CS 528 Mobile and Ubiquitous Computing

Lecture 11: Mobile Security and Mobile Software Vulnerabilities

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Mobile Security Issues

Introduction

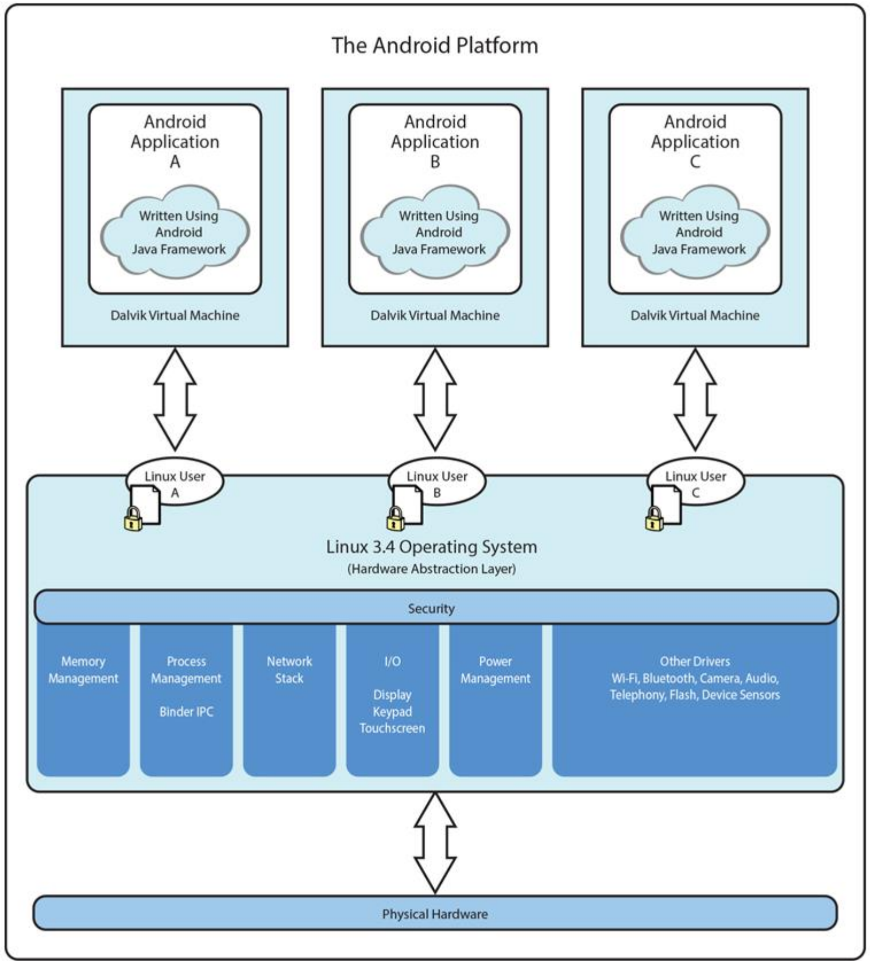
- So many cool mobile apps
- Access to web, personal information, social media, etc
- Security problems (not previously envisaged) have resulted
- Examples:
  - Malicious apps can steal your private information (credit card information, etc)
  - Smartphone sensors can leak sensitive information
  - Malware can lock your phone till you pay some money (ransomeware)
- Need deeper understanding of mobile security

Android Security Model

Android Security

- Security goals are to
  - Protect user data, system resources (hardware, software)
  - Provide application isolation

- **Foundations of Android Security**
  1. **Application Isolation:**
     - Application sandboxing: App 1 cannot interact directly with app 2
     - Secure inter-process communication
  2. **Permission Requirement:**
     - System-built and user-defined permissions
     - Application signing



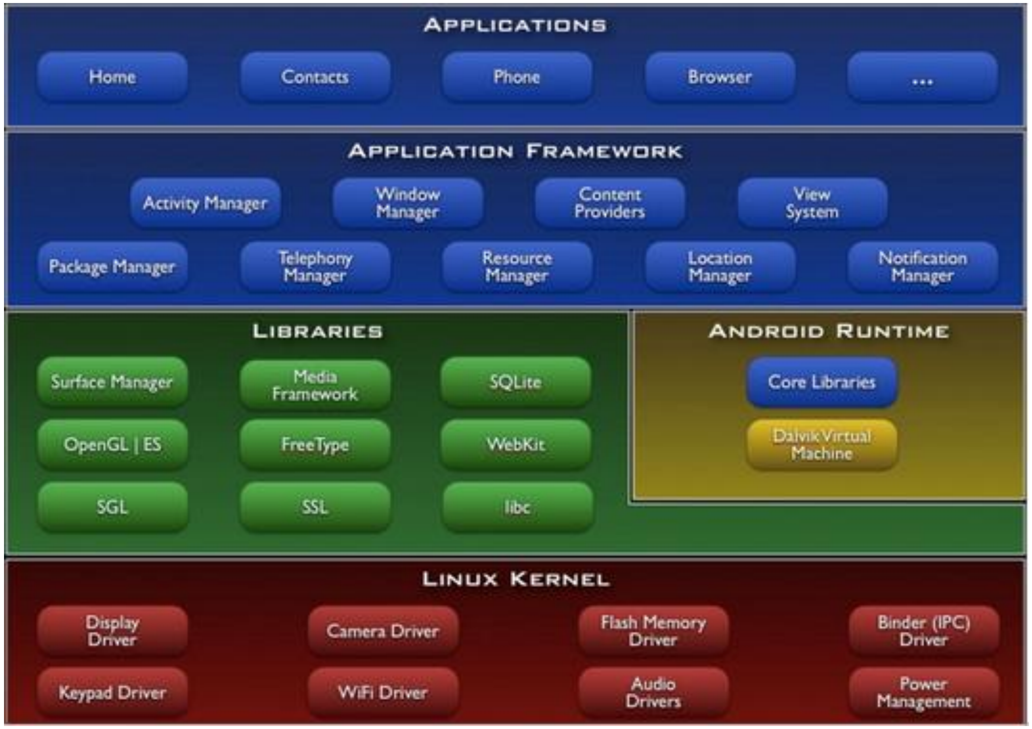
Recall: Android Software Framework

- Each Android app runs in its own security sandbox (VM, minimizes complete system crashes)
- Android OS multi-user Linux system
- Each app is a different user (assigned unique Linux ID)
- Access control: only process with the app's user ID can access its files
- Apps talk to each other only via intents, IPC or ContentProviders

Ref: Introduction to Android Programming, Annuzzi, Darcey & Conder

Recall: Android Software Framework

- Android software framework is layered
  - **OS:** Linux kernel, drivers
  - **Apps:** programmed & UI in Java
  - **Libraries:** OpenGL ES (graphics), SQLite (database), etc
- Each layer assumes layer below it is secure



Android Encryption

- Encryption encodes data so that unauthorized party cannot read it

- **Full-disk encryption:** Android 5.0+ provides full filesystem encryption
  - All user data can be encrypted in the kernel
  - User password needed to access files, even to boot device

- **File-based encryption:** Android 7.0+ allows specific files to be encrypted and unlocked independently

iPhone vs Android Encryption

- In earlier Androids, encryption was up to user
- iPhones encrypt automatically: almost all encrypted

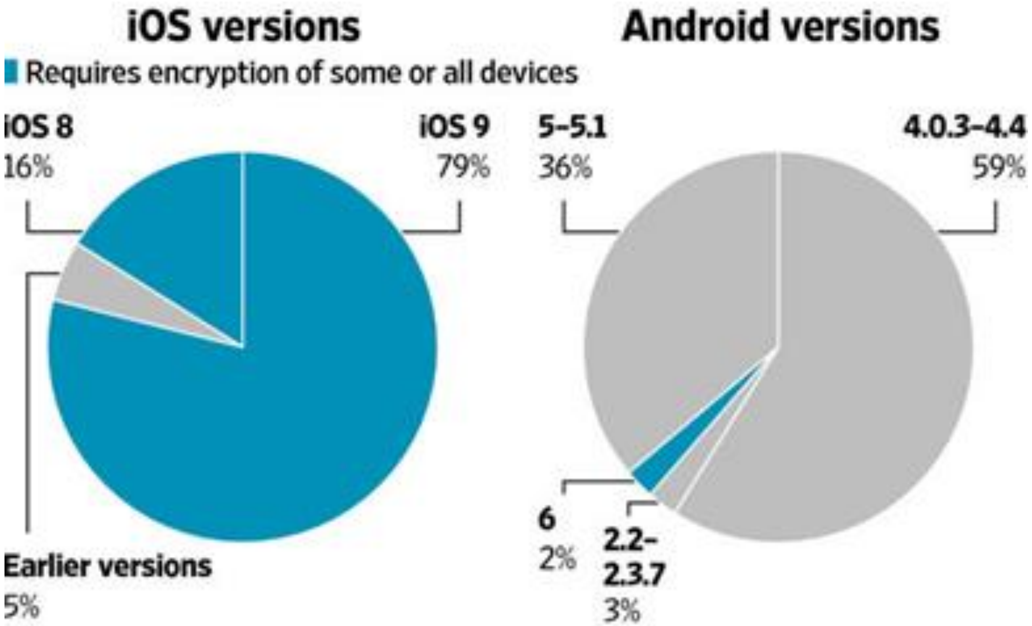
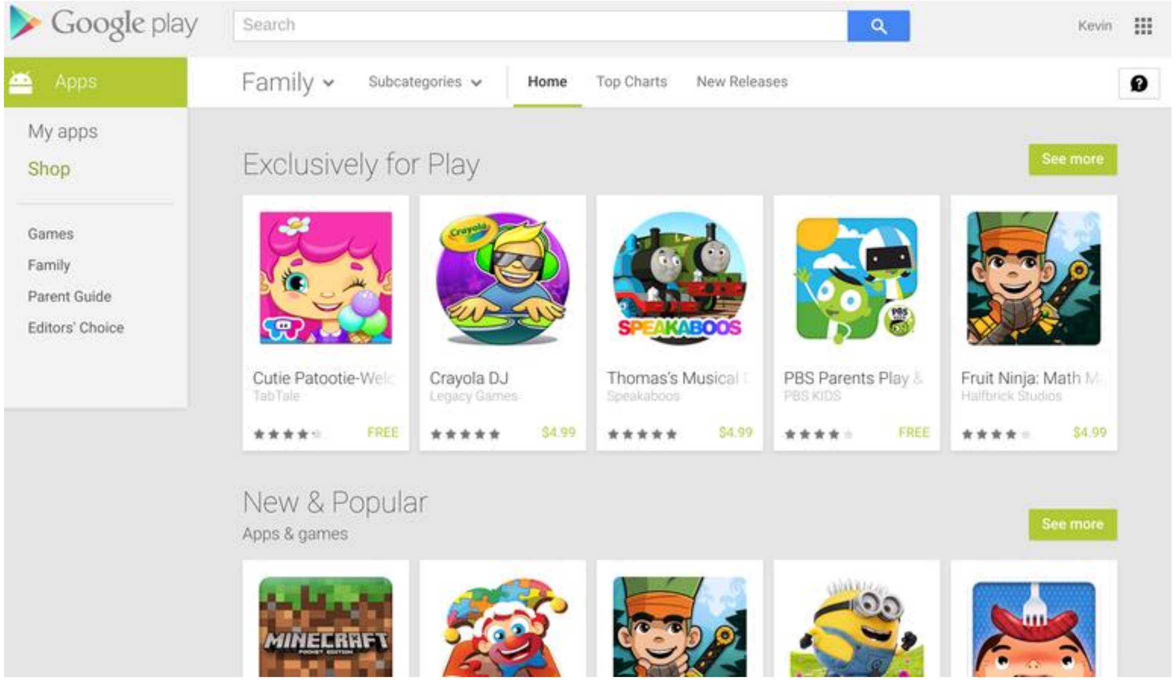


Image credit: wall street journal

App Markets

App Markets & Distribution

- Major OS vendors manage their own markets for “certified” apps
  - Android: the Google Play Store
  - iOS: the App Store is the sole source of apps



Google Play App Scanning

- Important for app markets to check security of apps, prevent malware
- Most current markets include some form of scan or verification prior to accepting/certifying an app
  - Typically, static analysis of source code to check for known malware, best practices, app performance, etc.
  - Crowd-sourced reports after approval also useful (e.g. users report suspicious apps)

- Google Play app scanning (called Google Play Protect)
  - Antivirus system scans Google Play for threats, malware
  - New “peer grouping system:
    - similar apps (e.g. all calculators) are grouped on app market.
    - If one app requests more permissions than similar apps, human takes a look

App Markets: Android Vs iOS

- Apple App Store
  - Highly regulated
  - All applications are reviewed by human
  - iOS devices can only obtain apps through here, unless jailbreaked
- Google Play (Android Market)
  - More automated scans
  - Some applications may be reviewed
  - Users may also install Android apps from 3rd party marketplaces (e.g. Pandaapp)
- Many malware developers target third-party markets
  - Weaker/no restrictions or analysis capabilities

Malware Evolution

Threat Types: Malware, Grayware & Personal Spyware

- What's the difference between??
  1. Malware
  2. Spyware
  3. Grayware

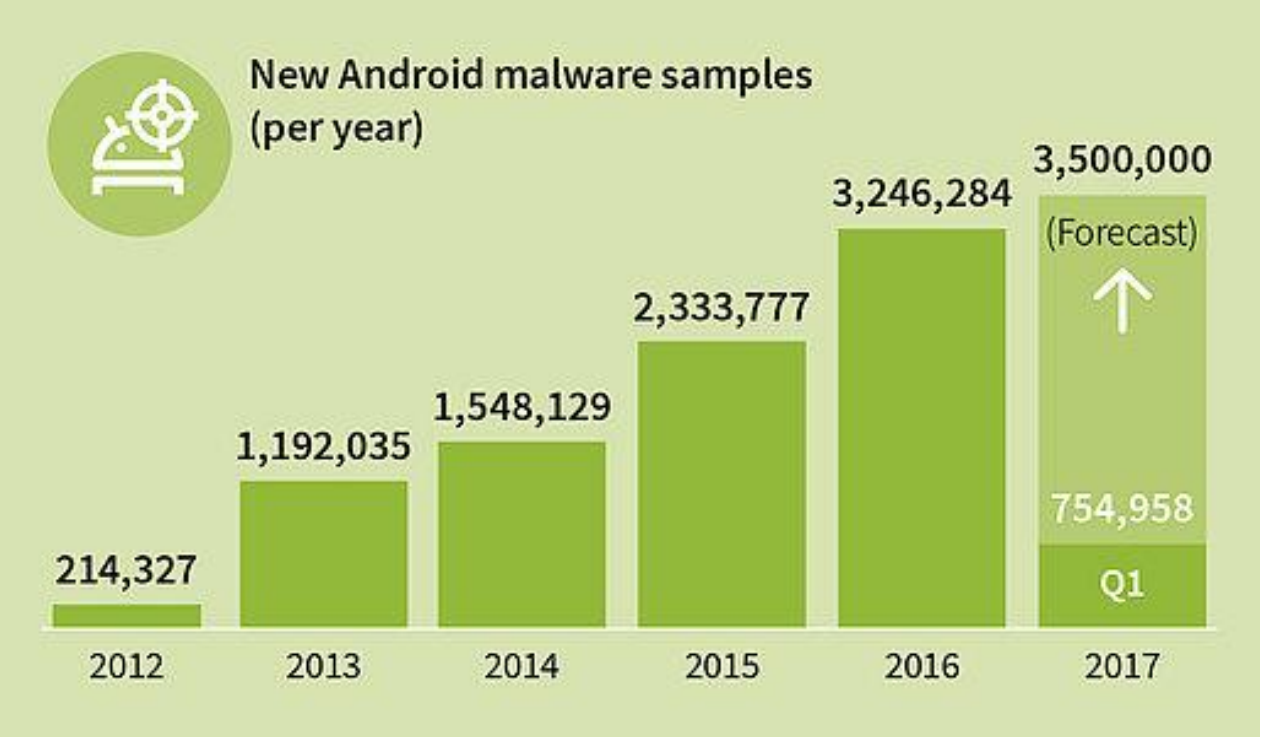
Threat Types: Malware, Grayware & Personal Spyware

- **Malware:**
  - Gains access to a mobile device in order to steal data, damage device, or annoying the user, etc. **Malicious!!**

- **Personal Spyware:**
  - Collects user's personal information over of time
  - Sends information to app **installer** instead of author
  - E.g. spouse may install personal spyware to get info

- **Grayware:**
  - Collect data on user, but with no intention to harm user
  - E.g. for marketing ,user profiling by a company

Growth of Android Malware



Ref: Bochum, Author: Christian Lueg8,400 new Android malware samples every day
https://www.gdatasoftware.com/blog/2017/04/29712-8-400-new-android-malware-samples-every-day

Mobile Malware Survey (*Felt et al*)

Mobile Malware Study?

A survey of mobile malware in the wild Adrienne Porter Felt, Matthew Finifter, Erika Chin, Steve Hanna, and David Wagner in Proc SPSM 2011

- First major mobile malware study in 2011 by Andrienne Porter Felt *et al*
  - Previously, studies mostly focused on PC malware
- Analyzed 46 malwares that spread Jan. 2009 – June 2011
  - 18 – Android
  - 4 – iOS
  - 24 – Symbian (discontinued)
- Analyzed information in databases collected by:
  - information in databases maintained by anti-virus companies
    - E.g., Symantec, F-Secure, Fortiguard, Lookout, and Panda Security
  - Mentions of malware in news sources
- Did not analyze spyware and grayware

Categorized Apps based on Behaviors

- **Novelty and amusement:** Minor damage. E.g.
  - Change user’s wallpaper
- **Selling user information:**
  - Personal information obtained via API calls
    - User’s location, contacts, download + browser history/preferences
  - Information can be sold for advertisement
    - $1.90 to $9.50 per user per month

Categorized Apps based on Behaviors

- **Stealing user credentials:**
  - People use smartphones for shopping, banking, e-mail, and other activities that require passwords and payment information
  - Malwares can log keys typed by user (keylogging), scan their documents for username + password
- In 2008, black market price of:
  - Bank account credentials: $10 to $1, 000,
  - Credit card numbers: $.10 to $25,
  - E-mail account passwords: $4 to $30

Categorized Apps based on Behaviors

- **Make premium-rate calls and SMS:**
  - Premium rate texts to specific numbers are expensive
  - Malware sends SMS to these numbers set up by attacker
  - Cell carrier (e.g. sprint) bills users
  - Attacker makes money
- **SMS spam:**
  - Used for commercial advertising and phishing
  - Sending spam email is illegal in most countries
  - Attacker uses malware app on user’s phone to send SPAM email
  - Harder to track down senders

Categorized Apps based on Behaviors

- **Search Engine Optimization (SEO):**
  - Malware makes HTTP requests for specific pages to increase its ranking (e.g. on Google)
  - Increases popularity of requested websites

- **Ransomeware**
  - Possess device, e.g. lock screen till money is paid
  - *Kenzero* – Japanese virus included in pornographic games distributed on the P2P network
    - Asked for Name, Address, Company Name for “registration” of software
    - Asked **5800 Yen** (~$60) to delete information from website (Paper information is wrong)
    - About 661 out of 5510 infections actually paid (12%)

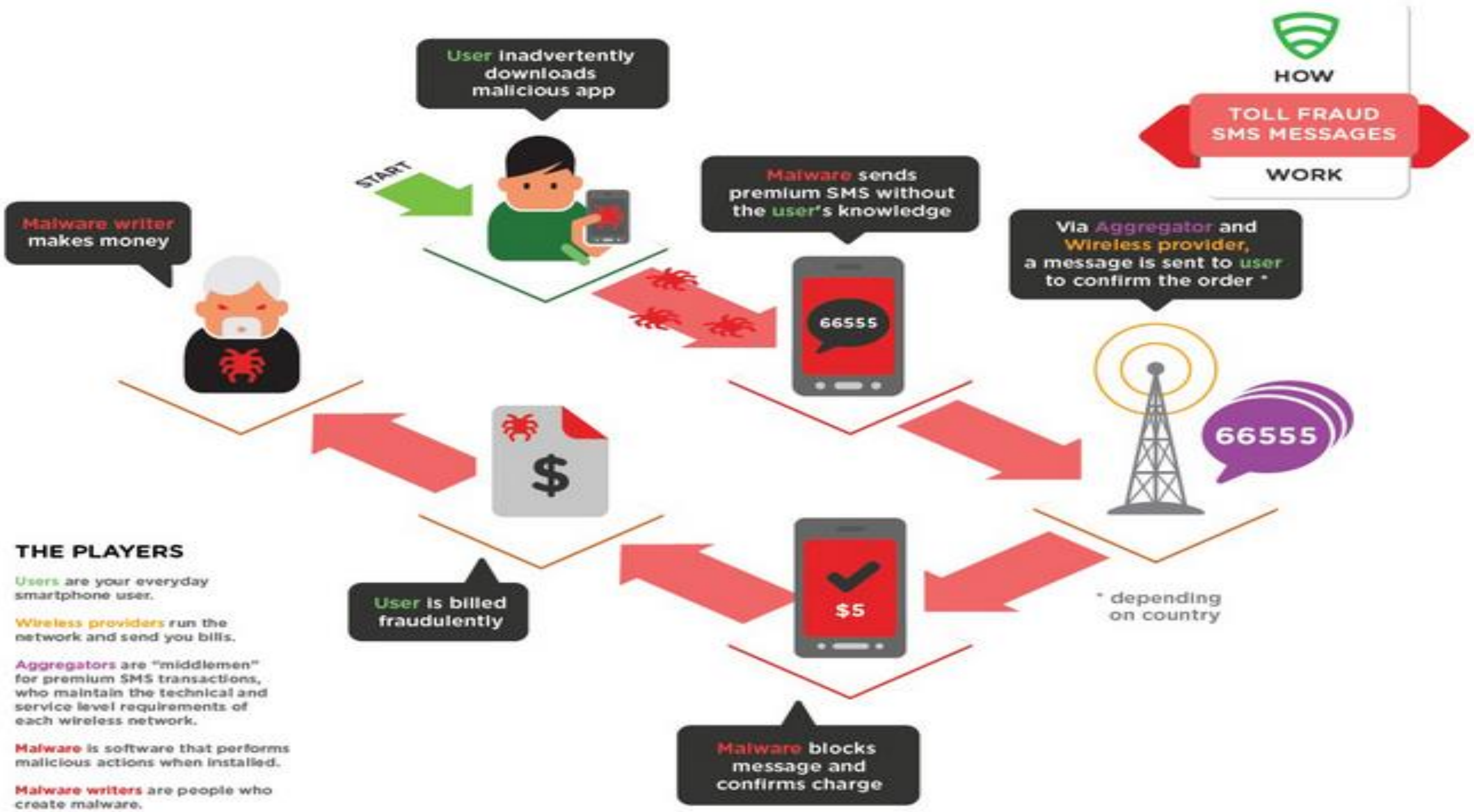
Categorization of Malware Behaviors

Exfiltrates user information	28
Premium calls or SMS	24
Sends SMS advertisement spam	8
Novelty and amusement	6
Exfiltrates user credentials	4
Search engine optimization	1
Ransom	1

Table 1: We classify 46 pieces of malware by behavior. Some samples exhibit more than one behavior, and every piece of malware exhibits at least one.

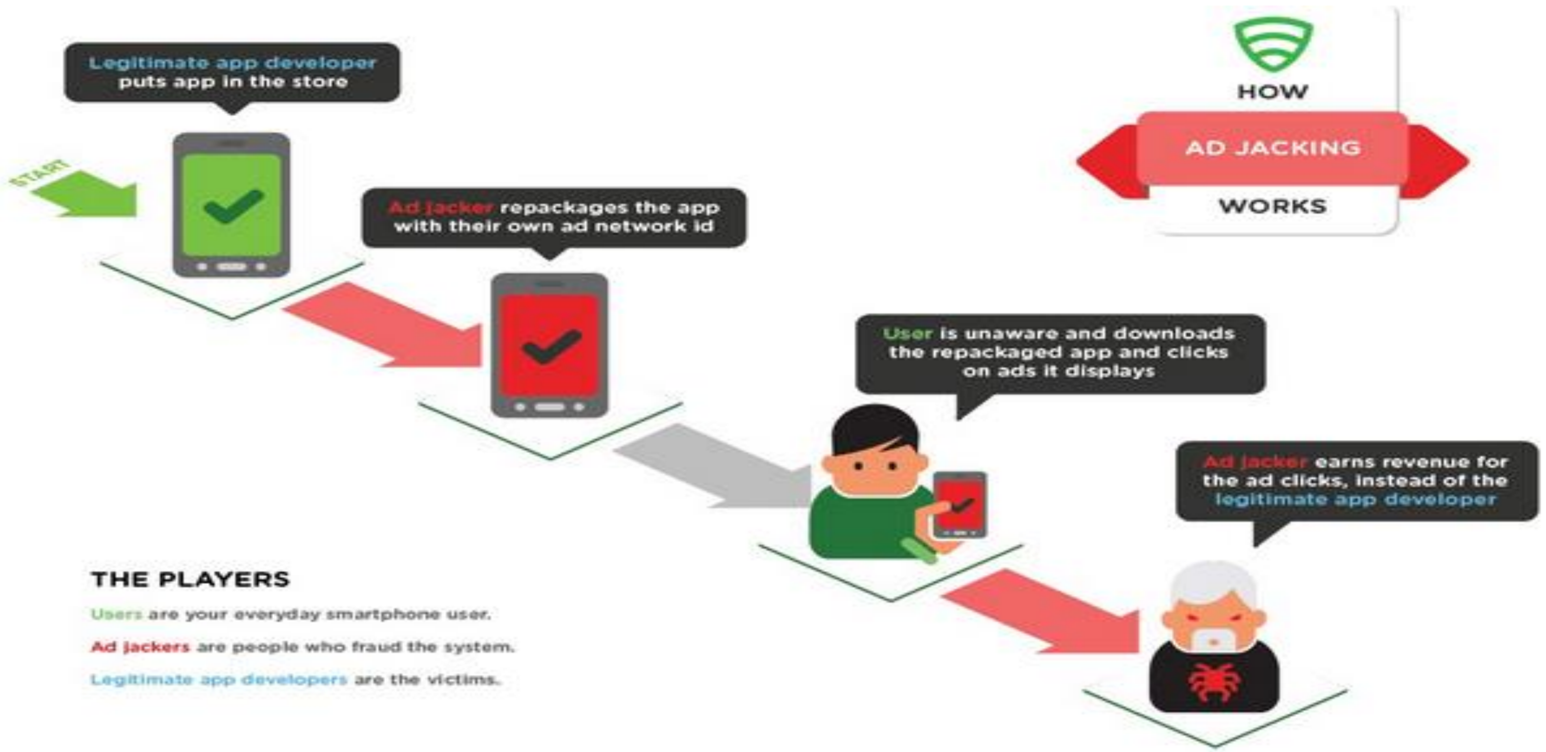
Malware Example: Toll Fraud

Source: Lookout State of Mobile Security 2012
https://www.lookout.com/resources/reports/state-of-mobile-security-2012



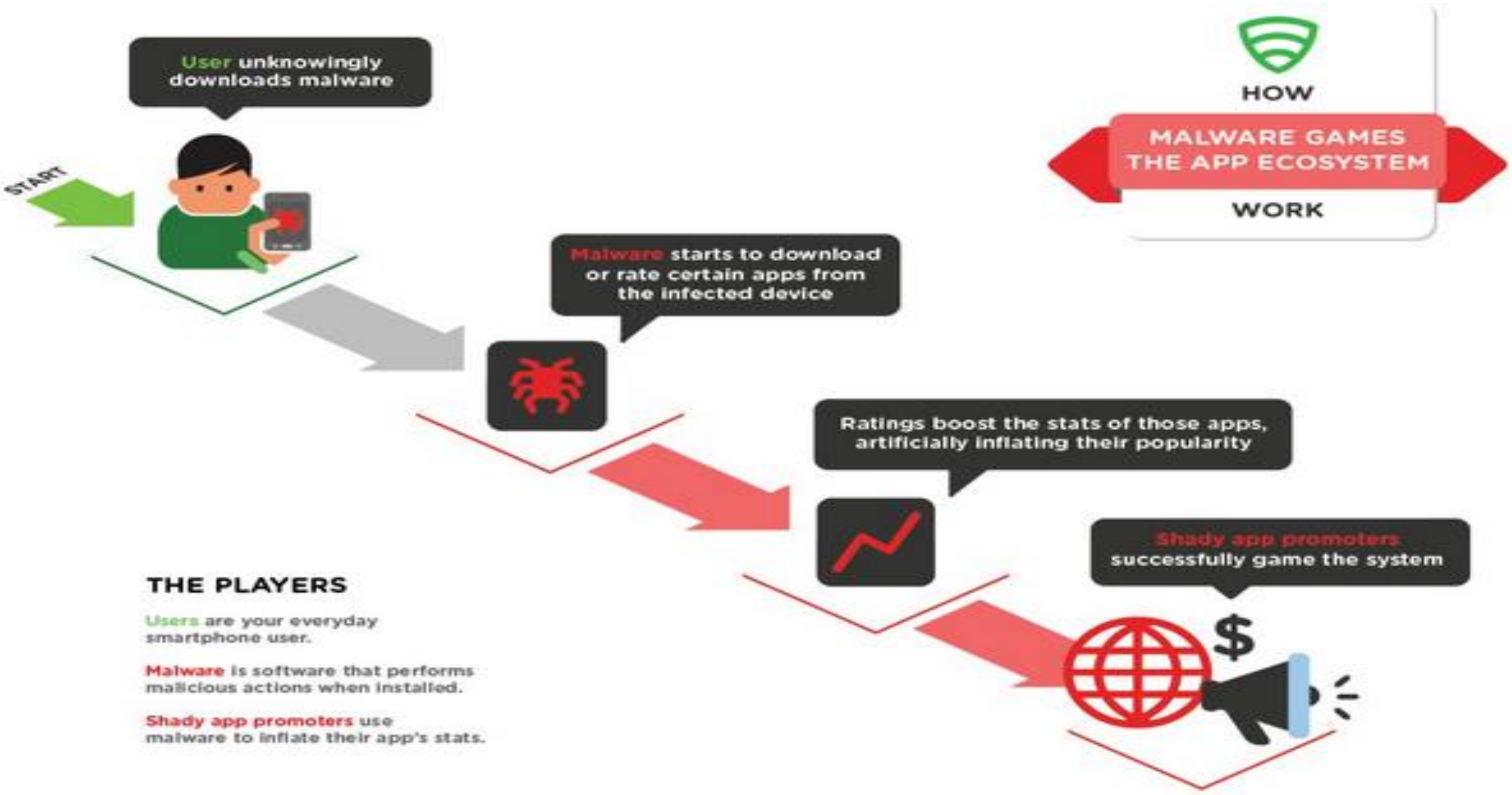
Malware Example: Ad Jacking

Source: Lookout State of Mobile Security 2012
https://www.lookout.com/resources/reports/state-of-mobile-security-2012



Malware Example: App Rating Manipulation

Source: Lookout State of Mobile Security 2012
https://www.lookout.com/resources/reports/state-of-mobile-security-2012



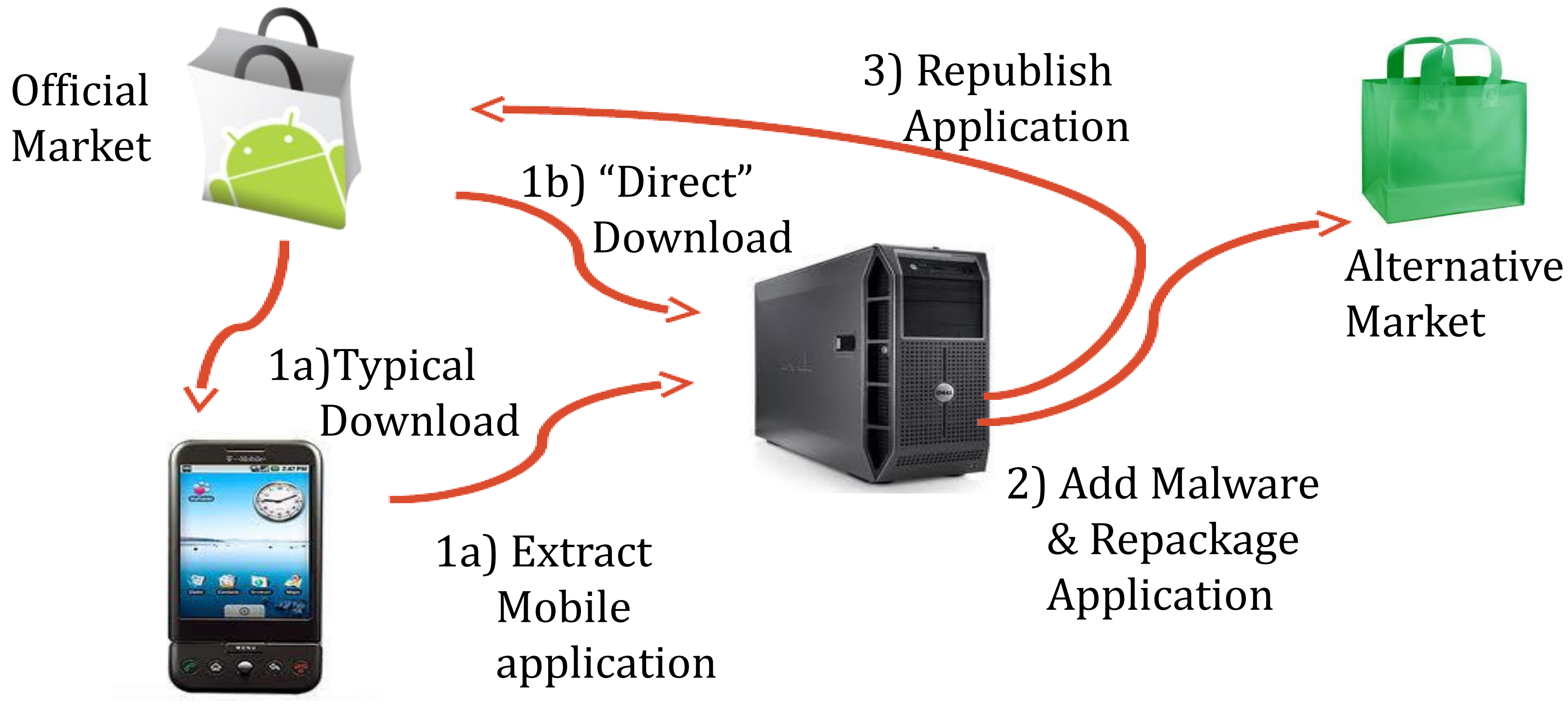
Ransomware

Ransomware: Type of malware that prevents or limits users from accessing their system, by locking smartphone's screen or by locking the users' files till a ransom is paid

Source: Lookout Top Threats
https://www.lookout.com/resources/top-threats/scarepakage

Source: MalwareBytes "State of Malware Report" 2017
https://www.malwarebytes.com/pdf/white-papers/stateofmalware.pdf

Application Repackaging



Malware Detection based on Permissions

- Does malware request more permissions?
- Analyzed permissions of 11 Android malwares

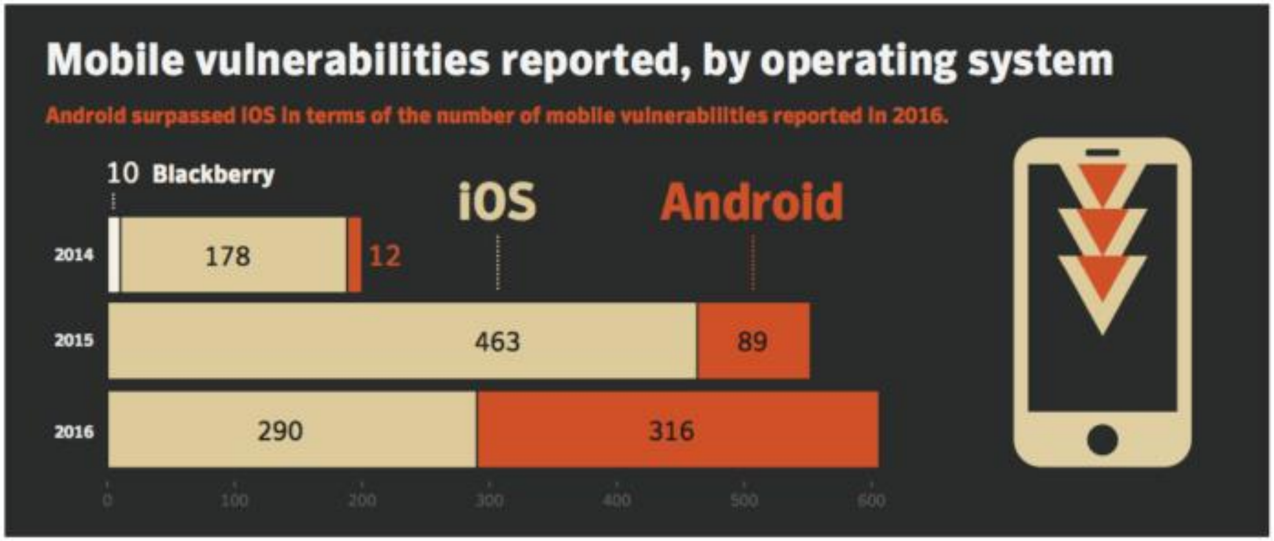
- **Findings: Yes!**
  - 8 of 11 malware request SMS permission (73%)
    - Only 4% of non-malicious apps ask for this
  - Malware 6.18 dangerous permissions
    - 3.46 for Non-malicious apps
  - Dangerous permissions: requests for personal info (e.g. contacts), etc

Number of Dangerous permissions	Number of non-malicious applications		Number of malicious applications
0	75	(8%)	-
1	154	(16%)	1
2	182	(19%)	1
3	152	(16%)	-
4	140	(15%)	2
5	82	(9%)	1
6	65	(7%)	-
7	28	(3%)	2
8	19	(2%)	1
9	21	(2%)	1
10	10	(1%)	1
11	6	(0.6%)	1
12	7	(0.7%)	-
13	4	(0.4%)	-
14	4	(0.4%)	-
15	2	(0.2%)	-
16	1	(0.1%)	-
17	1	(0.1%)	-
18	-		-
19	-		-
20	1	(0.1%)	-
21	-		-
22	-		-
23	1	(0.1%)	-
24	-		-
25	-		-
26	1	(0.1%)	-

Table 2: The number of "Dangerous" Android permissions requested by 11 pieces of malware and 956 non-malicious applications [28].

iOS Malware Review

- iOS generally fewer vulnerabilities (even till date)
  - All 4 pieces of Apple malware were spread through jailbroken devices;
  - not found on App Store
  - Human review more effective but slow!!?



Using Hand Gestures to Curb Mobile Malware (*Shrestha et al*)

Malware Protection using Hand Movements

Curbing Mobile Malware Based on User-Transparent Hand Movements Babins Shrestha,Manar Mohamed, Anders Borg, Nitesh Saxena and Sandeep Tamrakar in Proc ACM Percom 2015

- Real user will make certain natural hand gestures when:
  - Making phone call
  - Taking a picture
  - Swiping to use NFC reader
- These hand gestures will be missing if malware is requesting these services
- **Main idea:** Check for these gestures to separate malware requests from valid user requests

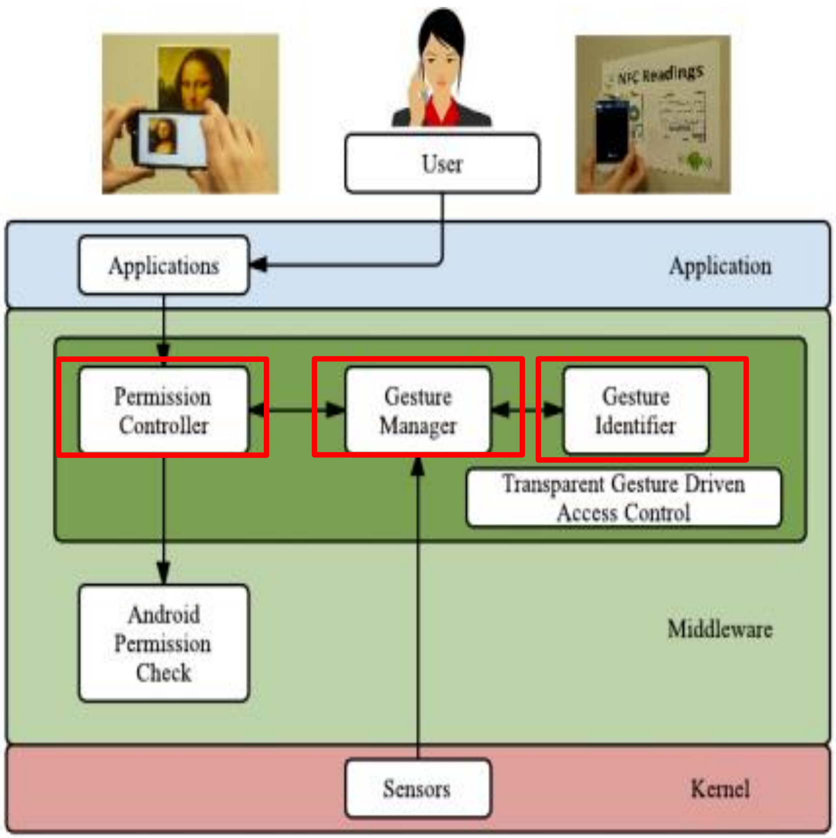
Sensors used for Gesture Identification

- Gesture Identifier used sensors to detect natural hand movements associated with phone dialing, taking picture, NFC usage
  - **Motion Sensors:** Accelerometer and gyroscope
  - **Position Sensors:** Magnetometer and orientation sensors
  - **Environmental Sensors:** Temperature, pressure and illuminance

TABLE I. SENSORS UTILIZED FOR GESTURE DETECTION

Type	Sensor	Description
Motion	Accelerometer (A)	The acceleration force including gravity
Motion	Gyroscope (Gy)	The rate of rotation
Motion	Linear Acceleration (LA)	The acceleration force excluding gravity
Motion	Rotation Vector (R)	The orientation of a device
Motion	Gravity (G)	The gravity force on the device
Position	Game Rotation (GR)	Uncalibrated rotation vector
Position	Magnetic Field (M)	The ambient magnetic field
Position	Orientation (O)	The device orientation
Environment	Pressure (P)	The ambient air pressure

System Architecture



- 3 Entities
  - **Gesture Identifier:** classifier to identify gesture
  - **Gesture Manager:** communicates gets phone movement from motion sensors, provides gesture ID result to permission controller
  - **Permission Controller:** checks for the permission token
- **Results:** Generally > 85% accuracy (user gesture detection)

Mobile Ad Vulnerabilities

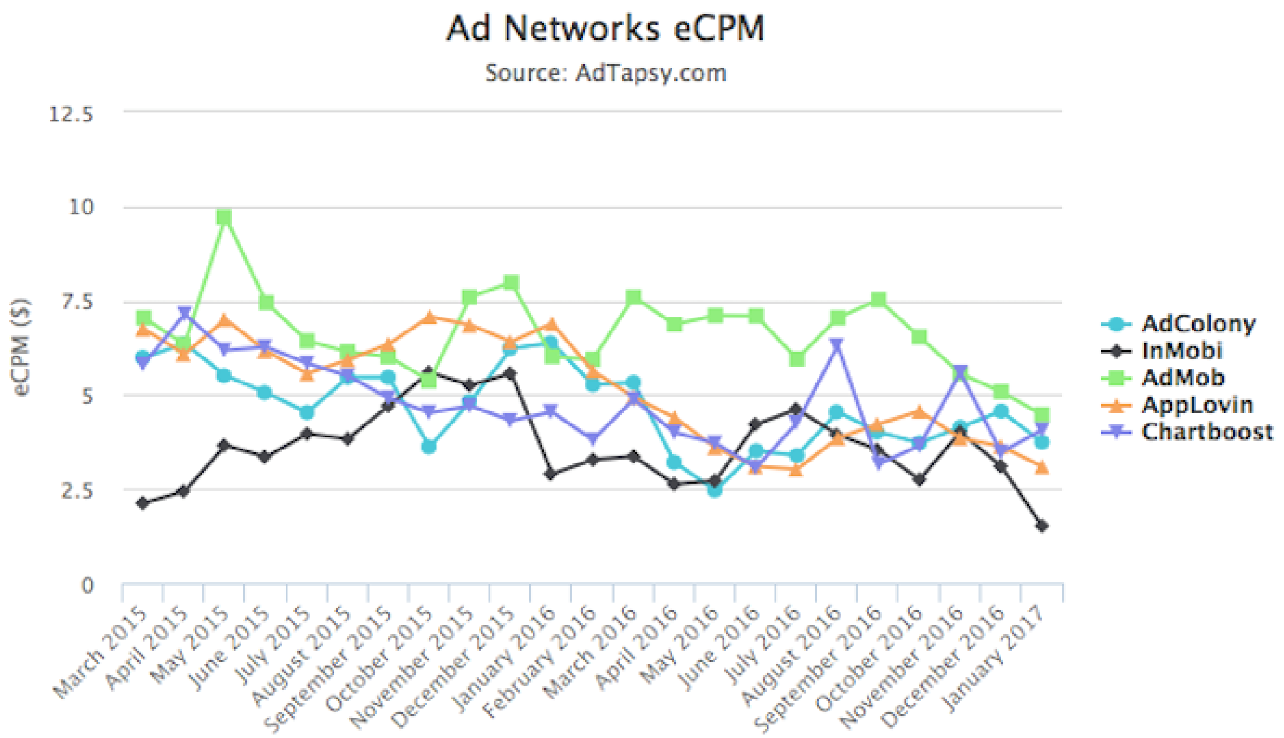
Ad Services

- App developers make money from apps in 2 main ways:
  - Charge users for apps
  - Getting $$$ from advertisers to include ads in apps
- App maker integrates mobile app library in app
- Mobile ad company serves ads to device

Ads

AdMob

- AdMob: Most popular mobile ad company
  - Acquired by Google in 2009



Permissions Requested by Ad Services

- Each has 1 AndroidManifest.xml file
- Total permissions in AndroidManifest.xml

  = permissions requested by app **+ permissions requested by ad service**

Rogue? Ad Services

- Google is careful about permissions requested by AdMob
- Some other mobile ad libraries require permissions to :
  - Access location data, camera, account details, calendar, call logs, browser bookmarks, contact lists, phone information, phone number, SMS, etc
  - Make phone calls, send SMS messages, vibrate
  - Change calendar and contacts

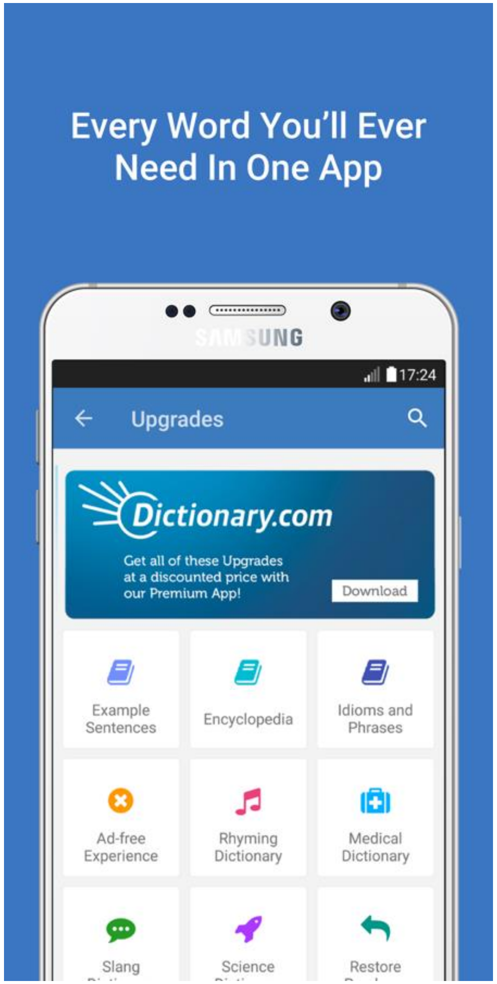
	Included in Apps	Probes Permissions	Uses Obfuscation	Uses Reflection	Uses JavaScript	Read Installed Packages	Location Data	Place Phone Call	Camera	List Accounts	Read Calendar	Read Contact/Call Logs	Read Browser Bookmarks	Read Phone Information	Read Phone Number	Read SMS	Send SMS	Change Calendar	Change Contacts	Use Vibrator	ClassLoader
admob/android/ads	27235	✓	✓	✓	✓	·	✓	·	·	·	·	·	·	·	·	·	·	·	·	·	·
google/ads	16323	✓	·	✓	·	·	✓	·	·	·	·	·	·	·	·	·	·	·	·	·	·
flurry	5152	✓	✓	·	✓	·	✓	·	·	·	·	·	·	·	·	·	·	·	·	·	·
google/../analytics	4551	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
millennialmedia	4228	✓	·	·	✓	·	·	·	·	·	·	·	·	✓	·	·	·	·	·	✓	·
mobclix	4190	✓	·	✓	✓	·	✓	·	·	✓	✓	✓	·	✓	·	·	·	✓	✓	✓	·
adwhirl	3915	✓	·	✓	·	·	✓	·	·	·	·	·	·	✓	·	·	·	·	·	·	·
qwapi	1745	✓	·	·	·	·	✓	·	·	·	·	·	·	✓	✓	·	·	·	·	·	·
youmi	1699	✓	✓	·	·	·	✓	·	·	·	·	·	·	✓	·	·	✓	·	·	·	·
mobfox	1524	✓	·	·	·	·	✓	·	·	·	·	·	·	✓	·	·	·	·	·	·	·
zestadz	1514	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
cauly	1249	·	·	·	·	·	✓	✓	·	·	·	·	·	✓	·	·	·	·	·	·	·
inmobi	1229	✓	·	·	·	·	✓	·	·	·	·	·	·	·	·	·	·	·	·	·	·
wooboo	1183	✓	✓	·	·	·	✓	·	·	·	·	·	·	✓	✓	·	✓	·	·	·	·
admarvel	1101	✓	·	·	✓	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
smaato	1077	✓	·	·	✓	·	✓	·	·	·	·	·	·	✓	·	·	·	·	·	·	·
[illegible]	[illegible]	✓	[illegible]	[illegible]	[illegible]	[illegible]	✓	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	✓	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Ref: Unsafe exposure analysis of mobile in-app advertisements
[M. Grace, W. Zhou, X. Jiang, A.-R. Sadeghi; WiSec 2012]

Final Words: Mobile Ad Services

- Many apps use multiple ad services
  - Angry Birds app (a game) includes 7+ ad services

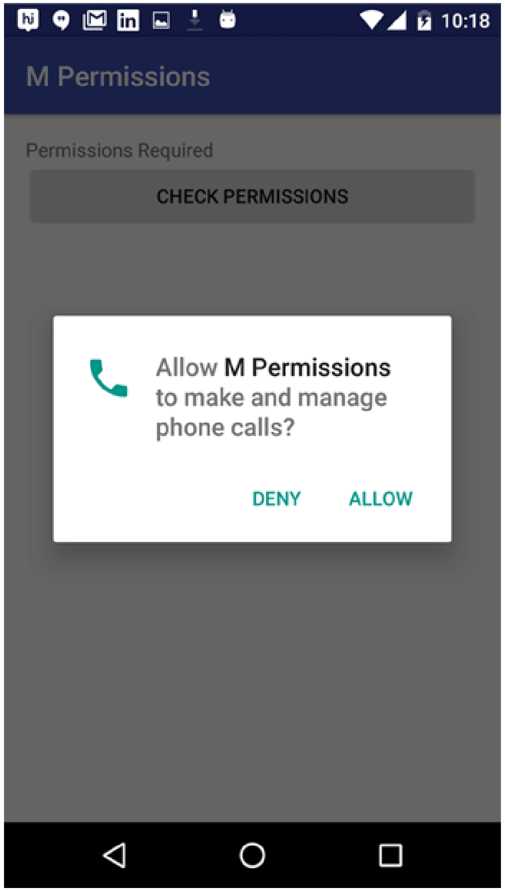
- One version of the Dictionary.com app requests permissions to **monitor phone calls** and **access location**



Run-Time Permissions Changed in Marshmallow (Android 6.0)

- "Normal" permissions don't require user consent
  - Normal permissions can do very little to harm app
  - E.g. change timezone
  - Automatically granted
  - Can be used freely by ad networks

- Run-time permissions required for "more dangerous" access
- **Dangerous?** contacts, etc



Android Analysis Tools

Analyzing Android Apps

- Analysis tools give attacker more information about Android app
- **Source code recovery:** generate app source code from executable
- **Static analysis (binaries or source code):** Understand app design without running it.
  - Examine application logic, APIs used
- **Dynamic analysis:** Observe how app executes
  - App memory usage, network usage, response time, performance, etc
- Many available (open source?) tools for all of the above!

Android Analysis Tools

- APKinspector
- Androguard
- AndroBugs
- Qark
- Epicc / IC3
- FlowDroid
- DidFail
- DroidBox
- MobSF

- Scary!!

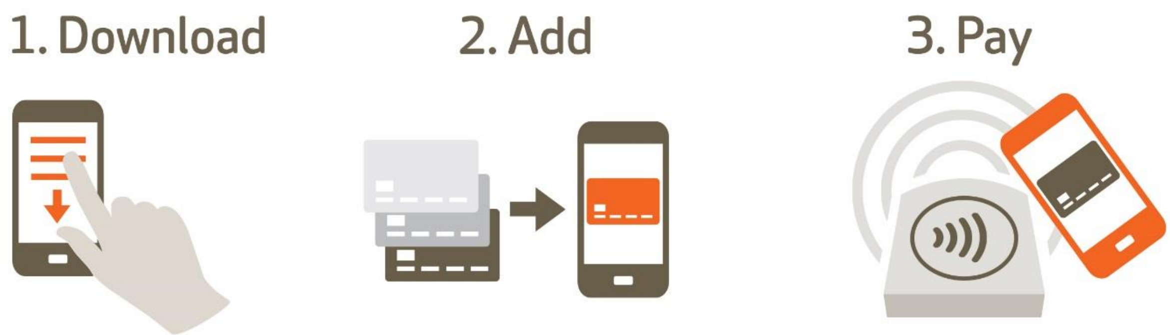
Android Pay using NFC

Android Pay

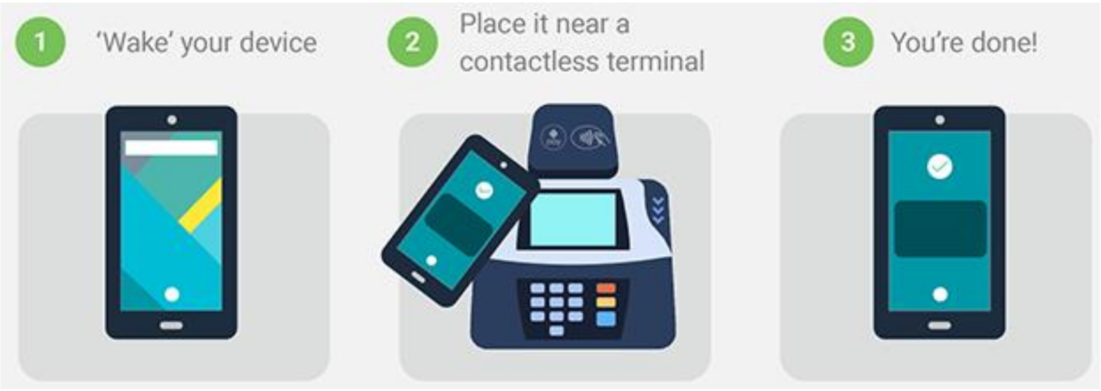
- Google Wallet → Android Pay (Sept 2015 initial release)
- **Vision:** Use smartphone to pay in stores
- E.g. Pay for donuts at Dunkin Donuts
- Easier way to track expenses, get rewards
  - Integrates with financial apps (banking, personal finance, etc)

How Android Pay Works

- First need to download Android Pay app, add credit cards

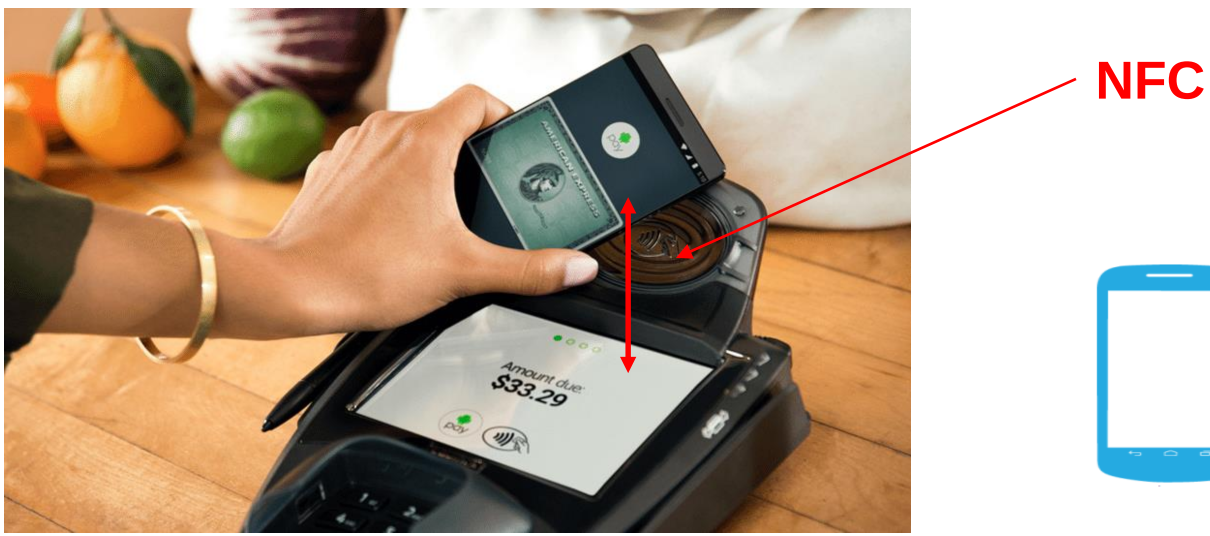


- To pay, place smartphone near Android pay terminal

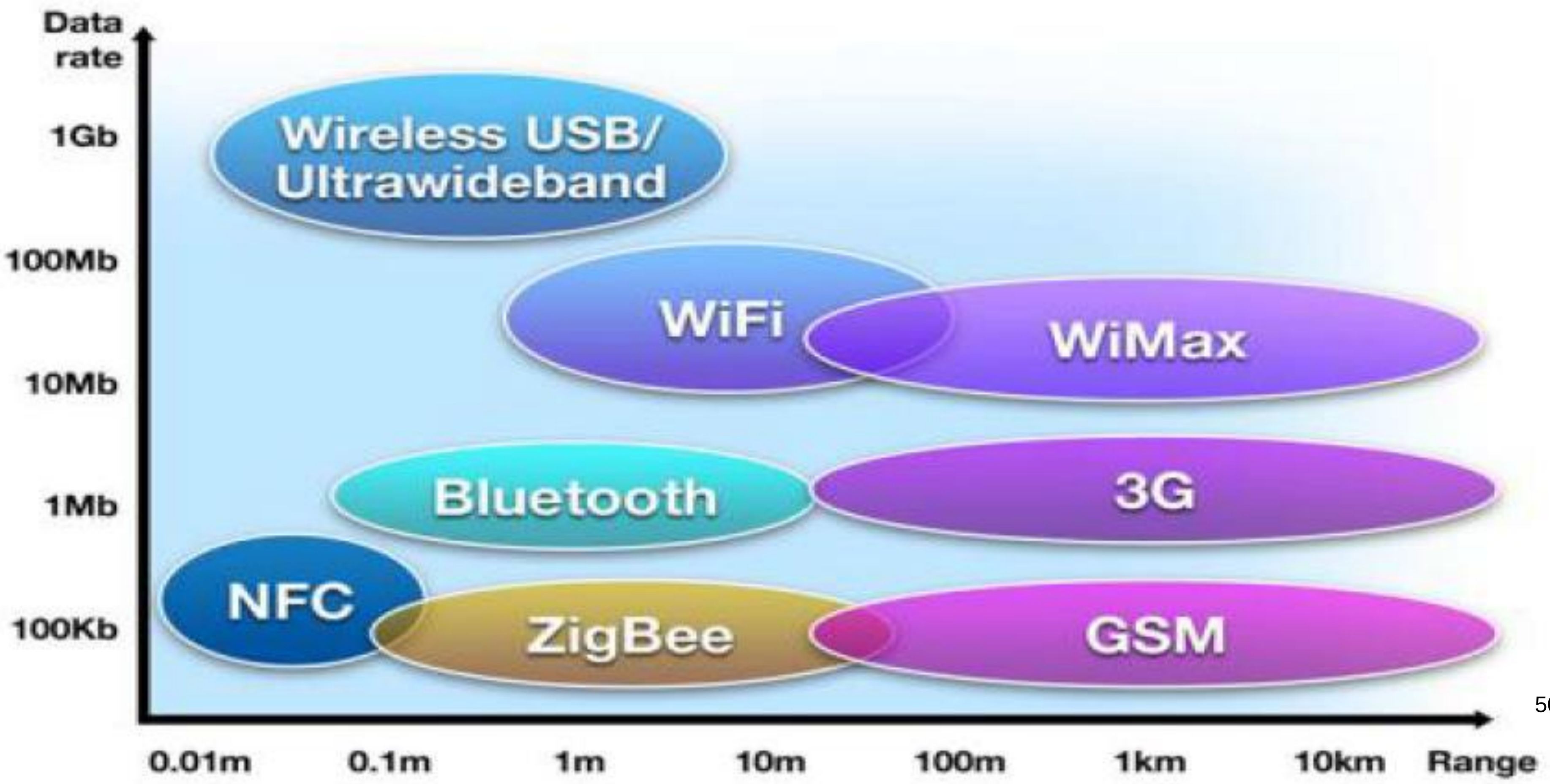


Mobile Pay Uses NFC

- Mobile payment (e.g. Android Pay) typically uses NFC for transaction
- NFC: Near Field Communication: short-range, low-rate wireless
- Enables communication between devices in close proximity
- Utilized by many smartphone mobile pay systems (e.g. Google Pay)
- E.g. pay at Dunkin donuts



Wireless Comparison



NFC: Short range, low bitrate

Why use NFC?

- Proximity makes it easier to verify payee
- **Convenient:** store all credentials inside the phone
- Integrates with other mobile services: eBooks, music downloads, barcodes, etc. (easier payments)

Types of NFC Devices

- **Active Device:**
  - Can read targets information and also send information to target
  - **2-way** communication possible
  - E.g. 2 smartphones

- **Passive Device:**
  - Information on passive device can only be read.
  - Cannot initiate communication
  - E.g. NFC tag

NFC Modes of Interaction

- **Reader/Writer:**
  - Active NFC device reads/writes from/to passive NFC tag (One way)

- **Peer-to-Peer:**
  - Active NFC devices interact with each other bi-directionally
  - Take turns being active vs passive

- **Card Emulation:**
  - An NFC device emulates a passive NFC tag that is read by an active NFC device

NFC Security / Threats

- NFC has similar threats as other wireless communications
  - Eavesdropping
  - Data corruption / modification / insertion
  - Man-in-the-middle attacks

- Eavesdropping: Another device listening to transaction
  - NFC itself provides no explicit protection against eavesdropping
  - Active-vs-Passive:
    - Harder to eavesdrop on passive exchange
    - Mainly because of shorter range (<1m passive, <10m active),

Data Modification & Injection

- Attacker modifies bits in flight based on standardized encoding, e.g., flip 0s to 1s

- **Data Injection:**
  - Attacker responds faster than intended target
  - Possible defenses:
    - Secure handshake w/ verifiable response

- MitM is difficult in NFC due to:
  - Close proximity requirement (MitM needs to be closer than tag)
  - Attacker can use sheet of Aluminum to block legitimate sender