

Lecture 08 Android Permissions Demystified

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Android Permission System

Stowaway

Keywords



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Keywords



- Android OS security
- ► Coarse permission model
- ► A lot of research on Android permissions
- Applications with unnecessary permissions
- ▶ Paper doesn't focus on the malicious use of permissions



- lacktriangle Java source code ightarrow compiled into .dex byte-code file
- ▶ .dex file + Manifest file + resources = .apk archive
- ▶ Application isolation → system level security
 - ► Linux process, address space
 - ▶ VM (Dalvik Virtual Machine) for each application
 - unique Linux user ID
 - direct access only to its own data
 - ► API-based access to other apps' resources
- ▶ Not a single entry-point (no main)
- Applications can start each other
- ► Based on Components and Intents

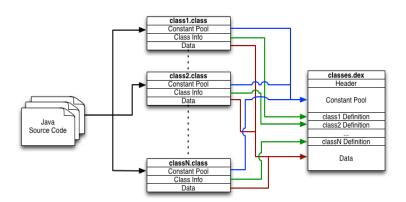


- .dex Dalvik Executable format
- ▶ Dalvik is optimised for mobile architectures
 - ▶ low memory consumption
 - ► Dex results in smaller binaries than JAR
- register-based architecture (JVM is stack-based)
- Java VM cannot execute Dalvik code
- ▶ 16-bit instructions
- copy-on-write memory sharing
- dx cross-compiler works with javac output (oracle and openJDK, but not GCJ or other java compilers)

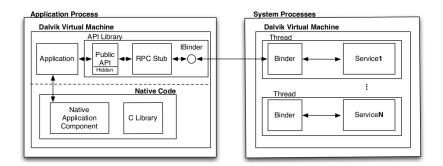


Java Compiler

dx









- ► Extends *Activity* base class
- ▶ User interfaces: UI elements(buttons, lists) and user input
- ▶ User interacts with one activity at a time
- ▶ Independent life-cycle, 4 states
 - active (running)
 - paused
 - stopped still resides in memory
 - killed removed from memory
- Activities stack
- Activities can launch other activities



- Extends Service base class
- Background processing
- ▶ It runs by default in the same process as the application
- ► Can provide functionality also for other applications



- Extends BroadcastReceiver base class
- Receive broadcast announcements, example: low battery, changed phone settings
- React to messages: start an activity or use NotificationManager
- Static registration specified in the Manifest file
- Dynamic registration Context.registerReceiver()
- Active only while it's responding to a broadcast message, no need to shut it down.



- ► Store and Share applications' data
- Required when sharing data between multiple applications
- Must be declared in the Manifest file
- Accessed with ContentResolver using URIs
- Uses relational databases
- Active only while it's responding to a request from a ContentResolver, no need to shut it down explicitly



Intents

- Extend Intent class
- ▶ Used for inter-component signaling
- Used for starting activities, services and sending broadcast messages
- ▶ IntentFilters specified in the Manifest file
- ► Contain actions to be performed and data for these actions
- ► Example: action = make a phone call, data = phone number
- ContentProviders do not use intents



- ► XML configuration file
- ► Every application must have it
- Contains:
 - ► application's name, icon, labels
 - linked libraries
 - application components: <activity>, <service>,
 <receiver>, provider> tags
 - Activity shown at launch time
 - ► Intent filters
 - Permissions



Panoramio App:

```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"</pre>
    package="com.google.android.panoramio">
    <application android:icon="@drawable/icon">
        <activity android:name=".Panoramio" android:label="@string/app name"
                android:theme="@style/Theme.Panoramio">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />
                <category android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
                <activity android:name=".ImageList" android:label="@string/app name"</pre>
                        android:theme="@android:style/Theme.Light"/>
                <activity android:name=".ViewImage" android:label="@string/app name"</pre>
                        android: theme="@style/Theme.Panoramio"/>
        <activity android:name=".ViewMap" android:label="@string/app name"/>
                <uses-library android:name="com.google.android.maps" />
    </application>
        <uses-permission android:name="android.permission.INTERNET"/>
    <uses-permission android:name="android.permission.ACCESS FINE LOCATION"/>
        <uses-permission android:name="android.permission.ACCESS COARSE LOCATION"/>
</manifest>
```



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- Android Framework Security
- ► Mandatory Access Control(MAC) enforced by middleware
- ► Components protected using access permission labels
 - declared in the AndroidManifest file
 - can not be changed after installation
 - ▶ 4 protection levels
 - normal always granted
 - dangerous requires user approval
 - signature matching certificate
 - signature or system matching certificate with system image



- ► At install-time each application requests a list of permissions
- ▶ All permissions must be granted at install time all or nothing
- ▶ Protect access to Android components, services and APIs
 - e.g API for access to phone's hardware
- $ightharpoonup \sim 130$ API-defined permissions in *Manifest.Permissions* class ¹
- Custom-defined permissions by developers
 - name conflicts may appear
 - current research on Android permissions doesn't take them into consideration



activity

- restricts access to the activity
- checked when starting activity
- throw SecurityException if caller does not have required permission

service

restricts who can start, stop or bind to the service

receiver

- restricts who can send broadcasts to the BroadcastReceiver.
- checked at delivery, after broadcast was sent
- does not throw exception in case of permission failure

provider

- restrict who can access the data
- ► read and write permissions
- checked when performing operations(e.g. query, insert)





Broadcast permissions

permission label as parameter to the sending method (sendBroadcast)

Direct permission check

- checkPermission methods
- check against PID, package name

URI Permissions

- ▶ Provide finer control over content sharing
- Record level delegation
- Set flags in the Intent that allow access (e.g. Intent.FLAG_GRANT_READ_URI_PERMISSION)
- ▶ example: view mail attachments



- Usability study by the same authors
- ▶ Are users paying attention to the permissions?
- ▶ Do users understand the permissions?
- ► Can users make correct security decisions?
- Results: too few users comprehend or pay attention
- ▶ ⇒ security risks



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- ▶ The problem: unnecessary use of permissions
- ▶ The proposed solution: static analysis of API calls
- Permission map identifies permissions for Intents, Content Provides, API calls
- ▶ Stowaway tool determines if an app is overprivileged or not
- ▶ 2011 paper → research performed on Android 2.2 SDK



- ▶ Map of permissions for each method in the Android API
- ► Log permission checks → modified middleware
- ► Test cases for API calls, Intents, Content Providers



► Feedback-Directed Testing

- Randoop unit test generator
- receives a list of classes as input
- tries to cover all possible combinations of calls
- use return values as parameters for other methods
- limitations
 - ▶ find an object of the correct type needed to invoke a method
 - object created through API calls with specific parameters
 - methods precede each other in a very specific order
 - native code generate segmentation faults if called out of order



- ► Customizable Test Case Generation
 - custom tool for building methods unit tests
 - ▶ list of method signatures as input
 - outputs at least one unit test for each method
 - allows manual adjustments of test sequences order, parameters



- Manual Verification
 - solves inconsistencies
 - argument-dependent permission requirment
 - ► API calls order-dependent
 - test cases with and without permissions
 - ▶ identified methods that require INTERNET permission
 - tests run until no security exceptions appeared



Content Providers

- collected all URIs
- ▶ test operations: query, insert, update, delete
- run test with and without permissions
- tests run until no security exceptions appeared

► Intents

- send/receive between a pair of applications
- searched API for all Intent action strings
- tested all Intent action on the pair of apps
- triggered system broadcasts



- ▶ 85% coverage of Android 2.2 API
- Proves the limitation of Android documentation of permissions
 - ▶ 1259 API calls with permission checks
 - only 78 methods with permission requirements in the documentation
 - documentation for 6 API calls is incorrect
- ► Characterized how permissions are distributed in the API
 - system permissions, hierarchical permissions, unused permissions
 - number of checks, permissions granularity
- Distribution of permissions per classes



- ► Available online for testing overprivileged applications
- ► Parses applications' API calls
- ▶ Identifies which declared permissions are actually needed



- Dissasembles Dexfiles Dedexer tool
 - ▶ easy to parse method calls
- Identifies API calls
- ▶ Identifies Content Provider URIs
- Uses ComDroid for Intents



- ▶ Dex files parsing
- Identifies calls to API methods
- Problems
 - Java Reflection
 - use heuristics
 - ▶ Internet and External Storage permissions
 - enforced by the kernel not the middleware checker
 - Stowaway parses the app's XML files



- Parses URI strings
 - detects strings with "content://"
 - detects URI API constants
- Cannot know the exact database operation from the URI



- ▶ Uses *ComDroid* static analysis tool²
- ComDroid tracks Intents
- ► For each Intent Stowaway checks
 - permission to send Intent
 - permission to receive Intent

²developed by the same authors - http://www.comdroid.org/⟨♠ → ⟨♠ → ♠ ♠ → ◇ △ ○



- ► Testbed of 940 applications
 - ▶ 40 apps Stowaway vs manual analysis
 - ▶ 900 apps automated analysis
- ▶ 7% false positives rate
- ▶ 35% applications were found to be overprivileged
 - ▶ 56% declare one extra permission
 - ▶ 94% have 4 or fewer extra permissions



Most common unnecessary permissions:

| Permission | \mathbf{Usage} |
|------------------------|------------------|
| ACCESS_NETWORK_STATE | 16% |
| READ_PHONE_STATE | 13% |
| ACCESS_WIFI_STATE | 8% |
| WRITE_EXTERNAL_STORAGE | 7% |
| CALL_PHONE | 6% |
| ACCESS_COARSE_LOCATION | 6% |
| CAMERA | 6% |
| WRITE_SETTINGS | 5% |
| ACCESS_MOCK_LOCATION | 5% |
| GET_TASKS | 5% |

► *Usage* - the percentage of applications that request the permission.



- ► Confusing permission names
 - request permissions in pairs when only one is required
- ▶ Deputies app sends Intent to another app
 - ▶ the deputy app requires the permission
 - ▶ the sender app doesn't need to declare the permission
 - ▶ e.g. INSTALL_PACKAGES Google Play app installs packages
 - camera, browser, phone dialer



- ► Related Methods getters and setters (read/write permissions)
 - ▶ app uses only getters but declares the WRITE.... permission
- Copy and Paste copying incorrect examples
- ► Deprecated Permissions
- ► Testing Artifacts used when developing and testing the app
 - ACCESS_MOCK_LOCATION
- Declared intentionally for automatic updates



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- Android
- operating system security
- permission system
- overpriviledged
- permission map

- ► API Calls
- Intents
- Content providers
- ► Randoop automated testing



- Stowaway http://android-permissions.org/
- Research on Android permissions: http://www.cs.berkeley.edu/~afelt/
- Understanding Android Security, William Enck, Machigar Ongtang, and Patrick McDaniel IEEE Security & Privacy Magazine, 7(1):50–57, January/February, 2009
- Android Permissions: User Attention, Comprehension, and Behavior, Adrienne Porter Felt et al, Symposium on Usable Privacy and Security (SOUPS) 2012
- Android Permissions documentation: http://developer.android.com/guide/topics/ security/permissions.html



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