11.1 Introduction

A typical Linux system has thousands of files. The Filesystem Hierarchy Standard (discussed in detail in a later chapter) provides a guideline for distributions on how to organize these files. In this chapter, you will see how software package management systems can provide you with information about the location of files belonging to a package.

The *Linux kernel* is at the core of the GNU/Linux operating system. This chapter will discuss the role of the Linux kernel and how it provides information about the system under the `/proc` and`/sys` *pseudo-filesystems*.

You will see how each command that you execute causes a process to be run and how you can view running processes with the `ps` command. You will also see discussion of how the system records or logs messages from the *background processes* called *daemons*.

Finally, you will see how to view the kernel *ring buffer* to view messages it contains with the `dmesg` command.

11.2 Linux Essentials Exam Objectives

This chapter will cover the topics for the following Linux Essentials exam objectives:

Topic 4: The Linux Operating System (weight: 8)

- **4.3: Where Data is Stored**
  - Weight: 3
  - Description: Where various types of information are stored on a Linux system.
  - Key Knowledge Areas:
    - Kernel
    - Processes
    - syslog, klog, dmesg
    - /lib, /usr/lib, /etc, /var/log
  - The following is a partial list of the used files, terms, and utilities:
    - Programs, libraries, packages and package databases, system configuration
    - Processes and process tables, memory addresses, system messaging and logging
    - ps, top, free

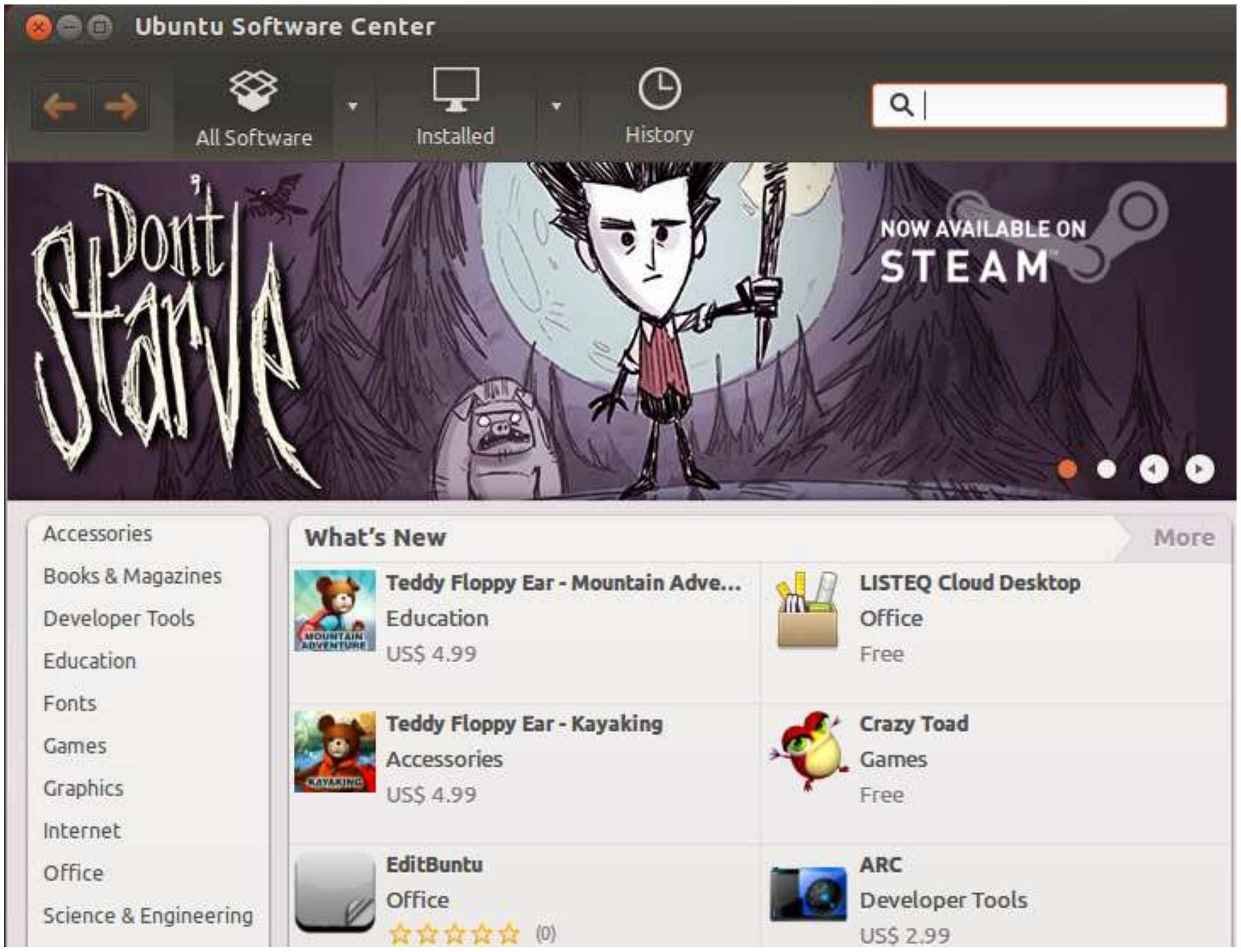
11.3 Package Management

Package management is a system by which software can be installed, updated, queried or removed from a filesystem. In Linux, there are many different software package management systems, but the two most popular are those from **Debian** and **Red Hat**.

11.3.1 Debian Package Management

The *Debian distribution* and its derivatives such as *Ubuntu* and *Mint*, use the Debian package management system. At the heart of Debian-derived distributions package management are the software packages that are distributed as files ending in ".deb".

The lowest level tool for managing these files is the `dpkg` command. This command can be tricky for novice Linux users, so the Advanced Package Tool, `apt-get`, a front-end program to the `dpkg` tool, makes management of packages even easier. There are other command line tools which serve as front-ends to `dpkg`, such as `aptitude`, as well as GUI front-ends like `synaptic` and `software-center` (shown below).



11.3.1.1 Debian - Adding Packages

The Debian repositories contain more than 65,000 different packages of software. To get an updated list from these Internet repositories, you can execute the `sudo apt-cache update` command.

To search for keywords within these packages, you can use the `sudo apt-cache search` *`keyword`* command.

Once you've found the package that you want to install, you can install it with the `sudo apt-get install` *`package`* command.

To execute these commands, your system will need access to the Internet. The `apt-cache` command searches repositories on the Internet for these software programs.

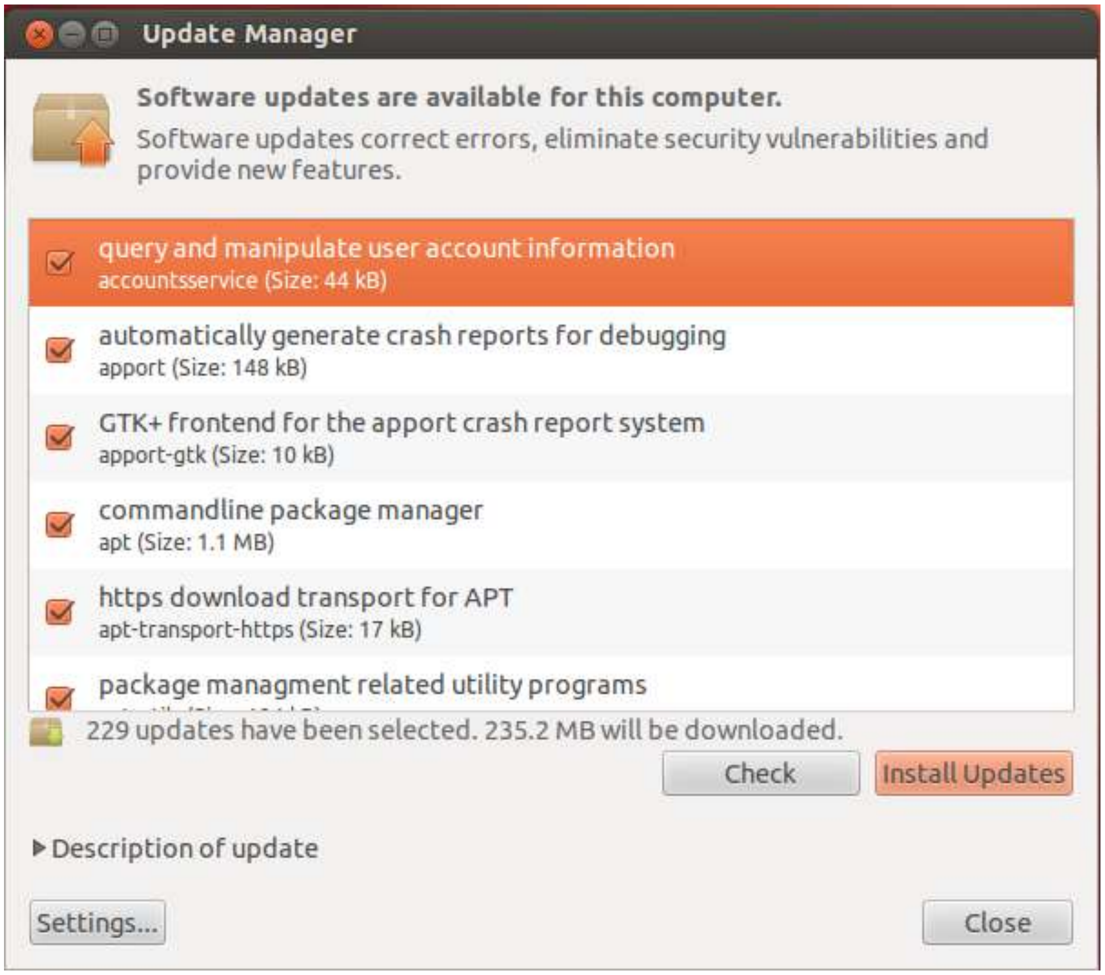
11.3.1.2 Debian - Updating Packages

If you want to update an individual package, you perform the command to install that package: `sudo apt-get install package`

If an older version of the package is already installed, then it will be upgraded. Otherwise, a new installation would take place.

If you want to update all possible packages, then you would execute the `sudo apt-get upgrade` command.

Users who log in with a graphical interface may have a message appear in the notification area from the `update-manager` indicating that updates are available, as shown below:


Update Manager

Software updates are available for this computer.

Software updates correct errors, eliminate security vulnerabilities and provide new features.

✓	query and manipulate user account information accountsservice (Size: 44 kB)
✓	automatically generate crash reports for debugging apport (Size: 148 kB)
✓	GTK+ frontend for the apport crash report system apport-gtk (Size: 10 kB)
✓	commandline package manager apt (Size: 1.1 MB)
✓	https download transport for APT apt-transport-https (Size: 17 kB)
✓	package managment related utility programs

229 updates have been selected. 235.2 MB will be downloaded.

11.3.1.3 Debian - Removing Packages

Beware that removing one package of software may result in the removal of other packages. Due to the *dependencies* between packages, if you remove a package, then all packages that need, or depend on that package will be removed as well.

If you want to remove all the files of a software package, except for the configuration files, then you can execute the `sudo apt-get remove package` command.

If you want to remove all the files of a software package, including the configuration files, then you can execute the `sudo apt-get --purge remove package` command.

You may want to keep the configuration files in the event that you plan to reinstall the software package at a later time.

11.3.1.4 Debian - Querying Packages

There are several different kinds of queries that administrators need to use. To get a list of all the packages that are currently installed on the system, execute the `dpkg -l` command.

To list the files that comprise a particular package, you can execute the `dpkg -L` *`package`* command.

To query a package for information, or its state, use the `dpkg -s` *`package`* command.

To determine if a particular file was put on the filesystem as the result of installing a package, use the `dpkg -S /path/to/file` command. If the file was part of a package, then the package name could be provided. For example:

```
sysadmin@localhost:~$ dpkg -S /usr/bin/who
coreutils: /usr/bin/who
```

The previous example shows the file `/usr/bin/who` is part of the `coreutils` package.

11.3.2 RPM Package Management

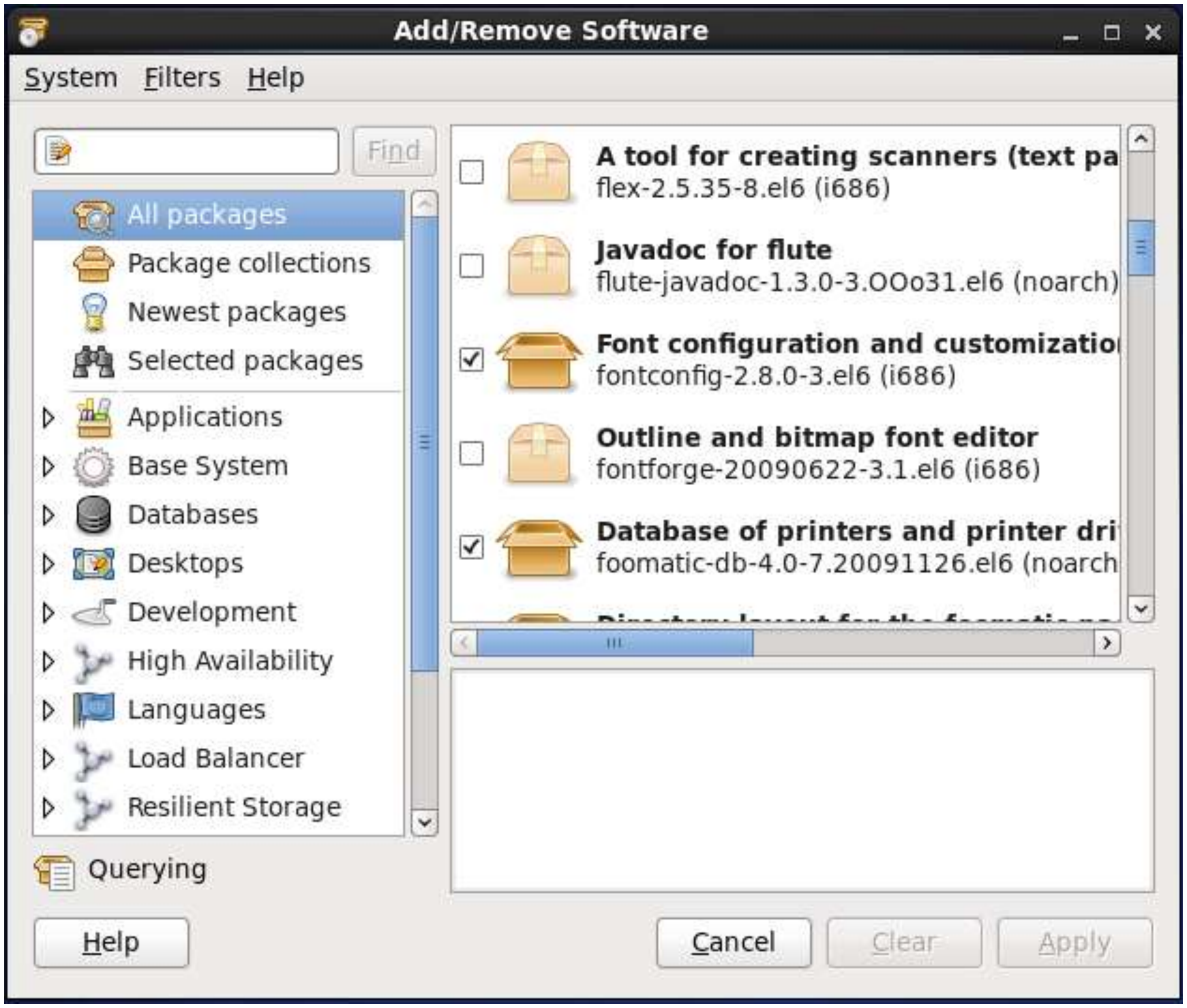
The **Linux Standards Base**, which is a Linux Foundation project, is designed to specify (through a consensus) a set of standards that increase the compatibility between conforming Linux systems. According to the Linux Standards Base, the standard package management system is RPM.

RPM makes use of an ".rpm" file for each software package. This system is what Red Hat-derived distributions (like Red Hat, Centos, and Fedora) use to manage software. In addition, several other distributions that are not Red Hat-derived (such as SUSE, OpenSUSE and Mandriva) also use RPM.

Like the Debian system, RPM Package Management systems track dependencies between packages. Tracking dependencies ensures that when you install a package, the system will also install any packages needed by that package to function correctly. Dependencies also ensure that software updates and removals are performed properly.

The back-end tool most commonly used for RPM Package Management is the `rpm` command. While the `rpm` command can install, update, query and remove packages, the command line front end tools such as `yum` and `up2date` automate the process of resolving dependency issues.

In addition, there are GUI-based front end tools such as `yumex` and `gpk-application` (shown below) that also make RPM package management easier.



A tool for creating scanners (text pa
flex-2.5.35-8.el6 (i686)
Javadoc for flute
flute-javadoc-1.3.0-3.OOo31.el6 (noarch)
Font configuration and customizatio
fontconfig-2.8.0-3.el6 (i686)
Outline and bitmap font editor
fontforge-20090622-3.1.el6 (i686)
Database of printers and printer dri
foomatic-db-4.0-7.20091126.el6 (noarch

You should note that the many of following commands will require root privileges. The rule of thumb is that if a command affects the state of a package, you will need to have administrative access. In other words, a regular user can perform a query or a search, but to add, update or remove a package requires the command be executed as the root user.

11.3.2.1 RPM - Adding Packages

To search for a package from the configured repositories, execute the `yum search keyword` command.

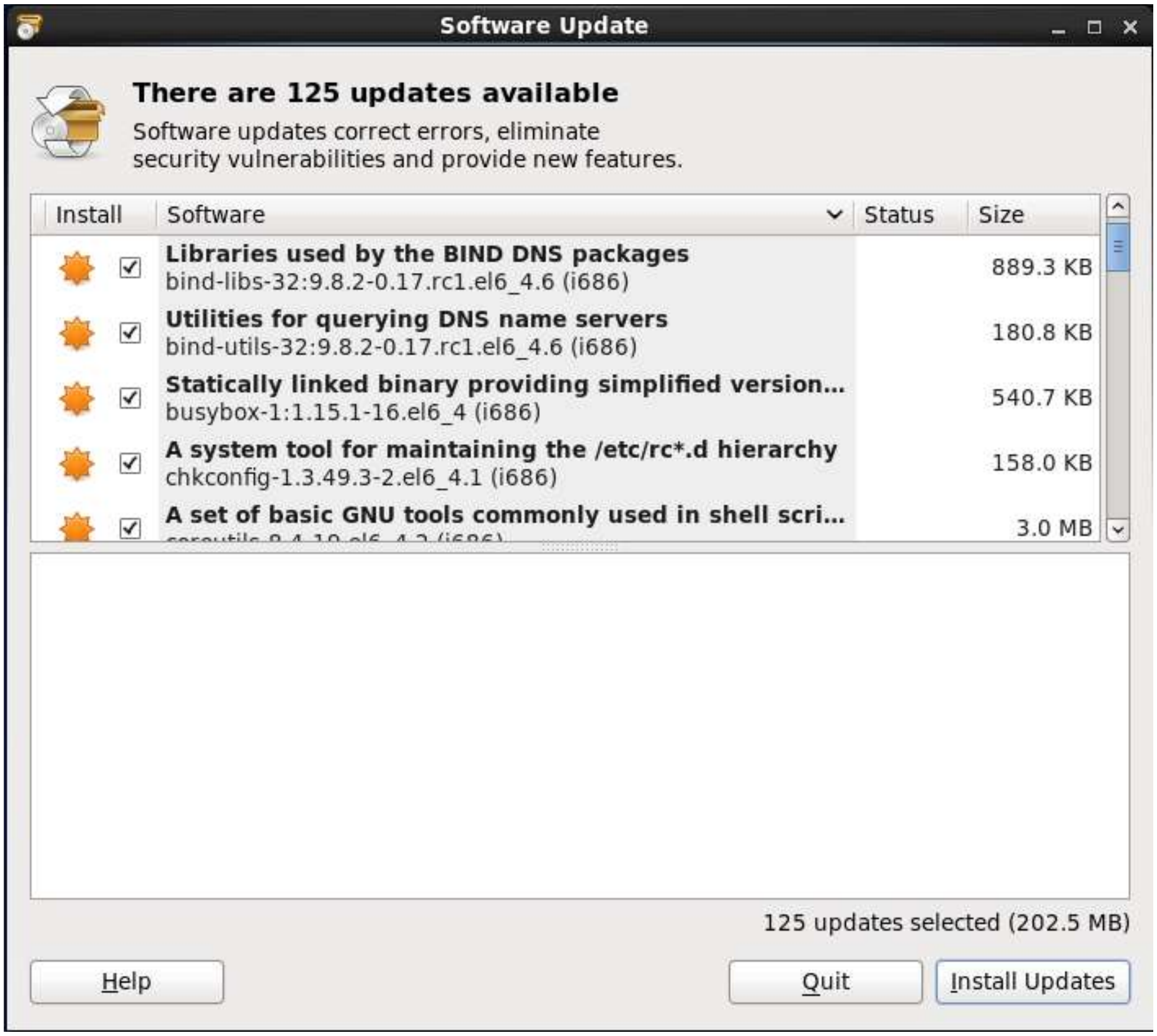
To install a package, along with its dependencies, execute the `yum install package`command.

11.3.2.2 RPM - Updating Packages

If you want to update an individual software package, you can execute the `yum update` *`package`*command.

If you want to update all packages, you can execute the `yum update` command.

If updates are available and the user is using the GUI, then the `gpk-update-viewer` may show a message in the notification area of the screen indicating that updates are available.



There are 125 updates available

Software updates correct errors, eliminate security vulnerabilities and provide new features.

Install	Software	Status	Size
✓	**Libraries used by the BIND DNS packages** bind-libs-32:9.8.2-0.17.rc1.el6_4.6 (i686)		889.3 KB
✓	**Utilities for querying DNS name servers** bind-utils-32:9.8.2-0.17.rc1.el6_4.6 (i686)		180.8 KB
✓	**Statically linked binary providing simplified version...** busybox-1:1.15.1-16.el6_4 (i686)		540.7 KB
✓	**A system tool for maintaining the /etc/rc*.d hierarchy** chkconfig-1.3.49.3-2.el6_4.1 (i686)		158.0 KB
✓	**A set of basic GNU tools commonly used in shell scri...**		3.0 MB

125 updates selected (202.5 MB)

11.3.2.3 RPM - Removing Packages

As is the case with any package management system that tracks dependencies, if you want to remove one package, then you may end up removing more than one, due to the dependencies. The easiest way to automatically resolve the dependency issues is to use a `yum` command:

```
yum remove package
```

While you can remove software packages with the `rpm` command, it won't remove dependency packages automatically.

11.3.2.4 RPM - Querying Packages

Red Hat package management is similar to Debian package management when it comes to performing queries. It is best to use the back-end tool (`rpm`) instead of the front-end tool (`yum`). While front-end tools can perform some of these queries, performance suffers because these commands typically connect to multiple repositories across the network when executing any command.
The `rpm` command performs its queries by connecting to a database that is local to the machine and doesn't connect over the network to any repositories.

To get a list of all the packages that are currently installed on the system, execute the `rpm -qa`command.

To list the files that comprise a particular package, execute the `rpm -ql package` command.

To query a package for information, or its state, execute the `rpm -qi package` command.

To determine if a particular file was put on the filesystem as the result of installing a package, execute the `rpm -qf /path/to/file` command.

11.4 Linux Kernel

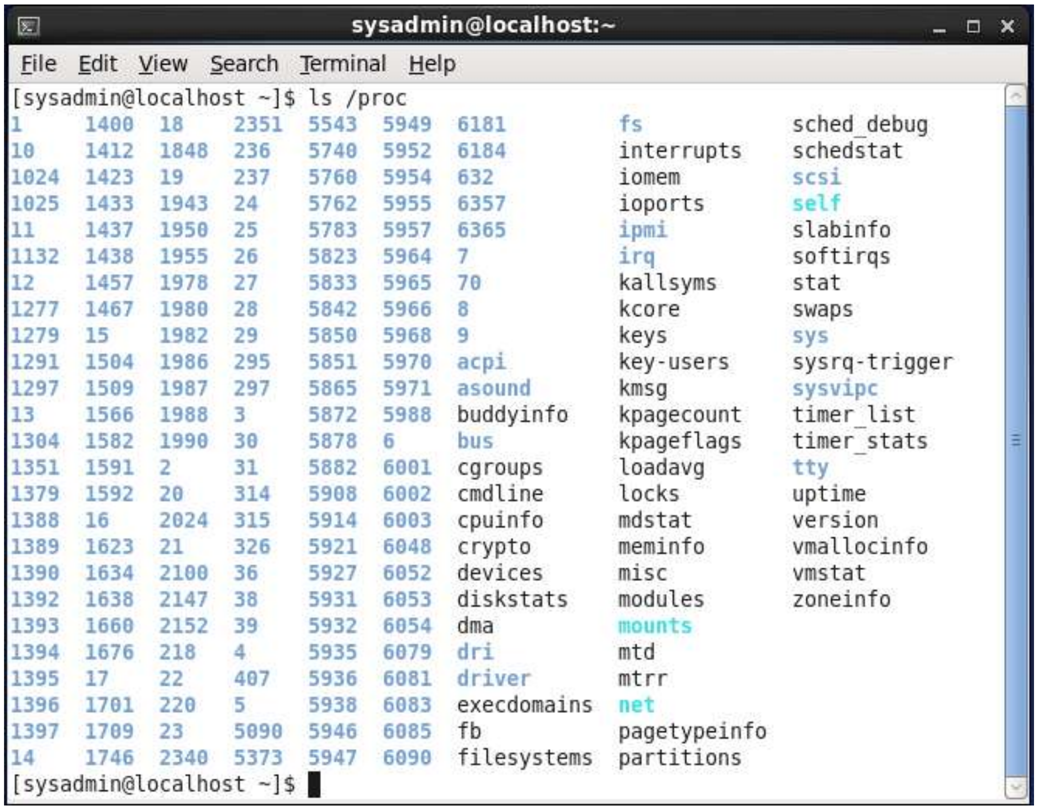
When most people refer to Linux, they are really referring to *GNU/Linux*, which defines the operating system. The *Gnu's Not Unix* (GNU) part of this combination is provided by a Free Software Foundation project. GNU is what provides the open source equivalents of many common UNIX commands, the bulk of the essential command line commands. The Linux part of this combination is the *Linux kernel*, which is core of the operating system. The kernel is loaded at boot time and stays loaded to manage every aspect of the running system.

The implementation of the Linux kernel includes many subsystems that are a part of the kernel itself and others that may be loaded in a modular fashion when needed. Some of the key functions of the Linux kernel include a system call interface, process management, memory management, virtual filesystem, networking, and device drivers.

In a nutshell, the kernel accepts commands from the user and manages the processes that carry out those commands by giving them access to devices like memory, disks, network interfaces, keyboards, mice, monitors and more.

The kernel provides access to information about running processes through a *pseudo filesystem*that is visible under the `/proc` directory. Hardware devices are made available through special files under the `/dev` directory, while information about those devices can be found in another pseudo filesystem under the `/sys` directory.

The `/proc` directory not only contains information about running processes, as its name would suggest (*process*), but it also contains information about the system hardware and the current kernel configuration. See an example output below:



```
[sysadmin@localhost ~]$ ls /proc
1     1400  18    2351  5543  5949  6181         fs            sched_debug
10    1412  1848  236   5740  5952  6184         interrupts    schedstat
1024  1423  19    237   5760  5954  632          iomem         scsi
1025  1433  1943  24    5762  5955  6357         ioports       self
11    1437  1950  25    5783  5957  6365         ipmi          slabinfo
1132  1438  1955  26    5823  5964  7            irq           softirqs
12    1457  1978  27    5833  5965  70           kallsyms      stat
1277  1467  1980  28    5842  5966  8            kcore         swaps
1279  15    1982  29    5850  5968  9            keys          sys
1291  1504  1986  295   5851  5970  acpi         key-users     sysrq-trigger
1297  1509  1987  297   5865  5971  asound       kmsg          sysvipc
13    1566  1988  3     5872  5988  buddyinfo    kpagecount    timer_list
1304  1582  1990  30    5878  6     bus          kpageflags    timer_stats
1351  1591  2     31    5882  6001  cgroups      loadavg       tty
1379  1592  20    314   5908  6002  cmdline      locks         uptime
1388  16    2024  315   5914  6003  cpuinfo      mdstat        version
1389  1623  21    326   5921  6048  crypto       meminfo       vmallocinfo
1390  1634  2100  36    5927  6052  devices      misc          vmstat
1392  1638  2147  38    5931  6053  diskstats    modules       zoneinfo
1393  1660  2152  39    5932  6054  dma          mounts
1394  1676  218   4     5935  6079  dri          mtd
1395  17    22    407   5936  6081  driver       mtrr
1396  1701  220   5     5938  6083  execdomains  net
1397  1709  23    5090  5946  6085  fb           pagetypeinfo
14    1746  2340  5373  5947  6090  filesystems  partitions
[sysadmin@localhost ~]$
```

The output from executing `ls /proc` shows more than one hundred numbered directories. There is a numbered directory for each running process on the system, where the name of the directory matches the PID (process ID) for the running process.

Because the `/sbin/init` process is always the first process, it has a PID of 1 and the information about the `/sbin/init` process can be found in the `/proc/1` directory. As you will see later in this chapter, there are several commands that allow you to view information about running processes, so it is rarely necessary for users to have to view the files for each running process directly.

You might also see that there are a number of regular files the `/proc` directory, such as`/proc/cmdline`, `/proc/meminfo` and `/proc/modules`. These files provide information about the running kernel:

- The `/proc/cmdline` file can be important because it contains all of the information that was passed to the kernel as the kernel was first started.
- The `/proc/meminfo` file contains information about the use of memory by the kernel.

- The `/proc/modules` file holds a list of *modules* currently loaded into the kernel to add extra functionality.

Again, there is rarely a need to view these files directly, as other commands offer more "user friendly" output and an alternative way to view this information.

While most of the "files" underneath the `/proc` directory cannot be modified, even by the root user, the "files" underneath the `/proc/sys` directory can be changed by the root user. These files are special in that making they change the behavior of the Linux kernel.

Direct modification of these files cause only temporary changes to the kernel. To make changes permanent, entries can be added to the `/etc/sysctl.conf` file.

For example, the `/proc/sys/net/ipv4` directory contains a file named`icmp_echo_ignore_all`. If that file contains a zero (0), as it normally does, then the system will respond to icmp requests. If that file contains a one (1), then the system will not respond to icmp requests:

```
[user@localhost ~]$ su -
Password:
[root@localhost ~]# cat /proc/sys/net/ipv4/icmp_echo_ignore_all
0
[root@localhost ~]# ping -c1 localhost
PING localhost.localdomain (127.0.0.1) 56(84) bytes of data.
64 bytes from localhost.localdomain (127.0.0.1): icmp_seq=1 ttl=64 time=0.026 ms

--- localhost.localdomain ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.026/0.026/0.026/0.000 ms
[root@localhost ~]# echo 1 > /proc/sys/net/ipv4/icmp_echo_ignore_all
[root@localhost ~]# ping -c1 localhost
PING localhost.localdomain (127.0.0.1) 56(84) bytes of data.

--- localhost.localdomain ping statistics ---
1 packets transmitted, 0 received, 100% packet loss, time 10000ms
```

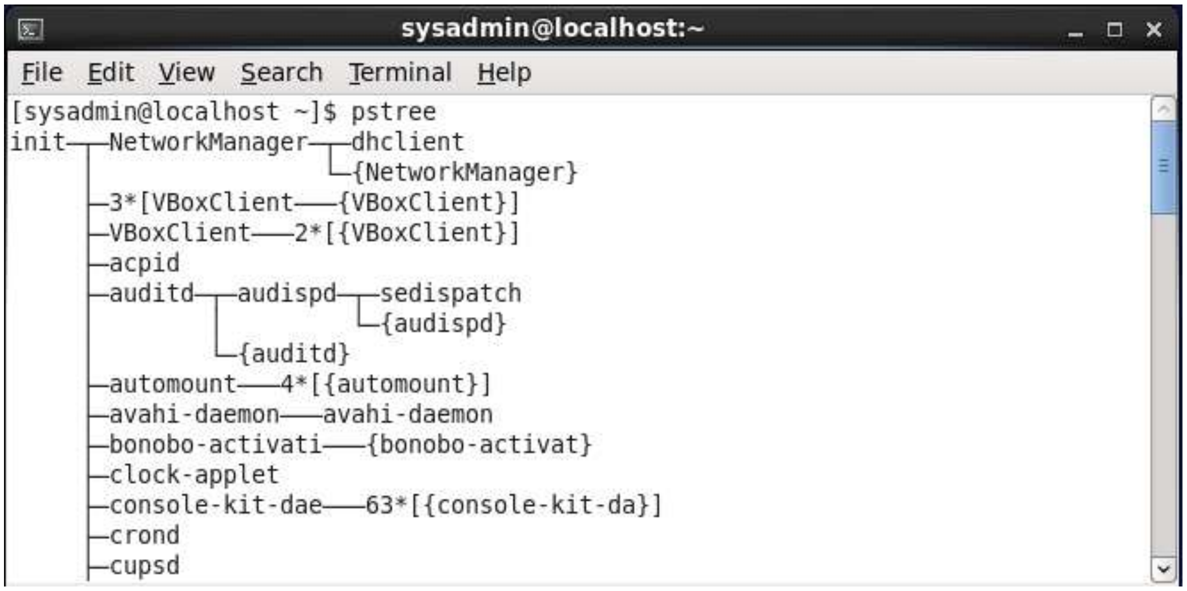
11.5 Process Hierarchy

When the kernel finishes loading during the boot procedure, it starts the `/sbin/init` process and assigns it a Process Id (PID) of 1. This process then starts other system processes and each process is assigned a PID in sequential order.

As the `/sbin/init` process starts up other processes, they in turn may start up processes, which may start up other processes, on and on. When one process starts another process, the process that performs the starting is called the *parent process* and the process that is started is called the *child process*. When viewing processes, the parent PID will be labeled PPID.

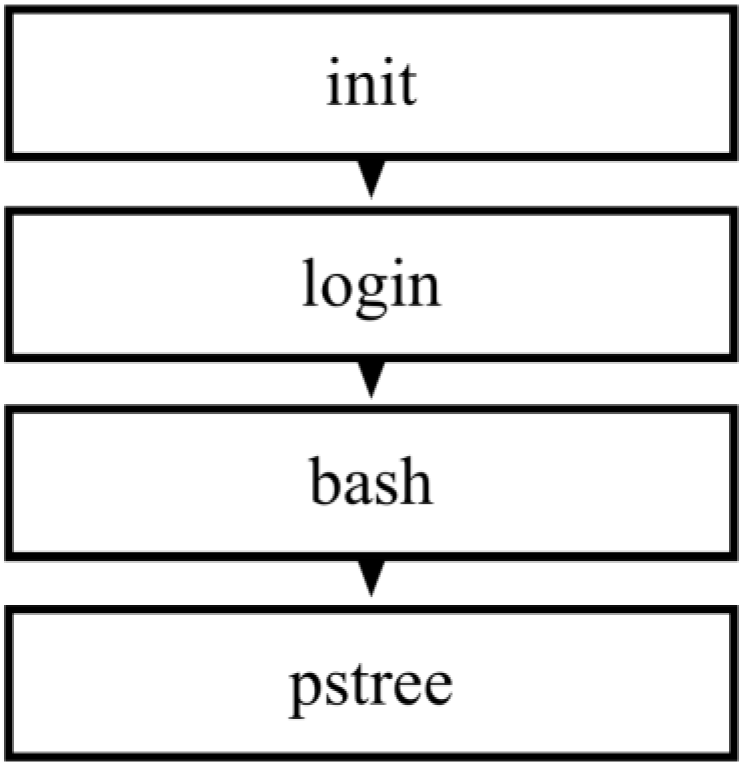
When the system has been running for a long time, it will eventually reach the *maximum PID value*, which can be viewed and configured through the `/proc/sys/kernel/pid_max` file. Once the largest PID has been used, the system will "roll over" and resume by assigning PID values that are available at the bottom of the range.

You can "map" processes into a family tree of parent and child couplings. If you want to view this tree, the command `pstree` will display it:



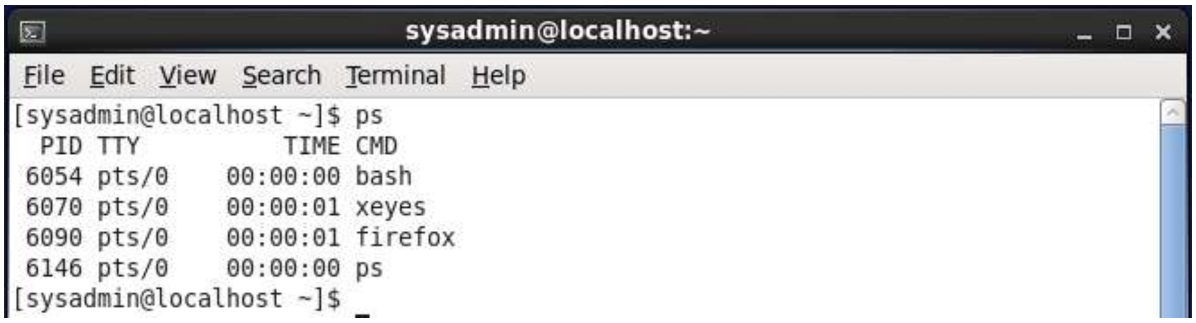
```
[sysadmin@localhost ~]$ pstree
init─┬─NetworkManager─┬─dhclient
     │                └─{NetworkManager}
     ├─3*[VBoxClient───{VBoxClient}]
     ├─VBoxClient───2*[{VBoxClient}]
     ├─acpid
     ├─auditd─┬─audispd─┬─sedispatch
     │        │         └─{audispd}
     │        └─{auditd}
     ├─automount───4*[{automount}]
     ├─avahi-daemon───avahi-daemon
     ├─bonobo-activati───{bonobo-activat}
     ├─clock-applet
     ├─console-kit-dae───63*[{console-kit-da}]
     ├─crond
     ├─cupsd
```

If you were to examine the parent and child processes relationship, using the output of the previous command, you could consider it to be like the following:



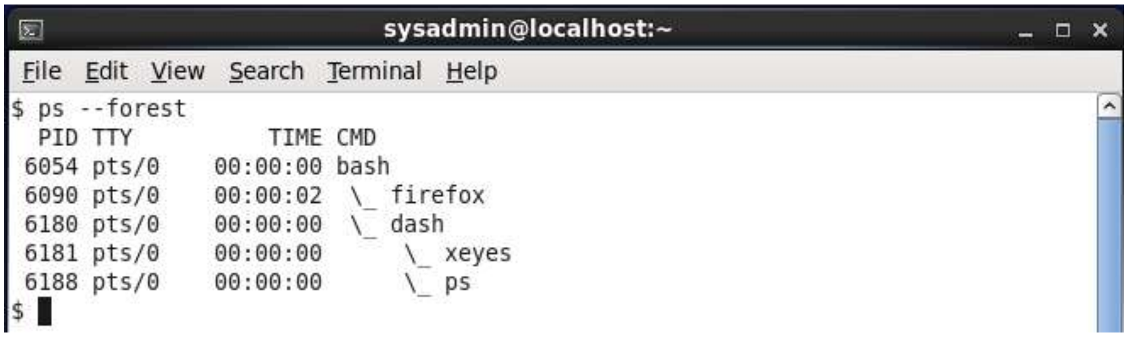
11.6 ps (Process) Command

Another way of viewing processes is with the `ps` command. By default, the `ps` command will only show the current processes running in the current shell. Ironically, you will see `ps` running when you want to see what else is running in the current shell:



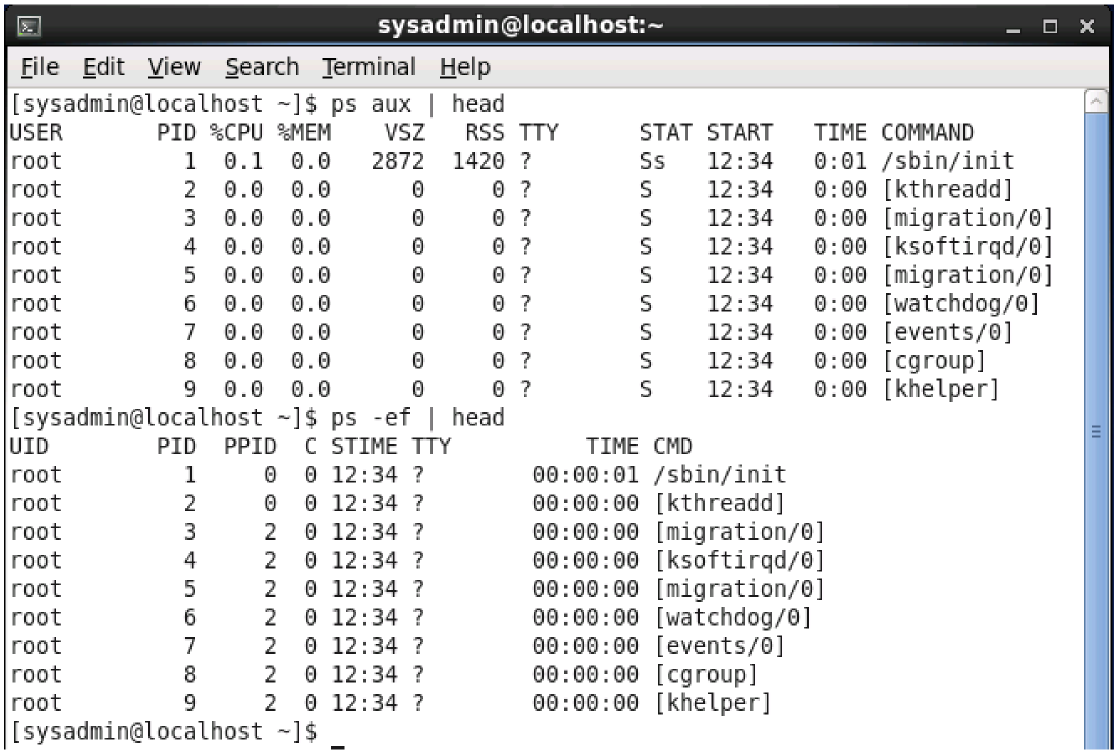
```
[sysadmin@localhost ~]$ ps
  PID TTY          TIME CMD
 6054 pts/0    00:00:00 bash
 6070 pts/0    00:00:01 xeyes
 6090 pts/0    00:00:01 firefox
 6146 pts/0    00:00:00 ps
[sysadmin@localhost ~]$ _
```

Similar to the `pstree` command, if you run `ps` with the option `--forest`, then it will show lines indicating the parent and child relationship:



```
$ ps --forest
  PID TTY          TIME CMD
 6054 pts/0    00:00:00 bash
 6090 pts/0    00:00:02  \_ firefox
 6180 pts/0    00:00:00  \_ dash
 6181 pts/0    00:00:00      \_ xeyes
 6188 pts/0    00:00:00      \_ ps
$ 
```

To be able to view all processes on the system you can execute either the `ps aux` command or the `ps -ef` command:



```
[sysadmin@localhost ~]$ ps aux | head
USER       PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root         1  0.1  0.0   2872  1420 ?        Ss   12:34   0:01 /sbin/init
root         2  0.0  0.0      0     0 ?        S    12:34   0:00 [kthreadd]
root         3  0.0  0.0      0     0 ?        S    12:34   0:00 [migration/0]
root         4  0.0  0.0      0     0 ?        S    12:34   0:00 [ksoftirqd/0]
root         5  0.0  0.0      0     0 ?        S    12:34   0:00 [migration/0]
root         6  0.0  0.0      0     0 ?        S    12:34   0:00 [watchdog/0]
root         7  0.0  0.0      0     0 ?        S    12:34   0:00 [events/0]
root         8  0.0  0.0      0     0 ?        S    12:34   0:00 [cgroup]
root         9  0.0  0.0      0     0 ?        S    12:34   0:00 [khelper]
[sysadmin@localhost ~]$ ps -ef | head
UID        PID  PPID  C STIME TTY          TIME CMD
root         1     0  0 12:34 ?        00:00:01 /sbin/init
root         2     0  0 12:34 ?        00:00:00 [kthreadd]
root         3     2  0 12:34 ?        00:00:00 [migration/0]
root         4     2  0 12:34 ?        00:00:00 [ksoftirqd/0]
root         5     2  0 12:34 ?        00:00:00 [migration/0]
root         6     2  0 12:34 ?        00:00:00 [watchdog/0]
root         7     2  0 12:34 ?        00:00:00 [events/0]
root         8     2  0 12:34 ?        00:00:00 [cgroup]
root         9     2  0 12:34 ?        00:00:00 [khelper]
[sysadmin@localhost ~]$ _
```

The output of all processes running on a system can definitely be overwhelming. In the example provided, the output of the `ps` command was filtered by the head command, so only the first ten processes were shown. If you don't filter the output of the `ps` command, then you are likely to have to scroll through hundreds of processes to find what might interest you.

A common way to run the `ps` command is to use the `grep` command to filter the output display lines that match a keyword, such as the process name. For example, if you wanted to view the information about the `firefox` process, you may execute a command like:

```
[sysadmin@localhost ~]$ ps -e | grep firefox
 6090 pts/0    00:00:07 firefox
```

As the root user, you may be more concerned about the processes of another user, than you are over your own processes. Because of the several styles of options that the `ps` command supports, there are different ways to view an individual user's processes. Using the traditional UNIX option, to view the processes of the "sysadmin" user, execute the following command:

```
[root@localhost ~]# ps -u username
```

Or use the BSD style of options and execute:

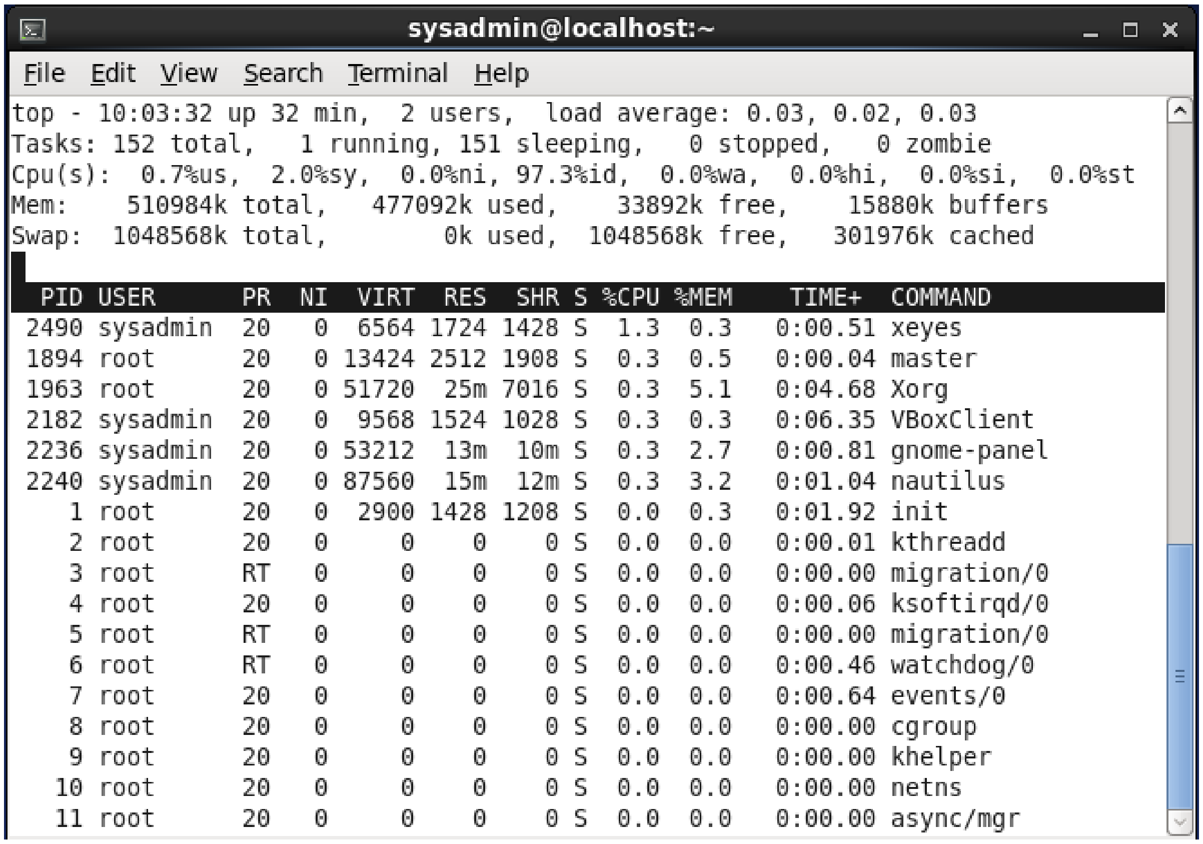
```
[root@localhost ~]# ps u U username
```

11.7 top Command

The `ps` command provides a "snapshot" of the processes running at the instant the command is executed, the `top` command that will regularly update the output of running processes. The `top` command is executed as follows:

```
sysadmin@localhost:~$ top
```

By default, the output of the `top` command is sorted by the % of CPU time that each process is currently using, with the higher values listed first. This means processes that are "CPU hogs" are listed first:



```
top - 10:03:32 up 32 min,  2 users,  load average: 0.03, 0.02, 0.03
Tasks: 152 total,   1 running, 151 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.7%us,  2.0%sy,  0.0%ni, 97.3%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Mem:    510984k total,   477092k used,    33892k free,    15880k buffers
Swap:  1048568k total,        0k used,  1048568k free,   301976k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 2490 sysadmin  20   0  6564 1724 1428 S  1.3  0.3   0:00.51 xeyes
 1894 root      20   0 13424 2512 1908 S  0.3  0.5   0:00.04 master
 1963 root      20   0 51720  25m 7016 S  0.3  5.1   0:04.68 Xorg
 2182 sysadmin  20   0  9568 1524 1028 S  0.3  0.3   0:06.35 VBoxClient
 2236 sysadmin  20   0 53212  13m  10m S  0.3  2.7   0:00.81 gnome-panel
 2240 sysadmin  20   0 87560  15m  12m S  0.3  3.2   0:01.04 nautilus
    1 root      20   0  2900 1428 1208 S  0.0  0.3   0:01.92 init
    2 root      20   0     0    0    0 S  0.0  0.0   0:00.01 kthreadd
    3 root      RT   0     0    0    0 S  0.0  0.0   0:00.00 migration/0
    4 root      20   0     0    0    0 S  0.0  0.0   0:00.06 ksoftirqd/0
    5 root      RT   0     0    0    0 S  0.0  0.0   0:00.00 migration/0
    6 root      RT   0     0    0    0 S  0.0  0.0   0:00.46 watchdog/0
    7 root      20   0     0    0    0 S  0.0  0.0   0:00.64 events/0
    8 root      20   0     0    0    0 S  0.0  0.0   0:00.00 cgroup
    9 root      20   0     0    0    0 S  0.0  0.0   0:00.00 khelper
   10 root      20   0     0    0    0 S  0.0  0.0   0:00.00 netns
   11 root      20   0     0    0    0 S  0.0  0.0   0:00.00 async/mgr
```

There is an extensive list of commands that can be executed from within the running top program:

Keys	Meaning
h or ?	Help
l	Toggle load statistics
t	Toggle time statistics
m	Toggle memory usage statistics
<	Move sorted column to the left
>	Move sorted column to the right

Keys	Meaning
F	Choose sorted field
R	Toggle sort direction
P	Sort by % CPU
M	Sort by % memory used
k	Kill a process (or send it a signal)
r	Renice priority of a process

One of the advantages of the `top` command is that it can be left running to stay on "top" of processes for monitoring purposes. If a process begins to dominate, or "run away" with the system, then it will by default appear at the top of the list presented by the top command. An administrator that is running the `top` command can then take one of two actions:

- Terminate the "run away" process: Pressing the **k** key while the `top` command is running will prompt the user to provide the PID and then a signal number. Sending the default signal will *request* the process terminate, but sending signal number 9, the "KILL" signal, will *force* the process to terminate.
- Adjust the priority of the process: Pressing the **r** key while the `top` command is running will prompt the user for the process to "renice", and then a niceness value. *Niceness* values can range from -20 to 19, and affect priority. Only the root user can use a niceness that is a lower number than the current niceness, or a negative niceness value, which causes the process to run with an increased priority. Any user can provide a niceness value that is higher than the current niceness value, which will cause the process to run with a lowered priority.

Another advantage of the `top` command is that it is able to give you an overall representation of how busy the system is currently and the trend over time. The *load averages* shown in the first line of output from the `top` command indicate how busy the system has been during the last one, five and fifteen minutes. This information can also be viewed by executing the `uptime` command or directly by displaying the contents of the `/proc/loadavg` file:

```
$ cat /proc/loadavg
```

```
0.12 0.46 0.25 1/254 3052
```

The first three numbers in this file indicate the load average over the last one, five and fifteen minute intervals. The fourth value is a fraction which shows the number of processes currently executing code on the CPU (1) and the total number of processes (254). The fifth value is the last PID value that executed code on the CPU.

The number reported as a load average is proportional to the number of CPU cores that are able to execute processes. On a single core CPU, a value of one would mean that the system is fully loaded. On a four core CPU, a value of one would mean that the system is only 1/4 or 25% loaded.

Another reason administrators like to keep the `top` command running is the ability to monitor memory usage in real-time. Both the `top` and the `free` command display statistics for how overall memory is being used.

The `top` command also has the ability to show the percent of memory used by each process, so a process that is consuming an inordinate amount of memory can quickly be identified.

11.8 free Command

Executing the `free` command without any options provides a snapshot of the memory used at that moment.

If you want to monitor memory usage over time with the `free` command, then you can execute it with the `-s` option and specify that number of seconds. For example, executing `free -s 10`would update the output every ten seconds.

To make it easier to interpret what the `free` command is outputting the `-m` or `-g` options can be useful to show the output in either megabytes or gigabytes, respectively. Without these options, the output is displayed in bytes:

```
$ free
                    total       used         free     shared    buffers    cached
Mem:               510984     495280        15704          0      60436    258988
-/+ buffers/cache: 175856     335128
Swap:             1048568          0      1048568
```

When reading the output of the `free` command:

- The first line is a descriptive header.
- The second line labeled "Mem:" is the statistics for the physical memory of the system.

- The third line represents the amount of physical memory after adjusting those values by not taking into account any memory that is in use by the kernel for buffers and caches. Technically, this "used" memory could be "reclaimed" if needed.
- The fourth line of output refers to "Swap" memory, also known as virtual memory. This is space on the hard disk that is used like physical memory when the amount of physical memory becomes low. Effectively, this makes it seem that the system has more memory than it really does, but using swap space can also slow down the system.

If the amount of memory and swap that is available becomes very low, then the system will begin to automatically terminate processes. This is one reason why it is important to monitor the system's memory usage. An administrator that notices the system becoming low on free memory can use `top` or `kill` to terminate the processes of their own choice, rather than letting the system choose.

11.9 Log Files

As the kernel and various processes run on the system, they produce output that describes how they are running. Some of this output is displayed in the terminal window where the process was executed, but some of this data is not sent to the screen, but instead it is written to various files. This is called "log data" or "log messages".

These log files are very important for a number of reasons; they can be helpful in trouble-shooting problems and they can be used for determining whether or not unauthorized access has been attempted.

Some processes are able to "log" their own data to these files, other processes rely on another process (a daemon) to handle these log data.

These logging daemons can vary from one distribution to another. For example, on some distributions, the daemons that run in the background to perform logging are called as `syslogd` and `klogd`. In other distributions, a single daemon such as `rsyslogd` in Red Hat and Centos or`systemd-journald` in the Fedora may serve this logging function.

Regardless of what the daemon process is named, the log files themselves are almost always placed into the `/var/log` directory structure. Although some of the file names may vary, here are some of the more common files to be found in this directory:

File	Contents
boot.log	Messages generated as services are started during the startup of the system.
cron	Messages generated by the `crond` daemon for jobs to be executed on a

File	Contents
	recurring basis.
dmesg	Messages generated by the kernel during system boot up.
maillog	Messages produced by the mail daemon for e-mail messages sent or received
messages	Messages from the kernel and other processes that don't belong elsewhere. Sometimes named "syslog" instead of "messages" after the daemon that writes this file.
secure	Messages from processes that required authorization or authentication (such as the login process).
Xorg.0.log	Messages from the X windows (GUI) server.

Log files are *rotated*, meaning older log files are renamed and replaced with newer log files. The file names that appear in the table above may have a numeric or date suffix added to them, for example: `secure.0` or `secure-20131103`

Rotating a log file typically occurs on a regularly scheduled basis, for example, once a week. When a log file is rotated, the system stops writing to the log file and adds a suffix to it. Then a new file with the original name is created and the logging process continues using this new file.

With the modern daemons, a date suffix is typically used. So, at the end of the week ending November 3, 2013, the logging daemon might stop writing to `/var/log/messages`, rename that file `/var/log/messages-20131103`, and then begin writing to a new `/var/log/messages` file.

Although most log files contain text as their contents, which can be viewed safely with many tools, other files such as the `/var/log/btmp` and `/var/log/wtmp` files contain binary. By using the`file` command, you can check the file content type before you view it to make sure that it is safe to view.

For the files that contain binary data, there are normally commands available that will read the files, interpret their contents and then output text. For example, the `lastb` and `last` commands can be used to view the `/var/log/btmp` and `/var/log/wtmp` files respectively.

For security reasons, most of the files found are not readable by ordinary users, so be sure to execute commands that interact with these files with root privileges.

11.10 dmesg Command

The `/var/log/dmesg` file contains the kernel messages that were produced during system startup. The `/var/log/messages` file will contain kernel messages that are produced as the system is running, but those messages will be mixed in with other messages from daemons or processes.

Although the kernel doesn't have its own log file normally, one can be configured for them typically by modifying either the `/etc/syslog.conf` or the `/etc/rsyslog.conf` file. In addition, the`dmesg` command can be used to view the *kernel ring buffer*, which will hold a large number of messages that are generated by the kernel.

On an active system, or one experiencing many kernel errors, the capacity of this buffer may be exceeded and some messages might be lost. The size of this buffer is set at the time the kernel is compiled, so it is not trivial to change.

Executing the `dmesg` command can produce up to 512 kilobytes of text, so filtering the command with a pipe to another command like `less` or `grep` is recommended. For example, if you were troubleshooting problems with your USB device, then searching for the text "USB" with the `grep`command being case insensitive may be helpful:

```
$ dmesg | grep -i usb

usbcore: registered new interface driver usbfs

usbcore: registered new interface driver hub

usbcore: registered new device driver usb

ehci_hcd: USB 2.0 'Enhanced' Host Controller (EHCI) Driver

ohci_hcd: USB 1.1 'Open' Host Controller (OHCI) Driver

ohci_hcd 0000:00:06.0: new USB bus registered, assigned bus number 1

usb usb1: New USB device found, idVendor=1d6b, idProduct=0001

usb usb1: New USB device strings: Mfr=3, Product=2, SerialNumber=1
```