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Android OS, its security and features

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Abstract– The android operating system is basically an operating system for mobiles and is rapidly gaining market share, with smart phones and tablets either released or set to be released. It is mobile operating system that uses a modified version of the Linux kernel 2.6. Initially developed by Android Inc., which Google bought in 2005, Android was unveiled in 2007, along with the founding of the Open Handset Alliance – a consortium of hardware, software, and telecommunication companies devoted to advancing open standards for mobile devices. Android's user interface is mainly based on direct manipulation, using touch gestures that loosely correspond to real-world actions, such as swiping, tapping and pinching, to manipulate on-screen objects, along with a virtual keyboard for text input. In addition to touch screen devices, Google has further developed Android TV for televisions, Android Auto for cars and Android Wear for wrist watches, each with a specialized user interface. Variants of Android are also used on notebooks, game consoles, digital cameras, and other electronics.

***Index Terms*— Android, android security, features, service SSL, version history**.

I. INTRODUCTION

Android is a software platform and operating system for mobile devices, based on the Linux kernel, and developed by Google and later the Open Handset Alliance. It allows developers to write managed code in the Java language, controlling the device via Google developed Java libraries. Android is available as open source. Android is a freely downloadable open source software stack for mobile devices that includes an operating system, middleware and google apps (Gapps). Google purchased the developer of Android in 2005, and Android was unveiled in 2007. Google released the Android code as open-source under the Apache License. Android has numerous developers writing applications (apps) all over the world. First of all the developers write their script in Java, and then download the apps from the third party sites or online stores. Android applications can use advanced level of hardware and software, as well as local and server data, exposed through the platform to bring innovation and value to consumers.As open source platform needs strong and rigorous security architecture to provide security. Android is designed with multilayered security that provides flexibleness needed for an open platform. Android is also designed with focused on user's perspective. Users can view how applications work, and manage those applications. Beginning with the first commercial Android device in September 2008, the operating system has gone through multiple major releases, with the current version being 7.0 "Nougat", released in August 2016. Android applications (apps) whether paid or free can be downloaded from the Google Play store, which features over 2.7 million apps as of February 2017. There are over 300 million Androids in use and over 850,000 devices activated every day.Android has been the best-selling OS on tablets also since 2013, and runs on the vast majority of smartphones. As of May 2017, Android has two billion monthly active users, and it has the largest installed base of any operating system.

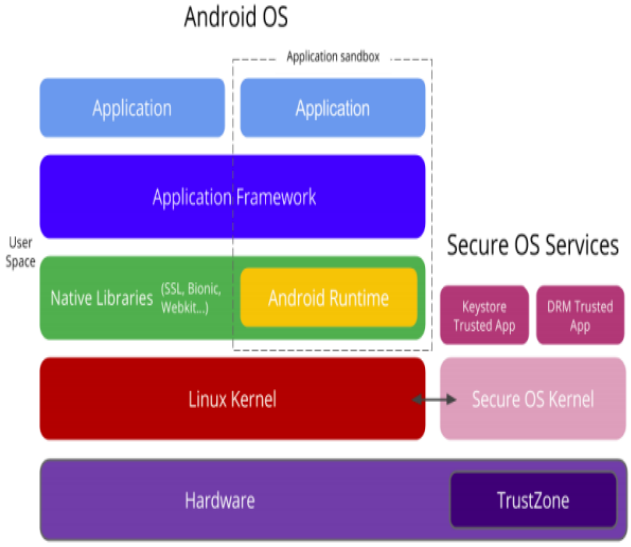

Figure 1: Android Architecture

II. VERSION HISTORY

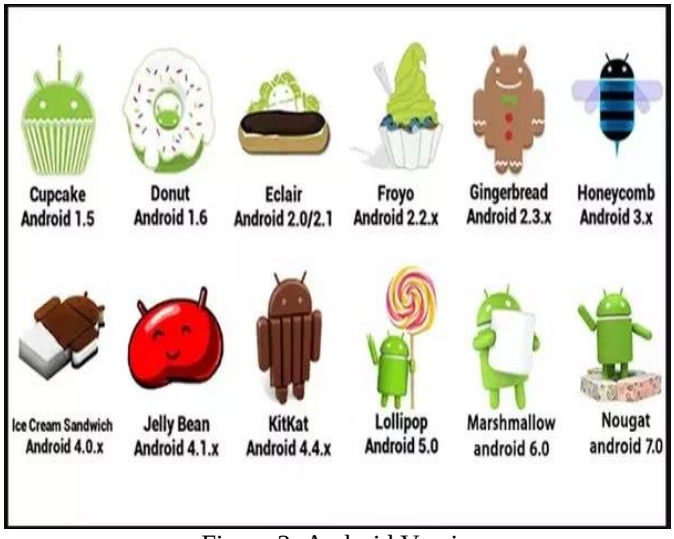

Figure 2: Android Versions

The version history of the Android mobile operating system began with the public release of the Android beta in November 5, 2007. The first commercial version, Android 1.0, was released in September 2008. Versions 1.0 and 1.1 were not released under specific code names, but the code names "Astro Boy" and "Bender" were used internally for some pre-1.0 milestones. Android code names are confectionery-themed and have been in alphabetical order since 2009's Android 1.5 Cupcake, with the most recent major version being Android 7.0 Nougat, released in August 2016.According to the rumors Android 8.0 i.e. Android O would be named as "Android Oreo".

CODE NAME	VERSION NO.	RELEASE DATE	API LEVEL	SUPPORT STATUS
(No code name)	1.0	September 23, 2008	1	Unsupported
(Internally known as "Petit Four")	1.1	February 9, 2009	2	Unsupported
Cupcake	1.5	April 27, 2009	3	Unsupported
Donut	1.6	September 15, 2009	4	Unsupported
Eclair	2.0-2.1	October 26, 2009	5-7	Unsupported
Froyo	2.2-2.2.3	May 20, 2010	8	Unsupported
Gingerbread	2.3-2.3.7	December 6, 2010	9-10	Unsupported
Honeycomb	3.0-3.2.6	February 22, 2011	1-13	Unsupported
Ice cream sandwich	4.0-4.0.4	October 18, 2011	14-15	Unsupported
Jellybean	4.1-4.3.1	July 9, 2012	16-18	Unsupported
Kitkat	4.4-4.4.4	October 31, 2013	19-20	Supported
Lollipop	5.0-5.1.1	November 12, 2014	21-22	Supported
Marshmallow	6.0-6.0.1	October 5, 2015	23	Supported
Nogut	7.0-7.1.2	August 22, 2016	24-25	Supported
'O'	8.0	TBA	26	Release candidate

Table1: Version History

A. 1.0

Android 1.0, the first commercial version of the software, was released on September 23, 2008. The first commercially available Android device was the HTC Dream. Android 1.0 incorporated the following features:

- Android Market allowed application downloads and updates through the Market application
- Web browser to show, zoom and pan full HTML and XHTML web pages – multiple pages show as windows.
- Camera support – however, this version lacked the option to change the camera's resolution, white balance, quality, etc
- Folders allowing the grouping of a number of application icons into a single folder icon on the Home screen
- Access to web email servers, supporting POP3, IMAP4, and SMTP
- Gmail synchronization with the Gmail application
- Google Contacts synchronization with the People application
- Google Calendar synchronization with the Calendar application
- Google Maps with Street View to view maps and satellite imagery, as well as find local business and obtain driving directions using GPS
- Google Sync, allowing management of over-the-air synchronization of Gmail, People, and Calendar
- Google Search, allowing users to search the Internet and phone applications, contacts, calendar, etc.
- Google Talk instant messaging
- Instant messaging, text messaging, and MMS
- Media Player, enabling management, importing, and playback of media files – however, this version lacked video and stereo Bluetooth support
- Notifications appear in the Status bar, with options to set ringtone, LED or vibration alerts
- Voice Dialer allows dialing and placing of phone calls without typing a name or number
- Wallpaper allows the user to set the background image or photo behind the Home screen icons and widgets
- YouTube video player
- Other applications include: Alarm Clock, Calculator, Dialer (Phone), Home screen (Launcher), Pictures (Gallery), and Settings
- Wi-Fi and Bluetooth support

B. 1.1

On February 9, 2009, the Android 1.1 update was released, initially for the HTC Dream only. Android 1.1 was known as "Petit Four" internally, though this name was not used officially. The update resolved bugs, changed the Android API and added a number of features:

- Details and reviews available when a user searches for businesses on Maps
- Longer in-call screen timeout default when using the speakerphone, plus ability to show/hide dialpad
- Ability to save attachments in messages
- Support added for marquee in system layouts

C. 1.5 Cupcake

On April 27, 2009, the Android 1.5 update was released, based on Linux kernel 2.6.27. This was the first release to officially use a codename based on a dessert item "Cupcake", a theme which would be used for all releases henceforth. The update included several new features and UI amendments:

- Support for third-party virtual keyboards with text prediction and user dictionary for custom words

- Support for Widgets – miniature application views that can be embedded in other applications such as the Home screen and receive periodic updates
- Video recording and playback in MPEG-4 and 3GP formats
- Auto-pairing and stereo support for Bluetooth (A2DP and AVRCP profiles)
- Copy and paste features in web browser
- User pictures shown for Favorites in Contacts
- Specific date/time stamp shown for events in call log, and one-touch access to a contact card from call log event
- Animated screen transitions
- Auto-rotation option
- New stock boot animation
- Ability to upload videos to YouTube
- Ability to upload photos to Picasa

D. 1.6 donnut

On September 15, 2009, Android 1.6 was released with code name donut.It was based on Linux kernel 2.6.29. Included in the update were numerous new features:

- Voice and text entry search enhanced to include bookmark history, contacts, and the web
- Ability for developers to include their content in search results
- Multi-lingual speech synthesis engine to allow any Android application to "speak" a string of text
- Easier searching and ability to view app screenshots in Android Market
- Gallery, camera and camcorder more fully integrated, with faster camera access
- Ability for users to select multiple photos for deletion
- Updated technology support for CDMA/EVDO, 802.1x, VPNs, and a text-to-speech engine
- Support for WVGA screen resolutions
- Speed improvements in searching and camera applications
- Expanded Gesture framework and new GestureBuilder development tool

E. 2.0/2.0.1/2.1 Eclair

On October 26, 2009, the Android 2.0 SDK was released, based on Linux kernel 2.6.29 and codenamed Eclair.The other two versions of android eclair 2.0.1 and 2.1 were released on December 3, 2009 and January 12, 2010 respectively with minor amendments in API. Changes include the ones listed below:

- Expanded Account sync, allowing users to add multiple accounts to a device for synchronization of email and contacts
- Microsoft Exchange email support, with combined inbox to browse email from multiple accounts in one page
- Bluetooth 2.1 support
- Ability to tap a Contacts photo and select to call, SMS, or email the person
- Ability to search all saved SMS and MMS messages, with delete oldest messages in a conversation automatically deleted when a defined limit is reached
- Numerous new camera features, including flash support, digital zoom, scene mode, white balance, color effect and macro focus
- Improved typing speed on virtual keyboard, with smarter dictionary that learns from word usage and includes contact names as suggestions
- Refreshed browser UI with bookmark thumbnails, double-tap zoom and support for HTML5
- Calendar agenda view enhanced, showing attending status for each invitee, and ability to invite new guests to events
- Optimized hardware speed and revamped UI
- Support for more screen sizes and resolutions, with better contrast ratio
- Improved Google Maps 3.1.2
- Motion Event class enhanced to track multi-touch events
- Addition of live wallpapers, allowing the animation of home-screen background images to show movement

F. 2.2/2.2.1/2.2.2/2.2.3 Froyo

On May 20, 2010, the SDK for Android 2.2 with code name Froyo was released, based on Linux kernel 2.6.32.The other versions of android froyo have only minor bug fixes but the major additional features of this version are:

- Speed, memory, and performance optimizations
- Additional application speed improvements, implemented through JIT compilation
- Integration of Chrome's V8 JavaScript engine into the Browser application
- Support for the Android Cloud to Device Messaging (C2DM) service, enabling push notifications
- Improved Microsoft Exchange support, including security policies, auto-discovery, GAL look-up, calendar synchronization and remote wipe
- Improved application launcher with shortcuts to Phone and Browser applications
- USB tethering and Wi-Fi hotspot functionality
- Option to disable data access over mobile network
- Updated Market application with batch and automatic update features
- Quick switching between multiple keyboard languages and their dictionaries
- Support for Bluetooth-enabled car and desk docks
- Support for numeric and alphanumeric passwords
- Support for file upload fields in the Browser application
- The browser now shows all frames of animated GIFs instead of just the first frame only
- Support for installing applications to the expandable memory
- Adobe Flash support

- Support for high-PPI displays (up to 320 ppi), such as four-inch 720p screens
- Gallery allows users to view picture stacks using a zoom gesture

G. 2.3/2.3.1-2.3.7 Gingerbread

On December 6, 2010, the Android 2.3 i.e Gingerbread SDK was released, based on Linux kernel 2.6.35.The other versions of android gingerbread leads to minor amendments and bug fixes whereas major Changes included are:

- Updated user interface design with increased simplicity and speed
- Support for extra-large screen sizes and resolutions (WXGA and higher)
- Native support for SIP VoIP internet telephony
- Faster, more intuitive text input in virtual keyboard, with improved accuracy, better suggested text and voice input mode
- Enhanced copy/paste functionality, allowing users to select a word by press-hold, copy, and paste
- Support for Near Field Communication (NFC), allowing the user to read an NFC tag embedded in a poster, sticker, or advertisement
- New audio effects such as reverb, equalization, headphone virtualization, and bass boost
- New Download Manager, giving users easy access to any file downloaded from the browser, email, or another application
- Support for multiple cameras on the device, including a front-facing camera, if available
- Support for WebM/VP8 video playback, and AAC audio encoding
- Improved power management with a more active role in managing applications that are keeping the device awake for too long
- Enhanced support for native code development
- Switched from YAFFS to ext4 on newer devices
- Audio, graphical, and input enhancements for game developers
- Concurrent garbage collection for increased performance
- Native support for more sensors such as gyroscopes and barometers

H. 3.0/3.1/3.2/3.2.1/-3.2.6 Honeycomb

On February 22, 2011, the Android 3.0 i.e Honeycomb SDK ,the first tablet-only Android update was released, based on Linux kernel 2.6.36 .The first device featuring this version, the Motorola Xoom tablet, was released on February 24, 2011.The update's features included are as follows:

- Optimized tablet support with a new "holographic" user interface
- Added System Bar, featuring quick access to notifications, status, and soft navigation buttons, available at the bottom of the screen
- Added Action Bar, giving access to contextual options, navigation, widgets, or other types of content at the top of the screen
- Simplified multitasking – tapping Recent Applications in the System Bar allows users to see snapshots of the tasks underway and quickly jump from one application to another
- Redesigned keyboard, making typing fast, efficient and accurate on larger screen sizes
- Simplified, more intuitive copy/paste interface
- Multiple browser tabs replacing browser windows, plus form auto-fill and a new "incognito" mode allowing anonymous browsing
- Quick access to camera exposure, focus, flash, zoom, front-facing camera, time-lapse, and other camera features
- Ability to view albums and other collections in full-screen mode in Gallery, with easy access to thumbnails for other photos
- New two-pane Contacts UI and Fast Scroll to let users easily organize and locate contacts
- New two-pane Email UI to make viewing and organizing messages more efficient, allowing users to select one or more messages
- Hardware acceleration
- Support for multi-core processors
- Ability to encrypt all user data
- HTTPS stack improved with Server Name Indication
- Disallows applications from having write access to secondary storage (memory cards on devices with internal primary storage) outside of designated, application-specific directories. Full access to primary internal storage is still allowed through a separate application-level permission.
- UI refinements
- Connectivity for USB accessories (USB On-The-Go).
- Expanded Recent Applications list
- Resizable Home screen widgets
- Support for external keyboards and pointing devices
- Support for joysticks and gamepads
- Support for FLAC audio playback
- High-performance Wi-Fi lock, maintaining high-performance Wi-Fi connections when device screen is off
- Support for HTTP proxy for each connected Wi-Fi access point
- mproved hardware support, including optimizations for a wider range of tablets
- Increased ability of applications to access files on the SD card, e.g. for synchronization
- Compatibility display mode for applications that have not been optimized for tablet screen resolutions
- New display support functions, giving developers more control over display appearance on different Android devices

I. 4.0/4.0.1/4.0.2/4.0.3/4.0.4 Ice cream sandwich

The SDK for Android 4.0.1 (Ice Cream Sandwich), based on Linux kernel 3.0.1, was publicly released on October 19, 2011.Google's Gabe Cohen stated that Android 4.0 was "theoretically compatible" with any Android 2.3.x device in production at that time.The source code for Android 4.0 became available on November 14, 2011. Ice Cream Sandwich was the last version to officially support Adobe Systems' Flash player.The update introduced numerous new features:

- Major refinements to the "Holo" interface with new Roboto font family
- Soft buttons from Android 3.x are now available for use on phones
- Separation of widgets in a new tab, listed in a similar manner to applications
- Easier-to-create folders, with a drag-and-drop style
- Improved visual voicemail with the ability to speed up or slow down voicemail messages
- Pinch-to-zoom functionality in the calendar
- Integrated screenshot capture (accomplished by holding down the Power and Volume-Down buttons)
- Improved error correction on the keyboard
- Ability to access applications directly from lock screen
- Improved copy and paste functionality
- Better voice integration and continuous, real-time speech to text dictation
- Face Unlock, a feature that allows users to unlock handsets using facial recognition software
- Automatic syncing of browser with users' Chrome bookmarks
- Data Usage section in settings that lets users set warnings when they approach a certain usage limit, and disable data use when the limit is exceeded
- Ability to shut down applications from the recent apps list with a swipe[101]
- Improved camera application with zero shutter lag, time lapse settings, panorama mode, and the ability to zoom while recording
- Built-in photo editor
- New gallery layout, organized by location and person
- Refreshed "People" application with social network integration, status updates and hi-res images
- Android Beam, a near-field communication feature allowing the rapid short-range exchange of web bookmarks, contact info, directions, YouTube videos and other data
- Support for the WebP image format
- Hardware acceleration of the UI
- Wi-Fi Direct
- 1080p video recording for stock Android devices
- Android VPN Framework (AVF), and TUN (but not TAP) kernel module. Prior to 4.0, VPN software required rooted Android.

J. 4.1/4.1.1/4.1.2/4.2/4.2.1/4.2.2/4.3/4.3.1 Jelly bean

Google announced Android 4.1 (Jelly Bean) at the Google I/O conference on June 27, 2012. Based on Linux kernel 3.0.31, Jelly Bean was an incremental update with the primary aim of improving the functionality and performance of the user interface. The performance improvement involved "Project Butter", which uses touch anticipation, triple buffering, extended vsync timing and a fixed frame rate of 60 fps to create a fluid and "buttery-smooth" UI. Android 4.1 Jelly Bean was released to the Android Open Source Project on July 9, 2012 and the Nexus 7 tablet, the first device to run Jelly Bean, was released on July 13, 2012.The major updated features of jelly bean are:

- Smoother user interface:
- Enhanced accessibility
- Bi-directional text and other language support
- User-installable keyboard maps
- Expandable notifications
- Ability to turn off notifications on an application-specific basis
- Shortcuts and widgets can automatically be re-arranged or re-sized to allow new items to fit on home screens
- Bluetooth data transfer for Android Beam
- Tablets with smaller screens now use an expanded version of the interface layout and home screen used by phones.
- Improved camera application
- Multichannel audio
- The Fraunhofer FDK AAC codec becomes standard in Android, adding AAC 5.1 channel encoding/decoding
- USB audio
- Audio chaining (also known as gapless playback)
- Ability for other launchers to add widgets from the application drawer without requiring root access
- Lock screen improvements, including widget support and the ability to swipe directly to camera
- Notification power controls ("Quick Settings")
- "Daydream" screensavers, showing information when idle or docked
- Multiple user accounts
- Rewritten Bluetooth stack switching from Bluej to Broadcom open source Blue Droid,allowing improved support for multiple displays and wireless display (Miracast)
- Native right-to-left, always-on VPN and application verification.
- A new NFC stack was added at the same time.
- Accessibility improvements: triple-tap to magnify the entire screen, pan and zoom with two fingers. Speech output and Gesture Mode navigation for blind users
- New clock application with built-in world clock, stop watch and timer
- All devices now use the same interface layout, previously adapted from phones on 4.1 for smaller tablets (with

centered software buttons, the system bar at the top of the screen, and a home screen with a dock and centered application menu), regardless of screen size
- Increased number of extended notifications and Actionable Notifications for more applications, allowing users to respond to certain notifications within the notification bar and without launching the application directly
- Premium SMS confirmation
- Fixed Bluetooth audio streaming bugs
- Long-pressing the Wi-Fi and Bluetooth icons in Quick Settings now toggles the on/off state
- New download notifications, which now shows the percentage and estimated time remaining for active application downloads
- New sounds for wireless charging and low battery
- New Gallery application animation allows faster loading
- USB debug whitelist
- Bugfixes and performance enhancements
- Bluetooth low energy support
- Bluetooth Audio/Video Remote Control Profile (AVRCP) 1.3 support
- OpenGL ES 3.0 support, allowing for improved game graphics
- Restricted access mode for new user profiles
- Filesystem write performance improvement by running fstrim command while device is idle
- Dial pad auto-complete in the Phone application[134]
- Volume for incoming calls (ringtone) and notification alerts is no longer adjustable separately
- Improvements to Photo Sphere
- Reworked camera UI, previously introduced on Google Play edition phones
- Addition of "App Ops", a fine-grained application permissions control system (hidden by default)
- SELinux enabled by default
- 4K resolution support
- Numerous security updates, performance enhancements, and bugfixes
- System-level support for geofencing and Wi-Fi scanning APIs
- Background Wi-Fi location still runs even when Wi-Fi is turned off
- Developer logging and analyzing enhancements
- Added support for five more languages
- Changed digital rights management (DRM) APIs
- Right-to-left (RTL) languages now supported
- Clock in the status bar disappears if clock is selected as lockscreen widget

K. 4.4/4.4.1/4.4.2/4.4.3/4.4.4 Kitkat

Google announced Android 4.4 KitKat on September 3, 2013. Although initially under the "Key Lime Pie" ("KLP") codename, the name was changed because very few people actually know the taste of a key lime pie. KitKat debuted on Google's Nexus 5 on October 31, 2013, and was optimized to run on a greater range of devices than earlier Android versions, having 512 MB of RAM as a recommended minimum.Features included are:

- Refreshed interface with white elements instead of blue
- Clock no longer shows bold hours; all digits are thin. The H, M, and S markings for the stopwatch and timer have been removed, leaving just the numbers.
- Ability for applications to trigger translucency in the navigation and status bars
- Ability for applications to use "immersive mode" to keep the navigation and status bars hidden while maintaining user interaction
- Action overflow menu buttons are always visible, even on devices with a "Menu" key, which was officially deprecated by Android 4.0.
- Restriction for applications when accessing external storage, except for their own directories
- Wireless printing capability
- NFC host card emulation, enabling a device to replace smart cards
- Web Views now based on Chromium engine
- Expanded functionality for notification listener services
- Public API for developing and managing text messaging clients
- Storage Access Framework, an API allowing apps to retrieve files in a consistent manner. As part of the framework, a new system file picker allows users to access files from various sources
- New framework for UI transitions
- Sensor batching, step detector and counter APIs
- Settings application now makes it possible to select default text messaging and home (launcher) application
- Audio tunneling, audio monitoring and loudness enhancer
- Built-in screen recording feature
- Native infrared blaster API
- Verified boot
- Enforcing SELinux
- Expanded accessibility APIs and system-level closed captioning settings
- Android Runtime (ART) introduced as a new experimental application runtime environment, not enabled by default, as a replacement for the Dalvik virtual machine
- Bluetooth Message Access Profile (MAP) support
- Disabled access to battery statistics by third-party applications
- Settings application no longer uses a multi-pane layout on devices with larger screens
- Wi-Fi and mobile data activity (TX/RX) indicators are moved to quick settings
- Disables text wrapping in the WebView browser component
- Improvements to auto focus, white balance and HDR+ for the Nexus 5 camera

- Better application compatibility for the experimental Android Runtime (ART)
- Camera application now loads Google+ Photos instead of Gallery when swiping away from the camera view

L. 5.0/5.0.1/5.0.2/5.1/5.1.1 Lollipop

Android 5.0 "Lollipop" was unveiled under the codename "Android L" on June 25, 2014, during Google I/O. It became available as official over-the-air (OTA) updates on November 12, 2014, for select devices that run distributions of Android serviced by Google, including Nexus and Google Play edition devices. Its source code was made available on November 3, 2014.Lollipop features a redesigned user interface built around a responsive design language referred to as "material design". Other changes include improvements to the notifications, which can be accessed from the lockscreen and displayed within applications as top-of-the-screen banners. Furthermore, Google made internal changes to the platform, with the Android Runtime (ART) officially replacing Dalvik for improved application performance, and with changes intended to improve and optimize battery usage, known internally as Project Volta. some features are listed below:

- Android Runtime (ART) with ahead-of-time (AOT) compilation and improved garbage collection (GC), replacing Dalvik that combines byte code interpretation with trace-based just-in-time (JIT) compilation
- Support for 64-bit CPUs
- OpenGL ES 3.1 and Android Extension Pack (AEP) on supported GPU configurations
- Recent activities screen with tasks instead of applications, up to a configured maximum of tasks per application
- Vector drawables, which scale without losing definition
- Support for print previews
- Material design, bringing a restyled user interface
- Refreshed lock screen, no longer supporting widgets
- Refreshed notification tray and quick settings pull-down
- Project Volta, for battery life improvements
- Searches can be performed within the system settings for quicker access to particular settings
- Lock screen provides shortcuts to application and notification settings
- Guest logins and multiple user accounts are available on more devices, such as phones.
- Audio input and output through USB devices
- Third-party applications regain the ability to read and modify data located anywhere on external storage, such as on SD cards.
- Pinning of an application's screen for restricted user activity.
- Recently used applications are remembered even after restarting the device.
- WebViews receive updates independently through Google Play for security reasons, instead of relying on system-wide vendor updates
- Addition of 15 new languages: Basque, Bengali, Burmese, Chinese (Hong Kong), Galician, Icelandic, Kannada, Kyrgyz, Macedonian, Malayalam, Marathi, Nepali, Sinhala, Tamil and Telugu
- Tap and Go allows users to quickly migrate to a new Android device, using NFC and Bluetooth to transfer Google Account details, configuration settings, user data and installed applications
- A flashlight-style application is included, working on supported devices with a camera flash.
- User-customizable priorities for application notifications.
- Smart lock feature
- SELinux in enforcing mode for all domains
- Improved accessibility support Block-based over-the-air (OTA) updates for new devices
- Ability to join Wi-Fi networks and control paired Bluetooth devices from quick settings
- Official support for multiple SIM cards
- Device protection: if a device is lost or stolen it will remain locked until the owner signs into their Google account, even if the device is reset to factory settings.
- High-definition voice calls, available between compatible 4G LTE devices running Android 5.1
- Improvements to the notification priority system, to more closely replicate the silent mode that was removed in Android 5.0

M. 6.0/6.0.1 Marshmallow

Android 6.0 "Marshmallow" was unveiled under the codename "Android M" during Google I/O on May 28, 2015,for the Nexus 5 and Nexus 6 phones, Nexus 9 tablet, and Nexus Player set-top box, under the build number MPZ44Q. The third developer preview (MPA44G) was released on August 17, 2015 for the Nexus 5, Nexus 6, Nexus 9 and Nexus Player devices, and was updated to MPA44I that brought fixes related to Android for Work profiles.

- Contextual search from keywords within apps.
- Introduction of Doze mode, which reduces CPU speed while the screen is off in order to save battery life
- App Standby feature
- Alphabetically accessible vertical application drawer
- Application search bar and favorites
- Native fingerprint reader support
- Direct Share feature for target-specific sharing between apps
- Renamed "Priority" mode to "Do Not Disturb" mode
- App Linking for faster instinctive opening of links with corresponding applications
- Larger Application folders with multiple pages
- Post-install/run-time permission requests
- USB Type-C support
- Demo Mode feature for screenshot-capture usage
- Automatic full data backup and restore for apps
- 4K display mode for apps

- Adoptable External storage to behave like Internal Storage
- MIDI support for musical instruments
- Experimental multi-window feature
- App permissions now granted individually at run-time, not all-or-nothing at install time.

N. 7.0/7.0.1/7.0.2/7.0.2 Nogut

Android N i.e. "Nougat" is the major 7.0 release of the Android operating system. It was first released as a developer preview on March 9, 2016, with factory images for current Nexus devices, as well as with the new "Android Beta Program" which allows supported devices to be upgraded directly to the Android Nougat beta via over-the-air update. Final release was on August 22, 2016. Features included are:

- Unicode 9.0 emoji and skin tone modifier support (and exposes a subset of ICU4J APIs).
- Ability to display color calibration
- Ability to screen zoom
- Ability to switch apps by double tapping in overview button
- Added Emergency information part
- Added the "Clear All" button in Overview screen
- Another system partition, which gets updated when not in use, allowing for seamless system updates
- Daydream virtual reality platform (VR interface)
- Improved Doze functionality, which aims to prolong battery life
- Improvements to file browser
- More Quick Settings options
- Multi-window support, which supports floating apps on a desktop layout
- New Data Saver mode, which can force apps to reduce bandwidth usage
- New JIT Compiler, making for 75 percent faster app installations and a 50 percent reduction in compiled code size
- Just in Time (JIT) compiler with code profiling to ART, which lets it constantly improve the performance of Android apps as they run
- Picture-in-picture support for Android TV
- Redesigned notification shade, featuring instant access to certain settings
- Redesigned Overview screen
- Replaced notification cards with notification sheets
- Settings app navigation drawer
- Vulkan 3D rendering API
- Multiple Device Locales
- Rearranged notification shade
- Night Light
- Touch/display performance improvements
- Moves (Fingerprint swipe down gesture – opt-in)
- Seamless A/B system updates
- Daydream VR mode
- Developer features:
- App shortcuts/shortcut manager APIs
- Circular app icons support
- Keyboard image insertion
- Fingerprint sensor gesture to open/close notification shade
- Manual storage manager Intent for apps
- Improved VR thread scheduling
- Enhanced wallpaper metadata
- Multi-endpoint call support
- Support for various MNO requirements
- PCDMA voice privacy property
- Source type support for Visual Voicemail
- Carrier config options for managing video telephony
- Manual storage manager – identifies files and apps using storage

O. 8.0 Android O

Android O is the upcoming 8th major release of the Android operating system. It was first released as a developer preview on March 21, 2017, with factory images for current Nexus and Pixel devices. The final developer preview was released on July 24, 2017, with the stable release expected in August or September 2017. Some expected features of android O are as follows:

- Redesigned Settings app
- Notification channels
- Picture-in-picture support
- Unicode 10.0 emoji
- Redesigned notification shade
- Redesigned lock screen
- Adaptive icons
- Notification dots
- Sony LDAC codec support
- App-specific unknown sources
- Wider colour gamut for apps

III. FEATURES OF ANDROID

A. Interface

Android's default user interface is mainly based on direct manipulation, using touch inputs that loosely correspond to real-world actions, like swiping, tapping, pinching, and reverse pinching to manipulate on-screen objects, along with a virtual keyboard. Game controllers and full-size physical keyboards are supported via Bluetooth or USB. The response to user input is designed to be immediate and provides a fluid touch interface, often using the vibration capabilities of the device to provide haptic feedback to the user. Internal hardware i.e. different sensors such as acclerometers, gyroscopes and proximity sensors are used by some applications to respond to additional user actions, for example adjusting the screen from portrait to landscape depending on how the device is oriented, or allowing the user

to steer a vehicle in a racing game by rotating the device, simulating control of a steering wheel.

Android devices boot to the homescreen, the primary navigation and information "hub" on Android devices, analogous to the desktop found on personal computers. Android homescreens are typically made up of app icons and widgets; app icons launch the associated app, whereas widgets display live, auto-updating content, such as a weather forecast directly on the homescreen. A homescreen may be made up of several pages, between which the user can swipe back and forth. Third-party apps available on Google Play and other app stores can extensively re-theme the homescreen, and even copy the look of other operating systems, such as Windows Phone with launcher apps. In addition to the above mentioned features, the top of the screen is a status bar, showing information about the device and its connectivity. This status bar can be swiped down to reveal a notification screen where apps display important information or updates.

Figure 3: Android User Interface(UI)

B. Applications

Applications (apps), which extend the functionality of devices are written using the Android software development kit (SDK) and often with the Java programming language. Java may be combined with C/C++, together with a choice of non-default runtimes that allow better C++ support. The Go programming language is also supported, although with a limited set of application programming interfaces (API). In May 2017, Google announced support for Android app development in the Kotlin programming language. The SDK includes a comprehensive set of development tools, including a debugger, software libraries, a handset emulator based on QEMU, documentation, sample code, and tutorials. Initially, Google's supported integrated development environment (IDE) was Eclipse using the Android Development Tools (ADT) plugin. In December 2014, Google released Android Studio as its primary IDE for Android application development.

Android has a growing selection of third-party applications, which can be acquired by users by downloading and installing the application's APK (Android application package) file, or by downloading them using an application store program that allows users to install, update, and remove applications from their devices. Google Play Store is the primary application store installed on Android devices that comply with Google's compatibility requirements and license the Google Mobile Services software. Google Play Store allows users to browse, download and update applications published by Google and third-party developers.In July 2013, there are more than one million applications available for Android in Play Store and 50 billion applications have been installed. As of May 2017, there are over one billion active users a month for Gmail, Android, Chrome, Google Play and Maps.Due to the open nature of Android, a number of third-party application marketplaces exist for Android.

Figure 4: Android Apps

C. Memory management

Since Android devices are usually battery-powered, Android is designed to manage processes to keep power consumption at a minimum. When an application is not in use the system suspends its operation so that, while available for immediate use rather than closed, it does not use battery power or CPU resources. Android manages the applications stored in memory automatically: when memory is low, the system will begin invisibly and automatically closing inactive processes, starting with those that have been inactive for longest.

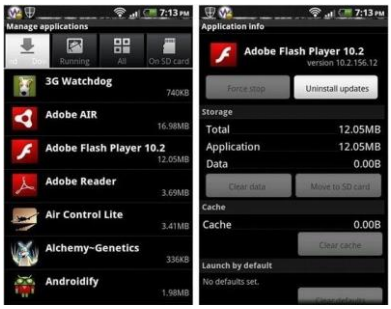

Figure 5: Memory Management in Android

D. Virtual reality

At Google I/O on May 2016, Google announced Daydream, a virtual reality platform that relies on a smartphone and provides VR capabilities through a virtual reality headset and controller designed by Google itself. The platform is built into Android starting with Android Nougat, differentiating from standalone support for VR capabilities.

Figure 6: Virtual Reality in Android

E. Tethering

Android supports tethering, which allows a phone to be used as wireless/wired Wi-Fi hotspot. Before Android 2.2 this was supported by third party applications or manufacturer customizations.

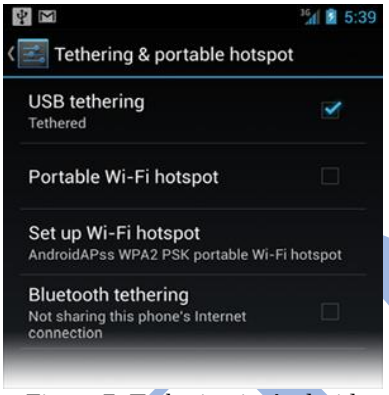

Figure 7: Tethering in Android

F. Screen capture

Android supports capturing a screenshot by pressing the power and volume-down buttons at the same time. Prior to Android 4.0, the only methods of capturing a screenshot were through manufacturer and third-party customizations or otherwise by using a PC connection. These alternative methods are still available with the latest Android.

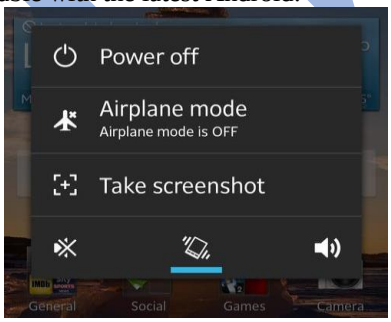

Figure 8: Screen Capturing in Android

G. Bluetooth

Android supports A2DP, AVRCP, sending files (OPP), accessing the phone book (PBAP), voice dialing and sending contacts between phones. Keyboard, mouse and joystick (HID) support is available in Android 3.1+, and in earlier versions through manufacturer customizations and third -party applications.

Figure 9: Bluetooth Logo

H. Java support

While most Android applications are written in Java, there is no Java Virtual Machine in the platform and Java byte code is not executed. Java classes are compiled into Dalvik executables and run on Dalvik, a specialized virtual machine designed specifically for Android and optimized for battery-powered mobile devices with limited memory and CPU. J2ME support can be provided via third party applications.

IV. ANDROID SECURITY

A. SSL

The Secure Sockets Layer (SSL) and its successor, Transport Layer Security (TLS), are cryptographic protocols that were introduced to protect network communication from eavesdropping and tampering. The SSL protocol aims primarily to provide privacy and data integrity between two communicating computer applications. To establish a secure connection, a client must securely gain access to the public key of the server. In most client/server setups, the server obtains an X.509 certificate that contains the server's public key and is signed by a Certificate Authority (CA). Trusted certificates can be used to create secure connections to a server via the Internet. When the client connects to the server, the certificate is transferred to the client. The client must then validate the certificate.

The basic validation checks include: a) Does the subject (CN) of the certificate match the destination selected by the client? b) Is the signing CA a trusted CA? c) Is the signature correct? And d) is the certificate valid in terms of 51its time of expiry? Additionally, revocation of a certificate and its corresponding certificate chain should be checked, but downloading Certificate Revocation Lists (CRLs) or using the Online Certificate Status Protocol (OCSP) is often omitted.

B. Android Security

The open nature of Android and its large user base have made it an attractive and profitable platform to attack. Common exploits and tool kits on the OS can be utilized across a wide number of devices. Google did take measures in the development of the Android kernel to build security measures in the Android OS which is sandboxed, preventing malicious processes from crossing between applications. Whilst this attempt to eliminate the concept of infection is admirable in some regards, it fails to address the issue of infection altogether.. One of the reasons the OS has succeeded in gaining market share so rapidly is that it is open source. Additionally this has led to substantial fragmentation of Android versions between devices and means that vendors have been reluctant to roll-out updates.

C. Service

A Service is code that is longlived and runs without a UI. A good example of this is a media player playing songs from a play list. In a media player application, there would probably

be one or more activities that allow the user to choose songs and start playing them. However, the music playback itself should not be handled by an activity because the user will expect the music to keep playing even after navigating to a new screen. In this case, the media player activity could start a service using Context Start Service to run in the background to keep the music going. The system will then keep the music playback service running until it has finished. Note that you can connect to a service and start it if it's not already running with the Context bind Service method. When connected to a service, you can communicate with it through an interface exposed by the service. For the music service, this might allow you to pause, rewind, etc.

D. Technical Security Features

Android applications run in a sandbox, an isolated area of the system that does not have access to the rest of the system's resources, unless access permissions are explicitly granted by the user when the application is installed. Since February 2012, Google has used its Google Bouncer malware scanner to watch over and scan apps available in the Google Play store. A "Verify Apps" feature was introduced in November 2012, as part of the Android 4.2 "Jelly Bean" operating system version, to scan all apps, both from Google Play and from third-party sources, for malicious behaviour. Originally only doing so during installation, Verify Apps received an update in 2014 to constantly scan apps, and in 2017 the feature was made visible to users through a menu in Settings. Before installing an application, the Google Play store displays a list of the requirements an app needs to function. After reviewing these permissions, the user can choose to accept or refuse them, installing the application only if they accept. In Android 6.0 Marshmallow, the permissions system was changed; apps are no longer automatically granted all of their specified permissions at installation time. An opt-in system is used instead, in which users are prompted to grant or deny individual permissions to an app when they are needed for the first time. Applications remember the grants, which can be revoked by the user at any time. The new permissions model is used only by applications developed for Marshmallow using its software development kit (SDK), and older apps will continue to use the previous all-or-nothing approach. Permissions can still be revoked for those apps, though this might prevent them from working properly, and a warning is displayed to that effect.

V. CONCLUSION

I've learned through my research that Android is a much more diverse operating system than iOS and Windows Phone Mobile. Android has grown rapidly over the past 4 years becoming the most used smartphone operating system in the world. It's because Android doesn't release 1 phone from 1 company with 1 new OS every year, but countless phones from numerous companies, adding their own twist, throughout the year, developing gradually day-by-day. Moreover Android is a fully customizable operating system and its an open sourse and can be downloaded from internet.

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