Linux For Embedded Systems

For Arabs

Course 102: Understanding Linux

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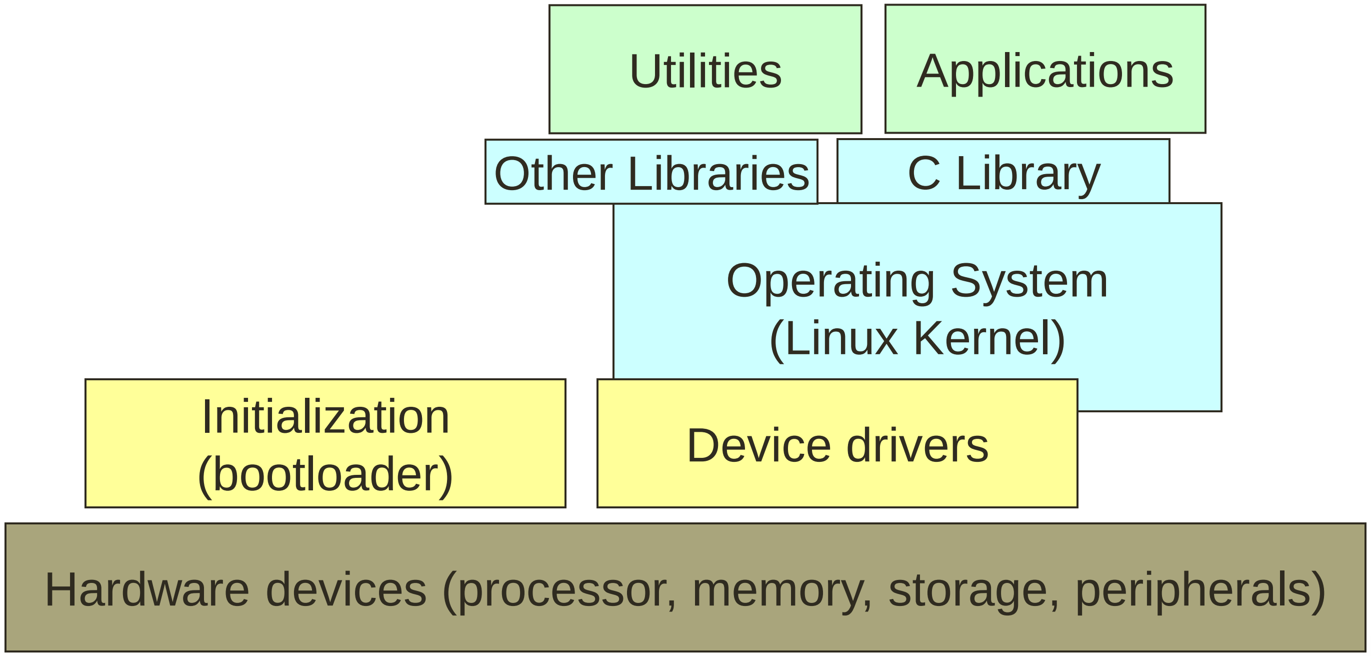
Lecture 25:

Devices & Device Drivers

What is a Device Driver ??


Utilities
Applications
Other Libraries
C Library
Operating System (Linux Kernel)
Initialization (bootloader)
Device drivers
Hardware devices (processor, memory, storage, peripherals)

What is a Device Driver ?

- A device driver is a kernel module responsible for handling a hardware device in order to isolate the operating system and the user application from the details of this hardware device
- This way, the Linux Kernel and the user applications running on top of it don't have to know about the details of the hardware device
- For example, the user application deals with a hard disk (of any kind) and a flash drive the same way, although the internal handling of them is completely different
- This leads to possibility for the introduction of new hardware devices everyday, and the Linux Kernel can support them using the proper device driver without the need to modify the kernel

Correct but not Complete ….

- This definition represent only some of the device drivers and not all of them
- device drivers are not limited to the support of hardware devices
- Some device drivers perform a complete software function and don't perform any hardware device interaction
- Examples are the device drivers supporting these devices,
    - Random number generator (**/dev/random** & **/dev/urandom**)
    - Zeros generator (**/dev/zero**)
    - Output Sink (**/dev/null**)
- We need to understand the more general definition of Devices and Device Driver

The Extendable Architecture of Linux

- Linux kernel is under continuous development with thousands of developers with different objectives
- It supports a lot of fancy and advanced features
- Not all of these features are required by all users
- It also has support for tons of hardware devices (printers, scanners, cameras, storage devices, ….)
- To build the kernel with all of its features and hardware device support will result in a <u>very large image</u> (unnecessarily) and some times with <u>conflicting functions</u>
- With such a large image, Linux may not be able to run on a lot of systems including embedded systems, and will need too much resources (again unnecessarily)

The Extendable Architecture of Linux

- The solution for that problem, is that a lot of the advanced features, and the hardware devices support functionality are considered optional features
- When building the kernel, we go through a configuration phase, to set for each optional feature,
  - **Enable**: to build the code for that feature and include it in the kernel image build in a static way
  - **Disable**: To bypass the build the code for that feature, and hence the kernel would not support it
  - **Module**: The code is built as a separate module, resulting in a separate binary (***.ko**), which can be dynamically added/removed to/from the kernel at run time on need basis
- Also, kernel modules can be developed and built independent of the kernel build and then added to the kernel tree for future load/unload
- A lot of the kernel features can be built as a "Kernel Loadable Modules" to keep the kernel image smaller, and to add the flexibility of adding or removing them when needed

Kernel Loadable Module (KLM)

- A KLM is a binary file (***.ko**) that can be created as an additional step when building the Linux Kernel, or as a completely separate procedure
- KLM's reside in the Linux tree in,

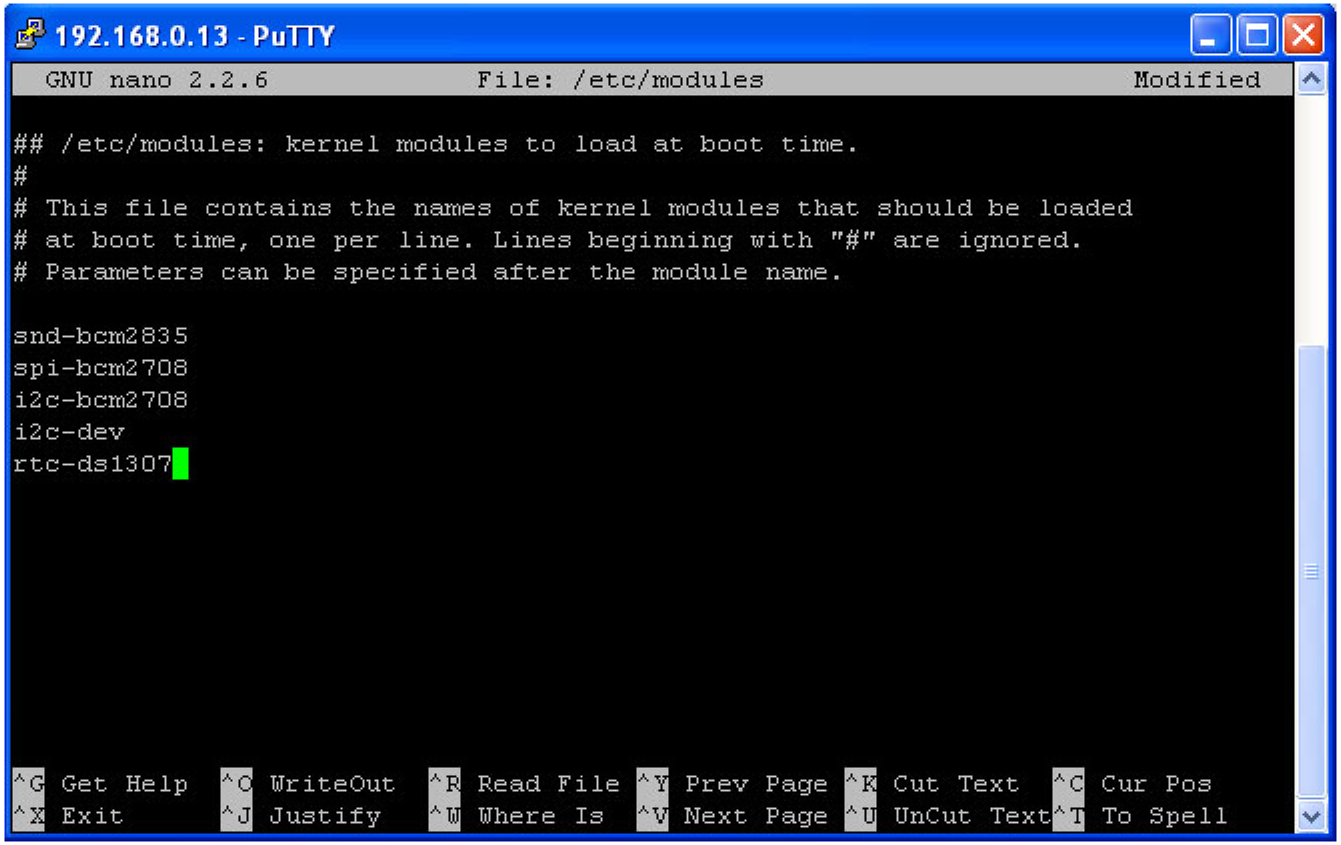
  /lib/modules/{kernel release}/
- KLM's can be loaded or unloaded to/from the Linux Kernel <u>at run time</u> (after the kernel has booted)
- Using KLM enables the following,
  - No need to <u>rebuild</u> the kernel every time a new KLM is introduced
  - No need to <u>reboot</u> the kernel every time we need to load/unload a KLM
- The KLM runs inside the kernel

Loading Kernel Modules

- Kernel Modules can be activated as follows,
  - Kernel modules can be loaded in the kernel on demand based on user commands (we will go this later in this lecture)
  - The Linux kernel supports automatic discovery of new hardware devices, and this may result in the automatic load of the associated kernel modules (using the **udev subsystem** in the kernel). An example is when inserting a USB flash drive
  - The Linux kernel has a list of kernel modules to load at startup (via some startup scripts)
  - Some Kernel Modules are needed in the boot process of the Linux Kernel, and hence they are statically built in the kernel
  - Other modules are necessary for system operation, and it is decided to build them statically in the kernel (they can not be unloaded, since they are becoming part of the kernel image)

Selecting Modules to Start at Boot (/etc/modules)

- The file ***/etc/modules*** will contain the list of modules to start at kernel startup



192.168.0.13 - PuTTY

```
  GNU nano 2.2.6              File: /etc/modules                       Modified

## /etc/modules: kernel modules to load at boot time.
#
# This file contains the names of kernel modules that should be loaded
# at boot time, one per line. Lines beginning with "#" are ignored.
# Parameters can be specified after the module name.

snd-bcm2835
spi-bcm2708
i2c-bcm2708
i2c-dev
rtc-ds1307
```

KLM Utilities

Inserting a Module (insmod Command)

$ insmod <module file>

$ insmod <module file> <arguments>

- This command inserts a module in the kernel

  ```
  $ sudo insmod  /lib/module/`uname –r`/my-driver.ko
  ```

  - Note that the module full path needs to be specified
- You can pass parameters to the module, these parameters are processed by the module code

  ```
  $ sudo insmod /lib/module/`uname –r`/my-device.ko  debug_enable=1
  ```

- Sometimes, a kernel module would require another module to be loaded first, the user has to take care of this dependency, otherwise, the ***insmod*** command may fail

Removing a Module (rmmod Command)

$ rmmod <kernel module>

- This command removes the kernel module from the kernel

  $ sudo rmmod my-driver

  - Since we are addressing now the kernel module inside the kernel and not its binary file inside the Linux tree, no path is specified. Just the module name

Load/Unload a Module (modprobe Command)

$ modprobe <kernel module name >

$ modprobe -r <kernel module name>

- This command replaces both ***insmod*** and ***rmmod*** Commands

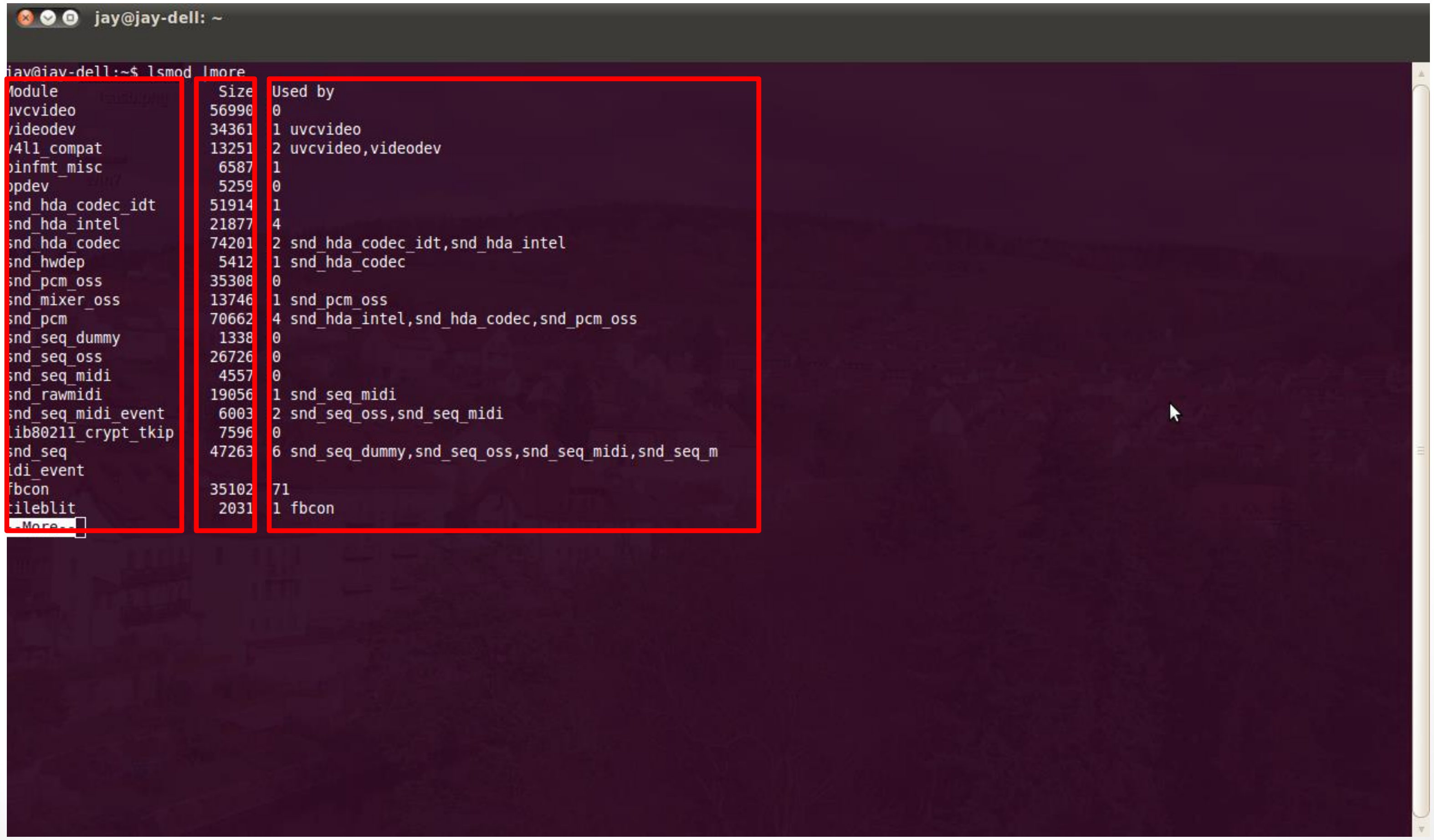
  $ sudo modprobe my-driver

  $ sudo modprobe –r my-driver

- It is a much richer command, because,
  - It has the capability of understanding the module dependencies, and load any modules needed (if not already loaded) before loading the desired module
  - When removing a module, any dependencies that are not used by other modules, will be removed as well
  - It also has a means to find the modules, so we don't need to specify the full path of the module file. The module name should be enough
- The ***modprobe*** command also performs other special features such as setting default parameter options in its configuration files, and using these options when loading the specified module
  - Default module parameters are specified in,
    - */etc/modprobe.conf*
    - */etc/modprobe.d/*.conf*

Listing the Loaded KLMs (lsmod Command)

$ lsmod



jay@jay-dell: ~

```
jay@jay-dell:~$ lsmod |more
Module                  Size  Used by
uvcvideo               56990  0
videodev               34361  1 uvcvideo
v4l1_compat            13251  2 uvcvideo,videodev
binfmt_misc             6587  1
ppdev                   5259  0
snd_hda_codec_idt      51914  1
snd_hda_intel          21877  4
snd_hda_codec          74201  2 snd_hda_codec_idt,snd_hda_intel
snd_hwdep               5412  1 snd_hda_codec
snd_pcm_oss            35308  0
snd_mixer_oss          13746  1 snd_pcm_oss
snd_pcm                70662  4 snd_hda_intel,snd_hda_codec,snd_pcm_oss
snd_seq_dummy           1338  0
snd_seq_oss            26726  0
snd_seq_midi            4557  0
snd_rawmidi            19056  1 snd_seq_midi
snd_seq_midi_event      6003  2 snd_seq_oss,snd_seq_midi
lib80211_crypt_tkip     7596  0
snd_seq                47263  6 snd_seq_dummy,snd_seq_oss,snd_seq_midi,snd_seq_m
idi_event
fbcon                  35102  71
tileblit                2031  1 fbcon
--More--
```

Displaying Kernel Module info (modinfo Command)

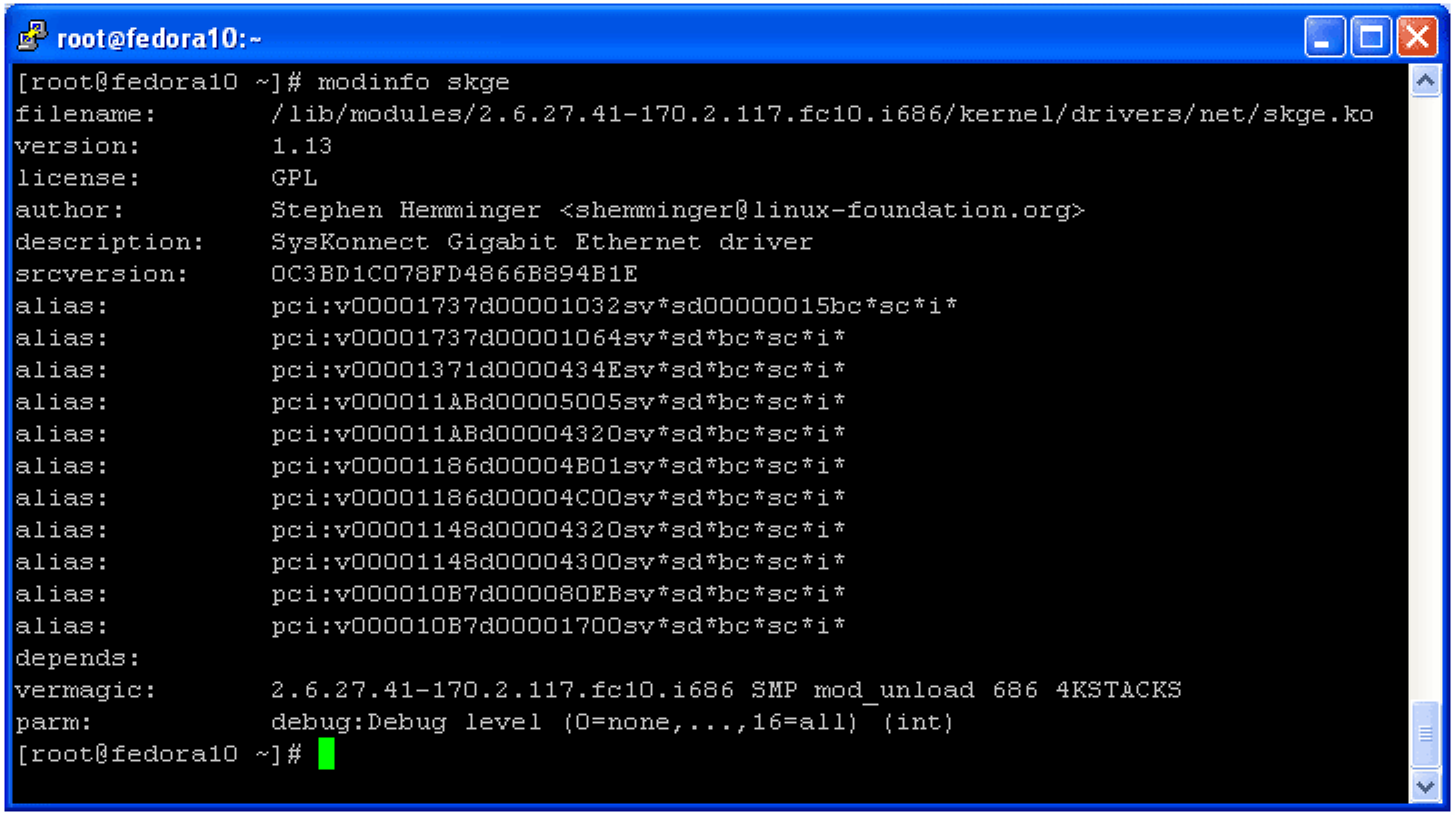
$ modinfo <kernel module name>

- This command shows information about the module

  $ modinfo my-driver

- This includes,
  - Full path for the **.ko** file
  - Author
  - License type
  - Description of the module function
  - Valid parameters
  - Dependencies on other modules

modinfo



root@fedora10:~

```
[root@fedora10 ~]# modinfo skge
filename:       /lib/modules/2.6.27.41-170.2.117.fc10.i686/kernel/drivers/net/skge.ko
version:        1.13
license:        GPL
author:         Stephen Hemminger <shemminger@linux-foundation.org>
description:    SysKonnect Gigabit Ethernet driver
srcversion:     0C3BD1C078FD4866B894B1E
alias:          pci:v00001737d00001032sv*sd00000015bc*sc*i*
alias:          pci:v00001737d00001064sv*sd*bc*sc*i*
alias:          pci:v00001371d0000434Esv*sd*bc*sc*i*
alias:          pci:v000011ABd00005005sv*sd*bc*sc*i*
alias:          pci:v000011ABd00004320sv*sd*bc*sc*i*
alias:          pci:v00001186d00004B01sv*sd*bc*sc*i*
alias:          pci:v00001186d00004C00sv*sd*bc*sc*i*
alias:          pci:v00001148d00004320sv*sd*bc*sc*i*
alias:          pci:v00001148d00004300sv*sd*bc*sc*i*
alias:          pci:v000010B7d000080EBsv*sd*bc*sc*i*
alias:          pci:v000010B7d00001700sv*sd*bc*sc*i*
depends:
vermagic:       2.6.27.41-170.2.117.fc10.i686 SMP mod_unload 686 4KSTACKS
parm:           debug:Debug level (0=none,...,16=all) (int)
[root@fedora10 ~]#
```

What are Device Drivers ??

- A device driver is a kernel module
- It can be either built statically in the kernel image, or loaded dynamically
  - Automatically loaded via ***udev***
  - *On* demand via user commands (modprobe)
  - At boot time via startup scripts
- The device driver registers itself to the system with a number (called the **major number**)
- The device driver runs in the kernel and performs the required functions (interacts with hardware interrupts, communicate with hardware devices, access Linux Kernel structures, communicate with other device drivers, …etc)
- The device driver supports one or more devices

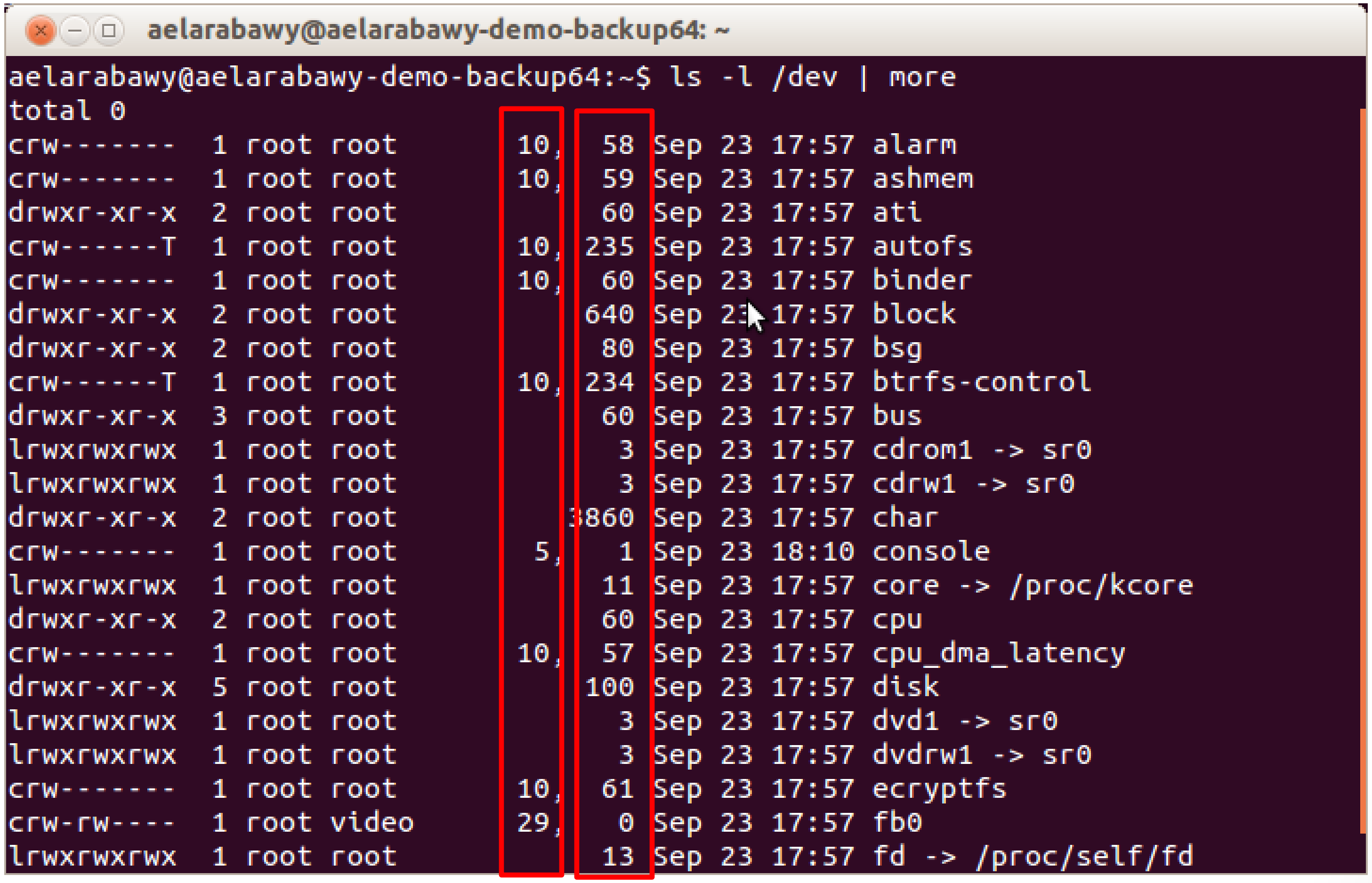
What are Devices ??

- A device is a special file (also called device node) representation located in ***/dev***
- The file is not a real file. It does not reside on the disk, it is just a place holder (that just lives in memory)
- Each device binds to a specific device driver at device creation time
- It is just an abstraction to enable the user plane to access the device driver as if it is normal file
- It is the way the Linux kernel uses to establish the statement **"Everything is a file"**, so you can,
  - Request information from the device driver by reading from the device file
  - Send information to it by writing to the device file
- One or more devices can bind with the same device driver (they must have the same ***Major Number***), but each one has to pick a unique number (called the **Minor Number**)

Major & Minor Numbers

- Each Device will have a pair of numbers,
  - Major Number:
    - This is the number that identify the device driver associated with this device
    - The Major number is reserved and registered by the device driver when it is loaded in the kernel
  - Minor Number:
    - This number is associated with the device file
    - It is the way to differentiate the different device files that are associated with the same device driver
    - It is also the way that the device driver file to know which device is communicating with it

Major & Minor Numbers



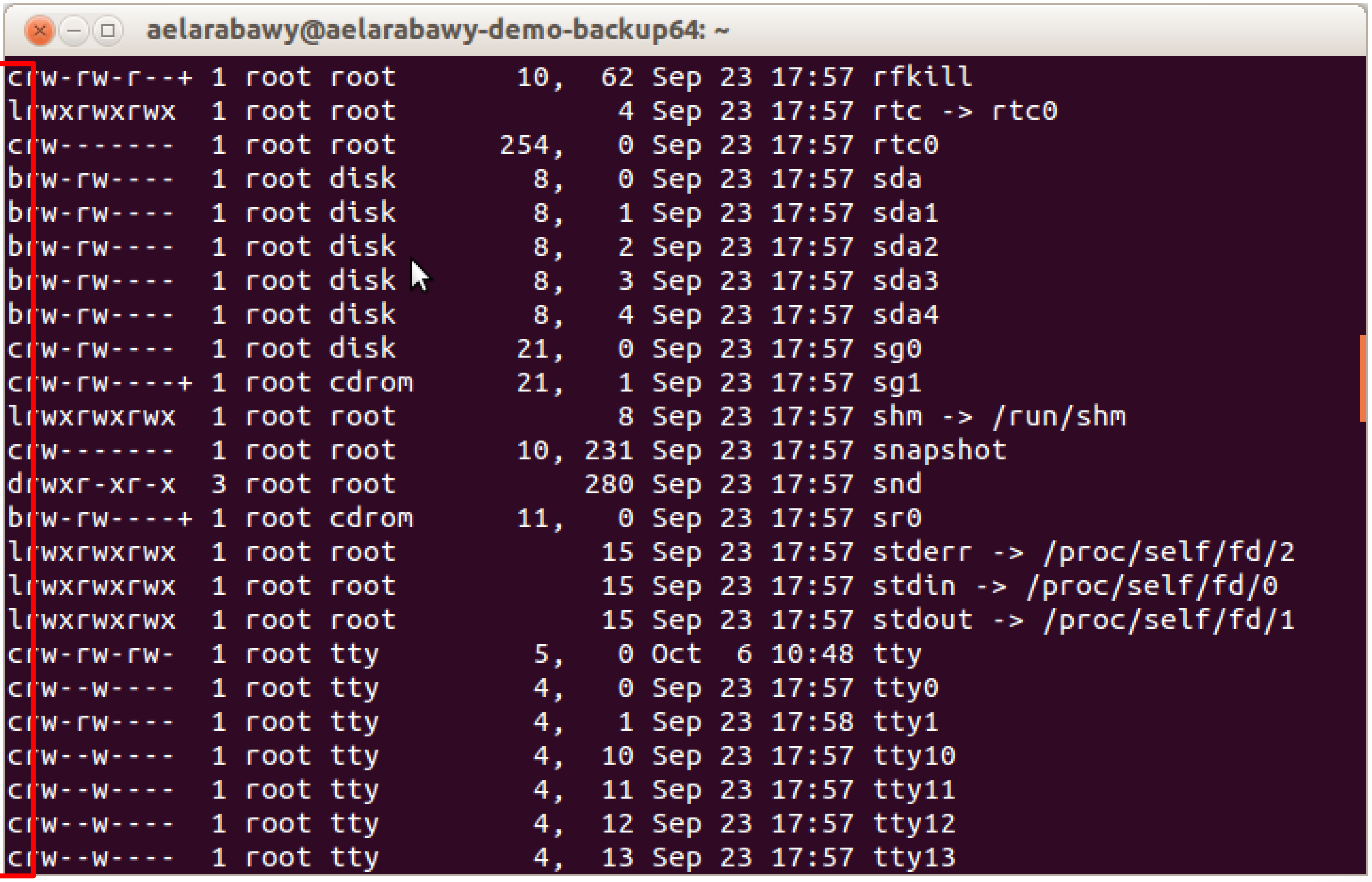
aelarabawy@aelarabawy-demo-backup64: ~

```
aelarabawy@aelarabawy-demo-backup64:~$ ls -l /dev | more
total 0
crw-------  1 root root      10,  58 Sep 23 17:57 alarm
crw-------  1 root root      10,  59 Sep 23 17:57 ashmem
drwxr-xr-x  2 root root           60 Sep 23 17:57 ati
crw------T  1 root root      10, 235 Sep 23 17:57 autofs
crw-------  1 root root      10,  60 Sep 23 17:57 binder
drwxr-xr-x  2 root root          640 Sep 23 17:57 block
drwxr-xr-x  2 root root           80 Sep 23 17:57 bsg
crw------T  1 root root      10, 234 Sep 23 17:57 btrfs-control
drwxr-xr-x  3 root root           60 Sep 23 17:57 bus
lrwxrwxrwx  1 root root            3 Sep 23 17:57 cdrom1 -> sr0
lrwxrwxrwx  1 root root            3 Sep 23 17:57 cdrw1 -> sr0
drwxr-xr-x  2 root root         3860 Sep 23 17:57 char
crw-------  1 root root       5,   1 Sep 23 18:10 console
lrwxrwxrwx  1 root root           11 Sep 23 17:57 core -> /proc/kcore
drwxr-xr-x  2 root root           60 Sep 23 17:57 cpu
crw-------  1 root root      10,  57 Sep 23 17:57 cpu_dma_latency
drwxr-xr-x  5 root root          100 Sep 23 17:57 disk
lrwxrwxrwx  1 root root            3 Sep 23 17:57 dvd1 -> sr0
lrwxrwxrwx  1 root root            3 Sep 23 17:57 dvdrw1 -> sr0
crw-------  1 root root      10,  61 Sep 23 17:57 ecryptfs
crw-rw----  1 root video     29,   0 Sep 23 17:57 fb0
lrwxrwxrwx  1 root root           13 Sep 23 17:57 fd -> /proc/self/fd
```

Device Classification

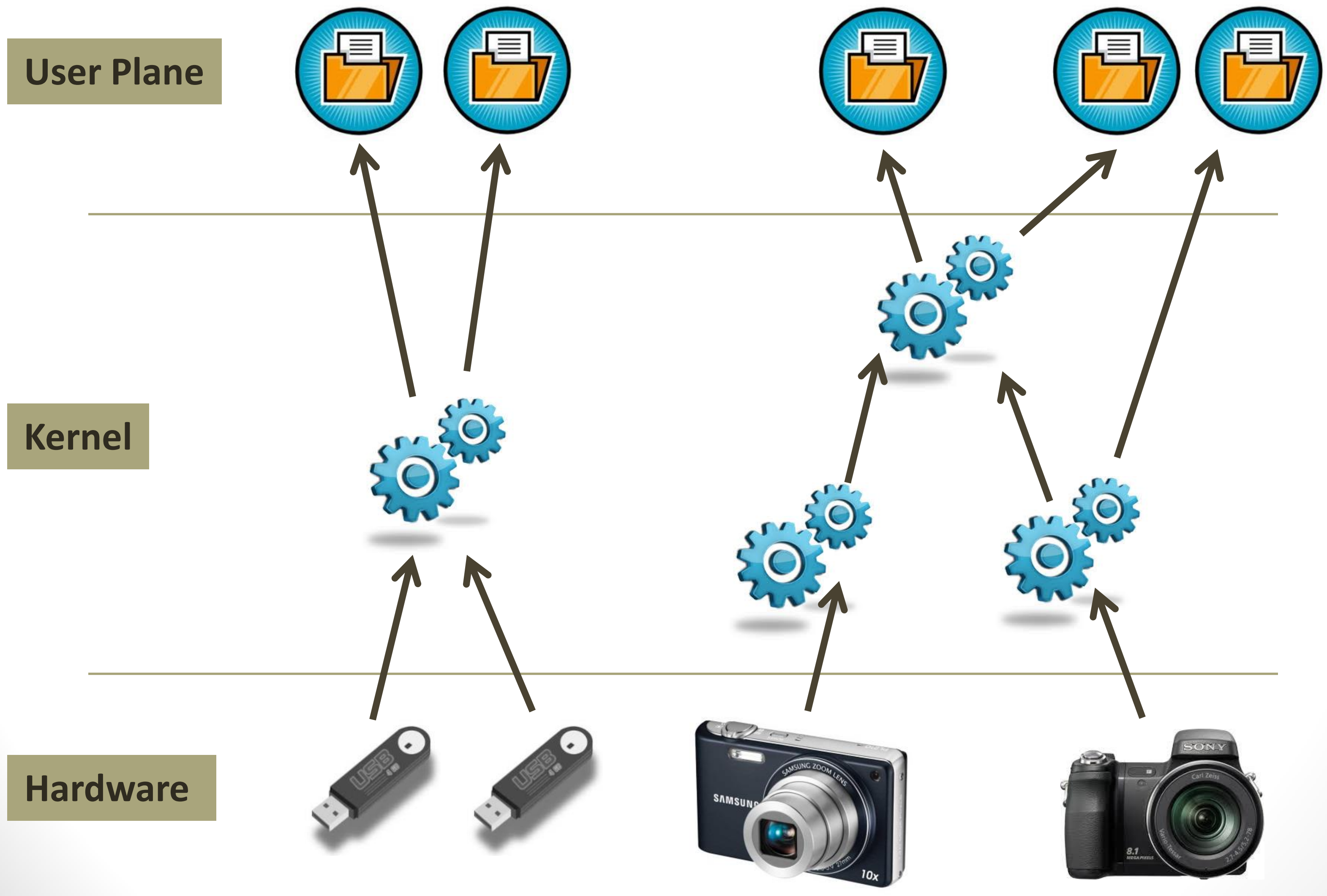
- Two main classes of devices:
  - **Character devices**
    - Serial streams of data
    - Read and Write operations are done in a serial manner
    - Examples:
      - Keyboard
      - Mouse
      - ***/dev/ones***
      - ***/dev/tty1***
      - ***/dev/ttyS1***
    - Represented by a file with type **“c”**
    - Most common devices
  - **Block devices**
    - Read and Write are performed in Blocks
    - Blocks are addressable, and hence can read in a non sequential way
    - Examples are:
      - Storage devices (hard disk, flash)
      - ***/dev/sda1***
    - Represented by a file with type **“b”**

Device Classification


aelarabawy@aelarabawy-demo-backup64: ~

```
crw-rw-r--+ 1 root root      10,  62 Sep 23 17:57 rfkill
lrwxrwxrwx  1 root root            4 Sep 23 17:57 rtc -> rtc0
crw-------  1 root root     254,   0 Sep 23 17:57 rtc0
brw-rw----  1 root disk       8,   0 Sep 23 17:57 sda
brw-rw----  1 root disk       8,   1 Sep 23 17:57 sda1
brw-rw----  1 root disk       8,   2 Sep 23 17:57 sda2
brw-rw----  1 root disk       8,   3 Sep 23 17:57 sda3
brw-rw----  1 root disk       8,   4 Sep 23 17:57 sda4
crw-rw----  1 root disk      21,   0 Sep 23 17:57 sg0
crw-rw----+ 1 root cdrom     21,   1 Sep 23 17:57 sg1
lrwxrwxrwx  1 root root            8 Sep 23 17:57 shm -> /run/shm
crw-------  1 root root      10, 231 Sep 23 17:57 snapshot
drwxr-xr-x  3 root root          280 Sep 23 17:57 snd
brw-rw----+ 1 root cdrom     11,   0 Sep 23 17:57 sr0
lrwxrwxrwx  1 root root           15 Sep 23 17:57 stderr -> /proc/self/fd/2
lrwxrwxrwx  1 root root           15 Sep 23 17:57 stdin -> /proc/self/fd/0
lrwxrwxrwx  1 root root           15 Sep 23 17:57 stdout -> /proc/self/fd/1
crw-rw-rw-  1 root tty        5,   0 Oct  6 10:48 tty
crw--w----  1 root tty        4,   0 Sep 23 17:57 tty0
crw-rw----  1 root tty        4,   1 Sep 23 17:58 tty1
crw--w----  1 root tty        4,  10 Sep 23 17:57 tty10
crw--w----  1 root tty        4,  11 Sep 23 17:57 tty11
crw--w----  1 root tty        4,  12 Sep 23 17:57 tty12
crw--w----  1 root tty        4,  13 Sep 23 17:57 tty13
```

Hardware Device, Device Driver, & Device File



Creating a Device file (mknod Command)

$ mknod <device file name> <c|b> <Major> <Minor>

$ mknod -m <permissions> <device file name> <c|b> <Major> <Minor>

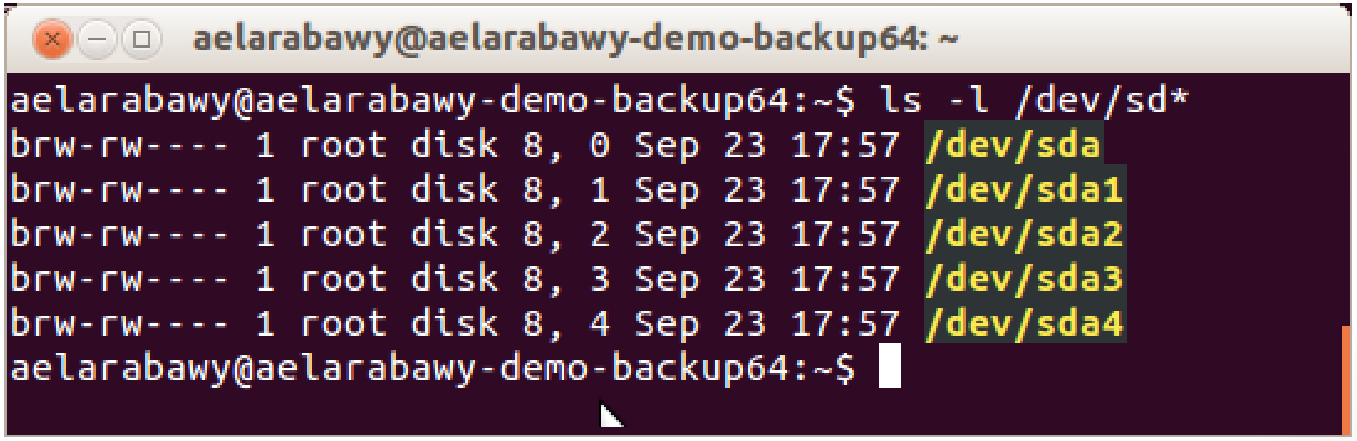
- This command creates a device file
  - The device file name is the file to be created. It should be located in /dev
  - The device class is either a "**Character**" or "**Block**" device
  - The Major Number is the number for the device driver to attach to
  - The Minor Number is the number for this device file (it should be unique within all devices attached to that device driver)
- You can deal with the device as a normal file
  - It can be read only, write only, or read-write
  - You can read from the file using like any file (use cat, or input redirection)
  - You can write to a device file like any file (for example use echo or output redirection)
- To create a device node

```
$ mknod /dev/my-new-device c 235 1
$ mknod -m 666 /dev/my-new-device c 235 1
```

Examples of Commonly Used Devices

SCSI Disk Drive Devices

- All SCSI Disk drive devices (such as those used for SCSI Hard-disks) are attached to the **sd driver** which registers the Major Number of 8
- The naming of the device files:
  - ***/dev/sd[a-z][1-15]***
  - The number at the end is the partition number
  - The device file without a number refers to the whole disk


aelarabawy@aelarabawy-demo-backup64: ~

```
aelarabawy@aelarabawy-demo-backup64:~$ ls -l /dev/sd*
brw-rw---- 1 root disk 8, 0 Sep 23 17:57 /dev/sda
brw-rw---- 1 root disk 8, 1 Sep 23 17:57 /dev/sda1
brw-rw---- 1 root disk 8, 2 Sep 23 17:57 /dev/sda2
brw-rw---- 1 root disk 8, 3 Sep 23 17:57 /dev/sda3
brw-rw---- 1 root disk 8, 4 Sep 23 17:57 /dev/sda4
aelarabawy@aelarabawy-demo-backup64:~$
```

TTY Terminals & Serial Interfaces

- All Linux virtual terminals have devices names
  - **/dev/tty[n]** (example ***/dev/tty1***)
- All Linux Serial Interfaces use the device names
  - **/dev/ttyS[n]** (example ***/dev/ttyS1***)

Device Utilities

Configuration of Serial Interfaces (setserial Command)

$ setserial <options> <serial device file> <parameters to set>

- This command is used to read/write configuration of serial ports
- This includes,
  - Setting the I/O port used by the serial interface
  - Setting the IRQ channel used by the serial interface
  - Baud rate
  - Other info
- Example:

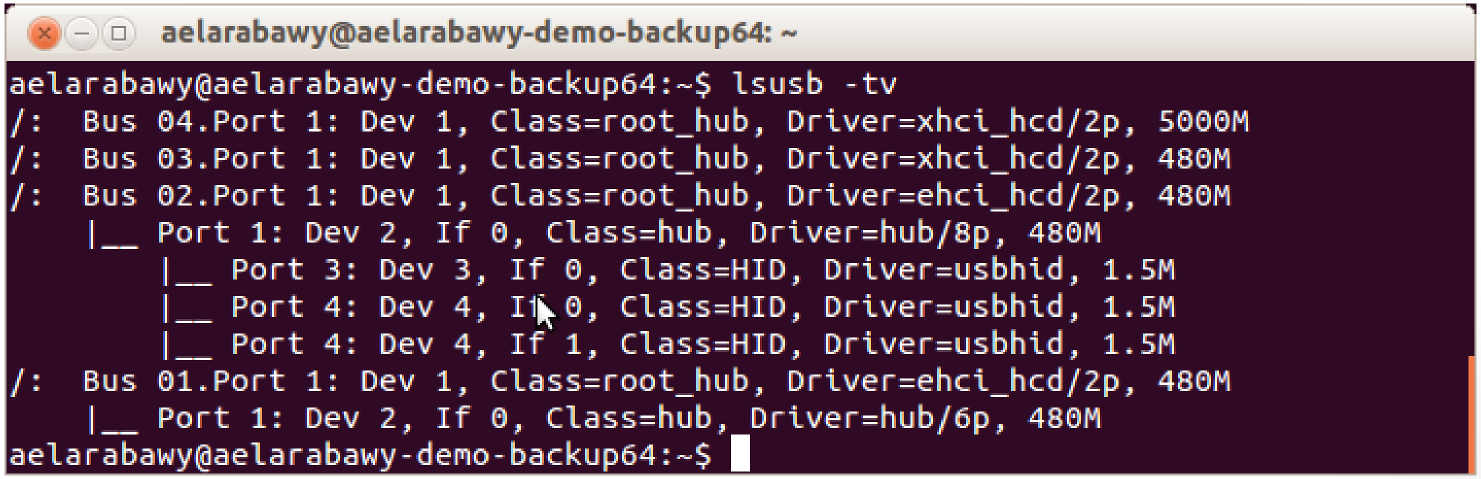
```
$ sudo setserial -a /dev/ttyS1
$ sudo setserial /dev/ttyS1 baud_base 115200
```

Listing USB Hardware Devices (lsusb Command)

$ lsusb

- This command lists the USB Hardware devices and information about them

$ lsusb	(List USB Devices)
$ lsusb -a	(List USB Devices with all information about them)
$ lsusb -t	(List USB Devices in a tree hierarchy structure)



```
aelarabawy@aelarabawy-demo-backup64:~$ lsusb -tv
/:  Bus 04.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/2p, 5000M
/:  Bus 03.Port 1: Dev 1, Class=root_hub, Driver=xhci_hcd/2p, 480M
/:  Bus 02.Port 1: Dev 1, Class=root_hub, Driver=ehci_hcd/2p, 480M
    |__ Port 1: Dev 2, If 0, Class=hub, Driver=hub/8p, 480M
        |__ Port 3: Dev 3, If 0, Class=HID, Driver=usbhid, 1.5M
        |__ Port 4: Dev 4, If 0, Class=HID, Driver=usbhid, 1.5M
        |__ Port 4: Dev 4, If 1, Class=HID, Driver=usbhid, 1.5M
/:  Bus 01.Port 1: Dev 1, Class=root_hub, Driver=ehci_hcd/2p, 480M
    |__ Port 1: Dev 2, If 0, Class=hub, Driver=hub/6p, 480M
aelarabawy@aelarabawy-demo-backup64:~$
```

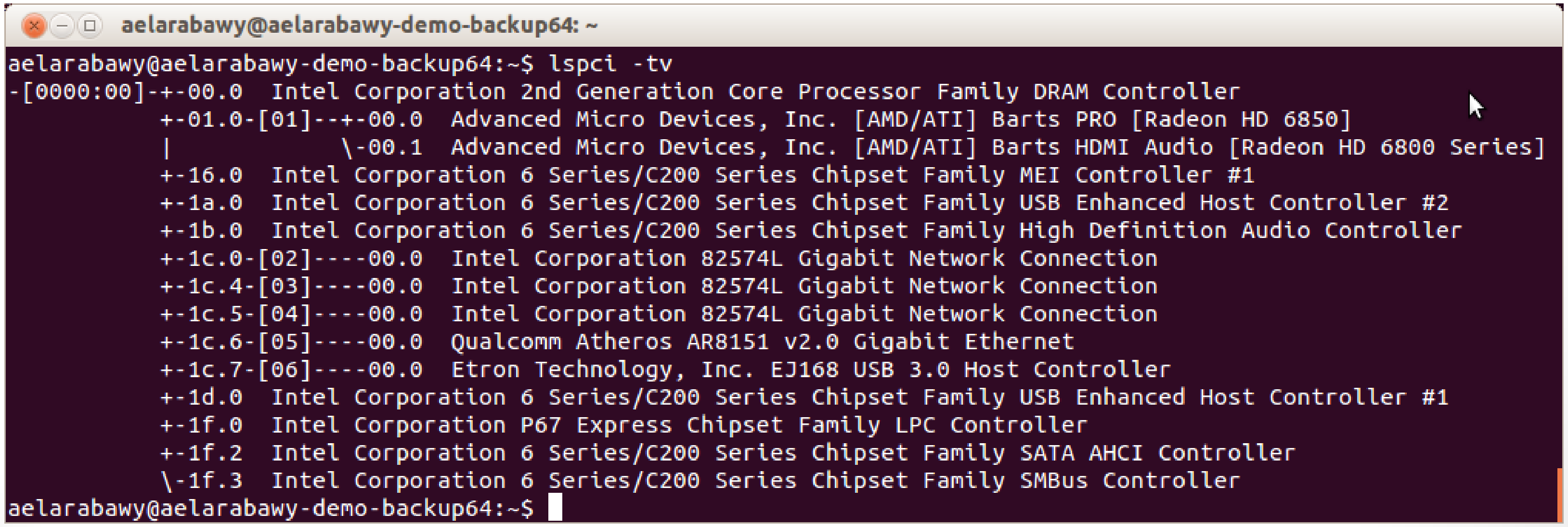
Listing PCI Hardware Devices (lspci Command)

$ lspci

- This command lists the PCI Hardware devices and information about them

  $ lspci

  $ lspci -tv (Use tree hierarchical Structure with detailed info)



aelarabawy@aelarabawy-demo-backup64: ~

```
aelarabawy@aelarabawy-demo-backup64:~$ lspci -tv
-[0000:00]-+-00.0  Intel Corporation 2nd Generation Core Processor Family DRAM Controller
           +-01.0-[01]--+-00.0  Advanced Micro Devices, Inc. [AMD/ATI] Barts PRO [Radeon HD 6850]
           |            \-00.1  Advanced Micro Devices, Inc. [AMD/ATI] Barts HDMI Audio [Radeon HD 6800 Series]
           +-16.0  Intel Corporation 6 Series/C200 Series Chipset Family MEI Controller #1
           +-1a.0  Intel Corporation 6 Series/C200 Series Chipset Family USB Enhanced Host Controller #2
           +-1b.0  Intel Corporation 6 Series/C200 Series Chipset Family High Definition Audio Controller
           +-1c.0-[02]----00.0  Intel Corporation 82574L Gigabit Network Connection
           +-1c.4-[03]----00.0  Intel Corporation 82574L Gigabit Network Connection
           +-1c.5-[04]----00.0  Intel Corporation 82574L Gigabit Network Connection
           +-1c.6-[05]----00.0  Qualcomm Atheros AR8151 v2.0 Gigabit Ethernet
           +-1c.7-[06]----00.0  Etron Technology, Inc. EJ168 USB 3.0 Host Controller
           +-1d.0  Intel Corporation 6 Series/C200 Series Chipset Family USB Enhanced Host Controller #1
           +-1f.0  Intel Corporation P67 Express Chipset Family LPC Controller
           +-1f.2  Intel Corporation 6 Series/C200 Series Chipset Family SATA AHCI Controller
           \-1f.3  Intel Corporation 6 Series/C200 Series Chipset Family SMBus Controller
aelarabawy@aelarabawy-demo-backup64:~$ 
```

Copy And Convert data (dd Command)

$ dd if=<source> of=<destination> <options>

- This command copies data from one file, perform any needed conversions, and store it an another file
- It is a very useful command specially that it can use device files as either source, destination, or both
- Be cautious when using this command. It can wipe a whole partition or drive on your machine
- Example:

```
$ dd if=/dev/urandom  of=~/random-data-file bs=4 count=1000
$ dd if=/dev/sr0 of=/my-file.iso  bs=2048   conv=noerror,sync
$ dd if=/dev/sda of=~/disk.img
$ dd if=/dev/sda of=/dev/sdb
```

Dump of a File (od Command)

$ od <Options> <file>

- This command dumps files in different formats
- Examples:

  $ od -x file.img (output the file in Hexadecimal format)

  $ od -s file.img (output the file in decimal format)

Linux4
Embedded Systems

http://Linux4EmbeddedSystems.com