The State of Mobile Security

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DIMVA 2012, Thu. July 26th 2012


UCSB Seclab
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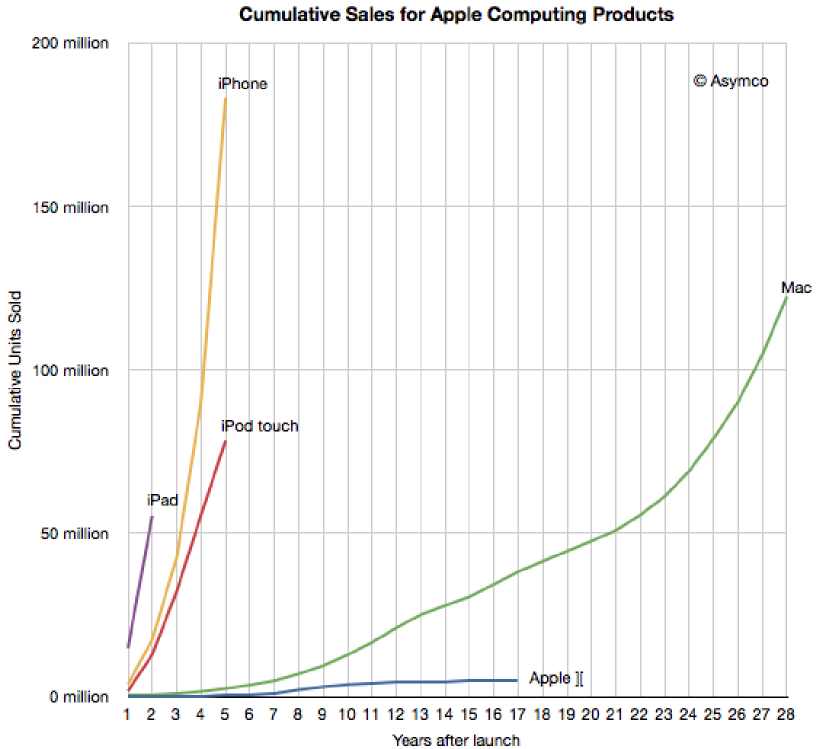
Smartphones are Ubiquitous

If not yet they are certainly on the way to get there:



365 million iDevices in total

400 million Android devices in total

Mobile Platforms

- Smartphones and tablets are ubiquitous
- Have access to (sensitive) user/company data
  - Addressbook
  - Calendar
  - etc.
- Sensors (e.g., GPS, camera, microphone) provide data that is available to third-party application developers
- App Stores drive the economy behind mobile applications

App Stores - Economy

Apple AppStore

- 650,000 Apps
- 400 million store accounts
- 30 billion downloads
- $5 billion to developers / $2.5 billion in 2011 alone

Google Play

- 490,000 Apps
- Top 200 Apps in Google Play $679,000 per day in Jan. 2012
- ~ $247 million / year

Where There's Money, …

Malware Reached Mobile Platforms

- Smartphones are targets b/c they store personal/sensitive information
  - Address books, GPS coordinates
  - Weakly protected online banking credentials
  - Zitmo intercepts mobile transaction numbers (mTAN)
  - Monetization through premium SMS and calls
- Different ecosystem than commodity computers

  (e.g., different level of control of the *user* over the device)
  - Root exploits against iOS and Android

Current State of Affairs

- Millions of users (potential victims)
- Easy access to data stored on their devices
- Existing mechanisms to monetize this data
- Bad guys that combine the above
- We need better security solutions

Overview

- Ubiquity of mobile systems
- Why mobile systems security
- Different security/protection approaches
  - iOS – Apple AppStore
  - Android – Google Play Store
- Static vs. Dynamic analysis for protection
- Challenges on Android systems
- Static analysis of iOS apps to detect privacy violations
- Recent developments / Lessons learned
- Summary

Security Models (iOS – AppStore)

- Developer pays $99/year for iPhone developer program
- Apple App Store – 650k apps available, 30bn downloaded
- Non-public vetting process for each submitted application
  - Probably a combination of static and dynamic analysis techniques
- Code signing and encryption
- Once the app is approved it is available on the AppStore

Security Models (iOS – Device)

- On app start-up OS loader decrypts the application and places the decrypted contents in memory (only!)
- Mandatory code signing:
  - No unsigned code will execute
  - Prevents self modifying code
  - Safari et al. have `dynamic-codesigning` entitlement
- Applications have unfettered access to most information on the device (noteworthy exceptions: GPS, SMS, Phone)
- Since iOS 4.3 ASLR
- All apps run as one user (i.e., `mobile`)
- Application sandboxing through MAC policy hooks

Security Models (Android – Google Play)

- 25$ registration fee – keeps spammers away
- Google Bouncer
  - Screens submitted applications for malicious code
  - Was circumvented (e.g., malicious apps on the Play store for weeks, download & execute of additional malicious code)
  - Was hacked (e.g., Oberheide and Miller got a shell on Bouncer, could inspect the analysis enviroment)
- Mandatory application signing
  - Self signed certificates accepted

Security Models (Android – Device)

- Each application is run as separate Linux user
- Install-time permissions for applications
  - Access address book or GPS location
  - Open network connections
  - Send & receive/intercept SMS
  - Permissions enforced at the kernel level ➜ to circumvent them, the attacker needs to exploit the kernel
- Common defensive techniques:
  - ProPolice (stack buffer overrun protection), Android 1.5+
  - Format string vulnerability protection, Android 2.3+
  - Address space layout randomization, Android 4.0+
  - Position independent executables, Android 4.1+

Security Models (Android – Device)

- CyanogenMod – aftermarket Android firmware
  - Revocation of install-time permissions
  - Apps might crash if they do not handle the changes gracefully
  - Faking data patch gives apps fake data from address book, location, etc.

Known Malicious Apps (iOS)

Apps that have been retracted from Apple AppStore

- Torch – Flashlight app that enables tethering (good for user, bad for network operators)
- Path, Gowalla et al. upload address book to remote servers
- Storm8 apps leaked phone numbers
- Find & Call – steals address book, sends text messages to contacts with spoofed sender number
- POC by Charlie Miller to circumvent mandatory code signing ➜ arbitrary code execution
- jailbreakme.com performs root exploit ➜ Drive-by download

Known Malicious Apps (Android)

Malicious apps on Google Play and third party markets

- Repackaged popular titles including malicious functionality often appear in third party markets
- If User needs to enable installation from untrusted sources and agree to the permissions at install time ➜ not a drive-by download
- Find & Call – steals address book, sends text messages to contacts (yes this is truly multi-platform!)

Find and Call

Support FindAndCall Подробнее
Re: Работа приложения
5 июля 2012 г. 12:10

Добрый день!
Система находится в стадии бета-тестирования. В результате сбоя одного из компонентов системы происходит самопроизвольная рассылка пригласительных смс. Данная ошибка сейчас исправляется. Смс отсылает система, поэтому на Вашем балансе это не отобразится.

Re: Application work

July 5, 2012. 12:10

Good day!

System is in process of beta-testing. In result of failure of one of the components there is a spontaneous sending of inviting SMS messages. This bug is in process of fixing. SMS are sent by the system, that is why it won't affect your mobile account.

When is Data Transmission Legitimate?

- Find & Call: “The Find and Call app has been removed from the App Store due to its unauthorized use of users’ address book data, a violation of App Store guidelines,” Apple spokesperson Trudy Muller told Wired.
- Text messages sent from backend server (iOS does not expose APIs to send text messages)
- Find & Call only caught b/c the app was advertising itself
- Path et al. do not use the address book information in similar obviously nefarious ways

Q: How can we tell such cases apart?

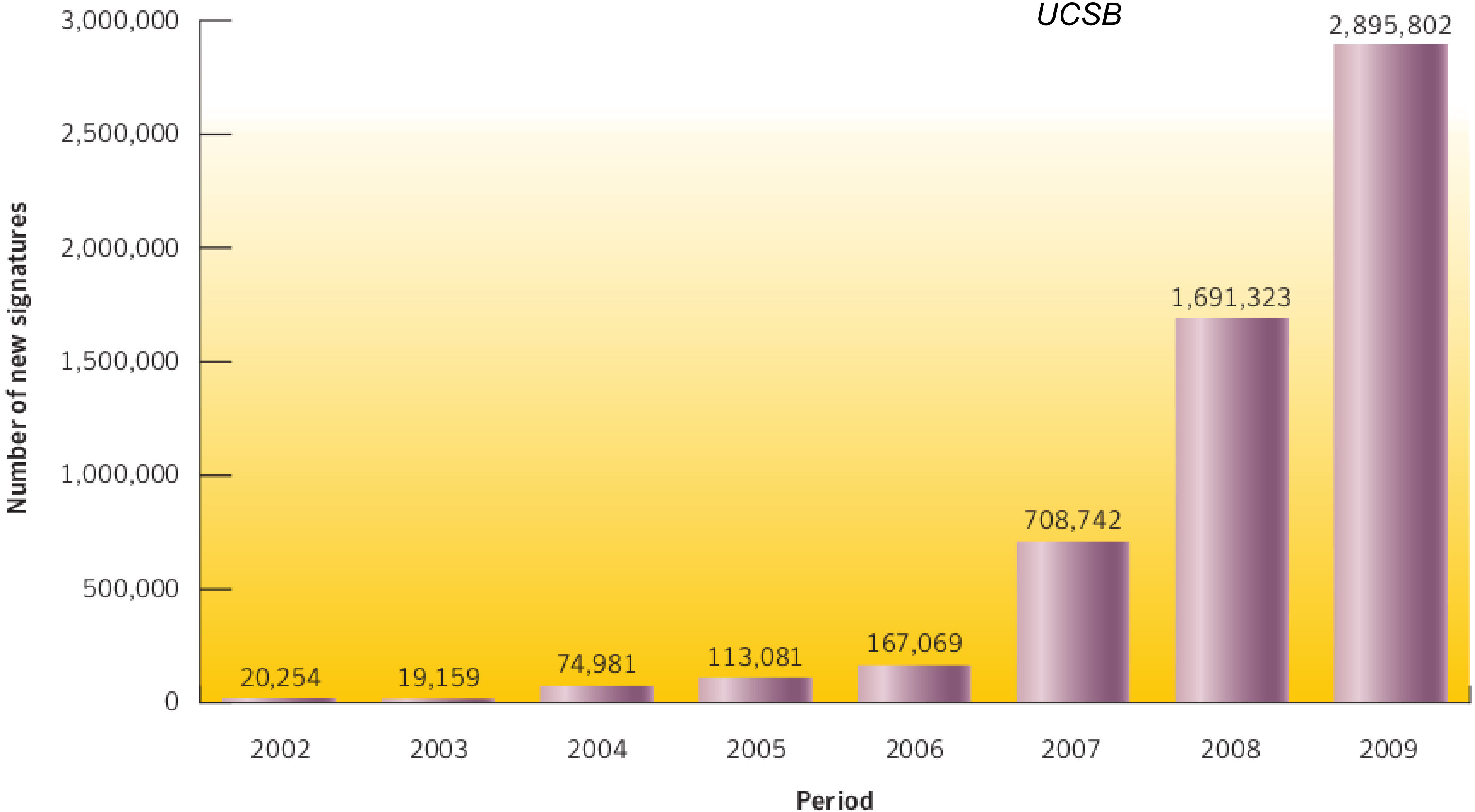
AV industry in 1998

AV industry in 2008

Image Copyright: IKARUS Security Software GmbH

Malware Growth on Commodity Systems

Computer Security Group at UCSB



Motivation for Mobile Malware Analysis

- Why don't we implement virus scanners on mobile devices?
  - Sandboxing prevents access to other applications
- Potentially huge number of malware samples
  - Generating signatures manually is slow and does not scale
  - Sophisticated targeted attacks ➜ no sample to create a signature
- Efficient and scalable way to answer:

  Q: *Is an unknown piece of code malicious or benign?*

Static vs. Dynamic Security Measures

- Static measures can be applied pre-launch
  - One time effort
  - All users benefit immediately
  - No performance overhead at runtime
  - Challenges for static analysis (obfuscation, dynamically loaded code, etc.)

Static vs. Dynamic Security Measures

- Dynamic security measures
  - Can be more precise than static measures
  - Incomplete path coverage ➜ pre-launch analysis is incomplete
  - Mobile apps are inherently user driven ➜ to increase coverage interaction with the application is required
  - Often each device has to perform its own analysis during execution
  - Performance overhead during execution

Why Bother with Static Analysis

- Apps on smartphones run in restricted environments
  - Sandboxed in Android and iOS
  - Permission model in Android
  - No side loading on iOS
  - No self modifying or dynamically loaded code in iOS
  - No self modifying code in Dalvik

➜ less freedom for attackers

Static Analysis Prerequisits

Many static analysis approaches require access to control flow graphs (CFG) and call graphs (CG):

- How can we extract CGs and CFGs for Android apps?
- How can we extract CGs and CFGs for iOS apps?

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CFG for Android

Easy case:

```
.class final Lcom/admob/android/ads/c;

.method public constructor <init>(Ljava/lang/String;...)V

    new-instance v0, Ljava/net/URL;

    invoke-direct {v0, p1}, Ljava/net/URL;-><init>(Ljava/lang/String;)V
```

Challenges for CFG (Android)

Interfaces and inheritance:

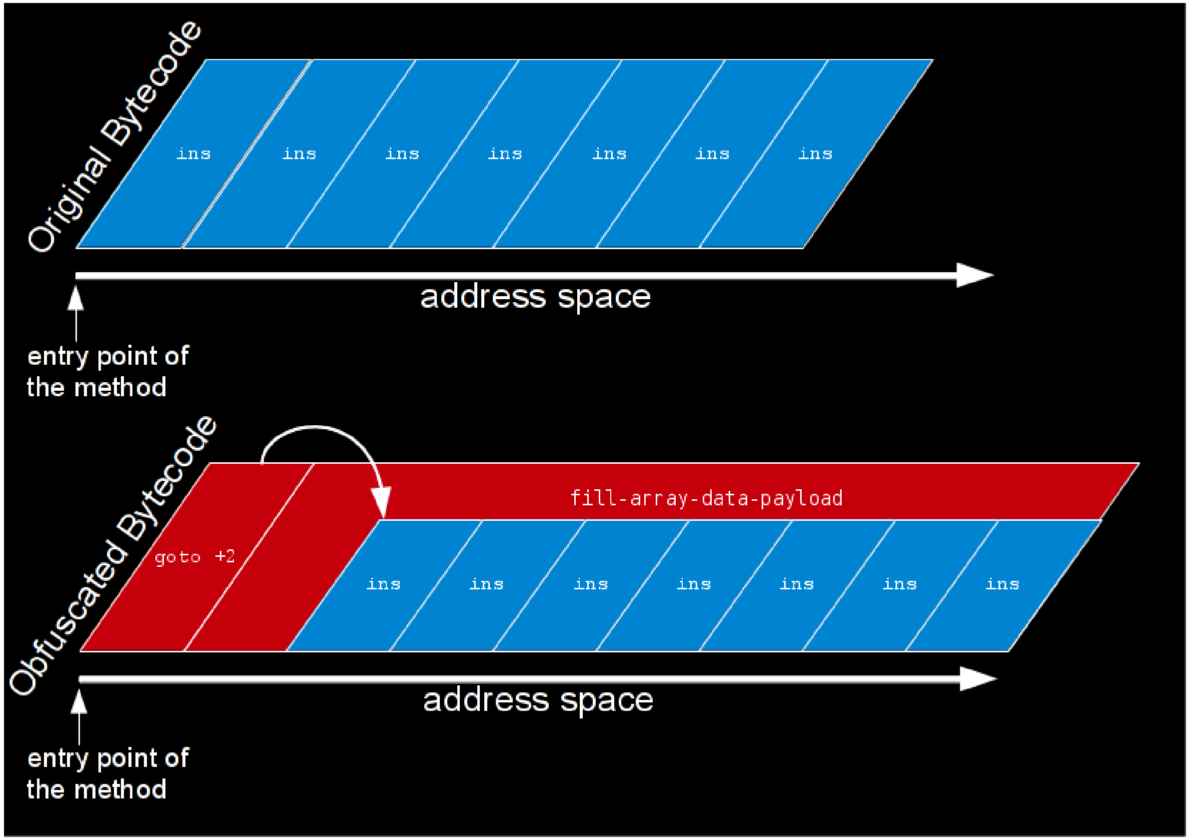
```
.class public interface abstract Lcom/admob/android/ads/n;
.method public abstract d()Ljava/lang/String;
…
.class public final Lcom/admob/android/ads/m;
.method public final a(Lcom/admob/android/ads/n;)V
    invoke-interface {p1}, Lcom/admob/android/ads/n;->d()Ljava/lang/String;
```

To determine what methods might be called by the invoke, we need to understand the possible types of `a`'s argument. To determine these types, we have to find all call-sites to `m.a()`.

Want more challenges? Reflective calls

More Fun Analyzing Android Apps

Junk byte injection



More Fun Analyzing Android Apps cont.

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IDA Pro 6.3

```
CODE:35B0C                 Method 3131 (0xc3b):
CODE:35B0C                 private java.lang.String
CODE:35B0C                 org.dexlabs.poc.dexdropper.DropActivity.exec(
CODE:35B0C                   java.lang.String p0)
CODE:35B0C this = v7                               # CODE XREF: DropActivity_down_exec@VL+6C↓j
CODE:35B0C p0 = v8
CODE:35B0C                 if-eq                           v0, v0, loc_35B1E
CODE:35B10                 fill-array-data                 v0, arraydata_35B16
CODE:35B10 # ---------------------------------------------------------------------------
CODE:35B16 arraydata_35B16:                        # DATA XREF: DropActivity_exec@LL+4↑r
CODE:35B16                 .short 0x300            # Array definition; 198 elements, each 1 bytes
CODE:35B18                 .short 1
CODE:35B1A                 .int 0xC6
CODE:35B1E # ---------------------------------------------------------------------------
CODE:35B1E # try 0x35B1E-0x35BB2:
CODE:35B1E
CODE:35B1E loc_35B1E:                              # CODE XREF: DropActivity_exec@LL↑j
CODE:35B1E                 new-instance                    v5, <t: StringBuilder> # Array Contents
CODE:35B22                 invoke-direct                   {v5}, <void StringBuilder.<init>() imp. @ _def_StringBuilder__init_@V>
CODE:35B28                 invoke-virtual                  {this}, <ref DropActivity.getApplicationContext() imp. @ _def_DropActivity_getApplicationContext@L>
CODE:35B2E                 move-result-object              v6
CODE:35B30                 invoke-virtual                  {v6}, <ref Context.getFilesDir() imp. @ _def_Context_getFilesDir@L>
CODE:35B36                 move-result-object              v6
CODE:35B38                 invoke-virtual                  {v5, v6}, <ref StringBuilder.append(ref) imp. @ _def_StringBuilder_append@LL>
CODE:35B3E                 move-result-object              v5
CODE:35B40                 const-string                    v6, aTemp # "/temp"
CODE:35B44                 invoke-virtual                  {v5, v6}, <ref StringBuilder.append(ref) imp. @ unk_D93C>
CODE:35B4A                 move-result-object              v5
CODE:35B4C                 invoke-virtual                  {v5}, <ref StringBuilder.toString() imp. @ _def_StringBuilder_toString@L>
CODE:35B52                 move-result-object              v5
CODE:35B54                 const/4                         v6, 0
CODE:35B56                 invoke-static                   {p0, v5, v6}, <ref DexFile.loadDex(ref, ref, int) imp. @ _def_DexFile_loadDex@LLLI>
CODE:35B5C                 move-result-object              v4
CODE:35B5E                 const-string                    v5, aBad # "bad"
CODE:35B62                 invoke-virtual                  {this}, <ref DropActivity.getClassLoader() imp. @ _def_DropActivity_getClassLoader@L>
CODE:35B68                 move-result-object              v6
CODE:35B6A                 invoke-virtual                  {v4, v5, v6}, <ref DexFile.loadClass(ref, ref) imp. @ _def_DexFile_loadClass@LLL>
```

Android Intents & Activities

"An intent is an abstract description of an operation to be performed."

"An activity is a single, focused thing that the user can do. Almost all activities interact with the user,..." often a screen/view

Use `startActivity(Intent)` upon a click event to switch to a new activity

Android Intents & Activities cont.


```
7730 new-instance        v0, <t: Intent>
7740 iget-object         v1, this, libraryApp$11_this$0
7744 const-class         v2, <t: webview_controller>
7748 invoke-direct       {v0, v1, v2}, <void Intent.<init>(ref, ref) imp. @
774E iget-object         v1, this, libraryApp$11_this$0
7752 const-string        v2, aHttpSeats_warw # "http://seats.warwick.ac.uk/a
7756 iput-object         v2, v1, libraryApp_URL
775A const-string        v1, aUrl # "URL"
775E iget-object         v2, this, libraryApp$11_this$0
7762 iget-object         v2, v2, libraryApp_URL
7766 invoke-virtual      {v0, v1, v2}, <ref Intent.putExtra(ref, ref) imp. @
776C iget-object         v1, this, libraryApp$11_this$0
7770 invoke-virtual      {v1, v0}, <void libraryApp.startActivity(ref) imp.
```

Enough of Android (For Now)

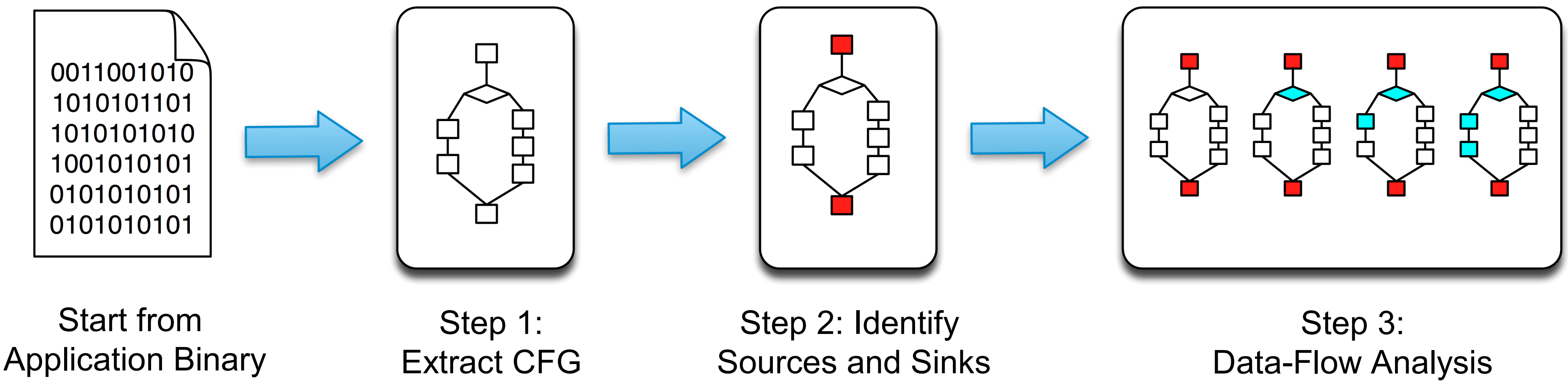
Let's look under the hood of iOS

- Signatures do not scale
- Behavior-based detection of apps that access privacy sensitive information and transmit this information over the Internet without user intervention or consent
- Model this functionality as a data-flow problem

Challenges

- Apps are binary only ➜ binary analysis
- Object-oriented concepts of Obj-C

iOS – App Analysis



1. Extract control flow graph (CFG) from binary application
2. Identify sources of sensitive information and network communication sinks
   – Perform reachability analysis between sources and sinks
3. Data flow analysis on detected paths

Static Analysis – IDA Pro

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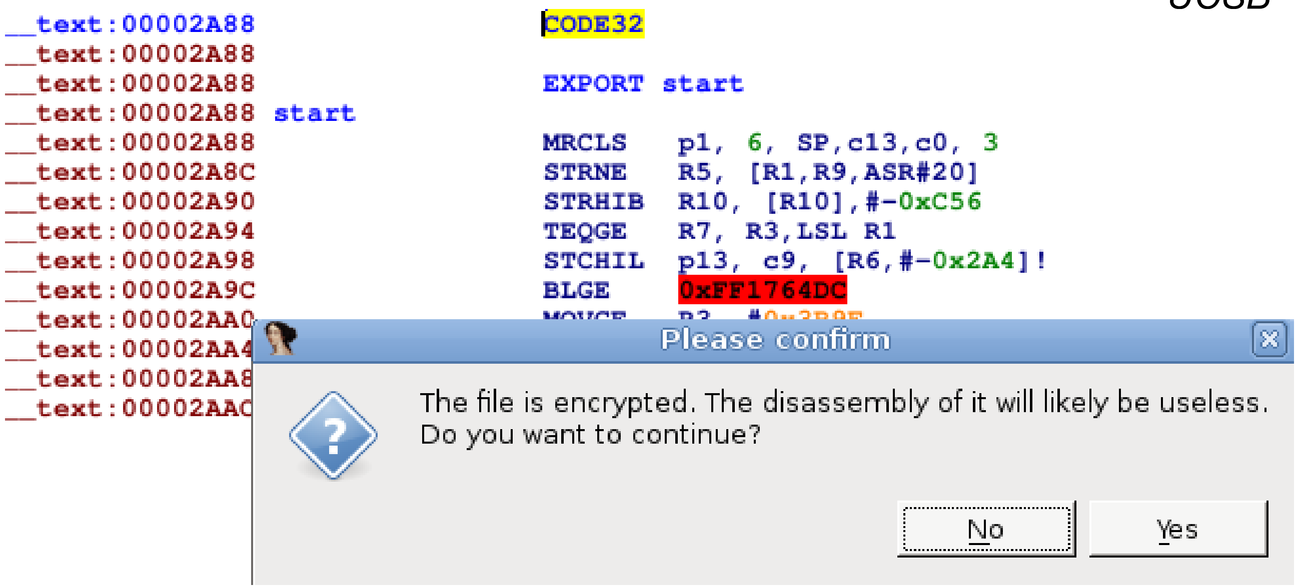

Background (iOS & DRM)

- App Store apps are encrypted and digitally signed by Apple
- Loader verifies signature and performs decryption in memory
- Decrypting App Store apps:
  - Attach with debugger while app is running
  - Dump decrypted memory regions
  - Reassemble binary, toggle encrypted flag

Static Analysis (Call Graph)

IDA Pro state of the art disassembler for binary analysis

call graph for “Bom

objc_msgSend

iOS – App Analysis (CFG)

- Most iOS apps are written in Objective-C
- Cornerstone: `objc_msgSend` dispatch function
- Task: Resolve type of receiver and value of selector for `objc_msgSend` calls
  - Backwards slicing
  - Forward propagation of constants and types
- Result: Inter and intra procedural CFG is constructed from successfully resolved `objc_msgSend` calls

Background (objc_msgSend)

- `objc_msgSend` dynamic dispatch function
- Arguments:
  - Receiver (Object)
  - Selector (Name of method, string)
  - Arguments (vararg)
- Method look-up:
  - Dynamically traverses class hierarchy
  - Calls the method denoted by selector

  ⇨ All information readily available at runtime, but challenging to do statically
- Similar to reflection in Java, Obj-C uses only reflection

iOS – App Analysis (Class Hierarchy)

- Problem: Multiple candidate types for receiver
- Class hierarchy is extracted from application and libraries
- All possible candidate types are inspected whether they implement a method
- If only one candidate implements the method that type is chosen for the receiver

iOS – App Analysis (CFG)

Novel object-oriented analysis approach for Obj-C binaries based on two key techniques:

(1) Resolve *type* of receiver and *value* of selector for `objc_msgSend` calls

(a) Backwards slicing

(b) Forward propagation of constants and types

(2) Multiple candidate types for receiver ➜ class hierarchy

Result: Inter and intra procedural CFG is constructed from successfully resolved `objc_msgSend` calls

Example ObjC to ASM

```
1   LDR    R0, =off_24C58          UIDevice
2   LDR    R1, =off_247F4          currentDevice
3   LDR    R0, [R0]
4   LDR    R1, [R1]
5   BLX    _objc_msgSend           UIDevice  currentDevice
6   LDR    R1, =off_247F0          uniqueIdentifier
7   LDR    R1, [R1]
8   BLX    _objc_msgSend           UIDevice  uniqueIdentifier
9   ADDS   R4, R0, #0
…
                       this .score
10  LDR    R3, [R6,R3]
11  STR    R3, [SP,#0x40+var_40]
12  ADDS   R3, R4, #0
…
13  BLX    _objc_msgSend           NSString ::initWithFormat:
(fmt: "uniqueid=%@&scores=%d")
…
14  BLX    _objc_msgSend           POSTScore ::startPostingData:toURL:
```

Example CFG

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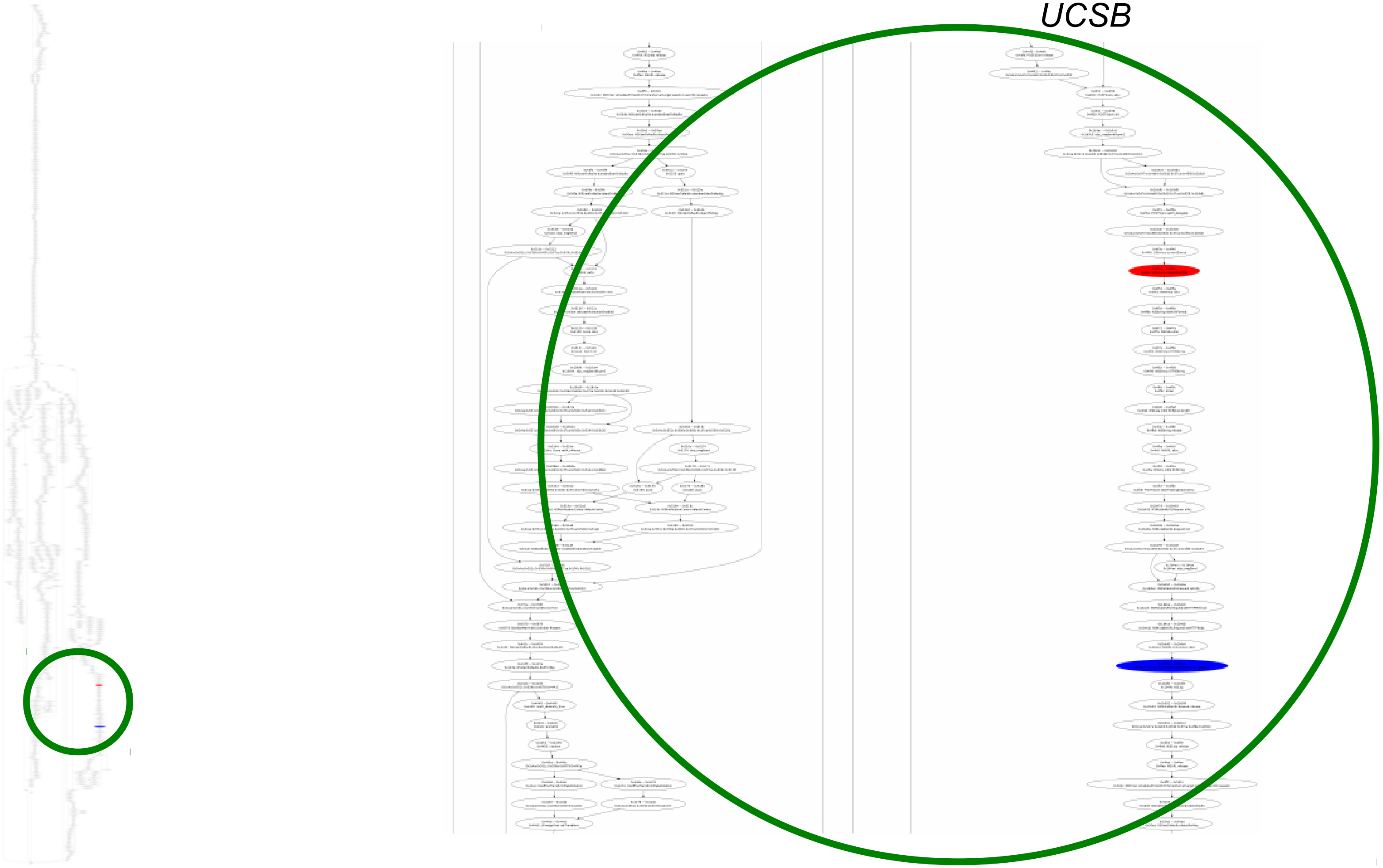
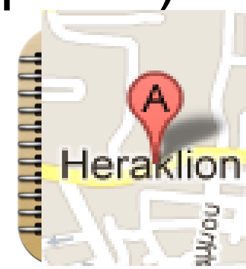


iOS Apps – Finding Privacy Leaks

- Based on inter and intra procedural CFG
- Reachability Analysis (find paths)
  - From interesting *sources*



  - To network *sinks*

- Data-flow analysis from source to sink

iOS Apps – Evaluation

- 1,407 Applications (825 from App Store, 582 from Cydia)
- Pervasive ad and statistic libraries:
  - 772 Apps (55%) contain at least one such library
  - Leak UDIDs, GPS coordinates, etc.

Ad and Statistic Libraries

- 82% use AdMob (Google)
- Transmit UDID and AppID on start-up and ad request
- Ad company can build detailed usage profiles
  - Gets info from all Apps using the ad library
- Problem: Location-based Apps
  - Access to GPS is granted per App
  - Libraries linked into location based apps have access to GPS too
- UDIDs cannot be linked to a person directly, but...

Is Leaking UDIDs a Problem?

- UDIDs cannot be linked to a person directly
- But: Combine UDID with additional information e.g.,
  - Google App can link UDID to a Google account
  - Social networking app get user's profile (often name)
- Linking ICC-ID with UDID is trivial
  - 114,000 iPad 3G users

Is Leaking UDIDs a Problem?

June 2010

AT&T Inc. acknowledged Wednesday that a security hole in its website had exposed its iPad customers' email addresses, a breach that highlights how corporations still have problems protecting private information.

View Full Image

Getty Images

Apple's new iPad is pictured in a shop in Barcelona.

A small group of computer experts that calls itself Goatse Security claimed responsibility for the intrusion, saying the group had exploited an opening in AT&T's website to find numbers that identify iPads connected to AT&T's mobile network.

Those numbers allowed the group to uncover 114,000 email addresses of thousands of iPad customers, including prominent officials in companies, politics and the military, the group said. Gawker Media LLC reported the breach Wednesday. It doesn't appear any financial or billing information was made public.

89014104243220[redacted] : [redacted]@nytimes.com	←	Janet Robinson, CEO of NY Times
89014104243219[redacted] : [redacted]@time.com	←	Ann Moore, CEO of Time Inc.
89014104243221[redacted] : [redacted]@newscorp.com	←	Chase Carey, President/COO of News Corp.
89014104243315[redacted] : [redacted]@hearst.com	←	Cathie Black, President of Hearst Magazines
89014104243315[redacted] : [redacted]@dowjones.com	←	Les Hinton, CEO of Dow Jones
89014104243221[redacted] : [redacted]@weinsteinco.com	←	Harvey Weinstein, Co-Founder of Weinstein Co.
89014104243315[redacted] : [redacted]@bloomberg.net	←	Michael Bloomberg, Founder of Bloomberg LP

PiOS – Evaluation: Leaked Data

Source	#App Store 825	#Cydia 582	Total 1407
DeviceID	170 (21%)	25(4%)	195(14%)
Location	35(4%)	1(0.2%)	36(3%)
Address book	4(0.5%)	1(0.2%)	5(0.4%)
Phone number	1(0.1%)	0(0%)	1(0.1%)
Safari history	0(0%)	1(0.2%)	1(0.1%)
Photos	0(0%)	1(0.2%)	1(0.1%)

PiOS – Evaluation: Case Studies

Address book contents:

- Apps have unrestricted access to the address book
- Facebook and Gowalla transmit the complete AB
- Feb. 2012: Mainstream media picks up this and similar cases
  ➜ Apple is changing policies and implements restrictions

Phone numbers:

- Nov. 2009 Apple removed all Storm8 titles from App Store
- Apps transmitted phone numbers (`SBFormattedPhoneNumber`)
- New versions don't have that code anymore
- Old version of “Vampires“ PiOS detected the privacy leak
- MogoRoad – Free version users get calls from telemarketers

Media Coverage

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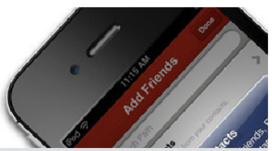
Infinite Loop | Apple, Mac O

Developers say Apple needs to overha

By Chris Foresman | Published February 15, 2012 5:15 PM



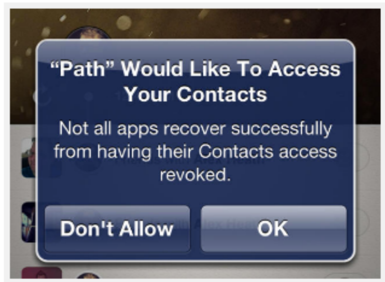
Forbes

TECH | 2/14/2012 @ 12:37PM | 6,629 views

Unauthorized iPhone And iPad Apps Leak Private Data Less Often Than Approved Ones

Users have learned over the last few years that Apple's "walled garden" approach to third party apps isn't quite as protective of their sensitive data as it might sound. More surprising, perhaps, is another revelation: that the popular unauthorized apps outside those walls tend to respect privacy better than the approved ones inside.

As the scandal swirled this past week



A screenshot of the ContactPrivacy feature in the unofficial Cydia iOS app platform.

"In the wake of news that the iPhone app Path uploads users' entire contact lists without permission, Forbes di
Systems Lab that aimed to analyze how and where iPhone apps transmit users' private data. Not only did the r
could potentially identify users and allow profiles to be built of their activities; they also discovered that program
far less frequently than Apple's approved apps. The researchers ran their analysis on 1,407 free apps (PDF) on
for instance, compared with only four percent of unauthorized apps."

100 of 179 comments loaded

technology review

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Technology Review

COMPUTING

Want tc an App for That

A new program analyzes iPhone apps and finds the ones that are grabbing your data.

TUESDAY, JANUARY 25, 2011 | BY ROBERT LEMOS

Audio »

More than half of all iPhone apps collect and share a unique code that could be used to track users without their knowledge, according to a recent study.

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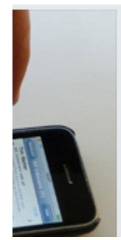

COMMUNICATIONS

Apple Ignored Warning on Address-Book Access

The company knew in 2010 that an app was grabbing users' personal information.

THURSDAY, FEBRUARY 16, 2012 | BY TOM SIMONITE

Audio »

Data Less Than Approved Ones

12:11AM

seclab | iseclab

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Lessons Learned

- Communicating privacy issues and raising awareness can be challenging
- Jailbroken iPhones are not necessarily less secure:
  - See PrivaCy application to opt out of ad tracking
  - Security patches for legacy systems
  - Experimental or research apps almost always require Jailbreak
- Would more fine grained permissions be helpful?
  - Users get tired of reading permission screens

Recent Developments

- Apple announced permissions for address book access for iOS 6
  - Will Apple come up with a working solution for permissions?
- Obfuscated Dalvik applications
  - Google advocates the use of ProGuard to protect IP – renaming class and method names to `a.a.b()` etc.
  - Recently: applications storing bytecode in arrays and jumping there – throws off linear sweep disassembler

Recent Developments cont.

Get in-app purchase for free on iOS and Apple Mac Store

- No Jailbreak required
- Install a trusted CA
- Install a trusted certificate for Apple's AppStore server
- Make DNS resolve the AppStore name to the fake AppStore
- Done
- Similar attack exists for the Mac Store on OS X

Interestingly, Apple immediately reacted and promised a fix with the next iOS update.

Developers + revenue vs. Privacy

Summary

- Mobile systems are ubiquitous
- Mobile systems implement new paradigms and security mechanisms
  - AppStores
  - Mandatory code signing
  - Permissions
- Static and dynamic analysis methods can be used to detect malware in mobile applications

Thanks for your attention

QUESTIONS?