Comparative Research on Recent Trends, Designs, and Functionalities of Various Operating Systems

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Abstract - **This paper presents a comparative survey of three well known operating systems which are Windows, Linux, and Macintosh. The basic criteria for studying them are mostly focusing on the fundamental memory and file management, architecture, security, versatility and other topics. These topics are being compared in this paper. This research study gives us an overview of the main topics and on the various similarities and differences in the basic use of operating systems. Every operating system has its own set of differences in the composition and structure of the operating system and this study focuses on the underlying strengths and weaknesses of each operating system.**

Keywords: Linux, Windows, Mac, UI, Architecture, File Management, Security

I. INTRODUCTION

The operating system is a software which works as an interface between a user of a computer and the computer hardware system and also manages and coordinates the use of hardware among various applications and users [1]. It is a collection of software that helps in managing hardware resources and provides common services for computer programs. It is one of the most essential parts of the computer. The five major activities of an operating system are Process creation, Processing state, Process synchronization, Process communication and Deadlock prevention. Applications require an operating system (OS) to perform and the computer itself needs OS to maintain the security of the system and for creating a GUI/CLI base for the user to access and perform tasks on the computer. There are many software functions that depend on OS such as cost allocation of processor time, mass storage, printing etc, while hardware functions such as input and output of memory allocation system calls etc need the OS as well. In this paper we look at three different types of OS and all their components and features (*Linux, Windows*, and *Macintosh*). We compare them based on several features like booting process, user interface information, handling system resources, file management, device management, security, versatility, efficiency, architecture, reliability, cost, choice etc. After every feature one tabular comparison of three

operating systems is presented to facilitate ease of understanding. Within the many different types of operating systems, the four main general types can be categorized into Real-Time Operating System(RTOS), Single-user single task, single-user multi-tasking, and multi-user.

RTOS is used to control control machinery, scientific instruments and industrial systems. An RTOS typically has very little userinterface capability, and no end-user utilities, since the system will be a "sealed box" when delivered for use. [2] These types of systems are amazing at managing its resources so tasks can be performed in a timely manner.

Single-user, single task systems are designed to let one user use the system effectively. It is mainly used for handheld devices. Single-user, multi-tasking a single user to perform or run several programs at the same time. This is the type of OS that is most allows commonly used in desktops and laptops. Windows and Mac OS are examples of this type of OS. [2]Multi-user operating system allows`multiple users to use the resources simultaneously in a balanced way. It makes sure there are sufficient resources as to not cause trouble to any of the active users. Examples of multi-user OS includes UNIX, VMS and mainframe OS.

Linux OS is a very popular operating system that is being used all over the world for not only personal use, but also used majorly in supercomputers and data centers. It has replaced Windows and Mac OS due to its numerous advantages in security and versatility of OS. Anyone can use and modify the system to their liking and a large number of distributions (distros) run on this kernel.[3]

Windows is an operating system which was developed by Microsoft and it's first version came up on November 20,1985.[4] It is based on the Disk Operating System(DOS) which is well known for it's black screen and command line. After the release of Windows 95, Windows started dominating the market. This was because Windows 95 was the first one to have Graphical User Interface(GUI) in its front and DOS in back.This was indeed a revolution for a non-computer person.

Mac operating system was developed by the apple in 1984 by the Apple Inc[5]. Macintosh computers used the

Motorola PowerPC Chip which is set with an advanced architecture enhanced for graphics and multimedia interface and usability. Macintosh OSs was strictly GUI environments, with no command-line option. Since 2005 the Apple Mac line of computers are Intel-based, but the Mac OS is only licensed to run on an Apple Mac which is the first multitasking operating system. Mac OS X, with its UNIX origins, gives us the option of a character-based interface Apple Computers is the only manufacturer of Macintosh computers. Transferring files and applications from old Mac to a new one is a more efficient process when the computer is to migrating from one windows PC to another. Apple's Mac operating system has some powerful productivity and multimedia apps that are preinstalled.

TABLE I. COMPARISON OF VARIOUS OS BASIC FEATURES

Linux	Windows	Mac Os
Released in 1991 in Finnish University. Mainly designed for GNU developers. Later it was integrated to Linux.	Released in 1985 and was supposed to be a Graphical User Interface(GUI) on top of MS-DOS. Later with the release of Windows 95 version all features were integrated. This was kind of a revolution in the market.	It is the oldest out of the three and was released in 1984. From the beginning, it was a Graphical User Interface (GUI). Later in 2005, its design and architecture were changed to Intel x86 based architecture.[9]

II. LINUX VERSUS WINDOWS VERSUS MACINTOSH

A. Booting Process

It is the first step that takes place when we switch on a computer or it is a process to start a computer. It can be done by both hardware(by pressing start button) and software (by command) means.

LINUX - The booting process takes place in six steps. First the MBR (Master Boot Record) is executed by the basic Input/Output system. Then the Grand Unified Bootloader(GRB) is executed by the MBR. Then the kernel gets executed by GRB. Then /sbin /init are executed by kernel. After this, runlevel programs are executed by Init and these run level programs are executed from /etc /rc.d /rc*.d as shown in Figure 1 below.
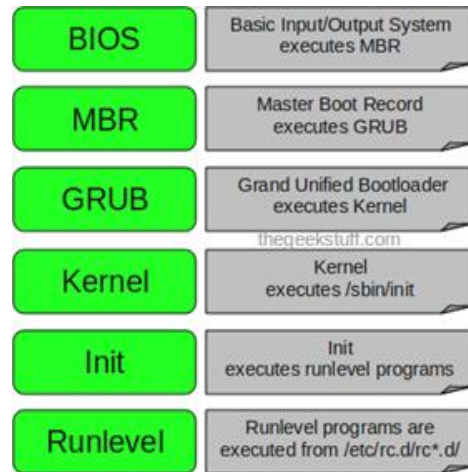

Fig. 1. BOOTING PROCESS OF LINUX OS

WINDOWS - Booting process begins when the computer is turned on, which is called a cold boot. On switching on the computer, it performs a Power On Self Test(POST).. MBR is looked for in the bootable device. Now boot sector and BOOTMGR is located through the MBR. BOOTMGR searches for active partition and reads the BCD file from the boot directory on the active partition.Drivers are loaded by winloader and are set to start at boot and then control is transferred to windows kernel. The step by step process is shown below in figure 2.
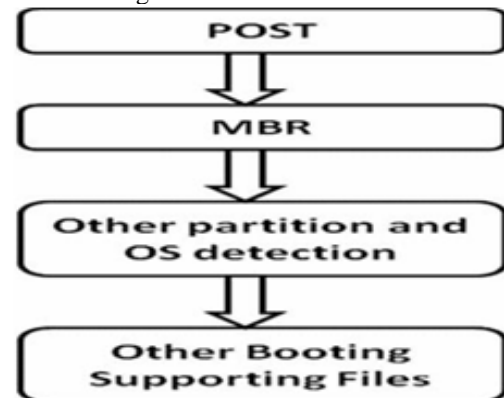

Fig. 2. BOOTING PROCESS OF WINDOWS OS

MAC - Here, when the power is switched on, the OF or EFI code is executed. Then all information about hardware is collected and it is initialized. Now control passes to the boot loader.[2] The kernel is loaded by BOOTX and also OS badges are drawn if any. Now the execution of the routine kernel takes place. The root device of the booting system is identified and at this point Firmware is not accessible any more. Now the initialization of the I/O kit takes place after which the kernel starts as seen below in figure 3.
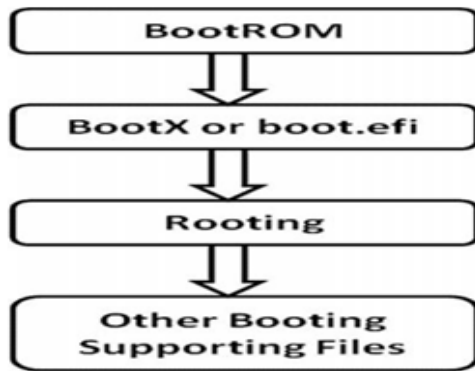
Fig. 3. BOOTING PROCESS OF MAC OS

TABLE II. COMPARISON OF VARIOUS OS BOOTING PROCESSES

OS → Features ↓	Windows	Linux	Mac
BIOS	Yes	Yes	No
POST	Yes	Yes	Yes
Boot Loader	NLTDR	GRUB or LiLo	BootX or boot.efi
Kernel	NTOSKERNEL	INIT , initrd	mach_init , launchd
Supporting Files	win.sys, HAL.DLL, system.ini,sysedit.exe,config.exe, autoexec.BAT, MSCONFIG.exe	/sbin//init, /etc/inittb /etc/rc.local , /runlevel	mkextcache, launchd, loginwindow , /System/Library/CoreServices

As seen in table 2, all three operating systems have the same POST step in common. This experiment also shows that out of the three OS, Mac is the only operating system which does not support BIOS and instead uses BootROM where it has a boot loader called BootX or Boot.efi. [2]

B. User Interface Info

A user interface is that part of an operating system that allows users to enter and modify information. In other words, it acts as a medium of communication between the users and operating system

LINUX - In Linux you have the option to use both GUI and CLI. Although CLI seems superior to the GUI, it is not true. CLI can never be used for editing videos and the user is far more likely to use a graphical audio player to set up playlists for example. Image editing also clearly requires a graphical user interface.

WINDOWS- The Graphical User Interface(GUI) is an integral component of Windows, so it is not replaceable. There is also command shell program(cmd) that can directly run. The name itself suggests that programs are run in separate "windows". Each program is run in a particular window, that's why we can have several programs running at the same time.This is the most popular operating system for home computers. The latest version of Windows is Windows 10.[6].

MAC OS - The graphical user interface and visual theme of Apple's Mac OS is "AQUA". It's original theme was 'water',, with droplet-like components and the concepts of reflection and translucency were used. Its aim is to "inculcate colour, depth and complex textures into a visually appealing interface" in macOS applications.The image below in Figure 5 shows the different UIs for the three operating systems and how they compare with each other. Clearly all three have their own looks and give users a comfortable user experience.
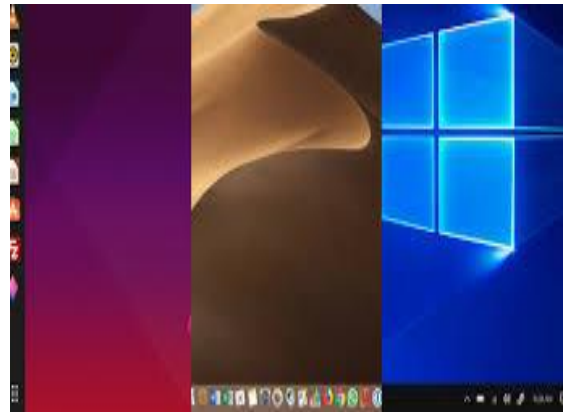

Fig. 4. USER INTERFACE OF LINUX, MAC, WINDOWS (LEFT TO RIGHT)

C. Handling System Resources

Monitoring system resources like memory,mass storage, network access, processor part is a necessary part of troubleshooting.

LINUX - The 'TOP' command in Linux helps in monitoring programs which is used often by many administrators to monitor system performance. This command is used to keep a list of running and active real-time processes and this list is updated regularly. It helps to display CPU usage, Memory usage, Swap memory, Cache size, Buffer size, Process pid, User, commands etc. Then the command 'Vmstat' shows details about virtual memory, system processes, disks, I/O blocks, interrupts, CPU activity etc. The command 'lsof' is used to display a list of all processes and open files.

WINDOWS - In Windows, a program makes a request to the operating system whenever it needs any hardware resources. Windows then responds to the request by providing the required software. The easiest way to monitor resources in Windows is to open the Task Manager window on the Performance Tab as seen in figure 6 below. The shortcut to open this window is Ctrl+Shift+Esc. Here we get to see CPU and memory usage.
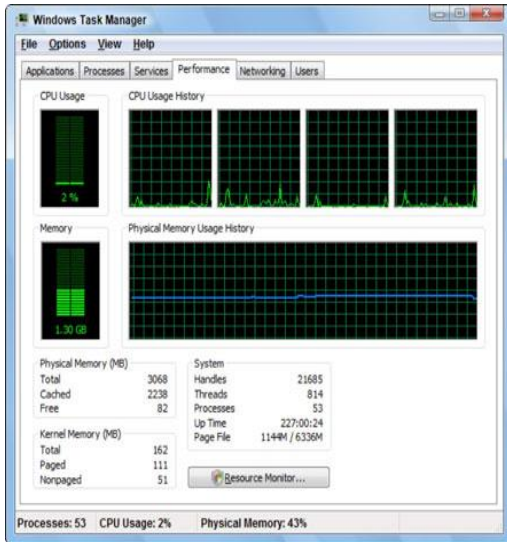
Fig. 5. TASK MANAGER FOR WINDOWS OS

MAC OS - In Mac OS, we have 'Activity Monitor' which shows the processes running on our system. By this we can manage resources and see how we can evaluate Mac's activity and performance. We can either find it through 'Spotlight' or open from the Utilities folder of Application as seen in figure 7 below. Activity Monitor shows processes like user apps, system apps used by Mac OS or background processes which are invisible.
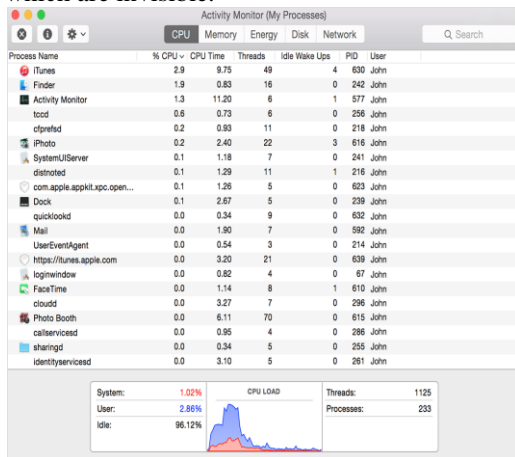

Fig. 6. ACTIVITY MONITOR IN MAC OS

D. File Management

File management is one of the most basic but important features found in operating system. It manages different types of files with various extensions. It can create, update and delete files

LINUX - Linux file systems refer to how linux based computers organize, store and track system files. The File system is basically a combination of directories or folder that serves as a placeholder for addresses of other files. In other words, there is no distinction between a file and a directory in Linux file system, because a directory is considered to be a file having names of other files. Hence, software programs, services, texts, images and so forth are all considered files. In the same way, input and output devices are considered to be files according to the file system. It also provides the namespace which comprises the naming convention as to

how a file can be named in terms of the length and character combinations. It also includes the organizational framework which is the logical structure of the files on disk, often arranged in a hierarchical form using directories.

WINDOWS- The job of file management is done by 'Windows Explorer' in Windows.[7] It shows a list of files, folders and storage drives on our computer. For eg- when a file has to be copied, we open the desired folder which has the file to be copied or moved and then drag and drop the file to target folder or drive. Windows explorer can be opened by the following steps:-

1. Start-> all programs-> accessories-> Windows explorer.

MAC OS - We use the 'FINDER' to organize and manage our files. Finder, in association with apps like Automator can help users locate documents, search files, manage folders and organize them.The shortcut to opening Finder is simultaneously pressing the "Command" and "N" keys. MacOs has APFS(Apple File System) as its proprietary file system. The Apple File System is primarily focused on encryption along with optimized flash and solid-state drive storage. It uses 64-bit inode numbers. The APFS uses commands like TRIM for better space management and performance. TO ensure Data Integrity for metadata, Apple File System uses checksums.

The different operating systems are being compared below in Table 3 with different types of file systems.[6]

TABLE III. COMPARING FILE SUPPORT SYSTEMS
(BOLD - DEFAULT FILE SYSTEMS)

File System	Windows	Linux	MAC OS
FAT, exFAT	Supported	Supported	Supported
UDF	Supported	Supported	Supported
ISO 9660	Supported	Supported	Supported
HFS+ , HFS	Supported via 3rd-party drivers	Supported	Supported
ext2, ext3, ext4	Supported via 3rd-party drivers	Supported	Supported via 3rd-party apps
NTFS	Supported	Supported	Supported Read Only

E. Device Management

It is the act of coordinating between devices of a computer by device drivers and device controllers. It is used in managing hardware, storage and input and output devices. It keeps track of status of all devices connected to a computer.

LINUX - There are very few devices that are compatible with Linux OS still. However for the hardware devices that are compatible but the ones that are supported work on all versions of linux. Linux is also a very developer friendly OS that allows developers all around the world to add on to its database. Due to its low cost and ability to easily customize,

linux is often used in non-mobile telecommunication networks. Most customer premises equipments and embedded systems use linux as well.

WINDOWS - Device management is a Control Panel applet in Windows Os which allows users to view and control the hardware attached to the computer. It provides a way to uniformly notify all apps and system features that may affect their operation or access to resources. It also allows us to update and reinstall drivers for individual devices.

MAC OS - Apple devices are not only able to safely access network services due to its multi-layered secured foundation but also protect important data. iOS and macOS, through the mobile device management (MDM) solution follow a policy of passcode and password thereby guaranteeing security. By chance an Apple device falls into the wrong hands, with the help of a user or an administrator a remote command can be used to erase all private information. A secure computing platform for Apple devices can be achieved through the following:

i) Methods are adopted to that prevent the unauthorized use of devices

ii) Protection of data at rest,when the device is stolen or even lost.

iii) Following networking protocols and encrypting data during transmission

iv) Apps run securely without having to compromise its platform integrity.

These capabilities work together to provide a secure computing platform.

F.   Security

It is the process of implementing mechanisms to protect an OS externally as well as internally. This is mainly done by ensuring integrity, confidentiality and availability in the operating system.

LINUX - Although Linux OS is well known for having better security than other operating systems, since most distributions are created with privacy, information security, and anonymity in mind, they are still vulnerable to some attacks. Similar to the risks that most computers face, Linux OS is still vulnerable to viruses that can be downloaded from the internet. This can be prevented by basic security including scanning for viruses, using firewalls and setting up file permissions.[6] Since linux is also an open source platform, new features and security patches are released frequently that allows the user to maintain its security.

WINDOWS- Microsoft Windows is the world's most popular consumer operating system and this is why it is so popular. It is used as a standard in many office environments. But at the same time, this popularity makes it a target for malware. Windows is a closed source operating system where the users or security community doesn't have access to the source code.[8] So while installing Windows , we can select privacy protecting options:-

i) While installing Windows, we have to accept 'Express settings' or we can simply click on Customize settings.

ii) Then on the first Customize settings, we have to turn on all the settings.

iii) Click on 'NEXT' to go to next customize settings screen.

iv) On the second Customise Settings screen leave Use SmartScreen online service to help protect against malicious content and downloads in sites loaded by Windows browsers and Store apps activated as it will enhance security. For the remaining options click 'on' to change them to 'off'.

v) Then we have to continue with Windows installation.

MAC OS - MAC operating system is very unique compared to the rest as they are specifically designed for Apple devices. There is no third-party developer. As a result, MAC has a strong shield around it that protects the OS from malwares and viruses. Along with this, MAC also supports the user acknowledgement while executing any files. Apple regularly releases update for Mac OS to enhance the security.

G.   Versatility

An operating system that is versatile allows the user to run multiple programs, and complete different types of work at the same time. It allows the user to change and modify the system to their liking.

LINUX - The biggest advantage when it comes to Linux is the ability for the user to change the distribution to the way they are comfortable with, especially on the desktop.[9] The OS is easy to use and allows the user to customize to their liking and comfortability since the operating system is open source. The majority of linux distributions are flexible enough to run on many devices (including mobile phones) and are reliable enough for critical systems. Linux distributions come with an advance package management system that allows users complete control of their system.

WINDOWS- Windows has developed a lot since 1985, when it was installed. It supports a wide range of activities. The latest version of Windows 10 has been redesigned to protect data from security threats. Windows Hello, an access control feature , is a password-free sign-in service that gives users hassle-free access to their devices.[10] Several new security features have been installed like fingerprint, face-unlock etc. It also includes Device Guard to safeguard intellectual property. Recently, new features like Windows Ink, Windows Edge and Cortana have been installed in Windows 10. The various versions of Windows 10 are :-

i) Windows Pro

ii) Windows home

iii) Windows enterprise

iv) Windows education [9]

MAC OS - Many Mac users believe that MacOS is easier to install and update, offers faster updates with less hassle, and allows applications to be installed and managed with greater ease. MacOS also comes with a deep range of applications for free, including the music composition tool GarageBand, video editing application iMovie, and a complete productivity package consisting of Pages (word processing and layout), Numbers (spreadsheet), and Keynote (presentations).[11] The MacOS Preview app provides a wide range of features, including editing PDFs.

H.   Efficiency

An efficient Operating system allows the computer system resources to be used efficiently which increases the processing speed of the computer.

LINUX - Linux OS is one of the fastest and most effective systems that is out in the real world right now. It is especially useful for older computer that can not support more intense Operating systems such as Microsoft and Mac. It helps older computers get back up to speed and gets them running smoothly again. Compared to Microsoft, Linux OS even consumes less RAM.[12] Since linux does not come with extras such as animations and other extra features, Linux OS can perform well in a system with just 2 GB of RAM while Windows might require 4GB of RAM. A linux system can also be made more efficient by disabling the graphical user interface (GUI). Unlike most other operating systems, Linux does not require a GUI. Almost everything can be done using command line interface (CLI). This process saves CPU cycles and memory.

WINDOWS - As new versions of windows came up, users started liking them. People liked Windows 7 because of its easy installation, cash-free nature, fabulous graphics support for HQ games, better UI and also best security. Recently, after Windows 10 came up, people liked it more because of its fast nature, reliability, takes responsibility of our every move . It's worth every penny because of its design, features, speed, accuracy, privacy and security. It contains so many new features. So as a whole every version of Windows OS has been fully efficient and has satisfied the users.

MAC OS - OS X Mavericks introduces powerful new technologies for energy efficiency.Mac Hardware are so designed to be capable of energy-saving with optimizations at every level of the operating system, right from the kernel and application frameworks to the built-in applications you use every day.[13] Mac OS X is based on Darwin, it which uses a kernel called XNU which has a hybrid characteristics and was created by a combination of a 4.3BSD kernel and the Mach kernel. On the other hand, Windows has its own Windows NT Kernel. A general overview can say that Mac OS X uses a more sturdy kernel compared to Windows. Moreover, Mac experience is about using it right away.

I. Architecture

The interface between a computer's hardware and its software is its architecture. The architecture is described by what the computer's instructions do, and how they are specified.

LINUX - Originally developed for Intel's x86 hardware, there are ports available for over two dozen CPU types including ARM.[14] The linux OS architecture has one of the Highest level of abstractions. There are three main levels of architecture including Conceptual, concrete and file system. The conceptual architecture as seen in Figure 8, shows the way the developers think about the linux OS while the concrete architecture as seen in Figure 9 shows the actual architecture of the operating system.
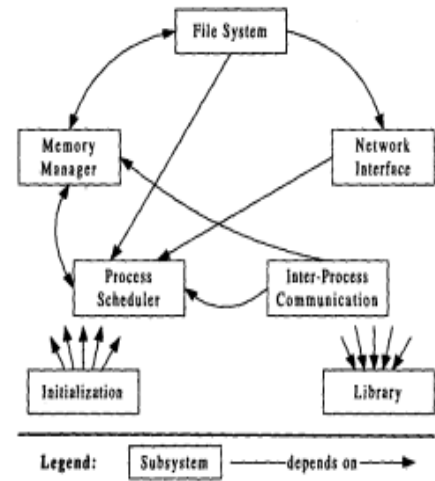

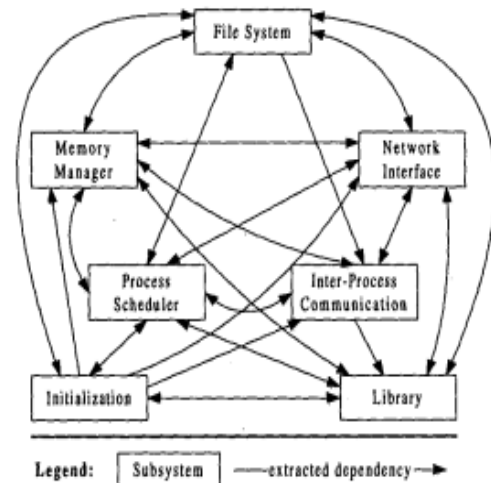Fig. 7. CONCEPTUAL LINUX ARCHITECTURE

Fig. 8. CONCRETE ARCHITECTURE OF LINUX OS

As seen in figures 8 and 9, the concrete architecture has the same subsystems but the dependency relations are very different. Conceptual architecture has relatively fewer dependencies between top level systems (around 19) while concrete architecture is almost fully connected (almost 37 out of 42 inter subsystem dependencies). [15]

WINDOWS- The several blocks of Windows OS are :-- i) Process refers to a running program in execution. ii) Executable binary: It comprises the initial code and data to execute code within process. iii)Private virtual address space: Used as allocating memory for code within process on requirement basis. iv) Primary token: This object stores multiple details regarding default security context of process and used as reference by threads within the process. v) Private handle table: Table used for managing executive objects such as events, semaphores and files. vi) Thread(s) for process execution. Processes are identified by unique process id. This ID remains constant till respective kernel process object exists. Now it's important to note that every running instance of same binary will get separate process and process id. vii)Virtual memory - The OS provides separate private linear virtual address space to every process which is used by processes to allocate memory to

executables, threads, DLL's etc. [16] This architecture can be seen below in Figure 10.
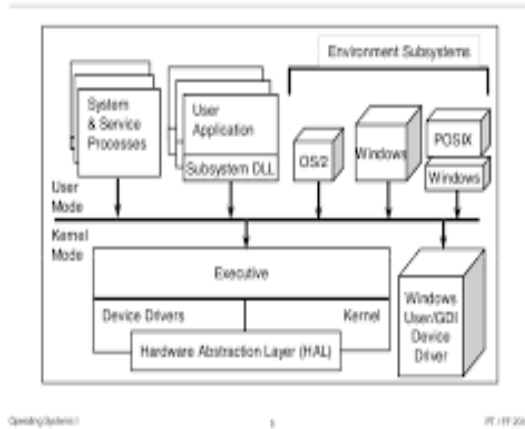

Fig. 9. SIMPLIFIED WINDOWS ARCHITECTURE

MAC operating system developed by Apple Inc. Mac OS X launched in 2001 is the tenth version of Mac OS. The multiple layers of Mac OS X are given below:

1. The base layer of the system is the Unix core called the Darwini.[17] The Darwin core supports features such as protected memory, preemptive multitasking, automatic memory management, advanced virtual memory, power management. etc. It also provides the I/O services for Mac OS X and supports hot-swapping and plug-and-play.

2. Next layer is the graphics system which contains Quartz, OpenGL and QuickTime.

- Quartz is responsible for the 2-D graphics in the graphics subsystem. It provides interface graphics, fonts, renders images etc.
- OpenGL supports the 3-D graphics in the system such as transparency, texture mapping, special effects antialiasing, atmospheric effects, etc. As a fact, even Unix and Windows System uses the same.[18]
- QuickTime is used in the different digital media such as video streaming, digital video, audio etc. It also supports creative applications such as iMovie, iTunes etc.

3. Then is the application layer which comprises of four components, namely Classic, Carbon, Cocoa and Java.

- The classic environment makes sure that applications run smoothly when written for the previous versions of the operating system.
- The carbon environment is used to transfer the existing applications to carbon application program interfaces. This is called carbonising the application.
- The cocoa environment provides the Mac OS X structure with an object-oriented application development environment.
- The Java applications applets are run using the Java environment.

4. The topmost layer called Aqua, is the user interface. It provides visual features as well as the tools to customize the user interface as per the requirements of the user. This architecture can be seen below in figure 11. Table 4 below compares the three different architectures with different architectures that it supports.[5]
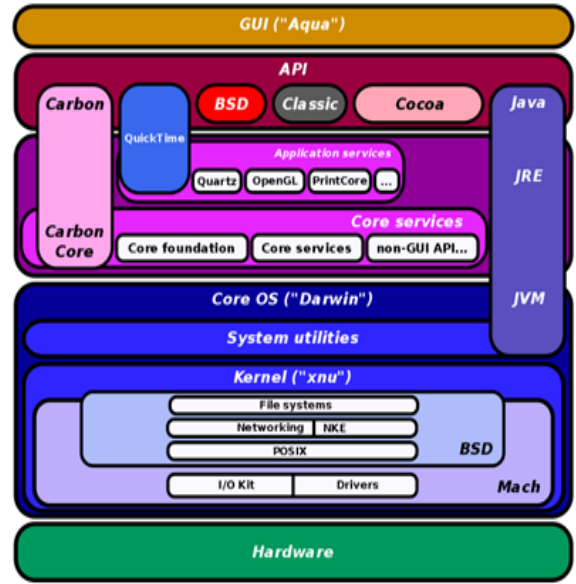

Fig 10. SCHEMATIC DIAGRAM OF MAC OS X ARCHITECTURE

TABLE IV. COMPARING ARCHITECTURE SUPPORT

Architecture	Linux	Windows	MAC OS
x86	Supported	Supported	Supported
x86-64	Supported	Supported	Supported
PowerPC	Supported	Not Supported	Supported
ARM	Supported	Supported via Windows NT	Supported

J. Reliability

Reliability of a computer is a measure of how consistently it performs according to its specifications. It is one of the main attributes that must be considered when making, buying, or using a computer product or component.

*LINUX - T*he majority of Linux variants and versions are notoriously reliable and can often run for months and years without needing to be rebooted. It powers about 99% of the top 500 supercomputers and they are usually the servers of many major websites (eg Google, Facebook, etc).

WINDOWS- According to statistical data, Windows has become much more reliable than it used to be.[19] But still Windows suffers from BSOD crashes and Linux can still be crashed by simply plugging a peripheral that its does not recognize so they are not perfectly reliable, despite years of improvement. Both are less reliable to Mac OS.

MAC OS - Mac Computers are designed from scratch by Apple.

1. The production line is taken care of from the beginning to the ending.

2. Apple devices are made incredibly stable as every component of the device is tested and assembled to work properly.

3. Many of the softwares are not compatible with MAC OS which makes it much Reliable And Smooth because it has no Virus.[20]

K. Cost

The cost of an operating system is how much it might cost the average consumer to buy and use that operating system.

LINUX - There is no comparing Windows to Linux when it comes to money. Linux is a well known open source platform while windows and mac are very expensive. Linux can be freely distributed freely through books, magazines etc, and downloaded freely and legally. Although there are linux distributions that the user has to pay for, it is still normally cheaper than windows. It is free , so anyone can download it and use it.

WINDOWS- Windows is not cheaper than Linux. This is because Linux is not a full operating system. It's only the kernel, the central part of the operating system, without which computer can't run programs or use devices such as hard disks. Microsoft Windows, on the other hand, is a proprietary 'closed' source software package that has its own kernel and software to present a user interface. Creating and supporting an Operating System for every modern CPU or piece of computer hardware takes considerable effort and Microsoft therefore charges for this: it's a business with employees and shareholders after all. Free and Open Source Software relies on the efforts of individuals doing this work for the challenge, fame or glory. It is expensive and its cost starts from $100.

MAC OS - Apple computers are way too expensive than some PCs, but are worth the amount when considering the value we receive for our money.[21] Macs get software updates on a regular basis which makes them more valuable and capable over time.Even vintage Macs are kept safe through bug fixes and patches available on the older versions of MacOS. Lastly, it's very hard to argue against its aesthetic value. Usually users love the way something looks than how it works. It's the most expensive compared to Windows and Linux as the user has to buy a whole Mac system built by Apple. Figure 11 below compares the average cost of all three types of operating system.[6]

Price Comparison

Fig. 11. COMPARISON OF PRICES OF THREE DIFFERENT OS

L. Choice

Choice in an operating system allows the user to customize and change the OS to their liking.

LINUX - Most Linux distros can be freely downloaded and legally installed on as many computers as you want. Because most distros are open source, you have access to the source code and can customize Linux to be whatever you want it to be; you can even create your own distro if you like. [3] Linux provides more choice in your OS than the other two operating systems. The user gets a freedom of choice within linux itself when they choose their version of distribution in Linux OS (Red Hat, SuSE, Mandrake, etc.).[22] Linux OS allows you the freedom to choose between the smallest of things to the most significant features such as the packages you want to be installed on the computer, how the user wants the hard drive to be partitioned to even the UI that you want (GUI vs CLI).

WINDOWS- Although windows is a very user friendly OS, it doesn't not allow for users to customize the OS as freely. The only choice users have are the day to day settings of the Computer as well as the choice of applications they choose to interact with. The Windows OS source code is not open source therefore it is not easily customizable by everyone.

MAC OS - Mac OS has a very easy to use interface that allows the users to navigate with ease. Like linux, mac is also open source now allowing users to customize their OS. It allows users to create their own apps with ease and lets them customize their desktop to their liking.[23]

Worldwide Server Operating Environment Shipments/Subscriptions and Nonpaid Deployment Share by Operating Environment, 2017
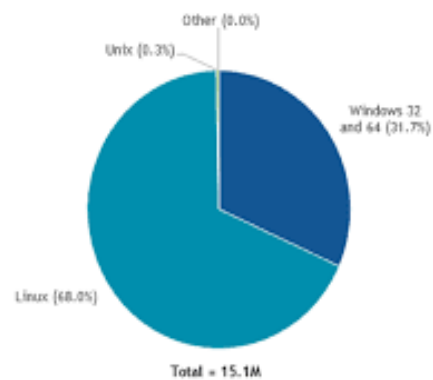
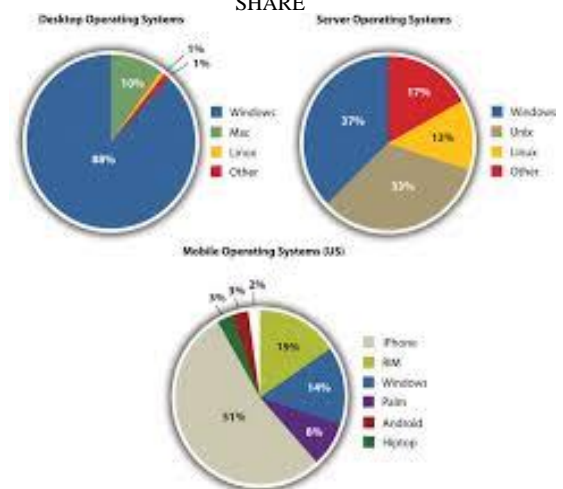Fig. 12. WORLDWIDE SERVER OPERATING SYSTEMS MARKET SHARE

FIGURE 13. COMPARISON ON VARIOUS FACTORS

Clearly, Windows is dominant over Linux and Mac Os as 90% of the users prefer Windows as seen in figure 12 and 13.[6] Linux is the least used operating system with 1% of users percentage. Mac is quite popular with 7% of user bases over the world.[24] As Windows has the largest number of people using it, it is most likely to be affected by malware. Linux and Mac has the minimum chances to be affected by malware.

III. CONCLUSIONS

Thus operating system acts as an interface between users and computer hardware. In this paper, we have compared operating systems like Linux, Windows, Mac OS on the basis of certain features. Result of our comparison is that none of them are bad. Each one has their own advantages and disadvantages. Our target is to give an overview to users, which can help them choose an operating system that fits their needs.[8]

REFERENCES

[1] Noopur Bardhan, Pooja Singh," Operating System Used in Cloud Computing", (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 6 (1) , 2015, 542- 544

[2] Amar Rajendra Mudiraj, "Windows, Linux, and Mac Operating System Booting Process: a Comparative Study", *International Journal of Research in Computer and Communication Technology*, volume 2(11), 2013, 2278-5841

[3] Peng, Yi, et al. "Modeling the Evolution of Operating Systems: An Empirical Study." *The Journal of Systems & Software*, vol. 80, no. 1, Jan. 2007, pp. 1–15. *EBSCOhost*, doi:10.1016/j.jss.2006.03.049

[4] S. Cahya, "Designing Operating System Simulator: A Learning Tool." pp. 156-160.

[5] Varun Chaudhary, Rajeev Mishra," Operating System Selection using AHP on the basis of Security, Cost and Boot Time", Volume 4, Issue 5, May 2014 ISSN: 2277 128X.

[6] Istyak Rana, Md. Mahmud Yusuf "Choosing Operating System: Windows, Linux or MAC?" American International University-Bangladesh.

[7] Blythe 06] Blythe, D.: "The Direct3D 10 System"; ACM Transactions on Graphics, 25, 3 (2006), 724-734

[8] M. R. Yaswinski, M. M. Chowdhury and M. Jochen, "Linux Security: A Survey," *2019 IEEE International Conference on Electro Information Technology (EIT)*, Brookings, SD, USA, 2019, pp. 357-362. doi: 10.1109/EIT.2019.8834112

[9] Sahil Bhardwaj, Sahib Arora, Sachin Malik, "Research Paper on Operating System", *(IJIRT) International Journal of Innovative Research in Technology*, volume 1 (5), 2014, 2349-6002

[10] "Linux as a Case Study: Its Extracted Software Architecture." *Proceedings of the 1999 International Conference on Software Engineering (IEEE Cat. No.99CB37002), Software Engineering, 1999. Proceedings of the 1999 International Conference On*, 1999, p. 555.

[11] Goran Martinovic, Josip Balen, Bojan Cukic, "Performance evaluation of recent Windows Operating system",Journal of Universal Computer Science, vol 18, no 2(2012), 218- 263.

[12] Sahil Hussain, Faisal Bahadur, Fariq Gul, Arif Iqbal, Ghazala Ashraf, Sumat Nazeer."Survey on Windows and Linux as server operating system", International Journal of Computer(IJC),ISSN 2307-4523.

[13] Hussain A. Alhassan, Dr. Christian Bach, "Operating system and Decision Making", ASEE 2014 Zone I Conference, April 3-5, 2014, University of Bridgeport, Bridgeport, CT, USA.

[14] W. Liu, X. Li, W. Huang et al., "OSISS: An operating system integrity surveillance system based on VMM." pp. 546-549.

[15] Goran Martinovic, Josip Balen, Bojan Cukic, "Performance evaluation of recent Windows Operating system",Journal of Universal Computer Science, vol 18, no 2(2012), 218- 263.

[16] Watson, R. N. M.: TrustedBSD: Adding Trusted Operating System Features to FreeBSD, Proceedings of the FREENIX Track: 2001 USENIX Annual Technical Conference, Berkeley, CA, USA, USENIX Association, pp. 15–28 (2001).

[17] W. Chengjun, "The analyses of Operating System structure." pp. 354- 357.

[18] S. Beyer, R. Taylor, and K. Mayes, "Operating system support for dynamic code loading in sensor networks." pp. 5 pp.-315

[19] L. Hongjuan, and L. Yuqing, "A Design of Trusted Operating System Based on Linux." pp. 4598-4601.

[20] G. Martinovic, J. Balen, and S. Rimac-Drlje, "Impact of the host operating systems on virtual machine performance." pp. 613-618.

[21] H.-Y. Zhou, and K.-m. Hou, "LIMOS: A lightweight multi-threading operating system dedicated to wireless sensor networks." pp. 3051-3054.

[22] W. Liu, X. Li, W. Huang et al., "OSISS: An operating system integrity surveillance system based on VMM." pp. 546-549.

[23] S. Cahya, "Designing Operating System Simulator: A Learning Tool." pp. 156-160.