

Assignment 2: Adding and testing a new system call to Linux kernel

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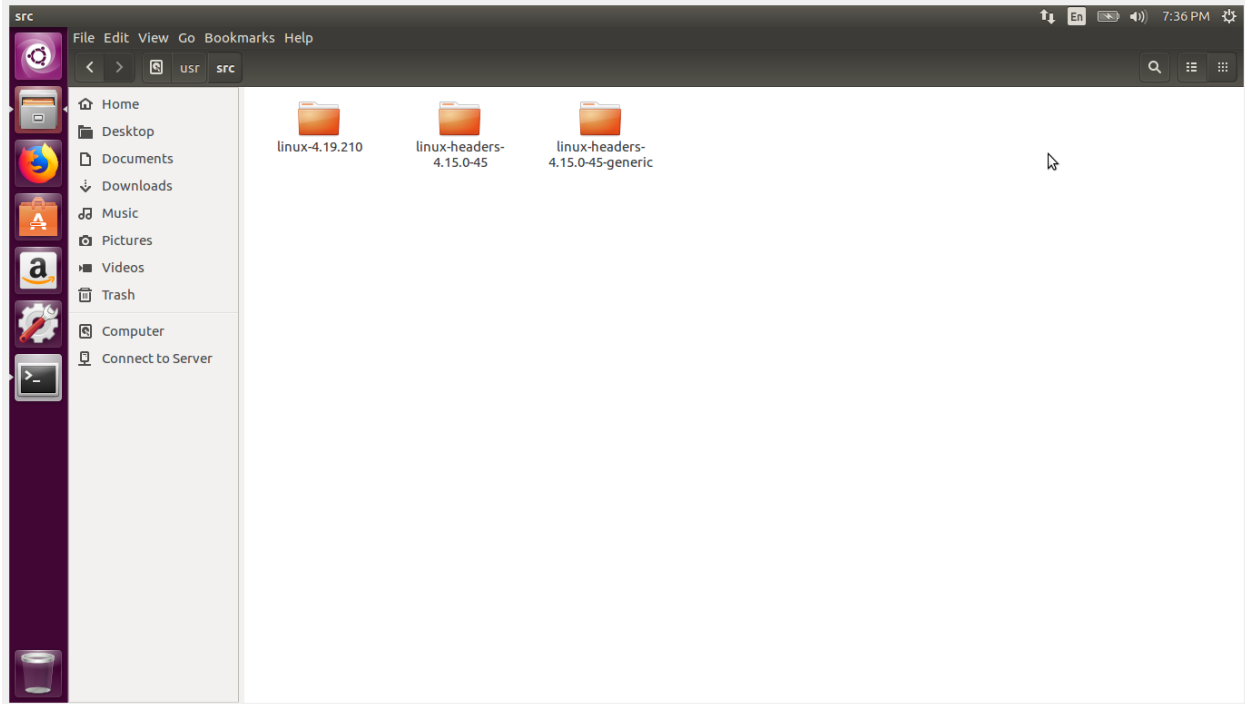
Roll no.: 2022201068

In this assignment, our task was to implement the system calls in the Linux kernel and test them out by compiling the kernel.

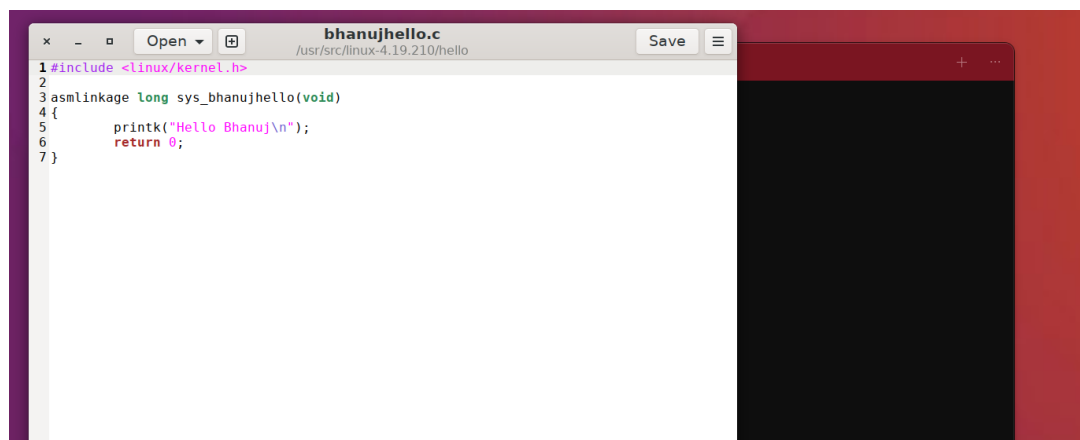
Steps Followed

1. Download the compressed file of *Linux Kernel version 4.19.210*.
2. Extract the downloaded kernel file in */usr/src*.

```
$ sudo tar -xvf linux-4.19.210.tar.xz -C/usr/src
```



1. Go to the extracted folder
2. Implement System Calls
 - a. **Question 1. : Write syscall to print a welcome message to Linux logs**
 - i. Create a Folder for a new system-call `hello`
 - ii. Create a C file inside it. `hello.c`
 - iii. Implement the system call as shown in `bhanujhello.c`



- iv. Create a make file in the `hello` folder named `Makefile` and include the following line in it.

```
obj-y := hello.o
```

- v. Add function call definition in `./include/syscall.h` header file.

```
asmlinkage long sys_bhanujhello(void);
```

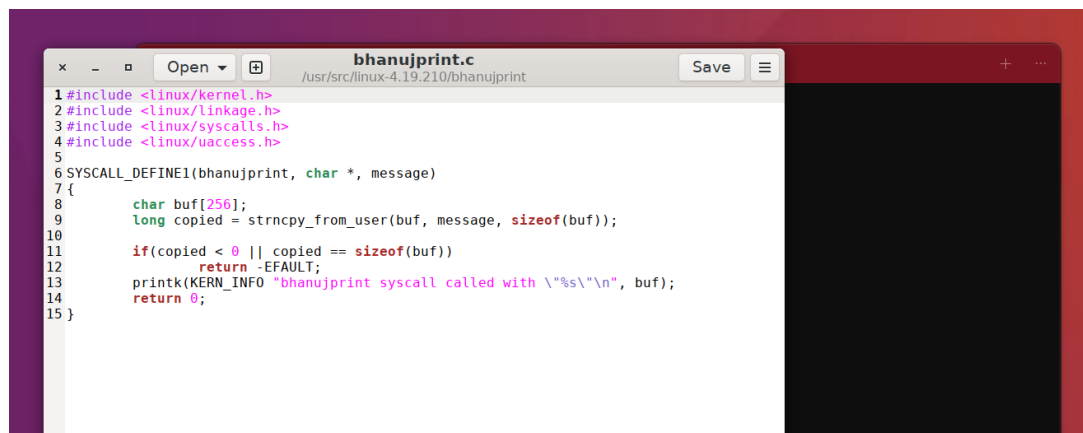
- vi. Add the system call entry in `syscalls_32.tbl`

- vii. Add folder name to `Makefile` of kernel

```
core-y += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ hello/
```

b. Question 2.: Write syscall which will receive string parameter and print it along with some message to kernel logs

- Create a Folder for a new system-call `bhanujprint`
- Create a C file inside it. `bhanujprint.c`
- Implement the system call as shown in `bhanujprint.c`



```
1 #include <linux/kernel.h>
2 #include <linux/linkage.h>
3 #include <linux/syscalls.h>
4 #include <linux/uaccess.h>
5
6 SYSCALL_DEFINE1(bhanujprint, char *, message)
7 {
8     char buf[256];
9     long copied = strncpy_from_user(buf, message, sizeof(buf));
10
11     if(copied < 0 || copied == sizeof(buf))
12         return -EFAULT;
13     printk(KERN_INFO "bhanujprint syscall called with \"%s\\n\"", buf);
14     return 0;
15 }
```

- iv. Create a make file in the `bhanujprint` folder named `Makefile` and include the following line in it.

```
obj-y := bhanujprint.o
```

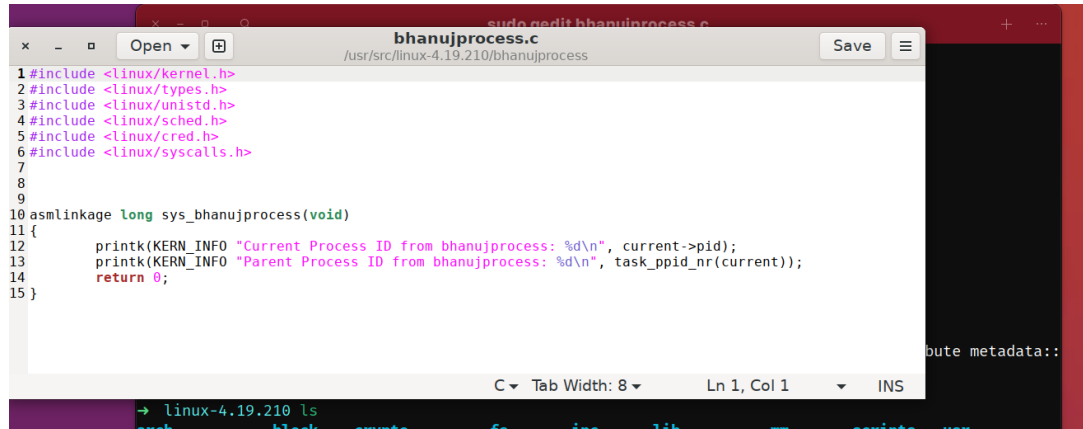
- v. Add the system call entry in `syscalls_32.tbl`

- vi. Add folder name to `Makefile` of kernel

```
core-y += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ hello/
bhanujprint/
```

c. **Question 3.: Write system call to print the parent process id and current process id upon calling it**

- i. Create a Folder for a new system-call `bhanujprocess`
- ii. Create a C file inside it. `bhanujprocess.c`
- iii. Implement the system call as shown in `bhanujprocess.c`



```
1 #include <linux/kernel.h>
2 #include <linux/types.h>
3 #include <linux/unistd.h>
4 #include <linux/sched.h>
5 #include <linux/cred.h>
6 #include <linux/syscalls.h>
7
8
9
10 asmlinkage long sys_bhanujprocess(void)
11 {
12     printk(KERN_INFO "Current Process ID from bhanujprocess: %d\n", current->pid);
13     printk(KERN_INFO "Parent Process ID from bhanujprocess: %d\n", task_ppid_nr(current));
14     return 0;
15 }
```

- iv. Create a make file in the `bhanujprocess` folder named `Makefile` and include the following line in it.

```
obj-y := bhanujprocess.o
```

- v. Add function call definition in `./include/syscall.h` header file.

```
asmlinkage long sys_bhanujprocess(void);
```

- vi. Add the system call entry in `syscalls_32.tbl`

- vii. Add folder name to `Makefile` of kernel

```
core-y += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ hello/
bhanujprint/ bhanujprocess/
```

d. **Question 4: Write system call to execute some predefined system call from your written system call**

In this question, I have implemented `getppid()` function call which is named as `bhanujgetppid()` which will return parent process' process id(pid).

1. Create a Folder for a new system-call `bhanujgetppid`
2. Create a C file inside it. `bhanujgetppid.c`

3. Implement the system call as shown in `bhanujgetppid.c`



```
sudo gedit bhanujgetppid.c
bhanujgetppid.c
/usr/src/linux-4.19.210/bhanujgetppid

1 #include <linux/kernel.h>
2 #include <linux/types.h>
3 #include <linux/unistd.h>
4 #include <linux/sched.h>
5 #include <linux/cred.h>
6 #include <linux/syscalls.h>
7
8
9 asmlinkage long sys_bhanujgetppid(void)
10 {
11     return task_ppid_nr(current);
12 }
```

4. Create a make file in the `bhanujgetppid` folder named `Makefile` and include the following line in it.

```
obj-y := bhanujgetppid.o
```

5. Add function call definition in `./include/syscall.h` header file.

```
asmlinkage long sys_bhanujgetppid(void);
```

6. Add the system call entry in `syscalls_32.tbl`

7. Add folder name to `Makefile` of kernel

```
core-y += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ hello/
```

```
bhanujprint/ bhanujprocess/ bhanujgetppid/
```



Final `syscalls_32.tbl` file will look like:

Last 4 entries have my implemented system calls for question 1, question 2, question 3, question 4, respectively

syscall_32.tbl				
/usr/src/linux-4.19.210/arch/x86/entry/syscalls				
354 340	1386	prlimit64	sys_prlimit64	__ia32_sys_prlimit64
355 341	1386	name_to_handle_at	sys_name_to_handle_at	__ia32_sys_name_to_handle_at
356 342	1386	open_by_handle_at	sys_open_by_handle_at	__ia32_compat_sys_open_by_handle_at
357 343	1386	clock_adjtime	sys_clock_adjtime	__ia32_compat_sys_clock_adjtime
358 344	1386	syncfs	sys_syncfs	__ia32_sys_syncfs
359 345	1386	sendmmsg	sys_sendmmsg	__ia32_compat_sys_sendmmsg
360 346	1386	setns	sys_setns	__ia32_sys_setns
361 347	1386	process_vm_readv	sys_process_vm_readv	__ia32_compat_sys_process_vm_readv
362 348	1386	process_vm_writev	sys_process_vm_writev	__ia32_compat_sys_process_vm_writev
363 349	1386	kcmp	sys_kcmp	__ia32_sys_kcmp
364 350	1386	finit_module	sys_finit_module	__ia32_sys_finit_module
365 351	1386	sched_setattr	sys_sched_setattr	__ia32_sys_sched_setattr
366 352	1386	sched_getattr	sys_sched_getattr	__ia32_sys_sched_getattr
367 353	1386	renameat2	sys_renameat2	__ia32_sys_renameat2
368 354	1386	seccomp	sys_seccomp	__ia32_sys_seccomp
369 355	1386	getrandom	sys_getrandom	__ia32_sys_getrandom
370 356	1386	memfd_create	sys_memfd_create	__ia32_sys_memfd_create
371 357	1386	bpf	sys_bpf	__ia32_sys_bpf
372 358	1386	execveat	sys_execveat	__ia32_compat_sys_execveat
373 359	1386	socket	sys_socket	__ia32_sys_socket
374 360	1386	socketpair	sys_socketpair	__ia32_sys_socketpair
375 361	1386	bind	sys_bind	__ia32_sys_bind
376 362	1386	connect	sys_connect	__ia32_sys_connect
377 363	1386	listen	sys_listen	__ia32_sys_listen
378 364	1386	accept4	sys_accept4	__ia32_sys_accept4
379 365	1386	getsockopt	sys_getsockopt	__ia32_compat_sys_getsockopt
380 366	1386	setsockopt	sys_setsockopt	__ia32_compat_sys_setsockopt
381 367	1386	getsockname	sys_getsockname	__ia32_sys_getsockname
382 368	1386	getpeername	sys_getpeername	__ia32_sys_getpeername
383 369	1386	sendto	sys_sendto	__ia32_sys_sendto
384 370	1386	sendmsg	sys_sendmsg	__ia32_compat_sys_sendmsg
385 371	1386	recvfrom	sys_recvfrom	__ia32_compat_sys_recvfrom
386 372	1386	recvmsg	sys_recvmsg	__ia32_compat_sys_recvmsg
387 373	1386	shutdown	sys_shutdown	__ia32_sys_shutdown
388 374	1386	userfaultfd	sys_userfaultfd	__ia32_sys_userfaultfd
389 375	1386	membarrier	sys_membarrier	__ia32_sys_membarrier
390 376	1386	mlock2	sys_mlock2	__ia32_sys_mlock2
391 377	1386	copy_file_range	sys_copy_file_range	__ia32_sys_copy_file_range
392 378	1386	preadv2	sys_preadv2	__ia32_compat_sys_preadv2
393 379	1386	pwritev2	sys_pwritev2	__ia32_compat_sys_pwritev2
394 380	1386	pkey_mprotect	sys_pkey_mprotect	__ia32_sys_pkey_mprotect
395 381	1386	pkey_alloc	sys_pkey_alloc	__ia32_sys_pkey_alloc
396 382	1386	pkey_free	sys_pkey_free	__ia32_sys_pkey_free
397 383	1386	statx	sys_statx	__ia32_sys_statx
398 384	1386	arch_prctl	sys_arch_prctl	__ia32_compat_sys_arch_prctl
399 385	1386	io_pgetevents	sys_io_pgetevents	__ia32_compat_sys_io_pgetevents
400 386	1386	rseq	sys_rseq	__ia32_sys_rseq
401 387	1386	hello	sys_bhanujhello	__ia32_sys_bhanujhello
402 388	1386	bhanujprint	sys_bhanujprint	__ia32_sys_bhanujprint
403 389	1386	bhanujprocess	sys_bhanujprocess	__ia32_sys_bhanujprocess
404 390	1386	bhanujgetppid	sys_bhanujgetppid	__ia32_sys_bhanujgetppid

syscalls_32.tbl file snapshot

Final `Makefile` in root directory of kernel will look like:

```

x - * Open [icon] Makefile
/usr/src/linux-4.19.210
975 echo "int main() {}" | $(HOSTCC) -xc -o /dev/null $(HOST_LIBELF_LIBS) -,-,1,0
976 ifeq ($(has_libelf),1)
977 objtool_target := tools/objtool FORCE
978 else
979 SKIP_STACK_VALIDATION := 1
980 export SKIP_STACK_VALIDATION
981 endif
982 endif
983
984 PHONY += prepare0
985
986 ifeq ($(KBUILD_EXTMOD),)
987 core-y += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ hello/ bhanujprint/ bhanujprocess/ bhanujgetppid/
988
989 vmlinux-dirs := $(patsubst %/,,$(filter %/, $(init-y) $(init-m) \
990 $(core-y) $(core-m) $(drivers-y) $(drivers-m) \
991 $(net-y) $(net-m) $(libs-y) $(libs-m) $(virt-y)))
992
993 vmlinux-all-dirs := $(sort $(vmlinux-dirs) $(patsubst %/,,$(filter %/, \
994 $(init-) $(core-) $(drivers-) $(net-) $(libs-) $(virt-))))
995
996 init-y := $(patsubst %/,,%/built-in.a, $(init-y))
997 core-y := $(patsubst %/,,%/built-in.a, $(core-y))
998 drivers-y := $(patsubst %/,,%/built-in.a, $(drivers-y))
999 net-y := $(patsubst %/,,%/built-in.a, $(net-y))
1000 libs-y1 := $(patsubst %/,,%/lib.a, $(libs-y))
1001 libs-y2 := $(patsubst %/,,%/built-in.a, $(filter-out %.a, $(libs-v)))

```

Makefile snapshot

3. Compile the Kernel

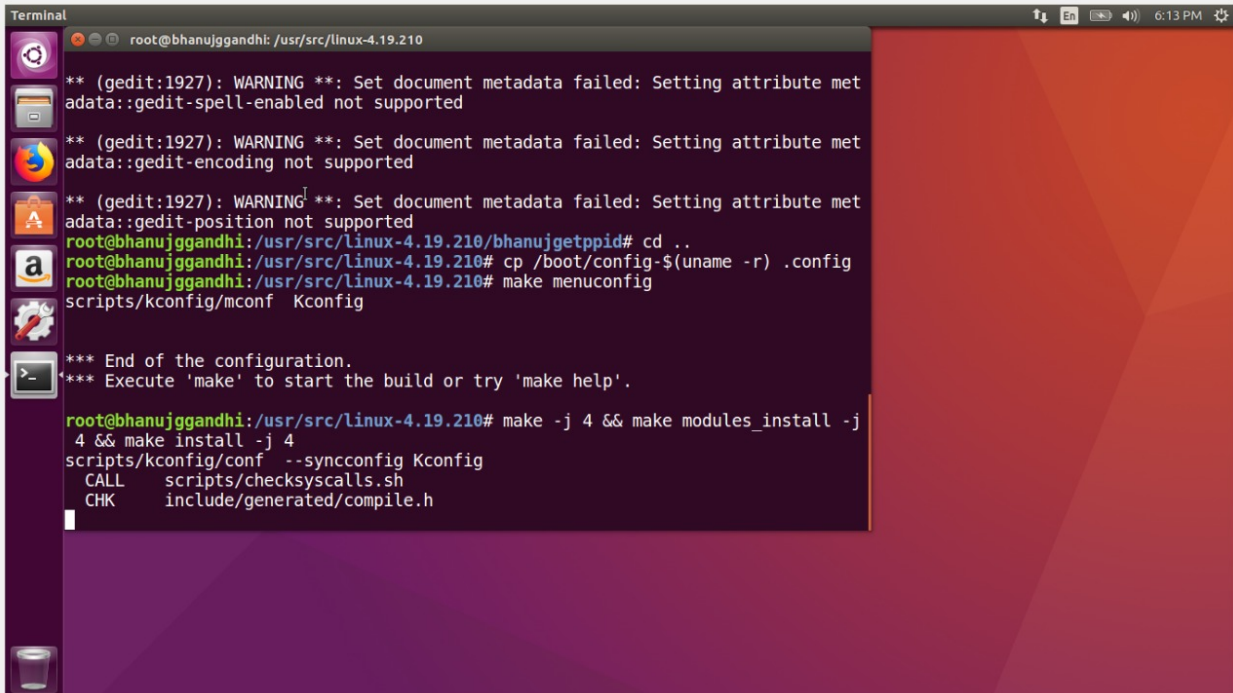
```
# Makefile for menuconfig
$ sudo make menuconfig

# Compiling kernel and kernel modules
$ sudo make -j 4 && sudo make modules_install -j 4

# Installing kernel
$ sudo make install -j 4

# Where -j n defines the number of cores to be give to the process
# that will run this command

# This is to update the kernel entries in the grub
$ sudo update-grub
$ sudo shutdown now -r
```

A terminal window titled 'Terminal' with the prompt 'root@bhanujggandhi: /usr/src/linux-4.19.210'. The terminal shows several warning messages from gedit, followed by the user running 'make menuconfig'. The output of 'make menuconfig' is displayed, showing the end of the configuration and instructions to execute 'make'. The user then runs 'make -j 4 && make modules_install -j 4', and the terminal shows the start of the compilation process, including the command 'scripts/kconfig/conf --syncconfig Kconfig' and the file 'include/generated/compile.h'.

```
Terminal
root@bhanujggandhi: /usr/src/linux-4.19.210

** (gedit:1927): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported

** (gedit:1927): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported

** (gedit:1927): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-position not supported
root@bhanujggandhi: /usr/src/linux-4.19.210/bhanujgetppid# cd ..
root@bhanujggandhi: /usr/src/linux-4.19.210# cp /boot/config-$(uname -r) .config
root@bhanujggandhi: /usr/src/linux-4.19.210# make menuconfig
scripts/kconfig/mconf Kconfig

*** End of the configuration.
*** Execute 'make' to start the build or try 'make help'.

root@bhanujggandhi: /usr/src/linux-4.19.210# make -j 4 && make modules_install -j
4 && make install -j 4
scripts/kconfig/conf --syncconfig Kconfig
CALL scripts/checksyscalls.sh
CHK include/generated/compile.h
```

Execution snapshot of *menuconfig* and *make* command

```
root@bhanujgandhi: /usr/src/linux-4.19.210
File Edit View Search Terminal Tabs Help

root@bhanujgandhi: ~
INSTALL sound/usb/line6/snd-usb-pod.ko
INSTALL sound/usb/line6/snd-usb-podhd.ko
INSTALL sound/usb/line6/snd-usb-toneport.ko
INSTALL sound/usb/line6/snd-usb-variax.ko
INSTALL sound/usb/misc/snd-ua101.ko
INSTALL sound/usb/snd-usb-audio.ko
INSTALL sound/usb/snd-usbmidi-lib.ko
INSTALL sound/usb/usx2y/snd-usb-us122l.ko
INSTALL sound/usb/usx2y/snd-usb-usx2y.ko
INSTALL sound/x86/snd-hdmi-lpe-audio.ko
INSTALL virt/lib/irqbypass.ko
DEPMOD 4.19.210
sh ./arch/x86/boot/install.sh 4.19.210 arch/x86/boot/bzImage \
System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.19.210 /boot/vmlinuz-4.19.210
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.19.210 /boot/vmlinuz-4.19.210
update-initramfs: Generating /boot/initrd.img-4.19.210
run-parts: executing /etc/kernel/postinst.d/pm-utils 4.19.210 /boot/vmlinuz-4.19.210
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 4.19.210 /boot/vmlinuz-4.19.210
run-parts: executing /etc/kernel/postinst.d/update-notifier 4.19.210 /boot/vmlinuz-4.19.210
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 4.19.210 /boot/vmlinuz-4.19.210
Generating grub configuration file ...
Warning: Setting GRUB_TIMEOUT to a non-zero value when GRUB_HIDDEN_TIMEOUT is set is no longer supported.
Found linux image: /boot/vmlinuz-4.19.210
Found initrd image: /boot/initrd.img-4.19.210
Found linux image: /boot/vmlinuz-4.15.0-45-generic
Found initrd image: /boot/initrd.img-4.15.0-45-generic
Found memtest86+ image: /boot/memtest86+.elf
Found memtest86+ image: /boot/memtest86+.bin
done
root@bhanujgandhi: /usr/src/linux-4.19.210#
```

Completion of make install command

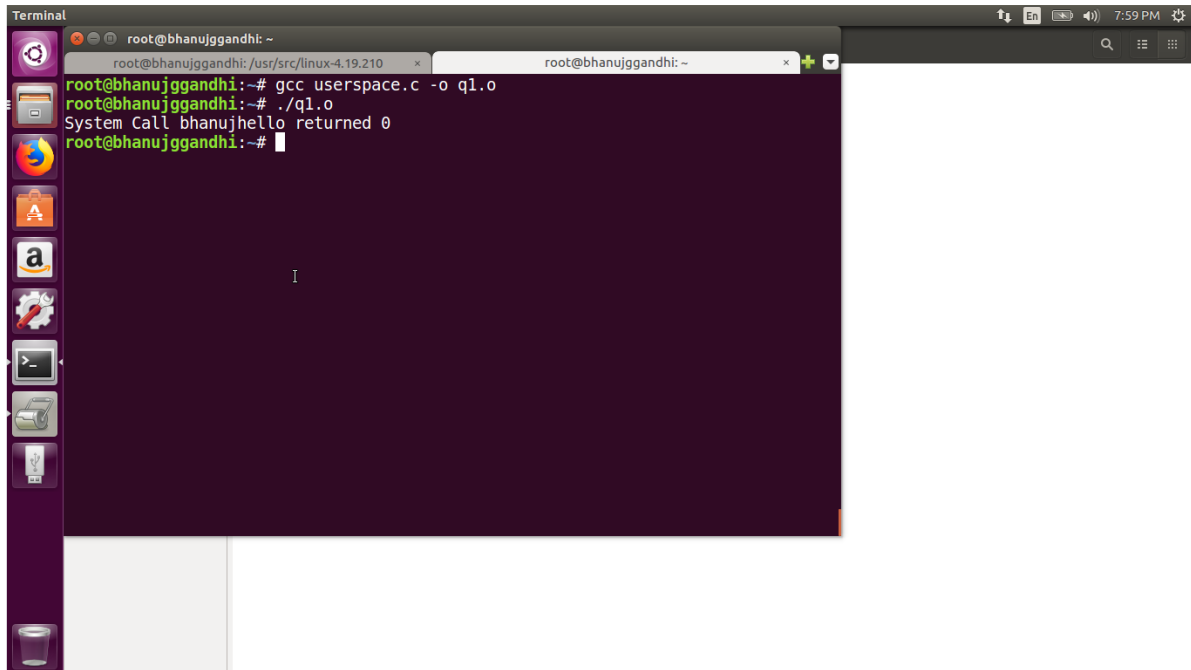
4. Test the system calls

a. Question 1:

```
Terminal
bhanujgandhi@bhanujgandhi: ~
[ 18.880860] audit: type=1400 audit(1663207379.764:11): apparmor="STATUS" operation="profile load" profile="unconfined" name="/usr/lib/lightdm/lightdm-guest-session" pid=587 comm="apparmor_parser"
[ 19.158301] Adding 998396k swap on /dev/sda5. Priority:-2 extents:1 across:998396k FS
[ 26.270967] IPv6: ADDRCONF(NETDEV_UP): enp0s3: link is not ready
[ 26.273164] IPv6: ADDRCONF(NETDEV_UP): enp0s3: link is not ready
[ 26.279328] e1000: enp0s3 NIC Link is Up 1000 Mbps Full Duplex, Flow Control: RX
[ 26.279675] IPv6: ADDRCONF(NETDEV_CHANGE): enp0s3: link becomes ready
[ 282.051575] Hello Bhanuj
bhanujgandhi@bhanujgandhi:~$ cat userspace.c
#include <stdio.h>
#include <linux/kernel.h>
#include <sys/syscall.h>
#include <unistd.h>

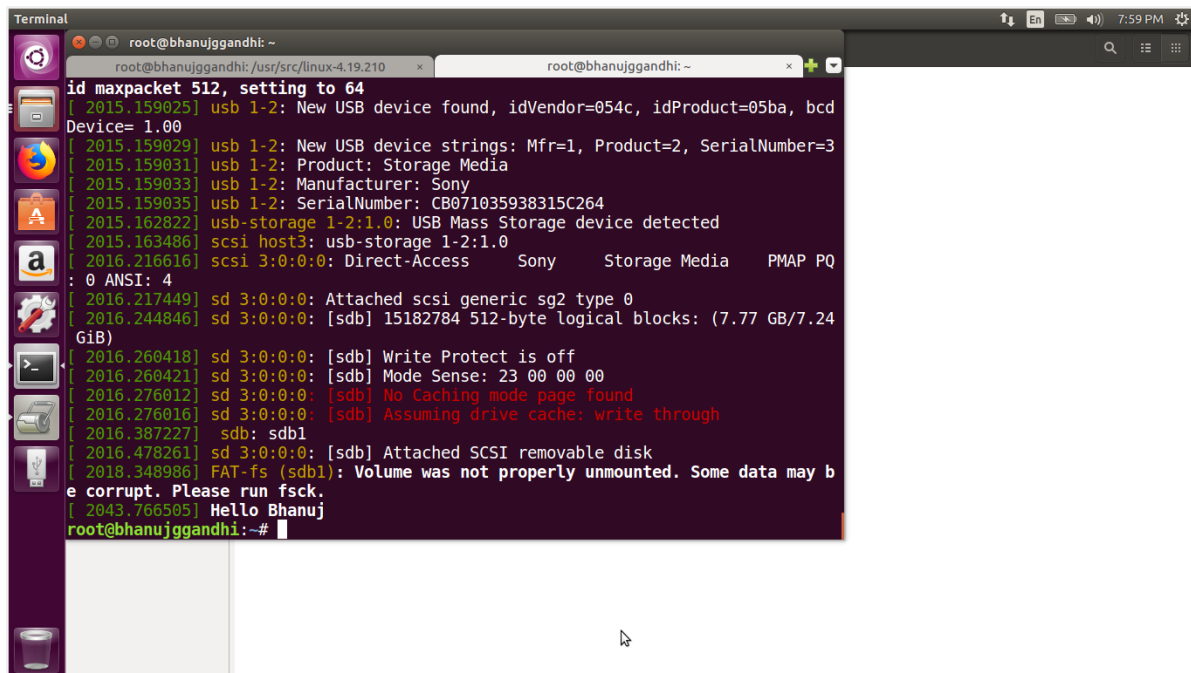
int main()
{
    long int message = syscall(387);
    printf("System Call bhanujhello returned %ld\n", message);
    return 0;
}
bhanujgandhi@bhanujgandhi:~$
```

Driver Code to Test question 1 sys_bhanujhello system call



```
root@bhanujgandhi: ~  
root@bhanujgandhi: /usr/src/linux-4.19.210  
root@bhanujgandhi:~# gcc userspace.c -o q1.o  
root@bhanujgandhi:~# ./q1.o  
System Call bhanujhello returned 0  
root@bhanujgandhi:~#
```

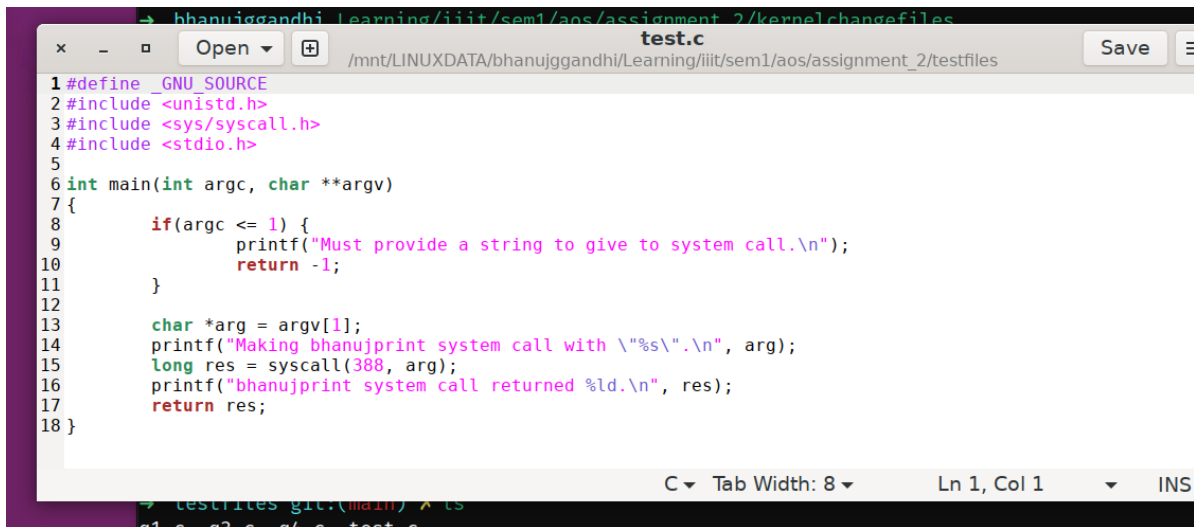
Upon running the out file after compiling



```
root@bhanujgandhi: ~  
root@bhanujgandhi: /usr/src/linux-4.19.210  
root@bhanujgandhi:~# id maxpacket 512, setting to 64  
[ 2015.159025] usb 1-2: New USB device found, idVendor=054c, idProduct=05ba, bcd  
Device= 1.00  
[ 2015.159029] usb 1-2: New USB device strings: Mfr=1, Product=2, SerialNumber=3  
[ 2015.159031] usb 1-2: Product: Storage Media  
[ 2015.159033] usb 1-2: Manufacturer: Sony  
[ 2015.159035] usb 1-2: SerialNumber: CB071035938315C264  
[ 2015.162822] usb-storage 1-2:1.0: USB Mass Storage device detected  
[ 2015.163486] scsi host3: usb-storage 1-2:1.0  
[ 2016.216616] scsi 3:0:0:0: Direct-Access Sony Storage Media PMAP PQ  
: 0 ANSI: 4  
[ 2016.217449] sd 3:0:0:0: Attached scsi generic sg2 type 0  
[ 2016.244846] sd 3:0:0:0: [sdb] 15182784 512-byte logical blocks: (7.77 GB/7.24  
GiB)  
[ 2016.260418] sd 3:0:0:0: [sdb] Write Protect is off  
[ 2016.260421] sd 3:0:0:0: [sdb] Mode Sense: 23 00 00 00  
[ 2016.276012] sd 3:0:0:0: [sdb] No Caching mode page found  
[ 2016.276016] sd 3:0:0:0: [sdb] Assuming drive cache: write through  
[ 2016.387227] sdb: sdb1  
[ 2016.478261] sd 3:0:0:0: [sdb] Attached SCSI removable disk  
[ 2018.348986] FAT-fs (sdb1): Volume was not properly unmounted. Some data may b  
e corrupt. Please run fsck.  
[ 2043.766505] Hello Bhanuj  
root@bhanujgandhi:~#
```

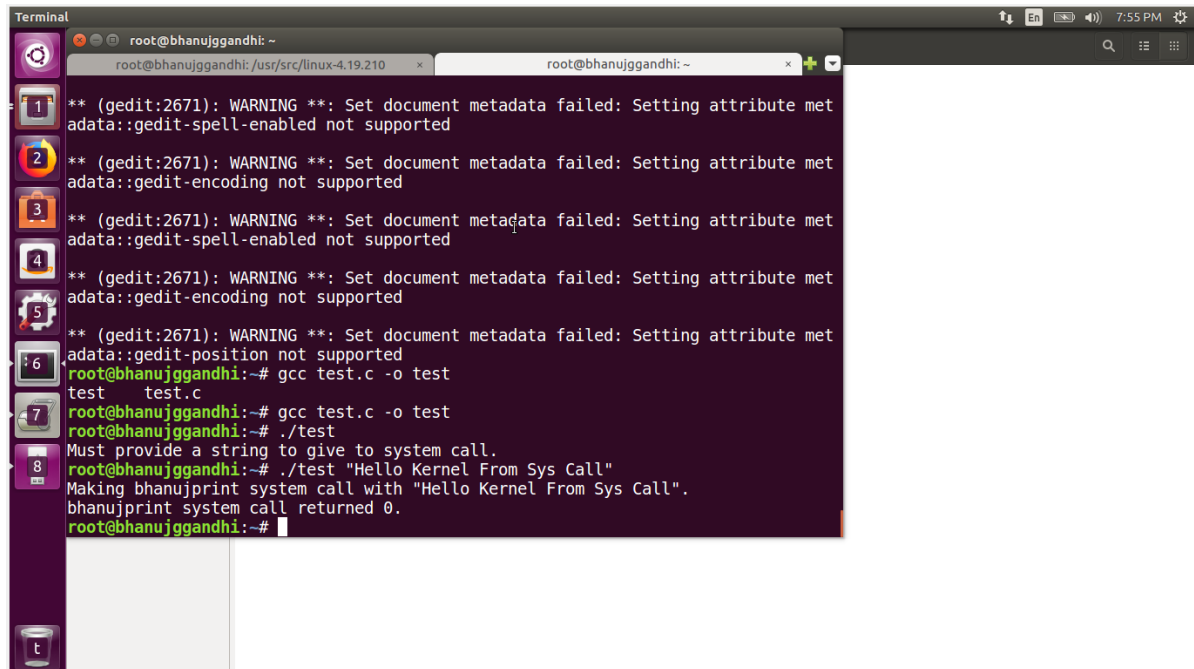
Output in dmesg by sys_bhanujhello system call

b. Question 2:



```
1 #define _GNU_SOURCE
2 #include <unistd.h>
3 #include <sys/syscall.h>
4 #include <stdio.h>
5
6 int main(int argc, char **argv)
7 {
8     if(argc <= 1) {
9         printf("Must provide a string to give to system call.\n");
10        return -1;
11    }
12
13    char *arg = argv[1];
14    printf("Making bhanujprint system call with \"%s\".\n", arg);
15    long res = syscall(388, arg);
16    printf("bhanujprint system call returned %ld.\n", res);
17    return res;
18 }
```

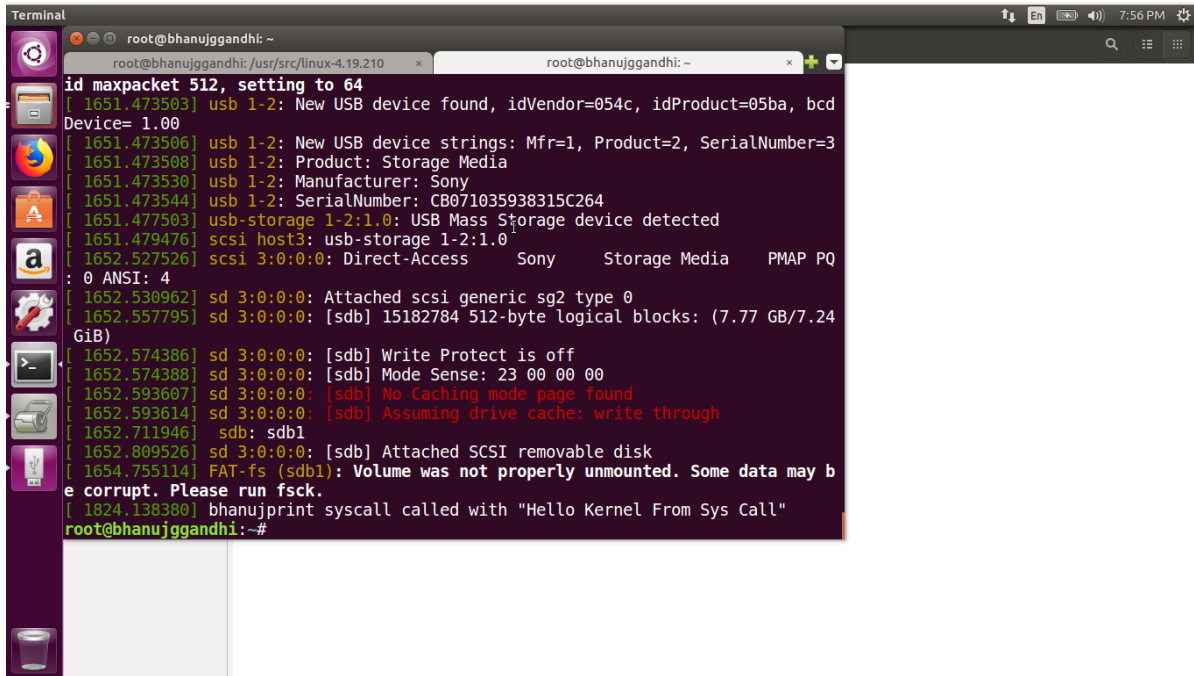
Driver code for bhanujprint system call



```
root@bhanujgandhi: ~
root@bhanujgandhi: /usr/src/linux-4.19.210
root@bhanujgandhi: ~

1 ** (gedit:2671): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported
2 ** (gedit:2671): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported
3 ** (gedit:2671): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported
4 ** (gedit:2671): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported
5 ** (gedit:2671): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported
6 ** (gedit:2671): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-position not supported
7 root@bhanujgandhi:~# gcc test.c -o test
test test.c
8 root@bhanujgandhi:~# gcc test.c -o test
root@bhanujgandhi:~# ./test
Must provide a string to give to system call.
root@bhanujgandhi:~# ./test "Hello Kernel From Sys Call"
Making bhanujprint system call with "Hello Kernel From Sys Call".
bhanujprint system call returned 0.
root@bhanujgandhi:~#
```

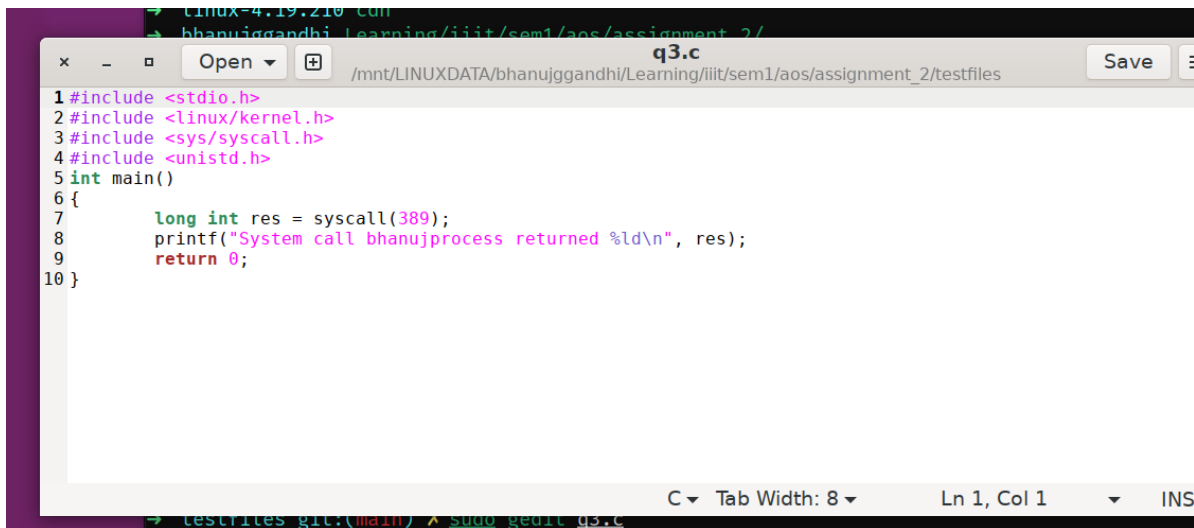
Upon compiling and running out file



```
Terminal
root@bhanujgandhi: ~
root@bhanujgandhi: /usr/src/linux-4.19.210
root@bhanujgandhi: ~
id maxpacket 512, setting to 64
[ 1651.473503] usb 1-2: New USB device found, idVendor=054c, idProduct=05ba, bcd
Device= 1.00
[ 1651.473506] usb 1-2: New USB device strings: Mfr=1, Product=2, SerialNumber=3
[ 1651.473508] usb 1-2: Product: Storage Media
[ 1651.473530] usb 1-2: Manufacturer: Sony
[ 1651.473544] usb 1-2: SerialNumber: CB071035938315C264
[ 1651.477503] usb-storage 1-2:1.0: USB Mass Storage device detected
[ 1651.479476] scsi host3: usb-storage 1-2:1.0
[ 1652.527526] scsi 3:0:0:0: Direct-Access    Sony      Storage Media    PMAP PQ
: 0 ANSI: 4
[ 1652.530962] sd 3:0:0:0: Attached scsi generic sg2 type 0
[ 1652.557795] sd 3:0:0:0: [sdb] 15182784 512-byte logical blocks: (7.77 GB/7.24
GiB)
[ 1652.574386] sd 3:0:0:0: [sdb] Write Protect is off
[ 1652.574388] sd 3:0:0:0: [sdb] Mode Sense: 23 00 00 00
[ 1652.593607] sd 3:0:0:0: [sdb] No Caching mode page found
[ 1652.593614] sd 3:0:0:0: [sdb] Assuming drive cache: write through
[ 1652.711946] sdb: sdb1
[ 1652.809526] sd 3:0:0:0: [sdb] Attached SCSI removable disk
[ 1654.755114] FAT-fs (sdb1): Volume was not properly unmounted. Some data may b
e corrupt. Please run fsck.
[ 1824.138380] bhanujprint syscall called with "Hello Kernel From Sys Call"
root@bhanujgandhi:~#
```

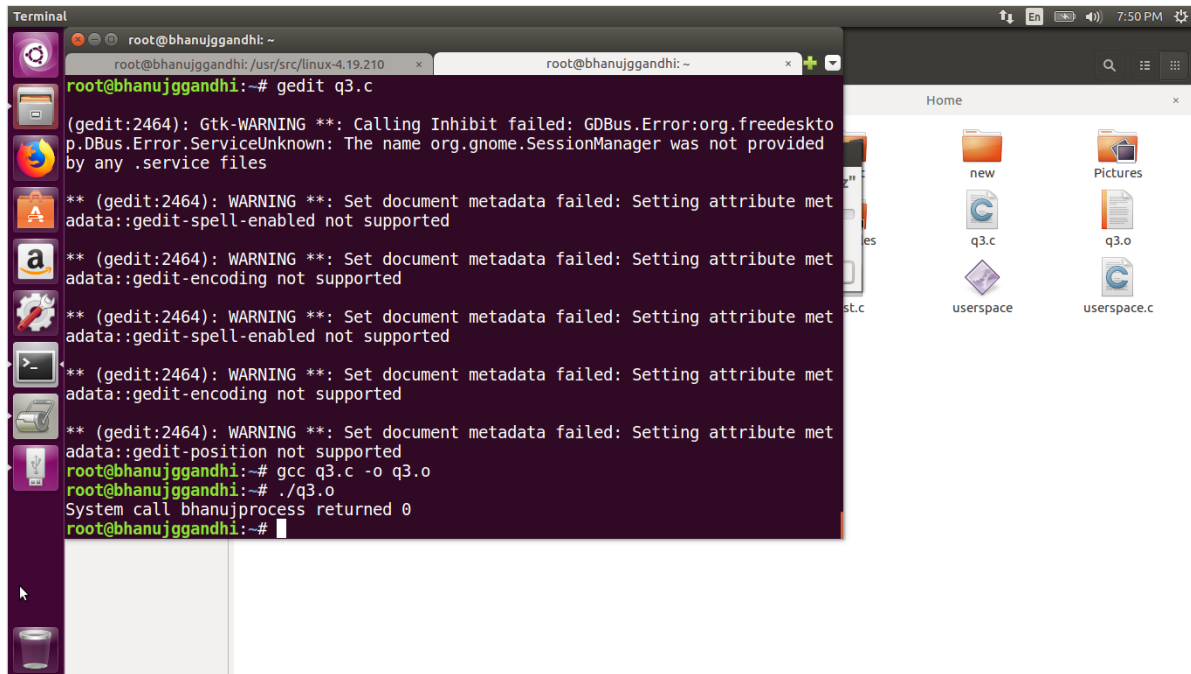
Output in dmesg by sys_bhanujprint system call

c. Question 3:



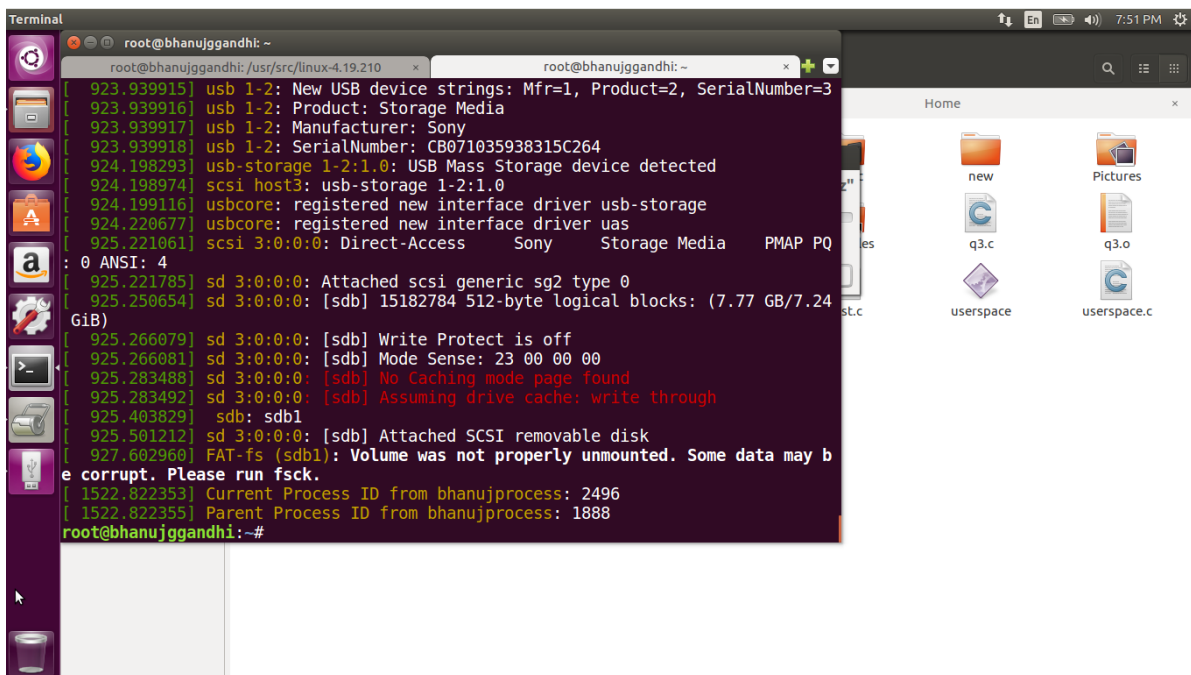
```
q3.c
/mnt/LINUXDATA/bhanujgandhi/Leaning/iit/sem1/aos/assignment_2/testfiles
1 #include <stdio.h>
2 #include <linux/kernel.h>
3 #include <sys/syscall.h>
4 #include <unistd.h>
5 int main()
6 {
7     long int res = syscall(389);
8     printf("System call bhanujprocess returned %ld\n", res);
9     return 0;
10 }
```

Driver code for sys_bhanujprocess system call



```
root@bhanujggandhi: ~  
root@bhanujggandhi: /usr/src/linux-4.19.210  
root@bhanujggandhi:~# gedit q3.c  
(gedit:2464): Gtk-WARNING **: Calling Inhibit failed: GDBus.Error:org.freedesktop.DBus.Error.ServiceUnknown: The name org.gnome.SessionManager was not provided by any .service files  
** (gedit:2464): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-spell-enabled not supported  
** (gedit:2464): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-encoding not supported  
** (gedit:2464): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-spell-enabled not supported  
** (gedit:2464): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-encoding not supported  
** (gedit:2464): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-position not supported  
root@bhanujggandhi:~# gcc q3.c -o q3.o  
root@bhanujggandhi:~# ./q3.o  
System call bhanujprocess returned 0  
root@bhanujggandhi:~#
```

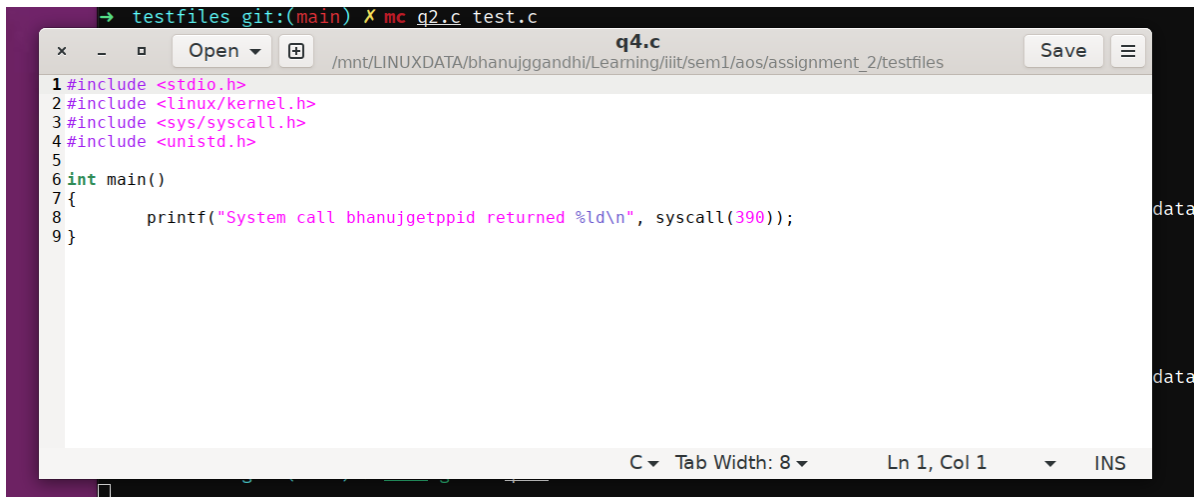
Upon compiling and running out file for question 3 system call



```
root@bhanujggandhi: ~  
root@bhanujggandhi: /usr/src/linux-4.19.210  
root@bhanujggandhi:~# dmesg  
[ 923.939915] usb 1-2: New USB device strings: Mfr=1, Product=2, SerialNumber=3  
[ 923.939916] usb 1-2: Product: Storage Media  
[ 923.939917] usb 1-2: Manufacturer: Sony  
[ 923.939918] usb 1-2: SerialNumber: CB071035938315C264  
[ 924.198293] usb-storage 1-2:1.0: USB Mass Storage device detected  
[ 924.198974] scsi host3: usb-storage 1-2:1.0  
[ 924.199116] usbcore: registered new interface driver usb-storage  
[ 924.220677] usbcore: registered new interface driver uas  
[ 925.221061] scsi 3:0:0:0: Direct-Access Sony Storage Media PMAP PQ  
: 0 ANSI: 4  
[ 925.221785] sd 3:0:0:0: Attached scsi generic sg2 type 0  
[ 925.250654] sd 3:0:0:0: [sdb] 15182784 512-byte logical blocks: (7.77 GB/7.24 GiB)  
[ 925.266079] sd 3:0:0:0: [sdb] Write Protect is off  
[ 925.266081] sd 3:0:0:0: [sdb] Mode Sense: 23 00 00 00  
[ 925.283488] sd 3:0:0:0: [sdb] No Caching mode page found  
[ 925.283492] sd 3:0:0:0: [sdb] Assuming drive cache: write through  
[ 925.403829] sdb: sdb1  
[ 925.501212] sd 3:0:0:0: [sdb] Attached SCSI removable disk  
[ 927.602960] FAT-fs (sdb1): Volume was not properly unmounted. Some data may be corrupt. Please run fsck.  
[ 1522.822353] Current Process ID from bhanujprocess: 2496  
[ 1522.822355] Parent Process ID from bhanujprocess: 1888  
root@bhanujggandhi:~#
```

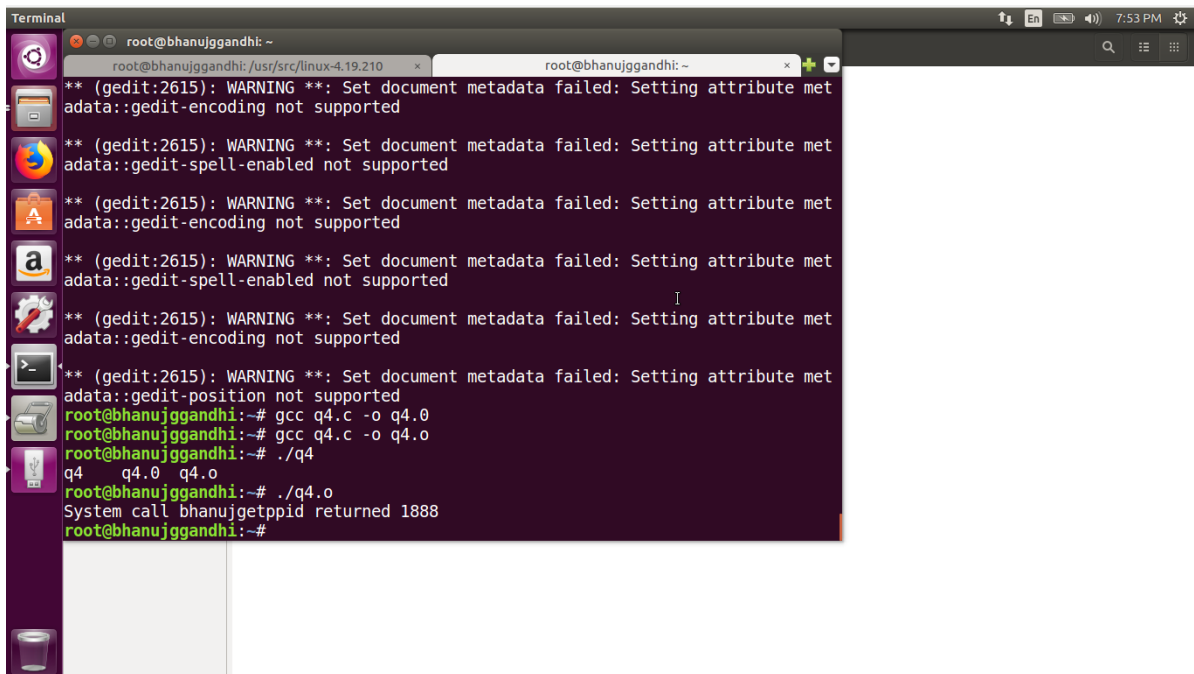
Output in dmesg by sys_bhanujprocess system call

d. Question 4:



```
testfiles git:(main) X mc q2.c test.c
q4.c
1 #include <stdio.h>
2 #include <linux/kernel.h>
3 #include <sys/syscall.h>
4 #include <unistd.h>
5
6 int main()
7 {
8     printf("System call bhanujgetppid returned %ld\n", syscall(390));
9 }
```

Driver code for sys_bhanujgetppid system call



```
Terminal
root@bhanujgandhi: ~
root@bhanujgandhi: /usr/src/linux-4.19.210
** (gedit:2615): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported
** (gedit:2615): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported
** (gedit:2615): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported
** (gedit:2615): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported
** (gedit:2615): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported
** (gedit:2615): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-position not supported
root@bhanujgandhi:~# gcc q4.c -o q4.0
root@bhanujgandhi:~# gcc q4.c -o q4.0
root@bhanujgandhi:~# ./q4
q4 q4.0 q4.0
root@bhanujgandhi:~# ./q4.0
System call bhanujgetppid returned 1888
root@bhanujgandhi:~#
```

Upon compiling and running the out file, the process outputs the pid of parent of the ./q4.o process.