FORENSIC ANALYSIS OF ANDROID BASED SPY APPLICATIONS

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Abstract—**Smartphones with Google's Android operating system are becoming more and more popular each year, and with this increased user base, comes increased opportunities to collect more of these users' private data. There have been several instances of malware being made available via the Google Play Store, which is one of the predominant means for users to download applications. One effective way of collecting users' private data is by using Android Spyware. In this paper, a forensic analysis of a malicious Android spyware application was conducted and present my findings. I also highlight what information the application accesses and what it does with that information. I then provide my findings on how Google's Play Protect service handles this spyware application. Lastly, I offer a simple framework that forensic investigators can follow for performing mobile application analysis.**

Index Terms—**Android, Malware, Mobile Forensics, Mobile Security, Spyware Analysis, Play Protect.**

I. Introduction

The Android Operating System (OS) is the most used mobile OS in the world, accounting for 76.61% of the global market share. This makes it an ideal target for cybercriminals who make their living stealing and selling persons' Personally Identifiable Information (PII). Malicious applications (apps) that make it possible for attackers to obtain such PII are called Spyware.

Google has put several measures in place to protect its users from malicious apps, including their more recent security implementation, the Play Protect service. Play Protect is advertised as an always on feature that provides protection against malicious applications on devices through machine learning, provides a means of locating a misplaced device through Find My Device, and provides secure Internet browsing with Safe Browsing protection in Chrome. Unfortunately, even with being in operation for well over a year, there have been instances where the Play Protect service was unable to detect and remove rogue apps before they were downloaded and used by millions of unsuspecting users from the Play Store.

This paper aims to provide an analysis of one such Spyware that was able to bypass Google's Play Protect service and also present an answer to two integral questions:

1) What does the Spyware do?
2) How does the Spyware accomplish what it does?

I believe that this information would be beneficial to other Android security researchers as it would highlight some app behaviors that indicate said app may be malicious.

The rest of this paper is organized as follows: Section 2 gives background information on the topic of Android Spyware detection. Section 3 specifies the experiment setup that was followed. my findings are presented in Section 4 while Section 5 offers a simple framework for performing application analysis. Section 6 concludes this paper.

II. Related Work

Within recent years, there have been several spyware attacks plaguing Android devices. Some of these attacks occurred in the wild and , while others were developed specifically to shed light on the need for improved security within the Android platform.

Abualola et al. developed a Trojan Spyware that leveraged the capabilities of Android's NotificationListener service. The malicious app was advertised as an SMS Backup app. However, the app came with a backdoor which allowed it to forward notification content from WhatsApp, Facebook Messenger, BBM and SMS to the attacker's email. The app was able to accomplish this with the use of two permissions: "Notification Access" and "Internet".

In addition to researcher-made spyware, there have been real-world spyware attacks perpetrated via the Google Play Store. In 2017, there were two such attacks. A rogue developer, who seemingly bore the same name as the legitimate company, WhatsApp Inc., was able to successfully upload a fake WhatsApp app, titled "Update WhatsApp Messenger". This fake app was downloaded over one million times despite only being an ad-loaded wrapper with Internet access permission. Once installed, the app would download another apk, called whatsapp.apk. Interestingly, this app was not first detected by Google's Play Protect service.

However, Play Protect did discover the deceptive Tizi spyware. Tizi is described as a full-featured Android backdoor that can gain root access on affected devices in order to steal users' PII. This PII may include data from popular social media apps like WhatsApp, Facebook, Twitter, etc., as well as SMS messages. In the event Tizi is unable to root the affected device, it still attempts to obtain sensitive data through the use of high level permissions the user would have granted.

There have been several malware detection techniques put forth; below I highlight five (5):

A. Behavior Based

Multi-Level Anomaly Detection for Android Malware (MADAM) was designed as a multi-level and behavior-based malware detection tool for Android. MADAM's detection ability relies on analyzing five groups of features from four levels of abstraction: kernel-level, application-level, user-level and package-level. These features pass through a Signature-based detector and a Behavior based detector before a decision is made on whether the app is malicious and should be removed. MADAM prides itself on being able to detect several classes of malware, including spyware. It also boasts a high detection rate of 96.9% and negligible performance overhead. However, this tool requires a rooted device to perform.

B. Taint Analysis

Rathi and Jindal define taint analysis as the analysis of an application and the presentation of potentially malicious data flows. With this in mind, these authors developed the Droid-Mark tool which is capable of detecting Android malware with 96.88

C. Network Traffic Analysis

Malik and Kaushal proposed an alternative method of detection, focused on analyzing apps' network traffic, specifically their Domain Name Server (DNS) queries and the type of information being transmitted to a remote server. Their approach, titled CREDROID, was able to successfully detect malicious apps and determine what PII was being transmitted to questionable remote servers. CREDROID was tested manually and was unable to identify malicious apps which did not generate network traffic.

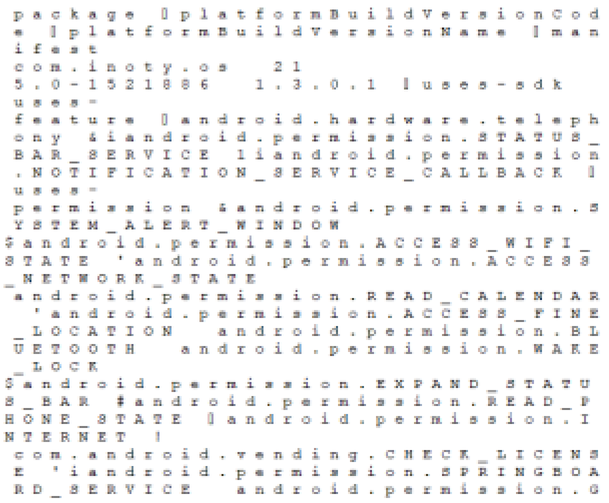
Ren et al. also focused on apps' network traffic to determine potential PII leaks. They developed a cross-platform system, titled ReCon, which uses machine learning, to offer its users a means of controlling those PII leaks. ReCon used a C4.5 Decision Tree to handle classification of network traffic that produce PII leaks. ReCon's accuracy was most desirable at 99

D. Hybrid

Kaur and Sharma utilized a hybrid approach to detect spyware and improve users' privacy. Their detection frameworks analyses apps based on the app's Description, Interface Layout and Source Code. When an app is installed or updated, the .apk file for that app is reverse engineered and its permissions are extracted from its AndroidManifest.xml file. These permissions are checked against the app's description and source code, to ensure only required permissions are being requested. This approach was able to achieve better detection rates than popular antiviruses like McAfee, Avast and AVG.

E. Machine Learning

Wang et al. re-purposed the XGBoostmodel to detect Android malware. Their detection system consisted of static analysis of both benign and malicious app .apk files to extract permission and API call features and the use of a Random-Forest Feature Selection model to reduce the feature set. They also based their classification accuracies on using select features, higher weighted features and various combinations of both permission features and API call features. This detection system was able to outperform or match the Support Vector Machine model as it was able to obtain high accuracy and reduced training time.



```
package ▯platformBuildVersionCod
e ▯platformBuildVersionName ▯man
ifest
com.inoty.os   21
5.0-1521886   1.3.0.1 ▯uses-sdk
uses-
feature ▯android.hardware.teleph
ony &iandroid.permission.STATUS_
BAR_SERVICE 1iandroid.permission
.NOTIFICATION_SERVICE_CALLBACK ▯
uses-
permission &android.permission.S
YSTEM_ALERT_WINDOW
$android.permission.ACCESS_WIFI_
STATE 'android.permission.ACCESS
_NETWORK_STATE
android.permission.READ_CALENDAR
 'android.permission.ACCESS_FINE
_LOCATION  android.permission.BL
UETOOTH  android.permission.WAKE
_LOCK
$android.permission.EXPAND_STATU
S_BAR #android.permission.READ_P
HONE_STATE ▯android.permission.I
NTERNET !
com.android.vending.CHECK_LICENS
E 'iandroid.permission.SPRINGBOA
RD_SERVICE  android.permission.G
```

Fig. 1: A snippet of the AndroidManifest.xml file

Mahindru and Singh also utilized machine learning in order to successfully detect Android malware. However, instead of using one classifier, they tested with five. Their method consisted of three phases. In the first phase, they would collect the .apk's for several Android apps. The second phase included a dynamic analysis of the .apks and the extraction of the permissions being requested by each app. The last phase saw the execution of five machine learning algorithms, as they classify each app as malware or benign depending on the permissions extracted. They achieved highest accuracy of 99.7

III. EXPERIMENTAL SETUP

For my malware analysis experiment, I opted to investigate the Android.Spy.277.origin malware family. I obtained a sample of the malware from GitHub. It was downloaded as a File type and had to be extracted to obtain the Android-Manifest.xml and classes.dex files. The classes.dex file was then converted to its corresponding classes.jar file, using the dex2jar tool. Analysis of the .jar file was done using the JD-GUI application.

All experiments were done on a Windows 10 system. I chose to use Android Studio version 3.1.3 to conduct my experiment on an Android Virtual Device. This device took the form of a Nexus S phone running Android 5.0 Lollipop (API 21). After the malware app was installed on the emulator, I used Wireshark version v2.6.1-0-g860a78b3, to capture the network traffic of the device while the app was active and while I performed some manipulations.

IV. SPYWARE ANALYSIS

In this section, I present observations and findings having analyzed the application's Manifest file, source code, installation and execution on an Android device.

A. A look at the AndroidManifest.xml file

After performing an analysis of the manifest file (see Figure 1), several interesting points were found.

1) Package name was identified as com.inoty.os with displayed version 1.3.0.1. The minSdkVersion for the app is 5.0 while the targetSdkVersion is 21. The package being used is net.suckga.inoty2.
2) Permissions: the app requests several seemingly benign permissions, if considered on their own, such as Receive, System Alert Window, Access Fine Location, Access Network State, etc. However, when these permissions are considered together, they can be used for nefarious reasons. For example, these permissions can allow a malicious app to capture incoming messages and transmit them, along with the device's location at the time, over a network. These and some other possibly harmful permissions are identified and briefly explained in Table 1.
3) Activities, Services, Receivers and Content-Filters: Some of the more important ones will be examined in Section 4.5 below.

B. An Initial Look at the App's Behavior

Installing the .apk file was as simple as dragging and dropping it onto the emulator'sscreen. After the app was installed it was presented as an app named "Notify Ios" as shown in Figure 2a. When the app is launched, the first screen, depicted in Figure 2b offers several personalization options as well as a means of enabling the app. When the "Enable Notify Ios" option is selected, the user is presented with two services that could be turned on: Accessibility and Notifications. This is shown in Figure 2c. When the user chooses the Accessibility option, they are taken to the Accessibility Settings where they will be able to turn on "Notify Ios". Once enabled, the user is told what privilege the app requires and asked for confirmation, as shown in Figure 2d. When the user chooses the Notifications option and enables the service, they are presented with a confirmation screen informing them of what access privileges the service will now have, as shown in Figure 3a. When the user enables both the accessibility and notification services, the app takes over the status bar (becomes the status bar) as shown in Figure 3b.

C. Manipulations made while the app was active (sending texts, etc.)

In order to test the functionality of the Notify Ios app, I enabled both the Accessibility and Notification services and then performed some activities to create notifications on the device. I sent text messages using the default Messages app and emails using the Gmail service. Figure 3c shows previously received notifications while Figure 3d shows an incoming notification from the Messages app.

D. Network Analysis Process

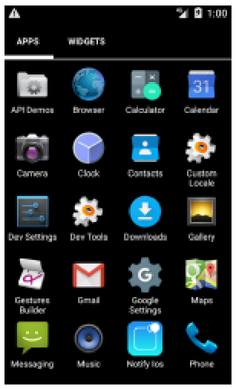
For us to determine whether the app was doing anything nefarious, I decided to capture the phone's network traffic while the app was active. I discovered that every time the app was opened, it sent a GET request with some of the user's private data to an IP address (204.11.56.48). I determined that this IP address was malicious and was based in the British Virgin Islands. Some information this app transmitted included the device's model, the Operating System version, the phone's IMEI number, the email address connected to the Google account on the device, the device's MAC address, the current carrier, whether the device is rooted or not, the country location, etc., as shown in Figure 4. When both services were enabled, the app sent another GET request with the same information to the same IP address. However, this time it included a list of all the currently installed packages on the device, as shown in Figure 5.

E. A look at the classes.jar file

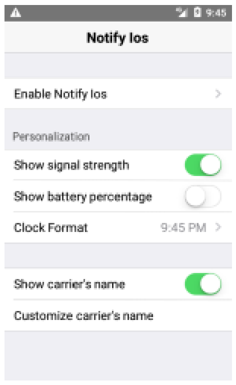
When the classes.jar file was opened with JD-GUI, I was presented with seven packages, each with several sub-packages which in turn contained several class files. The most interesting packages were found to be net.suckga.inoty2 and com.sweet.rangermob. The important classes and methods that were responsible for collecting and transmitting identifiable information about the device and user are highlighted below:

Permission	Details
android.permission.SYSTEM ALERT WINDOW	Allows an application to create windows that are shown on top of all other apps.
android.permission.ACCESS WIFI STATE	Allows applications to access information about Wi-Fi networks.
android.permission.ACCESS NETWORK STATE	Allows applications to access information about networks.
android.permission.READ CALENDAR	Allows an application to read the user's calendar data.
android.permission.ACCESS FINE LOCATION	Allows an app to access the device's precise location.
android.permission.BLUETOOTH	Allows applications to connect to paired Bluetooth devices.
android.permission.WAKE LOCK	Allows using PowerManager WakeLocks to keep processor from sleeping or screen from dimming.
android.permission.EXPAND STATUS BAR	Allows an application to expand or collapse the status bar.
android.permission.READ PHONE STATE	Allows read only access to the features of the phone, including the phone number of the device, current cellular network information, the status of any ongoing calls, and a list of any Phone Accounts registered on the device.
android.permission.INTERNET	Allows applications to open network sockets.
android.permission.GET ACCOUNTS	Allows access to the list of accounts in the Accounts Service.
com.android.launcher.permission.INSTALL SHORTCUT	Allows an application to install a shortcut in Launcher.
android.permission.WRITE EXTERNAL STORAGE	Allows an application to write to external storage.
com.inoty.os.permission.C2D MESSAGE	Only this application can receive the messages and registration result.
com.google.android.c2dm.permission.RECEIVE	This app has permission to register and receive messages

TABLE I: Table 1. Permissions the Notify Ios Application Requests



(a) label 1



Notify Ios

Enable Notify Ios

Personalization

Show signal strength

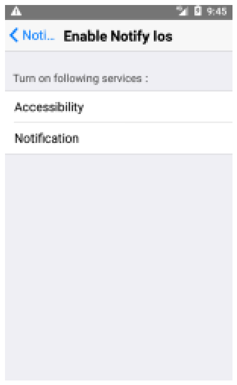
Show battery percentage

Clock Format 9:45 PM

Show carrier's name

Customize carrier's name

(b) label 2



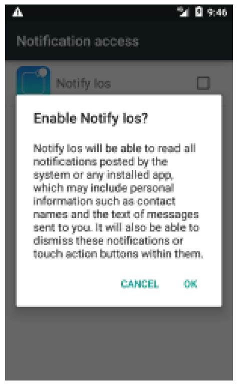
Enable Notify Ios

Turn on following services :

Accessibility

Notification

(c) label 2

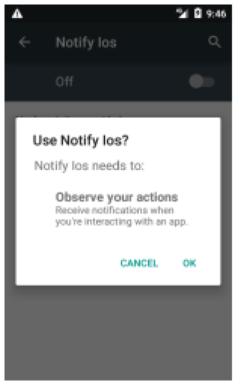


Enable Notify Ios?

Notify Ios will be able to read all notifications posted by the system or any installed app, which may include personal information such as contact names and the text of messages sent to you. It will also be able to dismiss these notifications or touch action buttons within them.

(d) label 2

Fig. 2: Figure 2. Screenshots of the Notify Ios app



Notify Ios

Off

Use Notify Ios?

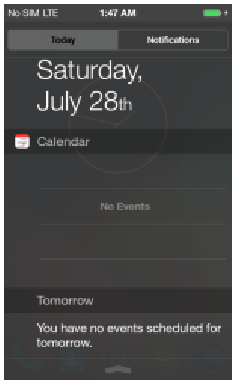
Notify Ios needs to:

Observe your actions

Receive notifications when you're interacting with an app.

CANCEL OK

(a) label 1



No SIM LTE 1:47 AM

Today Notifications

Saturday, July 28th

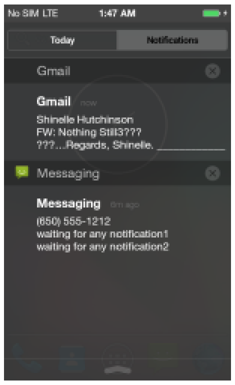
Calendar

No Events

Tomorrow

You have no events scheduled for tomorrow.

(b) label 2



No SIM LTE 1:47 AM

Today Notifications

Gmail

Gmail now

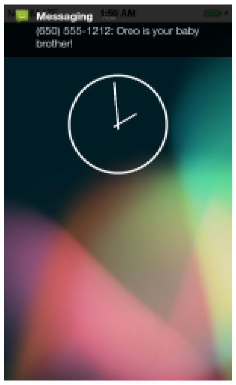
Shinelle Hutchinson
FW: Nothing Still3???
???...Regards, Shinelle.

Messaging

Messaging 8m ago

(650) 555-1212
waiting for any notification1
waiting for any notification2

(c) label 2

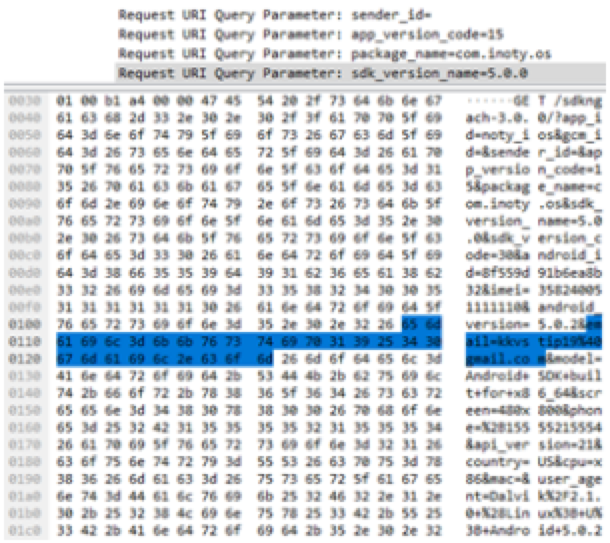


Messaging 1:50 AM

(650) 555-1212: Oreo is your baby brother!

(d) label 2

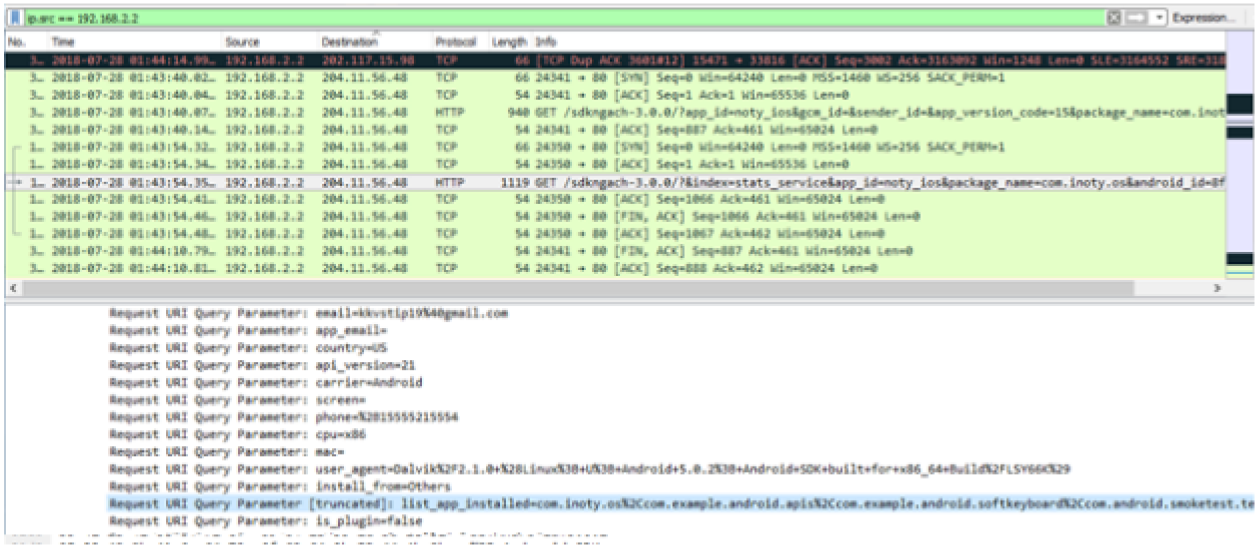
Fig. 3: Figure 3. Screenshots of the Notify Ios app



```
Request URI Query Parameter: sender_id=
Request URI Query Parameter: app_version_code=15
Request URI Query Parameter: package_name=com.inoty.os
Request URI Query Parameter: sdk_version_name=5.0.0

0030  01 00 b1 a4 00 00 47 45  54 20 2f 73 64 6b 6e 67   ......GE T /sdkng
0040  61 63 68 2d 33 2e 30 2e  30 2f 3f 61 70 70 5f 69   ach-3.0. 0/?app_i
0050  64 3d 6e 6f 74 79 5f 69  6f 73 26 67 63 6d 5f 69   d=noty_i os&gcm_i
0060  64 3d 26 73 65 6e 64 65  72 5f 69 64 3d 26 61 70   d=&sende r_id=&ap
0070  70 5f 76 65 72 73 69 6f  6e 5f 63 6f 64 65 3d 31   p_versio n_code=1
0080  35 26 70 61 63 6b 61 67  65 5f 6e 61 6d 65 3d 63   5&packag e_name=c
0090  6f 6d 2e 69 6e 6f 74 79  2e 6f 73 26 73 64 6b 5f   om.inoty .os&sdk_
00a0  76 65 72 73 69 6f 6e 5f  6e 61 6d 65 3d 35 2e 30   version_ name=5.0
00b0  2e 30 26 73 64 6b 5f 76  65 72 73 69 6f 6e 5f 63   .0&sdk_v ersion_c
00c0  6f 64 65 3d 33 30 26 61  6e 64 72 6f 69 64 5f 69   ode=30&a ndroid_i
00d0  64 3d 38 66 35 35 39 64  39 31 62 36 65 61 38 62   d=8f559d 91b6ea8b
00e0  33 32 26 69 6d 65 69 3d  33 35 38 32 34 30 30 35   32&imei= 35824005
00f0  31 31 31 31 31 31 30 26  61 6e 64 72 6f 69 64 5f   1111110& android_
0100  76 65 72 73 69 6f 6e 3d  35 2e 30 2e 32 26 65 6d   version= 5.0.2&em
0110  61 69 6c 3d 6b 6b 76 73  74 69 70 31 39 25 34 30   ail=kkvs tip19%40
0120  67 6d 61 69 6c 2e 63 6f  6d 26 6d 6f 64 65 6c 3d   gmail.co m&model=
0130  41 6e 64 72 6f 69 64 2b  53 44 4b 2b 62 75 69 6c   Android+ SDK+buil
0140  74 2b 66 6f 72 2b 78 38  36 5f 36 34 26 73 63 72   t+for+x8 6_64&scr
0150  65 65 6e 3d 34 38 30 78  38 30 30 26 70 68 6f 6e   een=480x 800&phon
0160  65 3d 25 32 42 31 35 35  35 35 32 31 35 35 35 34   e=%2B155 55215554
0170  26 61 70 69 5f 76 65 72  73 69 6f 6e 3d 32 31 26   &api_ver sion=21&
0180  63 6f 75 6e 74 72 79 3d  55 53 26 63 70 75 3d 78   country= US&cpu=x
0190  38 36 26 6d 61 63 3d 26  75 73 65 72 5f 61 67 65   86&mac=& user_age
01a0  6e 74 3d 44 61 6c 76 69  6b 25 32 46 32 2e 31 2e   nt=Dalvi k%2F2.1.
01b0  30 2b 25 32 38 4c 69 6e  75 78 25 33 42 2b 55 25   0+%28Lin ux%3B+U%
01c0  33 42 2b 41 6e 64 72 6f  69 64 2b 35 2e 30 2e 32   3B+Andro id+5.0.2
```

Fig. 4: Figure 4. Screenshot of PII data



```
ip.src == 192.168.2.2                                                                 Expression...

No.  Time                      Source        Destination    Protocol Length Info
3…   2018-07-28 01:44:14.99…   192.168.2.2   202.117.15.98  TCP      66 [TCP Dup ACK 3601#12] 15471 → 33816 [ACK] Seq=3002 Ack=3163092 Win=1248 Len=0 SLE=3164552 SRE=318
3…   2018-07-28 01:43:40.02…   192.168.2.2   204.11.56.48   TCP      66 24341 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM=1
3…   2018-07-28 01:43:40.04…   192.168.2.2   204.11.56.48   TCP      54 24341 → 80 [ACK] Seq=1 Ack=1 Win=65536 Len=0
3…   2018-07-28 01:43:40.07…   192.168.2.2   204.11.56.48   HTTP    940 GET /sdkngach-3.0.0/?app_id=noty_ios&gcm_id=&sender_id=&app_version_code=15&package_name=com.inot
3…   2018-07-28 01:43:40.14…   192.168.2.2   204.11.56.48   TCP      54 24341 → 80 [ACK] Seq=887 Ack=461 Win=65024 Len=0
1…   2018-07-28 01:43:54.32…   192.168.2.2   204.11.56.48   TCP      66 24350 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM=1
1…   2018-07-28 01:43:54.34…   192.168.2.2   204.11.56.48   TCP      54 24350 → 80 [ACK] Seq=1 Ack=1 Win=65536 Len=0
1…   2018-07-28 01:43:54.35…   192.168.2.2   204.11.56.48   HTTP   1119 GET /sdkngach-3.0.0/?&index=stats_service&app_id=noty_ios&package_name=com.inoty.os&android_id=8f
1…   2018-07-28 01:43:54.41…   192.168.2.2   204.11.56.48   TCP      54 24350 → 80 [ACK] Seq=1066 Ack=461 Win=65024 Len=0
1…   2018-07-28 01:43:54.46…   192.168.2.2   204.11.56.48   TCP      54 24350 → 80 [FIN, ACK] Seq=1066 Ack=461 Win=65024 Len=0
1…   2018-07-28 01:43:54.48…   192.168.2.2   204.11.56.48   TCP      54 24350 → 80 [ACK] Seq=1067 Ack=462 Win=65024 Len=0
3…   2018-07-28 01:44:10.79…   192.168.2.2   204.11.56.48   TCP      54 24341 → 80 [FIN, ACK] Seq=887 Ack=461 Win=65024 Len=0
3…   2018-07-28 01:44:10.81…   192.168.2.2   204.11.56.48   TCP      54 24341 → 80 [ACK] Seq=888 Ack=462 Win=65024 Len=0

            Request URI Query Parameter: email=kkvstip19%40gmail.com
            Request URI Query Parameter: app_email=
            Request URI Query Parameter: country=US
            Request URI Query Parameter: api_version=21
            Request URI Query Parameter: carrier=Android
            Request URI Query Parameter: screen=
            Request URI Query Parameter: phone=%2815555215554
            Request URI Query Parameter: cpu=x86
            Request URI Query Parameter: mac=
            Request URI Query Parameter: user_agent=Dalvik%2F2.1.0+%28Linux%3B+U%3B+Android+5.0.2%3B+Android+SDK+built+for+x86_64+Build%2FLSY66K%29
            Request URI Query Parameter: install_from=Others
            Request URI Query Parameter [truncated]: list_app_installed=com.inoty.os%2Ccom.example.android.apis%2Ccom.example.android.softkeyboard%2Ccom.android.smoketest.te
            Request URI Query Parameter: is_plugin=false
```

Fig. 5: List of all installed applications

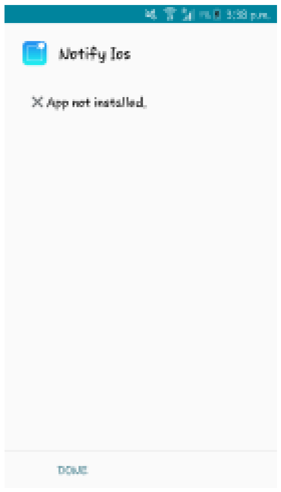
most interesting packages were found to be net.suckga.inoty2 and com.sweet.rangermob. The important classes and methods that were responsible for collecting and transmitting identifiable information about the device and user are highlighted below:

1) *net.suckga.inoty2.preferences.PreferencesActivity*: It is the first class that runs when the app is launched by pressing its icon.
2) *com.sweet.rangermob.helper.e.a(this.b)*: This method determines if there is an active internet connection. In such case, the com.sweet.rangermob.a() method is started.
3) *com.sweet.rangermob.a()*: This method collects identifying information about the device and user which is subsequently transmitted to the rogue IP address. This information is stored in a variable called localArrayList.
4) *RootUtil.a()*: It looks for superuser access (determines if phone is rooted). If the device is rooted, collects several other pieces of information, including whether the device has Google Play Store installed, whether there is an active device admin, etc., and adds this information to the localArrayList variable.
5) *paramAnonymousVarArgs URLEncodedUtils.format (localArrayList, "utf-8")*: converts the localArrayList to a URL.
6) *j.a() + paramAnonymousVarArgs*: This builds the website's URL and concatenates it with the Encoded URL from localArrayList with help from the com.sweet.rangermob.helper.c class.
7) *com.sweet.rangermob.helper.c*: This class contains variables used to build the HTTP GET request and the domain website.
8) *paramAnonymousVarArgs=com.sweet.rangermob.helper.b.b(j.a() + paramAnonymousVarArgs)*: This passes the completed URL string to be created in the HTTP GET request.
9) Within the com.sweet.rangermob.xser.RangerSer class, there is a method that handles collecting and sending the device and user information, in addition to a list of all the installed packages on the device, to the rogue IP address. This method closely resembles the one that runs every time the app is opened.

F. Interesting Findings

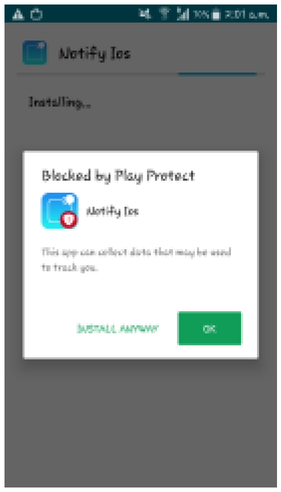
In an attempt to determine whether or not this app would be flagged by Google's Play Protect service, I attempted to install the Notify Ios app on a physical Samsung Galaxy S5 device running Android 6.0. The device was set to allow installation of apps from third parties. I performed this installation on three separate occasions because the Play Protect service detects malware using machine learning techniques. This will show us whether those techniques are efficient against such malware as Notify Ios.

1) July 28th, 2021: The .apk file was copied onto the device and was able to successfully install the app. When Play Protect scanned all the apps on the device, none were flagged as suspicious.



App not installed.

Fig. 6: Screenshot of Noty Ios app refusing to be installed.



This app can collect data that may be used to track you.

Fig. 7: Screenshot of Play Protect service blocking the installation of Noty Ios

2) Oct 12th, 2021: The .apk file was again copied onto the device and attempted to install the app. However, the Play Protect service immediately flagged the app as suspicious, as shown in Figure 6.

3) Oct 14th, 2021: One last attempt to install the app on the device, however this time there was no Play Protect warning and the app simply did not install, as shown in Figure 7. From these occurrences, I believe that the Play Protect service learned from my first installation of the Notify Ios app and now is able to block any installation of the app on devices.

V. Guidelines for Mobile Application Analysis

1) Static Analysis: Be sure to investigate the source code and app manifest files, looking for suspicious implementations and unnecessary permission requests that do not fit the described use of the app. This step can be extremely cumbersome should the app developer

obfuscate the source code, specifically class, method and variable names.

2) Dynamic Analysis: Static analysis alone tends to be insufficient for determining exactly what an app is doing. Once you have an idea of what the app is doing from the static analysis, be sure to install the app on a clean device and run it. This way, you can interact with the app, manipulate various features and note its effects on the device.
3) Network Analysis: Many apps, especially spyware apps, use network features and chances are if you suspect the app is doing something nefarious after doing static and dynamic analysis, the app may be communicating with a malicious, remote server. You should make network analysis a step during your dynamic analysis. Using a network sniffer like Wireshark could allow you to ascertain what communications the app is doing while it's running on a device. This includes determining what information the app is transmitting and to whom that data is going to.

After performing each of these, you should have a fairly comprehensive understanding of what the app does and how its features are implemented.

VI. CONCLUSION

Android smartphones are widely used, and their users require protection from nefarious individuals set on obtaining these users' PII. Unfortunately, it is possible for some apps to covertly collect user's PII and transmitted that data to unauthorized persons.

After my analysis of the Notify Ios malicious app, I determined that various pieces of users' PII were being transmitted to an unauthorized location. I also combed through the source code to identify exactly how this was being accomplished and quickly found that the app developer relied heavily on obfuscation of their code to mask their ill intent. I also tested the capacity of Google's Play Protect service to detect this malicious app and was able to prove that the service initially failed to detect the app. However, it was able to learn and flag the app on subsequent installations.

For future work, I intend to develop my own malicious spyware app in an attempt to successfully avoid detection by the Play Protect service. In doing so, I aim to identify certain malicious characteristics the service is still incapable of detecting as well as specific vulnerabilities the service is still susceptible to.

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