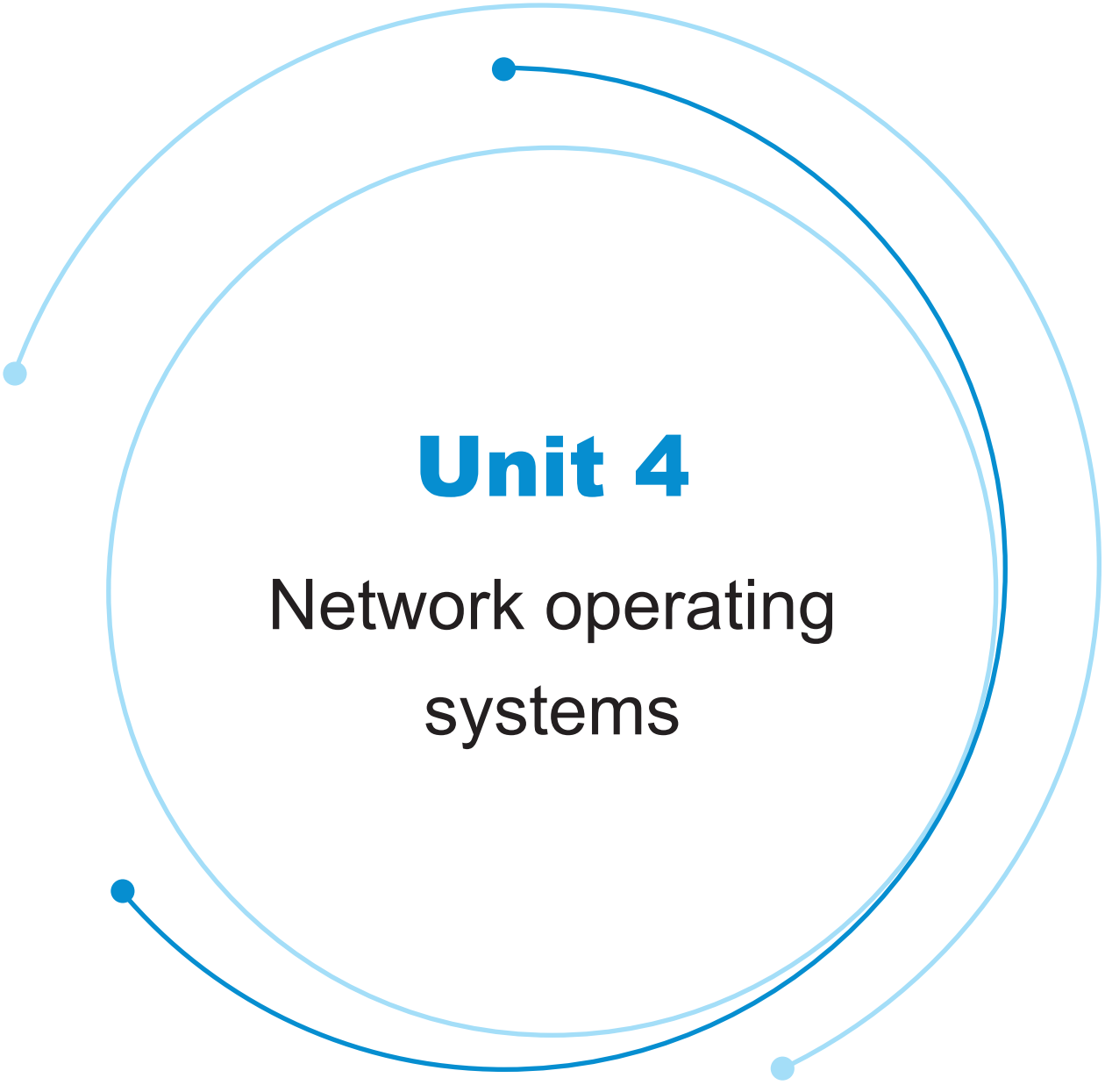
ELEC S212

Network Programming and Design



Unit 4

Network operating systems

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Overview

In Unit 1 you learned that computer networks facilitate critical business functions such as email, printing, file sharing, Internet access, remote dial-in capabilities, communication and management services. In client/server networks, these services are provided by powerful, dedicated server computers; in peer-to-peer networks, however, these services may also be provided by ordinary desktop computers.

The network operating system (NOS) is a piece of software that acts as an intermediary between a user and the network infrastructure. The purpose of the network operating system is to provide an environment in which a user can access network services and resources in a convenient and efficient manner.

The network operating system also provides a platform on which network services can be implemented and consumed by users. In other words, the network operating system practically controls all networking hardware and their communications with the network. As such, the network operating system plays a critical role in networking infrastructure. Without it, a client computer would not be able to communicate with the network, and a server computer would not be able to provide its services and share its resources to the users.

Network operating systems are entirely software-based, and can run on a number of different hardware platforms and network topologies. Once installed on a server computer, a network operating system can oversee central data storage, file and print sharing, communications, users and groups, security, and messaging. It may also support many other functions, such as Internet and remote connectivity, network management, and data backup and recovery.

A good network operating system can support an increasing number of users, increases in network traffic, different communication protocols and new applications. Some network operating systems may be software running on an operating system; a good example is Novell's NetWare, a network operating system for PCs that was extremely popular from the 1980s through the middle of the 1990s. Other NOSs may be integrated with an operating system such as UNIX or Windows Server 2008. In fact, most modern operating systems (including those for desktop computers) incorporate NOS features. From the user's point of view, therefore, it is often difficult to distinguish an operating system with NOS features from a network operating system.

In this unit, we discuss the basic concepts related to network operating systems and briefly introduce the important features of the most popular network operating systems, including Windows Server 2003/2008 and UNIX. After you have learned about the basic concepts in network operating systems, you will undertake some hands-on exercises in which you practise installing and using Linux, which is a UNIX-like operating system that has become very popular in the last ten years or so.

In short, this unit:

- describes network operating systems and their functions;
- outlines important features of network operating systems;
- discusses the features of major network operating systems including Windows Server 2003/2008 and UNIX-like operating systems;
- explains how UNIX can be internetworked with other network operating systems;
- outlines the installation of Linux on an Intel-based PC; and
- describes how to perform basic operations on a UNIX-like network operating system.

This unit is intended to take you three weeks (or approximately 24 hours) to complete.

Basic concepts in network operating systems

What is a network operating system (NOS)? The author of our textbook gives the following answer (Dean 2004, 415):

> **Network operating system (NOS)** — The software that runs on a server and enables the server to manage data, users, groups, security, applications, and other networking functions.

You should note that many desktop operating systems today (such as Windows XP and Windows Vista) also allow your computer to share its resources, and to provide certain network services. The NOS features provided by these desktop operating systems are usually limited and less powerful than the server version of these operating systems, however. Because of this, we do not generally treat these desktop operating systems as network operating systems, even though they do possess certain NOS features.

The most popular network operating systems today include Microsoft Windows Server 2003/2008, UNIX, Linux, **Mac OS X** and iPhone OS. Another network operating system that was once extremely popular (from the 1980s through the mid-1990s) is Novell's NetWare.

What can a network operating system do?

The functions of each NOS — and indeed of every version of a particular NOS — vary. In addition to the basic requirement that an NOS facilitates resource sharing and network services, an NOS is often expected to:

- centrally manage network services and resources such as programs, data, and devices (for example, printers);
- provide name and **directory** services (for network users, workstations and resources) and security features such as **authentication**, authorization, login restrictions and access control;
- provide user management, system administration, monitoring, and auditing tools with **graphical user interfaces (GUI)**;
- allow remote users to connect to a network and local users to connect to other networks (for example, the Internet);
- support internetworking such as routing and WAN ports;
- back up data, and make sure it is always available;
- allow for simple additions of clients and resources;
- distribute programs and software updates to clients;

- provide fault tolerance and in case of a hardware or software problem; and
- ensure efficient use of a server's capabilities.

Of course, not all NOSs provide all of the functions listed above; some provide more, while others provide less. Therefore, it is important to carefully evaluate the functions and capabilities of the NOSs available to you before choosing to install any particular one for your organization.

Selecting a network operating system

When choosing a network operating system, you should consider the strengths and weaknesses of the available options. In practical terms, however, your decision will probably depend largely on the existing infrastructure.

The following list summarizes the areas that you should consider before you can accurately decide which network operating system would best suit your needs:

- *Functionality* — Does the NOS support all of the required network services (both existing and potential ones)?
- *Support of additional services* — Is the NOS extendable? Will new services and additional functionalities be made available to it in the future?
- *Compatibility with the network infrastructure* — Infrastructure includes not only other network operating systems, but also LAN topology, protocols, transmission methods, and connectivity hardware. Clients on a large network may run different NOSs and thus use different communication protocols. Does the NOS in question support multiple communication protocols so that it can facilitate communication between clients on different platforms?
- *Provision of security control* — Different users on a network may have different rights for using the data and services on the network servers. Does the NOS have good capabilities in security control for network resources administration?
- *Performance* — What are the minimum hardware requirements to provide acceptable performance? Can it support a large number of users accessing the server's data and services concurrently and efficiently? Can the NOS support a lot of concurrent tasks (multitasking)? How many processors can it support (multiprocessing)?
- *Scalability* — Does the NOS allow the server to be upgraded easily (by adding more memory, processors, hard disks, etc.) to accommodate future growth of increasing number of users on the network?

- *Reliability and fault tolerance* — Because the data and services on a server are shared by the network's users, daily operation may be seriously affected if a server is down. Does the NOS provide good fault tolerance and high availability support such as clustering and redundancy capabilities?

- *Maintenance and administration* — Does the NOS provide a graphical user interface (GUI), backup and recovery, automation, scripting support, etc., to make administration tasks easier?

- *Usability* — Is the NOS easy to learn and use? Does it require the users (including the administrators) to learn unfamiliar or odd commands to use it effectively?

- *Hardware and software support* — Does the NOS support a large number of hardware devices (including the not-so-popular ones)? Does it require any special hardware to run? Does it support your existing applications? Are there a lot of software applications and software development tools available for it?

- *Total cost of ownership (TCO) of the NOS* — The importance of this concern will vary from one company to the next. If your company's profits depend on the availability of the network, and its IT budget is large, the cost of an NOS may be less important than its ability to accommodate future growth and the availability of vendor's technical support. In contrast, if your business is a local nonprofit organization, your greatest concern may be an NOS's cost.

  Note: It is extremely important that you realize that the cost of an NOS includes not only the cost to purchase a license for it, but also potential *support*, *maintenance*, *upgrade*, *user training* and *software development* costs. For example, most Linux distributions can be freely downloaded from the Internet, and therefore can be considered free to acquire. But the total cost of ownership for a Linux installation is *not* free, because the organization may need to make additional expenditures to employ higher-paid IT support staff who are experienced in using Linux servers; to provide training to end users who have only worked with Microsoft Windows previously; to redevelop custom software applications so that they can run on Linux; and so on.

The reading below sets out the questions you should ask when deciding to invest in a particular network operating system. As you make your decision, you need to weigh separately the importance of each factor in your organization's environment.

Reading

Dean (2012) 777–78.

Self-test 4.1

Name four factors you should consider before purchasing a network operating system.

Network operating system services and features

In this section you will learn more about fundamental NOS functions, and the meaning of terms used when comparing NOSs. You will also learn about some advanced features that enable NOSs to service clients more quickly and reliably. These features are available in all popular NOSs, although the degree to which each NOS can support these features varies.

The services and features that network operating systems provide can be categorized roughly as follows:

- client support
- identifying and organizing network elements
- sharing applications
- sharing printers
- system resource management.

The following reading provides a detailed discussion on these categories of network services and features.

Reading

Dean (2012) 779–91.

In the next topic we'll begin to evaluate the popular NOSs on the current market; the first one introduced is Microsoft Windows Server.

Microsoft Windows Server 2003/2008

This section gives you a broad overview of how Windows Server 2003 fits into a network environment. It recommends the minimum server requirement for a Windows Server 2003 installation. It explains how Windows Server 2003 manages its resources (such as files, users and server memory) and the directory service within an organization. You also explore some decisions you must make when installing and configuring Windows Server 2003 for your network. Finally, this section also briefly discusses how Microsoft internetworks with other network operating systems.

Although this section and the textbook discuss Windows Sever 2003, you should note that the newest version of Microsoft's network operating system, Windows Server 2008, has been released. The features described here and in the textbook are basically still valid, although there are many additional features and improvements to existing features in Windows Server 2008. You are recommended to visit the Windows Server 2008 website (https://www.microsoft.com/en-us/evalcenter/evaluate-windows-server-2012-r2) for details on this latest version of the popular Windows network operating system.

Introduction to Windows Server 2003/2008

The first notable version of Microsoft's series of network operating systems is Windows NT 3.1, which was released in 1993. Windows NT 3.1 was the first network operating system based entirely on a graphical user interface (GUI), making network administration easier than ever before. After releasing NT 3.5 (1994) and 3.51 (1995), Microsoft released NT 4.0 in mid-1996. NT 4.0 combines the user interface initially released with Windows 95 with the stability of the Windows NT architecture.

In 1999, Microsoft released four editions of new operating systems — Windows 2000 (Windows 2000 Professional, Windows 2000 server, Windows 2000 Advanced server, and Windows 2000 Datacenter server). Windows 2000 Professional is designed to serve as a network client operating system. Windows 2000 server is the introductory server platform designed for small- to medium-sized enterprises. Windows 2000 Advanced server is designed to cater to larger enterprises. It adds clustering, **load balancing** and has double the SMP support compared to the Windows 2000 server platform. Finally, Windows 2000 Datacenter server is designed for large enterprise deployments. It is optimized for large data warehouses and transaction processing.

In 2003, Microsoft released Windows Server 2003 as the successor to Window 2000 Server. According to Microsoft, Windows Server 2003 has many of the advantages of its predecessors, with additional and updated features including:

- **Internet Information Services (IIS)** 6.0 — a significantly improved version of IIS;
- increased default security over previous versions, due to the built-in firewall and having most services disabled by default;
- significant improvements to Message Queuing;
- Manage Your Server — a role management administrative tool that allows an administrator to choose what functionality the server should provide;
- improvements to **Active Directory**, such as the ability to deactivate classes from the schema, or to run multiple instances of the directory server (ADAM);
- improvements to Group Policy handling and administration;
- provides a backup system to restore lost files;
- improved disk management, including the ability to back up from shadows of files, allowing the backup of open files; and
- improved scripting and command line tools, which are part of Microsoft's initiative to bring a complete command shell to the next version of Windows.

Windows Server 2008, released in early 2008, is the latest release in Microsoft Window's server line. There are many new features and enhancements to existing features. The following are some examples:

- a rewritten network stack to provide native IPv6 support, native wireless support, and improvements in speed and security;
- improved image-based installation, deployment and recovery;
- improved diagnostics, monitoring, event logging and reporting tools;
- new security features such as BitLocker and ASLR;
- improved Windows Firewall with secure default configuration;
- built-in .NET Framework 3.0 technologies; and
- core **kernel**, memory and file system improvements.

You are recommended to visit the Microsoft website for details, as mentioned above.

The next reading addresses the advantages and disadvantages of Windows Server 2003. After this reading, you should be able to appreciate why the Windows Server 2003 is such a popular NOS.

Reading

Dean (2012) 791–92.

Self-test 4.2

In the reading above, the author states that Windows Server 2003 has many benefits. How would you summarize those benefits? Can you also identify and point out some disadvantages of using Windows Server?

Windows Server 2003 hardware requirements

In general, servers require more processing power, more memory, and more hard disk space than workstation machines. The type of server used for the network depends partly on the network operating system. Each network operating system demands specific server hardware requirements. Table 4.1 lists Microsoft's minimum server requirements for Windows Server 2003, Standard Edition. Please note that the minimum requirements specify the least amount of hardware configuration you must have to run the network operating system. Your organization's applications and performance demands, however, may require more resources.

Table 4.1 Minimum hardware requirements for Windows Server 2003, Standard Edition

Component	Requirement
Processor	133 MHz or higher Pentium or Pentium-compatible processor; 550 MHz recommended. Windows Server 2003, Standard Edition supports up to four CPUs in one server.
Memory	128 MB of RAM is the absolute minimum, but at least 256 MB is recommended. A computer running Windows Server 2003 may hold a maximum of 4 GB of memory.
Hard disk drive	A hard drive supported by Windows Server 2003 (as specified in the HCL) with a minimum of 1.5 GB of free space available for system files.
NIC	Although a NIC is not required by Windows Server 2003, it is required to connect to a network. Use a NIC found on the HCL. The NOS can support the use of more than one NIC.
CD-ROM	A CD-ROM drive found on the HCL is required unless the installation will take place over the network.
Pointing device	A mouse or other pointing device found on the HCL.
Floppy disk drive	Not required.

Source: Dean 2006, Table 8-2

The architecture of Windows Server 2003

Windows 2003 is an object-based system. This means that it is a modular operating system made up of small, self-contained software components that work together to perform operating system tasks. Each component provides a set of functions that act as an interface to the rest of the system.

To understand Windows Server 2003, therefore, you first need to understand its operating system architecture. Windows Server 2003 executes in two modes, *user mode* and *kernel mode*, as shown in Figure 4.1.

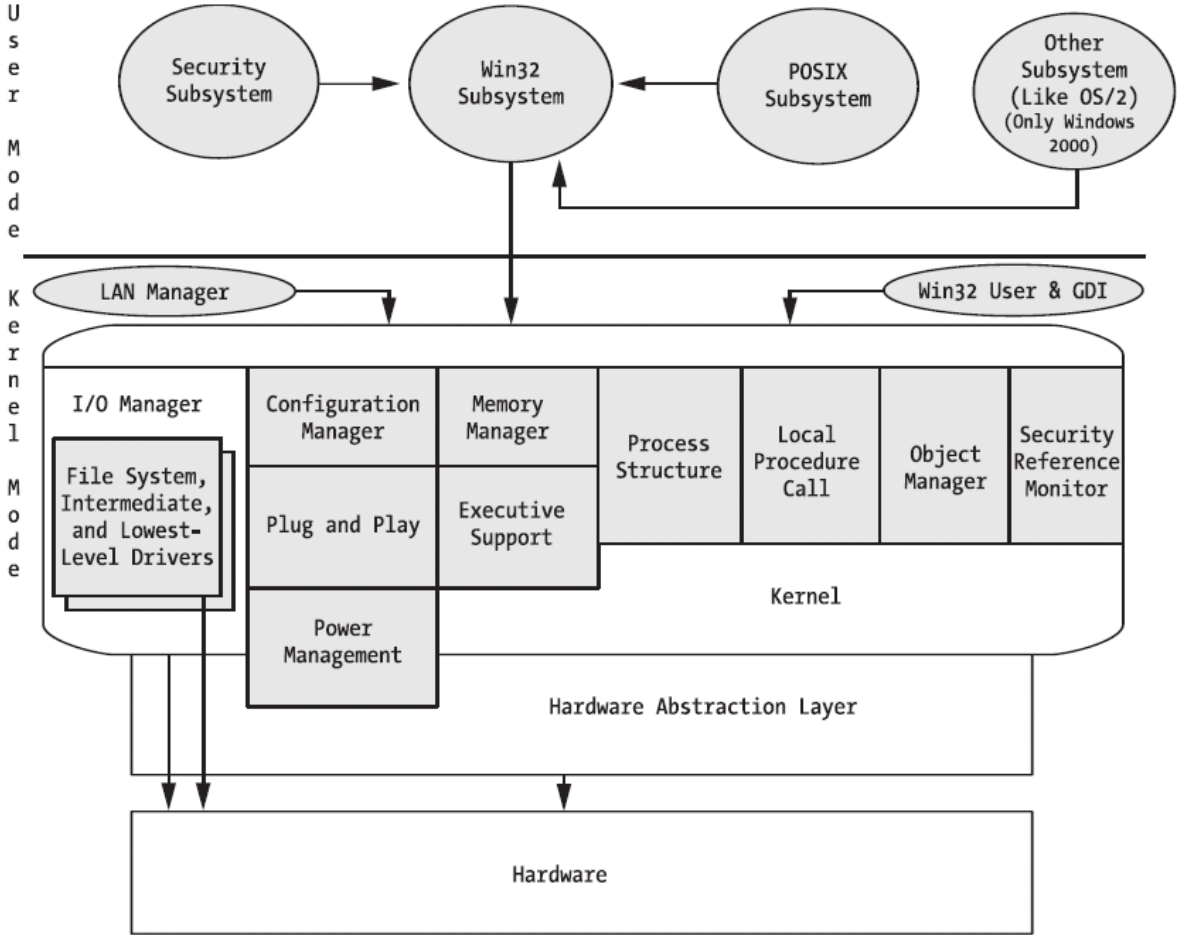

Figure 4.1 The operating system architecture of Windows Server 2003

The kernel mode is a highly-privileged processor mode, with direct access to all hardware and memory. The user mode is a less-privileged mode, with no direct access to hardware, and restricted access to memory. In Figure 4.1, you can see that the Windows 2003's Executive makes up the meatiest layer in the kernel mode, and performs most of the functions traditionally associated with operating systems.

Table 4.2 lists Windows Server 2003's Executive subsystems.

Table 4.2 Windows 2003's Executive subsystems and their functions

Executive subsystems	**Functions**
I/O Manager	Provides core services for device drivers and translate user-mode commands
File System	Accepts the oriented I/O requests and translates them into device-specific calls
Device Drivers	Low-level drivers that directly manipulate hardware to accept input or to write output
Cache Manager	Improves disk I/O by storing disk reads in system memory
Security Reference Manager	Enforces security policies on the local computer
Interprocess Communication (IPC) Manager	Manages communication between clients and servers
Virtual Memory Manager	Implements and controls virtual memory, a memory management that provides a private address space for each process and protects that address space
Process Manager	Creates and terminates processes and threads
Plug and Play Manager	Maintains central control of the Plug and Play process
Power Manager	Controls power management
Window Manager and Graphical Device Drivers	Manages the display system
Object Manager	Creates, manages and deletes objects that represent operating system resource

Windows Server 2003's memory model uses virtual memory to perform many complex tasks simultaneously.

The next reading from Dean describes important features of the Windows 2003 memory model. The reading then discusses the file systems supported by Windows Server 2003. You should focus on the features of separate memory space for each application in the Windows Server 2003's memory model. Also note the advantages of virtual memory. Finally, you should become familiar with the file systems in Windows Server 2003 such as:

- **File Allocation Table (FAT);**
- **FAT16;**
- **FAT32;**
- **CD-ROM File System (CDFS);** and
- **New Technology File System (NTFS).**

Reading

Dean (2012) 792–94.

Self-test 4.3

1 Differentiate between the user and kernel mode in Windows Server 2003.

2 Differentiate between FAT and NTFS.

Active Directory

The biggest change in Windows 2000 Server and Server 2003 is the release of Microsoft's directory service. In the previous version, Windows NT 4.0 networks were organized around the concept of domains. A **domain** is a collection of Windows NT servers that share a single security subsystem. The subsystem controls access to all resources in the domain. The optimum number and structure of domains in an organization depends on the organization's needs. When you install Windows NT server, you create a domain by assigning a **domain controller** — the server that keeps track of resources, users and privileges within a domain — and then by assigning resources to that domain. Every domain relies on a **primary domain controller (PDC)** to centrally manage its account information and security.

Windows NT 4.0 domains worked well in small and medium size environments. However, administrators of large environments were forced to partition their networks into multiple domains interconnected by trusts. Windows Server 2003 introduced the Active Directory to replace the NT 4.0 domain functionality. The Active Directory is a distributed database containing information about network resources. It not only provides authentication services for the network, but also integrates directly into email and other services. This unified approach presents an administration point for the network, thus eliminating the overhead associated with maintaining duplicate directory structures.

Figure 4.2 illustrates a typical Windows 2003 domain model network with Active Directory.

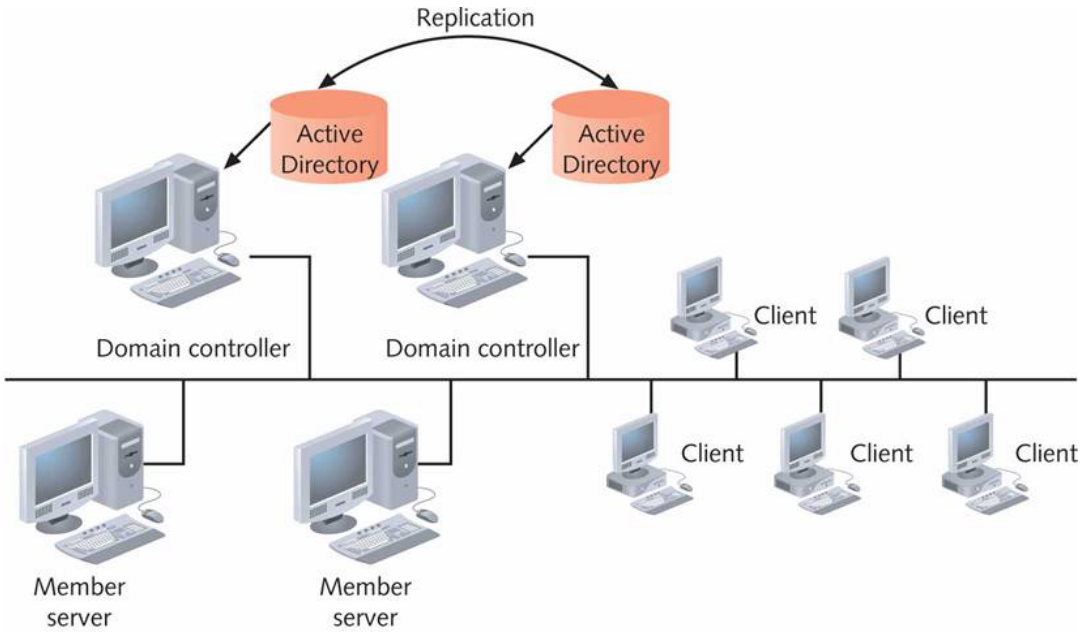

Figure 4.2 Domain model on a Windows Server 2003 network

The next reading gives you a very comprehensive description of the Windows 2003 Active Directory. You should be sure that you understand the foundation of Active Directory's structure, and the schema for identifying what types of object can be specified in Active Directory. Take a close look at the two types of **trust relationship** (two-way transitive trusts and explicit one-way trusts) supported by Active Directory. Finally, you are shown the naming or addressing conventions in Active Directory.

> ***Reading***
>
> Dean (2012) 794–801.

Installing and configuring Windows Server 2003/2008

Before you install and configure a network operating system, you should have a plan for your server and its location in your network. There are many factors to consider when developing this plan. Once you have installed and configured the network operating system, changing its configuration may prove difficult and cause service disruptions for users.

You can obtain a trial copy of the CD or download the Windows Server 2003 software from the following site:

http://www.microsoft.com/windowsserver2003/evaluation/trial/evalkit.mspx.

If you prefer to try out the latest Windows Server 2008 instead, visit this website:

http://www.microsoft.com/windowsserver2008/en/us/trial-software.aspx

Note: Windows Server 2003 came to an end on July 14, 2015. It is suggested that you use Windows Server 2012 or Microsoft Azure. Consult your tutor if you want to try the latest server technologies from Microsoft.

Internetworking with other network operating systems

Interoperability between different types of network operating system has become a challenge to system administrators because of increased demands to share information within organizations, and because of the increased number of corporation mergers and acquisitions.

To interoperate with Novell NetWare (which you'll learn about in the next topic), Microsoft provides an optional component of Windows Server 2003 — File and Print Services for NetWare (GSNW). Once connected, Windows Server presents the NetWare resources as locally-attached Windows resources. Alternatively, clients that depend on Windows Server 2003 can run Microsoft's Windows Services for NetWare (WSNW). WSNW is a service that runs on a Windows 2003 client and, in conjunction with NWLink, enables the client to log on directly the NetWare server to access its resources.

To interoperate with UNIX, Microsoft provides Microsoft's Services for UNIX, which allows customers to integrate Windows Server 2003 operating systems with their existing UNIX-based workstations and servers by providing access to core interoperability components.

UNIX and UNIX-like operating systems

This section introduces the UNIX operating system in general, and describes Linux in more detail. It recommends the minimum server requirement for Linux, which is a UNIX-like network operating system that is designed to work like UNIX does. It also explains the Linux memory model, file system and processing capabilities. This section then provides an overview of decisions you need to make when installing and configuring your Linux server. Finally, we'll again focus on internetworking with other network operating systems.

A very brief history of UNIX

In 1969, when UNIX was first developed by Ken Thompson, Dennis Ritchie and their colleagues at Bell Labs (which was then part of AT&T), they had no obvious aim of using it as a network operating system. During the late 1970s and early 1980s, the Computer Systems Research Group of the University of California, Berkeley, developed and distributed their UNIX derivative, called the **Berkeley Software Distribution (BSD)**. 4.1BSD, released in 1981, was the first UNIX variant that incorporated TCP/IP support, turning UNIX into a powerful network operating system.

Beginning in the early 1980s, the influence of UNIX in academic circles led to large-scale adoption of UNIX (particularly of the BSD) by commercial startups, the most notable of which are **Solaris**, HP-UX, **AIX**, and later Apple Macintosh's OS X.

Today, in addition to certified UNIX systems such as those already mentioned, UNIX-like operating systems such as Linux and BSD are commonly encountered. Sometimes traditional UNIX may be used to describe a UNIX or an operating system that has the characteristics of either Version 7 UNIX or UNIX **System V**.

The following figure shows the filiation of the various UNIX and UNIX-like operating systems.

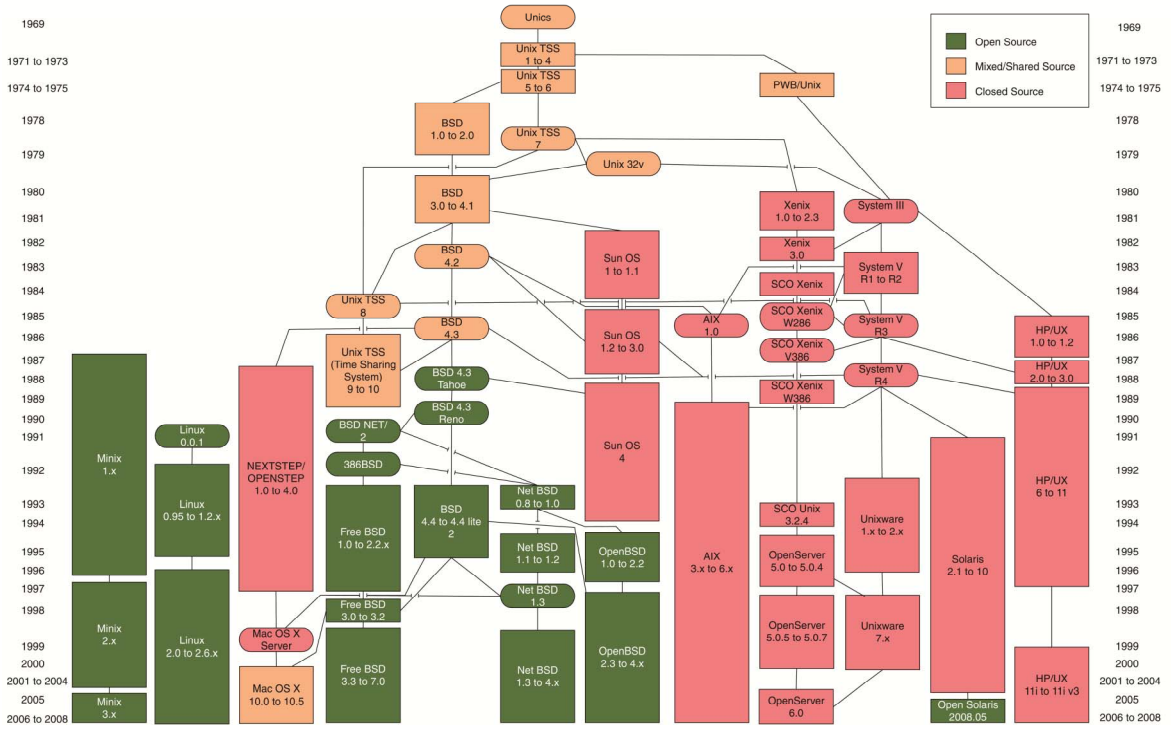

Figure 4.3 Filiation of UNIX and UNIX-like operating systems

Source: Wikipedia

In the past, UNIX provided only a text-mode user interface, and the commands used were quite difficult to remember. But with the help of X-Windows, which is software providing a graphical user interface for UNIX, the UNIX system has become more user-friendly. Compared to Windows Server 2003/2008, Mac OS X and NetWare, however, more expertise is still needed for managing its operations. UNIX provides excellent support to the TCP/IP protocol, and Internet services such as electronic mail can be implemented on it. However, the configurations for these servers are not as easy as those in Windows Server 2003/2008.

The reading below gives you a brief history of UNIX, and describes a number of varieties in UNIX implementation.

> ***Reading***
>
> Dean (2012) 802–3.

The current state of the market

As you saw in Figure 4.3, dozens of UNIX implementations are currently available in the marketplace. Each hardware vendor has its own version of UNIX optimized for its hardware. Although all UNIX implementations differ somewhat from each other, implementations from a given family are usually fairly close in file structure and command

syntax. Most of these UNIX implementations can be categorized into two UNIX market segments:

- proprietary implementation, and
- open source implementation.

Proprietary UNIX

Proprietary UNIX is an implementation of UNIX for which the source code is either unavailable or available only by purchasing a licensed copy from the **Santa Cruz Operation (SCO)**. The three most popular proprietary versions of UNIX are Solaris from Sun Microsystems, AIX from IBM, and HP-UNIX from Hewlett-Packard.

Open source UNIX

This group of UNIX variants has been developed and packaged by a few individuals and made available to anyone without licensing fees. Often referred to as **open source software** or **freely distributable software**, this category includes UNIX-like systems such as **GNU**/Linux and **FreeBSD**. Each of these systems, in turn, comes in a variety of implementations with slightly different features and capabilities. For example, the different flavors of Linux include Red Hat Linux, Open Linux, Debian Linux, Ubuntu, S.u.S.E. Linux and Stackware Linux. The kernel in Linux is maintained by a loosely-organized team of system programmers who collaborate mostly via the Internet. The resulting code is then distributed under the GNU public license, which ensures that the software must maintain open source and freely available.

Self-test 4.4

1 What reasons are commonly given for not including open source software in mission critical applications?

2 What are advantages and disadvantages of using UNIX?

3 What are advantages and disadvantages of using a UNIX-like operating system such as Linux?

Linux server hardware

In both UNIX and Linux, the use of a **graphical user interface (GUI)** remains optional. An administrator can use the GUI if necessary, or simply work with the command-line interface. The minimum hardware requirement for a Linux server is less than the requirement for Windows Server 2003/2008 or NetWare. Table 4.3 lists the minimum server

requirements for a Linux server. Remember that you'll need to add memory and disk space based on your applications' requirements.

Table 4.3 Minimum hardware requirements for a Linux server

Component	Requirement	Notes
Processor	Intel-compatible x86	Recent versions of the Linux kernel (2.0 and later) include support for as many as 32 Intel processors.
Memory	64 MB RAM	Consider adding more RAM for better performance; most network administrators opt for 256 MB of RAM or more for servers.
Hard disk	A hard drive supported by Linux with a minimum of 2 GB of free space	Most server implementations require additional free hard drive space; 10 GB of free space is recommended.
NIC	A NIC supported by Linux	
CD-ROM	A CD-ROM drive listed on the HCL	Recent versions of Linux support SCSI, IDE, and ATAPI CD-ROM drives.
Floppy disk	One or two 3.5-inch floppy disks, if no bootable CD-ROM drive is available	Floppy disks can be useful for creating emergency repair disks during installation.
Pointing device	Optional	A pointing device is only necessary if you install the GUI component.

Source: Dean 2006, Table 9-1

Linux operating system architecture

Linux provides many high-end operating system characteristics. It supports multiprocessing, **multitasking** and multithreading. It serves as a good server platform for applications. The advantages of Linux server include:

- Multiprocessing

  Like Windows 2003 and NetWare, Linux supports symmetric multiprocessing (SMP). The operating system supports SMP using a maximum of 16 processors per server.

- Memory

  Linux uses both physical and virtual memory efficiently. Linux allocates a memory area for each application. Current versions of Linux use a 32-bit addressing scheme that enables programs to access 4 GB of memory. 64-bit versions of Linux have also become available recently.

- File system

  Linux implements a hierarchical, multilevel tree **file system** with a common root directory, as illustrated in the following figure:

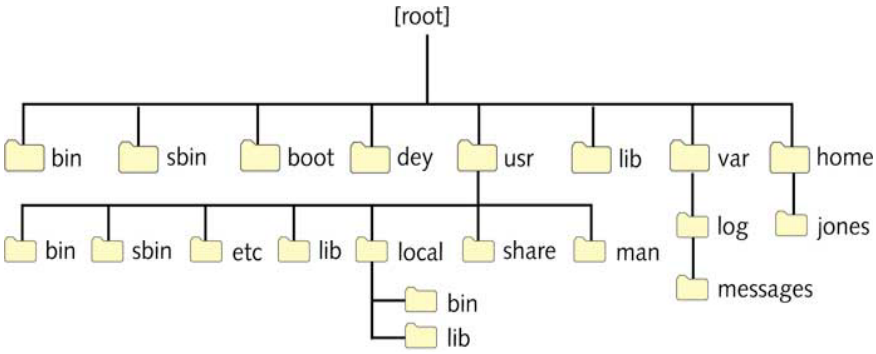

Figure 4.4 A typical Linux file system hierarchy

Source: Dean 2006, Figure 9-1

Linux is capable of supporting multiple file systems on a single disk. The default file system on most Linux distributions is **ext3**, which is a journaled file system that supports online file system growth and uses Htree indexing for larger directories. In addition, a large number of file systems are also supported, including ext2, ext4, ReiserFS, FAT/FAT16/FAT32, ISO 9660, UDF, NFS, NTFS, JFS, XFS and others. Given how many file system types Linux accommodates, it's easy to see why it has become such a popular server platform in large, diverse networks.

- Internet service

  UNIX has deep roots in Internet services. The leading Internet Web server is an open source software application called **Apache HTTP Server**, which provides a full range of Internet services as standard components.

The following reading describes the features of Linux server and compares those features with NetWare and Windows Server 2003.

Reading

Dean (2012) 803–6.

Self-test 4.5

1 Describe some of the unique features of the UNIX file system.

2 What is the relationship between the UNIX file system and NFS?

Internetworking with other network operating systems

The UNIX system has been modified over the years to work with other network operating systems and protocols besides TCP/IP. In this section we describe UNIX's interoperability with Microsoft Windows and NetWare.

To interoperate with Microsoft Windows, UNIX offers an application called **Samba**, which provides everything needed to make the UNIX system a fully-featured Windows file and printing-sharing server.

UNIX supports the Novell native networking protocol: IPX/SPX. Proprietary and open source software solutions, such as Calendra's NetWare for Linux, exist to turn your UNIX server into a NetWare server by including full NDS support.

Activity 4.1

This activity aims to get you started on Linux by guiding you through the process of installing a desktop version of Ubuntu Linux on your PC. To carry out this activity, you need to have the following:

- a PC with a 700MHz or faster x86 processor, at least 384MB of RAM, and at least 8GB of free disk space;
- Windows XP or Vista already installed on the PC;
- a blank, recordable CD and the ability to burn blank CDs; and
- an Internet connection.

Ubuntu (http://www.ubuntu.com) is a free Debian-based operating system based on GNU/Linux. Among the numerous Linux distributions, Ubuntu is relatively new (its first release was in October 2004), but it has quickly gained a reputation for its strong focus on usability and ease of installation.

Installation of Ubuntu is generally performed with the Live CD. You can download a Live CD image from the Ubuntu website, burn the image on a CD-ROM, and then boot from it. By booting the Live CD, a user can first choose to test-drive the Ubuntu OS (albeit with a performance loss due to the need to load applications from a CD), providing the opportunity to test hardware compatibility and driver support. The CD also contains the Ubiquity installer, which guides you through the permanent installation process.

Ubuntu also provides a free software called Wubi (Windows-based Ubuntu Installer). The goal of Wubi is to assist a Windows user unacquainted with Linux in trying out Ubuntu without risking any loss of

information due to disk formatting or partitioning. Wubi can also uninstall Ubuntu from within Windows.

Follow the steps below to install Ubuntu on your Windows PC using Wubi:

1 Download the CD image for the *desktop edition* of Ubuntu from this URL: http://www.ubuntu.com/getubuntu/download. As of 2 June 2009, the image file is named **`ubuntu-9.04-desktop-i386.iso`**.

2 Burn the CD image on a blank recordable CD.

3 After the burn is complete, put the Ubuntu CD back into your PC's CD-ROM. The setup program should launch automatically (If it does not, launch the setup program manually). Click **Install inside Windows** to continue.

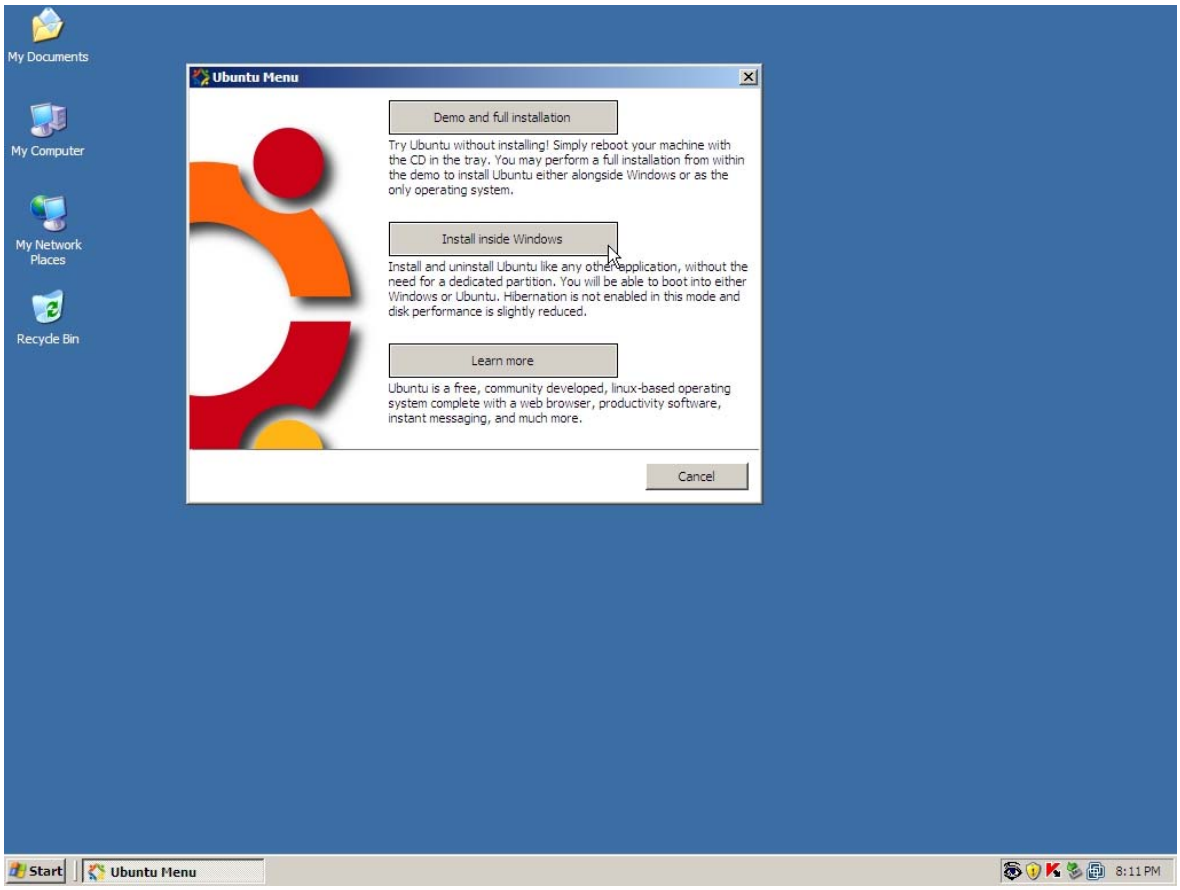

Figure 4.5 Ubuntu setup menu

4 In the following screen, select the installation drive, disk space for installation, installation language as appropriate. If you do not know what to use, accept the default settings. Enter your preferred user name and password, then click **Install**.

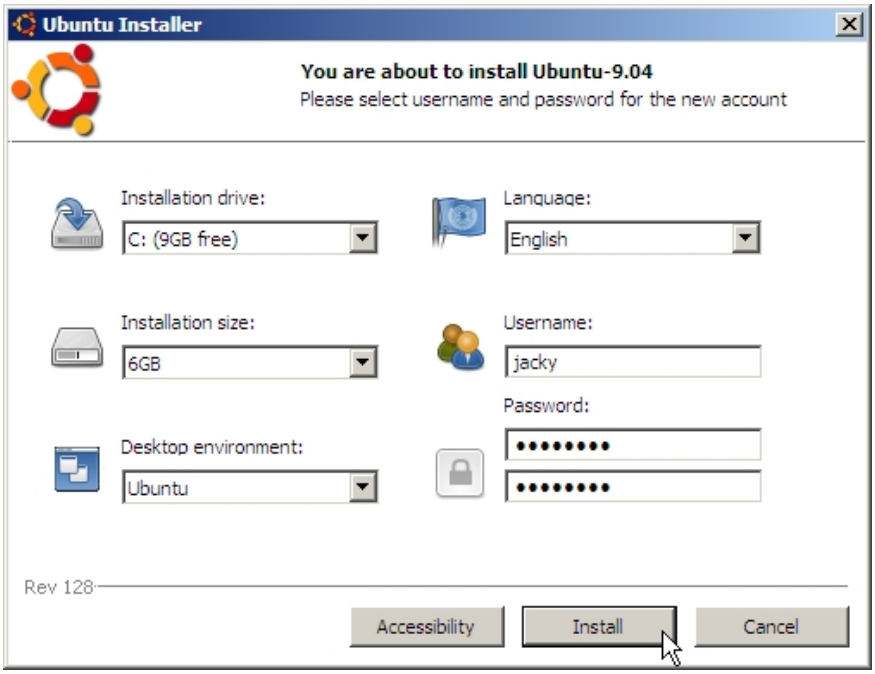

Figure 4.6 Ubuntu install menu

5 The installation will begin; it should take anywhere from just a few minutes to ten or twenty minutes, depending on the speed of your PC.

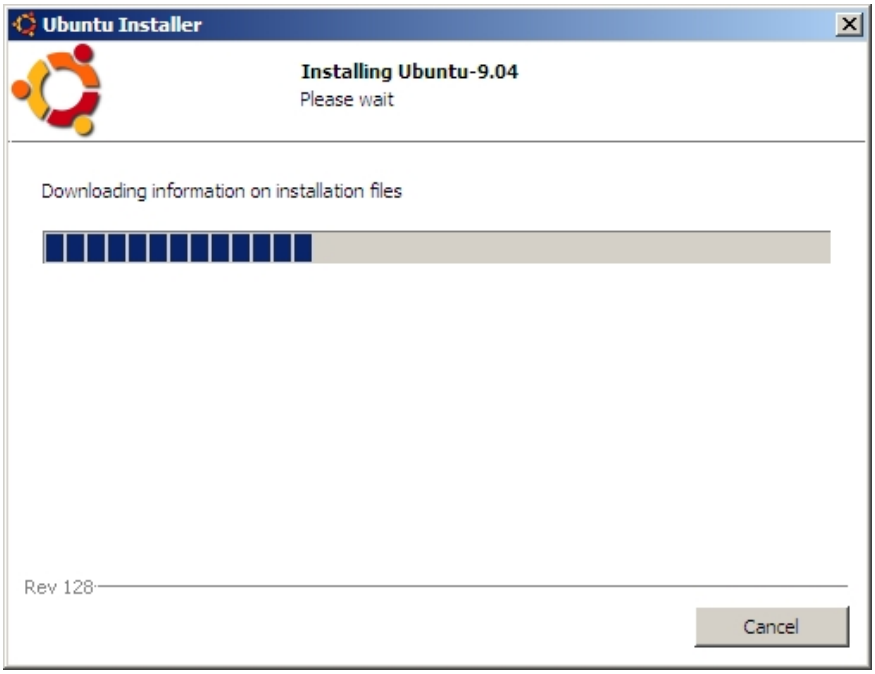

Figure 4.7 Ubuntu install in progress

6 When the installation is done, select **Reboot now** and click **Finish**.

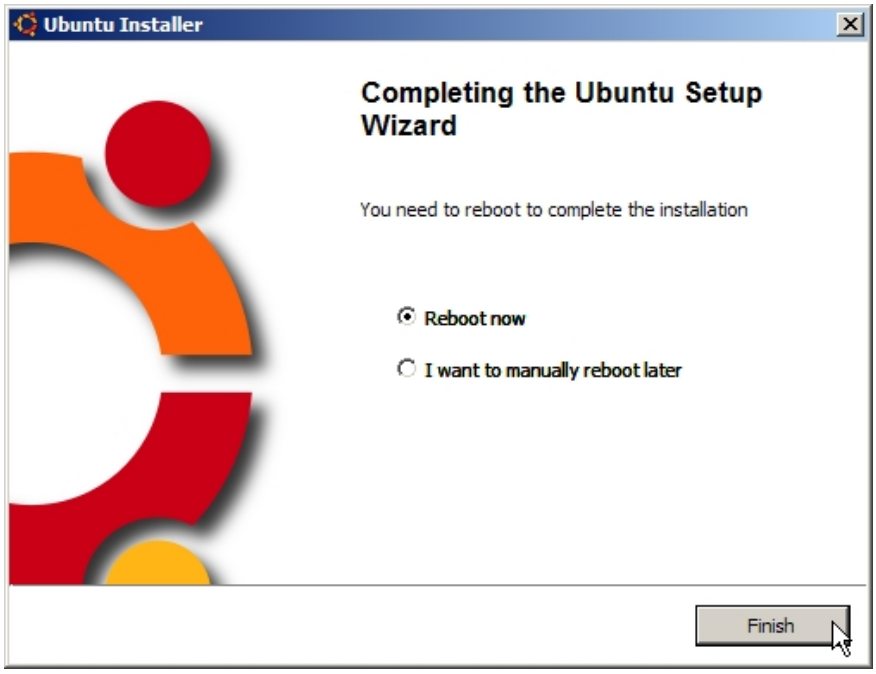

Figure 4.8 Completing the Ubuntu installation

7 When the PC reboots, an OS menu appears. Select **Ubuntu** and press **Enter**.

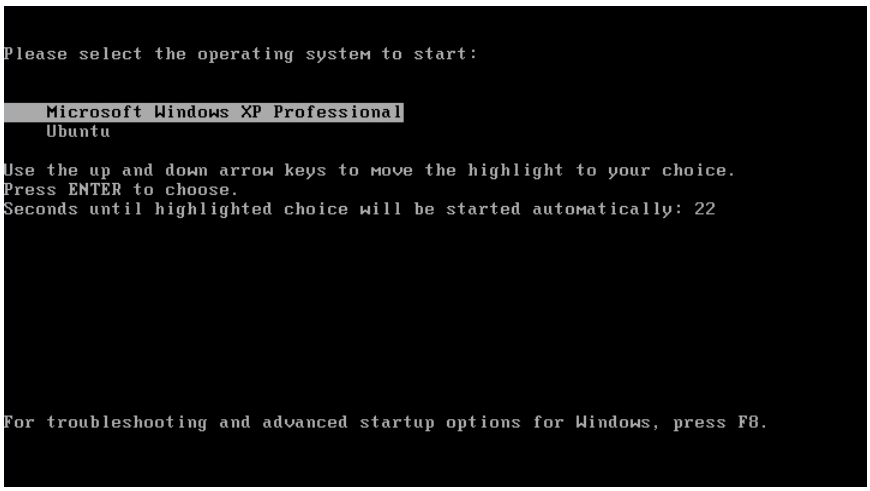

Figure 4.9 Original reboot menu

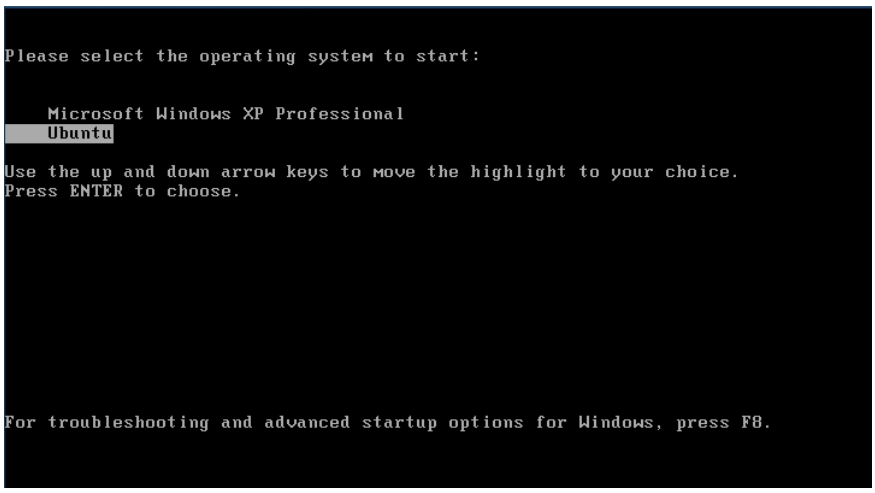

Figure 4.10 Selecting Ubuntu in the reboot menu

8 The system boots into Ubuntu, and the second step of the system installation continues inside Ubuntu.

Figure 4.11 Ubuntu loading

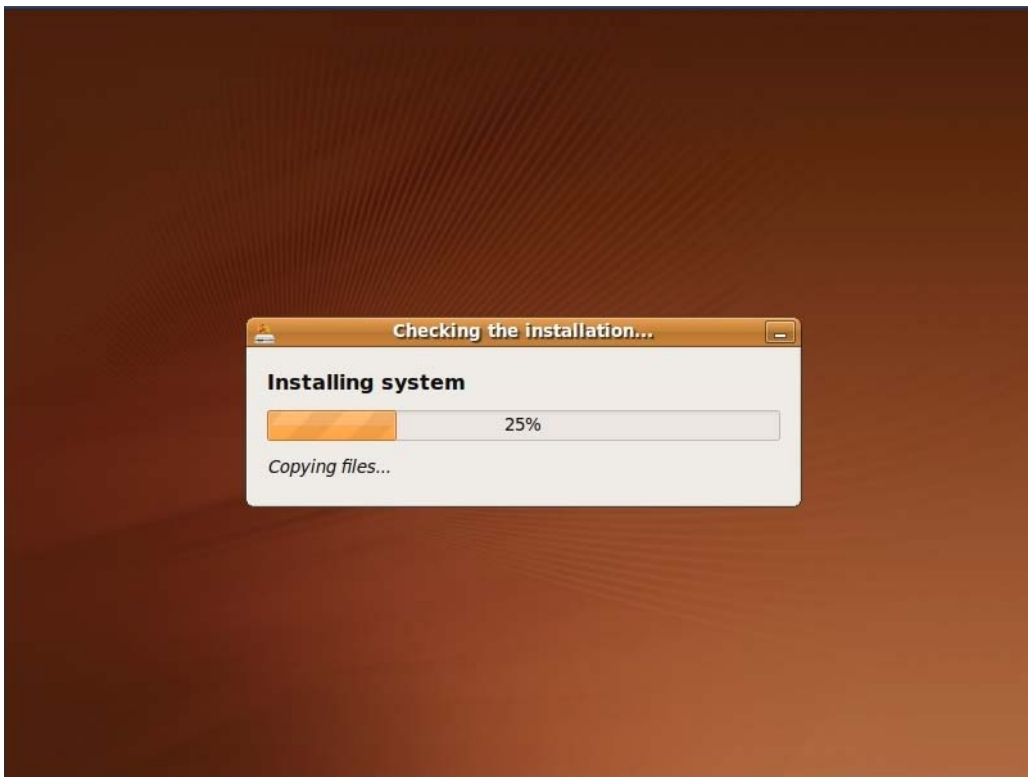

Figure 4.12 Ubuntu loading

9 When the second step of the system installation within Ubuntu completes, the system will reboot. Select Ubuntu again when you see the OS menu. Next, you will see the login screen. Enter the username and then the password that you have chosen previously.

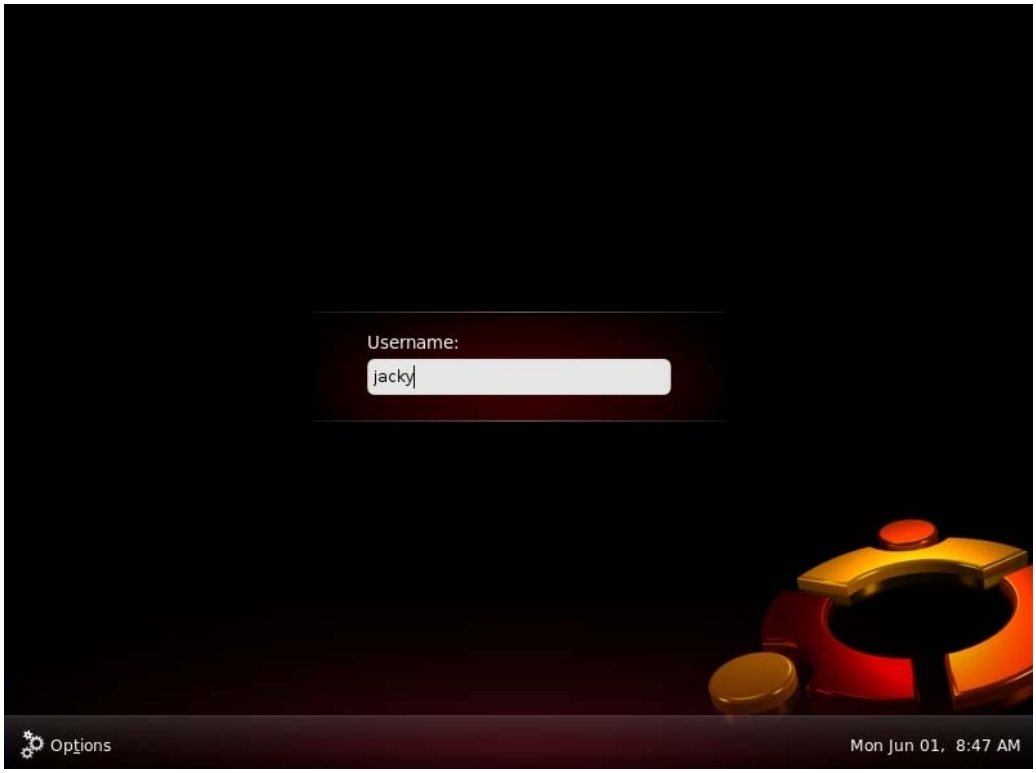

Figure 4.13 Ubuntu username prompt

10 Congratulations! You have successfully installed Ubuntu Linux on your PC!

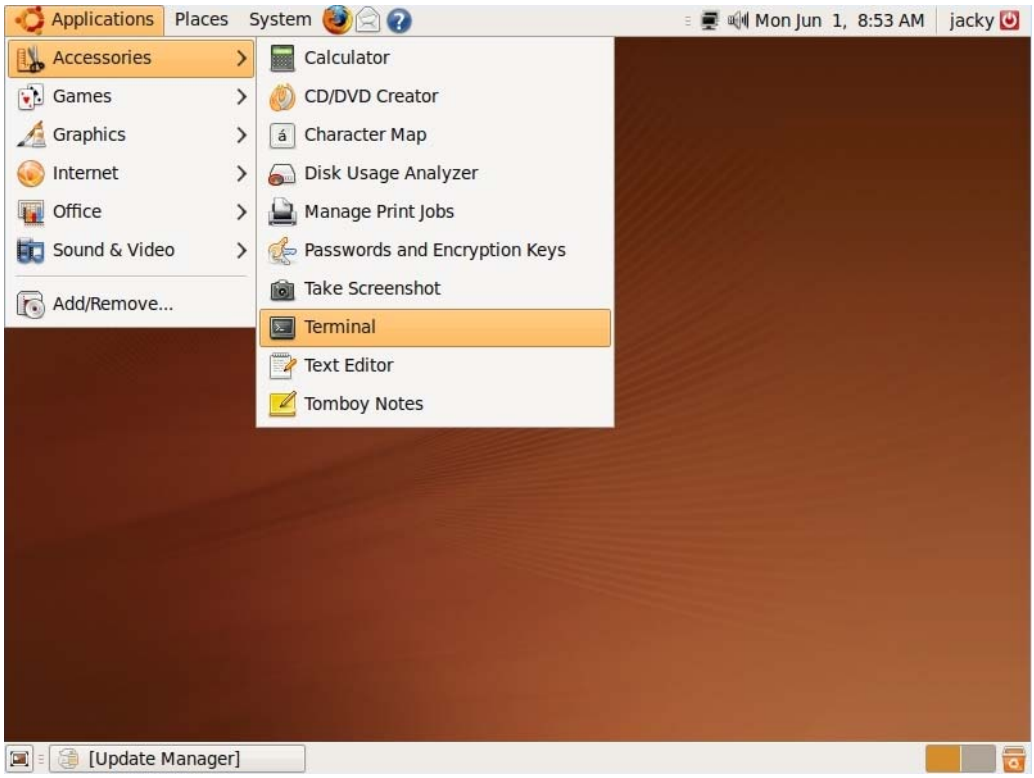

Figure 4.14 Ubuntu applications menu

Try to play around within the new Ubuntu desktop. Can you access the Internet using the installed Firefox browser right away? Can you open a Microsoft Word document and PowerPoint presentation using the installed OpenOffice? Can you play a music CD? Welcome to the world of Linux!

You can restart your PC anytime and get back into your Windows desktop. Try it.

Activity 4.2

In the previous activity, you installed the desktop edition of Ubuntu Linux on your PC. You will find that it is certainly convenient having a Linux desktop available, and we recommend you to practise using Linux on it as much as possible.

In the real world, however, a network administrator cannot always access a Linux server directly at his console. Instead, the network administrator often has to use an **SSH** client to connect to the remote server, and then interact with it using a command line interface only. It is therefore important that you know how to do so.

You should now work through Lab 1.1 of the 'Lab Book' (Kwan et al. 2009).

Summary

In this unit you learned the basic concepts related to network operating systems. Some network operating system functionalities were presented. These functionalities are representative of current network operating systems in general rather than any particular product.

This unit described in detail the three major network operating systems currently on the market: Windows Server 2003, NetWare and UNIX. Each NOS's multiprocessing capability, memory management, file system and directory structure was discussed. Considerations for the installation of these NOSs were also highlighted, and the installation processes of NOSs with user and user group's creation were described. Finally, this unit explained the interoperability between Windows Server 2003, NetWare and UNIX systems.

Admittedly, we have only introduced to you very basic knowledge of the network operating systems discussed. If you are interested in learning more about any one of these network operating systems, you are highly recommended to visit its official website and download a copy to try it out.

Suggested answers to self-tests

Self-test 4.1

It is useful to consider the following factors before purchasing a network operating system:

- whether it will integrate with the LAN's existing infrastructure;
- how much it costs, and how well the vendor supports it;
- whether it provides additional services (such as Web hosting or remote access) that users might want, and whether technical staff can manage it;
- whether it provides for future growth; and
- whether necessary applications will run smoothly on it.

Self-test 4.2

The advantages of using Windows Server 2003 are:

- support for multiple processors, multitasking, and symmetric multiprocessing;
- a comprehensive system for organizing and managing network objects, called Active Directory;
- simple centralized management of multiple clients, resources, and services through a customizable tool called the MMC (Microsoft Management Console);
- multiple, integrated Web development and delivery services that incorporate a high degree of security and an easy-to-use administrator interface;
- support for modern protocols and security standards;
- excellent integration with other NOSs, and support for many different client operating systems;
- integrated remote client services — for example, automatic software updates and client assistance;
- provisions for monitoring and improving server performance; and
- support for high-performance, large-scale storage devices.

The disadvantages of using Windows Server 2003 are:

- proprietary technologies may limit flexibility;
- high licensing costs;
- it is not as stable, fast and secure as UNIX; and
- it has high CPU, disk, and memory requirements.

Self-test 4.3

1 Applications are normally executed in Ring 3, known as user mode, in which they are limited to their own protected memory area. This prevents applications from writing into each other's memory space and thereby causing general protection faults and system crashes. In order to access the I/O manager portion of the Windows Server 2003 executive, applications must enter Ring 0, or kernel mode execution.

2 FAT is a legacy file application table compatible with DOS. NTFS is a new disk system written expressly for NT. Compared to FAT, NTFS offers local security, larger capacity, better reliability and increased recoverability.

Self-test 4.4

1 The key reasons usually given against the use of open source software include:

   - lack of consistency and longevity;
   - lack of centralized support; and
   - lack of a single company that can be held financially responsible if a catastrophic error occurs.

2 The advantages of using UNIX are:

   - it is a very stable operating system;
   - it can function as a workstation or a server;
   - it is very fast;
   - it includes hundreds, possibly thousands, of built-in tools and applications, including programming tools; and
   - it is highly secure and reliable.

   The disadvantages of using UNIX are:

   - it's complex and uses archaic commands — learning UNIX is often compared to learning a foreign language;
   - high licensing costs; and

- some companies sell versions of UNIX that will run only on their hardware.

3 The advantages of using Linux are:

- it is as easy to install as Windows XP, but takes less time;
- like UNIX, it is fast and reliable;
- it runs on a large number of platforms, including inexpensive PCs;
- it can be downloaded from the Internet free or for a minimal cost;
- hundreds of free software applications are available for Linux; and
- since the source code is freely available, bugs and security threats are fixed much faster than in any other NOS.

The disadvantages of using Linux are:

- It's still UNIX, which means there are hundreds of commands and applications to learn.
- Although Linux makes UNIX administration easier, it still requires a UNIX administrator, and it's may be difficult and more expensive to find and employ a good one.
- Only a few companies offer dedicated technical support for Linux for a fee. If you are relying on Linux as your primary server, then you must seriously considering budgeting for phone support and an experienced consultant.
- Many companies still do not consider Linux to be acceptable replacement for critical applications that require UNIX.

Self-test 4.5

1 UNIX implements a hierarchical, multilevel tree file system starting with the root directory. In fact, UNIX is able to support multiple file systems simultaneously on a single disk. In UNIX, files are treated by the kernel as just a sequence of bytes. The basic job of the file system in UNIX is to offer file services as a consistent interface without requiring user application programs to worry about the particulars of the physical storage hardware used.

2 NFS is the actual implementation of the UNIX file system developed by Sun Microsystems as part of their Open Network Computing environment. NFS allows multiple, different computing platforms to share files.

Glossary

Active Directory — The Windows Server (starting from Windows 2000) method for organizing and managing objects associated with the network.

AIX — a proprietary implementation of UNIX distributed by IBM.

Apache HTTP Server — an open source software Web server application often used on Linux Internet servers. It's the most popular HTTP server on the Web.

authentication — the process of verifying a user's validity and authority on a system. Different systems use different credentials to authenticate users.

backup — a copy of data or program files created for archiving or safekeeping purposes.

Berkeley Software Distribution (BSD) — a UNIX distribution that originated at the University of California at Berkeley.

CD-ROM File System (CDFS) — the read-only file system used to access resources on a CD. Windows Server 2003 supports this file system to allow CD-ROM file sharing.

directory — in general, a listing that organizes resources and correlates them with their properties. In the context of network operating systems, a method for organizing and managing objects.

domain — a group of users, servers and other resources that share account and security information through a Windows Server network operating system.

domain controller — a Windows Server 2003/2008 computer that contains a replica of the Active Directory database.

ext3 — the name of the primary file system used in most Linux distributions.

FAT (file allocation table) — the original PC file system designed in the 1970s to support floppy disks and, later, hard disks. FAT is inadequate for most server operating systems because of its partition size limitations, naming limitations, and fragmentation and speed issues.

FAT16 (16-bit file allocation table) — a file system designed for use with early DOS- and Windows-based computers that allocates file system space in 16-bit units. Compared to FAT32, FAT16 is less desirable because of its partition size, file naming, fragmentation, speed and security limitations.

FAT32 (32-bit file allocation table) — an enhanced version of FAT that accommodates the use of long filenames and smaller allocation units on a disk. FAT32 makes more efficient use of disk space than the original FAT.

file system — an operating system's method of organizing, managing and accessing its files through logical structures and software routines.

FreeBSD — a Unix-like free operating system descended from AT&T UNIX via the Berkeley Software Distribution (BSD) branch through the 386BSD and 4.4BSD operating systems.

freely distributable software — a term used to describe software with a very liberal copyright; often associated with open source software.

GNU — The name given to the public software project to implement a complete, free source code implementation of UNIX. It also refers to the collection of UNIX-inspired utilities and tools that are included with Linux distributions. The term GNU is an acronym within an acronym that stands for GNU's Not UNIX.

graphical user interface (GUI) — a pictorial representation of computer functions and elements that, in network operating systems, enables administrators to more easily manage files, users, groups, security, printers and other issues.

Internet Information Services (IIS) — a set of Internet-based services for servers created by Microsoft for use with Microsoft Windows. It's the second most popular Web server behind the industry leader Apache HTTP Server.

kernel — the core of an operating system.

Linux — a free distributable implementation of a UNIX-type of system originally developed by Finnish computer scientist Linus Torvalds.

load balancing — an automatic distribution of traffic over multiple links, hard disks or processors intended to optimize responses.

Mac OS X Server — a proprietary network operating system from Apple Computer that is based on UNIX.

multitasking — the ability of a processor to perform multiple activities in a brief period of time (often seeming simultaneous to the user).

network operating system (NOS) — the software that runs on a file server and that enables the server to manage data, users, groups, security, applications, and other networking functions.

New Technology File System (NTFS) — A file system developed by Microsoft for use with its Windows server operating systems beginning from Windows NT. NTFS integrates reliability, compression, the ability to handle massive files, system security and fast access. Most Windows Server 2003 partitions employ NTFS.

open source software — a term used to describe software that is distributed without any restriction, and whose source code is freely available.

primary domain controller (PDC) — a computer that centrally manages account information and security for an entire Windows domain. Only one PDC may exist for each domain.

Proprietary UNIX — any implementation of UNIX for which the source code is either unavailable or is available only by purchasing a licensed copy from The SCO Group (costing as much as millions of dollars). Redistribution of proprietary UNIX versions requires paying royalties to The SCO Group.

Samba — an open source software package that provides complete Windows NT-style file and printer sharing facility.

Santa Cruz Operation (SCO Group) — the company that owns the rights to the UNIX source code.

Solaris — a proprietary implementation of UNIX by Sun Microsystems.

SSH (Secure Shell) — a connection utility that provides authentication and encryption. With SSH, you can securely log on to a host, execute commands on that host, and copy files to or from that host. SSH encrypts data exchanged throughout the session.

symmetric multiprocessing — a method of multiprocessing that splits all operations equally among two or more processors.

System V — the proprietary version of UNIX that comes from Bell Labs.

trust relationship — an arrangement that grants users from one domain rights to resources in another domain.

References

Dean, T (2012) *Network+ Guide to Networks*, 6th edn, Course Technology.

Kwan, R et al. (2009) *A Practical Approach to Internet Programming and Multimedia Technologies*, The Open University Press.

Wikipedia, 'Unix history simple', http://upload.wikimedia.org/wikipedia/commons/thumb/7/77/Unix_history-simple.svg/800px-Unix_history-simple.svg.png.