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PROJECT TITLE:

ADDING SYSTEM CALLS TO XV6 OS

GROUP MEMBERS:

SUNAKSHI PRADHAN (18BCE2450)

YASHVARDHAN SINGH BHADAURIA (19BCE2129)

AYUSH TAMBI (19BCE2142)

MUKUND SINGH BISHT (19BCI0220)

SLOT: F2

GUIDED BY

Ms. RUBY D

ASSISTANT PROFESSOR SR. GRADE 1

CSE2005- OPERATING SYSTEMS

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1.ACKNOWLEDGEMENT

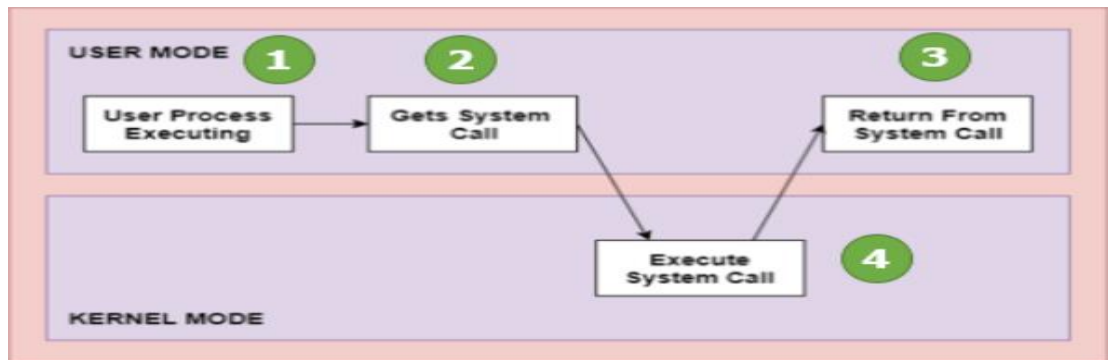
It is our privilege to express our sincerest regards to our project coordinator, RUBY D, for their valuable inputs, able guidance, encouragement, whole-hearted cooperation and constructive criticism throughout the duration of our project. I deeply express our sincere thanks to our Head of Department and Dean for encouraging and allowing us to present the project on the topic “ADDIN SYSTEM CALLS TO XV6” for operating system course. I take this opportunity to thank all our lecturers who have directly or indirectly helped our project. We pay our respects and love to our parents and all other family members and friends for their love and encouragement throughout our career. Last but not the least we express our thanks to our friends for their cooperation and support.

2.ABSTRACT

An operating system, as you all know, accepts two modes; kernel mode, and consumer mode. When a program requires access to RAM or a hardware resource in user mode, it must ask the kernel to give access to that particular resource. This is achieved by a machine request. The mode is moved from user mode to kernel mode while a device is making a machine call. Within an operating system, there are several system calls which execute different types of tasks when called.

3. AIM

This project explain how to add a system call in Linux Kernel xv6 and covers prerequisites to add any system call in XV6 Kernel, Project also include Explanation of Process and commands required in kernel compilation, and briefly explain the process of system call addition, commands and packages used to do so. It also explains about the scheduling involved in the XV6 and how to change the scheduling policy of XV6 kernel. It further explains about the data structure that could be used to store the data in the XV6 kernel.



Section 3

4. LITERATURE SURVEY

[1] The key concepts for operating systems were implemented in this text by observing one operating system, xv6, line by line. The meaning of the key ideas is expressed in certain code lines and each line is important; other code lines offer an example of how to execute a specific operating system concept and can be achieved in various ways easily.

[2] The key concepts for operating systems were implemented in this text by observing one operating system, xv6, line by line. The meaning of the key ideas is expressed in certain code lines and each line is important; other code lines offer an example of how to execute a specific operating system concept and can be achieved in various ways easily.

[3] The findings of the experiment running micro benchmark programs show that 1) the widely used basic kernel functions will operate similarly by leaving them in the proxy kernel, 2) there is a marginal cost of connectivity between the UV6 application kernel and its user method, and 3) there are instances where UV6 exceeds the original XV6. We have also demonstrated that UV6 kernel acceleration is feasible by the use of a processor's SIMD unit. [4] Except in the case of fail-stop failures, FSCQ is the first file system with a machinecheckable proof that its design satisfies a specification. Possibly, FSCQ prevents problems that have afflicted previous file systems, such as forgetting to zero out directory blocks or executing disk writes without ample obstacles.

[5] They are presenting our work on teaching operating systems using Android at Columbia University, an free, commercially funded development framework increasingly used on mobile and embedded devices. They are releasing a series of five Android kernel programming projects fitting for a one-semester introductory course in operating systems

5. SOURCE OF INSPIRATION

Xv6 is a teaching operating system that was developed by MIT in 2002, and being used as a material of operating system courses for graduate students since then. And it is becoming famous as a well-developed teaching operating system. In fact, in 2010, it is used as a teaching material of operating system courses in not only MIT, but also Rutgers University, Yale University, Johns Hopkins University, and Stanford University, because of its simplicity. To attack this problem, xv6 operating system was developed as a very compacted operating system that implements important operating system concepts which are mainly inspired from Unix version 6, but it is written in ANSI C programming language and runs on x86. So, Xv6 is becoming famous for a good teaching material that is written in readable source codes, and follows current architectures, but its line of codes keeps less than 10,000 and its commentary consists of less than 100 pages, which can be covered in a semester.

6. EDUCATIONAL USE

xv6 has been used in operating systems courses at many prestigious universities including Northwestern University, The George Washington University, Northeastern University, Yale University, Columbia University, Ben-Gurion University, Johns Hopkins University, Portland State University, Tsinghua University, Southern Adventist University, the University of Wisconsin–Madison, Binghamton University, the University of Utah, University of California, Irvine, University of California, Riverside, IIT Bangalore, IIT Bombay, IIT Madras, IIT Bhubaneswar and PEC Chandigarh in India, the Linnaeus University in Sweden, the University of Otago in New Zealand, the National University of Córdoba, the National University of Río Cuarto, in Argentina, the Federico Santa María Technical University in Chile.

7. HARDWARE-SOFTWARE REQUIREMENTS

7.1 HARDWARE REQUIREMENTS

Our team has Dell laptop which runs in Windows 10 Operating System. For the purpose of our OS project we dual booted our systems with different Linux Operating System which is Ubuntu. As our topic suggests we will now have to install xv6. We did not want to travel straight down the road by using a virtual setup in our Windows. By dual booting we were trying to explore possibilities and opening our path for more challenges.

Ubuntu Workstation from where Ubuntu OS .iso file is downloaded:
Software to burn .iso file into USB to make it bootable:

7.2 SOFTWARE REQUIREMENTS

We are using XV6 OS for our project. XV6 is a modern reimplementation of Sixth Edition Unix in ANSI C for multiprocessor X86 and RISC-V systems. Unlike Linux or BSD, XV6 is easy enough to cover in a semester, but it also includes Unix's essential principles and structure. Rather of learning the original V6 technology, the course uses XV6 because there are not commonly accessible PDP-11 computers and the original operating system was written in obsolete pre-ANSI C. It can be used to learn implementation of OS helping us to understand the OS.

There are certain requirements which must be fulfilled before adding a system call in Linux kernel XV6:

- a) Get XV6 OS from official MIT Github link.
- b) Set root password for Linux: After installation set root password by command: `sudo passwd root` and then execute `sudo passwd -u root` to unlock account.
- c) Access to root folder: There are many ways to do so, one among them is to go to terminal (by alt+tab+T) and type the following command: `sudo chmod -R 777/root`, after running this command one might see some error but when one will go to root folder, can have access to that folder but even after one gain access to root folder one can't create, delete or make changes in any existing file in root, usr or src folder. (to get this liberty refer next point)
- d) Permission to alter files in root, usr or src folder: There are various ways to get this but one may easily get this by typing command: `sudo nautilus`, in the terminal. After running this command, automatically a window will open and one will be able to do whatever one wants to do in root, src or usr folder.
- e) Installation of required packages: go to terminal and type command: `sudo apt-get install gcc`, `sudo apt-get update`, `sudo apt-get upgrade`.
- f) Extract the downloaded XV6 source code in home directory.

7.3 TO ADD SYSTEM CALL IN LINUX KERNEL (XV6 OS):

To add a system call that can be called in xv6's shell, you should change the following files

- **sysproc.c** add the real implementation of your method here
- **syscall.h** define the position of the system call vector that connect to your implementation
- **user.h** define the function that can be called through the shell
- **syscall.c** external define the function that connect the shell and the kernel, use the position defined in **syscall.h** to add the function to the system call vector
- **usys.S** use the macro to define connect the call of user to the system call function
- **defs.h** add a forward declaration for your new system call
- **proc.c** add the function that needs the os to make or change the process

8.IMPLEMENTATION

8.1 INSTALLATION OF QEMU

QEMU (short for Quick Emulator) is a free and open-source hosted hypervisor that performs hardware virtualization (not to be confused with hardware-assisted virtualization).

QEMU is a hosted virtual machine monitor: it emulates CPUs through dynamic binary translation and provides a set of device models, enabling it to run a variety of unmodified guest operating systems. It also can be used with KVM to run virtual machines at near-native speed (requiring hardware virtualization extensions on x86 machines). QEMU can also do CPU emulation for user-level processes, allowing applications compiled for one architecture to run on another.

STEP:

```
sudo apt-get install qemu
```

8.2 INSTALLATION OF XV6

Xv6 is a teaching operating system developed in the summer of 2006 for MIT's operating systems course.

git clone <https://github.com/mit-pdos/xv6-public>.git xv6

Changing the mode to give extra permissions to xv6:

```
chmod 700 -R xv6
```

8.3 RUNNING XV6

```
cd xv6  
make  
make qemu
```

Below is the list of the default system calls provided in the above installation of XV6:

System call	Description
fork()	Create process
exit()	Terminate current process
wait()	Wait for a child process to exit
kill(pid)	Terminate process pid
getpid()	Return current process's id
sleep(n)	Sleep for n seconds
exec(filename, *argv)	Load a file and execute it
sbrk(n)	Grow process's memory by n bytes
open(filename, flags)	Open a file; flags indicate read/write
read(fd, buf, n)	Read n bytes from an open file into buf
write(fd, buf, n)	Write n bytes to an open file
close(fd)	Release open file fd
dup(fd)	Duplicate fd
pipe(p)	Create a pipe and return fd's in p
chdir(dirname)	Change the current directory
mkdir(dirname)	Create a new directory
mknod(name, major, minor)	Create a device file
fstat(fd)	Return info about an open file
link(f1, f2)	Create another name (f2) for the file f1
unlink(filename)	Remove a file

Figure 0-2. Xv6 system calls

8.4 ADDING SYSTEM CALLS

NICE.C

```
#include "types.h"
#include "stat.h"
#include "user.h"

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

    if(argc < 3){
        printf(2, "USAGE: nice pid priority\n");
        exit();
    }
    pid = atoi ( argv[1] ); //1st argument is pid
    priority = atoi ( argv[2] ); //2nd is priority
    if ( priority < 0 || priority > 20 ) {
        printf(2, "Invalid priotiy should be between 0-20\n");
        exit();
    }
    printf(1, "pid=%d , pr=%d\n", pid, priority);
    chpr ( pid, priority );
    exit();
}
```

PRIGIV.C

```
#include "types.h"
#include "user.h"
#include "stat.h"

int
main(int argc, char *argv[])
{
    int k, n, id;
    double x=0, z, d;
    if(argc < 2)
        n=1; //default value we gave
    else
        n = atoi ( argv[1] ); //from command line the number of processes we want to create or
        processes
    if (n < 0 || n > 20)
        n=2;
    if(argc < 3 )
        d=1.0;
    else
```

```

d=atoi (argv[2] );
x=0;
id=0;
for ( k=0; k < n;k++){
    id = fork ();
    if ( id < 0) {
        printf(1,"%d failed in fork \n",getpid());
    }
    else if (id >0 ) { //parent
        printf(1,"parent %d creating child %d \n",getpid(),id);
        wait();
    }
    else {
        printf(1,"child %d created \n",getpid());
        for ( z=0; z <80000.0; z += d )
            x = x +3.14 * 89.64; //useless calculations to consume cpu time, so we see the state
        of other processes
        break;
    }
}
exit();
}

```

PS.C

```

#include "types.h"
#include "stat.h"
#include "user.h"
//19BCI0220
int
main(void)
{
    cps();

    exit();
}

```

9.RESULTS AND OUTPUTS

```
kudu@kudukudu: ~/xv6
cpu0: starting 0
sb: size 1000 nblocks 941 ninodes 200 nlog 30 logstart 2 inodestart 32 bmap sta8
init: starting sh
$ prigiv 2 0.01 &; prigiv 2 0.01 &;
$ child 9 created parent 5 creating
cchild 8parent 7 creatin hild 8 created

g child 9

$ ps
name      pid      state     priority
init       1        SLEEPING      10
sh         2        SLEEPING      10
prigiv     8        RUNNING       10
prigiv     9        RUNNABLE      10
prigiv     5        SLEEPING      10
prigiv     7        SLEEPING      10
ps         11       RUNNING       10
$ nice 8 19
pid=8 , pr=19
$ ps
name      pid      state     priority
init       1        SLEEPING      10
sh         2        SLEEPING      10
prigiv     8        RUNNABLE      19
prigiv     9        RUNNING       10
prigiv     5        SLEEPING      10
prigiv     7        SLEEPING      10
ps         13       RUNNING       10
$ QEMU: Terminated
kudu@kudukudu:~/xv6$
```

Section 9

CHANGES IN SYSTEM FILES:

1. MAKE FILE

```
13
14 EXTRA=\
15     mkfs.c ulib.c user.h cat.c echo.c forktest.c grep.c kill.c\
16     ln.c ls.c mkdir.c rm.c stressfs.c usertests.c wc.c zombie.c\
17     printf.c myprogram.c ps.c prigiv.c nice.c umalloc.c\
18     README dot-bochsrc *.pl toc.* runoff runoff1 runoff.list\
19     .gdbinit.tmpl gdbutil\
20
```

```

168 UPROGS=\
169     _cat\
170     _echo\
171     _forktest\
172     _grep\
173     _init\
174     _kill\
175     _ln\
176     _ls\
177     _mkdir\
178     _rm\
179     _sh\
180     _stressfs\
181     _usertests\
182     _wc\
183     _zombie\
184     _myprogram\
185     _ps\
186     _prigiv\
187     _nice\
188

```

Section 9

2. USYS.S

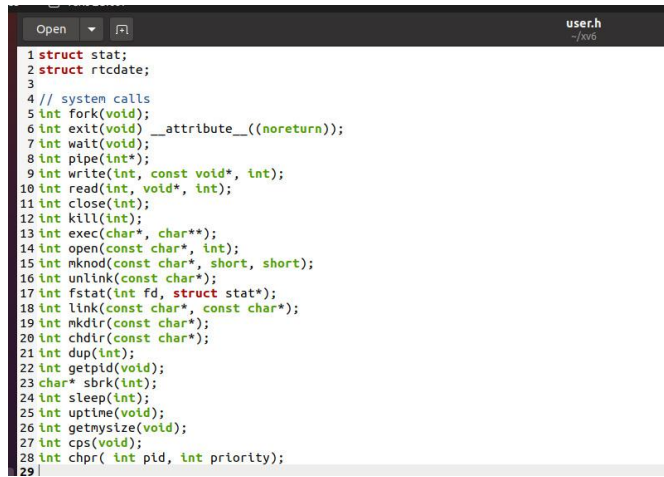
```

1 #include "syscall.h"
2 #include "traps.h"
3
4 #define SYSCALL(name) \
5     .globl name; \
6     name: \
7         movl $SYS_ ## name, %eax; \
8         int $T_SYSCALL; \
9         ret
10
11 SYSCALL(fork)
12 SYSCALL(exit)
13 SYSCALL(wait)
14 SYSCALL(pipe)
15 SYSCALL(read)
16 SYSCALL(write)
17 SYSCALL(close)
18 SYSCALL(kill)
19 SYSCALL(exec)
20 SYSCALL(open)
21 SYSCALL(mknod)
22 SYSCALL(unlink)
23 SYSCALL(fstat)
24 SYSCALL(link)
25 SYSCALL(mkdir)
26 SYSCALL(chdir)
27 SYSCALL(dup)
28 SYSCALL(getpid)
29 SYSCALL(sbrk)
30 SYSCALL(sleep)
31 SYSCALL(uptime)
32 SYSCALL(getmysize)
33 SYSCALL(cps)
34 SYSCALL(chpr)

```

Section 9

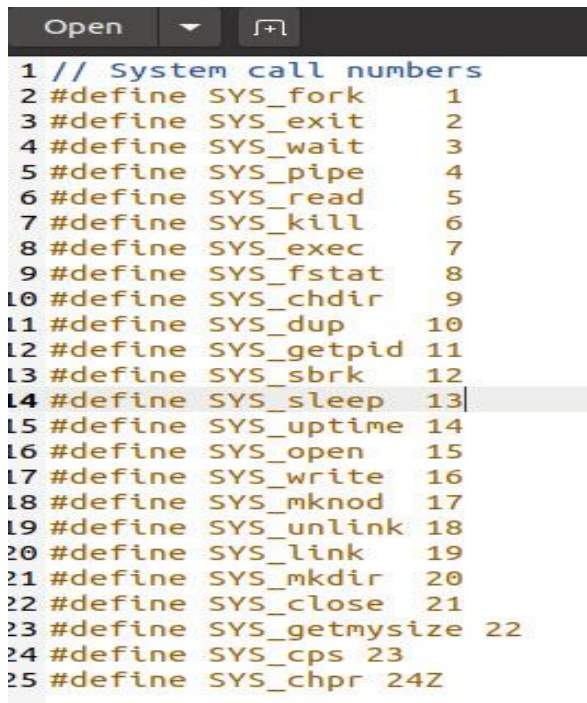
3. USER.H

A screenshot of a code editor window titled 'user.h'. The editor shows a list of system call prototypes in C. The first two lines are '1 struct stat;' and '2 struct rtcdate;'. Line 3 is empty. Line 4 is a comment '// system calls'. Lines 5 through 28 are prototypes for various system calls: fork, exit, wait, pipe, write, read, close, kill, exec, open, mknod, unlink, fstat, link, mkdir, chdir, dup, getpid, sbrk, sleep, uptime, getmysize, cps, and chpr. Line 29 is empty.

```
1 struct stat;
2 struct rtcdate;
3
4 // system calls
5 int fork(void);
6 int exit(void) __attribute__((noreturn));
7 int wait(void);
8 int pipe(int*);
9 int write(int, const void*, int);
10 int read(int, void*, int);
11 int close(int);
12 int kill(int);
13 int exec(char*, char**);
14 int open(const char*, int);
15 int mknod(const char*, short, short);
16 int unlink(const char*);
17 int fstat(int fd, struct stat*);
18 int link(const char*, const char*);
19 int mkdir(const char*);
20 int chdir(const char*);
21 int dup(int);
22 int getpid(void);
23 char* sbrk(int);
24 int sleep(int);
25 int uptime(void);
26 int getmysize(void);
27 int cps(void);
28 int chpr( int pld, int priority);
29
```

Section 9

4. SYSCALL.H

A screenshot of a code editor window showing the contents of syscall.h. The first line is a comment '// System call numbers'. Lines 2 through 25 are #define statements that map system call names to their respective numbers. The list includes SYS_fork (1), SYS_exit (2), SYS_wait (3), SYS_pipe (4), SYS_read (5), SYS_kill (6), SYS_exec (7), SYS_fstat (8), SYS_chdir (9), SYS_dup (10), SYS_getpid (11), SYS_sbrk (12), SYS_sleep (13), SYS_uptime (14), SYS_open (15), SYS_write (16), SYS_mknod (17), SYS_unlink (18), SYS_link (19), SYS_mkdir (20), SYS_close (21), SYS_getmysize (22), SYS_cps (23), and SYS_chpr (24Z).

```
1 // System call numbers
2 #define SYS_fork 1
3 #define SYS_exit 2
4 #define SYS_wait 3
5 #define SYS_pipe 4
6 #define SYS_read 5
7 #define SYS_kill 6
8 #define SYS_exec 7
9 #define SYS_fstat 8
10 #define SYS_chdir 9
11 #define SYS_dup 10
12 #define SYS_getpid 11
13 #define SYS_sbrk 12
14 #define SYS_sleep 13
15 #define SYS_uptime 14
16 #define SYS_open 15
17 #define SYS_write 16
18 #define SYS_mknod 17
19 #define SYS_unlink 18
20 #define SYS_link 19
21 #define SYS_mkdir 20
22 #define SYS_close 21
23 #define SYS_getmysize 22
24 #define SYS_cps 23
25 #define SYS_chpr 24Z
```

Section 9

5. SYSCALL.C

```
97 extern int sys_open(void);
98 extern int sys_pipe(void);
99 extern int sys_read(void);
100 extern int sys_sbrk(void);
101 extern int sys_sleep(void);
102 extern int sys_unlink(void);
103 extern int sys_wait(void);
104 extern int sys_write(void);
105 extern int sys_uptime(void);
106 extern int sys_getmysize(void);
107 extern int sys_cps(void);
108 extern int sys_chpr(void);
109 static int (*syscalls[])(void) = {
110 [SYS_fork] sys_fork,
111 [SYS_exit] sys_exit,
112 [SYS_wait] sys_wait,
113 [SYS_pipe] sys_pipe,
114 [SYS_read] sys_read,
115 [SYS_kill] sys_kill,
116 [SYS_exec] sys_exec,
117 [SYS_fstat] sys_fstat,
118 [SYS_chdir] sys_chdir,
119 [SYS_dup] sys_dup,
120 [SYS_getpid] sys_getpid,
121 [SYS_sbrk] sys_sbrk,
122 [SYS_sleep] sys_sleep,
123 [SYS_uptime] sys_uptime,
124 [SYS_open] sys_open,
125 [SYS_write] sys_write,
126 [SYS_mknod] sys_mknod,
127 [SYS_unlink] sys_unlink,
128 [SYS_link] sys_link,
129 [SYS_mkdir] sys_mkdir,
130 [SYS_close] sys_close,
131 [SYS_getmysize] sys_getmysize,
132 [SYS_cps] sys_cps,
133 [SYS_chpr] sys_chpr,
134 };
135 ..
--
```

Section 9

6. SYSPROC.C

```
100
101 int
102 sys_cps ( void )
103 {
104 return cps ();
105 }
106
107 int
108 sys_chpr (void)
109 {
110 int pid,pr;
111 if(argint(0, &pid) < 0)
112 return -1;
113 if(argint(1, &pr) < 0)
114 return -1;
115
116 return chpr (pid , pr);
117 }
118
```

Section 9

7. PROC.C

```
Open  ▾  proc.c
~/xv6

531     cprintf("%p", pc[i]);
532 }
533     cprintf("\n");
534 }
535 }
536
537 int
538 cps()
539 {
540     struct proc *p;
541     // enable interrupts on this processor
542     sti();
543     //loop over process table looking for process with pid.
544     acquire(&ptable.lock);
545     cprintf("name \t pid \t state \t priority \n");
546     for(p = ptable.proc; p < &ptable.proc[NPROC]; p++){
547         if ( p->state == SLEEPING )
548             cprintf("%s \t %d \t SLEEPING \t %d \n", p->name, p->pid, p->priority);
549         else if ( p->state == RUNNING )
550             cprintf("%s \t %d \t RUNNING \t %d \n", p->name, p->pid, p->priority);
551         else if ( p->state == RUNNABLE )
552             cprintf("%s \t %d \t RUNNABLE \t %d \n", p->name, p->pid, p->priority);
553     }
554     release(&ptable.lock);
555
556     return 22;
557 }
558
559 //changing priority function
560 int
561 chpr( int pid, int priority )
562 {
563     struct proc *p;
564     acquire(&ptable.lock);
565     for(p = ptable.proc; p < &ptable.proc[NPROC]; p++){
566         if(p->pid == pid) {
567             p->priority = priority;
568             break;
569         }
570     }
571     release(&ptable.lock);
572
573     return pid;
574 }
```

Section 9

8. PROC.H (adding variable PRIORITY)

```
Open  ▾  [ ]  proc.h  
~ /xv6  
user.h  x  
18 // Saved registers for kernel context switches.  
19 // Don't need to save all the segment registers (%cs, etc),  
20 // because they are constant across kernel contexts.  
21 // Don't need to save %eax, %ecx, %edx, because the  
22 // x86 convention is that the caller has saved them.  
23 // Contexts are stored at the bottom of the stack they  
24 // describe; the stack pointer is the address of the context.  
25 // The layout of the context matches the layout of the stack in swtch.S  
26 // at the "Switch stacks" comment. Switch doesn't save eip explicitly,  
27 // but it is on the stack and allocproc() manipulates it.  
28 struct context {  
29     uint edi;  
30     uint esi;  
31     uint ebx;  
32     uint ebp;  
33     uint eip;  
34 };  
35  
36 enum procstate { UNUSED, EMBRYO, SLEEPING, RUNNABLE, RUNNING, ZOMBIE };  
37  
38 // Per-process state  
39 struct proc {  
40     uint sz; // Size of process memory (bytes)  
41     pde_t* pgdir; // Page table  
42     char *kstack; // Bottom of kernel stack for this process  
43     enum procstate state; // Process state  
44     int pid; // Process ID  
45     struct proc *parent; // Parent process  
46     struct trapframe *tf; // Trap frame for current syscall  
47     struct context *context; // swtch() here to run process  
48     void *chan; // If non-zero, sleeping on chan  
49     int killed; // If non-zero, have been killed  
50     struct file *ofile[NOFILE]; // Open files  
51     struct inode *cwd; // Current directory  
52     char name[16]; // Process name (debugging)  
53     int priority; //new process priority between 0-20  
54 };  
55
```

10. INFERENCES FROM THE PROJECT

While performing our project, we figured out that Kernel is the heart of OS since our project was related to modifying Kernel by the means of adding system calls. OS is itself a program which runs multiple programs having various number of files with .c,.h extensions. We can add features to any Open Source OS similarly. We also understood the importance of scheduling in the Operating System. The XV6 kernel uses Round Robin scheduling and we changed that to Priority scheduling and thus saw the importance of Round Robin scheduling in the OS. We learnt the importance of structures and also the basic layout of any OS. We also learnt that the OS requires important data structure techniques to store the data. We understood the importance of memory management in this OS by making some changes in 'makefake.h'. The project was challenging and fun and we got to learn a lot from the same.

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