INTRODUCTION

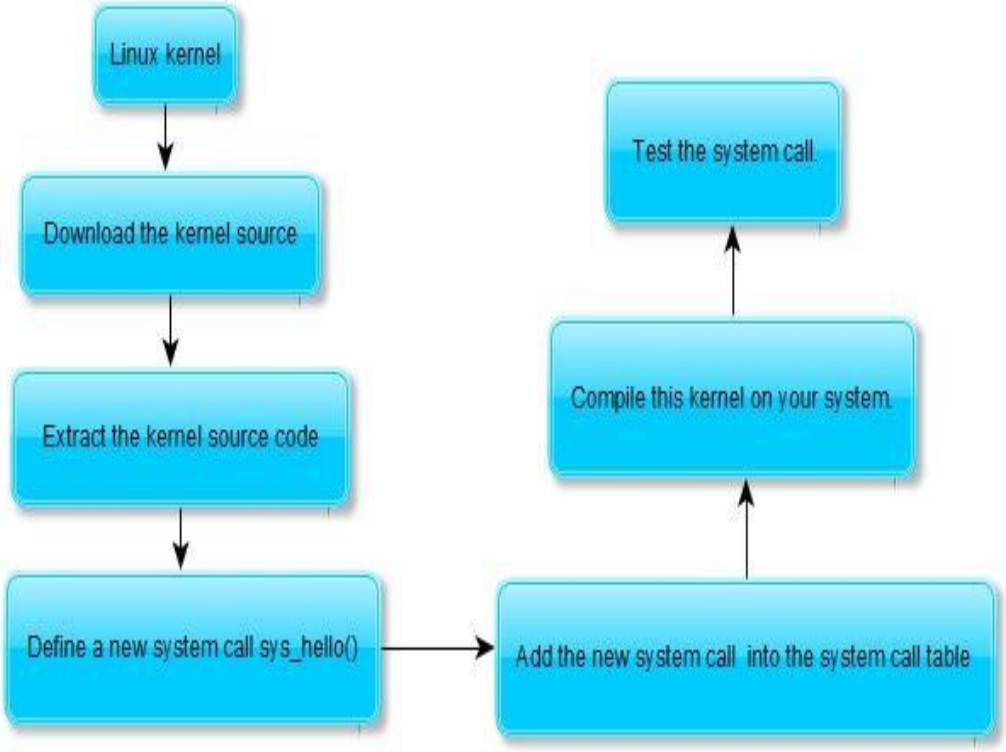
The Linux kernel is written in the version of the C programming language supported by GCC (which has introduced a number of extensions and changes to standard C), together with a number of short sections of code written in the assembly language of the target architecture. Because of the extensions to C it supports, GCC was for a long time the only compiler capable of correctly building the Linux kernel.

A system call is implemented in the Linux kernel. When a program makes a system call, the arguments are packaged up and handed to the kernel, which takes over execution of the program until the call completes. A system call isn't an ordinary function call, and a special procedure is required to transfer control to the kernel. However, the GNU C library (the implementation of the standard C library provided with GNU/Linux systems) wraps Linux system calls with functions so that you can call them easily. Low-level I/O functions such as open and read are examples of system calls on Linux.

PROJECT PLAN

We can customize the linux kernel by adding new system calls to make it more user friendly. We have chosen to implement the Hello world system call to the linux kernel.

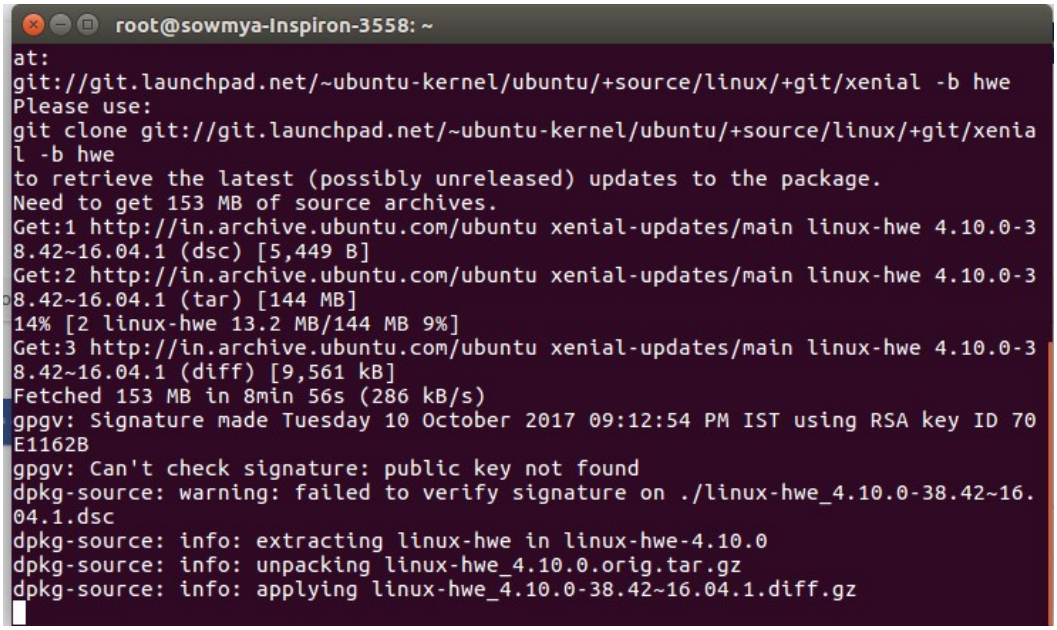
Design and architecture



WORKING METHODOLOGY

The steps followed for adding the system calls are as follows:

1. uname –r : know your linux version by the command
   Our version is linux-4.10.0
2. sudo –s : directs the control to the root.
3. apt-get source linux-image-4.10.0-36-generic: Download the source code of your kernel version using this command.



```
root@sowmya-Inspiron-3558: ~
at:
git://git.launchpad.net/~ubuntu-kernel/ubuntu/+source/linux/+git/xenial -b hwe
Please use:
git clone git://git.launchpad.net/~ubuntu-kernel/ubuntu/+source/linux/+git/xenia
l -b hwe
to retrieve the latest (possibly unreleased) updates to the package.
Need to get 153 MB of source archives.
Get:1 http://in.archive.ubuntu.com/ubuntu xenial-updates/main linux-hwe 4.10.0-3
8.42~16.04.1 (dsc) [5,449 B]
Get:2 http://in.archive.ubuntu.com/ubuntu xenial-updates/main linux-hwe 4.10.0-3
8.42~16.04.1 (tar) [144 MB]
14% [2 linux-hwe 13.2 MB/144 MB 9%]
Get:3 http://in.archive.ubuntu.com/ubuntu xenial-updates/main linux-hwe 4.10.0-3
8.42~16.04.1 (diff) [9,561 kB]
Fetched 153 MB in 8min 56s (286 kB/s)
gpgv: Signature made Tuesday 10 October 2017 09:12:54 PM IST using RSA key ID 70
E1162B
gpgv: Can't check signature: public key not found
dpkg-source: warning: failed to verify signature on ./linux-hwe_4.10.0-38.42~16.
04.1.dsc
dpkg-source: info: extracting linux-hwe in linux-hwe-4.10.0
dpkg-source: info: unpacking linux-hwe_4.10.0.orig.tar.gz
dpkg-source: info: applying linux-hwe_4.10.0-38.42~16.04.1.diff.gz
```

```
root@sowmya-Inspiron-3558: ~
linux-4.10/virt/kvm/arm/vgic/vgic-its.c
linux-4.10/virt/kvm/arm/vgic/vgic-kvm-device.c
linux-4.10/virt/kvm/arm/vgic/vgic-mmio-v2.c
linux-4.10/virt/kvm/arm/vgic/vgic-mmio-v3.c
linux-4.10/virt/kvm/arm/vgic/vgic-mmio.c
linux-4.10/virt/kvm/arm/vgic/vgic-mmio.h
linux-4.10/virt/kvm/arm/vgic/vgic-v2.c
linux-4.10/virt/kvm/arm/vgic/vgic-v3.c
linux-4.10/virt/kvm/arm/vgic/vgic.c
linux-4.10/virt/kvm/arm/vgic/vgic.h
linux-4.10/virt/kvm/async_pf.c
linux-4.10/virt/kvm/async_pf.h
linux-4.10/virt/kvm/coalesced_mmio.c
linux-4.10/virt/kvm/coalesced_mmio.h
linux-4.10/virt/kvm/eventfd.c
linux-4.10/virt/kvm/irqchip.c
linux-4.10/virt/kvm/kvm_main.c
linux-4.10/virt/kvm/vfio.c
linux-4.10/virt/kvm/vfio.h
linux-4.10/virt/lib/
linux-4.10/virt/lib/Kconfig
linux-4.10/virt/lib/Makefile
linux-4.10/virt/lib/irqbypass.c
root@sowmya-Inspiron-3558:~#
```

```
root@sowmya-Inspiron-3558: ~
linux-4.10/virt/lib/
linux-4.10/virt/lib/Kconfig
linux-4.10/virt/lib/Makefile
linux-4.10/virt/lib/irqbypass.c
root@sowmya-Inspiron-3558:~# ls
bankerr.c  examples.desktop                          optimal.c  rewr.c
b.c        f.c                                       os.c       rr.c
be.c       fcfs.c                                    output     rw1.c
cc1.cpp    ff.c                                      p.c        scan.c
chain.c    fifo.c                                    Pictures   sjf.c
cpog3.sh   fir.c                                     pr1.c      spro3.sh
cprog3.sh  j.c                                       pr.c       sprog2.sh
cprog4.sh  links                                     prep.c     sprog3.sh
cscan.cpp  linux-hwe-4.10.0                          pri.c      srtf.c
d          linux-hwe_4.10.0-38.42~16.04.1.diff.gz    pro.c      sstf.c
d.c        linux-hwe_4.10.0-38.42~16.04.1.dsc        procon.c   Templates
Desktop    linux-hwe_4.10.0.orig.tar.gz              proo.c     Videos
dini.c     lo.c                                      Public     w.c
dinin.c    lo.cpp                                    q.c        ww.c
dip.c      look.c                                    r.c        z.c
Documents  lru.c                                     read.c
Downloads  Music                                     readwr.c
e.c        mypipe                                    re.c
root@sowmya-Inspiron-3558:~#
```

4. ls: using this command we can see all the existing files in the current directory.(Note that linux-hwe_4.10.10.orig.tar.gz is the newly installed file)

```
root@sowmya-Inspiron-3558: /usr/src
bankerr.c  examples.desktop                                  optimal.c  rewr.c
b.c        f.c                                               os.c       rr.c
be.c       fcfs.c                                            output     rw1.c
cc1.cpp    ff.c                                              p.c        scan.c
chain.c    fifo.c                                            Pictures   sjf.c
cpog3.sh   fir.c                                             pr1.c      spro3.sh
cprog3.sh  j.c                                               pr.c       sprog2.sh
cprog4.sh  links                                             prep.c     sprog3.sh
cscan.cpp  linux-hwe-4.10.0                                  pri.c      srtf.c
d          linux-hwe_4.10.0-38.42~16.04.1.diff.gz            pro.c      sstf.c
d.c        linux-hwe_4.10.0-38.42~16.04.1.dsc                procon.c   Templates
Desktop    linux-hwe_4.10.0.orig.tar.gz                      proo.c     Videos
dini.c     lo.c                                              Public     w.c
dinin.c    lo.cpp                                            q.c        ww.c
dip.c      look.c                                            r.c        z.c
Documents  lru.c                                             read.c
Downloads  Music                                             readwr.c
e.c        mypipe                                            re.c
root@sowmya-Inspiron-3558:~# cd/usr/src
bash: cd/usr/src: No such file or directory
root@sowmya-Inspiron-3558:~# cd /usr/src
root@sowmya-Inspiron-3558:/usr/src# ls
linux-4.10  linux-headers-4.8.0-36  linux-headers-4.8.0-36-generic
root@sowmya-Inspiron-3558:/usr/src#
```

5. Cd /usr/src: directs the user to the usr/src directory.(This is where the kernel source code is present).
6. Cd /linux-4.10:direct to the linux-4.10 directory

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13# mkdir helloworld
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13# cd helloworld
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/helloworld# gedit helloworld.c

(gedit:24377): Gtk-WARNING **: Calling Inhibit failed: GDBus.Error:org.freedesktop.DBus.Error.Servi
ceUnknown: The name org.gnome.SessionManager was not provided by any .service files

** (gedit:24377): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-spell
-enabled not supported

** (gedit:24377): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-encod
ing not supported

** (gedit:24377): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-posit
ion not supported
```

7. mkdir helloworld: creating a directory for the helloworld file
8. cd helloworld: changes the shell's working directory
9. gedit helloworld.c: it is a text editor which will open the file named 'helloworld.c' for editing.(This is where the C program for our system call is written).

Open helloworld.c /usr/src/linux-4.10.13/helloworld Save

```
#include <linux/kernel.h>

asmlinkage long sys_helloworld(void)
{
        printk("HELLO WORLD\n");
        return 0;
}
```

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/helloworld# gedit Makefile

(gedit:24476): Gtk-WARNING **: Calling Inhibit failed: GDBus.Error:org.freedesktop.DBus.Error.Servi
ceUnknown: The name org.gnome.SessionManager was not provided by any .service files

** (gedit:24476): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-spell
-enabled not supported

** (gedit:24476): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-encod
ing not supported

** (gedit:24476): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-posit
ion not supported
```

Open Makefile /usr/src/linux-4.10.13/helloworld Save

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

Gedit makefile: it is a text editor which will open the file called makefile for editing, this means that kbuild should go into the directory helloworld. Once it moves to this directory, it looks at the Makefile in it to decide what objects should be built.

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
** (gedit:3248): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported

** (gedit:3248): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported

** (gedit:3248): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-position not supported
root@sowmya-Inspiron-3558:/usr/src/linux-4.10/helloworld# cd /usr/src/linux-4.10
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# gedit Makefile

(gedit:3362): Gtk-WARNING **: Calling Inhibit failed: GDBus.Error:org.freedeskto
p.DBus.Error.ServiceUnknown: The name org.gnome.SessionManager was not provided
by any .service files

** (gedit:3362): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported

** (gedit:3362): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported

** (gedit:3362): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-position not supported
root@sowmya-Inspiron-3558:/usr/src/linux-4.10#
```

```
Open ▾        *Makefile
              /usr/src/linux-4.10.13        Save
$(CONFIG_MODULE_SIG_KEY) certs/signing_key.x509
else
mod_sign_cmd = true
endif
export mod_sign_cmd


ifeq ($(KBUILD_EXTMOD),)
core-y          += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ helloworld/

vmlinux-dirs    := $(patsubst %/,%,$(filter %/, $(init-y) $(init-m) \
                     $(core-y) $(core-m) $(drivers-y) $(drivers-m) \
                     $(net-y) $(net-m) $(libs-y) $(libs-m) $(virt-y)))

vmlinux-alldirs := $(sort $(vmlinux-dirs) $(patsubst %/,%,$(filter %/, \
                     $(init-) $(core-) $(drivers-) $(net-) $(libs-) $(virt-))))

init-y          := $(patsubst %/, %/built-in.o, $(init-y))
core-y          := $(patsubst %/, %/built-in.o, $(core-y))
drivers-y       := $(patsubst %/, %/built-in.o, $(drivers-y))
net-y           := $(patsubst %/, %/built-in.o, $(net-y))
libs-y1         := $(patsubst %/, %/lib.a, $(libs-y))
libs-y2         := $(patsubst %/, %/built-in.o, $(libs-y))
libs-y          := $(libs-y1) $(libs-y2)
virt-y          := $(patsubst %/, %/built-in.o, $(virt-y))

# Externally visible symbols (used by link-vmlinux.sh)
export KBUILD_VMLINUX_INIT := $(head-y) $(init-y)
export KBUILD_VMLINUX_MAIN := $(core-y) $(libs-y) $(drivers-y) $(net-y) $(virt-y)
export KBUILD_LDS          := arch/$(SRCARCH)/kernel/vmlinux.lds
export LDFLAGS_vmlinux
# used by scripts/pacmage/Makefile
export KBUILD_ALLDIRS := $(sort $(filter-out arch/%,$(vmlinux-alldirs)) arch Documentation include
samples scripts tools)

vmlinux-deps := $(KBUILD_LDS) $(KBUILD_VMLINUX_INIT) $(KBUILD_VMLINUX_MAIN)
```

10. Cd /usr/src/linux-4.20: go back to the linux-4.10 directory

11. Gedit makefile: it is a text editor which will open the file called makefile for editing.(Here edit the file by adding the systemcall function name with "/").

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10/arch/x86/entry/syscalls
i2c-mux.h                   phy                         zlib.h
i2c-mux-pinctrl.h           phy_fixed.h                 zorro.h
i2c-ocores.h                phy.h                       zpool.h
i2c-omap.h                  phy_led_triggers.h          zsmalloc.h
i2c-pca-platform.h          pid.h                       zutil.h
root@sowmya-Inspiron-3558:/usr/src/linux-4.10/include/linux# gedit syscalls.h

(gedit:3681): Gtk-WARNING **: Calling Inhibit failed: GDBus.Error:org.freedeskto
p.DBus.Error.ServiceUnknown: The name org.gnome.SessionManager was not provided
by any .service files

** (gedit:3681): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-spell-enabled not supported

** (gedit:3681): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-encoding not supported

** (gedit:3681): WARNING **: Set document metadata failed: Setting attribute met
adata::gedit-position not supported
root@sowmya-Inspiron-3558:/usr/src/linux-4.10/include/linux# cd ../..
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# cd arch/x86/entry/syscalls
root@sowmya-Inspiron-3558:/usr/src/linux-4.10/arch/x86/entry/syscalls# ls
Makefile  syscall_32.tbl  syscall_64.tbl  syscallhdr.sh  syscalltbl.sh
root@sowmya-Inspiron-3558:/usr/src/linux-4.10/arch/x86/entry/syscalls#
```

```
Open ▾                    *syscalls.h                                Save
                          /usr/src/linux-4.10.13/include/linux
                                    const struct iovec __user *lvec,
                                    unsigned long liovcnt,
                                    const struct iovec __user *rvec,
                                    unsigned long riovcnt,
                                    unsigned long flags);
asmlinkage long sys_process_vm_writev(pid_t pid,
                                     const struct iovec __user *lvec,
                                     unsigned long liovcnt,
                                     const struct iovec __user *rvec,
                                     unsigned long riovcnt,
                                     unsigned long flags);

asmlinkage long sys_kcmp(pid_t pid1, pid_t pid2, int type,
                         unsigned long idx1, unsigned long idx2);
asmlinkage long sys_finit_module(int fd, const char __user *uargs, int flags);
asmlinkage long sys_seccomp(unsigned int op, unsigned int flags,
                            const char __user *uargs);
asmlinkage long sys_getrandom(char __user *buf, size_t count,
                              unsigned int flags);
asmlinkage long sys_bpf(int cmd, union bpf_attr *attr, unsigned int size);

asmlinkage long sys_execveat(int dfd, const char __user *filename,
                        const char __user *const __user *argv,
                        const char __user *const __user *envp, int flags);

asmlinkage long sys_membarrier(int cmd, int flags);
asmlinkage long sys_copy_file_range(int fd_in, loff_t __user *off_in,
                                    int fd_out, loff_t __user *off_out,
                                    size_t len, unsigned int flags);

asmlinkage long sys_mlock2(unsigned long start, size_t len, int flags);

asmlinkage long sys_pkey_mprotect(unsigned long start, size_t len,
                                  unsigned long prot, int pkey);
asmlinkage long sys_pkey_alloc(unsigned long flags, unsigned long init_val);
asmlinkage long sys_pkey_free(int pkey);

asmlinkage long sys_helloworld(void);
#endif
```

12. cd include/linux: we are further going to the directory include/linux

13. gedit syscalls.h: it is a text editor which opens the file called syscalls.h to edit it. It has a log of all system calls. Here we add our system call with asm linkage. Asm linkage tells your compiler to look on the CPU stack for the function parameters, instead of registers. The interesting part is **why** this is necessary. System calls are *services* that user space can call to request the kernel to perform something for them (and therefore execute in kernel space). These functions are quite unorthodox in the sense that you cannot expect them to behave like normal functions, where parameters are typically passed by writing to the program stack, but instead they are written to registers. While still in user space, calling a syscall requires writing certain values to certain registers stacks in the CPU is translated.

So, since all the information about the parameters passed all the way from user land to this point is nicely stored in the stack, the compiler must be instructed about this, hence the **asm linkage**.

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/include/linux# cd ../..
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13# cd arch/x86/entry/syscalls
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/arch/x86/entry/syscalls# ls
Makefile  syscall_32.tbl  syscall_64.tbl  syscallhdr.sh  syscalltbl.sh
```

14. edit syscall_64.tbl: it is an editor which opens the syscall_64.tbl file. It opens up the syscall table containing all system calls and we add our system call at the end index number, in this case our system call index number is 332.

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/arch/x86/entry/syscalls# gedit syscall_64.tbl

(gedit:24829): Gtk-WARNING **: Calling Inhibit failed: GDBus.Error:org.freedesktop.DBus.Error.Servi
ceUnknown: The name org.gnome.SessionManager was not provided by any .service files

** (gedit:24829): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-spell
-enabled not supported

** (gedit:24829): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-encod
ing not supported

** (gedit:24829): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-spell
-enabled not supported

** (gedit:24829): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-encod
ing not supported

** (gedit:24829): WARNING **: Set document metadata failed: Setting attribute metadata::gedit-posit
ion not supported
```

```
syscall_64.tbl
/usr/src/linux-4.10.13/arch/x86/entry/syscalls
315     common  sched_getattr           sys_sched_getattr
316     common  renameat2               sys_renameat2
317     common  seccomp                 sys_seccomp
318     common  getrandom               sys_getrandom
319     common  memfd_create            sys_memfd_create
320     common  kexec_file_load         sys_kexec_file_load
321     common  bpf                     sys_bpf
322     64      execveat                sys_execveat/ptregs
323     common  userfaultfd             sys_userfaultfd
324     common  membarrier              sys_membarrier
325     common  mlock2                  sys_mlock2
326     common  copy_file_range         sys_copy_file_range
327     64      preadv2                 sys_preadv2
328     64      pwritev2                sys_pwritev2
329     common  pkey_mprotect           sys_pkey_mprotect
330     common  pkey_alloc              sys_pkey_alloc
331     common  pkey_free               sys_pkey_free
332     64      helloworld              sys_helloworld

#
# x32-specific system call numbers start at 512 to avoid cache impact
# for native 64-bit operation.
#
512     x32     rt_sigaction            compat_sys_rt_sigaction
513     x32     rt_sigreturn            sys32_x32_rt_sigreturn
514     x32     ioctl                   compat_sys_ioctl
515     x32     readv                   compat_sys_readv
516     x32     writev                  compat_sys_writev
517     x32     recvfrom                compat_sys_recvfrom
518     x32     sendmsg                 compat_sys_sendmsg
519     x32     recvmsg                 compat_sys_recvmsg
520     x32     execve                  compat_sys_execve/ptregs
521     x32     ptrace                  compat_sys_ptrace
522     x32     rt_sigpending           compat_sys_rt_sigpending
523     x32     rt_sigtimedwait         compat_sys_rt_sigtimedwait
524     x32     rt_sigqueueinfo         compat_sys_rt_sigqueueinfo
525     x32     sigaltstack             compat_sys_sigaltstack
526     x32     timer_create            compat_sys_timer_create
527     x32     mq_notify               compat_sys_mq_notify
Plain Text   Tab Width: 8   Ln 341, Col 1   INS
```

15.cd ../..: changing directory from syscall to the initial directory

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/arch/x86/entry/syscalls# cd ../..
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13/arch/x86# cd ../..
```

```
root@sowmya-Inspiron-3558: /
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# cd ../../..
root@sowmya-Inspiron-3558:/# sudo apt-get install libncurses5-dev libncursesw5-d
ev
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libtinfo-dev
Suggested packages:
  ncurses-doc
The following NEW packages will be installed:
  libncurses5-dev libncursesw5-dev libtinfo-dev
0 upgraded, 3 newly installed, 0 to remove and 433 not upgraded.
Need to get 450 kB of archives.
After this operation, 2,642 kB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://in.archive.ubuntu.com/ubuntu xenial/main amd64 libtinfo-dev amd64 6
.0+20160213-1ubuntu1 [77.4 kB]
Get:2 http://in.archive.ubuntu.com/ubuntu xenial/main amd64 libncurses5-dev amd6
4 6.0+20160213-1ubuntu1 [175 kB]
Get:3 http://in.archive.ubuntu.com/ubuntu xenial/main amd64 libncursesw5-dev amd
64 6.0+20160213-1ubuntu1 [198 kB]
Fetched 450 kB in 2s (167 kB/s)
Selecting previously unselected package libtinfo-dev:amd64.
```

Cd ./../..:

Go back by three directories

Sudo apt-get install libncurses5-dev libncursesw5-dev:

Using this command we install the libncurses5, libncursesw5 packages.

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13# make menuconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/mconf.o
  SHIPPED scripts/kconfig/zconf.tab.c
  SHIPPED scripts/kconfig/zconf.lex.c
  SHIPPED scripts/kconfig/zconf.hash.c
  HOSTCC  scripts/kconfig/zconf.tab.o
  HOSTCC  scripts/kconfig/lxdialog/checklist.o
  HOSTCC  scripts/kconfig/lxdialog/util.o
  HOSTCC  scripts/kconfig/lxdialog/inputbox.o
  HOSTCC  scripts/kconfig/lxdialog/textbox.o
  HOSTCC  scripts/kconfig/lxdialog/yesno.o
  HOSTCC  scripts/kconfig/lxdialog/menubox.o
  HOSTLD  scripts/kconfig/mconf
scripts/kconfig/mconf  Kconfig
#
# using defaults found in /boot/config-4.4.0-31-generic
#
/boot/config-4.4.0-31-generic:958:warning: symbol value 'm' invalid for NF_CT_PROTO_DCCP
/boot/config-4.4.0-31-generic:960:warning: symbol value 'm' invalid for NF_CT_PROTO_SCTP
/boot/config-4.4.0-31-generic:961:warning: symbol value 'm' invalid for NF_CT_PROTO_UDPLITE
/boot/config-4.4.0-31-generic:979:warning: symbol value 'm' invalid for NF_NAT_PROTO_DCCP
/boot/config-4.4.0-31-generic:980:warning: symbol value 'm' invalid for NF_NAT_PROTO_UDPLITE
/boot/config-4.4.0-31-generic:981:warning: symbol value 'm' invalid for NF_NAT_PROTO_SCTP
/boot/config-4.4.0-31-generic:1631:warning: symbol value 'm' invalid for RXKAD
/boot/config-4.4.0-31-generic:3589:warning: symbol value 'm' invalid for SERIAL_8250_FINTEK
/boot/config-4.4.0-31-generic:7526:warning: symbol value 'm' invalid for EXT4_ENCRYPTION


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

16. make menuconfig: make menuconfig is one of five similar tools that can configure Linux source, a necessary early step needed to compile the source code. make menuconfig, with a menu-driven user interface, allows the user to choose the features of Linux (and other options) that will be compiled. It is normally invoked using the command `make menuconfig`, menuconfig is a target in Linux Makefile.

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
.config - Linux/x86 4.10.0 Kernel Configuration

                Linux/x86 4.10.0 Kernel Configuration
  Arrow keys navigate the menu.  <Enter> selects submenus ---> (or empty
  submenus ----).  Highlighted letters are hotkeys.  Pressing <Y>
  includes, <N> excludes, <M> modularizes features.  Press <Esc><Esc> to
  exit, <?> for Help, </> for Search.  Legend: [*] built-in  [ ]

      [*] 64-bit kernel
          General setup  --->
      [*] Enable loadable module support  --->
      [*] Enable the block layer  --->
          Processor type and features  --->
          Power management and ACPI options  --->
          Bus options (PCI etc.)  --->
          Executable file formats / Emulations  --->
      [*] Networking support  --->
          Device Drivers  --->
        ↓(+)

        <Select>    < Exit >    < Help >    < Save >    < Load >
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
.config - Linux/x86 4.10.0 Kernel Configuration

  Enter a filename to which this configuration
  should be saved as an alternate.  Leave blank to
  abort.

  .config

                < Ok >        < Help >
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
.config - Linux/x86 4.10.0 Kernel Configuration

configuration written to .config

(100%)
< Exit >
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
.config - Linux/x86 4.10.0 Kernel Configuration

Linux/x86 4.10.0 Kernel Configuration
Arrow keys navigate the menu.  <Enter> selects submenus ---> (or empty
submenus ----).  Highlighted letters are hotkeys.  Pressing <Y>
includes, <N> excludes, <M> modularizes features.  Press <Esc><Esc> to
exit, <?> for Help, </> for Search.  Legend: [*] built-in  [ ]

    [*] 64-bit kernel
        General setup  --->
    [*] Enable loadable module support  --->
    [*] Enable the block layer  --->
        Processor type and features  --->
        Power management and ACPI options  --->
        Bus options (PCI etc.)  --->
        Executable file formats / Emulations  --->
    [*] Networking support  --->
        Device Drivers  --->
        ↓(+)

    <Select>    < Exit >    < Help >    < Save >    < Load >
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
ROTO_DCCP
/boot/config-4.8.0-36-generic:1019:warning: symbol value 'm' invalid for NF_CT_P
ROTO_SCTP
/boot/config-4.8.0-36-generic:1020:warning: symbol value 'm' invalid for NF_CT_P
ROTO_UDPLITE
/boot/config-4.8.0-36-generic:1038:warning: symbol value 'm' invalid for NF_NAT_
PROTO_DCCP
/boot/config-4.8.0-36-generic:1039:warning: symbol value 'm' invalid for NF_NAT_
PROTO_UDPLITE
/boot/config-4.8.0-36-generic:1040:warning: symbol value 'm' invalid for NF_NAT_
PROTO_SCTP


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

root@sowmya-Inspiron-3558:/usr/src/linux-4.10# make oldconfig
  HOSTCC  scripts/kconfig/conf.o
  HOSTLD  scripts/kconfig/conf
scripts/kconfig/conf  --oldconfig Kconfig
#
# configuration written to .config
#
root@sowmya-Inspiron-3558:/usr/src/linux-4.10#
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
/boot/config-4.8.0-36-generic:1020:warning: symbol value 'm' invalid for NF_CT_P
ROTO_UDPLITE
/boot/config-4.8.0-36-generic:1038:warning: symbol value 'm' invalid for NF_NAT_
PROTO_DCCP
/boot/config-4.8.0-36-generic:1039:warning: symbol value 'm' invalid for NF_NAT_
PROTO_UDPLITE
/boot/config-4.8.0-36-generic:1040:warning: symbol value 'm' invalid for NF_NAT_
PROTO_SCTP


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

root@sowmya-Inspiron-3558:/usr/src/linux-4.10# make oldconfig
  HOSTCC  scripts/kconfig/conf.o
  HOSTLD  scripts/kconfig/conf
scripts/kconfig/conf  --oldconfig Kconfig
#
# configuration written to .config
#
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# make
scripts/kconfig/conf  --silentoldconfig Kconfig
  SYSTBL  arch/x86/entry/syscalls/../../include/generated/asm/syscalls_32.h
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
  HOSTCC  scripts/asn1_compiler
  HOSTCC  scripts/sign-file
scripts/sign-file.c:25:30: fatal error: openssl/opensslv.h: No such file or dire
ctory
compilation terminated.
scripts/Makefile.host:107: recipe for target 'scripts/sign-file' failed
make[1]: *** [scripts/sign-file] Error 1
Makefile:560: recipe for target 'scripts' failed
make: *** [scripts] Error 2
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# ^C
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# sudo apt-get install libssl-dev
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libssl-doc libssl1.0.0 zlib1g zlib1g-dev
The following NEW packages will be installed:
  libssl-dev libssl-doc zlib1g-dev
The following packages will be upgraded:
  libssl1.0.0 zlib1g
2 upgraded, 3 newly installed, 0 to remove and 431 not upgraded.
Need to get 3,722 kB of archives.
After this operation, 10.5 MB of additional disk space will be used.
Do you want to continue? [Y/n]
```

As we can see the error, which has occurred because we don't have the libssl package.

17. Sudo apt-get install libssl-dev:

Using this command we install the libssl package.

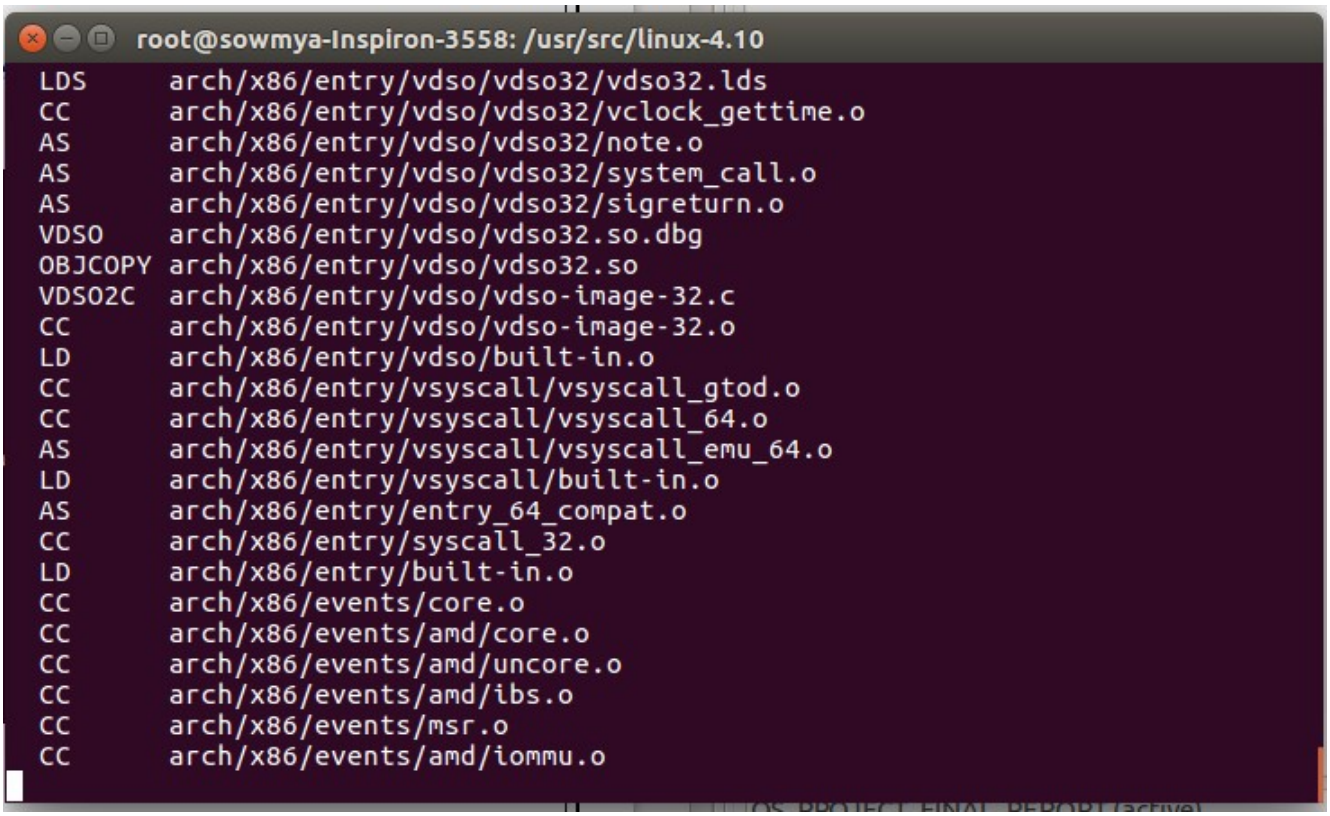
```
After this operation, 10.5 MB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://in.archive.ubuntu.com/ubuntu xenial-updates/main amd64 zlib1g amd64
 1:1.2.8.dfsg-2ubuntu4.1 [51.2 kB]
Get:2 http://in.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libssl1.0.0
amd64 1.0.2g-1ubuntu4.8 [1,081 kB]
Get:3 http://in.archive.ubuntu.com/ubuntu xenial-updates/main amd64 zlib1g-dev a
md64 1:1.2.8.dfsg-2ubuntu4.1 [168 kB]
Get:4 http://in.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libssl-dev a
md64 1.0.2g-1ubuntu4.8 [1,345 kB]
46% [4 libssl-dev 294 kB/1,345 kB 22%]                          139 kB/s 15s
```

```
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13# make oldconfig
  HOSTCC  scripts/kconfig/conf.o
  HOSTLD  scripts/kconfig/conf
scripts/kconfig/conf  --oldconfig Kconfig
#
# configuration written to .config
#
```

```
#
root@nikita-Inspiron-3543:/usr/src/linux-4.10.13# make
```

18. make oldconfig: : It reads the existing .config file and prompts the user for options in the current kernel source that are not found in the file. This is useful when taking an existing configuration and moving it to a new kernel.
19. make: utility for building and maintaining groups of programs.

COMPILING STARTS:



```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
LDS     arch/x86/entry/vdso/vdso32/vdso32.lds
CC      arch/x86/entry/vdso/vdso32/vclock_gettime.o
AS      arch/x86/entry/vdso/vdso32/note.o
AS      arch/x86/entry/vdso/vdso32/system_call.o
AS      arch/x86/entry/vdso/vdso32/sigreturn.o
VDSO    arch/x86/entry/vdso/vdso32.so.dbg
OBJCOPY arch/x86/entry/vdso/vdso32.so
VDSO2C  arch/x86/entry/vdso/vdso-image-32.c
CC      arch/x86/entry/vdso/vdso-image-32.o
LD      arch/x86/entry/vdso/built-in.o
CC      arch/x86/entry/vsyscall/vsyscall_gtod.o
CC      arch/x86/entry/vsyscall/vsyscall_64.o
AS      arch/x86/entry/vsyscall/vsyscall_emu_64.o
LD      arch/x86/entry/vsyscall/built-in.o
AS      arch/x86/entry/entry_64_compat.o
CC      arch/x86/entry/syscall_32.o
LD      arch/x86/entry/built-in.o
CC      arch/x86/events/core.o
CC      arch/x86/events/amd/core.o
CC      arch/x86/events/amd/uncore.o
CC      arch/x86/events/amd/ibs.o
CC      arch/x86/events/msr.o
CC      arch/x86/events/amd/iommu.o
```

//COMPLINING

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
  CC      arch/x86/boot/pm.o
  AS      arch/x86/boot/pmjump.o
  CC      arch/x86/boot/printf.o
  CC      arch/x86/boot/regs.o
  CC      arch/x86/boot/string.o
  CC      arch/x86/boot/tty.o
  CC      arch/x86/boot/video.o
  CC      arch/x86/boot/video-mode.o
  CC      arch/x86/boot/version.o
  CC      arch/x86/boot/video-vga.o
  CC      arch/x86/boot/video-vesa.o
  CC      arch/x86/boot/video-bios.o
  LD      arch/x86/boot/setup.elf
  OBJCOPY arch/x86/boot/setup.bin
  OBJCOPY arch/x86/boot/vmlinux.bin
  HOSTCC  arch/x86/boot/tools/build
  BUILD   arch/x86/boot/bzImage
Setup is 17436 bytes (padded to 17920 bytes).
System is 7122 kB
CRC 3b0623ac
Kernel: arch/x86/boot/bzImage is ready  (#1)
  Building modules, stage 2.
  MODPOST 4785 modules
```

//COMPILING

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
  IHEX2FW firmware/emi62/midi.fw
  IHEX    firmware/kaweth/new_code.bin
  IHEX    firmware/kaweth/trigger_code.bin
  IHEX    firmware/kaweth/new_code_fix.bin
  IHEX    firmware/kaweth/trigger_code_fix.bin
  IHEX    firmware/ti_3410.fw
  IHEX    firmware/ti_5052.fw
  IHEX    firmware/mts_cdma.fw
  IHEX    firmware/mts_gsm.fw
  IHEX    firmware/mts_edge.fw
  H16TOFW firmware/edgeport/boot.fw
  H16TOFW firmware/edgeport/boot2.fw
  H16TOFW firmware/edgeport/down.fw
  H16TOFW firmware/edgeport/down2.fw
  IHEX    firmware/edgeport/down3.bin
  IHEX2FW firmware/whiteheat_loader.fw
  IHEX2FW firmware/whiteheat.fw
  IHEX2FW firmware/keyspan_pda/keyspan_pda.fw
  IHEX2FW firmware/keyspan_pda/xircom_pgs.fw
  IHEX    firmware/cpia2/stv0672_vp4.bin
  IHEX    firmware/yam/1200.bin
  IHEX    firmware/yam/9600.bin
root@sowmya-Inspiron-3558:/usr/src/linux-4.10#
root@sowmya-Inspiron-3558:/usr/src/linux-4.10#
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
  INSTALL /lib/firmware/ti_5052.fw
  INSTALL /lib/firmware/mts_cdma.fw
  INSTALL /lib/firmware/mts_gsm.fw
  INSTALL /lib/firmware/mts_edge.fw
  INSTALL /lib/firmware/edgeport/boot.fw
  INSTALL /lib/firmware/edgeport/boot2.fw
  INSTALL /lib/firmware/edgeport/down.fw
  INSTALL /lib/firmware/edgeport/down2.fw
  INSTALL /lib/firmware/edgeport/down3.bin
  INSTALL /lib/firmware/whiteheat_loader.fw
  INSTALL /lib/firmware/whiteheat.fw
  INSTALL /lib/firmware/keyspan_pda/keyspan_pda.fw
  INSTALL /lib/firmware/keyspan_pda/xircom_pgs.fw
  INSTALL /lib/firmware/cpia2/stv0672_vp4.bin
  INSTALL /lib/firmware/yam/1200.bin
  INSTALL /lib/firmware/yam/9600.bin
  DEPMOD  4.10.0
sh ./arch/x86/boot/install.sh 4.10.0 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.10.0 /boot/vmlinuz-4.10.0
update-initramfs: Generating /boot/initrd.img-4.10.0
W: Possible missing firmware /lib/firmware/i915/kbl_dmc_ver1_01.bin for module i915
W: Possible missing firmware /lib/firmware/i915/kbl_guc_ver9_14.bin for module i915
W: Possible missing firmware /lib/firmware/i915/bxt_guc_ver8_7.bin for module i915
```

```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
  INSTALL /lib/firmware/keyspan_pda/xircom_pgs.fw
  INSTALL /lib/firmware/cpia2/stv0672_vp4.bin
  INSTALL /lib/firmware/yam/1200.bin
  INSTALL /lib/firmware/yam/9600.bin
  DEPMOD  4.10.0
sh ./arch/x86/boot/install.sh 4.10.0 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.10.0 /boot/vmlinuz-4.10.0
update-initramfs: Generating /boot/initrd.img-4.10.0
W: Possible missing firmware /lib/firmware/i915/kbl_dmc_ver1_01.bin for module i915
W: Possible missing firmware /lib/firmware/i915/kbl_guc_ver9_14.bin for module i915
W: Possible missing firmware /lib/firmware/i915/bxt_guc_ver8_7.bin for module i915
run-parts: executing /etc/kernel/postinst.d/pm-utils 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/update-notifier 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 4.10.0 /boot/vmlinuz-4.10.0
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-4.10.0
Found initrd image: /boot/initrd.img-4.10.0
Found linux image: /boot/vmlinuz-4.8.0-36-generic
Found initrd image: /boot/initrd.img-4.8.0-36-generic
Found Windows Boot Manager on /dev/sda1@/EFI/Microsoft/Boot/bootmgfw.efi
Adding boot menu entry for EFI firmware configuration
done
root@sowmya-Inspiron-3558:/usr/src/linux-4.10#
```

AFTER 10 HOURS OF COMPILATION

20. make modules_install install : to install the recently compiled kernel.

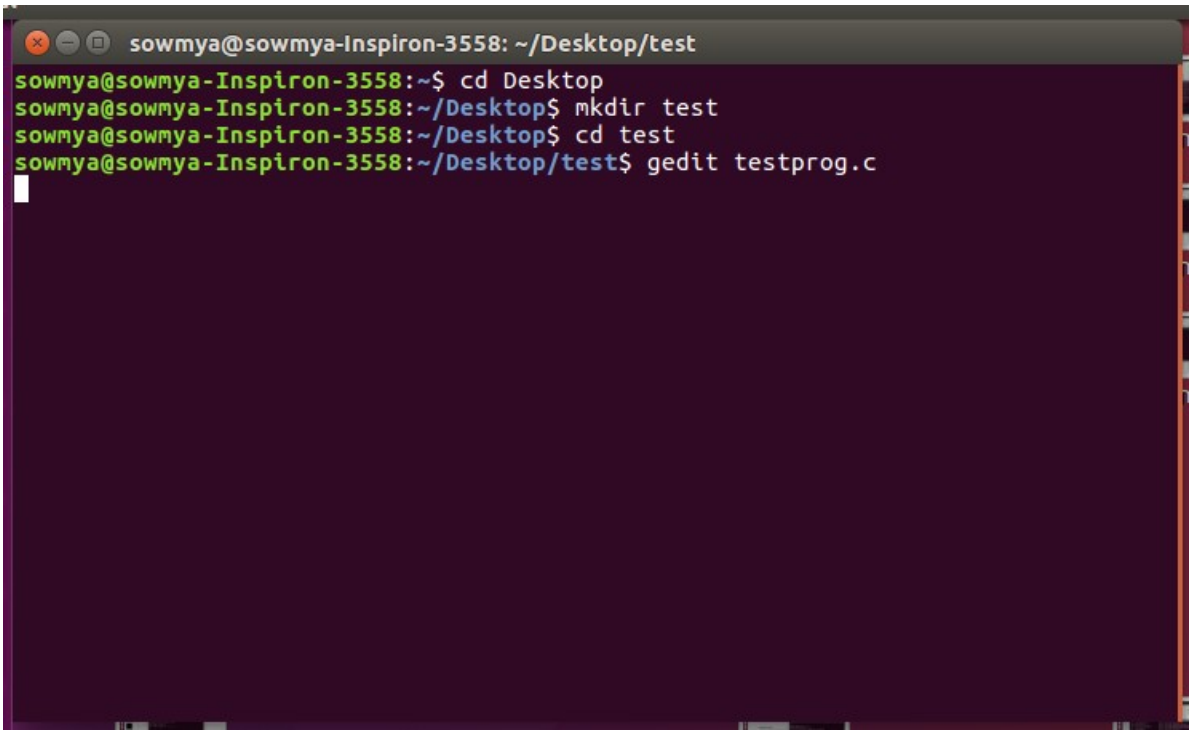
```
root@sowmya-Inspiron-3558: /usr/src/linux-4.10
  INSTALL /lib/firmware/keyspan_pda/xircom_pgs.fw
  INSTALL /lib/firmware/cpia2/stv0672_vp4.bin
  INSTALL /lib/firmware/yam/1200.bin
  INSTALL /lib/firmware/yam/9600.bin
  DEPMOD  4.10.0
sh ./arch/x86/boot/install.sh 4.10.0 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.10.0 /boot/vmlinuz-4.10.0
update-initramfs: Generating /boot/initrd.img-4.10.0
W: Possible missing firmware /lib/firmware/i915/kbl_dmc_ver1_01.bin for module i915
W: Possible missing firmware /lib/firmware/i915/kbl_guc_ver9_14.bin for module i915
W: Possible missing firmware /lib/firmware/i915/bxt_guc_ver8_7.bin for module i915
run-parts: executing /etc/kernel/postinst.d/pm-utils 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/update-notifier 4.10.0 /boot/vmlinuz-4.10.0
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 4.10.0 /boot/vmlinuz-4.10.0
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-4.10.0
Found initrd image: /boot/initrd.img-4.10.0
Found linux image: /boot/vmlinuz-4.8.0-36-generic
Found initrd image: /boot/initrd.img-4.8.0-36-generic
Found Windows Boot Manager on /dev/sda1@/EFI/Microsoft/Boot/bootmgfw.efi
Adding boot menu entry for EFI firmware configuration
done
root@sowmya-Inspiron-3558:/usr/src/linux-4.10# shutdown -r now
```

21.shutdown –r now: it will shut down the system.

RESULT

We successfully added the system calls to the UNIX Kernel.

//now that we have restarted our computer we check if the new kernel is installed



1. cd Desktop: going to the desktop.
2. mkdir test: creating a new directory named ‘test’
3. cd test: moving to this newly created directory
4. gedit testprog.c: it is a text editor opening the file’testprog’. Here we use our newly added system call.

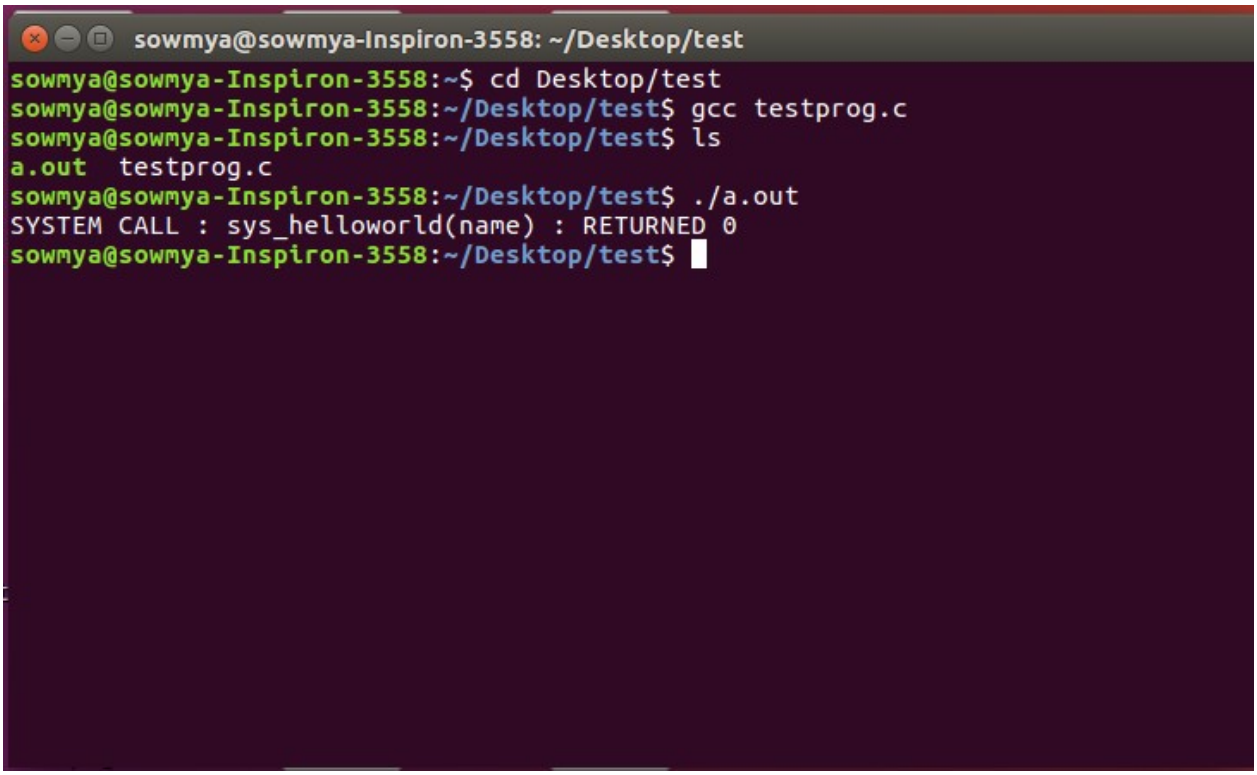
testprog.c (~/Desktop/test) - gedit

Open Save

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

int main()
{
long int s=syscall(332);
printf("SYSTEM CALL : sys_helloworld(name) : RETURNED %ld \n",s);
return 0;
}
//332 is he index of the helloworld system call
```

C Tab Width: 8 Ln 12, Col 48 INS



5. gcc testprog.c: used for compiling the file ‘testprog’
6. ls: shows file sunder the current directory
7. ./a.out: displays output after compilation
8. dmesg: writes the kernel message to standard output.

```
sowmya@sowmya-Inspiron-3558: ~/Desktop/test
[   71.062529] r8169 0000:07:00.0 enp7s0: link down
[   71.062669] IPv6: ADDRCONF(NETDEV_UP): enp7s0: link is not ready
[   71.086869] IPv6: ADDRCONF(NETDEV_UP): wlp6s0: link is not ready
[   71.089153] iwlwifi 0000:06:00.0: L1 Enabled - LTR Enabled
[   71.089499] iwlwifi 0000:06:00.0: L1 Enabled - LTR Enabled
[   71.201123] iwlwifi 0000:06:00.0: L1 Enabled - LTR Enabled
[   71.201476] iwlwifi 0000:06:00.0: L1 Enabled - LTR Enabled
[   71.216752] IPv6: ADDRCONF(NETDEV_UP): wlp6s0: link is not ready
[   71.396862] IPv6: ADDRCONF(NETDEV_UP): wlp6s0: link is not ready
[   76.344035] Bluetooth: RFCOMM TTY layer initialized
[   76.344052] Bluetooth: RFCOMM socket layer initialized
[   76.344073] Bluetooth: RFCOMM ver 1.11
[   80.519188] wlp6s0: authenticate with 6c:aa:b3:3c:65:2c
[   80.522783] wlp6s0: send auth to 6c:aa:b3:3c:65:2c (try 1/3)
[   80.523640] wlp6s0: authenticated
[   80.529352] wlp6s0: associate with 6c:aa:b3:3c:65:2c (try 1/3)
[   80.531428] wlp6s0: RX AssocResp from 6c:aa:b3:3c:65:2c (capab=0x401 status=0
 aid=1)
[   80.532284] wlp6s0: associated
[   80.532412] IPv6: ADDRCONF(NETDEV_CHANGE): wlp6s0: link becomes ready
[   80.539654] wlp6s0: Limiting TX power to 23 (23 - 0) dBm as advertised by 6c:
aa:b3:3c:65:2c
[ 1403.759914] Hello World
sowmya@sowmya-Inspiron-3558:~/Desktop/test$
```

//this is kernel log, helloworld is the message

CONCLUSION

Our new Hello World system call has been successfully added to our kernel.Here we have added a simple print command(which prints hello world, when the system call is used) which if printed returns the value 0. But we can add more complex programs and later incorporate them in our programs as system calls, hence building a better operating system.