SPECIFICATION STUDY OF ANDROID OPERATING SYSTEM

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ABSTRACT

Due to the vast development in technology, mobile terminals (smartphones, tablets) play an important role in our daily life by 24*7. Users need mobile devices for every work like official work, marketing, banking, shopping, online booking, etc. All mobile terminals are based on different types of platforms like android, ios, mac, etc. but android plays a vital role. Every year's millions of new users join android based mobile devices. The word Android used in many contexts like an operating system, an open-source project, and a development community. Android is a software stack (operating system, middleware, and key applications) and Linux (open-source) based OS developed for mobile devices like smartphones and tablets. In this paper, an overview of the android operating system is discussed that includes different versions, features, applications, architecture as well as security features.

KEYWORDS: Android, SDK, Dalvik VM, Sandbox.

I. INTRODUCTION

The word "Android" used in many contexts like an operating system, an open-source project, and a development community. In brief the whole ecosystem surrounded by the popular mobile operating system. Android is a most popular operating system [1] in handheld devices like smartphones and tablets, developed by open Handset led by Google, and other companies Alliance which is based on Linux kernel. It is an open source operating system that allows software developers to easily modify and add enhanced features or write own code to fulfill the requirements of the user in mobile technology [2].

Developers enjoy a complete software development kit (SDK) with various options for distributing and commercializing their application. The Android source code is an open source and under software licenses. Major portion of the code published by Google under the Apache License version 2.0 and the remaining parts such as Linux kernel changes, under the General Public License (GNU) version 2. An Android software development kit (SDK) helps to create applications or app by writing unique source code, create required software modules for Android users and marketplace for distribute apps. To develop apps using the SDK, use the java programming language for developing the app and extendible markup language files for describing data resources.

II. VERSION HISTORY

Android founded by a company named android Inc in October 2003. The founder was Andy Rubin, Chris White, Nick Sears, and Rich Miner. The primary goal was to develop a sophisticated OS by the company for digital cameras, but the company realized that the marketplace for such devices was not large enough. So, they paid attention to produce Smartphone OS.

In 2005, Google acquired Android and established a group named the Open Handset Alliance (OHA) in 2007. The objective was to accelerate mobile platform improvement and provide a better mobile experience to consumers. The Open Handset Alliance (OHA) members represent all components of the mobile ecosystem such as mobile handset manufacturer, software companies, mobile operators, semiconductor companies and many more. A VM (Virtual Machine) called DVM (Dalvik Virtual Machine) is used by the Android OS to execute Android applications. The primary reason for the success of Android is the constant improvement through many versions to fulfill user's requirements such as fast internet access, smooth touch; high-quality resolutions of a picture, camera quality, etc. play an important role in the success of Android. The second major reason for the popularity of Android is its strong collaboration with the manufacturer of mobile devices.

Due to the huge demand of mobile users, Android OS is updating day by day by since its release. the main purpose behind updating is to fixing bugs as well as add new features which help to solve customer problems or

to fulfill customer demands. Basically, all versions of the Android OS created under a code name based on a dessert item.

In the beginning, the Android operating system had two releases: alpha which was available only for Google and OHA members and beta which was released on 5th November 2007. This date is considered an Android birthday. The first marketable releases of Android OS i.e. version 1.0 (released on 23rd September 2008) was the only version which had no codename. After that release, every Android version has a codename. Table 1 gives a summary of all Android versions that contain a release date, key features, and symbol.

Table-1: Android Version and Key Features

Version with Codename	Release Date	Features	Symbol
1.0 (No Name)	September 23, 2008	It helps to download and update features by utilizing the Android Market application. Facilitates Web browser, Camera, protocols like POP3, SMTP, and IMAP4 to access web email servers. A number of applications in a single folder can be grouped by users. It also supports applications such as Gmail synchronization, Google Contacts, Google talk, Google Calendar, Google search, Google Map, and, text messaging and MMS. A variety of players are also supported such as Media Player, YouTube video player and stereo Bluetooth, voice dialer, and Wi-Fi. First phone which was launched with Android 1.0. Was T-Mobile G1 (HTC Dream).	
1.1	February 9, 2009	Search details and reviews are available. Ability to save attachments in messages. Support added for marquee in system layouts. Physical keyboard was used	
1.5 (Cupcake)	April 27, 2009	on-screen keyboard were used instead of a physical keyboard. It support third party virtual keyboards, Widgets, Video recording in MPEG-4 and 3GP formats. Ability to upload videos and photos to YouTube and Picasa respectively	Cupcake
1.6 (Donut)	September 15, 2009	Voice and text search supports and developers allowed to include their content in search results. Gallery, camera and camcorder more fully integrated, with faster	Donut

		camera access Users can select multiple photos for deletion purpose Technology support for CDMA, 802.1x, VPNs, and a text-to-speech engine	
2.0 (Éclair)	October 26, 2009	allowing users to add multiple accounts to a device for synchronization of email and contacts Bluetooth 2.1 support Ability to tap a Contacts photo and select to call, SMS, or email the person, Numerous new camera features, including flash support, digital zoom, scene mode Optimized hardware Improved Google Maps 3.1.2 Addition of live wallpapers, allowing t animation	Eclair

2.2 (Froyo)	May 20, 2010	Speed and memory optimizations
		    Integration of Chrome's V8 JavaScript engine
		    Android Cloud, USB tethering and Wi-Fi hotspot functionality supported
		    Numeric and alphanumeric passwords supports
		    Adobe Flash supports
			Froyo

2.3 (Gingerbread)	December 6, 2010	Updated UI design with increased simplicity and speed Large screen sizes and high resolutions are supported, Support for SIP VoIP internet telephony Improved power management and support Near Field Communication (NFC) Audio, graphical, and input features are improved for game developers	Singerbread
3.0 (Honeycomb)	February 22, 2011	Holographic user interface for tablet Action Bar, contextual options, navigation, widgets, or other types of content are added at the top of the screen Quick access to features is improved like camera exposure, focus, flash, zoom, front-facing camera, etc. Hardware acceleration and support for multi-core processors	Honeycomb

		Ability to encrypt all user data	

4.0 (IceCreamSandwitch)	October 18, 2011	Simple, Beautiful, Useful Refined, Evolved UI
		   Drag and drop style are used for folder
		   Improved visual and voicemail, copy and paste functionality
		   Support resizable widgets, quick response for incoming calls
		   Face unlock feature and Swipe to Dismiss Notifications, Tasks and Browser Tabs supported
		   Automatic syncing of browser
		   Improved camera application with zero shutter lag, panorama mode, time lapse settings, and the ability to zoom while recording
		   Android Beam , Wi-Fi direct, better Text Input and Spell-Checking
			Ice Cream Sandwich

4.1 (JellyBean)	July 9, 2012	Better UI, voice recognition/ voice typing, Google now for voice search support Android beam support for sharing snaps, songs, videos etc. Enhanced accessibility features Google Wallet and Google Now support	Jelly Bean
4.4 (KitKat)	October 31, 2013	Similar to iOS 7 uses translucent system, action and navigation bar Support full screen features for lettering applications To scale up the targeted area, double touch gestures and introduced two new composite sensors- A step detector and A step counter Secure NFC based transactions through HCE (Host Card Emulator) for payments, card access etc. To print any type of content support printing framework over Wi-Fi or cloud hosted services	KitKat

5.0 (Lollipop)	November 12, 2014	Support enhanced notifications that show on the lock screen, new lock screen which is unlock by swiping up side or swipe left to launch camera or right to launch the dialer
		   New notification bar , multitasking, to improve battery life new battery saver mode up to 90 minutes supports
		   To enhance security this version
			Lollipop

		support personal locking features To improve performance this version support 64 bit processors and upgrade to Art software library which is twice faster than Dalvik	
6.0 (Marshmallow)	October 5, 2015	Support app permission to decide which permission user want to allow or revoke Mobile payments using NFC and host card emulation techniques for tap to pay service First version of Android that support fingerprints for authorization purpose Support smart power managing features called doze, USB type –C for charging and app stand by features.	
7.0 (Nougat)	August 22, 2016	Designed to run fast and smooth functioning which support file based encryption, svelte, call blocking and capability to show color calibration, screen zoom features "Clear All" button added for emergency purpose, Improved battery life Doze functionality and to run app in background svelte project used Multi-window support	
8.0 (Oreo)	August 21, 2017	This version comes with new interesting features like Enhanced modular architecture hardware, Picture-in-picture support, redesigned setting menu, revamped file manager Support for Unicode 10.0 emoji (5.0) and turn on Wi-Fi automatically 2 times faster boot time compared to Nougat Apps background execution and location limits Google Play Protect Downloadable fonts Integrated printing support Color management (deep color and wide color gamut) Wi-Fi Assistant	
9.0 (Pie)	**August 6, 2018**	Adaptive battery feature to overcome battery drain and adaptive brightness for automatically adjust brightness. It supports quick and easy screen rotation, enhanced security features, new screenshot, shortcut, gesture	

		navigation.	
10 Q	**To be announced**	Enhanced Security Features supports with the help of TLS 1.3 Better biometric authentication system Foldable phones, Notification Bubbles, AV1 video codec , the HDR10+ video format, and the Opus audio codec supports APK supports to run embedded DEX code directly Improved Wi-Fi performance low latency mode Call screening, call redirection service, called ID and call quality improved	

III.   ARCHITECTURE

The structural design of the Android operating system is like a stack of the software components which is divided into four layers or five sections such as Linux Kernel, Libraries & Android Runtime, Application Framework, and Application.
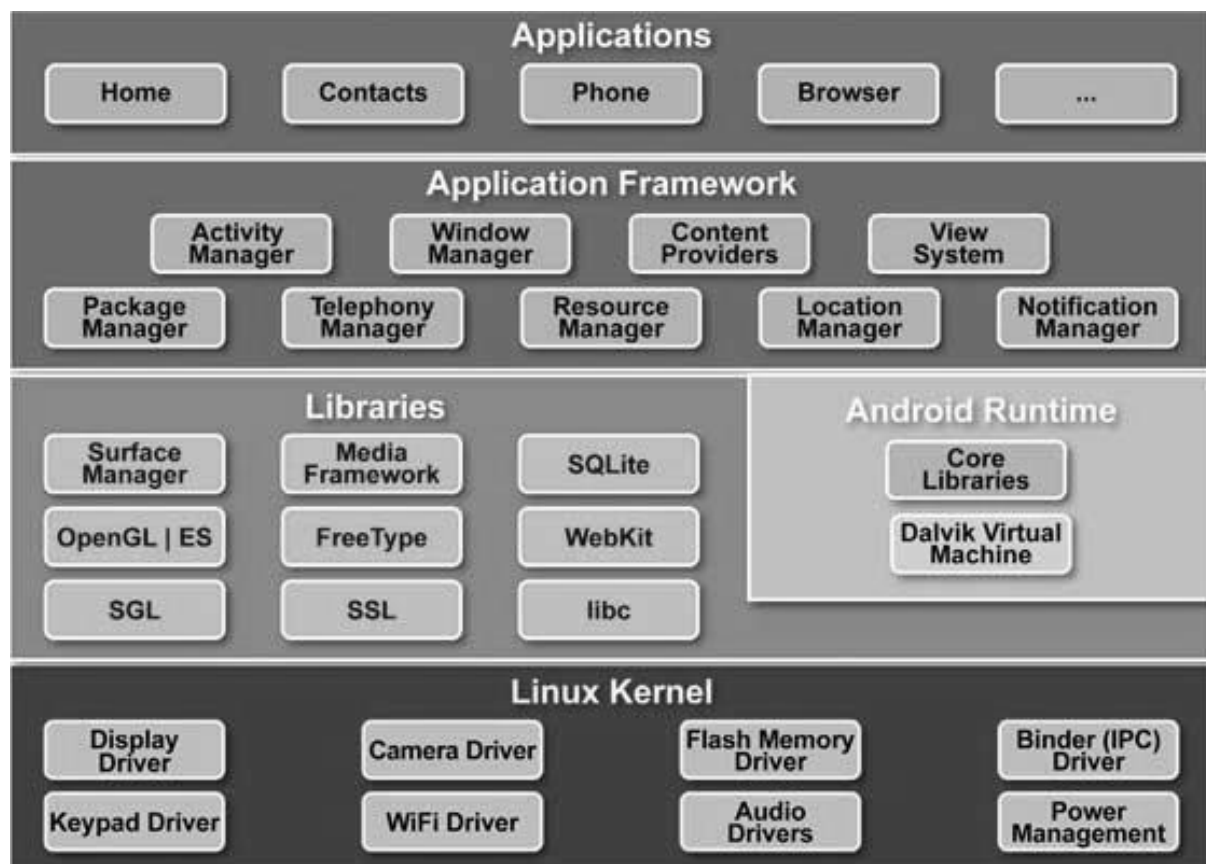
Figure 1: Architecture of Android operating system [2, 4]

Linux Kernel

The bottom layer of the Android architecture or software stack is Linux kernel which is Linux 2.6 with 115 patches. It plays an important role like main operating system. All fundamental functions such as process management, memory management, device management, security management, network management etc are taken care by Linux kernel. Entire Android Operating System is built on this layer with some changes made by Google [3]. This layer also helps the Android operating system to interact with H/W devices [4]. This layer also takes care of managing power management, networking, drivers and virtual memory [5].

Libraries

After the Linux kernel layer, there is a set of native libraries such as Surface Manager for manage display of the device, SQLite database for the repository for storage and sharing of application data, WebKit for HTML content which is an open-source web browser engine, Media framework for playbacks and recording of various audio, video and picture formats, libc for system-related C libraries [3], SSL for Internet security, etc. These native libraries are coded in C language or C++ language and java interface is used to call it.

Android Runtime

This is the third section of the Android architecture and available in the second layer as the library layer [3]. Dalvik VM (Virtual Machine) is the main key component of Android Runtime section. Dalvik VM is a type of JVM (Java Virtual Machine) which is specially designed and optimized for Android. The Dalvik Virtual machine makes use of Linux core features like process management, memory management and multithreading, which is intrinsic in the Java language.

The Dalvik Virtual Machine (Dalvik VM) enables every Android applications or app to run its own process, with its own instance of the Dalvik VM. It also includes a set of core libraries that help developers to write Android applications using Java programming language. It also allows multiple instances of VM to be created simultaneously by providing memory management, security, isolation, and threading supports [6].
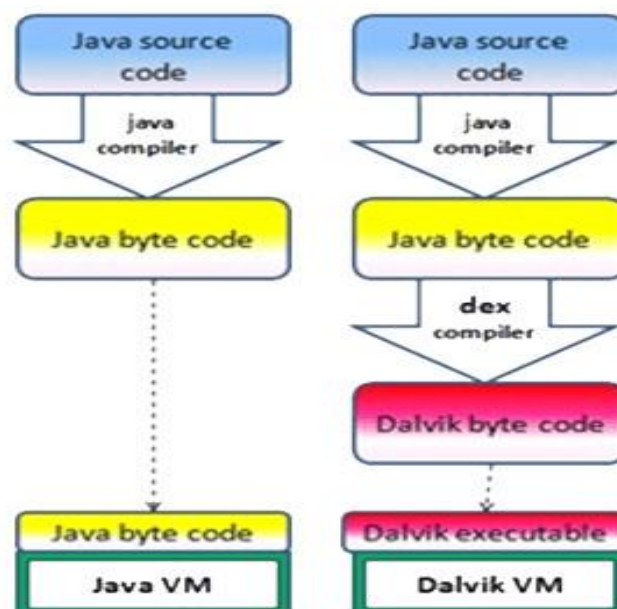
Fig-2: Execution steps of Dalvik VM and JVM [15]

Each android application or app runs in its own process is called Dalvik virtual machine. Dalvik uses its own 16 bit instruction set than java 8 bit stack instructions, which reduce the Dalvik instruction count and raised its interpreter speed. Dalvik Virtual Machine run .dex (Dalvik Executable) files which are created from .class file by dx tool. Dx tool is included in Android SDK. DVM is basically designed for low memory environments and low processing power. DVM is developed by Dan Bornstein from Google [7].

Application Framework

After the libraries & Android runtime layer, there is an application framework layer in Android architecture. This layer provides advantages to the developers like access location information, set alarms, run background services, add notifications to the status bar, and much more. Android developers are allowed to make use of these services in their applications [4]. There are some important blocks of Application framework with which developer's applications directly interact. The blocks are:

Activity Manager- manages the lifecycle of applications and provides a common navigation back stack.

Content Providers- enable applications to access data from other applications like Contacts, or to share their own data

Telephony Manager- it manages all telephony services available on the device such as all voice call related functionalities.

Location Manager- GPS or cell tower is used for Location management.

Resource Manager- providing access to non-code resources such as localized strings, graphics, and layout files [6].

IV.   FEATURES

Android is a powerful operating system for smartphones and tablets. There are some important features such as:

Storage: For the storage purpose a lightweight relational database i.e. SQLite, is used.

Network Connectivity: Android operating system supports wide variety of connectivity technology such as GSM (Global System for Mobile Communication)/EDGE, CDMA, UMTS, Bluetooth, Wi-Fi, LTE and WiMAX.

Messaging: It supports SMS and MMS.

Language Support: It supports multi language.

Web browser: Based on open source WebKit library which is used to display HTML content. WebKit library coupled with Chrome's V8 JavaScript engine supporting HTML5 and CSS3. It also includes LibWebCore which is a modern web browser engine which powers both the Android browser and an embeddable web view.

Java support: Most Android applications are written in Java language and compiled by dex compiler and run in Dalvik Virtual machine environment.

Multi touch: It supports multi touch feature which was initially made available in handsets such as the HTC Hero.

Bluetooth: This technology is used to send or share data between the mobile devices (smartphones and tablets) such as contents, pictures, media files etc. within limited range. It supports A2DP, AVRCP, OPP, and PBAP.

Tethering: This feature enables Android device to work like a wireless Wi-Fi hotspot.

Screen Capture: This feature provides to capture screenshot by using different methods such as to click screenshot icon or to press power button and volume down button at the same time. In the early versions of Android operating system (before Android 4.0) 0, the only

methods of capturing a screenshot were through manufacturer and third-party customizations.

User Interface: Android operating system has beautiful and intuitive user interface

Media Support: It supports wide range of advanced media formats such as H.263, H.264, MPEG-4 SP, AMR, AMR-WB, AAC, HE-AAC, AAC 5.1, MP3, MIDI, Ogg Vorbis, WAV, JPEG, PNG, GIF, and BMP.

Multi-tasking: With the help of this feature, user can jump from one task to another and same time i.e. various applications can run simultaneously.

Resizable widgets: According to the requirement user can resize widgets to show more content or shrink them to save space.

Google cloud Messaging: GCM service enable developers to send short message data to their users on Android device.

Wi-Fi Direct: A technology that let apps discover and pair directly, over a high bandwidth peer-to-peer connection over large area as compare to Bluetooth.

Android Beam: A popular NFC-based technology that let users instantly share, just by touching two NFC-enabled phones together.

Dalvik Virtual Machine: It is extremely low-memory based virtual machine, which was

designed especially for Android to run on embedded systems and work well in low power situations. It is also tuned to the CPU attributes. The Dalvik VM creates a special file format (.DEX) that is created through build time post processing. Conversion between Java classes and.DEX format is done by included "dx" tool.

V.   SECURITY FEATURES

Nowadays near all of the tasks that could only performed on a computer are also performed on mobile devices as well, with the help of the Android operating system. Data security is very important issue in Android device for both consumers and enterprises because sensitive information is stored on people mobile devices. Android software stack provides security to its application. To achieve the security of the components such as the security of users, user's data, applications, the device, and the network, Android provides these key security features [8]:

At Operating System Level:

Android operating system is based on Linux kernel and its open source nature attracts researcher for more research. Linux system contains a stable and secure kernel which provides more security features to the Android operating system such as:

a) A user-based permissions model: There are three types of user-based permissions in the Linux file system such as Owner, Group and Other Users. In Owner permission, permissions are applicable only on the owner's file or directory. In Group permissions, permissions are applied only on those files or directories kept in a particular group. In Other User permission, permissions are applied to all other users of the system. Every file or directory has three types of file permissions such as read denoted by 'r', write denoted by 'w' and execute denoted by 'x'. Here read permission describe that the user only can read the content of the file, write permission indicates that users can write or edit a file of the directory and execute permission means users have the ability to execute a file or list out the content of the directory[9].

b) Process isolation: The Android operating system assigns a unique user ID (UID) to each Android application and runs it as a separate process.

c) An extensible mechanism for secure IPC.

d) Ability to correct: It has the ability to remove unnecessary and insecure parts of the kernel [8].

Application Sandbox:

The term "security" is an important part of our life. Every person wants to be secured from untrusted people. Similarly, security also plays a vital role in the current age of the computer to secure our information on mobile devices. The latest and most sophisticated technology emerged over the years is Sandbox technology. It is a security mechanism that separates running programs and limits the resources of the device to running applications. It is used for creating confident execution environments were untested or untrusted programs or code possibly from unverified or untrusted third parties, suppliers, users or websites is often used to execute. Sandboxing technology is often used to test unverified programs or codes from an unverified source that may contain a virus or other malware code, without allowing the software or code to harm the user machine or operating system. Sandbox technology or application allows untrusted programs or codes to access only those resources of the user machine for which permission is granted. On the other hand, if untrusted or unverified programs or codes try to access other resources of the user machine or device than permission id denied [10]. The features of the sandbox provide a user-friendly environment that provides a platform to test malware or untrusted or risky source code.

Secure Inter Process Communication (IPC):

Network sockets, file system and shared files are traditional Linux techniques used by some application for inter-process communication but Android OS (Operating System) provides new mechanism such as Binder, Services, Intents and Content Providers for IPC. It defines mechanism through which Android components to communicate each other. It helps to set the security policies by the developers to verify the identity of application [11].

Application signing:

Application signing also plays a vital role in terms of security. Every application that we want to install or run on Android machine must be signed by the developer. It helps to developers to identify the author of the application and to update their application without creating complicated interfaces and permissions. Without developer signed, applications are rejected to install by either Google Play or the package installer on the Android device. On Android platform machine, application signing is the primary step to placing an application in its Application sandbox and ensures that one application cannot access any other application except through well-defined IPC. Keytool and Jarsigner are tools used to generate keys and sign application (.apk) files [13].

Application-defined and user-granted permissions:

The main purpose of permission is to protect or secure the privacy of the Android user. Android apps (applications) must request permissions from the user to access sensitive data like contact or SMS. By default, Android applications have no permissions granted to the applications, making them safe by not allowing them to gain access to protected APIs [12]. Some of the protected APIs include: Camera functions, Location data (GPS), Bluetooth functions, Telephony functions, SMS/MMS functions and Network or data connections. These resources are accessed only through the operating system [8].

VI. APPLICATIONS

Fig-3: Android Applications [14]

Android is a complete software stack for mobile devices that contains an operating system, middleware, and key application. Since Android is an open-source operating system, developers modify the existing code to develop new applications for selling in the android market. Android applications are composed of one or more application components such as activities, services, content providers, and broadcast receivers which are written in a java programming language. Each component has a different responsibility in the overall application behavior, and each one can be activated individually.

The main objective of Applications i.e. apps is to extend the functionality of devices. To develop applications, Android provides Android SDK (Software Development Kit) that includes a set of development tools including a debugger, libraries, documentation, sample code, a handset emulator based on QEMU and tutorials.

In starting days, An IDE (integrated development environment) supported by Google was Eclipse using the Android Development Tools (ADT) plug-in. Android Studio released by Google on December 2014, which is based on IntelliJ IDEA, as primary IDE for application development? Many Other development tools are available such as native development kit (NDK) used for applications or extensions in C or C++. With the help of Android Studio, Developers can easily develop apps that are required by the consumers. Once the application i.e. app is developed, Android applications can be packaged easily and sold out through stores like Google Play or the Amazon App store.

Google Play Store is the most important application store installed on Android devices that comply with Google's compatibility requirements and license the Google Mobile Services software. With the help of Google Play Store users are allowed to browse, download and update applications published by Google and third-party developers. There are more than 1 million applications available for Android mobile devices in Play Store till July 2013. 48 billion and 50 billion applications have been installed from Google Play Store in May 2013 and July 2013 respectively.

VII.   PROBLEMS WITH ANDROID SYSTEM

Problems	Expected Suggestion
Battery Drain	Disable unnecessary notifications and GPS, Minimize the use of 3D apps and games, Use authorized apps, Enable battery saving mode.
Frozen and slow user interface	Delete unused apps, Clean junk files manually or cleaning apps
Connectivity issues	Restart device or enable airplane mode then disable it
Overheating	Avoid overcharging, always use original charger and battery
Syncing Error	Make sure internet connection is ON, Verify account , remove account and add it again
App Crashes	Clean the cache data, uninstall and install again,
Apps Won't Download	Clear the cache data or clean cache of Google play store or clear local search history
Slow Processing	Use cache cleaner to delete temporary files, Use small or appropriate antivirus software to remove malware or Trojans, Turned off Bluetooth or Wi-Fi when they are not in use, Use Memory management software to manage internal or external Memory
Security Issues	Always use authorize apps, Before installation read permissions that the apps wants, Don't open those files in which operating systems warn you, Use ad blocker,
Insufficient Space in Device	Clean cache memory or junk files or temporary files or unused apps, Delete old call records or messages,

VIII.   CONCLUSION

The main objective of the research paper to provide an overview of the android operating system that includes history and versions, architecture, features, security features, and applications. Android is an open-source and Linux based operating system that has vast features that are summarized in different types of versions. To fulfill customer requirements Android operating system updated day by day, so different versions are available in the market. The above discussion shows that the Android Operating System follows a variety of security mechanisms such as when a developer installs an application than each application runs with its own instance of Dalvik VM. Hence applications cannot access each other's data but if applications want to access shared data or resources then they require permissions. The signing mechanism helps to allow the developer to control which applications can grant access to other application on the system.

IX.   REFERENCE

[1]   http://www.engineersgarage.com/articles/what-is-android-introduction

[2]   http://en.wikipedia.org/wiki/Android_(operating_system)

[3]   http://www.tkhts.com/android/android-architecture.jsp

[4]   http://www.tutorialspoint.com/android/android_architecture.htm

[5]   http://www.compiletimeerror.com/2012/12/blog-post.html#.UuYiIGC6bIU

[6]   http://www.android-appmarket.com/android-architecture.html

[7]   http://ptcoresec.eu/2013/05/02/part-1-getting-to-know-android/

[8]   http://source.android.com/devices/tech/security/

[9]   http://www.linux.com/learn/tutorials/309527-understanding-linux-file-permissions

[10]   http://en.wikipedia.org/wiki/Sandbox_(computer_security)

[11]   http://developer.android.com/training/articles/security-tips.html

[12]   http://www.ibm.com/developerworks/library/x-androidsecurity/

[13]   http://developer.android.com/tools/publishing/app-signing.html

[14]   Kirthika.B, Prabhu.S &Visalakshi. S (2015), on the Android Operating System: A Review, International Journal of Trend in Research and Development, Volume 2(5), ISSN 2394-9333

[15]   M. Narmatha, S. Venkata Krishna Kumar (2016), on the Study on Android Operating System And Its Versions, International Journal of Scientific Engineering and Applied Science (IJSEAS), Volume-2, Issue-2,   ISSN: 2395-3470