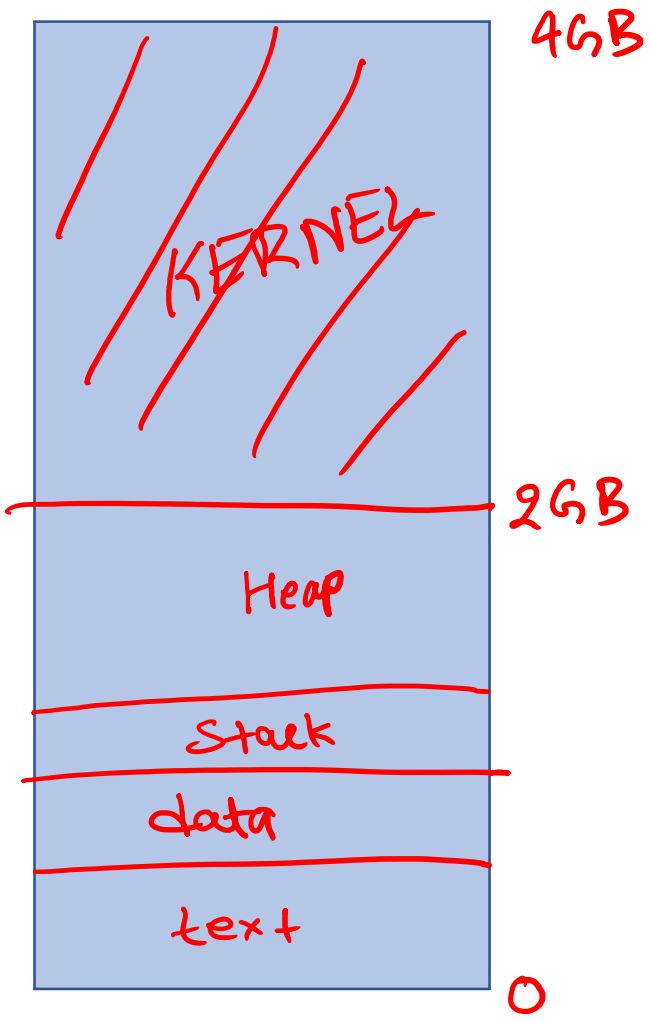
Process address space



- text
- data
- unmapped
- stack
- heap

exec: 6310

exec (char *path, char **argv)

- Open executable file
- Read elf header from the executable file
- Create page directory using setupkvm

setupkvm:1837

setupkvm()

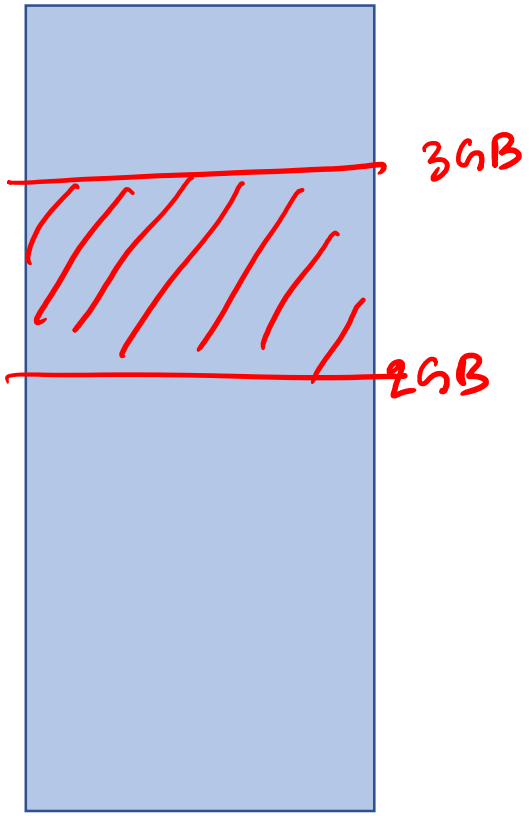
- Create page directory
- map I/O space
  - {“0”, “1MB”} -> {“KERNBASE”, “KERNBASE+1MB”}
- map kernel text
  - {“1MB”, “textsize”} -> {“KERNBASE+1MB”, “KERNBASE+1MB+textsize”}
- map rest of the RAM
  - {“1MB+textsize”, “ramsize”} -> {“KERNBASE+1MB+textsize”, “KERNBASE+ramsize”}

mappages:1779

mappages (pgdir, va, size, pa, perm)

- Map physical address range {pa, pa+size} to virtual address range {va, va+size}

Virtual address space after setupkvm



exec: 6310

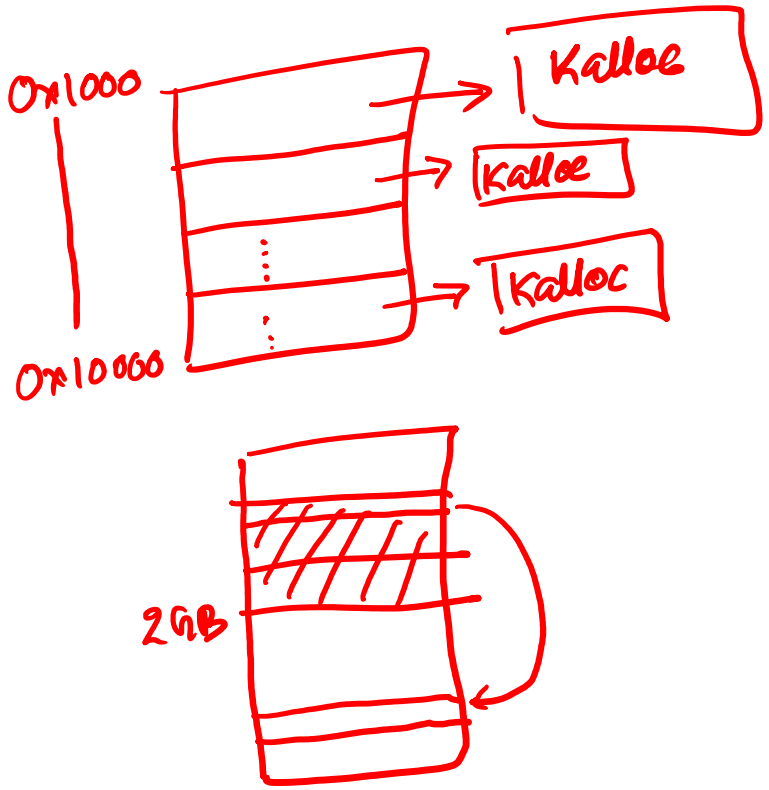
exec (char *path, char **argv)

vaddr ✓
memsz ✓

- read program headers from file
- for every program header
  - fetch the virtual address (vaddr) and memory size (memsz) of the section from the program header
  - call allocuvm to map physical pages at the virtual address range {vaddr, vaddr+memsz}

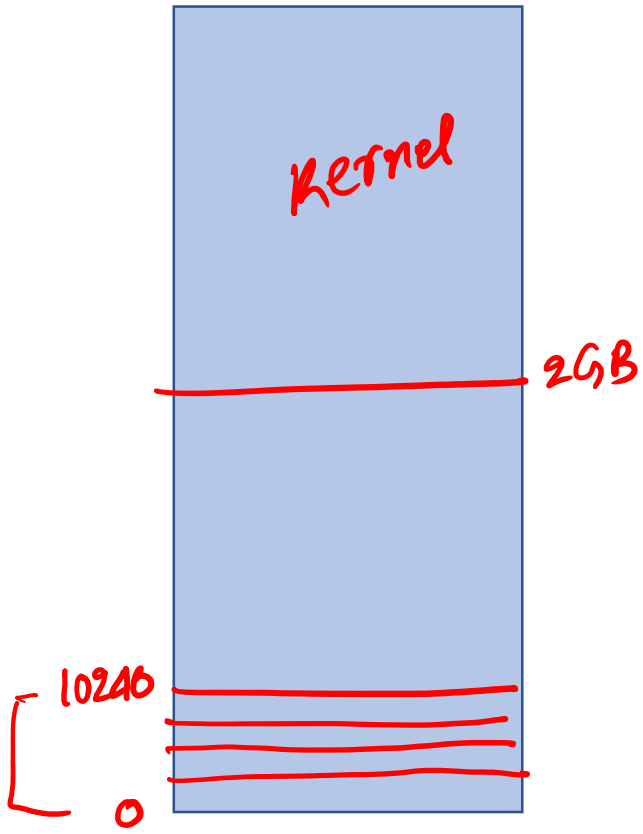
allocuvm: 1953

allocuvm (pgdir, oldsz, newsz)



- allocate physical pages for all the virtual pages between oldsz and newsz
- allocate physical pages using kalloc
- map physical pages using mappages
- return newsz on success

Virtual address space after allocuvm



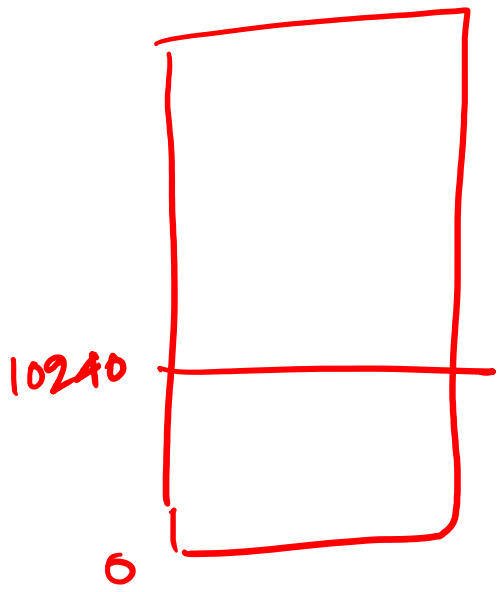
exec: 6310

exec (char *path, char **argv)

- read program headers from file
- for every program header
  - fetch the virtual address (vaddr) and memory size (memsz) of the section from the program header
  - call allocuvm to map physical pages at the virtual address range {vaddr, vaddr+memsz}
  - call loaduvm to load the content of the section from the file

loaduvm: 1918

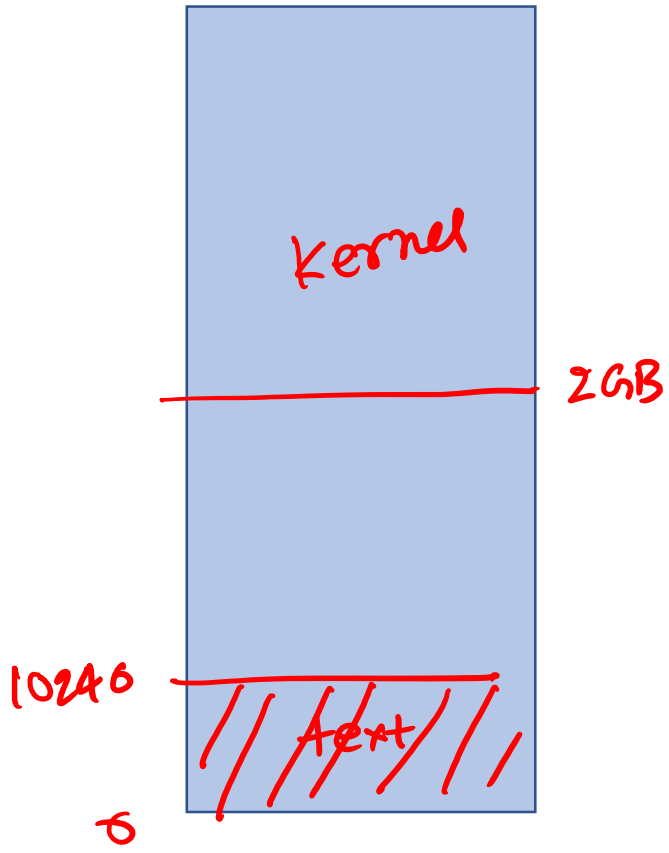
loaduvm (pgdir, addr, ip, offset, sz)



- read “sz” bytes from the input file at the given offset and store them at the virtual address “addr” mapped in the input pgdir

- Why does loaduvm walk the page directory to first get the physical address instead of directly copying into the virtual address?
  - pgdir may not be the currently active page table

Virtual address space after loaduvm

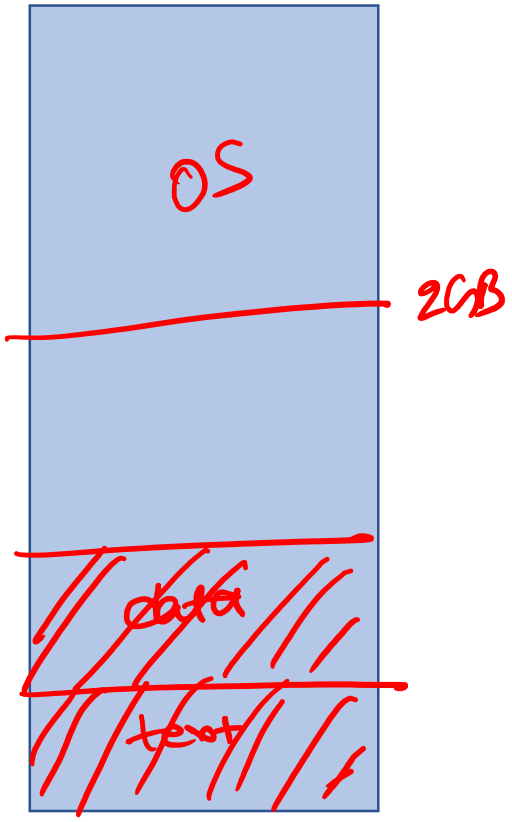


exec: 6310

exec (char *path, char **argv)

- read program headers from file
- for every program header
  - fetch the virtual address (vaddr) and memory size (memsz) of the section from the program header
  - call allocuvm to map physical pages at the virtual address range {vaddr, vaddr+memsz}
  - call loadvm to load the contents of the section from the file

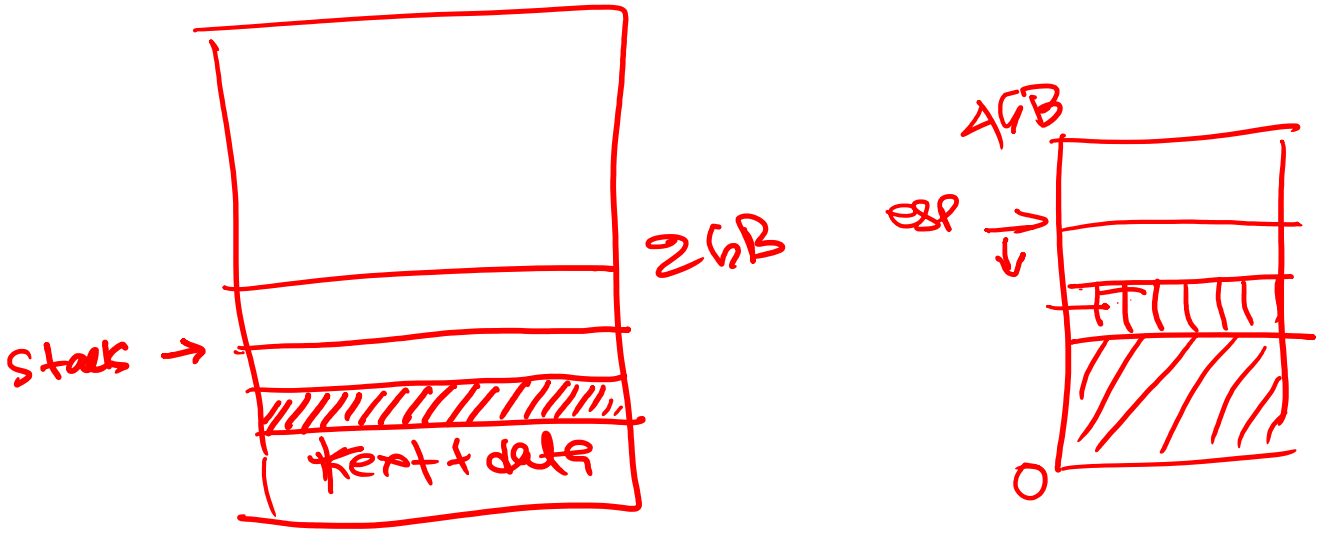
Virtual address space after for loop



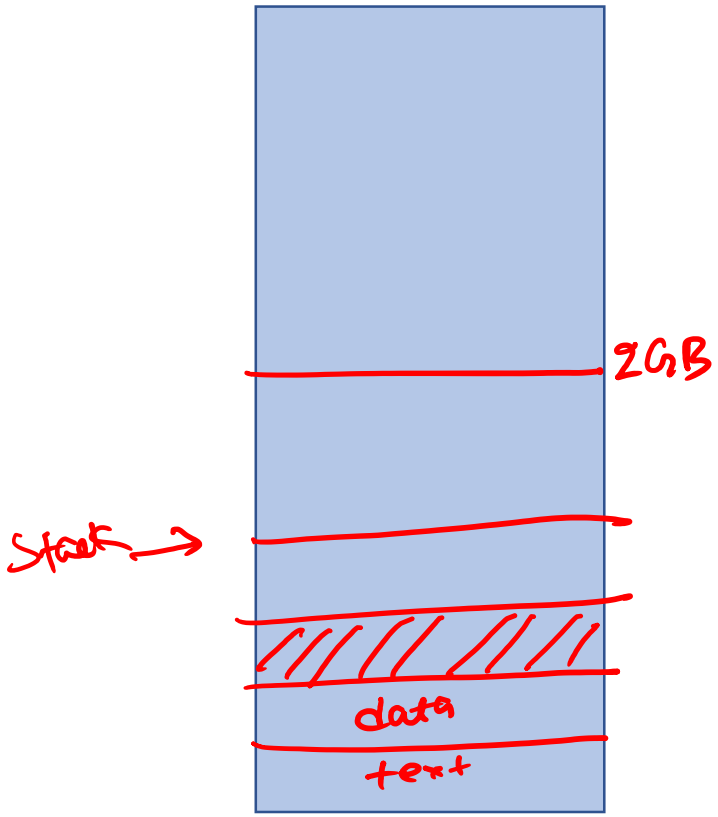
exec: 6310

exec (char *path, char **argv)

- read program headers from file
- load all sections
- allocate two pages for stack
- make the first page inaccessible
  - by revoking the user access



Virtual address space after stack allocation



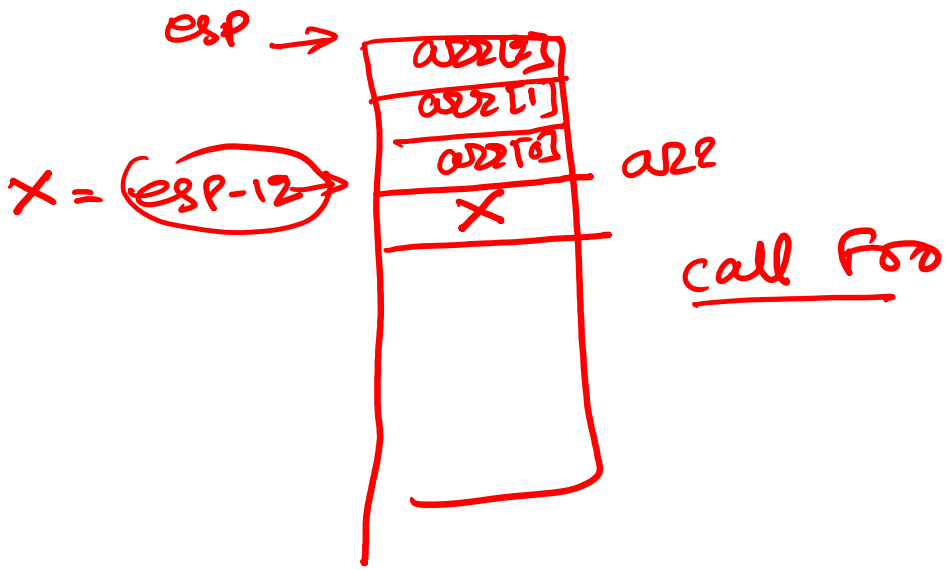
exec: 6310

exec (char *path, char **argv)

- read program headers from file
- load all sections
- allocate two pages for stack
- make the first page inaccessible
  - by revoking the user access
- copy arguments of main to stack

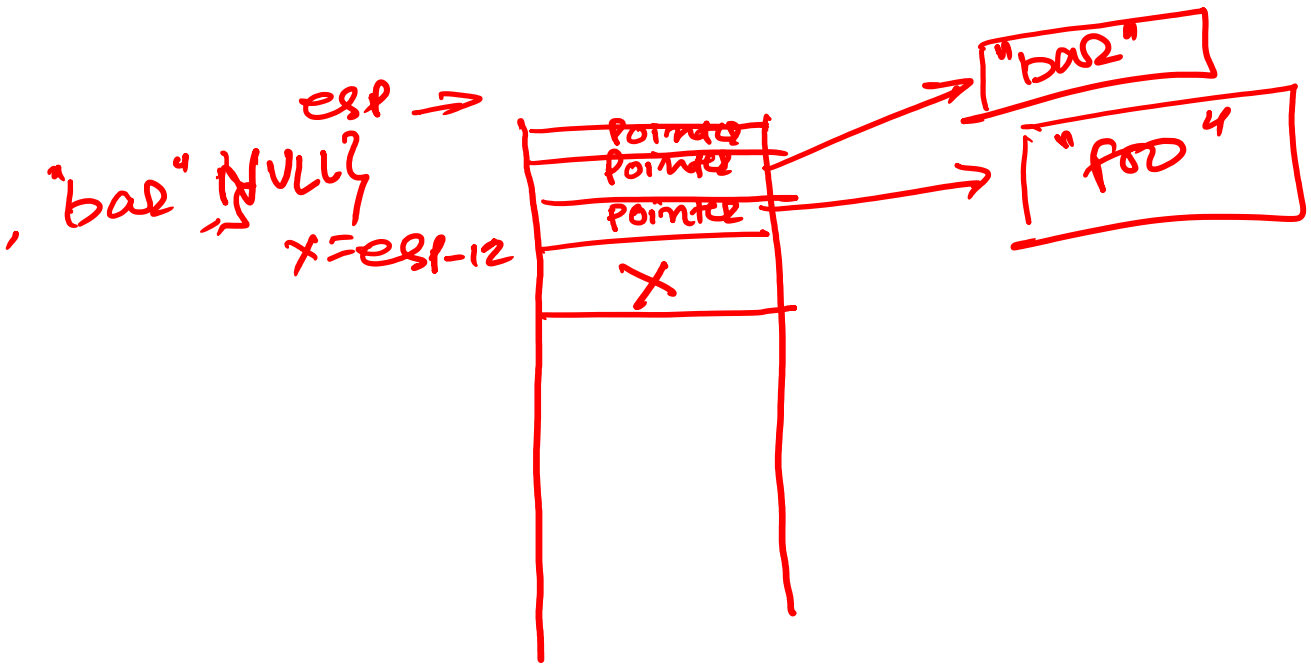
Local variables and argument passing in gcc

```
main ()
{
    int arr[3];
    foo (arr);
}
```



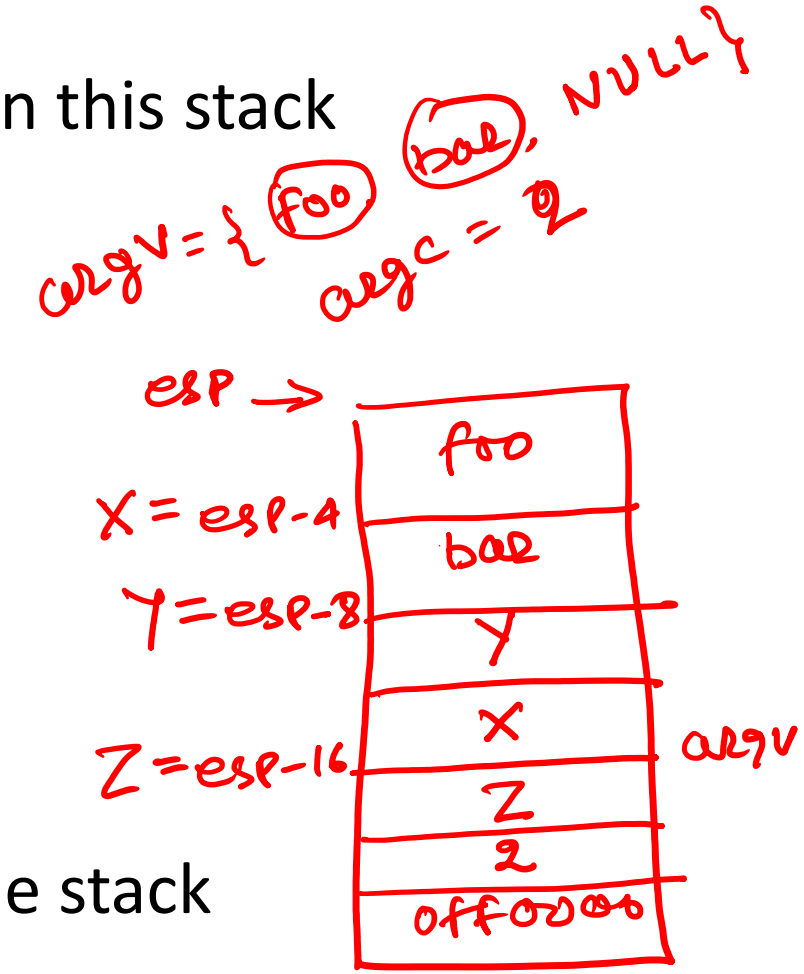
Local variables and argument passing in gcc

```
main ()
{
   char *arr[3];
   foo (arr);
}
```



Copy arguments to stack

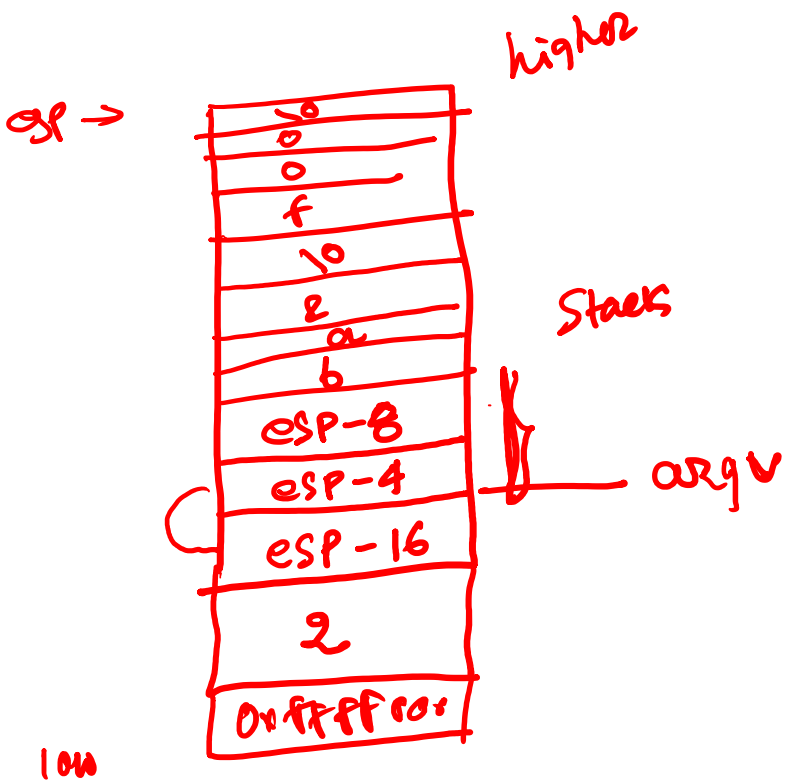
- Our goal is to call “main (int argc, char *argv[])” on this stack
- exec is called with null terminated “char **argv”
- for each string in argv
  - allocate space on stack
  - copy the string to the allocated space
- set up the arguments, a fake return address on the stack



Copy arguments to stack

char *argv[] = {“foo”, “bar”, NULL};

argc = 2;



exec (argv)

argv[] = {"foo", "bar", NULL};

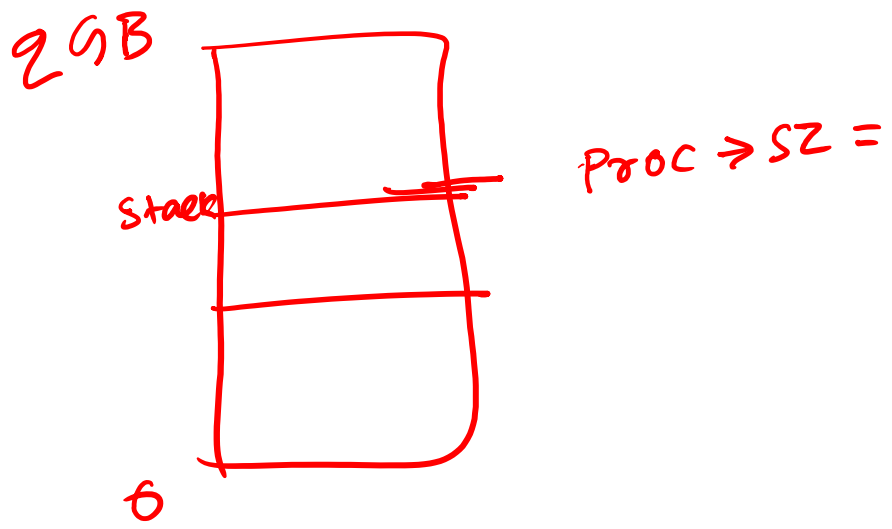
foo

bar

main(int argc, char *argv[])

exec: 6310

exec (char *path, char **argv)



- read program headers from file
- load all sections
- allocate stack and copy arguments
- adjust process size

exec: 6310

exec (char *path, char **argv)

- read program headers from file
- load all sections
- allocate stack and copy arguments
- adjust process size
- rewrite eip with the main of executable and esp with the new stack in the trap frame (pushed during the exec system call)

Trap


ss
esp
eflags
cs
eip
error code
vector id
ds
es
fs
gs
eax
ecx
edx
ebx
esp
ebp
esi
edi
jmp alltrap
esp
esp
call trap

alltraps: 3254

ss, esp, eflags, cs, eip // pushed by hardware

error_code, vector no // pushed by vectors.S

alltraps:

```
  push all segment registers
  push all general purpose registers
  trap (&esp)  /* esp contains the address of
                  trapframe */
```

trapframe : 602

```
struct trapframe {
  uint edi;
  …
  uint eax;
  ushort gs;
  ushort padding1;
  …
  uint trapno;
  uint err;
  uint eip;
  ushort cs;
  …
};
```

trap:3351

- trap (struct trapframe *tf)
- sets proc->tf to the current trapframe on system call at 3356
- exec sets “proc->tf->eip” to new executable “main” at 6396
- exec sets “proc->tf->esp” to new stack at 6397

exec: 6310

exec (char *path, char **argv)

- read program headers from file
- load all sections
- allocate stack and copy arguments
- adjust process size
- rewrite eip and esp in trapframe
- call switchuvm to load new page table

switchuvm: 1873

- disable interrupts
- setup TSS to point to the process kernel stack
- load the new page table
- restore the original interrupt flags

exec: 6310

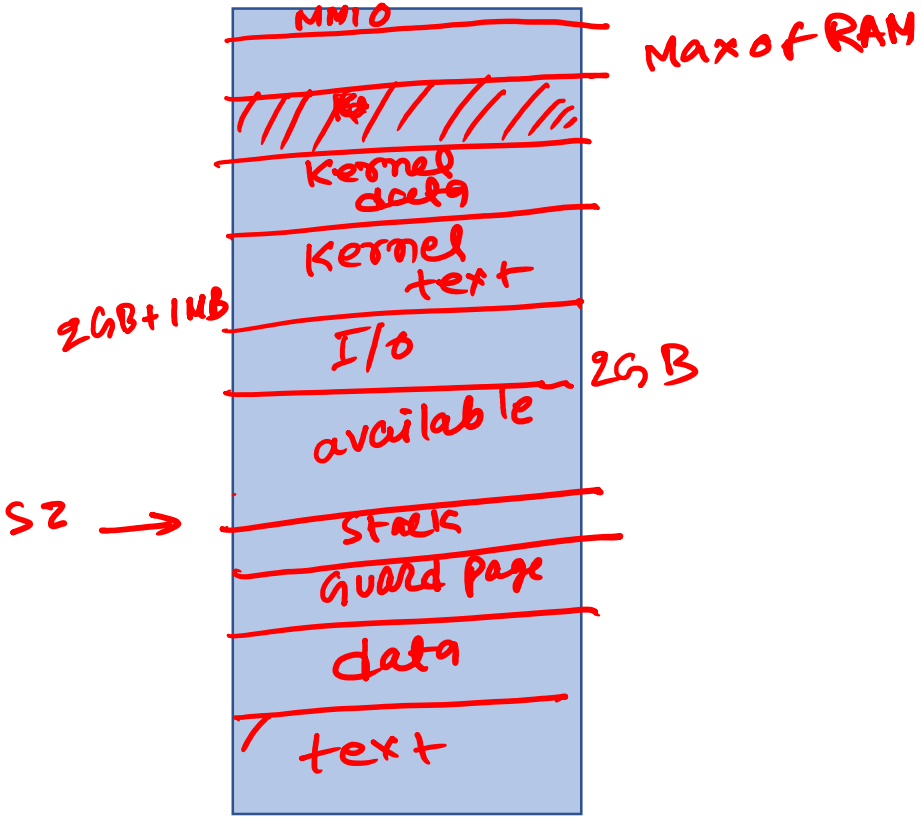
exec (char *path, char **argv)

- read program headers from file
- load all sections
- allocate stack and copy arguments
- rewrite eip and esp in trapframe
- adjust process size
- call switchuvm to load new page table
- call freevm to free all the user pages in the old page directory

freevm: 2015

- free all user pages
- free all page table pages
- free the page directory

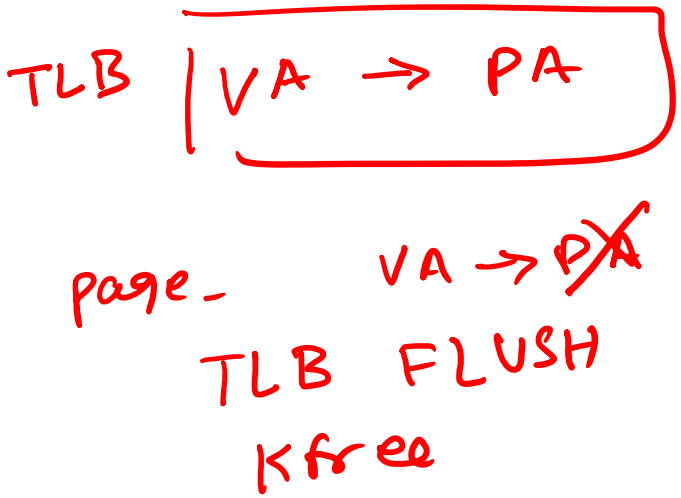
Virtual address space after exec



allocate space for heap

- malloc uses sbrk
- sys_sbrk (int n) : 3701
  - growproc(int n) : 2535
    - adjust the process size by n bytes
    - if n is positive
      - call allocuvm
    - if n is negative
      - call deallocuvm

- Why does “growproc” call “switchuvm”?
- Discuss a potential race condition in deallocuvm:1987



Other OS designs

- Linux reserves virtual addresses between 3GB – 4GB for kernel
- Windows reserves 2GB – 4GB for the kernel (similar to xv6) but can be configured to use 3GB – 4GB

Does OS has to map the entire RAM in the kernel address space?

- How to implement loaduvm : 1918 if the entire RAM is not mapped in the kernel address space?
  - Kernel can map and unmap user pages on demand

Page fault