Unit 14 Windows Operating Systems

Structure:

14.1 Introduction

In the previous unit, we have discussed about multiprocessor systems. Now it is the time to focus our attention on most popular series of operating systems viz. Windows.

Windows 2000, Windows XP and Windows Server 2003 are all part of the Windows NT (New Technology) family of Microsoft operating systems. They are all preemptive, reentrant operating systems, which have been designed to work with either uniprocessor- or symmetrical multi processor (SMP)-based Intel x86 computers. To process input/output (I/O) requests it uses packet-driven I/O which utilizes I/O request packets (IRPs) and asynchronous I/O. Starting with Windows XP, Microsoft began building in 64-bit support into their operating systems – before this their operating systems were based on a 32-bit model. This unit briefly discusses about various Windows operating systems.

Objectives:

After studying this unit, you should be able to:

- explain the architectural details of Windows NT
- discuss functionality and operations of Windows NT
- describe the services of Windows NT
- explain the deployment related issues in Windows NT

14.2 Windows NT Architecture

The Windows NT operating system family's architecture consists of two layers (user mode and kernel mode), with many different modules within

both of these layers. User mode in the Windows NT line is made of subsystems capable of passing I/O requests to the appropriate kernel mode software drivers by using the I/O manager. Two subsystems make up the user mode layer of Windows NT: the Environment subsystem (runs applications written for many different types of operating systems), and the Integral subsystem (operates system specific functions on behalf of the environment subsystem). Kernel mode in Windows NT has full access to the hardware and system resources of the computer. The kernel mode stops user mode services and applications from accessing critical areas of the operating system that they should not have access to.

The Executive interfaces with all the user mode subsystems. It deals with I/O, object management, security and process management. The hybrid kernel sits between the Hardware Abstraction Layer and the Executive to provide multiprocessor synchronization, thread and interrupt scheduling and dispatching, and trap handling and exception dispatching. The microkernel is also responsible for initializing device drivers at boot-up. Kernel mode drivers exist in three levels: highest level drivers, intermediate drivers and low level drivers. Windows Driver Model (WDM) exists in the intermediate layer and was mainly designed to be binary and source compatible between Windows 98 and Windows 2000. The lowest level drivers are either legacy Windows NT device drivers that control a device directly or can be a PnP hardware bus.

User mode

The user mode is made up of subsystems which can pass I/O requests to the appropriate kernel mode drivers via the I/O manager (which exists in kernel mode). Two subsystems make up the user mode layer of Windows NT: the *Environment subsystem* and the *Integral subsystem*.

The environment subsystem was designed to run applications written for many different types of operating systems. None of the environment subsystems can directly access hardware, and must request access to memory resources through the Virtual Memory Manager that runs in kernel mode. Also, applications run at a lower priority than kernel mode processes. Currently, there are three main environment subsystems: the Win32 subsystem, an OS/2 subsystem and a POSIX subsystem.

The Win32 environment subsystem can run 32-bit Windows applications. It contains the console as well as text window support, shutdown and hard-error handling for all other environment subsystems. It also supports Virtual DOS Machines (VDMs), which allow MS-DOS and 16-bit Windows 3.x (Win16) applications to be run on Windows. There is a specific MS-DOS VDM which runs in its own address space and which emulates an Intel 80486 running MS-DOS 5. Win16 programs, however, run in a Win16 VDM. Each program, by default, runs in the same process, thus using the same address space, and the Win16 VDM gives each program its own thread to run on. However, Windows NT does allow users to run a Win16 program in a separate Win16 VDM, which allows the program to be preemptively multitasked as Windows NT will pre-empt the whole VDM process, which only contains one running application. The OS/2 environment subsystem supports 16-bit character-based OS/2 applications and emulates OS/2 1.x, but not 2.x or later OS/2 applications. The POSIX environment subsystem supports applications that are strictly written to either the POSIX.1 standard or the related ISO/IEC standards.

The integral subsystem looks after operating system specific functions on behalf of the environment subsystem. It consists of a *security subsystem*, a *workstation service* and a *server service*. The security subsystem deals with security tokens, grants or denies access to user accounts based on resource permissions, handles logon requests and initiates logon authentication, and determines which system resources need to be audited by Windows NT. It also looks after Active Directory. The workstation service is an API to the network redirector, which provides the computer access to the network. The server service is an API that allows the computer to provide network services.

Kernel mode

Windows NT kernel mode has full access to the hardware and system resources of the computer and runs code in a protected memory area. It controls access to scheduling, thread prioritization, memory management and the interaction with hardware. The kernel mode stops user mode services and applications from accessing critical areas of the operating system that they should not have access to as user mode processes ask the kernel mode to perform such operations on its behalf.

Kernel mode consists of *executive services*, which are made up of many modules that do specific tasks, *kernel drivers*, a *microkernel* and a *Hardware Abstraction Layer*, or HAL.

Executive

The Executive interfaces with all the user mode subsystems. It deals with I/O, object management, security and process management. It contains various components, including the *I/O Manager*, the *Security Reference Monitor*, the *Object Manager*, the *IPC Manager*, the *Virtual Memory Manager* (VMM), a *PnP Manager* and *Power Manager*, as well as a *Window Manager* which works in conjunction with the Windows *Graphics Device Interface* (GDI). Each of these components exports a kernel-only support routine allows other components to communicate with one another. Grouped together, the components can be called *executive services*. No executive component has access to the internal routines of any other executive component.

The **object manager** is a special executive subsystem that all other executive subsystems must pass through to gain access to Windows NT resources – essentially making it a resource management infrastructure service. The object manager is used to reduce the duplication of object resource management functionality in other executive subsystems, which could potentially lead to bugs and make development of Windows NT harder. To the object manager, each resource is an object, whether that resource is a physical resource (such as a file system or peripheral) or a logical resource (such as a file). Each object has a structure or *object type* that the object manager must know about. When another executive subsystem requests the creation of an object, they send that request to the object manager which creates an empty object structure which the requesting executive subsystem then fills in. Object types define the object procedures and any data specific to the object. In this way, the object manager allows Windows NT to be an object oriented operating system, as object types can be thought of as classes that define objects.

Each instance of an object that is created stores its name, parameters that are passed to the object creation function, security attributes and a pointer to its object type. The object also contains an object close procedure and a reference count to tell the object manager how many other objects in the

system reference that object and thereby determines whether the object can be destroyed when a close request is sent to it. Every object exists in a hierarchical object namespace.

Further executive subsystems are the following:

(i) I/O manager: It allows devices to communicate with user-mode subsystems. It translates user-mode read and write commands in read or write IRPs which it passes to device drivers. It accepts file system I/O requests and translates them into device specific calls, and can incorporate low-level device drivers that directly manipulate hardware to either read input or write output. It also includes a cache manager to improve disk performance by caching read requests and write to the disk in the background

(ii) Security reference monitor (SRM): The primary authority for enforcing the security rules of the security integral subsystem. It determines whether an object or resource can be accessed, via the use of access control lists (ACLs), which are made up of access control entries (ACEs). ACEs contain a security identifier (SID) and a list of operations that the ACE gives a select group of trustees – a user account, group account, or logon session – permission (allow, deny, or audit) to that resource.

(iii) IPC manager: Short for Inter Process Communication Manager, this manages the communication between clients (the environment subsystem) and servers (components of the Executive). It can use two facilities: the *Local Procedure Call* (LPC) facility (clients and servers on the one computer) and the *Remote Procedure Call* (RPC) facility (where clients and servers are situated on different computers. Microsoft has had significant security issues with the RPC facility.

(iv) Virtual memory manager: It manages virtual memory, allowing Windows 2000 to use the hard disk as a primary storage device (although strictly speaking it is secondary storage). It controls the paging of memory in and out of physical memory to disk storage.

(v) Process manager: It handles process and thread creation and termination

(vi) PnP manager: It handles Plug and Play and supports device detection and installation at boot time. It also has the responsibility to stop and start devices on demand – sometimes this happens when a bus gains a new

device and needs to have a device driver loaded to support that device. Both FireWire and USB are hot-swappable and require the services of the PnP Manager to load, stop and start devices. The PnP manager interfaces with the HAL, the rest of the executive (as necessary) and with device drivers.

(vii) Power manager: The power manager deals with power events and generates power IRPs. It coordinates these power events when several devices send a request to be turned off it determines the best way of doing this.

The display system has been moved from user mode into the kernel mode as a device driver contained in the file *Win32k.sys*. There are two components in this device driver – the Window Manager and the GDI.

(viii) Window manager: It is responsible for drawing windows and menus. It controls the way that output is painted to the screen and handles input events (such as from the keyboard and mouse), then passes messages to the applications that need to receive this input

(ix) GDI: The Graphics Device Interface is responsible for tasks such as drawing lines and curves, rendering fonts and handling palettes. Windows 2000 introduced native alpha blending into the GDI.

(x) Microkernel & kernel-mode drivers: The Microkernel sits between the HAL and the Executive and provides multiprocessor synchronization, thread and interrupt scheduling and dispatching, and trap handling and exception dispatching. The Microkernel often interfaces with the process manager. The microkernel is also responsible for initializing device drivers at boot-up that are necessary to get the operating system up and running.

(xi) Hardware abstraction layer: The Windows NT Hardware Abstraction Layer, or HAL, is a layer between the physical hardware of the computer and the rest of the operating system. It was designed to hide differences in hardware and therefore provide a consistent platform on which applications may run. The HAL includes hardware specific code that controls I/O interfaces, interrupt controllers and multiple processors.

Self-Assessment Questions

1. User mode in the Windows NT line is made of subsystems capable of passing I/O requests to the appropriate kernel mode software drivers by using the I/O manager. (True / False)

2. HAL stands for _____.
3. The _____ is responsible for tasks such as drawing lines and curves, rendering fonts and handling palettes. (Pick the right option)
   a) GDI
   b) HAL
   c) Window Manager
   d) Power Manager

14.3 Windows 2000 Architecture

Windows 2000 (also referred to as **Win2K** or **W2K**) is a preemptible and interruptible, graphical, business-oriented operating system that was designed to work with either uniprocessor or symmetric multi-processor (SMP) 32-bit Intel x86 computers. It is part of the Microsoft Windows NT line of operating systems and was released on February 17, 2000. Windows 2000 comes in four versions: Professional, Server, Advanced Server, and Datacenter Server. Additionally, Microsoft offers Windows 2000 Advanced Server- Limited Edition, which was released in 2001 and runs on 64-bit Intel Itanium microprocessors. Windows 2000 is classified as a hybrid-kernel operating system, and its architecture is divided into two modes: user mode and kernel mode. The kernel mode provides unrestricted access to system resources and facilitates the user mode, which is heavily restricted and designed for most applications.

All versions of Windows 2000 have common functionality, including many system utilities such as the Microsoft Management Console (MMC) and standard system management applications such as a disk defragmentation utility. Support for people with disabilities has also been improved by Microsoft across their Windows 2000 line, and they have included increased support for different languages and locale information. All versions of the operating system support the Windows NT filesystem, NTFS 5, the Encrypted File System (EFS), as well as basic and dynamic disk storage. Dynamic disk storage allows different types of volumes to be used. The Windows 2000 Server family has enhanced functionality, including the ability to provide Active Directory services (a hierarchical framework of resources), Distributed File System (a file system that supports sharing of files) and fault-redundant storage volumes.

Windows 2000 can be installed and deployed to an enterprise through either an attended or unattended installation. Unattended installations rely on the use of answer files to fill in installation information, and can be performed through a bootable CD using Microsoft Systems Management Server (SMS), by the System Preparation Tool (Sysprep).

User mode

User mode in Windows 2000 is made of subsystems capable of passing I/O requests to the appropriate kernel mode drivers by using the I/O manager. Two subsystems make up the user mode layer of Windows 2000: the environment subsystem and the integral subsystem.

The environment subsystem was designed to run applications written for many different types of operating systems. These applications, however, run at a lower priority than kernel mode processes. There are three main environment subsystems:

Win32 subsystem runs 32-bit Windows applications and also supports Virtual DOS Machines (VDMs), which allows MS-DOS and 16-bit Windows 3.x (Win16) applications to run on Windows.

OS/2 environment subsystem supports 16-bit character-based OS/2 applications and emulates OS/2 1.3 and 1.x, but not 2.x or later OS/2 applications.

POSIX environment subsystem supports applications that are strictly written to either the POSIX.1 standard or the related ISO/IEC standards.

The integral subsystem looks after operating system specific functions on behalf of the environment subsystem. It consists of a *security subsystem* (grants/denies access and handles logons), *workstation service* (helps the computer gain network access) and a *server service* (lets the computer provide network services).

Kernel mode

Kernel mode in Windows 2000 has full access to the hardware and system resources of the computer. The kernel mode stops user mode services and applications from accessing critical areas of the operating system that they should not have access to.

The executive interfaces with all the user mode subsystems. It deals with I/O, object management, security and process management. It contains various components, including:

Object manager: A special executive subsystem that all other executive subsystems must pass through to gain access to Windows 2000 resources. This essentially is a resource management infrastructure service that allows Windows 2000 to be an object oriented operating system.

I/O manager: Allows devices to communicate with user-mode subsystems by translating user-mode read and write commands and passing them to device drivers.

Security reference monitor (SRM): The primary authority for enforcing the security rules of the security integral subsystem.

IPC manager: Manages the communication between clients (the environment subsystem) and servers (components of the executive).

Virtual memory manager: Manages virtual memory, allowing Windows 2000 to use the hard disk as a primary storage device (although strictly speaking it is secondary storage).

Process manager: Handles process and thread creation and termination.

PnP manager: Handles Plug and Play and supports device detection and installation at boot time.

Power manager: The power manager coordinates power events and generates power IRPs.

The display system is handled by a device driver contained in *Win32k.sys*. The **Window Manager** component of this driver is responsible for drawing windows and menus while the **GDI** (graphical device interface) component is responsible for tasks such as drawing lines and curves, rendering fonts and handling palettes.

The above features are same as that of Windows NT.

Self-Assessment Questions

4. Kernel mode in Windows 2000 has full access to the hardware and system resources of the computer. (True / False)
5. GDI stands for _____.

6. The _____ Manager manages the communication between clients (the environment subsystem) and servers (components of the executive). (Pick the right option)
   a) PnP
   b) IPC
   c) Window
   d) Power

14.4 Common Functionality

Certain features are common across all versions of Windows 2000 (both Professional and the Server versions), among them being NTFS 5, the Microsoft Management Console (MMC), the Encrypting File System (EFS), dynamic and basic disk storage, usability enhancements and multi-language and locale support. Windows 2000 also has several standard system utilities included as standard. As well as these features, Microsoft introduced a new feature to protect critical system files, called Windows File Protection (WFP). This prevents programs (with the exception of Microsoft's update programs) from replacing critical Windows system files and thus making the system inoperable. Microsoft recognized that the infamous Blue Screen of Death (or stop error) could cause serious problems for servers that needed to be constantly running and so provided a system setting that would allow the server to automatically reboot when a stop error occurred. Users have the option of dumping the first 64KB of memory to disk (the smallest amount of memory that is useful for debugging purposes, also known as a mini-dump), a dump of only the kernel's memory or a dump of the entire contents of memory to disk, as well as write that this event happened to the Windows 2000 event log. In order to improve performance on computers running Windows 2000 as a server operating system, Microsoft gave administrators the choice of optimizing the operating system for background services or for applications. Windows 2000 supports disk quotas, which can be set via the "Quotas" tab found in the hard disk properties dialog box.

NTFS 5

Microsoft released the third version of the NT File System (NTFS) – also known as version 5.0 – in Windows 2000; this introduced quotas, file-system-level encryption (called EFS), sparse files and reparse points. Sparse files allow for the efficient storage of data sets that are very large yet

contain many areas that only have zeroes. Reparse points allow the object manager to reset a file namespace lookup and let file system drivers implement changed functionality in a transparent manner. Reparse points are used to implement Volume Mount Points, Directory Junctions, Hierarchical Storage Management, Native Structured Storage and Single Instance Storage. Volume mount points and directory junctions allow for a file to be transparently referred from one file or directory location to another.

Encrypting file system

The Encrypting File System (EFS) introduced strong encryption into the Windows file world. It allowed any folder or drive on an NTFS volume to be encrypted transparently to the end user. EFS works in conjunction with the EFS service, Microsoft's CryptoAPI and the EFS File System Run-Time Library (FSRTL). As of February 2004, its encryption has not been compromised.

EFS works by encrypting a file with a bulk symmetric key (also known as the File Encryption Key, or FEK), which is used because it takes a relatively smaller amount of time to encrypt and decrypt large amounts of data than if an asymmetric key cipher is used. The symmetric key that is used to encrypt the file is then encrypted with a public key that is associated with the user who encrypted the file, and this encrypted data is stored in the header of the encrypted file. To decrypt the file, the file system uses the private key of the user to decrypt the symmetric key that is stored in the file header. It then uses the symmetric key to decrypt the file. Because this is done at the file system level, it is transparent to the user. Also, in case of a user losing access to their key, support for recovery agents that can decrypt files has been built in to the EFS system.

Basic and dynamic disk storage

Windows 2000 introduced the Logical Disk Manager for dynamic storage. All versions of Windows 2000 support three types of dynamic disk volumes (along with basic storage): *simple volumes*, *spanned volumes* and *striped volumes*:

Simple volume: This is a volume with disk space from one disk.

Spanned volumes: Multiple disks spanning up to 32 disks. If one disk fails, all data in the volume is lost.

Striped volumes: Also known as RAID-0, a striped volume stores all its data across several disks in *stripes*. This allows better performance because disk read and writes are balanced across multiple disks. Windows 2000 also added support for iSCSI protocol.

Accessibility support

The Windows 2000 onscreen keyboard map allows users who have problems with using the keyboard to use a mouse to input text.

Microsoft made an effort to increase the usability of Windows 2000 for people with visual and auditory impairments and other disabilities. They included several utilities designed to make the system more accessible.

FilterKeys are a group of keyboard related support for people with typing issues, and include:

SlowKeys: Windows is told to disregard keystrokes that are not held down for a certain time period.

BounceKeys: Multiple keystrokes to one key to be ignored within a certain timeframe.

RepeatKeys: Allows users to slow down the rate at which keys are repeated via the keyboard's key repeat feature.

ToggleKeys: When turned on, Windows will play a sound when either the CAPS LOCK, NUM LOCK or SCROLL LOCK keys are pressed.

MouseKeys: Allows the cursor to be moved around the screen via the numeric keypad instead of the mouse.

On screen keyboard: Assists those who are not familiar with a given keyboard by allowing them to use a mouse to enter characters to the screen.

SerialKeys: Gives Windows 2000 the ability to support speech augmentation devices.

StickyKeys: Makes modifier keys (ALT, CTRL and SHIFT) become "sticky" – in other words a user can press the modifier key, release that key and then press the combination key. Normally the modifier key must remain pressed down to activate the sequence.

On screen magnifier: Assists users with visual impairments by magnifying the part of the screen they place their mouse over.

Narrator: Microsoft Narrator assists users with visual impairments with system messages, as when these appear the narrator will read this out via the sound system.

High contrast theme: To assist users with visual impairments.
SoundSentry: Designed to help users with auditory impairments, Windows 2000 will show a visual effect when a sound is played through the sound system.

Language & locale support
Windows 2000 has support for many languages other than English. It supports Arabic, Armenian, Baltic, Central European, Cyrillic, Georgian, Greek, Hebrew, Indic, Japanese, Korean, Simplified Chinese, Thai, Traditional Chinese, Turkic, Vietnamese and Western European languages. It also has support for many different locales, a list of which can be found on Microsoft's website.

System utilities
The Microsoft Management Console (MMC) is used for administering Windows 2000 computers. Windows 2000 introduced the Microsoft Management Console (MMC), which is used to create, save, and open administrative tools. Each of the tools is called a *console*, and most consoles allow an administrator to administer other Windows 2000 computers from one centralized computer. Each console can contain one or many specific administrative tools, called *snap-ins*. Snap-ins can be either standalone (performs one function), or extensions (adds functionality to an existing snap-in). In order to provide the ability to control what snap-ins can be seen in a console, the MMC allows consoles to be created in author mode or created in user mode. Author mode allows snap-ins to be added, new windows to be created, all portions of the console tree can be displayed and for consoles to be saved. User mode allows consoles to be distributed with restrictions applied. User mode consoles can have full access granted user so they can make whatever changes they desire, can have limited access so that users cannot add to the console but they can view multiple windows in a console, or they can have limited access so that users cannot add to the console and also cannot view multiple windows in a console.

The Windows 2000 Computer Management console is capable of performing many system tasks. The main tools that come with Windows 2000 can be found in the Computer Management console (found in Administrative Tools in the Control Panel). This contains the event viewer – a means of seeing events and the Windows equivalent of a log file, a

system information viewer, the ability to view open shared folders and shared folder sessions, a device manager and a tool to view all the local users and groups on the Windows 2000 computer. It also contains a disk management snap-in, which contains a disk defragmenter as well as other disk management utilities. Lastly, it also contains a services viewer, which allows users to view all installed services and to stop and start them on demand, as well as configure what those services should do when the computer starts.

REGEDIT.EXE utility

Windows 2000 comes bundled with two utilities to edit the Windows registry. One acts like the Windows 9x REGEDIT.EXE program and the other could edit registry permissions in the same manner that Windows NT's REGEDT32.EXE program could. REGEDIT.EXE has a left-side tree view that begins at "My Computer" and lists all loaded hives. REGEDT32.EXE has a left-side tree view, but each hive has its own window, so the tree displays only keys. REGEDIT.EXE represents the three components of a value (its name, type, and data) as separate columns of a table. REGEDT32.EXE represents them as a list of strings. REGEDIT.EXE was written for the Win32 API and supports right-clicking of entries in a tree view to adjust properties and other settings. REGEDT32.EXE was also written for the Win32 API and requires all actions to be performed from the top menu bar. Because REGEDIT.EXE was directly ported from Windows 98, it does not support permission editing (permissions do not exist in Windows 9x). Therefore, the only way to access the full functionality of an NT registry was with REGEDT32.EXE, which uses the older multiple document interface (MDI), which newer versions of REGEDIT do not use. Windows XP was the first system to integrate these two programs into one, adopting the REGEDIT.EXE behavior with the additional NT functionality.

The System File Checker (SFC) also comes bundled with Windows 2000. It is a command line utility that scans system files and verifies whether they were signed by Microsoft and works in conjunction with the Windows File Protection mechanism. It can also repopulate and repair all the files in the Dllcache folder.

Recovery console

The Recovery Console is usually used to recover unbootable systems. The

Recovery Console is an application that is run from outside the installed copy of Windows and that enables a user to perform maintenance tasks that cannot be run from inside of the installed copy, or cannot be feasibly run from another computer or copy of Windows 2000. It is usually used, however, to recover the system from errors causing booting to fail, which would render other tools useless.

It presents itself as a simple command line interface. The commands are limited to ones for checking and repairing the hard drive(s), repairing boot information (including NTLDR), replacing corrupted system files with fresh copies from the CD, or enabling/disabling services and drivers for the next boot.

The console can be accessed in one of two ways:
Starting from the Windows 2000 CD, and choosing to enter the Recovery Console or Installing the Recovery Console via Winnt32.exe, with the /cmdcons switch. However, the console can then only be used if the system boots to the point where NTLDR can start it.

Self Assessment Questions

7. Microsoft introduced a new feature to protect critical system files, called Windows File Protection (WFP) in Windows 2000. (True / False)
8. MMC stands for _____.
9. _____ assists users with visual impairments with system messages and reads the messages via the sound system. (Pick the right option)
   a) StickyKeys
   b) SoundSentry
   c) Narrator
   d) On screen magnifier

14.5 Summary

Let’s recapitulate important points discussed in this unit:

- The Windows NT operating system family's architecture consists of two layers (user mode and kernel mode), with many different modules within both of these layers.

- The user mode is made up of subsystems which can pass I/O requests to the appropriate kernel mode drivers via the I/O manager (which exists in kernel mode).
- The environment subsystem was designed to run applications written for many different types of operating systems.
- The integral subsystem looks after operating system specific functions on behalf of the environment subsystem.
- Windows 2000 has support for many languages other than English.
- Windows 2000 introduced the Microsoft Management Console (MMC), which is used to create, save, and open administrative tools.

14.6 Terminal Questions

1. Explain the features of Windows NT operating system.
2. Describe the features of Windows 2000 operating system.
3. Bring out the common functionality in Windows systems.

14.7 Answers

Self Assessment Questions

1. True
2. Hardware Abstraction Layer
3. a) GDI
4. False
5. Graphical Device Interface
6. b) IPC
7. True
8. Microsoft Management Console
9. c) Narrator

Terminal Questions

1. The Windows NT operating system family's architecture consists of two layers (user mode and kernel mode), with many different modules within both of these layers. User mode in the Windows NT line is made of subsystems capable of passing I/O requests to the appropriate kernel mode software drivers by using the I/O manager. (Refer section 14.2 for detail)

2. Windows 2000 (also referred to as Win2K or W2K) is a pre-emptible and interruptible, graphical, business-oriented operating system that was designed to work with either uniprocessor or symmetric multi-processor (SMP) 32-bit Intel x86 computers. (Refer section 14.3 for detail)
3. Certain features are common across all versions of Windows 2000 (both Professional and the Server versions), among them being NTFS 5, the Microsoft Management Console (MMC), the Encrypting File System (EFS), dynamic and basic disk storage, usability enhancements and multi-language and locale support. (Refer section 14.4 for detail)

Acknowledgements, References and Suggested Readings

1. “Operating System Concepts”, Abraham Silberschatz & Peter Baer Galvin, PHI.
2. ‘‘Operating Systems: Design and Implementation’’, Andrew S. Tanenbaum, Pearson Education.
3. ‘‘Modern Operating Systems’’, Andrew S. Tanenbaum, TMH.