Demystifying the GRand Unified Bootloader

aka

Getting to know GRUB

grub > initrd /initrd.img

grub > kernel /vmlinuz

grub > chainloader +1

grub > geometry (hd0)

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Metro Detroit Linux Users Group (August 2008)

Topics To Be Covered

- Framework for GRUB: Hard Drive Topology and POST
- GRUB and the Master Boot Record
- GRUB Stages 1.5 and 2.0
- Booting from a GRUB Prompt
  - Linux
  - Non-Linux OSes
- Adding Bling to Your GRUB Menu
- Future of GRUB

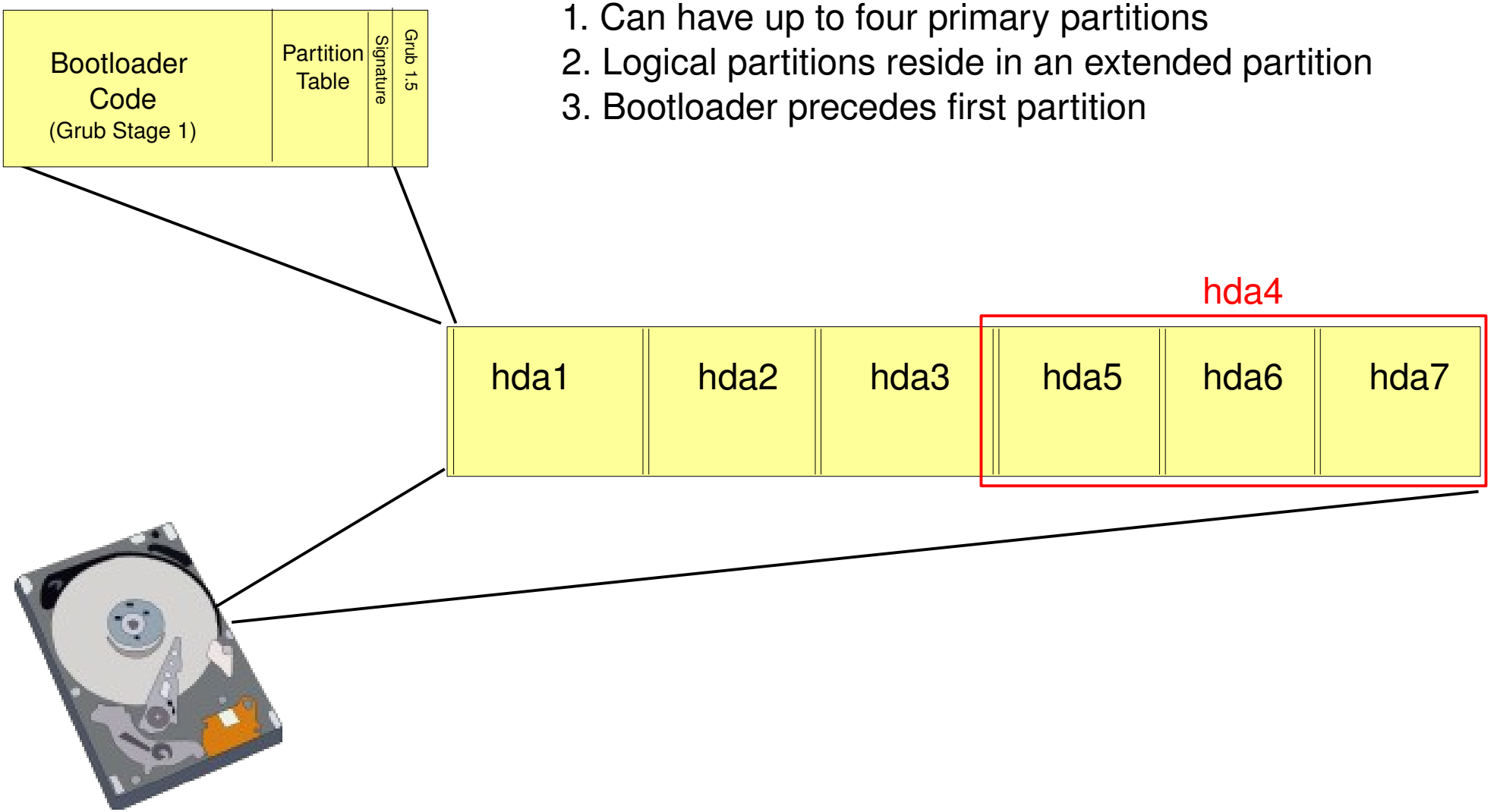
Resources

- Gnu.Org
- www.linuxselfhelp.com
- IBM DeveloperWorks
- http://lxr.linux.no
- LinuxQuestions.org
- http://mirror.href.com
- wikipedia
- linuxbasics.org

Hard Drive Topology

A typical hard drive with multiple partitions:

1. Can have up to four primary partitions
2. Logical partitions reside in an extended partition
3. Bootloader precedes first partition



In The Beginning – System BIOS

After you power on the computer, the BIOS performs several tasks:

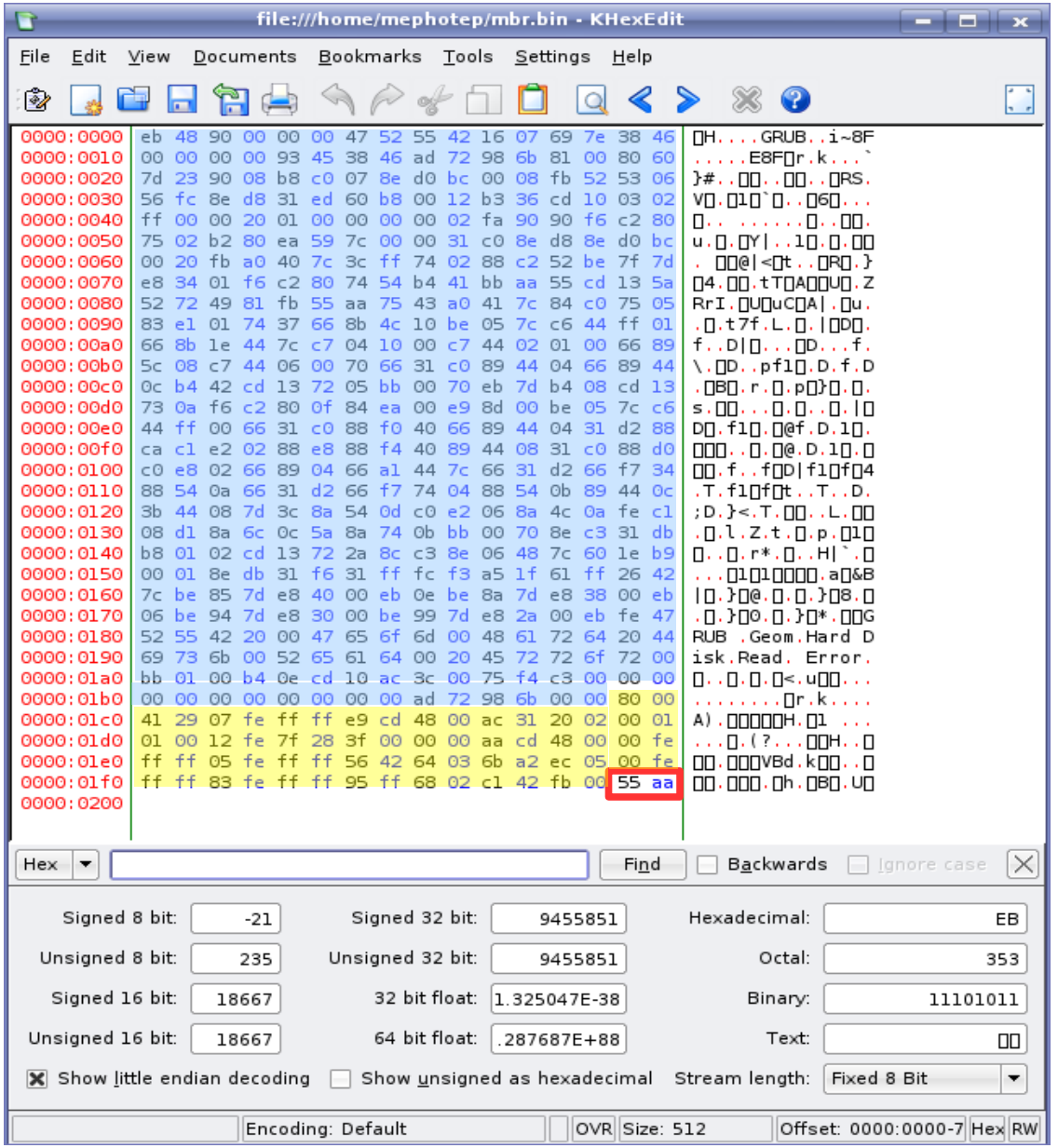
- Checks the hardware for physical faults (Power On Self Test--POST).
- Identifies and checks peripherals, i.e. keyboard, mouse, etc.
- Searches for bootable devices based on BIOS settings.
- Looks for a Master Boot Record (MBR) at the first sector.
- Loads MBR content into memory, then passes control to it.

The Master Boot Record (MBR)

Things to know about the Master Boot Record (MBR):

- Holds GRUB Stage 1 code.
- Occupies the first 512 bytes of the booting device:
  - The MBR program code starts at offset 0000.
  - The MBR messages start at offset 008b.
  - The partition table starts at offset 01be.
  - The signature is at offset 01fe.
- Contains instructions on how to load the boot-loader.
- Contains a special signature to indicate its end.
- Activates or loads the boot-loader, which takes over the process (if the boot-loader is installed in the MBR).

MBR & GRUB Stage 1



The Master Boot Record is 512 bytes in size:

1.(000000 – 0001bd): GRUB Stage 1 boot code (446 bytes long)

2.(**0001be - 0001fd**) : Partition table (64 bytes long)

3.(**0001fe – 0001ff**): The boot code signature of 55aa which is 2 bytes long identifies the end of the MBR. If the BIOS can't find this marker, the MBR does not get loaded.

FYI: Extracting the MBR

```
# dd if=/dev/hda of=mbr.bin bs=512 count=1
# od -xa mbr.bin
```

GRUB – Stage 1 Errors

Four errors that can occur during stage 1:

- **Geometry:** The location of the stage2 or stage1.5 is not in the portion of the disk supported directly by the BIOS read call
- **Hard Disk**: The stage2 or stage1.5 is being read from a hard disk, and the attempt to determine the size and geometry of the hard disk failed.
- **Floppy**: Same as above, but issue is on the boot floppy.
- **Read Error:** A disk-read error happened while trying to read the stage 2 or stage1.5.s.

```
89 44 \.□D..pf1□.D.f.D
cd 13 .□B□.r.□.p□}□.□.
7c c6 s.□□...□.□..□.|□
d2 88 D□.f1□.□@f.D.1□.
88 d0 □□□..□.□@.D.1□.□
f7 34 □□.f..f□D|f1□f□4
44 0c .T.f1□f□t..T..D.
fe c1 ;D.}<.T.□□..L.□□
31 db .□.l.Z.t.□.p.□1□
1e b9 □..□.r*.□..H|`.□
26 42 ...□1□1□□□□.a□&B
00 eb |□.}□@.□.□.}□8.□
fe 47 .□.}□0.□.}□*.□□G
20 44 RUB .Geom.Hard D
72 00 isk.Read. Error.
00 00 □..□.□.□<.u□□...
80 00 ........□r.k....
00 01 A).□□□□□H.□1 ...
00 fe ...□.(?...□□H..□
00 fe □□.□□□VBd.k□□..□
55 aa □□.□□□.□h.□B□.U□
```

GRUB – Stage 1.5

What is Grub 1.5

- Read into memory by the Stage 1 boot loader, if necessary.
- Required by some hardware as an intermediate step to get to the Stage 2 boot loader.
- Located in the space immediately following the MBR.
- Knows about the boot files system; opens the file system on the specified partition.
- Looks for Stage 2 executable.

What Can Go Wrong (aka Stage 1.5 errors)

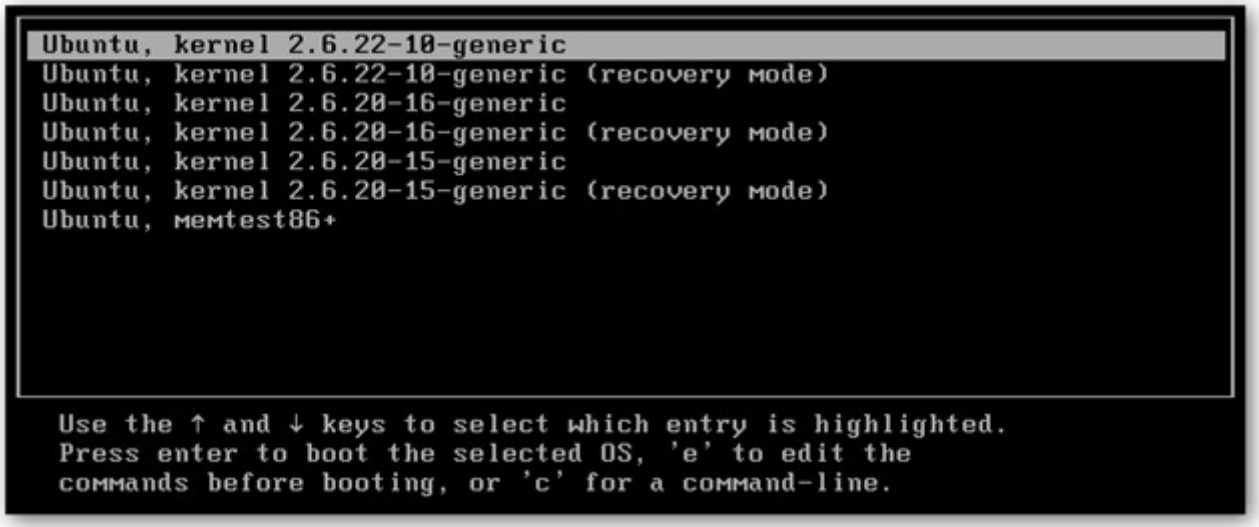
- Uses the same error list as stage 2.
- Will appear as 'Error #' with no accompanying error description (unlike stage 2). Example: If GRUB is unable to mount the designated partition:

  - Stage 1.5 error readout: `Error 17`
  - Stage 2 error readout: `Error 17: Cannot mount selected partition`

GRUB – Stage 2

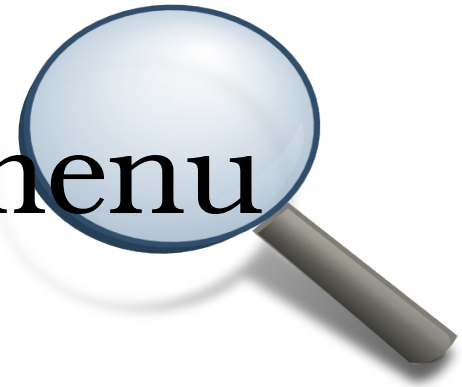
(What's on the Menu?)

- Opens menu.lst file in /boot/grub directory of the petition to be booted (or grub.conf on redhat).



- Reads instructions and if no manual intervention, boots specified kernel.
- Instructions contain pieces of information required to boot: root, kernel, and initrd.

GRUB – What's on the menu



```
title       Ubuntu 8.04.1, kernel 2.6.24-19-generic
root        (hd0,2)
kernel          /boot/vmlinuz-2.6.24-19-generic
   root=UUID=2762ce06-0457-41bb-9ea9-af99fd5eb172 ro quiet splash
initrd      /boot/initrd.img-2.6.24-19-generic
quiet
```

Other common commands for the GRUB menu

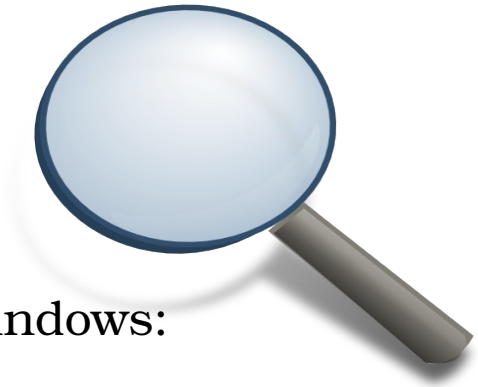
- **Default** – The menu selection that will boot if no human interaction occurs. Numbering starts at 0.
- **Fallback** -- if the default boot entry has any errors, instead of waiting for the user to do something, immediately start over using the num entry (same numbering as the default command (see default)). This obviously won't help if the machine was rebooted by a kernel that GRUB loaded. You can specify multiple fallback entry numbers.
- **Hiddenmenu** – hides the grub menu from view
- **Timeout** – Amount of time GRUB waits until booting the default.
- **Color** – Customizes grub menu colors
- **Splashimage** – Adds background image to GRUB menu display

Booting from `grub >`

Generally, GRUB can boot any Multiboot-compliant OS using the following commands:

- Set GRUB's root device to the drive where the OS images are stored.
  ```
  grub> root (hd0,2)
  ```
- Load the kernel image, set root partition.
  ```
  grub> kernel /vmlinuz root=/dev/sda3
  ```
- Load the initial ramdisk, if needed.
  ```
  grub> initrd /initrd.img
  ```
- If you need modules, load them via module or modulenounzip.
- Boot the operating system (boot).
  ```
  grub> boot
  ```

Booting Other OSes



GRUB can be used to boot other operating systems such Windows:

- Set GRUB's root device to the partition
  ```
  grub> rootnoverify (hd0,0)
  ```
- Set the active flag in the partition
  ```
  grub> makeactive
  ```
- Load the boot loader
  ```
  grub> chainloader +1
  ```
- Boot the operating system
  ```
  grub>  boot
  ```
- Booting Windows® from second hard disk:
  ```
  grub> root (hd1,0)
  grub> map (hd0) (hd1)
  grub> map (hd1) (hd0)
  grub> makeactive
  grub> chainloader +1
  grub> savedefault
  ```

Change GRUB Partition

If you install several distributions, it's quite possible that the pointer to the partition holding GRUB stage 2 could change:

```
grub> find /boot/grub/stage1
(hd0,2)
(hd0,6)
(hd0,7)
(hd0,9)

grub> root (hd0,2)

grub> setup (hd0)
Checking if "/boot/grub/stage1" exists... yes
Checking if "/boot/grub/stage2" exists... yes
Checking if "/boot/grub/e2fs_stage1_5" exists... yes
Running "embed /boot/grub/e2fs_stage1_5 (hd0)"...  17 sectors
  are embedded.
succeeded
Running "install /boot/grub/stage1 (hd0) (hd0)1+17 p
  (hd0,2)/boot/grub/stage2 /boot/grub/menu.lst"... succeeded
Done.
```

Adding Basic Bling To GRUB

- You can add color to the basic GRUB menu by adding this line :

```
color fore-color/back-color fore-color/back-color
```

- Syntax of this line consists of three elements: 1) command; 2) Normal color (fore/back); 3) highlighted color (fore/back

- Available background colors:
  - black
  - green
  - red
  - brown
  - blue
  - cyan
  - magenta
  - light-gray

- These below can be specified only for the foreground.
  - dark-gray
  - light-green
  - light-red
  - yellow
  - light-blue
  - light-cyan
  - light-magenta
  - white

- You can prefix blink- to foreground for a blinking foreground color.

Adding More Bling to GRUB

- GRUB can be configured to display an image when the menu is displayed.

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- Creating a nifty grub splash image requires a few simple steps:
  - Find your image
  - Reformat it to the following parameters:
  - Resize it to 640px X 480px (width and height respectively) using gimp or other image editor
  - Change color format to indexed with a maximum of 14 (gimp: Image > Mode > Indexed Colors. In the Maximum number of colors box, set to 14. Click OK)
  - Save as an '.xpm' file, e.g. grubsplashpic.xpm

- Implementing a nifty grub splash image.
  - Compress it using gzip. (gzip -c mygrubsplash.xpm > mygrubsplash.xpm.gz
  - Move it to the /boot/grub directory.
  - Modify menu.lst (or grub.conf) to point to your splash image: splashimage /boot/grub/splashimages/FILENAME.xpm.gz

Adding Bling to GRUB

Before

Adding Bling to GRUB

After

Tools for GRUB Menu

- Editing by hand using a text editor:
  - vi
  - emacs
  - kate
  - kwrite
  - nano

- Grub menu also can be edited graphically:
  - QGRUBEditor (qt-apps.org)
  - kgrubeditor (kde-apps.org)

The Future of GRUB

Will be replaced by GRUB2. (The original GRUB to be called GRUB Legacy)

- Replacement of Stage 1.5 with a compact core image
- Support for dynamic loading to the core image
- Trend towards making the overall GRUB framework object oriented
- Support for internationalization, such as non-ASCII character sets
- Support for different hardware architectures and different platforms (other than Linux)