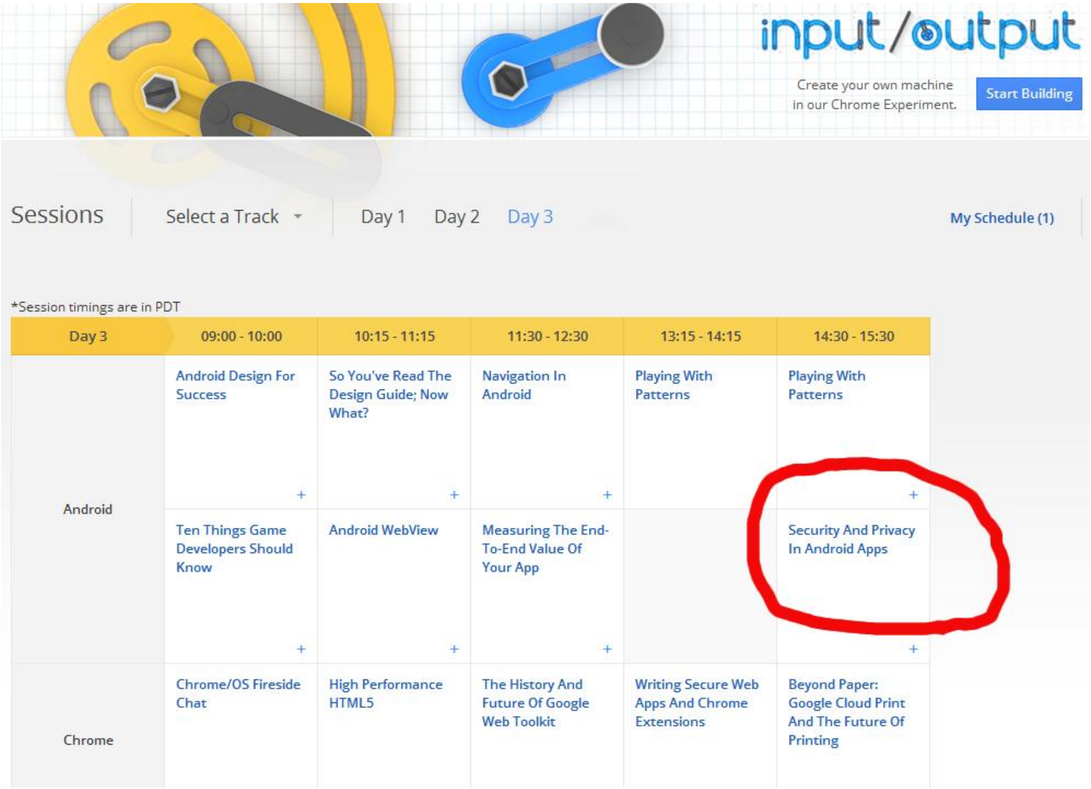
Google I/O 2012

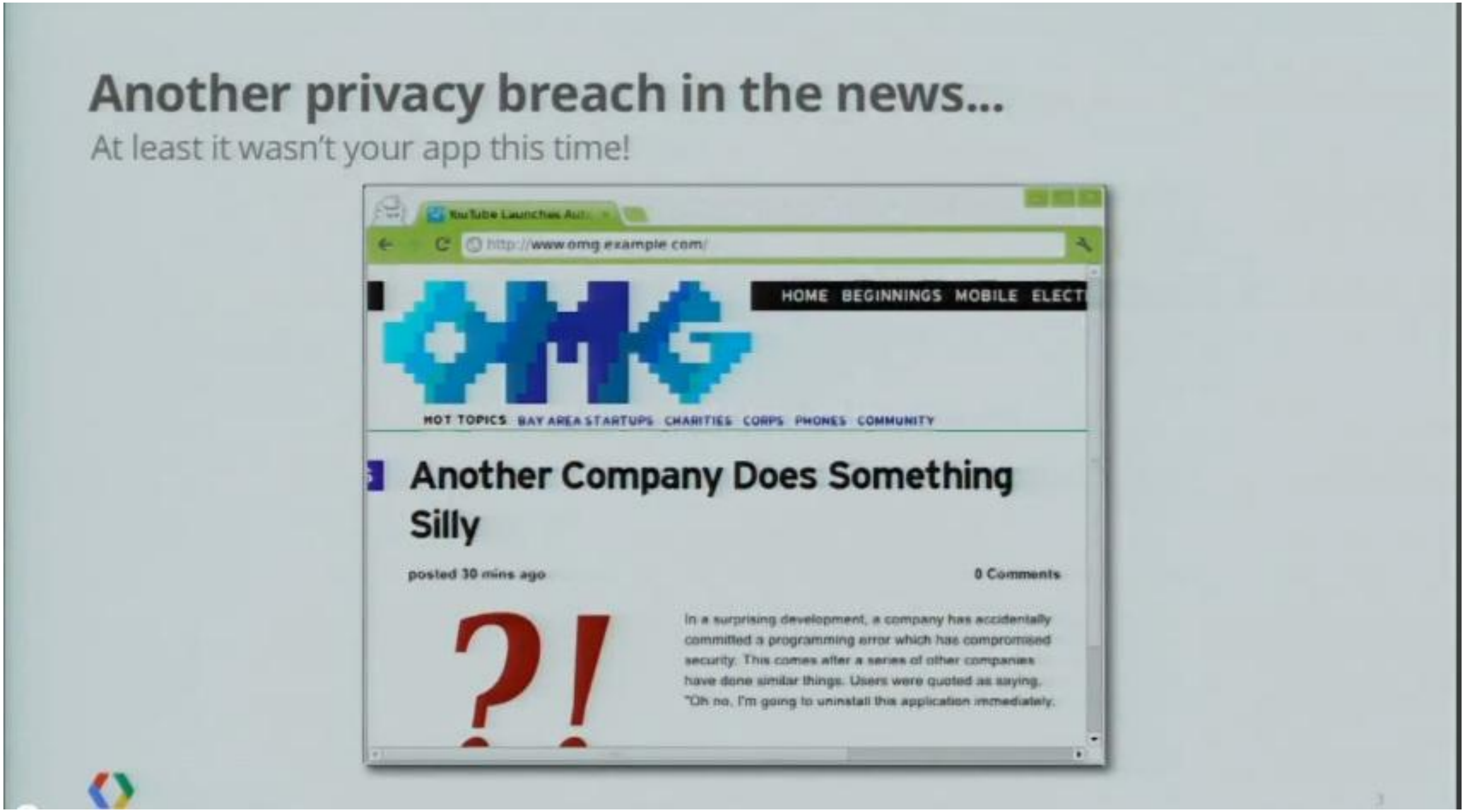
Security and Privacy Android Apps

- 2012/6/29(Day 3) 2:30PM - 3:30PM （1時間)
- https://developers.google.com/events/io/sessions/gooio2012/107/
- http://youtu.be/RPJENzweI-A



*Session timings are in PDT

Day 3	09:00 - 10:00	10:15 - 11:15	11:30 - 12:30	13:15 - 14:15	14:30 - 15:30
Android	Android Design For Success	So You've Read The Design Guide; Now What?	Navigation In Android	Playing With Patterns	Playing With Patterns
	Ten Things Game Developers Should Know	Android WebView	Measuring The End-To-End Value Of Your App		Security And Privacy In Android Apps
Chrome	Chrome/OS Fireside Chat	High Performance HTML5	The History And Future Of Google Web Toolkit	Writing Secure Web Apps And Chrome Extensions	Beyond Paper: Google Cloud Print And The Future Of Printing



Another privacy breach in the news...

At least it wasn't your app this time!

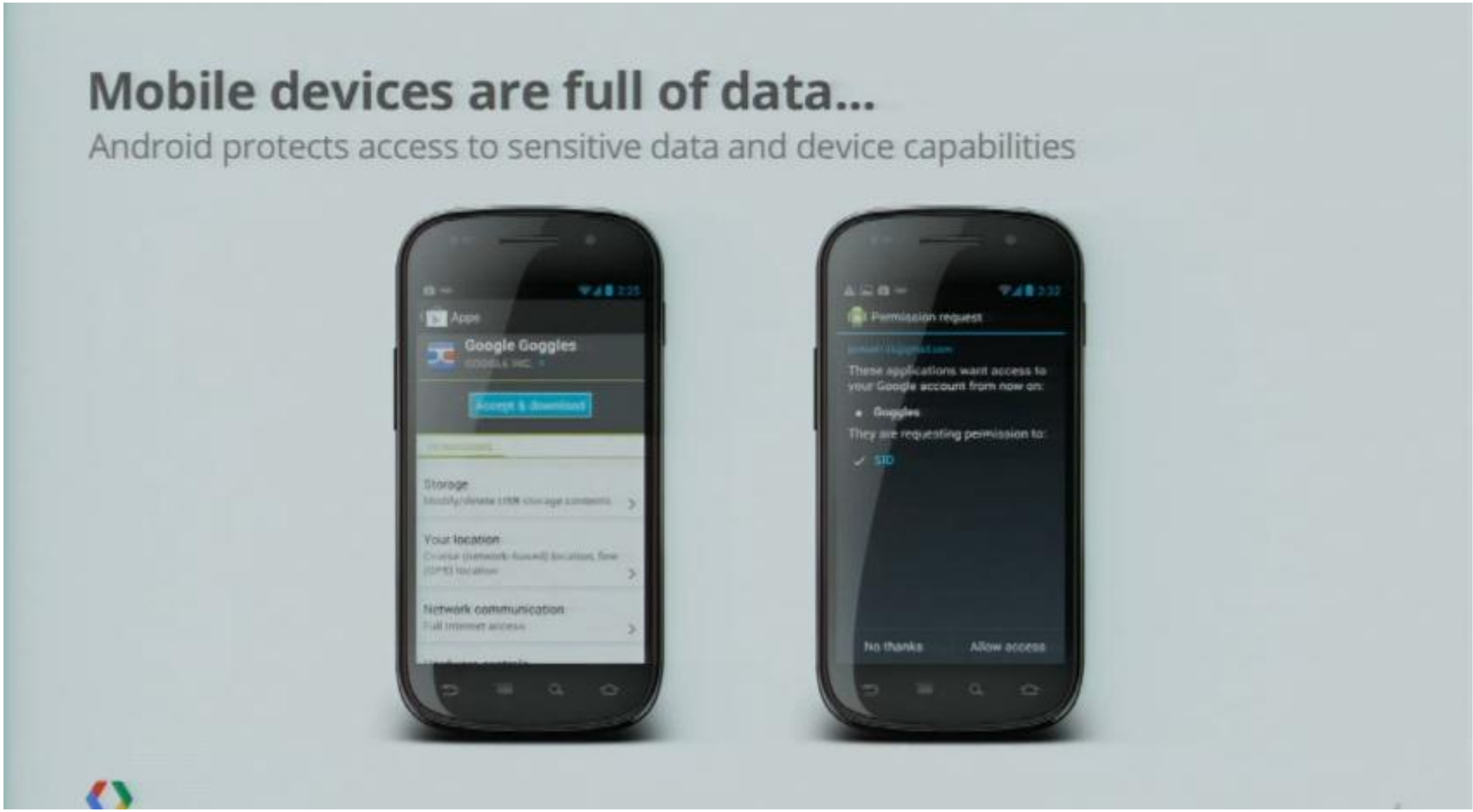
YouTube Launches Aut...
http://www.omg.example.com/
OMG
HOME BEGINNINGS MOBILE ELECT
HOT TOPICS BAY AREA STARTUPS CHARITIES CORPS PHONES COMMUNITY
?!

Another Company Does Something Silly

posted 30 mins ago

0 Comments

In a surprising development, a company has accidentally committed a programming error which has compromised security. This comes after a series of other companies have done similar things. Users were quoted as saying, "Oh no, I'm going to uninstall this application immediately.



Mobile devices are full of data...

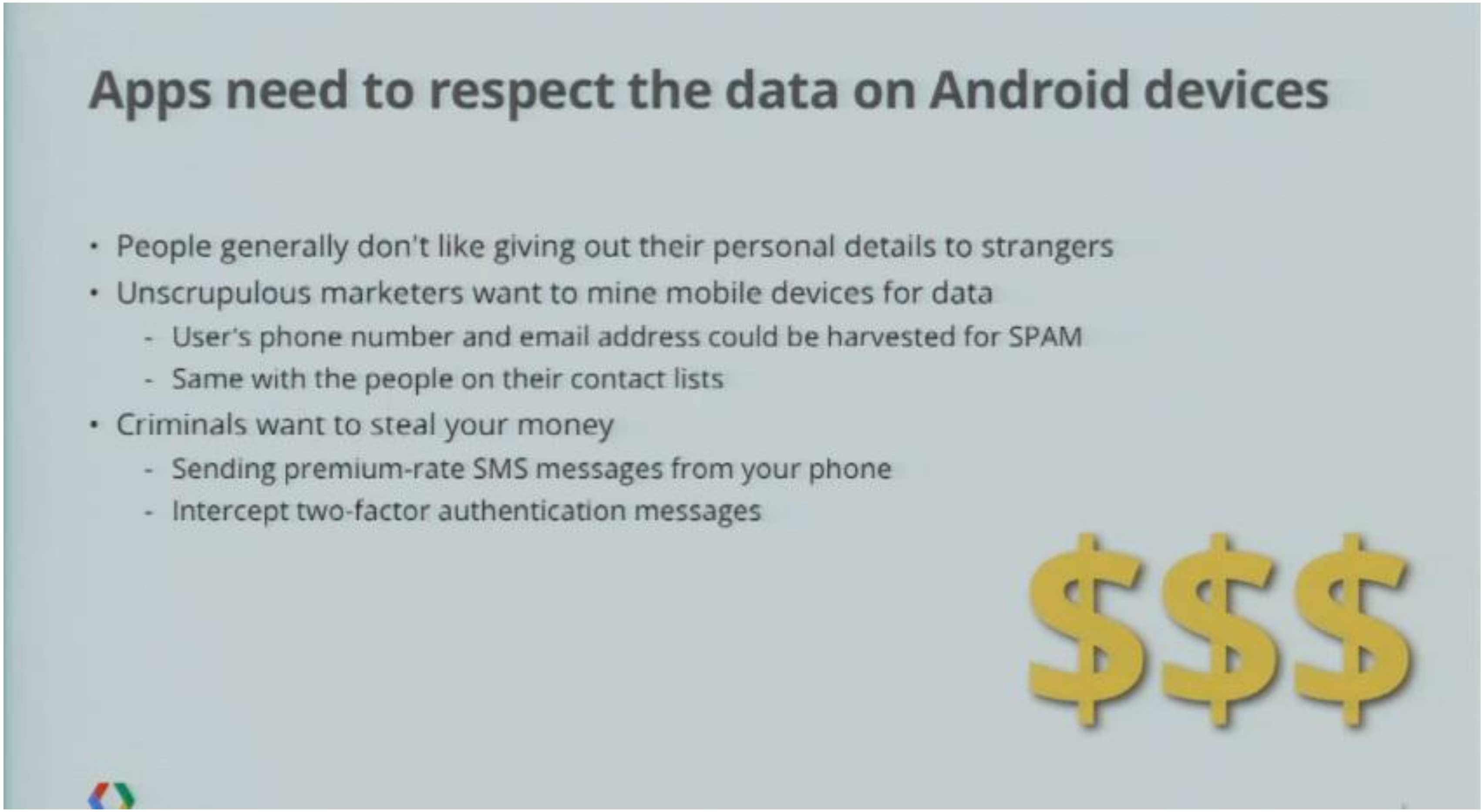
Android protects access to sensitive data and device capabilities

These applications want access to your Google account from now on:

- Goggles

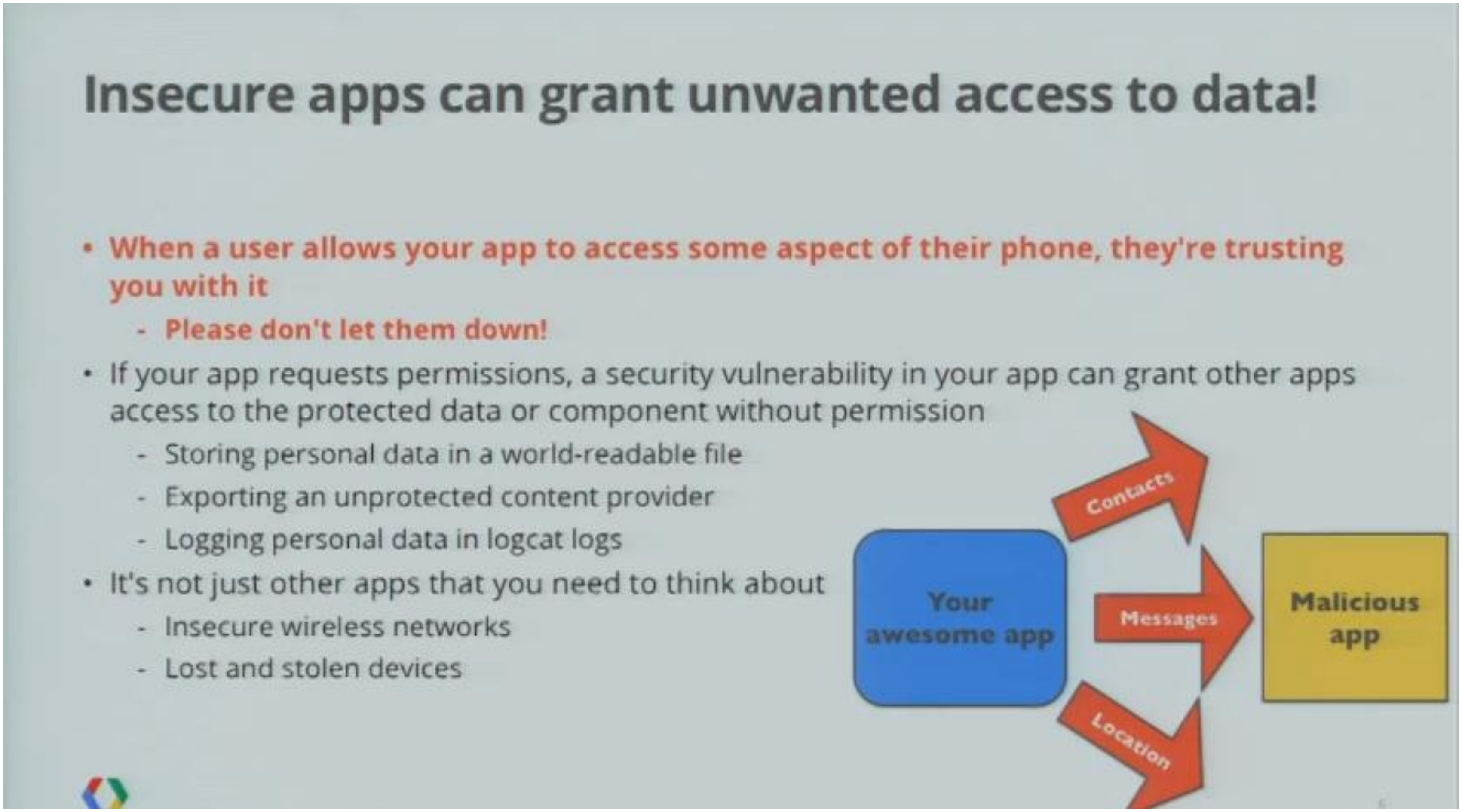
They are requesting permission to:

✓ SID



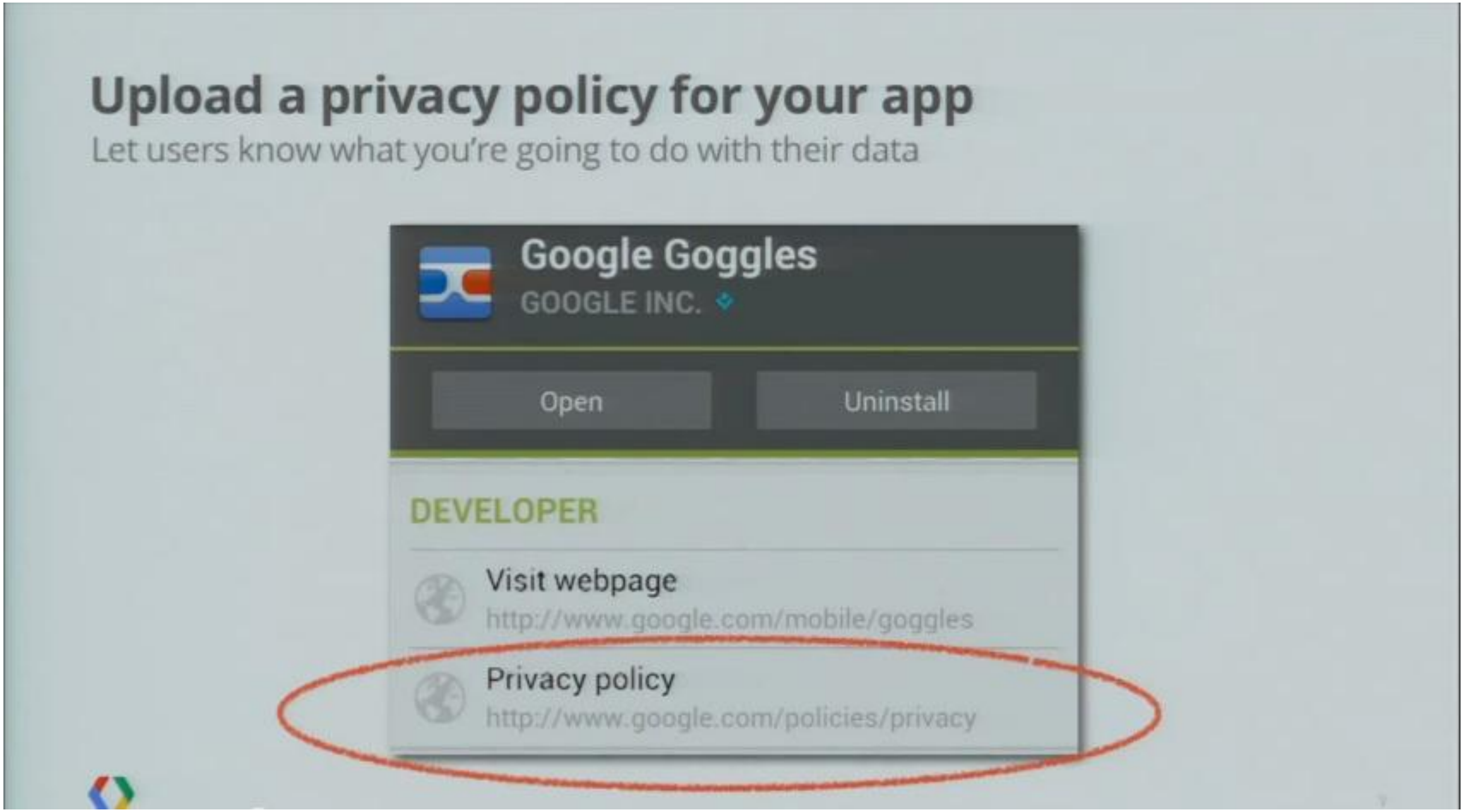
Apps need to respect the data on Android devices

- People generally don't like giving out their personal details to strangers
- Unscrupulous marketers want to mine mobile devices for data
  - User's phone number and email address could be harvested for SPAM
  - Same with the people on their contact lists
- Criminals want to steal your money
  - Sending premium-rate SMS messages from your phone
  - Intercept two-factor authentication messages



Insecure apps can grant unwanted access to data!

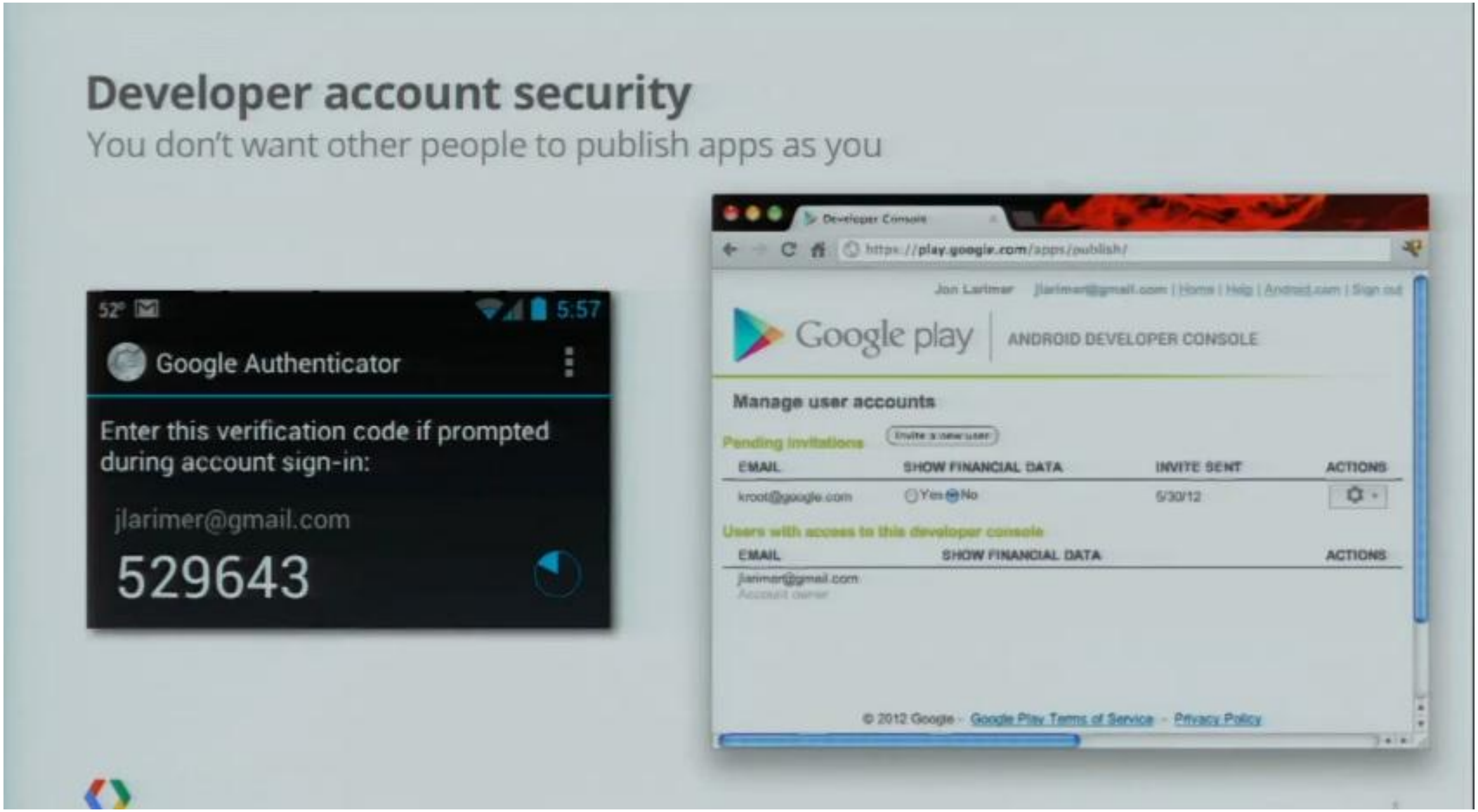
- When a user allows your app to access some aspect of their phone, they're trusting you with it
  - Please don't let them down!
- If your app requests permissions, a security vulnerability in your app can grant other apps access to the protected data or component without permission
  - Storing personal data in a world-readable file
  - Exporting an unprotected content provider
  - Logging personal data in logcat logs
- It's not just other apps that you need to think about
  - Insecure wireless networks
  - Lost and stolen devices



Upload a privacy policy for your app

Let users know what you're going to do with their data

Google Goggles
GOOGLE INC.
Open
Uninstall
DEVELOPER
Visit webpage
http://www.google.com/mobile/goggles
Privacy policy
http://www.google.com/policies/privacy



Developer account security

You don't want other people to publish apps as you

52° 5:57

Google Authenticator

Enter this verification code if prompted during account sign-in:

jlarimer@gmail.com

529643

Developer Console

https://play.google.com/apps/publish/

Jon Larimer jlarimer@gmail.com | Home | Help | Android.com | Sign out

Google play | ANDROID DEVELOPER CONSOLE

Manage user accounts

Pending invitations (Invite a new user)

EMAIL	SHOW FINANCIAL DATA	INVITE SENT	ACTIONS
kroot@google.com	○ Yes ● No	5/30/12	⚙ ▾

Users with access to this developer console

EMAIL	SHOW FINANCIAL DATA	ACTIONS
jlarimer@gmail.com Account owner		

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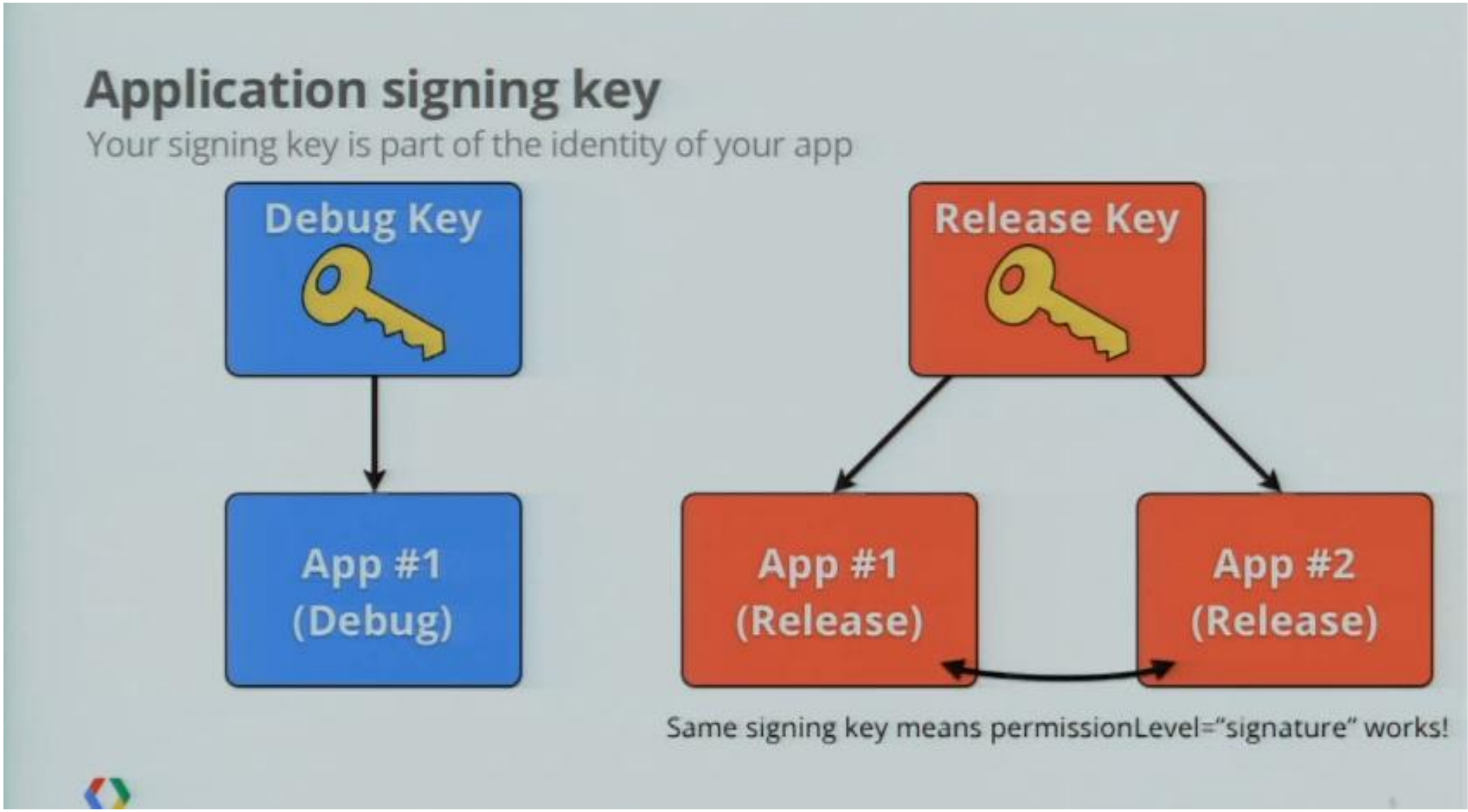


Application signing key

Your signing key is part of the identity of your app

Debug Key

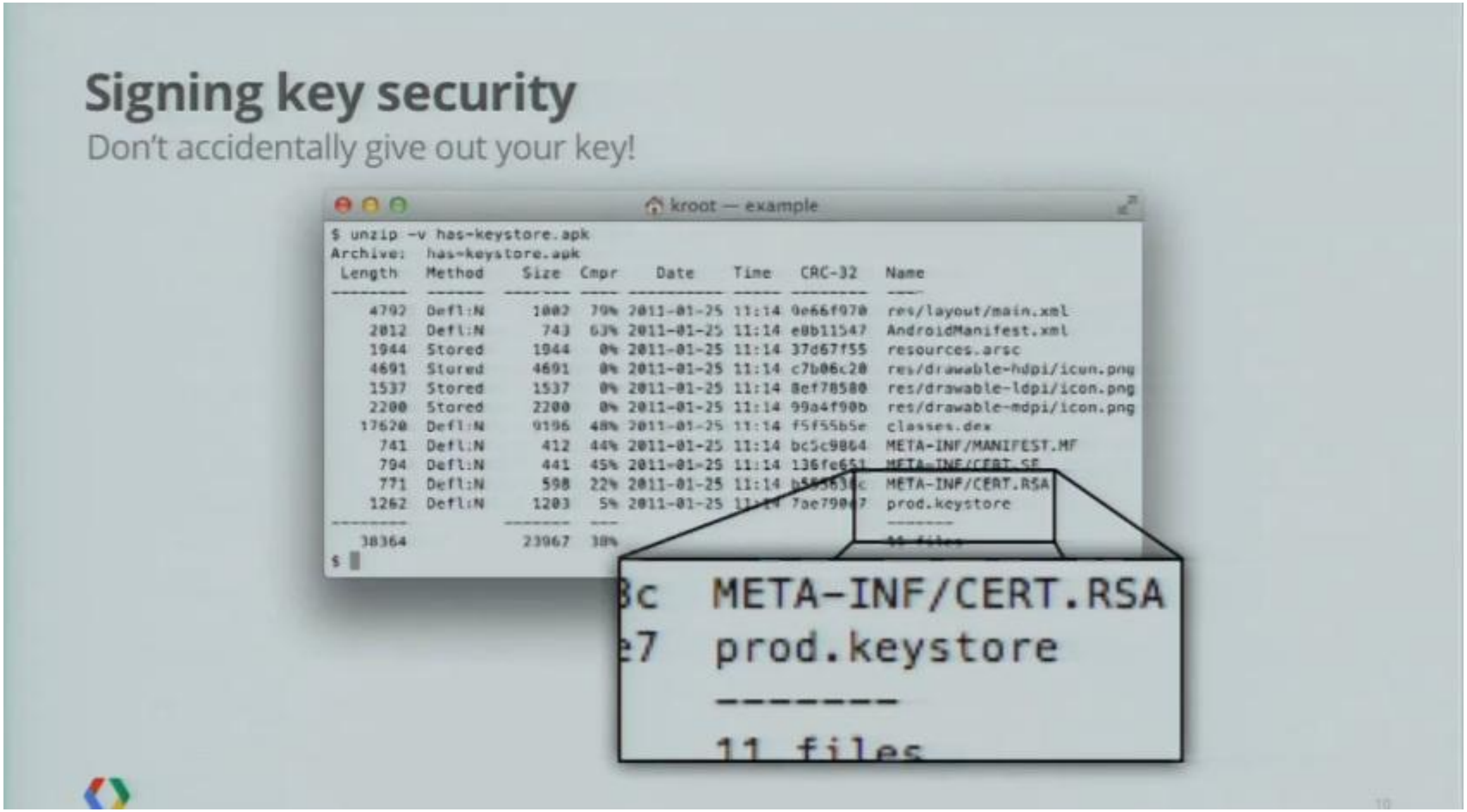
App #1 (Debug)

Release Key

App #1 (Release)

App #2 (Release)

Same signing key means permissionLevel="signature" works!

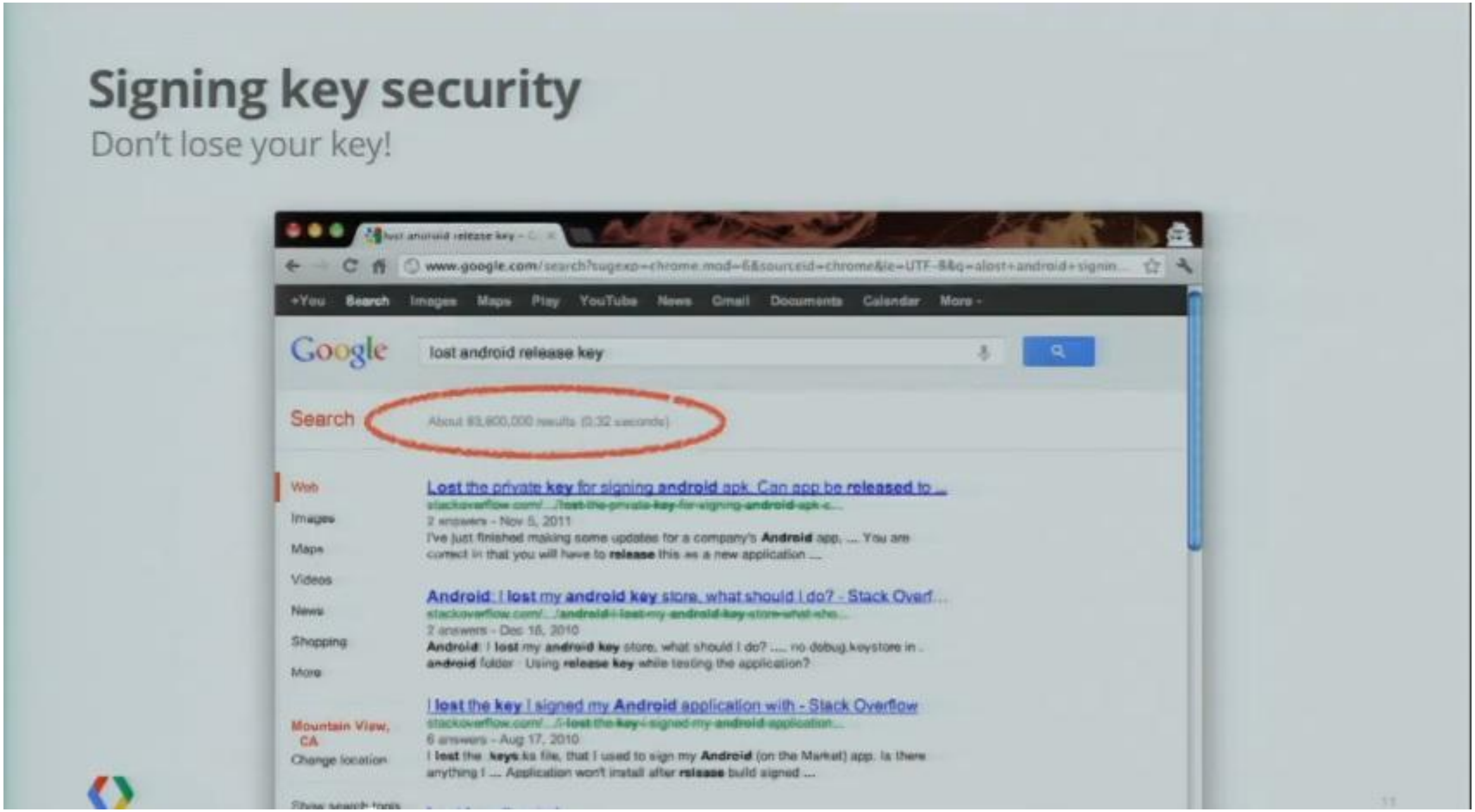


Signing key security

Don't accidentally give out your key!

```
$ unzip -v has-keystore.apk
Archive:  has-keystore.apk
 Length   Method    Size  Cmpr    Date    Time   CRC-32   Name
--------  ------  ------- ---- ---------- ----- --------  ----
    4792  Defl:N     1002  79% 2011-01-25 11:14 0e66f970  res/layout/main.xml
    2012  Defl:N      743  63% 2011-01-25 11:14 e8b11547  AndroidManifest.xml
    1944  Stored     1944   0% 2011-01-25 11:14 37d67f55  resources.arsc
    4691  Stored     4691   0% 2011-01-25 11:14 c7b06c20  res/drawable-hdpi/icon.png
    1537  Stored     1537   0% 2011-01-25 11:14 8ef78580  res/drawable-ldpi/icon.png
    2200  Stored     2200   0% 2011-01-25 11:14 99a4f90b  res/drawable-mdpi/icon.png
   17620  Defl:N     9196  48% 2011-01-25 11:14 f5f55b5e  classes.dex
     741  Defl:N      412  44% 2011-01-25 11:14 bc5c9864  META-INF/MANIFEST.MF
     794  Defl:N      441  45% 2011-01-25 11:14 136fe651  META-INF/CERT.SF
     771  Defl:N      598  22% 2011-01-25 11:14 b585363c  META-INF/CERT.RSA
    1262  Defl:N     1203   5% 2011-01-25 11:14 7ae790e7  prod.keystore
--------          -------  ---                            -------
   38364            23967  38%                            11 files
$ 
```

```
3c   META-INF/CERT.RSA
e7   prod.keystore
     --------
     11 files
```



Signing key security

Don't lose your key!

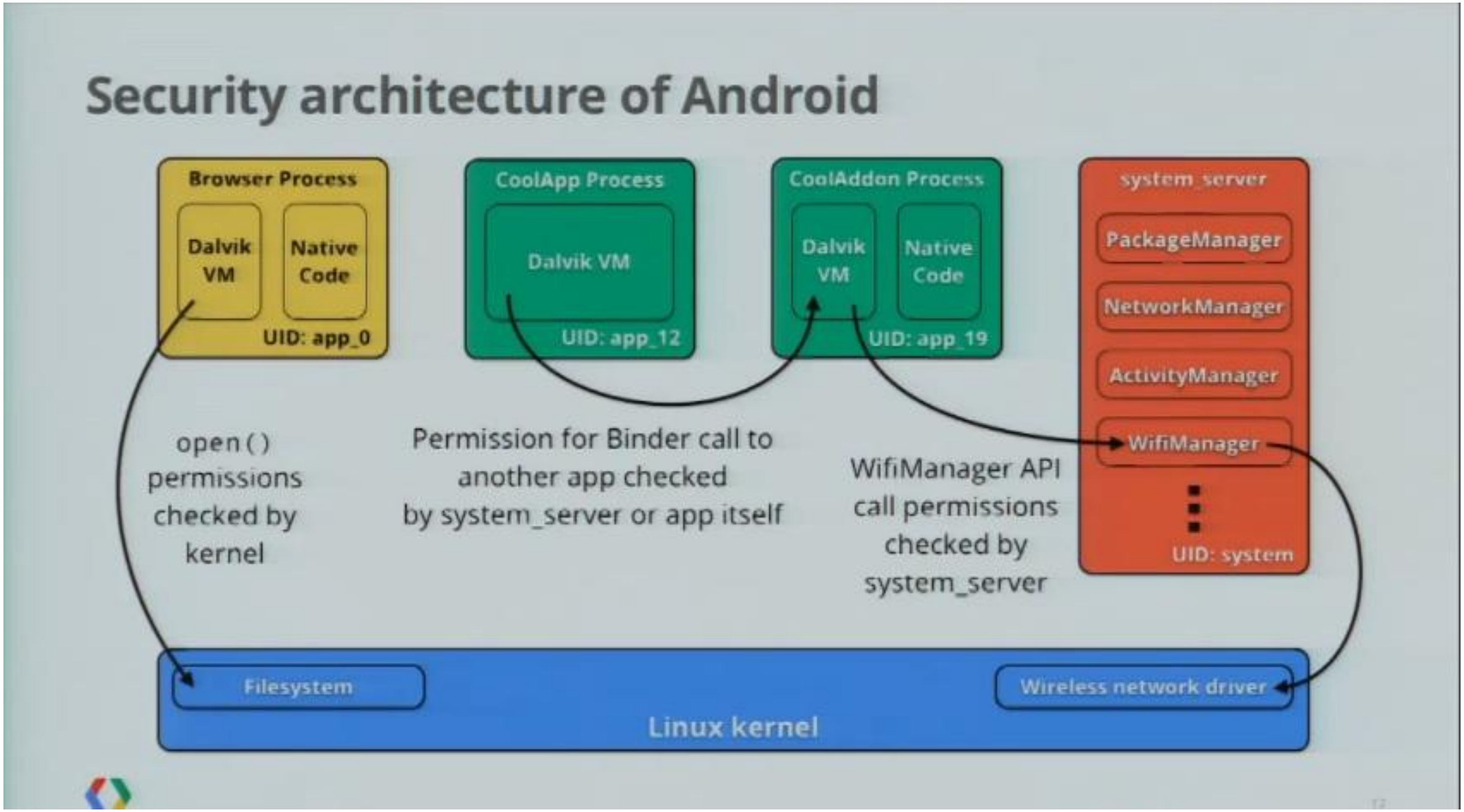
lost android release key

About 83,600,000 results (0.32 seconds)

Lost the private key for signing android apk. Can app be released to ...
stackoverflow.com/.../lost-the-private-key-for-signing-android-apk-c...
2 answers - Nov 5, 2011
I've just finished making some updates for a company's **Android** app. ... You are correct in that you will have to **release** this as a new application ...

Android: I lost my android key store, what should I do? - Stack Overf...
stackoverflow.com/.../android-i-lost-my-android-key-store-what-sho...
2 answers - Dec 16, 2010
Android: I **lost** my **android key** store, what should I do? ..... no debug.keystore in . **android** folder · Using **release key** while testing the application?

I lost the key I signed my Android application with - Stack Overflow
stackoverflow.com/.../i-lost-the-key-i-signed-my-android-application...
6 answers - Aug 17, 2010
I **lost** the .**keys**.ks file, that I used to sign my **Android** (on the Market) app. Is there anything I ... Application won't install after **release** build signed ...

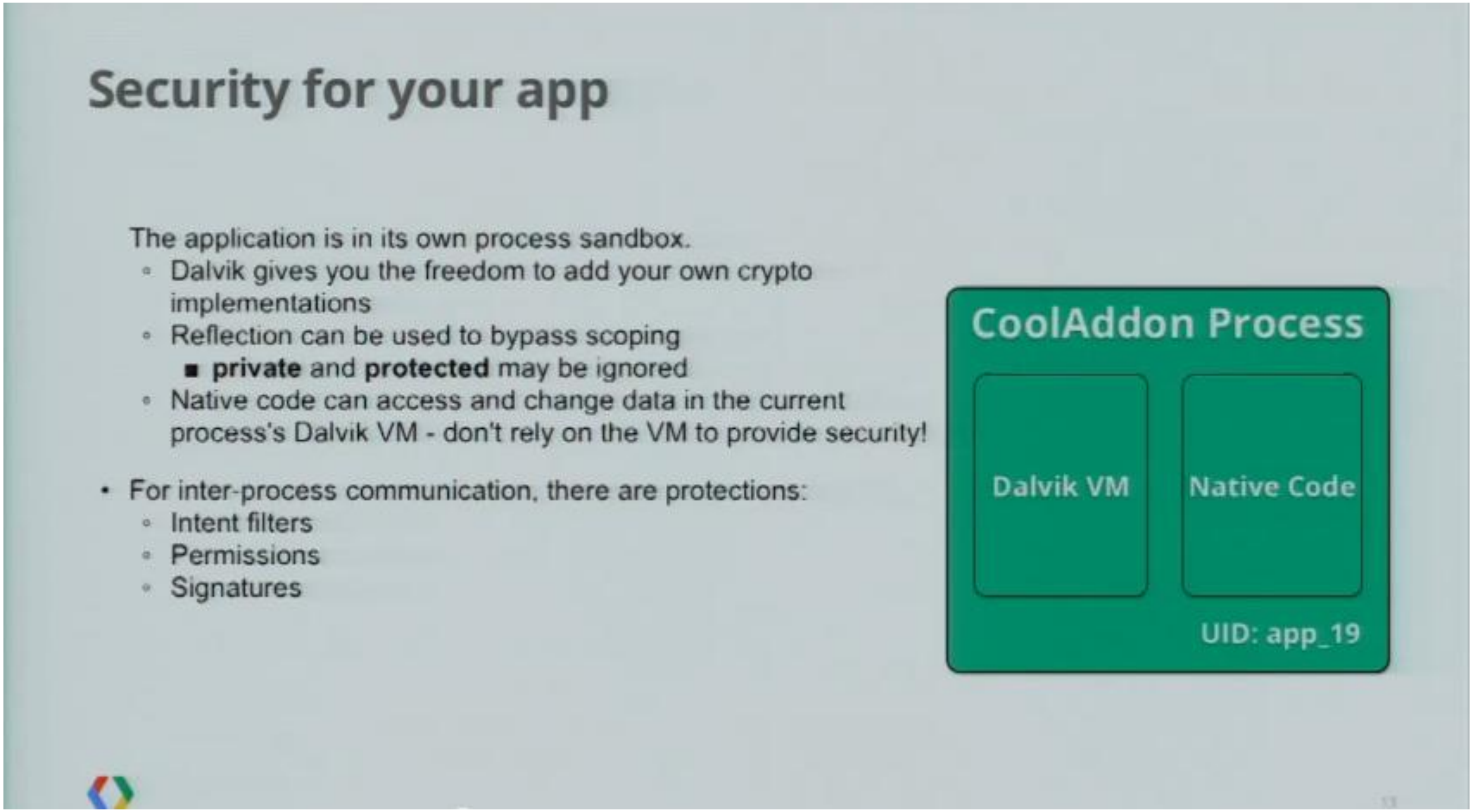


Security architecture of Android

open() permissions checked by kernel

Permission for Binder call to another app checked by system_server or app itself

WifiManager API call permissions checked by system_server



Security for your app

The application is in its own process sandbox.

- Dalvik gives you the freedom to add your own crypto implementations
- Reflection can be used to bypass scoping
  - **private** and **protected** may be ignored
- Native code can access and change data in the current process's Dalvik VM - don't rely on the VM to provide security!

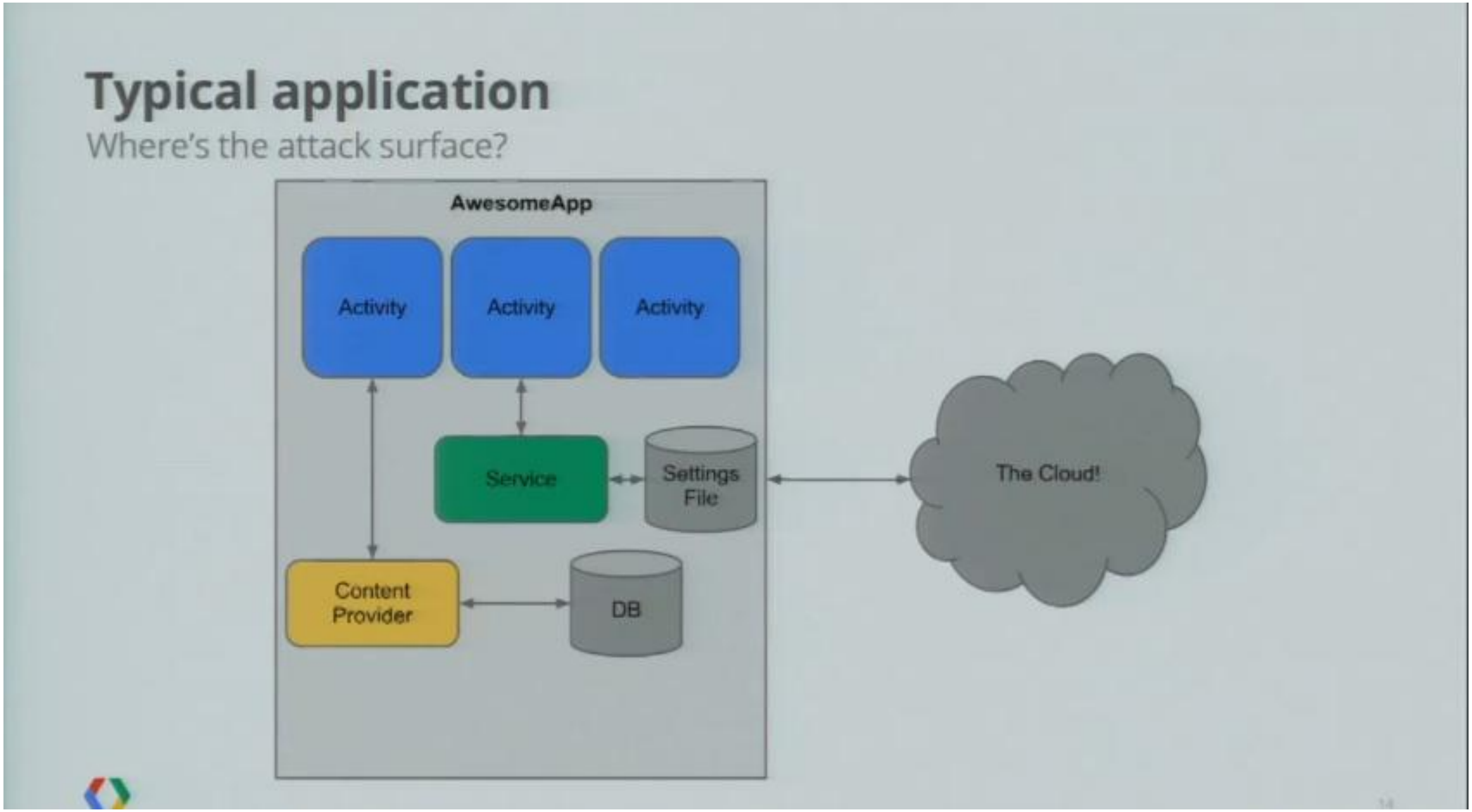
- For inter-process communication, there are protections:
  - Intent filters
  - Permissions
  - Signatures

CoolAddon Process

Dalvik VM

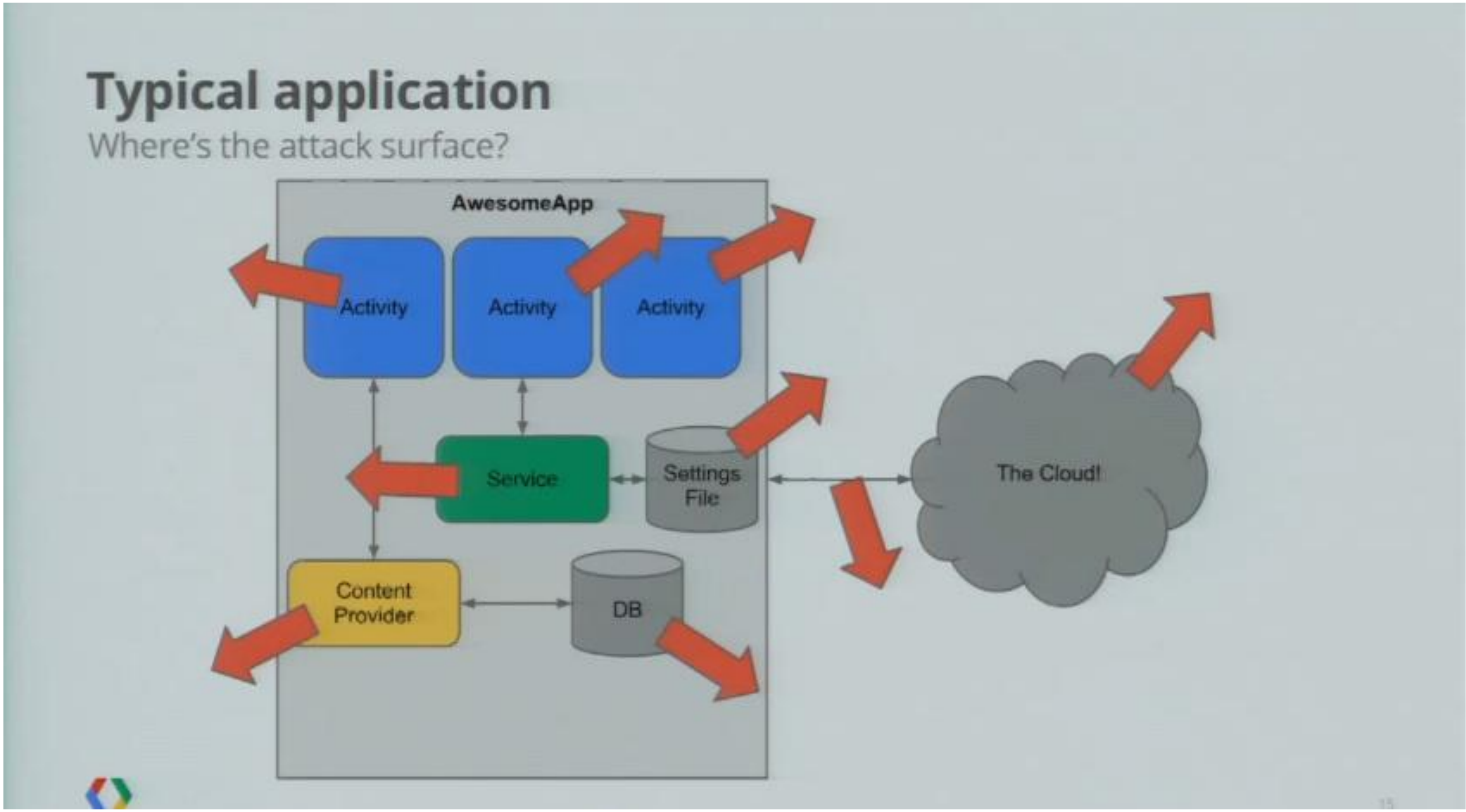
Native Code

UID: app_19



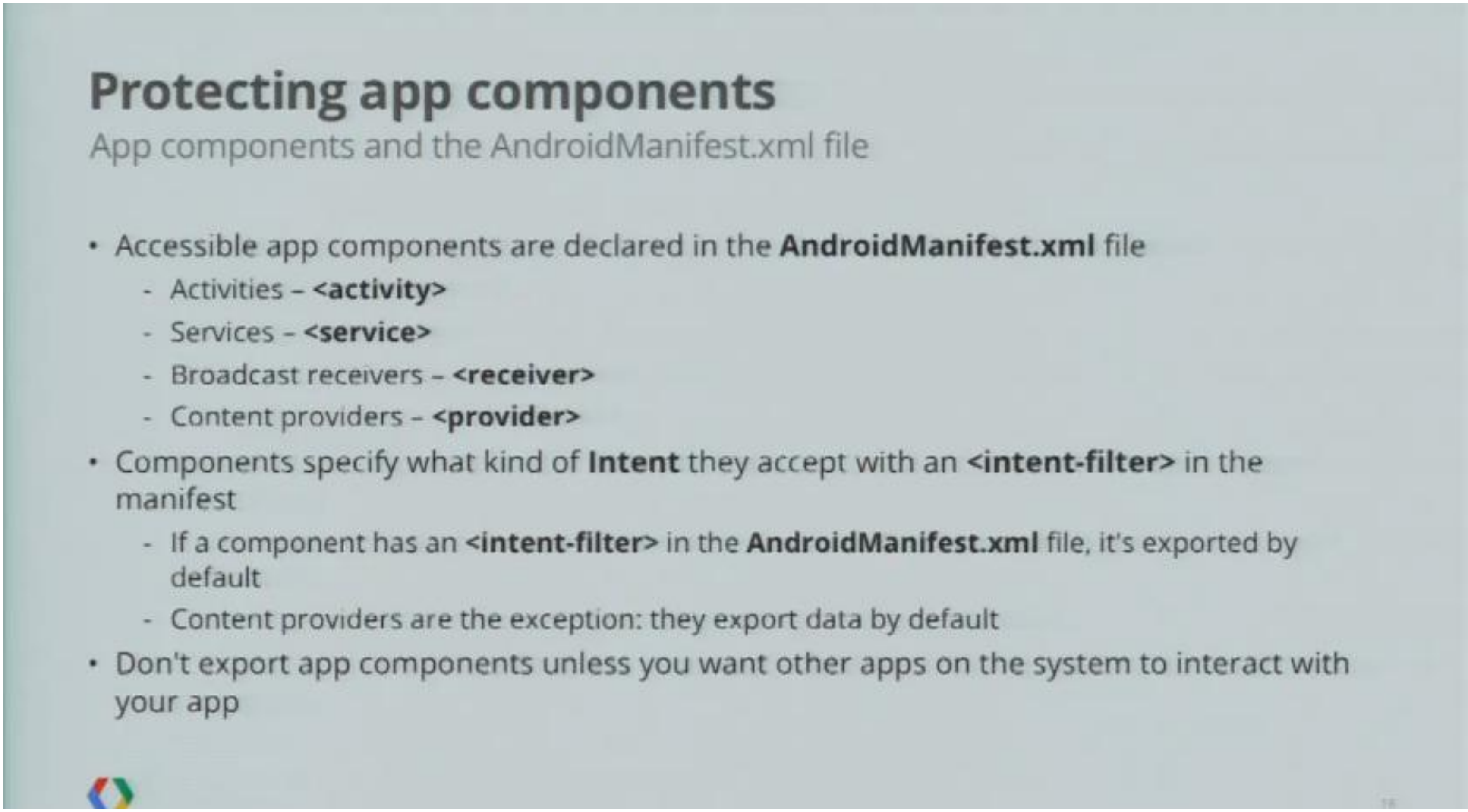
Typical application

Where's the attack surface?



Typical application

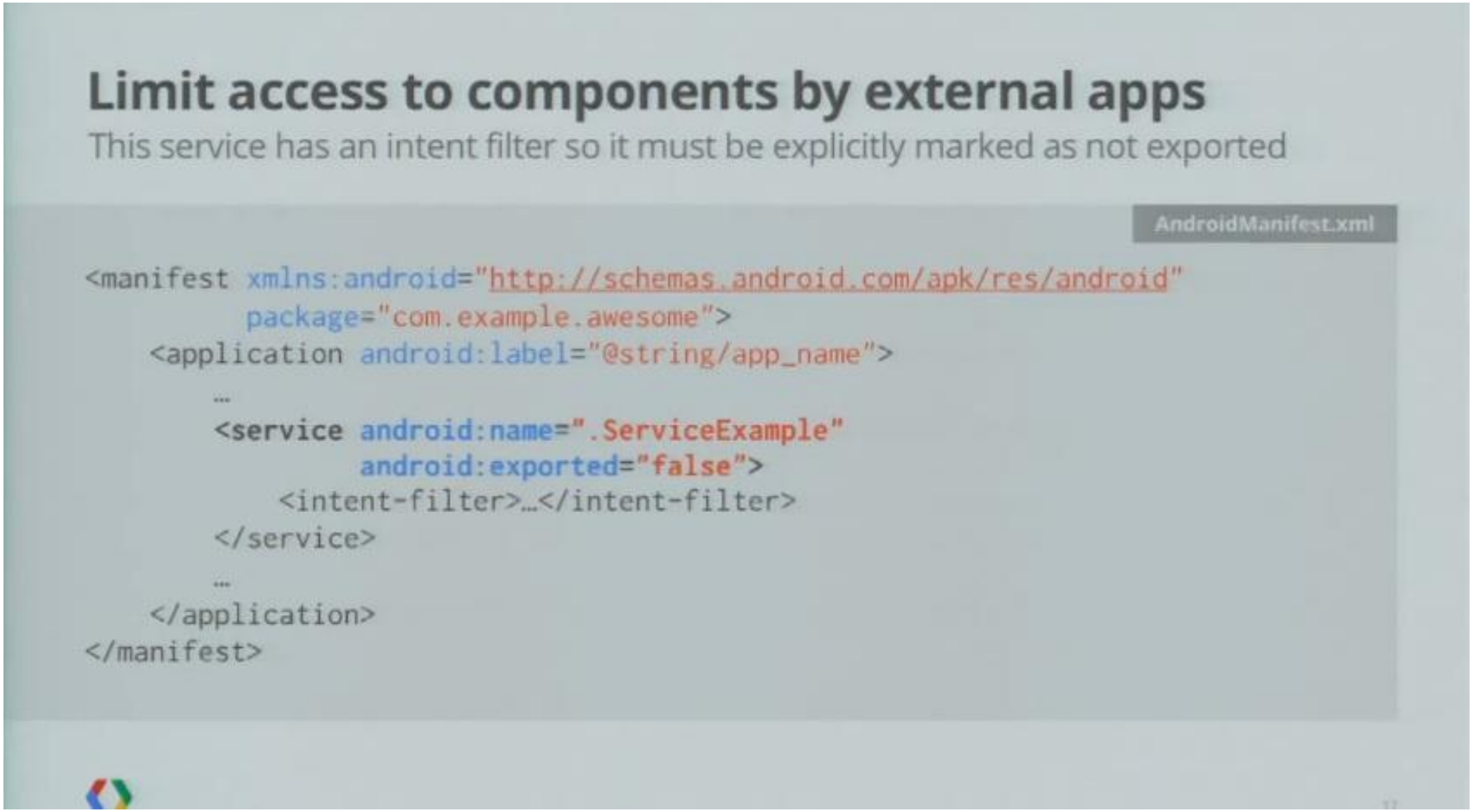
Where's the attack surface?



Protecting app components

App components and the AndroidManifest.xml file

- Accessible app components are declared in the **AndroidManifest.xml** file
  - Activities – **<activity>**
  - Services – **<service>**
  - Broadcast receivers – **<receiver>**
  - Content providers – **<provider>**
- Components specify what kind of **Intent** they accept with an **<intent-filter>** in the manifest
  - If a component has an **<intent-filter>** in the **AndroidManifest.xml** file, it's exported by default
  - Content providers are the exception: they export data by default
- Don't export app components unless you want other apps on the system to interact with your app

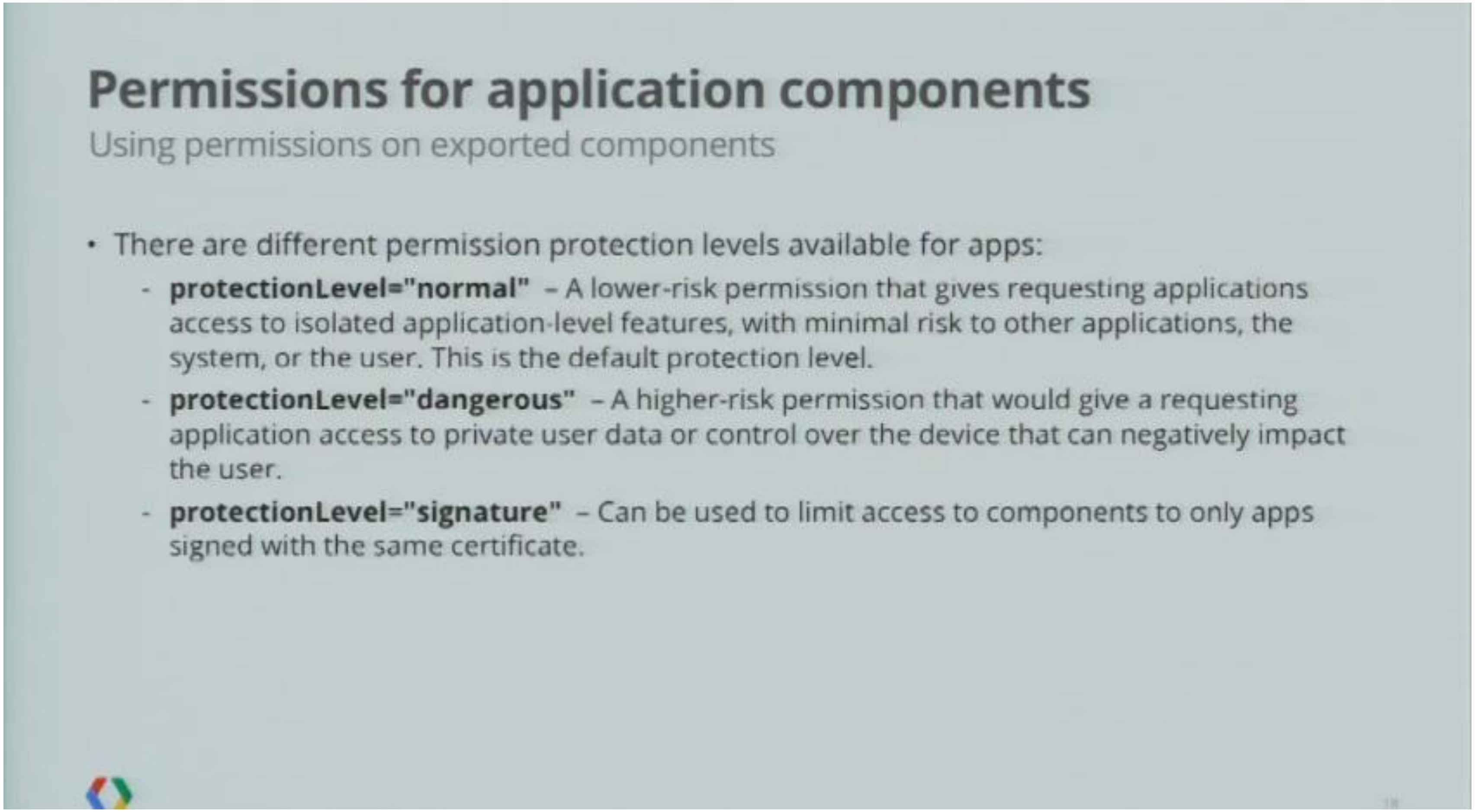


Limit access to components by external apps

This service has an intent filter so it must be explicitly marked as not exported

AndroidManifest.xml

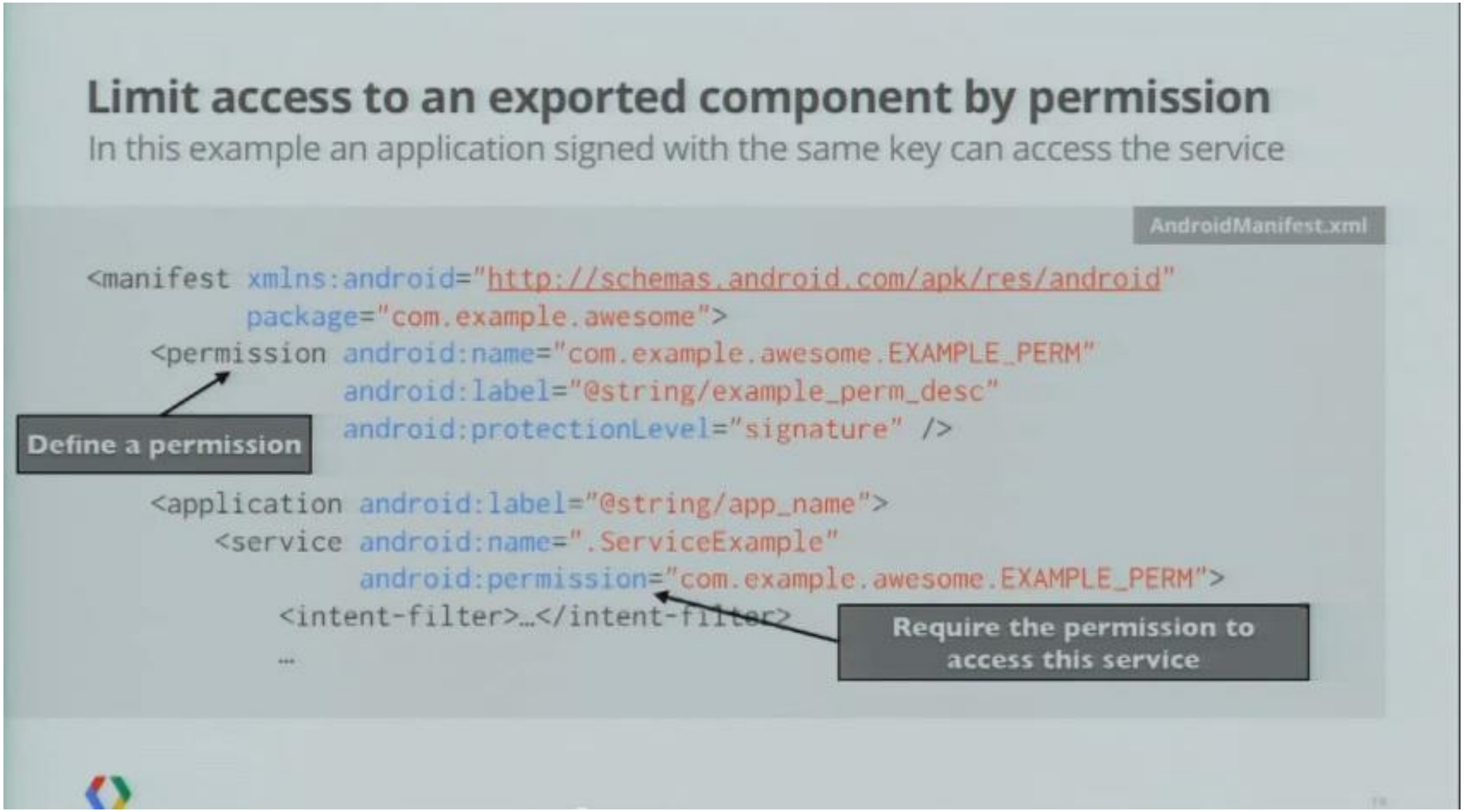
```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
          package="com.example.awesome">
    <application android:label="@string/app_name">
        …
        <service android:name=".ServiceExample"
                 android:exported="false">
            <intent-filter>…</intent-filter>
        </service>
        …
    </application>
</manifest>
```



Permissions for application components

Using permissions on exported components

- There are different permission protection levels available for apps:
  - **protectionLevel="normal"** – A lower-risk permission that gives requesting applications access to isolated application-level features, with minimal risk to other applications, the system, or the user. This is the default protection level.
  - **protectionLevel="dangerous"** – A higher-risk permission that would give a requesting application access to private user data or control over the device that can negatively impact the user.
  - **protectionLevel="signature"** – Can be used to limit access to components to only apps signed with the same certificate.



Limit access to an exported component by permission

In this example an application signed with the same key can access the service

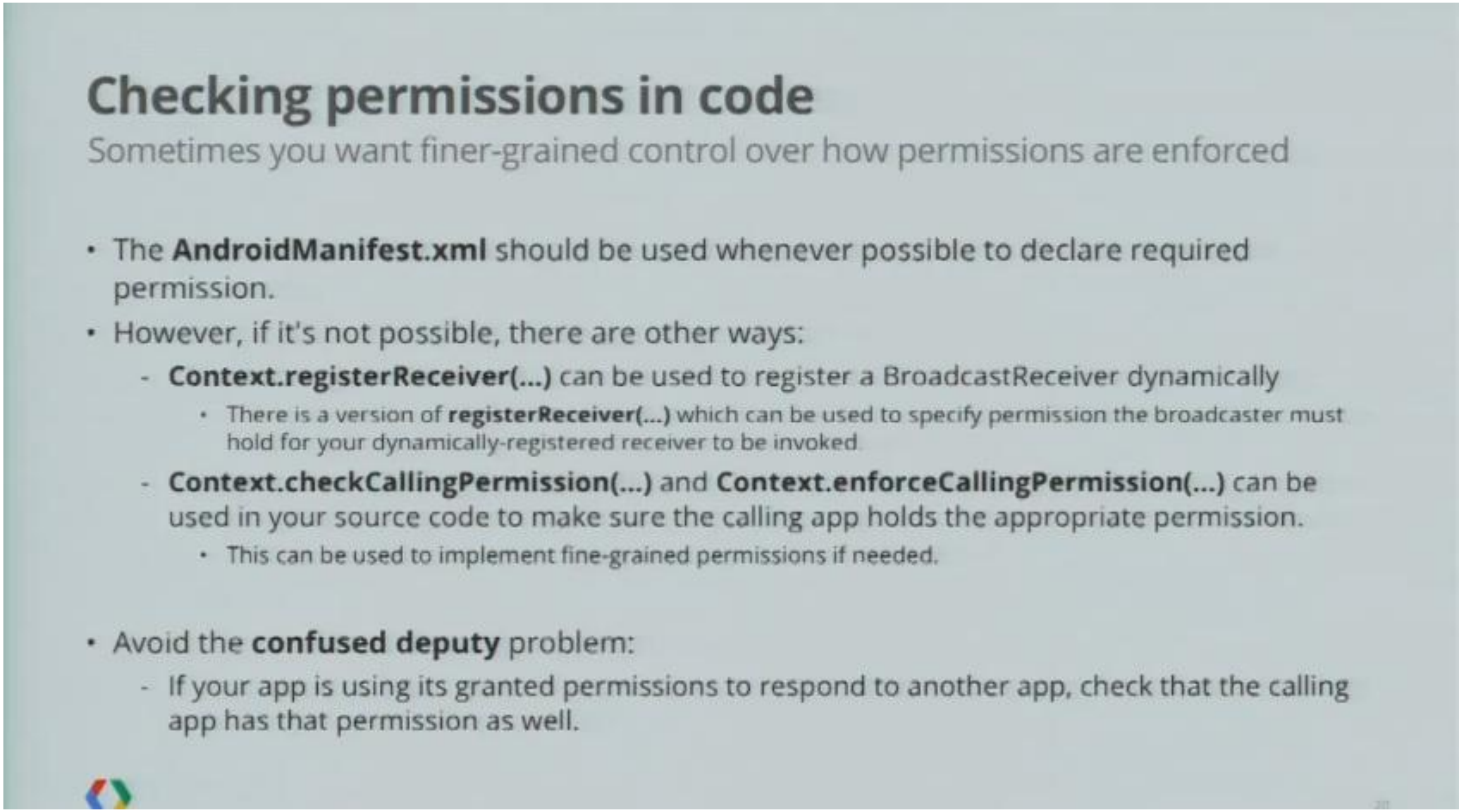
AndroidManifest.xml

```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
          package="com.example.awesome">
    <permission android:name="com.example.awesome.EXAMPLE_PERM"
                android:label="@string/example_perm_desc"
                android:protectionLevel="signature" />

    <application android:label="@string/app_name">
        <service android:name=".ServiceExample"
                 android:permission="com.example.awesome.EXAMPLE_PERM">
            <intent-filter>…</intent-filter>
            …
```

Define a permission

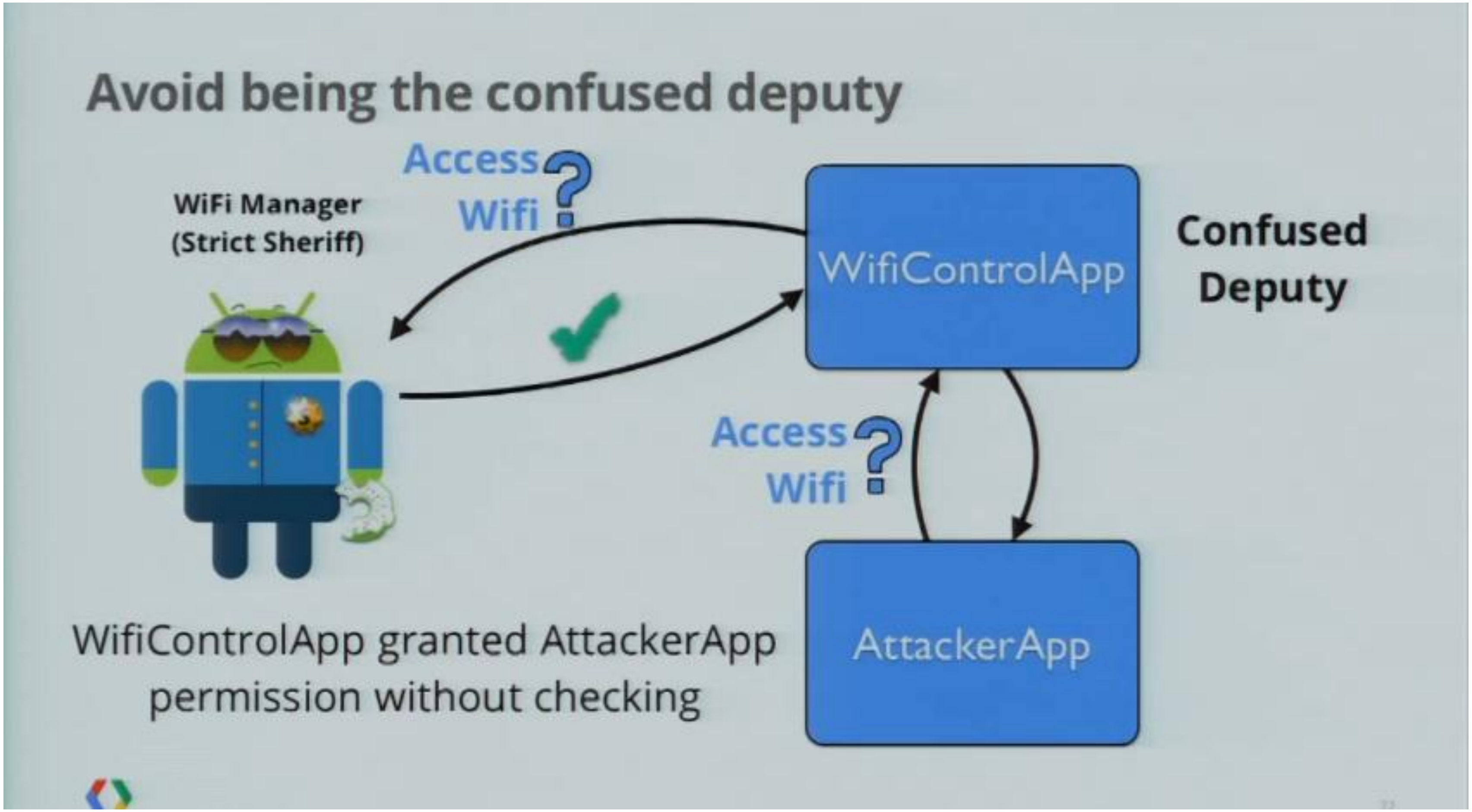
Require the permission to access this service



Checking permissions in code

Sometimes you want finer-grained control over how permissions are enforced

- The **AndroidManifest.xml** should be used whenever possible to declare required permission.
- However, if it's not possible, there are other ways:
  - **Context.registerReceiver(...)** can be used to register a BroadcastReceiver dynamically
    - There is a version of **registerReceiver(...)** which can be used to specify permission the broadcaster must hold for your dynamically-registered receiver to be invoked.
  - **Context.checkCallingPermission(...)** and **Context.enforceCallingPermission(...)** can be used in your source code to make sure the calling app holds the appropriate permission.
    - This can be used to implement fine-grained permissions if needed.
- Avoid the **confused deputy** problem:
  - If your app is using its granted permissions to respond to another app, check that the calling app has that permission as well.



Avoid being the confused deputy

WiFi Manager
(Strict Sheriff)

Access
Wifi ?

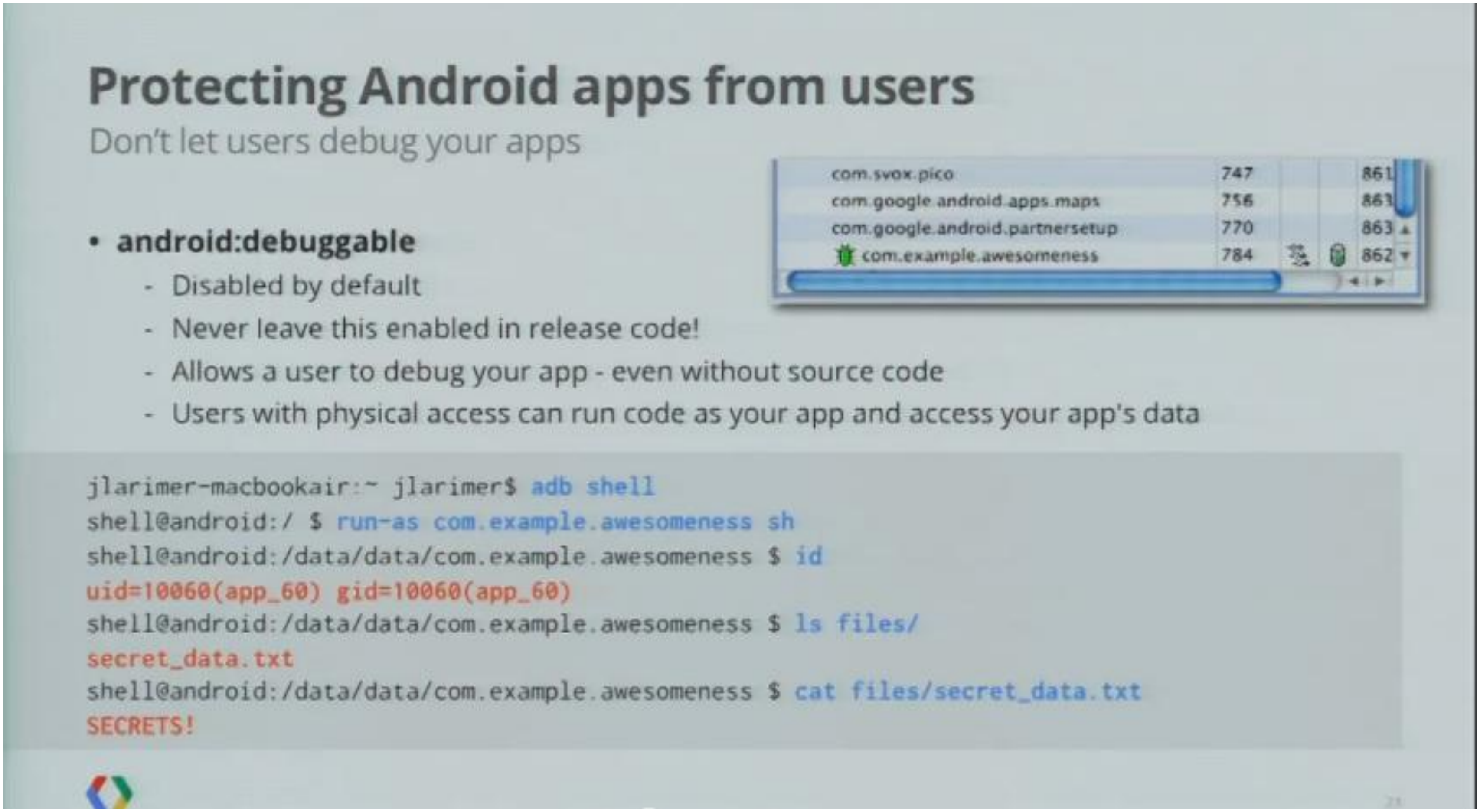
WifiControlApp

Confused
Deputy

Access
Wifi ?

AttackerApp

WifiControlApp granted AttackerApp
permission without checking



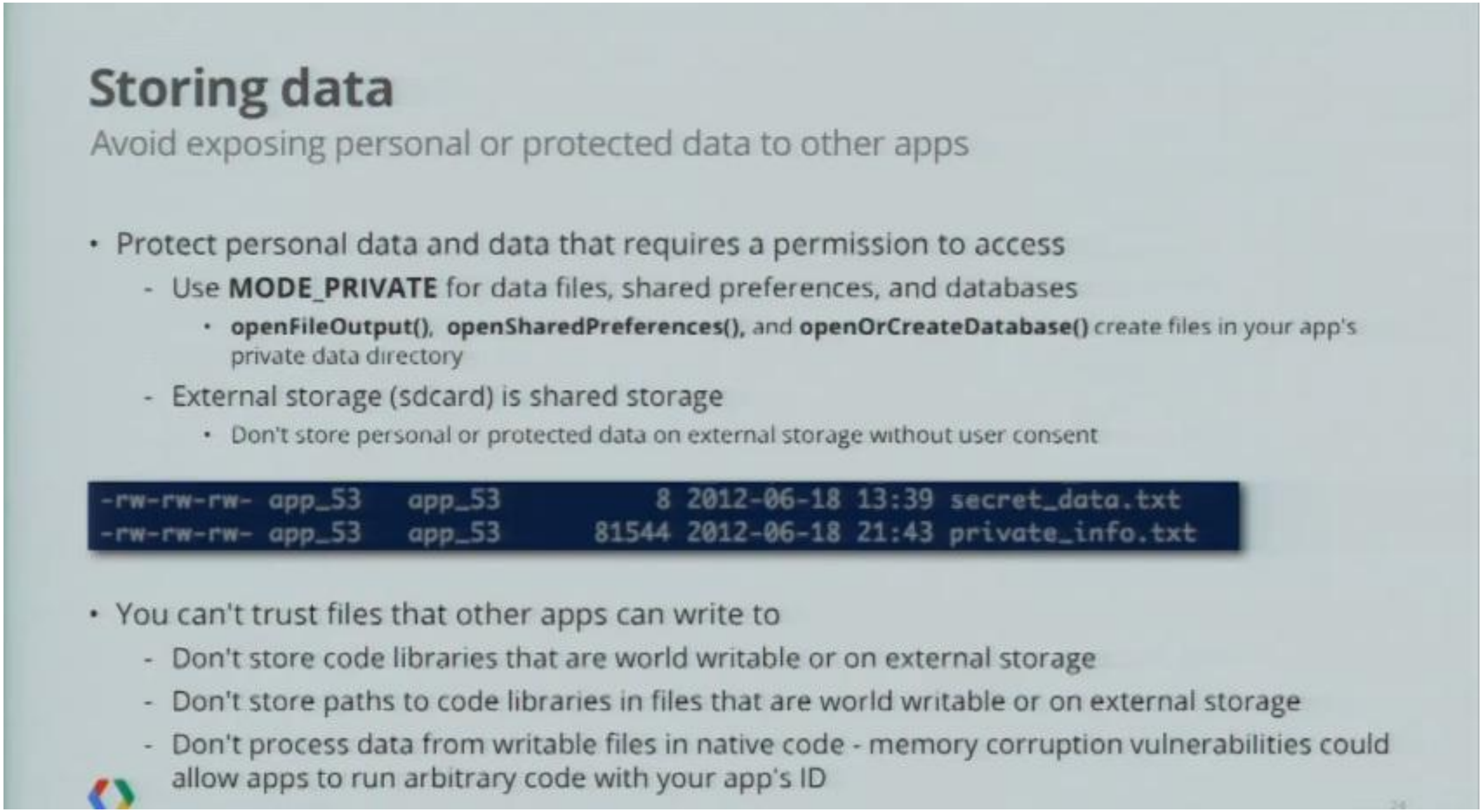
Protecting Android apps from users

Don't let users debug your apps

com.svox.pico	747			861
com.google.android.apps.maps	756			863
com.google.android.partnersetup	770			863
com.example.awesomeness	784			862

- **android:debuggable**
  - Disabled by default
  - Never leave this enabled in release code!
  - Allows a user to debug your app - even without source code
  - Users with physical access can run code as your app and access your app's data

```
jlarimer-macbookair:~ jlarimer$ adb shell
shell@android:/ $ run-as com.example.awesomeness sh
shell@android:/data/data/com.example.awesomeness $ id
uid=10060(app_60) gid=10060(app_60)
shell@android:/data/data/com.example.awesomeness $ ls files/
secret_data.txt
shell@android:/data/data/com.example.awesomeness $ cat files/secret_data.txt
SECRETS!
```



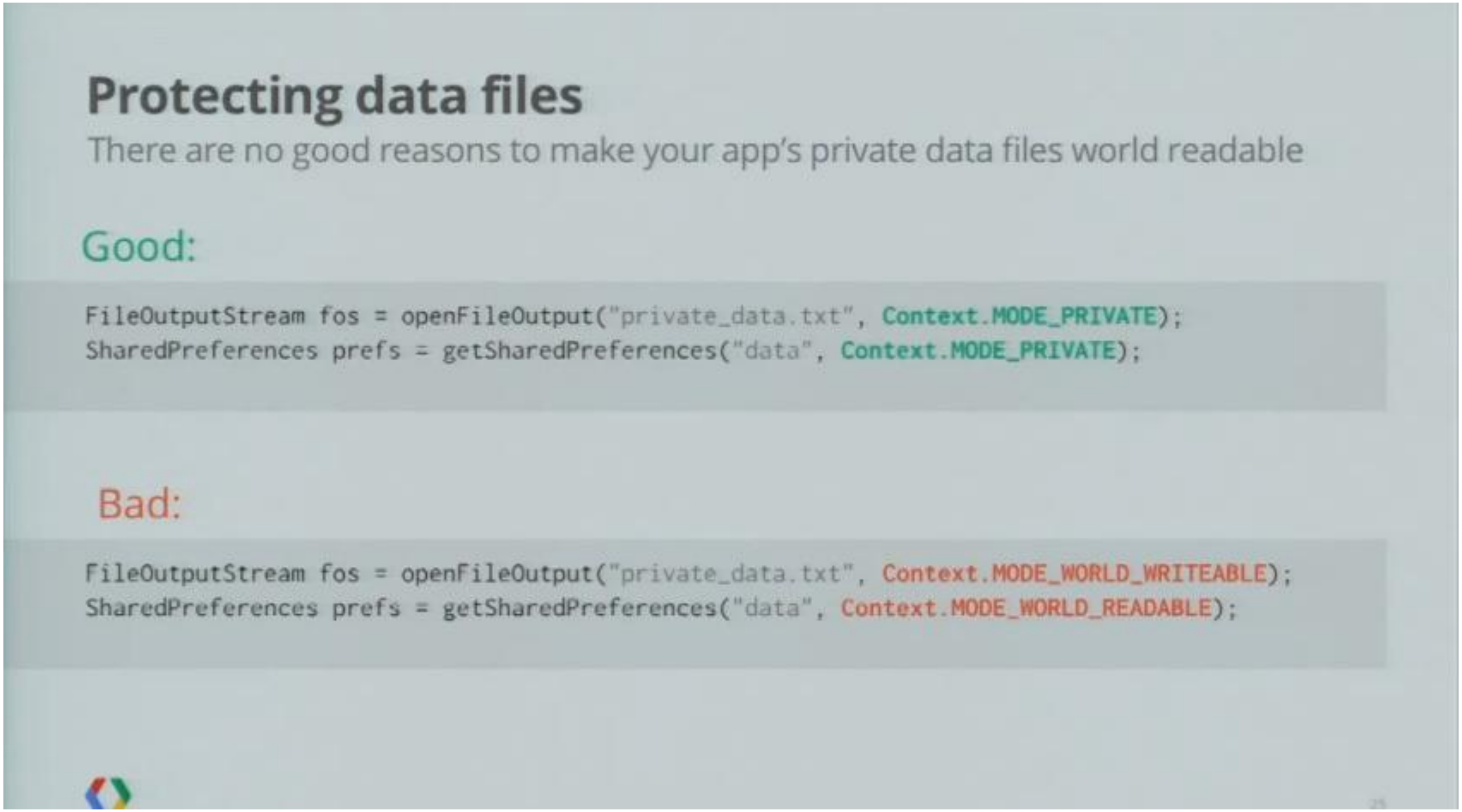
Storing data

Avoid exposing personal or protected data to other apps

- Protect personal data and data that requires a permission to access
  - Use **MODE_PRIVATE** for data files, shared preferences, and databases
    - **openFileOutput()**, **openSharedPreferences()**, and **openOrCreateDatabase()** create files in your app's private data directory
  - External storage (sdcard) is shared storage
    - Don't store personal or protected data on external storage without user consent

```
-rw-rw-rw- app_53    app_53           8 2012-06-18 13:39 secret_data.txt
-rw-rw-rw- app_53    app_53       81544 2012-06-18 21:43 private_info.txt
```

- You can't trust files that other apps can write to
  - Don't store code libraries that are world writable or on external storage
  - Don't store paths to code libraries in files that are world writable or on external storage
  - Don't process data from writable files in native code - memory corruption vulnerabilities could allow apps to run arbitrary code with your app's ID



Protecting data files

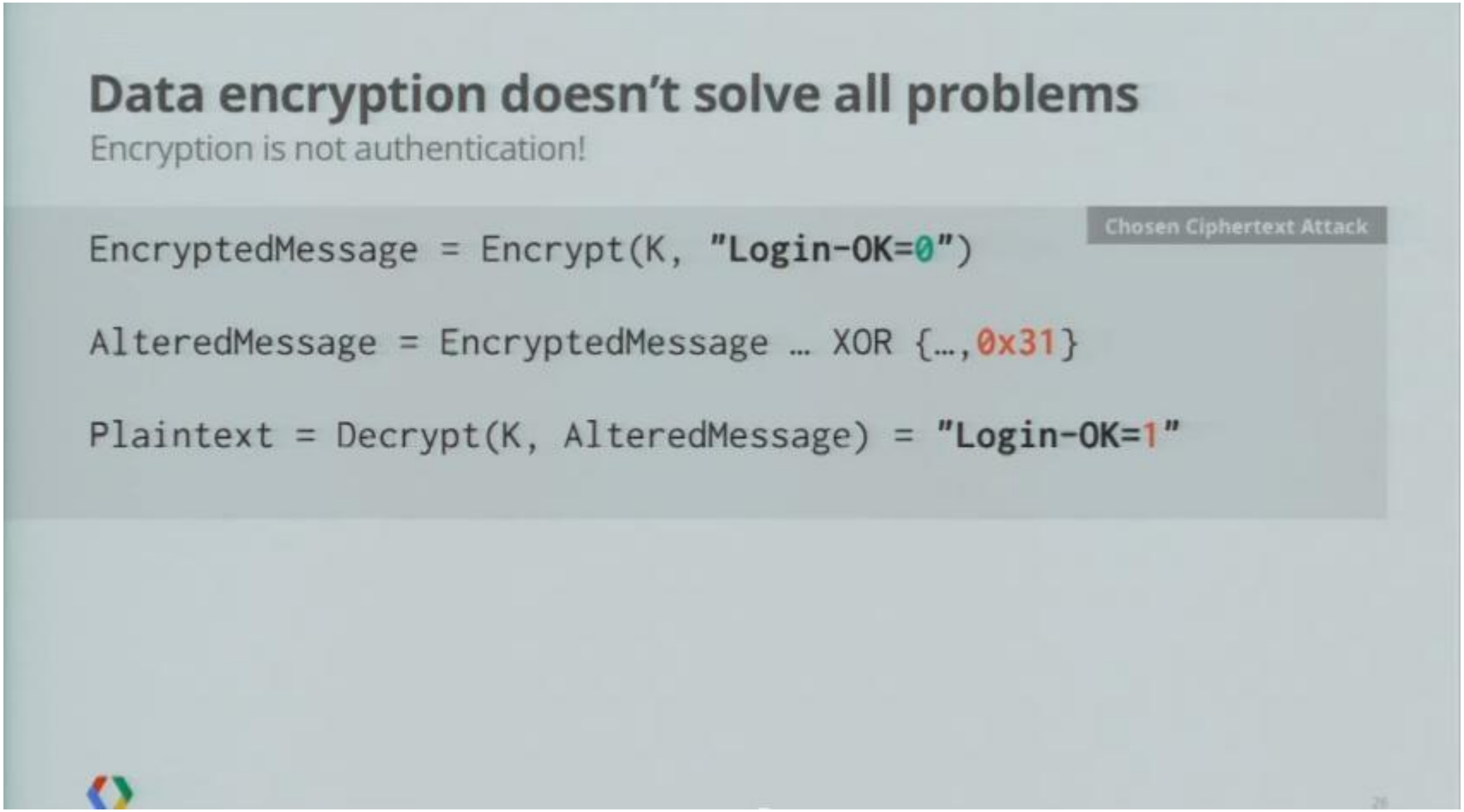
There are no good reasons to make your app's private data files world readable

Good:

```
FileOutputStream fos = openFileOutput("private_data.txt", Context.MODE_PRIVATE);
SharedPreferences prefs = getSharedPreferences("data", Context.MODE_PRIVATE);
```

Bad:

```
FileOutputStream fos = openFileOutput("private_data.txt", Context.MODE_WORLD_WRITEABLE);
SharedPreferences prefs = getSharedPreferences("data", Context.MODE_WORLD_READABLE);
```



Data encryption doesn't solve all problems

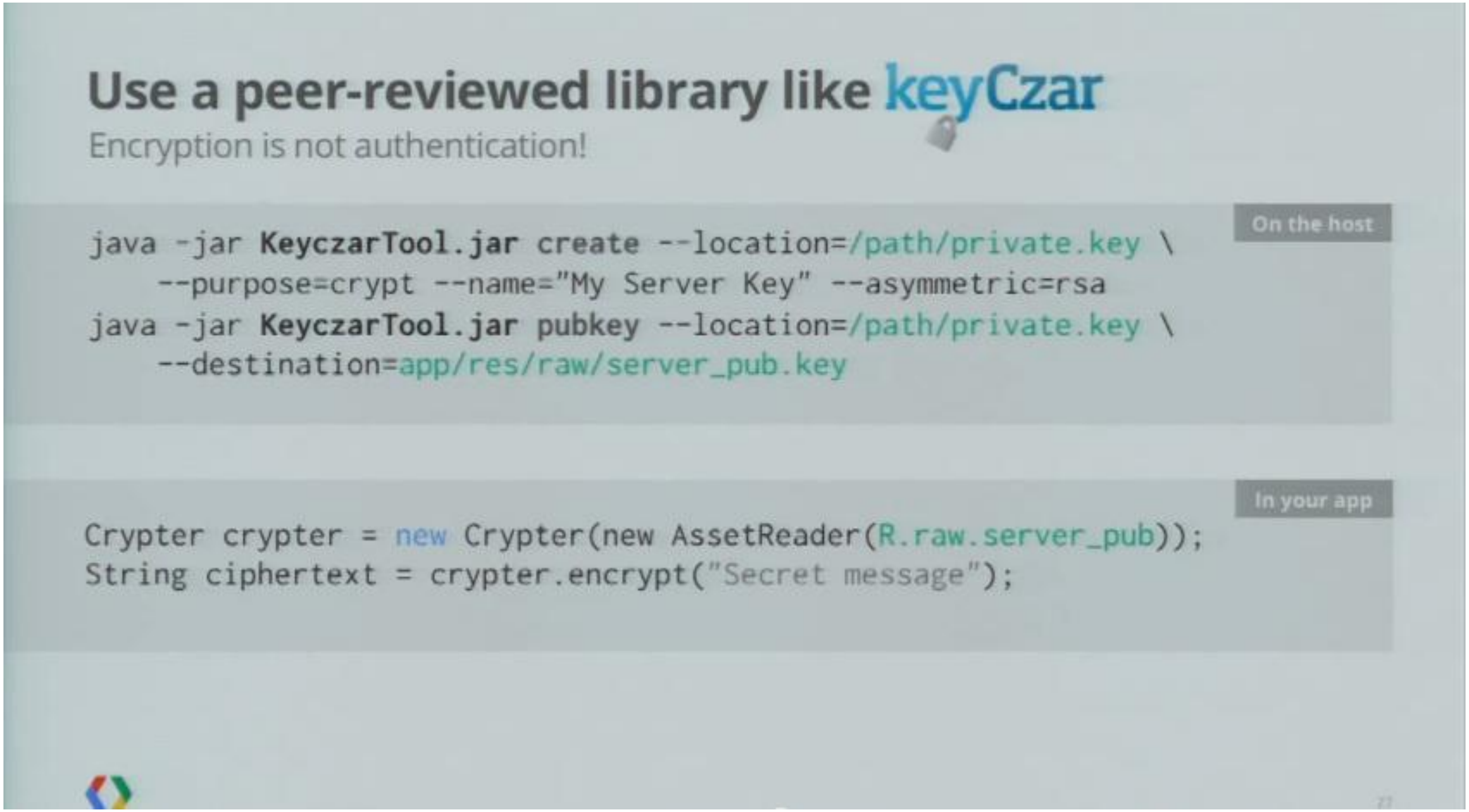
Encryption is not authentication!

Chosen Ciphertext Attack

```
EncryptedMessage = Encrypt(K, "Login-OK=0")

AlteredMessage = EncryptedMessage … XOR {…,0x31}

Plaintext = Decrypt(K, AlteredMessage) = "Login-OK=1"
```

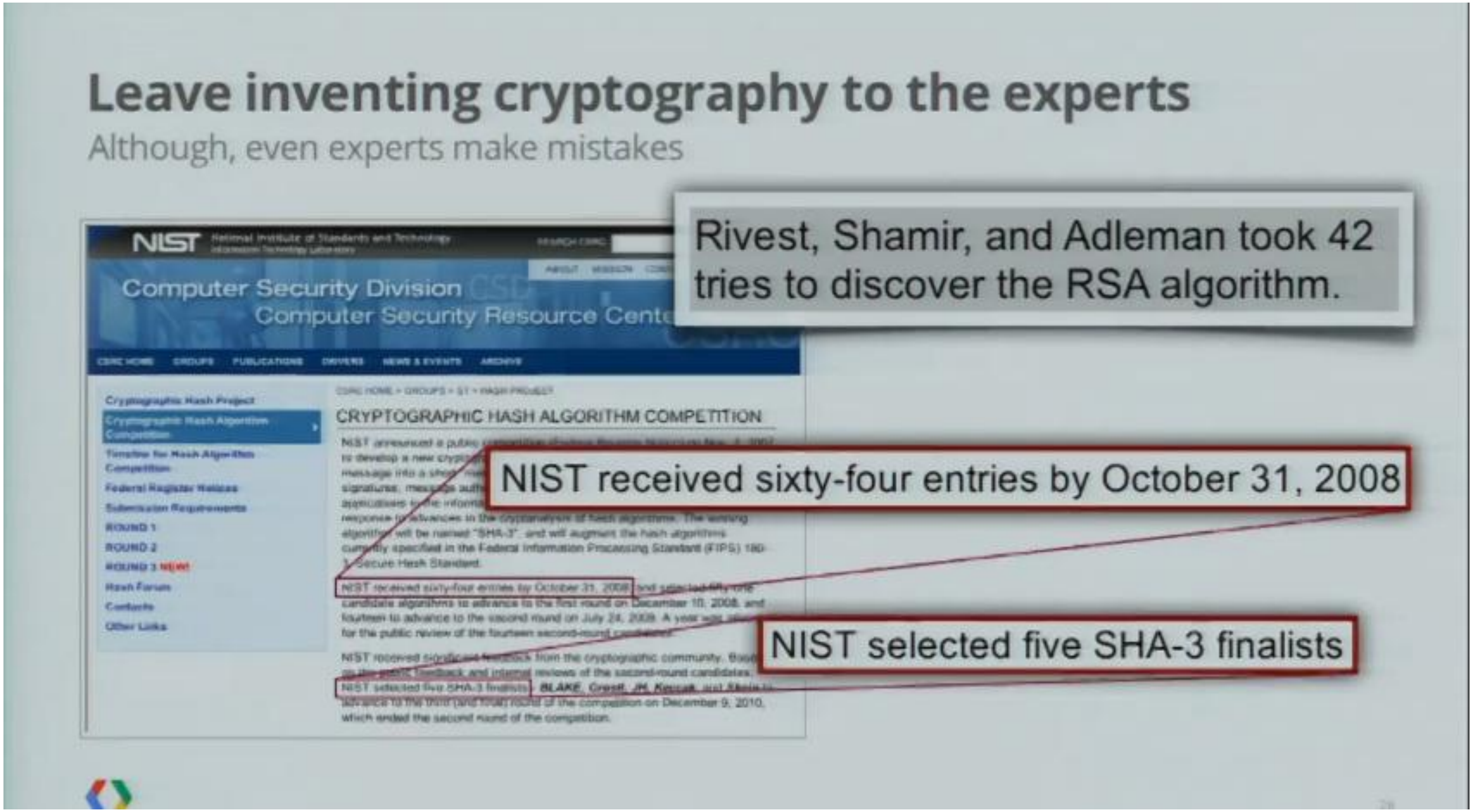


Use a peer-reviewed library like keyCzar

Encryption is not authentication!

```
java -jar KeyczarTool.jar create --location=/path/private.key \
    --purpose=crypt --name="My Server Key" --asymmetric=rsa
java -jar KeyczarTool.jar pubkey --location=/path/private.key \
    --destination=app/res/raw/server_pub.key
```

```
Crypter crypter = new Crypter(new AssetReader(R.raw.server_pub));
String ciphertext = crypter.encrypt("Secret message");
```



Leave inventing cryptography to the experts

Although, even experts make mistakes

Rivest, Shamir, and Adleman took 42 tries to discover the RSA algorithm.

NIST received sixty-four entries by October 31, 2008

NIST selected five SHA-3 finalists

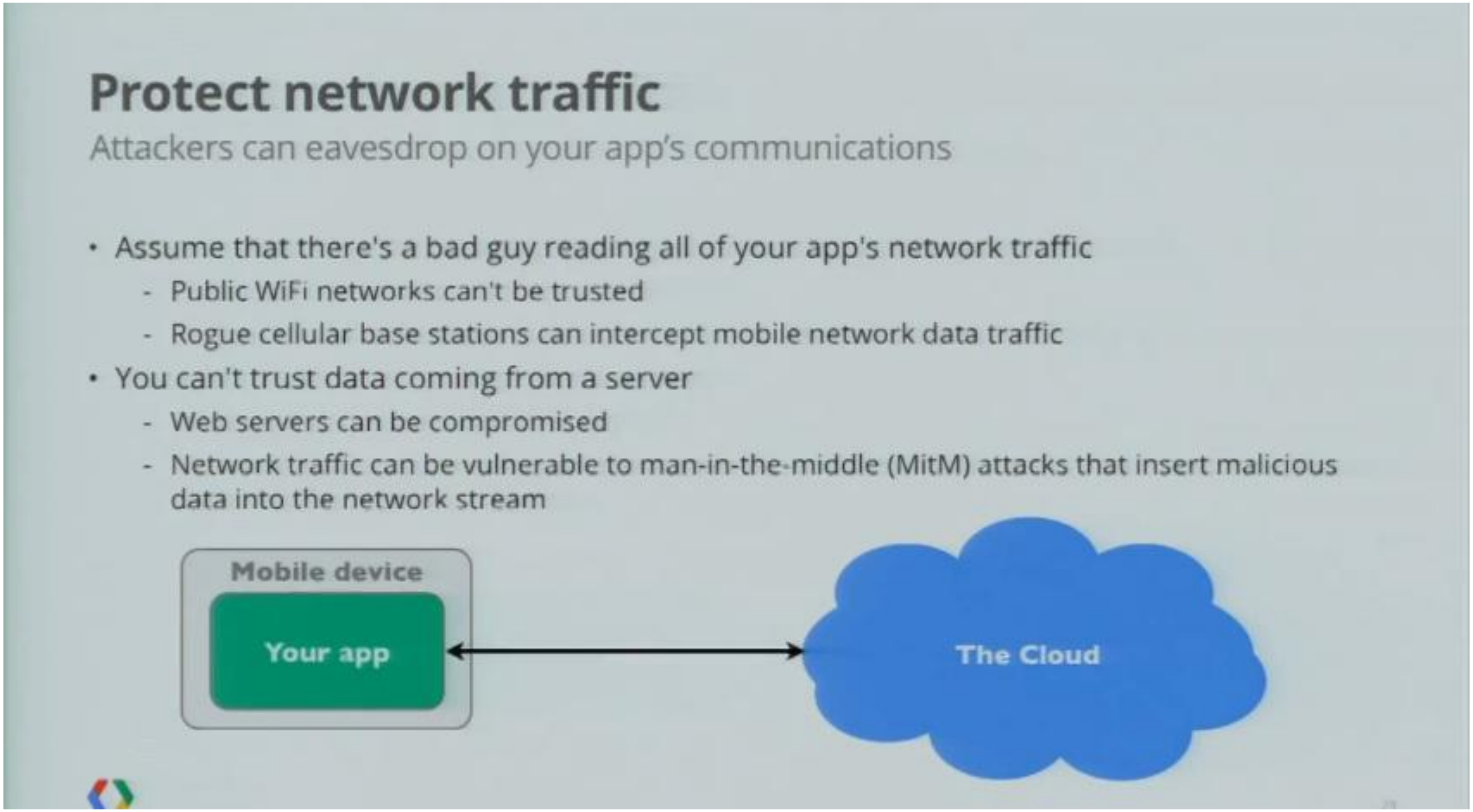
NIST National Institute of Standards and Technology
Information Technology Laboratory
SEARCH CSRC
ABOUT MISSION
Computer Security Division CSD
Computer Security Resource Center CSRC
CSRC HOME GROUPS PUBLICATIONS DRIVERS NEWS & EVENTS ARCHIVE
Cryptographic Hash Project
Cryptographic Hash Algorithm Competition
Timeline for Hash Algorithm Competition
Federal Register Notices
Submission Requirements
ROUND 1
ROUND 2
ROUND 3 NEW!
Hash Forum
Contacts
Other Links
CSRC HOME > GROUPS > ST > HASH PROJECT

CRYPTOGRAPHIC HASH ALGORITHM COMPETITION

NIST announced a public [illegible] 2007 to develop a new cryp[illegible] message into a sho[illegible] signatures, message auth[illegible] applications in the informa[illegible] response to advances in the cryptanalysis of hash algorithms. The winning algorithm will be named "SHA-3", and will augment the hash algorithms currently specified in the Federal Information Processing Standard (FIPS) 180-3, Secure Hash Standard.

NIST received sixty-four entries by October 31, 2008; and selected fifty-one candidate algorithms to advance to the first round on December 10, 2008, and fourteen to advance to the second round on July 24, 2009. A year was [illegible] for the public review of the fourteen second-round candidates.

NIST received significant feedback from the cryptographic community. Based on the public feedback and internal reviews of the second-round candidates, NIST selected five SHA-3 finalists – BLAKE, Grøstl, JH, Keccak, and Skein to advance to the third (and final) round of the competition on December 9, 2010, which ended the second round of the competition.



Protect network traffic

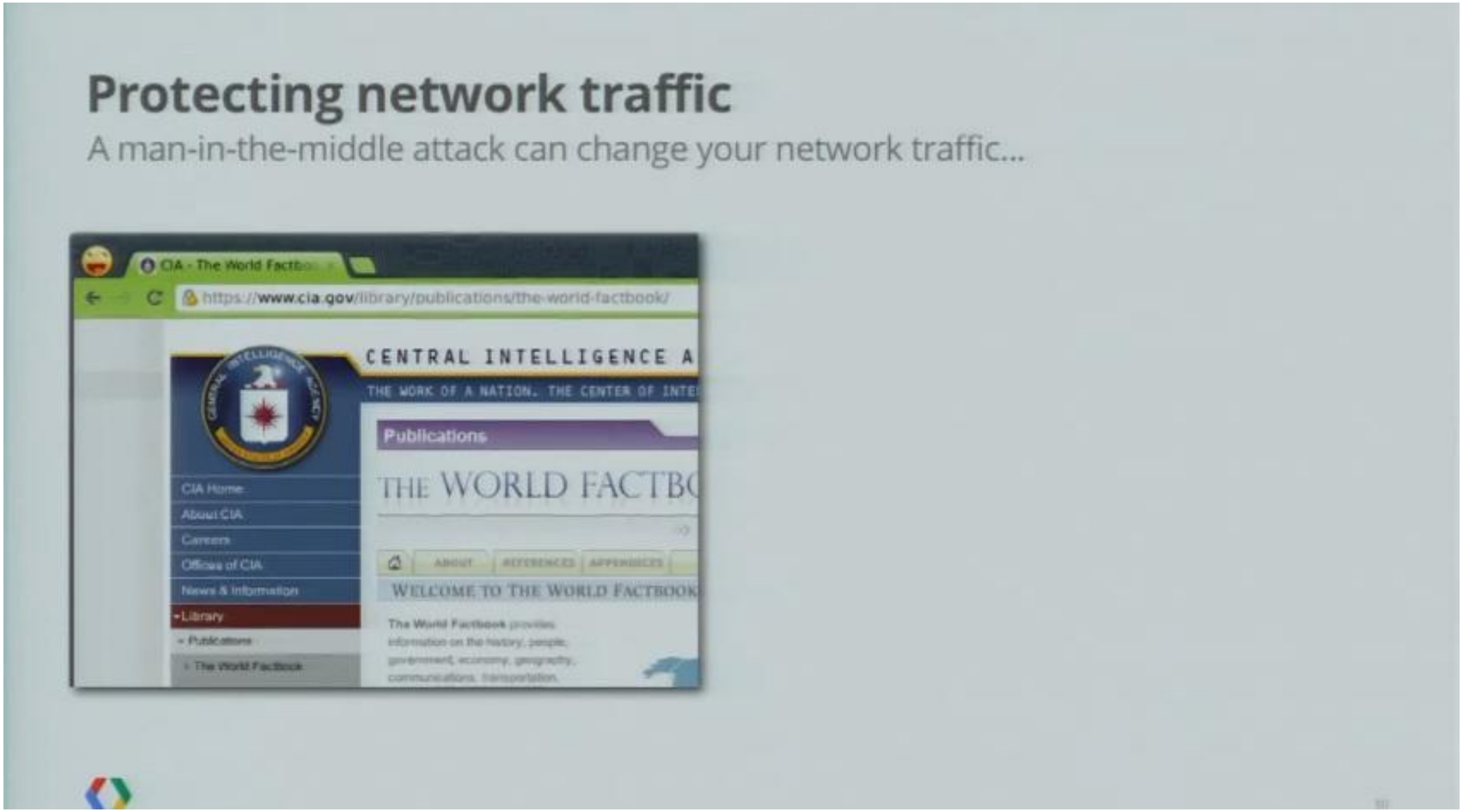
Attackers can eavesdrop on your app's communications

- Assume that there's a bad guy reading all of your app's network traffic
  - Public WiFi networks can't be trusted
  - Rogue cellular base stations can intercept mobile network data traffic
- You can't trust data coming from a server
  - Web servers can be compromised
  - Network traffic can be vulnerable to man-in-the-middle (MitM) attacks that insert malicious data into the network stream

Mobile device

Your app

The Cloud



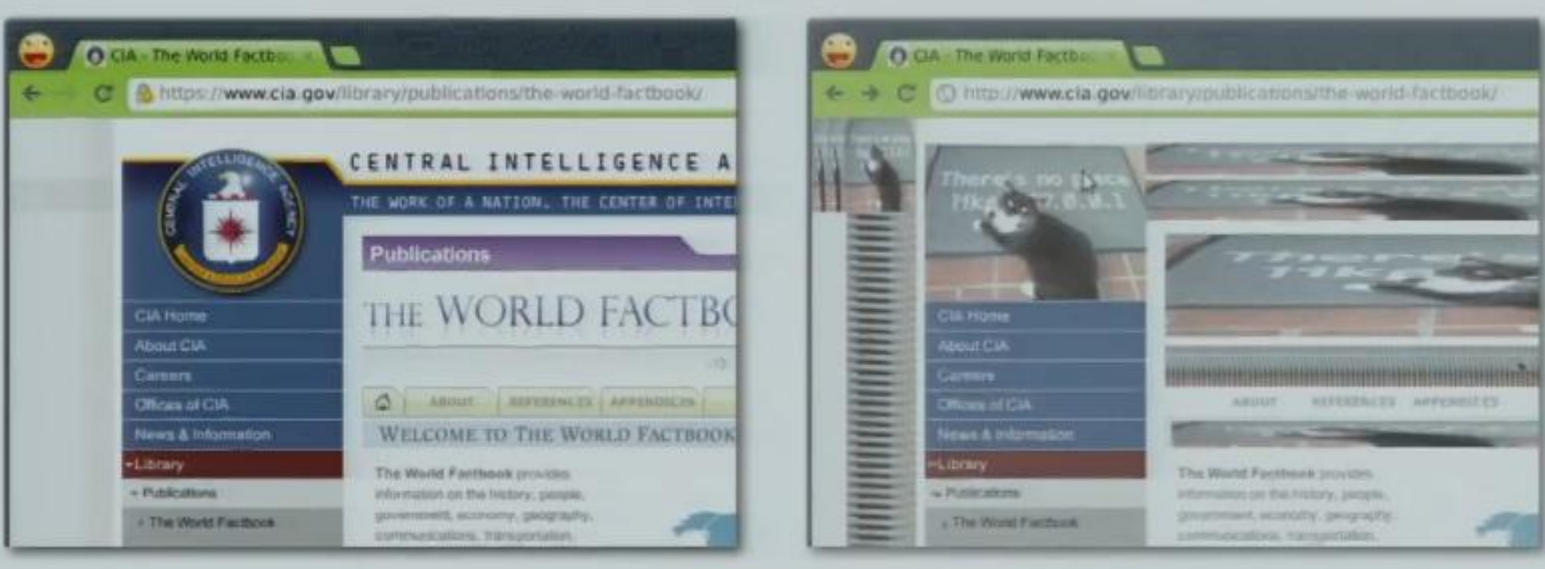
Protecting network traffic

A man-in-the-middle attack can change your network traffic...

The World Factbook provides information on the history, people, government, economy, geography, communications, transportation,

Protecting network traffic

A man-in-the-middle attack can change your network traffic...


CIA - The World Factbo
https://www.cia.gov/library/publications/the-world-factbook/
CENTRAL INTELLIGENCE A
THE WORK OF A NATION. THE CENTER OF INTE
Publications
THE WORLD FACTBO
CIA Home
About CIA
Careers
Offices of CIA
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ABOUT
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APPENDICES
WELCOME TO THE WORLD FACTBOOK
The World Factbook provides information on the history, people, government, economy, geography, communications, transportation
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http://www.cia.gov/library/publications/the-world-factbook/
There's no place
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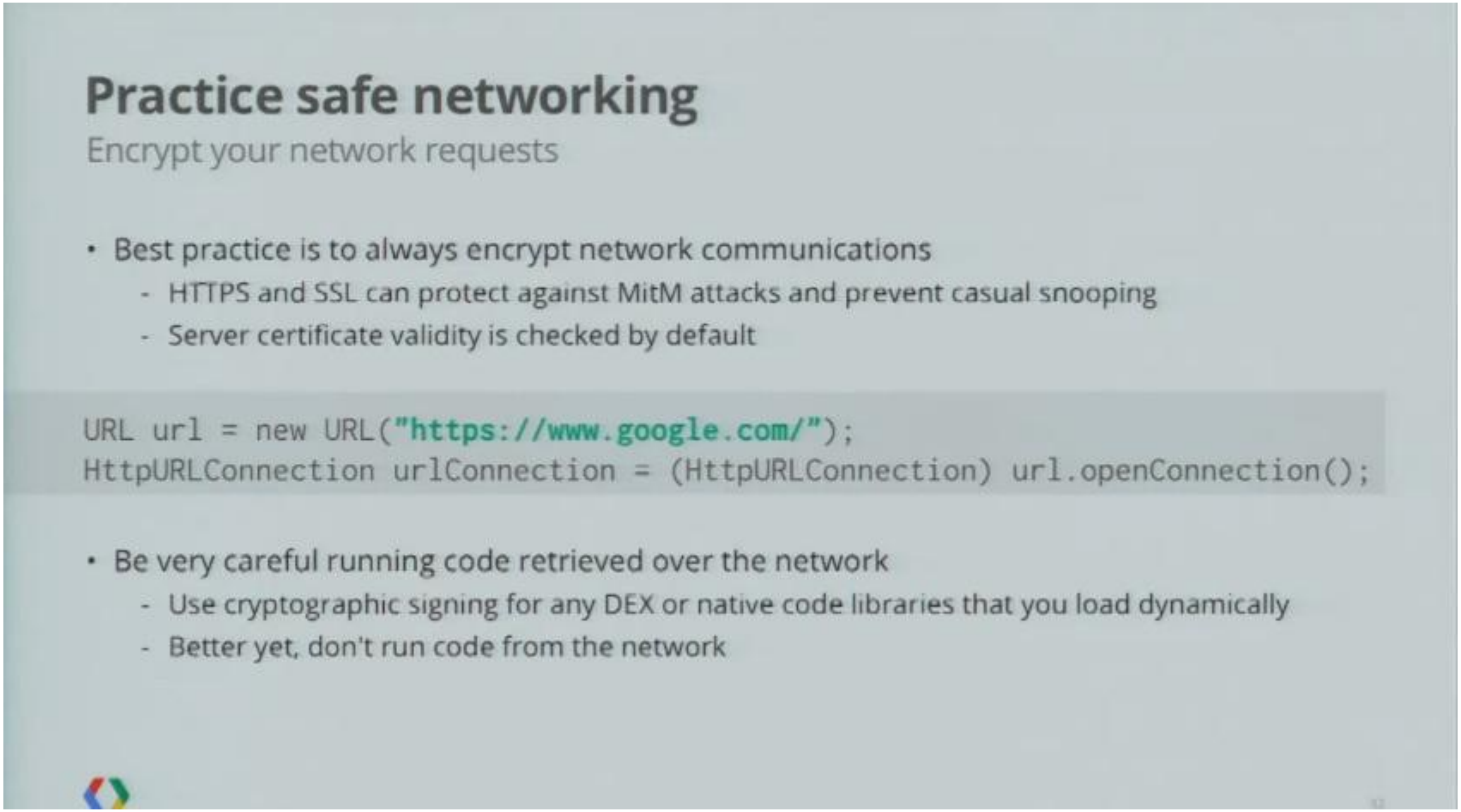


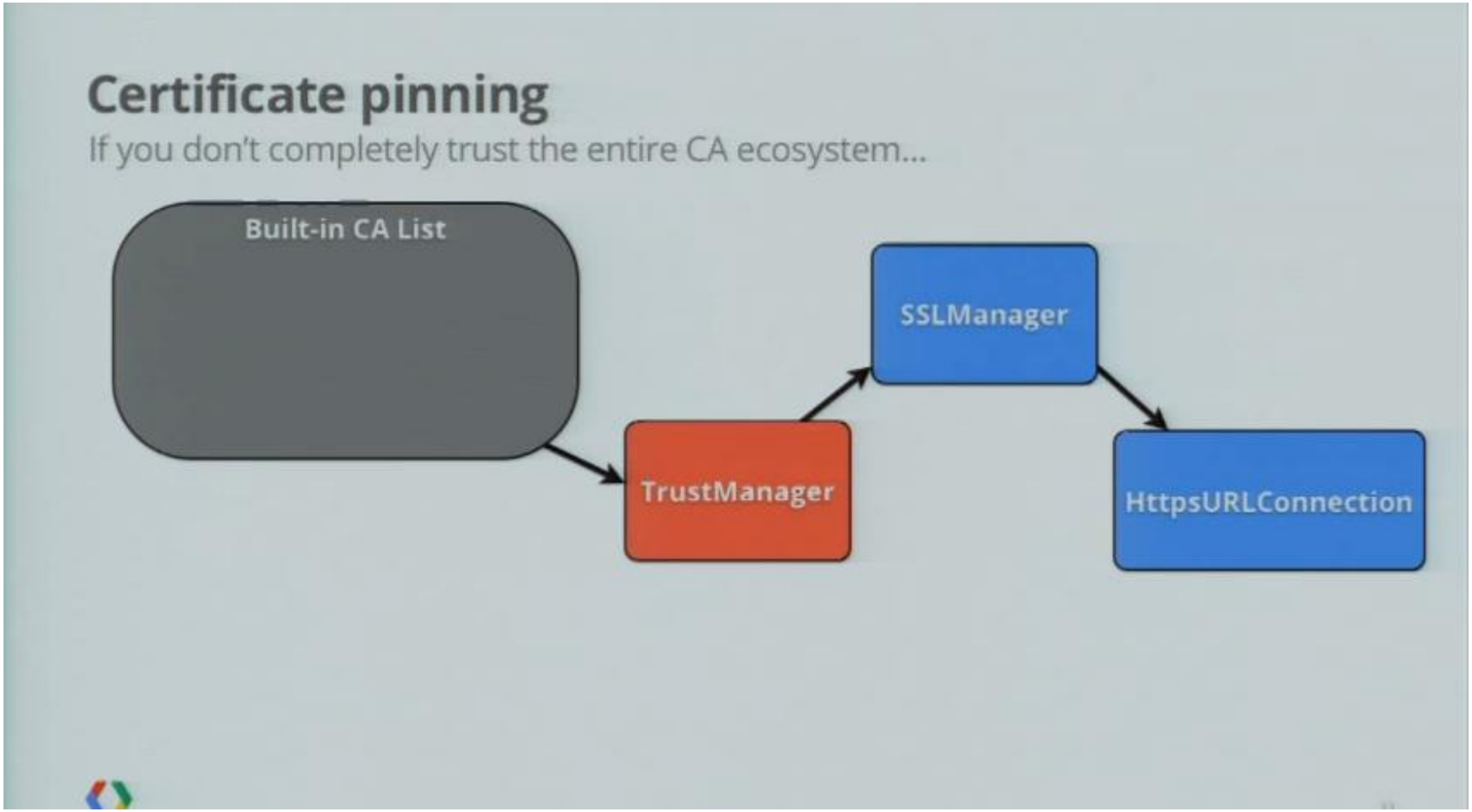
Practice safe networking

Encrypt your network requests

- Best practice is to always encrypt network communications
  - HTTPS and SSL can protect against MitM attacks and prevent casual snooping
  - Server certificate validity is checked by default

```
URL url = new URL("https://www.google.com/");
HttpURLConnection urlConnection = (HttpURLConnection) url.openConnection();
```

- Be very careful running code retrieved over the network
  - Use cryptographic signing for any DEX or native code libraries that you load dynamically
  - Better yet, don't run code from the network



Certificate pinning

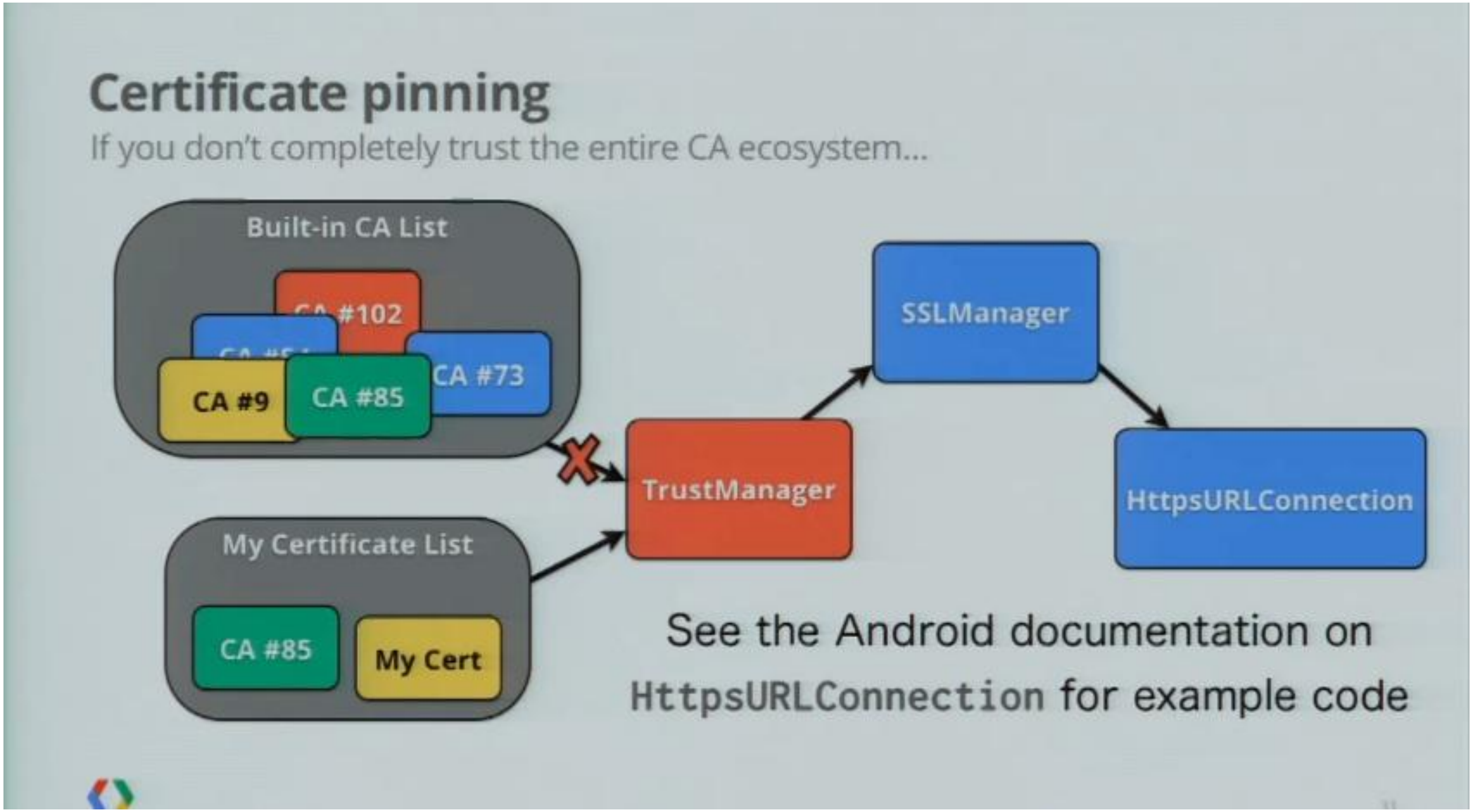
If you don't completely trust the entire CA ecosystem...

Built-in CA List

TrustManager

SSLManager

HttpsURLConnection



Certificate pinning

If you don't completely trust the entire CA ecosystem...

Built-in CA List

CA #102

CA #73

CA #9

CA #85

TrustManager

SSLManager

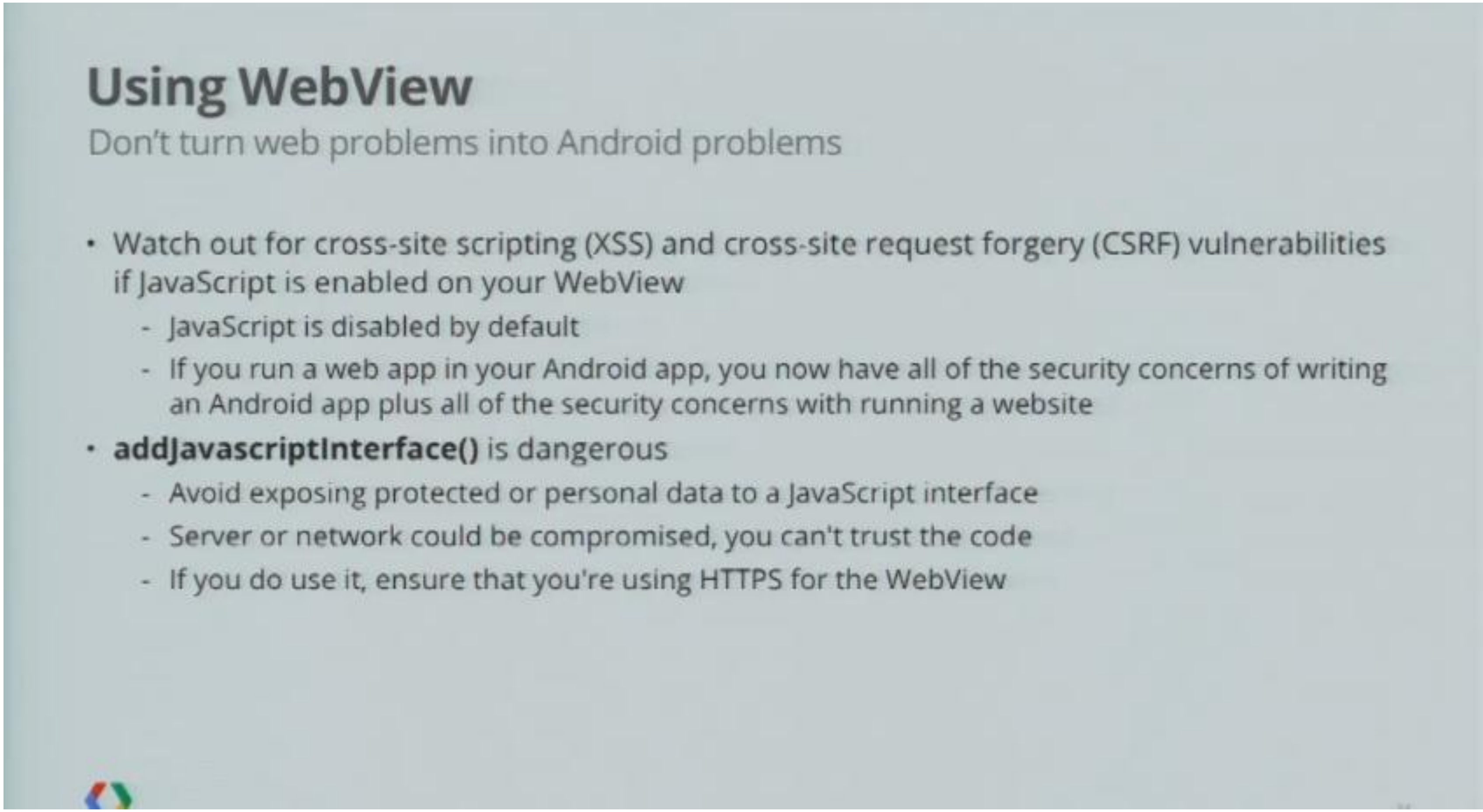
HttpsURLConnection

My Certificate List

CA #85

My Cert

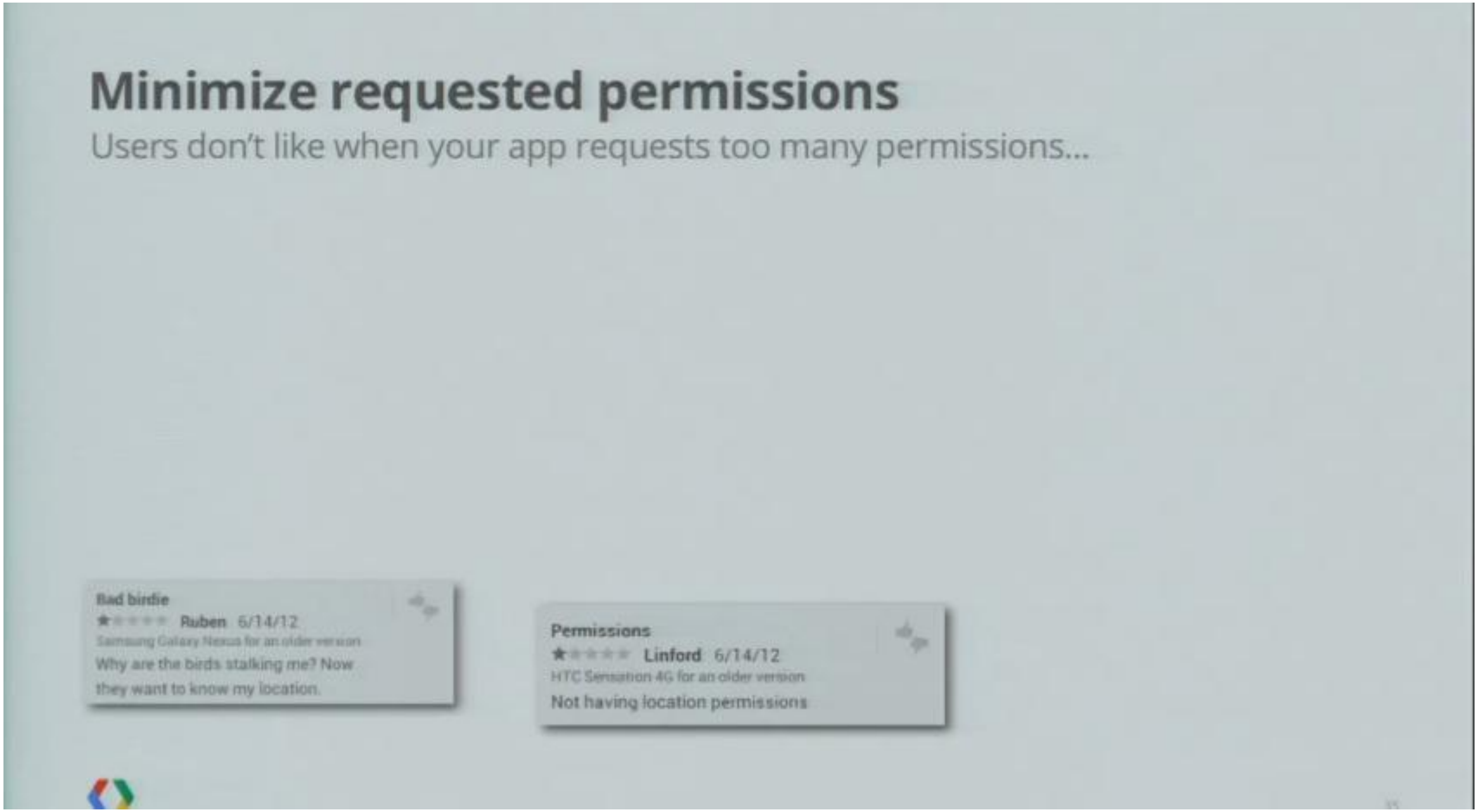
See the Android documentation on `HttpsURLConnection` for example code



Using WebView

Don't turn web problems into Android problems

- Watch out for cross-site scripting (XSS) and cross-site request forgery (CSRF) vulnerabilities if JavaScript is enabled on your WebView
  - JavaScript is disabled by default
  - If you run a web app in your Android app, you now have all of the security concerns of writing an Android app plus all of the security concerns with running a website
- **addJavascriptInterface()** is dangerous
  - Avoid exposing protected or personal data to a JavaScript interface
  - Server or network could be compromised, you can't trust the code
  - If you do use it, ensure that you're using HTTPS for the WebView

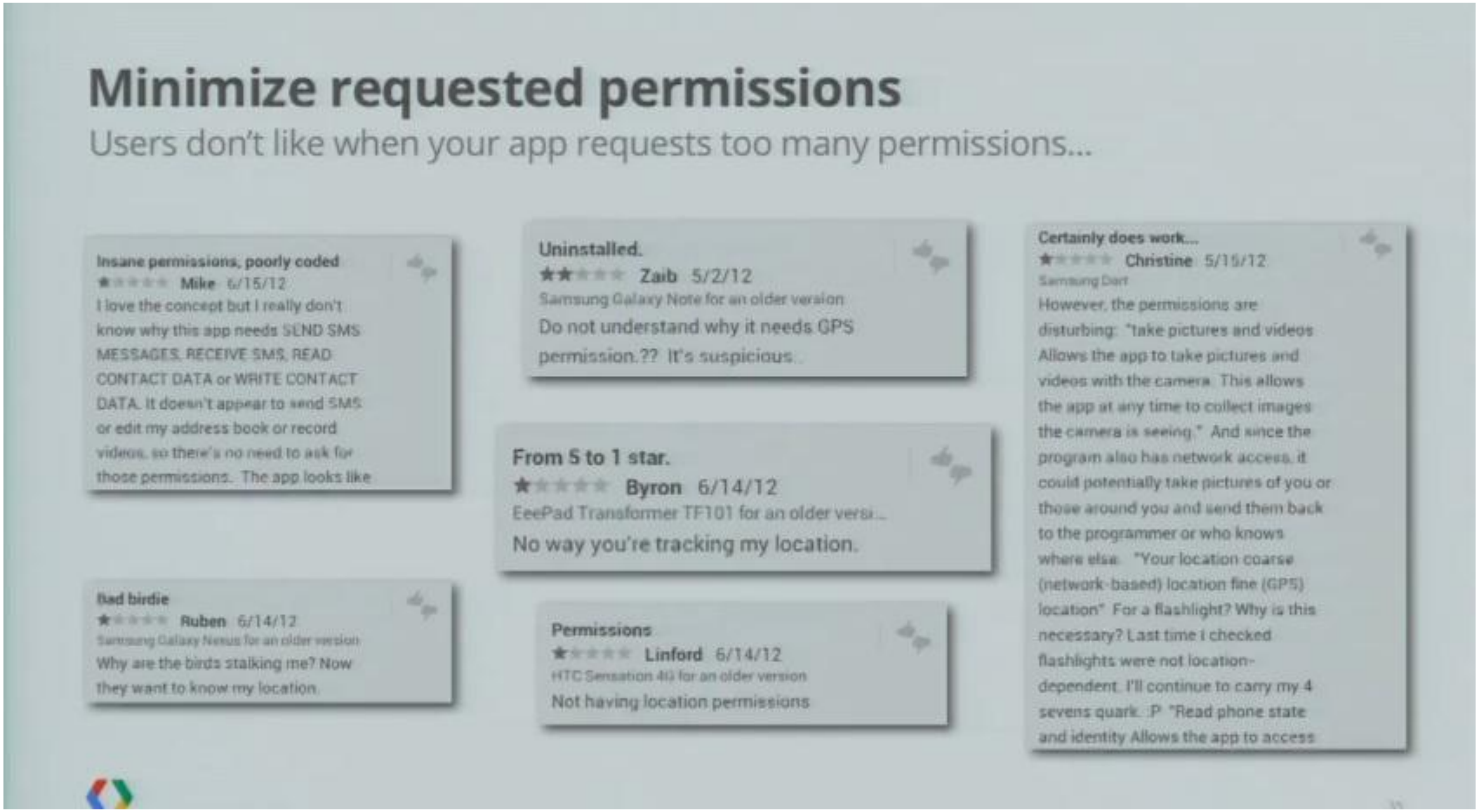


Minimize requested permissions

Users don't like when your app requests too many permissions...

Bad birdie
★☆☆☆☆ Ruben 6/14/12
Samsung Galaxy Nexus for an older version
Why are the birds stalking me? Now they want to know my location.

Permissions
★☆☆☆☆ Linford 6/14/12
HTC Sensation 4G for an older version
Not having location permissions



Minimize requested permissions

Users don't like when your app requests too many permissions...

Insane permissions, poorly coded
★☆☆☆☆ **Mike** 6/15/12
I love the concept but I really don't know why this app needs SEND SMS MESSAGES, RECEIVE SMS, READ CONTACT DATA or WRITE CONTACT DATA. It doesn't appear to send SMS or edit my address book or record videos, so there's no need to ask for those permissions. The app looks like

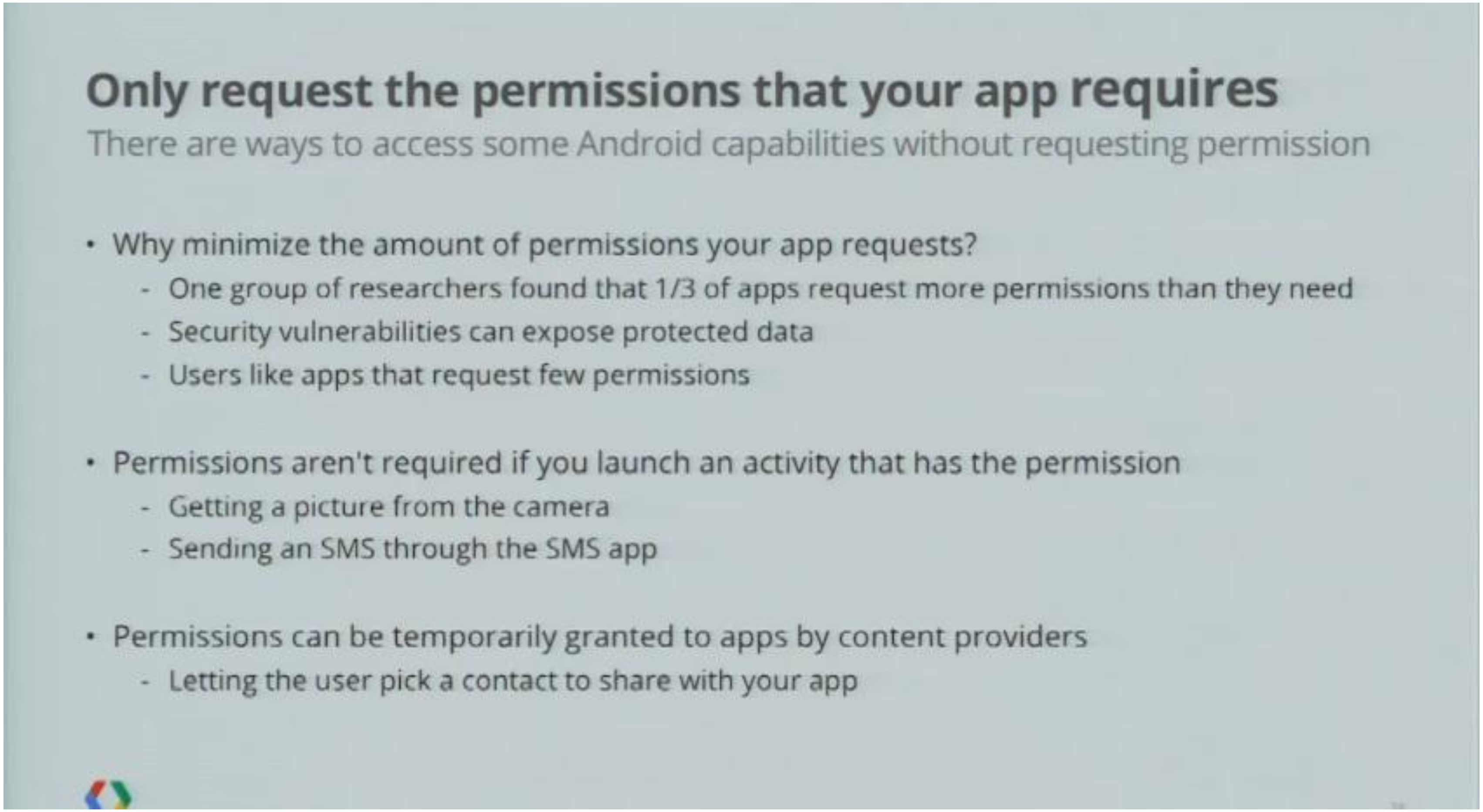
Uninstalled.
★★☆☆☆ **Zaib** 5/2/12
Samsung Galaxy Note for an older version
Do not understand why it needs GPS permission.?? It's suspicious.

From 5 to 1 star.
★☆☆☆☆ **Byron** 6/14/12
EeePad Transformer TF101 for an older versi...
No way you're tracking my location.

Bad birdie
★☆☆☆☆ **Ruben** 6/14/12
Samsung Galaxy Nexus for an older version
Why are the birds stalking me? Now they want to know my location.

Permissions
★☆☆☆☆ **Linford** 6/14/12
HTC Sensation 4G for an older version
Not having location permissions

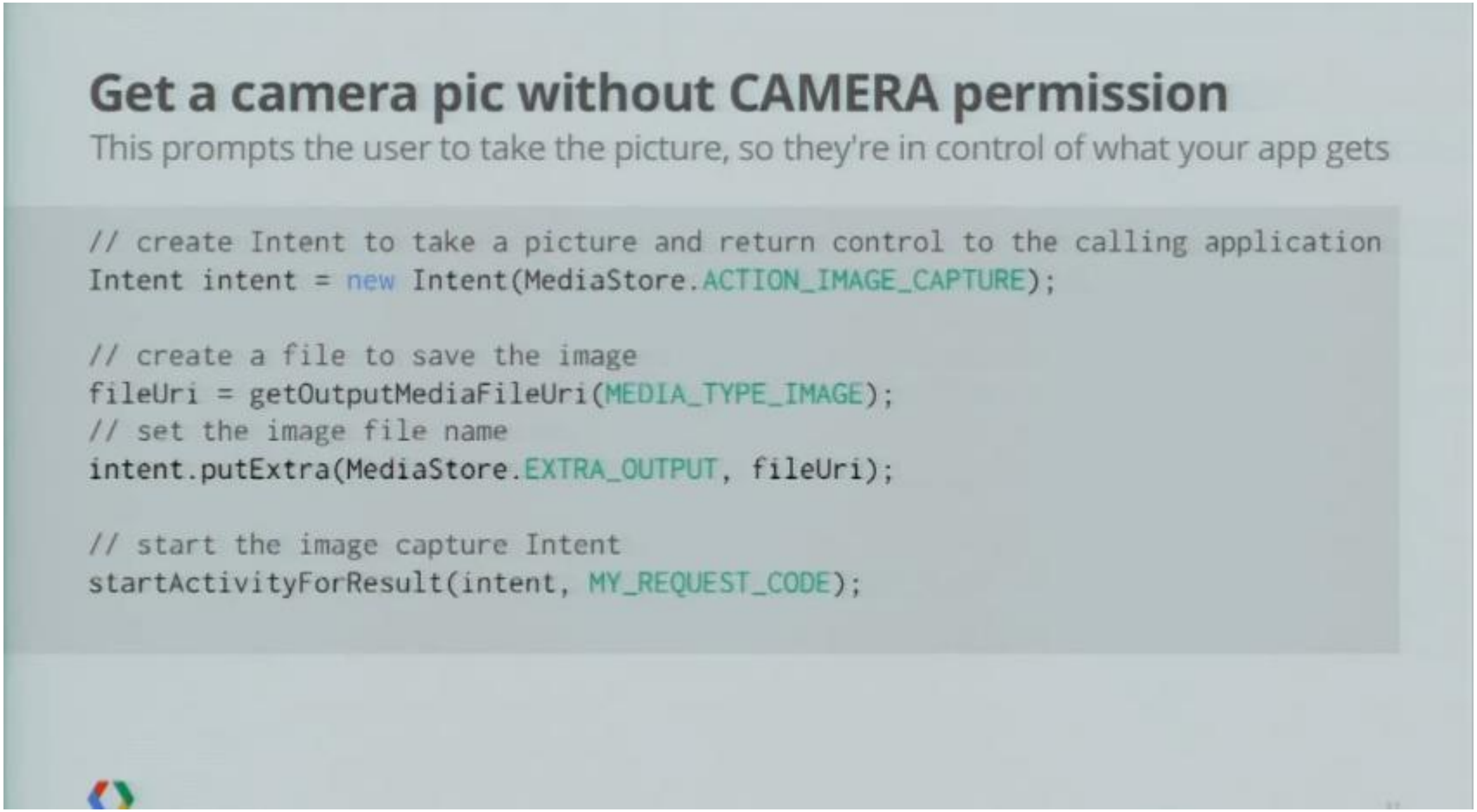
Certainly does work...
★☆☆☆☆ **Christine** 5/15/12
Samsung Dart
However, the permissions are disturbing: "take pictures and videos Allows the app to take pictures and videos with the camera. This allows the app at any time to collect images the camera is seeing." And since the program also has network access, it could potentially take pictures of you or those around you and send them back to the programmer or who knows where else. "Your location coarse (network-based) location fine (GPS) location" For a flashlight? Why is this necessary? Last time I checked flashlights were not location-dependent. I'll continue to carry my 4 sevens quark. :P "Read phone state and identity Allows the app to access



Only request the permissions that your app requires

There are ways to access some Android capabilities without requesting permission

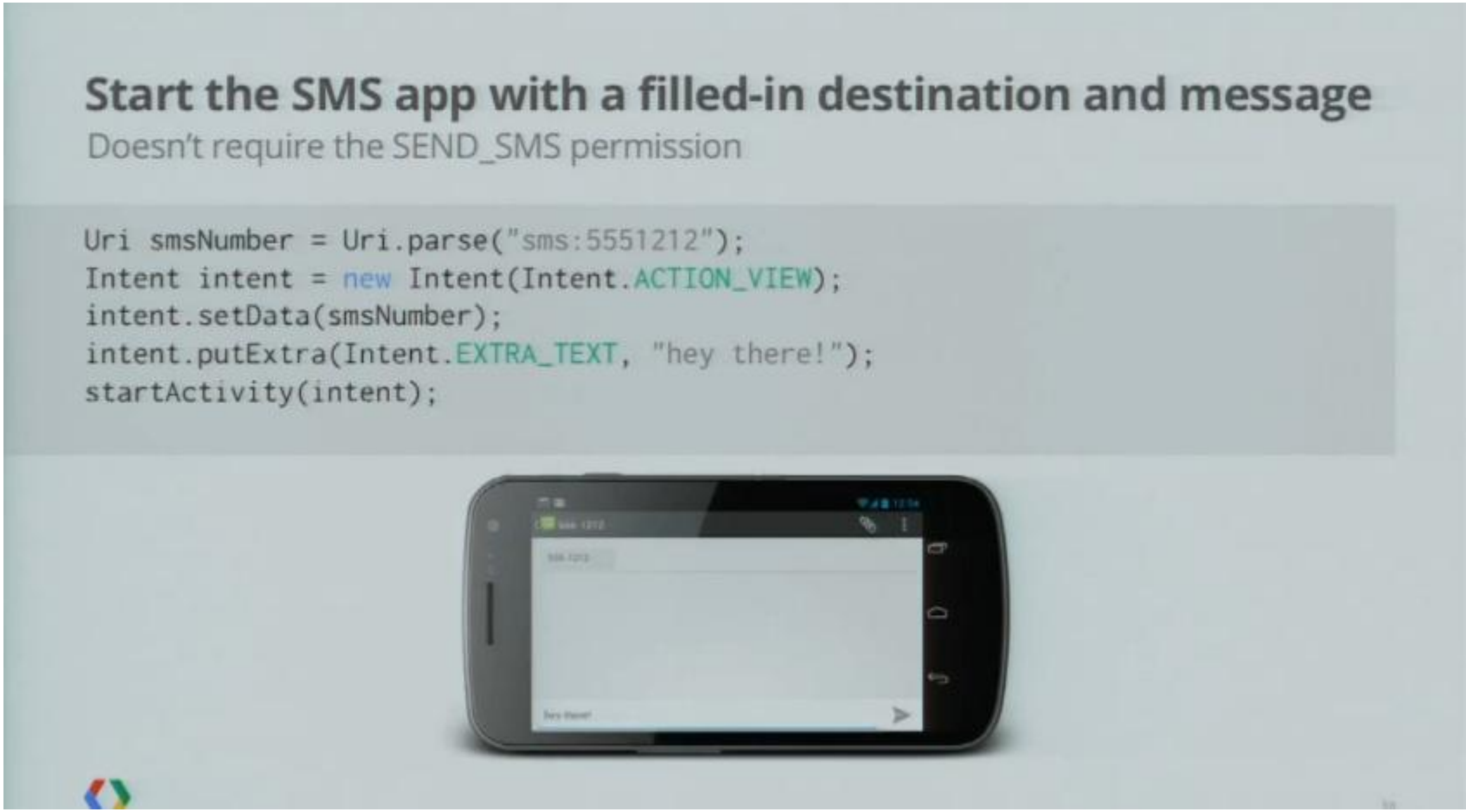
- Why minimize the amount of permissions your app requests?
  - One group of researchers found that 1/3 of apps request more permissions than they need
  - Security vulnerabilities can expose protected data
  - Users like apps that request few permissions
- Permissions aren't required if you launch an activity that has the permission
  - Getting a picture from the camera
  - Sending an SMS through the SMS app
- Permissions can be temporarily granted to apps by content providers
  - Letting the user pick a contact to share with your app



Get a camera pic without CAMERA permission

This prompts the user to take the picture, so they're in control of what your app gets

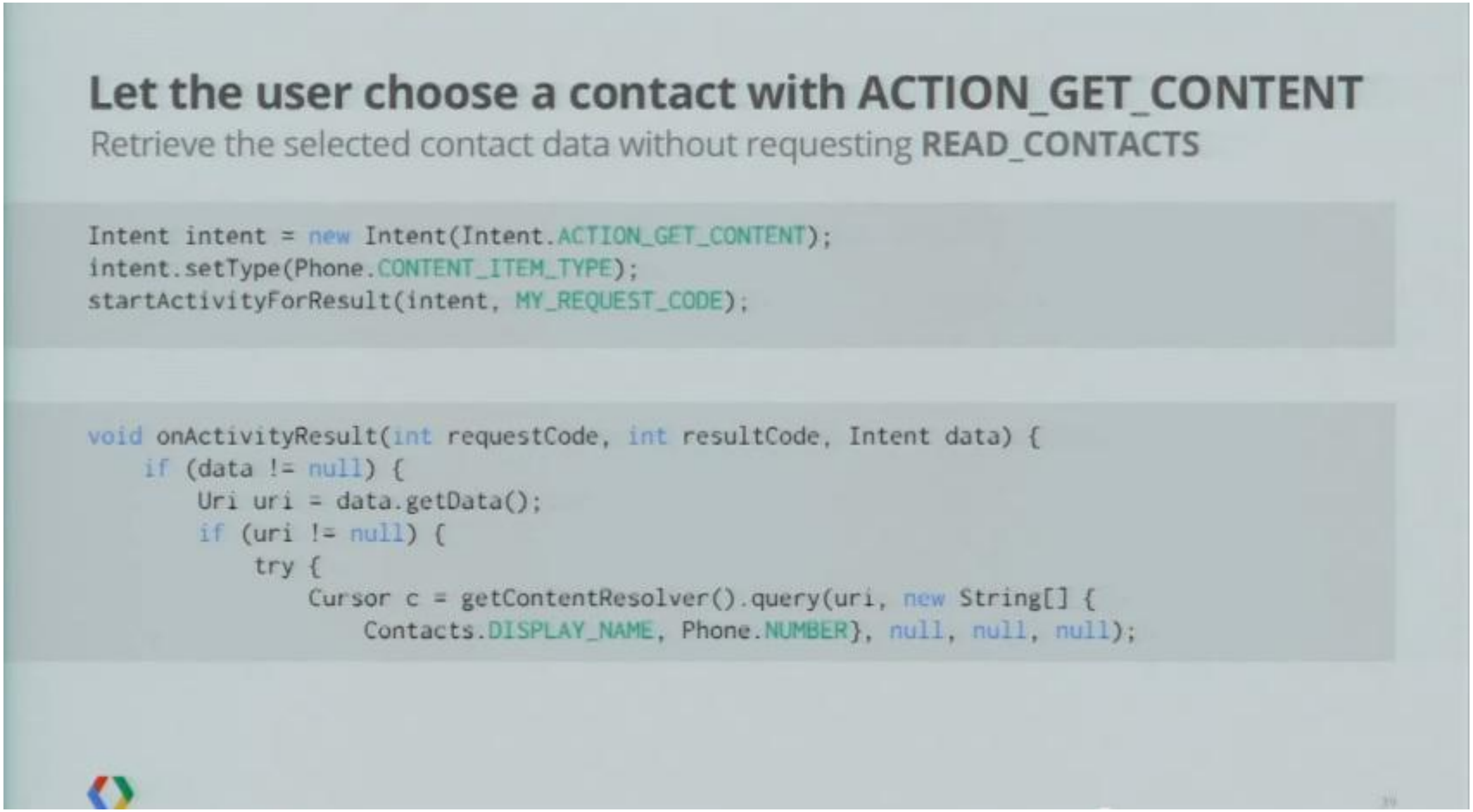
```
// create Intent to take a picture and return control to the calling application
Intent intent = new Intent(MediaStore.ACTION_IMAGE_CAPTURE);

// create a file to save the image
fileUri = getOutputMediaFileUri(MEDIA_TYPE_IMAGE);
// set the image file name
intent.putExtra(MediaStore.EXTRA_OUTPUT, fileUri);

// start the image capture Intent
startActivityForResult(intent, MY_REQUEST_CODE);
```



Start the SMS app with a filled-in destination and message

Doesn't require the SEND_SMS permission

```
Uri smsNumber = Uri.parse("sms:5551212");
Intent intent = new Intent(Intent.ACTION_VIEW);
intent.setData(smsNumber);
intent.putExtra(Intent.EXTRA_TEXT, "hey there!");
startActivity(intent);
```

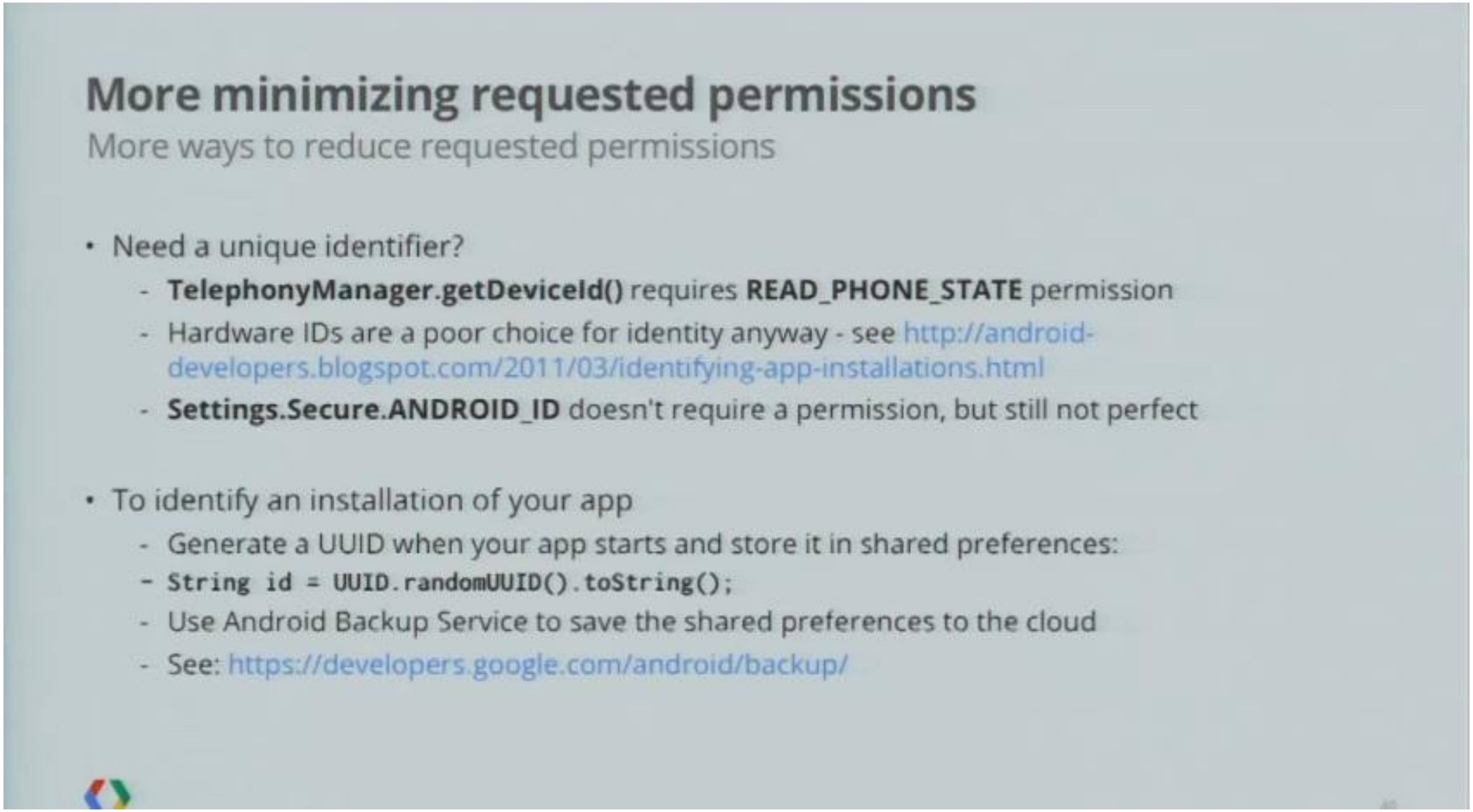


Let the user choose a contact with ACTION_GET_CONTENT

Retrieve the selected contact data without requesting **READ_CONTACTS**

```
Intent intent = new Intent(Intent.ACTION_GET_CONTENT);
intent.setType(Phone.CONTENT_ITEM_TYPE);
startActivityForResult(intent, MY_REQUEST_CODE);
```

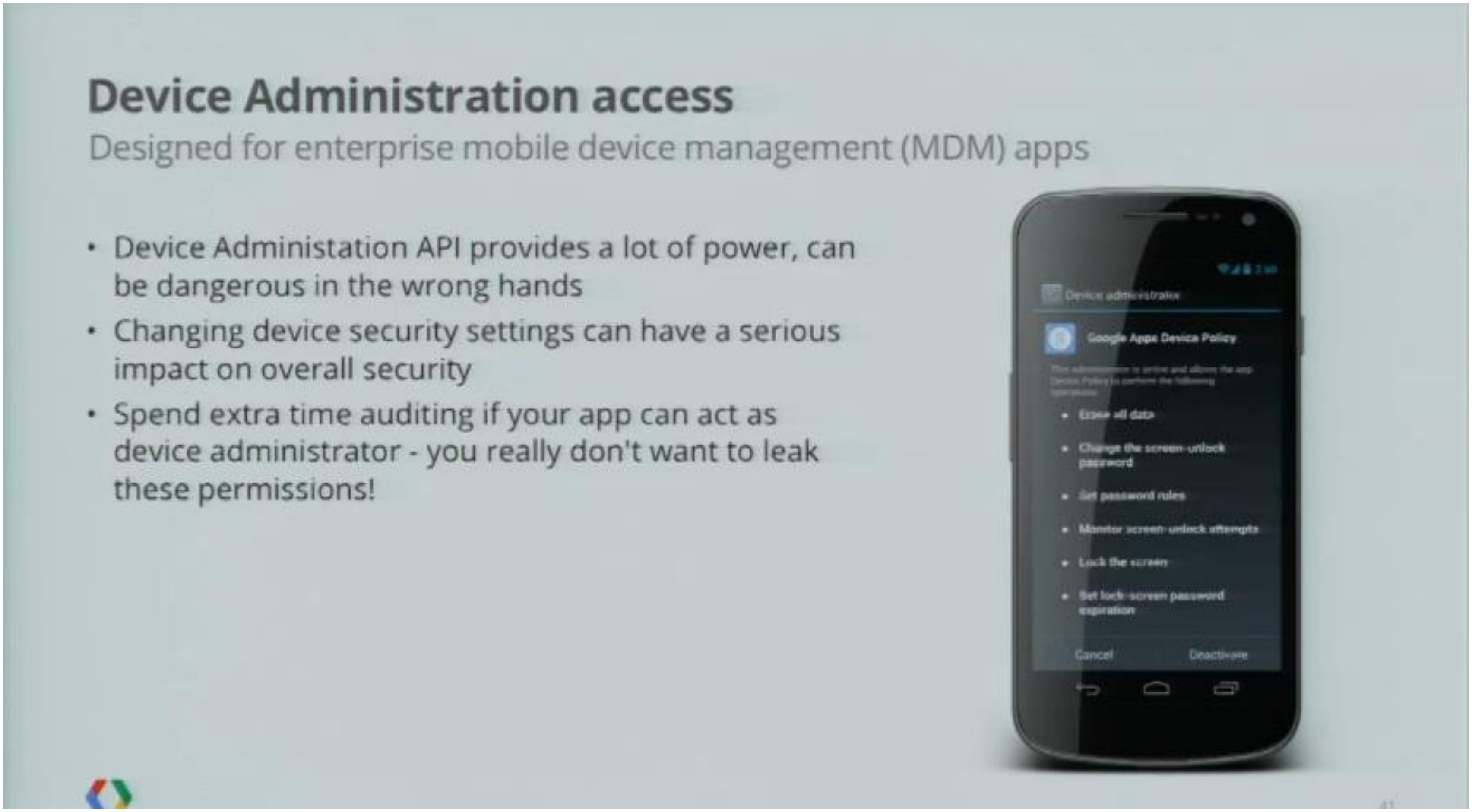
```
void onActivityResult(int requestCode, int resultCode, Intent data) {
    if (data != null) {
        Uri uri = data.getData();
        if (uri != null) {
            try {
                Cursor c = getContentResolver().query(uri, new String[] {
                    Contacts.DISPLAY_NAME, Phone.NUMBER}, null, null, null);
```



More minimizing requested permissions

More ways to reduce requested permissions

- Need a unique identifier?
  - **TelephonyManager.getDeviceId()** requires **READ_PHONE_STATE** permission
  - Hardware IDs are a poor choice for identity anyway - see http://android-developers.blogspot.com/2011/03/identifying-app-installations.html
  - **Settings.Secure.ANDROID_ID** doesn't require a permission, but still not perfect
- To identify an installation of your app
  - Generate a UUID when your app starts and store it in shared preferences:
  - `String id = UUID.randomUUID().toString();`
  - Use Android Backup Service to save the shared preferences to the cloud
  - See: https://developers.google.com/android/backup/



Device Administration access

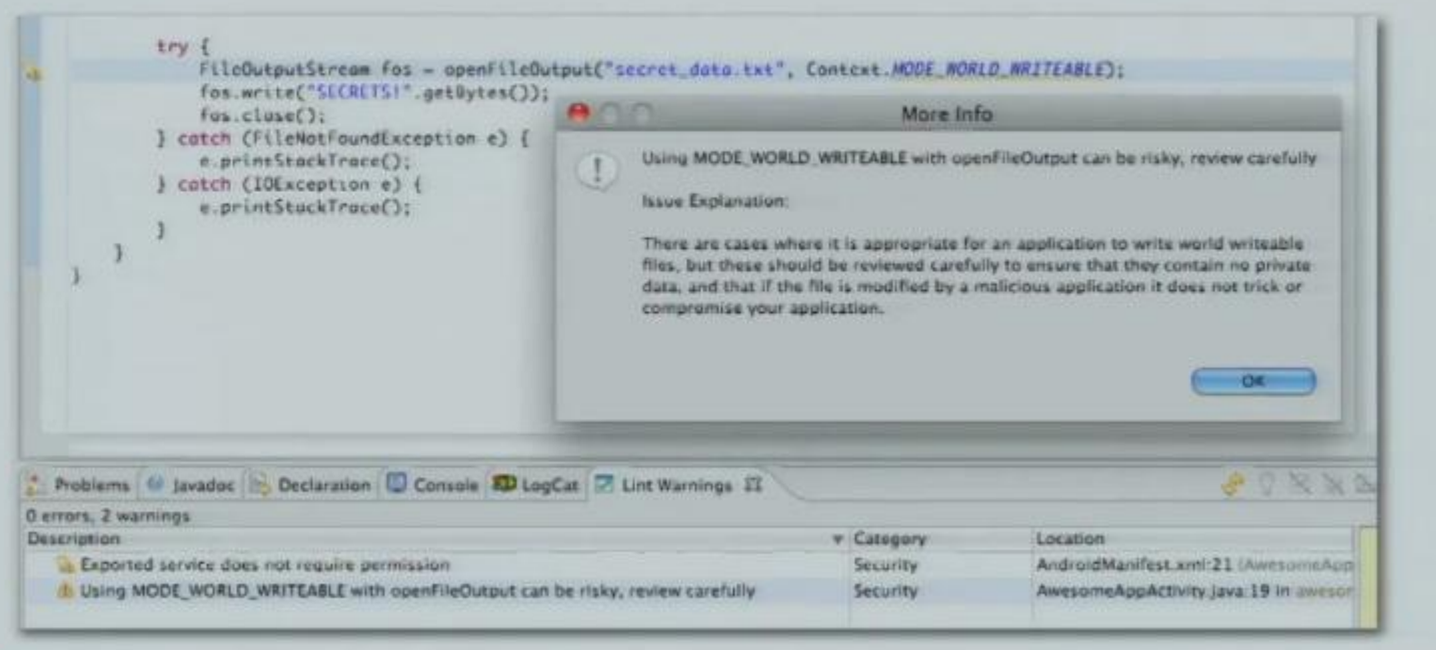
Designed for enterprise mobile device management (MDM) apps

- Device Administation API provides a lot of power, can be dangerous in the wrong hands
- Changing device security settings can have a serious impact on overall security
- Spend extra time auditing if your app can act as device administrator - you really don't want to leak these permissions!

Device administrator
Google Apps Device Policy
This administrator is active and allows the app Device Policy to perform the following operations:
• Erase all data
• Change the screen-unlock password
• Set password rules
• Monitor screen-unlock attempts
• Lock the screen
• Set lock-screen password expiration
Cancel
Deactivate

Use Android Lint

Lint comes with the Android SDK and detects common programming errors



```
        try {
            FileOutputStream fos = openFileOutput("secret_data.txt", Context.MODE_WORLD_WRITEABLE);
            fos.write("SECRETS!".getBytes());
            fos.close();
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

More Info

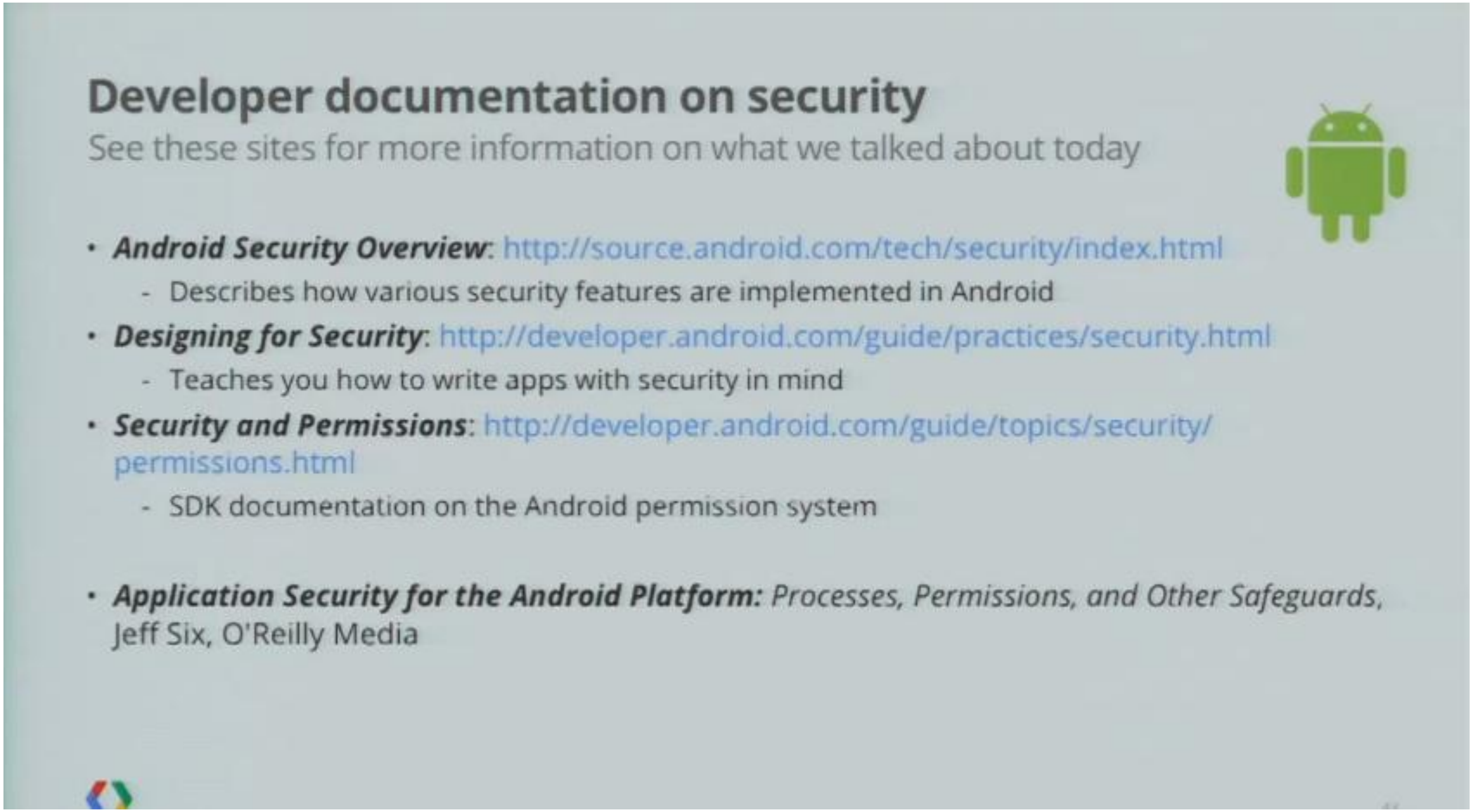
Using MODE_WORLD_WRITEABLE with openFileOutput can be risky, review carefully

Issue Explanation:

There are cases where it is appropriate for an application to write world writeable files, but these should be reviewed carefully to ensure that they contain no private data, and that if the file is modified by a malicious application it does not trick or compromise your application.

0 errors, 2 warnings

Description	Category	Location
Exported service does not require permission	Security	AndroidManifest.xml:21 (AwesomeApp
Using MODE_WORLD_WRITEABLE with openFileOutput can be risky, review carefully	Security	AwesomeAppActivity.java:19 in aweso



Developer documentation on security

See these sites for more information on what we talked about today

- ***Android Security Overview***: http://source.android.com/tech/security/index.html
  - Describes how various security features are implemented in Android
- ***Designing for Security***: http://developer.android.com/guide/practices/security.html
  - Teaches you how to write apps with security in mind
- ***Security and Permissions***: http://developer.android.com/guide/topics/security/permissions.html
  - SDK documentation on the Android permission system

- ***Application Security for the Android Platform:*** *Processes, Permissions, and Other Safeguards,* Jeff Six, O'Reilly Media