Lecture 08

Android Permissions Demystified

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Outline

Context

- 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

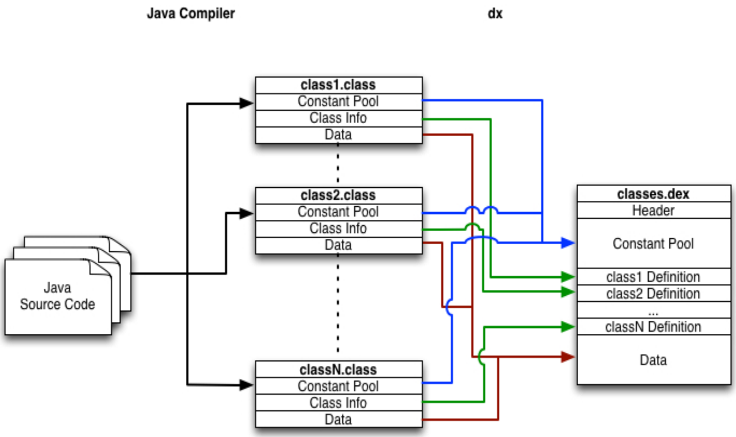
Android Applications

- Java source code → 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**

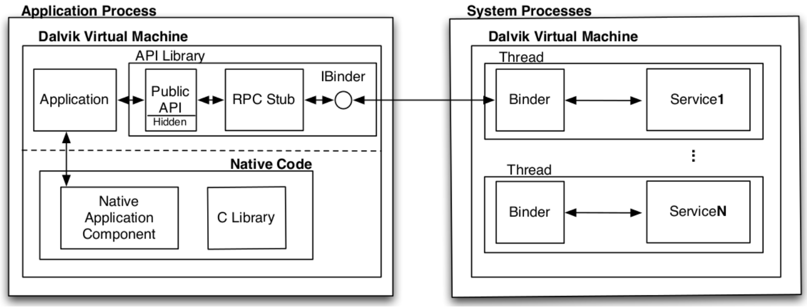
Dalvik Virtual Machine

- *.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)

Compiling Applications



Android Architecture



Components: Activity

- 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

Components: Service

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

Components: Broadcast Receiver

- 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.

Components: Content Provider

- 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

Inter-Component Communication

- **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

AndroidManifest

- 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**

AndroidManifest Example

Panoramio App:

```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    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"
                        android:theme="@android:style/Theme.Light"/>

                <activity android:name=".ViewImage" android:label="@string/app_name"
                        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>
```

Outline

Application Framework Security

- 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
- ∼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

[1] http://developer.android.com/reference/android/Manifest.permission.html

Permissions in AndroidManifest for components

- **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)

Permissions in source code

- **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

User Attention, Comprehension, and Behavior

- 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
- $\Rightarrow$ security risks

Outline

- 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 $\rightarrow$ research performed on Android 2.2 SDK

Permission Map

- Map of permissions for each method in the Android API
- Log permission checks $\rightarrow$ modified middleware
- Test cases for API calls, Intents, Content Providers

Permission Map: API Calls

- 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

Permission Map: API Calls

- 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

Permission Map: API Calls

- 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

Permission Map: Content Providers and Intents

- 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

Permission Map Results

- 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

Stowaway: Overview

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

Application analysis

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

Application analysis: API calls

- 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

Application analysis: Content Providers

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

Application analysis: Intents

- Uses *ComDroid* static analysis tool[2]
- ComDroid tracks Intents
- For each Intent Stowaway checks
  - permission to send Intent
  - permission to receive Intent

[2]developed by the same authors - http://www.comdroid.org/

Evaluation

- 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

Unncessary permissions

Most common unnecessary permissions:

Permission	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.

Developer errors

- 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

Developer errors (2)

- 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

Outline

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

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

Resources

- 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`