Linux Administration - The Beginning

Maruthi Inukonda
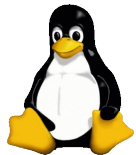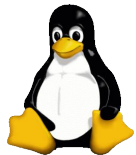
21st Feb 2018

Speaker

- Maruthi Seshidhar Inukonda
- Currently Ph.D(CSE) student at CANDLE lab@CSE, IIT Hyderabad.
- M.Tech (CSE) from IIT Roorkee
- Worked in operating systems' storage stack R&D for 13.5 years in the industry (Veritas, NetApp, EMC^2)
- Using Linux from 18 years.
- Member of SNIA, CCICI, Linux, CentOS, Openstack, Ceph.

Agenda

- Introduction
- Architecture
- Users and Groups
- Processes
- Packages
- Storage
- Networking

Introduction

Brief history

Linux
- Powering 90% of today's Internet.
- Initially developed by Linus Torvalds in 1991
- Written in C and assembly language
- Open sourced under GNU Public License (GPL).
- Actively maintained by Linux community
- About 14000 passionate developers in the Linux community.
- About 1000 code changes per day.

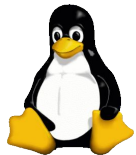Linus Torvalds

What is Linux? (1/2)

Linux is
- Multi-User
- Multi-Tasking
- Multi-Processing
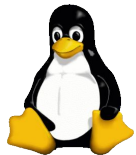- Multi-Tenant

Unix like operating system

Linux is not
- Distributed
- Cloud

operating system

What is Linux? (2/2)

- Free and secure

- Can run on 30 different architectures
  x86, ARM, ppc, …

- Can run on any size computer.
  Mobiles, PC, servers, embedded, supercomputers, …

- Being open source allows OS research &
  development

Linux, Fork, Distribution

Linux (more formally GNU/Linux)
- Kernel code from kernel.org
- Tools and libraries code from gnu.org
- Akin to river water

Linux fork
- Forks from Linux mainline
- Merges into mainline periodically
- Akin to tributaries

Linux distribution (aka Distro)
- Tested, packaged open source software
- Optional GUI from gnome.org, kde.org, ...
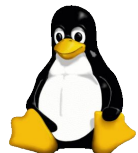 Akin to purified bottled water.

```
$ uname -o
GNU/Linux
```
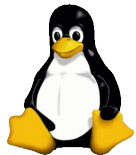
Linux distributions (1/4)

- Community supported & free
  - Cent OS
  - Fedora Core
  - Ubuntu
  - Debian
  - Open SuSe
  - Slackware
  - Arch Linux
  - many more ...

Linux distributions (2/4)

- Company supported & commercial
  - Red Hat Enterprise Linux (RHEL)
  - Ubuntu Server
  - SuSE Linux Enterprise Server (SLES)
  - Oracle unbreakable Enterprise Linux (OEL)
  - few more ...

Linux distributions (3/4)

- ## For desktop/laptop
  - Ubuntu desktop
  - Fedora Core
  - Open SuSe

- ## For server
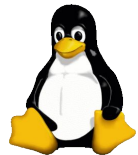 - Ubuntu server
  - CentOS
  - RHEL/Debian/SLES/OEL

- ## For kernel development
  - Slackware
  - ArchLinux

Note: Command line administration of Linux is applicable for servers and desktop/laptops. This presentation focuses primarily on command line administration.
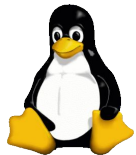
Linux distributions (4/4)

- rpm based
  - Fedora Core/OpenSuse
  - RHEL/CentOS/SLES/OEL
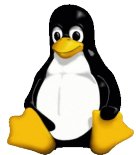
- deb based
  - Ubuntu server/desktop
  - Debian

Architecture

Linux Architecture - CLI

- Hardware
  - ➢ CPU, Memory, Disk, Graphics, Network, etc
- Kernel
  - ➢ Process, Memory, File, Network subsystems, Device drivers
- System Calls
  - ➢ read, write, fork, exec, clone, etc
- System Libraries
  - ➢ libc, libpthread, etc
- Commands & System programs
  - ➢ cd, ls, mkdir, top, vi, gcc, etc
- Command Line Interface (CLI) (Shell)
  - ➢ bash, sh, etc
- Command line applications
  - ➢ pine, git, gdb, etc
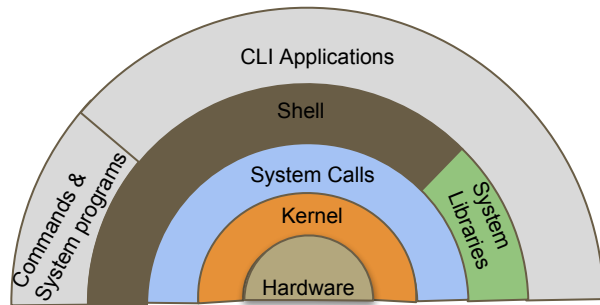
Linux Architecture - GUI

- Hardware
  - ➢ CPU, Memory, Disk, Graphics, Network, etc
- Kernel
  - ➢ Process, Memory, File, Network subsystems, Device drivers
- System calls
  - ➢ read, write, fork, exec, clone, etc
- System Libraries
  - ➢ libc, libpthread, etc
- Commands & System programs
  - ➢ cd, ls, mkdir, top, vi, gcc, etc
- Command Line Interface (CLI) (Shell)
  - ➢ bash, sh, etc
- **Graphical User Interface (GUI)**
  - ➢ X-Windows (Gnome, KDE, etc)
- Applications
  - ➢ Browser, eMail client, office suite, etc
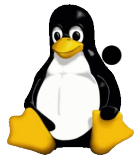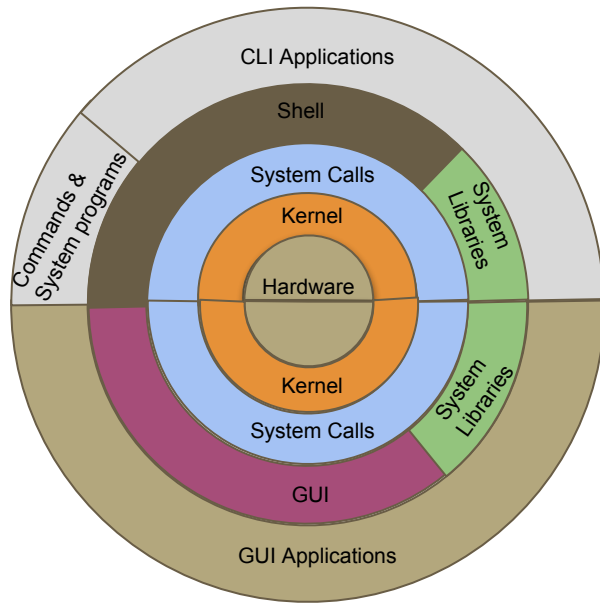
Kernel

```
# ls -lR /boot
-rw-r--r-- 1 root root  1240067 Jul 13  2016 abi-4.4.0-31-generic
-rw-r--r-- 1 root root   189558 Jul 13  2016 config-4.4.0-31-generic
drwxr-xr-x 5 root root     4096 Nov 14  2016 grub
-rw-r--r-- 1 root root 35907255 Nov 14  2016 initrd.img-4.4.0-31-generic
...
-rw------- 1 root root  3866473 Jul 13  2016 System.map-4.4.0-31-generic
-rw-r--r-- 1 root root  7047520 Nov 14  2016 vmlinuz-4.4.0-31-generic


# ls -lR /boot/grub
...
-rw-r--r-- 1 root root      712 Jul 20  2016 gfxblacklist.txt
-r--r--r-- 1 root root     8432 Nov 14  2016 grub.cfg
-rw-rw-r-- 1 root root     1024 Feb  2 10:40 grubenv
drwxr-xr-x 2 root root    12288 Nov 14  2016 i386-pc
...
```
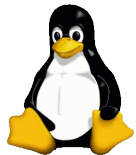
System calls

- Entry points into the kernel.

- C language APIs.

- About 400 system calls
  - open(), read(), write(), close(), ioctl()
  - fork(), wait(), clone()
  - socket(), connect(), accept(), shutdown()
  - mmap(), munmap(), fadvise()
  - ...

$ `man syscalls`

Shell

- First process after login
- Interprets and launches commands keyed-in at the command prompt

- Commonly used shells are
  - bash
  - sh

- Types of shells
  - root vs non-root shell (# vs $ prompt)
  - login vs non-login shell (-bash vs bash)

- Interpreter for shell scripts

```
maruthisi@godavari:~$ _
```

```
root@godavari:~# _
```

Commands

- Programs that are keyed-in by user and launched by shell

- Types of commands
  - Internal (builtin) commands
  - External commands

- Internal commands
  - Implemented by the shell itself.
    echo, fg, bg, cd, ...

- External commands
  - Implemented by programs in /bin or /sbin directory.
    ls, mkdir, top, df, ...

```
$ type cd
cd is a shell builtin

$ type mkdir
mkdir is /bin/mkdir
```
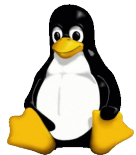
```
$ man ls
```
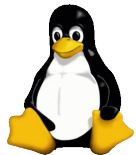
Users and Groups

Users (1/3)

- User is an account for
  - A super user (root)
  - A person
  - A service

- An integer number (UID) is assigned to each user account (/etc/passwd file)

- root has UID = 0

Users (2/3)

```
# useradd -s /bin/bash -m maruthisi
# useradd -s /bin/sh -m jyothin

# cat /etc/passwd
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
...
amits:x:10001:10001::/home/amits:/bin/nologin
sohailm:x:11001:11001::/home/sohailm:/bin/sh
davidk:x:20001:20001::/home/davidk:/bin/bash
maruthisi:x:20201:20201::/home/maruthisi:/bin/bash
jyothin:x:20202:20202::/home/jyothin:/bin/sh

# id maruthisi
uid=20201(maruthisi) gid=20201(maruthisi) groups=20201(maruthisi)
```
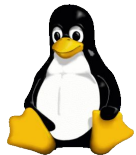
Passwords

```
# passwd maruthisi

# cat /etc/shadow
root:!:17119:0:99999:7:::
daemon:*:17001:0:99999:7:::

...
amits:$6$IRU45oem$RcHnDVg459/1GXNwRJmz7wqsyyfzb95k.6WEMV2Du04yf/lz0:17564:0:99999:7:::
sohailm:$6$FKFYEysx$xvwpzSRJPq1hLtlH577YQZJKLHX9.RCp01KKry6A2guclV0:17564:0:99999:7:::
jyothin:$6$NU9mvrF4$bgHrQxIV24lMlHynK2Mxefbo1UC9gMpcKNzCVaK/8mA9IS.:17564:0:99999:7:::
maruthisi:$6$WT483SxE$bzsX290lzla/nb8NZ6X2c3u0OFdhpcv.BynwFqP5.UPr1:17564:0:99999:7:::
```
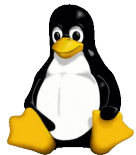
Note: ! or * in the beginning of second field, locks the account.

Groups (1/2)

Group is
- A logical collection of user accounts
- An integer number (GID) is assigned to each group (/etc/group file)
- Each user
  - Must belong to one primary group (preferably solo group)
  - May belong to many supplementary groups

Eg:
- All Ph.D CSE students from 2018 January
  ```
  cs18resch01
  ```
- All sudo users
- A solo group
  ```
  maruthisi
  ```

Groups (2/2)

```
# cat /etc/group
root:x:0:
daemon:x:1:
sudo:x:27:owner
...
maruthisi:x:20201:
jyothin:x:20202:


# id maruthisi
uid=20201(maruthisi) gid=20201(maruthisi) groups=20201(maruthisi)
```

Supplementary groups

```
# groupadd cs18resch01

# cat /etc/group
..
sudo:x:27:owner
...
cs18resch01:x:2051:

# usermod -aG sudo maruthisi
# usermod -aG cs18resch01 maruthisi
# usermod -aG cs18resch01 jyothin

# cat /etc/group
...
sudo:x:27:owner,maruthisi
...
cs18resch01:x:2051:maruthisi,jyothin

# id maruthisi
uid=20201(maruthisi) gid=20201(maruthisi) groups=20201(maruthisi),27(sudo),2051(cs18resch01)
```
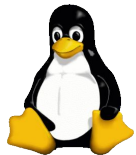
Home directories

- A directory in /home created one for each user
- Starting directory after login.
- Special character is ~

- Permissions play a key role for securing files from other users, other groups, others in the world.
- UMASK in `/etc/login.defs` should be set to 077.

- Per user storage space quotas can be enforced at home directory level.

Home directories

```
# ls -l /home/
total 36
drwx------  2 amits     amits        4096 Feb  2 10:50 amits
drwx------  2 davidk    davidk       4096 Feb  2 10:51 davidk
drwx------  2 jyothin   jyothin      4096 Feb  2 10:59 jyothin
drwx------  2 maruthisi maruthisi    4096 Feb  2 10:52 maruthisi
drwx------ 17 owner     owner        4096 Feb  2 11:19 owner
...
```

Users (3/3)

- To lock a user account from login

  ```
  # userdel -L jyothin
  ```

- To unlock a user account from login

  ```
  # userdel -U jyothin
  ```

- To delete a user account and home directory [irrecoverable]

  ```
  # userdel -r jyothin
  ```
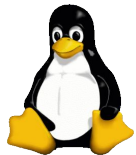
Processes

Processes

- A running program
- An integer number (PID) is used for uniquely identifying a process.

- Background processes are called daemons
- Foreground processes are called interactive

- Each process is launched from an user account.
- Daemons are launched from service accounts or root.
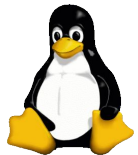
Processes tree

- All processes in a system form a hierarchy.

- The first process in the system is
  - init (in older distros, prior to 2016)
  - systemd (in current distros)

- Each process (except init/systemd) has unique parent (PPID)

```
# pstree
systemd-+-NetworkManager-+-dhclient
        |                 |-{NetworkManager}
        |                 |-{gdbus}
        |                 `-{gmain}
        |-acpid
        |-avahi-daemon---avahi-daemon
        |-crond
        |-login---bash---pstree
        |-smartd
        |-sshd
        |-systemd---(sd-pam)
        |-systemd-journal
        |-systemd-logind
        |-systemd-udevd
        `-wpa_supplicant
```

Note: This output is from an Ubuntu server (which does not come with GUI). The process tree has very few processes.

Listing processes (ubuntu)

- List processes in current login session
- List all processes in a system

```
$ ps -f
UID          PID   PPID  C STIME TTY       TIME      CMD
owner        2841  2834  0 05:51 pts/4    00:00:00 bash
owner        4970  2841  0 06:37 pts/4    00:00:00 ps -f

$ ps -ef
UID          PID   PPID  C STIME TTY       TIME      CMD
root         1     0     0 05:46 ?        00:00:01 /sbin/init splash
root         2     0     0 05:46 ?        00:00:00 [kthreadd]
root         27    2     0 05:46 ?        00:00:01 [kswapd0]
...
owner        1313  1     0 05:47 ?        00:00:00 /lib/systemd/systemd --user
...
owner        2834  1367  0 05:51 ?        00:00:07 /usr/lib/gnome-terminal/gnome-terminal
owner        2841  2834  0 05:51 pts/4    00:00:00 bash
owner        4971  2841  0 06:37 pts/4    00:00:00 ps -ef
...
```

Note: One in [ ] are kernel processes.

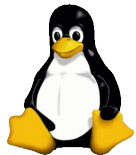# Listing processes (fedora)

- List processes in current login session
- List all processes in a system

```
$ ps -f
UID         PID    PPID   C STIME TTY          TIME      CMD
maruthi+    2734   2730   0 03:39 pts/0   00:00:00 bash
maruthi+    4542   2734   0 07:00 pts/0   00:00:00 ps -f

$ ps -ef
UID         PID    PPID   C STIME TTY      TIME      CMD
root        1      0      0 03:34 ?        00:00:02 /usr/lib/systemd/systemd --switched-root ...
root        2      0      0 03:34 ?        00:00:00 [kthreadd]
root        53     2      0 03:34 ?        00:00:06 [kswapd0]
...
maruthi+    2730   1      0 03:39 tty2     00:00:09 /usr/libexec/gnome-terminal-server
maruthi+    2734   2730   0 03:39 pts/0   00:00:00 bash
maruthi+    4431   2734   0 06:58 pts/0   00:00:00 ps -ef
...
```
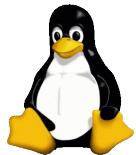
Packages

Online package management

- Packages are available online in repositories

- Repository is like warehouse of packages.
- Maintained by distribution vendors and other third parties

- Repository management tool
  - apt for Ubuntu/Debian
  - yum or dnf for CentOS/Fedora/RHEL/SuSE
- Repo tools automatically download and install prerequisite packages.

Installation using apt

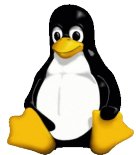- Install a package using `apt install <package_name>`

```
$ sudo apt install lsscsi
[sudo] password for owner:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
  lsscsi
0 upgraded, 1 newly installed, 0 to remove and 320 not upgraded.
Need to get 31.9 kB of archives.
After this operation, 110 kB of additional disk space will be used.
Get:1 http://in.archive.ubuntu.com/ubuntu xenial/main amd64 lsscsi amd64 0.27-3 [31.9 kB]
Fetched 31.9 kB in 0s (42.0 kB/s)
Selecting previously unselected package lsscsi.
(Reading database ... 210867 files and directories currently installed.)
Preparing to unpack .../lsscsi_0.27-3_amd64.deb ...
Unpacking lsscsi (0.27-3) ...
Processing triggers for man-db (2.7.5-1) ...
Setting up lsscsi (0.27-3) ...
```

Querying using apt

- List a single package using `apt list --installed <package_name>`
- List all packages using `apt list --installed`

```
$ sudo apt list --installed lsscsi
Listing... Done
lsscsi/xenial,now 0.27-3 amd64 [installed]
```
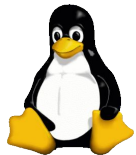
Uninstallation using apt

- Uninstall a package using `apt remove <package_name>`
- Uninstall a package and purge all configuration files using `apt purge <package_name>`

```
$ sudo apt remove lsscsi
(Reading database ... 210874 files and directories currently installed.)
Removing lsscsi (0.27-3) ...
Processing triggers for man-db (2.7.5-1) ...

$ sudo apt list
Listing... Done

$ sudo apt purge lsscsi
...
```

Installation using yum

- Install the package using `yum install`
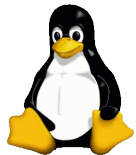
```
# yum install lsscsi
```

Querying using yum

- List a single package using `yum list <package_name>` or `yum info`
- List all packages using `yum list installed`

```
# yum list lsscsi
lsscsi.x86_64                        0.28-1.fc22                        @System

# yum list installed
Installed Packages
...
fedora-release.noarch                22-1                               @System
...
lsscsi.x86_64                        0.28-1.fc22                        @System
...
```
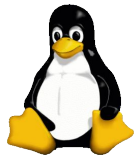
Uninstallation using yum

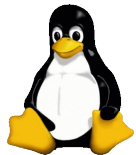- Uninstall a package using yum remove

```
# yum remove lsscsi

# yum list installed lsscsi
Error: No matching Packages to list
```

Offline package management

- Package management tool
  - dpkg for Ubuntu/Debian
  - rpm for Fedora/CentOS/RHEL/SuSE

Installation using dpkg

- Download a package from Internet or Copy from CD/DVD
- Install the package using dpkg

```
$ ls -l lsscsi_0.27-3_amd64.deb
-rw-r--r-- 1 owner owner 31884 Oct 25  2014 lsscsi_0.27-3_amd64.deb

$ sudo dpkg -i lsscsi_0.27-3_amd64.deb
[sudo] password for owner:
Selecting previously unselected package lsscsi.
(Reading database ... 210867 files and directories currently installed.)
Preparing to unpack lsscsi_0.27-3_amd64.deb ...
Unpacking lsscsi (0.27-3) ...
Setting up lsscsi (0.27-3) ...
Processing triggers for man-db (2.7.5-1) ...
```
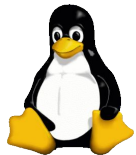
Querying using dpkg

- List a single package using `dpkg -l <package_name>`
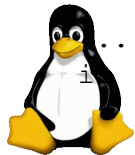- List all packages using `dpkg -l`

```
$ sudo dpkg -l lsscsi
Desired=Unknown/Install/Remove/Purge/Hold
| Status=Not/Inst/Conf-files/Unpacked/halF-conf/Half-inst/trig-aWait/Trig-pend
|/ Err?=(none)/Reinst-required (Status,Err: uppercase=bad)
||/ Name            Version        Architecture Description
+++-==============-=============-============-=================================
ii  lsscsi         0.27-3         amd64        list all SCSI devices (or hosts)

$ sudo dpkg -l
||/ Name            Version        Architecture Description
+++-==============-=============-============-=================================
ii  python3        3.5.1-3        amd64        interactive high-level object-oriented language
                                               (default python3 version)
...
i   lsscsi         0.27-3         amd64        list all SCSI devices (or hosts)
```
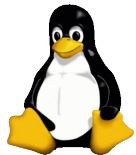
Uninstallation using dpkg

- Uninstall a package using `dpkg -r`
- Uninstall a package and purge all its configuration files using `dpkg -P`

```
$ sudo dpkg -r lsscsi
(Reading database ... 210874 files and directories currently installed.)
Removing lsscsi (0.27-3) ...
Processing triggers for man-db (2.7.5-1) ...

$ sudo dpkg -l lsscsi
dpkg-query: no packages found matching lsscsi

$ sudo dpkg -P lsscsi
(Reading database ... 210874 files and directories currently installed.)
Removing lsscsi (0.27-3) ...
Processing triggers for man-db (2.7.5-1) ...
```
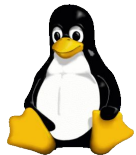
Installation using rpm

- Download a package from Internet or Copy from CD/DVD
- Install the package using `rpm -i`

```
$ ls -l lsscsi-0.28-1.fc22.x86_64.rpm
-rw-r--r--. 1 root root 56156 Feb  3 07:13 lsscsi-0.28-1.fc22.x86_64.rpm

# rpm -iv lsscsi-0.28-1.fc22.x86_64.rpm
Preparing packages...
lsscsi-0.28-1.fc22.x86_64
```

Querying using rpm

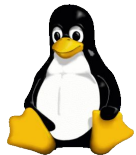- List a single package using `rpm -q <package_name>` or `rpm -qi`
- List all packages using `rpm -qa --last`

```
# rpm -q lsscsi
lsscsi-0.28-1.fc22.x86_64

# rpm -qa --last
ktouch-15.04.0-1.fc22.x86_64            Fri 19 Jan 2018 07:30:24 PM IST
...
lsscsi-0.28-1.fc22.x86_64              Mon 30 Nov 2015 07:52:59 PM IST
...
fedora-release-22-1.noarch            Fri 22 May 2015 12:25:09 AM IST
```
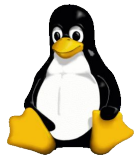
Uninstallation using rpm

- Uninstall a package using rpm -e

```
$ rpm -e lsscsi

$ rpm -q lsscsi
package lsscsi is not installed
```

Storage

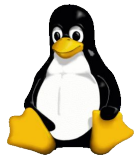# Disks

- Secondary storage device
- Accessible in units of sectors (512B, 1KiB or 4KiB)
- List all disk devices using `lsscsi`.

```
$ lsscsi
[0:0:1:0]   cd/dvd   TSSTcorp CDW/DVD SH-M522C TS04   /dev/sr0
[2:0:0:0]   disk     ATA      ST3500418AS      CC38   /dev/sda
[3:0:0:0]   disk     ATA       SEAGATE ST330006 NS00  /dev/sdb
[5:0:0:0]   disk     ATA       HITACHI HUA72202 N100  /dev/sdc
```

Disk partitioning

- Partition is a contiguous region on a hard disk for
  - file system
  - swap space
  - logical volumes

- OS manages information in each partition separately.

- Two types of disk partitioning schemes
  - Master Boot Record (MBR)
  - GUID Partition Table (GPT)

Master Boot Record (MBR) (1/2)

- Mostly used format for DOS PCs invented in 1987
- Does not support more than 15 partitions.
  - 4 primary
  - 3 primary + 12 logical
- Supports sector size of 512B only
- Does not support larger than 2TiB disks
- Prone to security issues (rootkit)
- This works with traditional motherboard firmware (BIOS)

Master Boot Record (MBR) (2/2)

- A sample MBR partition table
- List all disks' partitions using `parted -l` or `fdisk -l`

```
# parted -l
Model: ATA ST3500418AS (scsi)
Disk /dev/sda: 500GB
Sector size (logical/physical): 512B/512B
Partition Table: msdos
Disk Flags:

Number  Start    End     Size    Type      File system       Flags
 1      1049kB   538MB   537MB   primary   ext4              boot
 2      538MB    15.6GB  15.0GB  primary   ext4
 3      15.6GB   31.7GB  16.1GB  primary   xfs
 4      31.7GB   500GB   468GB   extended
 5      31.7GB   246GB   215GB   logical   xfs
 6      246GB    264GB   17.2GB  logical   linux-swap(v1)
 7      264GB    500GB   237GB   logical   ext4
```
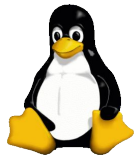
GUID Partition Table (GPT) (1/2)

- New format invented in 2005
- Support upto 4 million partitions.
- Supports upto 9.4 ZiB disks
- Supports sector sizes of 512B, 1KiB, 4KiB
- Addresses security issues (rootkit) using Secure boot feature
  - Ubuntu, RHEL support
  - Windows 8.x
  This requires newer motherboard firmware (UEFI)

GUID Partition Table (GPT) (2/2)

- A sample GPT disk
- List all disks' partitions using `parted -l`

```
# parted -l
Model: ATA SEAGATE ST330006 (scsi)
Disk /dev/sdb: 3001GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt
Disk Flags:

Number  Start    End     Size     File system     Name          Flags
 1      1049kB   3146kB  2097kB                                  bios_grub
 2      3146kB   21.0GB  21.0GB   ext4            fc18          msftdata
 3      21.0GB   41.9GB  21.0GB   ext3            centos        boot, esp
 4      41.9GB   62.9GB  21.0GB   ext4            fc18-gold     msftdata
 5      62.9GB   83.9GB  21.0GB   ext3            centos-gold   msftdata
 6      83.9GB   189GB   105GB    ext3            home          msftdata
 7      189GB    222GB   33.3GB   linux-swap(v1)  swap
 9      222GB    2222GB  2000GB   xfs             MyDrive       msftdata
10      2222GB   3001GB  779GB    xfs             MySpare       msftdata
```
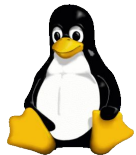
Block devices

- OS creates a logical block device layer on disk, its partitions
- Accessible in units of 512B, 1KiB, 4KiB.
- Main purpose is caching and ordering I/O.
- List all block devices using `lsblk -p`

```
$ lsblk -p
NAME          MAJ:MIN RM    SIZE RO TYPE MOUNTPOINT
/dev/sda        8:0    0 465.8G  0 disk
├─/dev/sda1     8:1    0   512M  0 part
├─/dev/sda2     8:2    0    14G  0 part
├─/dev/sda3     8:3    0    15G  0 part /
├─/dev/sda4     8:4    0     1K  0 part
├─/dev/sda5     8:5    0   200G  0 part /home
├─/dev/sda6     8:6    0    16G  0 part [SWAP]
└─/dev/sda7     8:7    0 220.3G  0 part
/dev/sr0       11:0    1  1024M  0 rom
```
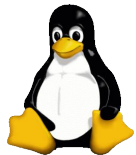
NOTE: device names sda, sdb are volatile. May change across reboots.

File system

- A subsystem in OS kernel
- Logical organization of disk sectors/blocks into files and directories.
- Does accounting of free/used space
- Provides quotas at user/group level
- Provides security using ownership, permissions, access controls (ACL).
- Addresses limitations of disk drives using
  - Logical blocking
  - Caching
- Different file systems types
  - xfs
 - ext4
  - tmpfs
  - iso9660
  - ...

File system

- List all file systems using `df -h`
- List all file systems types using `mount -v`

```
$ df -h
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda3        15G   13G  2.5G  84% /
tmpfs           1.9G   40K  1.9G   1% /tmp
/dev/sdb10      725G  315G  411G  44% /mnt/MySpare
/dev/sdb9       1.9T  763G  1.1T  41% /mnt/MyDrive
/dev/sda5       200G  8.0G  192G   4% /home
...

$ mount -v
/dev/sda3 on / type xfs (rw,relatime,seclabel,attr2,inode64,noquota)
/dev/sdb10 on /mnt/MySpare type xfs (rw,relatime,seclabel,attr2,inode64,noquota)
/dev/sdb9 on /mnt/MyDrive type xfs (rw,relatime,seclabel,attr2,inode64,noquota)
/dev/sda5 on /home type xfs (rw,relatime,seclabel,attr2,inode64,noquota)
tmpfs on /tmp type tmpfs (rw,seclabel)
...
```
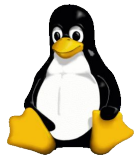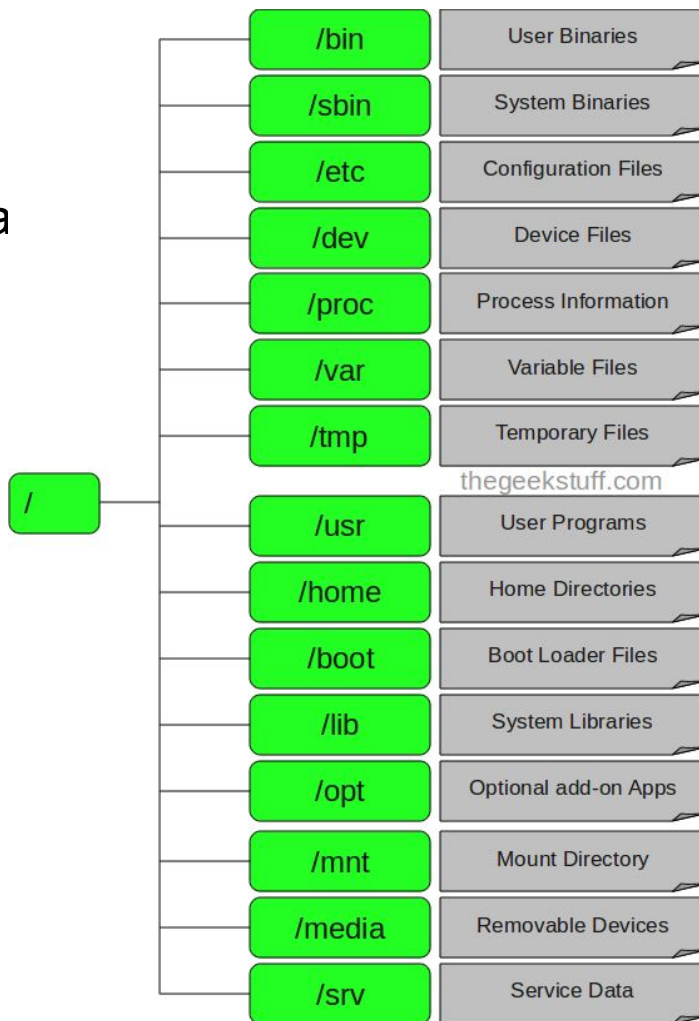
  NOTE: /tmp is stored in memory (and swap). Files in there may vanish after a reboot.
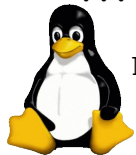
File systems hierarchy

- Multiple file systems organized in a tree structure
- Top most directory is / (called root directory)

Directory	Description
/bin	User Binaries
/sbin	System Binaries
/etc	Configuration Files
/dev	Device Files
/proc	Process Information
/var	Variable Files
/tmp	Temporary Files
/usr	User Programs
/home	Home Directories
/boot	Boot Loader Files
/lib	System Libraries
/opt	Optional add-on Apps
/mnt	Mount Directory
/media	Removable Devices
/srv	Service Data

/

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Type and permissions

- The first column in ls -l output

type	users	group	others
d l	r w x	r w x	r w x

```
# ls -l /share/
drwxr-xr-x  9 maruthisi    maruthisi        4096 Feb 19 17:29 public
drwxr-x---  9 maruthisi    cs18resch01       4096 Feb 19 17:29 cs18resch01
...
```
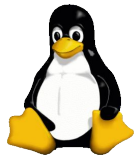
File types

- In Unix/Linux, everything in file-system is a file.
- There are many types of files:

Regular File
```
-rw-r--r-- 1 root root 35913142 Feb  3 04:34 initrd.img-4.4.0-31-generic
```

Directory
```
drwxr-xr-x 5 root root       4096 Nov 14  2016 grub
```

Block (buffered) device special file
```
brw-rw---- 1 root disk     8, 0 Feb  2 10:40 /dev/sda
```

Character (unbuffered) device special file
```
crw--w---- 1 owner tty   136, 0 Feb  3 04:36 /dev/pts/0
```
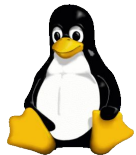
Symbolic link (aka soft link)
```
lrwxrwxrwx 1 root root 19 Nov 14  2016 /etc/mtab -> ../proc/self/mounts
```

Socket special file
```
srw-rw-rw-. 1 root root 0 Feb  3 03:34 /run/cups/cups.sock
```
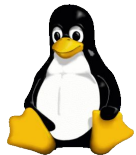
Named pipe special file
```
prw------- 1 root root 0 Feb  2 10:41 /run/systemd/inhibit/6.ref
```

File ownership

- ## Each file has
    - User ownership
    - Group ownership

- ## Use `chown` to change user ownership of any file
- ## Use `chgrp` to change group ownership of any file

```
# ls -l /share/
...
drwxr-xr-x  9 maruthisi     maruthisi        4096 Feb 19 17:29 public
drwxr-x---  9 maruthisi     cs18resch01      4096 Feb 19 17:29 cs18resch01
...
```

File permissions

- Three different categories of users
    - User (self)
    - Group (primary or suplementary)
    - Others (world)
- root user can read/write/delete everyone's files.
- Use chmod to change permissions of file (Only owners can change)

```
# ls -l /share/
drwxr-xr-x  9 maruthisi     maruthisi        4096 Feb 19 17:29 public
drwxr-x---  9 maruthisi     cs18resch01          4096 Feb 19 17:29 cs18resch01
...

# chmod g+w /share/cs18resch01

# ls -l /share/
drwxrwx---  9 maruthisi     cs18resch01          4096 Feb 19 17:29 cs18resch01
...
```
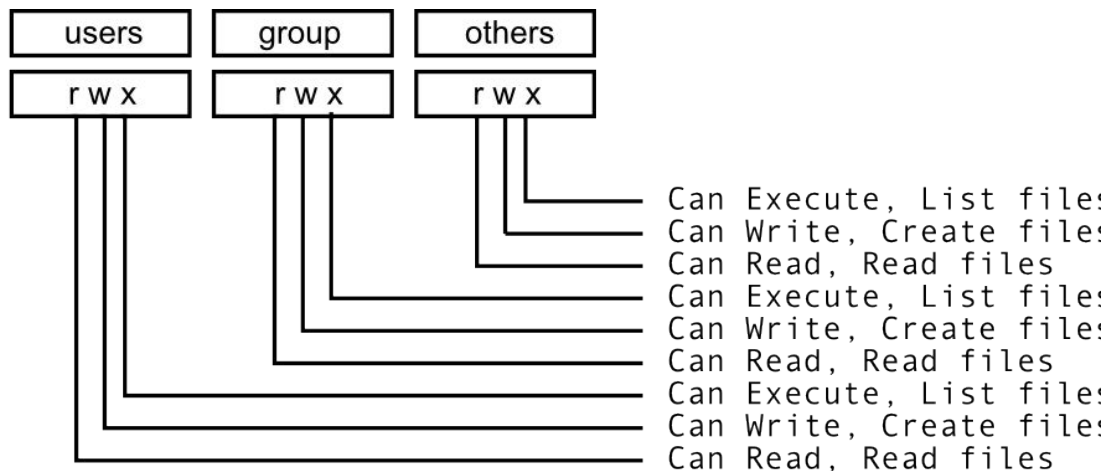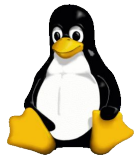
Permissions

```
# ls -l /share/

...
drwxr-xr-x  6 maruthisi        maruthisi        4096 Feb 19 17:29 public
drwxr-x---  9 maruthisi        cs18resch01      4096 Feb 19 17:29 cs18resch01
...
```

users	group	others
r w x	r w x	r w x

Can Execute, List files
Can Write, Create files
Can Read, Read files
Can Execute, List files
Can Write, Create files
Can Read, Read files
Can Execute, List files
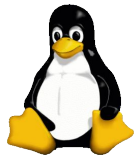Can Write, Create files
Can Read, Read files

Finding sizes

- File size could be found from `ls -lh` or more precisely `ls -l`
- Directory size could be found from `ls -ldh` or `ls -ld`
- Directory and its contents size could be found using `du -sh` or `du -s`

```
$ ls -lh ./Music/Ringtones/bhajare.mp3
-rwxr-----.  1 maruthisi maruthisi 610K Aug 11  2016 ./Music/Ringtones/bhajare.mp3

$ ls -ldh Downloads/
drwxr-xr-x. 17 maruthisi maruthisi   4K Feb  3 14:05 Downloads/

$ du -sh Downloads
1.1G    Downloads
```
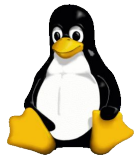
Finding files

- Searching files could be done using find
  - file extension
  - file type
  - file name

```
$ find . -name "*.mp3"
./Music/Ringtones/bhajare.mp3

$ find . -type d -name "Pictures"
./Pictures
```

Finding inside files

- Searching inside files could be done using `grep`
  - Inside a file
 - Inside all files recursively in a directory

```
$ grep -e "compare" Prog1.cu
Prog1.cu:int compare_print_result(int *h_a, int *h_b, int *h_c, int *hd_c, int size);
Prog1.cu:    if (compare_print_result(h_a, h_b, h_c, hd_c, size) != 0) {
Prog1.cu:int compare_print_result(int *h_a, int *h_b, int *h_c, int *hd_c, int size)


$ grep -R -e "compare" .
./Prog1.cu:int compare_print_result(int *h_a, int *h_b, int *h_c, int *hd_c, int size);
./Prog1.cu:    if (compare_print_result(h_a, h_b, h_c, hd_c, size) != 0) {
./Prog1.cu:int compare_print_result(int *h_a, int *h_b, int *h_c, int *hd_c, int size)
...
```
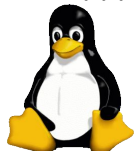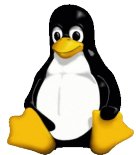
Networking

Network cards

- List network interface cards using `lspci`

```
$ lspci
...
00:07.0 Bridge: NVIDIA Corporation MCP61 Ethernet (rev a2)
...
```

Network interfaces

- List network logical interfaces using `ifconfig`

```
$ ifconfig
enp0s7: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.16.0.111  netmask 255.255.255.0  broadcast 172.16.0.255
        inet6 fe80::a00:27ff:fef1:b00d  prefixlen 64  scopeid 0x20<link>
        ether 48:5b:39:ca:17:7e  txqueuelen 1000  (Ethernet)
        RX packets 45  bytes 5329 (5.2 KiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 69  bytes 8221 (8.0 KiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        ...

wlp0s2f1u7: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.16.0.105  netmask 255.255.255.0  broadcast 172.16.0.255
        inet6 fe80::7e8b:caff:fe08:71af  prefixlen 64  scopeid 0x20<link>
        ether 7c:8b:ca:08:71:af  txqueuelen 1000  (Ethernet)
        RX packets 35448  bytes 8851296 (8.4 MiB)
        RX errors 0  dropped 124  overruns 0  frame 0
        TX packets 30856  bytes 16001132 (15.2 MiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```
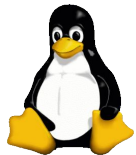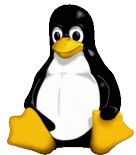
Wired interface details

- Wired (Ethernet) interface details using `ethtool <interface_name>`

```
# ethtool enp0s10
Settings for enp0s10:
    Supported ports: [ TP ]
    Supported link modes:   10baseT/Half 10baseT/Full
                            100baseT/Half 100baseT/Full
                            1000baseT/Full
    ...
    Advertised pause frame use: No
    Advertised auto-negotiation: Yes
    Speed: 1000Mb/s
    Duplex: Full
    Port: Twisted Pair
    PHYAD: 0
    Transceiver: internal
    Auto-negotiation: on
    MDI-X: off (auto)
Cannot get wake-on-lan settings: Operation not
permitted
    Current message level: 0x00000007 (7)
                  drv probe link
    Link detected: yes
```
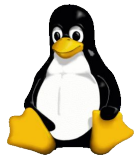
Wireless interface details

- Wireless (Wifi) interface details using `iwconfig`

```
$ iwconfig
wlp0s2f1u7  IEEE 802.11bgn  ESSID:"meghaduta"  Nickname:"<WIFI@REALTEK>"
          Mode:Managed  Frequency:2.457 GHz  Access Point: 48:EE:0C:46:B5:5E
          Bit Rate:72.2 Mb/s   Sensitivity:0/0
          Retry:off   RTS thr:off   Fragment thr:off
          Encryption key:****-****-****-****-****-****-****-****   Security mode:open
          Power Management:off
          Link Quality=15/100  Signal level=-68 dBm  Noise level=0 dBm
          Rx invalid nwid:0  Rx invalid crypt:0  Rx invalid frag:0
          Tx excessive retries:0  Invalid misc:0   Missed beacon:0
```

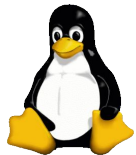Note: `Link Quality` is helpful in finding out a location with better wifi coverage.

Checking Connectivity

- Check Network layer connectivity, latency using `ping`

```
$ ping -c 3 172.16.0.1
PING 172.16.0.1 (172.16.0.1) 56(84) bytes of data.
64 bytes from 172.16.0.1: icmp_seq=1 ttl=255 time=2.86 ms
64 bytes from 172.16.0.1: icmp_seq=2 ttl=255 time=1.94 ms
64 bytes from 172.16.0.1: icmp_seq=3 ttl=255 time=1.47 ms

--- 172.16.0.1 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2003ms
rtt min/avg/max/mdev = 1.471/2.093/2.865/0.580 ms
```
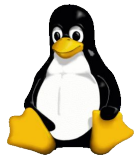
Finding MAC address

- Find MAC address of other networked device using `arping`

```
# arping -c 3 -I wlp0s2f1u7 172.16.0.1
ARPING 172.16.0.1 from 172.16.0.105 wlp0s2f1u7
Unicast reply from 172.16.0.1 [48:EE:0C:46:B5:5E]  2.807ms
Unicast reply from 172.16.0.1 [48:EE:0C:46:B5:5E]  2.561ms
Unicast reply from 172.16.0.1 [48:EE:0C:46:B5:5E]  2.566ms
Sent 3 probes (1 broadcast(s))
Received 3 response(s)
```

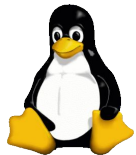Note: This command is helpful in detecting redundant IP addresses.

Routing Tables

- Find routing table using `route -n`

```
$ route -n
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
0.0.0.0          172.16.0.1       0.0.0.0          UG    600    0        0 wlp0s2f1u7
172.16.0.0       0.0.0.0          255.255.255.0    U     600    0        0 wlp0s2f1u7
192.168.122.0    0.0.0.0          255.255.255.0    U     0      0        0 virbr0
```

DNS lookup

- Hostname → IP address using `nslookup`
- IP address → hostname using `nslookup`

```
$ nslookup www.wikipedia.org
Server:      172.16.0.1
Address:     172.16.0.1#53

Non-authoritative answer:
Name:   www.wikipedia.org
Address: 91.198.174.192

$ nslookup 91.198.174.192
Server:      172.16.0.1
Address:     172.16.0.1#53

Non-authoritative answer:
192.174.198.91.in-addr.arpa    name = text-lb.esams.wikimedia.org.

Authoritative answers can be found from:
```

Static IP (ubuntu)

- ● Set `iface, address, gateway, netmask, network, dns-nameservers` in `/etc/network/interfaces`

```
$ sudo systemctl disable NetworkManager.service
$ sudo systemctl stop NetworkManager.service
$ sudo cat /etc/network/interfaces
...
##Static IP Configuration enp0s10
auto enp0s10
iface enp0s10 inet static
address 172.16.0.200
gateway 172.16.0.1
netmask 255.255.255.0
network 172.16.0.0
dns-nameservers 172.16.0.1

# ifdown enp0s10
# ifup enp0s10
```
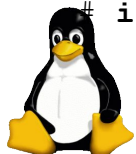
Note: For laptops/desktops it is more convenient to use NetworkManager (GUI)

Dynamic IP (DHCP) (ubuntu)

- For DHCP, edit `auto` and `iface` in `/etc/network/interfaces`

```
# systemctl disable NetworkManager.service
# systemctl stop NetworkManager.service

# cat /etc/network/interfaces
...
##To configure DHCP
auto enp0s7
iface enp0s7 inet dhcp
...

# ifdown enp0s7
# ifup enp0s7
```
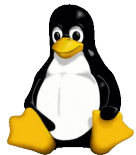
Static IP (fedora)

- Set `BOOTPROTO, IPADDR, PREFIX, GATEWAY, ONBOOT` in
  `/etc/sysconfig/network-scripts/ifcfg-<interface_name>`
- If the file does not exist, copy a sample from other interface and
  - change UUID to output of "uuidgen <inteface_name>" command
  - HWADDR to the MAC address displayed in ifconfig output

```
# systemctl disable NetworkManager.service
# systemctl stop NetworkManager.service
# cat /etc/sysconfig/network-scripts/ifcfg-enp0s10
...
HWADDR=08:00:27:34:be:7e
BOOTPROTO="none"
UUID=86ffec3f-6788-4b37-846d-3b83bc39b485
IPADDR=172.16.0.200
PREFIX=24
GATEWAY=172.16.0.1
ONBOOT="yes"
...
# ifdown enp0s10
# ifup enp0s10
```
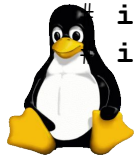
Note: For laptops/desktops it is more convenient to use NetworkManager (GUI)
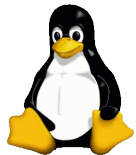
Dynamic IP (DHCP) (fedora)

- For DHCP, edit `BOOTPROTO`, `ONBOOT` in
  `/etc/sysconfig/network-scripts/ifcfg-<interface_name>`

```
# systemctl disable NetworkManager.service
# systemctl stop NetworkManager.service

# cat /etc/sysconfig/network-scripts/ifcfg-enp0s7
...
BOOTPROTO="dhcp"
ONBOOT="yes"
...

# ifdown enp0s7
# ifup enp0s7
```
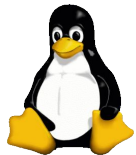
DNS (fedora)

- For DHCP, edit `BOOTPROTO, ONBOOT` in
  `/etc/sysconfig/network-scripts/ifcfg-<interface_name>`

```
# cat /etc/resolv.conf
nameserver 192.168.35.52
nameserver 172.16.0.1
search cse.iith.ac.in, iith.ac.in
```
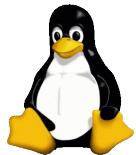
References

References

- Linux manual pages
- www.wikipedia.org
- www.vger.kernel.org/vger-lists.html
- www.kernel.org
- www.gnu.org
- www.gnome.org, www.kde.org
- Courtesy Google images

Q & A