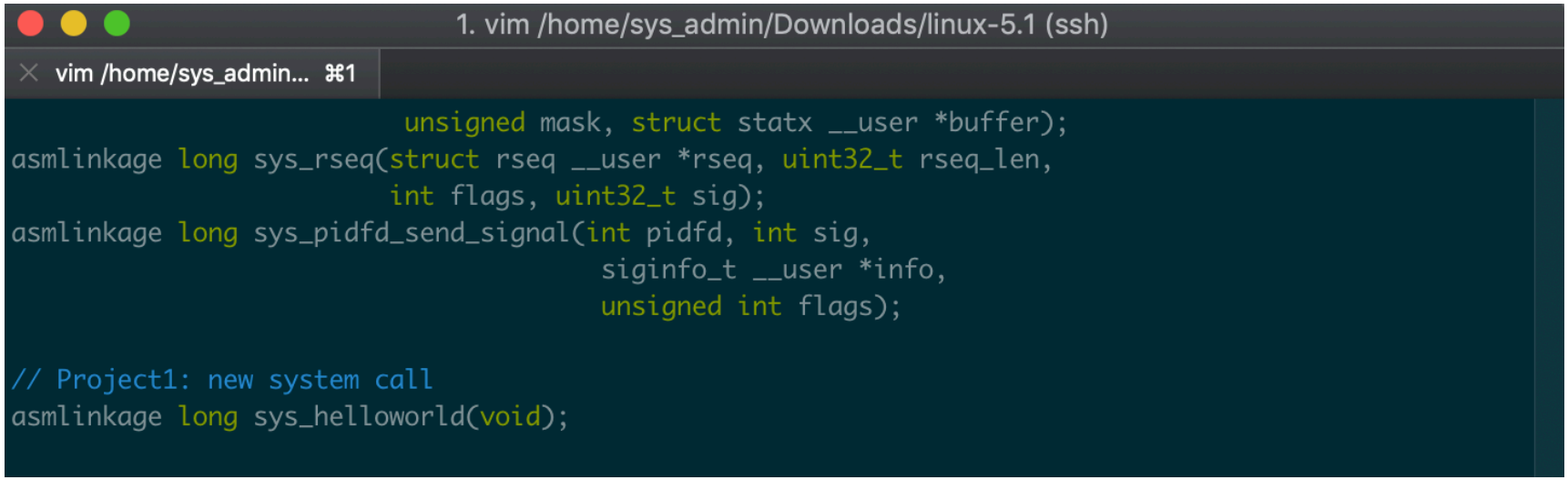
arch/x86/entry/syscalls/syscall_64.tbl



https://elixir.bootlin.com/linux/v5.0/source/arch/x86/entry/syscalls/syscall_64.tbl#L346

Step 2: declare your system call in the header file

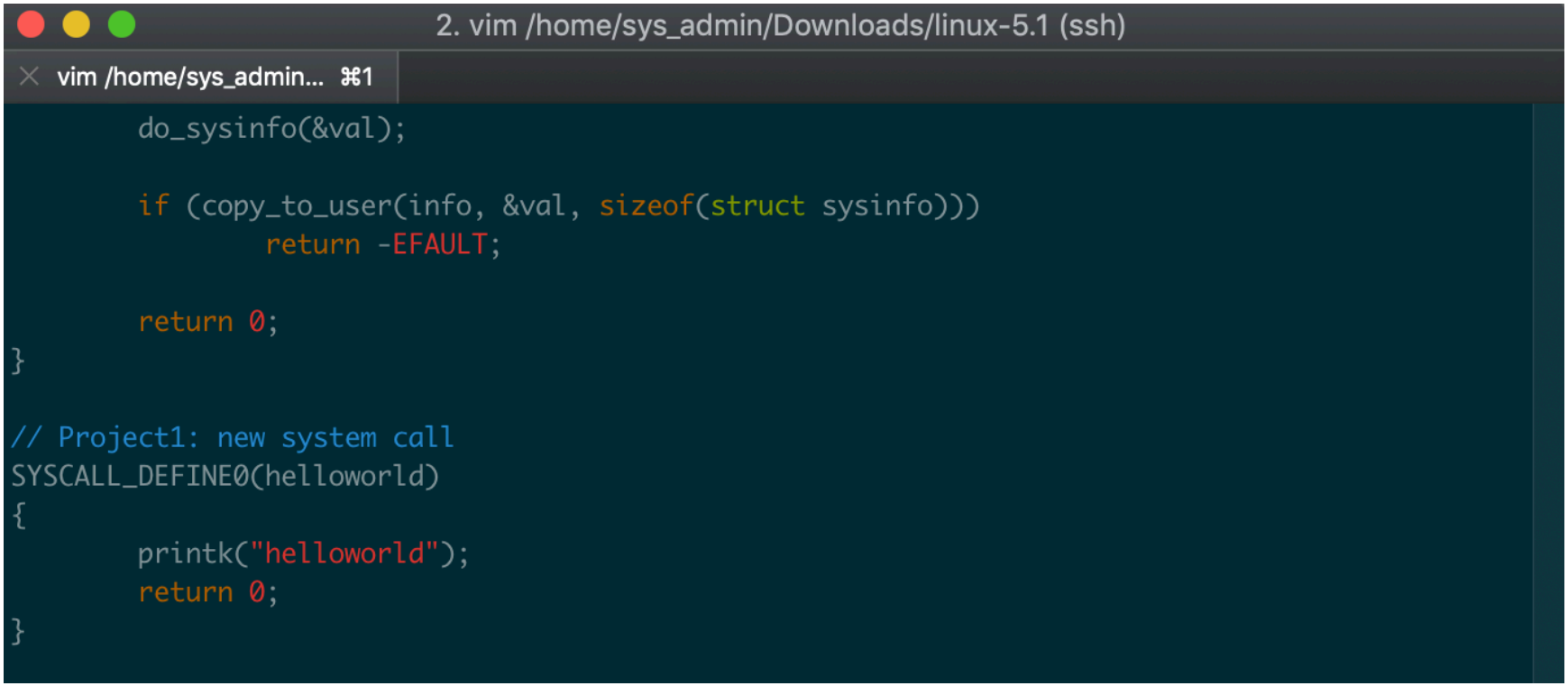
include/linux/syscalls.h



https://elixir.bootlin.com/linux/v5.0/source/include/linux/syscalls.h

Step 3: implement your system call

kernel/sys.c



https://elixir.bootlin.com/linux/v5.0/source/kernel/sys.c#L402

Step 4: write user level app to call it

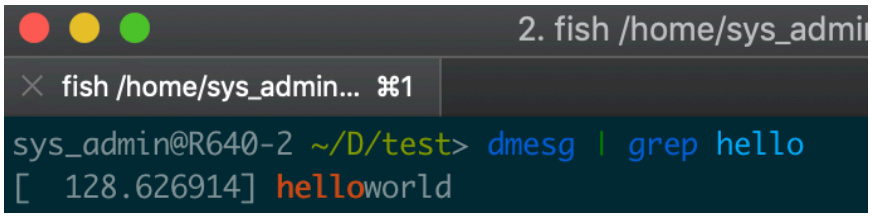
test_syscall.c：

```
****************************************
#include <linux/unistd .h>
#include <sys/syscall .h>
#include <sys/types .h>
#include <stdio .h>
#define __NR_helloworld 335

int main(int argc, char *argv[])
{
    syscall (__NR_helloworld) ;
    return 0 ;
}
****************************************

//If syscall needs parameter, then：
//syscall (__NR_helloworld，a，b，c) ;
```

Compile and execute：

```
$ gcc test_syscall.c -o test_syscall
$ ./test_syscall
```

The test program will call the new system call and output a helloworld message at the tail of the output of dmesg (system log).



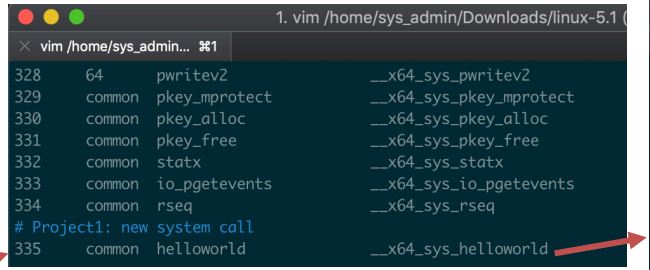
Put it all together

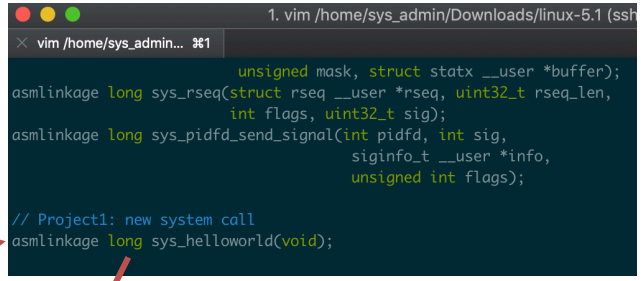
User space

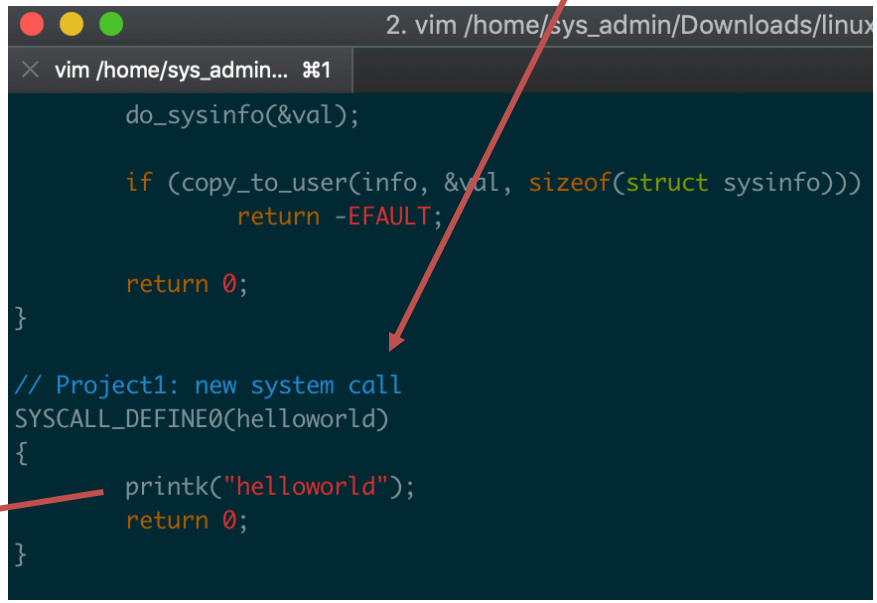
Kernel space

test_syscall.c:

```
**********************************************
#include <linux/unistd .h>
#include <sys/syscall .h>
#include <sys/types .h>
#include <stdio .h>
#define __NR_helloworld 335

int main(int argc, char *argv[])
{
    syscall (__NR_helloworld) ;
    return 0 ;
}
**********************************************
```







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- Given the above virtual memory areas used by a process, write a system call *sys_getPageInfo* to report the current status of specific addresses in these virtual memory areas. The system call takes the pid of a process as input and outputs the following information of start address *vm_start* in each *vm_area_struct* that the process has:

1. If the data in this address is in memory or on disk.
2. If the page which this address belongs to has been referenced or not.
3. If the page which this address belongs to is dirty or not.

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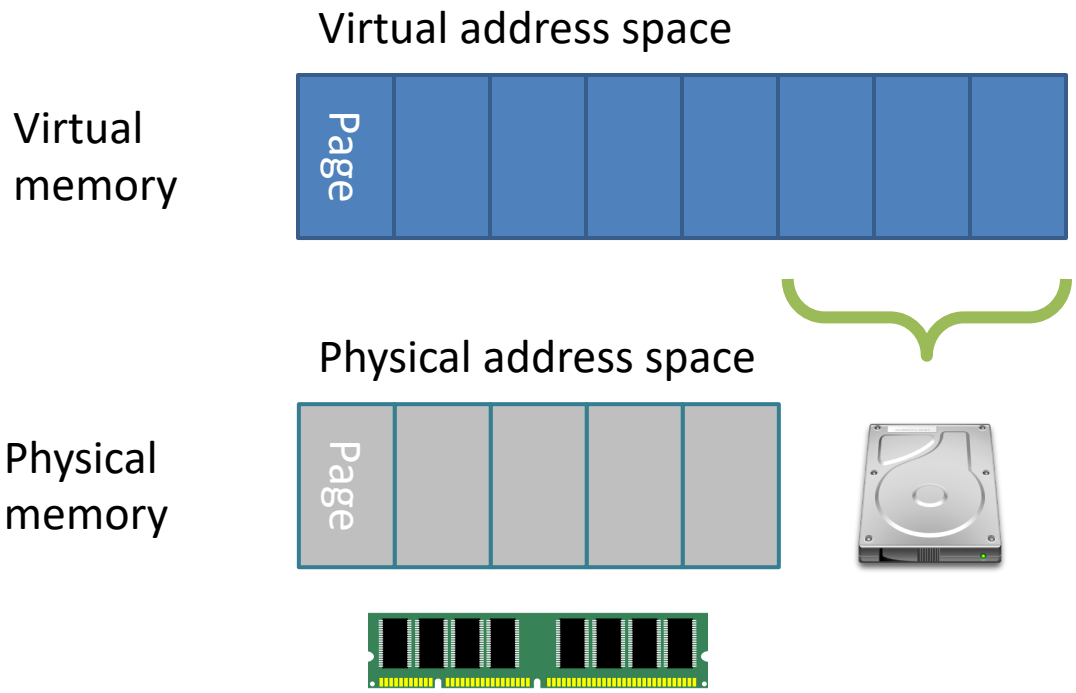
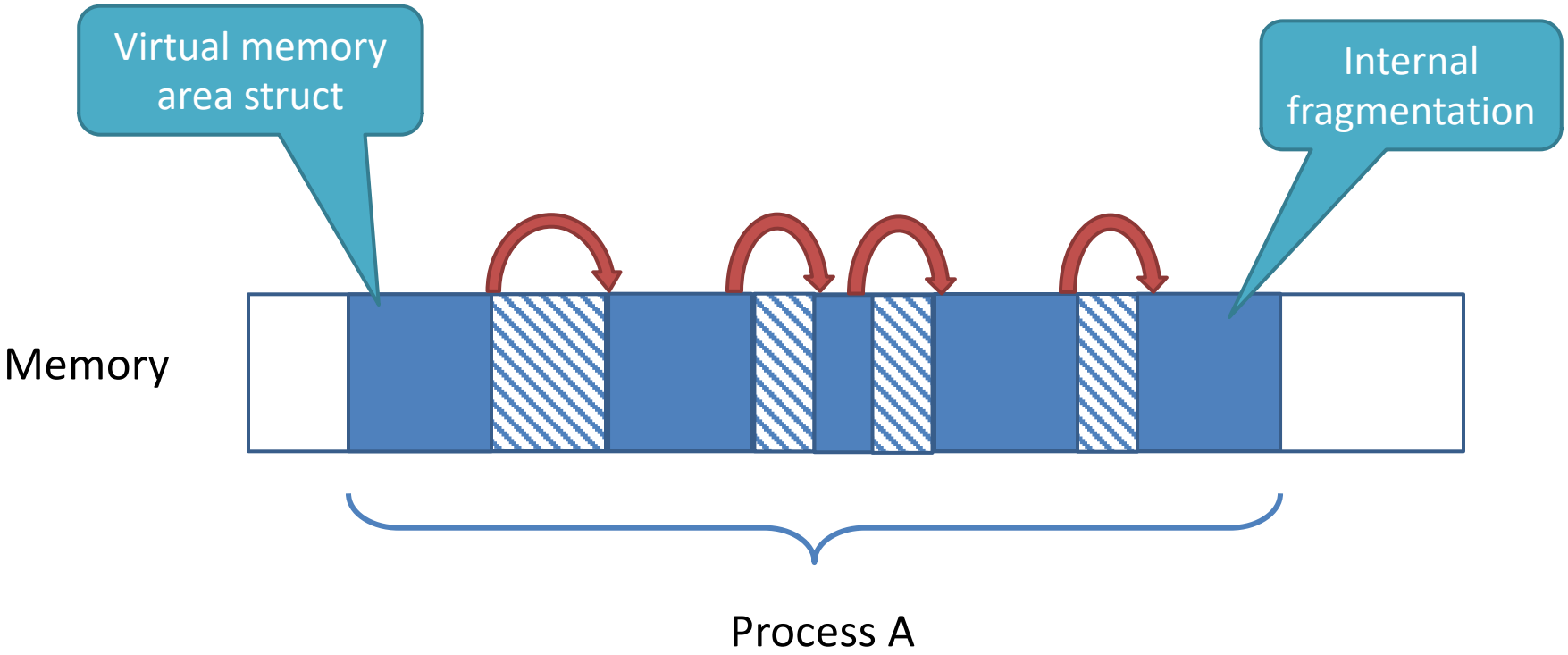
- Virtual memory address could be in memory or on disk.



Revisit Process Data Structure



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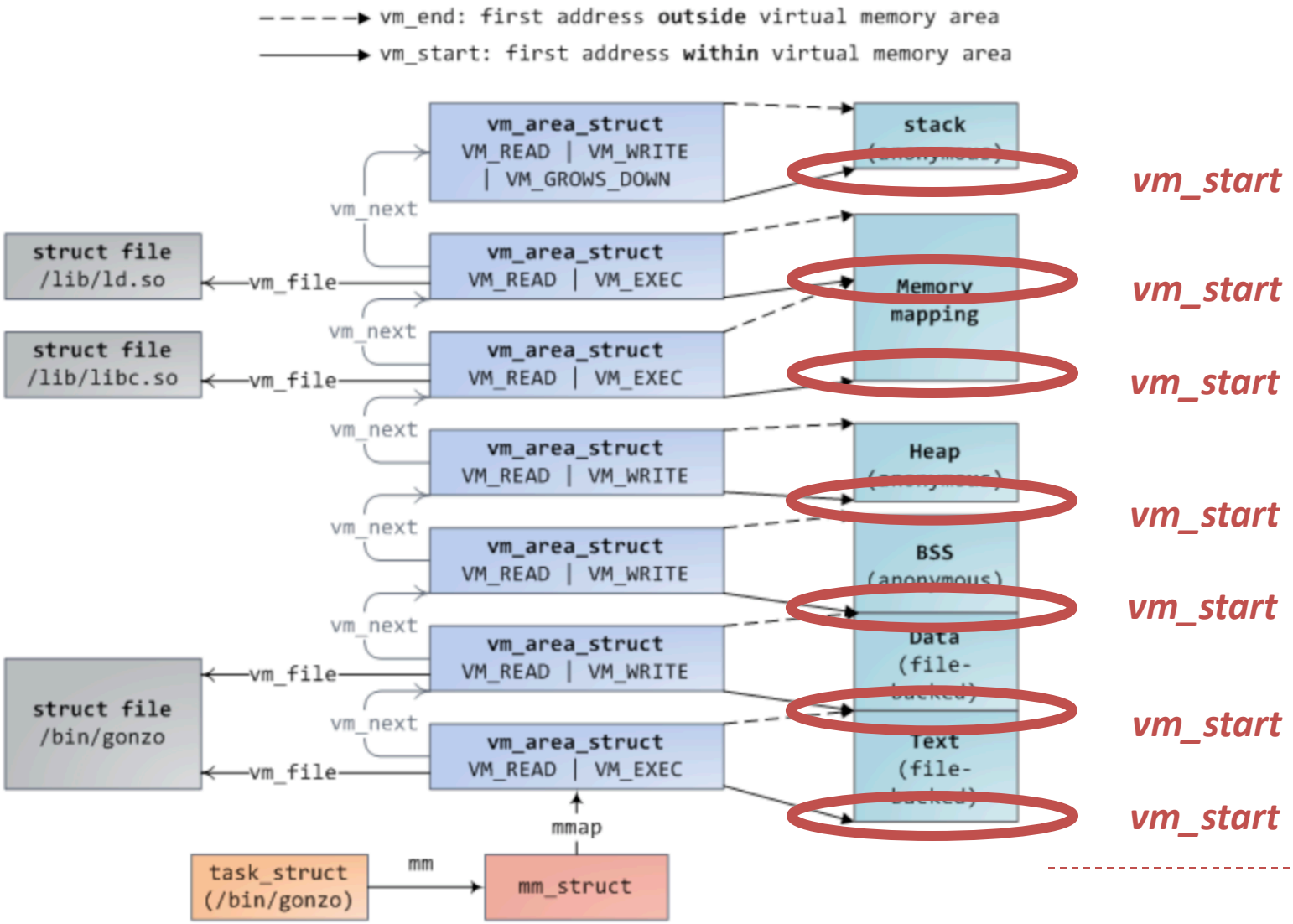
vm_end: first address outside virtual memory area
vm_start: first address within virtual memory area
vm_area_struct
VM_READ | VM_WRITE | VM_GROWS_DOWN
stack
vm_next
vm_area_struct
VM_READ | VM_EXEC
vm_file
struct file
/lib/ld.so
Memory mapping
vm_next
vm_area_struct
VM_READ | VM_EXEC
vm_file
struct file
/lib/libc.so
vm_next
vm_area_struct
VM_READ | VM_WRITE
Heap
vm_next
vm_area_struct
VM_READ | VM_WRITE
BSS
vm_next
vm_area_struct
VM_READ | VM_WRITE
vm_file
Data
(file-
vm_next
vm_area_struct
VM_READ | VM_EXEC
vm_file
struct file
/bin/gonzo
Text
(file-
mmap
task_struct
(/bin/gonzo)
mm
mm_struct
vm_start
vm_start
vm_start
vm_start
vm_start
vm_start

Revisit Process Data Structure

```
struct task_struct {
#ifdef CONFIG_THREAD_INFO_IN_TASK
        /*
         * For reasons of header soup (see current_thr
         * must be the first element of task_struct.
         */
        struct thread_info              thread_info;
#endif
        /* -1 unrunnable, 0 runnable, >0 stopped: */
        volatile long                   state;


        struct sched_info               sched_info;

        struct list_head                tasks;
#ifdef CONFIG_SMP
        struct plist_node               pushable_tasks;
        struct rb_node                  pushable_dl_tasks;
#endif

        struct mm_struct                *mm;
        struct mm_struct                *active_mm;
```

```
struct mm_struct {
        struct vm_area_struct *mmap;
        struct rb_root mm_rb;
        u32 vmacache_seqnum;
#ifdef CONFIG_MMU
        unsigned long (*get_unmapped_area) (st
                                    unsigned long
                                    unsigned long
#endif
        unsigned long mmap_base;
        unsigned long mmap_legacy_base;
        unsigned long task_size;
        unsigned long highest_vm_end;
        pgd_t * pgd;
        atomic_t mm_users;
        atomic_t mm_count;
        atomic_long_t nr_ptes;
#if CONFIG_PGTABLE_LEVELS > 2
```

Revisit Process Data Structure

```
struct mm_struct {
        struct vm_area_struct *mmap;
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        u32 vmacache_seqnum;
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        pgd_t * pgd;
        atomic_t mm_users;
        atomic_t mm_count;
        atomic_long_t nr_ptes;
#if CONFIG_PGTABLE_LEVELS > 2
```

```
struct vm_area_struct {
        /* The first cache line has the info for VMA tree walking. */

        unsigned long vm_start;          /* Our start address within vm_mm. */
        unsigned long vm_end;            /* The first byte after our end address
                                            within vm_mm. */

        /* linked list of VM areas per task, sorted by address */
        struct vm_area_struct *vm_next, *vm_prev;

        struct rb_node vm_rb;

        /*
         * Largest free memory gap in bytes to the left of this VMA.
         * Either between this VMA and vma->vm_prev, or between one of the
         * VMAs below us in the VMA rbtree and its ->vm_prev. This helps
         * get_unmapped_area find a free area of the right size.
         */
        unsigned long rb_subtree_gap;

        /* Second cache line starts here. */

        struct mm_struct *vm_mm;         /* The address space we belong to. */
        pgprot_t vm_page_prot;           /* Access permissions of this VMA. */
        unsigned long vm_flags;          /* Flags, see mm.h. */
```

Project 3

- Given the above virtual memory areas used by a process, write a system call *sys_getPageInfo* to report the current status of specific addresses in these virtual memory areas. The system call takes the **pid of a process as input** and **outputs** the following information of **start address *vm_start* in each *vm_area_struct*** that the process has:

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2. If the page which this address belongs to has been referenced or not.

3. If the page which this address belongs to is dirty or not.

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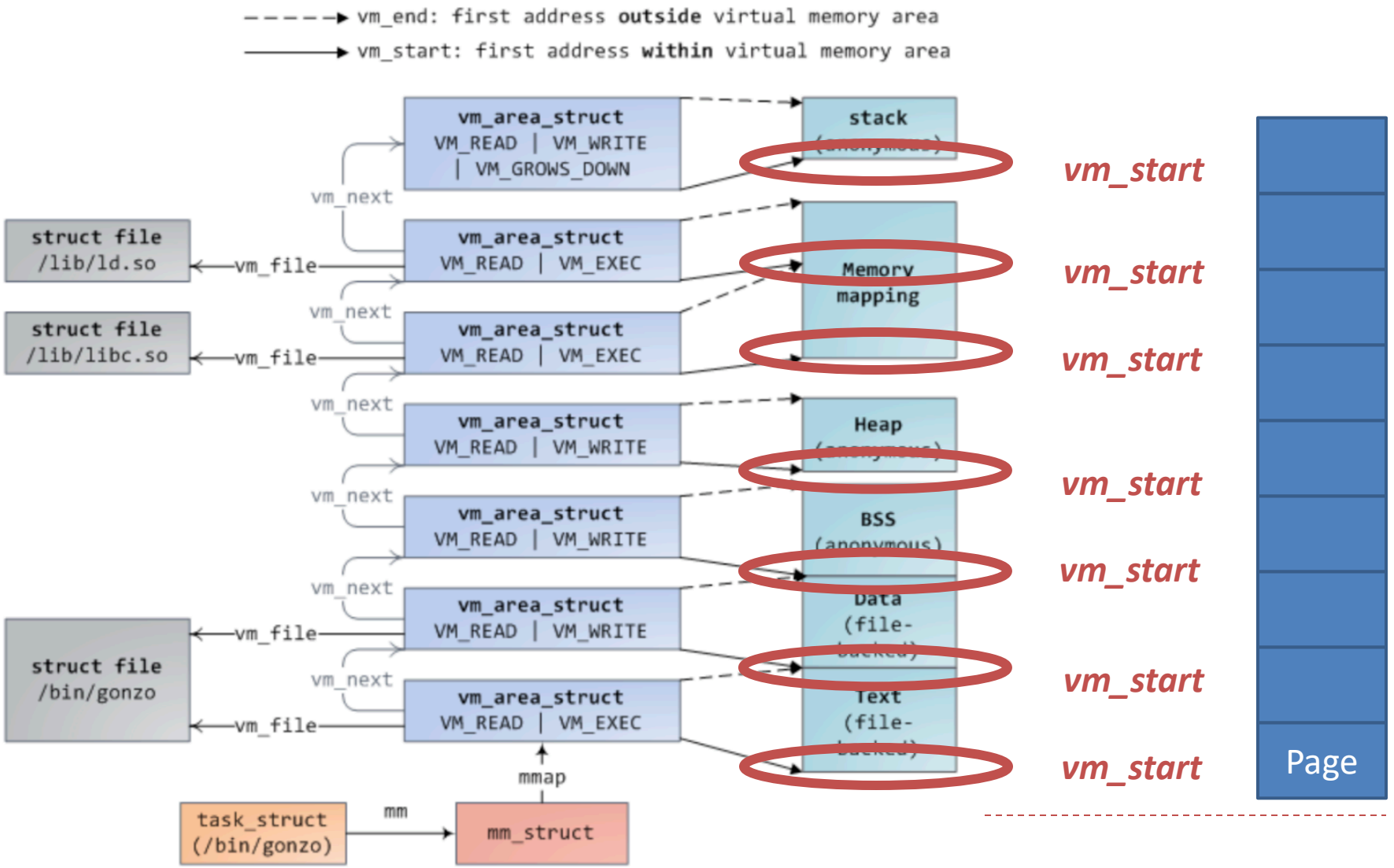
vm_end: first address outside virtual memory area
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vm_next
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VM_READ | VM_WRITE
Heap
vm_next
vm_area_struct
VM_READ | VM_WRITE
BSS
vm_next
vm_area_struct
VM_READ | VM_WRITE
Data
(file-
vm_next
struct file
/bin/gonzo
vm_file
vm_area_struct
VM_READ | VM_EXEC
Text
(file-
vm_file
mmap
task_struct
(/bin/gonzo)
mm
mm_struct
vm_start
vm_start
vm_start
vm_start
vm_start
vm_start
Page

Project 3

Table: Page Table Entry Status Bits

Bit	Function
_PAGE_PRESENT	Page is resident in memory and not swapped out.
_PAGE_ACCESSED	Set if the page is referenced.
_PAGE_DIRTY	Set if the page is written to.

```
static inline int pte_present(pte_t a)
{
        return pte_flags(a) & (_PAGE_PRESENT | _PAGE_PROTNONE);
}

static inline int pte_young(pte_t pte)
{
        return pte_flags(pte) & _PAGE_ACCESSED;
}

static inline int pte_dirty(pte_t pte)
{
        return pte_flags(pte) & _PAGE_DIRTY;
}
```

https://elixir.bootlin.com/linux/latest/source/arch/x86/include/asm/pgtable.h

Project 3

Table: Page Table Entry Status Bits

Bit	Function
_PAGE_PRESENT	Page is resident in memory and not swapped out.
_PAGE_ACCESSED	Set if the page is referenced.
_PAGE_DIRTY	Set if the page is written to.

- The function *pte_present* is used for judging a page is in memory or disk. If the return value is 1, the page is in the memory, otherwise it is in the disk.
- The function *pte_young* is used for judging a page is referenced or not. If the return value is 1, the page has been referenced, otherwise it has not been referenced yet.
- The function *pte_dirty* is used for judging a page is dirty or not. If the return value is 1, the page is dirty, otherwise it is not dirty.

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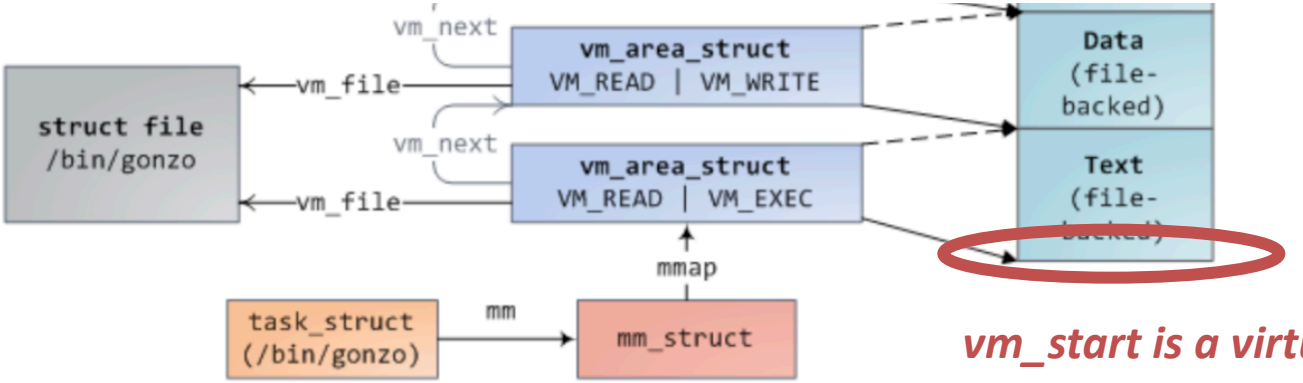
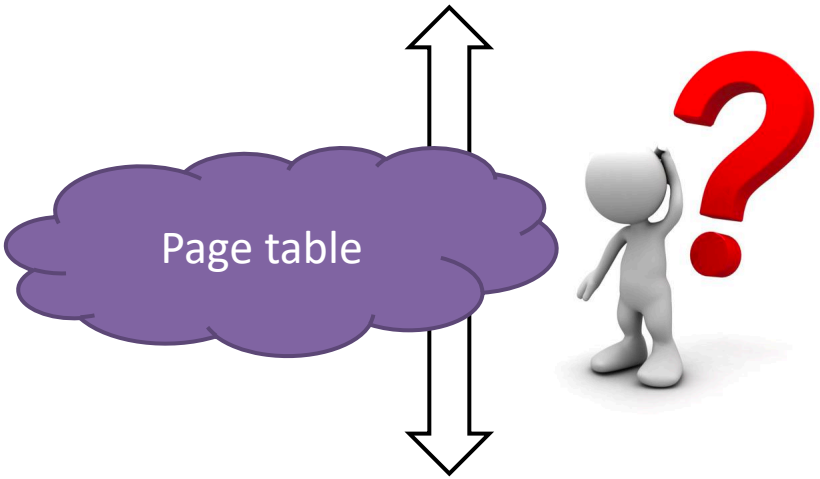


vm_start is a virtual memory address

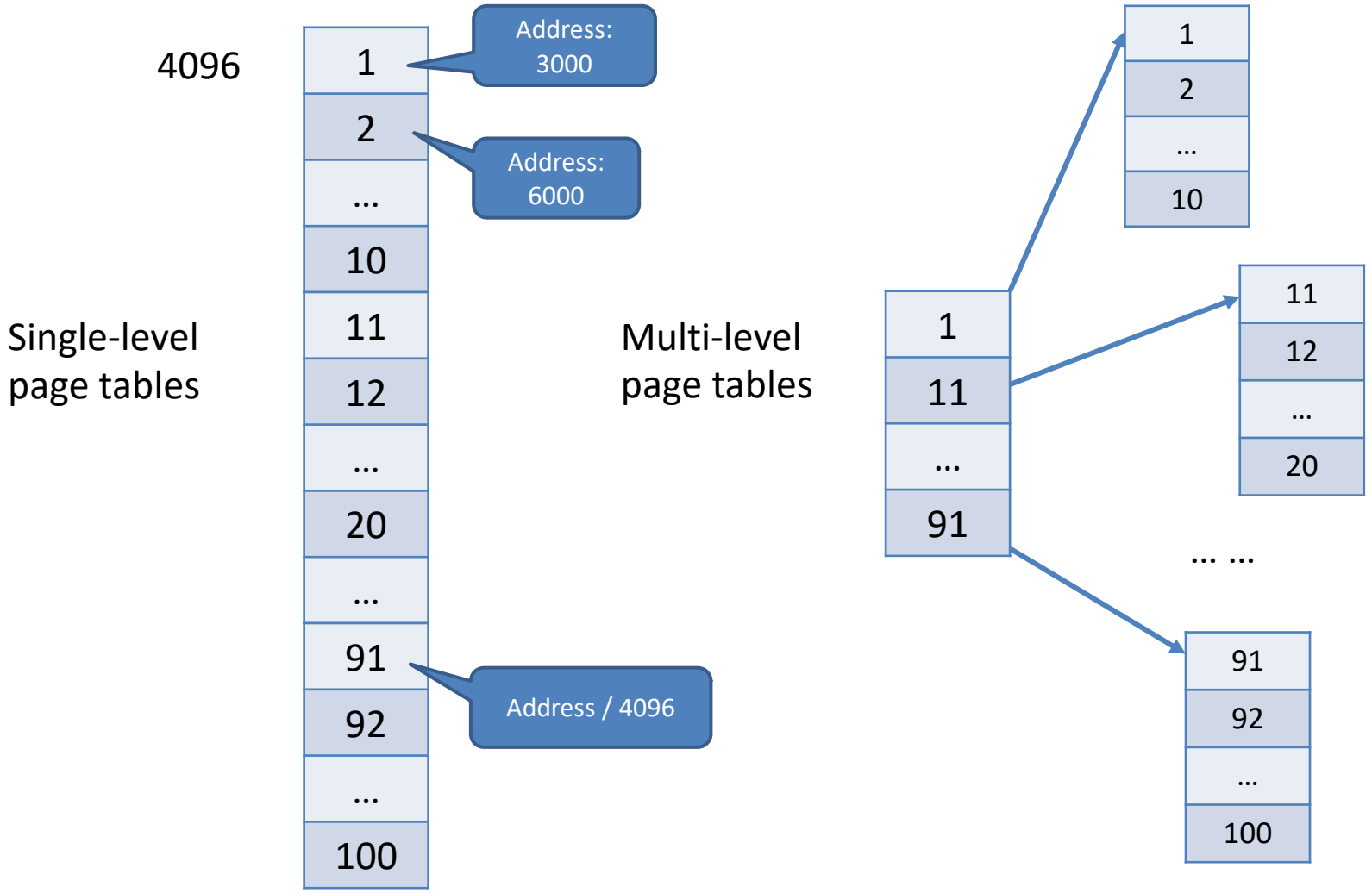



```
static inline int pte_present(pte_t a)
{
        return pte_flags(a) & (_PAGE_PRESENT | _
}

static inline int pte_young(pte_t pte)
{
        return pte_flags(pte) & _PAGE_ACCESSED;
}

static inline int pte_dirty(pte_t pte)
{
        return pte_flags(pte) & _PAGE_DIRTY;
}
```

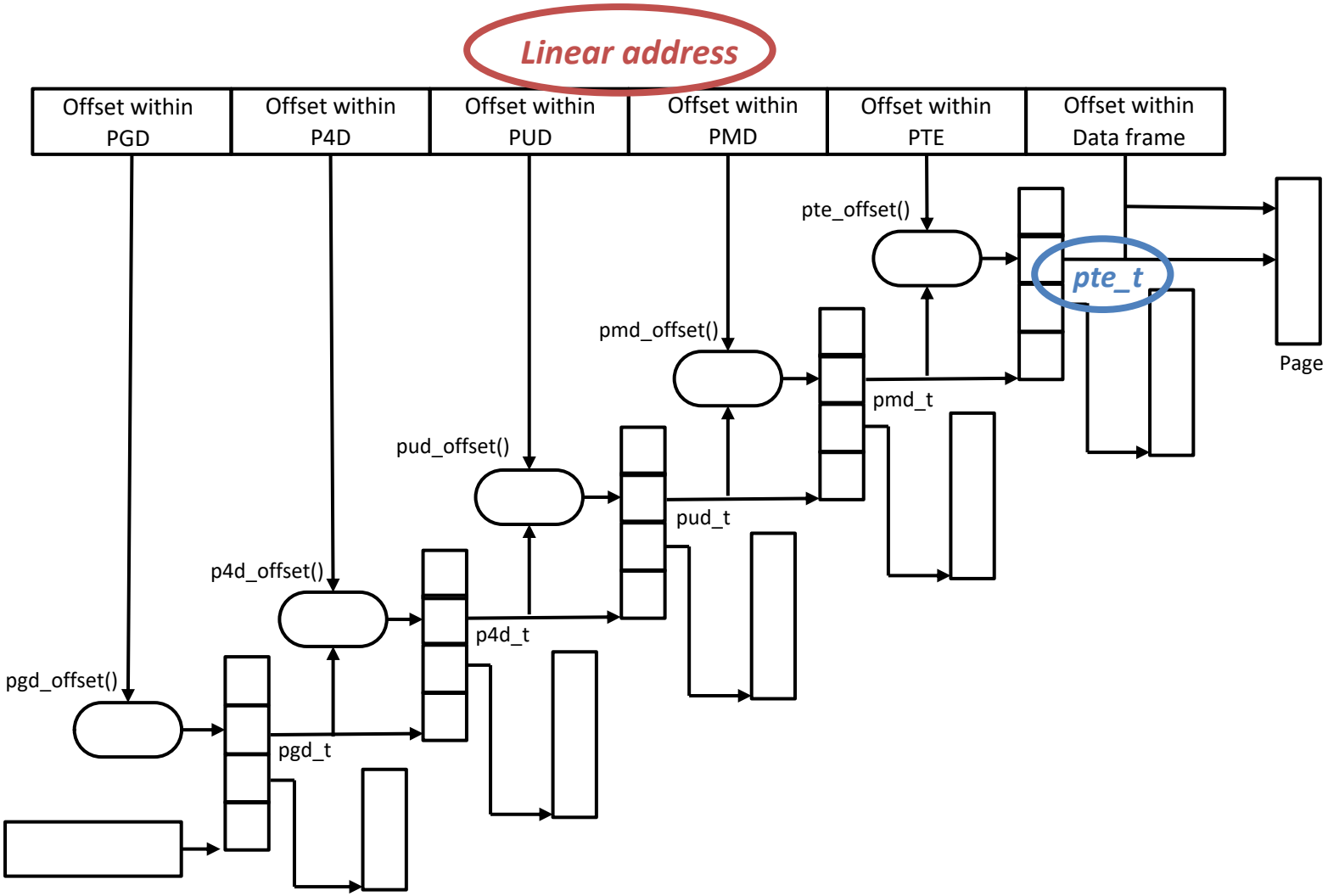
```
typedef struct { pteval_t pte; } pte_t;
```

pte_t is a memory page entry

Project 3: revisit memory address



Project 3: revisit memory address



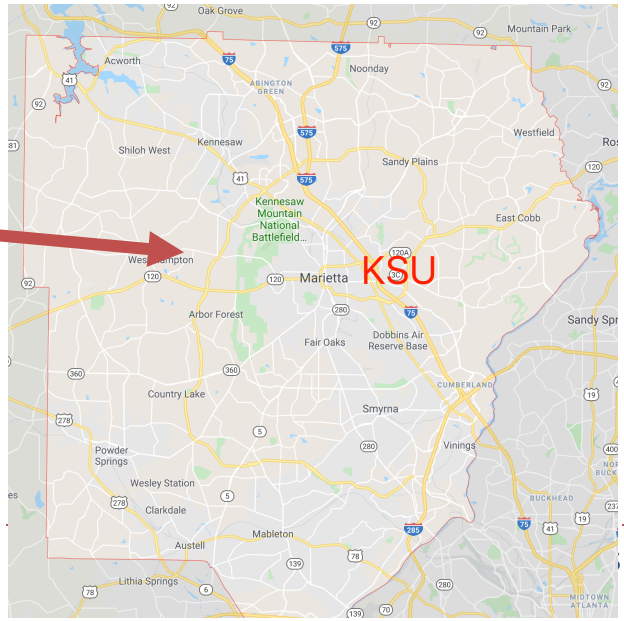
Virtual address

```c
/*
 * a shortcut to get a pgd_t in a given mm
 */
#define pgd_offset(mm, address) pgd_offset_pgd((mm)->pgd, (address))
```

```c
/* to find an entry in a page-table-directory. */
static inline p4d_t *p4d_offset(pgd_t *pgd, unsigned long address)
{
        if (!pgtable_l5_enabled())
                return (p4d_t *)pgd;
        return (p4d_t *)pgd_page_vaddr(*pgd) + p4d_index(address);
}

/* Find an entry in the third-level page table.. */
static inline pud_t *pud_offset(p4d_t *p4d, unsigned long address)
{
        return (pud_t *)p4d_page_vaddr(*p4d) + pud_index(address);
}

/* Find an entry in the second-level page table.. */
static inline pmd_t *pmd_offset(pud_t *pud, unsigned long address)
{
        return (pmd_t *)pud_page_vaddr(*pud) + pmd_index(address);
}

static inline pte_t *pte_offset_kernel(pmd_t *pmd, unsigned long address)
{
        return (pte_t *)pmd_page_vaddr(*pmd) + pte_index(address);
}
```

https://elixir.bootlin.com/linux/latest/source/arch/x86/include/asm/pgtable.h

Just like we search on maps



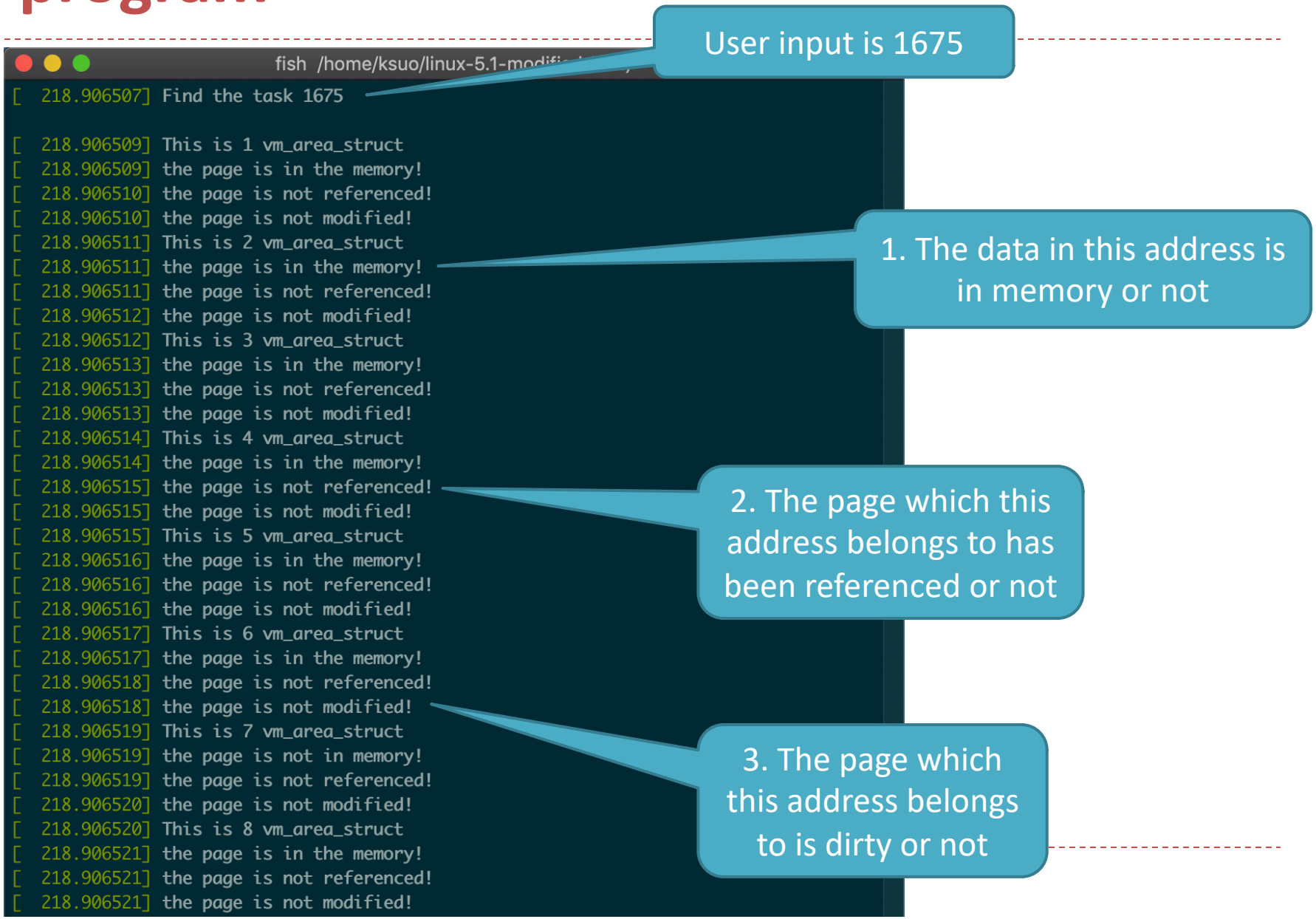
Project 3: user test program

```c
#include <linux/unistd.h>
#include <sys/syscall.h>
#include <sys/types.h>
#include <stdlib.h>
#include <stdio.h>
#include <unistd.h>

#define __NR_getPageInfo 339

/*
 * Execution: test using process pid=123
 * $ ./assignment2-user1.o  123
 */

int main(int argc, char *argv[])
{
    int pid = 0;

    pid = atoi(argv[1]);   //pid the proces
    syscall(__NR_getPageInfo, pid);

    return 0;
}
```

Input is the user process id

- The system call takes the pid of a process as input and outputs the following information of start address *vm_start* in each *vm_area_struct* that the process has:
  - Memory or disk?
  - Referenced or not?
  - Dirty or not?

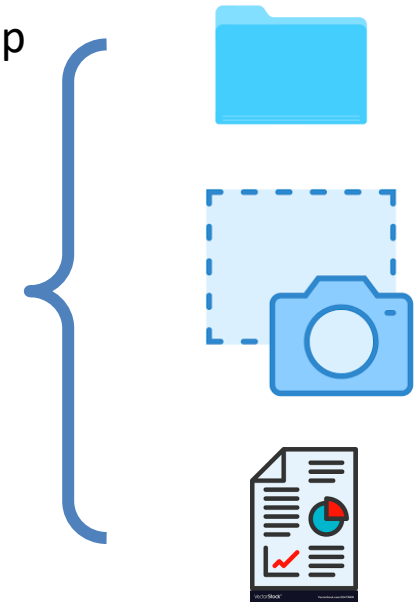
Project 3: expected output of user test program



Submission

Submit your assignment zip file through D2L using the appropriate assignment link.

CS3502_D2Lname.zip



Kernel code User code

Screenshot

Report