

### Thrashing

If the number of frames allocated to a low-priority process falls below the minimum number required by the computer architecture, we must suspend that process' execution. We should then page out its remaining pages, freeing all its allocated frames. This provision introduces a swap-in, swap-out level of intermediate CPU scheduling.

In fact, look at any process that does not have "enough" frames. Although it is technically possible to reduce the number of allocated frames to the minimum, there is some (larger) number of pages in active use. If the process does not have this number of frames, it will quickly page fault. At this point, it must replace some page. However, since all its pages are in active use, it must replace a page that will be needed again right away. Consequently, it quickly faults again, and again, and again. The process continues to fault, replacing pages for which it then faults and brings back in right away.

This high paging activity is called thrashing. A process is thrashing if it is spending more time paging than executing.

## An Introduction to Linux

### What is Linux?

With the availability of several advanced application based on Linux, the use of this operating system has increased. More and more applications are being deployed in Linux platform in this era of burgeoning IT growth. Stability, support, increased availability of skills and resource pools, and the application maturity, along with lower cost of ownership make this operating system acceptable in an increased level in different sectors.

### About Operating Systems

The basic software that are needed to control the different activities are called **system software or Operating systems**. System software makes the working of system software also control the operations of the CD drive, enable the use of modems and other peripherals connected to the computer. They help computer users to create files and folders, copy files and run applications. In other words, operating systems perform different management operations such as file management, memory management, device management and process management.

Several types of operating systems have evolved through the past several years. Earlier, operating systems were characterized by their limited capacities and reduced features. New operating systems are available with several advanced features. Some operating systems are developed for certain special cases. Presently, operating systems are classified based on their ability, area of use, working environments and the like.

Some of the classifications of operating systems are real time operating systems, server operating systems, single user Operating systems, multi user Operating systems and so on. Operating systems are now used also in mobile phones, PDAs (Personal Digital Assistants), music players, game consoles, digital cameras and several other gadgets. In these devices operating system software are embedded in the hardware. Unix, Windows, Solaris, Mac are some of the operating systems currently available for desktop systems.

## Free and Open Source Software

Open source, freeware and free software are now available for anyone and for any use. These are also available for any purpose including specialized jobs. Freeware and free software are different from each other. ***Freeware software*** is a type of software that is available free of cost and these can be easily distributed without any restrictions. There are no license agreements for freeware software.

The definition of free software is given by the Free Software Foundation (FSF). But in *free software*, the meaning of the word free is different and it does not mean that the software is available at zero cost. The term free in free software is used to indicate the different freedoms offered to the software user. Free software user is provided with the complete freedom to run the software for any purpose, freedom to study the working of the software, freedom to redistribute copies, freedom to improve the software and for releasing improved versions of the software. To improve the software and to adapt it to different needs, the source code of the free software must be easily available. While releasing new versions or after modifying the software, it is very essential that no restrictions negating the original freedoms must be imposed on the free software. Any software can be treated as free software if the users are provided with all the above freedoms. Being free to do the above things means that it is not necessary to ask or pay for permissions to do such things.

The concept of free software is not a new thing. It existed even at the time of the development of the first computer itself. In the initial period all the software was available as free software. Earlier computer users were scientists and developers, and they did not consider the software as a business asset. So there were no restrictions in copying the software or modifying it. But the main difficulty was the lack of standardization between different software. As a result, software in a system based on a particular architecture could not run in another machine having a different architecture. When computers were begun to be used for commercial activities, some restrictions were began to be imposed use of software. In order to overcome the difficulties associated with the restrictions in using different software, in 1983, Richard Stallman started the GNU or Gnu NotUnix Project. This project was aimed to spread the message of using free

software and to develop a free operating system similar to but different from the Unix operating system. In continuation of this project, later in 1985, Free Software Foundation (FSF) was formed. One of the primary goals of this foundation was the development of a free an open computer operating system and application software that can be used and shared among different users with complete freedom. The face of the African animal gnu was chosen as the logo of this project.

With the activities of the Free Software Foundation and the GNU project, several types of free software were made available. The GNU text editor Emacs and the GNU C compiler GCC were the very successful initial software. Two other notable developments were the Berkley Software Distribution (BSD), which is a reimplementation of the Unix operating system and the X Window system, a free, network transparent graphical computing environment. Development of the kernel-called as Hurd was found to be very difficult. In 1992 Linux kernel was made available under the GNU General Public License (GPL).

**Open source software** means that the source code of the software is openly available. This is contrary to proprietary software, where the source code is kept secret. Open source software license provides certain license to end users. This license provides the right to access the source code of the software, make copies of the software and distribute it and make improvement to the software. So anyone can distribute or sell the software. Also anybody can modify the software to suit his needs, and can provide support to users for the software. Open source software is developed collectively and hence these are transparent due to which bug fixing is easy. Open source types of software are developed by communities of developers who distribute the code without any charge and donate their labour to debug, improve and modify the software.

Parallel software development and debugging are other notable features of open source software development process and due to these, open source software are available at lesser prices. Usually open source software are sold for a price, which is attributed towards the cost of user manuals or for providing technical support or towards the charge for copying the software and the cost of copy disks.

Linux happens to be the first name that comes to people when speaking about free and open source software. But Linux is not the only software that is available in this category. Gedit is a lightweight free text editor and can be found in many Linux distributions, BSD and Unix systems.

Internet applications include applications for browsing the Internet, mail applications and messaging services. Mozilla Firefox, Mozilla Thunderbird, Iceweasel, Gaim, Evolution are some of the commonly used applications for different Internet based activities. MySQL is an open source database application available for different platforms. Besides these, there are several other open source software that are used as firewalls, IDS and so on. These are free software and are available in different versions suitable for different operating systems. Also these applications work integrated with several others of this kind. An absolutely free, open, feature-rich multi-platform office productivity suite is OpenOffice.org suite. The user interface and the different functionality of this suite are very similar to other commercial products like Microsoft Office. Besides these, several programming languages are also available under this category. Python is an easy to learn and a powerful programming language. It has a high-level data structure and a simple but effective approach for object-oriented programming. This is an ideal language for scripting and rapid application development in many areas on most platforms. Apache web server is open source software that has emerged as the most popular web server. Now several educational tools for different activities are also available as free software. These tools are aimed for children of different age groups. These different software are having simple and easy to use user interfaces and these work in an interactive and easy style. Users can adapt the software, improve them and share the software with others.

Besides the different advantages of open source software discussed earlier, these types of software offer several other advantages also. Open source software has changed the ways of developing software applications. These type of software reduce the tight coupling between the application and the platform on which these are deployed. When using open source software, cost does not escalate with the scaling up of business. Cost of licensing for open-source is less when compared to proprietary type software. Open

source software provide safeguard against forced future hardware upgrading. Maintenance cost associated with open source software is also less. Due to these reasons, the *total cost of ownership* (TCO) and the *total cost of acquisition* (TCA) are less for open source applications. With the increased use of free and open source software, the cost of commercial software will tend to fall. However, adoption of open source software has not increased much as expected due to several reasons. One reason is the lack of awareness about the advantages of using open source software. For example, though several open source and free software are having features that are comparable or sometimes superior to that offered by proprietary or closed source software they are not widely used. Another reason of less popularity of open source software is the less user friendly interfaces offered by such software. But new releases of Linux applications are having better user friendly graphic interfaces. Still, more applications in open source types of category are to be developed. Skill shortages in the use of free and open source software, lack of support, product immaturity are some other reasons for the less popularity of open source software. Open source software allows a broader perspective when comes to its support. Proprietary software vendors insist that customers avail the support from them or from authorized service vendors only. But the support option for open source software is different. Different vendors provide support and the vendors compete for support contracts, as the source code is available for anybody. This has also become a source of revenue for support service persons and firms. Apart from the commercial support, several support channels are available for open source applications.

Many open-source software projects are currently running in several places. The widely accepted open source software that has emerged as the platform of choice among the users, instead of proprietary software, is Linux. Linux has emerged as a *de facto* standard in several academic institutions and commercial establishments. Due to low cost solutions, Linux is gaining support from government in different countries around the world. Low cost, flexible license requirements, high level security, absence of proprietary vendor requirements, general stability and usability are some other features that are making Linux a demanding operating system -worldwide.

## Origin of Linux

DOS was the once dominated computer operating system. But the source code of DOS was not made available, by the developers of the operating system. Along with DOS, another operating system available was Unix. Unix was developed in 1969 and was developed using C programming language. Unix was different from other operating systems available at that time and Unix offered several advantages. Unix made it possible for different software to work on an hardware. Previously this was not possible owing to the lack of standards. The major attraction of Unix was that it created standards on which independent hardware and software manufacturers could work. Unix could work on a wide range of machines irrespective of the architecture or configuration. Another feature of Unix operating system was the ability for networking. This ability helped computers to interconnect themselves as well as to connect to the Internet. Due to these added features several derivatives of this operating system such as Sun OS Solaris, BSD (Berkely Software Distribution) and so on were soon developed. BSD was released as free and open source software and the license allowed the use of the operating system for any commercial purpose.

With the commercialization of Unix, the practice of distributing source code along with the software came to an end. The increased price of Unix and the difficult user interfaces kept Unix away from users. Efforts to develop a low cost operating system progressed and this led to the development of Minix. Andrew S Tanenbaum, a Dutch Professor, wrote this operating system to teach the students about the inner working of operating systems and the source code was freely distributed. Minix was developed for educational use and was released under BSD license. This operating system was written in C programming language and assembly language. Thus, for the first time, the code for an operating system was made available. Along with Minix, another operating system released was GNU (Gnu's Not Linuz). Both these operating systems were similar to Unix but used no code from Unix. These operating systems provided only limited abilities and more features were to be included for the effective working so as to function as a true and complete operating system.

This was the time when developers were actively involved in discussions related to the development of open source software. In 1991 Linus Trovalds, a student of Helsinki University developed an initial operating system and posted to newsgroups for feedbacks and discussions. Actually this was the initial version of the kernel used for the development of Linux operating system. With some modification, based on the discussions at newsgroups, an initial version of Linux 0.01 was released in mid September and was put on the Net. This was the beginning of the evolution of Linux operating system. Depending on user requirements new versions of Linux operating system were released from time to time. But all these versions were in skeleton forms only. The main difficulty with the different versions is that these versions provided support for only a limited number of hardware components, such as hard disks, keyboards or monitor types. Soon, the different versions were made available through different *ftp* sites. This type of different distributions of the software enabled hundreds of developers to work on the source code and to provide several worthy modifications. The efforts made by several developers led to the release of Linux for actual use in computers. Linus Trovalds later came to be known as the father of Linux operating system. He adopted the penguin nicknamed as Tux as the Linux mascot (see Figure 1.2). Later, Linux community adopted Tux as the mascot of Linux kernel and majority of people associate Linux with Tux. Tux can be seen in Linux related websites and along with Linux products and applications.

Soon Linux included under GNU General Public License (GPL) making the source code freely available for copying, studying as well as for editing purposes. GNU operating system used this Linux kernel to develop a complete operating system and thus the free operating system GNU/Linux was formed. After this, several commercial vendors entered the scene for developing advanced operating systems. With the introduction of graphical interfaces and X-Window, the popularity of Linux operating system also increased. Different vendors added several noteworthy features and made the software in a distributable format, ready for distribution. Red Hat and Debian were the first two who entered the scene for distributing Linux. Even today newer and newer

versions of Linux are being released periodically and hundreds of different Linux versions are currently available to users.

## Linux Kernel

The central nervous system of Linux operating system is the kernel. The kernel is responsible for running the entire system. It is responsible for all the basic functions performed by the operating system. Kernel provides a set of services and APIs on top of the hardware for the application to use. Kernel manages memory, controls different devices, execute commands, handles different errors and so on. The kernel is under constant revision and development by the Linux community. Due to this constant revision process, always a stable Linux version as well as an experimental version of Linux will be available. With every revision, new and new features are incorporated to the Linux kernel. Thousands of lines of codes are modified and tested before a new stable version of Linux is released for use. A full featured Linux kernel that provided the abilities for the management of different resources of the system was Linux 2.4. Later versions added several new features to this initial Linux version. The added features provided additional strength to the kernel. Also, the newly added functions and operations provided a better standardized environment. Support for new hardware components, increased concurrent processes and users, support for large number of users and groups, better scalability are some of the notable features available in newer kernels. Support for powerful hardware, increased memory, additional hardware controllers, increased networking hardware, large file size are their other salient features.

Linux kernel is developed in a modular architecture. Modular architecture means that the kernel is built using several modules or subsystems. Basically there will be a core that is made up of the minimum code for running the system. This kernel performs different functions of the operating system such as device management, memo management, process management and file management with the support of the core. All these management processes are performed using several advanced functions such as process and thread creation, inter process communication mechanism, interrupt handling, security file system, networking and so on. Different device drivers, protocols, and other

components are glued to this core as per requirements. These different components perform different tasks such as reading files, drive disks and the like. This type of modular architecture helps in an efficient working of the operating system by loading the system faster and using the minimum memory. It can be seen that whenever new versions of applications are released, requirement of memory is high when compared to previous versions. But the modular architecture of Linux helps to keep the additional memory requirements less for new versions.

Basically Linux kernel is made up of several device drivers. Device drivers are file systems through which users and programs interact with the hardware and other connected devices. These drivers are written to work in a variety of platforms. Support for new processors and new architectures are included in new kernel versions which provide support for almost all devices connected to the Linux system. Basically a tree like architecture is followed in Linux operating system for different device drivers. Instead of putting all device drivers in a single directory, Linux groups the drivers based on controllers. This type of architecture separates drivers for different platforms and for different devices. Also, the number of available namespaces is increased due to this architecture. The tree arrangement can be seen by exploring the system. This arrangement offers a greater-reliability and the different machine specific drivers can be added to the core of the kernel efficiently. Interrupt handling functions performed by the kernel helps to control different hardware systems. This is done by setting priorities for interrupts, enabling and disabling interrupts and scheduling interrupts. At the starting time, different hardware checking is done and the drivers are loaded and interrupts are set as required.

Bus architecture of computers is responsible for the efficient working of internal as well as external devices connected to them. Commonly used bus architectures are known by names such as ISA, PCI, MCA, USB and so on. New buses have additional features when compared to earlier bus architectures. Linux provide support to these architectures including support for plug and play devices inserted to the above mentioned buses as well as to those devices connected to serial buses and external buses. Several devices such as keyboards, mouse, speakers, printers, scanners and so on can be connected to the system using USB (Universal Serial Bus) and Linux supports this

architecture efficiently. Also a number of *I/O* devices are supported by Linux kernel. Different devices that are supported include IDE, SCSI and SATA disk drives. Newer versions provide support for increased numbers of controllers. Different floppy disks, tapes, DVDs and CDs are also supported by Linux kernel. Direct low level device addressing ability helps this operating system to communicate directly with different devices. It helps data to be written direct to the disk thereby minimizing the loss of data in the event of any failure. Support for RAID devices and multiple disks working together for redundant storage and speedy data access helps in the safe storage and retrieval of data in different computing environments. Linux kernel also supports serial ports and parallel ports, modems, sound cards, TV and radio tuners and a variety of video cards.

Support for different file systems-suitable for different platforms is another feature provided by Linux kernels. Different systems use different types of file systems namely FAT, FAT32, NTFS, VFAT, HPPS and so on. Support for different file systems helps in the seamless operation of Linux systems in hybrid environments. Support for different partition tables are another feature offered by Linux. This feature makes the operating system to read from any partition table. To manage memory, kernel provides support for a large memory address space, memory mapping and demand mapping. Several processes and threads can be created cheaply and easily using the Linux kernel. Also the kernel helps to share different files, memory and processes. Communication between processes and applications are also done efficiently by the kernel.

A complete implementation of networking protocols such as TCP, IP, UDP, NetBEUI and so on are included with the kernel. As a result, the kernel provides enough support for networking and making communication with the Internet, easily. Linux kernel supports several new networking devices and offers several networking functions. Firewalls, packet filters and the like have become common components of Linux kernels. These features help the easy integration of new as well as old components in networks. Protocols for messaging, mail operations as well as other common Internet services were included from earlier versions of Linux. The ability of Linux operating system to process HTTP requests makes the Internet accessing an easy process. Program loader portion of

Linux kernel helps to associate different files to the correct application. This helps in the easy opening of files and to run programs easily. Availability of documentation is another feature of Linux kernel. Detailed documentation files provide necessary support for running the operating system.

## **Linux Features**

Different features of Linux operating system can be explained under different groups as follows:

### **1. Free and Inexpensive**

Linux versions are available as free distributions and can be downloaded free from the Internet. Paid distributions of Linux are available at reduced prices. Linux is available under General Public License (GPL), which requires free distribution of the source code. All patches and updates are also available under this license. This license provides freedom to copy and modify the software without any restrictions.

### **2. Stable and Flexible**

Linux operating system has matured into a reliable, robust and stable operating system. Linux is flexible, as it is an open source operating system. High availability, fail over solutions, increased manageability and better storage enhancements are the major features of this operating system. Flexibility of Linux Systems is increased with the help of tools and applications that provide facilities for configuring the system for different users. Different tasks can be scheduled differently and can be configured to activate at the set time.

Virus attacks in Linux are less when compared to proprietary operating systems. Virus propagation mainly takes place through pirated copies. Linux can be obtained directly from official websites of distributors and hence the authenticity can be verified. Moreover, the source code is available for verification and if required, the code can be compiled for creating a new version of the operating system.

Security holes are fixed easily during the updating processes. Moreover, the kernel and file systems of Linux are derived from the secure Unix operating system. Hence the security offered by Linux is strong.

### **3. Fast and Reliable**

Linux operating system is fast and so it can manage different resources efficiently and effectively. One reason for the increased speed is the low memory requirement due to its modular architecture. Linux has the ability to add new modules as and when required and to release the resources after the use. Linux is equipped with several added features to increase the reliability of the system. The backup option provided by several Linux distributions offers facilities for simple backing up as well as backup restoration of machine contents in an easy manner.

System testing application available with several Linux distributions enables the testing of different hardware components and to report any errors. Using this facility it is possible to check the system for errors and thereby the performance of the system can be improved.

### **4. Easier to Use**

Graphical interfaces in Linux offers several facilities for ease of use. A number of graphical interfaces each having a different layout, can be chosen by the user for installation. To make the interface more attractive, options are available for customization. For quick access, applications can be placed as shortcuts in the desktop or can be added to the panel. Drag and drop functionality, point and click facility are some of the features of graphic user interfaces. Forward and backward buttons help to navigate through forward and backward windows at ease. Using the single click option, files and folders can be opened by single clicking of the mouse.

### **5. Robust Programming and Application Environments**

Highly robust and capable programming environments are available in Linux. Different software are available as free and are covered under the GNU Public License. Compilers for C, C++ languages, assembler, Perl, Python are available in Linux operating system. Scripts in Linux operating system are similar to batch files in Windows systems, but they perform better. Scripts provide abilities to automate different processes. Office productivity tools, e-mail solutions, Web applications, database systems and middleware

applications are some of the common applications bundled along with Linux operating system.

## **6. Built-in Networking Ability and Easy Access to the Internet**

Networking allows the sharing of files and devices connected in networks. Also, a single Internet connection can be shared among different networked computers. The Internet is based on Unix and the different protocols used in the Internet are developed from Unix operating system. Naturally Internet connectivity and networking of systems can be done easily when using Linux. It is to be noted that majority of web servers are running under Linux operating system. Most Linux distributions are provided with a web browser for Surfing the Net. Applications for using other Internet services such as mail management, chat services, messaging and so on are also available in different Linux distributions.

## **7. Increased Returns**

Linux deployments have increased recently since business organizations are interested in reducing investments on existing IT infrastructure and to extract maximum Return On Investments (ROI). Total Cost of Ownership (TCO) of a system is made up of the cost for owning the software, procuring the hardware, cost of maintenance and cost for administering the system. With Linux, getting maximum ROI is possible in an easy manner, as Linux has proved to be very cost-effective and easily maintainable.

## **8. Multi User and Multi Tasking Ability**

Linux is a true multi user and multi tasking operating system. Unix operating system from which Linux was developed is a multi tasking and multi user operating system. This ability helps several users to work simultaneously as well as to perform several tasks at the same time, so also, when using Linux operating system.

## **9. Entertaining and Educative**

Several applications available for Linux operating system help in the running of audio, video as well as other multimedia files. Support for CD, DVD and other media help to play high quality digital audio and video files in Linux. Support for TV and radio tuner cards help to watch television shows as well as to hear radio broadcasts. Now several games are installed by default, while installing Linux operating system. Availability of

several educational applications suited to students of different groups as well as different standards is another noteworthy feature of Linux.

## 10. Readily Available Help

Help option can be seen included with several Linux versions. Availability of content sensitive help is a major feature of different Linux distributions. These files help in troubleshooting and solving different problems. Exhaustive manual pages are provided with several new releases. These manual pages are divided into different sections for ease of use. Easy and powerful search option and easy navigation between manual pages are the other features of Linux manual pages.

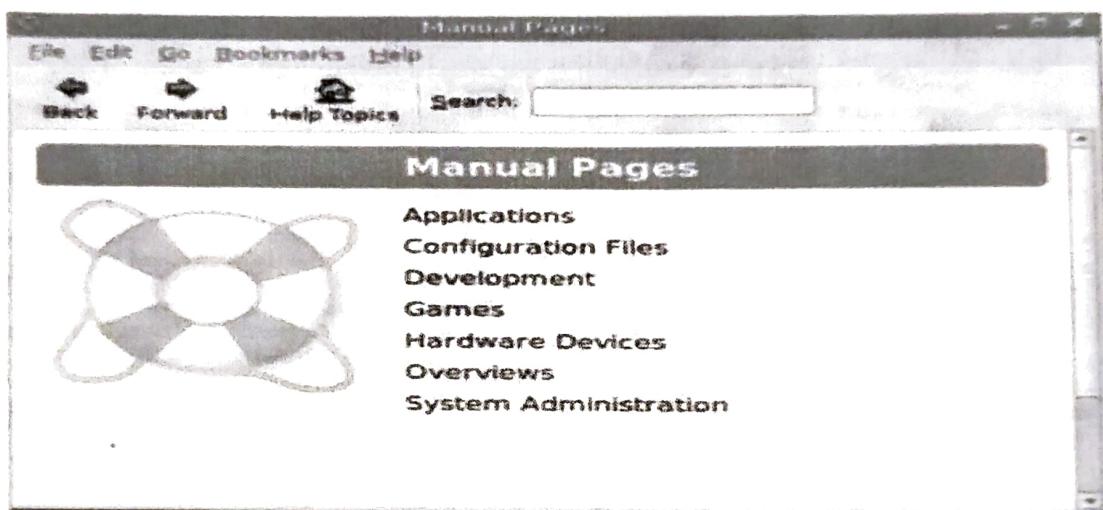


Figure 1.3 Manual Page in Linux.

Help for different applications are also available by clicking the Help menu available in the menu bar of different Linux applications. Clicking the menu displays a window showing the list of headings available. Clicking the heading opens the linked file having the necessary explanations for the selected item. Also, majority of Linux applications are provided with an instant pop up help tip window when the cursor is placed above buttons or icons. Another form of help available in Linux operating system is the presence of several HOWTO files. These files are available for almost all topics and these files are stored in compressed forms. Extracting the compressed files to a folder makes the files readable. Figure 1.4 shows a set of such help files available with a Linux distribution.



Apart from the built-in help option, commercial support is also offered by several vendors as well as support enterprises. Different Linux distributors provide commercial support to Linux in different ways such as network support (software and updates), basic support (24x7 global bases) and premier support (life time). To provide speedy support, some Linux distributors invite users to register their machines online. Help is also available from several websites. Besides these options, support to Linux is also provided by several Linux User Groups spread in different regions. These Linux user groups are known in short as LUGs. Help can also be obtained from developers spread around the world through discussions or bye-mails. Support for community driven Linux is available from the members of the community.