Mobile Platform Security Models

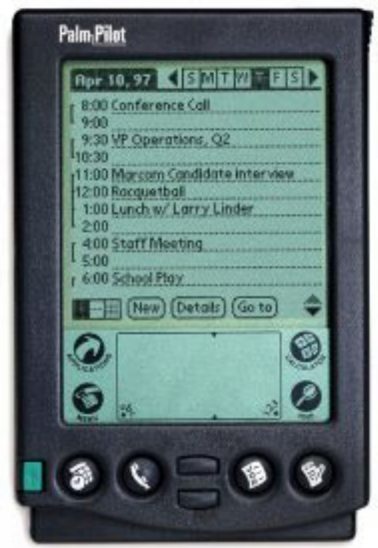
John Mitchell

Outline

- Introduction
  - Platforms
  - App market
  - Threats
- Android security model
- Apple iOS security model
- ~~Windows 7, 8 Mobile security model~~

Change takes time

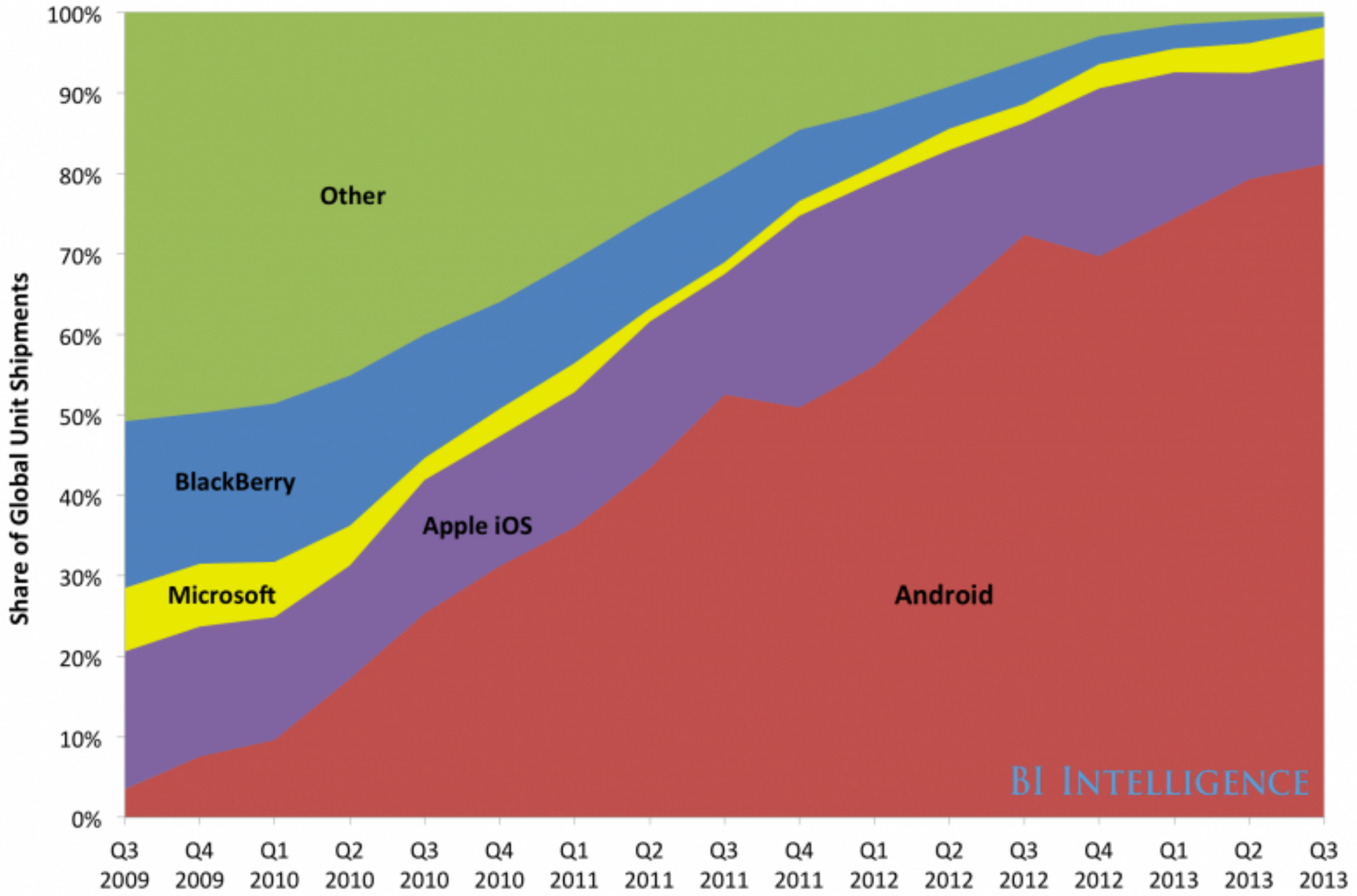
Apple Newton, 1987



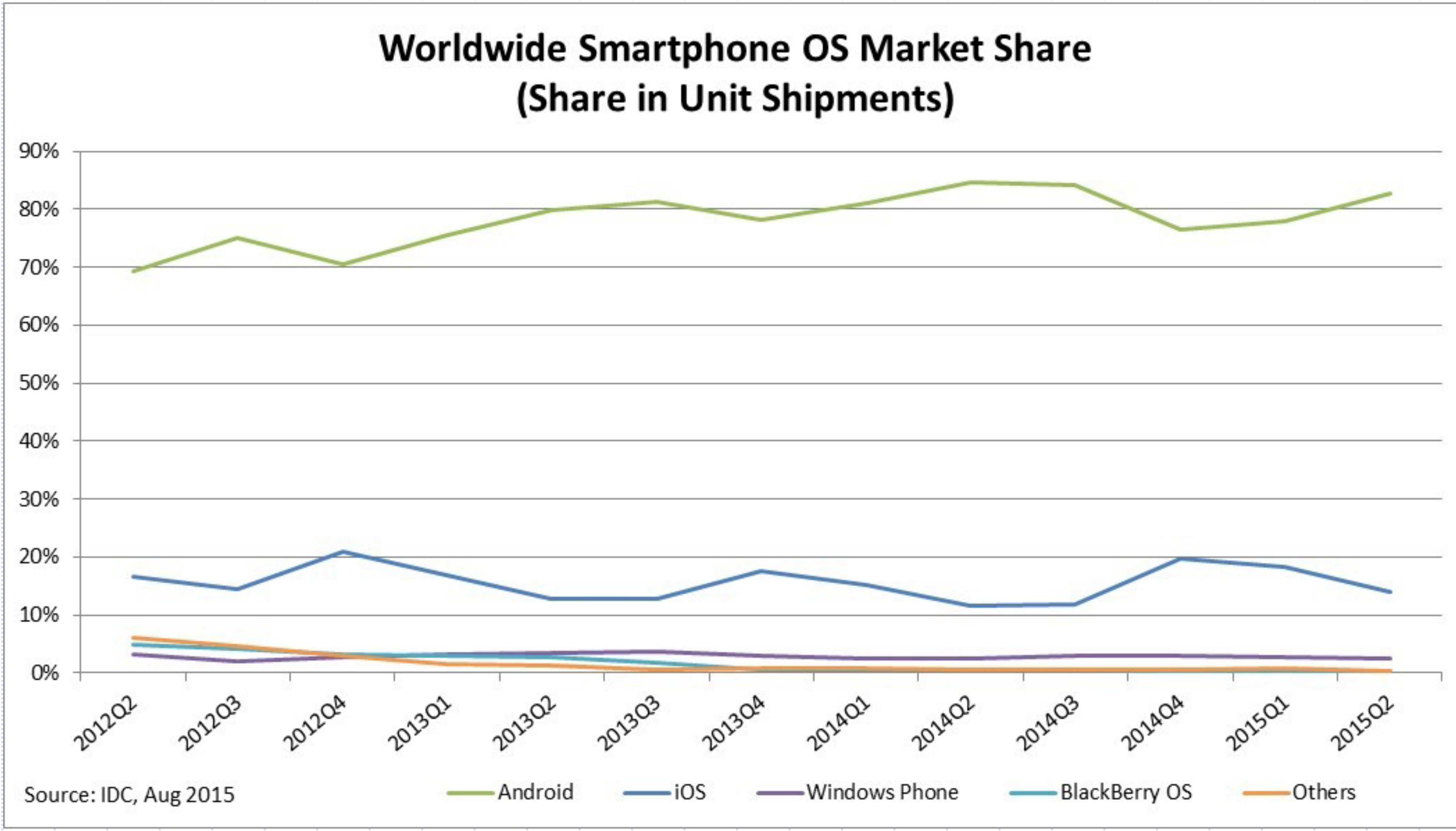
Palm Pilot, 1997

iPhone, 2007

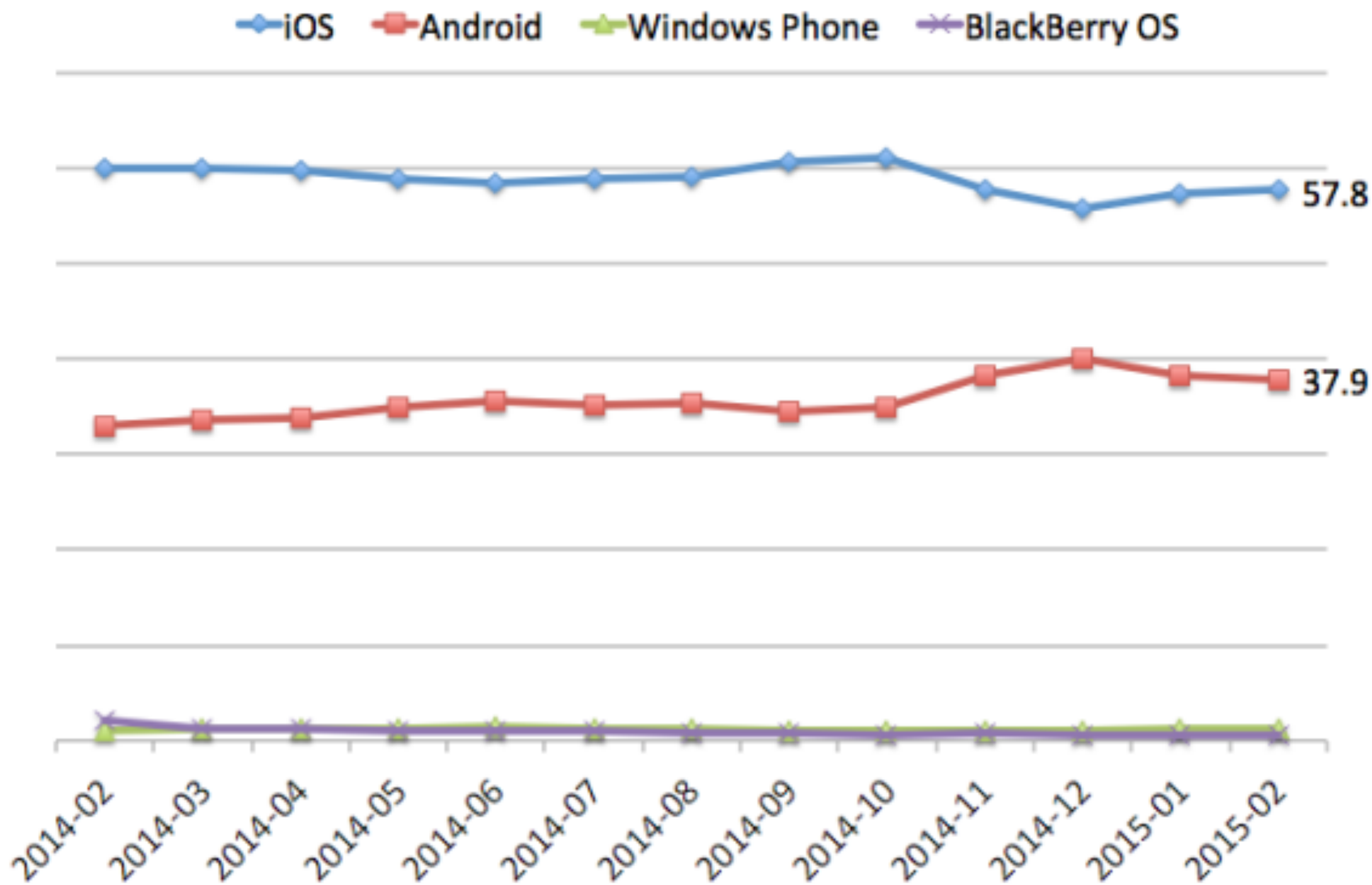
Global smartphone market share



Source: IDC, Strategy Analytics


Worldwide Smartphone OS Market Share
(Share in Unit Shipments)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2012Q2
2012Q3
2012Q4
2013Q1
2013Q2
2013Q3
2013Q4
2014Q1
2014Q2
2014Q3
2014Q4
2015Q1
2015Q2
Source: IDC, Aug 2015
Android
iOS
Windows Phone
BlackBerry OS
Others

US Mobile App Traffic



http://www.ironpaper.com/webintel/articles/web-design-statistics-2015/

Zillions of apps

App Marketplace

- App review before distribution
  - iOS: Apple manual and automated vetting
  - Android
    - Easier to get app placed on market
    - Transparent automated scanning, removal via Bouncer
- App isolation and protection
  - Sandboxing and restricted permission
  - Android
    - Permission model
    - Defense against circumvention

Threats to mobile applications

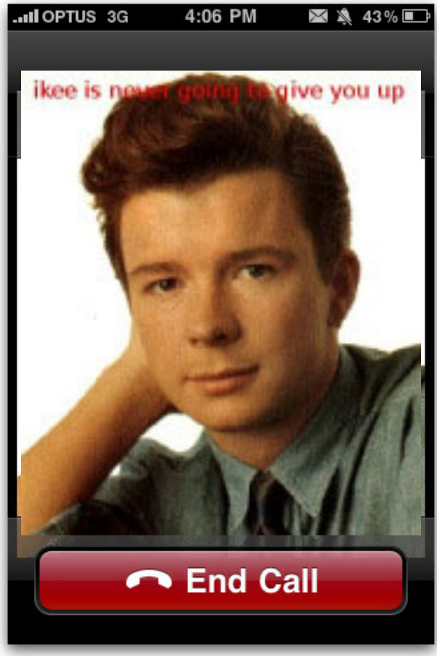
- Privacy
  - Data leakage, identifier leakage, third-party tags and libraries, location privacy
- Security
  - Phishing, malware & drive-bys, malicious intents on Android, Ikee/Zitmo and other mobile malware

OWASP Mobile Top Ten

- M1: Improper Platform Usage
- M2: Insecure Data
- M3: Insecure Communication
- M4: Insecure Authentication
- M5: Insufficient Cryptography
- M6: Insecure Authorization
- M7: Client Code Quality Issues
- M8: Code Tampering
- M9: Reverse Engineering
- M10: Extraneous Functionality

 https://www.owasp.org/index.php/Projects/OWASP_Mobile_Security_Project_-2015_Scratchpad

Mobile malware examples



- DroidDream (Android)
  - Over 58 apps uploaded to Google app market
  - Conducts data theft; send credentials to attacker
- Ikee (iOS)
  - Worm capabilities (targeted default ssh pwd)
  - Worked only on jailbroken phones with ssh installed
- Zitmo (Symbian,BlackBerry,Windows,Android)
  - Propagates via SMS; claims to install a “security certificate”
  - Captures info from SMS; aimed at defeating 2-factor auth
  - Works with Zeus botnet; timed with user PC infection

Sample FTC concerns

- FTC To Study Mobile Device Industry’s Security Update Practices (May 9, 2016)
- Federal Court Finds Amazon Liable for Billing Parents for Children’s Unauthorized In-App Charges (April 27, 2016)
- Tech Company Settles FTC Charges It Unfairly Installed Apps on Android Mobile Devices Without Users’ Permission (February 5, 2016)
- Defendants in Massive Spam Text Message, Robocalling and Mobile Cramming Scheme to Pay $10 Million to Settle FTC Charges (October 22, 2014)
- Snapchat Settles FTC Charges That Promises of Disappearing Messages Were False (May 8, 2014)

https://www.ftc.gov/news-events/media-resources/mobile-technology

Comparison between platforms

- Operating system (recall security features from lecture 3)
  - Unix
  - ~~Windows~~
- Approval process for applications
  - Market: Vendor controlled/Open
  - App signing: Vendor-issued/self-signed
  - User approval of permission
- Programming language for applications
  - Managed execution: Java, .Net
  - Native execution: Objective C

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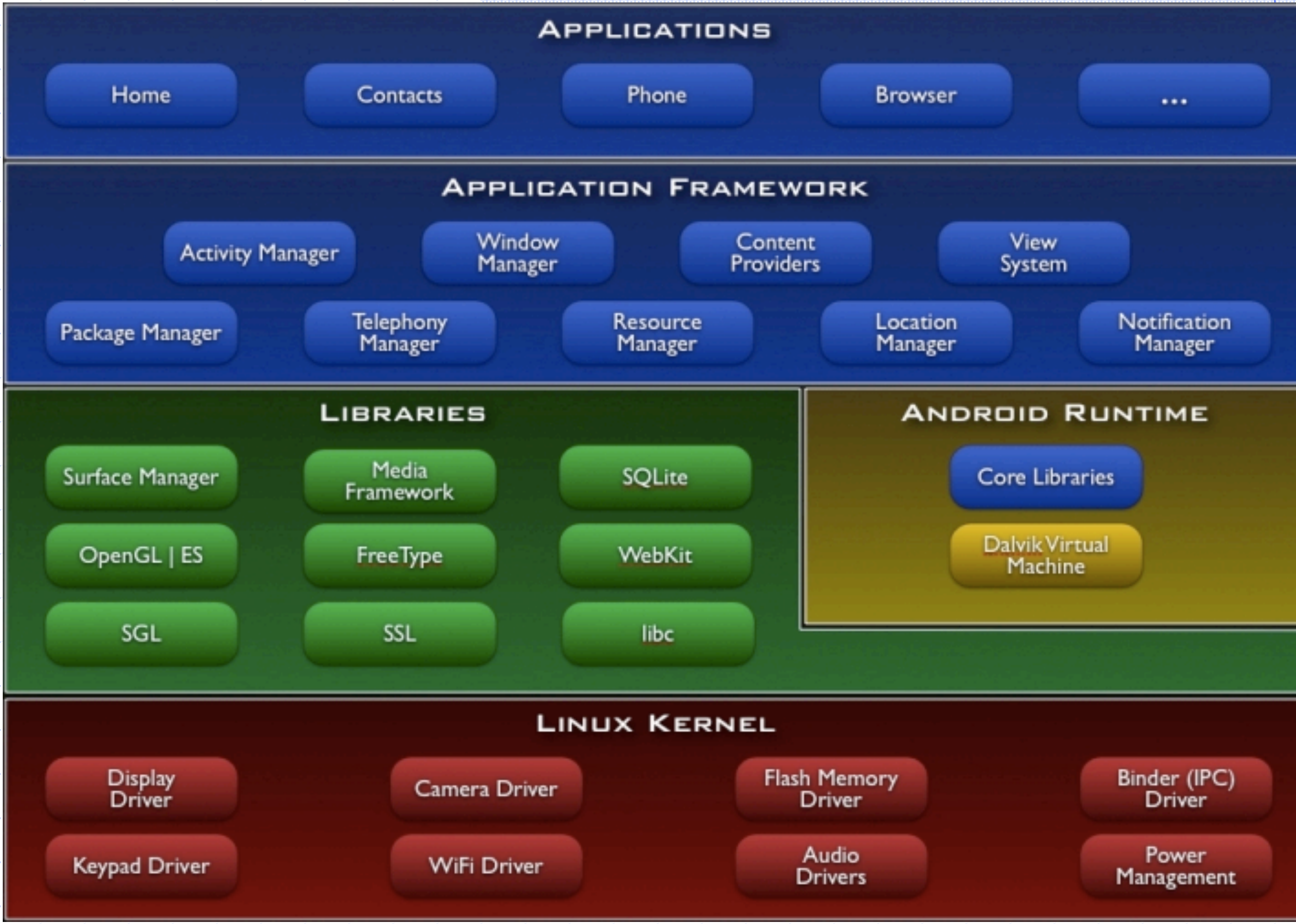
Android

- Platform outline:
  - Linux kernel, browser, SQL-lite database
  - Software for secure network communication
    - Open SSL, Bouncy Castle crypto API and Java library
  - C language infrastructure
  - Java platform for running applications
    - Dalvik bytecode, virtual machine



Applications
Home
Contacts
Phone
Browser
...
Application Framework
Activity Manager
Window Manager
Content Providers
View System
Package Manager
Telephony Manager
Resource Manager
Location Manager
Notification Manager
Libraries
Surface Manager
Media Framework
SQLite
OpenGL | ES
FreeType
WebKit
SGL
SSL
libc
Android Runtime
Core Libraries
Dalvik Virtual Machine
Linux Kernel
Display Driver
Camera Driver
Flash Memory Driver
Binder (IPC) Driver
Keypad Driver
WiFi Driver
Audio Drivers
Power Management

Android market

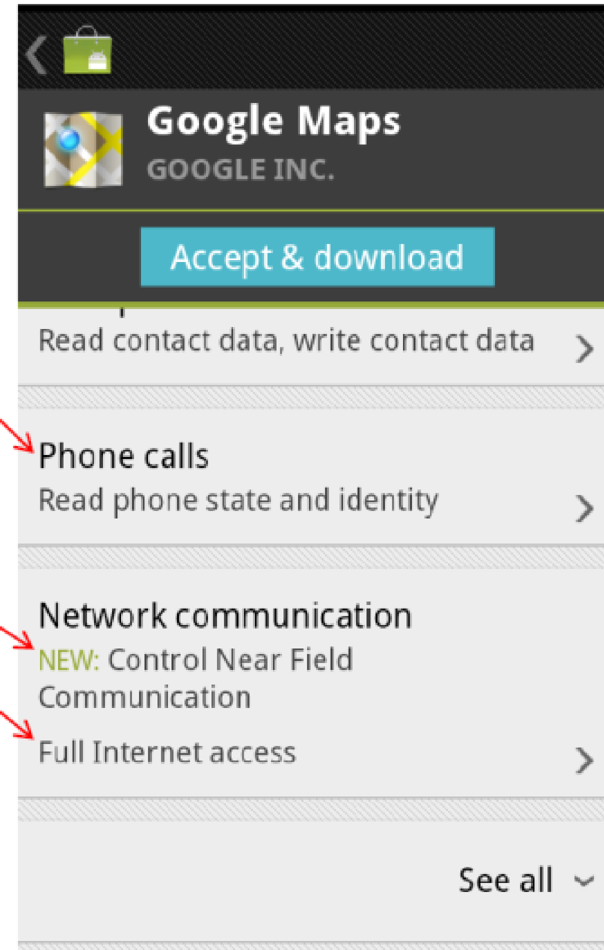
- Self-signed apps
- App permissions granted on user installation
- Open market
  - Bad applications may show up on market
  - Shifts focus from remote exploit to privilege escalation

Android permissions

- Example of permissions provided by Android
  - "android.permission.INTERNET"
  - "android.permission.READ_EXTERNAL_STORAGE
  - "android.permission.SEND_SMS"
  - "android.permission.BLUETOOTH"
- Also possible to define custom permissions

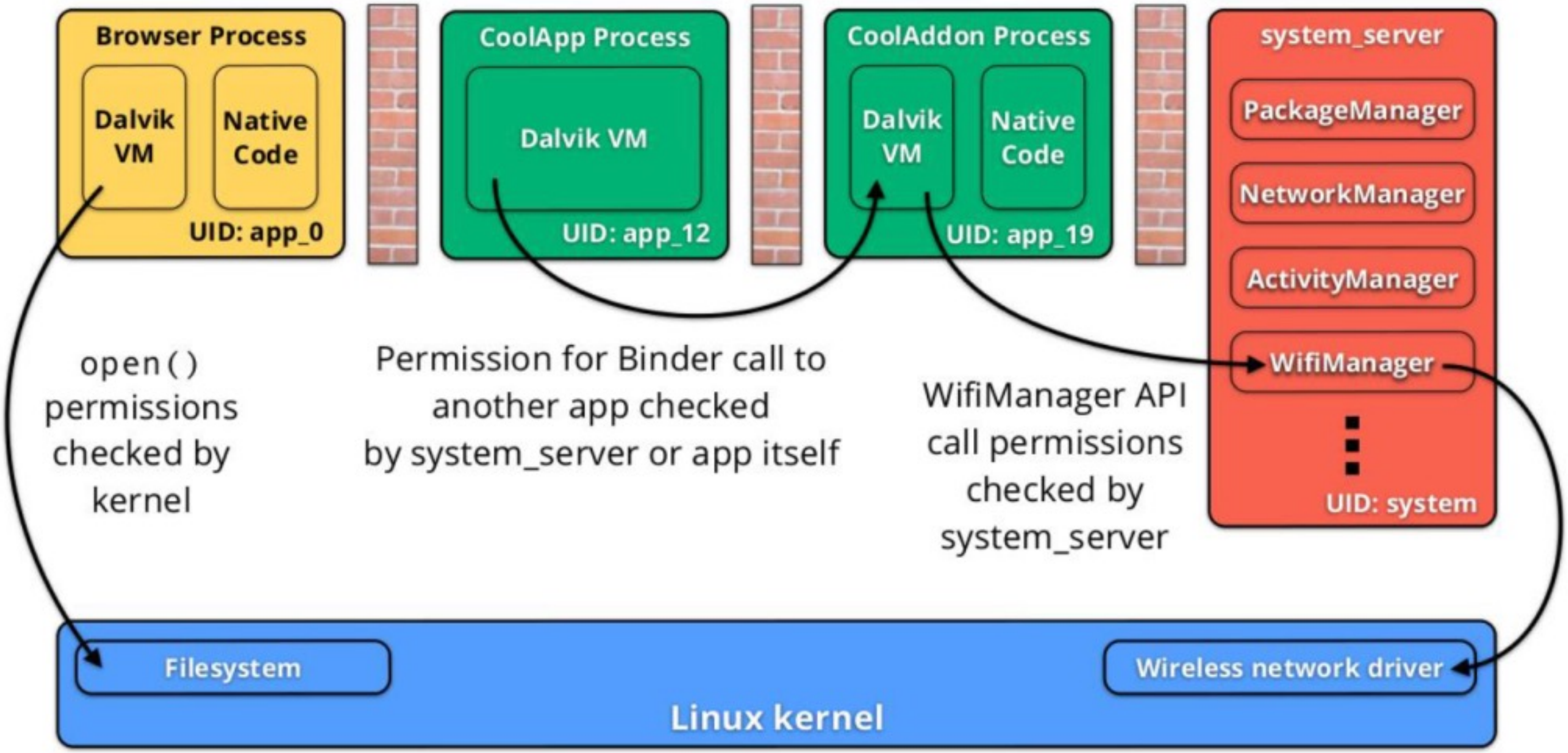
Android permission model

```
...
<uses-permission android:name="android.permission.READ_PHONE_STATE" />
<uses-permission android:name="android.permission.NFC" />
<uses-permission android:name="android.permission.INTERNET" />
...
```



https://www.owasp.org/images/3/3e/Danelon_OWASP_EU_Tour_2013.pdf

Android permission model



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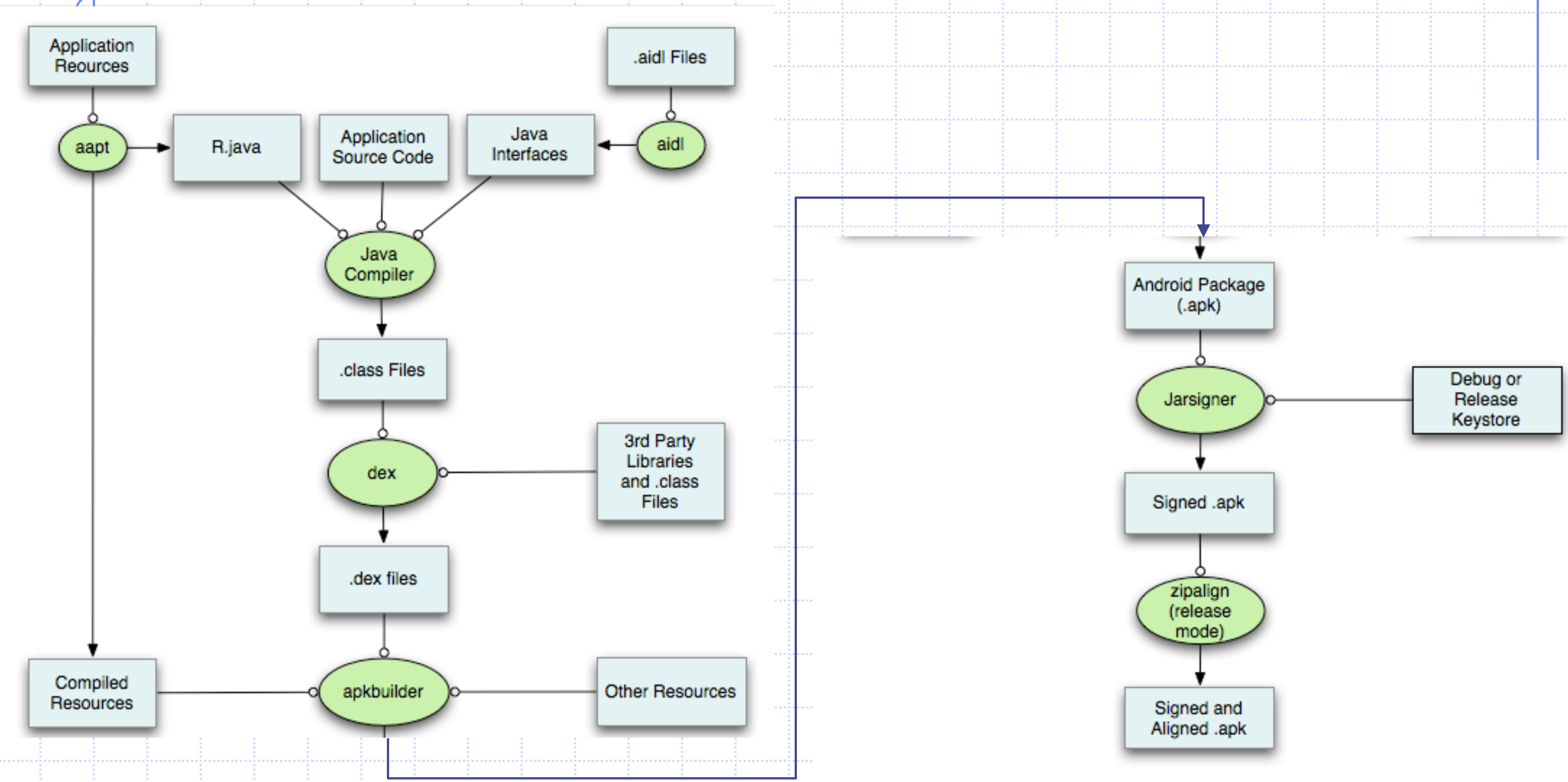
Application development process



Security Features

- Isolation
  - Multi-user Linux operating system
  - Each application normally runs as a different user
- Communication between applications
  - May share same Linux user ID
    - Access files from each other
    - May share same Linux process and Dalvik VM
  - Communicate through application framework
    - "Intents," based on Binder, discussed in a few slides
- Battery life
  - Developers must conserve power
  - Applications store state so they can be stopped (to save power) and restarted – helps with DoS

Application sandbox

- Application sandbox
  - Each application runs with its UID in its own Dalvik virtual machine
    - Provides CPU protection, memory protection
    - Authenticated communication protection using Unix domain sockets
    - Only ping, zygote (spawn another process) run as root
  - Applications announce permission requirement
    - Create a whitelist model – user grants access
      - Don't interrupt user – all questions asked as install time
    - Inter-component communication reference monitor checks permissions

Exploit prevention

- Open source: public review, no obscurity
- Goals
  - Prevent remote attacks, privilege escalation
  - Secure drivers, media codecs, new and custom features
- Overflow prevention
  - ProPolice stack protection
    - First on the ARM architecture
  - Some heap overflow protections
    - Chunk consolidation in DL malloc (from OpenBSD)
- ASLR
  - Avoided in initial release
    - Many pre-linked images for performance
  - Later developed and contributed by Bojinov, Boneh

dlmalloc (Doug Lea)

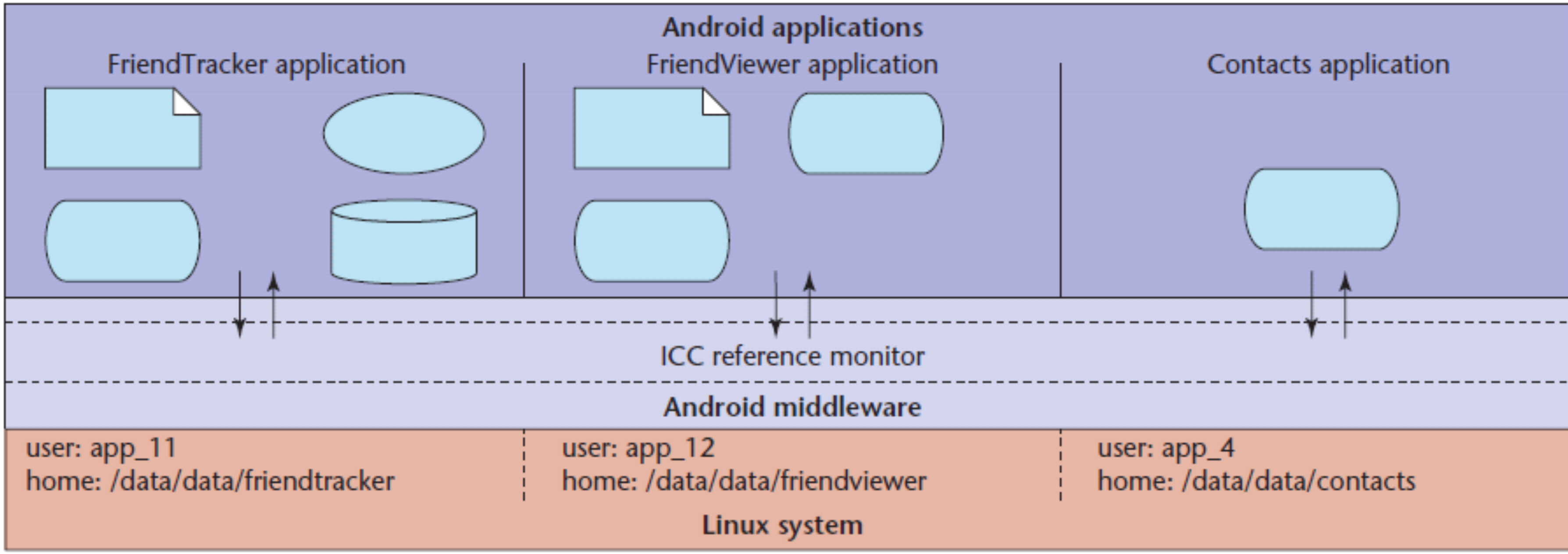
- Stores meta data in band
- Heap consolidation attack
  - Heap overflow can overwrite pointers to previous and next unconsolidated chunks
  - Overwriting these pointers allows remote code execution
- Change to improve security
  - Check integrity of forward and backward pointers
    - Simply check that back-forward-back = back, f-b-f=f
  - Increases the difficulty of heap overflow

Application development concepts

- Activity – one-user task
  - Example: scroll through your inbox
  - Email client comprises many activities
- Service – Java daemon that runs in background
  - Example: application that streams an mp3 in background
- Intents – asynchronous messaging system
  - Fire an intent to switch from one activity to another
  - Example: email app has inbox, compose activity, viewer activity
    - User click on inbox entry fires an intent to the viewer activity, which then allows user to view that email
- Content provider
  - Store and share data using a relational database interface
- Broadcast receiver
  - "mailboxes" for messages from other applications

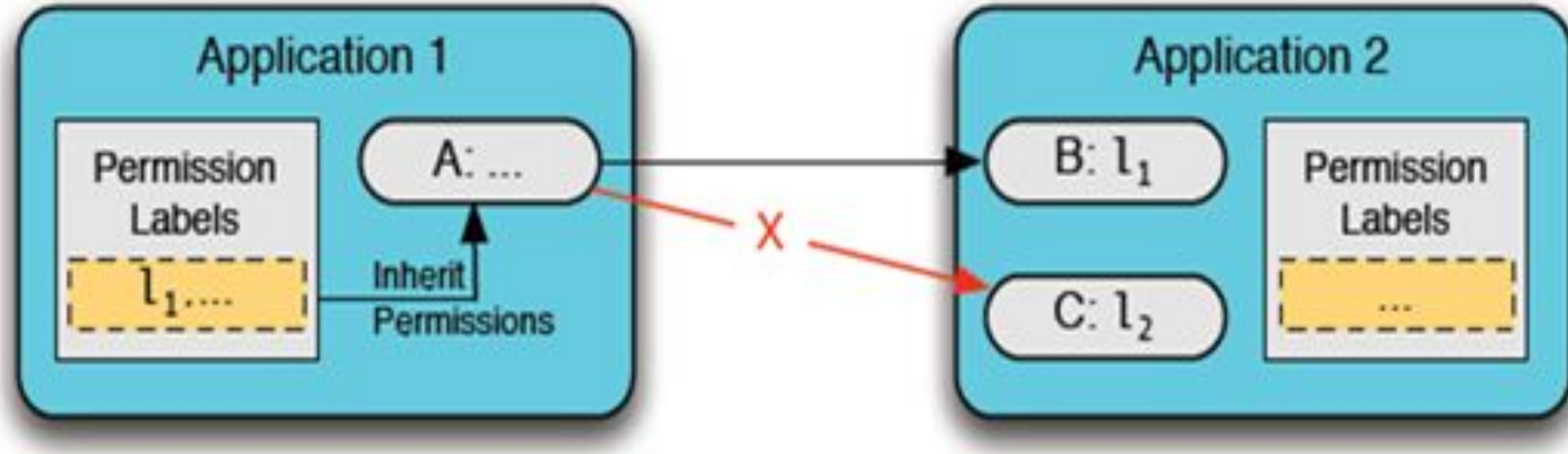
Android Intents

- Message between components in same or different app
- Intent is a bundle of information, e.g.,
  - 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



- Layers of security
  - Each application executes as its own user identity
  - Android middleware has reference monitor that mediates the establishment of inter-component communication (ICC)

Source: Penn State group Android security paper



MAC Policy Enforcement in Android. This is how applications access components of other applications via the reference monitor. Component A can access components B and C if permission labels of application 1 are equal or dominate labels of application 2.

Source: Penn State group, Android security tutorial

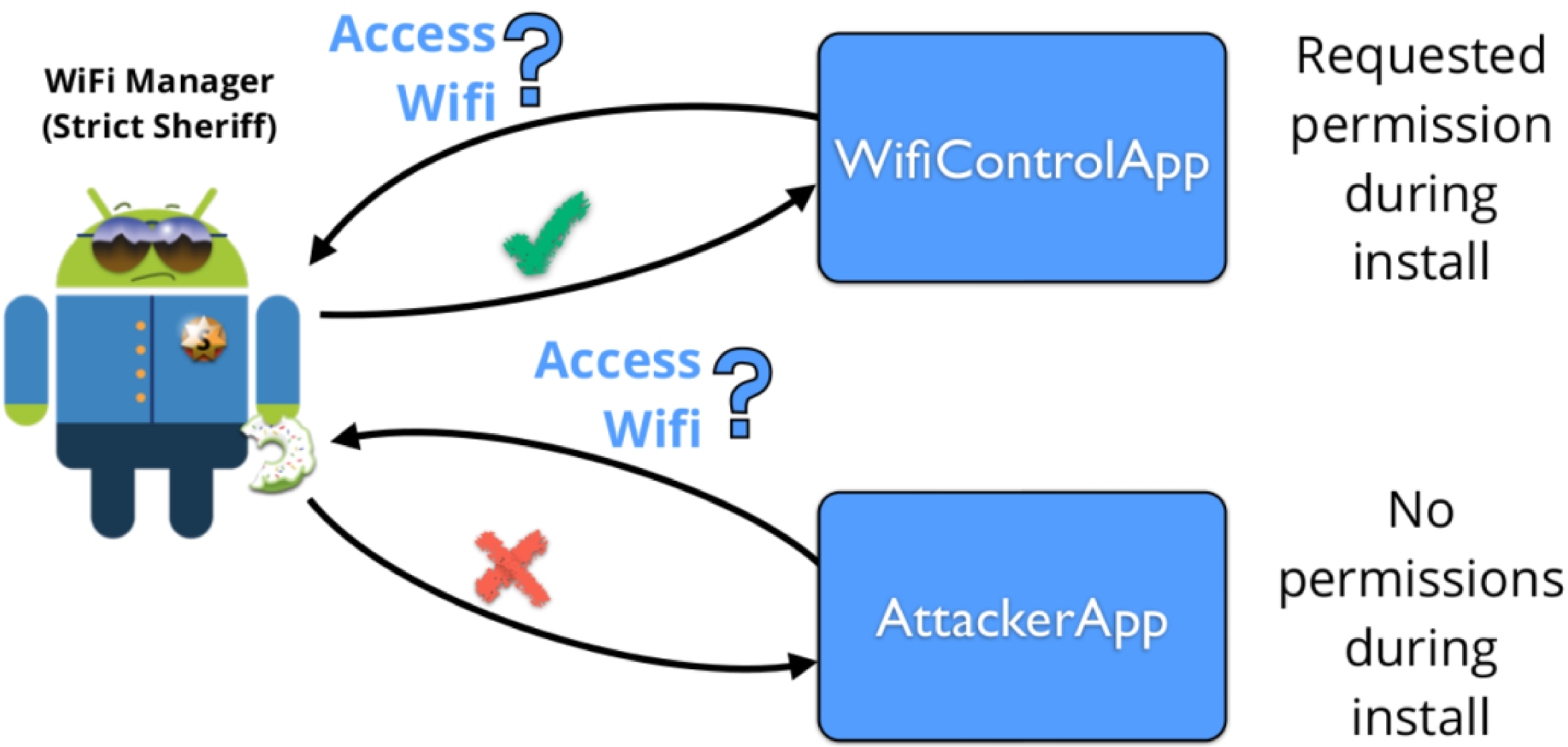
Security issues with intents

- Sender of an intent can verify that the recipient has a permission by specifying a permission with the method call
- Senders can use explicit intents to send the message to a single component (avoiding broadcasting)
- Receivers have to handle malicious intents

Attack: Permission redelegation

- Definition: an application without a permission gains additional privileges through another application
- Example of the “confused deputy” problem

Permission redelegation



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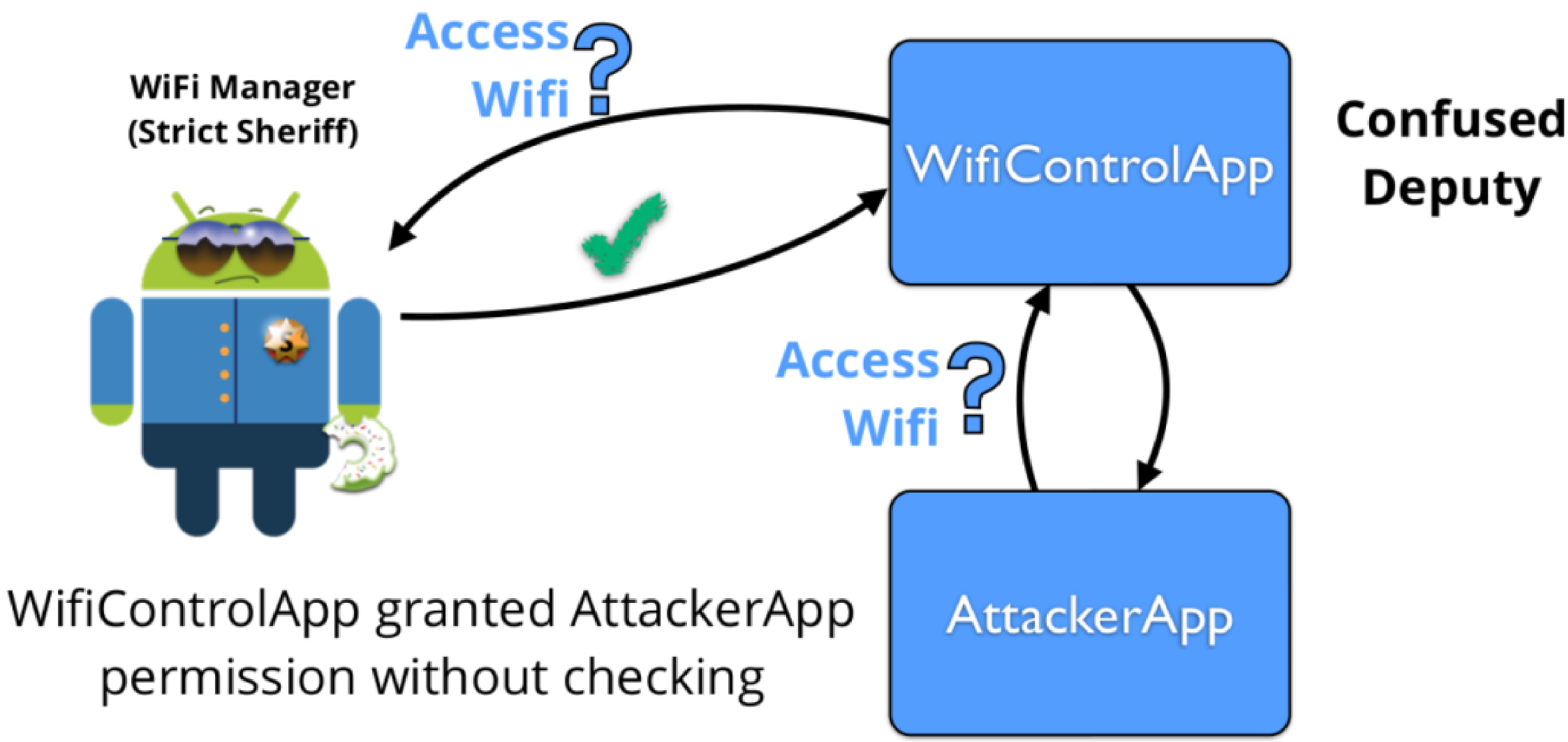
Permission redelegation



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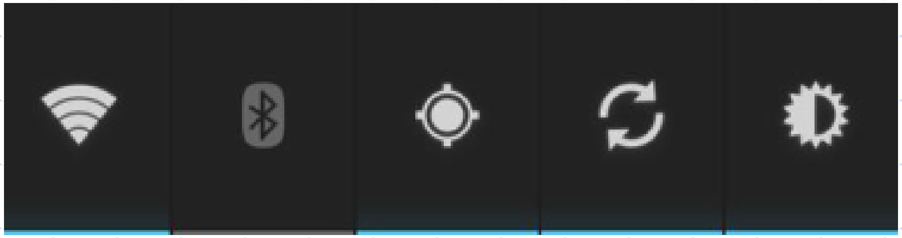
How could this happen?

- App w/ permissions exposes a public interface
- Study in 2011
  - Examine 872 apps
  - 320 of these (37%) have permissions and at least one type of public component
  - Construct attacks using 15 vulnerabilities in 5 apps
- Reference
  - Permission Re-Delegation: Attacks and Defenses, Adrienne Felt, Helen Wang, Alexander Moshchuk, Steven Hanna, Erika Chin, Usenix 2011

Example: power control widget

- Default widgets provided by Android, present on all devices



- Can change Wi-fi, BT, GPS, Data Sync, Screen Brightness with only one click
- Uses Intent to communicate the event of switching settings
- A malicious app without permissions can send a fake Intent to the Power Control Widget, simulating click to switch settings

https://www.owasp.org/images/3/3e/Danelon_OWASP_EU_Tour_2013.pdf

Vulnerable versions (in red)

Version	Codename	API	Distribution
1.6	**Donut**	**4**	**0.10%**
2.1	**Eclair**	**7**	**1.50%**
2.2	**Froyo**	**8**	**3.20%**
2.3 - 2.3.2	Gingerbread	9	0.10%
2.3.3 - 2.3.7		10	36.40%
3.2	Honeycomb	13	0.10%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	25.60%
4.1.x	**Jelly Bean**	16	29.00%
4.2.x		**17**	**4.00%**

- Principle of least privilege helps but is not a solution
- Apps with permissions need to manage security

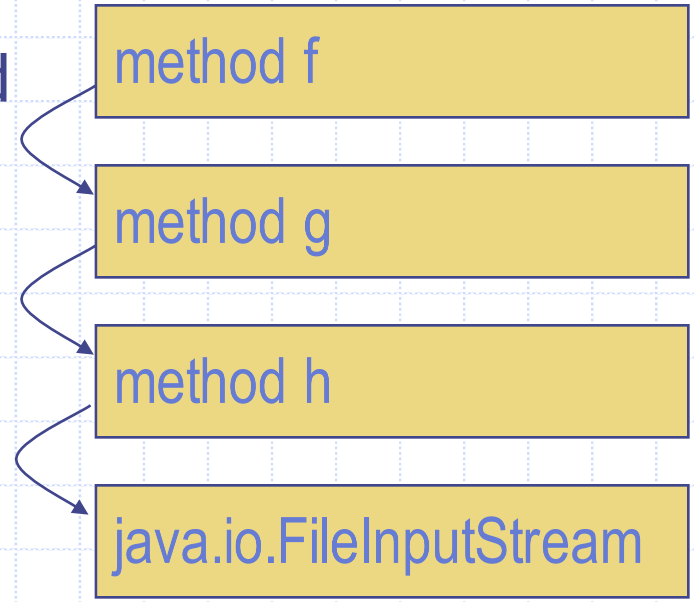
https://www.owasp.org/images/3/3e/Danelon_OWASP_EU_Tour_2013.pdf

Java Sandbox

- Four complementary mechanisms
  - Class loader
    - Separate namespaces for separate class loaders
    - Associates *protection domain* with each class
  - Verifier and JVM run-time tests
    - NO unchecked casts or other type errors, NO array overflow
    - Preserves private, protected visibility levels
  - Security Manager
    - Called by library functions to decide if request is allowed
    - Uses protection domain associated with code, user policy

Stack Inspection

- Permission depends on
  - Permission of calling method
  - Permission of all methods above it on stack
    - Up to method that is trusted and asserts this trust



Many details omitted here

Stories: Netscape font / passwd bug; Shockwave plug-in

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  - Platforms
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  - Threats
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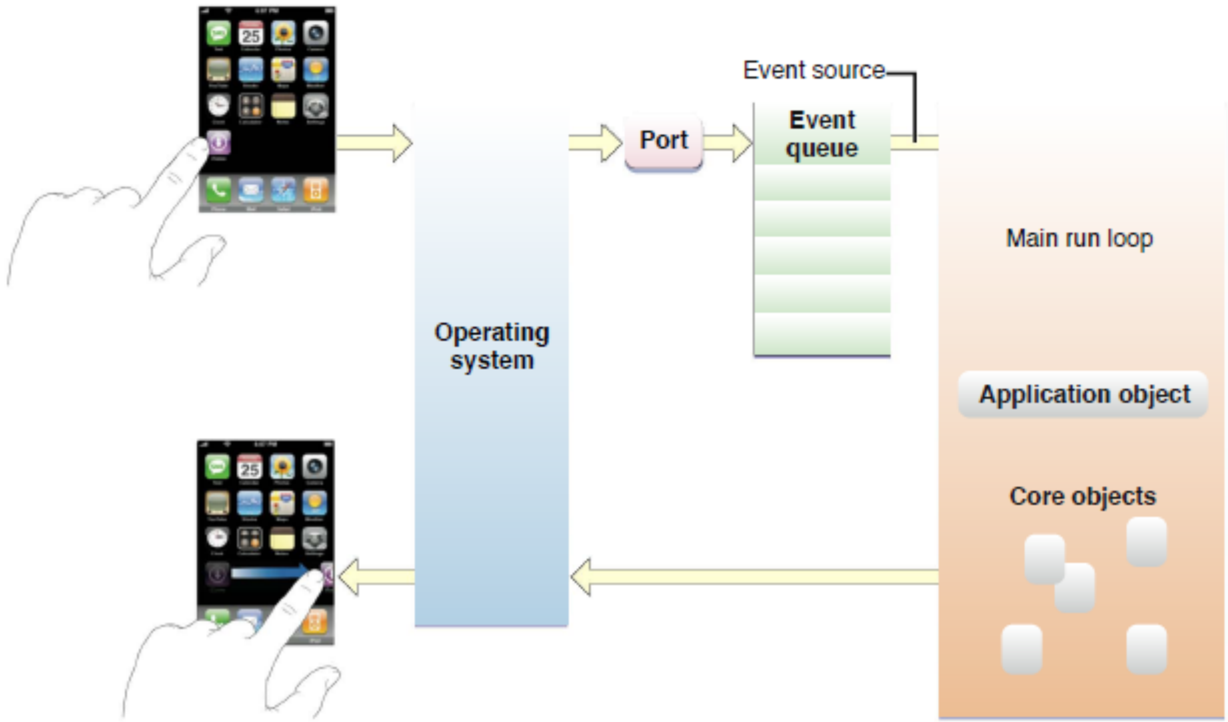
Apple iOS

From: iOS App Programming Guide

Reference

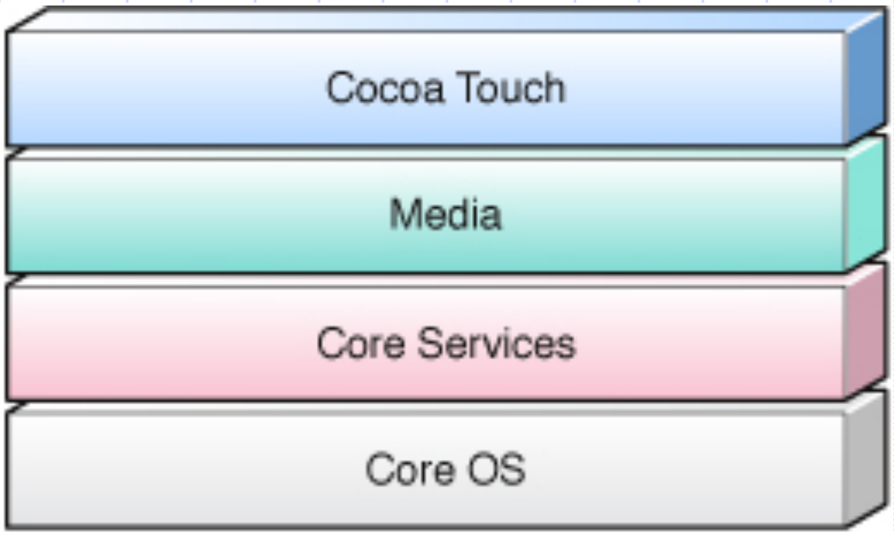
iOS Security (9.3), May 2016

iOS Application Development



- Apps developed in Objective-C using Apple SDK
- Event-handling model based on touch events
- Foundation and UIKit frameworks provide the key services used by all iOS applications

iOS Platform

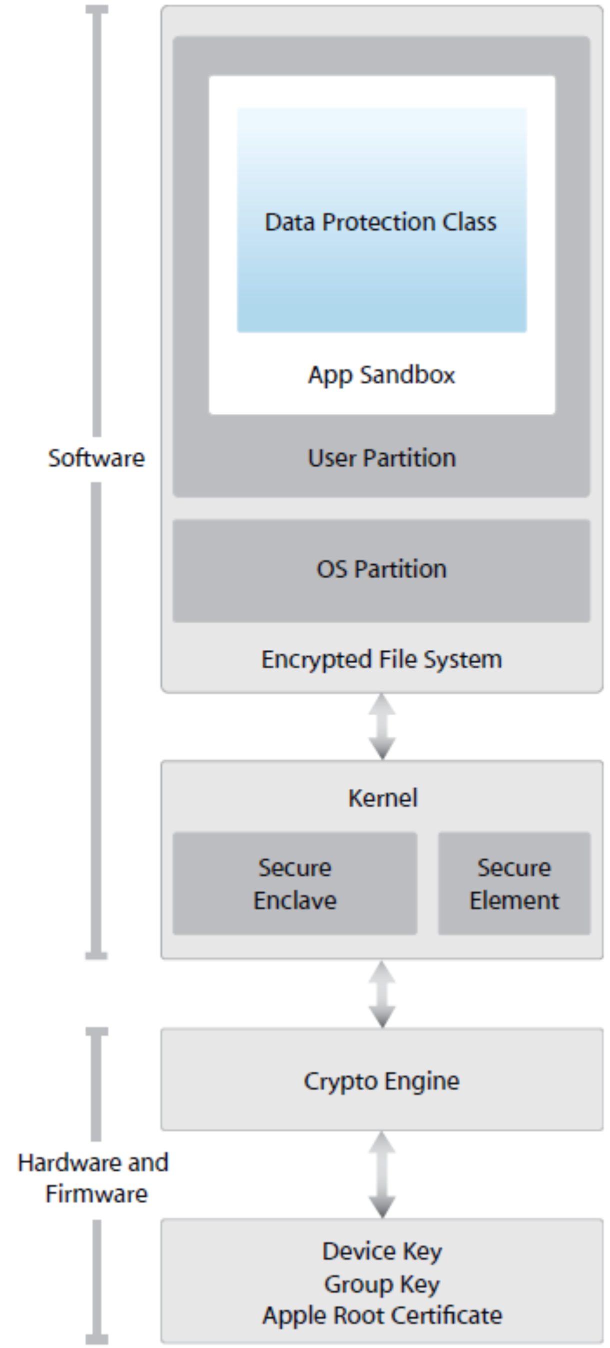


- Cocoa Touch: Foundation framework, OO support for collections, file management, network operations; UIKit
- Media layer: supports 2D and 3D drawing, audio, video
- Core OS and Core Services: APIs for files, network, … includes SQLite, POSIX threads, UNIX sockets
- Kernel: based on Mach kernel like Mac OS X

Implemented in C and Objective-C

Apple iOS Security

- Device security
  - Prevent unauthorized use of device
- Data security
  - Protect data at rest; device may be lost or stolen
- Network security
  - Networking protocols and encryption of data in transmission
- App security
  - Secure platform foundation

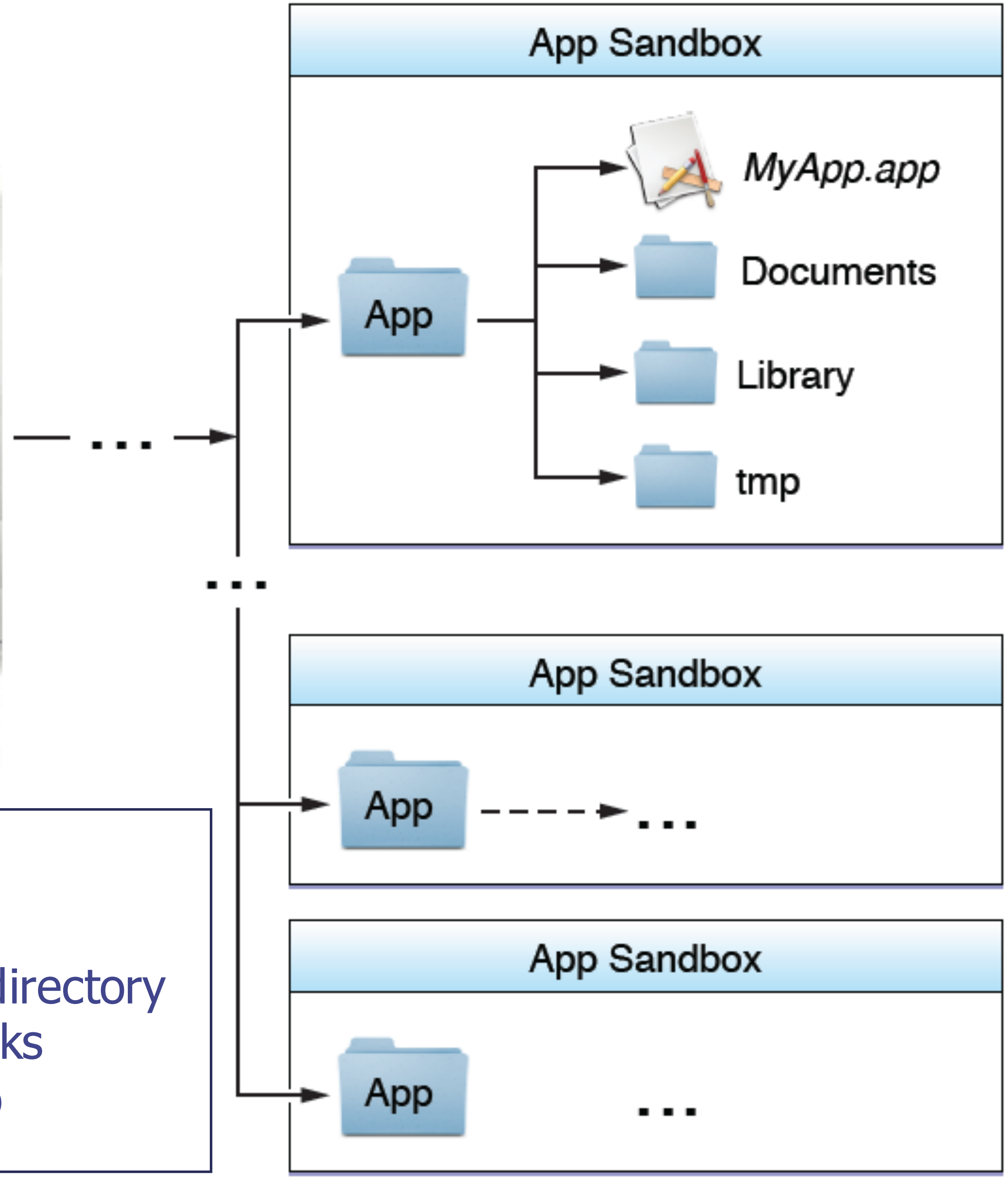


https://www.apple.com/business/docs/iOS_Security_Guide.pdf

App Security

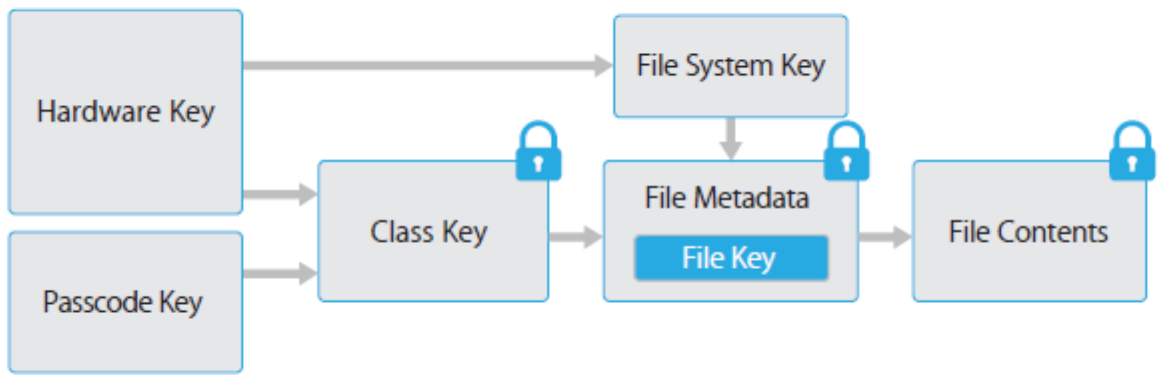
- Runtime protection
  - System resources, kernel shielded from user apps
  - App “sandbox” prevents access to other app’s data
  - Inter-app communication only through iOS APIs
  - Code generation prevented
- Mandatory code signing
  - All apps must be signed using Apple-issued certificate
- Application data protection
  - Apps can leverage built-in hardware encryption

iOS Sandbox



- Limit app's access to files, preferences, network, other resources
- Each app has own sandbox directory
- Limits consequences of attacks
- Same privileges for each app

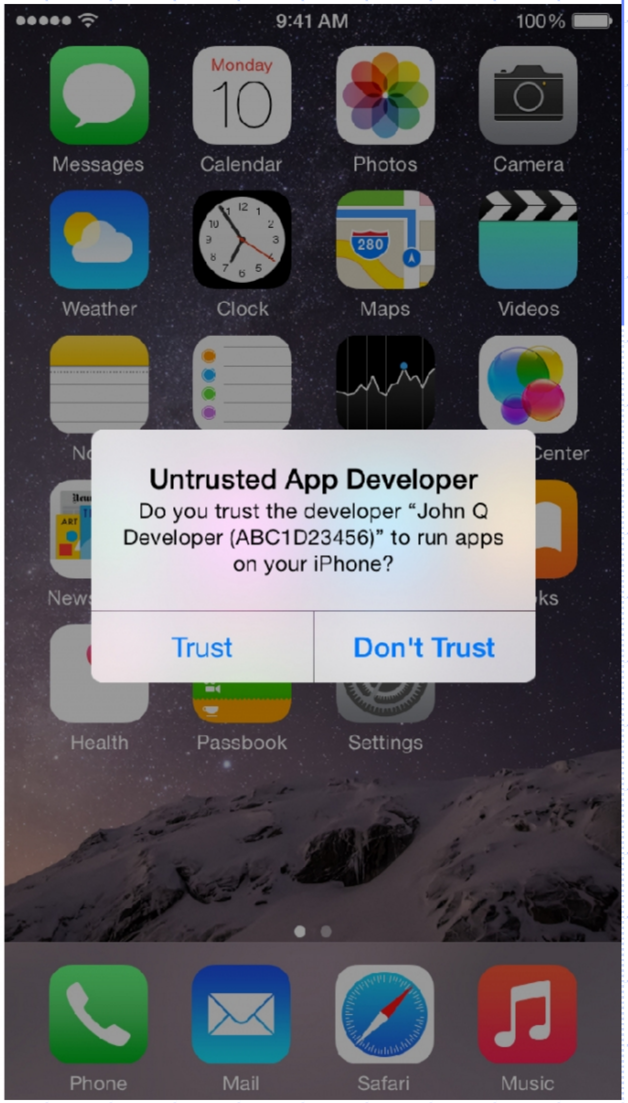
File encryption



- The content of a file is encrypted with a per-file key, which is wrapped with a class key and stored in a file's metadata, which is in turn encrypted with the file system key.
  - When a file is opened, its metadata is decrypted with the file system key, revealing the wrapped per-file key and a notation on which class protects it
  - The per-file key is unwrapped with the class key, then supplied to the hardware AES engine, decrypting the file as it is read from flash memory
- The metadata of all files is encrypted with a random key. Since it's stored on the device, used only for quick erased on demand.

“Masque Attack”

- iOS app installed using enterprise/ad-hoc provisioning could replace genuine app installed through the App Store, if both apps have same bundle identifier
- This vulnerability existed because iOS didn't enforce matching certificates for apps with the same bundle identifier



Comparison: iOS vs Android

- App approval process
  - Android apps from open app store
  - iOS vendor-controlled store of vetted apps
- Application permissions
  - Android permission based on install-time manifest
  - All iOS apps have same set of “sandbox” privileges
- App programming language
  - Android apps written in Java; no buffer overflow…
  - iOS apps written in Objective-C

Comparison

	iOS	Android	Windows
Unix	x	x	
Windows			
Open market		x	
Closed market	x		
Vendor signed	x		
Self-signed		x	
User approval of permissions		x	
Managed code		x	
Native code	x		

Comparison

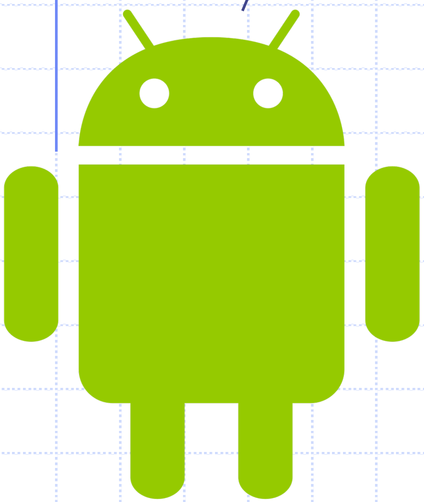
	iOS	Android	Windows
Unix	x	x	
Windows			x
Open market		x	
Closed market	x		x
Vendor signed	x		
Self-signed		x	x
User approval of permissions		x	7-> 8
Managed code		x	x
Native code	x		

Mobile Web Apps

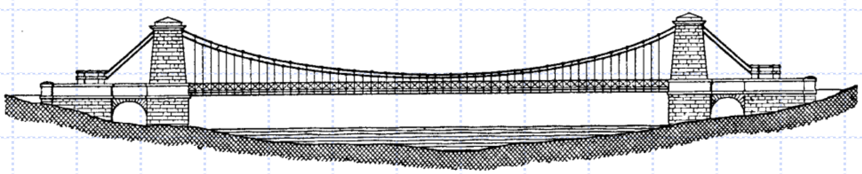
- Mobile web app: embeds a fully functional web browser as a UI element

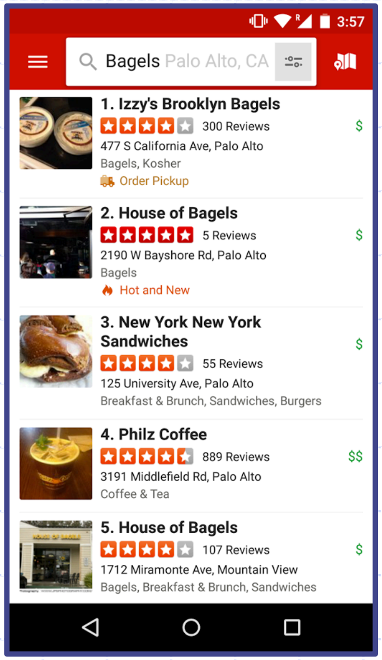
JavaScript Bridge

```
Obj foo = new Object();
addJavascriptInterface(foo, ‘f’);
```



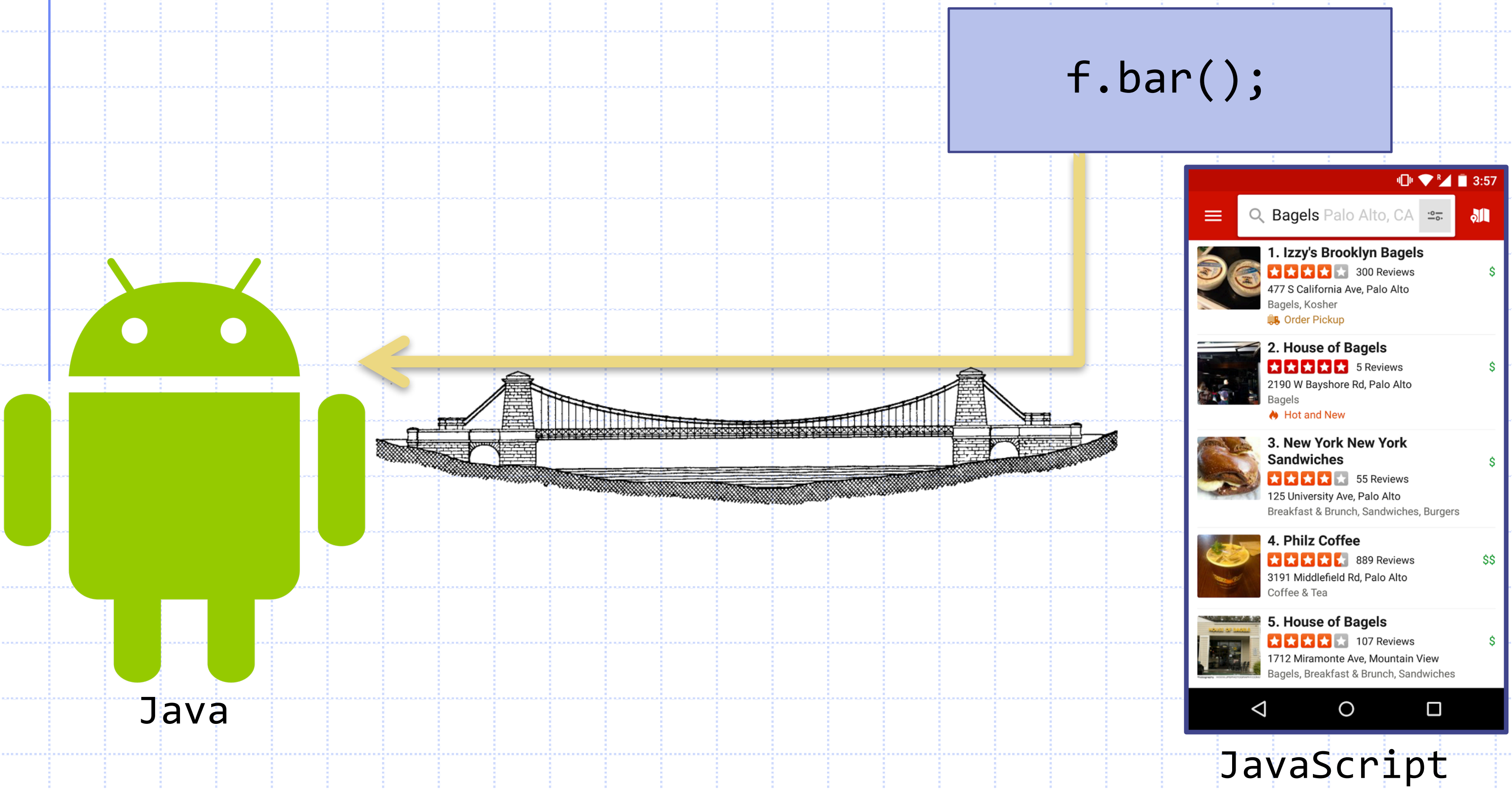
Java





JavaScript

JavaScript Bridge



Most significant vulnerabilities

- Loading untrusted web content
- Leaking URLs to foreign apps
- Exposing state changing navigation to foreign apps

Conclusion

- Overview: Platform, market, threats
- Android security model
  - Platform security features
  - Isolated process with separate VM
  - Permission model
  - App communication via intents
- Apple iOS security model
  - App sandbox based on file isolation
  - File encryption
- ~~Windows Mobile security model~~