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Evaluating the Dominance of Operating Systems in Mobile Computing: A Survey Approach

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Abstract— Mobile computing revolves around the idea of being able to carry around your computer wherever you go. It is also known as the capacity to engage data and information without being at a certain physical place or network connection. The primary goal of mobile computing is to eliminate the requirement for a physical connection to send data. Mobile computing relies on software, hardware, and wireless communication. This research aims to provide a comprehensive review of mobile computing devices and operating systems from various papers. Essentially, it is a review paper in which most of the central operating systems are defined and compared in terms of security, market coverage, and customer satisfaction. In addition, the security issues, benefits, and limitations of mobile computing are also discussed in detail.

Keywords— Operating System, Mobile Computing, Smartphone, Mobile, Windows.

I. INTRODUCTION

Mobile computing is a technology which allow interaction between humans and computer. It also allow users to send and receive data, audio, and video via a network of devices that are not physically attached. The fundamental idea behind mobile coworking is to transfer data without a physical connection. The phrase "mobile computing" refers to the usage of mobile devices that are linked to a wireless network. Mobile computing has attracted a lot of attention in computer science and engineering. This domain encompasses, to mention a few, wireless networking, distributed systems, operating systems, distributed databases, software engineering, and application development. [2]. When a computer is supposed to be motivating throughout regular use, it's called mobile computing. Software, hardware, and wireless connectivity all play a role in mobile computing. On the other hand, mobile software focuses on the needs of mobile apps. Additionally, hardware encompasses the components and gadgets required for mobility. In communication Protocols, data encryption, and specific technology are all in concerns. Computing on the move refers to using a computer while moving from one area to another [3]. Mobile computing is all about portability. It is also known as the capacity to employ computational capability without bound of location or access to a system to engage data and information [11]. Mobile computing includes three primary components which are mobile communication, mobile hardware, and mobile software (or applications). These refer to the communication infrastructure, which includes wireless network architecture, protocols, data formats, bandwidths, and web portals required to provide smooth connectivity and communication. Mobile Hardware: The hardware consists of mobile computing devices and supporting equipment that has the capabilities necessary to complete their respective operations and connect to networks. The operating system, also known as the "brain" of any computing system, is the most critical software component. Depending on the laptop, this may be Windows, Linux, or macOS; likewise, depending on the smartphone, this could be Android or iOS. The various programs that run on a smartphone are also considered part of the mobile software [12].

Any device built using mobile components, such as mobile hardware and software, is referred to as a mobile computing device. Mobile computing devices are small, portable computers that can operate, execute, and provide services and applications the same way that a traditional computing device would. Mobile computing devices are often referred to as portable or handheld computing devices. Mobile communication strategies have become the most widely accepted for communication between peoples in almost every country, having surpassed the penetration of all other electric devices combined. To do many things in mobile computing, like transfer data, make voice calls, send messages, use audio, video, camera features, etc. Mobile devices also need to have an operating system [10, 13]. Operating systems are used in mobile phones, tablets, wearable computers, 2-in-1 PCs, smart speakers, and other mobile devices. Mobile operating systems usually include a modem and a SIM card for making and receiving phone calls as well as sending and receiving data. To deliver a complete mobile computing experience, Add some extra features such as a touch screen instead of keyboard, Bluetooth connection, Wi-Fi connection, a global positioning system (GPS), mobile steering, camera, speech recognition, voice recorder, different music player, near field communication, and an electromagnetic blaster to the features of a personal computer OS. Users can connect to the application shops of device manufacturers, such as App Store off Apple, Android Market of googles, App World of blackberry, OVI Store of Nokia, Palm App Catalog of Palm, Windows Market place of Windows Mobile's, and so on, to acquire access to new programs and services [10].

Numerous mobile operating systems are available. Each of these operating systems has developed over time.

Different operating systems have a variety of different characteristics or features. There are a few studies that compare the progression of diverse properties of mobile operating systems, and clients of various mobile operating systems may or may not be aware of this evolution. In this paper, an analogy on existing popular computing devices and mobile operating systems are conducted. Moreover, a distinction on these devices and OS(s) are also established here based on their performance, security, user-friendliness and so on. Furthermore, their security challenges, benefits and limitations are also discussed here.

The aim of this research is to provide a comprehensive review of mobile computing devices and operating systems from various papers. Essentially, it is a review paper in which most of the central operating systems are defined and compared in terms of security, market coverage, and customer satisfaction. An overview of mobile computing devices and operating systems can be obtained by reading this study. Readers will also gain an understanding of the security risks associated with mobile computing. An ideal guideline for selecting operating systems are also provided in this study so that a reader can easily choose an operating system for their daily use.

This paper is organized by using five sections where firstly introduction, then it followed by the relevant works on the use of operating systems in mobile computing in section II. Then, section III contains the methodology. After that, section IV contains the findings of this research, as well as a discussion of the findings, and lastly, section V includes the conclusion.

II. BACKGROUND STUDY

The authors of this study [1] provided a comparison on three operating systems which are Android OS, the Symbian OS, and Apple's iOS to identify the function of an operating system in the advancement of effective mobile technology. It also emphasized the importance of open-source operating systems that simplify application development. They find out that Android uniquely produces something great. This article [2] presented an idea of mobile computing. They discussed its achievements, problems, and potential. Two distinct workshops on mobile computing, and its applications in 1996 and 1997 were also covered in this study. The authors of this paper [3] provided a clear overview of mobile computing. Personal digital assistants (PDAs), smartphones, tablet computers, ultra-mobile PCs, and wearable computers were among the devices studied. In addition, they described seven operating systems which are Symbian OS, Windows OS, Palm OS, BlackBerry OS, iOS, Android OS, and Bada OS. Towards the conclusion, the limitations of mobile computing were brought into question. In this paper, the author didn't describe different operating systems. This paper [4] explored the significance of low-end computing, specifically mobile computing, in today's world. To achieve this purpose, five benchmarked mobile phone operating systems were thoroughly examined: Android OS, Blackberry OS, iPhone (Mac OS X), Symbian OS, and Windows Mobile OS. Several security concerns relating to the Android operating system were also highlighted. For this purpose, an upgrade compatible with Android's software architecture has been proposed. This article [7] aimed to analyze the most popular features of mobile operating systems and determine which ones are optimal for both the user and the developer. This article compared the Android, iOS, Symbian, Blackberry, and Windows mobile operating systems regarding their viewpoints, features, and applicability for mobile devices. This article [8] provided an overview of the Android operating system. The history of the platform, including the enhancements made with each version and the system's architecture and project structure, were also highlighted. This paper's [9] objective was to present a discussion about several mobile OS which are mostly available including Android, iOS, Series 40, Symbian, Windows, and Blackberry. Additionally, the anticipated and available security measures were examined. The purpose of this article [10] was to provide an overview and comparative analysis of different OS like Android OS, iOS, Windows Phone, Blackberry OS, WebOS, and Symbian OS which are the six most popular mobile operating systems. Symbian has been the dominant mobile operating system for a long time. Nonetheless, alternative operating systems, such as Android OS, iOS, Blackberry OS, and Windows Phone OS, are currently dominating the smartphone industry. The goal of this article [6] was to look at the way mobile computing could be used to manage on-site information on infrastructure and to develop a model for mobile computing in construction information and communication management. Following the model, choosing a mobile computing strategy included defining the information management process, creating a summary for a mobile computing explanation, figuring out a strategy of mobile computing, and electing the efficient mobile computing technology.

III. METHODOLOGY

This study is a complete review of different operating systems used in mobile computing. For doing this study, we have reviewed several papers. From those papers, we are trying to identify some research gaps, such as some papers only described five different OS; some papers only described six different OS. But in this study, we are reviewing the top five different OS used for mobile computing devices. Again, some papers didn't mention mobile devices properly. One of them described but didn't briefly describe new trends in mobile devices. In

this paper, we mention five mobile devices with a brief discussion. Later, we compare different OS based on customer satisfaction, market coverage, code availability, and lacking applications. We have reviewed different papers from the list mentioned earlier; then, we analyze some pros and cons of different OS and compare them. We found some tables regarding the comparison from those papers, and we are importing them here. In previous work, most of the authors skipped the security challenges of Mobile Computing. Only a few papers described security issues of Mobile Computing, but they didn't describe them adequately. In this study, we describe the security challenges of Mobile computing and mention some core features for mobile computing security which should have in a mobile device. After that, we will describe the benefits and limitations of mobile computing. Mobile computing has some benefits and limitations, but most authors didn't mention those things. So, for a complete study, we also mention the benefits and limitations. For benefits, we are getting help from different web resources, and for limitations, we reviewed some papers and some resources. So, to conduct a complete study, we followed the above steps.

IV. FINDINGS AND DISCUSSION

As discussed earlier, this study focus on the comprehensive review of mobile computing devices and operating systems from various papers. So, different types of mobile computing devices, mobile computing operating systems, possible security challenges, benefits and drawbacks of mobile computing are briefly summarized here.

1. Mobile Computing Devices: Mobile computing devices are typically modern-day handheld devices equipped with the hardware and software necessary to run regular desktop and Web applications. Mobile computing devices feature hardware and software components comparable to those found in personal computers, including processors, random memory and storage, Wi-Fi, and a basic operating system. However, they vary from PC(s) in that they are designed primarily for mobile infrastructure and mobility, as opposed to PCS. There have been many devices for Mobile Computing since the 1990s, such as-

1.1 Personal Digital Assistant (PDA): Small, mobile, handheld devices are known as "Personal Digital Assistant" (PDA) and are used for keeping track of schedules, calendars, contacts, and other personal and professional information. Organizing and communicating on the go has never been easier with a PDA. A PDA is a palmtop computer or a personal data assistant, is a small handheld computer. PDAs often include touch screens for input with a finger or stylus, memory cards for extra storage, organizing software that is calendar and address book, and the ability to connect to a computer by a cable or a wireless protocol called Bluetooth. Apps, such as business software or games, can be installed. According to [3], a PDA meets all the criteria for connecting to the internet, including an electronic visual display that incorporates a web browser and audio capabilities that allow it to work as a portable media player. Most of the Personal Digital Assistant(s) can connect to the internet, intranets, or extranets utilizing wireless networks. However, they had been around for about a decade before Apple CEO John Sculley popularized the word in 1992. PDA, pager, and cellular phone makers began to merge the functions of those devices into a new type of gadget known as a smartphone in the mid-90s.

Figure 1. Sample PDA

1.2 Smartphone: An electronic device that connects to a cellular network is a "smartphone". Today, there are a variety of manufacturers offering smartphones, including Apple and Samsung. IBM invented the world's first smartphone in 1994. One of the first smartphones to incorporate a touchscreen and email and programs like a calculator and sketch pad was code-named Simon. From [3], it appears that the initial smartphones functioned as an extension of the personal digital assistant (PDA). High-resolution touchscreens and web browsers have been included into later generations of portable music players, low-end compact digital cameras, pocket video cameras, and GPS navigation equipment. High-speed data access and mobile internet are both made possible by Wi-Fi. Since then, the capabilities of mobile phones have improved significantly, notably after the year 2000. When Apple (AAPL) debuted the iPhone in 2007, it was a game-changer. Before iPhone 3G came out in 2008, more than 3.62 billion people used cell phones worldwide [17]. Smartphones now running Android, iOS, Symbian, BlackBerry, Samsung's Bada OS, Web, Sony Ericsson, and Microsoft's Windows Phone all utilize the most prevalent mobile operating systems (OS). As a result, these operating systems can work with many phone types.

Figure 2. Sample Smartphone

1.3 Tablet Computer: The phrase 'Tablet Computer' refers to a computer between the size of a laptop and a smartphone. Touch screens have replaced keyboards and styluses as the primary input means for tablet computers. The tablet computer's forerunners included the Stylator (1957) and the RAND Tablet (1961), both of which used a stylus to input data into a more extensive computer. In the last 2 centuries, conceptual ideas for the tablet were the most common ways to show off the idea. Commercial portable electronic gadgets based on this notion appeared in recent decades. In 2010, Apple introduced the iPad, a tablet computer with a touchscreen operating system, and it was the first commercially successful tablet. A new tablet market has been created, and many other manufacturers have followed suit. These include Samsung Electronics Co.; HTC; Motorola; RIM; Sony; Amazon; HP; Microsoft; Archos. There were a lot of tablets on the market with different operating systems, but Apple made the most popular ones, Android, Windows, and QNX, which are all made by RIM. In [3], a tablet can be used for wireless mobile browser functions, e-mail, and social media work. It can do this by using mobile data or WiFi. Possible capabilities of a mobile technology include instant messaging, conference calling (through loudspeaker or headset), GPS navigation, camera functions, photo viewing and editing, e-book reading, and downloadable programs like games, educational tools, or media players.

Figure 3. Sample Tablet Computer

1.4 Ultra-Mobile PC: An Ultra-Mobile PC (UMPC) is a small, handheld computing device that can run on Windows OS. Although it is smaller than a laptop, an Ultra Mobile PC has more outstanding capabilities than a palmtop. Ultra-mobile personal computers, often known as UMPCs, are smaller versions of pen computers. [4] state the facts: The initial Tablet PCs, announced in 2002 with much hoopla, were not a runaway success, but in 2005 Microsoft introduced the Origami Project with added software advancements. Samsung's Q1 and Tablet Kiosk series are examples of smaller, more powerful Tablets. At barely over 2 pounds, these devices have a 7-inch touchscreen display. When it comes to note-taking and editing, ultra-mobile PCs are the perfect tool. Many options for document production are available to the user. These include voice recognition, handwriting recognition and a virtual keyboard. High-performance computer tasks, such as graphics editing or gaming, cannot take advantage of their low power consumption. For the first time in this market, a Linux-powered tablet has emerged. Tablets have been overtaken by smaller PCs with keyboards. For example, Sony Vaio UX and OQO models are ultra-compact minis with 41/2 to 5-inch screens that weigh in at 1.2 pounds. They have both Wi-Fi and cellular data network access.

Figure 4. Sample Ultra-Mobile PC

1.5 Wearable Computers: A wearable computer is a small computing device that may be attached to a user's body, such as a wristwatch. [3] Known as "body-borne computers" or "wearable computers," these tiny electronic devices are connected to the wearer's body and may be used for many purposes. This type of wearable technology was created for the advancement of media and technology in general or in particular. Smartwatches, which can perform many of the same functions as a smartphone's "smart" capabilities, are one example of a wearable computer. Users can read and respond to emails, send text messages, surf the web, see images or videos and receive social media notifications using more advanced wearable computing devices. Wearables are usually worn on the wrist, strapped to the arm or head, or hung from the neck. In addition, it can perform multiple tasks at once. As a result, you don't have to interrupt your current activities to use the device. As with any prosthetic, the user has the option to incorporate these devices into their daily life. So, it can be an addition to the user's thoughts.

Figure 5. Sample Wearable Computer

2. Mobile Computing Operating Systems: Application programs operate on mobile devices, such as PDAs, tablets, cell phones, and smartphones, using a mobile operating system (sometimes known as a "Mobile OS"). When it comes to mobile operating systems, there have been three stages: PC-based operating systems, embedded systems (which have been available for a decade), and the current smartphone-oriented operating system. Mobile OS architecture has gone from sophisticated to simple to something in-between during the development process. Technological improvements in hardware, software, and the Internet naturally propel the evolution process forward. The use of mobile operating systems is increasing dramatically. Analysts are optimistic about even more significant breakthroughs in the coming days [9]. The mobile operating system may be classified as one of two things, based on the current computer operating system divides [16]-

a) Real-Time Operating System (RTOS)
b) Single user single-tasking operation system
c) Single user multi-tasking
d) Multi-user operating system

Today's marketplaces provide a diverse range of mobile phones from several manufacturers and with a variety of operating systems. An operating system's primary responsibilities are to manage and operate hardware units and to assist the user in their use (OS). Mobile operating systems have been designed to enable users to interact with phones in a manner like how personal computers were used a few decades ago. Among the most popular mobile operating systems are Android, iOS, Windows Phone OS, and Symbian (OSs). All four operating systems have market share ratios of 47.51%, 40.97%, 3.311%, and 2.571%, respectively. Other operating systems for mobile devices are less popular (BlackBerry, Samsung, etc.) [14, 15].

2.1 Android OS: According to [7], Android is a multi-process system where each application) execute its process. There are several challenges to overcome when dealing with Android OS security. Keeping an open platform safe necessitates a robust security architecture and precise security processes. According to [4,] Android is the most extensively used mobile operating system for touchscreen mobile devices such as smartphones and tablets. It was developed jointly by Google and the Open Handset Alliance. From [5, 9, 10], Android is currently the most popular smartphone platform built on the Linux kernel by Google. Each day, over a million new Android-powered smartphones are registered throughout the globe. It is a free and open-source software platform. Thus, many mobile manufacturers adapt and adopt it as their primary operating system, which is also true for a competing mobile phone platform, LiMo for Linux Mobile, an open-source initiative backed by Mozilla/Firefox, Panasonic, and Samsung. As of now, Motorola and Samsung are both selling LiMo-compatible smartphones. One more open-source mobile phone platform is the OpenMoko project. A consortium led by Google is creating the Android smartphone operating system. Google first showed off android in November of 2007. There is also a significant community of developers that create software (apps) that enhance the capabilities of Android-powered devices. Java is the programming language of choice for most developers. Android's core is open source; however, many of the programs installed on Android devices, such as the Google Play Store, are proprietary and licensed to their respective owners. Several firms are involved in the Open Handset Alliance (OHA), one of which is Android developer Motorola. These and other Android-developing companies formed the OHA. Mobile devices and services can be developed and distributed much more quickly and cheaply if new technologies are developed. The very first Android phone was introduced in October 2008, and by the end of 2010, it had surpassed Apple's iOS as the world's biggest smartphone platform, with a 59% market share in 2012 [3]. Essentially, there are four layers to the Android operating system. The Linux kernel is responsible for system services such as security, memory supervision, process management, and other similar functions. Android Runtime, which provides a suite of libraries for the functionality found in the Java libraries, is based on the Android platform. It has a set of C/C++ libraries that developers can use through the Android framework. The application framework provides an access layer to the framework API(s) used by the application [7].

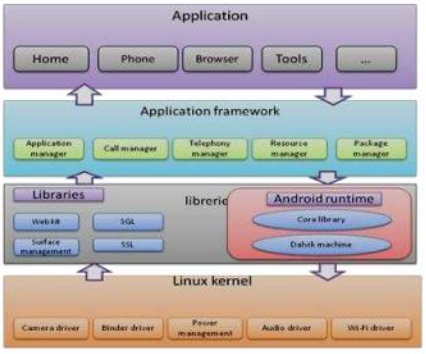

Figure 6. Architecture of Android Mobile OS

2.2 iOS: iOS, originally known as iPhone OS, is an operating system developed and sold by Apple Inc. This program, which was first released in 2007 for the iPhone and iPod Touch, has been upgraded to incorporate support for other Apple devices like as the iPad and Apple TV. iOS is based on OS X, which is based on Darwin, which implies that iOS, like OS X, is a Unix operating system. Apple's mobile operating system, iOS, is available on iPhones, iPads, and Macs. Since iOS is not an open-source operating system, third parties find it difficult to create or change it. A collection of required

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tools must exist [1]. In this case, the software development kit (SDK) is what you need. To obtain the iPhone SDK, you must first sign up for an Apple Developer Connection subscription [8]. Before downloading the free SDK, you must sign a contract that says you agree to the terms. Since the SDK can only be used on Mac OS, this is a significant barrier for iPhone developers. As of August 2008, Mac OS accounted for only 8% of the PC market, excluding 92% of prospective developers. According to [7], Apple doesn't let people put third-party programs on the iPhone, which could make it less likely to get infected with malware. Apple's operating system, iOS, has built-in security from the start. Apple's iOS platform consists of four layers: Core OS, Core Services, Media, and Cocoa Touch, according to [10].

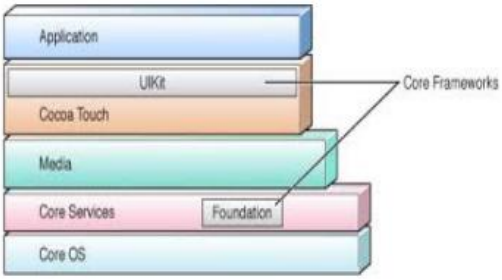

Figure 7. Architecture of Apple's iOS

2.3 Windows OS: Microsoft developed Windows as a series of mobile operating systems for smartphones to replace Windows Mobile and Zune. Windows Phone is no longer supported. Windows Phone introduced a new user interface modeled by the Metro design language. [3,9] Windows is the most widely used computer operating system. They have strengthened their attention on mobile operating systems during the last five years. It will debut a new user interface with a 'Metro' aesthetic. They created Windows CE (Compact Edition) for portable devices, based on the Windows API. Later that year, Microsoft released the Windows 7 operating system. The most current version of the Windows 8 mobile operating system, launched in June 2012, has various wonderful features such as support for multi-core processors, improved Wi-Fi screen quality, enhanced storage capacity, and near-field communications. Windows 8 on a mobile device is nearly identical to the desktop version. Windows 8.1's mobile version is under development and was released in 2014. Microsoft is working on Windows Phone devices with several different hardware manufacturers. [10] In February 2011, Nokia and Microsoft announced that Windows Phone 7 would be the dominant operating system for all future Nokia devices. Upgrades have been made to Windows Phone 7's software. ROMs in Windows CE.NET architecture store both the operating system and any included apps, such as Pocket Word and Pocket Excel, according to [7]. ROM-based modules must first be decompressed before being paged into RAM during the compression process. On a Windows CE system, the RAM is partitioned into two sections: one for object storage and one for program memory. The windows CE.NET scheduler maintains a priority list for each process and thread in the operating system. There can be many threads that form a distinct execution path for each process. The application layer, application framework layer, OS kernel, and hardware are the four primary layers of the Windows operating system. Between the OS kernel and API layer, there are three models: the App model, the UI model, and the integration of the cloud.

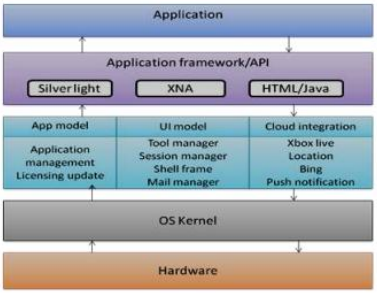

Figure 8. Architecture of Windows Mobile OS

2.4 Symbian OS: Mobile phones running Symbian OS are generally utilized on Nokia advanced or data-enabled smartphones. Symbian OS is based on Psion's EPOC, a primitive operating system designed for early electronic organizers based on ARM processors. In the late 1990s, the Psion EPOC OS was called EPOC16 to help people distinguish it from the newer 32bit operating system EPOC32, which later became Symbian OS. As mentioned in [3,9,10], Symbian Ltd. built the basic operating system and licensed it to Nokia and other phone makers. Symbian is a mobile operating system that incorporates common libraries, user interface frames, and other utilities. It is the direct successor to Psion's EPOC and is entirely powered by ARM processors. As a result of these considerations, Symbian OS has been optimized for low memory requirements and low battery use. As a multitasking operating system, it relies on a few external components. All applications are built to run in the background seamlessly. By adhering to established standards, the Symbian OS ensures applications' long-term viability and interoperability. Memory management is tailored to the needs of embedded software. The original Symbian OS was divided into two components: a core OS that supported a Device Family Reference Design (DFRD) and a DFRD-based user interface (UI). Different UIs might be created for different device kinds or for phones manufactured by different firms but sharing the same OS core. The Pearl UI by Nokia and the Quartz UI by Ericsson were two examples. After that, this concept was dropped to distribute various user interfaces to various enterprises. Symbian's operating system is separated into five layers: the user interface framework, application services, base services, kernel services, and hardware interface. Additionally, there are four service levels under the application services layer: general operating system services, communications services, multimedia and graphic services, and connection services [7].

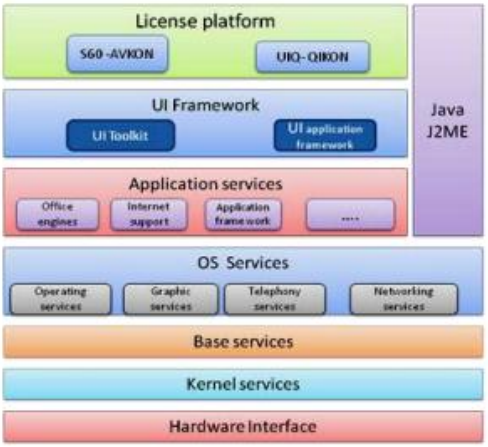

Figure 9. Architecture of Symbian Mobile OS

2.5 Blackberry OS: BlackBerry OS is a mobile operating system that is compatible with just BlackBerry phones manufactured by Research in Motion (RIM). BlackBerry is the manufacturer. BlackBerry phones such as the Bold, Curve, Pearl, and Storm use the BlackBerry operating system. The BlackBerry OS is a popular option for smartphone users because to its robust push Internet email features. This capability is provided by the BlackBerry Enterprise Server (BES), which is available in versions for Microsoft Exchange, Lotus Domino, and Novell Groupwise. BlackBerrys may be used as PDAs, media players, web browsers, game consoles, and cameras, among other things, according to [3]. Their most distinguishing characteristics are the ability to send and receive push email and instant messaging while maintaining a high degree of security with on-device message encryption. BlackBerry smartphones provide a variety of messaging programs, but the most popular is BlackBerry Messenger. End-to-end encryption is available, as indicated by [9,10] Blackberry. There are two methods for encrypting data. The Advanced Encryption Standard (AES) and the Triple Data Encryption Standard (TDES) are two methods of encryption (Triple DES). When it comes to Blackberry smartphones, Java is the only language used because of the strong integration. Blackberry phones have a unique (JVM) that can run both Java ME and Blackberry-specific Java APIs. Java is used to construct third-party software. The application, operating system, Java virtual machine, and hardware layers are all part of Blackberry OS.

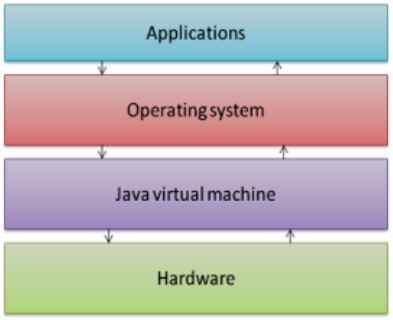

Figure 10. Architecture of Blackberry Mobile OS

3. Comparison of Different Mobile Computing OS: In paper [1], the author found that Android has a more significant advantage than other operating systems because this OS is easy to develop. As we know, Android OS is based on open-source OS, and Mac OS is closed. The programmer can develop Android OS quickly rather than Mac and Symbian OS. The Android operating system can run on a wide range of devices. Users had already installed Android on devices manufactured before the Android operating system was made publicly available. Android is an open-source OS that is free for everyone to use and modify. A Java-based app can be created and deployed to an Android phone or tablet. For this reason, many applications are available for Android OS, whereas, in Apple OS and Symbian OS, there is a lack of applications. The author also didn't discuss the satisfaction of people, market coverage, and security issues. But in paper [4], the authors surveyed the satisfaction level of different customers over five OS: Android OS, BlackBerry OS, iPhone OS, Symbian OS, and Windows OS.

Table 1. Survey Summary of Mobile Platform Categories

	Android	Blackberry	iPhone	Symbian	Windows Mobile
Network Scanning	Satisfied	Partially Satisfied	Partially Satisfied	Satisfied	Satisfied
Network Interface Selection	Partially Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Bluetooth I/O	Satisfied	Satisfied	Not Satisfied	Satisfied	Satisfied
Network Interface Control	Satisfied	Satisfied	Not Satisfied	Not Satisfied	Satisfied
Background Processing / Multitasking	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Energy Monitoring	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Power Saving	Satisfied	Satisfied	Partially Satisfied	Satisfied	Satisfied
Low-level Memory Management	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Location Sensing	Satisfied	Not Satisfied	Satisfied	Satisfied	Satisfied
Persistent Storage	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

Openness	Satisfied	Not Satisfied	Not Satisfied	Partially Satisfied	Partially Satisfied
Security	Partially Satisfied	Satisfied	Satisfied	Partially Satisfied	Partially Satisfied
Cost	Satisfied	Partially Satisfied	Not Satisfied	Partially Satisfied	Partially Satisfied
Hardware Independency	Satisfied	Not Satisfied	Not Satisfied	Satisfied	Satisfied
Usability	Satisfied	Partially Satisfied	Satisfied	Partially Satisfied	Partially Satisfied

The survey found that Android's openness and user-friendliness were among the research's top competitors. Apple's iOS was elected the second choice in the research. Many people like the look of iOS right now, which makes it a good choice for a second choice. But in this paper, the author didn't show the market coverage of OSes and the security issues of different OS. In the paper [9], the author showed the market coverage of different OS. They analyze all the Operating Systems and find out the market coverage of different Mobile OSes.

Table 2. Market Coverage of Mobile OS

Mobile OS	Percent
Android	37.19%
iOS	27.18%
Symbian OS	7.98%
Blackberry OS	3.27%
Windows Mobile	1.18%

The analysis found that Android holds the first position in market coverage with 37.19%. iOS is in the second position of market coverage which is 27.18%, and surprisingly older version of the Nokia phone OS holds the third position, known as the Series40 OS. In paper [7,9], the author analyzes the security of five Mobile OSes: Android, iOS, Symbian, Windows, and BlackBerry. They found that as Android OS is an open platform, the security instrument presents a significant threat. Android was created with multi-layered security in mind to give the tractability required for an open platform while also protecting all users of the platform. This operating system security capabilities enable application separation, user data protection, application signatures, and secure inter-process. iPhone doesn't have any security software, and Apple doesn't allow to put third-party programs on them, which could make them less likely to get malware. iOS comes with built-in security when you turn on your phone or tablet. However, the data stored on iOS devices was not very secure. Symbian OS provides a level of protection like that of a gatekeeper. Before installing any programs, the system requests the user's permission. They used The Trusted Computing Base to manage the security measures at the lowest level and are responsible for the system's integrity. Windows operating system focuses on-device encryption, data encryption, data leak prevention, and digital signatures, among other things. However, they are still susceptible to attack. Blackberry devices provide end-to-end encryption. It employs two distinct encryption techniques: Advanced Encryption Standard (AES) and Triple Data Encryption Standard (TDES) (Triple DES). It has been set to utilize two-factor authentication using RSA Secure ID. Users will be needed to grant additional authorization when accessing application data or corporate intranets. This operating system is very secure. The following table illustrates the major difference in these mobile computing OS.

Table 3. Major Differences between Different Mobile Computing OS

Mobile OS	Descriptions
Android	a) An open-source OS made by Google. b) A Java-based app can be created and deployed to an Android phone or tablet. For this reason, many applications are available for Android OS. c) Very easy to use, and you can build your own UI for yourself by rooting the device. d) OS frequently gets an update, thus making you feel that your phone got old in just a year. e) Android smartphones are prone to viruses; thus, the phone deteriorates in a couple of years.
iOS	a) Developed and sold by Apple Inc. b) Not an open-source OS, third parties find it difficult to create or change it. c) Great UI, yet more difficult than Android. d) Everything good in the app store will cost you. e) iTunes is the only recommended means of transferring data.
Windows	a) Windows 8.1 is good Windows 10 looks great. b) Doesn't have many apps in comparison to Android and IOS. c) Not be able to explore every feature of a Windows Phone
Blackberry	a) Designed for blackberry mobiles. b) Mostly considered is a business centric OS. c) Utmost safety.
Symbian	a) Was considered as the handiest OS back in the days. b) S60 was the topmost OS of Symbian lineup. c) Was the OS of renowned Nokia E series, N series, and Asha series. d) Almost came to an end.

4. Security Challenges in Mobile Computing: According to [3], security is a big worry when it comes to using mobile computing standards in the fleet. Mobile networks are connected to the public network, and sometimes it requires careful use of a VPN. It's straightforward to attack the VPN because there are so

many other networks connected to the same VPN. According to [4], open-source operating systems are complicated to secure. Malware attacks took place regularly to achieve malevolent objectives. Hackers alter the operating system's data to achieve their nefarious intentions. Security challenges with open-source mobile operating systems include detecting harmful applications. According to [14], malware is a sort of harmful software that targets and compromises the security of mobile devices. They typically masquerade as respectable and useful applications that people may download and utilize. Nonetheless, they conceal deceptive scripts that perform a variety of actions in the background, jeopardizing the user's security. Identity theft is the act of conspiring to breach a user's privacy by stealing personal information such as their credit card number, login history, or password. Consequently, the device's integrity is compromised. Obtaining monetary compensation is a typical occurrence. Botnets, which are networks of infected computers controlled by a robot or bot that conducts a broad variety of damaging activities on the developer's behalf, are one of the most prevalent kinds of malware. DoS is being deployed with extensive promotional efforts. Once an attacker has access to a victim's smartphone, he or she may use it to steal the victim's identity. Identification may be obtained through the user's sim card or via the phone itself. Malware may also target the device's integrity if the attacker forces the hijacked phone to make phone calls. The attacker may turn the smartphone into a zombie machine that can be used to send spam through SMS or email. Additionally, this form of assault jeopardizes the device's general integrity. This action jeopardizes the organization's integrity. Additionally, mobile operating systems may contain viruses. Personal information and credentials can be stolen because of the malware. According to [9], some requirements for mobile operating security include authorization, device management, identity, and access management, data management, logging, personnel and facility management, network access control, software validation, and patch management, among other things. A mobile operating system can be made more secure and capable of dealing with security challenges.

5. Benefits Of Mobile Computing: According to [18], mobile computing has completely changed how we live our lives now. It has made it easier for us to get things done. After that, here are the main benefits of Mobile Computing-

- ***a) Location Flexibility-*** These have made it possible for people to operate from anywhere if there is a way to connect. A user doesn't have to be in the same place when they work. Their mobility means that they can do a lot of different things at the same time and do their jobs.
- ***b) Saves Time-*** Travel time to and from work has been reduced. Access to crucial papers and files via a secure route or portal is now possible.
- ***c) Enhanced Productivity-*** Users can work wherever they feel most at ease, allowing them to be more productive. As a result, they can work more efficiently.
- ***d) Ease of Research-*** Less time spent in the field collecting data has made research more accessible. It also allows field officers and researchers to collect and feed data without traveling back and forth from the office to the field.
- ***e) Entertainment-*** Mobile computing has facilitated access to various films, instructional, and informational materials. With the progression and availability of faster data connections at a reasonable price, one can access any form of entertainment they desire while browsing the internet for streamed data.

6. Limitations Of Mobile Computing: Numerous disadvantages of mobile computer devices should be addressed, including insufficient bandwidth, insufficient security standards, excessive power consumption, transmission interference, potential health hazards, and human interface with gadgets [3]. The following is a description of what they are-

- ***a) Insufficient Bandwidth-*** Mobile web connectivity is often slower than direct cable connections, GPRS and EDGE technologies, and, more recently, 3G networks. These networks are often available at irregular periods determined by the availability of low-cost mobile phone towers. While high-speed wireless local area networks are reasonably priced, their range is limited [19].
- ***b) Security Standard-*** Security could be a significant issue regarding the fleet's mobile computing standards. A VPN may be attacked through a huge network of networks that are linked via a road [19].
- ***c) Power Consumption-*** Mobile computers must run on battery power when there isn't a power outlet or a portable generator. Due to the compact size of many mobile devices, extra-expensive batteries are required to provide adequate battery life [3].
- ***d) Transmission Interference-*** Weather, terrain, and differences from the closest signal purpose will all affect how well the signal works. Most of the time, reception in tunnels, some buildings, and rural areas is terrible [3, 19].
- ***e) Potential Health Hazards-*** Cell phones may harm delicate medical equipment. There have been claims that mobile phone radiation can cause health problems [19].
- ***f) Human Interface with Device-*** It may be problematic due to the tiny size of displays and keyboards. Additional training time and resources are required for other input modalities, such as voice or handwriting recognition [3].

V. CONCLUSION

People's lives can be made more accessible, safer, more convenient, and more secure because of the rapid advancement of mobile computing and communication technology. Mobile computing offers a plethora of fascinating possibilities. Throughout this paper, a comprehensive description of mobile computing is provided. The personal digital assistant (PDA), smartphone, tablet computer, ultra-mobile

personal computer, and wearable computer are all discussed. Android, iOS, Windows OS, Symbian OS, and BlackBerry OS are just a few of the operating systems briefly mentioned here. A comparison of multiple major operating systems is also presented based on market coverage, security, and customer happiness. Results indicates that smartphone and tablet computer are the most popular mobile computing devices now. For customers' satisfaction and market coverage, android OS is the best mobile computing OS followed by iOS. For security purposes, BlackBerry offers the safest operating system due to hundreds of security procedures running on a dedicated server. Security challenges such as Malware assault and Virus attacks are also discussed in this section. Finally, the advantages and disadvantages of mobile computing are explained and summarized. When users pick an operating system for their career or personal interests, they emphasize various aspects. Its advantages include simplicity of use, high security, professional movements, and a broad range of functions, including official activities, entertainment, financial transactions, search, and news. Based on how vital users think their needs are, they can see which operating system can meet them. They can then select an appropriate and secure one. This study will assist a user in making an informed choice of the operating system.

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