Micro Link
IT COLLEGE

[Level - Beginner]

# Linux Server Fundamentals

## Student Material

(Volume 1 - Notes and Workbook)

redhat. LINUX

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# Chapter 1. Introduction to Unix and Linux

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## 1.1. Unix History

### 1.1.1. AT&T Bell Labs

In 1969 **Dennis Ritchie** and **Ken Thompson** wrote **UNICS** (Uniplexed Information and Computing System) at Bell Labs. Together with **Douglas McIlroy** they are seen as the creators of **Unix**. The name **Unics** is a play on the **Multics Operating System** for mainframe computers. Unics (later renamed to Unix) was written for mini-computers like the DEC PDP-series. In 1973 they decided to write Unix in C (instead of assembler), to make it portable to other computers. Unix was made available to universities, companies and the US government, including the full source code. This meant that every C programmer could make changes. By 1978 about 600 computers were running Unix.

**Table 1.1. Early Unix Timeline**

<table>
<tr><th>1969-1977</th><th>1978-1980</th><th>1981</th><th>1982</th></tr>
<tr><td rowspan="3">UNIX Time Sharing System</td><td rowspan="2">BSD</td><td rowspan="2">4.1BSD</td><td>4.1BSD</td></tr>
<tr><td>SunOS 1.0</td></tr>
<tr><td colspan="2">Unix</td><td>Unix System III</td></tr>
</table>

### 1.1.2. The Unix Wars

The unity and openness that existed in the Unix world until 1977 was long gone by the end of the eighties. Different vendors of distinct versions of Unix tried to set the standard. Sun and AT&T joined the **X/Open** group to unify Unix. Other vendors joined the Open Software Foundation or **OSF**. These struggles were not good for Unix, allowing for new operating system families like OS/2, Novell Netware and

Microsoft Windows NT to take big chunks of server market share in the early nineties. The table below shows the evolution of a united **Unix** into several Unixes in the eighties.

**Table 1.2. Eighties Unix Timeline**

<table>
<tr><th>1983</th><th>1984</th><th>1985</th><th>1986</th><th>1987</th><th>1988</th><th>1989</th><th>1990</th><th>1991</th><th>1992</th></tr>
<tr><td colspan="3" rowspan="2">4.1BSD</td><td colspan="5">4.3BSD</td><td colspan="2">BSD Net/2</td></tr>
<tr><td colspan="2">4.3BSD</td><td colspan="5">NeXTSTEP</td></tr>
<tr><td colspan="3">SunOS1.0</td><td colspan="2">SunOS3.2</td><td colspan="3" rowspan="2">SystemVr4</td><td colspan="2">Solaris</td></tr>
<tr><td colspan="5">System V</td><td colspan="2">UnixWare</td></tr>
<tr><td colspan="3">System V</td><td colspan="7">AIX</td></tr>
<tr><td>III + V</td><td colspan="9">HP-UX</td></tr>
</table>

## 1.1.3. University of California, Berkeley

Students of Berkeley were happy to join in the development of Bell Labs Unix, but were not so happy with the restrictive licensing. Unix was open source software, but it still required purchase of a license. So during the eighties, they rewrote all the Unix tools until they had a complete Unix-like operating system. By 1991, the **BSD** (Berkeley Software Distribution) branch of Unix was completely separate from the Bell Labs Unix. **NetBSD**, **FreeBSD**, and **OpenBSD** are three current Unix-like operating systems derived from the 1991 **BSD Net/2** codebase. Sun Solaris, Microsoft Windows NT, and Apple Mac OS X all used source code from BSD. The table below shows operating systems still in use today that are in a way derived from the 1978-1981 BSD codebase.

**Table 1.3. Current BSD Timeline**

<table>
<tr><th>1991</th><th>1992</th><th>1993</th><th>1994</th><th>1995</th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th>2000-2008</th></tr>
<tr><td colspan="2" rowspan="3">BSD Net/2</td><td colspan="8">FreeBSD</td></tr>
<tr><td colspan="8">NetBSD</td></tr>
<tr><td colspan="3">NetBSD</td><td colspan="5">OpenBSD</td></tr>
<tr><td colspan="8">NeXTSTEP</td><td colspan="2">Mac OS X</td></tr>
<tr><td colspan="10">Solaris</td></tr>
</table>

## 1.1.4. GNU's not Unix

Largely because of discontent with the restrictive licensing on existing Unix implementations, **Richard Stallman** initiated the **GNU Project** in 1983. The GNU project aims to create free software. Development of the GNU operating system started, aiming to create a complete Unix-like branch, separate from the two other (BSD and Bell Labs). Today the GNU compiler **gcc** and most other GNU utilities (like

**bash**) are among the most popular on many Unix-like systems. The official kernel of this project is **GNU/Hurd**, but you can hardly call that kernel a finished product.

### 1.1.5. Linux

Where **GNU/Hurd** failed, the Linux kernel succeeded! In 1991 a Finnish student named **Linus Torvalds** started writing his own operating system for his intel 80386 computer. In January 1992, Linus decided to release Linux under the GNU GPL. Thanks to this, thousands of developers are now working on the Linux kernel. Linus Torvalds is in charge of the kernel developers.

Contrary to popular belief, they are not all volunteers. Today big companies like Red Hat, Novell, IBM, Intel, SGI, Oracle, Montavista, Google, HP, NetApp, Cisco, Fujitsu, Broadcom, and others are actively paying developers to work on the Linux kernel. According to the Linux Foundation "over 3700 individual developers from over 200 different companies have contributed to the kernel between 2005 and april 2008". 1057 developers from 186 different companies contributed code to make kernel version 2.6.23 into 2.6.24.

## 1.2. Licensing

### 1.2.1. Proprietary

Some flavors of Unix, like HP-UX, IBM AIX, and Sun Solaris 9 are delivered in binary form after purchase. You are not authorized to install or use these without paying a licensing fee. You are not authorized to distribute these copies to other people and you are not authorized to look at or change the closed source code of the operating system. This software is usually protected by copyright, patents, and extensive software licensing.

### 1.2.2. BSD

BSD style licenses are close to the public domain. They essentially state that you can copy the software, but you have to leave the copyright notice that refers to BSD. This license gives a lot of freedom but offers few protection to someone copying and selling your work.

### 1.2.3. GNU General Public License (GPL)

More and more software is being released under the **GPL** (in 2006 Java was released under the GPL). The goal of the GPL is to guarantee that free software stays free. Everyone can work together on GPL software, knowing that the software will be freely available to everyone. The GPL can protect software, even in court.

Free is to be understood as in **freedom of speech**, not to be confused with free as in not having to pay for your free beer. In other words, or even better, in other languages free software translates to **vrije software** (Dutch) or **Logiciel Libre** (French) whereas the free from free beer translates to gratis.

Briefly explained, the GPL allows you to copy software, the GPL allows you to distribute (sell or give away) that software, and the GPL grants you the right to read and change the source code. But the person receiving or buying the software from you has the same rights. And should you decide to distribute modified versions of GPL software, then you are obligated to put the same license on the modifications (and provide the source code of your modifications).

### 1.2.4. Others...

*There are many other licenses on software. You should read and understand them before using any software.*

## 1.3. Current Distributions

### 1.3.1. What is a distribution ?

Unix comes in many flavors usually called **distributions**. A distribution (or in short distro) is a collection of software packages distributed on CD, online, or pre-installed on computers. All the software in a distribution is tested and integrated nicely into a whole. Software is maintained (patched) by the distributor and is managed by an **integrated package manager**. Many distros have a central **repository of approved software**. Installing software from outside the distro can sometimes be cumbersome and may void your warranty on the system.

### 1.3.2. Linux Distributions

There are hundreds of Linux distributions, just take a look at the distrowatch.com website. For many years, Red Hat, Suse, and Mandrake were considered the big three for end users. Red Hat is still the biggest commercial Linux vendor and since 2008 the most popular Linux distribution for home users is **Ubuntu** from Canonical.

#### Linux distribution detection

Depending on the distribution used, there are distinct files that contain the distribution version.

The **/etc/redhat-release** file contains the Red Hat version on most of the Red Hat and Red Hat derived systems. Debian and Ubuntu systems contain **/etc/debian-version**. Note that Ubuntu was originally derived from Debian.

```
paul@RHELv4u4:~$ cat /etc/redhat-release
Red Hat Enterprise Linux AS release 4 (Nahant Update 4)

serge@venusia:~$ cat /etc/debian_version
lenny/sid
```

The **/etc/lsb-release** file can be found on distributions that follow the Linux Standard Base. Other variations to these files are **/etc/slackware-version**, **/etc/SuSE-release**, **/etc/gentoo-release** and **/etc/mandrake-release**.

```
serge@venusia:~$ cat /etc/lsb-release
DISTRIB_ID=Ubuntu
DISTRIB_RELEASE=8.04
DISTRIB_CODENAME=hardy
DISTRIB_DESCRIPTION="Ubuntu 8.04.1"
```

## Red Hat

Redhat has been a company since 1993. They distribute **Red Hat Enterprise Linux** (RHEL) to companies and manage the **Fedora** project. RHEL is probably the most popular Linux-based distro on servers. Fedora is a very popular and user friendly Linux-based distro, aimed towards home users. The company makes a profit of around one hundred million dollars a year selling support contracts. Red Hat contributes a lot to the Linux kernel and other free software projects.

### Red Hat Linux

Red Hat Linux was distributed from 1994 until 2003. It was one of the oldest common Linux distributions. Red Hat Linux was the first distro to use the **rpm** package format. Many other distros are originally derived from Red Hat Linux. The company **Red Hat, Inc.** decided to split Red Hat Linux into **Fedora** and **Red Hat Enterprise Linux**.

### Fedora

**Fedora** is sponsored by Red Hat which is aimed toward home users. There is no official support from Red Hat. Every six to eight months, there is a new version of Fedora. Fedora usually has more recent versions of kernel and applications than RHEL. Fedora 9 was released May 2008.

### Red Hat Enterprise Linux 4

Since 2005 Red Hat has distributed four different RHEL4 variants. **RHEL AS** is for mission-critical computer systems. **RHEL ES** is for small to mid-range servers. **RHEL WS** is for technical power user desktops and critical design. **Red Hat Desktop** is for multiple deployments of single user desktops. Red Hat does not give an explanation for the meaning of AS, ES and WS, but it might be Advanced Server, Entry-level Server, and Workstation.

### Red Hat Enterprise Linux 5

Red Hat Enterprise Linux version 5 has been available since March 2007. One of the notable new features is the inclusion of **Xen**. Xen is a free virtual machine application that allows NetBSD and Linux to serve as host for guest operating systems. Besides virtualization, RHEL 5 also has better SELinux support, clustering, network storage and smart card integration.

### CentOS and Unbreakable Linux

Both **CentOS** and Oracle's **Unbreakable Linux** are directly derived from RHEL, but all references to Red Hat trademarks are removed. Companies are allowed to do this (GPL), and are hoping to make a profit selling support (without having the cost of developing and maintaining their own distribution). Red Hat is not really worried about this since they develop a lot on Linux and thus can offer much better support. The Oracle offering is still very recent, so let's wait and see how many organizations will buy a complete solution from Oracle.

## Ubuntu

**Ubuntu** is a rather new distribution, based on **Debian**, and funded by South African developer and billionaire astronaut **Mark Shuttleworth**. Ubuntu is giving away free (as in beer and speech) CDs with **Ubuntu, Linux for Human Beings**. Many people consider Ubuntu to be the most user friendly Linux distribution. The company behind Ubuntu is **Canonical** which intends to make a profit of selling support soon. Ubuntu is probably the most popular Unix-like distribution on personal desktops.

Image copied from **xkcd.com**.


## Novell Suse

A couple of years ago, **Novell** bought the German company **Suse**. They are seen as the main competitor to Red Hat with their SLES (Suse Linux Enterprise Server) and

SLED (Suse Linux Enterprise Desktop) versions of Suse Linux. Similar to Fedora, Novell hosts the **OpenSUSE** project as a testbed for upcoming SLED and SLES releases.

Novell has signed a very controversial deal with Microsoft. Some high-profile open source developers have left the company because of this agreement and many people from the open source community are actively advocating to abandon Novell completely.

### Debian

Debian is one of the most secure Linux distros. It is known to be stable and reliable. The Debian people also have a strong focus towards freedom. You will not find patented technologies or non-free software in the standard Debian repositories. A lot of distributions (Ubuntu, Knoppix, ...) are derived from the Debian codebase. Debian has **aptitude**, which is considered the best package management system.

### Mandriva

Mandriva is the unification of the Brazilian distro Conectiva with the French distro Mandrake. They are considered a user friendly distro with support from the French government.

## 1.3.3. BSD Distributions

### FreeBSD

**FreeBSD** is a complete operating system. The kernel and all of the utilities are held in the same source code tree. FreeBSD runs on many architectures and is considered to be reliable and robust. Millions of websites are running on FreeBSD, including some large ones like yahoo.com, apache.org, sony.co.jp, netcraft, php.net, and freebsd.org. Apple's MacOSX contains the FreeBSD virtual file system, network stack, and more.

### NetBSD

**NetBSD** development started around the same time (1993) as FreeBSD. NetBSD aims for maximum portability and thus runs on many architectures. NetBSD is often used in embedded devices.

### OpenBSD

Co-founder **Theo De Raadt** from NetBSD founded the **OpenBSD** project in 1994. OpenBSD aims for maximum security. Over the past ten years, only two vulnerabilities have been found in the default install of OpenBSD. All source code is thoroughly checked. OpenBSD runs on sixteen different architectures and is commonly used for firewalls and IDS. The OpenBSD people also bring us **OpenSSH**.

## 1.3.4. Major Vendors of Unix

We should at least mention IBM's **AIX**, Sun's **Solaris**, and Hewlett-Packard's **HP-UX**, which are all based on the original Unix from Bell Labs (Unix System V). Sun's **SunOS**, HP's **Tru64** (originally from DEC), and Apple's **MacOSX** are more derived from the BSD branch. But most Unixes today may contain source code and implementations from both original Unix-branches.

## 1.3.5. Solaris

### Solaris 8 and Solaris 9

All **Sun Solaris** releases before Solaris 10 are proprietary binary only, just like IBM AIX and HP-UX.

### Solaris 10

Solaris 10 is the officially supported Sun distribution. It is a free (as in beer) download. Sun releases binary patches and updates. Sun would like a community built around the Solaris kernel, similar to the Linux community. Sun released the Solaris kernel under the CDDL, a license similar to the GPL, hoping this will happen.

### Nevada and Solaris Express

Nevada is the codename for the next release of Solaris (Solaris 11). It is currently under development by Sun and is based on the OpenSolaris code. Solaris Express Community Edition is an official, free binary release including open source OpenSolaris and some closed source technologies, updated twice a month without any support from Sun. Solaris Express Developer Edition is the same, but with some support, thorough testing before release, and is released twice a year.

### OpenSolaris, Belenix and Nexenta

OpenSolaris is an open source development project (yes, it is only source code). Future versions of the Solaris operating system are based on this source code. The **Belenix** LiveCD is based on OpenSolaris. Another famous OpenSolaris based distro is **Nexenta**. Nexenta (www.gnusolaris.org) looks like **Ubuntu** and feels like **Debian**. The goal of this **GNU/Solaris** project is to have the best Linux desktop (Ubuntu) including the **aptitude** package manager running on a Sun Solaris kernel.

# Chapter 2. Getting help

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# 2.1. man pages

Most Unix files and commands have pretty good man pages to explain their use. Man pages also come in handy when you are using multiple flavors of Unix or several Linux distributions since options and parameters sometimes vary.

## 2.1.1. man $command

Type **man** followed by a command (for which you want help) and start reading. Press **q** to quit the manpage. Some man pages contain examples (near the end).

```
paul@laika:~$ man whois
Reformatting whois(1), please wait...
```

## 2.1.2. man $configfile

Most **configuration files** have their own manual.

```
paul@laika:~$ man syslog.conf
Reformatting syslog.conf(5), please wait...
```

## 2.1.3. man $daemon

This is also true for most **daemons** (background programs) on your system..

```
paul@laika:~$ man syslogd
Reformatting syslogd(8), please wait...
```

## 2.1.4. man -k (apropos)

**man -k** (or **apropos**) shows a list of man pages containing a string.

```
paul@laika:~$ man -k syslog
lm-syslog-setup (8)  - configure laptop mode to switch syslog.conf ...
```

```
logger (1)           - a shell command interface to the syslog(3) ...
syslog-facility (8)  - Setup and remove LOCALx facility for sysklogd
syslog.conf (5)      - syslogd(8) configuration file
syslogd (8)          - Linux system logging utilities.
syslogd-listfiles (8) - list system logfiles
```

### 2.1.5. whatis

To see just the description of a manual page, use **whatis** followed by a string.

```
paul@u810:~$ whatis route
route (8)            - show / manipulate the IP routing table
```

### 2.1.6. whereis

The location of a manpage can be revealed with **whereis**.

```
paul@laika:~$ whereis -m whois
whois: /usr/share/man/man1/whois.1.gz
```

This file is directly readable by **man**.

```
paul@laika:~$ man /usr/share/man/man1/whois.1.gz
```

### 2.1.7. man sections

By now you will have noticed the numbers between the round brackets. **man man** will explain to you that these are section numbers. Executable programs and shell commands reside in section one.

```
1 Executable programs or shell commands
2 System calls (functions provided by the kernel)
3 Library calls (functions within program libraries)
4 Special files (usually found in /dev)
5 File formats and conventions eg /etc/passwd
6 Games
7 Miscellaneous (including macro packages and conventions), e.g. man(7)
8 System administration commands (usually only for root)
9 Kernel routines [Non standard]
```

### 2.1.8. man $section $file

Therefor, when referring to the man page of the passwd command, you will see it written as **passwd(1)**; when referringto the passwd file, you will see it written as **passwd(5)**. The screenshot explains how to open the man page in the correct section.

```
[paul@RHEL52 ~]$ man passwd      # opens the lowest section (1)
[paul@RHEL52 ~]$ man 5 passwd    # opens a page from section 5
```

### 2.1.9. man man

If you want to know more about **man**, then Read The Fantastic Manual (RTFM).

*Unfortunately, manual pages do not have the answer to everything...*

```
paul@laika:~$ man woman
No manual entry for woman
```

### 2.1.10. mandb

Should you be convinced that a man page exists, but you can't access it, then try running **mandb**.

```
root@laika:~# mandb
0 man subdirectories contained newer manual pages.
0 manual pages were added.
0 stray cats were added.
0 old database entries were purged.
```

## 2.2. online help

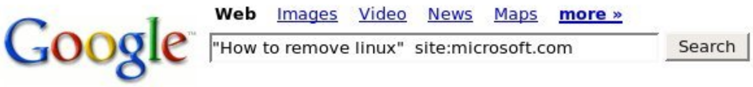
### 2.2.1. Google

Google is a powerful tool to find help about Unix, or anything else. Here are some tricks.

Look for phrases instead of single words.


Search only pages from the .be TLD (or substitute .be for any other Top Level Domain). You can also use "country:be" to search only pages from Belgium (based on ip rather than TLD).


Search for pages inside one domain




Search for pages **not** containing some words.


## 2.2.2. Wikipedia

Wikipedia is a web-based, free-content encyclopedia. Its growth over the past two years has been astonishing. You have a good chance of finding a clear explanation by typing your search term behind **http://en.wikipedia.org/wiki/** like this example shows.


## 2.2.3. The Linux Documentation Project

You can find much documentation, faqs, howtos and man pages about Linux and many of the programs running on Linux on **www.tldp.org** .

## 2.2.4. Red Hat

Red Hat has a lot of info online at **http://www.redhat.com/docs/manuals/** in both pdf and html format. These manuals are good, but unfortunately are not always up to date.

## 2.2.5. Ubuntu

Help for every Ubuntu release is available at **https://help.ubuntu.com**. Ubuntu also has video of how to perform tasks on Ubuntu at **http://screencasts.ubuntu.com**.

# Chapter 3. Working with directories

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# 3.1. working with directories

To explore the Linux **file tree**, you will need some basic tools. This chapter is small overview of the most common commands to work with directories : **pwd, cd, ls, mkdir, rmdir**. These commands are available on any Linux (or Unix) system.

## 3.1.1. pwd

The **you are here** sign can be displayed with the **pwd** command (Print Working Directory). Go ahead, try it: Open a command line interface (like gnome-terminal, konsole, xterm, or a tty) and type **pwd**. The tool displays your **current directory**.

```
paul@laika:~$ pwd
/home/paul
```

## 3.1.2. cd

You can change your current directory with the **cd** command (Change Directory).

```
paul@laika$ cd /etc
paul@laika$ pwd
/etc
paul@laika$ cd /bin
paul@laika$ pwd
/bin
paul@laika$ cd /home/paul/
paul@laika$ pwd
/home/paul
```

### cd ~

You can pull off a trick with cd. Just typing **cd** without a target directory, will put you in your home directory. Typing **cd ~** has the same effect.

```
paul@laika$ cd /etc
```

```
paul@laika$ pwd
/etc
paul@laika$ cd
paul@laika$ pwd
/home/paul
paul@laika$ cd ~
paul@laika$ pwd
/home/paul
```

### cd ..

To go to the **parent directory** (the one just above your current directory in the directory tree), type **cd ..** .

```
paul@laika$ pwd
/usr/share/games
paul@laika$ cd ..
paul@laika$ pwd
/usr/share
paul@laika$ cd ..
paul@laika$ cd ..
paul@laika$ pwd
/
```

*To stay in the current directory, type* ***cd .*** *;-)*

### cd -

Another useful shortcut with cd is to just type **cd -** to go to the previous directory.

```
paul@laika$ pwd
/home/paul
paul@laika$ cd /etc
paul@laika$ pwd
/etc
paul@laika$ cd -
/home/paul
paul@laika$ cd -
/etc
```

## 3.1.3. absolute and relative paths

You should be aware of **absolute and relative paths** in the file tree. When you type a path starting with a slash, then the root of the file tree is assumed. If you don't start your path with a slash, then the current directory is the assumed starting point.

The screenshot below first shows the current directory (/home/paul). From within this directory, you have to type **cd /home** instead of **cd home** to go to the /home directory.

```
paul@laika$ pwd
/home/paul
paul@laika$ cd home
bash: cd: home: No such file or directory
paul@laika$ cd /home
paul@laika$ pwd
/home
```

When inside /home, you have to type **cd paul** instead of **cd /paul** to enter the subdirectory paul of the current directory /home.

```
paul@laika$ pwd
/home
paul@laika$ cd /paul
bash: cd: /paul: No such file or directory
paul@laika$ cd paul
paul@laika$ pwd
/home/paul
```

In case your current directory is the root directory, then both **cd /home** and **cd home** will get you in the /home directory.

```
paul@laika$ cd /
paul@laika$ pwd
/
paul@laika$ cd home
paul@laika$ pwd
/home
paul@laika$ cd /
paul@laika$ pwd
/
paul@laika$ cd /home
paul@laika$ pwd
/home
```

This was the last screenshot with **pwd** statements. From now on, the current directory will often be displayed in the prompt. Later in this book we will explain how the shell variable **$PS1** can be configured to show this.

## 3.1.4. path completion

The **tab key** can help you in typing a path without errors. Typing **cd /et** followed by the tab key will expand the command line to **cd /etc/**. When typing **cd /Et** followed by the tab key, nothing will happen because you typed the wrong path (uppercase E).

You will need fewer key strokes when using the tab key, and you will be sure your typed path is correct!

## 3.1.5. ls

You can list the contents of a directory with **ls**.

```
paul@pasha:~$ ls
allfiles.txt  dmesg.txt  httpd.conf  stuff  summer.txt
paul@pasha:~$
```

## ls -a

A frequently used option with ls is **-a** to show all files. Showing all files means including the **hidden files**. When a filename on a Unix file system starts with a dot, it is considered a hidden file and it doesn't show up in regular file listings.

```
paul@pasha:~$ ls
allfiles.txt  dmesg.txt  httpd.conf  stuff  summer.txt
paul@pasha:~$ ls -a
.   allfiles.txt   .bash_profile  dmesg.txt   .lesshst  stuff
..  .bash_history  .bashrc        httpd.conf  .ssh      summer.txt
paul@pasha:~$
```

## ls -l

Many times you will be using options with ls to display the contents of the directory in different formats or to display different parts of the directory. Typing just **ls** gives you a list of files in the directory. Typing **ls -l** (that is a letter L, not the number 1) gives you a long listing (more information on the contents).

```
paul@pasha:~$ ls -l
total 23992
-rw-r--r-- 1 paul paul 24506857 2006-03-30 22:53 allfiles.txt
-rw-r--r-- 1 paul paul    14744 2006-09-27 11:45 dmesg.txt
-rw-r--r-- 1 paul paul     8189 2006-03-31 14:01 httpd.conf
drwxr-xr-x 2 paul paul     4096 2007-01-08 12:22 stuff
-rw-r--r-- 1 paul paul        0 2006-03-30 22:45 summer.txt
```

## ls -lh

Another frequently used ls option is **-h**. It shows the numbers (file sizes) in a more human readable format. Also shown below is some variation in the way you can give the options to ls. We will explain the details of the output later in this book.

```
paul@pasha:~$ ls -l -h
total 24M
-rw-r--r-- 1 paul paul  24M 2006-03-30 22:53 allfiles.txt
-rw-r--r-- 1 paul paul  15K 2006-09-27 11:45 dmesg.txt
-rw-r--r-- 1 paul paul 8.0K 2006-03-31 14:01 httpd.conf
drwxr-xr-x 2 paul paul 4.0K 2007-01-08 12:22 stuff
-rw-r--r-- 1 paul paul    0 2006-03-30 22:45 summer.txt
paul@pasha:~$ ls -lh
total 24M
-rw-r--r-- 1 paul paul  24M 2006-03-30 22:53 allfiles.txt
-rw-r--r-- 1 paul paul  15K 2006-09-27 11:45 dmesg.txt
```

```
-rw-r--r-- 1 paul paul 8.0K 2006-03-31 14:01 httpd.conf
drwxr-xr-x 2 paul paul 4.0K 2007-01-08 12:22 stuff
-rw-r--r-- 1 paul paul    0 2006-03-30 22:45 summer.txt
paul@pasha:~$ ls -hl
total 24M
-rw-r--r-- 1 paul paul  24M 2006-03-30 22:53 allfiles.txt
-rw-r--r-- 1 paul paul  15K 2006-09-27 11:45 dmesg.txt
-rw-r--r-- 1 paul paul 8.0K 2006-03-31 14:01 httpd.conf
drwxr-xr-x 2 paul paul 4.0K 2007-01-08 12:22 stuff
-rw-r--r-- 1 paul paul    0 2006-03-30 22:45 summer.txt
paul@pasha:~$ ls -h -l
total 24M
-rw-r--r-- 1 paul paul  24M 2006-03-30 22:53 allfiles.txt
-rw-r--r-- 1 paul paul  15K 2006-09-27 11:45 dmesg.txt
-rw-r--r-- 1 paul paul 8.0K 2006-03-31 14:01 httpd.conf
drwxr-xr-x 2 paul paul 4.0K 2007-01-08 12:22 stuff
-rw-r--r-- 1 paul paul    0 2006-03-30 22:45 summer.txt
```

## 3.1.6. mkdir

Walking around the Unix file tree is fun, but it is even more fun to create your own directories with **mkdir**. You have to give at least one parameter to **mkdir**, the name of the new directory to be created. Think before you type a leading / .

```
paul@laika:~$ mkdir MyDir
paul@laika:~$ cd MyDir
paul@laika:~/MyDir$ ls -al
total 8
drwxr-xr-x  2 paul paul 4096 2007-01-10 21:13 .
drwxr-xr-x 39 paul paul 4096 2007-01-10 21:13 ..
paul@laika:~/MyDir$ mkdir stuff
paul@laika:~/MyDir$ mkdir otherstuff
paul@laika:~/MyDir$ ls -l
total 8
drwxr-xr-x 2 paul paul 4096 2007-01-10 21:14 otherstuff
drwxr-xr-x 2 paul paul 4096 2007-01-10 21:14 stuff
paul@laika:~/MyDir$
```

### mkdir -p

When given the option **-p**, then mkdir will create parent directories as needed.

```
paul@laika:~$ mkdir -p MyDir2/MySubdir2/ThreeDeep
paul@laika:~$ ls MyDir2
MySubdir2
paul@laika:~$ ls MyDir2/MySubdir2
ThreeDeep
paul@laika:~$ ls MyDir2/MySubdir2/ThreeDeep/
```

## 3.1.7. rmdir

When a directory is empty, you can use **rmdir** to remove the directory.

```
paul@laika:~/MyDir$ rmdir otherstuff
paul@laika:~/MyDir$ ls
stuff
paul@laika:~/MyDir$ cd ..
paul@laika:~$ rmdir MyDir
rmdir: MyDir/: Directory not empty
paul@laika:~$ rmdir MyDir/stuff
paul@laika:~$ rmdir MyDir
```

## rmdir -p

And similar to the mkdir -p option, you can also use rmdir to recursively remove directories.

```
paul@laika:~$ mkdir -p dir/subdir/subdir2
paul@laika:~$ rmdir -p dir/subdir/subdir2
paul@laika:~$
```

# 3.2. practice : working with directories

1. Display your current directory.

2. Change to the /etc directory.

3. Now change to your home directory using only three key presses.

4. Change to the /boot/grub directory using only eleven key presses.

5. Go to the parent directory of the current directory.

6. Go to the root directory.

7. List the contents of the root directory.

8. List a long listing of the root directory.

9. Stay where you are, and list the contents of /etc.

10. Stay where you are, and list the contents of /bin and /sbin.

11. Stay where you are, and list the contents of ~.

12. List all the files (including hidden files) in your home directory.

13. List the files in /boot in a human readable format.

14. Create a directory testdir in your home directory.

15. Change to the /etc directory, stay here and create a directory newdir in your home directory.

16. Create in one command the directories ~/dir1/dir2/dir3 (dir3 is a subdirectory from dir2, and dir2 is a subdirectory from dir1 ).

17. Remove the directory testdir.

18. If time permits (or if you are waiting for other students to finish this practice), use and understand pushd and popd. Use the man page of bash to find information about pushd, popd and dirs.

# 3.3. ~~solution~~ : working with directories

1. Display your current directory.

```
pwd
```

2. Change to the /etc directory.

```
cd /etc
```

3. Now change to your home directory using only three key presses.

```
cd (and the enter key)
```

4. Change to the /boot/grub directory using only eleven key presses.

```
cd /boot/grub (use the tab key)
```

5. Go to the parent directory of the current directory.

```
cd .. (with space between cd and ..)
```

6. Go to the root directory.

```
cd /
```

7. List the contents of the root directory.

```
ls
```

8. List a long listing of the root directory.

```
ls -l
```

9. Stay where you are, and list the contents of /etc.

```
ls /etc
```

10. Stay where you are, and list the contents of /bin and /sbin.

```
ls /bin /sbin
```

11. Stay where you are, and list the contents of ~.

```
ls ~
```

12. List all the files (including hidden files) in your home directory.

```
ls -al ~
```

13. List the files in /boot in a human readable format.

```
ls -lh /boot
```

14. Create a directory testdir in your home directory.

```
mkdir ~/testdir
```

15. Change to the /etc directory, stay here and create a directory newdir in your home directory.

```
cd /etc ; mkdir ~/newdir
```

16. Create in one command the directories ~/dir1/dir2/dir3 (dir3 is a subdirectory from dir2, and dir2 is a subdirectory from dir1 ).

```
mkdir -p ~/dir1/dir2/dir3
```

17. Remove the directory testdir.

```
rmdir testdir
```

18. If time permits (or if you are waiting for other students to finish this practice), use and understand pushd and popd. Use the man page of bash to find information about pushd, popd and dirs.

```
man bash
```

The Bash shell has two built-in commands called **pushd** and **popd**. Both commands work with a common stack of previous directories. Pushd adds a directory to the stack and changes to a new current directory, popd removes a directory from the stack and sets the current directory.

```
paul@laika:/etc$ cd /bin
paul@laika:/bin$ pushd /lib
/lib /bin
paul@laika:/lib$ pushd /proc
/proc /lib /bin
paul@laika:/proc$
paul@laika:/proc$ popd
/lib /bin
paul@laika:/lib$
paul@laika:/lib$
paul@laika:/lib$ popd
/bin
paul@laika:/bin$
```

# Chapter 4. Working with files

## Table of Contents



# 4.1. working with files

## 4.1.1. all files are case sensitive

Linux is **case sensitive**, this means that **FILE1** is different from **file1**, and **/etc/hosts** is different from **/etc/Hosts** (the latter one does not exist on a typical Linux computer).

This screenshot shows the difference between two files, one with uppercase **W**, the other with lowercase **w**.

```
paul@laika:~/Linux$ ls
winter.txt  Winter.txt
paul@laika:~/Linux$ cat winter.txt
It is cold.
paul@laika:~/Linux$ cat Winter.txt
It is very cold!
```

## 4.1.2. file

The **file** utility determines the file type. Linux does not use extensions to determine the file type. Your editor does not care whether a file ends in .TXT or .DOC. As a system administrator, you should use the **file** command to determine the file type. Here are some examples on a typical Linux system.

```
paul@laika:~$ file pic33.png
pic33.png: PNG image data, 3840 x 1200, 8-bit/color RGBA, non-interlaced
paul@laika:~$ file /etc/passwd
/etc/passwd: ASCII text
paul@laika:~$ file HelloWorld.c
HelloWorld.c: ASCII C program text
```

Here's another example of the file utility. It shows different type of binaries on different architectures.

```
# Solaris 9 on Intel
bash-2.05$ file /bin/date
/bin/date:      ELF 32-bit LSB executable 80386 Version 1, dynamically \
linked, stripped
```

```
# Ubuntu Linux on AMD64
paul@laika:~$ file /bin/date
/bin/date: ELF 64-bit LSB executable, AMD x86-64, version 1 (SYSV), for\
 GNU/Linux 2.6.0, dynamically linked (uses shared libs), for GNU/Linux \
2.6.0, stripped

# Debian Sarge on SPARC
paul@pasha:~$ file /bin/date
/bin/date: ELF 32-bit MSB executable, SPARC, version 1 (SYSV), for GNU/\
Linux 2.4.1, dynamically linked (uses shared libs), for GNU/Linux 2.4.1\
, stripped

# AIX on RS/6000
serena@AIX7 /home/serena$ file /bin/date
/bin/date: executable (RISC System/6000) or object module
```

The file command uses a magic file that contains patterns to recognize filetypes. The magic file is located in **/usr/share/file/magic**. Type **man 5 magic** for more information.

## 4.1.3. touch

One easy way to create a file is with **touch**. (We will see many other ways for creating files later in this book.)

```
paul@laika:~/test$ touch file1
paul@laika:~/test$ touch file2
paul@laika:~/test$ touch file555
paul@laika:~/test$ ls -l
total 0
-rw-r--r-- 1 paul paul 0 2007-01-10 21:40 file1
-rw-r--r-- 1 paul paul 0 2007-01-10 21:40 file2
-rw-r--r-- 1 paul paul 0 2007-01-10 21:40 file555
```

### touch -t

Of course, touch can do more than just create files. Can you determine what by looking at the next screenshot? If not, check the manual for touch.

```
paul@laika:~/test$ touch -t 200505050000 SinkoDeMayo
paul@laika:~/test$ touch -t 130207111630 BigBattle
paul@laika:~/test$ ls -l
total 0
-rw-r--r-- 1 paul paul 0 1302-07-11 16:30 BigBattle
-rw-r--r-- 1 paul paul 0 2005-05-05 00:00 SinkoDeMayo
```

## 4.1.4. rm

When you no longer need a file, use **rm** to remove it. Unlike some graphical user interfaces, the command line in general does not have a *waste bin* or *trashcan* to recover files. When you use rm to remove a file, the file is gone. Therefore, be careful when removing files!

```
paul@laika:~/test$ ls
BigBattle  SinkoDeMayo
paul@laika:~/test$ rm BigBattle
paul@laika:~/test$ ls
SinkoDeMayo
```

### rm -i

To prevent yourself from accidentally removing a file, you can type **rm -i**.

```
paul@laika:~/Linux$ touch brel.txt
paul@laika:~/Linux$ rm -i brel.txt
rm: remove regular empty file `brel.txt'? y
paul@laika:~/Linux$
```

### rm -rf

By default, rm will not remove non-empty directories. However rm accepts several options that will allow you to remove any directory. The **rm -rf** statement is famous because it will erase anything (providing that you have the permissions to do so). When you are logged on as root, be very careful with **rm -rf** (the **f** means **force** and the **r** means **recursive**) since being root implies that permissions don't apply to you, so you can literally erase your entire file system by accident.

```
paul@laika:~$ ls test
SinkoDeMayo
paul@laika:~$ rm test
rm: cannot remove `test': Is a directory
paul@laika:~$ rm -rf test
paul@laika:~$ ls test
ls: test: No such file or directory
```

## 4.1.5. cp

To copy a file, use **cp** with a source and a target argument. If the target is a directory, then the source files are copied to that target directory.

```
paul@laika:~/test$ touch FileA
paul@laika:~/test$ ls
FileA
paul@laika:~/test$ cp FileA FileB
paul@laika:~/test$ ls
FileA  FileB
paul@laika:~/test$ mkdir MyDir
paul@laika:~/test$ ls
```

```
FileA  FileB  MyDir
paul@laika:~/test$ cp FileA MyDir/
paul@laika:~/test$ ls MyDir/
FileA
```

## cp -r

To copy complete directories, use **cp -r** (the **-r** option forces **recursive** copying of all files in all subdirectories).

```
paul@laika:~/test$ ls
FileA  FileB  MyDir
paul@laika:~/test$ ls MyDir/
FileA
paul@laika:~/test$ cp -r MyDir MyDirB
paul@laika:~/test$ ls
FileA  FileB  MyDir  MyDirB
paul@laika:~/test$ ls MyDirB
FileA
```

## cp multiple files to directory

You can also use cp to copy multiple files into a directory. In this case, the last argument (aka the target) must be a directory.

```
cp file1 file2 dir1/file3 dir1/file55 dir2
```

## cp -i

To prevent cp from overwriting existing files, use the -i (for interactive) option.

```
paul@laika:~/test$ cp fire water
paul@laika:~/test$ cp -i fire water
cp: overwrite `water'? no
paul@laika:~/test$
```

## cp -p

To preserve permissions and time stamps from source files, use **cp -p**.

```
paul@laika:~/perms$ cp file* cp
paul@laika:~/perms$ cp -p file* cpp
paul@laika:~/perms$ ll *
-rwx------ 1 paul paul    0 2008-08-25 13:26 file33
-rwxr-x--- 1 paul paul    0 2008-08-25 13:26 file42

cp:
total 0
-rwx------ 1 paul paul 0 2008-08-25 13:34 file33
-rwxr-x--- 1 paul paul 0 2008-08-25 13:34 file42
```

```
cpp:
total 0
-rwx------ 1 paul paul 0 2008-08-25 13:26 file33
-rwxr-x--- 1 paul paul 0 2008-08-25 13:26 file42
```

## 4.1.6. mv

Use **mv** to rename a file or to move the file to another directory.

```
paul@laika:~/test$ touch file100
paul@laika:~/test$ ls
file100
paul@laika:~/test$ mv file100 ABC.txt
paul@laika:~/test$ ls
ABC.txt
paul@laika:~/test$
```

When you need to rename only one file then **mv** is the preferred command to use.

## 4.1.7. rename

The **rename** command can also be used but it has a more complex syntax to enable renaming of many files at once. Below are two examples, the first switches all occurrences of txt to png for all filenames ending in .txt. The second example switches all occurrences of uppercase ABC in lowercase abc for all filenames ending in .png . The following syntax will work on debian and ubuntu (prior to Ubuntu 7.10).

```
paul@laika:~/test$ ls
123.txt  ABC.txt
paul@laika:~/test$ rename 's/txt/png/' *.txt
paul@laika:~/test$ ls
123.png  ABC.png
paul@laika:~/test$ rename 's/ABC/abc/' *.png
paul@laika:~/test$ ls
123.png  abc.png
paul@laika:~/test$
```

On Red Hat Enterprise Linux (and many other Linux distributions like Ubuntu 8.04), the syntax of rename is a bit different. The first example below renames all *.conf files replacing any occurrence of conf with bak. The second example renames all (*) files replacing one with ONE.

```
[paul@RHEL4a test]$ ls
one.conf  two.conf
[paul@RHEL4a test]$ rename conf bak *.conf
[paul@RHEL4a test]$ ls
one.bak  two.bak
[paul@RHEL4a test]$ rename one ONE *
[paul@RHEL4a test]$ ls
ONE.bak  two.bak
```

```
[paul@RHEL4a test]$
```

# 4.2. practice : working with files

1. List the files in the /bin directory

2. Display the type of file of /bin/cat, /etc/passwd and /usr/bin/passwd.

3a. Download wolf.jpg and book.pdf from http://www.linux-training.be (wget http://linux-training.be/files/studentfiles/wolf.jpg and wget http://linux-training.be/files/books/LinuxFun.pdf)

3b. Display the type of file of wolf.jpg and book.pdf

3c. Rename wolf.jpg to wolf.pdf (use mv).

3d. Display the type of file of wolf.pdf and book.pdf.

4. Create a directory ~/touched and enter it.

5. Create the files today.txt and yesterday.txt in touched.

6. Change the date on yesterday.txt to match yesterday's date.

7. Copy yesterday.txt to copy.yesterday.txt

8. Rename copy.yesterday.txt to kim

9. Create a directory called ~/testbackup and copy all files from ~/touched in it.

10. Use one command to remove the directory ~/testbackup and all files in it.

11. Create a directory ~/etcbackup and copy all *.conf files from /etc in it. Did you include all subdirectories of /etc ?

12. Use rename to rename all *.conf files to *.backup . (if you have more than one distro available, try it on all!)

# 4.3. solution : working with files

1. List the files in the /bin directory

```
ls /bin
```

2. Display the type of file of /bin/cat, /etc/passwd and /usr/bin/passwd.

```
file /bin/cat /etc/passwd /usr/bin/passwd
```

3a. Download wolf.jpg and book.pdf from http://www.linux-training.be (wget http://linux-training.be/files/studentfiles/wolf.jpg and wget http://linux-training.be/files/books/LinuxFun.pdf)

```
wget http://linux-training.be/files/studentfiles/wolf.jpg
wget http://linux-training.be/files/studentfiles/wolf.png
wget http://linux-training.be/files/books/LinuxFun.pdf
```

3b. Display the type of file of wolf.jpg and book.pdf

```
file wolf.jpg book.pdf
```

3c. Rename wolf.jpg to wolf.pdf (use mv).

```
mv wolf.jpg wolf.pdf
```

3d. Display the type of file of wolf.pdf and book.pdf.

```
file wolf.pdf book.pdf
```

4. Create a directory ~/touched and enter it.

```
mkdir ~/touched ; cd ~/touched
```

5. Create the files today.txt and yesterday.txt in touched.

```
touch today.txt yesterday.txt
```

6. Change the date on yesterday.txt to match yesterday's date.

```
touch -t 200810251405 yesterday.txt (substitute 20081025 with yesterday)
```

7. Copy yesterday.txt to copy.yesterday.txt

```
cp yesterday.txt copy.yesterday.txt
```

8. Rename copy.yesterday.txt to kim

```
mv copy.yesterday.txt kim
```

9. Create a directory called ~/testbackup and copy all files from ~/touched in it.

```
mkdir ~/testbackup ; cp -r ~/touched ~/testbackup/
```

10. Use one command to remove the directory ~/testbackup and all files in it.

```
rm -rf ~/testbackup
```

11. Create a directory ~/etcbackup and copy all *.conf files from /etc in it. Did you include all subdirectories of /etc ?

```
cp -r /etc/*.conf ~/etcbackup
```

```
Only *.conf files that are directly in /etc/ are copied.
```

12. Use rename to rename all *.conf files to *.backup . (if you have more than one distro available, try it on all!)

```
On RHEL: touch 1.conf 2.conf ; rename conf backup *.conf
```

```
On Debian: touch 1.conf 2.conf ; rename 's/conf/backup/' *.conf
```

# Chapter 5. Working with filecontents

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# 5.1. file contents

## 5.1.1. head

You can use **head** to display the first ten lines of a file.

```
paul@laika:~$ head /etc/passwd
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/bin/sh
bin:x:2:2:bin:/bin:/bin/sh
sys:x:3:3:sys:/dev:/bin/sh
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/bin/sh
man:x:6:12:man:/var/cache/man:/bin/sh
lp:x:7:7:lp:/var/spool/lpd:/bin/sh
mail:x:8:8:mail:/var/mail:/bin/sh
news:x:9:9:news:/var/spool/news:/bin/sh
paul@laika:~$
```

The head command can also display the first n lines of a file.

```
paul@laika:~$ head -4 /etc/passwd
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/bin/sh
bin:x:2:2:bin:/bin:/bin/sh
sys:x:3:3:sys:/dev:/bin/sh
```

Head can also display the first n bytes.

```
paul@laika:~$ head -c4 /etc/passwd
rootpaul@laika:~$
```

## 5.1.2. tail

Similar to head, the **tail** command will display the last ten lines of a file.

```
paul@laika:~$ tail /etc/services
vboxd           20012/udp
```

```
binkp           24554/tcp               # binkp fidonet protocol
asp             27374/tcp               # Address Search Protocol
asp             27374/udp
csync2          30865/tcp               # cluster synchronization tool
dircproxy       57000/tcp               # Detachable IRC Proxy
tfido           60177/tcp               # fidonet EMSI over telnet
fido            60179/tcp               # fidonet EMSI over TCP

# Local services
paul@laika:~$
```

You can give **tail** the number of lines you want to see.

```
$ tail -3 count.txt
six
seven
eight
```

The **tail** command has other useful options, some of which we will use some of them during this course.

## 5.1.3. cat

The **cat** command is one of the most universal tools. All it does is copy standard input to standard output. In combination with the shell this can be very powerful and diverse. Some examples will give a glimpse into the possibilities. The first example is simple, you can use cat to display a file on the screen. If the file is longer than the screen, it will scroll to the end.

```
paul@laika:~$ cat /etc/resolv.conf
nameserver 194.7.1.4
paul@laika:~$
```

### concatenate

**cat** is short for **concatenate**. One of the basic uses of cat is to concatenate files into a bigger (or complete) file.

```
paul@laika:~$ echo one > part1
paul@laika:~$ echo two > part2
paul@laika:~$ echo three > part3
paul@laika:~$ cat part1 part2 part3
one
two
three
paul@laika:~$
```

### create files

You can use **cat** to create files with one or more lines of text. Type the command as shown in the screenshot below. Then type one or more lines, finishing each line with the enter key. After the last line, type and hold the Control (Ctrl) key and press d. The **Ctrl d** key combination will send an **EOF** (End of File) to the running process ending the **cat** command.

```
paul@laika:~/test$ cat > winter.txt
It is very cold today!
paul@laika:~/test$ cat winter.txt
It is very cold today!
paul@laika:~/test$
```

You can choose this end marker for **cat** with **<<** as is shown in this screenshot.

```
paul@laika:~/test$ cat > hot.txt <<stop
> It is hot today!
> Yes it is summer.
> stop
paul@laika:~/test$ cat hot.txt
It is hot today!
Yes it is summer.
paul@laika:~/test$
```

### copy files

In the third example you will see that cat can be used to copy files. We will explain in detail what happens here in the bash shell chapter.

```
paul@laika:~/test$ cat winter.txt
It is very cold today!
paul@laika:~/test$ cat winter.txt > cold.txt
paul@laika:~/test$ cat cold.txt
It is very cold today!
paul@laika:~/test$
```

## 5.1.4. tac

Just one example will show you the purpose of **tac** (as the opposite of cat).

```
paul@laika:~/test$ cat count
one
two
three
four
paul@laika:~/test$ tac count
four
three
two
one
paul@laika:~/test$
```

## 5.1.5. more and less

The **more** command is useful for displaying files that take up more than one screen. More will allow you to see the contents of the file page by page. Use the spacebar to see the next page, or **q** to quit. Some people prefer the **less** command to **more**.

## 5.1.6. strings

With the **strings** command you can display readable ascii strings found in (binary) files. This example locates the **ls** binary then displays readable strings in the binary file (output is truncated).

```
paul@laika:~$ which ls
/bin/ls
paul@laika:~$ strings /bin/ls
/lib/ld-linux.so.2
librt.so.1
__gmon_start__
_Jv_RegisterClasses
clock_gettime
libacl.so.1
...
```

# 5.2. practice : file contents

1. Display the first 12 lines of /etc/services.

2. Display the last line of /etc/passwd.

3. Use cat to create a file named count.txt that looks like this:

```
One
Two
Three
Four
Five
```

4. Use cp to make a backup of this file to cnt.txt.

5. Use cat to make a backup of this file to catcnt.txt

6. Display catcnt.txt, but with all lines in reverse order (the last line first).

7. Use more to display /var/log/messages.

8. Display the readable character strings from the /usr/bin/passwd command.

9. Use ls to find the biggest file in /etc.

# 5.3. solution : file contents

1. Display the first 12 lines of /etc/services.

```
head -12 /etc/services
```

2. Display the last line of /etc/passwd.

```
tail -1 /etc/passwd
```

3. Use cat to create a file named count.txt that looks like this:

```
One
Two
Three
Four
Five
```

```
cat > count.txt
```

4. Use cp to make a backup of this file to cnt.txt.

```
cp count.txt cnt.txt
```

5. Use cat to make a backup of this file to catcnt.txt

```
cat count.txt > catcnt.txt
```

6. Display catcnt.txt, but with all lines in reverse order (the last line first).

```
tac catcnt.txt
```

7. Use more to display /var/log/messages.

```
more /var/log/messages
```

8. Display the readable character strings from the /usr/bin/passwd command.

```
strings /usr/bin/passwd
```

9. Use ls to find the biggest file in /etc.

```
cd ; ls -lrS /etc
```

# Chapter 6. The Linux file system tree

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# 6.1. file system tree

## 6.1.1. everything is a file

A directory is a special kind of file, but it is still a file. Even a terminal window or a hard disk is represented somewhere in the file system hierarchy as a file. It will become clear throughout this course that everything on Linux is a file.

## 6.1.2. / (the root directory)

All Linux systems have a directory structure that starts at the **root directory**. The root directory is represented by a slash, like this: /. Everything that exists on your linux system can be found below this root directory. Let's take a brief look at the contents of the root directory.

```
[paul@RHELv4u3 ~]$ ls /
bin   dev  home  media  mnt  proc  sbin     srv  tftpboot  usr
boot  etc  lib   misc   opt  root  selinux  sys  tmp       var
[paul@RHELv4u3 ~]$
```

## 6.1.3. man hier

There are some differences in the filesystems between Linux distributions. For help about your machine, enter **man hier** to find information about the file system hierarchy. This manual will explain the directory structure on your computer.

## 6.1.4. filesystem hierarchy standard

Many Linux distributions partially follow the **Filesystem Hierarchy Standard** (FHS). The FHS may help make more Unix/Linux file system trees conform better in the future. The **FHS** is available online at **http://www.pathname.com/fhs/** where we read: "The filesystem hierarchy standard has been designed to be used by Unix distribution developers, package developers, and system implementors. However, it is primarily intended to be a reference and is not a tutorial on how to manage a Unix filesystem or directory hierarchy."

## 6.1.5. common directories

Below we will discuss the most common directories in alphabetical order.

### /bin binaries

The **/bin** directory contains binaries for use by all users. According to the FHS the **/bin** directory should contain **/bin/cat** and **/bin/date** (among others). You will find a bin subdirectory in many other directories. Binaries are sometimes called **executables**. In the screenshot below you see common Unix/Linux commands like cat, cp, cpio, date, dd, echo, grep, and so on. Many of these will be covered in this book.

```
paul@laika:~$ ls /bin
archdetect       egrep             mt               setupcon
autopartition    false             mt-gnu           sh
bash             fgconsole         mv               sh.distrib
bunzip2          fgrep             nano             sleep
bzcat            fuser             nc               stralign
bzcmp            fusermount        nc.traditional   stty
bzdiff           get_mountoptions  netcat           su
bzegrep          grep              netstat          sync
bzexe            gunzip            ntfs-3g          sysfs
bzfgrep          gzexe             ntfs-3g.probe    tailf
bzgrep           gzip              parted_devices   tar
bzip2            hostname          parted_server    tempfile
bzip2recover     hw-detect         partman          touch
bzless           ip                partman-commit   true
bzmore           kbd_mode          perform_recipe   ulockmgr
cat              kill              pidof            umount
...
```

### /boot static files to boot the system

The **/boot** directory contains all files needed to boot the computer. These files don't change very often. On Linux systems you typically find the **/boot/grub** directory here. **/boot/grub** contains **/boot/grub/menu.lst** (the grub configuration file is often linked to **/boot/grub/grub.conf**) which defines the boot menu that is displayed before the kernel starts.

### /dev device files

Device files in **/dev** appear to be ordinary files, but are not actually located on the hard disk. The **/dev** directory is populated with files as the kernel is recognizing hardware.

#### common physical devices

Common hardware such as hard disk devices are represented by device files in **/dev**. Below a screenshot of SATA device files on a laptop and then IDE attached drives on a desktop. (The detailed meaning of these devices will be discussed later.)

```
#
# SATA or SCSI
#
paul@laika:~$ ls /dev/sd*
/dev/sda  /dev/sda1  /dev/sda2  /dev/sda3  /dev/sdb  /dev/sdb1  /dev/sdb2

#
# IDE or ATAPI
#
paul@barry:~$ ls /dev/hd*
/dev/hda  /dev/hda1  /dev/hda2  /dev/hdb  /dev/hdb1  /dev/hdb2  /dev/hdc
```

Besides representing physical hardware, some device files are special. These special devices can be very useful.

### /dev/tty and /dev/pts

For example, **/dev/tty1** represents a terminal or console attached to the system. (Don't break your head on the exact terminology of 'terminal' or 'console', what we mean here is a command line interface.) When typing commands in a terminal that is part of a graphical interface like Gnome or KDE, then your terminal will be represented as **/dev/pts/1** (1 can be another number).

### /dev/null

On Linux you will find other special devices such as **/dev/null** which can be considered a black hole; it has unlimited storage, but nothing can be retrieved from it. Technically speaking, anything written to /dev/null will be discarded. /dev/null can be useful to discard unwanted output from commands. */dev/null is not a good location to store your backups ;-).*

## /etc configuration files

All of the machine-specific configuration files should be located in **/etc**. Many times the name of a configuration files is the same as the application, daemon, or protocol with **.conf** added as the extension. There is much more to be found in **/etc**.

```
paul@laika:~$ ls /etc/*.conf
/etc/adduser.conf        /etc/ld.so.conf       /etc/scrollkeeper.conf
/etc/brltty.conf         /etc/lftp.conf        /etc/sysctl.conf
/etc/ccertificates.conf  /etc/libao.conf       /etc/syslog.conf
/etc/cvs-cron.conf       /etc/logrotate.conf   /etc/ucf.conf
/etc/ddclient.conf       /etc/ltrace.conf      /etc/uniconf.conf
/etc/debconf.conf        /etc/mke2fs.conf      /etc/updatedb.conf
/etc/deluser.conf        /etc/netscsid.conf    /etc/usplash.conf
/etc/fdmount.conf        /etc/nsswitch.conf    /etc/uswsusp.conf
/etc/hdparm.conf         /etc/pam.conf         /etc/vnc.conf
/etc/host.conf           /etc/pnm2ppa.conf     /etc/wodim.conf
/etc/inetd.conf          /etc/povray.conf      /etc/wvdial.conf
/etc/kernel-img.conf     /etc/resolv.conf
paul@laika:~$
```

### /etc/X11/

The graphical display (aka **X Window System** or just **X**) is driven by software from the X.org foundation. The configuration file for your graphical display is **/etc/X11/xorg.conf**.

### /etc/skel/

The **skeleton** directory **/etc/skel** is copied to the home directory of a newly created user. It usually contains hidden files like a **.bashrc** script.

### /etc/sysconfig/

This directory, which is not mentioned in the FHS, contains a lot of Red Hat Enterprise Linux configuration files. We will discuss some of them in greater detail. The screenshot below is the **/etc/sysconfig** directory from RHELv4u4 with everything installed.

```
paul@RHELv4u4:~$ ls /etc/sysconfig/
apmd          firstboot     irda              network      saslauthd
apm-scripts   grub          irqbalance        networking   selinux
authconfig    hidd          keyboard          ntpd         spamassassin
autofs        httpd         kudzu             openib.conf  squid
bluetooth     hwconf        lm_sensors        pand         syslog
clock         i18n          mouse             pcmcia       sys-config-sec
console       init          mouse.B           pgsql        sys-config-users
crond         installinfo   named             prelink      sys-logviewer
desktop       ipmi          netdump           rawdevices   tux
diskdump      iptables      netdump_id_dsa    rhn          vncservers
dund          iptables-cfg  netdump_id_dsa.p  samba        xinetd
paul@RHELv4u4:~$
```

The file **/etc/sysconfig/firstboot** tells the Red Hat Setup Agent not to run at boot time. If you want to run the Red Hat Setup Agent at the next reboot, then simply remove this file, and run **chkconfig --level 5 firstboot on**. The Red Hat Setup Agent allows you to install the latest updates, create a user account, join the Red Hat Network and more. It will then create the /etc/sysconfig/firstboot file again.

```
paul@RHELv4u4:~$ cat /etc/sysconfig/firstboot
RUN_FIRSTBOOT=NO
```

The **/etc/sysconfig/harddisks** file contains some parameters to tune the hard disks. The file explains itself.

You can see hardware detected by **kudzu** in **/etc/sysconfig/hwconf**. Kudzu is software from Red Hat for automatic discovery and configuration of hardware.

The keyboard type and keymap table are set in the **/etc/sysconfig/keyboard** file. For more console keyboard information, check the manual pages of **keymaps(5)**, **dumpkeys(1)**, **loadkeys(1)** and the directory **/lib/kbd/keymaps/**.

```
root@RHELv4u4:/etc/sysconfig# cat keyboard
KEYBOARDTYPE="pc"
KEYTABLE="us"
```

We will discuss networking files in this directory in the networking chapter.

## /home sweet home

You will find a lot of locations with an extensive hierarchy of personal or project data under **/home**. It is common (but not mandatory) practice to name the users home directory after the username in the format **/home/$USERNAME**. For example:

```
paul@pasha:~$ ls /home
geert  guillaume  maria  paul  tom
```

Besides giving every user (or every project or group) a location to store personal files, the home directory of a user also serves as a location to store the user profile. A typical Unix user profile contains many hidden files (files whose filename starts with a dot). The hidden files of the Unix user profiles contain settings specific for that user.

```
paul@pasha:~$ ls -d /home/paul/.*
/home/paul/.               /home/paul/.bash_profile  /home/paul/.ssh
/home/paul/..              /home/paul/.bashrc        /home/paul/.viminfo
/home/paul/.bash_history   /home/paul/.lesshst       /home/paul/.Xauthority
```

## /initrd

This empty directory is used as a mount point by Red Hat Enterprise Linux during boot time. Do not remove this directory, doing so causes a kernel panic during the next boot.

## /lib shared libraries

Binaries, like those found in **/bin**, often use shared libraries located in **/lib**. Below is a screenshot of the partial contents of **/lib**.

```
paul@laika:~$ ls /lib/libc*
/lib/libc-2.5.so     /lib/libcfont.so.0.0.0  /lib/libcom_err.so.2.1
/lib/libcap.so.1     /lib/libcidn-2.5.so     /lib/libconsole.so.0
/lib/libcap.so.1.10  /lib/libcidn.so.1       /lib/libconsole.so.0.0.0
/lib/libcfont.so.0   /lib/libcom_err.so.2    /lib/libcrypt-2.5.so
```

### /lib/modules

Typically, the kernel loads kernel modules from **/lib/modules/$kernel-version**. This directory is discussed in detail in the Linux kernel chapter.

### /lib32 and /lib64

We currently are in a transition between 32-bit and 64-bit systems. Therefore, you may encounter directories named **/lib32** and **/lib64** which clarify the register size used during compilation time of the libraries. My current 64-bit laptop has some older 32-bit binaries and libraries for compatibility with legacy applications. This screenshot uses the **file** utility to demonstrate the difference.

```
paul@laika:~$ file /lib32/libc-2.5.so
/lib32/libc-2.5.so: ELF 32-bit LSB shared object, Intel 80386, \
version 1 (SYSV), for GNU/Linux 2.6.0, stripped
paul@laika:~$ file /lib64/libcap.so.1.10
/lib64/libcap.so.1.10: ELF 64-bit LSB shared object, AMD x86-64, \
version 1 (SYSV), stripped
```

The ELF **(Executable and Linkable Format)** is used in almost every Unix-like operating system since System V.

## /media for removable media

The **/media** directory serves as a mount point for removable media devices such as CD-ROM's, digital cameras, and various usb-attached devices. Since **/media** is rather new in the Unix world, you could very well encounter systems running without this directory. Solaris 9 does not have it, Solaris 10 does. Most Linux distributions today mount all removable media in **/media**.

```
paul@laika:~$ ls /media/
cdrom  cdrom0  usbdisk
```

## /mnt standard mount point

Unix and Linux administrators used to mount many directories here, like /mnt/something/. According to the FHS, **/mnt** should only be used to mount something temporarily. You likely will encounter many systems with more than one directory mounted on **/mnt** and used as a mountpoints for various local and remote filesystems.

## /opt optional software

Most systems today have an empty **/opt** directory. It is considered outdated, but you may find some systems with add-on software installed in /opt. If that is the case, the package should install all its files in the typical **/bin**, **/lib**, **/etc** subdirectories within **/opt/$packagename/**. If for example the package is called wp, then it installs in **/opt/**

**wp**, putting binaries in **/opt/wp/bin** and manpages in **/opt/wp/man**. Little, if any, of the default software which comes along with the distributions will be installed in **/opt**.

## /proc conversation with the kernel

**/proc** is another special directory, appearing to be ordinary files, but not taking up disk space. It is actually a view of the kernel, or better, what the kernel manages, and is a means to interact with it directly. **/proc** is a proc filesystem.

```
paul@RHELv4u4:~$ mount -t proc
none on /proc type proc (rw)
```

When listing the /proc directory, you will see many numbers (on any Unix), and some interesting files (on Linux)

```
mul@laika:~$ ls /proc
1      2339   4724  5418  6587  7201       cmdline      mounts
10175  2523   4729  5421  6596  7204       cpuinfo      mtrr
10211  2783   4741  5658  6599  7206       crypto       net
10239  2975   4873  5661  6638  7214       devices      pagetypeinfo
141    29775  4874  5665  6652  7216       diskstats    partitions
15045  29792  4878  5927  6719  7218       dma          sched_debug
1519   2997   4879  6     6736  7223       driver       scsi
1548   3      4881  6032  6737  7224       execdomains  self
1551   30228  4882  6033  6755  7227       fb           slabinfo
1554   3069   5     6145  6762  7260       filesystems  stat
1557   31422  5073  6298  6774  7267       fs           swaps
1606   3149   5147  6414  6816  7275       ide          sys
180    31507  5203  6418  6991  7282       interrupts   sysrq-trigger
181    3189   5206  6419  6993  7298       iomem        sysvipc
182    3193   5228  6420  6996  7319       ioports      timer_list
18898  3246   5272  6421  7157  7330       irq          timer_stats
19799  3248   5291  6422  7163  7345       kallsyms     tty
19803  3253   5294  6423  7164  7513       kcore        uptime
19804  3372   5356  6424  7171  7525       key-users    version
1987   4      5370  6425  7175  7529       kmsg         version_signature
1989   42     5379  6426  7188  9964       loadavg      vmcore
2      45     5380  6430  7189  acpi       locks        vmnet
20845  4542   5412  6450  7191  asound     meminfo      vmstat
221    46     5414  6551  7192  buddyinfo  misc         zoneinfo
2338   4704   5416  6568  7199  bus        modules
```

Let's investigate the file properties inside **/proc**. Looking at the date and time will display the current date and time showing the files are constantly updated (a view on the kernel).

```
paul@RHELv4u4:~$ date
Mon Jan 29 18:06:32 EST 2007
paul@RHELv4u4:~$ ls -al /proc/cpuinfo
-r--r--r--  1 root root 0 Jan 29 18:06 /proc/cpuinfo
paul@RHELv4u4:~$
paul@RHELv4u4:~$  ...time passes...
paul@RHELv4u4:~$
paul@RHELv4u4:~$ date
Mon Jan 29 18:10:00 EST 2007
```

```
paul@RHELv4u4:~$ ls -al /proc/cpuinfo
-r--r--r--  1 root root 0 Jan 29 18:10 /proc/cpuinfo
```

Most files in /proc are 0 bytes, yet they contain data--sometimes a lot of data. You can see this by executing cat on files like **/proc/cpuinfo**, which contains information about the CPU.

```
paul@RHELv4u4:~$ file /proc/cpuinfo
/proc/cpuinfo: empty
paul@RHELv4u4:~$ cat /proc/cpuinfo
processor       : 0
vendor_id       : AuthenticAMD
cpu family      : 15
model           : 43
model name      : AMD Athlon(tm) 64 X2 Dual Core Processor 4600+
stepping        : 1
cpu MHz         : 2398.628
cache size      : 512 KB
fdiv_bug        : no
hlt_bug         : no
f00f_bug        : no
coma_bug        : no
fpu             : yes
fpu_exception   : yes
cpuid level     : 1
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic mtrr pge...
bogomips        : 4803.54
```

*Just for fun, here is /proc/cpuinfo on a Sun Sunblade 1000...*

```
paul@pasha:~$ cat /proc/cpuinfo
cpu : TI UltraSparc III (Cheetah)
fpu : UltraSparc III integrated FPU
promlib : Version 3 Revision 2
prom : 4.2.2
type : sun4u
ncpus probed : 2
ncpus active : 2
Cpu0Bogo : 498.68
Cpu0ClkTck : 000000002cb41780
Cpu1Bogo : 498.68
Cpu1ClkTck : 000000002cb41780
MMU Type : Cheetah
State:
CPU0: online
CPU1: online
```

*... and on a Sony Playstation 3.*

```
[root@ps3 tmp]# uname -a
Linux ps3 2.6.20-rc5 #58 SMP Thu Jan 18 13:35:01 CET 2007 ppc64 ppc64
ppc64 GNU/Linux
[root@ps3 tmp]# cat /proc/cpuinfo
processor       : 0
cpu             : Cell Broadband Engine, altivec supported
clock           : 3192.000000MHz
```

```
revision        : 5.1 (pvr 0070 0501)

processor       : 1
cpu             : Cell Broadband Engine, altivec supported
clock           : 3192.000000MHz
revision        : 5.1 (pvr 0070 0501)

timebase        : 79800000
platform        : PS3
machine         : PS3
```

Most of the files in /proc are read only, some require root privileges, some files are writable, and many files in **/proc/sys** are writable. Let's discuss some of the files in /proc.

### /proc/filesystems

The **/proc/filesystems** file displays a list of supported file systems. When you mount a file system without explicitly defining one, then mount will first try to probe **/etc/filesystems** and then probe **/proc/filesystems** for all the filesystems without the **nodev** label. If **/etc/filesystems** ends with a line containing only an asterisk (*) then both files are probed.

```
paul@RHELv4u4:~$ cat /proc/filesystems
nodev   sysfs
nodev   rootfs
nodev   bdev
nodev   proc
nodev   sockfs
nodev   binfmt_misc
nodev   usbfs
nodev   usbdevfs
nodev   futexfs
nodev   tmpfs
nodev   pipefs
nodev   eventpollfs
nodev   devpts
        ext2
nodev   ramfs
nodev   hugetlbfs
        iso9660
nodev   relayfs
nodev   mqueue
nodev   selinuxfs
        ext3
nodev   rpc_pipefs
nodev   vmware-hgfs
nodev   autofs
paul@RHELv4u4:~$
```

### /proc/interrupts

On the x86 architecture, **/proc/interrupts** displays the interrupts.

```
paul@RHELv4u4:~$ cat /proc/interrupts
```

```
           CPU0
  0:   13876877    IO-APIC-edge  timer
  1:         15    IO-APIC-edge  i8042
  8:          1    IO-APIC-edge  rtc
  9:          0   IO-APIC-level  acpi
 12:         67    IO-APIC-edge  i8042
 14:        128    IO-APIC-edge  ide0
 15:     124320    IO-APIC-edge  ide1
169:     111993   IO-APIC-level  ioc0
177:       2428   IO-APIC-level  eth0
NMI:          0
LOC:   13878037
ERR:          0
MIS:          0
paul@RHELv4u4:~$
```

On a machine with two CPU's, the file looks like this.

```
paul@laika:~$ cat /proc/interrupts
          CPU0      CPU1
  0:    860013         0  IO-APIC-edge     timer
  1:      4533         0  IO-APIC-edge     i8042
  7:         0         0  IO-APIC-edge     parport0
  8:   6588227         0  IO-APIC-edge     rtc
 10:      2314         0  IO-APIC-fasteoi  acpi
 12:       133         0  IO-APIC-edge     i8042
 14:         0         0  IO-APIC-edge     libata
 15:     72269         0  IO-APIC-edge     libata
 18:         1         0  IO-APIC-fasteoi  yenta
 19:    115036         0  IO-APIC-fasteoi  eth0
 20:    126871         0  IO-APIC-fasteoi  libata, ohci1394
 21:     30204         0  IO-APIC-fasteoi  ehci_hcd:usb1, uhci_hcd:usb2
 22:      1334         0  IO-APIC-fasteoi  saa7133[0], saa7133[0]
 24:    234739         0  IO-APIC-fasteoi  nvidia
NMI:        72        42
LOC:    860000    859994
ERR:         0
paul@laika:~$
```

## /proc/kcore

The physical memory is represented in **/proc/kcore**. Do not try to cat this file, instead use a debugger. The size of /proc/kcore is the same as your physical memory, plus four bytes.

```
paul@laika:~$ ls -lh /proc/kcore
-r-------- 1 root root 2.0G 2007-01-30 08:57 /proc/kcore
paul@laika:~$
```

## /proc/swaps

You can find information about **swap partition(s)** in **/proc/swaps**.

```
paul@RHELv4u4:~$ cat /proc/swaps
Filename                          Type        Size    Used    Priority
```

```
/dev/mapper/VolGroup00-LogVol01    partition   1048568 0       -1
paul@RHELv4u4:~$
```

## /root the superuser's home

On many systems, **/root** is the default location for the root user's personal data and profile. If it does not exist by default, then some administrators create it.

## /sbin system binaries

**/sbin** is similar to **/bin**, but it is mainly used for booting and configuration tools used for configuring the system. Many of the system binaries require root priviledge to perform certain tasks. You will find other **/sbin** subdirectories in other directories.

## /srv served by your system

You may find **/srv** to be empty on many systems, but not for long. The FHS suggests locating cvs, rsync, ftp and www data in this location. The FHS also approves administrative naming in /srv, like /srv/project55/ftp and /srv/sales/www. Red Hat plans to move some data currently located in /var to /srv.

## /sys Linux 2.6 hot plugging

The **/sys** directory was created for the Linux 2.6 kernel. Since 2.6, Linux uses **sysfs** to support **usb** and **IEEE 1394** (**FireWire**) hot plug devices. See the manual pages of udev(8) (the successor of **devfs**) and hotplug(8) for more info (or visit http://linux-hotplug.sourceforge.net/ ).

```
paul@RHELv4u4:~$ ls /sys/*
/sys/block:
dm-0 fd0 hdb md0  ram1  ram11 ram13 ram15 ram3 ram5 ram7 ram9
dm-1 hda hdc ram0 ram10 ram12 ram14 ram2  ram4 ram6 ram8 sda

/sys/bus:
i2c  ide  pci  platform  pnp  scsi  serio  usb

/sys/class:
firmware i2c-adapter input misc netlink printer scsi_device tty
graphics i2c-dev     mem   net  pci_bus raw     scsi_host   usb

/sys/devices:
pci0000:00  platform  system

/sys/firmware:
acpi

/sys/module:
ac       dm_mirror    ext3      ip_conntrack    ipt_state  md5
autofs4  dm_mod       floppy    iptable_filter  ipv6       mii
battery  dm_snapshot  i2c_core  ip_tables       jbd        mptbase
button   dm_zero      i2c_dev   ipt_REJECT      lp         mptfc
```

```
/sys/power:
state
paul@RHELv4u4:~$
```

## /tmp for temporary files

Applications and users should use **/tmp** to store temporary data when needed.Data stored in **/tmp** may use either disk space or RAM. Both of which are managed by the operating system. Never use **/tmp** to store data that is important or which you wish to archive.

## /usr Unix system resources

Although **/usr** is pronounced like user, remember that it stands for Unix System Resources. The /usr hierarchy should contain **sharable, read only** data. Some people choose to mount **/usr** as read only. This can be done from its own partition or from a read only NFS share.

## /var variable data

Data that is unpredictable in size, such as log files (**/var/log**), print spool directories (**/var/spool**), and various caches (**/var/cache**) should be located in **/var**. But **/var** is much more than that since it contains Process ID files in **/var/run** and temporary files that survive a reboot in **/var/tmp**. There will be more examples of /var usage further in this book.

### /var/lib/rpm

Red Hat Enterprise Linux keeps files pertaining to **RPM** in **/var/lib/rpm/**.

### /var/spool/up2date

The **Red Hat Update Agent** uses files in **/var/spool/up2date**. This location is also used when files are downloaded from the **Red Hat Network**.

# 6.2. practice : file system tree

1. Does the file **/bin/cat** exist ? What about **/bin/dd** and **/bin/echo**. What is the type of these files ?

2. What is the size of the Linux kernel file(s) (vmlinu*) in **/boot** ?

3. Create a directory ~/test. Then issue the following commands:

```
cd ~/test

dd if=/dev/zero of=zeroes.txt count=1 bs=100

od zeroes.txt
```

**dd** will copy one times (count=1) a block of size 100 bytes (bs=100) from the file **/dev/zero** to ~/test/zeroes.txt. Can you describe the functionality of **/dev/zero** ?

4. Now issue the following command:

```
dd if=/dev/random of=random.txt count=1 bs=100 ; od random.txt
```

**dd** will copy one times (count=1) a block of size 100 bytes (bs=100) from the file **/dev/random** to ~/test/random.txt. Can you describe the functionality of **/dev/random** ?

5. Issue the following two commands, and look at the first character of each output line.

```
ls -l /dev/sd* /dev/hd*

ls -l /dev/tty* /dev/input/mou*
```

The first ls will show block(b) devices, the second ls shows character(c) devices. Can you tell the difference between block and character devices ?

6. Use cat to display **/etc/hosts** and **/etc/resolv.conf**. What is your idea about the purpose of these files ?

7. Are there any files in **/etc/skel/** ? Check also for hidden files.

8. Display **/proc/cpuinfo**. On what architecture is your Linux running ?

9. Display **/proc/interrupts**. What is the size of this file ? Where is this file stored ?

10. Can you enter the **/root** directory ? Are there (hidden) files ?

11. Are ifconfig, fdisk, parted, shutdown and grub-install present in **/sbin** ? Why are these binaries in **/sbin** and not in **/bin** ?

12. Is **/var/log** a file or a directory ? What about **/var/spool** ?

13. Open two command prompts (Ctrl-Shift-T in gnome-terminal) or terminals (Ctrl-Alt-F1, Ctrl-Alt-F2, ...) and issue the **who am i** in both. Then try to echo a word from one terminal to the other.

14. Read the man page of **random** and explain the difference between **/dev/random** and **/dev/urandom**.

# 6.3. solution : file system tree

1. Does the file **/bin/cat** exist ? What about **/bin/dd** and **/bin/echo**. What is the type of these files ?

```
ls /bin/cat ; file /bin/cat

ls /bin/dd ; file /bin/dd

ls /bin/echo ; file /bin/echo
```

2. What is the size of the Linux kernel file(s) (vmlinu*) in **/boot** ?

```
ls -lh /boot/vm*
```

3. Create a directory ~/test. Then issue the following commands:

```
cd ~/test

dd if=/dev/zero of=zeroes.txt count=1 bs=100

od zeroes.txt
```

**dd** will copy one times (count=1) a block of size 100 bytes (bs=100) from the file **/dev/zero** to ~/test/zeroes.txt. Can you describe the functionality of **/dev/zero** ?

**/dev/zero** is a Linux special device. It can be considered a source of zeroes. You cannot send something to **/dev/zero**, but you can read zeroes from it.

4. Now issue the following command:

```
dd if=/dev/random of=random.txt count=1 bs=100 ; od random.txt
```

**dd** will copy one times (count=1) a block of size 100 bytes (bs=100) from the file **/dev/random** to ~/test/random.txt. Can you describe the functionality of **/dev/random** ?

**/dev/random** acts as a **random number generator** on your Linux machine.

5. Issue the following two commands, and look at the first character of each output line.

```
ls -l /dev/sd* /dev/hd*

ls -l /dev/tty* /dev/input/mou*
```

The first ls will show block(b) devices, the second ls shows character(c) devices. Can you tell the difference between block and character devices ?

Block devices are always written to (or read from) in blocks. For hard disks, blocks of 512 bytes are common. Character devices act as a stream of characters (or bytes). Mouse and keyboard are typical character devices.

6. Use cat to display **/etc/hosts** and **/etc/resolv.conf**. What is your idea about the purpose of these files ?

```
/etc/hosts contains hostnames with their ip address
```

```
/etc/resolv.conf should contain the ip address of a DNS name server.
```

7. Are there any files in **/etc/skel/** ? Check also for hidden files.

```
Issue "ls -al /etc/skel/". Yes, there should be hidden files there.
```

8. Display **/proc/cpuinfo**. On what architecture is your Linux running ?

```
The file should contain at least one line with Intel or other cpu.
```

9. Display **/proc/interrupts**. What is the size of this file ? Where is this file stored ?

The size is zero, yet the file contains data. It is not stored anywhere because /proc is a virtual file system that allows you to talk with the kernel. (If you answered "stored in RAM-memory, that is also correct...).

10. Can you enter the **/root** directory ? Are there (hidden) files ?

```
Try "cd /root". Yes there are (hidden) files there.
```

11. Are ifconfig, fdisk, parted, shutdown and grub-install present in **/sbin** ? Why are these binaries in **/sbin** and not in /bin ?

```
Because those files are only meant for system administrators.
```

12. Is **/var/log** a file or a directory ? What about **/var/spool** ?

```
Both are directories.
```

13. Open two command prompts (Ctrl-Shift-T in gnome-terminal) or terminals (Ctrl-Alt-F1, Ctrl-Alt-F2, ...) and issue the **who am i** in both. Then try to echo a word from one terminal to the other.

```
tty-terminal: echo Hello > /dev/tty1
```

```
pts-terminal: echo Hello > /dev/pts/1
```

14. Read the man page of **random** and explain the difference between **/dev/random** and **/dev/urandom**.

```
man 4 random
```

# Chapter 7. Introduction to the shell

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# 7.1. introduction to the shell

## 7.1.1. several shells

The command line interface used on most Linux systems is **bash**, which stands for **Bourne again shell**. The **bash** shell incorporates features from **sh** (the original Bourne shell), **csh** (the C shell), and **ksh** (the Korn shell). Ubuntu recently started including the **dash** (Debian ash) shell.

This chapter will explain general features of a shell mainly using the **/bin/bash** shell. Important differences in **/bin/ksh** will be mentioned separately.

## 7.1.2. external or built-in commands

Not all commands are external to the shell, some are built-in. **External commands** are programs that have their own binary and reside somewhere in the file system. Many external commands are located in **/bin** or **/sbin**. **Builtin commands** are functions inside the shell program itself.

## 7.1.3. type

To find out whether a command given to the shell will be executed as an **external command** or as a **built-in command**, use the **type** command.

```
paul@laika:~$ type cd
cd is a shell builtin
paul@laika:~$ type cat
cat is /bin/cat
```

You can also use this command to show you whether the command is aliased or not.

```
paul@laika:~$ type ls
ls is aliased to `ls --color=auto'
```

## 7.1.4. running external commands

Some commands have both built-in and external versions. When one of these commands is executed, the builtin version takes priority. To run the external version, you must enter the full path to the command.

```
paul@laika:~$ type -a echo
echo is a shell builtin
echo is /bin/echo
paul@laika:~$ /bin/echo Running the external echo command...
Running the external echo command...
```

## 7.1.5. which

The **which** command will search for binaries in the **PATH** environment variable. (Variables will be explained later.) In the screenshot below, it is determined that cd is built-in, and ls, cp, rm, mv, mkdir, pwd, and which are external commands.

```
[root@RHEL4b ~]# which cp ls mv rm cd mkdir pwd which
/bin/cp
/bin/ls
/bin/mv
/bin/rm
/usr/bin/which: no cd in (/usr/kerberos/sbin:/usr/kerberos/bin:...
/bin/mkdir
/bin/pwd
/usr/bin/which
```

## 7.1.6. alias

### create an alias

The shell allows you to create **aliases**. Aliases are often used to create an easier to remember name for an existing command or to easily supply parameters.

```
[paul@RHELv4u3 ~]$ cat count.txt
one
two
three
[paul@RHELv4u3 ~]$ alias dog=tac
[paul@RHELv4u3 ~]$ dog count.txt
three
two
one
```

## abbreviate commands

An **alias** can also be useful to abbreviate an existing command.

```
paul@laika:~$ alias ll='ls -lh --color=auto'
paul@laika:~$ alias c='clear'
paul@laika:~$
```

## default options

Aliases can be used to supply commands with default options. The example below shows how to set the **-i** option default when typing **rm**.

```
[paul@RHELv4u3 ~]$ rm -i winter.txt
rm: remove regular file `winter.txt'? no
[paul@RHELv4u3 ~]$ rm winter.txt
[paul@RHELv4u3 ~]$ ls winter.txt
ls: winter.txt: No such file or directory
[paul@RHELv4u3 ~]$ touch winter.txt
[paul@RHELv4u3 ~]$ alias rm='rm -i'
[paul@RHELv4u3 ~]$ rm winter.txt
rm: remove regular empty file `winter.txt'? no
[paul@RHELv4u3 ~]$
```

Some distributions enable default aliases to protect users from accidentally erasing files ('rm -i', 'mv -i', 'cp -i')

## viewing aliases

You can provide one or more aliases as arguments to the **alias** command to get their definitions. Providing no arguments gives a complete list of current aliases.

```
paul@laika:~$ alias c ll
alias c='clear'
alias ll='ls -lh --color=auto'
```

## unalias

You can undo an alias with the **unalias** command.

```
[paul@RHEL4b ~]$ which rm
/bin/rm
[paul@RHEL4b ~]$ alias rm='rm -i'
[paul@RHEL4b ~]$ which rm
alias rm='rm -i'
        /bin/rm
[paul@RHEL4b ~]$ unalias rm
[paul@RHEL4b ~]$ which rm
/bin/rm
```

```
[paul@RHEL4b ~]$
```

### 7.1.7. echo

This book frequently uses the **echo** command to demonstrate shell features. The echo command echoes the input that it receives.

```
paul@laika:~$ echo Burtonville
Burtonville
paul@laika:~$ echo Smurfs are blue
Smurfs are blue
```

### 7.1.8. shell expansion

The shell is very important because every command on your Linux system is processed and most likely changed by the shell. After you type the command, but before the command is executed, the shell might change your command line! The manual page of a typical shell contains more than one hundred pages.

One of the primary features of a shell is to perform a **command line scan**. When you enter a command at the shell's command prompt and press the enter key, then the shell will start scanning that line. While scanning the line, the shell may make many changes to the command line you typed. This process is called **shell expansion**. After the shell has finished scanning and modifying that line, it will be executed. Shell expansion is influenced by the following topics: control operators, white space removal, filename generation, variables, escaping, embedding, and shell aliases. All of these topics are discussed in the next sections.

### 7.1.9. displaying shell expansion

You can display the shell expansion with **set -x**, and stop displaying it with **set +x**. You might want to use this further on in this course, or when in doubt about exactly what the shell is doing with your command.

```
[paul@RHELv4u3 ~]$ set -x
++ echo -ne '\033]0;paul@RHELv4u3:~\007'
[paul@RHELv4u3 ~]$ echo $USER
+ echo paul
paul
++ echo -ne '\033]0;paul@RHELv4u3:~\007'
[paul@RHELv4u3 ~]$ echo \$USER
+ echo '$USER'
$USER
++ echo -ne '\033]0;paul@RHELv4u3:~\007'
[paul@RHELv4u3 ~]$ set +x
+ set +x
[paul@RHELv4u3 ~]$ echo $USER
paul
```

## 7.1.10. shell options

Both **set** and **unset** are built-in shell commands. They can be used to set options of the bash shell itself. The next example will clarify this. By default, the shell will treat unset variables as a variable having no value. By setting the -u option, the shell will treat any reference to unset variables as an error. See the man page of bash for more information.

```
[paul@RHEL4b ~]$ echo $var123

[paul@RHEL4b ~]$ set -u
[paul@RHEL4b ~]$ echo $var123
-bash: var123: unbound variable
[paul@RHEL4b ~]$ set +u
[paul@RHEL4b ~]$ echo $var123

[paul@RHEL4b ~]$
```

To list all the set options for your shell, use **echo $-**. The **noclobber** (or **-C**) option will be explained later in this book (in the I/O redirection chapter).

```
[paul@RHEL4b ~]$ echo $-
himBH
[paul@RHEL4b ~]$ set -C ; set -u
[paul@RHEL4b ~]$ echo $-
himuBCH
[paul@RHEL4b ~]$ set +C ; set +u
[paul@RHEL4b ~]$ echo $-
himBH
[paul@RHEL4b ~]$
```

# 7.2. practice: introduction to the shell

1. Is **tac** a shell built-in command ?

2. Is there an existing alias for **rm** ?

3. Read the man page of **rm**, make sure you understand the **-i** option of rm. Create and remove a file to test the -i option.

4. Execute: **alias rm='rm -i'** . Test your alias with a test file. Does this work as expected ?

5. List all current aliases.

6. Create an alias called 'city' that echoes your hometown.

7. Use your alias to test that it works.

8. Execute **set -x** to display shell expansion for every command.

9. Test the functionality of **set -x** by executing your **city** and **rm** aliases.

10 Execute **set +x** to stop displaying shell expansion.

11. Remove your city alias.

12. What is the location of the **cat** and the **passwd** commands ?

13. Explain the difference between the following commands:

```
echo

/bin/echo
```

14. Explain the difference between the following commands:

```
echo Hello

echo -n Hello
```

# 7.3. solution: introduction to the shell

1. Is **tac** a shell built-in command ?

```
type tac
```

2. Is there an existing alias for **rm** ?

```
alias rm
```

3. Read the man page of **rm**, make sure you understand the **-i** option of rm. Create and remove a file to test the -i option.

```
man rm

touch testfile

rm -i testfile
```

4. Execute: **alias rm='rm -i'** . Test your alias with a test file. Does this work as expected ?

```
touch testfile

rm testfile (should ask for confirmation)
```

5. List all current aliases.

```
alias
```

6. Create an alias called 'city' that echoes your hometown.

```
alias city='echo Antwerp'
```

7. Use your alias to test that it works.

```
city (it should display Antwerp)
```

8. Execute **set -x** to display shell expansion for every command.

```
set -x
```

9. Test the functionality of **set -x** by executing your **city** and **rm** aliases.

```
shell should display the resolved aliases and then execute the command:
paul@deb503:~$ set -x
paul@deb503:~$ city
+ echo antwerp
antwerp
```

10 Execute **set +x** to stop displaying shell expansion.

```
set +x
```

11. Remove your city alias.

```
unalias city
```

12. What is the location of the cat and the passwd commands ?

`which cat (probably /bin/cat)`

`which passwd (probably /usr/bin/passwd)`

13. Explain the difference between the following commands:

```
echo
```

```
/bin/echo
```

The **echo** command will be interpreted by the shell as the **built-in echo** command. The **/bin/echo** command will make the shell execute the **echo binary** located in the **/bin** directory.

14. Explain the difference between the following commands:

```
echo Hello
```

```
echo -n Hello
```

The -n option of the echo command will prevent echo from echoing a trailing newline. **echo Hello** will echo six characters in total, **echo -n hello** only echoes five characters.

The -n option might not work in the Korn shell.

# Chapter 8. Shell control operators

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# 8.1. control operators

## 8.1.1. ; semicolon

You can put two or more commands on the same line separated by a semicolon **;** . The shell will scan the line until it reaches the semicolon. All the arguments before this semicolon will be considered a separate command from all the arguments after the semicolon. Both series will be executed sequentially with the shell waiting for each command to finish before starting the next one.

```
[paul@RHELv4u3 ~]$ echo Hello
Hello
[paul@RHELv4u3 ~]$ echo World
World
[paul@RHELv4u3 ~]$ echo Hello ; echo World
Hello
World
[paul@RHELv4u3 ~]$
```

## 8.1.2. & ampersand

When a line ends with an ampersand **&**, the shell will not wait for the command to finish. You will get your shell prompt back, and the command is executed in background. You will get a message when this command has finished executing in background.

```
[paul@RHELv4u3 ~]$ sleep 20 &
[1] 7925
[paul@RHELv4u3 ~]$
...wait 20 seconds...
[paul@RHELv4u3 ~]$
[1]+  Done                    sleep 20
```

The technical explanation of what happens in this case is explained in the chapter about **processes**.

## 8.1.3. && double ampersand

The shell will interprete **&&** as a **logical AND**. When using **&&** the second command is executed only if the first one succeeds (returns a zero exit status).

```
paul@barry:~$ echo first && echo second
first
second
paul@barry:~$ zecho first && echo second
-bash: zecho: command not found
```

Another example of the same **logical AND** principle. This example starts with a working **cd** followed by **ls**, then a non-working **cd** which is **not** followed by **ls**.

```
[paul@RHELv4u3 ~]$ cd gen && ls
file1  file3  File55  fileab  FileAB   fileabc
file2  File4  FileA   Fileab  fileab2
[paul@RHELv4u3 gen]$ cd gen && ls
-bash: cd: gen: No such file or directory
[paul@RHELv4u3 gen]$
```

## 8.1.4. || double vertical bar

The **||** represents a **logical OR**. The second command is executed only when the first command fails (returns a non-zero exit status).

```
paul@barry:~$ echo first || echo second ; echo third
first
third
paul@barry:~$ zecho first || echo second ; echo third
-bash: zecho: command not found
second
third
paul@barry:~$
```

Another example of the same **logical OR** principle.

```
[paul@RHELv4u3 ~]$ cd gen || ls
[paul@RHELv4u3 gen]$ cd gen || ls
-bash: cd: gen: No such file or directory
file1  file3  File55  fileab  FileAB   fileabc
file2  File4  FileA   Fileab  fileab2
[paul@RHELv4u3 gen]$
```

## 8.1.5. Combining && and ||

You can use this logical AND and logical OR to write an **if-then-else** structure on the command line. This example uses **echo** to display whether the **rm** command was successful.

```
paul@laika:~/test$ rm file1 && echo It worked! || echo It failed!
It worked!
paul@laika:~/test$ rm file1 && echo It worked! || echo It failed!
rm: cannot remove `file1': No such file or directory
It failed!
paul@laika:~/test$
```

## 8.1.6. # pound sign

Everything written after a **pound sign** (#) is ignored by the shell. This is useful to write a **shell comment**, but has no influence on the command execution or shell expansion.

```
paul@barry:~$ mkdir test    # we create a directory
paul@barry:~$ cd test       #### we enter the directory
paul@barry:~/test$ ls       # is it empty ?
paul@barry:~/test$
```

## 8.1.7. \ escaping special characters

The backslash \ character enables the use of control characters, but without the shell interpreting it, this is called **escaping** characters.

```
[paul@RHELv4u3 ~]$ echo hello \; world
hello ; world
[paul@RHELv4u3 ~]$ echo hello\ \ \ world
hello   world
[paul@RHELv4u3 ~]$ echo escaping \\\ \#\ \&\ \"\ \'
escaping \ # & " '
[paul@RHELv4u3 ~]$ echo escaping \\\?\*\"\'
escaping \?*"'
```

## 8.1.8. end of line backslash

Lines ending in a backslash are continued on the next line. The shell does not interpret the newline character and will wait on shell expansion and execution of the command line until a newline without backslash is encountered.

```
[paul@RHEL4b ~]$ echo This command line \
> is split in three \
> parts
This command line is split in three parts
[paul@RHEL4b ~]$
```

# 8.2. practice: control operators

0. Each question can be answered by one command line!

1. When you type **passwd**, which file is executed ?

2. What kind of file is that ?

3. Execute the **pwd** command twice. (remember 0.)

4. Execute **ls** after **cd /etc**, but only if **cd /etc** did not error.

5. Execute **cd /etc** after **cd etc**, but only if **cd etc** fails.

6. Execute **sleep 6**, what is this command doing ?

7. Execute **sleep 200** in background (do not wait for it to finish).

8. Use echo to display "Hello World with strange' characters \ * [ } ~ \\ ." (including all quotes)

9. Use one echo command to display three words on three lines.

10. Echo **it worked** when **touch test42** works, and echo **it failed** when the touch failed. All on one command line as a normal user (not root). Test this line in your home directory and in **/bin/** .

# 8.3. solution: control operators

0. Each question can be answered by one command line!

1. When you type **passwd**, which file is executed ?

```
which passwd
```

2. What kind of file is that ?

```
file /usr/bin/passwd
```

3. Execute the **pwd** command twice. (remember 0.)

```
pwd ; pwd
```

4. Execute **ls** after **cd /etc**, but only if **cd /etc** did not error.

```
cd /etc && ls
```

5. Execute **cd /etc** after **cd etc**, but only if **cd etc** fails.

```
cd etc || cd /etc
```

6. Execute **sleep 6**, what is this command doing ?

```
pausing for six seconds
```

7. Execute **sleep 200** in background (do not wait for it to finish).

```
sleep 200 &
```

8. Use echo to display "Hello World with strange' characters \ * [ } ~ \\ ." (including all quotes)

```
echo \"Hello World with strange\' characters \\ \* \[ \} \~ \\\\ \. \"
```

```
or
```

```
echo \""Hello World with strange' characters \ * [ } ~ \\ . "\"
```

9. Use one echo command to display three words on three lines.

```
echo -e "one \ntwo \nthree"
```

10. Echo **it worked** when **touch test42** works, and echo **it failed** when the touch failed. All on one command line as a normal user (not root). Test this line in your home directory and in **/bin/** .

```
paul@deb503:~$ cd ; touch test42 && echo it worked || echo it failed
it worked
paul@deb503:~$ cd /bin; touch test42 && echo it worked || echo it failed
touch: cannot touch `test42': Permission denied
it failed
```

# Chapter 9. Shell variables

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# 9.1. shell variables

## 9.1.1. $ dollar sign

Another important character interpreted by the shell is the dollar sign **$**. The shell will look for an **environment variable** named like the string following the **dollar sign** and replace it with the value of the variable (or with nothing if the variable does not exist).

These are some examples using $HOSTNAME, $USER, $UID, $SHELL, and $HOME.

```
[paul@RHELv4u3 ~]$ echo This is the $SHELL shell
This is the /bin/bash shell
[paul@RHELv4u3 ~]$ echo This is $SHELL on computer $HOSTNAME
This is /bin/bash on computer RHELv4u3.localdomain
[paul@RHELv4u3 ~]$ echo The userid of $USER is $UID
The userid of paul is 500
[paul@RHELv4u3 ~]$ echo My homedir is $HOME
My homedir is /home/paul
```

## 9.1.2. case sensitive

An example is the $USER variable. The example shows that shell variables are case sensitive!

```
[paul@RHELv4u3 ~]$ echo Hello $USER
Hello paul
[paul@RHELv4u3 ~]$ echo Hello $user
Hello
```

## 9.1.3. $PS1

The **$PS1** variable determines your shell prompt. You can use backslash escaped special characters like **\u** for the username or **\w** for the working directory. The bash manual has a complete reference.

In this example we change the value of **$PS1** a couple of times.

```
paul@deb503:~$ PS1=prompt
prompt
promptPS1='prompt '
prompt
prompt PS1='> '
>
> PS1='\u@\h$ '
paul@deb503$
paul@deb503$ PS1='\u@\h:\W$'
paul@deb503:~$
```

## 9.1.4. $PATH

The **$PATH** variable is very important, it determines where the shell is looking for commands to execute (unless the command is built-in). The shell will not look in the current directory for commands to execute! (Looking for executables in the current directory provided an easy way to crack DOS computers). If you want the shell to look in the current directory, then add a . to your path.

```
[[paul@RHEL4b ~]$ echo $PATH
/usr/kerberos/bin:/usr/local/bin:/bin:/usr/bin:
[paul@RHEL4b ~]$ PATH=$PATH:.
[paul@RHEL4b ~]$ echo $PATH
/usr/kerberos/bin:/usr/local/bin:/bin:/usr/bin:.
[paul@RHEL4b ~]$
```

Your path might be different when using su instead of **su -** because the latter will take on the environment of the target user. The root user will have some sbin directories added to the PATH variable.

```
[paul@RHEL3 ~]$ su
Password:
[root@RHEL3 paul]# echo $PATH
/usr/local/bin:/bin:/usr/bin:/usr/X11R6/bin
[root@RHEL3 paul]# exit
[paul@RHEL3 ~]$ su -
Password:
[root@RHEL3 ~]# echo $PATH
/usr/local/sbin:/usr/local/bin:/sbin:/bin:/usr/sbin:/usr/bin:
[root@RHEL3 ~]#
```

## 9.1.5. $? dollar question mark

The exit code of the previous command is stored in the shell variable **$?**. Actually **$?** is a shell parameter and not a variable, since you cannot assign a value to **$?**.

```
paul@laika:~/test$ touch file1 ; echo $?
0
paul@laika:~/test$ rm file1 ; echo $?
```

```
0
paul@laika:~/test$ rm file1 ; echo $?
rm: cannot remove `file1': No such file or directory
1
```

## 9.1.6. unbound variables

The example below tries to display the value of the $MyVar variable, but it fails because the variable does not exist. By default the shell will display nothing when a variable is unbound (does not exist).

```
[paul@RHELv4u3 gen]$ echo $MyVar

[paul@RHELv4u3 gen]$
```

There is, however, the **nounset** shell attribute that you can use to generate an error when a variable does not exist.

```
paul@laika:~$ set -u
paul@laika:~$ echo $Myvar
bash: Myvar: unbound variable
paul@laika:~$ set +u
paul@laika:~$ echo $Myvar

paul@laika:~$
```

In the bash shell **set -u** is identical to **set -o nounset** and likewise **set +u** is identical to **set +o nounset**.

## 9.1.7. creating and setting variables

This example creates the variable **$MyVar** and sets its value.

```
[paul@RHELv4u3 gen]$ MyVar=555
[paul@RHELv4u3 gen]$ echo $MyVar
555
[paul@RHELv4u3 gen]$
```

## 9.1.8. set

You can use the **set** command to display a list of environment variables. On Ubuntu and Debian systems, the **set** command will also list shell functions after the shell variables. Use **set | more** to see the variables then.

## 9.1.9. unset

Use the **unset** command to remove a variable from your shell environment.

```
[paul@RHEL4b ~]$ MyVar=8472
[paul@RHEL4b ~]$ echo $MyVar;unset MyVar;echo $MyVar
8472

[paul@RHEL4b ~]$
```

## 9.1.10. env

The **env** command without options will display a list of **exported variables**. But **env** can also be used to start a clean shell (a shell without any inherited environment). The **env -i** command clears the environment for the subshell.

Notice in this screenshot that **bash** will set the **$SHELL** variable on startup.

```
[paul@RHEL4b ~]$ bash -c 'echo $SHELL $HOME $USER'
/bin/bash /home/paul paul
[paul@RHEL4b ~]$ env -i bash -c 'echo $SHELL $HOME $USER'
/bin/bash
[paul@RHEL4b ~]$
```

You can also use the **env** command to set the **$LANG**, or any other, variable for just one instance of **bash** with one command. The example below uses this to show the influence of the **$LANG** variable on file globbing (see the chapter on shell file globbing).

```
[paul@RHEL4b test]$ env LANG=C bash -c 'ls File[a-z]'
Filea  Fileb
[paul@RHEL4b test]$ env LANG=en_US.UTF-8 bash -c 'ls File[a-z]'
Filea  FileA  Fileb  FileB
[paul@RHEL4b test]$
```

## 9.1.11. exporting variables

You can export shell variables to other shells with the **export** command. This will export the variable to child shells.

```
[paul@RHEL4b ~]$ var3=three
[paul@RHEL4b ~]$ var4=four
[paul@RHEL4b ~]$ export var4
[paul@RHEL4b ~]$ echo $var3 $var4
three four
[paul@RHEL4b ~]$ bash
[paul@RHEL4b ~]$ echo $var3 $var4
four
```

But it will not export to the parent shell (previous screenshot continued).

```
[paul@RHEL4b ~]$ export var5=five
```

```
[paul@RHEL4b ~]$ echo $var3 $var4 $var5
four five
[paul@RHEL4b ~]$ exit
exit
[paul@RHEL4b ~]$ echo $var3 $var4 $var5
three four
[paul@RHEL4b ~]$
```

## 9.1.12. delineate variables

Until now, we have seen that bash interpretes a variable starting from a dollar sign, continuing until the first occurrence of a non-alphanumeric character that is not an underscore. In some situations, this can be a problem. This issue can be resolved with curly braces like in this example.

```
[paul@RHEL4b ~]$ prefix=Super
[paul@RHEL4b ~]$ echo Hello $prefixman and $prefixgirl
Hello  and
[paul@RHEL4b ~]$ echo Hello ${prefix}man and ${prefix}girl
Hello Superman and Supergirl
[paul@RHEL4b ~]$
```

## 9.1.13. quotes and variables

Notice that double quotes still allow the parsing of variables, whereas single quotes prevent this.

```
[paul@RHELv4u3 ~]$ MyVar=555
[paul@RHELv4u3 ~]$ echo $MyVar
555
[paul@RHELv4u3 ~]$ echo "$MyVar"
555
[paul@RHELv4u3 ~]$ echo '$MyVar'
$MyVar
```

The bash shell will replace variables with their value in double quoted lines, but not in single quoted lines.

```
paul@laika:~$ city=Burtonville
paul@laika:~$ echo "We are in $city today."
We are in Burtonville today.
paul@laika:~$ echo 'We are in $city today.'
We are in $city today.
```

# 9.2. practice: shell variables

1. Use echo to display Hello followed by your username. (use a bash variable!)

2. Copy the value of $LANG to $MyLANG.

3. List all current shell variables.

4. Create a variable MyVar with a value of 1201.

5. Do the **env** and **set** commands display your variable ?

6. Destroy your variable.

7. Find the list of shell options in the man page of bash. What is the difference between "set -u" and "set -o nounset" ?

8. Create two variables, and export one of them.

9. Display the exported variable in an interactive child shell.

10. Create a variable, give it the value 'Dumb', create another variable with value 'do'. Use echo and the two variables to echo Dumbledore.

11. Activate **nounset** in your shell. Test that it shows an error message when using non-existing variables.

12. Deactivate nounset.

13. Find the list of backslash escaped characters in the manual of bash. Add the time to your PS1 prompt.

# 9.3. solution: shell variables

1. Use echo to display Hello followed by your username. (use a bash variable!)

```
echo Hello $USER
```

2. Copy the value of $LANG to $MyLANG.

```
MyLANG=$LANG
```

3. List all current shell variables.

```
set
```

```
set|more on Ubuntu/Debian
```

4. Create a variable MyVar with a value of 1201.

```
MyVar=1201
```

5. Do the **env** and **set** commands display your variable ?

```
env | more
set | more
```

You will notice that **set** displays all variables, whereas **env** does not.

6. Destroy your variable.

```
unset MyVar
```

7. Find the list of shell options in the man page of bash. What is the difference between "set -u" and "set -o nounset" ?

read the manual of bash (man bash), search for nounset -- both mean the same thing.

8. Create two variables, and export one of them.

```
var1=1; export var2=2
```

9. Display the exported variable in an interactive child shell.

```
bash
```

```
echo $var2
```

10. Create a variable, give it the value 'Dumb', create another variable with value 'do'. Use echo and the two variables to echo Dumbledore.

```
varx=Dumb; vary=do
```

```
echo ${varx}le${vary}re
solution by Yves from Dexia : echo $varx'le'$vary're'
solution by Erwin from Telenet : echo "$varx"le"$vary"re
```

11. Activate **nounset** in your shell. Test that it shows an error message when using non-existing variables.

```
set -u
```

```
set -o nounset
```

Both these lines have the same effect (read the manual of bash, search for nounset).

12. Deactivate nounset.

```
set +u
```

```
set +o nounset
```

13. Find the list of backslash escaped characters in the manual of bash. Add the time to your PS1 prompt.

```
PS1='\t \u@\h$ '
```

# Chapter 10. Shell arguments

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# 10.1. shell arguments

## 10.1.1. white space removal

Before execution, the shell scans at the command line. Parts that are separated by one or more consecutive **white spaces** (or tabs) are considered separate **arguments**, any white space is removed. The first **argument** is the command to be executed, the other **arguments** are given to the command. The shell effectively cuts your command into one or more arguments.

This explains why the following four different command lines are the same after **shell expansion**.

```
[paul@RHELv4u3 ~]$ echo Hello World
Hello World
[paul@RHELv4u3 ~]$ echo Hello   World
Hello World
[paul@RHELv4u3 ~]$ echo   Hello   World
Hello World
[paul@RHELv4u3 ~]$    echo      Hello      World
Hello World
```

The **echo** command will display each argument it receives from the shell. The **echo** command will also add a new whitespace between the arguments it received.

It is important for troubleshooting any script to know that the shell cuts your command line in distinct arguments.

## 10.1.2. single quotes

You can prevent the removal of white spaces by quoting the spaces. The contents of the quoted string are considered as one argument. In the screenshot below the **echo** receives only one **argument**.

```
[paul@RHEL4b ~]$ echo 'A line with      single    quotes'
A line with      single    quotes
[paul@RHEL4b ~]$
```

### 10.1.3. double quotes

You can also prevent the removal of white spaces by double quoting the spaces. Same as above, **echo** only receives one **argument**.

```
[paul@RHEL4b ~]$ echo "A line with      double    quotes"
A line with      double    quotes
[paul@RHEL4b ~]$
```

The only difference between single and double quotes is the parsing of shell **variables**. You can already see the difference in this screenshot.

```
paul@laika:~$ echo 'My user is $USER'
My user is $USER
paul@laika:~$ echo "My user is $USER"
My user is paul
```

### 10.1.4. echo and quotes

Quoted lines can include special escaped characters recognized by the **echo** command (when using **echo -e**). The screenshot below shows how to use **\n** for a newline and **\t** for a tab (usually eight white spaces).

```
[paul@RHEL4b ~]$ echo -e "A line with \na newline"
A line with
a newline
[paul@RHEL4b ~]$ echo -e 'A line with \na newline'
A line with
a newline
[paul@RHEL4b ~]$ echo -e "A line with \ta tab"
A line with     a tab
[paul@RHEL4b ~]$ echo -e 'A line with \ta tab'
A line with     a tab
[paul@RHEL4b ~]$
```

The echo command can generate more than white spaces, tabs and newlines. Look in the man page for a list of options (and remember that echo may be both built-in and external).

### 10.1.5. shell embedding

Shells can be embedded on the command line, or in other words, the command line scan can spawn new processes containing a fork of the current shell. You can use variables to prove that new shells are created. In the screenshot below, the variable $var1 only exists in the (temporary) sub shell.

```
[paul@RHELv4u3 gen]$ echo $var1

[paul@RHELv4u3 gen]$ echo $(var1=5;echo $var1)
5
[paul@RHELv4u3 gen]$ echo $var1

[paul@RHELv4u3 gen]$
```

You can embed a shell in an **embedded shell**, this is called **nested embedding** of shells.

This screenshot shows an embedded shell inside an embedded shell.

```
paul@deb503:~$ A=shell
paul@deb503:~$ echo $C$B$A $(B=sub;echo $C$B$A; echo $(A=sub;echo $C$B$A))
shell subshell subsub
```

## 10.1.6. back ticks

Single embedding can be useful to avoid changing your current directory. The screenshot below uses **back ticks** instead of dollar-bracket to embed.

```
[paul@RHELv4u3 ~]$ echo `cd /etc; ls -d * | grep pass`
passwd passwd- passwd.OLD
[paul@RHELv4u3 ~]$
```

## 10.1.7. back ticks or single quotes

Placing the embedding between **backticks** uses one character less than the dollar and parenthesis combo. Be careful however, backticks are often confused with single quotes. The technical difference between **'** and **`** is significant! You can not use **backticks** to nest embedded shells.

```
[paul@RHELv4u3 gen]$ echo `var1=5;echo $var1`
5
[paul@RHELv4u3 gen]$ echo 'var1=5;echo $var1'
var1=5;echo $var1
[paul@RHELv4u3 gen]$
```

# 10.2. practice: shell arguments

1. Display **A B C** with two spaces between B and C.

2. Complete the following command (do not use spaces) to display exactly the following output:

```
echo -e "4+4=8" ; echo -e "10+14=24"
```

```
4+4     =8
10+14   =24
```

3. Use echo to display the following exactly:

```
??\\
```

4. Use one echo command to display three words on three lines.

5. Execute **cd /var** and **ls** in an embedded shell.

6. Create the variable embvar in an embedded shell and echo it. Does the variable exist in your current shell now ?

7. Explain what "set -x" does. Can this be useful ?

8. Given the following screenshot, add exactly four characters to that command line so that the total output is FirstMiddleLast.

```
[paul@RHEL4b ~]$ echo  First; echo  Middle; echo  Last
First
Middle
Last
```

9. Display a **long listing** (ls -l) of the **passwd** command using the **which** command inside back ticks.

# 10.3. solution: shell arguments

1. Display **A B C** with two spaces between B and C.

```
echo "A B  C"
```

2. Complete the following command (do not use spaces) to display exactly the following output:

```
4+4     =8
10+14   =24
```

The solution is to use tabs with \t.

```
echo -e "4+4\t=8" ; echo -e "10+14\t=24"
```

3. Use echo to display the following exactly:

```
echo '??\\'
```

4. Use one echo command to display three words on three lines.

```
echo -e "one \ntwo \nthree"
```

5. Execute **cd /var** and **ls** in an embedded shell.

```
echo $(cd /var ; ls)
```

The **echo** command is only needed to show the result of the **ls** command. Omitting will result in the shell trying to execute the first file as a command.

6. Create the variable embvar in an embedded shell and echo it. Does the variable exist in your current shell now ?

```
$(embvar=emb;echo $embvar) ; echo $embvar (the last echo fails).

$embvar does not exist in your current shell
```

7. Explain what "set -x" does. Can this be useful ?

```
It displays shell expansion for troubleshooting your command.
```

8. Given the following screenshot, add exactly four characters to that command line so that the total output is FirstMiddleLast.

```
[paul@RHEL4b ~]$ echo  First; echo  Middle; echo  Last
First
Middle
Last
```

```
echo -n First; echo -n Middle; echo Last
```

9. Display a **long listing** (ls -l) of the **passwd** command using the **which** command inside back ticks.

```
ls -l `which passwd`
```

# Chapter 11. Shell history

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# 11.1. shell history

## 11.1.1. history variables

The **bash** shell will remember the commands you type so you can easily repeat previous commands. Some variable definitions are used for this: **$HISTFILE** points to the location of the history file, **$HISTSIZE** will tell you how many commands will be remembered in your current shell session, and **$HISTFILESIZE** is the limit of the number of commands that will be kept in the history file. The file will be truncated when this limit is exceeded. Your shell session history is written to the file when exiting the shell. This screenshot lists some history variables in bash.

```
[paul@RHELv4u3 ~]$ echo $HISTFILE
/home/paul/.bash_history
[paul@RHELv4u3 ~]$ echo $HISTFILESIZE
1000
[paul@RHELv4u3 ~]$ echo $HISTSIZE
1000
[paul@RHELv4u3 ~]$
```

The $HISTFILE (defaults to .sh_history in the home directory) and $HISTSIZE variables are also used by the Korn shell (ksh).

```
$ set | grep -i hist
HISTSIZE=5000
```

## 11.1.2. repeating commands in bash

To repeat the last command in bash, type **!!**. This is pronounced as **bang bang**. To repeat older commands, use **history** to display the shell command history and type **!** followed by a number. The shell will echo the command and execute it.

```
[paul@RHELv4u3 ~]$ history
2  cat /etc/redhat-release
3  uname -r
4  rpm -qa | grep ^parted
...
[paul@RHELv4u3 ~]$ !3
uname -r
2.6.9-34.EL
```

```
[paul@RHELv4u3 ~]$
```

You can also use bang followed by one or more characters, **bash** will then repeat the last command that started with those characters. But this can be very dangerous, you have to be certain that the last command in your current shell history that starts with those characters is the command you wish to execute.

```
[paul@RHEL4b ~]$ ls file4
file4
[paul@RHEL4b ~]$ !ls
ls file4
file4
```

You can also use a colon followed by a regular expression to manipulate the previous command.

```
[paul@RHEL4b ~]$ !ls:s/4/5
ls file5
file5
```

The history command can also receive a value indicating the number of the most recent history lines to display.

```
[paul@RHEL4b ~]$ history 4
  422  ls file4
  423  ls file4
  424  ls file5
  425  history 4
[paul@RHEL4b ~]$
```

## 11.1.3. repeating commands in ksh

Repeating a command in the Korn shell is very similar. The Korn shell also has the **history** command, but uses the letter **r** to recall lines from history.

This screenshot shows the history command. Note the different meaning of the parameter.

```
$ history 17
17      clear
18      echo hoi
19      history 12
20      echo world
21      history 17
```

Repeating with r can be combined with the line numbers given by the history command, or with the first few letters of the command.

```
$ r e
echo world
world
$ cd /etc
$ r
cd /etc
$
```

# Chapter 12. Shell globbing

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# 12.1. file globbing

## 12.1.1. * asterisk

The shell is also responsible for **file globbing** (or dynamic filename generation). The asterisk ***** is interpreted by the shell as a sign to generate filenames, matching the asterisk to any combination of characters (even none). When no path is given, the shell will use filenames in the current directory. See the man page of **glob(7)** for more information. (This is part of LPI topic 1.103.3.)

```
[paul@RHELv4u3 gen]$ ls
file1  file2  file3  File4  File55  FileA  fileab  Fileab  FileAB  fileabc
[paul@RHELv4u3 gen]$ ls File*
File4  File55  FileA  Fileab  FileAB
[paul@RHELv4u3 gen]$ ls file*
file1  file2  file3  fileab  fileabc
[paul@RHELv4u3 gen]$ ls *ile55
File55
[paul@RHELv4u3 gen]$ ls F*ile55
File55
[paul@RHELv4u3 gen]$ ls F*55
File55
[paul@RHELv4u3 gen]$
```

## 12.1.2. ? question mark

Similar to the asterisk, the question mark **?** is interpreted by the shell as a sign to generate filenames, matching the question mark with exactly one character.

```
[paul@RHELv4u3 gen]$ ls
file1  file2  file3  File4  File55  FileA  fileab  Fileab  FileAB  fileabc
[paul@RHELv4u3 gen]$ ls File?
File4  FileA
[paul@RHELv4u3 gen]$ ls Fil?4
File4
[paul@RHELv4u3 gen]$ ls Fil??
File4  FileA
[paul@RHELv4u3 gen]$ ls File??
File55  Fileab  FileAB
[paul@RHELv4u3 gen]$
```

## 12.1.3. [] square brackets

The square bracket **[** is interpreted by the shell as a sign to generate filenames, matching any of the characters between **[** and the first subsequent **]**. The order in this list between the brackets is not important. Each pair of brackets is replaced by exactly one character.

```
[paul@RHELv4u3 gen]$ ls
file1  file2  file3  File4  File55  FileA  fileab  Fileab  FileAB  fileabc
[paul@RHELv4u3 gen]$ ls File[5A]
FileA
[paul@RHELv4u3 gen]$ ls File[A5]
FileA
[paul@RHELv4u3 gen]$ ls File[A5][5b]
File55
[paul@RHELv4u3 gen]$ ls File[a5][5b]
File55  Fileab
[paul@RHELv4u3 gen]$ ls File[a5][5b][abcdefghijklm]
ls: File[a5][5b][abcdefghijklm]: No such file or directory
[paul@RHELv4u3 gen]$ ls file[a5][5b][abcdefghijklm]
fileabc
[paul@RHELv4u3 gen]$
```

You can also exclude characters from a list between square brackets with the exclamation mark **!**. And you are allowed to make combinations of these **wild cards**.

```
[paul@RHELv4u3 gen]$ ls
file1  file2  file3  File4  File55  FileA  fileab  Fileab  FileAB  fileabc
[paul@RHELv4u3 gen]$ ls file[a5][!Z]
fileab
[paul@RHELv4u3 gen]$ ls file[!5]*
file1  file2  file3  fileab  fileabc
[paul@RHELv4u3 gen]$ ls file[!5]?
fileab
[paul@RHELv4u3 gen]$
```

## 12.1.4. a-z and 0-9 ranges

The bash shell will also understand ranges of characters between brackets.

```
[paul@RHELv4u3 gen]$ ls
file1  file3  File55  fileab  FileAB   fileabc
file2  File4  FileA   Fileab  fileab2
[paul@RHELv4u3 gen]$ ls file[a-z]*
fileab  fileab2  fileabc
[paul@RHELv4u3 gen]$ ls file[0-9]
file1  file2  file3
[paul@RHELv4u3 gen]$ ls file[a-z][a-z][0-9]*
fileab2
[paul@RHELv4u3 gen]$
```

## 12.1.5. $LANG and square brackets

But, don't forget the influence of the **LANG** variable. Some languages include lowercase letters in an uppercase range (and vice versa).

```
paul@RHELv4u4:~/test$ ls [A-Z]ile?
file1  file2  file3  File4
paul@RHELv4u4:~/test$ ls [a-z]ile?
file1  file2  file3  File4
paul@RHELv4u4:~/test$ echo $LANG
en_US.UTF-8
paul@RHELv4u4:~/test$ LANG=C
paul@RHELv4u4:~/test$ echo $LANG
C
paul@RHELv4u4:~/test$ ls [a-z]ile?
file1  file2  file3
paul@RHELv4u4:~/test$ ls [A-Z]ile?
File4
paul@RHELv4u4:~/test$
```

# 12.2. practice : shell globbing, options and history

1. Create a test directory and enter it.

2. Create files file1 file10 file11 file2 File2 File3 file33 fileAB filea fileA fileAAA file( file 2 (the last one has 6 characters including a space)

3. List (with ls) all files starting with file

4. List (with ls) all files starting with File

5. List (with ls) all files starting with file and ending in a number.

6. List (with ls) all files starting with file and ending with a letter

7. List (with ls) all files starting with File and having a digit as fifth character.

8. List (with ls) all files starting with File and having a digit as fifth character and nothing else.

9. List (with ls) all files starting with a letter and ending in a number.

10. List (with ls) all files that have exactly five characters.

11. List (with ls) all files that start with f or F and end with 3 or A.

12. List (with ls) all files that start with f have i or R as second character and end in a number.

13. List all files that do not start with the letter F.

14. Copy the value of $LANG to $MyLANG.

15. Show the influence of $LANG in listing A-Z or a-z ranges.

16. Write a command line that executes 'rm file55'. Your command line should print 'success' if file55 is removed, and print 'failed' if there was a problem.

17. You receive information that one of your servers was cracked, the cracker probably replaced the ls command. You know that the echo command is safe to use. Can echo replace ls ? How can you list the files in the current directory with echo ?

18. The cd command is also compromised, can echo be used to list files in other directories ? Explain how this works (list the contents of /etc and /bin without ls).

19. Is there another command besides cd to change directories ?

20. Make sure bash remembers the last 5000 commands you typed.

21. Open more than one console (press Ctrl-shift-t in gnome terminal) with the same user account. When is command history written to the history file ?

22. Issue the date command. Now display the date in YYYY/MM/DD format.

23. Issue the cal command. Display a calendar of 1582 and 1752. Notice anything special ?

# 12.3. solution: shell globbing, options and history

1. Create a test directory and enter it.

```
mkdir testdir; cd testdir
```

2. Create files file1 file10 file11 file2 File2 File3 file33 fileAB filea fileA fileAAA file( file 2 (the last one has 6 characters including a space)

```
touch file1 file10 file11 file2 File2 File3
touch file33 fileAB filea fileA fileAAA
touch "file("
touch "file 2"
```

3. List (with ls) all files starting with file

```
ls file*
```

4. List (with ls) all files starting with File

```
ls File*
```

5. List (with ls) all files starting with file and ending in a number.

```
ls file*[0-9]
```

6. List (with ls) all files starting with file and ending with a letter

```
ls file*[a-z]
```

7. List (with ls) all files starting with File and having a digit as fifth character.

```
ls File[0-9]*
```

8. List (with ls) all files starting with File and having a digit as fifth character and nothing else.

```
ls File[0-9]
```

9. List (with ls) all files starting with a letter and ending in a number.

```
ls [a-z]*[0-9]
```

10. List (with ls) all files that have exactly five characters.

```
ls ?????
```

11. List (with ls) all files that start with f or F and end with 3 or A.

```
ls [fF]*[3A]
```

12. List (with ls) all files that start with f have i or R as second character and end in a number.

```
ls f[iR]*[0-9]
```

13. List all files that do not start with the letter F.

```
ls [!F]*
```

14. Copy the value of $LANG to $MyLANG.

```
MyLANG=$LANG
```

15. Show the influence of $LANG in listing A-Z or a-z ranges.

```
see example in book
```

16. Write a command line that executes 'rm file55'. Your command line should print 'success' if file55 is removed, and print 'failed' if there was a problem.

```
rm file55 && echo success || echo failed
```

17. You receive information that one of your servers was cracked, the cracker probably replaced the ls command. You know that the echo command is safe to use. Can echo replace ls ? How can you list the files in the current directory with echo ?

```
echo *
```

18. The cd command is also compromised, can echo be used to list files in other directories ? Explain how this works (list the contents of /etc and /bin without ls).

```
echo /etc/* # the shell expands the directory for you
```

```
echo /bin/*
```

19. Is there another command besides cd to change directories ?

```
pushd popd
```

20. Make sure bash remembers the last 5000 commands you typed.

```
HISTSIZE=5000
```

21. Open more than one console (press Ctrl-shift-t in gnome terminal) with the same user account. When is command history written to the history file ?

```
when you type exit
```

22. Issue the date command. Now display the date in YYYY/MM/DD format.

```
date +%Y/%m/%d
```

23. Issue the cal command. Display a calendar of 1582 and 1752. Notice anything special ?

```
cal 1582
```

The calendars are different depending on the country. Check the file studentfiles/dates.txt

# Chapter 13. Shell I/O redirection

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# 13.1. shell i/o redirection

## 13.1.1. stdin, stdout, and stderr

The shell (and almost every other Linux command) takes input from **stdin** (stream **0**) and sends output to **stdout** (stream **1**) and error messages to **stderr** (stream **2**) .

The keyboard often server as **stdin**, **stdout** and **stderr** both go to the disply. The shell allows you to redirect these streams.

## 13.1.2. > output redirection

**stdout** can be redirected with a **greater than** sign. While scanning the line, the shell will see the > sign and will clear the file.

```
[paul@RHELv4u3 ~]$ echo It is cold today!
It is cold today!
[paul@RHELv4u3 ~]$ echo It is cold today! > winter.txt
[paul@RHELv4u3 ~]$ cat winter.txt
It is cold today!
[paul@RHELv4u3 ~]$
```

Let me repeat myself here: While scanning the line, the shell will see the > sign and will clear the file! This means that even when the command fails, the file will be cleared!

```
[paul@RHELv4u3 ~]$ cat winter.txt
It is cold today!
[paul@RHELv4u3 ~]$ zcho It is cold today! > winter.txt
-bash: zcho: command not found
[paul@RHELv4u3 ~]$ cat winter.txt
[paul@RHELv4u3 ~]$
```

Note that the > notation is in fact the abbreviation of **1>** (**stdout** being referred to as stream **1**.

# 13.1.3. noclobber

Erasing a file while using > can be prevented by setting the **noclobber** option.

```
[paul@RHELv4u3 ~]$ cat winter.txt
It is cold today!
[paul@RHELv4u3 ~]$ set -o noclobber
[paul@RHELv4u3 ~]$ echo It is cold today! > winter.txt
-bash: winter.txt: cannot overwrite existing file
[paul@RHELv4u3 ~]$ set +o noclobber
[paul@RHELv4u3 ~]$
```

The **noclobber** can be overruled with **>|**.

```
[paul@RHELv4u3 ~]$ set -o noclobber
[paul@RHELv4u3 ~]$ echo It is cold today! > winter.txt
-bash: winter.txt: cannot overwrite existing file
[paul@RHELv4u3 ~]$ echo It is very cold today! >| winter.txt
[paul@RHELv4u3 ~]$ cat winter.txt
It is very cold today!
[paul@RHELv4u3 ~]$
```

# 13.1.4. >> append

Use >> to **append** output to a file.

```
[paul@RHELv4u3 ~]$ echo It is cold today! > winter.txt
[paul@RHELv4u3 ~]$ cat winter.txt
It is cold today!
[paul@RHELv4u3 ~]$ echo Where is the summer ? >> winter.txt
[paul@RHELv4u3 ~]$ cat winter.txt
It is cold today!
Where is the summer ?
[paul@RHELv4u3 ~]$
```

# 13.1.5. 2> error redirection

Redirecting **stderr** is done with **2>**. This can be very useful to prevent error messages from cluttering your screen. The screenshot below shows redirection of **stdout** to a file, and **stderr** to **/dev/null**. Writing **1>** is the same as >.

```
[paul@RHELv4u3 ~]$ find / > allfiles.txt 2> /dev/null
[paul@RHELv4u3 ~]$
```

# 13.1.6. 2>&1

To redirect both **stdout** and **stderr** to the same file, use **2>&1**.

```
[paul@RHELv4u3 ~]$ find / > allfiles_and_errors.txt 2>&1
[paul@RHELv4u3 ~]$
```

Note that the order of redirections is significant. For example, the command

```
ls > dirlist 2>&1
```

directs both standard output (file descriptor 1) and standard error (file descriptor 2) to the file dirlist, while the command

```
ls 2>&1 > dirlist
```

directs only the standard output to file dirlist, because the standard error was made a copy of the standard output before the standard output was redirected to dirlist.

## 13.1.7. < input redirection

Redirecting **stdin** is done with < (short for 0<).

```
[paul@RHEL4b ~]$ cat < text.txt
one
two
[paul@RHEL4b ~]$ tr 'onetw' 'ONEZZ' < text.txt
ONE
ZZO
[paul@RHEL4b ~]$
```

## 13.1.8. << here document

The **here document** (sometimes called here-is-document) is a way to append input until a certain sequence (usually EOF) is encountered. The **EOF** marker can be typed literally or can be called with Ctrl-D.

```
[paul@RHEL4b ~]$ cat <<EOF > text.txt
> one
> two
> EOF
[paul@RHEL4b ~]$ cat text.txt
one
two
[paul@RHEL4b ~]$ cat <<brol > text.txt
> brel
> brol
[paul@RHEL4b ~]$ cat text.txt
brel
[paul@RHEL4b ~]$
```

## 13.1.9. confusing i/o redirection

The shell will scan the whole line before applying redirection. The following command line is very readable and is correct.

```
cat winter.txt > snow.txt 2> errors.txt
```

But this one is also correct, but less readable.

```
2> errors.txt cat winter.txt > snow.txt
```

Even this will be understood perfectly by the shell.

```
< winter.txt > snow.txt 2> errors.txt cat
```

## 13.1.10. quick file clear

So what is the quickest way to clear a file ?

```
>foo
```

And what is the quickest way to clear a file when the **noclobber** option is set ?

```
>|bar
```

## 13.1.11. swapping stdout and stderr

When filtering an output stream, e.g. through a regular pipe ( | ) you only can filter **stdout**. Say you want to filter out some unimportant error, out of the **stderr** stream. This cannot be done directly, and you need to 'swap' **stdout** and **stderr**. This can be done by using a 4th stream referred to with number 3:

```
3>&1 1>&2 2>&3
```

This Tower Of Hanoi like construction uses a temporary stream 3, to be able to swap **stdout** (1) and **stderr** (2). The following is an example of how to filter out all lines in the **stderr** stream, containing $uninterestingerror.

```
$command 3>&1 1>&2 2>&3 | grep -v $error 3>&1 1>&2 2>&3
```

But in this example, it can be done in a much shorter way, by using a pipe on STDERR:

```
/usr/bin/$somecommand |& grep -v $uninterestingerror
```

# 13.2. practice : i/o redirection

1. Use **ls** to output the contents of the **/etc/** directory to a file called **etc.txt**.

2. Activate the **noclobber** shell option.

3. Verify that **nocclobber** is active by repeating your **ls** on **/etc/**.

4. When listing all shell options, which character represents the **noclobber** option ?

5. Deactivate the **noclobber** option.

6. Make sure you have two shells open on the same computer. Create an empty **tailing.txt** file. Then type **tail -f tailing.txt**. Use the second shell to **append** a line of text to that file. Verify that the first shell displays this line.

7. Create a file that contains the names of five people. Use **cat** and output redirection to create the file and use a **here document** to end the input.

# 13.3. solution : i/o redirection

1. Use **ls** to output the contents of the **/etc/** directory to a file called **etc.txt**.

```
ls /etc > etc.txt
```

2. Activate the **noclobber** shell option.

```
set -o noclobber
```

3. Verify that **nocclobber** is active by repeating your **ls** on **/etc/**.

```
ls /etc > etc.txt (should not work)
```

4. When listing all shell options, which character represents the **noclobber** option ?

```
echo $- (noclobber is visible as C)
```

5. Deactivate the **noclobber** option.

```
set +o noclobber
```

6. Make sure you have two shells open on the same computer. Create an empty **tailing.txt** file. Then type **tail -f tailing.txt**. Use the second shell to **append** a line of text to that file. Verify that the first shell displays this line.

```
paul@deb503:~$ > tailing.txt
paul@deb503:~$ tail -f tailing.txt
hello
world

in the other shell:
paul@deb503:~$ echo hello >> tailing.txt
paul@deb503:~$ echo world >> tailing.txt
```

7. Create a file that contains the names of five people. Use **cat** and output redirection to create the file and use a **here document** to end the input.

```
paul@deb503:~$ cat > tennis.txt << ace
> Justine Henin
> Venus Williams
> Serena Williams
> Martina Hingis
> Kim Clijsters
> ace
paul@deb503:~$ cat tennis.txt
Justine Henin
Venus Williams
Serena Williams
Martina Hingis
Kim Clijsters
paul@deb503:~$
```

# Chapter 14. Pipes and filters

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# 14.1. pipes

## 14.1.1. about pipes

One of the most powerful advantages of **Linux** is the use of **pipes**.

A pipe takes **stdout** from the previous command and sends it as **stdin** to the next command. All commands in a **pipe** run simultaneously.

## 14.1.2. | vertical bar

A **pipe** is represented by a vertical bar **|** between two commands. Below is a very simple pipe.

```
[paul@RHEL4b pipes]$ cat count.txt | tac
five
four
three
two
one
[paul@RHEL4b pipes]$
```

## 14.1.3. multiple pipes

One command line can use multiple **pipes**. All commands in the **pipe** can run at the same time.

```
[paul@RHEL4b pipes]$ cat count.txt | tac | tac
one
two
three
four
five
[paul@RHEL4b pipes]$
```

# 14.2. filters

## 14.2.1. about filters

Tools that are written to be used with a **pipe** are often called **filters**. These **filters** are very small programs (or tools) that do one specific thing very efficiently. They can be used as **building blocks** for solutions.

## 14.2.2. cat does nothing

When between two **pipes**, the **cat** command does nothing (except putting **stdin** on **stdout**.

```
[paul@RHEL4b pipes]$ tac count.txt | cat | cat | cat | cat | cat
five
four
three
two
one
[paul@RHEL4b pipes]$
```

## 14.2.3. tee

Writing long **pipes** in Unix is fun, but sometimes you might want intermediate results. This is were **tee** comes in handy. The **tee** filter puts **stdin** on **stdout** and also into a file. So **tee** is almost the same as **cat**, except that it has two identical outputs.

```
[paul@RHEL4b pipes]$ tac count.txt | tee temp.txt | tac
one
two
three
four
five
[paul@RHEL4b pipes]$ cat temp.txt
five
four
three
two
one
[paul@RHEL4b pipes]$
```

## 14.2.4. grep

The **grep** filter is famous among Unix users. The most common use of **grep** is to filter lines of text containing (or not containing) a certain string.

```
[paul@RHEL4b pipes]$ cat tennis.txt
Amelie Mauresmo, Fra
Kim Clijsters, BEL
```

```
Justine Henin, Bel
Serena Williams, usa
Venus Williams, USA
[paul@RHEL4b pipes]$ cat tennis.txt | grep Williams
Serena Williams, usa
Venus Williams, USA
```

You can write this without the cat.

```
[paul@RHEL4b pipes]$ grep Williams tennis.txt
Serena Williams, usa
Venus Williams, USA
```

One of the most useful options of grep is **grep -i** which filters in a case insensitive way.

```
[paul@RHEL4b pipes]$ grep Bel tennis.txt
Justine Henin, Bel
[paul@RHEL4b pipes]$ grep -i Bel tennis.txt
Kim Clijsters, BEL
Justine Henin, Bel
[paul@RHEL4b pipes]$
```

Another very useful option is **grep -v** which outputs lines not matching the string.

```
[paul@RHEL4b pipes]$ grep -v Fra tennis.txt
Kim Clijsters, BEL
Justine Henin, Bel
Serena Williams, usa
Venus Williams, USA
[paul@RHEL4b pipes]$
```

And of course, both options can be combined to filter all lines not containing a case insensitive string.

```
[paul@RHEL4b pipes]$ grep -vi usa tennis.txt
Amelie Mauresmo, Fra
Kim Clijsters, BEL
Justine Henin, Bel
[paul@RHEL4b pipes]$
```

With **grep -A1** one line **after** the result is also displayed.

```
paul@deb503:~/pipes$ grep -A1 Henin tennis.txt
Justine Henin, Bel
Serena Williams, usa
```

With **grep -B1** one line **before** the result is also displayed.

```
paul@deb503:~/pipes$ grep -B1 Henin tennis.txt
Kim Clijsters, BEL
```

```
Justine Henin, Bel
```

With **grep -C1** (context) one line **before** and one **after** are also displayed. All three options (A,B, and C) can display any number of lines (using e.g. A2, B4 or C20).

```
paul@deb503:~/pipes$ grep -C1 Henin tennis.txt
Kim Clijsters, BEL
Justine Henin, Bel
Serena Williams, usa
```

## 14.2.5. cut

The **cut** filter can select columns from files, depending on a delimiter or a count of bytes. The screenshot below uses **cut** to filter for the username and userid in the **/etc/passwd** file. It uses the colon as a delimiter, and selects fields 1 and 3.

```
[[paul@RHEL4b pipes]$ cut -d: -f1,3 /etc/passwd | tail -4
Figo:510
Pfaff:511
Harry:516
Hermione:517
[paul@RHEL4b pipes]$
```

When using a space as the delimiter for **cut**, you have to quote the space.

```
[paul@RHEL4b pipes]$ cut -d" " -f1 tennis.txt
Amelie
Kim
Justine
Serena
Venus
[paul@RHEL4b pipes]$
```

This example uses **cut** to display the second to the seventh character of **/etc/passwd**.

```
[paul@RHEL4b pipes]$ cut -c2-7 /etc/passwd | tail -4
igo:x:
faff:x
arry:x
ermion
[paul@RHEL4b pipes]$
```

## 14.2.6. tr

You can translate characters with **tr**. The screenshot shows the translation of all occurrences of e to E.

```
[paul@RHEL4b pipes]$ cat tennis.txt | tr 'e' 'E'
```

```
AmEliE MaurEsmo, Fra
Kim ClijstErs, BEL
JustinE HEnin, BEl
SErEna Williams, usa
VEnus Williams, USA
```

Here we set all letters to uppercase by defining two ranges.

```
[paul@RHEL4b pipes]$ cat tennis.txt | tr 'a-z' 'A-Z'
AMELIE MAURESMO, FRA
KIM CLIJSTERS, BEL
JUSTINE HENIN, BEL
SERENA WILLIAMS, USA
VENUS WILLIAMS, USA
[paul@RHEL4b pipes]$
```

Here we translate all newlines to spaces.

```
[paul@RHEL4b pipes]$ cat count.txt
one
two
three
four
five
[paul@RHEL4b pipes]$ cat count.txt | tr '\n' ' '
one two three four five [paul@RHEL4b pipes]$
```

The **tr -s** filter can also be used to squeeze multiple occurrences of a character to one.

```
[paul@RHEL4b pipes]$ cat spaces.txt
one    two        three
     four   five  six
[paul@RHEL4b pipes]$ cat spaces.txt | tr -s ' '
one two three
 four five six
[paul@RHEL4b pipes]$
```

You can also use **tr** to 'encrypt' texts with **rot13**.

```
[paul@RHEL4b pipes]$ cat count.txt | tr 'a-z' 'nopqrstuvwxyzabcdefghijklm'
bar
gjb
guerr
sbhe
svir
[paul@RHEL4b pipes]$ cat count.txt | tr 'a-z' 'n-za-m'
bar
gjb
guerr
sbhe
svir
[paul@RHEL4b pipes]$
```

This last example uses **tr -d** to delete characters.

```
paul@deb503:~/pipes$ cat tennis.txt | tr -d e
Amli Maursmo, Fra
Kim Clijstrs, BEL
Justin Hnin, Bl
Srna Williams, usa
Vnus Williams, USA
```

## 14.2.7. wc

Counting words, lines and characters is easy with **wc**.

```
[paul@RHEL4b pipes]$ wc tennis.txt
  5  15 100 tennis.txt
[paul@RHEL4b pipes]$ wc -l tennis.txt
5 tennis.txt
[paul@RHEL4b pipes]$ wc -w tennis.txt
15 tennis.txt
[paul@RHEL4b pipes]$ wc -c tennis.txt
100 tennis.txt
[paul@RHEL4b pipes]$
```

## 14.2.8. sort

The **sort** filter will default to an alphabetical sort.

```
paul@deb503:~/pipes$ cat music.txt
Queen
Brel
Led Zeppelin
Abba
paul@deb503:~/pipes$ sort music.txt
Abba
Brel
Led Zeppelin
Queen
```

But the **sort** filter has many options to tweak its usage. This example shows sorting different columns (column 1 or column 2).

```
[paul@RHEL4b pipes]$ sort -k1 country.txt
Belgium, Brussels, 10
France, Paris, 60
Germany, Berlin, 100
Iran, Teheran, 70
Italy, Rome, 50
[paul@RHEL4b pipes]$ sort -k2 country.txt
Germany, Berlin, 100
Belgium, Brussels, 10
France, Paris, 60
Italy, Rome, 50
Iran, Teheran, 70
```

The screenshot below shows the difference between an alphabetical sort and a numerical sort (both on the third column).

```
[paul@RHEL4b pipes]$ sort -k3 country.txt
Belgium, Brussels, 10
Germany, Berlin, 100
Italy, Rome, 50
France, Paris, 60
Iran, Teheran, 70
[paul@RHEL4b pipes]$ sort -n -k3 country.txt
Belgium, Brussels, 10
Italy, Rome, 50
France, Paris, 60
Iran, Teheran, 70
Germany, Berlin, 100
```

## 14.2.9. uniq

With **uniq** you can remove duplicates from a **sorted list**.

```
paul@deb503:~/pipes$ cat music.txt
Queen
Brel
Queen
Abba
paul@deb503:~/pipes$ sort music.txt
Abba
Brel
Queen
Queen
paul@deb503:~/pipes$ sort music.txt |uniq
Abba
Brel
Queen
```

**uniq** can also count occurrences with the **-c** option.

```
paul@deb503:~/pipes$ sort music.txt |uniq -c
      1 Abba
      1 Brel
      2 Queen
```

## 14.2.10. comm

Comparing streams (or files) can be done with the **comm**. By default **comm** will output three columns. In this example, Abba, Cure and Queen are in both lists, Bowie and Sweet are only in the first file, Turner is only in the second.

```
paul@deb503:~/pipes$ cat > list1.txt
Abba
Bowie
```

```
Cure
Queen
Sweet
paul@deb503:~/pipes$ cat > list2.txt
Abba
Cure
Queen
Turner
paul@deb503:~/pipes$ comm list1.txt list2.txt
  Abba
Bowie
  Cure
  Queen
Sweet
 Turner
```

The output of **comm** can be easier to read when outputting only a single column. The digits point out which output columns should not be displayed.

```
paul@deb503:~/pipes$ comm -12 list1.txt list2.txt
Abba
Cure
Queen
paul@deb503:~/pipes$ comm -13 list1.txt list2.txt
Turner
paul@deb503:~/pipes$ comm -23 list1.txt list2.txt
Bowie
Sweet
```

# 14.2.11. od

European humans like to work with ascii characters, but computers store files in bytes. The example below creates a simple file, and then uses **od** to show the contents of the file in hexadecimal bytes, in octal bytes and in ascii (or backslashed) characters.

```
paul@laika:~/test$ cat > text.txt
abcdefg
1234567
paul@laika:~/test$ od -t x1 text.txt
0000000 61 62 63 64 65 66 67 0a 31 32 33 34 35 36 37 0a
0000020
paul@laika:~/test$ od -b text.txt
0000000 141 142 143 144 145 146 147 012 061 062 063 064 065 066 067 012
0000020
paul@laika:~/test$ od -c text.txt
0000000   a   b   c   d   e   f   g  \n   1   2   3   4   5   6   7  \n
0000020
paul@laika:~/test$
```

# 14.2.12. sed

The **s**tream **ed**itor **sed** can perform editing functions in the stream, using **regular expressions**.

```
paul@deb503:~/pipes$ echo level5 | sed 's/5/42/'
level42
paul@deb503:~/pipes$ echo level5 | sed 's/level/jump/'
jump5
```

Add **g** for global replacements (all occurrences of the string per line).

```
paul@deb503:~/pipes$ echo level5 level7 | sed 's/level/jump/'
jump5 level7
paul@deb503:~/pipes$ echo level5 level7 | sed 's/level/jump/g'
jump5 jump7
```

With **d** you can remove lines from a stream containing a character.

```
paul@deb503:~/test42$ cat tennis.txt
Venus Williams, USA
Martina Hingis, SUI
Justine Henin, BE
Serena williams, USA
Kim Clijsters, BE
Yanina Wickmayer, BE
paul@deb503:~/test42$ cat tennis.txt | sed '/BE/d'
Venus Williams, USA
Martina Hingis, SUI
Serena williams, USA
```

# 14.3. some pipeline examples

## 14.3.1. who | wc

How many users are logged on to this system ?

```
[paul@RHEL4b pipes]$ who
root     tty1         Jul 25 10:50
paul     pts/0        Jul 25 09:29 (laika)
Harry    pts/1        Jul 25 12:26 (barry)
paul     pts/2        Jul 25 12:26 (pasha)
[paul@RHEL4b pipes]$ who | wc -l
4
```

## 14.3.2. who | cut | sort

Display a sorted list of logged on users.

```
[paul@RHEL4b pipes]$ who | cut -d' ' -f1 | sort
Harry
paul
paul
root
```

Display a sorted list of logged on users, but every user only once.

```
[paul@RHEL4b pipes]$ who | cut -d' ' -f1 | sort | uniq
Harry
paul
root
```

### 14.3.3. grep | cut

Display a list of all bash user accounts on this computer. Users accounts are explained in detail later.

```
paul@deb503:~$ grep bash /etc/passwd
root:x:0:0:root:/root:/bin/bash
paul:x:1000:1000:paul,,,:/home/paul:/bin/bash
serena:x:1001:1001::/home/serena:/bin/bash
paul@deb503:~$ grep bash /etc/passwd | cut -d: -f1
root
paul
serena
```

# 14.4. practice : pipes and filters

1. Put a sorted list of all bash users in bashusers.txt.

2. Put a sorted list of all logged on users in onlineusers.txt.

3. Make a list of all files in **/etc** that contain the string samba.

4. Make a sorted list of all files in **/etc** that contain the case insensitive string samba.

5. Look at the output of **/sbin/ifconfig**. Write a line that displays only ip address and the subnet mask.

6. Write a line that removes all non-letters from a stream.

7. Write a line that receives a textfile, and outputs all words on a separate line.

8. Write a spell checker on the command line. (There might be a dictionary in **/usr/share/dict/** .)

# 14.5. solution : pipes and filters

1. Put a sorted list of all bash users in bashusers.txt.

```
grep bash /etc/passwd | cut -d: -f1 | sort > bashusers.txt
```

2. Put a sorted list of all logged on users in onlineusers.txt.

```
who | cut -d' ' -f1 | sort > onlineusers.txt
```

3. Make a list of all files in **/etc** that contain the string samba.

```
ls /etc | grep samba
```

4. Make a sorted list of all files in **/etc** that contain the case insensitive string samba.

```
ls /etc | grep -i samba | sort
```

5. Look at the output of **/sbin/ifconfig**. Write a line that displays only ip address and the subnet mask.

```
/sbin/ifconfig | head -2 | grep 'inet ' | tr -s ' ' | cut -d' ' -f3,5
```

6. Write a line that removes all non-letters from a stream.

```
paul@deb503:~$ cat text
This is, yes really! , a text with ?&* too many str$ange# characters ;-)
paul@deb503:~$ cat text | tr -d ',!$?.*&^%#@;()-'
This is yes really  a text with  too many strange characters
```

7. Write a line that receives a textfile, and outputs all words on a separate line.

```
paul@deb503:~$ cat text2
it is very cold today without the sun

paul@deb503:~$ cat text2 | tr ' ' '\n'
it
is
very
cold
today
without
the
sun
```

8. Write a spell checker on the command line. (There might be a dictionary in **/usr/share/dict/** .)

```
paul@rhel ~$ echo "The zun is shining today" > text

paul@rhel ~$ cat > DICT
is
shining
sun
the
today
```

```
paul@rhel ~$ cat text | tr 'A-Z ' 'a-z\n' | sort | uniq | comm -23 - DICT
zun
```

You could also add the solution from question number 6 to remove non-letters, and **tr -s ' '** to remove redundant spaces.

# Chapter 15. Basic Unix tools

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# 15.1. common tools

## 15.1.1. find

The **find** command can be very useful at the start of a pipe to search for files. Here are some examples. You might want to add **2>/dev/null** to the command lines to avoid cluttering your screen with error messages.

Find all files in **/etc** and put the list in etcfiles.txt

```
find /etc > etcfiles.txt
```

Find all files of the entire system and put the list in allfiles.txt

```
find / > allfiles.txt
```

Find files that end in .conf in the current directory (and all subdirs).

```
find . -name "*.conf"
```

Find files of type file (not directory, pipe or etc.) that end in .conf.

```
find . -type f -name "*.conf"
```

Find files of type directory that end in .bak .

```
find /data -type d -name "*.bak"
```

Find files that are newer than file42.txt

```
find . -newer file42.txt
```

Find can also execute another command on every file found. This example will look for *.odf files and copy them to /backup/.

```
find /data -name "*.odf" -exec cp {} /backup/ \;
```

Find can also execute, after your confirmation, another command on every file found. This example will remove *.odf files if you approve of it for every file found.

```
find /data -name "*.odf" -ok rm {} \;
```

## 15.1.2. locate

The **locate** tool is very different from **find** in that it uses an index to locate files. This is a lot faster than traversing all the directories, but it also means that it is always outdated. If the index does not exist yet, then you have to create it (as root on Red Hat Enterprise Linux) with the **updatedb** command.

```
[paul@RHEL4b ~]$ locate Samba
warning: locate: could not open database: /var/lib/slocate/slocate.db:...
warning: You need to run the 'updatedb' command (as root) to create th...
Please have a look at /etc/updatedb.conf to enable the daily cron job.
[paul@RHEL4b ~]$ updatedb
fatal error: updatedb: You are not authorized to create a default sloc...
[paul@RHEL4b ~]$ su -
Password:
[root@RHEL4b ~]# updatedb
[root@RHEL4b ~]#
```

Most Linux distributions will schedule the **updatedb** to run once every day.

## 15.1.3. date

The **date** command can display the date, time, timezone and more.

```
paul@rhel55 ~$ date
Sat Apr 17 12:44:30 CEST 2010
```

A date string can be customized to display the format of your choice. Check the man page for more options.

```
paul@rhel55 ~$ date +'%A %d-%m-%Y'
Saturday 17-04-2010
```

Time on any Unix is calculated in number of seconds since 1969 (the first second being the first second of the first of January 1970). Use **date +%s** to display Unix time in seconds.

```
paul@rhel55 ~$ date +%s
1271501080
```

When will this seconds counter reach two thousand million ?

```
paul@rhel55 ~$ date -d '1970-01-01 + 2000000000 seconds'
Wed May 18 04:33:20 CEST 2033
```

## 15.1.4. cal

The **cal** command displays the current month, with the current day highlighted.

```
paul@rhel55 ~$ cal
     April 2010
Su Mo Tu We Th Fr Sa
             1  2  3
 4  5  6  7  8  9 10
11 12 13 14 15 16 17
18 19 20 21 22 23 24
25 26 27 28 29 30
```

You can select any month in the past or the future.

```
paul@rhel55 ~$ cal 2 1970
   February 1970
Su Mo Tu We Th Fr Sa
 1  2  3  4  5  6  7
 8  9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
```

## 15.1.5. sleep

The **sleep** command is sometimes used in scripts to wait a number of seconds. This example shows a five second **sleep**.

```
paul@rhel55 ~$ sleep 5
paul@rhel55 ~$
```

## 15.1.6. time

The **time** command can display how long it takes to execute a command. The **date** command takes only a little time.

```
paul@rhel55 ~$ time date
Sat Apr 17 13:08:27 CEST 2010

real    0m0.014s
user    0m0.008s
sys     0m0.006s
```

The **sleep 5** command takes five **real** seconds to execute, but consumes little **cpu time**.

```
paul@rhel55 ~$ time sleep 5

real    0m5.018s
user    0m0.005s
sys     0m0.011s
```

This **bzip2** command compresses a file and uses a lot of **cpu time**.

```
paul@rhel55 ~$ time bzip2 text.txt
```

```
real    0m2.368s
user    0m0.847s
sys     0m0.539s
```

# 15.2. compression tools

## 15.2.1. gzip - gunzip

Users never have enough disk space, so compression comes in handy. The **gzip** command can make files take up less space.

```
paul@rhel55 ~$ ls -lh text.txt
-rw-rw-r-- 1 paul paul 6.4M Apr 17 13:11 text.txt
paul@rhel55 ~$ gzip text.txt
paul@rhel55 ~$ ls -lh text.txt.gz
-rw-rw-r-- 1 paul paul 760K Apr 17 13:11 text.txt.gz
```

You can get the original back with **gunzip**.

```
paul@rhel55 ~$ gunzip text.txt.gz
paul@rhel55 ~$ ls -lh text.txt
-rw-rw-r-- 1 paul paul 6.4M Apr 17 13:11 text.txt
```

## 15.2.2. zcat - zmore

Text files that are compressed with **gzip** can be viewed with **zcat** and **zmore**.

```
paul@rhel55 ~$ head -4 text.txt
/
/opt
/opt/VBoxGuestAdditions-3.1.6
/opt/VBoxGuestAdditions-3.1.6/routines.sh
paul@rhel55 ~$ gzip text.txt
paul@rhel55 ~$ zcat text.txt.gz | head -4
/
/opt
/opt/VBoxGuestAdditions-3.1.6
/opt/VBoxGuestAdditions-3.1.6/routines.sh
```

## 15.2.3. bzip2 - bunzip2

Files can also be compressed with **bzip2** which takes a little more time than **gzip**, but compresses better.

```
paul@rhel55 ~$ bzip2 text.txt
```

```
paul@rhel55 ~$ ls -lh text.txt.bz2
-rw-rw-r-- 1 paul paul 569K Apr 17 13:11 text.txt.bz2
```

Files can be uncompressed again with **bunzip2**.

```
paul@rhel55 ~$ bunzip2 text.txt.bz2
paul@rhel55 ~$ ls -lh text.txt
-rw-rw-r-- 1 paul paul 6.4M Apr 17 13:11 text.txt
```

## 15.2.4. bzcat - bzmore

And in the same way **bzcat** and **bzmore** can display files compressed with **bzip2**.

```
paul@rhel55 ~$ bzip2 text.txt
paul@rhel55 ~$ bzcat text.txt.bz2 | head -4
/
/opt
/opt/VBoxGuestAdditions-3.1.6
/opt/VBoxGuestAdditions-3.1.6/routines.sh
```

# 15.3. practice : basic Unix tools

1. Explain the difference between these two commands. This question is very important. If you don't know the answer, then look back at the **shell** chapter.

```
find /data -name "*.txt"

find /data -name *.txt
```

2. Explain the difference between these two statements. Will they both work when there are 200 **.odf** files in **/data** ? How about when there are 2 million .odf files ?

```
find /data -name "*.odf" > data_odf.txt

find /data/*.odf > data_odf.txt
```

3. Write a find command that finds all files created after January 30th 2010.

4. Write a find command that finds all *.odf files created in September 2009.

5. Count the number of *.conf files in /etc and all its subdirs.

6. Two commands that do the same thing: copy *.odf files to /backup/ . What would be a reason to replace the first command with the second ? Again, this is an important question.

```
cp -r /data/*.odf /backup/

find /data -name "*.odf" -exec cp {} /backup/ \;
```

7. Create a file called **loctest.txt**. Can you find this file with **locate** ? Why not ? How do you make locate find this file ?

8. Use find and -exec to rename all .htm files to .html.

# 15.4. solution : basic Unix tools

1. Explain the difference between these two commands. This question is very important. If you don't know the answer, then look back at the **shell** chapter.

```
find /data -name "*.txt"

find /data -name *.txt
```

When ***.txt** is quoted then the shell will not touch it. The **find** tool will look in the **/data** for all files ending in **.txt**.

When ***.txt** is not quoted then the shell might expand this (when one or more files that ends in **.txt** exist in the current directory). The **find** might show a different result, or can result in a syntax error.

2. Explain the difference between these two statements. Will they both work when there are 200 **.odf** files in **/data** ? How about when there are 2 million .odf files ?

```
find /data -name "*.odf" > data_odf.txt

find /data/*.odf > data_odf.txt
```

The first **find** will output all **.odf** filenames in **/data** and all subdirectories. The shell will redirect this to a file.

The second find will output all files named **.odf** in **/data** and will also output all files that exist in directories named ***.odf** (in **/data**).

With two million files the command line would be expanded beyond the maximum that the shell can accept. The last part of the command line would be lost.

3. Write a find command that finds all files created after January 30th 2010.

```
touch -t 201001302359 marker_date
find . -type f -newer marker_date

There is another solution :
find . -type f -newerat "20100130 23:59:59"
```

4. Write a find command that finds all *.odf files created in September 2009.

```
touch -t 200908312359 marker_start
touch -t 200910010000 marker_end
find . -type f -name "*.odf" -newer marker_start ! -newer marker_end
```

The exclamation mark **! -newer** can be read as **not newer**.

5. Count the number of *.conf files in /etc and all its subdirs.

```
find /etc -type f -name '*.conf' | wc -l
```

6. Two commands that do the same thing: copy *.odf files to /backup/ . What would be a reason to replace the first command with the second ? Again, this is an important question.

```
cp -r /data/*.odf /backup/
```

```
find /data -name "*.odf" -exec cp {} /backup/ \;
```

The first might fail when there are too many files to fit on one command line.

7. Create a file called **loctest.txt**. Can you find this file with **locate** ? Why not ? How do you make locate find this file ?

You cannot locate this with **locate** because it is not yet in the index.

```
updatedb
```

8. Use find and -exec to rename all .htm files to .html.

```
paul@rhel55 ~$ find . -name '*.htm'
./one.htm
./two.htm
paul@rhel55 ~$ find . -name '*.htm' -exec mv {} {}l \;
paul@rhel55 ~$ find . -name '*.htm*'
./one.html
./two.html
```

# Chapter 16. Introduction to vi

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# 16.1. about vi(m)

The **vi** editor is installed on almost every Unix. Linux will very often install **vim** (**vi improved**) which is similar. Every system administrator should know **vi(m)**, because it is an easy tool to solve problems.

The **vi** editor is not intuitive, but once you get to know it, **vi** becomes a very powerful application. Most Linux distributions will include the **vimtutor** which is a 45 minute lesson in **vi(m)**.

# 16.2. introduction to using vi(m)

## 16.2.1. command mode and insert mode

The vi editor starts in **command mode**. In command mode, you can type commands. Some commands will bring you into **insert mode**. In insert mode, you can type text. The **escape key** will return you to command mode.

**Table 16.1. getting to command mode**

| key | action |
|---|---|
| Esc | set vi(m) in command mode. |

## 16.2.2. start typing (a A i I o O)

The difference between a A i I o and O is the location where you can start typing. a will append after the current character and A will append at the end of the line. i will insert before the current character and I will insert at the beginning of the line. o will put you in a new line after the current line and O will put you in a new line before the current line.

**Table 16.2. switch to insert mode**

| command | action |
|---|---|
| a | start typing after the current character |
| A | start typing at the end of the current line |
| i | start typing before the current character |
| I | start typing at the start of the current line |
| o | start typing on a new line after the current line |
| O | start typing on a new line before the current line |

## 16.2.3. replace and delete a character (r x X)

When in command mode (it doesn't hurt to hit the escape key more than once) you can use the x key to delete the current character. The big X key (or shift x) will delete the character left of the cursor. Also when in command mode, you can use the r key to replace one single character. The r key will bring you in insert mode for just one key press, and will return you immediately to command mode.

**Table 16.3. replace and delete**

| command | action |
|---|---|
| x | delete the character below the cursor |
| X | delete the character before the cursor |
| r | replace the character below the cursor |
| p | paste after the cursor (here the last deleted character) |
| xp | switch two characters |

## 16.2.4. undo and repeat (u .)

When in command mode, you can undo your mistakes with u. You can do your mistakes twice with . (in other words, the . will repeat your last command).

**Table 16.4. undo and repeat**

| command | action |
|---|---|
| u | undo the last action |
| . | repeat the last action |

## 16.2.5. cut, copy and paste a line (dd yy p P)

When in command mode, dd will cut the current line. yy will copy the current line. You can paste the last copied or cut line after (p) or before (P) the current line.

**Table 16.5. cut, copy and paste a line**

| command | action |
|---|---|
| dd | cut the current line |
| yy | (yank yank) copy the current line |
| p | paste after the current line |
| P | paste before the current line |

## 16.2.6. cut, copy and paste lines (3dd 2yy)

When in command mode, before typing dd or yy, you can type a number to repeat the command a number of times. Thus, 5dd will cut 5 lines and 4yy will copy (yank) 4 lines. That last one will be noted by vi in the bottom left corner as "4 line yanked".

**Table 16.6. cut, copy and paste lines**

| command | action |
|---|---|
| 3dd | cut three lines |
| 4yy | copy four lines |

## 16.2.7. start and end of a line (0 or ^ and $)

When in command mode, the 0 and the caret ^ will bring you to the start of the current line, whereas the $ will put the cursor at the end of the current line. You can add 0 and $ to the d command, d0 will delete every character between the current character and the start of the line. Likewise d$ will delete everything from the current character till the end of the line. Similarly y0 and y$ will yank till start and end of the current line.

**Table 16.7. start and end of line**

| command | action |
|---|---|
| 0 | jump to start of current line |
| ^ | jump to start of current line |
| $ | jump to end of current line |
| d0 | delete until start of line |
| d$ | delete until end of line |

## 16.2.8. join two lines (J) and more

When in command mode, pressing **J** will append the next line to the current line. With **yyp** you duplicate a line and with **ddp** you switch two lines.

**Table 16.8. join two lines**

| command | action |
|---|---|
| J | join two lines |
| yyp | duplicate a line |
| ddp | switch two lines |

## 16.2.9. words (w b)

When in command mode, **w** will jump to the next word and **b** will move to the previous word. w and b can also be combined with d and y to copy and cut words (dw db yw yb).

**Table 16.9. words**

| command | action |
|---|---|
| w | forward one word |
| b | back one word |
| 3w | forward three words |
| dw | delete one word |
| yw | yank (copy) one word |
| 5yb | yank five words back |
| 7dw | delete seven words |

## 16.2.10. save (or not) and exit (:w :q :q! )

Pressing the colon : will allow you to give instructions to vi (technically speaking, typing the colon will open the **ex** editor). **:w** will write (save) the file, **:q** will quit an unchanged file without saving, and **:q!** will quit vi discarding any changes. **:wq** will save and quit and is the same as typing **ZZ** in command mode.

**Table 16.10. save and exit vi**

| command | action |
|---|---|
| :w | save (write) |
| :w fname | save as fname |
| :q | quit |
| :wq | save and quit |
| ZZ | save and quit |
| :q! | quit (discarding your changes) |
| :w! | save (and write to non-writable file!) |

The last one is a bit special. With **:w! vi** will try to **chmod** the file to get write permission (this works when you are the owner) and will **chmod** it back when the write succeeds. This should always work when you are root (and the file system is writable).

## 16.2.11. Searching (/ ?)

When in command mode typing / will allow you to search in vi for strings (can be a regular expression). Typing /foo will do a forward search for the string foo and typing ?bar will do a backward search for bar.

**Table 16.11. searching**

| command | action |
|---|---|
| /string | forward search for string |
| ?string | backward search for string |
| n | go to next occurrence of search string |
| /^string | forward search string at beginning of line |
| /string$ | forward search string at end of line |
| /br[aeio]l | search for bral brel bril and brol |
| /\<he\> | search for the word **he** (and not for **he**re or t**he**) |

## 16.2.12. Replace all ( :1,$ s/foo/bar/g )

To replace all occurrences of the string foo with bar, first switch to ex mode with : . Then tell vi which lines to use, for example 1,$ will do the replace all from the first to the last line. You can write 1,5 to only process the first five lines. The s/foo/bar/g will replace all occurences of foo with bar.

**Table 16.12. replace**

| command | action |
|---|---|
| :4,8 s/foo/bar/g | replace foo with bar on lines 4 to 8 |
| :1,$ s/foo/bar/g | replace foo with bar on all lines |

## 16.2.13. Reading files (:r :r !cmd)

When in command mode, :r foo will read the file named foo, :r !foo will execute the command foo. The result will be put at the current location. Thus :r !ls will put a listing of the current directory in your text file.

**Table 16.13. read files and input**

| command | action |
|---|---|
| :r fname | (read) file fname and paste contents |
| :r !cmd | execute cmd and paste its output |

## 16.2.14. text buffers

There are 36 buffers in vi to store text. You can use them with the **"** character.

**Table 16.14. text buffers**

| command | action |
|---|---|
| "add | delete current line and put text in buffer a |
| "g7yy | copy seven lines into buffer g |
| "ap | paste from buffer a |

## 16.2.15. multiple files

You can edit multiple files with vi. Here are some tips.

**Table 16.15. multiple files**

| command | action |
|---|---|
| vi file1 file2 file3 | start editing three files |
| :args | lists files and marks active file |
| :n | start editing the next file |
| :e | toggle with last edited file |
| :rew | rewind file pointer to first file |

## 16.2.16. abbreviations

With **:ab** you can put abbreviations in vi. Use **:una** to undo the abbreviation.

**Table 16.16. abbreviations**

| command | action |
|---|---|
| :ab str long string | abbreviate **str** to be 'long string' |
| :una str | un-abbreviate str |

## 16.2.17. key mappings

Similarly to their abbreviations, you can use mappings with **:map** for command mode and **:map!** for insert mode.

This example shows how to set the F6 function key to toggle between **set number** and **set nonumber**. The <bar> seperates the two commands, **set number!** toggles the state and **set number?** reports the current state.

```
:map <F6> :set number!<bar>set number?<CR>
```

## 16.2.18. setting options

Some options that you can set in vim.

```
:set number  ( also try :se nu )
:set nonumber
:syntax on
:syntax off
:set all  (list all options)
:set tabstop=8
:set tx   (CR/LF style endings)
:set notx
```

You can set these options (and much more) in **~/.vimrc** for vim or in **~/.exrc** for standard vi.

```
paul@barry:~$ cat ~/.vimrc
set number
set tabstop=8
set textwidth=78
map <F6> :set number!<bar>set number?<CR>
paul@barry:~$
```

# 16.3. practice : vi(m)

1. Start the vimtutor and do some or all of the exercises. You might need to run **aptitude install vim** on xubuntu.

2. What 3 key combination in command mode will duplicate the current line.

3. What 3 key combination in command mode will switch two lines' place (line five becomes line six and line six becomes line five).

4. What 2 key combination in command mode will switch a character's place with the next one.

5. vi can understand macro's. A macro can be recorded with q followed by the name of the macro. So qa will record the macro named a. Pressing q again will end the recording. You can recall the macro with @ followed by the name of the macro. Try this example: i 1 'Escape Key' qa yyp 'Ctrl a' q 5@a (Ctrl a will increase the number with one).

6. Copy /etc/passwd to your ~/passwd. Open the last one in vi and press Ctrl v. Use the arrow keys to select a Visual Block, you can copy this with y or delete it with d. Try pasting it.

7. What does dwwP do when you are at the beginning of a word in a sentence ?

# 16.4. solution : vi(m)

1. Start the vimtutor and do some or all of the exercises. You might need to run **aptitude install vim** on xubuntu.

```
vimtutor
```

2. What 3 key combination in command mode will duplicate the current line.

```
yyp
```

3. What 3 key combination in command mode will switch two lines' place (line five becomes line six and line six becomes line five).

```
ddp
```

4. What 2 key combination in command mode will switch a character's place with the next one.

```
xp
```

5. vi can understand macro's. A macro can be recorded with q followed by the name of the macro. So qa will record the macro named a. Pressing q again will end the recording. You can recall the macro with @ followed by the name of the macro. Try this example: i 1 'Escape Key' qa yyp 'Ctrl a' q 5@a (Ctrl a will increase the number with one).

6. Copy /etc/passwd to your ~/passwd. Open the last one in vi and press Ctrl v. Use the arrow keys to select a Visual Block, you can copy this with y or delete it with d. Try pasting it.

```
cp /etc/passwd ~
vi passwd
(press Ctrl-V)
```

7. What does **dwwP** do when you are at the beginning of a word in a sentence ?

**dwwP** can switch the current word with the next word.

# Chapter 17. Understanding scripts

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# 17.1. introduction to scripting

## 17.1.1. scripts are everywhere

Shells like **bash** and **Korn** have support for programming constructs that can be saved as **scripts**. These **scripts** in turn then become more **shell** commands. Many Linux commands are **scripts**. **User profile scripts** are run when a user logs and **init scripts** are run when a **daemon** is stopped or started.

This means that system administrators also need basic knowledge of **scripting** to understand how their servers and their applications are started, updated, upgraded, patched, maintained, configured and removed, and also to understand how a user environment is built.

## 17.1.2. hello world

Just like in every programming course, we start with a simple **hello_world** script. The following script will output **Hello World**.

```
echo Hello World
```

After creating this simple script in **vi** or with **echo**, you'll have to **chmod +x hello_world** to make it executable. And unless you add the scripts directory to your path, you'll have to type the path to the script for the shell to be able to find it.

```
[paul@RHEL4a ~]$ echo echo Hello World > hello_world
[paul@RHEL4a ~]$ chmod +x hello_world
[paul@RHEL4a ~]$ ./hello_world
Hello World
```

```
[paul@RHEL4a ~]$
```

### 17.1.3. she-bang

Let's expand our example a little further by putting **#!/bin/bash** on the first line of the script. The **#!** is called a **she-bang** (sometimes called **sha-bang**), where the **she-bang** is the first two characters of the script.

```
#!/bin/bash
echo Hello World
```

You can never be sure which shell a user is running. A script that works flawlessly in **bash** might not work in **ksh**, **csh**, or **dash**. To instruct a shell to run your script in a certain shell, you can start your script with a **she-bang** followed by the shell it is supposed to run in. This script will run in a bash shell.

```
#!/bin/bash
echo -n hello
echo A bash subshell `echo -n hello`
```

This script will run in a Korn shell (unless **/bin/ksh** is a hard link to **/bin/bash**). The **/etc/shells** file contains a list of shells on your system.

```
#!/bin/ksh
echo -n hello
echo a Korn subshell `echo -n hello`
```

### 17.1.4. comment

Let's expand our example a little further by adding comment lines.

```
#!/bin/bash
#
# Hello World Script
#
echo Hello World
```

### 17.1.5. variables

Here is a simple example of a variable inside a script.

```
#!/bin/bash
#
# simple variable in script
#
var1=4
echo var1 = $var1
```

Scripts can contain variables, but since scripts are run in their own shell, the variables do not survive the end of the script.

```
[paul@RHEL4a ~]$ echo $var1
```

```
[paul@RHEL4a ~]$ ./vars
var1 = 4
[paul@RHEL4a ~]$ echo $var1

[paul@RHEL4a ~]$
```

## 17.1.6. sourcing a script

Luckily, you can force a script to run in the same shell; this is called **sourcing** a script.

```
[paul@RHEL4a ~]$ source ./vars
var1 = 4
[paul@RHEL4a ~]$ echo $var1
4
[paul@RHEL4a ~]$
```

The above is identical to the below.

```
[paul@RHEL4a ~]$ . ./vars
var1 = 4
[paul@RHEL4a ~]$ echo $var1
4
[paul@RHEL4a ~]$
```

## 17.1.7. prevent setuid root spoofing

Some user may try to perform **setuid** based script **root spoofing**. This is a rare but possible attack. To improve script security and to avoid interpreter spoofing, you need to add **--** after the **#!/bin/bash**, which disables further option processing so the shell will not accept any options.

```
#!/bin/bash -
or
#!/bin/bash --
```

Any arguments after the -- are treated as filenames and arguments. An argument of - is equivalent to --.

# 17.2. practice : introduction to scripting

0. Give each script a different name, keep them for later!

1. Write a script that outputs the name of a city.

2. Make sure the script runs in the bash shell.

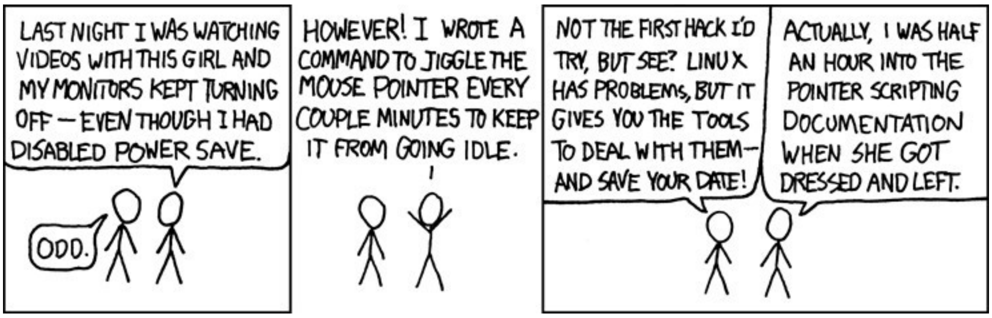
3. Make sure the script runs in the Korn shell.

4. Create a script that defines two variables, and outputs their value.

5. The previous script does not influence your current shell (the variables do not exist outside of the script). Now run the script so that it influences your current shell.

6. Is there a shorter way to **source** the script ?

7. Comment your scripts so that you know what they are doing.



# 17.3. solution : introduction to scripting

0. Give each script a different name, keep them for later!

1. Write a script that outputs the name of a city.

```
$ echo 'echo Antwerp' > first.bash
$ chmod +x first.bash
$ ./first.bash
Antwerp
```

2. Make sure the script runs in the bash shell.

```
$ cat first.bash
#!/bin/bash
echo Antwerp
```

3. Make sure the script runs in the Korn shell.

```
$ cat first.bash
#!/bin/ksh
echo Antwerp
```

Note that while first.bash will technically work as a Korn shell script, the name ending in .bash is confusing.

4. Create a script that defines two variables, and outputs their value.

```
$ cat second.bash
#!/bin/bash

var33=300
var42=400

echo $var33 $var42
```

5. The previous script does not influence your current shell (the variables do not exist outside of the script). Now run the script so that it influences your current shell.

```
source second.bash
```

6. Is there a shorter way to **source** the script ?

```
. ./second.bash
```

7. Comment your scripts so that you know what they are doing.

```
$ cat second.bash
#!/bin/bash
# script to test variables and sourcing

# define two variables
var33=300
var42=400

# output the value of these variables
echo $var33 $var42
```

# 17.4. scripting tests and loops

## 17.4.1. test [ ]

The **test** command can test whether something is true or false. Let's start by testing whether 10 is greater than 55.

```
[paul@RHEL4b ~]$ test 10 -gt 55 ; echo $?
1
[paul@RHEL4b ~]$
```

The test command returns 1 if the test fails. And as you see in the next screenshot, test returns 0 when a test succeeds.

```
[paul@RHEL4b ~]$ test 56 -gt 55 ; echo $?
0
[paul@RHEL4b ~]$
```

If you prefer true and false, then write the test like this.

```
[paul@RHEL4b ~]$ test 56 -gt 55 && echo true || echo false
true
[paul@RHEL4b ~]$ test 6 -gt 55 && echo true || echo false
false
```

The test command can also be written as square brackets, the screenshot below is identical to the one above.

```
[paul@RHEL4b ~]$ [ 56 -gt 55 ] && echo true || echo false
true
[paul@RHEL4b ~]$ [ 6 -gt 55 ] && echo true || echo false
false
```

Below are some example tests. Take a look at **man test** to see more options for tests.

```
[ -d foo ]              Does the directory foo exist ?
[ '/etc' = $PWD ]       Is the string /etc equal to the variable $PWD ?
[ $1 != 'secret' ]      Is the first parameter different from secret ?
[ 55 -lt $bar ]         Is 55 less than the value of $bar ?
[ $foo -ge 1000 ]       Is the value of $foo greater or equal to 1000 ?
[ "abc" < $bar ]        Does abc sort before the value of $bar ?
[ -f foo ]              Is foo a regular file ?
[ -r bar ]              Is bar a readable file ?
[ foo -nt bar ]         Is file foo newer than file bar ?
[ -o nounset ]          Is the shell option nounset set ?
```

Tests can be combined with logical AND and OR.

```
paul@RHEL4b:~$ [ 66 -gt 55 -a 66 -lt 500 ] && echo true || echo false
true
paul@RHEL4b:~$ [ 66 -gt 55 -a 660 -lt 500 ] && echo true || echo false
false
paul@RHEL4b:~$ [ 66 -gt 55 -o 660 -lt 500 ] && echo true || echo false
true
```

## 17.4.2. if if, then then, or else

The **if then else** construction is about choice. If a certain condition is met, then execute something, else execute something else. The example below tests whether a file exists, and if the file exists then a proper message is echoed.

```
#!/bin/bash

if [ -f isit.txt ]
then echo isit.txt exists!
else echo isit.txt not found!
fi
```

If we name the above script 'choice', then it executes like this.

```
[paul@RHEL4a scripts]$ ./choice
isit.txt not found!
[paul@RHEL4a scripts]$ touch isit.txt
[paul@RHEL4a scripts]$ ./choice
isit.txt exists!
[paul@RHEL4a scripts]$
```

## 17.4.3. for loop

The example below shows the syntax of a classical **for loop** in bash.

```
for i in 1 2 4
do
   echo $i
done
```

An example of a **for loop** combined with an embedded shell.

```
#!/bin/ksh
for counter in `seq 1 20`
do
   echo counting from 1 to 20, now at $counter
   sleep 1
done
```

This **for loop** use file globbing (from the shell expansion). Putting the instruction on the command line has identical functionality.

```
kahlan@solexp11$ ls
count.ksh  go.ksh
kahlan@solexp11$ for file in *.ksh ; do cp $file $file.backup ; done
kahlan@solexp11$ ls
count.ksh  count.ksh.backup  go.ksh  go.ksh.backup
```

## 17.4.4. while loop

Below a simple example of a **while loop**.

```
let i=100;
while [ $i -ge 0 ] ;
do
   echo Counting down, from 100 to 0, now at $i;
```

```
   let i--;
done
```

Endless loops can be made with **while true** or **while :** , where the **colon** is the equivalent of **no operation** in the **Korn** and **bash** shells.

```
#!/bin/ksh
# endless loop
while :
do
 echo hello
 sleep 1
done
```

## 17.4.5. until loop

Below a simple example of an **until loop**.

```
let i=100;
until [ $i -le 0 ] ;
do
   echo Counting down, from 100 to 1, now at $i;
   let i--;
done
```

# 17.5. practice : scripting tests and loops

1. Write a script that uses a **for** loop to count from 3 to 7.

2. Write a script that uses a **for** loop to count from 1 to 17000.

3. Write a script that uses a **while** loop to count from 3 to 7.

4. Write a script that uses an **until** loop to count down from 8 to 4.

5. Write a script that counts the number of files ending in **.txt** in the current directory.

6. Wrap an **if** statement around the script so it is also correct when there are zero files ending in **.txt**.

# 17.6. solution : scripting tests and loops

1. Write a script that uses a **for** loop to count from 3 to 7.

```
#!/bin/bash

for i in 3 4 5 6 7
do
 echo Counting from 3 to 7, now at $i
done
```

2. Write a script that uses a **for** loop to count from 1 to 17000.

```
#!/bin/bash

for i in `seq 1 17000`
do
 echo Counting from 1 to 17000, now at $i
done
```

3. Write a script that uses a **while** loop to count from 3 to 7.

```
#!/bin/bash

i=3
while [ $i -le 7 ]
do
 echo Counting from 3 to 7, now at $i
 let i=i+1
done
```

4. Write a script that uses an **until** loop to count down from 8 to 4.

```
#!/bin/bash

i=8
until [ $i -lt 4 ]
do
 echo Counting down from 8 to 4, now at $i
 let i=i-1
done
```

5. Write a script that counts the number of files ending in **.txt** in the current directory.

```
#!/bin/bash

let i=0
for file in *.txt
do
 let i++
done
echo "There are $i files ending in .txt"
```

6. Wrap an **if** statement around the script so it is also correct when there are zero files ending in **.txt**.

```
#!/bin/bash

ls *.txt > /dev/null 2>&1
if [ $? -ne 0 ]
```

```
then echo "There are 0 files ending in .txt"
else
 let i=0
 for file in *.txt
 do
  let i++
 done
 echo "There are $i files ending in .txt"
fi
```

# 17.7. parameters and options

## 17.7.1. script parameters

A **bash** shell script can have parameters. The numbering you see in the script below continues if you have more parameters. You also have special parameters containing the number of parameters, a string of all of them, and also the process id, and the last error code. The man page of **bash** has a full list.

```
#!/bin/bash
echo The first argument is $1
echo The second argument is $2
echo The third argument is $3

echo \$ $$  PID of the script
echo \# $#  count arguments
echo \? $?  last error code
echo \* $*  all the arguments
```

Below is the output of the script above in action.

```
[paul@RHEL4a scripts]$ ./pars one two three
The first argument is one
The second argument is two
The third argument is three
$ 5610 PID of the script
# 3 count arguments
? 0 last error code
* one two three all the arguments
[paul@RHEL4a scripts]$ ./pars 1 2
The first argument is 1
The second argument is 2
The third argument is
$ 5612 PID of the script
# 2 count arguments
? 0 last error code
* 1 2 all the arguments
[paul@RHEL4a scripts]$
```

## 17.7.2. shift through parameters

The **shift** statement can parse all **parameters** one by one. This is a sample script.

```
kahlan@solexp11$ cat shift.ksh
#!/bin/ksh

if [ "$#" == "0" ]
 then
  echo You have to give at least one parameter.
  exit 1
fi

while (( $# ))
 do
```

```
  echo You gave me $1
  shift
 done
```

Below is some sample output of the script above.

```
kahlan@solexp11$ ./shift.ksh one
You gave me one
kahlan@solexp11$ ./shift.ksh one two three 1201 "33 42"
You gave me one
You gave me two
You gave me three
You gave me 1201
You gave me 33 42
kahlan@solexp11$ ./shift.ksh
You have to give at least one parameter.
```

## 17.7.3. runtime input

You can ask the user for input with the **read** command in a script.

```
#!/bin/bash
echo -n Enter a number:
read number
```

## 17.7.4. sourcing a config file

```
[paul@RHEL4a scripts]$ cat myApp.conf
# The config file of myApp

# Enter the path here
myAppPath=/var/myApp

# Enter the number of quines here
quines=5

[paul@RHEL4a scripts]$ cat myApp.bash
#!/bin/bash
#
# Welcome to the myApp application
#

. ./myApp.conf

echo There are $quines quines

[paul@RHEL4a scripts]$ ./myApp.bash
There are 5 quines
[paul@RHEL4a scripts]$
```

## 17.7.5. get script options with getopts

The **getopts** function allows you to parse options given to a command.

```
kahlan@solexp11$ cat options.ksh
```

```
#!/bin/ksh

while getopts ":afz" option;
do
 case $option in
  a)
   echo received -a
   ;;
  f)
   echo received -f
   ;;
  z)
   echo received -z
   ;;
  *)
   echo "invalid option -$OPTARG"
   ;;
 esac
done
```

This is sample output from the script above.

```
kahlan@solexp11$ ./options.ksh
kahlan@solexp11$ ./options.ksh -af
received -a
received -f
kahlan@solexp11$ ./options.ksh -zfg
received -z
received -f
invalid option -g
kahlan@solexp11$ ./options.ksh -a -b -z
received -a
invalid option -b
received -z
```

You can also check for options that need an argument, as this example shows.

```
kahlan@solexp11$ cat argoptions.ksh
#!/bin/ksh

while getopts ":af:z" option;
do
 case $option in
  a)
   echo received -a
   ;;
  f)
   echo received -f with $OPTARG
   ;;
  z)
   echo received -z
   ;;
  :)
   echo "option -$OPTARG needs an argument"
   ;;
  *)
   echo "invalid option -$OPTARG"
   ;;
 esac
done
```

This is sample output from the script above.

```
kahlan@solexp11$ ./argoptions.ksh -a -f hello -z
```

```
received -a
received -f with hello
received -z
kahlan@solexp11$ ./argoptions.ksh -zaf 42
received -z
received -a
received -f with 42
kahlan@solexp11$ ./argoptions.ksh -zf
received -z
option -f needs an argument
```

## 17.7.6. get shell options with shopt

You can toggle the values of variables controlling optional shell behavior with the **shopt** built-in shell command. The example below first verifies whether the cdspell option is set; it is not. The next shopt command sets the value, and the third shopt command verifies that the option really is set. You can now use minor spelling mistakes in the cd command. The man page of bash has a complete list of options.

```
paul@laika:~$ shopt -q cdspell ; echo $?
1
paul@laika:~$ shopt -s cdspell
paul@laika:~$ shopt -q cdspell ; echo $?
0
paul@laika:~$ cd /Etc
/etc
```

# 17.8. practice : parameters and options

1. Write a script that receives four parameters, and outputs them in reverse order.

2. Write a script that receives two parameters (two filenames) and outputs whether those files exist.

3. Write a script that asks for a filename. Verify existance of the file, then verify that you own the file, and whether it is writable. If not, then make it writable.

4. Make a configuration file for the previous script. Put a logging switch in the config file, logging means writing detailed output of everything the script does to a log file in /tmp.

# 17.9. solution : parameters and options

1. Write a script that receives four parameters, and outputs them in reverse order.

```
echo $4 $3 $2 $1
```

2. Write a script that receives two parameters (two filenames) and outputs whether those files exist.

```
#!/bin/bash

if [ -f $1 ]
then echo $1 exists!
else echo $1 not found!
fi

if [ -f $2 ]
then echo $2 exists!
else echo $2 not found!
fi
```

3. Write a script that asks for a filename. Verify existance of the file, then verify that you own the file, and whether it is writable. If not, then make it writable.

4. Make a configuration file for the previous script. Put a logging switch in the config file, logging means writing detailed output of everything the script does to a log file in /tmp.

# 17.10. more scripting

## 17.10.1. eval

**eval** reads arguments as input to the shell (the resulting commands are executed). This allows using the value of a variable as a variable.

```
paul@deb503:~/test42$ answer=42
paul@deb503:~/test42$ word=answer
paul@deb503:~/test42$ eval x=\$$word ; echo $x
42
```

Both in **bash** and **Korn** the arguments can be quoted.

```
kahlan@solexp11$ answer=42
kahlan@solexp11$ word=answer
kahlan@solexp11$ eval "y=\$$word" ; echo $y
42
```

## 17.10.2. (( ))

The **(( ))** allows for evaluation of numerical expressions.

```
paul@deb503:~/test42$ (( 42 > 33 )) && echo true || echo false
true
paul@deb503:~/test42$ (( 42 > 1201 )) && echo true || echo false
false
paul@deb503:~/test42$ var42=42
paul@deb503:~/test42$ (( 42 == var42 )) && echo true || echo false
true
paul@deb503:~/test42$ (( 42 == $var42 )) && echo true || echo false
true
paul@deb503:~/test42$ var42=33
paul@deb503:~/test42$ (( 42 == var42 )) && echo true || echo false
false
```

## 17.10.3. let

The **let** built-in shell function instructs the shell to perform an evaluation of arithmetic expressions. It will return 0 unless the last arithmetic expression evaluates to 0.

```
[paul@RHEL4b ~]$ let x="3 + 4" ; echo $x
7
[paul@RHEL4b ~]$ let x="10 + 100/10" ; echo $x
20
[paul@RHEL4b ~]$ let x="10-2+100/10" ; echo $x
18
[paul@RHEL4b ~]$ let x="10*2+100/10" ; echo $x
30
```

The **shell** can also convert between different bases.

```
[paul@RHEL4b ~]$ let x="0xFF" ; echo $x
255
[paul@RHEL4b ~]$ let x="0xC0" ; echo $x
192
[paul@RHEL4b ~]$ let x="0xA8" ; echo $x
168
[paul@RHEL4b ~]$ let x="8#70" ; echo $x
56
[paul@RHEL4b ~]$ let x="8#77" ; echo $x
63
[paul@RHEL4b ~]$ let x="16#c0" ; echo $x
192
```

There is a difference between assigning a variable directly, or using **let** to evaluate the arithmetic expressions (even if it is just assigning a value).

```
kahlan@solexp11$ dec=15 ; oct=017 ; hex=0x0f
kahlan@solexp11$ echo $dec $oct $hex
15 017 0x0f
kahlan@solexp11$ let dec=15 ; let oct=017 ; let hex=0x0f
kahlan@solexp11$ echo $dec $oct $hex
15 15 15
```

## 17.10.4. case

You can sometimes simplify nested if statements with a case construct.

```
[paul@RHEL4b ~]$ ./help
What animal did you see ? lion
You better start running fast!
[paul@RHEL4b ~]$ ./help
What animal did you see ? dog
Don't worry, give it a cookie.
[paul@RHEL4b ~]$ cat help
#!/bin/bash
#
# Wild Animals Helpdesk Advice
#
echo -n "What animal did you see ? "
read animal
case $animal in
        "lion" | "tiger")
                echo "You better start running fast!"
        ;;
        "cat")
                echo "Let that mouse go..."
        ;;
        "dog")
                echo "Don't worry, give it a cookie."
        ;;
        "chicken" | "goose" | "duck" )
                echo "Eggs for breakfast!"
        ;;
        "liger")
                echo "Approach and say 'Ah you big fluffy kitty...'."
        ;;
        "babelfish")
                echo "Did it fall out your ear ?"
        ;;
```

```
        *)
                echo "You discovered an unknown animal, name it!"
        ;;
esac
[paul@RHEL4b ~]$
```

## 17.10.5. shell functions

Shell **functions** can be used to group commands in a logical way.

```
kahlan@solexp11$ cat funcs.ksh
#!/bin/ksh

function greetings {
echo Hello World!
echo and hello to $USER to!
}

echo We will now call a function
greetings
echo The end
```

This is sample output from this script with a **function**.

```
kahlan@solexp11$ ./funcs.ksh
We will now call a function
Hello World!
and hello to kahlan to!
The end
```

A shell function can also receive parameters.

```
kahlan@solexp11$ cat addfunc.ksh
#!/bin/ksh

function plus {
let result="$1 + $2"
echo  $1 + $2 = $result
}

plus 3 10
plus 20 13
plus 20 22
```

This script produces the following output.

```
kahlan@solexp11$ ./addfunc.ksh
3 + 10 = 13
20 + 13 = 33
20 + 22 = 42
```

# 17.11. practice : more scripting

1. Write a script that asks for two numbers, and outputs the sum and product (as shown here).

```
Enter a number: 5
Enter another number: 2

Sum:        5 + 2 = 7
Product:    5 x 2 = 10
```

2. Improve the previous script to test that the numbers are between 1 and 100, exit with an error if necessary.

3. Improve the previous script to congratulate the user if the sum equals the product.

4. Write a script with a case insensitive case statement, using the shopt nocasematch option. The nocasematch option is reset to the value it had before the scripts started.

5. If time permits (or if you are waiting for other students to finish this practice), take a look at linux system scripts in /etc/init.d and /etc/rc.d and try to understand them. Where does execution of a script start in /etc/init.d/samba ? There are also some hidden scripts in ~, we will discuss them later.

# 17.12. solution : more scripting

1. Write a script that asks for two numbers, and outputs the sum and product (as shown here).

```
Enter a number: 5
Enter another number: 2

Sum:        5 + 2 = 7
Product:    5 x 2 = 10
```

```
#!/bin/bash

echo -n "Enter a number : "
read n1

echo -n "Enter another number : "
read n2

let sum="$n1+$n2"
let pro="$n1*$n2"

echo -e "Sum\t: $n1 + $n2 = $sum"
echo -e "Product\t: $n1 * $n2 = $pro"
```

2. Improve the previous script to test that the numbers are between 1 and 100, exit with an error if necessary.

```
echo -n "Enter a number between 1 and 100 : "
read n1

if [ $n1 -lt 1 -o $n1 -gt 100 ]
then
       echo Wrong number...
       exit 1
fi
```

3. Improve the previous script to congratulate the user if the sum equals the product.

```
if [ $sum -eq $pro ]
then echo Congratulations $sum == $pro
fi
```

4. Write a script with a case insensitive case statement, using the shopt nocasematch option. The nocasematch option is reset to the value it had before the scripts started.

```
#!/bin/bash
#
# Wild Animals Case Insensitive Helpdesk Advice
#

if shopt -q nocasematch; then
  nocase=yes;
else
  nocase=no;
  shopt -s nocasematch;
fi

echo -n "What animal did you see ? "
read animal
```

```
case $animal in
  "lion" | "tiger")
    echo "You better start running fast!"
  ;;
  "cat")
    echo "Let that mouse go..."
  ;;
  "dog")
    echo "Don't worry, give it a cookie."
  ;;
  "chicken" | "goose" | "duck" )
    echo "Eggs for breakfast!"
  ;;
  "liger")
    echo "Approach and say 'Ah you big fluffy kitty.'"
  ;;
  "babelfish")
    echo "Did it fall out your ear ?"
  ;;
  *)
    echo "You discovered an unknown animal, name it!"
  ;;
esac

if [ nocase = yes ] ; then
        shopt -s nocasematch;
else
        shopt -u nocasematch;
fi
```

5. If time permits (or if you are waiting for other students to finish this practice), take a look at linux system scripts in /etc/init.d and /etc/rc.d and try to understand them. Where does execution of a script start in /etc/init.d/samba ? There are also some hidden scripts in ~, we will discuss them later.

# Chapter 18. Introduction to users

## Table of Contents



# 18.1. identify yourself

## 18.1.1. whoami

The **whoami** command tells you your username.

```
[root@RHEL5 ~]# whoami
root
[root@RHEL5 ~]# su - paul
[paul@RHEL5 ~]$ whoami
paul
```

## 18.1.2. who

The **who** command will give you information about who is logged on the system.

```
[paul@RHEL5 ~]$ who
root     tty1         2008-06-24 13:24
sandra   pts/0        2008-06-24 14:05 (192.168.1.34)
paul     pts/1        2008-06-24 16:23 (192.168.1.37)
```

## 18.1.3. who am i

With **who am i** the who command will display only the line pointing to your current session.

```
[paul@RHEL5 ~]$ who am i
paul     pts/1        2008-06-24 16:23 (192.168.1.34)
```

## 18.1.4. w

The **w** command shows you who is logged on and what they are doing.

```
$ w
 05:13:36 up 3 min,  4 users,  load average: 0.48, 0.72, 0.33
USER    TTY    FROM          LOGIN@    IDLE  JCPU  PCPU WHAT
root    tty1   -             05:11     2.00s 0.32s 0.27s find / -name shad
inge    pts/0  192.168.1.33  05:12     0.00s 0.02s 0.02s -ksh
laura   pts/1  192.168.1.34  05:12    46.00s 0.03s 0.03s -bash
paul    pts/2  192.168.1.34  05:13    25.00s 0.07s 0.04s top
```

## 18.1.5. id

The **id** command will give you your user id, primary group id, and a list of the groups that you belong to.

```
root@laika:~# id
uid=0(root) gid=0(root) groups=0(root)
root@laika:~# su - brel
brel@laika:~$ id
uid=1001(brel) gid=1001(brel) groups=1001(brel),1008(chanson),11578(wolf)
```

# 18.2. users

## 18.2.1. user management

User management on any Unix can be done in three complimentary ways. You can use the **graphical** tools provided by your distribution. These tools have a look and feel that depends on the distribution. If you are a novice linux user on your home system, then use the graphical tool that is provided by your distribution. This will make sure that you do not run into problems.

Another option is to use **command line tools** like useradd, usermod, gpasswd, passwd and others. Server administrators are likely to use these tools, since they are familiar and very similar accross many different distributions. This chapter will focus on these command line tools.

A third and rather extremist way is to **edit the local configuration files** directly using vi (or vipw/vigr). Do not attempt this as a novice on production systems!

## 18.2.2. /etc/passwd

The local user database on Linux (and on most Unixes) is **/etc/passwd**.

```
[root@RHEL5 ~]# tail /etc/passwd
inge:x:518:524:art dealer:/home/inge:/bin/ksh
ann:x:519:525:flute player:/home/ann:/bin/bash
frederik:x:520:526:rubius poet:/home/frederik:/bin/bash
steven:x:521:527:roman emperor:/home/steven:/bin/bash
pascale:x:522:528:artist:/home/pascale:/bin/ksh
geert:x:524:530:kernel developer:/home/geert:/bin/bash
wim:x:525:531:master damuti:/home/wim:/bin/bash
sandra:x:526:532:radish stresser:/home/sandra:/bin/bash
annelies:x:527:533:sword fighter:/home/annelies:/bin/bash
laura:x:528:534:art dealer:/home/laura:/bin/ksh
```

As you can see, this file contains seven columns separated by a colon. The columns contain the username, an x, the user id, the primary group id, a description, the name of the home directory, and the login shell.

## 18.2.3. root

The **root** user also called the **superuser** is the most powerful account on your Linux system. This user can do almost anything, including the creation of other users. The root user always has userid 0 (regardless of the name of the account).

```
[root@RHEL5 ~]# head -1 /etc/passwd
root:x:0:0:root:/root:/bin/bash
```

## 18.2.4. useradd

You can add users with the **useradd** command. The example below shows how to add a user named yanina (last parameter) and at the same time forcing the creation of the home directory (-m), setting the name of the home directory (-d), and setting a description (-c).

```
[root@RHEL5 ~]# useradd -m -d /home/yanina -c "yanina wickmayer" yanina
[root@RHEL5 ~]# tail -1 /etc/passwd
yanina:x:529:529:yanina wickmayer:/home/yanina:/bin/bash
```

The user named yanina received userid 529 and **primary group** id 529.

## 18.2.5. /etc/default/useradd

Both Red Hat Enterprise Linux and Debian/Ubuntu have a file called **/etc/default/useradd** that contains some default user options. Besides using cat to display this file, you can also use **useradd -D**.

```
[root@RHEL4 ~]# useradd -D
GROUP=100
HOME=/home
INACTIVE=-1
EXPIRE=
SHELL=/bin/bash
SKEL=/etc/skel
```

## 18.2.6. userdel

You can delete the user yanina with **userdel**. The -r option of userdel will also remove the home directory.

```
[root@RHEL5 ~]# userdel -r yanina
```

## 18.2.7. usermod

You can modify the properties of a user with the **usermod** command. This example uses **usermod** to change the description of the user harry.

```
[root@RHEL4 ~]# tail -1 /etc/passwd
harry:x:516:520:harry potter:/home/harry:/bin/bash
[root@RHEL4 ~]# usermod -c 'wizard' harry
[root@RHEL4 ~]# tail -1 /etc/passwd
harry:x:516:520:wizard:/home/harry:/bin/bash
```

# 18.3. passwords

## 18.3.1. passwd

Passwords of users can be set with the **passwd** command. Users will have to provide their old password before twice entering the new one.

```
[harry@RHEL4 ~]$ passwd
Changing password for user harry.
Changing password for harry
(current) UNIX password:
New UNIX password:
BAD PASSWORD: it's WAY too short
New UNIX password:
Retype new UNIX password:
passwd: all authentication tokens updated successfully.
[harry@RHEL4 ~]$
```

As you can see, the passwd tool will do some basic verification to prevent users from using too simple passwords. The root user does not have to follow these rules (there will be a warning though). The root user also does not have to provide the old password before entering the new password twice.

## 18.3.2. /etc/shadow

User passwords are encrypted and kept in **/etc/shadow**. The /etc/shadow file is read only and can only be read by root. We will see in the file permissions section how it is possible for users to change their password. For now, you will have to know that users can change their password with the **/usr/bin/passwd** command.

```
[root@RHEL5 ~]# tail /etc/shadow
inge:$1$yWMSimOV$YsYvcVKqByFVYLKnU3ncd0:14054:0:99999:7:::
ann:!!:14054:0:99999:7:::
frederik:!!:14054:0:99999:7:::
steven:!!:14054:0:99999:7:::
pascale:!!:14054:0:99999:7:::
geert:!!:14054:0:99999:7:::
wim:!!:14054:0:99999:7:::
sandra:!!:14054:0:99999:7:::
annelies:!!:14054:0:99999:7:::
laura:$1$Tvby1Kpa$lL.WzgobujUS3LClIRmdv1:14054:0:99999:7:::
```

The /etc/shadow file contains nine colon separated columns. The nine fields contain (from left to right) the user name, the encrypted password (note that only inge and laura have an encrypted password), the day the password was last changed (day 1 is January 1, 1970), number of days the password must be left unchanged, password expiry day, warning number of days before password expiry, number of days after expiry before disabling the account, and the day the account was disabled (again, since 1970). The last field has no meaning yet.

# 18.3.3. password encryption

## encryption with passwd

Passwords are stored in an encrypted format. This encryption is done by the **crypt** function. The easiest (and recommended) way to add a user with a password to the system is to add the user with the **useradd -m user** command, and then set the user's password with **passwd**.

```
[root@RHEL4 ~]# useradd -m xavier
[root@RHEL4 ~]# passwd xavier
Changing password for user xavier.
New UNIX password:
Retype new UNIX password:
passwd: all authentication tokens updated successfully.
[root@RHEL4 ~]#
```

## encryption with openssl

Another way to create users with a password is to use the -p option of useradd, but that option requires an encrypted password. You can generate this encrypted password with the **openssl passwd** command.

```
[root@RHEL4 ~]# openssl passwd stargate
ZZNX16QZVgUQg
[root@RHEL4 ~]# useradd -m -p ZZNX16QZVgUQg mohamed
```

## encryption with crypt

A third option is to create your own C program using the crypt function, and compile this into a command.

```
[paul@laika ~]$ cat MyCrypt.c
#include <stdio.h>
#define __USE_XOPEN
#include <unistd.h>

int main(int argc, char** argv)
{
 if(argc==3)
   {
       printf("%s\n", crypt(argv[1],argv[2]));
   }
   else
   {
       printf("Usage: MyCrypt $password $salt\n" );
   }
  return 0;
}
```

This little program can be compiled with **gcc** like this.

```
[paul@laika ~]$ gcc MyCrypt.c -o MyCrypt -lcrypt
```

To use it, we need to give two parameters to MyCript. The first is the unencrypted password, the second is the salt. The salt is used to perturb the encryption algorithm in one of 4096 different ways. This variation prevents two users with the same password from having the same entry in /etc/shadow.

```
paul@laika:~$ ./MyCrypt stargate 12
12L4FoTS3/k9U
paul@laika:~$ ./MyCrypt stargate 01
01Y.yPnlQ6R.Y
paul@laika:~$ ./MyCrypt stargate 33
330asFUbzgVeg
paul@laika:~$ ./MyCrypt stargate 42
42XFxoT4R75gk
```

Did you notice that the first two characters of the password are the salt ?

The standard output of the crypt function is using the DES algorithm which is old and can be cracked in minutes. A better method is to use MD5 passwords which can be recognized by a salt starting with $1$.

```
paul@laika:~$ ./MyCrypt stargate '$1$12'
$1$12$xUIQ4116Us.Q5Osc2Khbm1
paul@laika:~$ ./MyCrypt stargate '$1$01'
$1$01$yNs8brjp4b4TEw.v9/IlJ/
paul@laika:~$ ./MyCrypt stargate '$1$33'
$1$33$tLh/Ldy2wskdKAJR.Ph4M0
paul@laika:~$ ./MyCrypt stargate '$1$42'
$1$42$Hb3nvP0KwHSQ7fQmIlY7R.
```

The MD5 salt can be up to eight characters long. The salt is displayed in /etc/shadow between the second and third $, so never use the password as the salt!

```
paul@laika:~$ ./MyCrypt stargate '$1$stargate'
$1$stargate$qqxoLqiSVNvGr5ybMxEVM1
```

## 18.3.4. password defaults

### /etc/login.defs

The **/etc/login.defs** file contains some default settings for user passwords like password aging and length settings. (You will also find the numerical limits of user ids and group ids and whether or not a home directory should be created by default).

```
[root@RHEL4 ~]# grep -i pass /etc/login.defs
# Password aging controls:
# PASS_MAX_DAYS  Maximum number of days a password may be used.
# PASS_MIN_DAYS  Minimum number of days allowed between password changes.
# PASS_MIN_LEN   Minimum acceptable password length.
# PASS_WARN_AGE  Number of days warning given before a password expires.
PASS_MAX_DAYS   99999
PASS_MIN_DAYS   0
PASS_MIN_LEN    5
PASS_WARN_AGE   7
```

### chage

The **chage** command can be used to set an expiration date for a user account (-E), set a mimimum (-m) and maximum (-M) password age, a password expiration date, and set the number of warning days before the password expiration date. Much of this functionality is also available from the **passwd** command. The **-l** option of chage will list these settings for a user.

```
[root@RHEL4 ~]# chage -l harry
Minimum:        0
Maximum:        99999
Warning:        7
Inactive:       -1
Last Change:            Jul 23, 2007
Password Expires:       Never
Password Inactive:      Never
Account Expires:        Never
[root@RHEL4 ~]#
```

## 18.3.5. disabling a password

Passwords in /etc/shadow cannot begin with an exclamation mark. When the second field in /etc/passwd starts with an exclamation mark, then the password can not be used.

Using this feature is often called **locking**, **disabling**, or **suspending** a user account. Besides vi (or vipw) you can also accomplish this with **usermod**.

The first line in the next screenshot will disable the password of user harry, making it impossible for harry to authenticate using this password.

```
[root@RHEL4 ~]# usermod -L harry
[root@RHEL4 ~]# tail -1 /etc/shadow
harry:!$1$143TO9IZ$RLm/FpQkpDrV4/Tkhku5e1:13717:0:99999:7:::
```

The root user (and users with **sudo** rights on **su**) still will be able to **su** to harry (because the password is not needed here). Also note that harry will still be able to login if he has set up passwordless ssh!

```
[root@RHEL4 ~]# su - harry
[harry@RHEL4 ~]$
```

You can unlock the account again with **usermod -U**.

Watch out for tiny differences in the command line options of **passwd**, **usermod**, and **useradd** on different distributions! Verify the local files when using features like **"disabling, suspending, or locking"** users and passwords!

## 18.3.6. editing local files

If you still want to manually edit the **/etc/passwd** or **/etc/shadow**, after knowing these commands for password management, then use **vipw** instead of vi(m) directly. The **vipw** tool will do proper locking of the file.

```
[root@RHEL5 ~]# vipw /etc/passwd
vipw: the password file is busy (/etc/ptmp present)
```

# 18.4. home directories

## 18.4.1. creating home directories

The easiest way to create a home directory is to supply the **-m** option with **useradd** (it is likely set as a default option on Linux).

A less easy way is to create a home directory manually with **mkdir** which also requires setting the owner and the permissions on the directory with **chmod** and **chown** (both commands are discussed in detail in another chapter).

```
[root@RHEL5 ~]# mkdir /home/laura
[root@RHEL5 ~]# chown laura:laura /home/laura
[root@RHEL5 ~]# chmod 700 /home/laura
[root@RHEL5 ~]# ls -ld /home/laura/
drwx------ 2 laura laura 4096 Jun 24 15:17 /home/laura/
```

## 18.4.2. /etc/skel/

When using **useradd** with the **-m** option, the **/etc/skel/** directory is copied to the newly created home directory. The **/etc/skel/** directory contains some (usually hidden) files that contain profile settings and default values for applications. In this way **/etc/skel/** serves as a default home directory and as a default user profile.

```
[root@RHEL5 ~]# ls -la /etc/skel/
total 48
drwxr-xr-x  2 root root  4096 Apr  1 00:11 .
drwxr-xr-x 97 root root 12288 Jun 24 15:36 ..
-rw-r--r--  1 root root    24 Jul 12  2006 .bash_logout
-rw-r--r--  1 root root   176 Jul 12  2006 .bash_profile
-rw-r--r--  1 root root   124 Jul 12  2006 .bashrc
```

## 18.4.3. deleting home directories

The -r option of **userdel** will make sure that the home directory is deleted together with the user account.

```
[root@RHEL5 ~]# ls -ld /home/wim/
drwx------ 2 wim wim 4096 Jun 24 15:19 /home/wim/
[root@RHEL5 ~]# userdel -r wim
[root@RHEL5 ~]# ls -ld /home/wim/
ls: /home/wim/: No such file or directory
```

# 18.5. user shell

## 18.5.1. login shell

The **/etc/passwd** file specifies the **login shell** for the user. In the screenshot below you can see that user annelies will log in with the **/bin/bash** shell, and user laura with the **/bin/ksh** shell.

```
[root@RHEL5 ~]# tail -2 /etc/passwd
annelies:x:527:533:sword fighter:/home/annelies:/bin/bash
laura:x:528:534:art dealer:/home/laura:/bin/ksh
```

You can use the usermod command to change the shell for a user.

```
[root@RHEL5 ~]# usermod -s /bin/bash laura
[root@RHEL5 ~]# tail -1 /etc/passwd
laura:x:528:534:art dealer:/home/laura:/bin/bash
```

## 18.5.2. chsh

Users can change their login shell with the **chsh** command. First, user harry obtains a list of available shells (he could also have done a **cat /etc/shells**) and then changes his login shell to the **Korn shell** (/bin/ksh). At the next login, harry will default into ksh instead of bash.

```
[harry@RHEL4 ~]$ chsh -l
/bin/sh
/bin/bash
/sbin/nologin
/bin/ash
/bin/bsh
/bin/ksh
/usr/bin/ksh
/usr/bin/pdksh
/bin/tcsh
/bin/csh
/bin/zsh
[harry@RHEL4 ~]$ chsh -s /bin/ksh
Changing shell for harry.
Password:
Shell changed.
[harry@RHEL4 ~]$
```

# 18.6. switch users with su

## 18.6.1. su to another user

The **su** command allows a user to run a shell as another user.

```
[paul@RHEL4b ~]$ su harry
Password:
[harry@RHEL4b paul]$
```

## 18.6.2. su to root

Yes you can alsu **su** to become **root**, when you know the **root password**.

```
[harry@RHEL4b paul]$ su root
Password:
[root@RHEL4b paul]#
```

## 18.6.3. su as root

Uness you are logged in as **root**, running a shell as another user requires that you know the password of that user. The **root** user can become any user without knowing the user's password.

```
[root@RHEL4b paul]# su serena
[serena@RHEL4b paul]$
```

## 18.6.4. su - $username

By default, the **su** command maintains the same shell environment. To become another user and also get the target user's environment, issue the **su -** command followed by the target username.

```
[paul@RHEL4b ~]$ su - harry
Password:
[harry@RHEL4b ~]$
```

## 18.6.5. su -

When no username is provided to **su** or **su -**, the command will assume **root** is the target.

```
[harry@RHEL4b ~]$ su -
Password:
[root@RHEL4b ~]#
```

# 18.7. run a program as another user

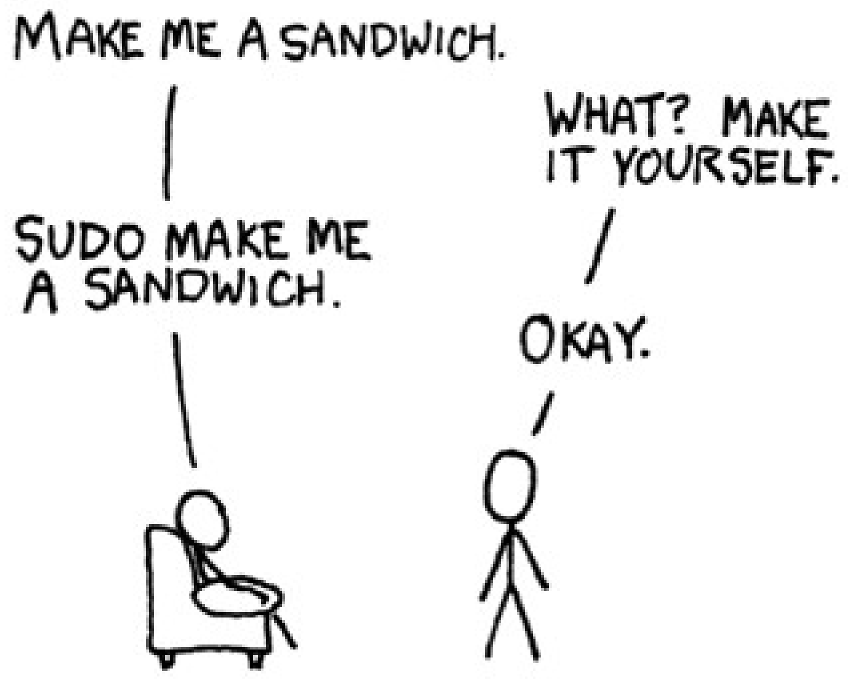
## 18.7.1. about sudo

The sudo program allows a user to start a program with the credentials of another user. Before this works, the system administrator has to set up the **/etc/sudoers** file. This can be useful to delegate administrative tasks to another user (without giving the root password).

The screenshot below shows the usage of **sudo**. User **paul** received the right to run **useradd** with the credentials of **root**. This allows **paul** to create new users on the system without becoming **root** and without knowing the **root password**.

```
paul@laika:~$ useradd -m inge
useradd: unable to lock password file
paul@laika:~$ sudo useradd -m inge
[sudo] password for paul:
paul@laika:~$
```

Image copied from **xkcd.com**.




## 18.7.2. setuid on sudo

The **sudo** binary has the **setuid** bit set, so any user can run it with the effective userid of root.

```
paul@laika:~$ ls -l `which sudo`
-rwsr-xr-x 2 root root 107872 2008-05-15 02:41 /usr/bin/sudo
paul@laika:~$
```

## 18.7.3. visudo

Check the man page of **visudo** before playing with the /etc/sudoers file.

## 18.7.4. sudo su

On some linux systems like Ubuntu and Kubuntu, the **root** user does not have a password set. This means that it is not possible to login as **root** (extra security). To perform tasks as **root**, the first user is given all **sudo rights** via the **/etc/sudoers**. In fact all users that are members of the admin group can use sudo to run all commands as root.

```
root@laika:~# grep admin /etc/sudoers
# Members of the admin group may gain root privileges
%admin ALL=(ALL) ALL
```

The end result of this is that the user can type **sudo su -** and become root without having to enter the root password. The sudo command does require you to enter your own password. Thus the password prompt in the screenshot below is for sudo, not for su.

```
paul@laika:~$ sudo su -
Password:
root@laika:~#
```

# 18.8. practice: users

1. Create the users Serena Williams, Venus Williams and Justine Henin, all of them with password set to stargate, with username (lowercase!) as their first name, and their full name in the comment. Verify that the users and their home directory are properly created.

2. Create a user called **kornuser**, give him the Korn shell (/bin/ksh) as his default shell. Log on with this user (on a command line or in a tty).

3. Create a user named **einstime** without home directory, give him **/bin/date** as his default logon shell. What happens when you log on with this user ? Can you think of a useful real world example for changing a user's login shell to an application ?

4. Try the commands who, whoami, who am i, w, id, echo $USER $UID .

5a. Lock the **venus** user account with usermod.

5b. Use **passwd -d** to disable the serena password. Verify the serena line in **/etc/shadow** before and after disabling.

5c. What is the difference between locking a user account and disabling a user account's password ?

6. As **root** change the password of **einstime** to stargate.

7. Now try changing the password of serena to serena as serena.

8. Make sure every new user needs to change his password every 10 days.

9. Set the warning number of days to four for the kornuser.

10a. Set the password of two separate users to stargate. Look at the encrypted stargate's in /etc/shadow and explain.

10b. Take a backup as root of /etc/shadow. Use vi to copy an encrypted stargate to another user. Can this other user now log on with stargate as a password ?

11. Put a file in the skeleton directory and check whether it is copied to user's home directory. When is the skeleton directory copied ?

12. Why use **vipw** instead of **vi** ? What could be the problem when using **vi** or **vim** ?

13. Use chsh to list all shells, and compare to cat /etc/shells. Change your login shell to the Korn shell, log out and back in. Now change back to bash.

14. Which useradd option allows you to name a home directory ?

15. How can you see whether the password of user harry is locked or unlocked ? Give a solution with grep and a solution with passwd.

# 18.9. solution: users

1. Create the users Serena Williams, Venus Williams and Justine Henin, all of them with password set to stargate, with username (lowercase) as their first name, and their full name in the comment. Verify that the users and their home directory are properly created.

```
useradd -m -c "Serena Williams" serena ; passwd serena
useradd -m -c "Venus Williams" venus ; passwd venus
useradd -m -c "Justine Henin" justine ; passwd justine
tail /etc/passwd ; tail /etc/shadow ; ls /home
```

```
Keep user logon names in lowercase!
```

2. Create a user called **kornuser**, give him the Korn shell (/bin/ksh) as his default shell. Log on with this user (on a command line or in a tty).

```
useradd -s /bin/ksh kornuser ; passwd kornuser
```

3. Create a user named **einstime** without home directory, give him **/bin/date** as his default logon shell. What happens when you log on with this user ? Can you think of a useful real world example for changing a user's login shell to an application ?

```
useradd -s /bin/date einstime ; passwd einstime
```

It can be useful when users need to access only one application on the server. Just logging on opens the application for them, and closing the application automatically logs them off.

4. Try the commands who, whoami, who am i, w, id, echo $USER $UID .

```
who ; whoami ; who am i ; w ; id ; echo $USER $UID
```

5a. Lock the **venus** user account with usermod.

```
usermod -L venus
```

5b. Use **passwd -d** to disable the serena password. Verify the serena line in **/etc/shadow** before and after disabling.

```
grep serena /etc/shadow; passwd -d serena ; grep serena /etc/shadow
```

5c. What is the difference between locking a user account and disabling a user account's password ?

Locking will prevent the user from logging on to the system with his password (by putting a ! in front of the password in /etc/shadow). Disbling with passwd will erase the password from /etc/shadow.

6. As **root** change the password of **einstime** to stargate.

```
Log on as root and type: passwd einstime
```

7. Now try changing the password of serena to serena as serena.

```
log on as serena, then execute: passwd serena... it should fail!
```

8. Make sure every new user needs to change his password every 10 days.

```
For an existing user: chage -M 10 serena
```

```
For all new users: vi /etc/login.defs (and change PASS_MAX_DAYS to 10)
```

9. Set the warning number of days to four for the kornuser.

```
chage -W 4 kornuser
```

10a. Set the password of two separate users to stargate. Look at the encrypted stargate's in /etc/shadow and explain.

If you used passwd, then the salt will be different for the two encrypted passwords.

10b. Take a backup as root of /etc/shadow. Use vi to copy an encrypted stargate to another user. Can this other user now log on with stargate as a password ?

```
Yes.
```

11. Put a file in the skeleton directory and check whether it is copied to user's home directory. When is the skeleton directory copied ?

```
When you create a user account with a new home directory.
```

12. Why use **vipw** instead of **vi** ? What could be the problem when using **vi** or **vim** ?

```
vipw will give a warning when someone else is already using that file.
```

13. Use chsh to list all shells, and compare to cat /etc/shells. Change your login shell to the Korn shell, log out and back in. Now change back to bash.

```
On Red Hat Enterprise Linux: chsh -l
On Debian/Ubuntu: cat /etc/shells
```

14. Which useradd option allows you to name a home directory ?

```
-d
```

15. How can you see whether the password of user harry is locked or unlocked ? Give a solution with grep and a solution with passwd.

```
grep harry /etc/shadow
```

```
passwd -S harry
```

# 18.10. shell environment

It is nice to have these preset and custom aliases and variables, but where do they all come from ? The **shell** uses a number of startup files that are checked (and executed) whenever the shell is invoked. What follows is an overview of startup scripts.

## 18.10.1. /etc/profile

Both the **bash** and the **ksh** shell will verify the existence of **/etc/profile** and execute it if it exists.

When reading this script, you might notice (at least on Debian Lenny and on Red Hat Enterprise Linux 5) that it builds the PATH environment variable. The script might also change the PS1 variable, set the HOSTNAME and execute even more scripts like **/etc/inputrc**

You can use this script to set aliases and variables for every user on the system.

## 18.10.2. ~/.bash_profile

When this file exists in the users home directory, then **bash** will execute it. On Debian Linux it does not exist by default.

RHEL5 uses a brief **~/.bash_profile** where it checks for the existence of **~/.bashrc** and then executes it. It also adds $HOME/bin to the $PATH variable.

```
[serena@rhel53 ~]$ cat .bash_profile
# .bash_profile

# Get the aliases and functions
if [ -f ~/.bashrc ]; then
 . ~/.bashrc
fi

# User specific environment and startup programs

PATH=$PATH:$HOME/bin

export PATH
```

## 18.10.3. ~/.bash_login

When **.bash_profile** does not exist, then **bash** will check for **~/.bash_login** and execute it.

Neither Debian nor Red Hat have this file by default.

## 18.10.4. ~/.profile

When neither **~/.bash_profile** and **~/.bash_login** exist, then bash will verify the existence of **~/.profile** and execute it. This file does not exist by default on Red Hat.

On Debian this script can execute **~/.bashrc** and will add $HOME/bin to the $PATH variable.

```
serena@deb503:~$ tail -12 .profile
# if running bash
if [ -n "$BASH_VERSION" ]; then
    # include .bashrc if it exists
    if [ -f "$HOME/.bashrc" ]; then
 . "$HOME/.bashrc"
    fi
fi

# set PATH so it includes user's private bin if it exists
if [ -d "$HOME/bin" ] ; then
    PATH="$HOME/bin:$PATH"
fi
```

## 18.10.5. ~/.bashrc

As seen in the previous points, the **~/.bashrc** script might be executed by other scripts. Let us take a look at what it does by default.

Red Hat uses a very simple **~/.bashrc**, checking for **/etc/bashrc** and executing it. It also leaves room for custom aliases and functions.

```
[serena@rhel53 ~]$ more .bashrc
# .bashrc

# Source global definitions
if [ -f /etc/bashrc ]; then
 . /etc/bashrc
fi

# User specific aliases and functions
```

On Debian this script is quite a bit longer and configures $PS1, some history variables and a number af active and inactive aliases.

```
serena@deb503:~$ ls -l .bashrc
-rw-r--r-- 1 serena serena 3116 2008-05-12 21:02 .bashrc
```

## 18.10.6. ~/.bash_logout

When exiting **bash**, it can execute **~/.bash_logout**. Debian and Red Hat both use this opportunity to clear the screen.

```
serena@deb503:~$ cat .bash_logout
# ~/.bash_logout: executed by bash(1) when login shell exits.

# when leaving the console clear the screen to increase privacy

if [ "$SHLVL" = 1 ]; then
    [ -x /usr/bin/clear_console ] && /usr/bin/clear_console -q
fi
```

```
[serena@rhel53 ~]$ cat .bash_logout
# ~/.bash_logout

/usr/bin/clear
```

## 18.10.7. Debian overview

Below is a table overview of when Debian is running any of these bash startup scripts.

**Table 18.1. Debian User Environment**

| script | su | su - | ssh | gdm |
|---|---|---|---|---|
| ~./bashrc | no | yes | yes | yes |
| ~/.profile | no | yes | yes | yes |
| /etc/profile | no | yes | yes | yes |
| /etc/bash.bashrc | yes | no | no | yes |

## 18.10.8. RHEL5 overview

Below is a table overview of when Red Hat Enterprise Linux 5 is running any of these bash startup scripts.

**Table 18.2. Red Hat User Environment**

| script | su | su - | ssh | gdm |
|---|---|---|---|---|
| ~./bashrc | yes | yes | yes | yes |
| ~/.bash_profile | no | yes | yes | yes |
| /etc/profile | no | yes | yes | yes |
| /etc/bashrc | yes | yes | yes | yes |

# Chapter 19. Introduction to groups

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# 19.1. about groups

Users can be listed in **groups**. Groups allow you to set permissions on the group level instead of having to set permissions for every individual user. Every Unix or Linux distribution will have a graphical tool to manage groups. Novice users are advised to use this graphical tool. More experienced users can use command line tools to manage users, but be careful: Some distributions do not allow the mixed use of GUI and CLI tools to manage groups (YaST in Novell Suse). Senior administrators can edit the relevant files directly with **vi** or **vigr**.

# 19.2. groupadd

Groups can be created with the **groupadd** command. The example below shows the creation of five (empty) groups.

```
root@laika:~# groupadd tennis
root@laika:~# groupadd football
root@laika:~# groupadd snooker
root@laika:~# groupadd formula1
root@laika:~# groupadd salsa
```

# 19.3. /etc/group

Users can be a member of several groups. Group membership is defined by the **/etc/group** file.

```
root@laika:~# tail -5 /etc/group
```

```
tennis:x:1006:
football:x:1007:
snooker:x:1008:
formula1:x:1009:
salsa:x:1010:
root@laika:~#
```

The first field is the group's name. The second field is the group's (encrypted) password (can be empty). The third field is the group identification or **GID**. The fourth field is the list of members, these groups have no members.

# 19.4. usermod

Group membership can be modified with the useradd or **usermod** command.

```
root@laika:~# usermod -a -G tennis inge
root@laika:~# usermod -a -G tennis katrien
root@laika:~# usermod -a -G salsa katrien
root@laika:~# usermod -a -G snooker sandra
root@laika:~# usermod -a -G formula1 annelies
root@laika:~# tail -5 /etc/group
tennis:x:1006:inge,katrien
football:x:1007:
snooker:x:1008:sandra
formula1:x:1009:annelies
salsa:x:1010:katrien
root@laika:~#
```

Be careful when using **usermod** to add users to groups. By default, the **usermod** command will **remove** the user from every group of which he is a member if the group is not listed in the command! Using the **-a** (append) switch prevents this behaviour.

# 19.5. groupmod

You can change the group name with the **groupmod** command.

```
root@laika:~# groupmod -n darts snooker
root@laika:~# tail -5 /etc/group
tennis:x:1006:inge,katrien
football:x:1007:
formula1:x:1009:annelies
salsa:x:1010:katrien
darts:x:1008:sandra
```

# 19.6. groupdel

You can permanently remove a group with the **groupdel** command.

```
root@laika:~# groupdel tennis
```

```
root@laika:~#
```

# 19.7. groups

A user can type the **groups** command to see a list of groups where the user belongs to.

```
[harry@RHEL4b ~]$ groups
harry sports
[harry@RHEL4b ~]$
```

# 19.8. gpasswd

You can delegate control of group membership to another user with the **gpasswd** command. In the example below we delegate permissions to add and remove group members to serena for the sports group. Then we **su** to serena and add harry to the sports group.

```
[root@RHEL4b ~]# gpasswd -A serena sports
[root@RHEL4b ~]# su - serena
[serena@RHEL4b ~]$ id harry
uid=516(harry) gid=520(harry) groups=520(harry)
[serena@RHEL4b ~]$ gpasswd -a harry sports
Adding user harry to group sports
[serena@RHEL4b ~]$ id harry
uid=516(harry) gid=520(harry) groups=520(harry),522(sports)
[serena@RHEL4b ~]$ tail -1 /etc/group
sports:x:522:serena,venus,harry
[serena@RHEL4b ~]$
```

Group administrators do not have to be a member of the group. They can remove themselves from a group, but this does not influence their ability to add or remove members.

```
[serena@RHEL4b ~]$ gpasswd -d serena sports
Removing user serena from group sports
[serena@RHEL4b ~]$ exit
```

Information about group administrators is kept in the **/etc/gshadow** file.

```
[root@RHEL4b ~]# tail -1 /etc/gshadow
sports:!:serena:venus,harry
[root@RHEL4b ~]#
```

To remove all group administrators from a group, use the **gpasswd** command to set an empty administrators list.

```
[root@RHEL4b ~]# gpasswd -A "" sports
```

# 19.9. vigr

Similar to vipw, the **vigr** command can be used to manually edit the **/etc/group** file, since it will do proper locking of the file. Only experienced senior administrators should use **vi** or **vigr** to manage groups.

# 19.10. practice: groups

1. Create the groups tennis, football and sports.

2. In one command, make venus a member of tennis and sports.

3. Rename the football group to foot.

4. Use vi to add serena to the tennis group.

5. Use the id command to verify that serena is a member of tennis.

6. Make someone responsible for managing group membership of foot and sports. Test that it works.

# 19.11. solution: groups

1. Create the groups tennis, football and sports.

```
groupadd tennis ; groupadd football ; groupadd sports
```

2. In one command, make venus a member of tennis and sports.

```
usermod -a -G tennis,sports venus
```

3. Rename the football group to foot.

```
groupmod -n foot football
```

4. Use vi to add serena to the tennis group.

```
vi /etc/group
```

5. Use the id command to verify that serena is a member of tennis.

```
id (and after logoff logon serena should be member)
```

6. Make someone responsible for managing group membership of foot and sports. Test that it works.

```
gpasswd -A (to make manager)
```

```
gpasswd -a (to add member)
```

# Chapter 20. Standard file permissions

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# 20.1. file ownership

## 20.1.1. user owner and group owner

The **users** and **groups** of a system can be locally managed in **/etc/passwd** and **/etc/group**, or they can be in a NIS, LDAP, or Samba domain. These users and groups can **own** files. Actually, every file has a **user owner** and a **group owner**, as can be seen in the following screenshot.

```
paul@RHELv4u4:~/test$ ls -l
total 24
-rw-rw-r--  1 paul paul  17 Feb  7 11:53 file1
-rw-rw-r--  1 paul paul 106 Feb  5 17:04 file2
-rw-rw-r--  1 paul proj 984 Feb  5 15:38 data.odt
-rw-r--r--  1 root root   0 Feb  7 16:07 stuff.txt
paul@RHELv4u4:~/test$
```

User paul owns three files, two of those are also owned by the group paul; data.odt is owned by the group proj. The root user owns the file stuff.txt, as does the group root.

## 20.1.2. chgrp

You can change the group owner of a file using the **chgrp** command.

```
root@laika:/home/paul# touch FileForPaul
root@laika:/home/paul# ls -l FileForPaul
-rw-r--r-- 1 root root 0 2008-08-06 14:11 FileForPaul
root@laika:/home/paul# chgrp paul FileForPaul
root@laika:/home/paul# ls -l FileForPaul
-rw-r--r-- 1 root paul 0 2008-08-06 14:11 FileForPaul
```

## 20.1.3. chown

The user owner of a file can be changed with **chown** command.

```
root@laika:/home/paul# ls -l FileForPaul
-rw-r--r-- 1 root paul 0 2008-08-06 14:11 FileForPaul
root@laika:/home/paul# chown paul FileForPaul
root@laika:/home/paul# ls -l FileForPaul
-rw-r--r-- 1 paul paul 0 2008-08-06 14:11 FileForPaul
```

You can also use **chown** to change both the user owner and the group owner.

```
root@laika:/home/paul# ls -l FileForPaul
-rw-r--r-- 1 paul paul 0 2008-08-06 14:11 FileForPaul
root@laika:/home/paul# chown root:project42 FileForPaul
root@laika:/home/paul# ls -l FileForPaul
-rw-r--r-- 1 root project42 0 2008-08-06 14:11 FileForPaul
```

# 20.2. list of special files

When you use **ls -l**, for each file you can see ten characters before the user and group owner. The first character tells us the type of file. Regular files get a **-**, directories get a **d**, symbolic links are shown with an **l**, pipes get a **p**, character devices a **c**, block devices a **b**, and sockets an **s**.

**Table 20.1. Unix special files**

| first character | file type |
|---|---|
| - | normal file |
| d | directory |
| l | symbolic link |
| p | named pipe |
| b | block device |
| c | character device |
| s | socket |

# 20.3. permissions

## 20.3.1. rwx

The nine characters following the file type denote the permissions in three triplets. A permission can be **r** for read access, **w** for write access, and **x** for execute. You need the **r** permission to list (ls) the contents of a directory. You need the **x** permission to enter (cd) a directory. You need the **w** permission to create files in or remove files from a directory.

**Table 20.2. standard Unix file permissions**

| permission | on a file | on a directory |
|---|---|---|
| r (read) | read file contents (cat) | read directory contents (ls) |
| w (write) | change file contents (vi) | create files in (touch) |
| x (execute) | execute the file | enter the directory (cd) |

## 20.3.2. three sets of rwx

We already know that the output of **ls -l** starts with ten characters for each file. This screenshot shows a regular file (because the first character is a - ).

```
paul@RHELv4u4:~/test$ ls -l proc42.bash
-rwxr-xr--  1 paul proj 984 Feb  6 12:01 proc42.bash
```

Below is a table describing the function of all ten characters.

**Table 20.3. Unix file permissions position**

| position | characters | function |
|---|---|---|
| 1 | - | this is a regular file |
| 2-4 | rwx | permissions for the **user owner** |
| 5-7 | r-x | permissions for the **group owner** |
| 8-10 | r-- | permissions for **others** |

When you are the **user owner** of a file, then the **user owner permissions** apply to you. The rest of the permissions have no influence on your access to the file.

When you belong to the **group** that is the **group owner** of a file, then the **group owner permissions** apply to you. The rest of the permissions have no influence on your access to the file.

When you are not the **user owner** of a file and you do not belong to the **group owner**, then the **others permissions** apply to you. The rest of the permissions have no influence on your access to the file.

## 20.3.3. permission examples

Some example combinations on files and directories are seen in this screenshot. The name of the file explains the permissions.

```
paul@laika:~/perms$ ls -lh
total 12K
drwxr-xr-x 2 paul paul 4.0K 2007-02-07 22:26 AllEnter_UserCreateDelete
-rwxrwxrwx 1 paul paul    0 2007-02-07 22:21 EveryoneFullControl.txt
```

```
-r--r----- 1 paul paul    0 2007-02-07 22:21 OnlyOwnersRead.txt
-rwxrwx--- 1 paul paul    0 2007-02-07 22:21 OwnersAll_RestNothing.txt
dr-xr-x--- 2 paul paul 4.0K 2007-02-07 22:25 UserAndGroupEnter
dr-x------ 2 paul paul 4.0K 2007-02-07 22:25 OnlyUserEnter
paul@laika:~/perms$
```

To summarize, the first **rwx** triplet represents the permissions for the **user owner**. The second triplet corresponds to the **group owner**; it specifies permissions for all members of that group. The third triplet defines permissions for all **other** users that are not the user owner and are not a member of the group owner.

## 20.3.4. setting permissions (chmod)

Permissions can be changed with **chmod**. The first example gives the user owner execute permissions.

```
paul@laika:~/perms$ ls -l permissions.txt
-rw-r--r-- 1 paul paul 0 2007-02-07 22:34 permissions.txt
paul@laika:~/perms$ chmod u+x permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwxr--r-- 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

This example removes the group owners read permission.

```
paul@laika:~/perms$ chmod g-r permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwx---r-- 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

This example removes the others read permission.

```
paul@laika:~/perms$ chmod o-r permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwx------ 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

This example gives all of them the write permission.

```
paul@laika:~/perms$ chmod a+w permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwx-w--w- 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

You don't even have to type the a.

```
paul@laika:~/perms$ chmod +x permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwx-wx-wx 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

You can also set explicit permissions.

```
paul@laika:~/perms$ chmod u=rw permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rw--wx-wx 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

Feel free to make any kind of combination.

```
paul@laika:~/perms$ chmod u=rw,g=rw,o=r permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rw-rw-r-- 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

Even fishy combinations are accepted by chmod.

```
paul@laika:~/perms$ chmod u=rwx,ug+rw,o=r permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwxrw-r-- 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

## 20.3.5. setting octal permissions

Most Unix administrators will use the **old school** octal system to talk about and set permissions. Look at the triplet bitwise, equating r to 4, w to 2, and x to 1.

**Table 20.4. Octal permissions**

| binary | octal | permission |
|---|---|---|
| 000 | 0 | --- |
| 001 | 1 | --x |
| 010 | 2 | -w- |
| 011 | 3 | -wx |
| 100 | 4 | r-- |
| 101 | 5 | r-x |
| 110 | 6 | rw- |
| 111 | 7 | rwx |

This makes **777** equal to rwxrwxrwx and by the same logic, 654 mean rw-r-xr-- . The **chmod** command will accept these numbers.

```
paul@laika:~/perms$ chmod 777 permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwxrwxrwx 1 paul paul 0 2007-02-07 22:34 permissions.txt
paul@laika:~/perms$ chmod 664 permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rw-rw-r-- 1 paul paul 0 2007-02-07 22:34 permissions.txt
paul@laika:~/perms$ chmod 750 permissions.txt
paul@laika:~/perms$ ls -l permissions.txt
-rwxr-x--- 1 paul paul 0 2007-02-07 22:34 permissions.txt
```

## 20.3.6. umask

When creating a file or directory, a set of default permissions are applied. These default permissions are determined by the **umask**. The **umask** specifies permissions that you do not want set on by default. You can display the **umask** with the **umask** command.

```
[Harry@RHEL4b ~]$ umask
0002
[Harry@RHEL4b ~]$ touch test
[Harry@RHEL4b ~]$ ls -l test
-rw-rw-r--  1 Harry Harry 0 Jul 24 06:03 test
[Harry@RHEL4b ~]$
```

As you can also see, the file is also not executable by default. This is a general security feature among Unixes; newly created files are never executable by default. You have to explicitly do a **chmod +x** to make a file executable. This also means that the 1 bit in the **umask** has no meaning--a **umask** of 0022 is the same as 0033.

# 20.4. practice: standard file permissions

1. As normal user, create a directory ~/permissions. Create a file owned by yourself in there.

2. Copy a file owned by root from /etc/ to your permissions dir, who owns this file now ?

3. As root, create a file in the users ~/permissions directory.

4. As normal user, look at who owns this file created by root.

5. Change the ownership of all files in ~/permissions to yourself.

6. Make sure you have all rights to these files, and others can only read.

7. With chmod, is 770 the same as rwxrwx--- ?

8. With chmod, is 664 the same as r-xr-xr-- ?

9. With chmod, is 400 the same as r-------- ?

10. With chmod, is 734 the same as rwxr-xr-- ?

11a. Display the umask in octal and in symbolic form.

11b. Set the umask to 077, but use the symbolic format to set it. Verify that this works.

12. Create a file as root, give only read to others. Can a normal user read this file ? Test writing to this file with vi.

13a. Create a file as normal user, give only read to others. Can another normal user read this file ? Test writing to this file with vi.

13b. Can root read this file ? Can root write to this file with vi ?

14. Create a directory that belongs to a group, where every member of that group can read and write to files, and create files. Make sure that people can only delete their own files.

# 20.5. solution: standard file permissions

1. As normal user, create a directory ~/permissions. Create a file owned by yourself in there.

```
mkdir ~/permissions ; touch ~/permissions/myfile.txt
```

2. Copy a file owned by root from /etc/ to your permissions dir, who owns this file now ?

```
cp /etc/hosts ~/permissions/
```

The copy is owned by you.

3. As root, create a file in the users ~/permissions directory.

```
(become root)# touch /home/username/permissions/rootfile
```

4. As normal user, look at who owns this file created by root.

```
ls -l ~/permissions
```

The file created by root is owned by root.

5. Change the ownership of all files in ~/permissions to yourself.

```
chown user ~/permissions/*
```

You cannot become owner of the file that belongs to root.

6. Make sure you have all rights to these files, and others can only read.

```
chmod 644 (on files)
```

```
chmod 755 (on directories)
```

7. With chmod, is 770 the same as rwxrwx--- ?

yes

8. With chmod, is 664 the same as r-xr-xr-- ?

No

9. With chmod, is 400 the same as r-------- ?

yes

10. With chmod, is 734 the same as rwxr-xr-- ?

no

11a. Display the umask in octal and in symbolic form.

```
umask ; umask -S
```

11b. Set the umask to 077, but use the symbolic format to set it. Verify that this works.

```
umask -S u=rwx,go=
```

12. Create a file as root, give only read to others. Can a normal user read this file ? Test writing to this file with vi.

```
(become root)

# echo hello > /home/username/root.txt

# chmod 744 /home/username/root.txt

(become user)

vi ~/root.txt
```

13a. Create a file as normal user, give only read to others. Can another normal user read this file ? Test writing to this file with vi.

```
echo hello > file ; chmod 744 file
```

Yes, others can read this file

13b. Can root read this file ? Can root write to this file with vi ?

Yes, root can read and write to this file. Permissions do not apply to root.

14. Create a directory that belongs to a group, where every member of that group can read and write to files, and create files. Make sure that people can only delete their own files.

```
mkdir /home/project42 ; groupadd project42

chgrp project42 /home/project42 ; chmod 775 /home/project42
```

You can not yet do the last part of this exercise...

# Chapter 21. Advanced file permissions

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# 21.1. sticky and setgid bits

## 21.1.1. sticky bit on directory

You can set the **sticky bit** on a directory to prevent users from removing files that they do not own as a user owner. The sticky bit is displayed at the same location as the x permission for others. The sticky bit is represented by a **t** (meaning x is also there) or a **T** (when there is no x for others).

```
root@RHELv4u4:~# mkdir /project55
root@RHELv4u4:~# ls -ld /project55
drwxr-xr-x  2 root root 4096 Feb  7 17:38 /project55
root@RHELv4u4:~# chmod +t /project55/
root@RHELv4u4:~# ls -ld /project55
drwxr-xr-t  2 root root 4096 Feb  7 17:38 /project55
root@RHELv4u4:~#
```

The **sticky bit** can also be set with octal permissions, it is binary 1 in the first of four triplets.

```
root@RHELv4u4:~# chmod 1775 /project55/
root@RHELv4u4:~# ls -ld /project55
drwxrwxr-t  2 root root 4096 Feb  7 17:38 /project55
root@RHELv4u4:~#
```

You will typically find the **sticky bit** on the **/tmp** directory.

```
root@barry:~# ls -ld /tmp
drwxrwxrwt 6 root root 4096 2009-06-04 19:02 /tmp
```

## 21.1.2. setgid bit on directory

**setgid** can be used on directories to make sure that all files inside the directory are owned by the group owner of the directory. The **setgid** bit is displayed at the same location as the x permission for group owner. The **setgid** bit is represented by an **s** (meaning x is also there) or a **S** (when there is no x for the group owner). As this example shows, even though **root** does not belong to the group proj55, the files created by root in /project55 will belong to proj55 since the **setgid** is set.

```
root@RHELv4u4:~# groupadd proj55
root@RHELv4u4:~# chown root:proj55 /project55/
root@RHELv4u4:~# chmod 2775 /project55/
root@RHELv4u4:~# touch /project55/fromroot.txt
root@RHELv4u4:~# ls -ld /project55/
drwxrwsr-x  2 root proj55 4096 Feb  7 17:45 /project55/
root@RHELv4u4:~# ls -l /project55/
total 4
-rw-r--r--  1 root proj55 0 Feb  7 17:45 fromroot.txt
root@RHELv4u4:~#
```

You can use the **find** command to find all **setgid** directories.

```
paul@laika:~$ find / -type d -perm -2000 2> /dev/null
/var/log/mysql
/var/log/news
/var/local
...
```

## 21.1.3. setgid and setuid on regular files

These two permissions cause an executable file to be executed with the permissions of the **file owner** instead of the **executing owner**. This means that if any user executes a program that belongs to the **root user**, and the **setuid** bit is set on that program, then the program runs as **root**. This can be dangerous, but sometimes this is good for security.

Take the example of passwords; they are stored in **/etc/shadow** which is only readable by **root**. (The **root** user never needs permissions anyway.)

```
root@RHELv4u4:~# ls -l /etc/shadow
-r--------  1 root root 1260 Jan 21 07:49 /etc/shadow
```

Changing your password requires an update of this file, so how can normal non-root users do this? Let's take a look at the permissions on the **/usr/bin/passwd**.

```
root@RHELv4u4:~# ls -l /usr/bin/passwd
-r-s--x--x  1 root root 21200 Jun 17  2005 /usr/bin/passwd
```

When running the **passwd** program, you are executing it with **root** credentials.

You can use the **find** command to find all **setuid** programs.

```
paul@laika:~$ find /usr/bin -type f -perm -04000
/usr/bin/arping
/usr/bin/kgrantpty
```

```
/usr/bin/newgrp
/usr/bin/chfn
/usr/bin/sudo
/usr/bin/fping6
/usr/bin/passwd
/usr/bin/gpasswd
...
```

In most cases, setting the **setuid** bit on executables is sufficient. Setting the **setgid** bit will result in these programs to run with the credentials of their group owner.

# 21.2. practice: sticky, setuid and setgid bits

1a. Set up a directory, owned by the group sports.

1b. Members of the sports group should be able to create files in this directory.

1c. All files created in this directory should be group-owned by the sports group.

1d. Users should be able to delete only their own user-owned files.

1e. Test that this works!

2. Verify the permissions on **/usr/bin/passwd**. Remove the **setuid**, then try changing your password as a normal user. Reset the permissions back and try again.

3. If time permits (or if you are waiting for other students to finish this practice), read about file attributes in the man page of chattr and lsattr. Try setting the i attribute on a file and test that it works.

# 21.3. solution: sticky, setuid and setgid bits

1a. Set up a directory, owned by the group sports.

```
groupadd sports
```

```
mkdir /home/sports
```

```
chown root:sports /home/sports
```

1b. Members of the sports group should be able to create files in this directory.

```
chmod 770 /home/sports
```

1c. All files created in this directory should be group-owned by the sports group.

```
chmod 2770 /home/sports
```

1d. Users should be able to delete only their own user-owned files.

```
chmod +t /home/sports
```

1e. Test that this works!

Log in with different users (group members and others and root), create files and watch the permissions. Try changing and deleting files...

2. Verify the permissions on **/usr/bin/passwd**. Remove the **setuid**, then try changing your password as a normal user. Reset the permissions back and try again.

```
root@deb503:~# ls -l /usr/bin/passwd
-rwsr-xr-x 1 root root 31704 2009-11-14 15:41 /usr/bin/passwd
root@deb503:~# chmod 755 /usr/bin/passwd
root@deb503:~# ls -l /usr/bin/passwd
-rwxr-xr-x 1 root root 31704 2009-11-14 15:41 /usr/bin/passwd
```

A normal user cannot change password now.

```
root@deb503:~# chmod 4755 /usr/bin/passwd
root@deb503:~# ls -l /usr/bin/passwd
-rwsr-xr-x 1 root root 31704 2009-11-14 15:41 /usr/bin/passwd
```

3. If time permits (or if you are waiting for other students to finish this practice), read about file attributes in the man page of chattr and lsattr. Try setting the i attribute on a file and test that it works.

```
paul@laika:~$ sudo su -
[sudo] password for paul:
root@laika:~# mkdir attr
root@laika:~# cd attr/
root@laika:~/attr# touch file42
root@laika:~/attr# lsattr
------------------ ./file42
root@laika:~/attr# chattr +i file42
```

```
root@laika:~/attr# lsattr
----i------------- ./file42
root@laika:~/attr# rm -rf file42
rm: cannot remove `file42': Operation not permitted
root@laika:~/attr# chattr -i file42
root@laika:~/attr# rm -rf file42
root@laika:~/attr#
```

# Chapter 22. Access control lists

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# 22.1. access control lists

## 22.1.1. acl in /etc/fstab

File systems that support **access control lists**, or **acls**, have to be mounted with the **acl** option listed in **/etc/fstab**. In the example below, you can see that the root file system has **acl** support, whereas /home/data does not.

```
root@laika:~# tail -4 /etc/fstab
/dev/sda1        /              ext3     acl,relatime    0  1
/dev/sdb2        /home/data     auto     noacl,defaults  0  0
pasha:/home/r    /home/pasha    nfs      defaults        0  0
wolf:/srv/data   /home/wolf     nfs      defaults        0  0
```

## 22.1.2. getfacl

Reading **acls** can be done with **/usr/bin/getfacl**. This screenshot shows how to read the **acl** of **file33** with **getfacl**.

```
paul@laika:~/test$ getfacl file33
# file: file33
# owner: paul
# group: paul
user::rw-
group::r--
mask::rwx
other::r--
```

## 22.1.3. setfacl

Writing or changing **acls** can be done with **/usr/bin/setfacl**. These screenshots show how to change the **acl** of **file33** with **setfacl**.

First we add **u**ser **sandra** with octal permission **7** to the **acl**.

```
paul@laika:~/test$ setfacl -m u:sandra:7 file33
```

Then we add the **g**roup tennis with octal permission **6** to the **acl** of the same file.

```
paul@laika:~/test$ setfacl -m g:tennis:6 file33
```

The result is visible with **getfacl**.

```
paul@laika:~/test$ getfacl file33
# file: file33
# owner: paul
# group: paul
user::rw-
user:sandra:rwx
group::r--
group:tennis:rw-
mask::rwx
other::r--
```

## 22.1.4. remove an acl entry

The **-x** option of the **setfacl** command will remove an **acl** entry from the targeted file.

```
paul@laika:~/test$ setfacl -m u:sandra:7 file33
paul@laika:~/test$ getfacl file33 | grep sandra
user:sandra:rwx
paul@laika:~/test$ setfacl -x sandra file33
paul@laika:~/test$ getfacl file33 | grep sandra
```

Note that omitting the **u** or **g** when defining the **acl** for an account will default it to a user account.

## 22.1.5. remove the complete acl

The **-b** option of the **setfacl** command will remove the **acl** from the targeted file.

```
paul@laika:~/test$ setfacl -b file33
paul@laika:~/test$ getfacl file33
# file: file33
# owner: paul
# group: paul
user::rw-
group::r--
other::r--
```

## 22.1.6. the acl mask

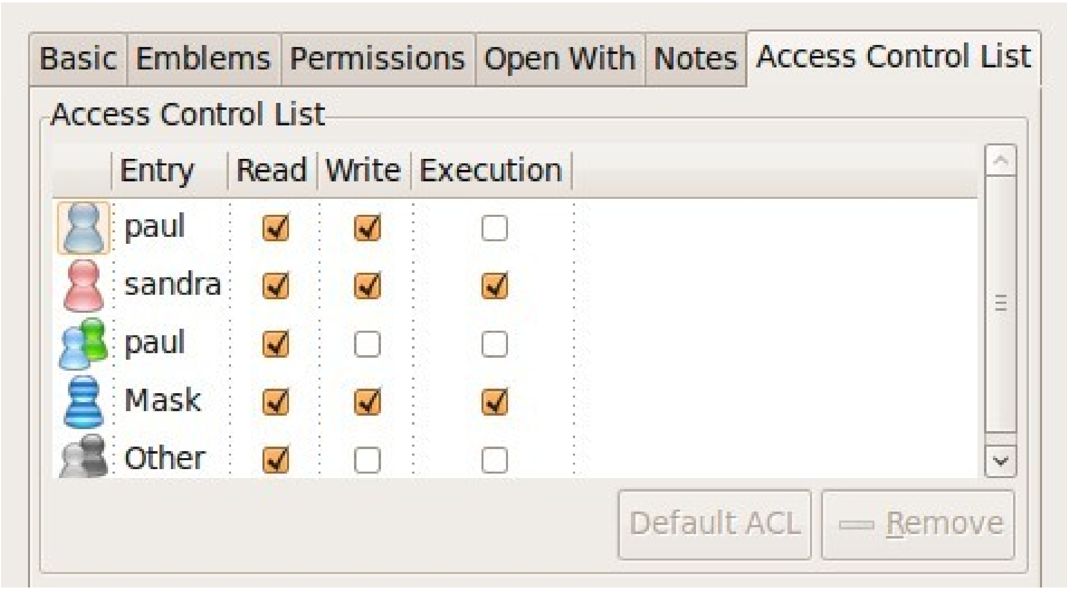
The **acl mask** defines the maximum effective permissions for any entry in the **acl**. This **mask** is calculated every time you execute the **setfacl** or **chmod** commands.

You can prevent the calculation by using the **--no-mask** switch.

```
paul@laika:~/test$ setfacl --no-mask -m u:sandra:7 file33
paul@laika:~/test$ getfacl file33
# file: file33
# owner: paul
# group: paul
user::rw-
user:sandra:rwx    #effective:rw-
group::r--
mask::rw-
other::r--
```

## 22.1.7. eiciel

Desktop users might want to use **eiciel** to manage **acls** with a graphical tool.




You will need to install **eiciel** and **nautilus-actions** to have an extra tab in **nautilus** to manage **acls**.

```
paul@laika:~$ sudo aptitude install eiciel nautilus-actions
```

# Chapter 23. File links

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# 23.1. inodes

To understand links in a file system, you first have to understand what an **inode** is.

## 23.1.1. inode contents

An **inode** is a data structure that contains metadata about a file. When the file system stores a new file on the hard disk, it stores not only the contents (data) of the file, but also extra properties like the name of the file, the creation date, its permissions, the owner of the file, and more. All this information (except the name of the file and the contents of the file) is stored in the **inode** of the file.

The **ls -l** command will display some of the inode contents, as seen in this screenshot.

```
root@rhel53 ~# ls -ld /home/project42/
drwxr-xr-x 4 root pro42 4.0K Mar 27 14:29 /home/project42/
```

## 23.1.2. inode table

The **inode table** contains all of the **inodes** and is created when you create the file system (with **mkfs**). You can use the **df -i** command to see how many **inodes** are used and free on mounted file systems.

```
oot@rhel53 ~# df -i
Filesystem            Inodes   IUsed   IFree IUse% Mounted on
/dev/mapper/VolGroup00-LogVol00
                     4947968  115326 4832642    3% /
/dev/hda1              26104      45   26059    1% /boot
tmpfs                  64417       1   64416    1% /dev/shm
/dev/sda1             262144    2207  259937    1% /home/project42
/dev/sdb1              74400    5519   68881    8% /home/project33
/dev/sdb5                  0       0       0    -  /home/sales
/dev/sdb6             100744      11  100733    1% /home/research
```

In the **df -i** screenshot above you can see the **inode** usage for several mounted **file systems**. You don't see numbers for **/dev/sdb5** because it is a **fat** file system.

### 23.1.3. inode number

Each **inode** has a unique number (the inode number). You can see the **inode** numbers with the **ls -li** command.

```
paul@RHELv4u4:~/test$ touch file1
paul@RHELv4u4:~/test$ touch file2
paul@RHELv4u4:~/test$ touch file3
paul@RHELv4u4:~/test$ ls -li
total 12
817266 -rw-rw-r--  1 paul paul 0 Feb  5 15:38 file1
817267 -rw-rw-r--  1 paul paul 0 Feb  5 15:38 file2
817268 -rw-rw-r--  1 paul paul 0 Feb  5 15:38 file3
paul@RHELv4u4:~/test$
```

These three files were created one after the other and got three different **inodes** (the first column). All the information you see with this **ls** command resides in the **inode**, except for the filename (which is contained in the directory).

### 23.1.4. inode and file contents

Let's put some data in one of the files.

```
paul@RHELv4u4:~/test$ ls -li
total 16
817266 -rw-rw-r--  1 paul paul  0 Feb  5 15:38 file1
817270 -rw-rw-r--  1 paul paul 92 Feb  5 15:42 file2
817268 -rw-rw-r--  1 paul paul  0 Feb  5 15:38 file3
paul@RHELv4u4:~/test$ cat file2
It is winter now and it is very cold.
We do not like the cold, we prefer hot summer nights.
paul@RHELv4u4:~/test$
```

The data that is displayed by the **cat** command is not in the **inode**, but somewhere else on the disk. The **inode** contains a pointer to that data.

## 23.2. about directories

### 23.2.1. a directory is a table

A **directory** is a special kind of file that contains a table which maps filenames to inodes. Listing our current directory with **ls -ali** will display the contents of the directory file.

```
paul@RHELv4u4:~/test$ ls -ali
total 32
817262 drwxrwxr-x   2 paul paul 4096 Feb  5 15:42 .
800768 drwx------  16 paul paul 4096 Feb  5 15:42 ..
817266 -rw-rw-r--   1 paul paul    0 Feb  5 15:38 file1
817270 -rw-rw-r--   1 paul paul   92 Feb  5 15:42 file2
817268 -rw-rw-r--   1 paul paul    0 Feb  5 15:38 file3
paul@RHELv4u4:~/test$
```

### 23.2.2. . and ..

You can see five names, and the mapping to their five inodes. The dot **.** is a mapping to itself, and the dotdot **..** is a mapping to the parent directory. The three other names are mappings to different inodes.

## 23.3. hard links

### 23.3.1. creating hard links

When we create a **hard link** to a file with **ln**, an extra entry is added in the directory. A new file name is mapped to an existing inode.

```
paul@RHELv4u4:~/test$ ln file2 hardlink_to_file2
paul@RHELv4u4:~/test$ ls -li
total 24
817266 -rw-rw-r--  1 paul paul  0 Feb  5 15:38 file1
817270 -rw-rw-r--  2 paul paul 92 Feb  5 15:42 file2
817268 -rw-rw-r--  1 paul paul  0 Feb  5 15:38 file3
817270 -rw-rw-r--  2 paul paul 92 Feb  5 15:42 hardlink_to_file2
paul@RHELv4u4:~/test$
```

Both files have the same inode, so they will always have the same permissions and the same owner. Both files will have the same content. Actually, both files are equal now, meaning you can safely remove the original file, the hardlinked file will remain. The inode contains a counter, counting the number of hard links to itself. When the counter drops to zero, then the inode is emptied.

### 23.3.2. finding hard links

You can use the **find** command to look for files with a certain inode. The screenshot below shows how to search for all filenames that point to **inode** 817270. Remember that an **inode** number is unique to its partition.

```
paul@RHELv4u4:~/test$ find / -inum 817270 2> /dev/null
/home/paul/test/file2
/home/paul/test/hardlink_to_file2
```

# 23.4. symbolic links

Symbolic links (sometimes called **soft links**) do not link to inodes, but create a name to name mapping. Symbolic links are created with **ln -s**. As you can see below, the **symbolic link** gets an inode of its own.

```
paul@RHELv4u4:~/test$ ln -s file2 symlink_to_file2
paul@RHELv4u4:~/test$ ls -li
total 32
817273 -rw-rw-r--  1 paul paul  13 Feb  5 17:06 file1
817270 -rw-rw-r--  2 paul paul 106 Feb  5 17:04 file2
817268 -rw-rw-r--  1 paul paul   0 Feb  5 15:38 file3
817270 -rw-rw-r--  2 paul paul 106 Feb  5 17:04 hardlink_to_file2
817267 lrwxrwxrwx  1 paul paul   5 Feb  5 16:55 symlink_to_file2 -> file2
paul@RHELv4u4:~/test$
```

Permissions on a symbolic link have no meaning, since the permissions of the target apply. Hard links are limited to their own partition (because they point to an inode), symbolic links can link anywhere (other file systems, even networked).

# 23.5. removing links

Links can be removed with **rm**.

```
paul@laika:~$ touch data.txt
paul@laika:~$ ln -s data.txt sl_data.txt
paul@laika:~$ ln data.txt hl_data.txt
paul@laika:~$ rm sl_data.txt
paul@laika:~$ rm hl_data.txt
```

# 23.6. practice : links

1. Create two files named winter.txt and summer.txt, put some text in them.

2. Create a hard link to winter.txt named hlwinter.txt.

3. Display the inode numbers of these three files, the hard links should have the same inode.

4. Use the find command to list the two hardlinked files

5. Everything about a file is in the inode, except two things : name them!

6. Create a symbolic link to summer.txt called slsummer.txt.

7. Find all files with inode number 2. What does this information tell you ?

8. Look at the directories /etc/init.d/ /etc/rc.d/ /etc/rc3.d/ ... do you see the links ?

9. Look in /lib with ls -l...

10. Use **find** to look in your home directory for regular files that do not(!) have one hard link.

# 23.7. solution : links

1. Create two files named winter.txt and summer.txt, put some text in them.

```
echo cold > winter.txt ; echo hot > summer.txt
```

2. Create a hard link to winter.txt named hlwinter.txt.

```
ln winter.txt hlwinter.txt
```

3. Display the inode numbers of these three files, the hard links should have the same inode.

```
ls -li winter.txt summer.txt hlwinter.txt
```

4. Use the find command to list the two hardlinked files

```
find . -inum xyz
```

5. Everything about a file is in the inode, except two things : name them!

The name of the file is in a directory, and the contents is somewhere on the disk.

6. Create a symbolic link to summer.txt called slsummer.txt.

```
ln -s summer.txt slsummer.txt
```

7. Find all files with inode number 2. What does this information tell you ?

It tells you there is more than one inode table (one for every formatted partition + virtual file systems)

8. Look at the directories /etc/init.d/ /etc/rc.d/ /etc/rc3.d/ ... do you see the links ?

```
ls -l /etc/init.d

ls -l /etc/rc.d

ls -l /etc/rc3.d
```

9. Look in /lib with ls -l...

```
ls -l /lib
```

10. Use **find** to look in your home directory for regular files that do not(!) have one hard link.

```
find ~ ! -links 1 -type f
```

# Chapter 24. Introduction to Processes

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# 24.1. terminology

## 24.1.1. process

A **process** is compiled source code that is currently running on the system.

## 24.1.2. PID

All processes have a **process id** or **PID**.

## 24.1.3. PPID

Every process has a parent process (with a **PPID**). The **child** process is often started by the **parent** process.

## 24.1.4. init

The **init** process always has process ID 1. The **init** process is started by the **kernel** itself so technically it does not have a parent process. **init** serves as a **foster parent** for **orphaned** processes.

## 24.1.5. kill

When a process stops running, the process dies, when you want a process to die, you **kill** it.

## 24.1.6. daemon

Processes that start at system startup and keep running forever are called **daemon** processes or **daemons**. These **daemons** never die.

### 24.1.7. zombie

When a process is killed, but it still shows up on the system, then the process is referred to as **zombie**. You cannot kill zombies, because they are already dead.

## 24.2. basic process management

### 24.2.1. $$ and $PPID

Some shell environment variables contain information about processes. The **$$** variable will hold your current **process ID**, and **$PPID** contains the **parent PID**. Actually **$$** is a shell parameter and not a variable, you cannot assign a value to it.

Below we use **echo** to display the values of **$$** and **$PPID**.

```
[paul@RHEL4b ~]$ echo $$ $PPID
4224 4223
```

### 24.2.2. pidof

You can find all process id's by name using the **pidof** command.

```
root@rhel53 ~# pidof mingetty
2819 2798 2797 2796 2795 2794
```

### 24.2.3. parent and child

Processes have a **parent-child** relationship. Every process has a parent process.

When starting a new **bash** you can use **echo** to verify that the **pid** from before is the **ppid** of the new shell. The **child** process from above is now the **parent** process.

```
[paul@RHEL4b ~]$ bash
[paul@RHEL4b ~]$ echo $$ $PPID
4812 4224
```

Typing **exit** will end the current process and brings us back to our original values for **$$** and **$PPID**.

```
[paul@RHEL4b ~]$ echo $$ $PPID
4812 4224
[paul@RHEL4b ~]$ exit
exit
[paul@RHEL4b ~]$ echo $$ $PPID
```

```
4224 4223
[paul@RHEL4b ~]$
```

## 24.2.4. fork and exec

A process starts another process in two phases. First the process creates a **fork** of itself, an identical copy. Then the forked process executes an **exec** to replace the forked process with the target child process.

```
[paul@RHEL4b ~]$ echo $$
4224
[paul@RHEL4b ~]$ bash
[paul@RHEL4b ~]$ echo $$ $PPID
5310 4224
[paul@RHEL4b ~]$
```

## 24.2.5. exec

With the **exec** command, you can execute a process without forking a new process. In the following screenshot a **Korn shell** (ksh) is started and is being replaced with a **bash shell** using the **exec** command. The **pid** of the **bash shell** is the same as the **pid** of the **Korn shell**. Exiting the child **bash shell** will get me back to the parent **bash**, not to the **Korn shell** (which does not exist anymore).

```
[paul@RHEL4b ~]$ echo $$
4224                                # PID of bash
[paul@RHEL4b ~]$ ksh
$ echo $$ $PPID
5343 4224                           # PID of ksh and bash
$ exec bash
[paul@RHEL4b ~]$ echo $$ $PPID
5343 4224                           # PID of bash and bash
[paul@RHEL4b ~]$ exit
exit
[paul@RHEL4b ~]$ echo $$
4224
```

## 24.2.6. ps

One of the most common tools on Linux to look at processes is **ps**. The following screenshot shows the parent child relationship between three bash processes.

```
[paul@RHEL4b ~]$ echo $$ $PPID
4224 4223
[paul@RHEL4b ~]$ bash
[paul@RHEL4b ~]$ echo $$ $PPID
4866 4224
[paul@RHEL4b ~]$ bash
[paul@RHEL4b ~]$ echo $$ $PPID
```

```
4884 4866
[paul@RHEL4b ~]$ ps fx
  PID TTY      STAT   TIME COMMAND
 4223 ?        S      0:01 sshd: paul@pts/0
 4224 pts/0    Ss     0:00  \_ -bash
 4866 pts/0    S      0:00      \_ bash
 4884 pts/0    S      0:00          \_ bash
 4902 pts/0    R+     0:00              \_ ps fx
[paul@RHEL4b ~]$ exit
exit
[paul@RHEL4b ~]$ ps fx
  PID TTY      STAT   TIME COMMAND
 4223 ?        S      0:01 sshd: paul@pts/0
 4224 pts/0    Ss     0:00  \_ -bash
 4866 pts/0    S      0:00      \_ bash
 4903 pts/0    R+     0:00          \_ ps fx
[paul@RHEL4b ~]$ exit
exit
[paul@RHEL4b ~]$ ps fx
  PID TTY      STAT   TIME COMMAND
 4223 ?        S      0:01 sshd: paul@pts/0
 4224 pts/0    Ss     0:00  \_ -bash
 4904 pts/0    R+     0:00      \_ ps fx
[paul@RHEL4b ~]$
```

On Linux, **ps fax** is often used. On Solaris **ps -ef** (which also works on Linux) is common. Here is a partial output from **ps fax**.

```
[paul@RHEL4a ~]$ ps fax
PID TTY      STAT   TIME COMMAND
1 ?        S      0:00 init [5]

...

3713 ?        Ss     0:00 /usr/sbin/sshd
5042 ?        Ss     0:00  \_ sshd: paul [priv]
5044 ?        S      0:00      \_ sshd: paul@pts/1
5045 pts/1    Ss     0:00          \_ -bash
5077 pts/1    R+     0:00              \_ ps fax
```

## 24.2.7. pgrep

Similar to the **ps -C**, you can also use **pgrep** to search for a process by its command name.

```
[paul@RHEL5 ~]$ sleep 1000 &
[1] 32558
[paul@RHEL5 ~]$ pgrep sleep
32558
[paul@RHEL5 ~]$ ps -C sleep
  PID TTY          TIME CMD
32558 pts/3    00:00:00 sleep
```

You can also list the command name of the process with pgrep.

```
paul@laika:~$ pgrep -l sleep
```

```
9661 sleep
```

## 24.2.8. top

Another popular tool on Linux is **top**. The **top** tool can order processes according to **cpu usage** or other properties. You can also **kill** processes from within top. Press **h** inside **top** for help.

In case of trouble, top is often the first tool to fire up, since it also provides you memory and swap space information.

# 24.3. signalling processes

## 24.3.1. kill

The **kill** command will kill (or stop) a process. The screenshot shows how to use a standard **kill** to stop the process with **pid** 1942.

```
paul@ubuntu910:~$ kill 1942
paul@ubuntu910:~$
```

By using the **kill** we are sending a **signal** to the process.

## 24.3.2. list signals

Running processes can receive signals from each other or from the users. You can have a list of signals by typing **kill -l**, that is a letter **l**, not the number 1.

```
[paul@RHEL4a ~]$ kill -l
1) SIGHUP       2) SIGINT       3) SIGQUIT      4) SIGILL
5) SIGTRAP      6) SIGABRT      7) SIGBUS       8) SIGFPE
9) SIGKILL     10) SIGUSR1     11) SIGSEGV     12) SIGUSR2
13) SIGPIPE     14) SIGALRM     15) SIGTERM     17) SIGCHLD
18) SIGCONT     19) SIGSTOP     20) SIGTSTP     21) SIGTTIN
22) SIGTTOU     23) SIGURG      24) SIGXCPU     25) SIGXFSZ
26) SIGVTALRM   27) SIGPROF     28) SIGWINCH    29) SIGIO
30) SIGPWR      31) SIGSYS      34) SIGRTMIN    35) SIGRTMIN+1
36) SIGRTMIN+2  37) SIGRTMIN+3  38) SIGRTMIN+4  39) SIGRTMIN+5
40) SIGRTMIN+6  41) SIGRTMIN+7  42) SIGRTMIN+8  43) SIGRTMIN+9
44) SIGRTMIN+10 45) SIGRTMIN+11 46) SIGRTMIN+12 47) SIGRTMIN+13
48) SIGRTMIN+14 49) SIGRTMIN+15 50) SIGRTMAX-14 51) SIGRTMAX-13
52) SIGRTMAX-12 53) SIGRTMAX-11 54) SIGRTMAX-10 55) SIGRTMAX-9
56) SIGRTMAX-8  57) SIGRTMAX-7  58) SIGRTMAX-6  59) SIGRTMAX-5
60) SIGRTMAX-4  61) SIGRTMAX-3  62) SIGRTMAX-2  63) SIGRTMAX-1
64) SIGRTMAX
[paul@RHEL4a ~]$
```

## 24.3.3. kill -1 (SIGHUP)

It is common on Linux to use the first signal **SIGHUP** (or HUP or 1) to tell a process that it should re-read its configuration file. Thus, the **kill -1 1** command forces the **init** process (**init** always runs with **pid 1**) to re-read its configuration file.

```
root@deb503:~# kill -1 1
root@deb503:~#
```

It is up to the developer of the process to decide whether the process can do this running, or whether it needs to stop and start. It is up to the user to read the documentation of the program.

## 24.3.4. kill -15 (SIGTERM)

The **SIGTERM** signal is also called a **standard kill**. Whenever **kill** is executed without specifying the signal, a **kill -15** is assumed.

Both commands in the screenshot below are identical.

```
paul@ubuntu910:~$ kill 1942
paul@ubuntu910:~$ kill -15 1942
```

## 24.3.5. kill -9 (SIGKILL)

The **SIGKILL** is different from most other signals in that it is not being sent to the process, but to the **Linux kernel**. A **kill -9** is also called a **sure kill**. The **kernel** will shoot down the process. As a developer you have no means to intercept a **kill -9** signal.

```
root@rhel53 ~# kill -9 3342
```

## 24.3.6. killall

The **killall** command will also default to sending a **signal 15** to the processes.

This command and its SysV counterpart **killall5** can by used when shutting down the system. This screenshot shows how Red Hat Enterprise Linux 5.3 uses **killall5** when halting the system.

```
root@rhel53 ~# grep killall /etc/init.d/halt
action $"Sending all processes the TERM signal..." /sbin/killall5 -15
action $"Sending all processes the KILL signal..."  /sbin/killall5 -9
```

## 24.3.7. pkill

You can use the **pkill** command to kill a process by its command name.

```
[paul@RHEL5 ~]$ sleep 1000 &
[1] 30203
[paul@RHEL5 ~]$ pkill sleep
[1]+  Terminated              sleep 1000
[paul@RHEL5 ~]$
```

## 24.3.8. top

Inside **top** the **k** key allows you to select a **signal** and **pid** to kill. Below is a partial screenshot of the line just below the summary in **top** after pressing **k**.

```
PID to kill: 1932

Kill PID 1932 with signal [15]: 9
```

## 24.3.9. SIGSTOP and SIGCONT

A running process can be **suspended** when it receives a **SIGSTOP** signal. This is the same as **kill -19** on Linux, but might have a different number in other Unix systems.

A **suspended** process does not use any **cpu cycles**, but it stays in memory and can be re-animated with a **SIGCONT** signal (**kill -18** on Linux).

Both signals will be used in the section about **background** processes.

# 24.4. practice : basic process management

1. Use **ps** to search for the **init** process by name.

2. What is the **process id** of the **init** process ?

3. Use the **who am i** command to determine your terminal name.

4. Using your terminal name from above, use **ps** to find all processes associated with your terminal.

5. What is the **process id** of your shell ?

6. What is the **parent process id** of your shell ?

7. Start two instances of the **sleep 3342** in background.

8. Locate the **process id** of all **sleep** commands.

9. Display only those two **sleep** processes in **top**. Then quit top.

10. Use a **standard kill** to kill one of the **sleep** processes.

11. Use one command to kill all **sleep** processes.

# 24.5. solution : basic process management

1. Use **ps** to search for the **init** process by name.

```
root@rhel53 ~# ps -C init
  PID TTY          TIME CMD
    1 ?        00:00:04 init
```

2. What is the **process id** of the **init** process ?

```
1
```

3. Use the **who am i** command to determine your terminal name.

```
root@rhel53 ~# who am i
paul     pts/0        2010-04-12 17:44 (192.168.1.38)
```

4. Using your terminal name from above, use **ps** to find all processes associated with your terminal.

```
oot@rhel53 ~# ps fax | grep pts/0
 2941 ?        S      0:00      \_ sshd: paul@pts/0
 2942 pts/0    Ss     0:00          \_ -bash
 2972 pts/0    S      0:00              \_ su -
 2973 pts/0    S      0:00                  \_ -bash
 3808 pts/0    R+     0:00                      \_ ps fax
 3809 pts/0    R+     0:00                      \_ grep pts/0
```

or also

```
root@rhel53 ~# ps -ef | grep pts/0
paul      2941  2939  0 17:44 ?        00:00:00 sshd: paul@pts/0
paul      2942  2941  0 17:44 pts/0    00:00:00 -bash
root      2972  2942  0 17:45 pts/0    00:00:00 su -
root      2973  2972  0 17:45 pts/0    00:00:00 -bash
root      3816  2973  0 21:25 pts/0    00:00:00 ps -ef
root      3817  2973  0 21:25 pts/0    00:00:00 grep pts/0
```

5. What is the **process id** of your shell ?

```
2973 in the screenshot above, probably different for you
```

**echo $$** should display same number as the one you found

6. What is the **parent process id** of your shell ?

```
2972 in the screenshot above, probably different for you
```

in this example the PPID is from the **su -** command, but when inside gnome then for example gnome-terminal can be the parent process

7. Start two instances of the **sleep 3342** in background.

```
sleep 3342 &
sleep 3342 &
```

8. Locate the **process id** of all **sleep** commands.

```
pidof sleep
```

9. Display only those two **sleep** processes in **top**. Then quit top.

```
top -p pidx,pidy (replace pidx pidy with the actual numbers)
```

10. Use a **standard kill** to kill one of the **sleep** processes.

```
kill pidx
```

11. Use one command to kill all **sleep** processes.

```
pkill sleep
```