463.11.1 Mobile OS Security

Computer Security II
CS463/ECE424
University of Illinois
Security News of the Day

https://www.zdnet.com/article/google-releases-second-android-12-developer-preview/

Google releases second Android 12 developer preview

The latest preview includes rounded corners APIs, improved picture-in-picture APIs, controls and extended security for lockscreen notification actions.

HOW ARE WE DOING WITH ANDROID’S OVERLAY ATTACKS IN 2020?

Emilian Cebuc, 27 March 2020

463.11.1 Mobile OS Security Overview (Today)
463.11.2 Attacks on Android (Next Class)
Mobile Phone Evolution

- **Basic Phone**
  - Phone call + SMS

- **Feature Phones**
  - Extra features on the phone firmware itself
  - Typically provided by the phone manufacturer

- **Smart Phones**
  - API available that enables third-party apps
# Mobiles, Tablets, PC sales

## Worldwide Device Shipments by Device Type, 2018-2021 (Millions of Units)

<table>
<thead>
<tr>
<th>Device Type</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional PCs (Desk-Based and Notebook)</td>
<td>195,317</td>
<td>189,472</td>
<td>182,823</td>
<td>175,058</td>
</tr>
<tr>
<td>Ultramobiles (Premium)</td>
<td>64,471</td>
<td>68,869</td>
<td>74,432</td>
<td>79,871</td>
</tr>
<tr>
<td><strong>Total PC Market</strong></td>
<td><strong>259,787</strong></td>
<td><strong>258,341</strong></td>
<td><strong>257,255</strong></td>
<td><strong>254,929</strong></td>
</tr>
<tr>
<td>Ultramobiles (Basic and Utility)</td>
<td>149,561</td>
<td>147,963</td>
<td>145,811</td>
<td>143,707</td>
</tr>
<tr>
<td><strong>Computing Device Market</strong></td>
<td><strong>409,348</strong></td>
<td><strong>406,304</strong></td>
<td><strong>403,066</strong></td>
<td><strong>398,636</strong></td>
</tr>
<tr>
<td>Mobile Phones</td>
<td>1,811,922</td>
<td>1,802,394</td>
<td>1,824,628</td>
<td>1,798,356</td>
</tr>
<tr>
<td><strong>Total Device Market</strong></td>
<td><strong>2,221,270</strong></td>
<td><strong>2,208,697</strong></td>
<td><strong>2,227,694</strong></td>
<td><strong>2,196,992</strong></td>
</tr>
</tbody>
</table>

Source: Gartner (April 2019)
PC versus Smart Phones

• Why worry specifically about mobile OS security?
  – Why not use the same security principles we developed for PC?

• PC vs. smart phones
  – Users: root privileges typically not given to user
  – Persistent personal data
    o Input is cumbersome, so credentials are frequently stored
  – Battery performance is an issue
    o Implementing some security features may drain battery
  – Network usage can be expensive
PC vs. Smart Phones

• Unique features in Smart Phones
  – Location Data
    o GPS and Wifi-based tracking
  – Premium SMS Messages (expensive)
  – Placing and recording phone calls
  – Different authentication mechanisms
    o Fingerprint reader (available across platform)
    o Face Unlock (Android 5.0)
    o Trusted Places, Devices, Voice (Android 5.0)
  – Specific third-party app markets
  – Mobile payments
Mobile OS Security Frameworks

Android Security Model

Apple iOS Security (Briefly)
iOS Platform

- Kernel, Core OS, and Core services
  - Kernel: based on Mach kernel (like Mac OS X)
  - APIs: files, network, SQLite, POSIX threads, UNIX sockets, etc.
- Media layer
  - Supports 2D and 3D drawing, audio, video
- Cocoa Touch
  - Application framework, file management, network operations, UIKit
- Implemented in C, Objective-C, or Swift
iOS Security

- **System security**: integrated software/hardware
  - Crypto engines built in hardware (apple’s TPM)
  - Support secure enclave

- **Encryption and data protection**: protects user data even when a device is lost
  - E.g., the file system is encrypted

- **App security**: secure platform foundation
  - E.g., app sandboxing

- **Device controls**: prevent unauthorized use of the device and enable remote device management
FBI–Apple Encryption Dispute

• Why passcode matters?
  – The passcode is also used together with hardware ID for generating encryption keys

• File system is encrypted even when powered off
  – The file system key is encrypted (wrapped) with an ephemeral key (never stored on disk)
  – Ephemeral key is stored in secure enclave (RAM) when powered on, thrown away once powered off
  – Ephemeral key is re-created when the device is turned on combining user passcode and hardware UID
iOS System Security

• Secure boot chain (application processor)
  – All startup process components are crypto-signed by Apple
  – Ensure integrity and proceed only after verifying the chain of trust
  – BootROM -> {Low-level bootloader ->} iBoot -> kernel

• Secure enclave coprocessor (Apple’s interpretation of TPM)
  – Secure crypto-processor (secure boot; encrypted memory)
  – Provides primitive cryptographic functions
  – Provides secure storage of cryptographic keys
  – Responsible of processing fingerprint/face data.

• Touch ID/Face ID

A strong passcode forms the foundation of iOS device’s cryptographic protection
iOS App Security

• Mandatory code signing
  – All apps must be signed using an apple-issued certificate

• Runtime protection
  – App “sandbox” prevents access to other app’s data
  – System resources, kernel shielded from user apps: third-party apps and majority of iOS run under a non-privileged user-id: “mobile”
  – Inter-app communication and background tasks only through iOS APIs
  – Access to user information (or iCloud) by third-party must be declared

• Application data protection
  – Apps can take advantage of built-in hardware encryption
iOS Permissions

- iOS apps all have common default permissions (e.g. Internet)
- iOS 6, Sep 2012 onwards: certain permissions need to be enabled dynamically (e.g., location)
Android

• Platform outline:
  – Linux kernel
  – Embedded Web Browser
  – SQL-lite database
  – Software for secure network communication
    o Open SSL, Bouncy Castle crypto API and Java library
  – Java platform for running applications
  – C language infrastructure
  – Video APIs, Bluetooth, vibrate phone, etc.
Android Run Time (ART) after v4.4
Android Market

• Open market
  – Not necessarily rigorously reviewed by Google
  – Bad applications may show up on market
  – Malware writers can get code onto platform: self-signed applications are possible

• App permissions granted on user installation Android < 6, at runtime for Android >= 6
Android Application Structure

• Four main components
  – Activity – one-user task
    o E.g., scroll through your inbox
  – Service – Java daemon that runs in background
    o E.g., application that streams an mp3
  – Broadcast receiver
    o “mailboxes” for messages from other applications
  – Content provider
    o Store and share data using a relational database interface

• Activating components
  – Using “Intents” (a form of IPC)
Android **Intents**

- Message between components in same or different apps
- Intent is a bundle of information
  - **action** to be taken
  - **data** to act on
  - **category** of component to handle the intent
  - instructions on how to launch a target *activity*
- Routing can be
  - **Explicit**: delivered only to a specific receiver
  - **Implicit**: all components that have registered to receive that action will get the message (more “dangerous”)

Android Manifest File

- Declarations
  - Components
  - Component capabilities
    - Intent filters
    - Permissions etc.
  - App requirements
    - Permissions
    - Sensors etc.
Android Permissions

• Example of permissions provided by Android
  – “android.permission.INTERNET”
  – “android.permission.READ_EXTERNAL_STORAGE”

• Protection levels
  – Dangerous
  – Normal
  – Signature
  – SignatureOrSystem

- Granted in runtime
- Granted during app installation
- Custom permission (granted at installation)
  Allow/disallow other apps to use your features
- Permission to call system components
Android Runtime Permissions

• Dangerous permissions granted at runtime

• Normal and signature permissions still granted at installation

• Only valid for apps API >= 23

• Permissions granted based on a permission group basis (changes in Oreo v8)
# Android Permission Groups

- All dangerous permissions in a group will be granted!

<table>
<thead>
<tr>
<th>Permission Group</th>
<th>Permissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CALENDAR</strong></td>
<td>• READCALENDAR&lt;br&gt;• WRITECALENDAR</td>
</tr>
<tr>
<td><strong>CAMERA</strong></td>
<td>• CAMERA</td>
</tr>
<tr>
<td><strong>CONTACTS</strong></td>
<td>• READCONTACTS&lt;br&gt;• WRITECONTACTS&lt;br&gt;• GETACCOUNTS</td>
</tr>
<tr>
<td><strong>LOCATION</strong></td>
<td>• ACCESS_FINE_LOCATION&lt;br&gt;• ACCESS_COARSE_LOCATION</td>
</tr>
<tr>
<td><strong>MICROPHONE</strong></td>
<td>• RECORD_AUDIO</td>
</tr>
<tr>
<td><strong>PHONE</strong></td>
<td>• READ_PHONE_STATE&lt;br&gt;• CALL_PHONE&lt;br&gt;• READ_CALL_LOG&lt;br&gt;• WRITE_CALL_LOG&lt;br&gt;• ADD_VOICEMAIL&lt;br&gt;• USE_SIP&lt;br&gt;• PROCESS_OUTGOING_CALLS</td>
</tr>
<tr>
<td><strong>SENSORS</strong></td>
<td>• BODY_SENSORS</td>
</tr>
<tr>
<td><strong>SMS</strong></td>
<td>• SEND_SMS&lt;br&gt;• RECEIVE_SMS&lt;br&gt;• READ_SMS&lt;br&gt;• RECEIVE_WAP_PUSH&lt;br&gt;• RECEIVE_MMS</td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td>• READ_EXTERNAL_STORAGE&lt;br&gt;• WRITE_EXTERNAL_STORAGE</td>
</tr>
</tbody>
</table>
Isolation

- Multi-user Linux operating system

- Each app normally runs as “a different user”
  - Each app has its own VM
  - Traditional linux-based permissions (DAC: Discretionary Access Control)

- Applications announce permission requirements
  - Create a whitelist model – user grants access
  - Inter-component communication (ICC) reference monitor checks permissions (MAC: Mandatory Access Control)
Binder IPC & Permission Enforcement

App 1
  A1C1

App 2
  A2C1

Intent

File System, Sockets

Android Middleware

Binder IPC

Linux Kernel

ICC Reference Monitor

MAC

DAC
Skype Privacy Leak

```bash
# ls -l /data/data/com.skype.merlin_mecha/files/shared.xml
-rw-rw-rw- app_152 app_152  56136 2011-04-13 00:07 shared.xml

# grep Default /data/data/com.skype.merlin_mecha/files/shared.xml
<Default>jcaseap</Default>
```

```bash
# ls -l /data/data/com.skype.merlin_mecha/files/jcaseap
-rw-rw-rw- app_152 app_152  331776 2011-04-13 00:08 main.db
-rw-rw-rw- app_152 app_152  119528 2011-04-13 00:08 main.db-journal
-rw-rw-rw- app_152 app_152  40960 2011-04-11 14:05 keyval.db
-rw-rw-rw- app_152 app_152   3522 2011-04-12 23:39 config.xml
-rw-rw-rwrx app_152 app_152  2011-04-11 14:05 voicemail
-rw-rw-rw- app_152 app_152    0 2011-04-11 14:05 config.lck
-rw-rw-rw- app_152 app_152  61440 2011-04-13 00:08 bistats.db
-rw-rw-rwrx app_152 app_152  2011-04-12 21:49 chatsync
-rw-rw-rw- app_152 app_152 12824 2011-04-11 14:05 keyval.db-journal
-rw-rw-rw- app_152 app_152  33344 2011-04-13 00:08 bistats.db-journal
```
Skype Privacy Leak

20 April 2011: This vulnerability has been fixed. Please update Skype on your Android device.

It has been brought to our attention that, were you to install a malicious third-party application onto your Android device, then it could access the locally stored Skype for Android files.

These files include cached profile information and instant messages. We take your privacy very seriously and are working quickly to protect you from this vulnerability, including securing the file permissions on the Skype for Android application.

To protect your personal information, we advise users to take care in selecting which applications to download and install onto their device.

Posted to: Privacy

Skype Privacy Leak

Privacy vulnerability in Skype for Android fixed

After a period of developing and testing we have released a new version of the Skype for Android application onto the Android Market, containing a fix to the vulnerability reported to us. Please update to this version as soon as possible in order to help protect your information.

We have had no reported examples of any 3rd party malicious application misusing information from the Skype directory on Android devices and will continue to monitor closely. Please rest assured that we do take your privacy and security very seriously and we sincerely apologise for any concern this issue may have caused.

Please ensure that you download Skype only from skype.com, or from the Android Market links on skype.com.

Posted to: Privacy

Comparison: iOS vs Android

• App approval process
  – Android apps from “open” app store
  – iOS vendor-controlled store of vetted apps

• Application permissions
  – Android permission: install-time manifest (< 6.0), + ask-on-first-use (≥ 6.0)
  – All iOS apps have same set of “sandbox” privileges, modified from iOS6 onwards

• App programming language
  – Android apps written in Java; no buffer overflow
  – iOS apps written in Objective-C (now Swift)

• TPM on smartphones!
Countermeasures

• App-store based model
  – Rely on manual audit and accountability
  – Rely on automated analysis

• Hardened Platform Security
  – Security Enhancements for Android (SEAndroid)
    o SELinux equivalent for Android
Google Bouncer

- Perform Static and Dynamic Analysis
  - Exact details not known
- Static Analysis (conjectured)
  - Look at information flow from sources to sinks
  - Impractical to do it for all possible cases
    - Choose some sensitive sinks and sources
- Dynamic Analysis (reverse engineered)
  - Run app for 5 minutes (emulator)
  - Look for hidden behavior
    - Unknown heuristics
- If flagged ➔ manual analysis ➔ suspension
Discussion Questions

• Should Apple allow the FBI to access phones? What security and practical implications would such a decision entail?
Discussion Questions

• Which permission model do you prefer: Installation-Time vs Ask-On-First-Use vs something else?
• We’ve seen that most of mobile malware target Android phones? Why do you think this is happening? Is iOS more secure?
• What could a malware do on a mobile device vs a desktop machine?
Reading

- https://source.android.com/security/
- [WijesekeraUsenix15]: Primal Wijesekera, University of British Columbia; Arjun Baokar, Ashkan Hosseini, Serge Égelman, and David Wagner, University of California, Berkeley; Konstantin Beznosov, University of British Columbia