

Building a custom kernel

For the upcoming homework #3, you will be asked to implement some new functionality in the Linux kernel. For that, you need to know how to build a custom kernel from source.

This tutorial shows you how to build a custom kernel on Fedora Linux. If you have not built a Linux kernel from source code before, you can try to follow the tutorial and hopefully you will know how to do it in the end.

Note that there are many webpages on the Internet teaching people how to build Linux kernel from source code. You are encouraged to look up those pages, too, in case the information in this tutorial is outdated or may you prefer a different Linux distribution (e.g. Ubuntu), in which case the steps for building custom kernel are slightly different.

- A. Make sure the system has all the necessary packages installed.

```
su -c 'yum install rpmdevtools yum-utils'  
su -c 'yum install qt3-devel libXi-devel'
```

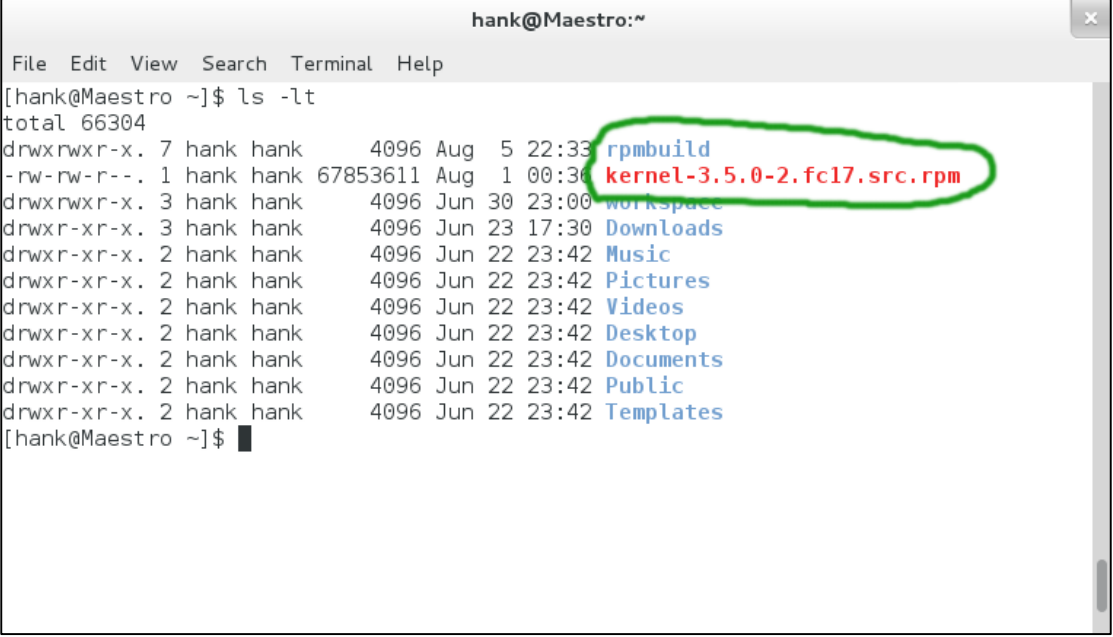
- B. Prepare a RPM package building environment in your home directory.

```
rpmdev-setuptree
```

- C. Get the source.

```
yumdownloader --source kernel
```

At your home directory, you should have the kernel source rpm and the rpmbuild directory as follow:



A terminal window titled 'hank@Maestro:~' showing the output of the command 'ls -lt'. The output lists various directories and files in the home directory. The 'rpmbuild' directory and the file 'kernel-3.5.0-2.fc17.src.rpm' are highlighted with a green oval. The file is a red color in the terminal output, indicating it is a file, while the directory is blue.

```
hank@Maestro:~  
File Edit View Search Terminal Help  
[hank@Maestro ~]$ ls -lt  
total 66304  
drwxrwxr-x. 7 hank hank 4096 Aug 5 22:33 rpmbuild  
-rw-rw-r--. 1 hank hank 67853611 Aug 1 00:36 kernel-3.5.0-2.fc17.src.rpm  
drwxrwxr-x. 3 hank hank 4096 Jun 30 23:00 workspace  
drwxr-xr-x. 3 hank hank 4096 Jun 23 17:30 Downloads  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Music  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Pictures  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Videos  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Desktop  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Documents  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Public  
drwxr-xr-x. 2 hank hank 4096 Jun 22 23:42 Templates  
[hank@Maestro ~]$
```

Figure 1. kernel rpm and rpmbuild directory

D. Install build dependencies for the kernel source

```
su -c 'yum-builddep kernel-<version>.src.rpm'
```

Note that you need to replace <version> with the version of the kernel source you downloaded. For instance, the version of the kernel in Figure 1 is “3.5.0-2.fc17”.

E. Install the kernel source

```
rpm -Uvh kernel-<version>.src.rpm
```

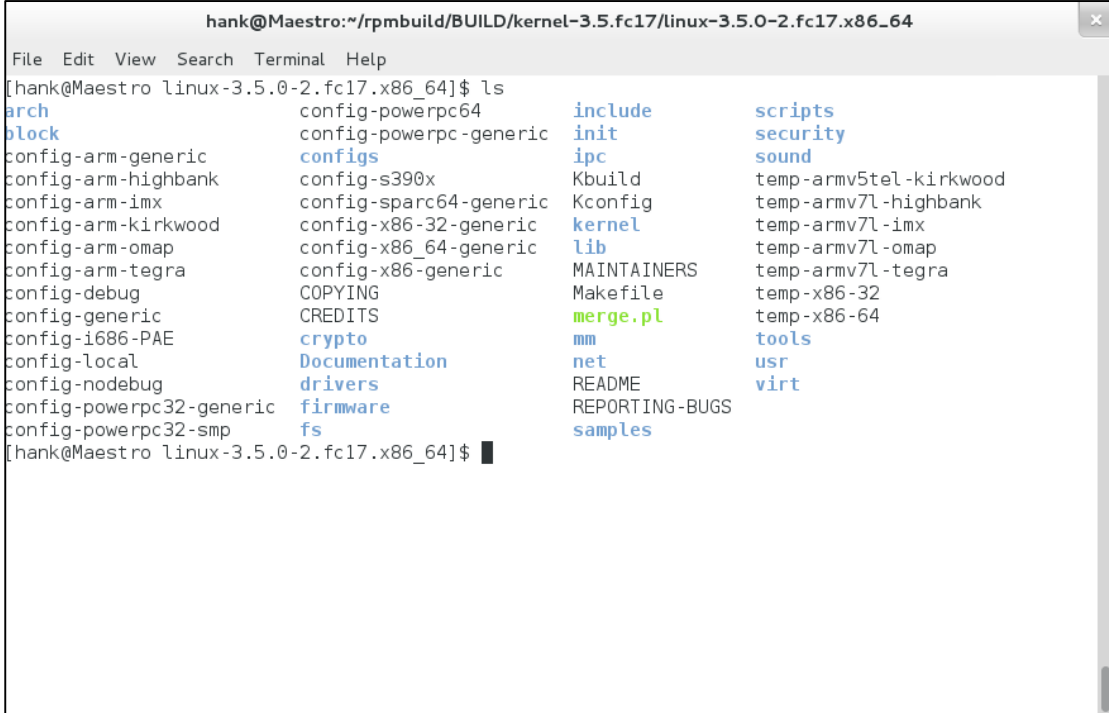
This command writes the RPM contents into `${HOME}/rpmbuild/SOURCES` and `${HOME}/rpmbuild/SPECS`, where `${HOME}` is your home directory.

F. Prepare the kernel source tree

```
cd ~/rpmbuild/SPECS  
rpmbuild -bp --target=$(uname -m) kernel.spec
```

The kernel source tree is now located in the `~/rpmbuild/BUILD/kernel-<version>/linux-<version>.<arch>` direct

ory. For instance, the kernel source tree directory should look like:



A terminal window titled "hank@Maestro:~/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64" showing the output of the 'ls' command. The directory contents are listed in four columns, with some items in blue text indicating they are directories. The items are: arch, block, config-arm-generic, config-arm-highbank, config-arm-imx, config-arm-kirkwood, config-arm-omap, config-arm-tegra, config-debug, config-generic, config-i686-PAE, config-local, config-nodetug, config-powerpc32-generic, config-powerpc32-smp, config-powerpc64, config-powerpc-generic, config-s390x, config-sparc64-generic, config-x86-32-generic, config-x86_64-generic, config-x86-generic, COPYING, CREDITS, crypto, Documentation, drivers, firmware, fs, include, init, ipc, Kbuild, Kconfig, kernel, lib, MAINTAINERS, Makefile, merge.pl, mm, net, README, REPORTING-BUGS, samples, scripts, security, sound, temp-armv5tel-kirkwood, temp-armv7l-highbank, temp-armv7l-imx, temp-armv7l-omap, temp-armv7l-tegra, temp-x86-32, temp-x86-64, tools, usr, and virt.

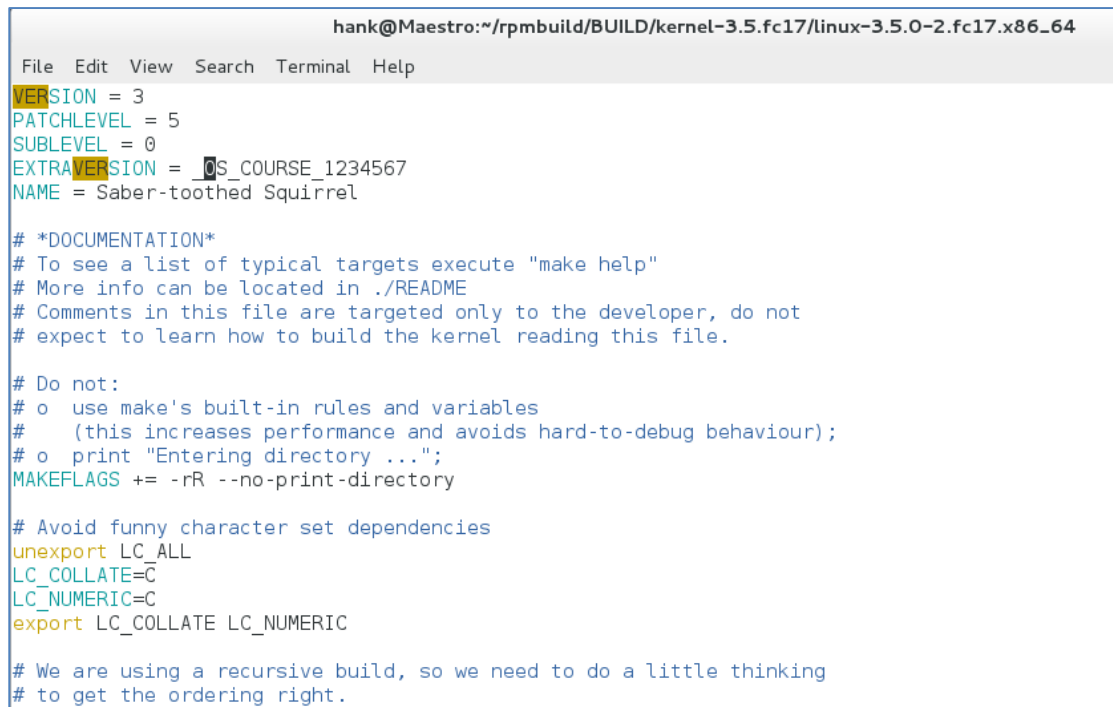
```
hank@Maestro:~/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
File Edit View Search Terminal Help
[hank@Maestro linux-3.5.0-2.fc17.x86_64]$ ls
arch                config-powerpc64    include             scripts
block              config-powerpc-generic  init                security
config-arm-generic  configs             ipc                 sound
config-arm-highbank config-s390x          Kbuild              temp-armv5tel-kirkwood
config-arm-imx       config-sparc64-generic Kconfig              temp-armv7l-highbank
config-arm-kirkwood  config-x86-32-generic kernel                temp-armv7l-imx
config-arm-omap       config-x86_64-generic lib                   temp-armv7l-omap
config-arm-tegra      config-x86-generic   MAINTAINERS          temp-armv7l-tegra
config-debug          COPYING              Makefile              temp-x86-32
config-generic         CREDITS              merge.pl              temp-x86-64
config-i686-PAE        crypto                mm                     tools
config-local           Documentation          net                     usr
config-nodetug         drivers                README                 virt
config-powerpc32-generic firmware              REPORTING-BUGS
config-powerpc32-smp   fs                     samples
[hank@Maestro linux-3.5.0-2.fc17.x86_64]$
```

Figure 2. Kernel Source Tree

G. Configure Kernel Options

```
cd ~/rpmbuild/BUILD/kernel-$ver.$fedver/linux-$ver.$arch/
make xconfig
```

H. Give your kernel a unique name by changing EXTRAVERSION in Makefile



```
hank@Maestro:~/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
File Edit View Search Terminal Help
VERSION = 3
PATCHLEVEL = 5
SUBLEVEL = 0
EXTRAVERSION = OS_COURSE_1234567
NAME = Saber-toothed Squirrel

# *DOCUMENTATION*
# To see a list of typical targets execute "make help"
# More info can be located in ./README
# Comments in this file are targeted only to the developer, do not
# expect to learn how to build the kernel reading this file.

# Do not:
# o use make's built-in rules and variables
#   (this increases performance and avoids hard-to-debug behaviour);
# o print "Entering directory ...";
MAKEFLAGS += -rR --no-print-directory

# Avoid funny character set dependencies
unexport LC_ALL
LC_COLLATE=C
LC_NUMERIC=C
export LC_COLLATE LC_NUMERIC

# We are using a recursive build, so we need to do a little thinking
# to get the ordering right.
```

Figure 3. Customizing kernel name

I. Build Kernel Image

```
make bzImage
```

If the build is successful, you should see the following screen

```
hank@Maestro:~/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
File Edit View Search Terminal Help
VOFFSET arch/x86/boot/voffset.h
LDS arch/x86/boot/compressed/vmlinux.lds
AS arch/x86/boot/compressed/head_64.o
CC arch/x86/boot/compressed/misc.o
CC arch/x86/boot/compressed/string.o
CC arch/x86/boot/compressed/cmdline.o
CC arch/x86/boot/compressed/early_serial_console.o
OBJCOPY arch/x86/boot/compressed/vmlinux.bin
GZIP arch/x86/boot/compressed/vmlinux.bin.gz
HOSTCC arch/x86/boot/compressed/mkpiggy
MKPIGGY arch/x86/boot/compressed/piggy.S
AS arch/x86/boot/compressed/piggy.o
CC arch/x86/boot/compressed/eboot.o
AS arch/x86/boot/compressed/efi_stub_64.o
LD arch/x86/boot/compressed/vmlinux
ZOFFSET arch/x86/boot/zoffset.h
AS arch/x86/boot/header.o
CC arch/x86/boot/main.o
CC arch/x86/boot/mca.o
CC arch/x86/boot/memory.o
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 16864 bytes (padded to 16896 bytes).
System is 4645 kB
CRC 24e703de
Kernel: arch/x86/boot/bzImage is ready (#1)
[hank@Maestro linux-3.5.0-2.fc17.x86_64]$
```

Figure 4. Build kernel successfully

J. Build modules

make modules

If the build is successful, you will see the following screen

```
hank@Maestro:~/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
File Edit View Search Terminal Help
IHEX firmware/qlogic/sd7220.fw
IHEX firmware/korg/k1212.dsp
IHEX firmware/ess/maestro3_assp_kernel.fw
IHEX firmware/ess/maestro3_assp_minisrc.fw
IHEX firmware/yamaha/dsl_ctrl.fw
IHEX firmware/yamaha/dsl_dsp.fw
IHEX firmware/yamaha/dsle_ctrl.fw
IHEX firmware/tehuti/bdx.bin
IHEX firmware/tigon/tg3.bin
IHEX firmware/tigon/tg3_tso.bin
IHEX firmware/tigon/tg3_tso5.bin
IHEX firmware/3com/typhoon.bin
HOSTCC firmware/ihex2fw
IHEX2FW firmware/emi26/loader.fw
IHEX2FW firmware/emi26/firmware.fw
IHEX2FW firmware/emi26/bitstream.fw
IHEX2FW firmware/emi62/loader.fw
IHEX2FW firmware/emi62/bitstream.fw
IHEX2FW firmware/emi62/spdif.fw
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
H16T0FW firmware/edgeport/boot.fw
H16T0FW firmware/edgeport/boot2.fw
H16T0FW firmware/edgeport/down.fw
H16T0FW 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
[hank@Maestro linux-3.5.0-2.fc17.x86_64]$
```

Figure 5. Build modules successfully

K. Install modules

```
su -c 'make modules_install'
```

Modules will be installed under `/lib/modules`. For instance, following the example above, the modules will be installed under `/lib/modules/3.5.0_OS_COURSE_1234567` (Figure 6).

```
hank@Maestro:/lib/modules
File Edit View Search Terminal Help
[hank@Maestro modules]$ ls -l /lib/modules/3.5.0_OS_COURSE_1234567/
total 2452
lrwxrwxrwx. 1 root root 67 Aug 10 20:56 build -> /home/hank/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
drwxrwxr-x. 12 root root 4096 Aug 10 20:59 kernel
-rw-r--r--. 1 root root 639919 Aug 10 21:01 modules.alias
-rw-r--r--. 1 root root 630139 Aug 10 21:01 modules.alias.bin
-rw-rw-r--. 1 root root 6523 Aug 10 20:56 modules.builtin
-rw-r--r--. 1 root root 8682 Aug 10 21:02 modules.builtin.bin
-rw-r--r--. 1 root root 232540 Aug 10 21:00 modules.dep
-rw-r--r--. 1 root root 337499 Aug 10 21:00 modules.dep.bin
-rw-r--r--. 1 root root 274 Aug 10 21:03 modules.devname
-rw-rw-r--. 1 root root 90524 Aug 10 20:56 modules.order
-rw-r--r--. 1 root root 131 Aug 10 21:02 modules.softdep
-rw-r--r--. 1 root root 231816 Aug 10 21:02 modules.symbols
-rw-r--r--. 1 root root 293450 Aug 10 21:02 modules.symbols.bin
lrwxrwxrwx. 1 root root 67 Aug 10 20:56 source -> /home/hank/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
[hank@Maestro modules]$
```

Figure 6. Kernel modules installation location

L. Install kernel image

```
su -c 'make install'
```

The kernel image will be installed under /boot as shown in Figure 7.

```
hank@Maestro:~/rpmbuild/BUILD/kernel-3.5.fc17/linux-3.5.0-2.fc17.x86_64
File Edit View Search Terminal Help
System.map "/boot"
[hank@Maestro linux-3.5.0-2.fc17.x86_64]$ ls -l /boot/
total 90164
-rw-r--r--. 1 root root 115179 May 8 01:35 config-3.3.4-5.fc17.x86_64
-rw-r--r--. 1 root root 116714 Jun 19 03:58 config-3.4.3-1.fc17.x86_64
-rw-r--r--. 1 root root 118625 Jul 30 23:05 config-3.5.0-2.fc17.x86_64
drwxr-xr-x. 4 root root 1024 May 23 04:40 efi
-rw-r--r--. 1 root root 178436 Mar 27 17:11 elf-memtest86+-4.20
drwxr-xr-x. 2 root root 1024 May 23 04:40 grub
drwxr-xr-x. 6 root root 1024 Aug 10 21:19 grub2
-rw-rw-r--. 1 root root 17472729 Jun 22 12:00 initramfs-3.3.4-5.fc17.x86_64.img
-rw-r--r--. 1 root root 17772445 Jun 23 11:10 initramfs-3.4.3-1.fc17.x86_64.img
-rw-r--r--. 1 root root 17923915 Aug 3 08:51 initramfs-3.5.0-2.fc17.x86_64.img
-rw-rw-r--. 1 root root 9703029 Aug 10 21:19 initramfs-3.5.0_OS_COURSE_1234567.img
drwx----- 2 root root 12288 Jun 22 11:58 lost+found
-rw-r--r--. 1 root root 176760 Mar 27 17:11 memtest86+-4.20
lrwxrwxrwx. 1 root root 40 Aug 10 21:16 System.map -> /boot/System.map-3.5.0_OS_COURSE_1234567
-rw----- 1 root root 2412391 May 8 01:35 System.map-3.3.4-5.fc17.x86_64
-rw----- 1 root root 2440456 Jun 19 03:58 System.map-3.4.3-1.fc17.x86_64
-rw----- 1 root root 2466258 Jul 30 23:05 System.map-3.5.0-2.fc17.x86_64
-rw-rw-r--. 1 root root 2466258 Aug 10 21:16 System.map-3.5.0_OS_COURSE_1234567
lrwxrwxrwx. 1 root root 37 Aug 10 21:16 vmlinux -> /boot/vmlinux-3.5.0_OS_COURSE_1234567
-rw-r--r--. 1 root root 4662160 May 8 01:35 vmlinux-3.3.4-5.fc17.x86_64
-rw-r--r--. 1 root root 4711472 Jun 19 03:58 vmlinux-3.4.3-1.fc17.x86_64
-rw-r--r--. 1 root root 4772672 Jul 30 23:05 vmlinux-3.5.0-2.fc17.x86_64
-rw-rw-r--. 1 root root 4772832 Aug 10 21:16 vmlinux-3.5.0_OS_COURSE_1234567
[hank@Maestro linux-3.5.0-2.fc17.x86_64]$
```

Figure 7. kernel image installation location

M. Boot with the new kernel

