Booting of a Computer System

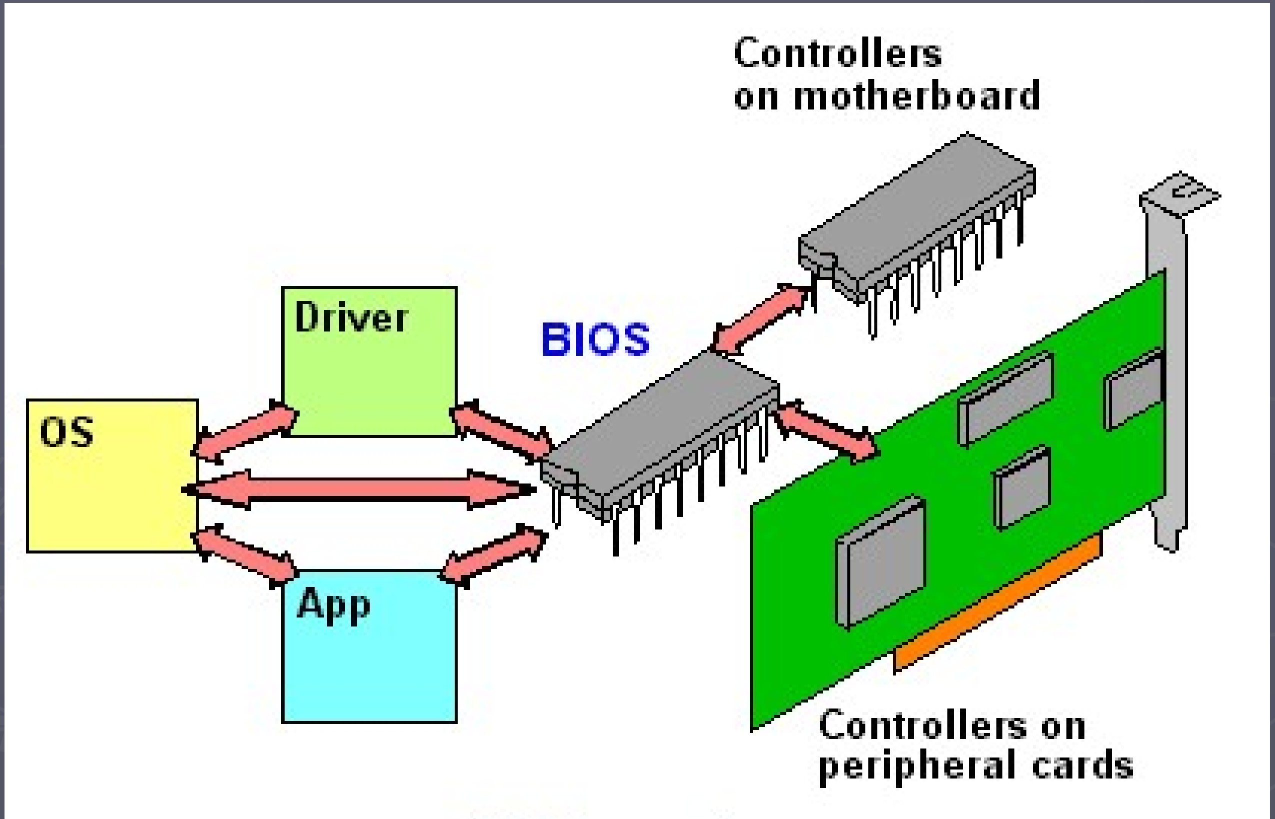
Why is Booting Required ?

- Hardware doesn’t know where the operating system resides and how to load it.
- Need a special program to do this job – Bootstrap loader.
    - E.g. BIOS – Basic Input Output System.
- Bootstrap loader locates the kernel, loads it into main memory and starts its execution.
- In some systems, a simple bootstrap loader fetches a more complex boot program from disk, which in turn loads the kernel.

How Boot process occurs ?

- Reset event on CPU (power up, reboot) causes instruction register to be loaded with a predefined memory location. It contains a jump instruction that transfers execution to the location of Bootstrap program.
- This program is form of ROM, since RAM is in unknown state at system startup. ROM is convenient as it needs no initialization and can’t be affected by virus.

BIOS Interaction

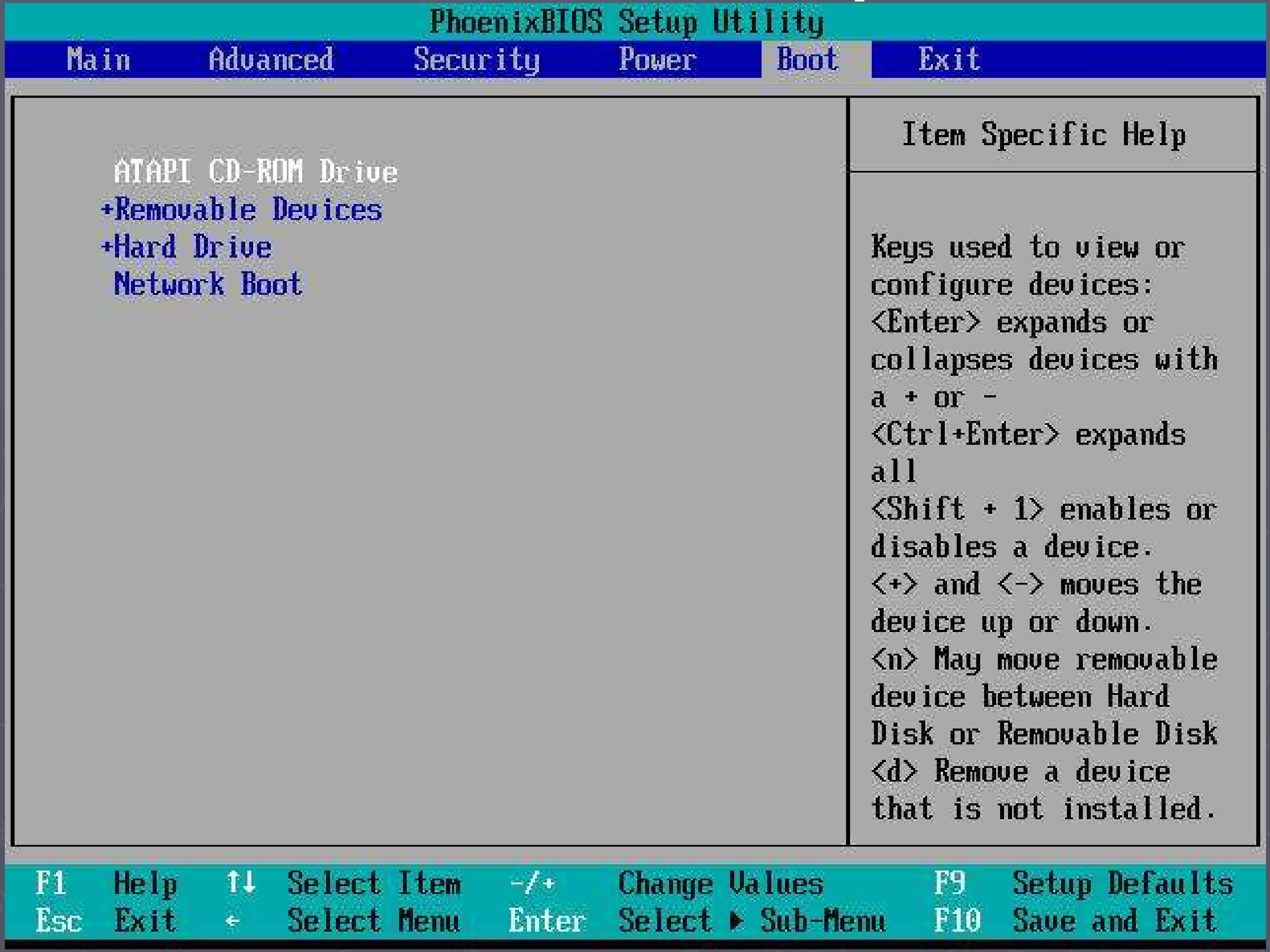


BIOS Interaction

Tasks performed at boot up

- Run diagnostics to determine the state of machine. If diagnostics pass, booting continues.
- Runs a Power-On Self Test (*POST*) to check the devices that the computer will rely on, are functioning.
- BIOS goes through a preconfigured list of devices until it finds one that is bootable. If it finds no such device, an error is given and the boot process stops.
- Initializes CPU registers, device controllers and contents of the main memory. After this, it loads the OS.

BIOS Setup



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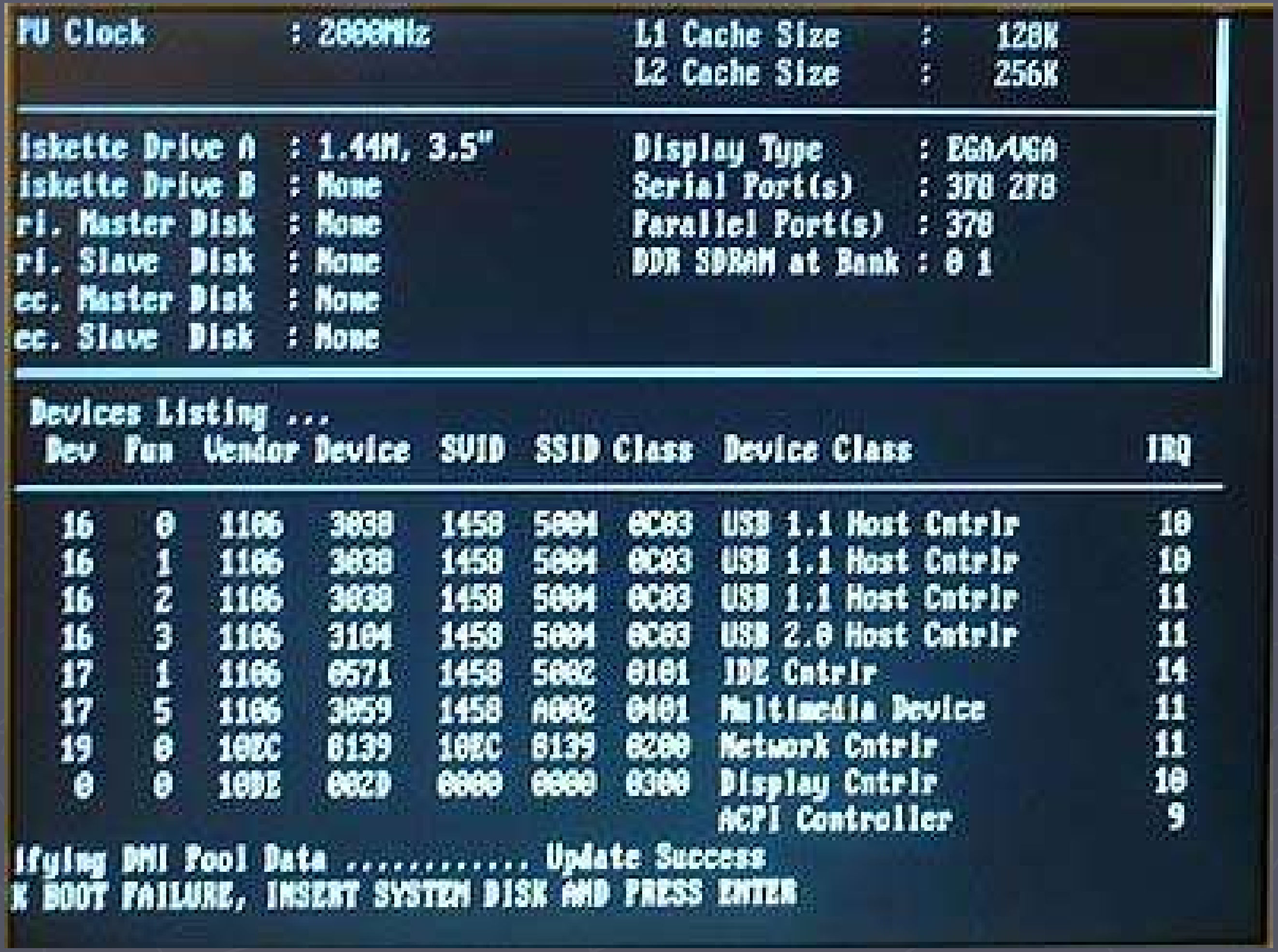
ATAPI CD-ROM Drive
+Removable Devices
+Hard Drive
 Network Boot
```

Item Specific Help

Keys used to view or configure devices:
<Enter> expands or collapses devices with a + or -
<Ctrl+Enter> expands all
<Shift + 1> enables or disables a device.
<+> and <-> moves the device up or down.
<n> May move removable device between Hard Disk or Removable Disk
<d> Remove a device that is not installed.

Boot Procedure



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PU Clock          : 2000MHz              L1 Cache Size     :    128K
                                         L2 Cache Size     :    256K

iskette Drive A  : 1.44M, 3.5"           Display Type      : EGA/VGA
iskette Drive B  : None                  Serial Port(s)    : 3F8 2F8
ri. Master Disk  : None                  Parallel Port(s)  : 378
ri. Slave  Disk  : None                  DDR SDRAM at Bank : 0 1
ec. Master Disk  : None
ec. Slave  Disk  : None

 Devices Listing ...
  Dev  Fun  Vendor Device  SVID  SSID Class  Device Class              IRQ

   16    0   1106   3038   1458  5004  0C03  USB 1.1 Host Cntrlr        10
   16    1   1106   3038   1458  5004  0C03  USB 1.1 Host Cntrlr        10
   16    2   1106   3038   1458  5004  0C03  USB 1.1 Host Cntrlr        11
   16    3   1106   3104   1458  5004  0C03  USB 2.0 Host Cntrlr        11
   17    1   1106   0571   1458  5002  0101  IDE Cntrlr                 14
   17    5   1106   3059   1458  A002  0401  Multimedia Device          11
   19    0   10EC   8139   10EC  8139  0200  Network Cntrlr             11
    0    0   10DE   002D   0000  0000  0300  Display Cntrlr             10
                                             ACPI Controller             9
ifying DMI Pool Data ............ Update Success
K BOOT FAILURE, INSERT SYSTEM DISK AND PRESS ENTER
```

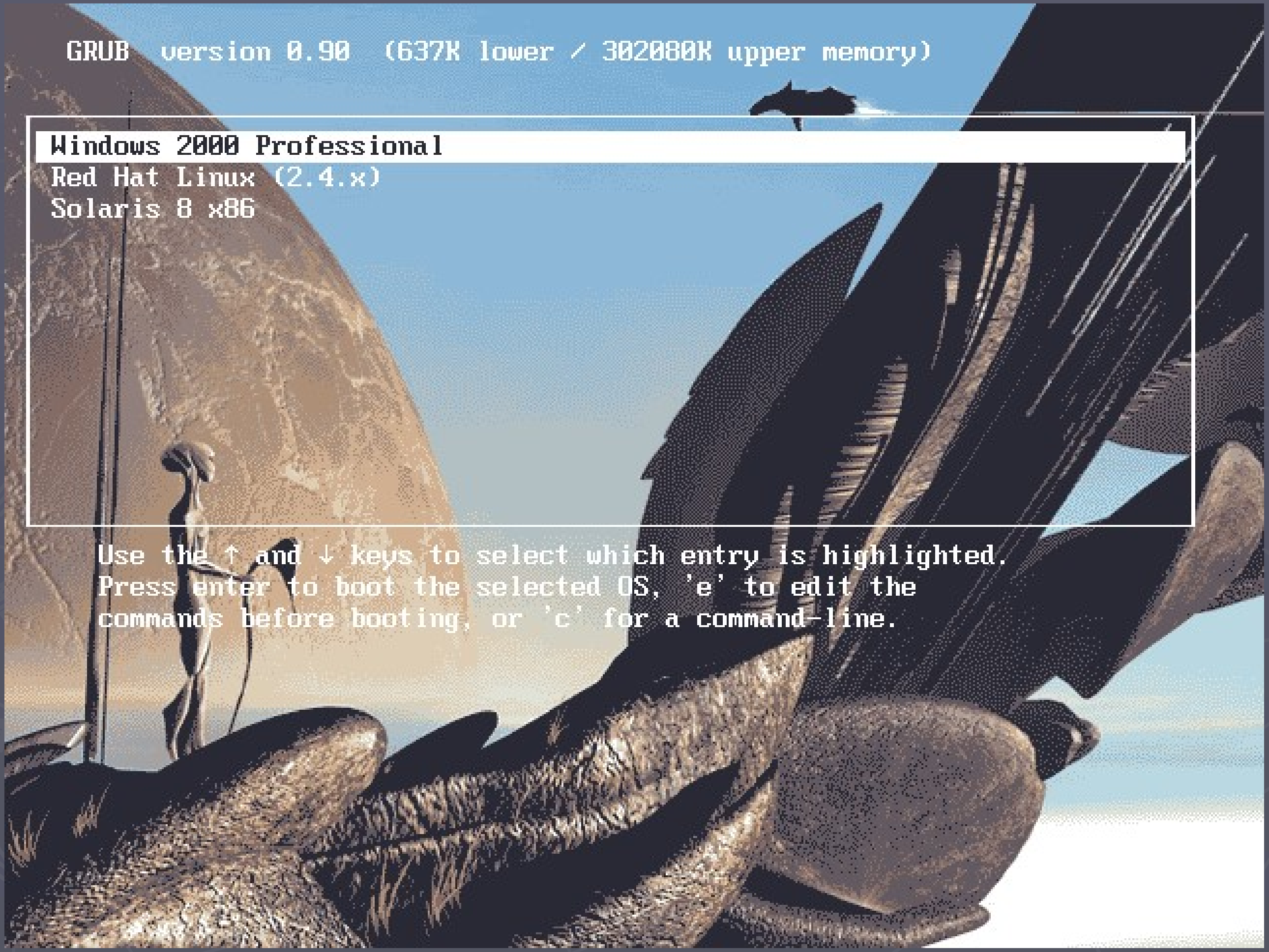
Tasks performed at boot up (Contd)

- On finding a bootable device, the BIOS loads and executes its boot sector. In the case of a hard drive, this is referred to as the master boot record (*MBR*) and is often not OS specific.
- The MBR code checks the partition table for an active partition. If one is found, the MBR code loads that partition's boot sector and executes it.
- The boot sector is often operating system specific, however in most operating systems its main function is to load and execute a kernel, which continues startup.

Secondary Boot Loaders

- If there is no active partition or the active partition's boot sector is invalid, the MBR may load a secondary boot loader and pass control to it and this secondary boot loader will select a partition (often via user input) and load its boot sector.
- Examples of secondary boot loaders
  - GRUB – GRand Unified Bootloader
  - LILO – LInux LOader
  - NTLDR – NT Loader

GRUB Loader



```
GRUB  version 0.90  (637K lower / 302080K upper memory)

 Windows 2000 Professional
 Red Hat Linux (2.4.x)
 Solaris 8 x86

    Use the ↑ and ↓ keys to select which entry is highlighted.
    Press enter to boot the selected OS, 'e' to edit the
    commands before booting, or 'c' for a command-line.
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Booting and ROM

- System such as cellular phones, PDAs and game consoles stores entire OS on ROM. Done only for small OS, simple supporting hardware, and rugged operation.
- Changing bootstrap code would require changing ROM chips.
  - EPROM – Erasable Programmable ROM.
- Code execution in ROM is slower. Copied to RAM for faster execution.

Example : DOS

- After identifying the location of boot files, BIOS looks at the first sector (512 bytes) and copies information to specific location in RAM (7C00H) - Boot Record.
- Control passes from BIOS to a program residing in the boot record.
- Boot record loads the initial system file into RAM. For DOS, it is IO.SYS .
- The initial file, IO.SYS includes a file called SYSINIT which loads the remaining OS into the RAM.
- SYSINIT loads a system file MSDOS.SYS that knows how to work with BIOS.
- One of the first OS files that is loaded is the system configuration file, CONFIG.SYS in case of DOS. Information in the configuration file tells loading program which OS files need to be loaded (e.g. drivers)
- Another special file that is loaded is one which tells what specific applications or commands user wants to be performed as part of booting process. In DOS, it is AUTOEXEC.BAT. In Windows, it’s WIN.INI .

References

- Operating System Principles – Silberchatz, Galvin and Gagne.
- http://en.wikipedia.org/wiki/Booting
- http://computer.howstuffworks.com/bios2.htm

Questions

- What is the effect on boot sector and boot loader when you install two OS, for e.g. Windows and Linux in two separate partitions ?
- Suppose, you install Windows first. The default boot loader installed in MBR is NTLDR and contains information regarding the active partition of Windows. When you install Linux on this system, the installation prompts to overwrite a new secondary boot loader which identifies both Windows and Linux active partitions and therefore we get a choice of booting the desired OS when the system is started.

  In contrast, if Linux is installed first and then Windows, the Windows Installer overwrites the MBR with its own boot loader which doesn't recognize the Linux active partition. This creates a problem. The problem can be corrected by using a LiveCD or any bootable disc which can be used to reinstall a secondary boot loader which identifies both the OS and gives true choice.

Questions

- (1) Why is ROM slower than RAM ?

  (2) How is the boot loader copied from ROM to RAM ?

- (1) Semi-conductor Technology used in constructing these two type of memories gives the answer. RAM is based on positive feedback/capacitive charge for storing the information while ROM contains permanent and non-changeable information stored in its structure.

  (2) There is a small routine loaded by the BIOS which does this task. This routine could also be part of BIOS (though not sure).

Questions

- Examples of Applications that access the BIOS directly.
- Windows Server 2003 SP1 versions of the Windows Preinstallation Environment (WinPE) - http://www.microsoft.com/technet/prodtechnol/windowsserver2003/library/BookofSP1/e0f862a3-cf16-4a48-bea5-f2004d12ce35.mspx
- The operating system and application programs both directly access BIOS routines to provide better compatibility for such functions as screen display.

Questions

- If I have only a single OS, is there a secondary boot loader present on the system ?
- Older machines might not have this feature. But now-a-days, even Windows is installed with a default secondary boot loader (NTLDR). Linux is also installed usually with LILO or GRUB as the default boot loader.

  You might have also encountered that your system (Windows) is not able to boot after flashing the BIOS and is displaying the message "NTLDR missing". This is because the primary boot loader transfer to NTLDR which might have become corrupt or deleted by mistake.

Questions

- Difference between Boot Loader and Boot Manager ?
- Basically, these two are different but are sometimes combined into a single program.
- IBM's Boot Manager, PowerQuest's BootMagic and V Communications' System Commander are some examples of boot managers.
- **Dual booting** is the act of installing multiple operating systems on a computer, and being able to choose which one to boot when switching on the computer. The program, which makes dual booting possible is called a boot loader.

Information

- Dual Boot
- In the OS/2 world, the term *dual boot* has a more specific meaning.
- In a *dual boot* installation, two (or more) operating systems are installed in a *single* partition. Selection of which operating system to boot is performed by running a *dual boot* utility program, which switches around the necessary boot loaders programs (by renaming files and copying boot sectors) to ensure that the chosen operating system is loaded at the next boot.
- In a *boot manager* installation, by contrast, the two (or more) operating systems are installed in their own, separate, individual, partitions. Rather than booting directly into an operating system, the machine boots into a specialised, operating system neutral, boot loader program (such as IBM's eponymous *Boot Manager*) installed on a floppy disk or in its own partition on a hard disk. This boot loader program presents a list of the available bootable partitions from which the user can choose, and then loads and invokes the boot loader in the boot sector of the chosen partition, to boot the chosen operating system.

Information

- When installing an OS on a computer from scratch, here is how the partition table is created.
- The hard disk is denoted as “hda” where hd=hard disk, and the third letter could mean the hard-disk on the system. For e.g. the first hard disk is “hda”, the second is “hdb”.
- When the partitioning is done, “hda0” is the place of MBR. “hda1” is the primary partition. Then a secondary partition may be created which is further subdivided into logical drives. Another OS could be installed on any of these logical drives.
- hda0 – MBR

  hda1 – Primary Partition e.g. Windows XP

  hda2 – Secondary Partition

  - hda3 – Logical Drive 1 (FAT32 or NTFS partition)
  - hda4 – Logical Drive 2 (FAT32 or NTFS partition)
  - hda5 – Logical Drive 3 (Swap for Linux Partition)
  - hda6 – Logical Drive 4 (Root for Linux Partition)

The above example is a simple example. Specific cases can be different.

Information

- When the kernel is being loaded, the control is in the privileged mode. If the user is allowed to login in the same mode, any user will be “root” or “administrator” (super-user). When the booting is almost complete, which is with the privileged right. But this login program, after verifying your password, gives you a shell by creating another process which intentionally drops the super-user privileges and assume the privileges of this user. Login program is trusted by the kernel. If that is hacked or replaced, you can get a root shell from any login.