ANALYZING SECURITY BREACH AND DATA LEAKAGE IN MOBILE APPLICATIONS USING ILLEGITIMATE SERVER CONNECTIONS

Thesis Submitted in Partial Fulfillment of Requirements for the Award of the Degree
Of

Master of Technology in
INFORMATION SYSTEM

SUBMITTED BY
VIKRANT DHAMA
(2K14/ISY/17)

UNDER THE GUIDANCE OF
ANAMIKA CHAUHAN
ASSISTANT PROFESSOR

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
BAWANA ROAD, DELHI-110042
(2014-2016)

CERTIFICATE

This is to certify that Mr. **VIKRANT DHAMA (2K14/ISY/17)** has carried out the major project titled **“Analyzing Security Breach and Data Leakage in Mobile Applications using Illegitimate Server Connections”** as a partial requirement for the award of **Master of Technology** degree in **Information System** by **Delhi Technological University, Delhi.**

The Major project is a bonafide piece of work carried out and completed under my supervision and guidance during the academic session 2014-2016. The Matter contained in this thesis has not been submitted elsewhere for the award of any other degree.

Date:

(Project Guide)

Ms. Anamika Chauhan

Assistant Professor

Department Of Computer Science and Engineering

Delhi Technological University

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VIKRANT DHAMA

Roll No.: 2K14/ISY/17

M.Tech (Information System)

Department of Computer Science and Engineering

Delhi Technological University, Delhi

ABSTRACT

In past few years, an incredible increase is measured in the popularity and pervasiveness of android smart phones. Also it has observed that new mobile applications are built almost everyday. These apps provides functionalities such as social networking, games, and a lot more to users. A few of the mobile applications have a direct purchasing cost or may be freely available but having an ad-support in it for the revenue and in return these applications provides user's private/confidential data to the ad providers without letting the users consent. Worryingly, most of ad libraries ask for the permissions beyond their requirement and sometimes additional ones from that are listed in their documentation. Some apps also track their users with a network sniffer across ad providers and its applications. Though for security point in concern, users have full right to know that if someone is taking his/her private data or information. This is often ineffective at conveying meaningful, useful information on how a user's privacy might be impacted by using an application.

In this research work, the effect on user privacy of some grossing Android apps was examined that includes apps which provide private data of user without their permission. Android device is firstly rooted for this work and then made some useful changes to collect the required traffic from different applications. On basis of certain parameters, traffic is analyzed and effective results concluded. Using third party connections that an app makes, a threshold is defined to know about legitimacy of application. Some other parameters were also added to check whether an app is stealing users' private information.

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Chapter 1

INTRODUCTION

1.1. Information Security:

Information security aka InfoSec is a branch of security which defends information in various aspects such as unauthorized access, use, disruption, inspection, modification, disclosure, perusal, recording or destruction. Information technology security or information security is protecting the computing devices either it would be a desktop, router, data collection center, server etc. The data should be remain safe either it is a natural disaster or any sort of security breach or even it is a system failure. In today's world almost every bit of information is kept on computers, so the security specialists are needed to overcome with such issues. The most basic method of giving information assurance is having a backup of data at off-site. We can define information security as "Preservation of integrity, availability and confidentiality of information with authenticity, accountability, non-repudiation and reliability" [1]. Information security basic principles are as:

- Confidentiality.
- Integrity.
- Availability.

1.1.1. Confidentiality:

This means preserving the privacy. Confidentiality is allowing access to authenticated persons only. No unauthorized person could make access to information.

1.1.2. Integrity:

Integrity means preserving and maintaining the accuracy and consistency of data. Data should never be affected in the transmission way by unauthorized or protected manner.

1.1.3. Availability:

When information is needed it should be available. No unauthorized person should able to reveal the information. Attacker tries DoS and DDos attacks to do this, which interrupts the information availability for the users.

These mentioned above are basic and main principles of information security. There are two more principles in addition to above which have same importance. Both are mentioned below:

1.1.4. Authenticity:

In security, this is mandatory that the parties which are communicating should be genuine. With the help of digital signature, one can authenticate the validity. It may be happen that an imposter person may get involved in the transaction. It is the responsibility of security personal to perform authentication in advance.

1.1.5. Non-repudiation:

It means one's intention to fulfill the terms and conditions of contract. It also insures that if one party perform a transaction, other cannot deny later having receiving of transaction nor the second party deny having made a transaction.

1.2. Network Security:-

It is a specialized branch in computer networking that functions protecting infrastructure of computer network. It is the duty of network administrator who implants network hardware, its software and ensures security policies regarding to secure a network and their resources, not to be accessed in unauthorized manner. And also promise that authorized persons should have adequate access to resources and network. Network security is a strategy and provisions of an organization for ensuring security of its assets and network traffic [2]. To maintain security of an organization a strategy is followed which includes:

- Policy.
- Enforcement.
- Auditing

1.2.1. Policy:

The principle document of network security is the IT security. The goal is to shape out the rules for guarantee the security in an organization. All set of rules are entitled in this document, how and in what ways to access organizational assets and resources. These are made according to the organization's use and culture. The enforcement and auditing procedures for any general compliance of the organization are required so to meet security policy [3].

1.2.2. Enforcement:

Enforcement primly focuses regarding analyzing network traffic flows and aim to maintain the CIA triad (confidentiality, integrity, and availability) of every system and information on the network. Enforcement also emphases the employees to obey the IT security policy sincerely [3].

1.2.3. Auditing:

The primary aim of auditing is to verify enforcement measures to determine how actually they are engaged with the IT security policy. It also motivates to the contiguous enhancement in the security policy with time to time. It also provides the opportunity to the organization to align and adjust their enforcement strategy and policy[3].

1.3. Type of attacks in network security:

There are various types of attacks that are possible in network, which can be divided into two categories:

1.3.1. Passive attacks:

In passive attack, attacker only examines the traffic and looks for useful informat-
-ion such as unencrypted passwords. In these kind of attacks, attacker plays no active role and also it is very difficult to revealed the identity of attackers. Sniffing, eavesdropping and wiretapping, come under this category [2].

1.3.2. Active attacks:

In active attacks, attacker focus to break the secure system or network. This can be possible by sending Trojan, virus or any malicious packet and there are chances that attacker can get traced. Denial of Service , DNS spoofing, Man in the middle attack, ARP poisoning, Buffer overflow, Heap overflow and SQL Injection are some of the popular active type attacks [2].

1.4. Mobile Security:

The term “digital” is primly used in computers. And therefore digital security comes in zone of protecting the information that is available on internet or computer. In larger view, we can also named it as internet security that promises the information, your personal internet identity and resources. As it has observed in last few decades, the counting of users of digital tech has increased in a surprising way. Around 3 billion users are using internet [4] [5] and 156 million users are having smartphone approx. [6].Digital security is to protect the digital identity. It involves taking sufficient precautions to insecure identity, technology and assets in online and mobile world. Any digital product which is online or connected to a network can be stolen or hacked, so a hacker can get personal information of any digital product. It involves stealing of credit card number, passwords of bank accounts or social security number (only in US). In brief, digital Security is basically about being safe about everything which is connected to a network. Eg., when one starts to learn about internet and computer, it is guided not to reveal any sort of personal information on internet, like contact numbers or full name. After this, one learns how to use antivirus software and other security precautions that keeps one safe from digital or cyber-attacks. When one talks about digital security in smartphones, the platform which used for smartphone are not that much secure and very vulnerable for attack. And the smartphone users are also not that much aware regarding the security of their phone.

Primary platforms that used in smartphone are android, iOS, Windows, blackberry, Symbian, Bada etc. As per 2014 statistics, the share of android in global market is 81.5%, 14.8% of iOS, windows are nearby 2.7% and blackberry has only 0.4% [7]. Some of above mentioned operating systems like Bada, Symbian etc are obsolete now. The reason of android has become so popular is it’s cheaper than its rival iOS and also allow the users to create applications for revenue or fun and easy to register on google play store. With this android has moved to unbelievable level of use but left us open to a large number of insecurities because the applications created by a user are not necessarily having a secure and proper mechanisms to use. This makes attacker's or hacker's to attack. In past, Gmail app which is product of google was attack by hackers. In short, if a google application can hacked then how could we think, a naïve user who is desining an application for the very first time, able to make his application that secure and protect its users against attack. This new operating system is vulnerable to attack and need changes.

A vast range of applications are designed like health monitoring apps, online banking, social networking applications etc. Many app developers releases their apps (i.e applications) for free and earn revenue from ads. For this, they provide users' personal data to ads providers. On the basis of information provided, ads companies recommends only those ads which are most relevant to users. The more precise information ad provider will get, the more profitable and suitable ads will be. When an ad library is located in a mobile app into the user's smartphone, it requests for an advertisement from the server and then it transfer secret information of the user and device to the ad servers, hence it in-lights concern regarding users' digital privacy. Online mobile application may store the credit/debit card numbers and passwords of users which can be a powerful breach in their account. A person having health monitoring application installed can store every details regarding his health onto server and many other related information which is clearly a complete breach in that person's personal life. These applications have intension to look on customers' personal information. Suspicious applications which steal users' personal data may behave in the same way as, transmitting personal information to any third party server or to the cloud. Hence, transmission of personal information by itself may not stipulate actual privacy leakage; a good demonstration could be whether the transmission of information is on users' willingness or not.

- ***User-intended data transmission***: When a user wants to use an application on the extended mode, he may tolerates when personal data is taken from his device with the help of some communication channels. Few applications may ask for registration using a phone number or an email id, like WhatsApp which is a sort of social networking app which needs access to read users' personal contacts, messages, images and other private information. If user deny to allow access to these information, he/she is not be able to use the services of the app, so users is indirectly forced to provide such personal information. One more example, GPS service, if one wants to use services of this app, He/she knows that [8] his/her location could be sent out to get intended contents tailored to the specific location. Hence, in order to use application, user has to provide personal data for the functional use and which is to be with his/her own willingness. Therefore one cannot treat such type of transmission as data privacy leakage.

- ***Unintended data transmission*:** The suspicious transmission of sensitive information done by an application that is without user intension and not at all related to the function application providing or user demanding, is elucidated as un-intentional data transmission or the privacy leakage. In many cases, the malicious apps generally do this in a stealthy manner and without informing to users.

In a recent study it has observed that, Android applications continuously send private data of user to unspecified destinations without consent [9]. Thus, to prevent this from happening and secures' users' data leakage, strong analyzing tools are needed for Android applications that can identify and then remove malicious applications. Some known approaches which detect privacy leakage over smartphones has been derived that focus on detection of sensitive data transmission [10, 11, 12, 13, 14]. Also, most of applications use cloud computing, and because of this, privacy leakage by mobile applications is became a serious subject that is needed to be considered again. Most of these applications provide services to the end users using cloud and in order do so such applications generally collect sensitive data from users activity such as from location, contact, calendar etc to transmit to the cloud. Malicious application which steals user personal data also exhibits the exact same behavior as any other legitimate application do.

1.5. Challenges of Mobile security:

As above mentioned, smartphone users are open to various threats. From Google's

Android security report 2014, there is 26% increment in third quarter. These threats disrupt the operating of smartphone and transmit private data. The main threat targets are:

1. **Data**: It is the primary target of each attacker. Sensitive information such as Debit/Credit card number or passwords may get stolen.
2. **Identity:** Each smartphone has its different identity as IMSI, UDID or IMEI. Applications may transmit these information to steal the owner's identity.

3. **Availability**: Someone can disturb the services or limit the access by performing an attack on a smartphone.

1.6. Types of attacks in mobiles:

As the mobile phone are gaining popularity, it results easy for attacker to attack as they are having a larger platform to target. And yes, the users have less knowledge regarding what to use and How to use. From the invention of smartphones and the very new technology "android", the growth of market extended exponentially. There are many ways in which someone can conclude the type of attacks in mobiles. Few from them are explained as:

1.6.1. SMS and MMS based attacks:

Few of mobile devices have shortcoming and it results in difficult for them to treat an unaware state if any occur. Some devices have trouble in treating the binary SMS messages. It is very possible that by framing an ill-formed message can leads phone to restart and results in denial of service attack. Siemens S55 is an eg., if one sends a text message in Chinese font, the software may get crashed. Also in Nokia mobile, mobile may perform dysfunction if it receives a mail from mail id of having length more than 32 characters. One more way to attack is sending an MMS with having an attachment, which might be infected with virus. As receiver receives the MMS and the attachment gets downloaded and opened, phone gets infected [15].

1.6.2. Attack based on GSM Networks:

The attacker targets the encryption mechanism followed by the GSM network i.e. A5. There are two variants of this algorithm: A5/1 and A5/2. Both of these were made public and which allows to break the encryption. It is feasible to do eavesdropping and cryptanalysis in these algorithm. With eavesdropping someone can attack on mobile radio networks from a virtual base station called IMSI catcher. At the time when encryption algorithm of GSM is broken, anyone can interact with all unencrypted communications done from the victim's mobile [15].

1.6.3. Wi-Fi based attacks:

An attacker can intercept the Wi-Fi communication by doing eavesdropping. The security is more vulnerable in WLAN. First, WEP encryption system was used but it was vulnerable because the length of key was limited or short. It was possible for an attacker to break the password and then he can simply get in the local network of the victim. And if attacker gets success in cracking identification key, it becomes feasible to attack the entire network not only the device [15].

1.6.4. Bluetooth based attacks:

There are various issues about the security in Bluetooth system. Any uninvolved service does not require any authentication and virtual serial port is used by the vulnerable applications to control phone. To order to attack through the Bluetooth service, the device must be in range of attacker and the Bluetooth should be in discoverable mode. File is sent via Bluetooth and a malicious file is transferred, if the recipient accepts. Cabir is a worm which propagates via Bluetooth connection [15].

1.6.5. Web browser based attack:

Mobile web browsers are new area which attracts attacker as like other because they include plug-ins and widgets and importantly they are in developing stage. In web browser based attacks, attacker uses the leverages such as stack based overflow and other vulnerabilities in libraries. This is possible in all kind of operating system either Android or iOS. Smartphones are also vulnerable to phishing and other malicious web site based attacks and there is a big problem with smartphones is they don’t have strong antivirus protection yet [15].

1.6.6. Operating System based attacks:

One may apply any number of secure mechanisms but if there is vulnerability in operating system, it might be going to affect one day surely. There are several loopholes in operating systems of smartphones as these are in earlier stages and developers are not much aware about the kind of attacks possible. It was possible to circumvent the security of operating system and bypass the bytecode verifier and access underlying operating system. Similarly in windows mobile OS, it possible to edit its pointer from general configuration file to a modifiable file. Also it is possible one using the malicious certificate may do changes in the directory whenever an application is installed as at that time it has root privileges [15].

Chapter 2

LITERATURE SURVEY

Security is the prior thing in today's world. Nothing is secure if it is connected to any network. Day by day the attacks are increasing as the programmers making code is having loop holes and that lures attackers. The way the applications are made is not secure, even in software industry security is taken as last step. But security is needed everywhere in design, modelling and programming. With the use of smartphones, security becomes more crucial as the platform is new and it is in its developing stage. Programmers need more proactive approach to save their apps and users get affected from different attacks. It is ridicule to see that more than 80% of users have no knowledge to use the internet and apps. Users are not aware about their security; it never comes in their mind to read the terms and conditions of use any application. As it may so happen that developer of application may reading its private information and using it for some personal benefit or purpose. With the idea of Internet of Things, it becomes individuals' responsibility to be secure as almost everything will be on internet from household things to business. This puts everything on edge as things becomes more vulnerable. More the things get online, more they get prone to attack. To have a better view on the application interaction with our smartphones, rooting of android device was done that allows having root privileges to users to see what it is going through.

2.1. Mobile Operating Systems:

There are numerous operating systems for mobile phones like Android, iOS, Windows, Symbian, Bada, Blackberry etc. Each operating system has its major features and with that some of the shortcomings. In this section, discussion about every operating system is given briefly and their popularity.

2.1.1. Android:

Android is Linux kernel based mobile operating system developed by the Google in 2003 by Andy Rubin, Rich Miner, Nick Sears and Chris White. Its default interface is based on direct touch using touching pads. ARMv7 and ARMv8 with x86 and MIPS are officially supported hardware for Android operating system. It evolved in years from version **Froyo** released in 2008 to the latest version **Lollipop** that is released in May 2015. Android's source code is released under open source license by Google. Android is pretty much popular as it is ready-made, customizable and low cost operating system. Android operating system is written in combination of C, C++ and Java. The core part is written in c and UI part is mainly developed in C++ and java. It supports the monolithic type of kernel. It is widely available in 68 languages. It supports the application made for supporting android platform and those are widely published under Google Play Store where any one can register and publish his/her application. With the upbringing of Android it gave more challenges and fun to developers to get recognition and revenue through creating different application [16].

2.1.2. iOS:

The most popular operating system is iOS that was designed by Apple in 2007 and it supports only the Apple hardware including iPhone, iPad and iPod touch. This one is developed by the Steve Jobs and Scott Forstall. It belongs to Unix- like (BSD) and OS X family and supports a hybrid type kernel. It is written in C, C++ and Swift languages. This was the proprietary of Apple not released under any open source community like the Android. It is available in 34 major languages. It supports the ARM architecture of 64 and 32 bit. The default user interface for iOS is Cocoa touch. The operating system evolved through the years from OS X to iOS 9 by adding multiple and lucrative features in it. Due to the constant evolution in it, it remained the popular in market. The application for the iOS can be found on Apple Store and one can create the iOS app using the SDK released by the Apple only and can get revenue and recognition. It has the most secure feature to keep itself safe from the carious intrusion in market [17].

2.1.3. Blackberry OS:

Blackberry OS came at earlier than other OS like Android, iOS. It came 1998 and firstly used blackberry pager. As the name indicates it was developed by Blackberry. It follows the JVM type of kernel and support only proprietary of Blackberry. It is released in multiple languages. It supports the graphical interface. It is developed in C++ language by Blackberry developers. It evolved from version Blackberry 1.0 to Blackberry 10 but after that it discontinued the service but only provide the support to the existing system. Blackberry was the most popular in corporate world as its' native support to corporate email and synchronization with Microsoft Exchange, calendar, notes and tasks etc. used with Blackberry Enterprise Server. Anyone could develop the blackberry use using third party SDK and get it digitally signed [18].

2.1.4. Symbian:

Symbian is the popular operating system developed by the Nokia Company in 1997. But it was actually developed by Accenture Company for Nokia. It follows the RTOS family. It's a proprietary of Nokia but in earlier stages it was released as an open source. It also supports the multiple languages as the popularities of Nokia mobiles in earlier years of 21st Century. It was developed in completely C++ language. It has real time micro kernel EKA2. The platform supported by Symbian is ARM and x86. It remained in service till 2010 after that Nokia adopted the Windows OS. It supports the graphical interface as well as Mini QWERTY keypad. The application can be created in C++, python, Adobe flash light and Java ME. It features the multi-tasking and memory management like all other popular operating systems [19].

2.1.5. Windows OS:

Windows came into mobile family in 2000 and developed by Microsoft. Before that Microsoft only dealt with the desktop related OS and applications. It was name as Windows mobile in 2003 with the idea dealing with enterprise consumers and business. By 2007, it became the most popular smartphone in U.S. It was written in C++ language. It has evolved from Windows CE released in 2000 almost 15 years back to windows 10. After the release of Windows 10, it discontinued the services as facing the competition from rivalries like iOS and Android. Like all other operating system it also supports the graphical user interface. It has a hybrid kernel. Earlier it was used by Nokia smartphones but later it was used in Windows mobile phones [20].

2.1.6. Bada:

Bada is the operating system developed by the Samsung Electronics in April 2010. The name was derived from Korean word which name Ocean. Samsung released it under open source license. It was completely developed in C++ language. It comes into POSIX family. It supports multiple languages. The kernel type was RTOS. It uses graphical and Touch wiz user interface. The applications are found at Samsung Kies. It discontinued service in 2013 when Samsung started using the Android version of OS. It had released two versions of it. It shared almost 5% of market in its popularity time [21].

2.2. Application Security:

Application security is a branch of security that considers mainly about the security of application created for various platforms like web application, system application and mobile application. This ensures that there is no flaw in design, development, deployment and maintenance of application. It checks the complete code’s life cycle of an application to avoid the security gaps in policy. OWASP and WASC define the provisions that one considers before building any application and also keep updating with latest upgrades. OWASP mainly provide solution to web applications. In application security, one learn what the known threats are and how to secure your application from attackers [22].

2.2.1. Types of Threats possible:

There are several threats possible in applications but here in this section only the most popular and important threats are discussed that one should take care before building any application.

2.2.1.1. Input validation:

This is the most dangerous and general type of attack. Generally developers forget to put validation on user what they can feed into. Taking advantage of this some malicious user provides unauthorized input that leads to crash or infect the application. Before publishing of any application, its responsibility of developer that he/she puts limitations that what type and of what length a user can provide the input. Some popular attacks in this category are Buffer overflow, Cross-site scripting and SQL injection [22].

2.2.1.2. Authentication:

Authentication is that one should provide the credentials to prove the legitimacy to use application. Authentication mechanism should be applied to some sensitive application so that on unknown or illegitimate person can do interference. Some attacks in this category are: Brute force attack, Cookie reply, Dictionary attack and Credential theft [22].

2.2.1.3. Authorization:

Authorization is having right permission to use the application. One may have access to application but not allowed to access the critical and sensitive features and for that authorization should be applied. Attacks possible: Elevation of privileges, data tempering and disclosure of sensitive information [22].

2.2.1.4. Session Management:

It is increasing area of possible attacks as the numbers of users are increasing exponentially in digital world. In this, whenever a connection is made to any web application a session ID is created. It may be possible that by luring the users attacker may hijack their session Id and can steals the private and sensitive information. For that proper security measures should be taken like HTTPS, TLS/SSL layer security. Attacks possible: Session Hijacking, man in the middle attack and session replay [22].

2.2.1.5. Parameter Manipulation:

In this type attacks, attacker tries to manipulate the fields that provided the leverage to user to run certain tasks. In this, attackers do its malicious activity by providing some malicious command or query. Attacks possible: HTTP header manipulation, Form field manipulation, query string manipulation and cookie manipulation [22].

2.2.1.6. Exception Management:

Exception management comes into picture whenever any organization is using a legacy application that needs to be updated or it may get breached but organization is not in situation to do that. Another scenario is organization using third party services to run the, application and the third party not having the proper security measures. These scenarios lures attackers to attack the application as they have the enough time to attack the application because of inability of organization to update the package. Attacks possible are: Denial of Service and information disclosure [22].

These are the certain type of attacks possible to an application. OWASP generated a report and shows the top 10 risks to mobile application security. These top 10 risks are lined as follows [23]:

- Weak Server side Control.

- Insecure data storage.
- Insufficient transport layer security.
- Unintended data leakage.
- Poor authentication and authorization.
- Broken Cryptography.
- Client side injection.
- Security decisions via untrusted inputs.
- Improper session handling.
- Lack of binary protection.

2.3. Rooting (Android):

Rooting is a process of allowing users of smartphones and other handheld devices to attain privileged control or root access. Android is having Linux like Kernel so rooting the Android devi-+ce will give us similar access to administrative permissions as on Linux or any other system [24].Rooting is performed with goal of overcoming limitations that carriers and hardware manufacturers put on devices. Thus, rooting gives ability to modify or replace system settings and applications. With this one can also run specialized applications that require administrator or root level permissions. With the help of rooting, one can do removal or replacement of operating system with latest release.

2.3.1. Advantages of rooting:

There are several advages of rooting as it gives complete control over device. Some of popular adantages are given below:

1. Full control on theming capabilities like changing and theming from color of battery indicator to the look of the contacts and dialer pad.
2. Full control of CPU and kernel.
3. Full control on applications that includes ability to backup, restore. Also remove the bloatware that comes pre-loaded on various smartphones.
4. Automate the processes on device using applications like Tasker.

5. Allow user to install a custom firmware that provides control on a rooted device at an additional levels. Also Android is an open source operating system, anyone having proper skills can create their own customized version.

2.3.2. Disadvantages of rooting:

With great advantages rooting has some disadvantages also. With great joy of rooting one may have to pay a price of losing control over phone. Some of disadvantages are given below:

1. Phone might get bricked.
2. End up voiding phone's warranty.
3. Can become vulnerable to malwares.

2.4. Proposed Approaches:

There has been proposed a lot of approaches to the leakage of digital information in smartphones. Some of popular approaches are described below:

C. Mann et al. [25] have presented the framework to detect the privacy violating information flow in Android based applications using static analysis of byte code of an application. This framework was designed in such a way that it supports the Dalvik virtual machine instruction set. They identified the set of sources and sinks of private information which used to indicate the privacy policy to be enforced by framework via analyzing the Android API. System presented was mainly to track flow of explicit information only. The main focus of theirs is to detect the implicit information leaks due to program control flow for Dalvik byte code as implicit leaks in application sinks are easily detectable. The security system checks whether Dalvik bytecode implementation of android application confirms the privacy policy. In this, they completely analyzed the Android API for possible sinks and sources of private data. And regarding this some of the novel research results exhibited like systematization of Dalvik VM instruction set (218 instructions) into abstract instruction set (61 instructions) by capturing pertinent information flow aspects, Set of sinks and sources are carefully identified in the android API of private information which is used to define a private policy and detecting the explicit information leaks in security type system.

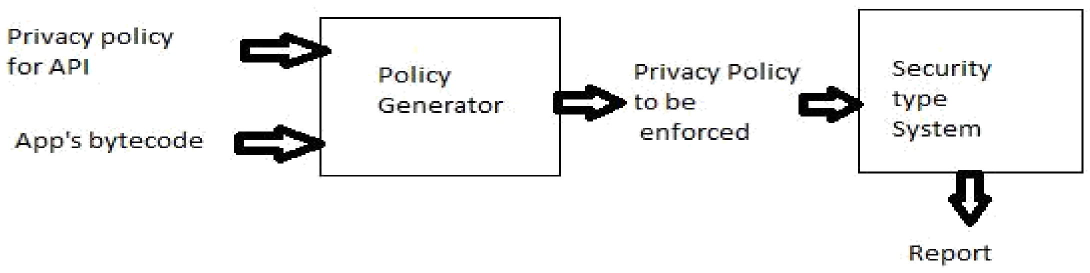


Figure.2.1 Framework for static analysis [25]

Z. Yang et al. [26] presented a new approach i.e. AppIntent. It detects the privacy leakage in android applications. AppIntent framework is designed to know if the data transmission is user intended or not. For this event-space constraint guided symbolic execution technique is proposed and in that it extract the app inputs that were present in some user interactions and using dynamic analysis platform it institutively display context information of sensitive data that is transmitted. With this wonderful work, AppIntent has some limitations also that any kind of native code is not supported by it because of what it can't capture the privacy leakage in native code.

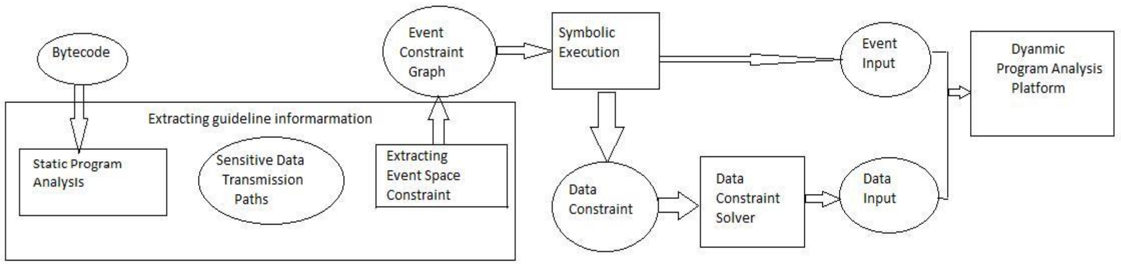

Bytecode
Extracting guideline informarmation
Static Program Analysis
Sensitive Data Transmission Paths
Extracting Event Space Constraint
Event Constraint Graph
Symbolic Execution
Event Input
Dyanmic Program Analysis Platform
Data Constraint
Data Constraint Solver
Data Input

Figure.2.2 Framework of AppIntent [26]

S. Rosen et al. [27] proposed a system i.e. AppProfiler that detects the application behavior through well-defined framework. This system mainly works in two steps which are: building knowledge base of API calls and that to be of their privacy relevant behavior and second step is using this knowledge base to provide behavior profiles for apps. For this around 80,000 applications were used in making knowledge base and then defining the behavior profile. The goal of this application is to provide users the ability to make some informed decisions about applications they install.

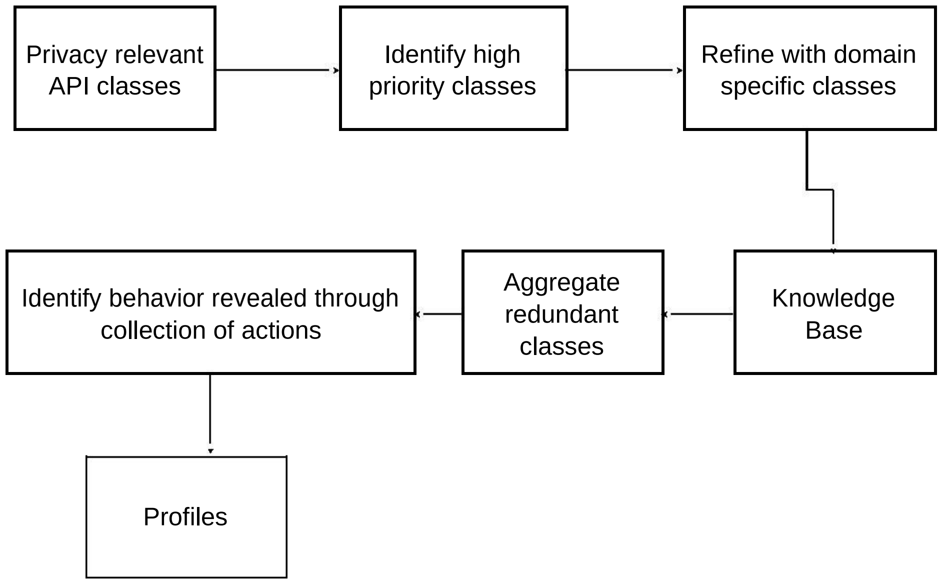

Privacy relevant API classes
Identify high priority classes
Refine with domain specific classes
Knowledge Base
Aggregate redundant classes
Identify behavior revealed through collection of actions
Profiles

Figure2.3 Framework of AppProfiler [27]

R. Stevens et al. [28] proposed a solution that was to analyze the Ad libraries those were embedded in smartphone applications. In this, it has been found that many of the ad libraries extract and use private information of users that these are not intended to be. To have a clear vision on this they chose a set of ad providers from top 500 applications on android platform and with some specific tools they realized that some of the ad provider breaching the privacy policy. In search of dig the deep, they manually analyzed each and every ad libraries, its functions and permissions. They found a certain set of ad providers that taking data that is optional and some are transmitting data that they are not supposed to be. Also it was found that this data is transmitted over network with least security measures that means users' private information may get leaked anywhere.

Although not a single ad provider provides complete private user profile but it has seen that UDID field present in nearly all app ad requests. Using UDID fields, it allows the observer to create a long-term user profile that includes targeting information and GPS locations. Finally, a solutions is proposed to several common ad libraries privacy vulnerabilities that includes failure to user data protection in ad requests, misuse of UDIDs and lack of privileges separation between ad and application code on Android.

L. Btyuk et al. [29] proposed a static analysis for automatic assessment of android application and also the mitigation of unwanted and malicious activities provided. The process was folded in two steps: first, a system was designed that is able to assess android applications for static analysis and generate readable reports to the user. The next step comes to mitigate security and privacy threats. And to provide these automated reverse-engineering on binary application packages id done according to users' security preferences. This Deep static analysis of smartphone apps with comprehensive reports and privacy and security threat mitigation gives an end user great benefit in numerous ways. With this user gets an insight in privacy and security related information of any application.

Having this comprehensive reach to internal, user gets ability to decide whether particular functionality is malicious or not and also they have provided the proof of concept prototype of the implementation.

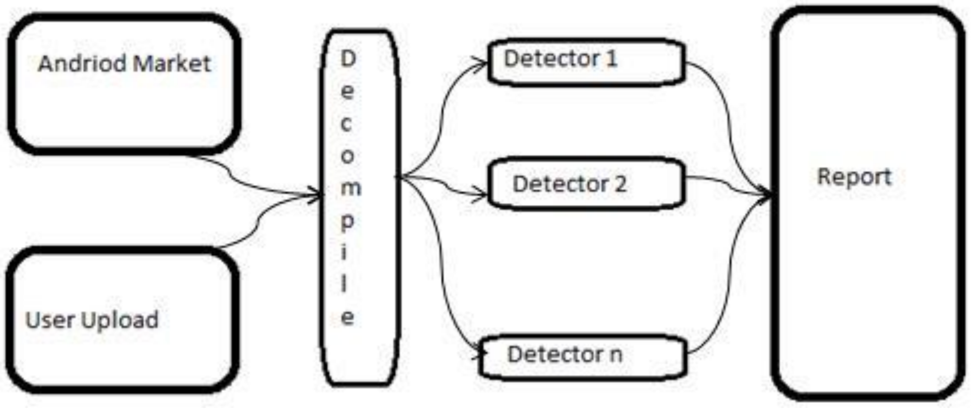


Figure.2.4 Static analysis for automatic assessment of android application [29]

I. Bilogrevic et al. [30] presented a novel approach to preserve private information-sharing system that checks in (semi)automated way whether to share contextual information and also to what extent. They used the active machine learning for this. Their system adapts accordingly user's behavior and decides level if sharing information without making any harm to private information to any third party. This system was evaluated over 70 participants and it gave the stunning results on sharing decisions. Its accuracy is up to 90% .

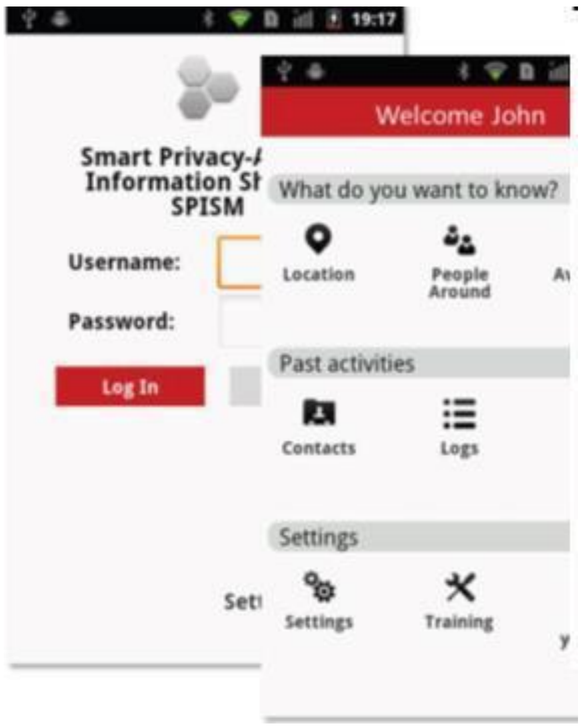


Figure.2.5 The interface of application to detect privacy leak [30]

W. Zhou et al. [31] presented PiggyApp approach, to detect the piggybacked applications existing in Android market. Their presented system was fast and scalable. In this approach, they decoupled the primary and non-primary modules of a piggybacked app. Also they developed a fingerprint technique that extracts the various semantic features from the primary module and used this to construct featured vector. A metric space was made and a linear arithmetic algorithm of complexity O (nlogn) was proposed to detect piggybacked applications scalable and efficiently. The system was tested on around 84767 application collected from Android market and analyzed and results were very promising.

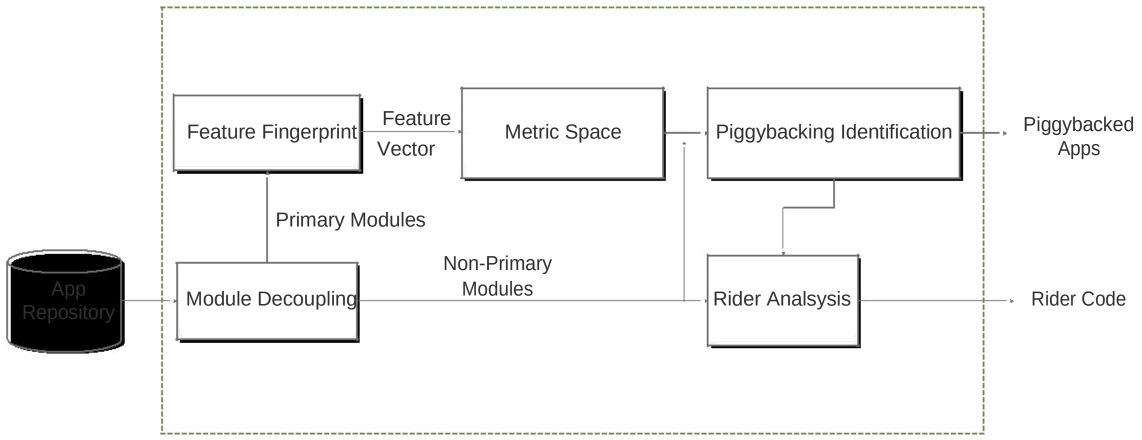


Figure.2.6 System Architecture of PiggyApp [31]

J. I. Hong et al. [32] presented a toolkit Confab, for development of private information sensitive ubiquitous computing application. To develop this toolkit, all end user and application developer needs were collected using several surveys and various research papers. This toolkit provides support to ubiquitous computing apps and provide framework to customize privacy mechanism. It also provides mechanism securing the location privacy. Using all these standards one toolkit was developed to spectrum the privacy needs and trust levels. As all know ubiquitous computing is mostly criticized for the privacy risks it has. However many designing and architecture changes are made to keep it effective and mange privacy. To develop the Confab the end user requirements were clear value proposition, plausible deniability, decentralized control, limited retention of data, special exception for emergencies and simple and appropriate control and feedback [32].

P. Pearce et al. [33] presented an approach AdDroid, to detect privacy and security threats due to Advertising. Keeping in mind that, they integrated the advertising API i.e. AdDroid into Android platform. To protect the API, AdDroid used the privilege separation to distinguish sensitive information advertising network activity from the apps and provided other advertising permissions. PoC (Proof of Concept) of implementation of advertising API and AdDroid was also given. With the involvement of this Advertising API system into Android application not only Android system can evolve but privacy and security can also be increased. It is economically beneficial for developers, advertisers and platform itself. A study was performed of Android market and it was found that almost 46% applications supporting advertisement were suffering from over privilege security permissions and also 34% apps of remaining block request for the access like location just for the adverting purpose.

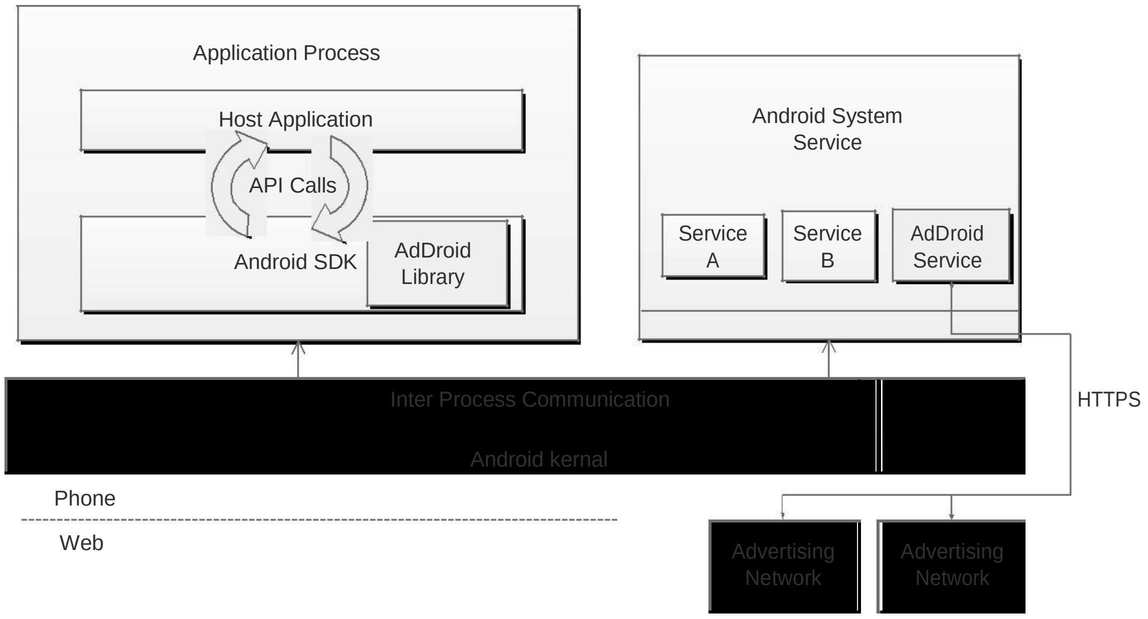


Figure.2.7 AdDroid Design [33]

R. Balebako et al. [34] presented an approach where they calculated number private information sent. For this they first discussed the misconceptions regarding smartphone applications regarding the private information shared. To measure this gap into privacy leakage and the understanding of users' two parameters are taken into considerations: JIT (just in time) information that demonstrate at the moment data is shared and finally visualizing the all data shared through a session. It has seen that most of users' were not aware by the information sharing and the damage it can lead to them. But their approach alarms the user at the time if any application tries to steal any private information. This also demonstrated that finally what and where the data is transmitted by visual. These troubles come mainly because of the app and ad industry. To avoid this, there is a need to explore interface and tools that can improve users' awareness on leakage of private of information.

I. Leontiadis et al. [35] presented an approach prospectively look in the problem of privacy protection for smart phones. In this, they targeted the applications of Android market to identify significance of advertisement in a free application for mobile phones. The solutions is designed to detect the link between ad supported apps and private information sent about users that can bear risks regarding the breaking business model that provides the financial support. The provided prototype solution was aimed to introduce a mechanism that protects privacy that is interlinked with the free apps that supports ads to get revenue. This was done by entrenching a feedback control loop and to maintain equilibrium within the ad revenue and private information privacy controls are dynamically adjusted.

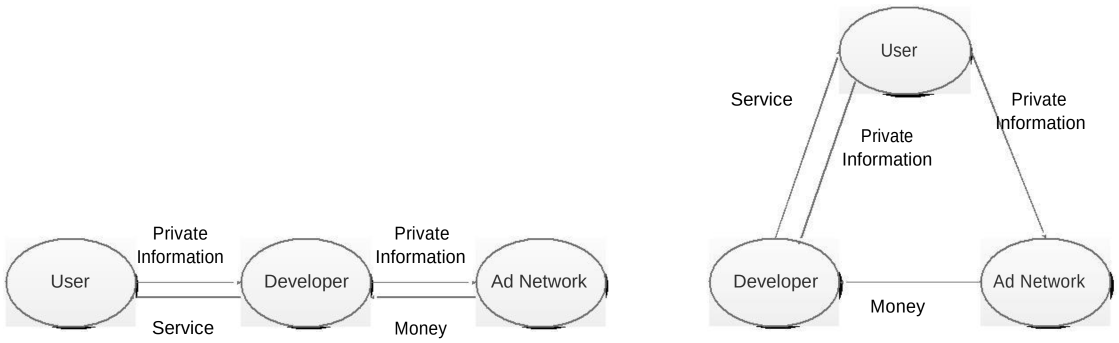


Figure.2.8 Mobile Advertisement Models [35]

E. Chin et al. [36] have given idea that mobile phone ecosystem that includes application market, used pattern and application vendors are quite different and new from desktop computing. So to provide a security and improve computing, there is need to understand the privacy and security implications of users' behaviors and their perceptions at different step of the ecosystem. By understanding it comprehensively, solution can be provided to protect from the potential attacks and threats offered by mobile platforms. It was found in a study that users are feared of four main factors: data loss and fear of theft, misunderstanding about the security provisions, fears of touching or clicking accidently the wrong application and less trustworthiness nature of smartphone applications. To avoid these, an approach was proposed that contains new security measures that ensure privacy and security of users and it also guide users to avoid using untrusted applications. Also it is recommend that devices that come readymade services in which it is to remote lock, use data backup and remote wipe services. It is also believed that mistrust applications could be eradicated by building up centralized markets with the information provided by users and application reviews.

S. Ickin et al. [37] have presented research on mobile's Quality of Experience. They presented the approach that considers both procedures quality and quantity where users are an active part of research. Firstly, information is gathered from different applications that with the directly in interaction with users and then is employed to ESM (Experience Sampling Method). Second, backtracked analysis of application's user experience and factors of employing are required. Then it is employed to DRM (Day Reconstruction method) to sync with the collection of past 24 hours. It was seen that DRM was very supporting for validating gathered data thorough CSS app. An analysis was presented with collected data and some factoring by impacting user's QoE. The novelty of this approach was that it concludes the influence of phone features, app performance, app interface design and user routines, usability and many more. It was seen that increased RTT and SRT values to study the QoS.

N. li et al. [38] presented an approach that is used only for location sharing applications. In this they have given a brief description of LSNs (Location Sensing Networks) that are used to share the location. It is used to connect the users socially based on their location.

A user's location is very private and sensitive information. They studied different location sharing locations sensing mechanism and did a trace based analysis to get the actual way of real world sharing of location. It was also found that there is huge similarity between the information transmitted based on gender, age, and geographical locations. And almost similar protection measures are taken in friends. An extensive research is done and a model is designed on basis of friendship and user classification to trace the data. Finally it was concluded that it was the first large scale empirical study of LSNs.

Chapter 3
PROBLEM STATEMENT

3.1. Gaps in Study:

Mobile applications are now everywhere. Mobile applications now days are used for business, entertainment, bill payment, shopping and much more. But because of the time constraint and high competition among app developers, very less stress is laid on the security aspect while developing the applications. So there is need to encourage and educate the app developers to consider the security aspect and attacks associated with the mobile applications. The security flaws will not only affect the business and reputation of the company but it can also lead to loss in terms of money for example the app vulnerabilities can allow an attacker to transfer funds from one account to another. There are a very few automated vulnerabilities assessment tools that are available in market that aims to analyze the applications for presence of security vulnerabilities in mobile applications. One of the major problems in mobile applications is that these make connection to third party servers for the transmission of private information related to user. But because of unawareness users are still using such application those are stealing their private information. The main problem is that still there are no tools that can detect or prevent such data leaks and provide security to users.

3.2. Problem Definition:

After studying the problem in the existing domain, this conclusion has been derived that the mobile platform still has a number of flaws and developers are not much aware about these. The applications made by developers are somewhere damaging the user's privacy and stealing the private information that is not good as per security perspective. Developers embed the Ad libraries in their application code for information gathering purpose and when users install the app these libraries steal user information and send it to the Ad server to understand the user needs and providing the specific ads to increase their revenue. Similarly developers also get paid by embedding these Ad libraries and from this they generate revenue. Some of the gathered information is sold to some other organization and this may lead to breach in privacy of the user. If this information gets caught in wrong hands it can lead to huge damage to the user. Thus seeing mentioned gap, it was decided to look into the problem of making third party connection and made a novel approach to reveal the secrets behind this. For this detection mechanism was proposed that detects the illegitimate applications which make connections to third party servers.

3.3. Objectives:

1. To detect third party connections made by an application on an Android device.
2. To define the threshold that derives the legitimacy of mobile applications.
3. Monitor the APi calls and system calls using “Attackers” method.
4. To verify and validate apps based on experimentation performed using the test bed scenarios.

Chapter 4

IMPLEMENTATION AND EXPERIMENTAL RESULTS

This section describes the design of framework and methodologies. This work used different approaches to derive the desired results and those are explained in this section. An approach was proposed that is using the third party server connections made by a particular application. Also there are certain other parameters that were taken to provide the trust value to an application. The main focus of ours was to set a threshold value that defines the legitimacy of an application based on the trust value that it gets on different parameters. The framework to detect the legitimacy of an application is given below

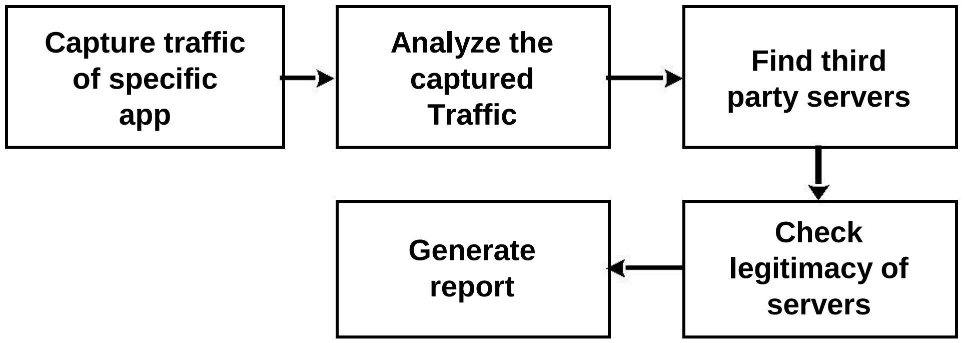

Capture traffic of specific app
Analyze the captured Traffic
Find third party servers
Check legitimacy of servers
Generate report

Figure.4.1 Framework to find third party servers

The main focus was to set a threshold value that defines the legitimacy of an application based on the trust value that it gets on different parameters. The parameters taken are as follows:

- Permission request.
- Number of third party server connections.
- Size of a particular application.
- Number of connection to a particular third party server and data uploaded to it.

Keeping above parameters in mind, different mechanisms was used to detect the private data leakage in mobile applications. The approaches used are given following:

4.1. Implementation using AirPcap:

AirPcap was used to capture the Wi-Fi traffic of the Android phone and Wireshark & Network Miner is used to analyze it. Step by step procedure is given below:

a) Connect AirPcap to a windows machine.

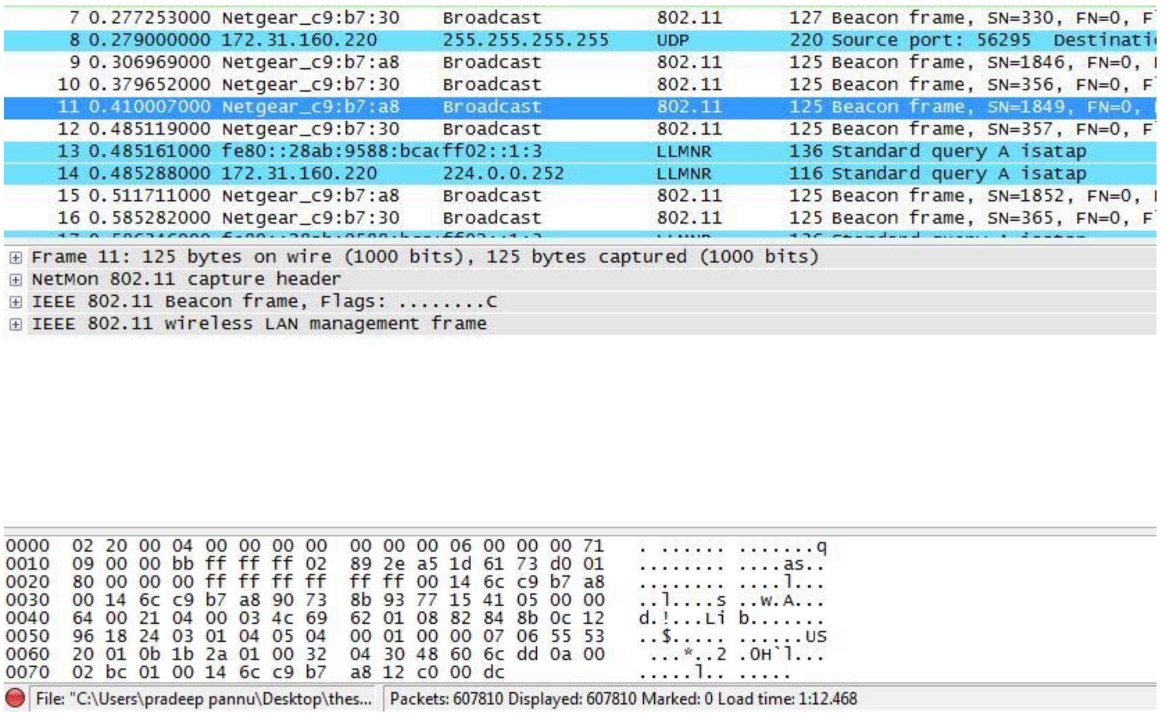
b) Setup Windows machine with

- Wireshark
- Microsoft Network Monitor

c) Connect Android Phone of user1 to Wi-Fi network.

d) Launch mobile apps one by one to communicate with internet.

e) Capture packets and analyze.



```
     7 0.277253000 Netgear_c9:b7:30     Broadcast           802.11      127 Beacon frame, SN=330, FN=0, F
     8 0.279000000 172.31.160.220       255.255.255.255     UDP         220 Source port: 56295  Destinati
     9 0.306969000 Netgear_c9:b7:a8     Broadcast           802.11      125 Beacon frame, SN=1846, FN=0,
    10 0.379652000 Netgear_c9:b7:30     Broadcast           802.11      125 Beacon frame, SN=356, FN=0, F
    11 0.410007000 Netgear_c9:b7:a8     Broadcast           802.11      125 Beacon frame, SN=1849, FN=0,
    12 0.485119000 Netgear_c9:b7:30     Broadcast           802.11      125 Beacon frame, SN=357, FN=0, F
    13 0.485161000 fe80::28ab:9588:bca(ff02::1:3          LLMNR       136 Standard query A isatap
    14 0.485288000 172.31.160.220       224.0.0.252         LLMNR       116 Standard query A isatap
    15 0.511711000 Netgear_c9:b7:a8     Broadcast           802.11      125 Beacon frame, SN=1852, FN=0,
    16 0.585282000 Netgear_c9:b7:30     Broadcast           802.11      125 Beacon frame, SN=365, FN=0, F

⊞ Frame 11: 125 bytes on wire (1000 bits), 125 bytes captured (1000 bits)
⊞ NetMon 802.11 capture header
⊞ IEEE 802.11 Beacon frame, Flags: ........C
⊞ IEEE 802.11 wireless LAN management frame

0000   02 20 00 04 00 00 00 00  00 00 00 06 00 00 00 71   . ...... .......q
0010   09 00 00 bb ff ff ff 02  89 2e a5 1d 61 73 d0 01   ........ ....as..
0020   80 00 00 00 ff ff ff ff  ff ff 00 14 6c c9 b7 a8   ........ ....l...
0030   00 14 6c c9 b7 a8 90 73  8b 93 77 15 41 05 00 00   ..l....s ..w.A...
0040   64 00 21 04 00 03 4c 69  62 01 08 82 84 8b 0c 12   d.!...Li b.......
0050   96 18 24 03 01 04 05 04  00 01 00 00 07 06 55 53   ..$..... ......US
0060   20 01 0b 1b 2a 01 00 32  04 30 48 60 6c dd 0a 00    ...*..2 .0H`l...
0070   02 bc 01 00 14 6c c9 b7  a8 12 c0 00 dc            .....l.. .....

File: "C:\Users\pradeep pannu\Desktop\thes...   Packets: 607810 Displayed: 607810 Marked: 0 Load time: 1:12.468
```

Figure 4.2 Screenshot of Wireshark for management traffic

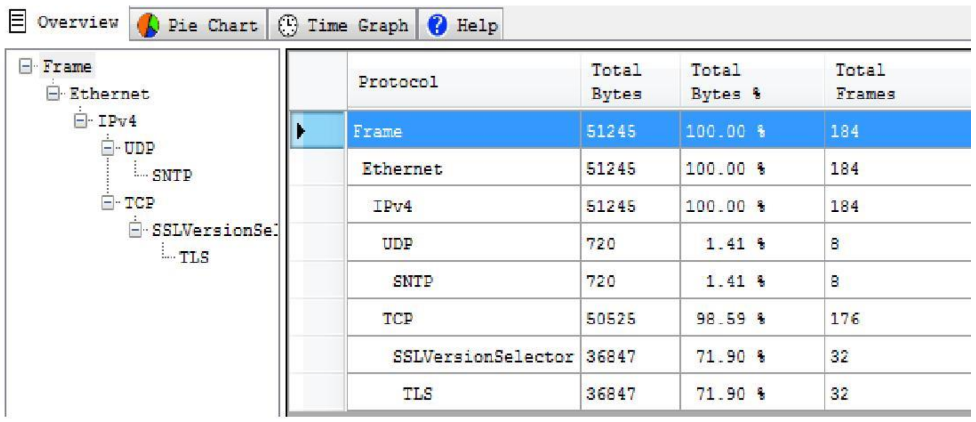
Results:

AirPcap captured Wi-Fi traffic between android and DSL modem. The following results are concluded:

a. Only management traffic, control traffic and packet with TLS encryption were present in captured packets. The private key of individual app was required for decrypting the data frames.

b. This method was not suitable for the case study and therefore not all desired results were drawn.

c. This approach was unable to see the encrypted TLS packets.



Protocol	Total Bytes	Total Bytes %	Total Frames
Frame	51245	100.00 %	184
Ethernet	51245	100.00 %	184
IPv4	51245	100.00 %	184
UDP	720	1.41 %	8
SNTP	720	1.41 %	8
TCP	50525	98.59 %	176
SSLVersionSelector	36847	71.90 %	32
TLS	36847	71.90 %	32

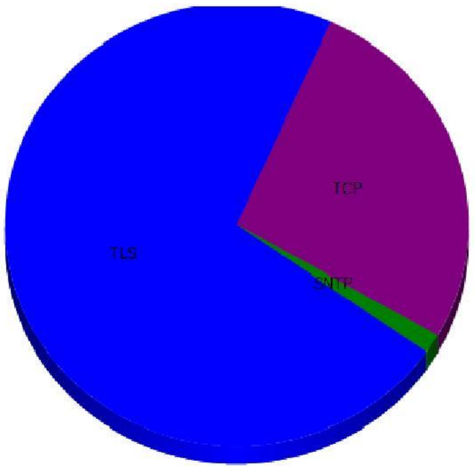


Figure 4.3 Screenshot of Network Monitor for TLS encrypted data frames

4.2. Implementation using tPacketCapture pro:

tPacketCapture pro was used to capture the traffic for specific app. Step by step procedure is given below:

a) tPacketCapture pro was installed from Play Market on Android phone.

b) Launch mobile apps one by one and traffic is collected of one app at a time.

c) Captured packets were saved in pcap format and analyzed using different tools:

- Network Investigator
- Microsoft Network Miner
- Microsoft Visual Round Trip Analyzer

d) Number of connections made to third party servers was calculated for particular application. For this a windows shell script was created which detect the illegitimate FQDN (Fully Qualified Domain Name) for a particular app.

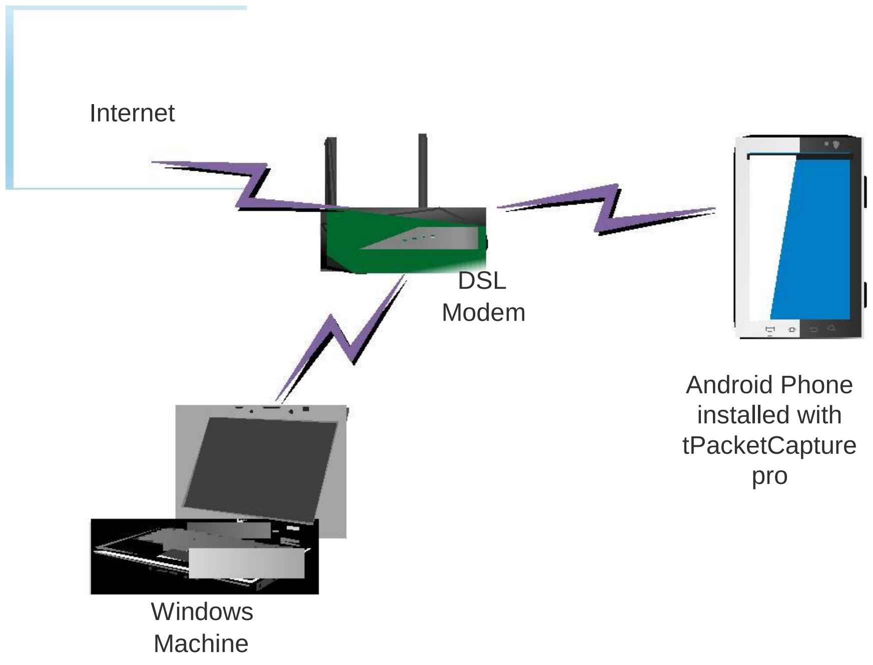
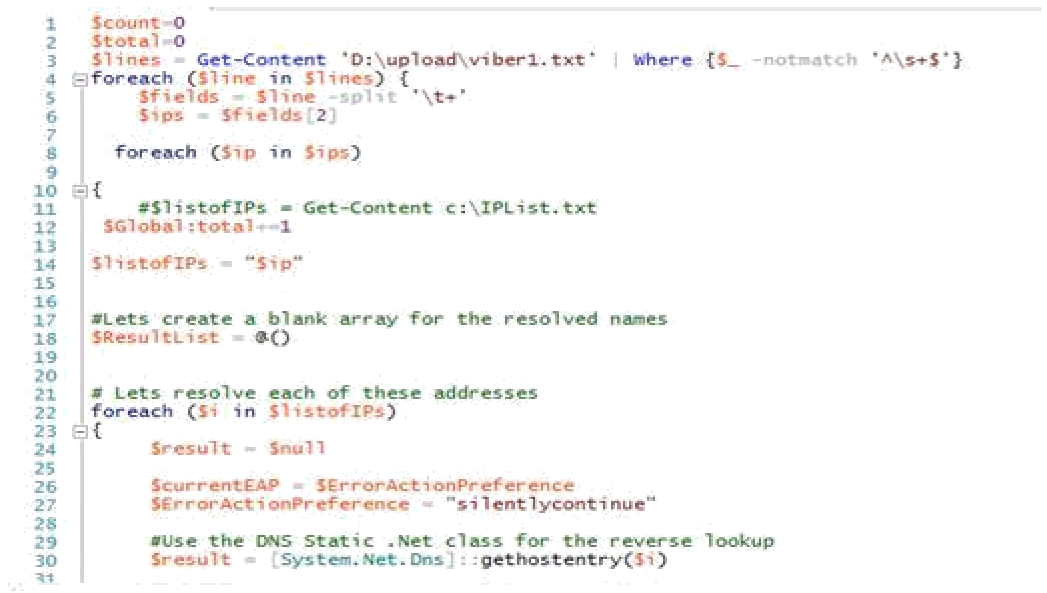


Figure 4.4 Network setup using tPacketCapture pro



```
$count=0
$total=0
$lines = Get-Content 'D:\upload\viber1.txt' | Where {$_ -notmatch '^\s+$'}
foreach ($line in $lines) {
    $fields = $line -split '\t+'
    $ips = $fields[2]

  foreach ($ip in $ips)

{
    #$listofIPs = Get-Content c:\IPList.txt
 $Global:total+=1

$listofIPs = "$ip"


#Lets create a blank array for the resolved names
$ResultList = @()


# Lets resolve each of these addresses
foreach ($i in $listofIPs)
{
     $result = $null

     $currentEAP = $ErrorActionPreference
     $ErrorActionPreference = "silentlycontinue"

     #Use the DNS Static .Net class for the reverse lookup
     $result = [System.Net.Dns]::gethostentry($i)
```

Figure.4.5 Code snippet to match FQDN

Results:

a. *Third Party Connections:* In this scenario, if an application is connecting to the particular third party servers many times. It may so happen that it is transmitting the users' private data. An app has to make connection to its legitimate server more to provide the functionality, rather to a third party server. It is also seen that apps transfer bulk of data to third party servers that indicates in breaching the security policies. To support this parameter some apps were analyzed and their top connected third party servers are shown in table given below:

TABLE 4.1 Top third party connection to particular app in social networking domain

Application Name	Server Name (third party)	No. of connections
App 1	ec2-**-254-***-132.ap-*******-1.compute******.com	1133
	server-**-230-***-90.**m2.r.*******.net	585
	server-**.192.***.35.**m2.r.*******.net	377
	server-**-230-***-90.**m2.r.*******.net	447
App 2	a***-51-***-234.deploy.static.*********.com	2514
	2-.73.***.221.compute-1.*******.com	150
	2-54.*.251.***.compute-1.*******.com	174

App 3	***.192.***.18-static.revrese.******.com	72
	.168..121-static.revrese.******.com	76
	.168..227-static.revrese.*******.com	196
App 4	**2-**.169.***.8.ap-*******-1.compute.*******.com	193
	*3-ap-southeast-1.*******.com	117
	2-.169.191.3.ap-*******-1.compute.******.com	562
App 5	edge-star-****-01-***1.*****.com	1536
	edge-mqqt-***-01-***1.*****.com	1392
	a***-56-***-215.deploy.************.com	287
App 6	server-**-230-***-100.a**50.r.******.net	106
	a***.56.***.41.deploy.**********.com	148
	server-**.231.***.41.a**50.r.*******.net	155
	edge-star-***-01-***1.********.com	197
	*3-eu-west-1.*******.com	722
	a***.56.***.40.deploy.************.com	347
App 7	**2-***.22.***.119.compute-1.******.com	324
	edge-star-***-01-***1.********.com	321
	***01*06-i*-*13.**100.net	553
	server-**-230-***-133.***2.r.******.net	153
	2-50..207.1***.compute-1.********.com	765
	***01*06-i*-*15.1*00.net	987

**Due to confidentiality name of applications and third party servers are not revealed*

b. *Permission Request:* Whenever users install an app, it requests a set of access permissions and in those permissions, application request like read contacts, IMEI, phone name, operating system, camera, messages and many more. To run an application a certain set of permission is necessary but in addition to that application request for extra permissions those are for information gathering purpose for third party server and ad servers. When captured packet using tPacketCpature pro was analyzed then it was seen that some apps asking more than the permissions it actually requires to provide functionality. The screenshot of flashlight application permission justifies our argument.

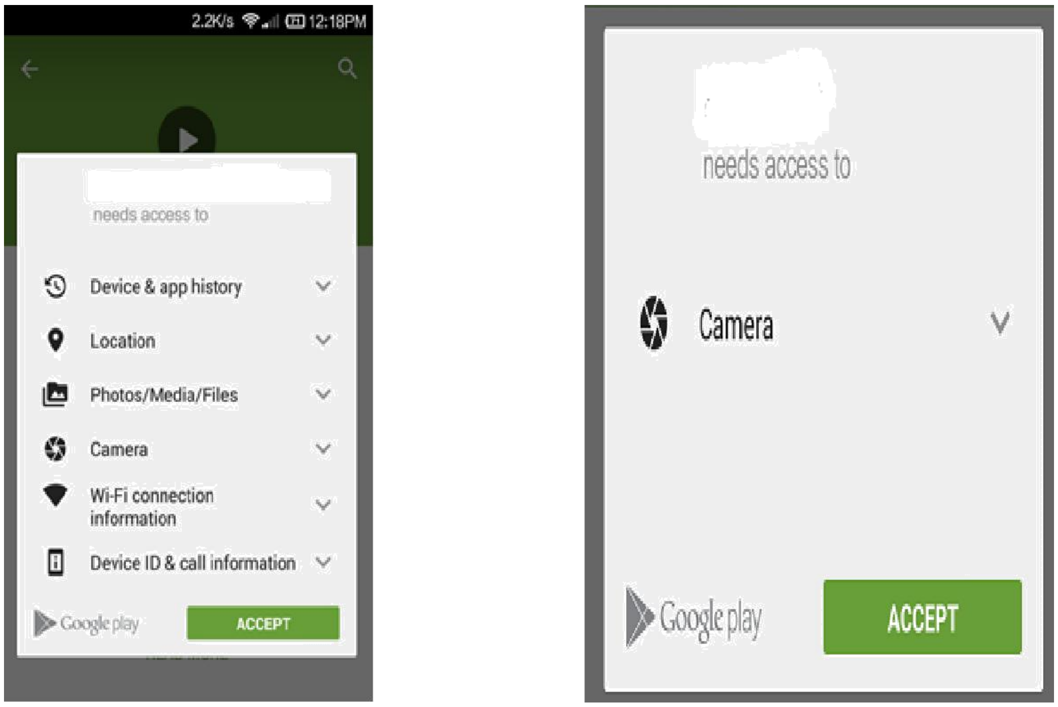


Figure 4.6 Comparison between the permission requests of flashlight apps

c. *Size of app:* Almost all applications of a domain provide the similar functionality and hope to be of same size probably. But it generally happens that these applications vary in size a lot. Thus it shows that an application of larger size having some other extra package in it and that can be of ad libraries for the information gathering. As the size grows more doubtful the app becomes with respect to third party connections. For example, the social networking domain was analyzed and certain measuring difference were seen in their size which leave some doubt in mind that it may contains some extra and unusual functionalities.

TABLE 4.2 Size variations in social networking domain apps

Application	**Size (MB)**	**Messaging**	**Call**	**Media**
App1	24	Y	Y	Y
App2	29	Y	Y	Y
App3	32	Y	Y	Y
App4	50	Y	Y	Y
App5	56	Y	Y	Y

4.3. Implementation Using Fiddler as Man-in-the-Middle:

The following setup is built in which fiddler was installed on a windows machine and Man-in-the Middle setup was established to capture the traffic in Wi-Fi environment. Step by step procedure is given below:

a) Install fiddler on windows machine and connect that machine to DSL modem.

b) Setup a wireless hotspot on windows machine using netsh command.

c) Connect the Android phone to Wi-Fi on hotspot of windows machine.

d) Start fiddler on windows machine. All traffic of android phone is now routed through windows machine.

e) Download the fiddler certificate to phone and add it to certificates.

f) Launch mobile apps one by one from Android phone to communicate with outside world.

g) Traffic was captured on windows machine and analyzed.

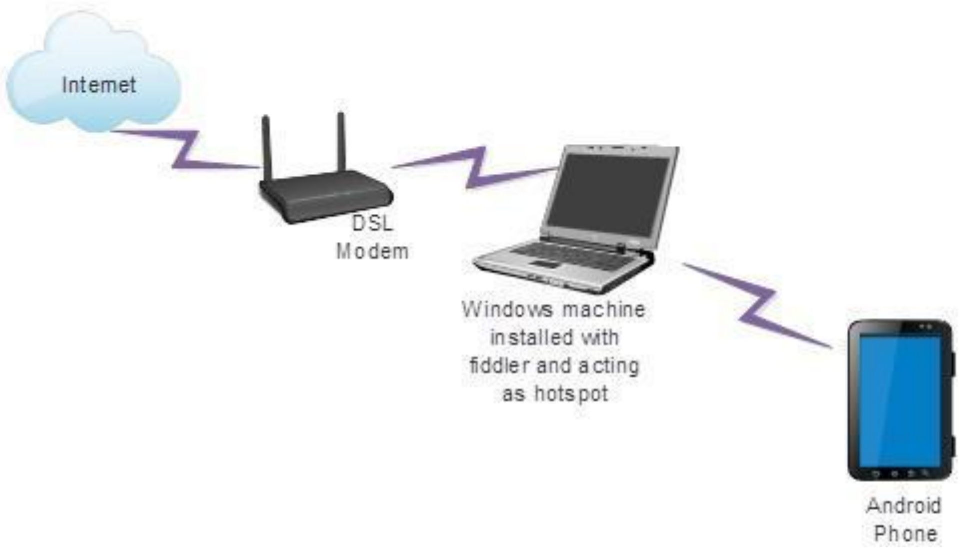

Internet
DSL Modem
Windows machine installed with fiddler and acting as hotspot
Android Phone

Figure 4.7 Network Setup Using Fiddler as proxy on Windows Machine

Results:

The following observations were made from the captured traffic:

a. A large number of requests per host were initiated. A number of Ad sites and analytics were connected. This confirms the third party transfers.

b. Since no advertisements were offered on app while using, all traffic being generated is suspicious.

c. A large number of data packets, basically javascripts were downloaded to mobile devices.

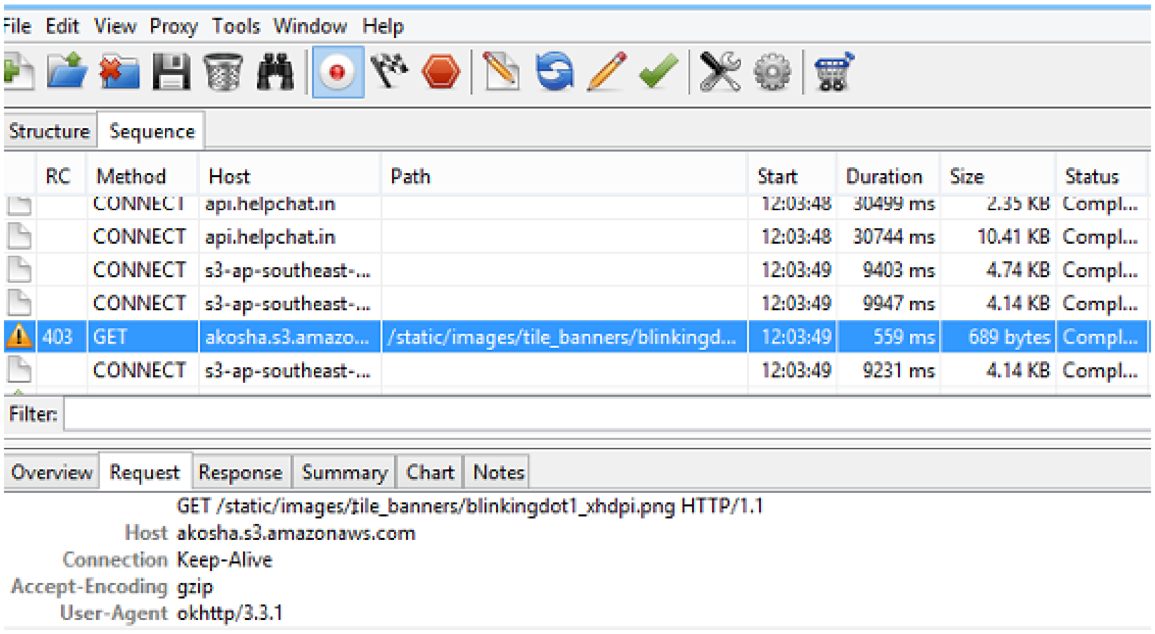
d. Possibly app has downloaded its malicious function onto device and may trigger it later on depending on the suitability of parameters or time triggered.

e. A number of apps were found to transmit user identity in terms of name, age, gender etc. Mobile operator information was also transmitted by some of apps.

f. Some of applications were seen to capture the phone book of users.

4.4 Implementation Using a "Attacker's" method:

- Setup a proxy as an attacker usually does. Make your workstation to behave/act as a proxy Server. Now launch the proxy tool.
- Now enable your device to use your workstation as a proxy server by going back to the Wi-Fi settings by entering your workstation ip address in the proxy Server field, including the port number.
- Now the whole traffic will be pass through your workstation.
- Now launch the aps from your device one by one and record all the Api calls that are running in the foreground and the background as well.
- The above procedure will help to record all the Api calls of http protocol but not for https protocol, to do so, we need to add some certificates from the internet to our device
- Based on th Api calls, we can now find the system calls and verify them.
- We use Api call as feature to know what operations the Applications wants to execute that may be sensitive. Mainly, we focus on those permission-protected APi's from the permission map.


File Edit View Proxy Tools Window Help
Structure Sequence
Filter:
Overview Request Response Summary Chart Notes

RC	Method	Host	Path	Start	Duration	Size	Status
	CONNECT	api.helpchat.in		12:03:48	30499 ms	2.35 KB	Compl...
	CONNECT	api.helpchat.in		12:03:48	30744 ms	10.41 KB	Compl...
	CONNECT	s3-ap-southeast-...		12:03:49	9403 ms	4.74 KB	Compl...
	CONNECT	s3-ap-southeast-...		12:03:49	9947 ms	4.14 KB	Compl...
403	GET	akosha.s3.amazo...	/static/images/tile_banners/blinkingd...	12:03:49	559 ms	689 bytes	Compl...
	CONNECT	s3-ap-southeast-...		12:03:49	9231 ms	4.14 KB	Compl...

```
                GET /static/images/tile_banners/blinkingdot1_xhdpi.png HTTP/1.1
           Host akosha.s3.amazonaws.com
     Connection Keep-Alive
Accept-Encoding gzip
     User-Agent okhttp/3.3.1
```

Figure 4.8 Recording transaction of app and identifying APi calls behind transaction.

Results:

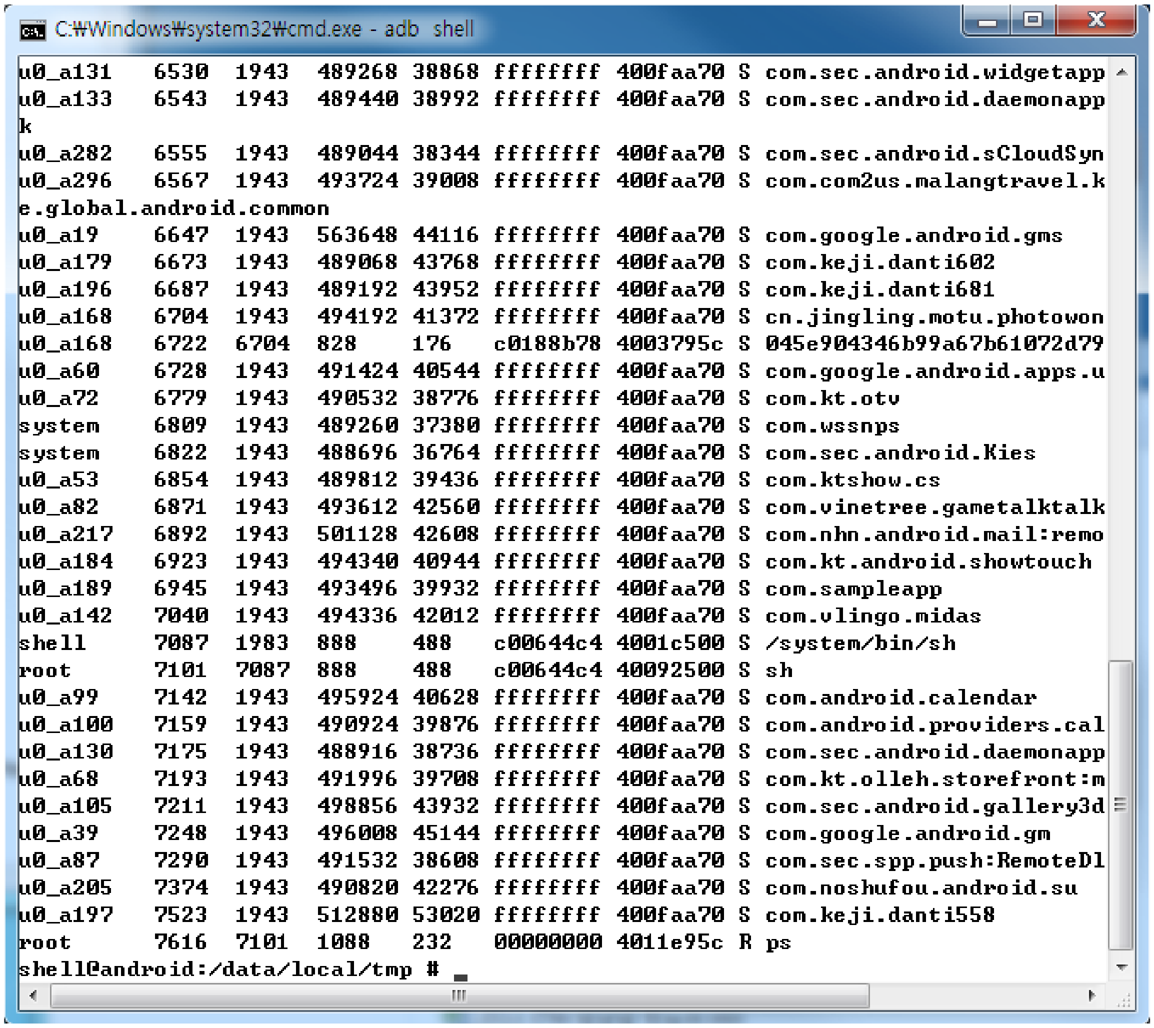
The following has been concluded from the recorded transaction of various apps:

a. It is observed that some of the malicious application invokes *getdeviceId()* Api call in service component that runs in the background while benign application calling such APi in activity component that is visible in user interface.

b. Some malicious apps like BaseBridge and ArtifactDataCable apps, changes the wifi option without the user knowing and other applications is installed to damage by leaking sms, personal data, call records etc.

c. Applications like Super History Eraser and Task Killer Pro when get installed, they blocks waiting for user's to interact by selecting, filling froms, validating the buttons. These are predefined in malware by the attacker to interact with user.

d. Some of the System calls like fchown32, fdatasync, mkdir, rmdir, ststfs64 and umask etc. are frequently invoked by the malicious apps, whereas the normal apps transactions is clean and its hard to found log of such system calls.



```
u0_a131   6530  1943  489268 38868 ffffffff 400faa70 S com.sec.android.widgetapp
u0_a133   6543  1943  489440 38992 ffffffff 400faa70 S com.sec.android.daemonapp
k
u0_a282   6555  1943  489044 38344 ffffffff 400faa70 S com.sec.android.sCloudSyn
u0_a296   6567  1943  493724 39008 ffffffff 400faa70 S com.com2us.malangtravel.k
e.global.android.common
u0_a19    6647  1943  563648 44116 ffffffff 400faa70 S com.google.android.gms
u0_a179   6673  1943  489068 43768 ffffffff 400faa70 S com.keji.danti602
u0_a196   6687  1943  489192 43952 ffffffff 400faa70 S com.keji.danti681
u0_a168   6704  1943  494192 41372 ffffffff 400faa70 S cn.jingling.motu.photowon
u0_a168   6722  6704  828    176   c0188b78 4003795c S 045e904346b99a67b61072d79
u0_a60    6728  1943  491424 40544 ffffffff 400faa70 S com.google.android.apps.u
u0_a72    6779  1943  490532 38776 ffffffff 400faa70 S com.kt.otv
system    6809  1943  489260 37380 ffffffff 400faa70 S com.wssnps
system    6822  1943  488696 36764 ffffffff 400faa70 S com.sec.android.Kies
u0_a53    6854  1943  489812 39436 ffffffff 400faa70 S com.ktshow.cs
u0_a82    6871  1943  493612 42560 ffffffff 400faa70 S com.vinetree.gametalktalk
u0_a217   6892  1943  501128 42608 ffffffff 400faa70 S com.nhn.android.mail:remo
u0_a184   6923  1943  494340 40944 ffffffff 400faa70 S com.kt.android.showtouch
u0_a189   6945  1943  493496 39932 ffffffff 400faa70 S com.sampleapp
u0_a142   7040  1943  494336 42012 ffffffff 400faa70 S com.vlingo.midas
shell     7087  1983  888    488   c00644c4 4001c500 S /system/bin/sh
root      7101  7087  888    488   c00644c4 40092500 S sh
u0_a99    7142  1943  495924 40628 ffffffff 400faa70 S com.android.calendar
u0_a100   7159  1943  490924 39876 ffffffff 400faa70 S com.android.providers.cal
u0_a130   7175  1943  488916 38736 ffffffff 400faa70 S com.sec.android.daemonapp
u0_a68    7193  1943  491996 39708 ffffffff 400faa70 S com.kt.olleh.storefront:m
u0_a105   7211  1943  498856 43932 ffffffff 400faa70 S com.sec.android.gallery3d
u0_a39    7248  1943  496008 45144 ffffffff 400faa70 S com.google.android.gm
u0_a87    7290  1943  491532 38608 ffffffff 400faa70 S com.sec.spp.push:RemoteDl
u0_a205   7374  1943  490820 42276 ffffffff 400faa70 S com.noshufou.android.su
u0_a197   7523  1943  512880 53020 ffffffff 400faa70 S com.keji.danti558
root      7616  7101  1088   232   00000000 4011e95c R ps
shell@android:/data/local/tmp #
```

Figure4.9 Activated system call events

4.4. Implementation Using TaintDroid:

It is a system that provides dynamically taint tracking and analysis of applications simultaneously via tracking various sensitive data sources. By having leverage in Android's virtualized environment, one can do real-time analysis in TaintDroid. It is an extension to Android platform that helps in tracking private data through third party apps. The goal of ours is to detect what data is leaked and which app is helping it to do so. This system labels or taints the data that is leaked from sensitive sources. Whenever this tainted packet leaves the system, destination address, application responsible and type of data gets logged in TaintDroid system. Users get a better insight into what apps are actually working. Multiple granularity approach is followed by the TaintDroid system: file-level, method-level, variable-level and message-level. The multilevel approach tracking is as follows:

1. VM interpreter is used for variable-level tracking in third party applications using variable semantics and only data is tainted.
2. Secondly, message-level tracking is performed, in which messages were tainted not the data in the messages.
3. Next, method level tracking is done to run the native code and flow is tainted using flow semantics.
4. Lastly, file-level tracking is done to check the taint marking is conservatively retained or not on persistent information.

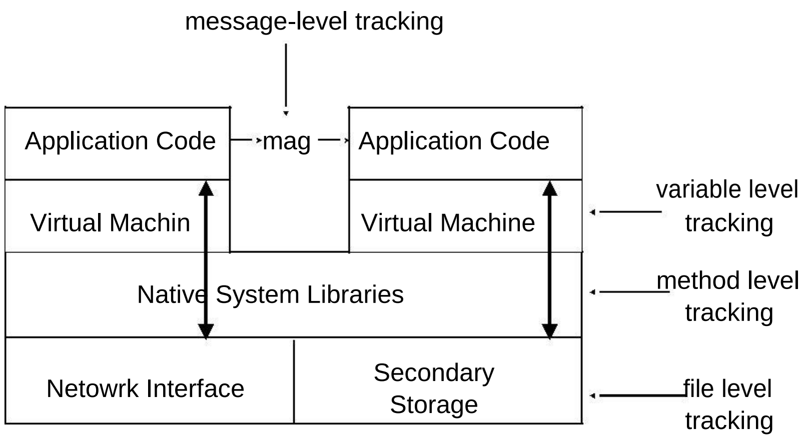


Figure 4.10 The multilevel approach architecture for taint tracking

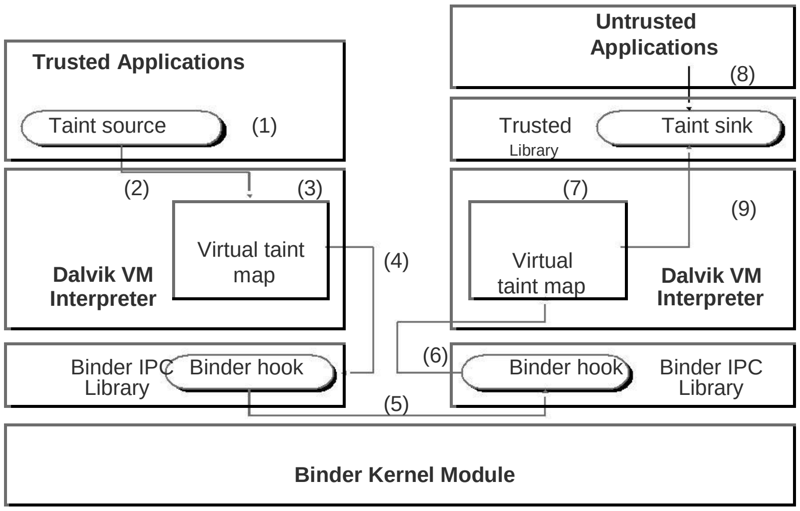


Figure 4.11 TaintDroid Architecture

To use TaintDroid in our work, a Micromax phone with Android operating system was used. First of all, phone was rooted so that TaintDroid could get installed on that. Secondly, TaintDroid was installed on this phone with access to kernel level processes. Special changes were made in configuration to make it possible to capture the required traffic and communication made by apps.

The working of TaintDroid is shown as follows:

1. Using sufficient context information is tainted in a trusted app.
2. Using native methods taint marking is done in virtual taint map with the help pgf Dalvik VM interpreter.
3. Taint tags are propagated according to rules of data flow using Dalvik VM interpreter.
4. Taint tag is ensured by binder library in which taint tag reflects the combined taint marking of all data.
5. Then packet is transfer to remote untrusted application through kernel.
6. All read values are assigned the taint tag by binder library.
7. Taint tags are propagated to untrusted applications identically by remote Dalvik VM interpreter.
8. When taint sink library is invoked by untrusted application, it retrieves the taint tag and report the event.

Results:

a. It has seen that many applications access the various sensitive information of user’s phone. Results are shown below in the table.

TABLE 4.3 Permission requests made by applications

Application Name	Permissions			
	Location	Camera	Audio	Phone State
App1	Y			
App2	Y			Y
App3	Y	Y		Y
App4		Y		
App5	Y	Y	Y	

Chapter 5
CONCLUSION AND FUTURE SCOPE

5.1. Conclusion:

One of the severe problem faced by smartphone market is addressed in this work i.e. detection of privacy leakage in mobile applications. Unlike the approaches given earlier, a new idea was presented on basis of third party connections made by an application and APi calls and system calls are monitored. In this work, it is argued that the transmission made by an app to a legitimate server or a third party server and data transmission made by an app did not violate the access permissions but it may affect the security and privacy of users severely. As per best of my knowledge no work has been done in this particular domain i.e. third party connection. It was presented with different domains of applications taking various parameters into account. This work also addressed users to educate more about their security and privacy. Before installing any application if user take proper care of what permission the app is requiring and making intelligent decision to allow it or not. Hence we recommend that the "Security based ranking" should be given to each app and hence helping the user to know about the app in detail.

5.2. Future Scope:

Here in this work, only the detection mechanism has provided that shows that applications are stealing users' private information without their consent. To make it more effective one can make an application that deals with such issues like permission requests made by application requiring more than what it actually needs. Secondly taking actions to application which is making connections to outside world: third party servers. One can either terminate the connection or completely disabling the application. Also extra features can be added those show all the information transmitted by the application to any outside connection. An alarming functionality can be added which alarms user if any application tries to steal the private information and it asks the users that action should be allowed or not.

REFERENCES

[1]. https://en.wikipedia.org/?title=Information_security

[2]. https://en.wikipedia.org/wiki/Network_security

[3]. https://www.paloaltonetworks.com/resources/learning-center/what-is-network-security.html

[4]. http://en.wikipedia.org/wiki/Global_Internet_usage

[5]. http://www.internetlivestats.com/internet-users/

[6]. http://en.wikipedia.org/wiki/List_of_countries_by_smartphone_penetration

[7]. http://www.google.com/mobile/maps/

[8]. Y. Zhou and X. Jiang. Dissecting android malware: Characterization and evolution, in *IEEE Symposium on Security and Privacy*, 2012.

[9]. M. Egele, C. Kruegel, E. Kirda, and G. Vigna. Pios: Detecting privacy leaks in iOS applications, In *NDSS*, 2011.

[10]. W. Enck, P. Gilbert, B.-G. Chun, L. P. Cox, J. Jung, P. McDaniel, and A. N. Sheth. Taintdroid: an information-flow tracking system for real time privacy monitoring on smartphones, in *OSDI*, pages 1–6, 2010.

[11]. P. Gilbert, B.-G. Chun, L. P. Cox, and J. Jung.Vision: automated security validation of mobile apps at app markets, in *Proc. MCS)*, 2011.

[12]. P. Hornyack, S. Han, J. Jung, S. Schechter, and D. Wetherall: These aren't the droids you're looking for: retrofitting android to protect data from imperious applications, in *CCS*, pages 639–652, 2011.

[13]. O. Tripp, M. Pistoia, S. J. Fink, M. Sridharan, and O. Weisman. Taj: effective taint analysis of web Applications, in *PLDI*, pages 87–97, 2009.

[14]. M. C. Grace, W. Zhou, X. Jiang, and A.-R. Sadeghi: Unsafe exposure analysis of mobile in-app advertisements in *WiSec*, 2012.

[15]. https://en.wikipedia.org/wiki/Mobile_security

[16]. https://en.wikipedia.org/wiki/Android_(operating_system)

[17]. https://en.wikipedia.org/wiki/IOS

[18]. https://en.wikipedia.org/wiki/BlackBerry_OS

[19]. https://en.wikipedia.org/wiki/Symbian

[20]. https://en.wikipedia.org/wiki/Windows_Mobile

[21]. https://en.wikipedia.org/wiki/Bada

[22]. https://en.wikipedia.org/wiki/Application_security

[23]. https://www.owasp.org/index.php/Projects/OWASP_Mobile_Security_Project_-_Top_Ten_Mobile_Risks

[24]. http://en.wikipedia.org/wiki/Rooting_(Android_OS)

[25]. C. Mann and A. Starostin: A Framework for Static Detection of Privacy Leaks in Android Applications, in SAC'12, pages 1457-1462, 2012.

[26]. Z. Yang, M. Yang, Y. Yang, G. Gu, P. Ning, X. Sean Wang: AppIntent: analyzing sensitive data transmission in android for privacy leakage detection, in *CCS'13,* pages 1043-1054, 2013.

[27]. S. Rosen, Z. Quin and Z. Morley, AppProfiler: A Flexible Method of Exposing Privacy-Related Behavior in Android Applications to End Users, in CODASPY'13, Pages 221-232, 2013.

[28]. R. Stevens, C.Gibler, J. Erickson and H. Chen: Investigating User Privacy in Android Ad Libraries, In Workshop on Mobile Security Technologies (MoST), 2012.

[29]. L. Batyuk, M. Herpich, S. Ahmet Camtepe,K. Raddatz, A. Derrick Schmidt and S. Albayrak: Using Static Analysis for Automatic Assessment and Mitigation of Unwanted and Malicious ActivitiesWithin Android Applications, in MALWARE ,pages 66-72,2011.

[30]. Igor Bilogrevic, K´evin Huguenin, Berker Agir, Murtuza Jadliwala and Jean-Pierre Hubaux, "Adaptive Information-Sharing for Privacy-Aware Mobile Social Networks", *UbiComp'13*, September 8–12, 2013.

[31]. W. Zhou, Y. Zhou, M. Grace, X. Jiang and S. Zou: Fast, Scalable Detection of "Piggybacked" Mobile Applications, *CODASPY'13,* February 18–20, 2013.

[32]. J. I. Hong and J. A. Landay, "An Architecture for Privacy-Sensitive Ubiquitous Computing", *MobiSys'04,* June 6–9, 2004.

[33]. P. Pearce, A. P. Felt, G. Nunez and D. Wagner: AdDroid: Privilege Separation for Applications and Advertisers in Android, ASIACCS '12, May 2–4, 2012.

[34]. R. Balebako, J. Jung and W. Lu: “Little Brothers Watching You:” Raising Awareness of Data Leaks on Smartphones, Symposium on Usable Privacy and Security (SOUPS) 2013, July 24–26, 2013.

[35]. I. Leontiadis, C. Efstratiou, M. Picon and C. Mascolo: Don’t kill my ads! Balancing Privacy in an Ad-Supported Mobile Application Market, HotMobile’12 February 28–29, 2012.

[36]. E. Chin, A. P. Felt, V. Sekar and D. Wagner: Measuring User Confidence in Smartphone Security and Privacy, Symposium on Usable Privacy and Security (SOUPS) 2012, July 11-13, 2012.

[37]. S. Ickin, K. Wac, M. Fiedler, L. Janowski, J. Hong and Anind K. Dey: Factors Influencing Quality of Experience of Commonly Used Mobile Applications, *Communications Magazine, IEEE* , vol.50, no.4, pp.48,56, April 2012.

[38]. N. li and G. Chen: Sharing Location in Online Social Networks, *Network, IEEE* , vol.24, no.5, pp.20,25, September-October 2010.