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Investigation on Trends of Mobile Operating Systems

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***Abstract*- In today's world, everybody from a lay man to an industrialist is using a mobile phone. Therefore, it becomes a challenging factor for the mobile industries to provide best features and easy to use interface to its customer. Due to rapid advancement of the technology, the mobile industry is also continuously growing. However, perfection is the key requirement of the mobile users which needs the continous technology refinement in due course of time. This paper reviews the different mobile operating systems *viz.* Android, Symbian, iOS, Windows, and Blackberry considering the different parameters like architecture, user interfaces, processor used, memory utilization, device security, power management, connectivity, cross platforming and cloud readiness etc. This comparative study of various mobile operating systems would help the end users and developers to opt and choose for the right kind of mobile OS to meet their requirement.**

Key words: Android, iOS, Symbian, Windows, Blackberry.

I. INTRODUCTION

Today our life is more connected than a few years back to keep up with the rapid evolution of new mobile phones. With the availability of powerful mobile operating system and with the tremendous growth in mobile communication technology, mobile computing is projected to have the most potential for future growth in both academia and industry.

1.1 Motivation

Mobile operating system allows a user to effectively utilize their time by being in constant touch with their official work while utilizing their commuting and traveling time. Hundred of frequency bands and different operating systems providing thousands of features to the customers seem to be a mind boggling market. This creates confusion for the customers to choose the right mobile and operating system to fulfill their requirements. An operating system is the soul of the mobile device, and every mobile industry want to provide best features in their mobiles. This paper intends to explore different OS perspectives, features & suitability for mobile devices and compares between Android, iOS, Symbian, Blackberry & Windows mobile OS.

1.2 Background

The mobile operating system models are used to provide various interfaces of communication between the software components at the application layer, middleware layers, and hardware devices.

The operating system models were compared based on the parameters like user interfaces, processors, memory utilization, security, power management, connectivity, cross plat-forming, cloud readiness and, execution of software on diversified hardware components and as a development platform. These parameters are indicative for exploring a mobile operating system [1] which is user friendly and helpful for the developer.

Features like camera, global positioning system (GPS), browser, messaging, and music are also gaining popularity in mobile operating systems. However, in the present study, emphasis has been given to the operating system features. Among different operating systems, Android and iOS has taken over the market largely because of their uniqueness [2,3]. At the same time Windows, Blackberry are closely following the lead, depend upon the customer's satisfaction. While Android is java based and freely available, iOS is best at features and quality. Although operating systems attempts to provide very nice libraries with best features, but still they face a stiff market competition [4]. Tools like cross platforming, cloud, updater, mail etc. are gaining popularity in mobile operating system depending on web development tools like Hyper Text Markup Language (HTML5), Cascading Style Sheets, and Java Scripts. Some mobile operating systems that provide drag and drop features require very less programming skills for developing these applications. In market so many tools are available for mobile operating system; the developers are confused in keeping and discarding the useful ones.

All operating system are trying to provide something unique to attract customers, with high performance mobile operating system in front. The technology giant like Nokia, Google, Symbian, Microsoft, Apple, Black Berry are playing important role. They try to give product that popular fit in the market. A few years before, Symbian was the most popular mobile operating system but currently its OS share is down than earlier and the only reason for this is the rapidly changing mobile operating systems market with competition from giants.

New mobile operating systems with advance features should be convenient for developers to deploy and create new applications. The new features like Wi-Fi, gallery, Bluetooth and contact etc are developed in mobile operating system are advantageous for end developers because they need not start from the scratch. Still customers are confused while they opt to purchase a mobile that which mobile operating system is best suitable for them. This paper compares five mobile operating system to help the end-users.

1.3 Aim of the research.

Review five mobile operating system in terms of major parameters as user interface, processor, memory utilization, security, power management, cross plat forming, connectivity, and cloud readiness.

II. CHALLENGES OF OS IN MOBILE ENVIRONMENT

The mobile operating system provides various interfaces of communication between the software components at the application layer middleware layers and hardware devices. The OS manages the hardware and software resources within a device. It performs and manages basic tasks such as the recognition of input from the device keyboard and generation of output to the device's screen. OS also ensures that different programs running at the same time do not interfere with each other [5]. It is responsible for the memory management and for communication within the device. OS can be extended to add additional complexity and functionality to the code. Mobile OS supports the important UI (User Interface) function. The OS is purposely hidden from the user. It's, a base onto which the applications required by the user are loaded. The OS is not only a key element in terms of the tasks it performs but the choice of OS will constrain or enable the functionality of the end device in two key respects; firstly that which is technically possible with any given OS and secondly that which is available, i.e. what applications have been developed for that OS. The OS also provides a consistent interface for applications, regardless of the hardware it is loaded on. Communication between the OS and the applications is done through an API (Application Program Interface) which allows a software developer to write an application for one device and have a high level of confidence that it will be running on another running the same OS.

The mobile OS can be differentiated, as follows, based on the divisions of the existing operating systems used by the computers [6].

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

2.1 Real-Time Operating System (RTOS)

Real-Time Operating System which responds to inputs, immediately and generates results, instantly. This type of system is usually used to control scientific devices and similar small instruments where memory and resources are crucial and constricted. This type of devices have very limited or zero-end user utilities, so more effort goes into making the OS really memory efficient and fast (less coding), so as to minimize the execution time ,in turn saving on power as well. e.g.: 8086 etc.

2.2. Single user, single tasking operation system

This type of OS is better version of Real time OS, where one user can do effectively one thing at a time, which means that doing more than one thing at a time is difficult in this type of OS. For instance the palm OS in palm hand held computer is an example of single-task OS.

2.3. Single user multi tasking operating system

It allows more than one program to run concurrently like printing, scanning, word processing etc. e.g. MS Windows and Apple's Mac OS.

2.4. Multi user operating system

It allows two or more users to run programs at the same time. Some OS permit hundreds or even thousands of concurrent users. e.g. UNIX, and Main Frame OS.

III. RESEARCHABLE ISSUES.

3.1. Architectures comparision of Mobile Phone

The mobile phone OS considered for comparison are Android, iOS, Windows, Symbians, and Blackberry.

3.1.1 Android

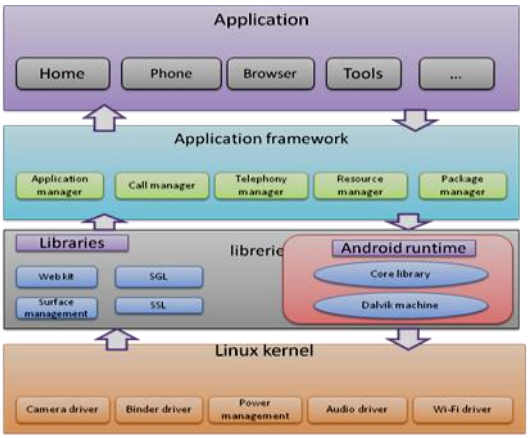

Fig 1 Architecture of Android Mobile OS

Android Inc. was founded by Andy Rubin. In 2005, after Google acquisition, the Rubin's team developed the Linux based kernel. On the November 5, 2007 the Open Handset Alliance – an alliance of several companies including Google, HTL, - released their first product of Android in Market [7]. The internal architecture of Android OS is shown in Fig 1. The OS is divided into components, as application layer, application framework, libraries, android runtime, and a Linux kernel. There is a distinct separation between each component layer with message passing protocol communication between layers. The first commercially

available phone to run the Android operating system was the HTC Dream, released on 22 October 2008. Applications are usually developed in the Java using the Android Software Development Kit. Android offers open development platform. Android OS is used on smart phones, notebooks and tablets, including the Dell Streak, Samsung Galaxy Tab, TV and other devices.

The main hardware platform for Android is the ARM architecture (ARMv7 or later, Android 5.0 also supports ARMv8-A), with x 86 and MIPS architectures also officially supported. Both 64-bit and 32-bit variants of all three architectures are supported since the release of Android 5.0.Since 2012, Android devices with Intel processors began to appear, including phones and tablets.

Linux supports core system services such as security, memory management, process management, network stack, and driver mode. The kernel acts as an abstraction layer between the hardware and the rest of the software stack. Runtime includes core libraries and Dalvik virtual machine. Core libraries have a set of core libraries that provides most of the functionality available in the core libraries of the Java programming language. Every Android application runs in its own process, with its own instance of the Dalvik virtual machine. The Dalvik VM executes files in the Dalvik Executable (.dex) format which is optimized for minimal memory footprint. The VM is register-based, and runs classes compiled by a Java language compiler that have been transformed into the .dex format by the included "dx" tool. The Dalvik VM relies on the Linux kernel for underlying functionality such as threading and low-level memory management.

Android has a set of C/C++ libraries. The system C library is a BSD-derived implementation of the standard C system library [4]. The media libraries are based on Packet Video's open CORE which supports playback and recording of many popular audio formats.

All Android applications are written with Java programming language. Developers have full access to the same framework APIs used by the core applications [8]. Content providers enable applications to access data from other applications or to share data with others. The resource manager providing access to non-code resources such as localized strings, graphics and layout files. The notification manager enable all applications to display custom alter in the status bar. The activity manager manages the lifecycle of applications and provides a common navigation back stack.

3.1.2 iOS

Iphone 6 features an A8 chip built on second-generation 64-bit desktop-class architecture. It is enhanced by an M8 motion coprocessor that measures activity from advanced sensors. Earlier versions were developed from ARM processors.

In iPhone, Hardware refers to the physical chips soldered to the iPhone's circuitry. The actual processor falls under this layer, but the instruction set and in-memory descriptor tables are contained within the "processor" layer [9].

Firmware refers to the chip-specific code that is either contained with memory in/around the peripheral itself, or within the drive for said peripherals.

iphone OS is the kernel, drivers, and services that comprise of the iPhone Operating System. It sits between the user space and hardware.

Objective-C runtime is comprised of both the Objective-C dynamically-linked runtime libraries, as well as the underlying C libraries.

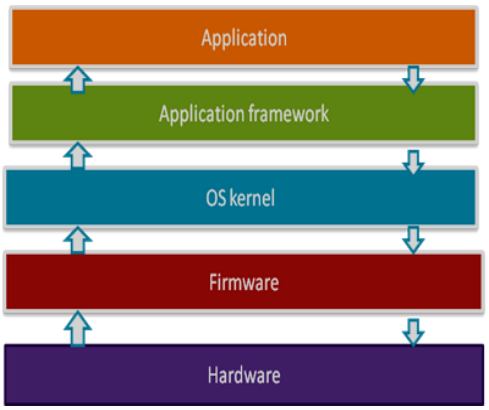

Fig 2 Architecture of iOS Mobile OS

Frameworks/API layer has API calls which are Apple-distributed headers with the iPhone SDK, with some dynamic linking occurring at runtime. These reside on top of the Objective-C runtime, as many of these are written in Objective-C [10].

The application stored in iPhone has to be purchased through the application store [12]. This application was compiled to native code by the Apple-distributed iPhone compiler, and linked with the Objective-C runtime and C library by the linker. The application also runs entirely within the user space environment set up by the iPhone OS.

3.1.3 Symbian

Symbian mobile operating system with libraries, UI frames works and common tools. It is descendant of Psions EPOC and run exclusively on ARM processors. Symbian OS was built to follow three design rules in order to support extended always on operation [13].

- The integration and security of user data is important.
- User time must not be wasted.

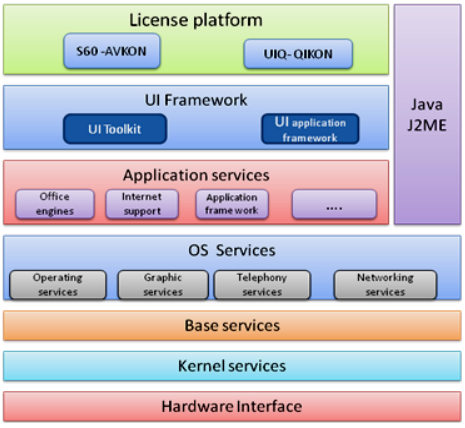

Fig 3: Architecture of Symbian Mobile OS

For hardware, the OS is optimized for low power battery based and for ROM based systems. The later version of Symbian has a real time Kernel and a platform security model (version 8 and 9).

There is a strong emphasis on conserving resources, using Symbian specific programming features such as descriptors and clean up stack. All Symbian OS programming is event-based, and the CPU is switched off when applications are not directly dealing with an event. Similarly, the OS approach to thread vs. process is driven by reducing over heads. It supports fast real time response, that a single core executes both the user application and signaling stack in a mobile phone. This feature is not available in Linux also. This feature makes Symbian OS phones to become smaller cheaper and more power efficient.

The Symbian OS model contains the following layers.

- UI frame work layer.
- Application services layer containing the following services:-
  a. Generic OS services.
  b. Communications services.
  c. Multimedia and graphic services.
  d. Connectivity services.
- Base service layer.
- Kernel services and hardware interface layer.

The base services layer is the lowest level, reachable by user side operation. It includes the file server and user library, the plug in framework which manages all plugs in store, control, Data Base Management System (DBMS) and cryptographic services. It also includes the Text window server and the Text shell, complete functional port can be created from this, without the need for any higher level services.

Symbian OS has a Microkernel architecture that provides robustness availability and responsiveness. It contains a scheduler, memory management and device drivers. Other services like networking telephony and file system support are present in the OS services layer or base services layer. The inclusion of device drivers means the kernel is not a true microkernel but a nanokernel containing only the basic primitives and supporting an extended kernel to implicate any other abstractions Symbian OS is designed for compatibility with other devices.

There is a large networking and communication subsystem for EPOC telephony. The subsystem also contains code for short range communication like Bluetooth, IrDA (Infra Red Data Association) and USB. In Symbian OS the actual UI are maintained by
third parties.A JVM (Java ME) is also included above the OS services layer.

3.1.4 Windows

In Windows CE. NET based architecture, the ROM stores the entire OS as well as the applications that come with the system, like Pocket Word, Pocket Excel. If a module is uncompressed ROM-based modules are executed in place. If the ROM based module is compressed, then first decompressed and then paged into RAM. All read and write data are loaded into RAM1 [10]. The option to enable compression in ROM is controlled by the original equipment manufacturer (OEM) executing programs directly from ROM.

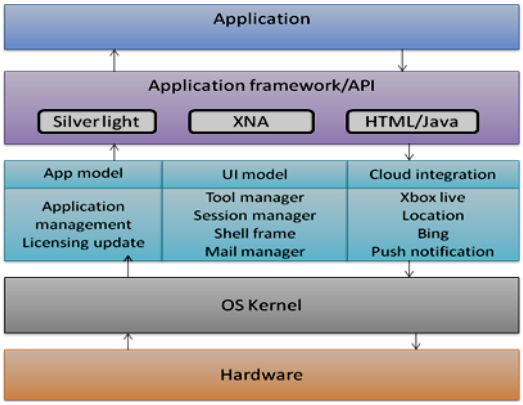

Fig 4: Architecture of Windows Mobile OS

The RAM on a Windows CE device is dividing into two areas one is object store and the program memory [14]. The object store resembles a permanent virtual RAM disk. Data in object store is retained when the system is suspended or soft reset, and devices typically have a backup power supply for the RAM to preserve data if the main supply is interrupted temporarily. As a preemptive, multitasking OS, CE supports up to 32 processes running simultaneously within the system. The actual number of additional threads is limited only by the available system resources.

The windows CE.NET scheduler maintains a priority list of each process and thread in the OS. Each process can contain multiple threads, and each of these threads composes a path of execution. The scheduler controls the order in which these different paths of execution are sequenced and allows them to interact in a predictable fashion. Scheduler performs its work both from the kernel and in a predefined scheduling mechanism.

3.1.5 Blackberry

Within Blackberry devices Java is integrated tightly and represents the only possible programming language for the Blackberry device. So it is possible to write native code for Blackberry device [13].

Blackberry devices have a proprietary Java virtual machine (JVM) which offers both Java ME standard features as well as Blackberry specific Java API extensions. Java is used for third party application development including email, contacts, calendar, web browser, etc.

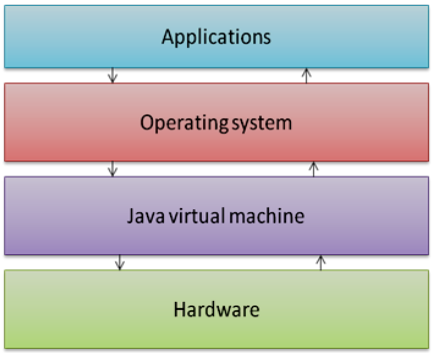

Fig 5: Architecture of Blackberry Mobile OS

It also supports a large set of additional Java APIs that are not part of the standard Java ME specification for greater support of any particular hardware. Of course it is always not necessary to use these specific classes as greater features and functionality often provided within standard Java ME specification.

For Blackberry some groups of Java APIs are available. These are used to integrate with the existing Blackberry applications like phone, email, calendar, browser, and tax list and the groups are –

- User Interface APIs.
- Event listener
- Networking Data Storage APIs.
- Application integration APIs.
- Persistent Data storage APIs

In Blackberry more utilities like additional APIs for data encryption and compression, XML parsing, location based services, Bluetooth connectivity etc are available. The specific libraries of Blackberry offer extensive support of phone related features. For example it is possible to add, view or change contacts of user in the address book, manipulate call logs.

Blackberry applications can be developed as standard Java ME applications extending MIDlet class defined in MIDP (Mobile Information Device Profile) specification. This is opposed to Blackberry specific programs built as CLDC (Connected Limited Device Configuration) applications by extending the class UI application. Whereas MIDlet can be ported to any device featuring the used Java APIs, usages of Blackberry UI applications is restricted to the Blackberry platform and devices.

3.2 User Interface

Having a user friendly interface is an important marketing feature of mobile device. The UI of a device defines the look and feel of the on-screen menu system. How it works, its color scheme, how it responds to button presses, all of these things are part of the user interface. Mobile UI is classified in terms of deference, clarity and depth, and also in terms of declarative and procedural knowledge. Android UI is better in terms of both declarative and procedural compares to others. iOS has comparatively better UI in terms of deference, clarity and depth with respect to others. It is the fact that all iOS applications must conform to the iOS user interface (UI) standards and user friendly. While Android's UI might not be as elegant as iOS, Android does have its own advantages. Android's UI is highly configurable. To get interactive information out of an application in iOS or Blackberry, it has to load the application and view it. In Android it may configure a widget and interact with that information in a dashboard like view, in a more convenient fashion. Blackberry has made strides of its own with Blackberry OS 7, which is now smoother and more responsive than ever. However, one common complaint about Blackberries is that the UI seems somewhat cluttered [15]. The user interface of Windows mobile changed much between versions but the basic functionality has remained similar. The latter version of Windows phone is more targeted to consumer market than the enterprise market, and it replaces the traditional Windows OS look and feel with a new Metro design system user interface. Metro's interface consists largely of a "Start screen" made up of "Live Tiles," which are link to applications and features that are dynamic and update in real time [17].

There are five user interfaces made to run on top of Symbian. Series 60, series 80, series 90, are Nokia smart phones. Series 60 has most common user interface [16]. It also known as AVKON. This system was designed to be manipulated with keyboard interface such as the 15 key augmented phone keypad. Series 90 is the user interface of Nokia's touch screen phones 7710and 7700. Series 80 is the user interface used by Nokia communicators. Symbian becomes open source in the near future so its UI structure will also change.

3.3 Processor Used

The most important part of a modern smartphone is its processor – the brains of a smartphone. We investigate the history of processors on smartphones and tablets and look at how it can compare the performance of different smartphones. When looking at smartphone processors, there are typically two main ways in which we can superficially compare them. The first is the number of processor cores, essentially the number of "brains" that your mobile phone has. Most of the latest high-end smartphones either feature a quad-core processor (e.g. HTC One X and Samsung) or a dual-core processor (e.g. Apple iPhone 4S). Many older and low-end smartphones simply feature a single-core processor, though this doesn't necessarily mean they are slower. The second figure that we typically use to compare smartphone processors is the clock speed - typically measured in megahertz (MHz) or gigahertz (GHz).

From start all mobile system considered ARM RISC processor. Earlier it was single core with multiple pipeline stages. Now it has Quad-core processor. Today, the ARM family accounts for approximately 75 per cent of all embedded 32-bit RISC CPUs, making it one of the most widely used 32-bit architectures. Because of their power saving features, ARM CPUs are dominant in the mobile electronics market, where low power consumption is critical design goals.

The popular perception is that number of cores and maximum clock speed are both good indicators of how well a smartphone will perform, with higher numbers in each category. Whilst, this is true to some extent, it isn't the full story. Devices such as the BlackBerry Bold 9900 and Nokia Lumia 800 often come out badly in side-by-side comparisons as both feature only a single-core processor [18].

In reality, comparing smartphone processors based on the number of cores and clock speed can be superficial and may have no resemblance to how fast the phones feel in day-to-day use. The responsiveness of a smartphone also depends upon the operating system and user such as HTCSence and Samsung Touch Witz that can also affect the responsiveness of your device. (OK)

The OS provided by the original company Nokia Ltd which is currently under name Accenture Ltd, uses a single-core processor on its flagship Lumia smartphones, often argues that dual-core and quad-core processors aren't particularly useful and simply drain battery unnecessarily. Whilst dual-core and quad-core processors can allow your smartphone to run more applications simultaneously, the usefulness of this can be questionable due to the fact that smartphones typically only display one application on the screen at a time.

3.4 MemoryUtilization

Memory footprint refers to the amount of main memory that a program uses or references while running. Android does not offer swap space for memory, but it does use paging and memory-mapping. Since Android devices are usually battery-powered, Android is designed to manage memory (RAM) to keep power consumption at a minimum. When an Android application is no longer in use, the system will automatically suspend in memory; while the application is still technically "open", suspended applications consume no resources (for example, battery power or processing power) and sit idly in the background until needed again. This brings a dual benefit by increasing the general responsiveness of Android devices, since applications do not need to be closed and reopened from scratch each time, and by ensuring that background applications do not consume power needlessly. Android manages the applications stored in memory automatically: when memory is low, the system will begin killing applications and processes that have been inactive for a while, in reverse order since they were last used (oldest first). This process is designed to be invisible to the user, so that users do not need to manage memory or the killing of applications themselves. Memory management in iOS supports ARC (Automatic reference counting).

Symbian has a integrated memory management unit (MMU) and a cache, to operate in various privileged access modes, and to handle interrupts and exceptions. The CPU, MMU and cache along with timers and hardware drivers, all reside on the system-on-chip [19]. Symbian mobile OS support maximum up to 2GB RAM. Within Symbian OS applications share RAM but have exclusive access to its allocated memory area. Flash and expansion card memory is used for storage, Kernel runs with in its own protected address space so a program memory leak of stack over – run cannot over write the kernel's stack or heap which would cause a system crash. Symbian OS presents a virtual machine model to all running programs and the programs use linear virtual memory environment facilitated by the use of MMU [20].

Windows Mobile devices do not use hard drives for storage like desktop PCs—except when a Compact Flash or PC Card hard drive is used as an accessory for additional storage. Instead, ROM, random access memory (RAM), and flash memory are used for storage. Storage cards—either flash memory or hard drives—can increase the amount of storage space for a Windows Mobile device, but they cannot increase the amount of memory available for running programs. Programs can only run in the memory installed on the device. It is therefore important to limit the amount of data and programs stored in RAM (for older devices) and in so doing maximize the amount of free memory available for running programs. Fortunately, an increasing number of Windows Mobile devices include built-in, nonvolatile, flash memory—in addition to ROM and RAM. For these devices it is recommended that applications, and optionally data, be installed in the built-in storage—keeping most of the RAM free for running the operating system and programs.

Blackberry smart phones contain a slot for external memory and can support up to 32GB micro SD cards, a unique feature. The memory can be extending to save more media files such as pictures, videos, ring tones and songs. Both the internal and external memory can be viewed on a computer with memory card adapter or USB cable. In Blackberry it is possible to change the amount of memory that is available for all media files. For memory management or at the time of full memory in Blackberry mobiles, files deleted manually by pressing the menu button and selecting delete, only media files are deleted that added by the user [21].

3.5 Security Mobile OS – Comparative Study

3.5.1 Android

Android is a multi-process system, in which each application (and parts of the system) runs in its own process. As Android OS is an open platform, the security mechanism is a key challenge. Securing an open platform requires tough security architecture and accurate security programs. Android was designed with multi-layered security that provides the flexibility required for an open platform, while providing protection for all users of the platform. It was designed with device users in mind. Users are provided visibility into how applications work, and control over those applications. This design includes the expectation that attackers would attempt to perform common attacks, such as social engineering attacks to convince device users to install malware, and attacks on third-party applications on Android. Android was designed to both reduce the probability of these attacks and greatly limit the impact of the attack in the event it was successful [22]**.** It seeks to be the most secure and usable operating system for mobile platforms by re-purposing traditional operating system security controls to:

- Provide application isolation.
- Protect user data.
- Application signing.
- Secure inter process communication.

- Robust security at the OS level through the Linux kernel.
- Application-defined and user-granted permissions.
- Protect system resources(network also included)

3.5.2 iOS

iphone has no security software and Apple doesn't let people load third-party programs on the device, which could reduce the risk of infection from malicious software. iOS provides built-in security from the moment you turn on your device. Low-level hardware and firmware features are designed to protect against malware and viruses, while high-level OS features help to secure access to personal information and corporate data. To guard privacy, applications requesting location information or data from Calendar, Contacts, Reminders, and Photos must first get user permission. User can set a pass code lock to prevent unauthorized access to the device and configure it to delete all data after too many unsuccessful pass code attempts. This pass code also automatically encrypts and protects stored email as well as allows thirdparty applications to encrypt their stored data. iOS supports encrypted network communication that applications can use to protect your sensitive information during transmission and in case the device is lost or stolen, find My iPhone allows user to locate it on a map and remotely delete all data. When user gets it back, then the user can restore everything from its last backup.

3.5.3 Symbian

Symbian OS offers gate keeper type security. The system asks user permission to install any applications. There are three concepts, which are the foundation of Symbian OS platform security architecture.

Tires of Trust: A mobile phone tends to be used by one person only, this is particularly true of smart phones which hold personal information such as contact details and calendar entries. The design of Symbian OS assumes the Trusted Computing Base and Trusted Computing Environment.

Trusted Computing Base controls the lowest level of the security mechanisms and has the responsibility for maintaining the integrity of the system. The trusted computing base includes the operating system kernel, which looks after the details of each process, including the set of privileges assigned to it. Some Symbian OS phones are 'closed', that is they do not support installation of native add-on software; on such a closed phone, the kernel, including the kernel-side device drivers and the file server are the only fully-trusted component by other processes.

3.5.4 Windows

Windows operating systems are mainly taking care of

- Device encryption.
- Data Encryption.
- Data Leak Prevention.
- Digital Signature.

Device Encryption is full internal storage encryption to protect information. It is built on Windows Bit Locker architecture. Data Encryption helps provide privacy and authentication between two communicating parties who have exchanged a shared secret. Data Leak Prevention (DLP) Information Rights Management (IRM) helps prevent intellectual property from being leaked. It helps to protects emails and documents on the phone from unauthorized distribution. Easy to deploy on Exchange Server and SharePoint Active Directory Rights Management supports all your Mobile Information Management (MIM) needs. Digital Signature helps to authenticate another party, or information sent by that party, without prior exchange of a shared secret.

3.5.5 Blackberry

Blackberry provides end to end encryption. It is using two encryption options. Advanced Encryption Standard (AES) and Triple Data Encryption Standard (Triple DES). Data sent to the Blackberry smart phone is encrypted by BlackBerry Enterprise Server, using the private key retrieved from the user's mailbox. The encrypted information travels securely across the network to the smart phone where it is decrypted with the key stored there. It's enabled RSA Secure ID Two-Factor Authentication. Additional authorization also available when users access application data or corporate intranets.

3.6 Power Management

The research is on going for prolong mobile battery life. Power demands in mobiles are increasing rapidly because of its more and more power hungry applications are developed for mobile platforms. For slow development of battery technologies and fact people want sleeker and compact form that could fit into a pocket, the battery capacity growth could not be performed. Due to this the power management becoming a complex problem on mobile devices, the holistic approach is needed to be taken. The power management of mobile OS work is initially on processor power management that has been done already. Current focus is on device power management. Recent days it is a mechanism has been developed to manage the power of input output devices at run time [23]. Run time power management for I/O devices could mechanically put I/O devices into whatever suitable low power states they support when the corresponding devices are detected as ideal at runtime. Runtime power management for I/O devices could automatically put I/O devices into whatever low power state they support when ideal corresponding devices are detected as ideal runtime. In addition to managing the power of I/O devices while they are ideal. There are some technology innovation to I/O devices power while they are action.

3.6.1 Android

Android supports its own Power Management which is on top of the standard Linux Power Management. The CPU shouldn't consume power if no applications or services require power. Android requires "wake locks" for CPU services request. Android allows third party application to run in the background which may hold a wake clock for no such reason and suck the power quietly.

3.6.2 iOS

The iphone do not have the power management toolkit as Mac OS does Embedded into the core layer is Support Sleep mode or Airline mode [24]. It's research result of 2010 regarding iOS mobile OS but at 2012 research shows that it is still not able to catch up increasing demands on power for various new features. It is estimated by Aries, mobile network Management Company that iphone 4S users consume twice as much data as the previous iPhone model due to use of online services like virtual assistance.

3.6.3 Symbian

On overall studies it is found that Symbian operating system mobile phones were based on two-chip solution, with one processor dedicated to telephony application and associated signaling stacks and other for Symbian OS. Usually telephony processor performs battery monitoring and management. The OS gets information between the two devices through the communication channel. Even in future we may see single chip and single core solution. In Symbian mobile OS when the battery level drops below a certain level, the system-wide power policy might be that the window server must ask the screen driver to switch the display driver to a different mode, lowering the resolution and refresh rate to conserve power [25].

3.6.4 Windows

There a new feature came in Windows 8 that is battery saver. Mainly it has two new functions one is enable Microsoft's built-in battery saving features, and allowing to see which applications using most amount of battery. In Windows operating system the battery saver is enabled, it turn off other non essential background features for that it is not possible to receive the email or calendar updates automatically but later it can be sync manually whenever user want. Even by turning off Bluetooth and Wi-Fi it can saves power [26].

3.6.5 Blackberry

In Blackberry mobiles, power management can be done nicely by taking following things into consideration [27].

- Close any running Blackberry smart phone applications that are not being actively used.
- Close applications correctly.
- Close browser tabs that are not in use.
- Configure instant messaging and social Networking app settings.
- Close media applications.
- Disable wireless connections when not in use.
- With proper device settings like adjust backlighting settings, configure a power efficient notification profile.

3.7 Connectivity

3.7.1 Android

Now let's put our focus on the case study of Android connectivity. It provides rich APIs to let your applications connect and interact with other devices over Bluetooth, NFC, Wi-Fi P2P, USB, and SIP, in addition to standard network connections. Mostly HTTP is used to send and receive data that network connected to Android applications. Android includes two HTTP clients Http URL connection and Apache HTTP client [29]. Both of them support HTTPS, streaming uploads and downloads, configurable timeouts, IPv6 and connection pooling.

- *Apache HTTP Client*

The extensible HTTP clients are Default Http client and its siblings, Android Http Client, those are sustain for web browsers. These have large and flexible APIs. That implementation is stable and they have few bugs. But the large size of this API makes it difficult for the user to improve it without compatibility breaking. The Android team is not aggressively working on Apache HTTP client.

- *HttpURLConnection*

Http URL Connection is a general-purpose, lightweight HTTP client suitable for most of the applications. This class has meek beginnings, but focused API has made it easy for us to improve steadily [28].

3.7.2 iOS

There are a couple ways in which Mac and iOS devices will soon work together under Yosemite and iOS 8. These new capabilities center around iCloud Drive and a cluster of features Apple is calling Continuity. The first offers user a big Dropbox-like storage locker for all the application documents and projects, the second provides an integrated framework to access a variety of services seamlessly as user move between its Macs and iOS devices. As implemented in OS X Yosemite, those services fall into five distinct categories: Phone, SMS, Handoff, Instant Hotspot, and Airdrop.

If the phone is within Bluetooth range of Mac, it will see caller ID information on Mac's screen, whenever phone receives a call. It will be able to accept or decline the call right from the computer. It is also possible to initiate calls from your Mac by clicking on a phone number in Contacts; on a webpage; or in an email or text message.

The iPhone and upgrade iOS 8, will be able to push SMS messages--those "green bubble" messages from buddies who don't use an iPhone to text to your Mac or other iOS devices, so that it can possible to write and reply on any device chosen. It is also possible initiate SMS messages on the Mac.

Most of the user own more than one Apple device these days. While iCloud already helps user to keep some information in sync between those devices, the process of switching back and forth between them is still often rough. Handoff aims to help smooth that out: If user starts writing an email on iPhone, it will be able to pick up composition on Mac from wherever user left off. In the middle of reading an interesting article on iPad when user need to head out the door? It will be able to open up iPhone and keep reading, right from the same scroll position.

Third-party developers can also take advantage of Handoff. Apple is providing a framework for developers those want to have their apps talk to each other on iOS and the Mac. Obviously users have to wait to see what kind of clever uses for Handoff those developers come up with.

Currently, if cellular carrier supports iPhone's hotspot features, it can configure iPhone to create an ad-hoc wireless

connection to Mac, letting it use phone's data plan for Internet access. Under Yosemite, however, whenever iPhone is within Bluetooth range of Mac, the phone automatically appears (along with its signal strength and battery level) in OS X's system wide Wi-Fi menu. If user choose phone from this menu, it automatically sets up a secure Wi-Fi hotspot and Mac connects to it-no other action required. And Mac automatically disconnects when it's not actively accessing the network to preserve the phone's battery life.

AirDrop now works between iOS devices and Macs, meaning user will be able to exchange files on an ad hoc basis between the two, without the need for an Internet connection or even being on the same local network. Need to get a photo to Mac from iPhone? Fire up Airdrop. Want to send that PDF from Mac to iPad? It is again same thing and user will also be able to limit sharing so that only iCloud contacts can see share requests.

3.7.3 Symbian

From connectivity point of view Symbian OS support WAP (Wireless Application Protocol) stack for mobile browsing. Wi-Fi 802.11 and HSDPA (High Speed Downlink Packet Access) are appearing on Symbian OS 9.3. The last version of Symbian that is 9.5 includes native support for mobile digital television broadcasts in DVB-H and ISDB-T formats and also location services. Latest Bluetooth 2.0 version in Symbian OS introduces an Enhanced Data Rate (EDR) for faster data transfer.

3.7.4 Windows

In early times Windows mobile able to managed and synced from a remote computer using Active Sync. A data synchronization technology and protocol developed by Microsoft, allowed servers running Microsoft Exchange Server, or other third party variants, to act as a personal information manager and share information such as calendar, email, appointments, contacts or internet favorites. Now the new version Windows Vista provides many front end enhancements, allowing a home user to sync PIM (personal Information Manager) information with Microsoft Outlook 2003 and later, photos from Windows Photo Gallery, videos or music from Windows Media Player and favorites with Internet Explorer, without the need for a server back end. Devices at this time also included a base driver compatible with Mobile Device Center so a user can connect to a computer without a need for any configuration [30].

3.7.5 Blackberry

Blackberry smart phones uses radio communication technologies such as CDMA, GPRS and Wi-Fi technology to communicate over wireless connections. It works with different network transports over those radio technologies to connect to internet or private network. In Blackberry 6.0 and later version the communication API encapsulates all the operations that are required to connect to an HTTP server that is located on the internet or behind an organizations firewall.

The Blackberry SDK offers the network API and GCF the two APIs that a user can create network connection manually. Blackberry device use the network API in software 5.0 and later version. It provides simple interface and wide variety of parameters for a connection. GCF used in previous version of Blackberry to create network connection in smart phones. The Blackberry Application platform supports the following protocols like HTTP, HTTPS, TLS, SSL, Socket and UDP (User Data gram Protocol).

3.8 Cross Platforming in Mobile

Cross platforming is the ability that enables programmers to develop software for several competing platforms by writing a program only once [31].Cross-platform software can run on most or all mobile platforms with little or no modification. It is also called multi-platform.

Smartphone's and tablets are becoming ubiquitous, and with them, mobile applications. So it is essential for the developers to develop applications that are used by one or more mobile platform by cross platforming. Once an application is built it can be used by more than one mobile platform.

Android platform collectively account for 50% of worldwide smart phone sales, where there is a huge variations in features as resolution, screen size, memory, speed features and OS version. The idea of developing a single application that run in that entire version is a challenging option which is attractive to the customer. In solution to this problem Cross Platform Compiler comes into picture [33].

As we considered in our research five mobile platform, from these five mobile platform Android, Symbian, Windows mobile platform are supporting cross platforming and at the same time iOS, Blackberry mobile platform are not supporting cross platforming.

There are many cross platform tools in the industry and after evaluating some of them we realize it is not too much of cost saving. Anyway, there are advantage and disadvantage of using the cross platform mobile development framework.

Advantages:

1. One code for all for example phone gap supports around 7 platforms.
2. Most platform use HTML5, JavaScript and CSS3 to develop mobile application. No need to learn a platform specific development.
3. Rapid testing and deployment.
4. Could do more platform specific things on the device than its default browser.
5. Most of them are open source with lot of plug-in and support to the community.

Disadvantages:

1 Poor performance of some applications compared to its native counterpart.
2 Applications are tools or framework dependents. For example, Titanium provides a few good APIs to access the hardware devices. Application becomes dependent on the framework and if the framework where to be gone in the market, then some parts of the code have to be re-written.
3 Even though you have lot of plug-in, there isn't for everything. So, if you have to use something which doesn't have one then you got to build it from scratch. That is going to take a lot of time.
4 If the target application requires to support high graphics or high intense calculation, high performances then it is better to go native [32].

Some popular mobile cross platforming tools are Appcelerator's Titanium, Phone Gap, Rhodes and Xamarin.

3.9 Cloud Readiness in Mobile Devices

According to the National Institute of Standards and Technology (NIST), which is an agency of the U.S, rules and standard exist by which a mobile device can be declare to be cloud ready. Following their recommendation Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

The essential characteristics are 1) On-demand self-service 2) Broad network access 3) Resource pooling 4) Rapid elasticity 5) Measured service. All mobile platforms that we have considered follow all these characteristics [34].
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Three service models are 1) Software as a Service (SaaS) 2) Platform as a Service (PaaS 3) Infrastructure as a Service (IaaS).and four deployment model are 1) Private cloud. 2) Community cloud. 3) Public cloud. 4) Hybrid cloud.

Table: 1- Comparison of different OS Characteristics

Table attached in Annexure-I

CONCLUSION

With evolution of mobile phones our life is more connected and it has become almost a necessary commodity in day to day life. This is irrespective of peoples of age, class creed, color, or which part of world they belong. With the availability of powerful mobile operating system and with the tremendous growth in mobile communication technology mobile computing is projected as the future growth area in both academia and industry. There is thus vast scope of potential research and development in this area.

The aim of this project is to reviews most popular mobile operating system features and decides which should be the best to support the user and the developer. Providing a comparison table for useful features of mobile OS allows mobile users to make a proper choice based upon their need. This work would be helpful to all members of our society.

With growing use of mobile phones with personal uses as banking, trading, email, sharing and storing images, the question of theft and security of personal mobile devices poses a big security issue. For this, continuous effort should be given on this field.

Another area of research is the issue of power management for mobile phones. Increasing the battery life without increasing the weight of the phone is a challenging design issue; necessary steps should be taken to overcome these problems.

FUTURE WORK

Potential improvement is possible in the multiple areas of mobile operating system research. This includes memory management, security, power management, handling of multiple tasks. Research should be given priority based on user demand.

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Table: 1- Comparison of different OS Characteristics Annexure-1

Researchable Issues	Android	iOS	Symbian	Windows	Blackberry	Comment
Architecture	Divided into components(app layer, libraries, runtime and Linux kernel)	This OS has kernel which interact with Driver run time, Kernel, U.I.	OS with applications, UI frame works and Kernel on ARM processor	Here OS divided into API, Next App model, UI Model, Cloud Model followed by OS Kernel	Application layer on top of OS Kernel which is a Java based V.M. This resides on top of the H.W.	Blackberry has least number of layers between Kernel and UI
User Interface	U.I. is highly configurable	It has to load application and view it	User Friendly	User Friendly	UI not user friendly	Android easily tailored to user request
Processor used	Quadcore processor(1.4 GHz)	Dual core (1GHz)	Single core(1.4 GHz)	Snapdragon Quadcore processor	Single core(1.2GHz)	Android and Windows has most efficient processor
Memory Utilization	Paging, Memory Map, No Swapping	Automatic reference counting, No Garbage collection	MMU**and cache all resides on a SOC*. Total 2 GB RAM Virtual Machine	ROM/RAM is flash memory used for Virtual Memory storage. Programs can only run from main memory.	Contain slot for external memory supports 32GB Micro SD card at the time of full memory.	Symbian has a MMU with cache on SOC.
Security	Multi layer security. Most secure and usable OS	Low level software hardware and farm ware security	Gate keeper type of security every time ask for user permission	Windows OS does data encryption, leak prevention and	Blackberry provides two methods data encryption	iOS and Blackberry is very secure because it does not allow third party

		features, does not allow third party program		digital signature that helps authentication between two parties		program. Android security software complexity is much higher compare to other OS
Power management.	Power management is not optimal compared to OS	Not optimized power management compared to other OS	When power goes below threshold then switches to low resolution display and refresh it.	Manually has to close application for better power management.	When power goes below threshold close application that are not in use	Symbian is better than rest OS
Connectivity	Good connectivity provide reach APIs and easy connection Bluetooth, NFC***, Wi-Fi P 2 P****, USB and SIP*****	Mac device and iOS device can work under the Yosemite and iOS 8. They can work with i cloud connectivity	Symbian OS support WAP******* stack for mobile browsing it also connect to Bluetooth	Window OS use active sync software to manage and collect data from remote computer	Blackberry smart phone uses CDMA, GPRS and Wi-Fi for wireless communication.	Among all OS Blackberry is best and Android comes next to it.
Cross platforming	Android supports cross platforming	iOS don't support cross platforming	Symbian supports cross plat forming	Windows support cross platforming	Blackberry don't supoort cross platforming	As Symbian and Android both have good cross platforming
Cloud readiness	Followed certain rules set by NIST*******	Followed certain rules set by NIST	Followed certain rules set by NIST	Followed certain rules set by NIST	Followed certain rules set by NIST	All follow NIST rules
Smartphone Name	Huawei P8	iphone 6	Rightly out of market	Windows 10	Blackberry leap	These are current updates

* SOC- System on Chip
** MMU - Memory Management Unit
*** NFC - Near Field Communication
**** P2P - Pear to Pear
***** SIP - Session Initiation protocol
****** WAP - Wireless Application Protocol
******* NIST - National Institute of Standard and Technology