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Android Open Source Project: A study of contribution analysis & degree of openness in governance

Master's thesis in the Entrepreneurship and Business Design program

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SUMMARY

The term Open Source has been emerging as a popular way to collaborate & innovate. Android Open Source Project is one such, latest and widely, discussed open source project which is a Google initiative. Since its launch as an open source project, it has been one of the most widely talked about projects in technology space. While it has garnered interest from technologists and software developers across the globe, some others have started looking it through a lens of legal & business aspects. An alliance of around 80 companies was formed in the year 2007 known as Open Handset Alliance, to support and develop Android as an open and innovative mobile platform. Android has already reflected this commitment of alliance by leading the smartphone market and gaining market share at rapid pace. There are several studies conducted on Android in the recent past both as a technology platform and as its business implication. However, a little attention has been paid over the openness and governance of the platform. The objective of this thesis is to explore the openness in the governance of the Android open source project by analysis of the contributions made to the project. The contributions are studied to find key trends and their relationship with the governance. This study is unique in the way that it involves technological, legal, and business aspects in the analysis of contributions and its relationship with the governance.

The study of the contribution revealed that not all the actors who are member of Open Handset Alliance are contributing to the project. Some of those who are contributing, are contributing either to push their technology or capitalize on the market strength of the Android to push products to the market. There are a lot of individuals who are also contributing to the project. The motivations behind such contributions are skill development, better job prospects etc. Some actors are not contributing to the platform directly, but they are contributing by circumventing the open contribution method. This could be due to the result of the legal implication of the contribution agreement with respect to IPRs. It was found during the study that Android Open Source Project is not governed by a group of actors by democratic means but is primarily governed by Google keeping its own interests into consideration. The project has elements of open source to the extent that the source code is available for all but when it comes to the future direction of the project is driven by only one actor, Google.

Keywords: Android, open source

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Abbreviations and Definitions

OSI – Open Source Initiative (OSI) is a non-profit corporation with global scope formed to educate about and advocate for the benefits of open source and to build bridges among different constituencies in the open source community.

OSD – Open Source Definition (OSD) refers to the definition of Open Source as stated by Open Source Initiative.

AOSP – Android Open Source Project (AOSP) is an open source project with a goal to develop and promote the Android software platform.

OHA – Open Handset Alliance (OHA) is a group of 80 technology companies that have together to accelerate innovation in mobile and offer a richer, less expensive, and better mobile experience. AOSP is an OHA initiative.

IPR – Intellectual Property Rights (IPR) refers to the intangible property which is a result of creativity.

CTS – Compatibility Test Suite (CTS) is a software test suite that is used to manufacture an Android compatible device.

CDD - Compatibility Definition Document (CDD) is a set of policies that must be followed to develop an Android compatible product.

SDK – Software Development Kit (SDK) is a set of developmental tools that allow application development for a software or hardware platform.

VCS – Version Control System refers to technologies and practices for tracking and controlling changes to the project files.

Software Stack – It refers to a layered set of software built upon each other.

1. Introduction

This introductory chapter presents the background, purpose, methods and overview of thesis, delimitations and reflections on the validity and reliability of the study.

1.1 Background

The term open source is generally associated with computer software but historically it has influenced other aspects of society as well. Over the period, it has not only played its role in the development of several technologies or software platforms but also areas like food and beverages. Although open source as a term was formally coined and promoted in last few decades, the philosophy of community contribution and further distribution had been practiced within the society. During 1960's, several computer software was developed in various academic institutions like MIT & Berkeley and in-house research groups in corporations like Palo Alto Research Centre. The source code of various projects was shared among the programming community. (Feller, 2005). As a result of such focused work during this period various successful projects were developed like UNIX by AT&T lab. Later, Usenet emerged in 1970's as facilitator of sharing of source code. This informal development of open source software without any intellectual property guidelines let the debate around UNIX. This led to the drafting of the formal rules of engagement this open source space. This initiative was primarily started with Free Software Movement led by Richard Stallman in early 1983 and formal licensing mechanism was created.

The relative success of various open source projects has given impetus for thinkers to explore other industries as well. In an article, The Economist[1] speculates if an open source software model can also be replicated in pharma industry. However, that remains to be seen if this thought is possible in an industry which is highly patent intensive & thrive on monopoly.

At present, different actors are using the open source framework not only to encourage innovation but also deploying them as commercial businesses. Android open source project is one such project which has been continuously discussed these days. Android Open Source Project is an initiative by Google along with members of Open Handset Alliance to develop and promote Android as a cheap, innovate, free mobile Operating system for mobiles and tablets. According to the market research by Gartner[2] "… more than 296 million smart phones shipped last year. Out of that, Symbian secured 37.6 percent market share, followed by Android's 22.7 percent share, and BlackBerry OS with 16 percent of the market. In 2011, the number of smart phone shipments around the world will explode to nearly 468 million units. That growth will help Android snag 38.5 percent market share by the end of the year, followed

[1] https://www.economist.com/technology-quarterly/2004/06/12/an-open-source-shot-in-the-arm
[2] https://www.cnet.com/news/gartner-android-market-share-to-near-50-percent/

by Apple's iOS at 19.4 percent, and Symbian at 19.2 percent". A more discussion around Android and Open Handset Alliance has been done in separate sections in chapter 2.

In an open source project, different contributors, based on their areas of expertise, makes a proposal for contribution to a segment or layer of the project. This proposal is then discussed and debated within a group or sub-community comprising of similar expertise. More often, multiple proposals are made by different group members to address an issue or suggest an improvement and only the best proposal is accepted based on voting after deliberations and assessments within the group. The goal behind this process is that only the best solution must be incorporated into the project. Such openness, thus, encourages more participation from different community or group members to come up with best proposals. The presence of such process not necessarily means that all the group members will always contribute or contribute is similar quantum but it ensures that anyone having a good proposal will get a chance to put it forward and will receive a feedback for acceptance or rejection. Different open source project makes different set of groups and bylaws based on the nature of project & technology involved. Android Open Source Project is one such project where different actors from industry like semiconductor companies, handset manufacturers, software companies contribute to source code of the Android with an expectation to make is more efficient and to deliver better performance. Although small, individual actors are also contributing to this project actively. Thus, AOSP has varied group of contributors. A contribution means that any kind of addition or modification made to the source code to achieve better performance or enhanced functionality. These contributions can be made on the Android server, which is the server where Android Open Source Project is hosted. All the contributions which are being made to AOSP are stored in this server and this data is retrieved and further studied in this thesis work.

Due to the rapid popularity and market acceptance by the industry and user, there are lots of studies going on both in industry as well as in academia around Android Open Source Project. This makes this topic of the thesis interesting to explore more on Android as an open source project. Thus far, majority of the work on Android has been done on the technical functionalities and at the developmental level or it is based on the business implications with respect to market share among mobile OS. However, there are no studies done regarding the openness of the project and how it impacts the governance.

1.2 Purpose

The success of an open source project is often attributed to the community behind the project. More active participation by contributors not only lead to more innovative ideas but also work as feedback mechanism in the future development. And hence, how the contributions from wide range of contributors, from large corporations to individual tech enthusiasts, are governed in open but goal-oriented manner becomes a key challenge for any open source project. Like a democracy, the notion of an open source project is that every contributor has a vote that would be counted in decision making at some level or the other. But not all open source project

subscribes to this idea. Different projects are governed in different ways with a varying degree of openness. Android Open source is one such project which has seen tremendous commercial success in recent past and seems to be backed by a powerhouse group of tech corporations in form of Open Handset Alliance lead by Google. This thesis will study the degree of openness in the governance of the Android Open Source Project. As discussed in the previous section, an open source project must have an open forum for all contributors where the contributions are discussed, debated between the group members. There must also be freedom to access the source code and right to use the developed version of the project. In absence of all these, there will be minimal participation from the community in an open source project. If contributions are still made, there could be different motivations and purpose behind such contributions. This research will thus analyze all the contributions made to the AOSP and investigate contribution patterns by different corporates and non-corporate actors and trying to understand their motivation & incentives behind contributions. If the contributions from different contributors are well spread across technology segments and if the open debates take place in structured manners with some sort of voting mechanism, then the project is said to be open in its governance. Otherwise, the project is quite closed, with minimal participation from the community. Hence, to determine such openness in the governance of the AOSP, the thesis will try to answer the following questions:

- Who are the key contributors for AOSP and from which segment of industry they belong to?
- What is the motivation & incentives behind contributions by different segment of contributors?
- What is technical nature of these contributions and in which capacity these contributions are being made?
- What are they key trends in contributions?
- How these contributions reflect upon the governance of the AOSP?
- What is the degree of openness in the governance of AOSP?

1.3 Research methodology & overview of thesis

As stated in the purpose of the thesis, the study is only limited to the Android Open Source Project. The study broadly consists of the following parts - gathering the contribution data, study of trends & patterns and perform analysis to derive conclusions. The contribution data has been gathered from Android Open Source Project server using Gerrit, a review system used by Google. This database comprises of publicly open data and serves as the foundation of this study. To acquire the subject knowledge and to understand prevalent industry practices, I have had ten interviews with various subject matter experts from different segments of the telecommunication & semiconductor industry. The essence of these discussions is used throughout the analysis of the data. However, due to confidentiality reasons the names of individuals and organizations they are associated with are disclosed in this work. Several web

sources like news articles, blogs, journals etc. have also been studied for better understanding of the subject matter and strengthening the conclusions.

The data simply refers to all the contributions made by various actors to the Android Open Source Project. The data retrieved through Gerrit is sorted by Id, subject, owner, project, branch, update date, owner email and organization. The Id is a unique numbering system which point to a subject, which is a description of the contribution made by the owner. The project is a specific segment of the AOSP where the contribution has been made to a branch, a sub-segment of the project, on a specific date to keep track of the changes. Each contribution also includes the email id of the owner and the organization with which he/she is associated. All contribution is categorized as either open, merged or abandoned. If a contribution is shown as "open" in the data, this means that it has not been included or excluded in the project. The decision made about that contribution would change its tag as either "merged" or "abandoned" depending on if it was accepted or rejected.

1.4 Research Workflow

During the thesis, a workflow has been followed to make the process efficient. The step by step flow of the research work followed during the thesis can be seen in the Figure 1:

Conceptual study of the subject – Conceptual study of the subject means the study of the Android and Android Open Source Project. It includes all the background information and elements needed to start the project like what is the process of contribution. How contributions are counted? Which features of open source are being involved in AOSP?

Data retrieval – In order to gather the data for contributions, it was important to study the working of the source of the data and different components of Android server where project is being hosted. It was also important to figure out how data can be retrieved in a convenient and efficient way. The data was quite raw in nature and some set methods were adopted to arrange it structural way so that it can be conveniently studied. The detailed discussion around contribution process and data retrieval will be discussed in Chapter 3.

Market study – The Market study means the study of Android in terms of market performance and overall behavior of industry. This study would not be useful for explicitly but rather it was useful implicitly to analyze the big picture and the trends of the contribution.

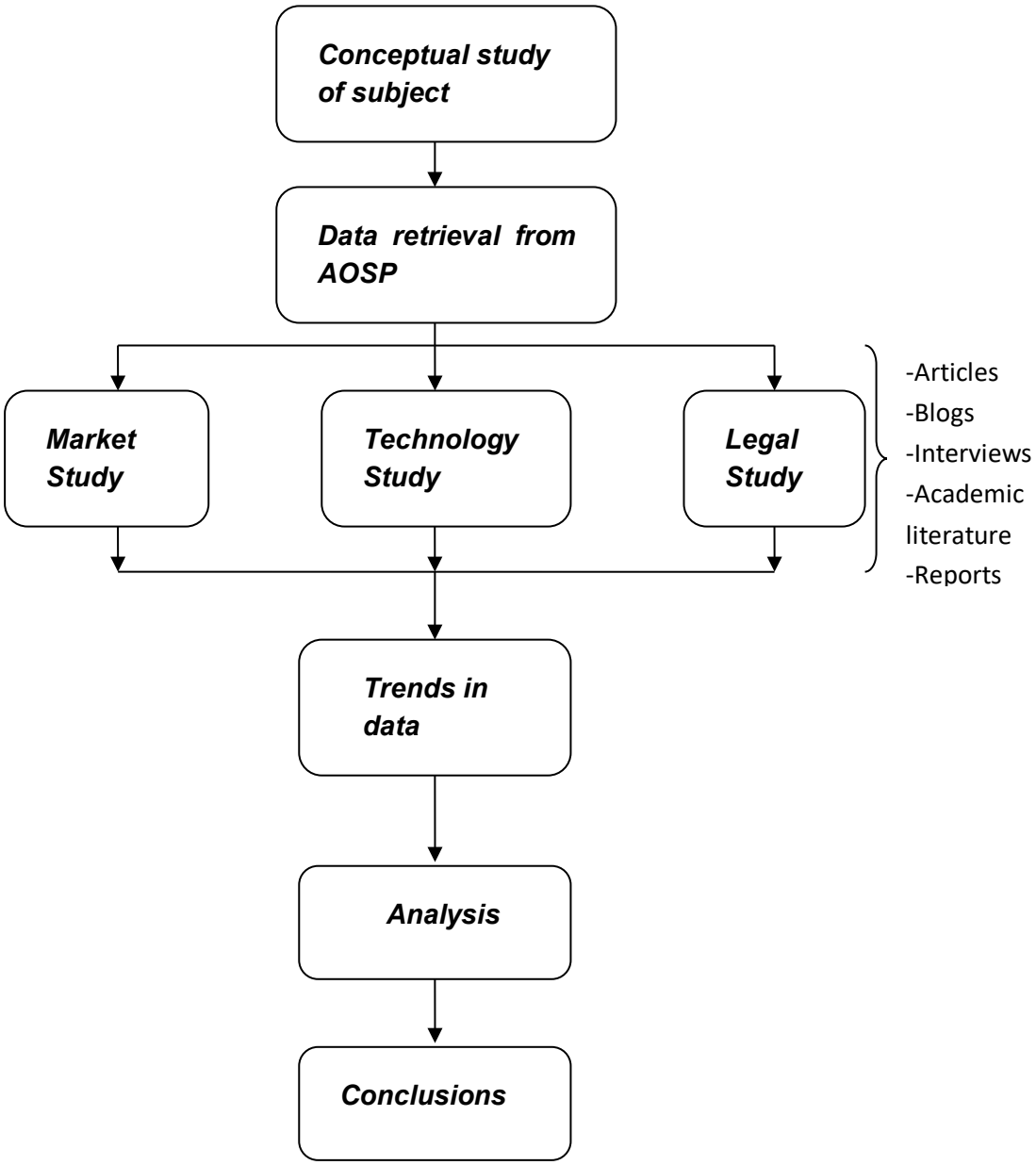


Figure 1: Flowchart stating research workflow

Technology study – This part focuses on the various technological aspects of the Android platform where contributions are mapped to the different layers of the Android. This study has importance in analyzing the nature of contributions and possible incentives for contributors to contribute to the project.

Legal study – The legal study was carried out to understand how IPR binds the open source project and how different agreements and licenses play a vital role in the governance of open source.

Trends in the data – The contribution data was being studied with background of market, technology and legal study being discussed above to observe some trends and would be discussed and concluded in the later chapters of the thesis.

Analysis – The analysis would be done over the data gathered and trends and observations being made. To categorize the different sections of the industry in orderly manner all the members of OHA would be used along with some additional categories like individual actors.

Conclusions - Finally based on the analysis and discussion some conclusion will be made and the research question will be answered in this section.

1.5 Scope and delimitations

The scope of this thesis is limited to data on Android Source tree[3] available in the public domain. It is beyond the scope of this thesis to figure out and consider the data which is not available on this server.
The data considered here limits within the duration October 2008 till February 2011. Considering the amount of data involved, approximations are being made to interpret them in best possible way. It important to mention here is that legal agreement and market positioning plays a vital role in the contribution patterns by different industrial actors. But to limit that we would briefly discuss these points and would be considered as ground for further discussion. The views are highly based on the different interviews and personal opinions of various individuals involved in Android all over the industry. No official compilation of the interview will be presented in this work due to confidentiality reasons.

1.6 Reflection on validity & reliability

Validity of the data and results analyzed is measure of degree of error in the collection of data and its interpretation with respect to the objectives of the research questions. Reliability refers to the extent to which the retrieval and measurement procedure yields the same results on repeated trials during the same period. The validity and reliability of data, process and theoretical and conceptual background will be discussed below:

2. Theory

This chapter is aimed to provide an insight about the theoretical framework behind the thesis. The chapter will discuss various aspects of Open source and different perspectives by different

[3] https://review.source.android.com

key individuals. The chapter will also cover some theoretical aspects of Android and its governing body Open Handset Alliance.

2.1 Open Source

Open is sometimes considered as a pragmatic approach or sometimes it is considered as a philosophy. However, Open Source can be simply understood as practices in production and development of the product that promote access to the end product's source material. Open source has been used in various contexts; some of them are computer software, electronics, beverages, digital content, health & science, robotics etc. However, with the emergence of information age and nature of the product computer software are the most interesting category of Open source. With various pros of having an open source software, there comes disadvantages as well like cleaning for the code, making it user friendly, compatibility with new project etc. Hence, open source software is not necessarily a free software, it has its own cost associated with it.

"Confusion about the term freedom was the very reason why the term open source was created." – Lawrence Rosen

In computer software, the programmer writes the source code and the computer itself executes the program. But to understand the source code so that it can be modified and studied it should be open. This is the key aspect of Open source which is widely debated and discussed throughout various corners of the industry. The point which is being made here is that abiding to the open source license does not mean the total freedom to use this software.

To understand the functional aspect of open source it is important to understand how open source is defined. There are different views being presented by various thinkers on open source, some of them can be viewed as follows:

Different views and definitions on Open Source:

1. According to Bruce Perens (Perens, 1999) "The Open Source Definition is a bill of rights for the computer user. It defines certain rights that a software license must grant you to be certified as Open Source. Those who don't make their programs Open Source are finding it difficult to compete with those who do, as users gain a new appreciation of rights they always should have had. Programs like the Linux operating system and Netscape's web browser have become extremely popular, displacing other software that has more restrictive licenses. Companies that use open-source software have the advantage of its very rapid development, often by several collaborating companies, and much of it contributed by individuals who simply need an improvement to serve their own needs."

He also adds "The volunteers who made products like Linux possible are only there, and the companies are only able to cooperate, because of the rights that come with Open Source. The average computer programmer would feel stupid if he put lots of work into a program, only to have the owner of the program sell his improvement without giving anything back. Those same

programmers feel comfortable contributing to Open Source because they are assured of these rights:

- The right to make copies of the program and distribute those copies.
- The right to have access to the software's source code, a necessary preliminary before you can change it.
- The right to make improvements to the program. “

2. The most recent definition of Open source (OSD) is defined by Open source Initiative[4]. Open source can be defined by the below mentioned aspects.

- **Free redistribution** - The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale.

- **Source code** - The program must include source code and must allow distribution in source code as well as compiled form. Where some form of a product is not distributed with source code, there must be a well-publicized means of obtaining the source code for no more than a reasonable reproduction cost preferably, downloading via the Internet without charge. The source code must be the preferred form in which a programmer would modify the program. Deliberately obfuscated source code is not allowed. Intermediate forms such as the output of a preprocessor or translator are not allowed.

- **Derived works** - The license must allow modifications and derived works and must allow them to be distributed under the same terms as the license of the original software.

- **Integrity of the author’s source code** - The license may restrict source-code from being distributed in modified form *only* if the license allows the distribution of "patch files" with the source code for the purpose of modifying the program at build time. The license must explicitly permit distribution of software built from modified source code. The license may require derived works to carry a different name or version number from the original software.

- **No discrimination against persons or groups** - The license must not discriminate against any person or group of persons.

- **No discrimination against fields of endeavor** - The license must not restrict anyone from making use of the program in a specific field of endeavor. For example, it may not restrict the program from being used in a business, or from being used for genetic research.

[4] http://opensource.org/docs/osd

- **Distribution of license** - The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties.

- **License must not be specific to a product** - The rights attached to the program must not depend on the program's being part of a particular software distribution. If the program is extracted from that distribution and used or distributed within the terms of the program's license, all parties to whom the program is redistributed should have the same rights as those that are granted in conjunction with the original software distribution.

- **License must not restrict other software** - The license must not place restrictions on other software that is distributed along with the licensed software. For example, the license must not insist that all other programs distributed on the same medium must be open-source software.

- **License must be technology neutral** - No provision of the license may be predicated on any individual technology or style of interface.

3. Lawrence Rosen (Lawrence, 2005) in his book simplifies the definition of Open source and views these simplifications as Open Source Principles. These principles are consistent with the original open source definition (OSD). This principle basically involves discussion around licenses and contracts. These principles are:

- Licensees are free to use open source software for any purpose whatsoever.

- Licensees are free to make copies of open source software and to distribute them without payment of royalties to a licensor.

- Licensees are free to create derivative works of open source software and to distribute them without payment of royalties to a licensor.

- Licensees are free to access and use the source code of open source software.

- Licensees are free to combine open source and other software.

Role of Intellectual Property in Open Source:

Intellectual Property is often defined as intangible property which is often a result of creativity. The open source software is typically described as a combination of art and science. Lawrence Rosen (Lawrence, 2005) again highlights that “Art is said to be the product of our right brain, the right hemisphere of our cerebral cortex that supposedly controls feelings and emotions. Scientific creations, it is said, are the product of our left brain, the left hemisphere that uses logic. Whether, true or not, this bicameral description of the two products of human intellect – art and science – useful to help us understand what we do when we create software. Intellectual property law distinguishes these two kinds of intellectual creations. Our right brain creations are expressions, most often found in painting, music, fiction, and poetry. Our left-brain

creations are ideas, found in our scientific and technical innovations. Expressions are subject to copyright law and ideas are subject to patent law." Rosen also highlights the importance of trademarks as "….the one that captures consumer attention though effective marketing."
It is important to note that IP is the key of Open Source projects which are being governed by various licenses and agreements. In a system of collective development, it is always necessary to know who own what and in which capacity they can make use of the collaborative work, further distribution etc.

Licensing in Open Source:
The term can be simply described as the permission to do something. This permission to do something is always based on some term and condition which are part of the license agreements. Licenses are the informal currency for the transaction of Intellectual Property like copyright, patents, and trademarks. There are different kinds of licenses proprietary licenses as well as open source licenses.
Open Source projects are largely governed by license or licenses depending on the nature of the project. As describe by OSI website[5] some of the widely used licenses with strong community are as follows:

- Apache license 2.0
- BSD Licenses (New and simplified)
- GNU General Public License (GPL)
- GNU library or Lesser Genral Public License (LGPL)
- MIT License
- Mozilla Public License 1.1 (MPL)
- Common Development and Distribution License
- Eclipse Public License

More information about these licenses can be found on Open Source Initiative website[6].
Licensing is important in understanding Open source when it comes to contributing to the project. The nature of license sometime the way different actors contribute to a project. Sometimes licenses are created for specific project; in such cases one should be careful about the term that it should not restrict contributions. However, it always preferred to choose the existing license structure rather than creating a new one. According to Ron Goldman & Richard P. Gabriel (Gabriel, 2005) "Even a short, clearly written new license is an additional hurdle that limits outside participation--and most new licenses tend to be neither short nor clear. Legal departments in universities and in other, non-commercial organizations are reluctant even to read a new license for their clientele, so if you want to address the university user and developer communities, writing your own license will probably backfire". Hence it important to be careful while choosing license. A new license agreement has been created for contributors in

[5] http://opensource.org/licenses/category

AOSP called as Contributors Agreement License Grant, which make it interesting and rather important to look upon its effect on contributions made by different actors.

2.2 Android

The term "Android" has its origin in the Greek word andr-, meaning "man or male" and the suffix -eides, used to mean "alike or of the species". This together means as much as "human like being".

Android is a software stack for mobile devices that includes an operating system, middleware, and key applications. A software stack is a hierarchical layered set of programs that work together to produce a result. It may refer to any group of applications that work in sequence toward a common result or to any set of utilities or routines that work as a group. Android's mobile operating system is based on modified version of Linux kernel.

Android Inc. was founded in Palo Alto, California in 2003 by Andy Rubin, Rich Miner, Nick Sears, and Chris White with a vision "to develop smarter mobile devices that are more aware of its owner's location and preferences"[7]. In the year 2005, Android was acquired by Google as wholly owned subsidiary of Google Inc.

2.2.1 Android Open Source Project

Android is continuously evolving and getting better and better by the contributions made by different actors in the process. Google is responsible for managing all the contributions and keeping a check on the different versions. Google has some dedicated employees who work with Android in different capacities. Apart from Google, other industrial actors who are part of OHA are also committed towards the development of Android. Android also has a large community of application developers who develop various applications which further extends the functionality of an Android device. All the Android applications are available on Android Market, which is an online store for all Android applications. It also provides Google specific application like Google Voice. However, Google also allow independent application store to operate for Android. At present Android Market have over 200,000 applications available for download, which can be downloaded from third party sites.

In an annual Google event called Google I/O[8], Google announced that Android is being activated on 400,000 devices every day and so far, more 100 million devices have been activated.

[7] Andy Rubin in an interview to Business Week, 2003.
https://web.archive.org/web/20110205190729/http://www.businessweek.com/technology/content/aug2005/tc20050817_0949_tc024.htm

[8] https://googleblog.blogspot.com/2011/05/android-momentum-mobile-and-more-at.html

The first Android based phone was HTC Dream[9] which was released on 22 October 2008. Also, in 2010 Google also launched its flagship phone Nexus One[10] with collaboration with HTC. At present HTC, Samsung, Motorola, and Sony Ericsson are key Android Handset manufacturers. Android also being evolving for netbooks and tablets like Dell Streak, Samsung Galaxy Tab and it will soon be used in TV and other devices.

2.2.2 Android market share

Android is growing very rapidly in term of market share in the smart phone segment giving intense competition to its competitors in the segment like Apple iOS, RIM Blackberry OS, Microsoft Windows Mobile, Palm/Web OS and Symbian OS. As per Nielsen Mobile Insight by March 2011, Android had 50% market share out of total new addition of smart phones with Apple iOS as immediate competitor with 25% of total market share.

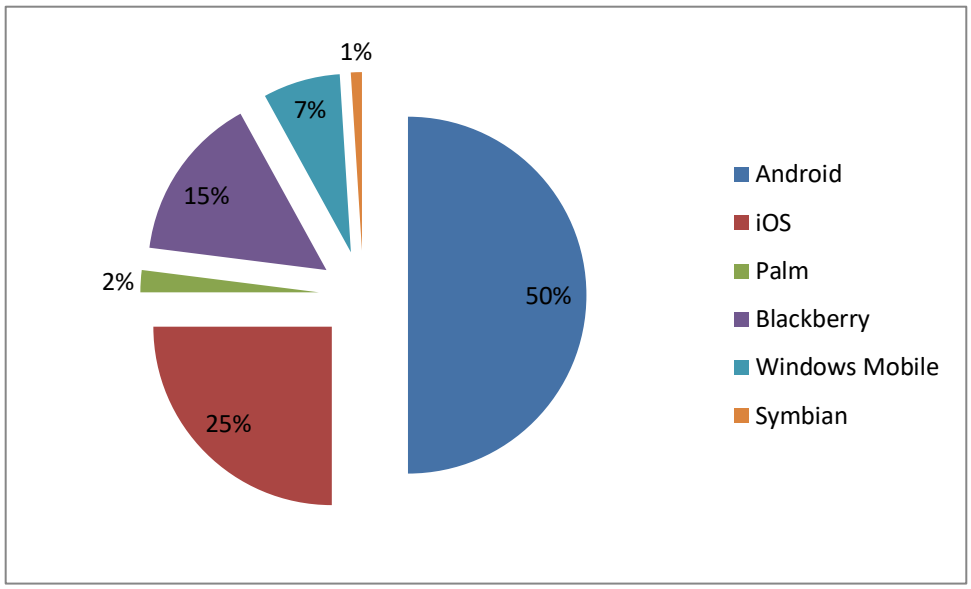


Figure 2:Smartphone market share[11]

2.2.3 Android Versions

Android had it first release of Android version1.0 or simply Android 1.0 in the year 2008. Since then they have released some frequent versions. Android has a tradition of nomenclature of various versions after some dessert like Cupcake, Donut etc. The timeline of various release of Android version is shown in figure. Honeycomb is the latest in the series and is launched in Year 2011. The next version to be released will be Ice-cream[12].

[9] https://gizmodo.com/t-mobile-g1-full-details-of-the-htc-dream-android-phon-5053264
[10] https://sites.google.com/a/pressatgoogle.com/nexusone/press-release
[11] Nielsen Mobile Insight, 2011
[12]https://arstechnica.com/information-technology/2011/05/google-announces-android-ice-cream-sandwich-will-merge-phone-and-tablet-oses/?comments=1

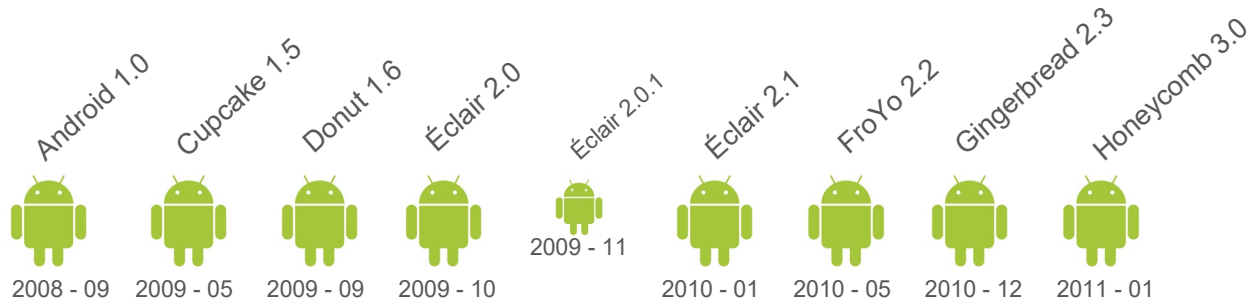


Figure 3: Android versions time line

2.2.4 Android Architecture

Google usually refer Android architecture as a software platform stack. A particular layer on the stack group together with several programs that supports specific operating system functionality. The software stack of Android is divided in four different layers, which include 5 key sections. These sections can be seen in figure 4 which contains the official release of Android Architecture[13] by Google aimed for Android application developers.

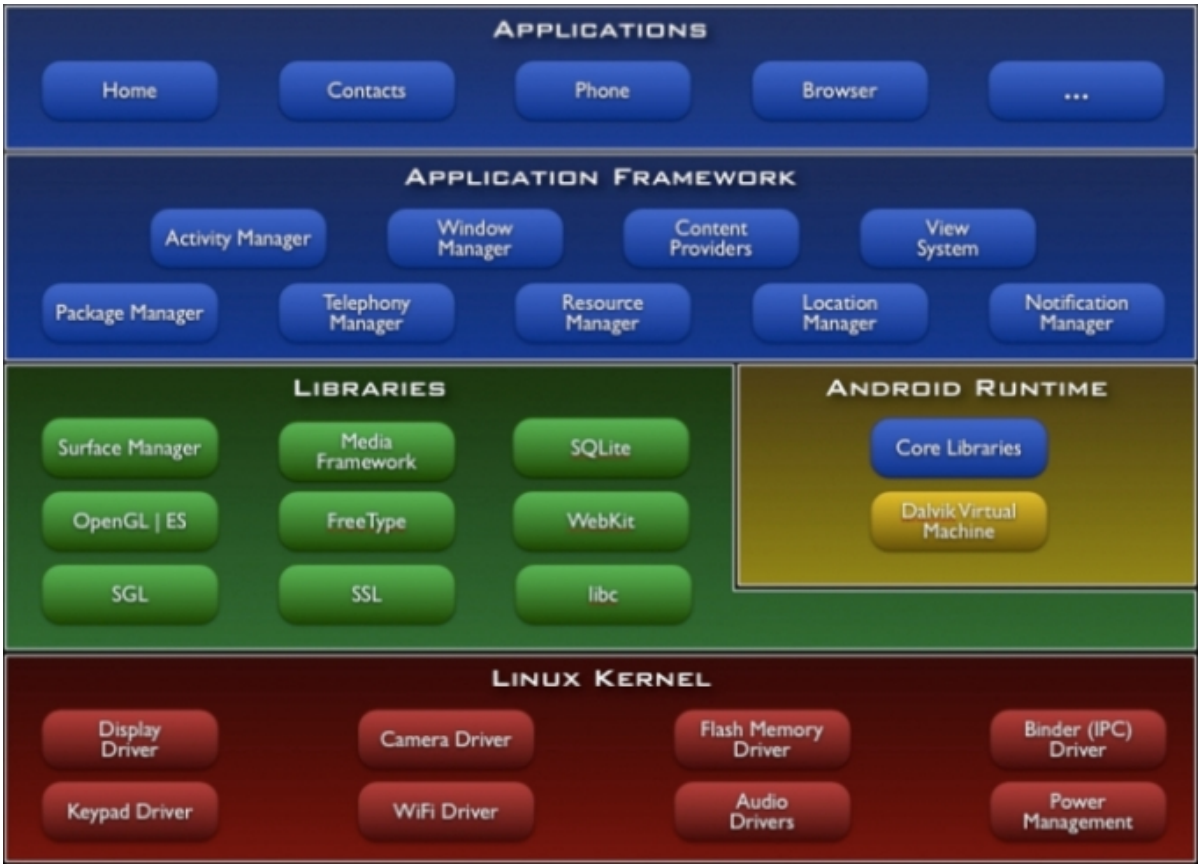


Figure 4: Android Architecture

Application Layer:

[13] http://developer.android.com/guide/basics/what-is-android.html

The application layer comprises of basic applications like browser, email client, maps, calendars, messaging or SMS programs, contacts etc. These applications are programmed using Java programming language. These applications can be used at the same time, for instance it is possible type message and listen to music at the same time. This layer is closest to the end user and serves as the face of Android to the outside world. Application developer and handset manufacturers usually work extensively on this layer.

Application framework layer:
The application framework is a software framework which is used to implement standard structure of an application for the operating system. It contains various managers like activity manager, resource manager, window manager etc., content providers and other services different functions can be reassembled and can be used by other existing applications.

Libraries:
Libraries can be understood as set of instructions or dedicated sub-routines which handle data in a specific manner. The libraries in Android software stack are written in C and C++, which are called by a Java Interface. These include Surface Manager (for composite window), media Codec like MPEG4, MP3, 2 dimensional and 3-dimensional graphics, web browser engine Web kit and SQL database SQLite.

Android Runtime:
The Android runtime[14] works on same level as the "libraries layer" on the software stack. It contains two components – core libraries and Dalvik Virtual machine. The core libraries are written in Java programming language. The Dalvik Virtual Machine works as interpreter between applications and the operating system. Android OS uses virtual machine to run each application as its own process. It has three important implications:

- No application is dependent on another hence enhanced performance.
- If one application crashes, then other application should not be affected.
- It makes memory management more efficient.

Kernel Layer:
The kernel layer is the innermost layer of the stack and serves as base of the stack. It uses Linux version 2.6, which has device drivers which control hardware, process management, networking, and memory management.

The architecture in figure 4 is primarily released for Android developers. To understand it clearly and able to map the contributions, the architecture has been simplified and is shown in

[14] https://source.android.com/devices/tech/dalvik

figure 5[15]. The simplified version be a layered structure with three key layers which are explained as follows:

Top layer: It is the topmost layer and closest to the user. All the applications are facilitated here. Handset manufacturers get differentiation at this level.

Middle layer: This is the layer which includes the framework to develop applications which enable/use a Service, with help of the APIs. Contributions to this layer can be understood but not to a specific fragment as it is considered as Framework, services & API work together. However, further breakdown is possible which the scope of this thesis.

Bottom layer: This is the innermost and core layer which contains all libraries, kernel & file system. Device driver, hardware & JRT engine are contained in this layer. Most of the hardware specific contributions are done here.

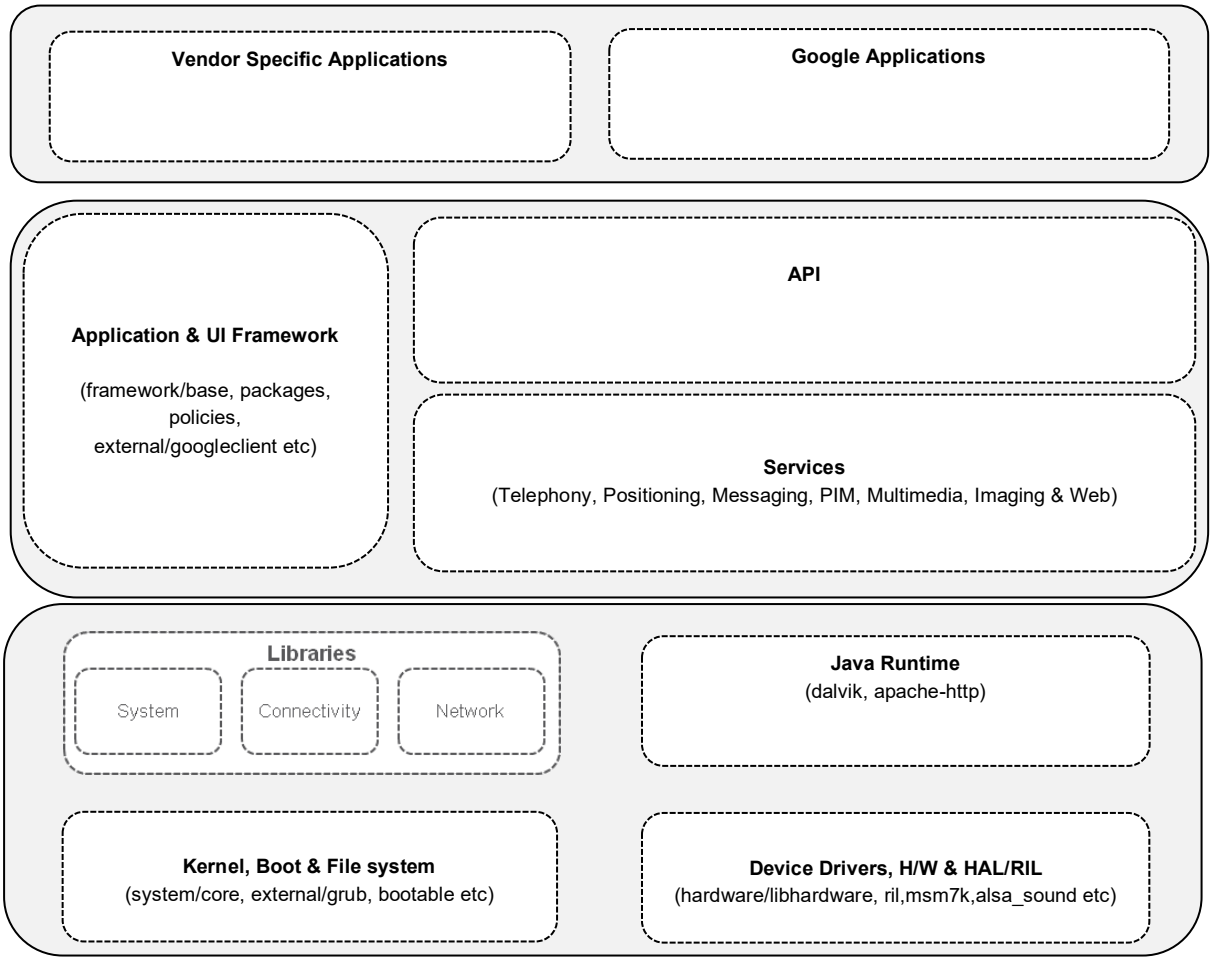


Figure 5: Modified dipiction of Android Architecture

[15] This modification is result of my own understanding and its scope is limited to this thesis.

2.3 Open Handset Alliance

In November 2007, Google along with some other actors of Open Handset Alliance stated Android Open source project as a flagship project for the alliance.
The Open Handset Alliance is a group of 80 technology and mobile companies who have come together to accelerate innovation in mobile and offer consumers a richer, less expensive, and better mobile experience. Together all the member companies of OHA have developed Android, the first complete, open, and free mobile platform. They are committed to commercially deploy handsets and services using the Android Platform. The need for Android development and goals of OHA as described in the overview[16] are the following:

Building better phone for consumers - There 1.5 billion television sets in use around the world. 1 billion people are on the Internet. But nearly 3 billion people have a mobile phone, making it one of the world's most successful consumer products. Building a better mobile phone would enrich the lives of countless people across the globe. The Open Handset Alliance is a group of mobile and technology leaders who share this vision for changing the mobile experience for consumers.

Innovating in the open - Each member of the Open Handset Alliance is strongly committed to greater openness in the mobile ecosystem. Increased openness will enable everyone in our industry to innovate more rapidly and respond better to consumers' demands. Our first joint project as a new Alliance is Android™. Android was built from the ground up with the explicit goal to be the first open, complete, and free platform created specifically for mobile devices.

Making the vision a reality - Android is not just a blueprint for the faraway future, but a complete platform that will give mobile operators, handset manufacturers, and developers everything they need to build innovative devices, software, and services. We are committed to commercially deploy handsets and services using the Android Platform.

List of companies as per official website of OHA[17] is as follows:

Mobile Operator	Company
1	Bouyges Telecom
2	China Mobile Communications Corporation
3	China Telecommunication Corporation
4	China United Network Communications
5	KDDI Corporation
6	NTT Docomo
7	Softbank Mobile Corp
8	Sprint Nextel
9	T-Mobile
10	Telecom Italia

[16] http://www.openhandsetalliance.com/oha_overview.html
[17] http://www.openhandsetalliance.com/oha_members.html

11	Telefonica
12	Telus
13	Vodafone
Handset Manufacturers	
1	Acer
2	Alcatel mobile phones
3	ASUSTeK Computers Inc.
4	Compal Comm (CCI)
5	Dell
6	Foxconn International Holdings Ltd
7	Garmin International Inc.
8	Haier Telecom Co. Ltd.
9	HTC Corporation
10	Huawei Technologies
11	Kyocera
12	Lenovo Mobile Comm. Technology Ltd.
13	LG Electronics Inc.
14	Motorola Inc.
15	NEC Corporation
16	Samsung Electronics
17	Sharp Corporation
18	Sony Ericsson
19	Toshiba Corporation
20	ZTE Corporation
Semiconductor Companies	
1	AKM Semiconductor Inc
2	Audience
3	ARM
4	Atheros Communications
5	Broadcom Corporation
6	CSR Plc.
7	Cypress Semiconductor Corporation
8	Freescale Semiconductor
9	Gemalto
10	Intel Corporation
11	Marvell Semiconductor Inc.
12	MediaTek Inc.
13	MIPS Technologies Inc.
14	NVIDIA Corporation
15	Qualcomm Inc.
16	Renesas Electronics Corporation
17	ST-Ericsson
18	Synaptics Inc
19	Texas Instruments inc.
20	Via Telecom

Software Companies	
1	ACCESS Co. Ltd
2	Ascender Corp.
3	Cooliris Inc.
4	eBay Inc.
5	Google Inc
6	livingImage Ltd.
7	Myriad
8	Motoya Co. Ltd.
9	Nuance Communication Inc.
10	NXP Software
11	OMRON Software Co. ltd
12	Packet Video
13	SkyPop
14	SONiVOX
15	SVOX
16	VisualOn Inc.
Commercialization Companies	
1	Accenture
2	Aplix Corporation
3	Borqs
4	L&T Infotech
5	Noser Engineering Inc.
6	Sasken Communication Tech. Ltd
7	SQLStar International(Embinux group)
8	TAT
9	Teleca AB
10	Wind River
11	Wipro Technologies

Table 1: List of OHA memeber companies

2.4 Agreements & Licenses

Legal license agreements play a vital role in every open source project and Android Open Source Project is no exception and in fact these licenses play even more important role in understand the nature and pattern of contributions being made by different actors. In this section we will briefly look at the key agreements involved and some major points which may affect the contributions.

To see the whole chain of agreements it is required to see them at the level of different actors involved. There are three entities and two level of transaction possible, which can be briefly viewed in figure 6.

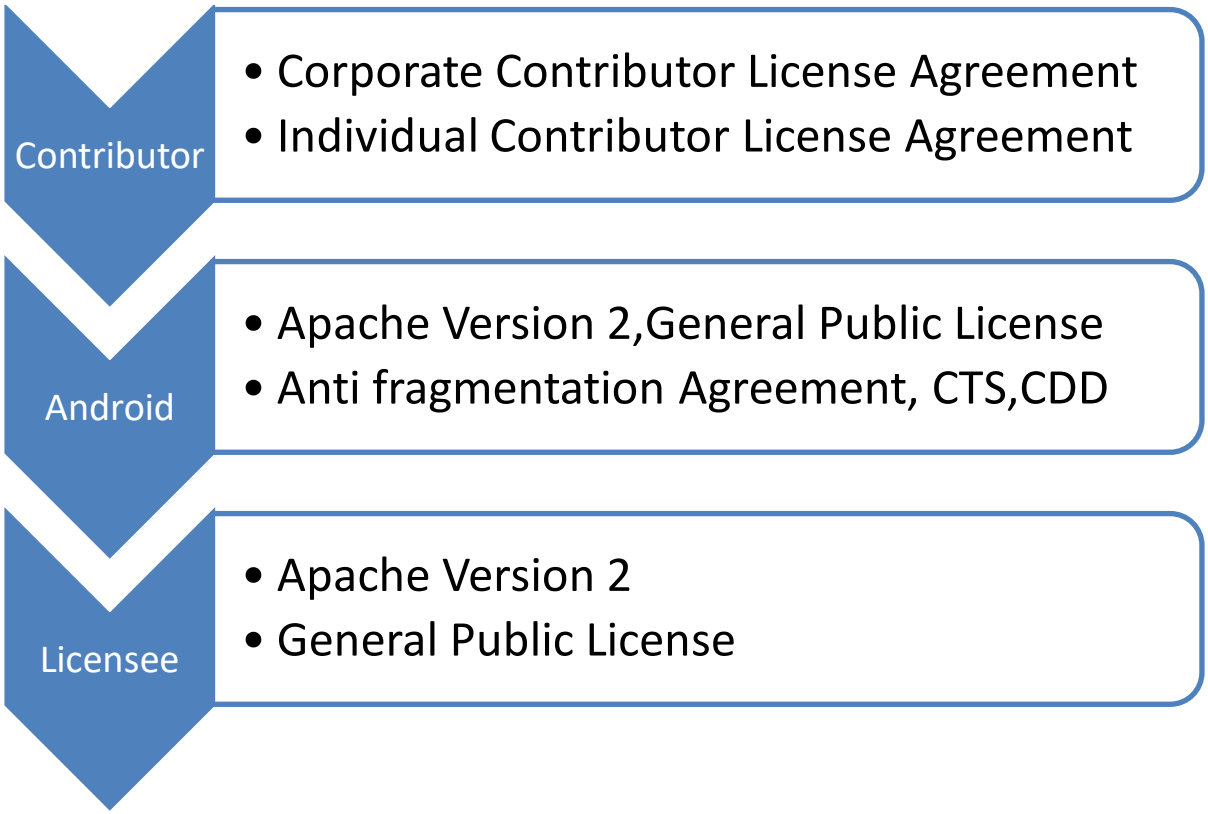


Figure 6: License Agreements involved in AOSP

The detailed analysis of these agreements is beyond the scope of this thesis hence for more reading of Contributors Agreement License and Apache Version 2 License Appendices may be referred. Also, the details of all other licenses may be found at Open Source Initiative website.

Contributors Agreement License - The key features of Contributors Agreement License which is relevant to the subject of thesis are as follows:

Definitions

You (or Your)

- Copyright owner or,
- Legal Entity authorized by the copyright owner that is making this Grant to the Project Leads.

Legal entities:

The entity making a Contribution and, all other entities that control, are controlled by, or are under common control with that entity are considered to be a single Contributor.

For the purposes of this definition, "control" means:

- the power, direct or indirect, to cause the direction or management of such entity, whether by contract or otherwise, or

- ownership of fifty percent (50%) or more of the outstanding shares, or
- Beneficial ownership of such entity.

- "Contribution" shall mean the code, documentation or other original works of authorship expressly identified in Schedule B, as well as any original work of authorship, including any modifications or additions to an existing work, that is intentionally submitted by You to the Project Leads for inclusion in, or documentation of, any of the products managed or maintained by the Project Leads (the "Work").

- For the purposes of this definition, "submitted" means any form of electronic, verbal, or written communication sent to the Project Leads or their representatives, including but not limited to communication on electronic mailing lists, source code control systems, and issue tracking systems that are managed by, or on behalf of, the Project Leads for the purpose of discussing and improving the Work, but excluding communication that is conspicuously marked or otherwise designated in writing by You as "Not a Contribution."

Key highlight here is that this would mean that due to the nature of agreement a company might give away royalty free license to the project for contributing with contribution which read on to the patent of the company. And this might affect the contributions of a particular company.

CTS - Compatibility Test Suite is test which a device must pass to be considered as an Android device.
The CTS is designed to be run on an actual device. Like any software, the CTS may itself contain bugs. The CTS will be versioned independently of the Compatibility Definition, and multiple revisions of the CTS may be released for Android version. Device implementations MUST pass the latest CTS version available at the time the device software is completed.

CDD - Compatibility Definition Document is an Android compatibility definition defined by Google. It is stated as "As Android is an extensible platform, device implementers MUST allow each Intent pattern defined in core system apps to be overridden by third-party applications. The upstream Android open source project allows this by default; device implementers MUST NOT attach special privileges to system applications' use of these Intent patterns or prevent third-party applications from binding to and assuming control of these patterns. This prohibition specifically includes but is not limited to disabling the "Chooser" user interface which allows the user to select between multiple applications which all handle the same Intent pattern."

3. Empirical Study

This chapter aims to give an overview of the contribution process. This chapter will explain what does contribution means, how contribution is being made and who is contributing?

3.1 Technological Infrastructure & terminologies:

To understand the process of contribution and the contribution data it is prerequisite to understand various technological infrastructures used and terminologies / definition involved in the Android Open Source Project.

Technological Infrastructure:

GIT:

There are generally two models in version control systems: centralized and distributed. Tools such as Subversion typically require a network connection to a centralized server. You make a change to your project and then commit that change, which is sent to the centralized server to track. Other developers can then immediately access your changes[18] (Swicegood, 2010). It was developed by Linus Torvalds primarily for the development of Linux.

Distributed revision control system takes the peer to peer approach and not the client server approach. All peers have a working copy of the code base, which serve as a bona fide repository. Synchronization is conducted by exchanging patches or change sets from peer to peer. So, basically DRCS is one of system which keeps track of software revisions and allows many developers to work on a given project without necessarily being connected to a common network. GIT is a DRCS with emphasis on speed.

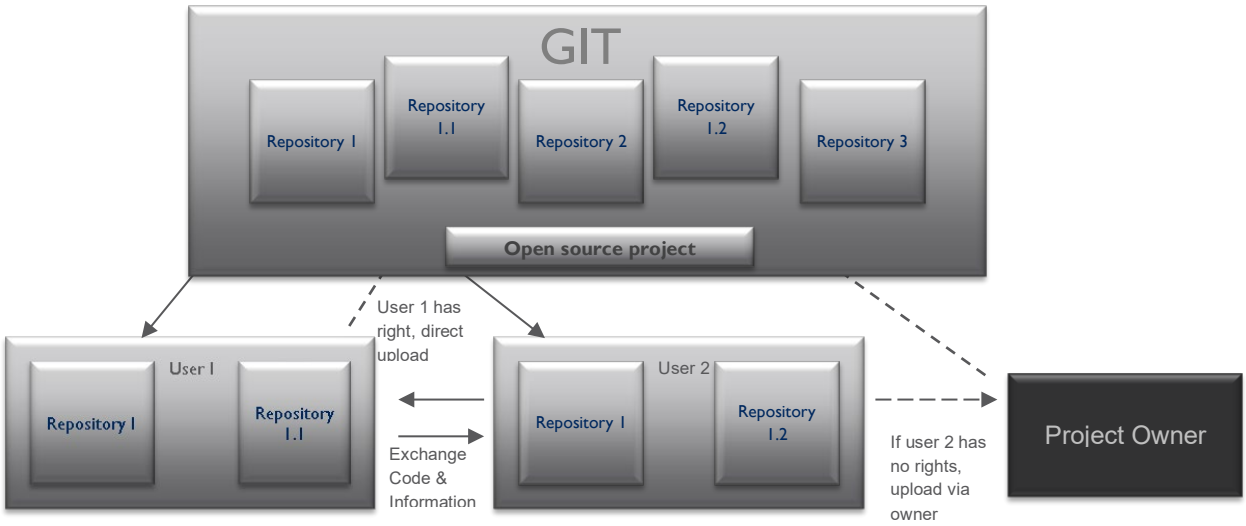


Figure 7: GIT struture & interaction with user

[18] http://img105.job1001.com/upload/adminnew/2015-04-18/1429345520-IAYYBZD.pdf

GIT serves as a host to a specific open source project which comprises of several repositories. A repository is a storage location from which software package may be retrieved and stored on a local computer. Any repository of interest to the end user then can be cloned at the local computer and then the user can make changes/addition or any modification to that repository and once he feels that the modification is good enough, that repository can be placed back to the GIT. The administrator or the project manager reviews it accepts it. By acceptance it means that the modified repository will be the part of the project. In some cases, the users also have direct rights to upload the repository back to GIT depending on different criterions. Some of them could be the expertise level of the user specific to the project, level of contributions made by the end user to the project.
One more interesting aspect of the GIT is that different users, if their interest areas collide or they are working on a same repository, can exchange code and information among themselves. This enables more level of cooperation and leads to better development of the project.

REPO[19]:
There is more important term which is important part of Open source projects. REPO is a tool built on the top of the GIT. It basically helps in managing different GIT repositories and uploads to revision control system. It automates the part of the project development workflow. REPO command is written in executable Python script that can be put anywhere in the path.

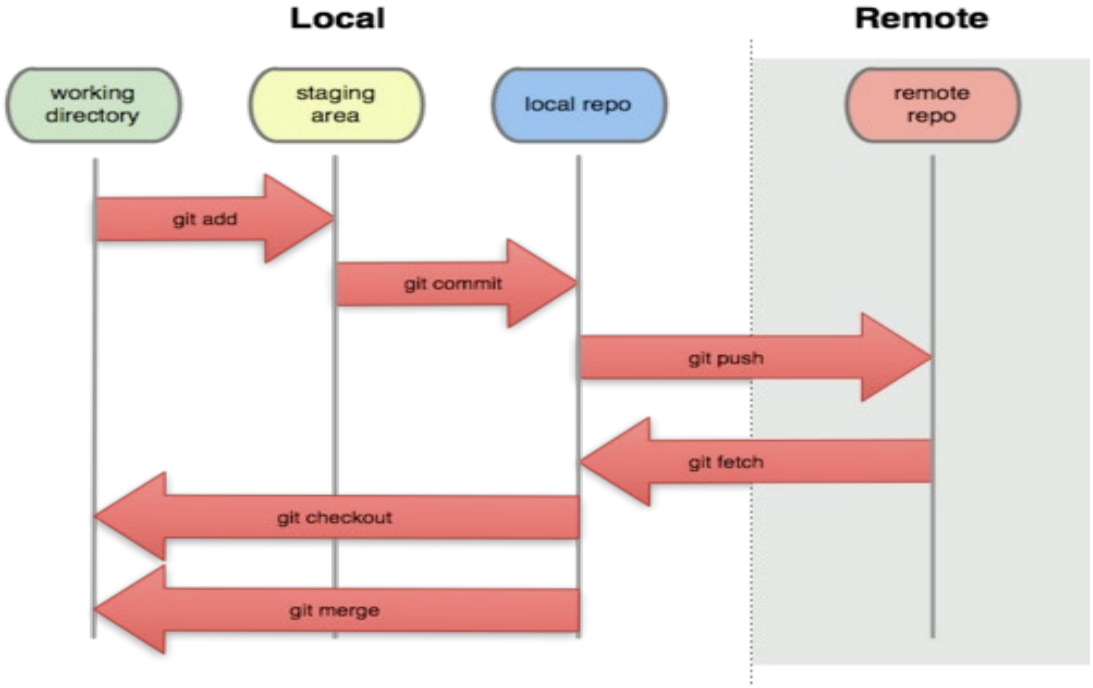


Figure 8: Local & remote working environment on GIT

CLONE:

[19] https://gerrit.googlesource.com/git-repo/

Clone is simply copy of a repository. On the surface, its result is equivalent to svn checkout, where you download source code from some other repository.

GERRIT:
GERRIT is a web-based code review system which facilitates online code reviews for projects using the GIT version control system. Gerrit makes review easier by showing the changes in a side by side display and allowing inline comments to be added by any reviewer. It simplifies GIT based project maintainer ship by permitting any authorized user to submit changes to the master GIT repository, rather than requiring all approved changes to be merged in by hand by the project maintainer. This functionality enables a more centralized usage of GIT.
Gerrit act as an additional interface layer between the users and the project hosted over GIT. As we have seen in the Distributed Revision Control System, the Project manager has to approve each commit or change if the user is not authorized to submit the change but with the introduction of Gerrit the registered user can submit the changes themselves.

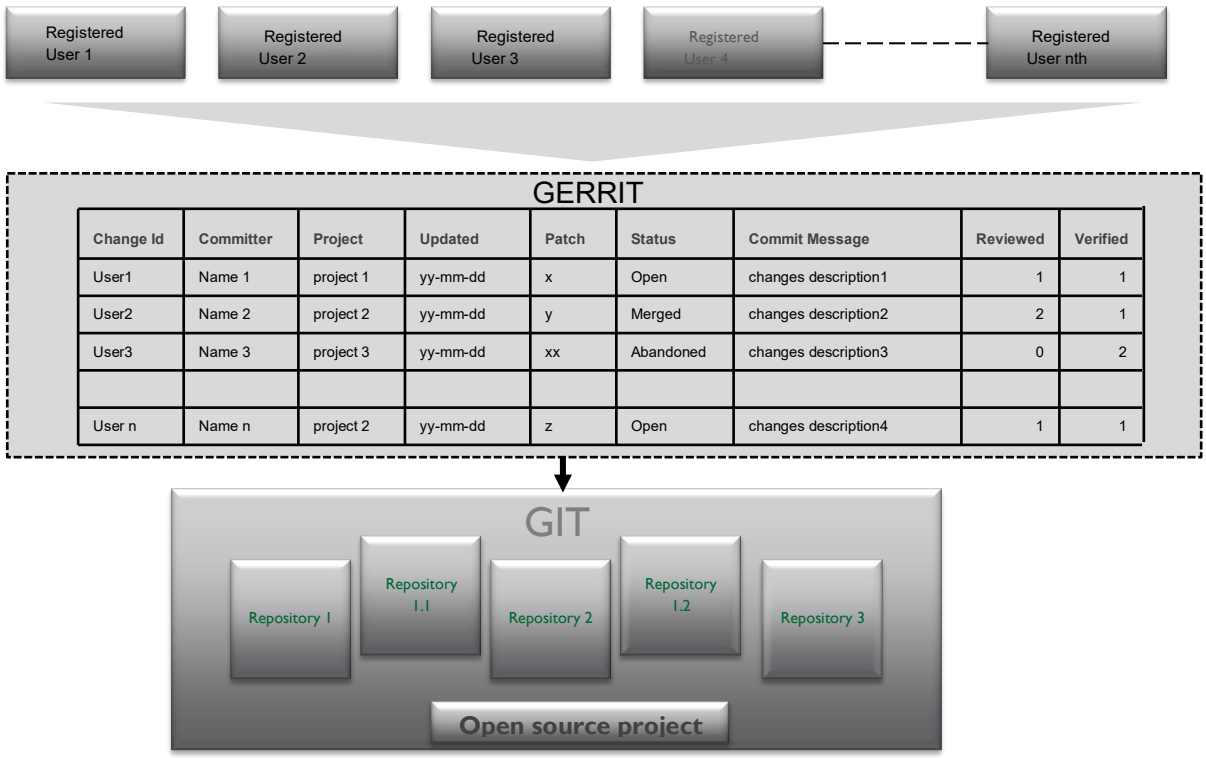


Figure 9: GERRIT as interface between users and GIT

Terminologies and Definitions:

Project Lead[20]:

Android consists of several sub-projects; you can see these in the git repository, as individual .git files. Tech Leads are senior Contributors who oversee the engineering for individual Android projects. Typically, these tech leads will be Google employees. A Project Lead for an individual project is responsible for the following:

- Lead all technical aspects of the project, for example, the project roadmap, development, release cycles, versioning, and QA.
- Ensure that the project is QA-ed in time for scheduled Android platform releases.
- Designate Verifiers and Approvers for submitted patches.
- Be fair and unbiased while reviewing changes. Accept or reject patches based on technical merit and alignment with the Android strategy.
- Review changes in a timely manner and make best efforts to communicate when changes are not accepted.
- Optionally maintain a web site for the project for information and documents specific to the project.
- Act as a facilitator in resolving technical conflicts.
- Be a public face for the project and the go-to person for questions related to the project.

Contributor:

A contributor is any individual who contributes to the source code of Android. It could a Google employee or a represented of any other company, there is no distinction between contributors based on their employment background. An individual who contributes to Android source code who does not represent any company or contributes by its own is also considered as a contributor. All the contributors, who are engineers, use same tools and resource to develop the source code. These tools are primarily git, Gerrit and repo.

Developer:

A developer is an individual who develops application or “apps” which runs on Android platform. There is no distinction between a contributor and a developer in terms of qualification or skill set but distinction is based on the way they contribute and where they contribute. Any contribution to the source code is seen as contribution by the contributor by using git, gerrit and repo whereas any contribution done by developing an application which runs on Android platform by using SDK or software development kit is considered as contribution by a developer. Due to the nature of study we will only focus on contribution by contributors.

Verifier:

A verifier is an individual who is responsible of testing change request. If the verifier finds the change which is not serving its purpose or adds stated functionality, he can reject the change or may ask for modification. An author may further improve the code and again submit it.

[20] http://source.android.com/source/roles.html

Approver:
Approvers are experienced members of the project who have demonstrated their design skills and have made significant technical contributions to the project. In the code-review process, an Approver decides whether to include or exclude a change. Project Leads (who are typically employed by Google) choose the Approvers, sometimes promoting to this position Verifiers who have demonstrated their expertise within a specific project.

Reviewer:
Reviewer is the one who review the patch submitted by a contributor. The reviewer goes through the code

Author:
Author is an individual who writes the actual code lines to be included in the source code of the Android. Author has no specific role in the AOSP workflow management.

Owner:
Owner is an individual who initiates or owns the project and uploads the code.

Committer:
Is the one who contribute with the patch set or change and also, he signs the agreement.

Change id/ Change set:
These are changes which are contributed. This is unique for each instance.

Patch set/Patch:
These are the code sets which are being associated with a change. “Each patch set is a contribution”

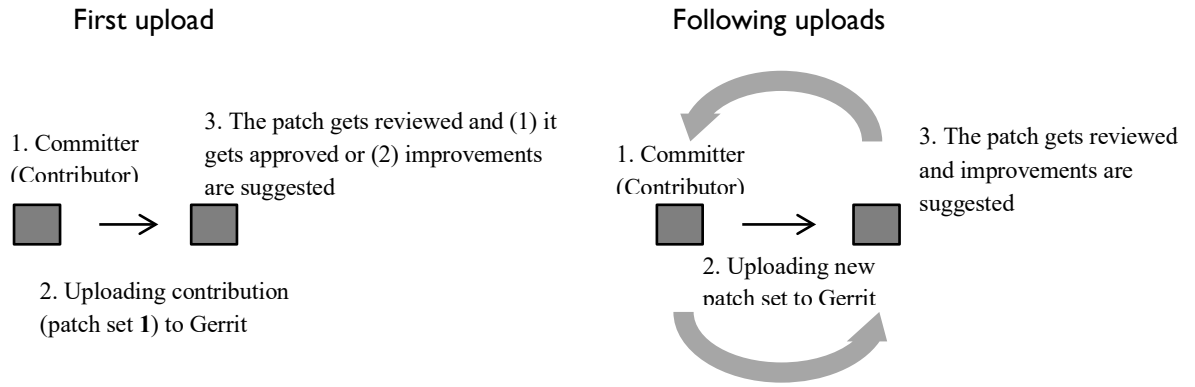
Dependencies:
These are the other projects which depend or use a particular patch set or change.

Commit message:
These are the remarks which a committer leaves after submitting the contribution.

Branch:
It is something that is within a repository. Conceptually, it represents a thread of development.

3.2 Understanding contribution

A contribution to Android Open Source Project means any code, documentation, any modifications, or additions to existing work. This means that even small bug fixes or a large set of code which implement an entire functionality would be considered as a contribution. Generally, bug fixes are not considered to be original enough to be protected by copyright and hence not considered as code. The contribution must be intentionally submitted to the original work. There "submitted" means any form of communication with the Project Leads with the purpose of improving the Work, if it is not explicitly stated as not a contribution. Any of the projects maintained by Project lead can be understood as "work". The contribution should not necessarily be contributed through conventional contribution method through GERRIT to be considered as a contribution.



This process is regarded as one single contribution in data.

Figure 10: Understanding a contribution

3.3 Process of contribution

The contributions which are made to the AOSP follow a specific process to make the process smooth and convenient to manage the contributions, review and to be finally part of the AOSP. All the contributions are being made to the experimental branch for a certain period. The project manager or Google work in parallel for a stable and to be released final version. This version is out for the different vendors and parties to work upon. This version is the final version which is out in the market. However, this final version is not made available to the public at once but to a specific vendor, which is chosen based by Google. Google works closely with this vendor to make the Android version ready to go to market and integrate it well from top to bottom to satisfy the various performance factors.

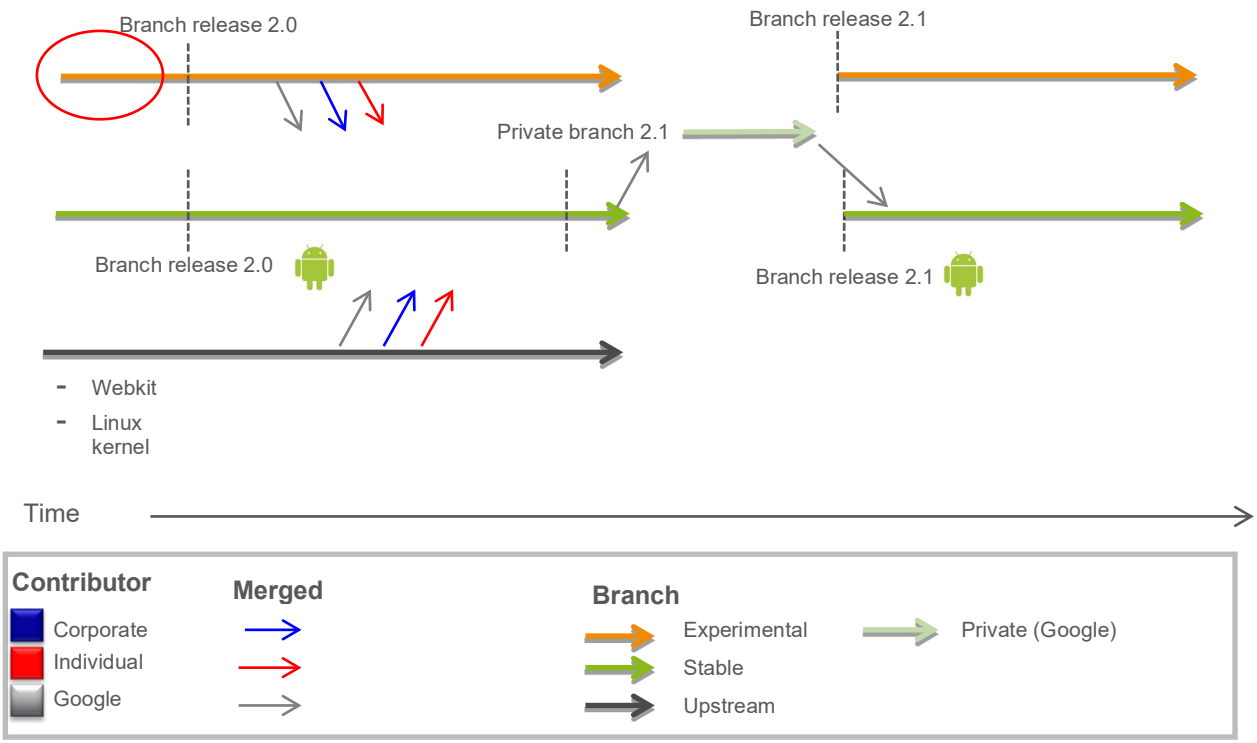


Figure 11: Public and private branch

As it can be seen in the figure 11, Google releases a branch of the Android at a given point of time. A branch here refers to a developmental thread where contribution can be accepted. The source code is available for everyone at this point of time and different actors make contributions; Google, different corporate actors and also the individuals as represented by arrows. At some point of time Google stop accepting contribution to this branch and in the meantime, Project lead review the code, test it and finalize the Android version. This version of Android, along with a handset manufacturer chosen by Google is being developed for the lead product. The stable branch represents the code on which Google work to finalize all the features and functionalities of a given version. Upstream projects are the project which are not just part of Android but also, they are separate open source projects which are included in AOSP like Linux, web kit etc. Google after ensuring that the Android version is stable releases the private branch for the public. It is important to note here that Google retain responsibility for all the strategic directions regarding Android and decision to create a new branch is taken internally by Google.

3.4 Contribution workflow

The process of contribution starts with Author's local environment where a working repository is pulled from public repository. The author then makes changes with contribution and push it back to the GERRIT or commit change. This change then goes to the verification process, if it verified then verified bit is set else author is being notified about it and author looks further into it to work upon it as per the feedback. The verified change is then merged into the public

repository after being checked for any conflict it may cause with other change commits. If it not conflicted it is finally merged into public repository and would be available for future syncs else the author is notified. The author can again work on it depending on the feedback and the process continues. This can be seen in figure 10 in form of a flow diagram.

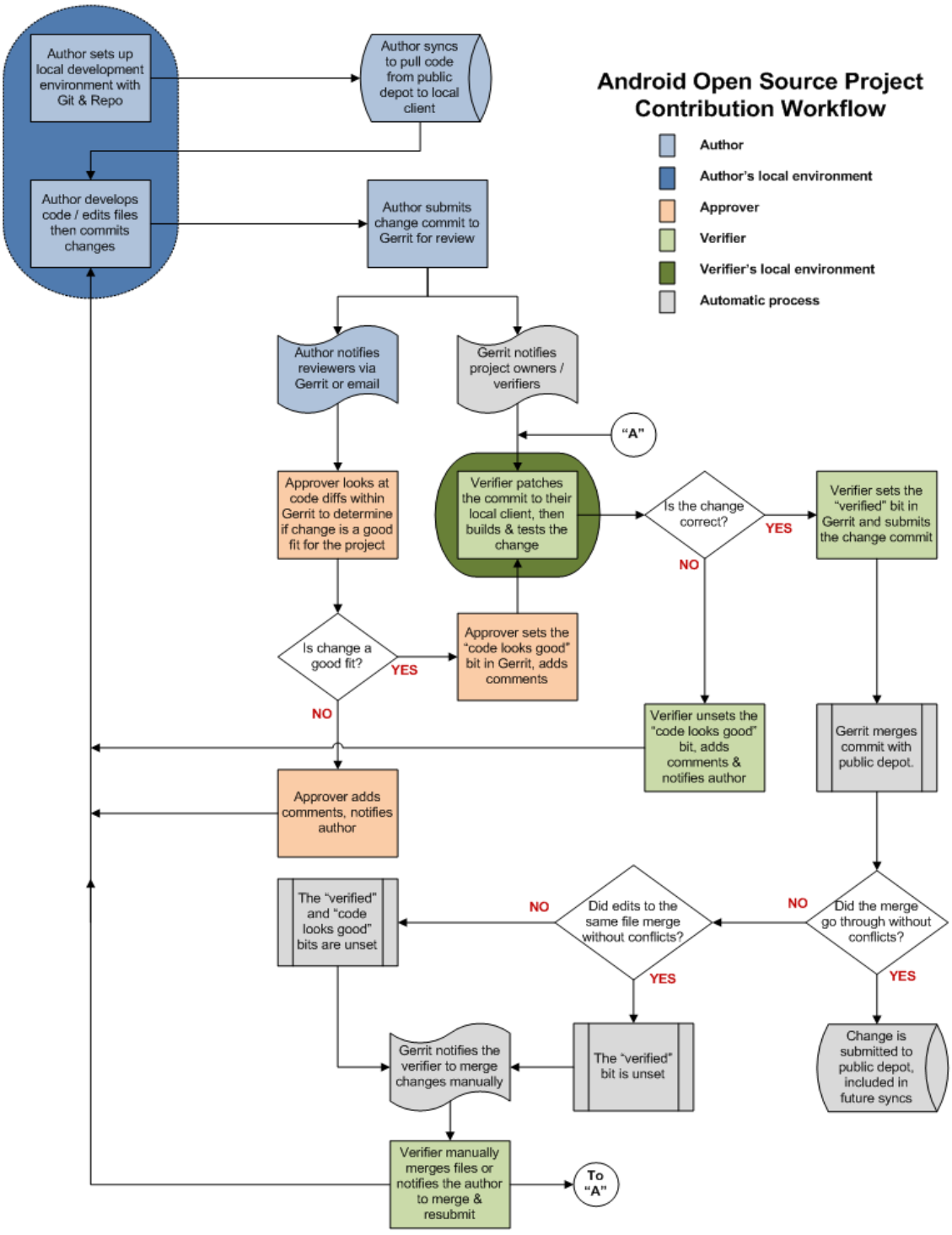


Figure 12: AOSP contribution work flow

3.5 Overview of contributions

This section presents the overview of the contributions made to the Android Open Source Project. The total number of contributions made to the project during the period of October 2008 to February 2011 is 13403. As mentioned in the previous section, there are different kind of categories of the all the contributions made namely open, merged, and abandoned. Open contributions are the one on which there is no decision has been made if they are included in the source code of the Android Open Source Project. This means that they might be included or excluded in the project. These contributions are either being tested, verified, or reviewed by the authorized personals to figure out if they are fit to be included in the source code. Merged contributions are the ones which are successfully tested, verified, and reviewed and found good enough to be included in the source code. Abandoned contributions are the ones which were at any stage of testing, verifying, or reviewing were found not a good fit into the source code and are thus being not accepted to the source code.

The table below provides an overview of the different contributions made in these three categories (which represent the status) during the above stated period.

Status	**Contributions**
Abandoned	2599
Open	1323
Merged	9481
Total	**13403**

Table 2: Open,Merged & Abondoned contributions

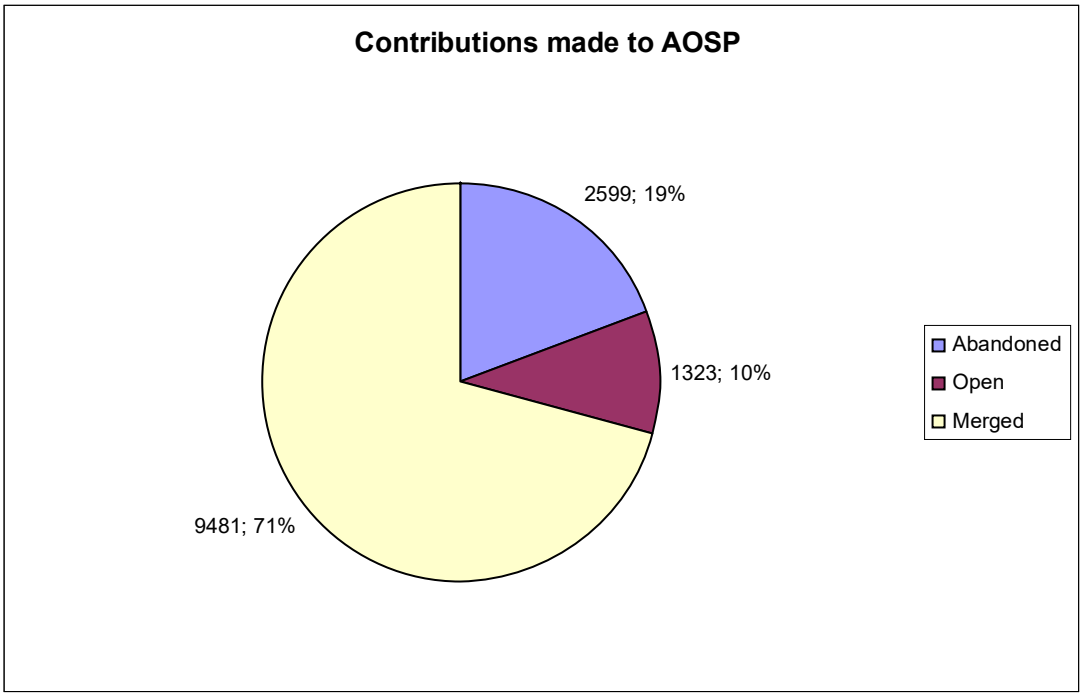


Figure 13: Open, Merged and Abandoned Contribution

3.5.1 Contribution timeline

The various contributors started contributing to the Android Open Source Project from the year 2008. There is a considerable change observed in the number of contributions being made by different actors. The comparative Table 3 below shows the top ten contributors over the period from the year 2008 to the year 2011.

As described by Lerner J. & Pathak P. A. & Tirole, J[21].; like any other open source project, we observe that contributions by for-profit corporations are higher than the individual contributions. It can also be observed that some companies that were present in the data in the initial years are not contributing in the later years. The reason behind this could be that Android had adopted some other kind of technologies in the later years and hence contribution by those companies has gone down significantly.

[21] http://economics.mit.edu/files/3023

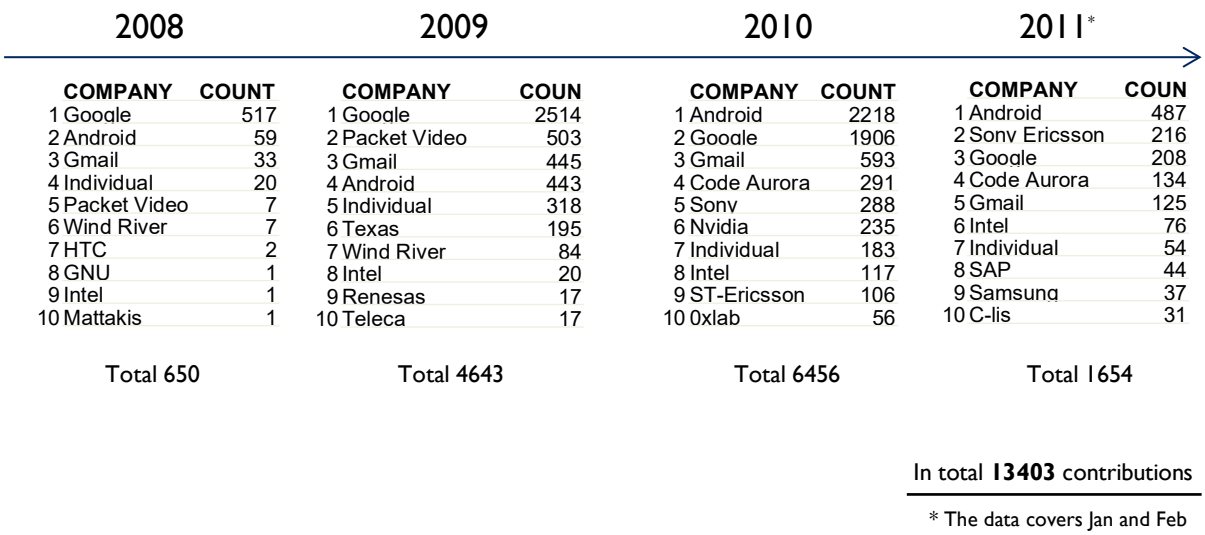


Table 3: Contribution timeline

3.5.2 Contributions to AOSP

The table below shows the total contributions made by different actors during the period from October 2008 to February 2011:

S.No	Company	Count
1	Google	5145
2	Android	3207
3	Gmail	1196
4	Packet Video	520
5	Sony Ericsson	504
6	Code Aurora	428
7	Individual	404
8	Nvidia	265
9	Texas Inst.	250
10	Intel	214
11	Dodologics	171
12	ST Ericsson	137
13	Windriver	116
14	SAP	89
15	Linux Taiwan	77
16	0xlab	57
17	Garmin	46
18	Mirbsd	46
19	Samsung	43
20	Teleca	41

S.No	Company	Count
43	Dataforce	5
44	HTC	5
45	Mattakis	5
46	WDS global	5
47	Clearwire	4
48	Graphtech	4
49	Nearverse	4
50	Sprint	4
51	Vircado	4
52	f5	3
53	FunkyAndroid	3
54	NTT Docomo	3
55	Parrot	3
56	Sasken	3
57	TAT	3
58	Unisaran	3
59	Concisoft	2
60	Farsitel	2
61	GNU	2
62	Jayway	2

21	Broadcom	36	63	Kyocera	2
22	Acer	31	64	Marvell	2
23	C-lis	31	65	Moctel	2
24	Renesas	30	66	Motoya	2
25	NEC	21	67	Noplay	2
26	Sharp	21	68	Appnotes	1
27	LGE	19	69	Bambuser	1
28	Real VNC	19	70	Bluecherry	1
29	Degel	17	71	Botech	1
30	T-Mobile	16	72	Cellti	1
31	Ericsson	15	73	Chromium	1
32	Freescale	13	74	Comcast	1
33	Macrobug	13	75	Inqmobile	1
34	MIPS	11	76	Intrinsyc	1
35	Motorola	10	77	Justin TV	1
36	Arm	9	78	Koolu	1
37	Synchronica	9	79	Mbdsys	1
38	Credil	7	80	Netville	1
39	Huawei	7	81	Syntronic	1
40	Foxconn	6	82	Worksmartlabs	1
41	Invensense	6	83	Yahoo Inc.	1
42	CTSO	5			

Table 4: Total contributions to AOSP

Note: To ease the study process, all the contributions made to AOSP by Gmail email addresses are categorized as “Gmail”. Similarly, the category “Individuals” is the ones who are individually contributing to the project and bear no implied association with any corporate actor. This will be discussed in detail in a further section.

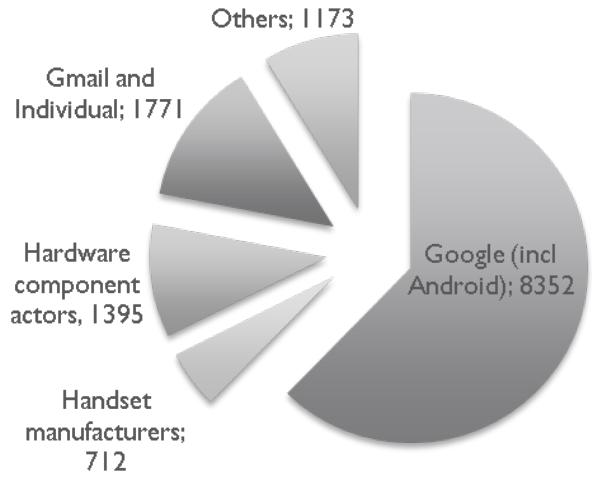


Figure 14: Distribution of contributions by different actors

There are some key basic observations which can be made from this data. The direct key point which can be concluded on firsthand glimpse at data are as follows:

- Google and Android collectively have the highest number of contributions which constitutes around 62% of the total 13403 contributions.
- The amounts of contributions made by each actor declines abruptly from few thousands to hundreds and then to tens.
- There are arguably major android players who are not seen to be contributing to the project.
- On the table above 65 contributors have single digit contributions, which infer that the spread of contribution is not uniformly distributed.
- Handset manufactures and Hardware or semiconductor companies are the two big groups which are prominent in the industrial actors.

4. Analysis

This chapter will discuss and analyze the contributions made by all five groups of companies who are members of Open Handset Alliance. The other important actors or categories which are not part of OHA will also be discussed in this section. The focus of analysis would be on the key following points:

- Detailed observation of number of contributions
- Motivations behind contributing to AOSP
- Analysis of contribution over technology platform wherever required
- Observation of the trends

The emphasis would be however to cover and discuss the contribution by the category or actors which has significant effect or role in the contribution process.

4.1 Mobile Operators

The mobile operators have relatively very less impact on the contributions as they hardly get any direct benefit or advantage from the contributions. Except few contributions by T- Mobile and NTT Docomo, no significant contribution can be seen. This might be because of the fact that most of the operators look for giving differentiation at the service level, provided to the end user.

Company	Contributions
T-Mobile	16
NTT Docomo	3
Bouyges Telecom	0
China Mobile Communications Corporation	0
China Telecommunication Corporation	0
China United Network Communications	0
KDDI Corporation	0
Softbank Mobile Corp	0
Sprint Nextel	0
Telecom Italia	0
Telefonica	0
Telus	0
Vodafone	0

Table 5: Contributions by Mobile Operators

4.2 Handset Manufacturers

This category comprises of some of the most prominent companies which are quite closely associated with the end user. They are the face of the Android among the users and includes the likes of HTC, Samsung, Motorola, Sony Ericsson etc. As described in one of the previous sections that there are in total 20 handset manufacturers listed with Open Handset Alliance. If we look at the contributions made by them separately, we find that out of 20 companies, 8 of them are not present in the data at all.

Company	Contributions
Sony Ericsson	504
Garmin International Inc.	46
Samsung Electronics	43
Acer	31
NEC Corporation	21
Sharp Corporation	21
LG Electronics Inc.	19
Motorola Inc.	10
Huawei Technologies	7
Foxconn International Holdings Ltd	6
HTC Corporation	5
Kyocera	2
Alcatel mobile phones	0
ASUSTeK Computers Inc.	0
Compal Comm (CCI)	0
Dell	0
Haier Telecom Co. Ltd.	0
Lenovo Mobile Comm. Technology Ltd.	0
Toshiba Corporation	0
ZTE Corporation	0

Table 6: Contributions by Handset manufacturers

Handset manufacturers receive a version of Android, which they wish to be the latest and get it at the earliest, from Google. The received version of Android must be then integrated with the hardware of the respective manufacturers. It is because of this fact that it can be assumed that this category of companies must contribute a lot to the AOSP so that they find it easier to integrate their hardware with the software to obtain the best performance of the device. A Senior Engineer[22] and key responsible personal for the project of a prominent handset

[22] During an interview conducted telephonically.

manufacturer company suggest that contributions to the project help them get some functionality in built in the software which reduces their effort at the time of handset development. And this reduction in efforts eventually leads to reduce the time to roll the products to the market and hence more sales.

As discussed, the need and importance for the contributions for handset manufacturers, it is interesting to observe 8 of them not contributing at all. It is even more interesting to note that some of the lead Android device vendors like HTC, Motorola, and Samsung have contributed significantly less. If it is necessary to contribute for attaining better performance, then what is the reason these actors are not contributing to the AOSP. Is there any other way they are achieving these objectives? The most possible answer could be that these companies are not contributing openly could be due to the risk of giving away royalty free patent licenses. Therefore, in order to contribute they might be giving away code directly to Google.

Contribution spread over the Android platform:

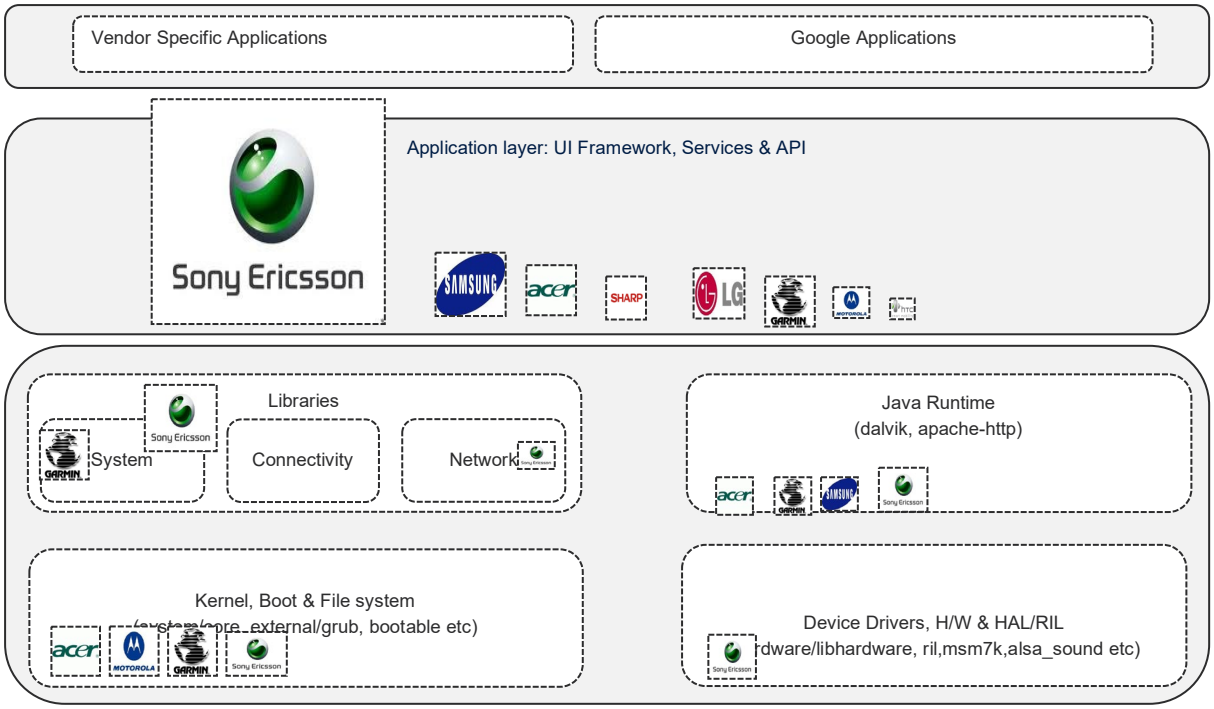


Figure 15: Spread of Handset manufacturer over AOSP platform

To observe the levels at which these contributions were made, a mapping of the contributing companies is done. It is to be noted that this mapping is done based on the breakdown as mentioned in Appendix 8.3. The size of a company represents the amount of contributions, which are meant for qualitative analysis based on total number of contributions. There are some observations which can be made from this mapping in figure 15. Some of them are as follows:

- Most of the actors are contributing to the Application and User interface layer.

- Some are widely spread and also present in the innermost layer for example Sony Ericsson can be seen in middle and the lower layer as well.
- Maximum contributions at the top could be due to the fact that in order to add additional vendor specific application the contribution at Application layer becomes crucial.
- As observed at the contribution numbers, some of the big actors are not seen much over the platform.

4.3 Semiconductor companies

The semiconductor companies basically provide the chipset for an Android device. There are some quite big industry players in this category both in terms of market dominance and IPR portfolio. It is interesting to observe, that out of total 20 semiconductor companies 10 of them are not even present in the contribution data gathered from the AOSP.

Company	Contributions
NVIDIA Corporation	265
Texas Instruments inc.	250
Intel Corporation	214
ST-Ericsson	137
Broadcom Corporation	36
Renesas Electronics Corporation	30
Freescale Semiconductor	13
MIPS Technologies Inc.	11
ARM	9
Marvell Semiconductor Inc.	2
AKM Semiconductor Inc	0
Audience	0
Atheros Communications	0
CSR Plc.	0
Cypress Semiconductor Corporation	0
Gemalto	0
MediaTek Inc.	0
Qualcomm Inc.	0
Synaptics Inc	0
Via Telecom	0

Table 7: Contributions by Semiconductor companies

The semiconductor companies also have a big advantage of contributing to the platform which the enhanced performance they may achieve with the software stack. As per one of the Senior

Engineer[23] at such company revealed that “more a company will have the contribution to the platform, better performance they can achieve and also it will make it easier for future upgrades to be rolled quickly”. Most of these companies which are contributing they are contributing with the specific contributions which help their product to be integrated well within the platform. Form the breakdown of all the contributions we observe that Nvidia is contributing towards “tegra” which is their own system. Similarly, Intel is contributing towards “x86” again their own processor and Texas Instruments is contributing towards “OMAP”, which stands for Open Multimedia Application Platform, developed by Texas Instruments.
It is however quite surprising to observe that Qualcomm is not even present in the data, which appears to be very actively involved in the project and is one of largest manufacturer of chipset used by various handset manufacturers. It is unrealistic that such an active actor is not contributing to the platform. It is found out that Qualcomm is using a third party set up to contribute to the AOSP. They use a Not for profit organization Code Aurora Forum[24] to contribute to the project. More about Code Aurora’s activities can be found in Appendices.

Contribution spread over the Android platform:

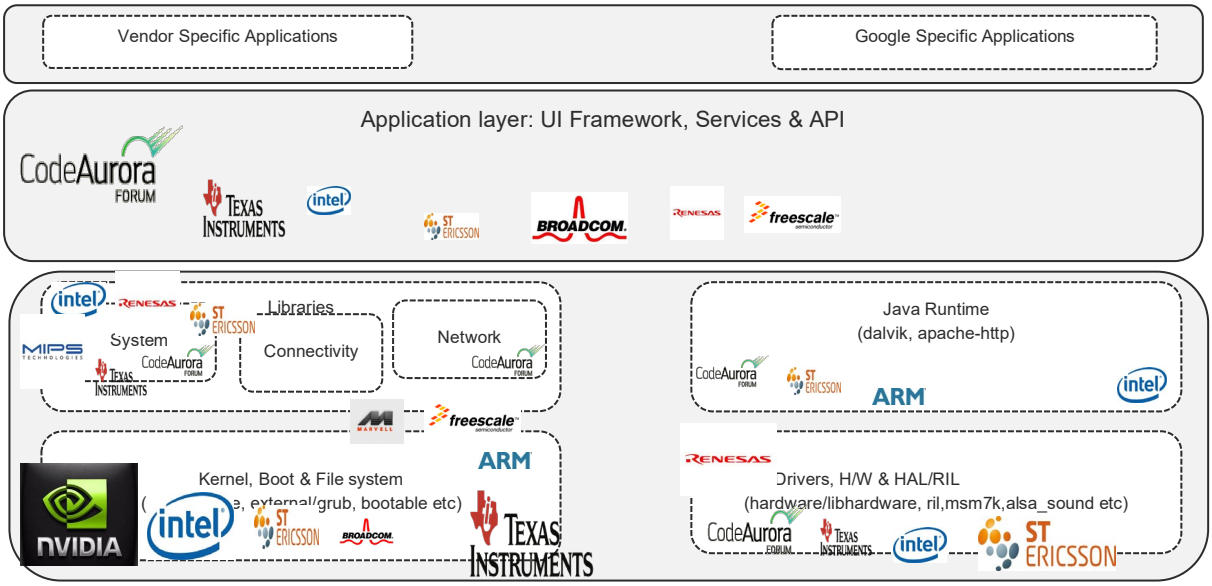


Figure 16: Spread of Semi-conductor companies over AOSP platform

It is to be noted that this mapping is also done based on the breakdown as mentioned in Appendix 8.3. The size of a company represents the amount of contributions, which are meant for qualitative analysis based on total number of contributions. There are some observations which can be made from this mapping in figure 16. Some of them are as follows:

[23] In a telephonic interview.
[24] https://www.codeaurora.org/about

- It can be observed that most of the semiconductor companies are contributing to the bottom layer i.e. close to the Linux kernel, device drivers and hardware.
- It can also be seen that the spread of the contributions is wider than what we have observed in case of handset manufacturers.
- If we consider that the Qualcomm is represented by Code Aurora Forum, then we find that they are contributing relatively high to the platform and they are widely spread too.
- Moreover, the high presence of Code Aurora at the application layer could possibly be to create some sort of lock-in effect.

4.4 Software Companies

Software companies are the companies which are supposed to contribute with their software services to the Android Open Source Project. The group has 16 members in OHA but it is interesting to see that they are not contributing to the platform. Most of the contributions are coming from Google which is in totality contributing a major chunk of contributions. This is justified as Google is the project initiator and facilitator for the project. Apart from Google, Packet Video is next contributor to the project in this segment. Packet Video is basically contributing with the contribution primarily toward the codec and media packages, which could be considered an area where Google itself has limited expertise. It can be seen from the timeline that there is significant fall in the rate of contributions by Packet Video over the period of time. This is might be because of the inclusion of other codecs being implemented in the project. Other than these two, only Motoya Co. Ltd. has 2 contributions, rest all are not contributing to the project at all.

Company	Contributions
Google Inc	5145
Packet Video	520
Motoya Co. Ltd.	2
ACCESS Co. Ltd	0
Ascender Corp.	0
Cooliris Inc.	0
eBay Inc.	0
livingImage Ltd.	0
Myriad	0
Nuance Communication Inc.	0
NXP Software	0
OMRON Software Co. ltd	0
SkyPop	0
SONiVOX	0
SVOX	0
VisualOn Inc.	0

Table 8: Contributions by Software companies

It is to be noted that Android itself is not included in this category. It could be due to the fact that Android is not part of OHA, and all the contributions made by Android can be viewed along with Google, which makes majority percentage of contributions.

4.5 Commercialization Companies

The Commercialization companies are the actors which provide commercial services to various other actors around Android. They are much diversified in their services from integration and customization for handset manufacturers to providing software solutions for wireless services etc.

Wind River is highest contributor in the group which is visible in the platform with 116 contributions. Teleca, Sasken and TAT are also present in some small numbers. It might be the case that these companies are providing services to some other actors and that is why they are not visible in the data. The big players like Accenture, Borgs and Wipro are not visible in the data.

Company	Contributions
Wind River	116
Teleca AB	41
Sasken Communication Tech. Ltd	3
TAT	3
Accenture	0
Aplix Corporation	0
Borqs	0
L&T Infotech	0
Noser Engineering Inc.	0
SQLStar International(Embinux group)	0
Wipro Technologies	0

Table 9: Contributions by Commercialization companies

4.6 Gmail Contributors

This category of contributors is outside the boundaries of OHA and as the classification suggests it is categorized as “Gmail” because contributions were made from the Gmail id. It is important to highlight this is not at all an official or recognized categorization, but it is used for the simplicity of the study of the data during the course of this thesis. These contributions constitute a large percentage of total contributions, so it is important to study them separately. This category may contain some random individuals to some companies which prefer to contribute via Gmail ids.

Individuals	No. Of Contributions	Employed *
Grzegorz Kossakowski	116	Apache Software Foundation
Christian Mehlmauer	103	Unknown
Oleksandr Kucherenko	81	Owner of Artfulbits Inc.
L & T Infotech	41	Company using Gmail account
Gert Scholten	34	HVR Software
André Goddard Rosa	33	Unknown
Jozef Babjak	27	Unknown
Haris Peco	23	Unknown
Hristo Bojinov	19	PhD Stanford
Jey Michael	16	Unknown
Alan Jones	16	Unknown
Kenny Gong	15	Unknown

Table 10: Contributions by Gmail accounts

It is not possible to mention all the Gmail contributors, but we have tabulated top contributors in the table above. It is interesting to note that some of these contributors are visible more than some of the large corporations and not using Gmail account to register their contributions. Also, an attempt to find out where they are employed has been made. However, it was not possible to find the precise information but some of the interesting facts were figured out by looking at them. We observe that L&T InfoTech which is a commercialization company in OHA is visible in the data with 41 contributions. L&T InfoTech was not observed to be contributing in their OHA segment.

4.7 Individual Contributors

The category “Individual contributor” comprises of the contributors who are contributing on individual basis. No domain of a corporation was used to register the contribution at AOSP. There are some cases where these individuals work for some small companies or they are just a “one-man company”. Mostly these contributors are computer programming enthusiasts both professionals and students. The contributions made by them and their associations can be summed up in the table below:

Individuals	Contributions	Employed at	Associations
Steve Kondik	21	Penthera Technologies	Chemlab.org
Sinker	48	Independent Professional (Past-Trend Micro)	xlabs.org
Patrick Georgi	12	S/W Engineer at Secunet AG	Coreboot
Pascal Merle	11	Independent Professional	PBXes.com
Martin Storsjö	34	Bambuser (Past- Nokia,Ericsson)	martin.st
Marcus Comstedt	25	M.Sc student at Linköping university	lysator.liu.se
Kenny Root	43	Android framework Engineer at Google	the-b.org

Jay Freeman	13	Ph.D. -University of California (iPhone Dev)	saurik.com
Ian Kent	21	Vault Logix Data protection	themaw.net
Christopher Lais	16	Independent Professional	zenthought.org
Other	160	N/A	N/A

Table 11: Contributions by Individuals other than Gmail accounts

5. Discussions

In the previous chapters we have analyzed the process of contributions, contributions made by different contributors, the trends and participation of various members of OHA and other individual contributors in the AOSP.

The present chapter will have a discussion around the motivation & incentives for different contributors, nature of contributions and their role in the governance of the AOSP to determine the openness with which the project is governed.

5.1 Motivations & Incentives

To explain the contributions landscape of AOSP it is prerequisite to understand the various incentives for different actors in the entire value chain of Android Open Source Project.

The value chain of Android starts from the Google and goes till the Android phone users; and rest all other actors fall in between these two limits. We will discuss the motivations & incentives for each actor involved in between. The figure 17 shows the incentive structure for the different actors involved in the Android contribution cycle.

- Google – AOSP is believed to be a project driven by Open Handset Alliance but virtually it is Google who is managing and governing the project. Google first acquired the Android Inc. as they foresaw mobile computing as the future of Internet. Google then realized that the entire industry needs a common mobile platform to attain synergies. The fact that there was no such well performing open mobile system which gives boost to Google's plan to go beyond desktop computing and thus launch Android as an Open Source Project. Blair Levin[25] made statement to Financial Times that "We believe Google is trying to make the value chain in the wireless mobile world more like the value chain in the fixed/broadband/ internet world, in which applications are developed more independently of device manufacturers and network operators". If such independent approach can be achieved efficiently, Google's vision of having more devices connected though Android@home[26] could be possible soon.

  The key incentives which Google aim for from this project is that market dominance can be best achieved by this kind of open initiative. Google need more "eyeballs" to boost their advertisement revenue and this can be best supported by such project. The most importantly by this Google would be able keep on their "Freemium service provider" image by pushing Google applications among the end users. In an interview

[25] Blair Levin is Telcom & Media Regulatory analyst at Stifel Nicolaus.

[26] https://googleblog.blogspot.com/2011/05/android-momentum-mobile-and-more-at.html

the Head of Mobile development[27] verified this by calling Google still being considered among end users as "Father of the earth", which provides everything for free. The idea of having connected home appliances and perhaps other devices also through Android further strengthens Google's dominance.

- Open Handset Alliance - Open Handset Alliance came into existence as a joint effort from the various players in mobile communication space, with a goal to build an Open mobile platform to maximize their individual benefits. It can be observed that all these corporations are separate actors with individual business interests but OHA, as a standalone entity, also has some common interests. One of them could be creating a technologically efficient mobile platform which is free of cost. The common benefit that these players could get is to align their resources efficiently in a planned manner depending on their respective potentials to create synergies. The motivation could be to attract the interest of application developers by providing open access to SDK and giving them a sense of community.

- Mobile/Network Operators - Mobile operators joined the Android Open Source Project so that they can play big on the lower handset cost and they will have flexibility to customize their product line. This will help them to achieve the differentiation factor. They might get benefit of innovation being carried out by the handset manufacturers. Moreover, uniformity and stability of the platform may lead to a greater number of users and hence add to revenues. The mobile operators have good control over the application which runs on the handset and hence they are crucial player to build the image of Android among the end users.

- Semiconductor Companies – Semiconductor companies are motivated to provide system-on-chip solution for the handsets. Processors are evolving rapidly and are getting multi core to achieve better performance. The goal of semiconductor companies would be to integrate their hardware with the software stack to achieve optimal efficiency of the system. They might also look into development of some application by contributing to the top layer to map their hardware to create some sort of "lock-in" for handset manufacturers, so that to extract a better performance they stick to their hardware. More handset manufacturers will use their chipset, more would be the revenues.

- Handset Manufacturers – Handset manufacturers invest lot of time and resources in development of the software and customization of the software platform to be integrated with their handsets. This results in increase in the manufacturing cost. By contributing to the AOSP handset companies can lower down the cost and hence invest more in adding differentiating attributes and aggressive marketing. Also, they can reduce the time to market their handsets to achieve more revenues. One more important advantage would be that maintenance cost and effort can also be reduced drastically by contributing to the AOSP. As per one of the Senior Engineer[28] with a Handset Manufacturer company "a company can save up to 70% of resources in maintenance and up gradation by contributing directly to AOSP". Additionally, more contributions

[27] During a telephonic interview.
[28] During a telephonic interview.

can be seen as insignia of high commitment towards Android which could be used for effective PR communication and would build a trust relationship with the end user.

- Software & Commercialization Companies – Software and Commercialization companies can be grouped together due to the similarities in nature of services provided by them. For these companies, contributing to AOSP seems to be useful as integrating the software components to the open platform. These actors provide various services around Android. Once again lower cost of mobile platform and possibility to integrate various differentiating software components is the key incentive. Most of the commercialization actor work on behalf of other actors because of their better skills and relationship with governing actors of AOSP.

- Individual Contributors – Individual actors contribute to AOSP because of the motivation for being recognized and self-development. They contribute to AOSP because some believe either getting any good future opportunity in terms of job being offered by a well-known actor or any kind of developmental contract as some of the individual actors are also one-person company or a group of software enthusiasts. However, it becomes challenging for individual contributors if they take up new jobs in corporations where the contributing to an open source projects may conflict with the policy of employer or poses other IPR related challenges.

- Application Developers – Application developers are not contributing to Android Platform, but it is worth discussing about their incentives briefly as they play a crucial role in development of Android ecosystem. Their motivation is of course some sort of revenues from Applications sales. Also, recognition and flair toward development for self- development are also some of the factors.

- End User - End user is the last in the Android value chain. They are not the contributors to Android in any way, but they are recipients of the Android package or the target segment of Android. What they get out of all these developments and contribution by different actors is an affordable mobile platform with more innovative feature. They can experience the core functionalities of Android and can also experience differentiation provided by the handset manufacturers at the UI level. End user can also enjoy the thousands of “apps” developed by developers worldwide based on their interest and likings.

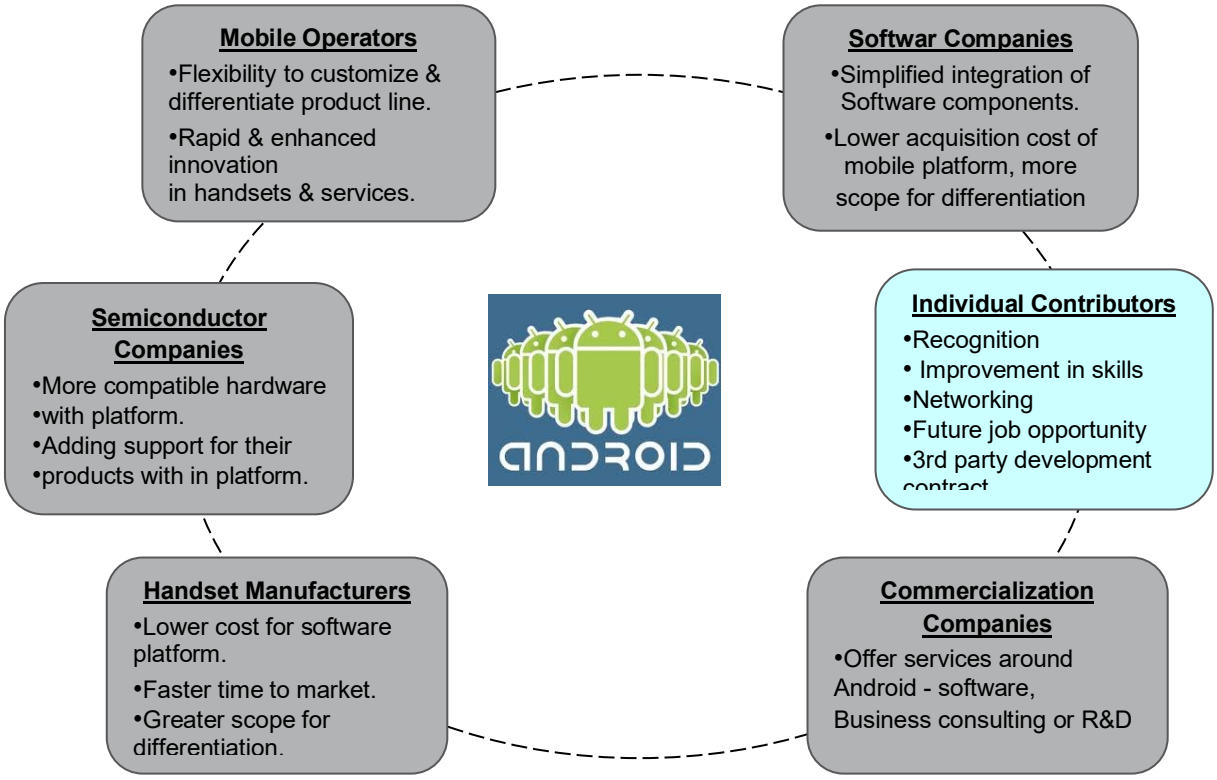


Figure 17: Android Stakeholder's incentive & motivation

5.2 Contributing segment & nature of contribution

As it is clear from the contribution data in Chapter 3 that segment of industry which is contributing data is the one who has direct advantages in integrating their functionalities and with platform either to save resources during the development process or to push the technology. In this segment we have Handset manufacturer companies and Semi-conductor companies. It is interesting to note that the contributions are quite uniform across the segments. Typically, Semi-conductor companies are contributing with own products and functionalities like NVIDIA tegra, OMAP, x86. This indicates that they are just integrating their technologies with platform. Whereas, in the handset manufacturer companies segment some of the companies are not contributing according to their association with the Android. Some big companies like HTC and Motorola are visible much in the data. One might suspect that they are contributing though some other way like giving away code to Google, by using third party etc. As per a Senior Engineer[29] at a handset manufacturing company "Google just buys code…they ask you to do something to implement and you just give away the code". There could be another reason behind it that some companies don't want to lose their IPR. As we observe that due to the nature of agreements involved one might find the other way to make contribution rather than just contributing directly to the platform via GERRIT. We can see in the table in section 3 that Qualcomm is not visible in the data even though its chipset is used

[29] Stated in an interview on condition of anonymity.

widely in the Android phones. They have formed a Not for Profit organization called as Code Aurora Forum and they are contributing though them. If we observe closely majority of commits are made by employees of either Qualcomm or Qualcomm Innovation Center[30]. The potential reason for this kind of contribution is to avoid any IPR leakage[31] as their revenues are highly based on technology licensing.

Mobile operators are not contributing much to the project as they are closer to the commercial or market side of Android. The reason why they are still the members of OHA is that the market success and good services for end user are equally important as technical development of a platform. Software and commercialization companies are mostly contributing with software services around Android. Commercialization companies offer their expertise and skill to other companies and hence they are also not directly visible in data. As they develop the code and give it away to their clients.

Apart from these members of OHA, there are several contributors which contribute individually to the AOSP. These are mostly one-person company or computer enthusiasts. Some of the contributions are being made by Gmail ids. Upon close observation of the data, it is being found that a majority of contributions from the Gmail accounts are from Google employees. When it was investigated, the reason which came up was that this happens due to "some technical problem" encountered while submitting the code.

5.3 Governance of AOSP

Android started off a startup before Google acquired it in 2007 was never an open source project from the beginning. As a startup, it generated huge entrepreneur value for the founders in the very nascent stage itself. It successfully overcome the challenge of commodifying the intellectual construct (Petrusson, 2004) i.e. the when the project was started as open source project, there exist is ready to use product with all the key elements inherited from a closed project. Post-acquisition, Android saw new sets of value constructions when it was announced as an Open Source Project, an initiative by Google to promote innovative, open, and low-cost mobile platform. The project was joined by several other industrial actors in form of an alliance known as Open Handset Alliance since the project was announced as an Open Source project. As per Android governance philosophy[32] *"…. a group of organizations with shared needs has pooled resources to collaborate on a single implementation of a shared product. The Android philosophy is pragmatic, first and foremost. The objective is a shared product that each contributor can tailor and customize."* While this philosophy sounds very democratic and inclusive of all, in practice, there is hardly any presence of these elements. The governance of the project is entirely in the hands of Google. During the study of the project and several interviews given by different professionals employed with different segments of OHA, it has

[30] According to the data analyzed from the Gerrit.
[31] This is my own assessment.
[32] http://source.android.com/about/philosophy.html

been identified that Google is more than a manager of the project. The goals and guidelines are being set by Google and rest all other actors must align their strategy and resources accordingly. There is absence of any formal democratic discussion among the members of the alliance. In one of the interviews the Head of Mobile Business Development of one of the OHA members reveals that "Google decides what the strategy would be for the next few months and rest of the actors plan their resources and set a timeline. If Google sees some incentives in a different strategy, they change the decided strategy without the consent of the other members. As a result, the resources and planning of other companies get wasted."

Google chooses different partners for a specific functionality or components or the lead devices based on several factors which are interesting to observe. As per one of the Strategic Alliance Manager[33] of a telecom company "Google bet on winning horses". This means that Google differentiate in assigning major job between companies within OHA. For instance, to choose a lead device for a specific version of Android, which enjoys some privileges of being first, Google considers some of the factors as shown in Figure 18.

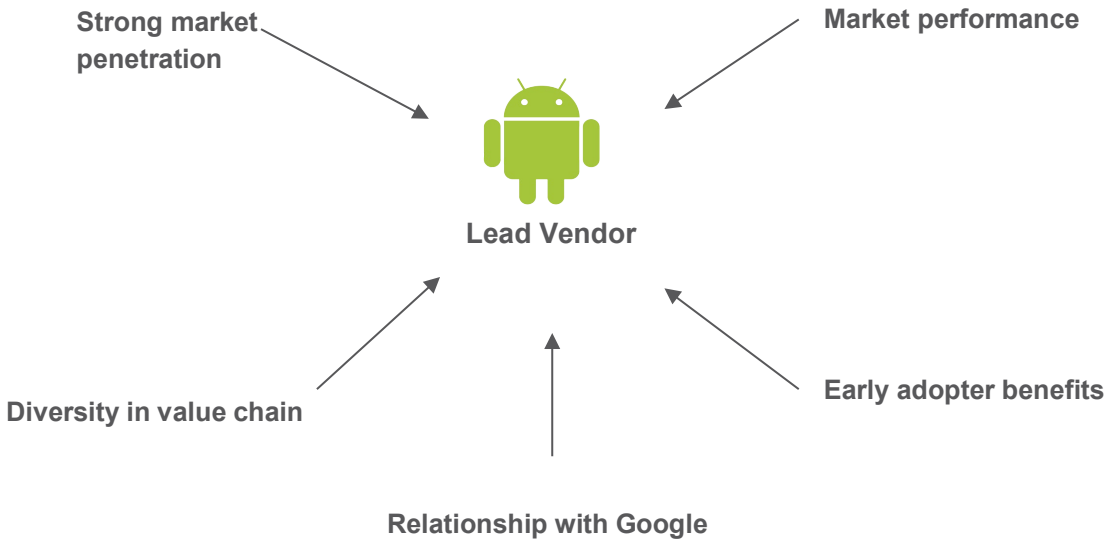


Figure 18: Factors affecting Lead vendorship

Looking at the contribution scenario, Google certainly considers other factors rather than just the number of contributions to AOSP. The difference between the contributions made by different companies clearly verifies this statement.

The factors which might be considered by Google while making decision could be:

- Strong market penetration i.e. the more the sales the stronger efforts would be put in by the vendor to make the Android successful both in terms of marketing and performance. The more successful the Android is (more users) the greater the number of eyeballs and

[33] In a face to face interview, details of which are kept confidential.

hence more advertising revenues which is the prime unsaid goal of Google's Android strategy.

- It is also likely that Google considers the diversity of the vendor in the value chain, for example, Samsung has capabilities in semiconductors apart from handset manufacturing.
- Also, Google might give early partners an edge over others like HTC, who was the one who supported Android initially. One more reason for this could be that Google seek ongoing support from HTC as they took active part in initial development.
- Relationship with Google is also a crucial factor in getting such privileges of being a leading actor.

An important point is that Google doesn't give chance to more than one vendor. One can argue that by doing so Google achieves its ultimate goal – more and more eyeballs on the platform by increased Android sales along with stronger market dominance with equally good relationship with all the vendors. The stronger market dominance is optimally achieved when different vendors push hard with all their strength and resources. If one looks at this practically, Google can't afford to deal with multiple vendors simultaneously because it need to provide technical support to the vendor for product development and it cannot handle it for all vendors altogether and second, it works as "alluring chip" for vendors to do well, cooperate and contribute more towards the success of Android. Thus, the entire process becomes a win-win proposition.

Following are the key points summarizing governance of AOSP:

› Google has a fantastic tool called "Android Compatibility Program" which enables to keep a check on what is being included as part of Android platform.

› At all important positions, Google has assigned its employee to mark all important decisions. They take care of things which are in favor of Android and hence Google.

› Decisions about Android Open Source Project are not taken as a group by OHA members, but the guidelines are set by Google and rest all try to capitalize their interests either in terms of technology or in terms of market.

Hence, this discussion shows that Google takes almost all crucial decision of its own and no other actor is involved in the governance of the Android Open Source Project.

6. Conclusions

During the course of this thesis the extensive contributions to the AOSP have been made. The work started from the making conceptual framework around AOSP and then data was retrieved and formatted for further study and analysis. From the study of data supported by discussion in section 5, various literature and interviews, the following conclusions can be made:

- Android Open Source Project is growing rapidly and is attracting interest of several actors both from industry and individuals. Google along with Android is the largest visible contributor for the Android Open source project.

- There are different motivations behind the contributions by different actors. Industrial actors who are contributing to AOSP are trying either to push their technology to the market or to integrate feature in the platform to reduce the maintenance cost incurred during developmental process.

- AOSP has attracted attention and popularity among some Individual contributors and they are significantly contributing towards the project.

- There are 80 members in Open Handset Alliance, which is an alliance of different actors throughout the industry to promote Android; most of them are not contributing to the AOSP directly or openly i.e. they are not visible in the data. The data confirms the indirect contributions by some members if the alliance.

- Some industrial actors enjoy more privileges than other similar actors irrespective of the amount of contribution they are making to the project.

- The legal implication of the license agreements might be a reason for some of the companies not contributing directly to the project.

- The project is more opaque than open as the process of contribution is not very transparent; this means that some of the actors are able to contribute to the Android Open Source Project by some other means than contributing via Android server publicly. However, the process of contribution looks transparent at the conventional method of contributing i.e. publicly on Android server. Processes to contribute are very well defined but processes to exclude contributions are not very well communicated.

- The governance of Android Open Source Project is handled by Google and rest all actors just follow Google's decisions. All the key roles in the project are assigned to Google, strategy is defined by Google and the guidelines for compatibility with Android are also set by Google. The governance is open in terms of technology process but in terms of strategy it is very closely governed by Google. The use of Android trademark, the compatibility test and tight control of Google's employees make is less open but certainly make it a successful open source project commercially. If Android will be governed by the same approach, it is likely that it will redefine the mobile computing of the future. Contractually, to an extent GPL & Apache Software License Version 2.0 drives it towards openness but Corporate Contributor License Agreement along with

Android as a trademark drags it away from openness. Hence, the Android Open Source Project is governed with significantly low degree of openness.

7. Future Research

Mobile communication is converging with other technologies at a rapid pace. We have seen how quickly communication and computing has become synonymous to each other. If the current trend continues there will more and more technologies that will become inseparable and eventually will part of mobile communication ecosystem. It appears more likely that in future, Android will continue to venture into various new sectors & verticals and will continue to be the mobile OS for the masses.

For future research, it would be interesting to see how Google collaborate with technology companies which operate in technologies non-core to Google like Fintech, Health care etc. It would be interesting to investigate if and how the contribution landscape changes in such scenario and if the governance becomes more open as against the current situation. Does the OHA expands and participates actively in governance of the platform?

With growing dominance of Android as the most used mobile OS & the way it is governed today, it would be worthwhile to study if it violates any anti-trust regulations, particularly when anti-trust laws and IPR laws often believed to be breaching each other's territory.

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9. Appendices

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9.3 Breakdown of contributions over Android platform

All the contributions to the Android platform can be broken down to understand where exactly the contributions are being made by different actors. This breakdown of platform is shown in table below:

Device	HTC	dream dream-sapphire passion passion-common sapphire	
	Samsung	crespo	
Kernal	common experimental msm OMAP Samsung Tegra		
Platform	bionics bootable	 bootloader diskinstaller recovery	 legacy
	build cts dalvik development external	 aes alsa-lib alsa-utils apache-http bison bluetooth bluez bsdiff bzip2 clearsilver dbus dhcpcd dnsmsq dosfstools dropbear e2fsprogs	 bluez glib

		elfcopy elfutils embunit emma esd expat fdlibm freetype fsck_msdos gdata genext2fs giflib google client grub guava icu4c ipsec-tools iptables jdiff jhead jpeg jsilver jsr305 kernel-headers libffi libnfc-nxp libpcap libpng libxml2 mtd-utils netcat netperf neven opencore openssl oprofile ping ppp progaurd protobuf qemu quake safe-iop skia sonivox sqlite srec stlport	

		strace	
		svox	
		tagsoup	
		tcpdump	
		tesseracttinyxml	
		tremolo	
		tremor	
		webkit	
		wpa-supplicant	
		yaffs2	
		zlib	
	frameworks	base	
		opt	emoji
			com.google.android.googlelogin
			com.google.android
		policies	base
	hardware	alsa-sound	
		htc	dream
		libhardware	
		libhardware_legacy	
		msm 7k	
		qcom	gps
		ril	
		ti	omap3
	libcore		
	manifest		
	ndk		
	packages	apps	AccountsAndSync
			AlarmClock
			Bluetooth
			Browser
			Calculator
			Camera
			CertInstaller
			Contacts
			DeskClock
			Email
			Gallery
			Gallery3D
			GoogleSearch
			HTMLViewer
			IM
			Launcher
			Mms
			Music
			OTAProvisioningClient
			PackageInstaller
			Phone

			ProvisionQuickSearchBoxSettings
			SoundRecorder
			Stk
			Sync
			Updater
			VoiceDialer
		inputmethods	LatinIME
			PinyinIME
		providers	CalenderProvider
			ContactsProvider
			DownloadProvider
			Drmprovider
			GoogleContactsProvider
			GoogleSubscribedFeedsProvider
			IMProvider
			MediaProvider
			TelephonyProvider
		wallpapers	MagicSmoke
			MusicVisualization
			Basic
	prebuilt		
	recovery		
	sdk		
	system	bluetooth	
		core	
		extras	
		media	
		netd	
		wlan	ti
			broadcom
		vold	
	vendor	aosp	
		asus	eee-701
		csr	unifi-105x
		htc	common-open
			dream-open
			prebuilt-open
			sapphire-open
		pv-open	
		qcom	android-open
			proprietary-open
		renesas	ms7724
		st-ericsson	u300
toolchain	benchmark		
	binutils		
	gcc		
	gdb		

tools	executablewar gerrit gimd gwtexpui gwtorm manifest repo test	manifest	