Introduction to Operating System

Even though the CPU is very fast, it can basically do simple operations like adding two numbers, multiplying two numbers, etc.; but not much more. Even simple operations like input of a number or output of a number or converting a string of characters to uppercase or displaying an image on the screen must be built on top of these basic capabilities by writing a series of basic instructions. Also, the computer has a large number of peripheral devices like keyboard, mouse, monitor, hard disk, optical disk, printers and other removable devices. Operating these devices require executing a long and complex series of basic instructions.

A modern computer system has a variety of resources like the CPU, memory, secondary storage, network, peripheral devices, etc. These are accessed by multiple programs running concurrently, sometimes on behalf of different users with different set of access rights. Clearly, there needs to be some "authority" that regulates and mediates access to these resources.

A computer without any kind of software for above operations is a practically unusable device, because it may not even have the basic user interface to interact with the user. In order to provide a consistent experience to the user, there needs to be a common framework for the common human-computer interactions. To make the computer easier to use, such framework should also provide several types of abstractions and metaphors. A file system metaphor is one such example that has been discussed in detail later in this chapter.

Thus an operating system exists to satisfy all these needs. Because it controls the whole system, it is always the first program to be started when the computer system is turned on.

What is an Operating System ?

An operating system is the controller, resource allocator and common services provider for a computer system. Like the government, it performs these functions to ensure smooth and mostly trouble-free operation of the computer.

The Startup Process of a Computer

When the computer is supplied power and turned on, the CPU takes control of the whole system. It initializes itself by bringing all its subcomponents in a known and ready-to-use state. Now it is like a vehicle whose ignition has been turned on and is ready to be "driven". But where is the "driver" (the instructions to be executed by the CPU) ? The computer has a type of permanent memory called ROM (on personal computers, this is often called ROM BIOS (Basic Input Output System or simply BIOS) that contains an initial program. This initial program, called POST (Power On Self Test), performs a basic check on all other components and peripheral devices in the computer and initializes them so they are ready for use. Hence the next step in this sequence is to locate

operating systems on the attached storage devices, select the one to be loaded in many memory, load it and start executing it. Once the operating system starts its execution, it takes control of the entire computer system. This entire process is called "booting" the computer to a particular operating system.

Functions of an Operating System

An operating system (OS) performs different set of basic functions as mentioned below :

- Providing hardware access as a common service.
- Controlling, Regulating and Supervising resources in the Computer
- Handling Multiprocessor Systems
- Starting and Stopping Program Execution
- Controlling Access to the Memory
- Serving Multiple Users at the Same Time
- Providing Security
- Providing Other Common Services

In this section we have described some common functions often performed by the operating systems.

Providing Hardware Access as a Common Service

In the earliest days of computing, each computer program would come with a set of instructions to handle a fixed set of devices like printers, etc. If a new kind of printer was added to a computer, it became necessary to add the necessary instructions to handle the new printer to each and every program to be executed on that computer. With the rapid increase in the number of devices and device manufacturers as well as the number of programs to be run, this approach soon became infeasible. Thus, the operating systems started providing a common service of handling the hardware devices. The code (instructions) to handle particular devices would be part of the operating system and the operating system would provide access to these devices to individual programs as a common service. When a new device came into use, the new instructions needed to operate it would only have to be added to the operating system and thousands of individual programs were spared of any modification.

Controlling, Regulating and Supervising Resources in the Computer

Modern computers are far more powerful than their humble predecessors and have access to far greater amounts of resources like processing power, main memory, storage, etc. As a result, they are now capable of running not just one program at a time, but many programs at a time. This ability is called multiprogramming. This creates new issues as well. When only one program is running at a time, it has full access to all the resources and there is no harm in it. But what happens when many programs are running at a time and two programs start printing to the same printer at the same time or start writing to the same location of the same storage medium at the same time ? Obviously, access to common resources must be controlled in such an environment. The operating system plays the crucial role of resource controller, regulator and supervisor for all hardware resources.

Handling Multiprocessor Systems

A computer system may have more than one CPU (processor) as well. A computer system having more than one processor is known as a multiprocessor system. Operating systems for such multiprocessor systems are considerably more complex than those designed only for single processor systems. Managing which processor to be used for execution is also job of operating system.

Starting and Stopping Program Execution

When the computer starts, initially it runs only the operating system. The operating system takes complete control of the computer system. It also runs a special program called the shell. The shell provides the user a user interface (UI) to work with. The user interface allows the user to indicate what they want to do. It accepts requests for performing operations from the user (these requests may be in the form of typing a command or clicking with a mouse, or touching on a touch panel, etc.) and initiates actions to fulfill those requests. If it is required to start a program to fulfill a request, it requests the operating system to do so. As the operating system has full control over the system, only the operating system can start or stop programs.

Controlling Access to the Memory

The main memory is an important resource for the computer system, because it is the only large-scale form of memory that can match the speed of the CPU and can be directly accessed by the CPU. Any program to be run must be loaded into main memory and any non-trivial data set to be manipulated must also be in main memory for the manipulation to occur. Hence it is very important that this resource be used judiciously. As a result, access to the main memory is also under complete control of the operating system, just like access to other resources. A process needing to get or release some amount of main memory must request the operating system to do so and no process is permitted to access memory not allocated to it by the operating system. This is known as memory protection.

Serving Multiple Users at the Same Time

An operating system may be designed for use by only one user at a time (a single user system) or by several users simultaneously (a multiuser system). With a multiuser operating system, it is actually possible to run the programs of many users on a single computer usually called server, with each user performing input/output through their "terminal" that may have keyboard, mouse and monitor. This is useful when all users cannot be provided with the powerful computers they need (due to the cost factor) and a single powerful computer must be shared among many of them.

A multiuser system also provides additional benefits of centralized management and resource (e.g. file) sharing. Sometimes, a computer system in a faraway corner of the world can be accessed remotely by users over the Internet. This enables travelling employees of large organizations to access their computers from anywhere in the world for doing their work. It also enables the technical support staff of the organization to access computers in different offices and to diagnose and solve their problems without wasting time on physical travel. Some companies even provide their employees the option to work from their home.

Providing Security

When multiple users are accessing the same computer system, the operating system must provide some level of isolation between the users so that one user cannot disturb the work of another user. At the same time, where users are collaborating on a joint project, they must be able to share some resources. Hence the operating system must provide a security mechanism that ensures that all authorized uses of a resource are permitted, while all attempts at unauthorized use are strictly denied. Modern operating systems are designed to provide such security.

With the heavy use of computer networks and the Internet, it is also possible to access and use a computer system remotely, possibly from thousands of kilometers away. While this facility is a boon for organizations having multiple offices around the world or for employees like sales persons and managers who have to travel a lot and still need to access their office computer, it can also be misused for gaining unauthorized access to someone's computer. Modern operating systems provide some basic mechanisms to protect against such hazards, though they may not be sufficient by themselves.

Providing Other Common Services

Apart from these functionalities, operating systems also provide many common services to make the operation of the computer systems easier. Many of these services remain hidden from the user because they are used by the other programs in the computer and not by the human users directly. Operating systems also often come with some companion programs (utilities or accessories) that are small and simple and yet useful to most users of the computer.

These include a utility to explore the information stored on the computer (a file browser), a basic text editor, a calculator, programs to view and edit images, programs to play audio and video, a web browser for surfing the Internet, etc. All operating systems, except for the embedded systems, must also provide at least one shell program to allow the user to interact with the computer system. Though these are not essential parts of an operating system, most operating systems come with some such utilities as an added bonus. Some operating systems, especially the free ones, come with a comprehensive set of software ready for daily use in different usage scenarios like homes, educational institutes and offices.

Typical Components of an Operating System

In this section we briefly discuss the components typically associated with an operating system and the full environment surrounding the operating system. Keep visiting figure 5.1 while reading the description. This figure provides a simplified layered view of the operation of the computer system in the context of operating system study.

The Device Drivers

At the lowest level is the raw hardware of the computer. As we have seen earlier, this part, often called the "raw iron", is an immensely powerful machine, but has no clue as to what to do. This layer also consists of a diverse set of devices, each requiring potentially different set of instructions to operate. The device drivers are small programs that contain the instructions

necessary for using these devices. While many of them come bundled with the operating system, some may have to be installed separately from a disk or the Internet. They are loaded and unloaded as and when needed by the kernel. The kernel uses them for operating and controlling the hardware.

The Kernel

The kernel is the core component or the main program of the operating system. A traditional kernel performs all the key functions of an operating system including detecting new hardware when attached and loading appropriate device drivers to access it, accessing and controlling all hardware devices (through the device drivers), resource allocation and management, creating, stopping and controlling program execution, scheduling program execution, providing CPU, I/O and memory protection, I/O management, memory management, security, etc. By some definitions, the kernel IS the operating system.

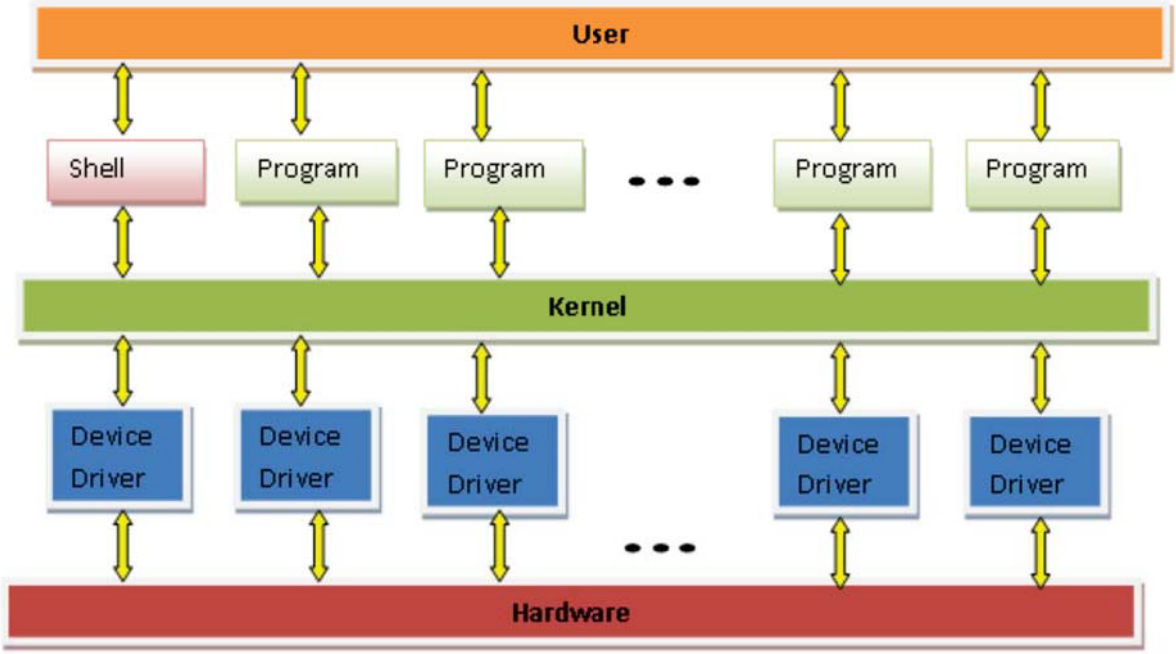

Figure 5.1 : The Operating System Context

The Shell

The shell is the most visible component of an operating system bundle; so much so that most people identify the operating system by the looks of the shell. The shell allows the user to express their wishes (what they want the computer to do) to the computer system by providing a user interface (UI). There are two main categories of user interfaces - a Command Line Interface (CLI) and a Graphical User Interface (GUI). The CLI expects only a low-cost low-power text-based terminal. It works by repeatedly accepting textual commands from the user and executing them. One needs to remember the commands (though help may be available) and a certain level of typing skills are needed to operate such a system. In the early days of computing when technology was not as advanced, the CLI was the only option. Later on the Graphical User Interface was developed.

In the GUI environment, the screen contains pictorial elements like a desktop that acts as a background for everything else, windows (a rectangular portion of the screen dedicated to a particular program or interaction), icons (small pictures representative of programs and other elements), menus (a list of actions from which the user may select one), buttons (small rectangular areas that react to a mouse click), etc. The latter elements belong to a particular window. The windows may hide behind other windows and reappear and can often be moved around or resized, minimized to a small part at the bottom of the screen, maximized to occupy the whole screen, etc. Apart from the keyboard for input, there is a mouse pointer that can be moved around using a mouse or track pad. There are one to three buttons that can be clicked and a scroll wheel or scroll area too.

The File System

The operating system provides a file system interface to secondary storage. The concept of a file system is modeled after the filing cabinets commonly found in offices, but with new twists. A file system chiefly contains two types of objects – files and directories (also known as folders). A file is the basic unit of secondary data storage on computers. Any data that the user wants to store will go in some file in the file system. The files are identified by their names, which are much easier for humans to remember than absolute addresses known as block numbers. As a disk may have a large number of files, directories are used to organize them. A directory is nothing but a container that may contain files as well as other directories known as its subdirectories. In fact, there is no theoretical limit to such nesting (putting one container object inside another). However, every file system starts with what is called its root directory and then the root directory may contain files as well as subdirectories and it can go on and on like that. Figure 5.2 illustrates this concept. Here the green nodes represent directories (indicated by d), while the blue ones represent files (indicated by f).

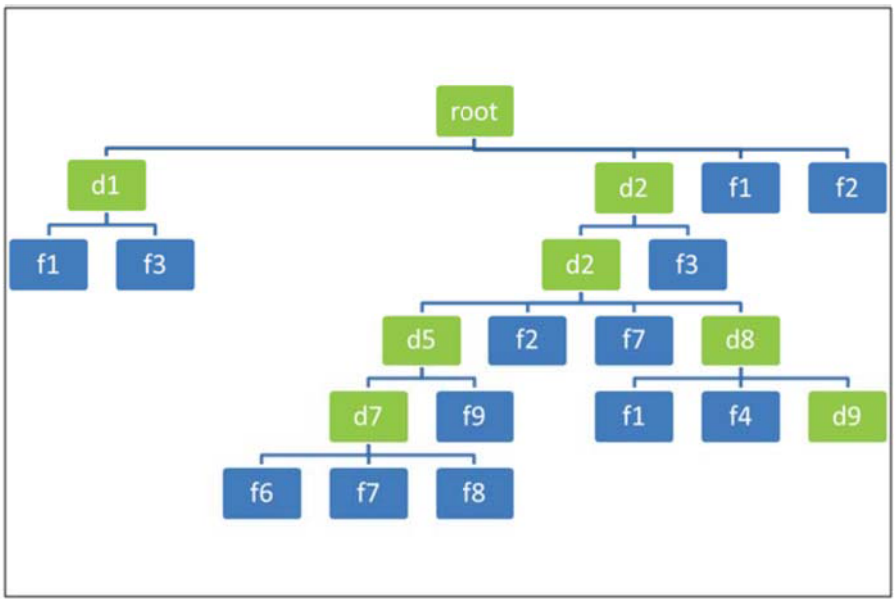

Figure 5.2 : The File System Structure

The file systems follow certain basic rules. Each file system has a single root directory that is the starting point of the file system. Each directory in the file system contains a number of objects (files and directories), each of which must have a name unique within that directory. Thus, there can never be two objects with the same name in the same directory. However, two different directories can have two different objects with the same name. As long as you know the directory containing the object you want to use, knowing its name may be enough as it is guaranteed to be unique within its directory. Otherwise, you will have to specify the absolute (or full) path leading to the object. That is, you start with the root directory, then the subdirectory, and so on, until you reach to the directory that contains the object in question and finally the object itself. Each of these components is separated by a special character that is not permitted in file or directory names. This uniquely identifies an object in the entire file system.

A blank disk initially contains no file system. The initial blank file system structure is created by an operation known as formatting the disk. Formatting a disk that already contains a file system destroys the existing file system and replaces it with a new blank one. Certain types of disks such as the hard disks can contain multiple partitions. Each partition may be formatted to contain a separate and independent file system. Formatting one partition does not affect the others. The operating system provides utilities for viewing, modifying and formatting the disks and their partitions.

File System of Linux Operating System

Linux generally uses some version of the extended file system (ext2, ext3 or ext4), though several others are also available and in use. These are quite powerful and feature rich file systems. The extended file system is case sensitive, i.e. capital and small letters are treated as two different characters. So you may have two files with the names f1 and F1 in the same directory. It uses the / (slash) character as the path separator. The concept of using the extension part of the filename to signify its type is not mandatory and is weakly used. USB flash disks and memory cards used with mobile phones usually come formatted with the FAT file system, but the former can be reformatted as NTFS to obtain the benefits of performance and some security. CDs generally use the ISO9660 file system, while DVDs use the UDF file system. These different file systems have different characteristics.

GUI and Components of Operating System

Everything that comes with the operating system is theoretically changeable, except the kernel. The device drivers, the shells, the libraries and the utility programs can all be changed without changing the operating system. In fact, some free and open source operating systems like Linux provide a number of choices for each of these. And though some proprietary operating systems do not offer a choice in shells or utilities, such choices are available from third party vendors as well as the open source community. Hence identifying an operating system based on these components would be a fallacy. These considerations have given rise to a definition that the kernel, and only

the kernel, is THE operating system. All other things are changeable; and hence are just auxiliary accessories.

Users often mistakenly associate a particular user experience with a particular operating system. But they forget that the user experience is provided by the shell and the shell is changeable. To emphasize this fact, just look at the four screenshots in figure 5.3 and try to identify the operating system in each case. We will not be able to differentiate between these screens to a large extent. Here the upper two screenshots were taken on Windows systems, while the lower two were taken on Linux systems.

Different Categories of Computing Devices and Operating Systems for Them

There is a wide array of computing devices serving a variety of purposes. Here we present them in order from the largest to the smallest.

Supercomputers

The largest and the most powerful computers ever built are known as supercomputers. These are computers that can perform millions of billions of floating point (real number) operations per second. For example, in November 2011, the K supercomputer of Japan (see figure 5.4) became the first super computer in the world to be able to perform 10 Peta FLOPS, i.e. 10^{16} FLOPS (Floating Point Operations Per Second). India is one of the few countries in the world to have developed her own supercomputers. Such computers are used on some of the most complex and computation-intensive problems in the world like weather forecasting, nuclear test simulation, molecular modeling, etc. These computers are vastly different from the common variety personal computers. They utilize the power of thousands of processors connected using very high speed channels and working on a single problem in parallel to achieve very high speed. The most critical aspects for an operating system for a supercomputer are performance optimization as well as distribution and coordination of both data and computation among the thousands of processors. The operating systems typically used are variants of lightweight kernels like CNK or CNL at individual node level, while using a Linux variant for managing the overall operations.

Mainframe Computers

The next class of computers is called mainframe computers (see figure 5.5). These are used in government and corporate environments where, apart from high performance, a very high level of reliability and compatibility with existing mainframe-based software are key aspects. The very high levels of reliability and availability are achieved by providing multiple redundant components for almost every aspect of the machine, so that if one component fails; another identical component can take on its responsibility and the computer continues working without a hitch. The duplication goes from CPUs all the way down to power supplies and even cooling fans. This makes these machines run continuously for years and years without any problems. Example operating systems are IBM z/OS and Linux variants.

Figure 5.3 : GUI of Some Operating Systems

Figure 5.4 : The K Supercomputer of Japan

Figure 5.5 : The IBM Z Mainframe

Server Computers

Server computers are powerful computers that provide some computing or storage service to a large number of client computers. The critical aspects for these computers are performance, reliability, compatibility with already existing software and scalability, the ability to incrementally increase performance as and when needed by adding components, rather than replacing the whole computer. These computers most commonly use Unix or Linux as their operating systems. Some also use a Microsoft Windows server operating system.

High-end Workstations

High-end workstations are computers used for demanding scientific computing as well as multimedia applications like special effects in movies, making animated movies, 3D modeling, Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), etc. these require very high graphics performance and an effective management of the larger amount of resources available (processing power, memory, disk space, network bandwidth). Here also Unix, Linux or Microsoft Windows is used as operating system.

Personal Computers

The category of computers most familiar to us is that of personal computers. These computers provide a general platform that caters to the widest possible range of uses and also to users with vastly different skill sets. For a large number of users, user-friendliness is a very important aspect. Subsequently, the operating systems in use are Microsoft Windows family operating systems, the OS X operating system (on the Apple Mac series computers) and Linux. All three provide rich graphical user interfaces.

Smartphones and Tablets

Though you may not have realized it yet, a smartphone is also a computer in its own right. Tablet PCs are a hybrid between the smartphones and personal computers. These devices pose unique challenges for operating system designers because they have severe constraints on processing power, memory, energy usage (because higher energy usage would mean the battery would drain out faster) and screen real estate (the screen size is quite small compared to the PC, and yet, most facilities of a PC are expected). They also have quite different input methods (numeric keypad or small QWERTY keypad with navigation keys or touch gestures and an onscreen keyboard on a touch screen or even voice input).

These characteristics demanded completely different solutions. As a result, most mobiles few years back used operating systems specially designed for them. However, with increasing processing power and memory, specialized versions of PC operating systems have now become the most popular choices for smartphones and tablets. Examples include Google Android and Apple iOS (both based on Linux/Unix) and Microsoft Windows Phone OS. Variants of full scale Linux for use on such devices are currently under development. A convergence of operating systems for touch screen based smartphones, tablets and ultraportable devices and operating systems for mainstream personal

computers is widely anticipated and both Microsoft Windows 8 and Linux variants using the GNOME 3 or Unity interfaces have started the process by redesigning their interfaces for touch input.

Embedded Systems

Even phones are not the smallest computers on the planet. There are hundreds of millions of tiny computers embedded in places we cannot even imagine; from industrial machines to car engines, from TV set top boxes and DVD players to washing machines and microwave ovens they are hidden everywhere. These computers are programmed for special purpose tasks. They typically have little or no user interface. They get their input from a variety of sensors in the form of electrical signals, process the input and send output in the form of electrical signals to actuators that may activate some physical action in the machine. They have extremely severe constraints on all resources, including processing power, memory, and, most importantly, price.

Since there is hardly any scope for changing the programming once the tiny devices are manufactured and fitted in their respective machines, correctness of the software is really very important. But the software for these embedded systems is developed on the PC and it is very difficult to simulate the real time behavior of the environment on the PC; so testing the software for correctness is very difficult. Embedded systems professionals use specialized tools for their work. The usage of embedded systems is growing at a rapid pace. The operating systems used include QNX and RTLinux.

In the above description of different categories of devices and their operating systems, you must have noticed that in spite of widely different characteristics and demands of the environments, Unix/ Linux variants is the only family of operating systems that is used on all these devices from the most powerful supercomputers to tiny embedded systems. In the next chapter we shall see the reasons for this as we explore the Linux operating system in more detail.

An Operating System for Smartphones: Android

We are going to discuss the Ubuntu Linux operating system in much more detail in the next chapter. In this chapter, we look at Android, a popular operating system for smartphones and tablet PCs.

Figure 5.6 : The Android Icon and Logo

Categories of Mobile Phones

A mobile phone that is only a mobile phone, and not much more, is called a basic mobile phone. A mobile phone that provides some additional features over the basic phone, like a music player, video player, simple games, limited web browsing, basic support for third party applications, etc. is called a feature phone. Even though there are no standard definitions of these terms, the key features of a smartphone are touch screen operations, full web browsing capability, the availability of office productivity applications, a powerful programming system that enables development of a rich and diverse set of software applications that go much beyond the functions of a mobile phone, one or more application stores from where new applications (free as well as paid) may be downloaded, a range of sensor devices for input, etc.

A smartphone or a tablet (or phablet) is actually a small computer and functions as a combination of a phone, a Personal Digital Assistant (PDA) providing secretary-like functions (calendar with scheduling, memos and notes, to-do lists, meeting reminders, access to office documents, messaging service or instant email notifications, etc.) and a portable entertainment hub. However, with improvement in technology, each category is moving up the features ladder and release of intermediate models by companies blurs the lines between these categories. Often, the distinction is made based on price, with the three categories mentioned above sporting successively higher price tags.

What is Android ?

Android is a free and open source operating system for smartphones that is being developed by the Open Handset Alliance, whose most prominent member is Google, Inc. Android uses a slightly modified version of the Linux kernel. It is designed to support a diverse set of devices. Even though the list of devices running Android include watches, phones with small screens and only numeric or qwerty keyboards, touch screen phones, mid-sized phablets (phone + tablet), larger sized tablet computers, TVs and even microwave ovens, the operating system is primarily designed to provide a rich and attractive user experience and a large number of small software applications ("apps") for smartphones and tablet computers. At the time of writing this, Android is world's No. 1 operating system for smartphones in terms of volume shipments (number of phones sold). Many leading mobile phone manufacturers make Android based smartphones.

Key Features of Android

Android provides several features and benefits as a smartphone or tablet operating system. It is free and open source and it is not tied to one particular device maker. Manufacturers also have the option of tweaking the operating system and making changes and/or improvements to distinguish their product from others because the source code is available. Because of competition among the manufacturers, prices are relatively lower and companies constantly try to add new features to their devices. It provides an attractive user interface and rich multimedia support. It has support for accessing and controlling almost all hardware features of the latest smartphones and tablets, like touch screen with multi-touch gestures, phone location information (positioning using satellite), motion sensors,

wireless networking (2G/3G/4G mobile network, Wi-Fi, Bluetooth, Near Field Communication or NFC), voice and video telephony, text messaging (SMS), Internet access, listening to podcasts (live audio on the Internet), watching webcasts (live video on the Internet) and Live TV programs, camera(s), microphones and speakers, etc. not only from the built-in applications but also from third party applications and our own applications. Clever use of inputs from these diverse set of sensors along with Android's built-in capabilities allows the development of innovative, highly interactive, very useful and visually stunning apps with creative modes of interacting with the device.

3G & 4G make it possible to make video calls where the two parties can see each other. The availability of positioning information (the mobile's current location) and information-rich worldwide maps makes it possible to create location aware applications that guide you with directions in an unknown city (both in the form of a map as well as voice guidance like "Now turn left…"), lead you to a restaurant when you are hungry, show you the nearest bank branch or ATM when you need some cash, then take you to the nearest shopping mall so you can use up that cash :-), tell you when one of your friends is by chance in the same area at that time so you may meet them and finally show you the bus/railway/metro routes on the map along with the schedule and guide you to the nearest station when you are ready to leave the city. The ability to access motion sensors is used by the operating system itself to switch between portrait and landscape modes when you rotate your phone. It is also used by games that are played by simply tilting and rotating the phone and applications that let you control the phone just by moving it. For example, if you are busy and your phone rings, you may simply turn it upside down to reject the call.

You may use your phone network or a public/home wireless network (Wi-Fi hotspot) to access the Internet. Using Bluetooth, you may exchange files with another phone or laptop, connect a headset, hands-free set or a keyboard with your phone, etc. Using NFC, you may exchange contacts, visiting cards or files or make payment by simply waving your phone at (or making it touch) another device. Access to the camera enables applications that allow you to take a picture and upload it to a social networking site instantly, or take the picture of a place or a product and obtaining more information about it (not very accurate yet), or scan bar codes or QR codes ("Quick Response" codes specially designed for mobile phones), etc. If your parents have a phone with a QR code reader (sometimes called barcode reader) application, scan the code in Figure 5.7 with it and uncover the message encoded in it!

Figure 5 7 : A QR Code

Voice recognition technology, though in early stages, not only enables you to issue voice commands to your phone, it also allows the user to dictate notes and messages and search the web simply by speaking out what you are looking for. Android also has security features. It provides a well-known programming system for developing apps with a large set of built-in functions. The biggest advantage Android enjoys is that it is backed by the search giant Google, it already has a large number of programmers developing apps for the platform and hundreds of thousands of apps have already been developed for it, including apps for various phone related functions, Internet surfing, email, chat, social networking, photo editing, audio and video playing and editing, office productivity (like word processor, spreadsheet, presentation), simple and highly demanding 2D and 3D games, etc. Generally, Android phones have access to Google's Google Play app store, which, at the time of writing, had 6,00,000 apps. Some other companies have their own app stores for their Android phones.

Android as an Operating System

In spite of the seemingly large differences, operating systems for mobile phones follow the same general principles that we discussed above. They perform similar functions, have analogous components and fit in the same general definition of an operating system. The tablets presently have 7 inches or 10 inches touch screens and therefore are comfortable to work with. They provide almost all features for users (not developers) which are available on normal PC or laptop. However, the challenges faced by the mobile phone operating systems is a resource-constrained environment (smaller screens, less processing power, less memory and the need to conserve battery power), need to support different set(s) of input/output devices and far greater variation in the hardware. In recent times, the fast pace of technological advancement has also made the job more difficult. But it is the same development that has enabled us to do things that were not even conceivable in the not-so-distant past. We are living in an exciting era.

Summary

In this chapter we were introduced to an operating system. We learnt about different characteristics of an OS. We came to know that an operating system performs several functions including management of processes, input/output and memory and all other resources. It also provides protection of resources and enforces policies on computer system usage and responsiveness. An operating system typically comes with many utility programs, though whether they form part of the operating system or not is a matter of debate. Operating systems form an essential ingredient of computer systems of all shapes and sizes.

Operating systems based on Unix/Linux are used across the whole spectrum of computing devices. We also learnt that though smartphone operating systems like Android have radically different user and device interfaces and face a different set of challenges, at the core they are still the operating systems.

EXERCISE

1. List the major functions of an operating system.
2. What is multiprogramming ?
3. What is a multiprocessor system ?
4. What is the role of the operating system with regard to resources in the system ?
5. How does a multiuser system work ?
6. Why is security important in multiuser systems ?
7. List the typical components of an operating system.
8. What is the kernel ? What are its main jobs ?
9. Differentiate between CLI and GUI.
10. What is a file system ?
11. Why do we need a file system ?
12. What is QR code ?
13. Which are the common features of tablets ?
14. **Choose the most appropriate option from those given below :**

(1) What is the full form of BIOS ?

(a) Best Input Output Software (b) Basic Input Output Software

(c) Best Input Output System (d) Basic Input Output System

(2) Which of the following component acts as an intermediary between the operating system and the hardware ?

(a) kernel (b) shell

(c) device drivers (d) utility programs

(3) Which of the following is a function of the operating system ?

(a) resource management (b) Time management

(c) memory management (d) All of these

(4) Which of the following component of the operating system interacts with the user ?

(a) shell (b) kernel

(c) device drivers (d) I/O devices

(5) The hardware devices are directly accessed by which of the following entity ?

(a) the operating system (b) the kernel

(c) the device drivers (d) the shell

(6) Which of the following is the core component of an operating system ?

(a) the shell (b) the kernel

(c) the device drivers (d) the GUI

(7) What is the full form of CLI ?

(a) Command Line Interface (b) Command Line Interaction

(c) Common Line Interaction (d) Common Line Interface

(8) What is the full form of GUI ?

(a) Graphical User Interaction (b) Graphical Understandable Interaction

(c) Graphical User Interface (d) Graphical Useful Interaction

(9) Which of the following cannot be an object in a file system ?

(a) directory (b) file

(c) user data (d) folder

(10) Which of these sometimes come with only the kernel and not much more ?

(a) proprietary OS (b) free OS

(c) embedded systems OS (d) super computer OS

(11) Which of the following is NOT a limitation on a smart phone ?

(a) processing power (b) power consumption

(c) memory (d) network

(12) Which are the smallest computers on the planet ?

(a) smartphones (b) tablet computers

(c) embedded systems (d) PDAs

(13) Which operating system family is present in all categories of devices ?

(a) Microsoft Windows (b) Unix/Linux

(c) i/OS (d) OS X

(14) Android is developed by -

(a) Microsoft (b) Google, Inc.

(c) Open Handset Alliance (d) Samsung

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