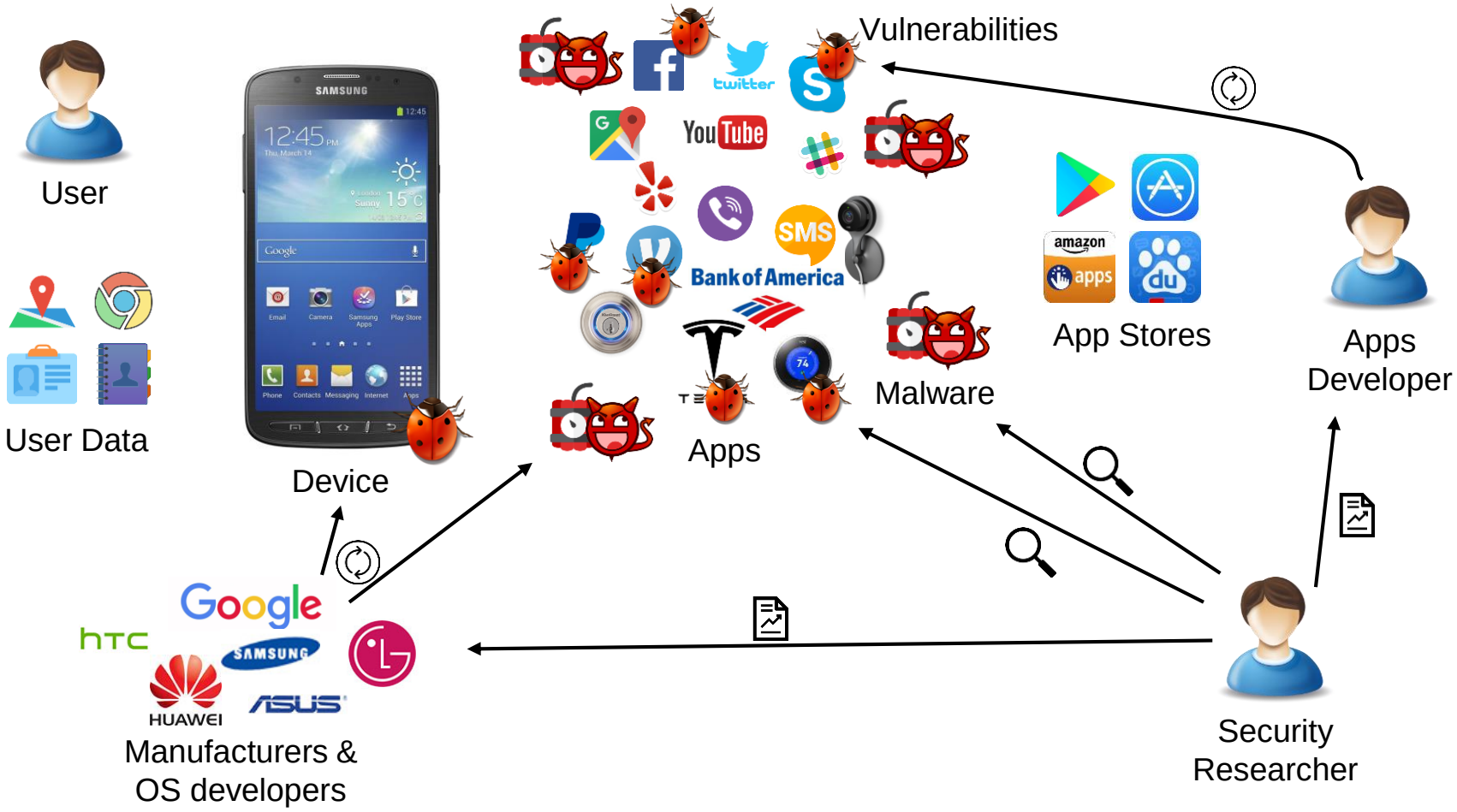
Overview on Mobile Ecosystem & Security

Mobile Systems and Smartphone Security (MOBISEC)

Prof: Yanick Fratantonio
EURECOM

Mobile Security: What's the point?

- Keep mobile devices safe... safe from what?
- Mobile ecosystem is very complex
- "Bad guys" have many incentives to do damage
  - Many different incentives
  - Many ways of doing damage
  - Each complexity and "weakness" of the ecosystem can be abused


User
User Data
SAMSUNG
Device
Vulnerabilities
Malware
Apps
App Stores
Apps Developer
Manufacturers & OS developers
Security Researcher

Users

- One of the main problems of the ecosystem
- Highly irrational creatures
- Very distracted
- Well-known interests
  - Download and play game X at all costs
  - Very interesting in browsing some "particular" parts of the Internet
  - When "under pressure", it's easy to push them to do idiotic things

Apps

- Developers write apps
- Publish them on app store(s)
- Bad guys could republish them on other stores
  - How do you know they are different?
  - If they do differ, maybe they are just different versions?

Devices

- Many different players
  - Many different hardware manufacturers
  - Google develops AOSP...
  - ... but OEM (Original Equipment Manufacturer)
    - Customize their software/hardware stack

- Many different Android versions
  - Not all devices support all versions
  - Some devices don't get updated
  - Most devices get updates only for 2/3 years
  - Android versions distribution dashboard

Android Fragmentation

- The biggest problem for Android security
- Hundreds of devices with custom hardware and software
- Customization makes development and patching tricky

The Long Life of a Security Bug

- Discovery
  - Security researcher (Google's or external) finds a bug
- Disclosure
  - Report the bug to Google
- Reception
  - [Hope the bug reaches the right Google employee]
  - Google acknowledges the bug and will work on a fix

The Long Life of a Security Bug

- ~~Responsible~~ Coordinated Disclosure
  - [Wait n days, industry standard: 90 days]
  - Publicly disclose the bug

- Security patch distribution
  - Google distributes the patches to other manufactures
  - Patch is published as part of the Monthly Security Bulletin

- Supported Google devices get the patch

The perils of customization

- Google sends patch to third-party company X
  - Company X now needs to apply the patch
- Is the patch compatible with X's customizations?
  - What if the patch conflicts with code that was slightly modified?
  - Would including the patch make everything unstable?
  - Would it introduce backward compatibility problems?
    - Run all the tests! But are the tests comprehensive enough?
- Patch deployment can be risky
  - 2B+ monthly Android active users. Broken patch can do damage.

Project Treble

- Previously: no clear interface between Android OS framework and vendor implementation

- When the Android OS is updated
  - Vendors lose time integrating the new patches
  - This introduce significant costs & overhead & delays

- Project Treble helps defining a clear interface
  - Note: this is useful for non-security patches as well

Project Treble

- Up to Android 7.x

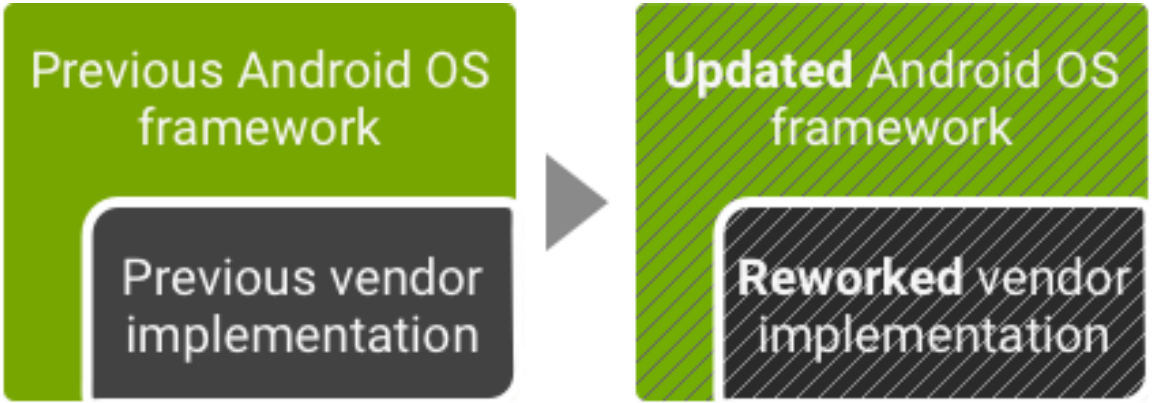


Image from https://source.android.com/devices/architecture

Project Treble

- In Android 8.0+ (with Project Treble)

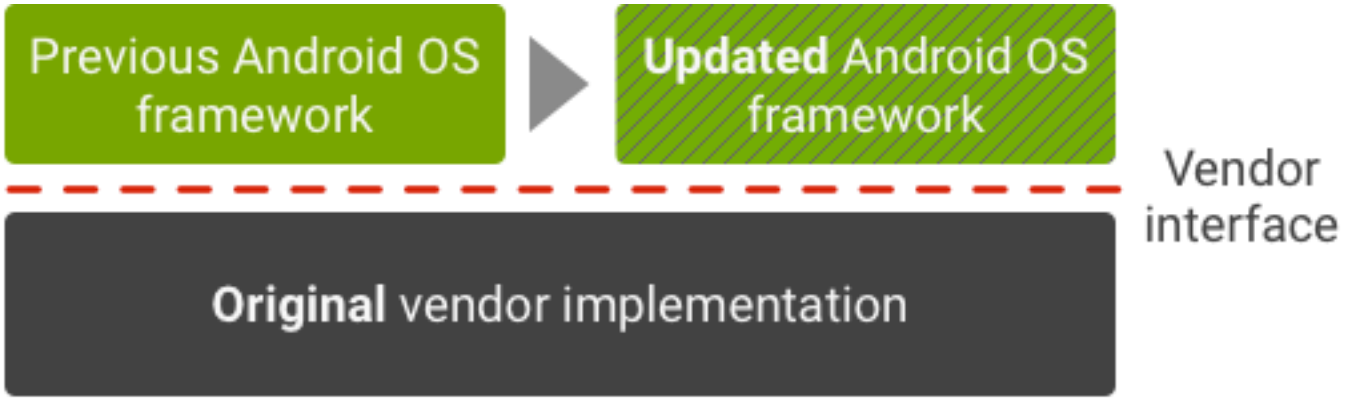


Image from https://source.android.com/devices/architecture

Most devices don't get security patches

- Even with all this progress, many devices don't receive security updates
- Most devices get support for only 2/3 years
- Even Google's flagship devices!

Minimum update & support periods

Phone	No guaranteed Android version updates after	No guaranteed security updates after	No guaranteed telephone or online support after
Pixel 3 XL	October 2021	October 2021	October 2021
Pixel 3	October 2021	October 2021	October 2021
Pixel 2 XL	October 2020	October 2020	October 2020*
Pixel 2	October 2020	October 2020	October 2020*
Pixel XL	October 2018	October 2019	October 2019
Pixel	October 2018	October 2019	October 2019

Table from https://support.google.com/nexus/answer/4457705?hl=en

The role of security researchers

- Identify malware
  - Once a new malware is found, it's added to blacklists
  - Any app "similar" to the malware will be flagged and removed

- Security vulnerabilities
  - Once they are found, they are reported to Google
  - Monetary rewards for security bugs: "Bug Bounties"

Bug Bounties

- Google pays researcher when they report a bug
- Keep security researchers motivated to disclose bugs
- Security bugs have a major role in security
  - Used by attackers to compromise devices
  - Used by malware to bypass security barriers
  - Some bugs are extremely valuable (e.g., those that enable RCE)

Bug Bounties

Severity	Complete Report* + PoC	Payment range (if report includes an exploit leading to Kernel compromise)**	Payment range (if report includes an exploit leading to TEE compromise)**
Critical	Required	Up to $150,000	Up to $200,000
High	Required	Up to $75,000	Up to $100,000
Moderate	Required	Up to $20,000	Up to $35,000
Low	Required	Up to $330	Up to $330

Table from https://www.google.com/about/appsecurity/android-rewards/

- Depending on the kind of bugs, governments may pay much higher amounts...

Attacker's goal

- In general: run code on your device and do XYZ

- Two main important topics
  - Malware analysis, detection, containment
  - Vulnerability analysis, detection, prevention, patching

Mobile Malware

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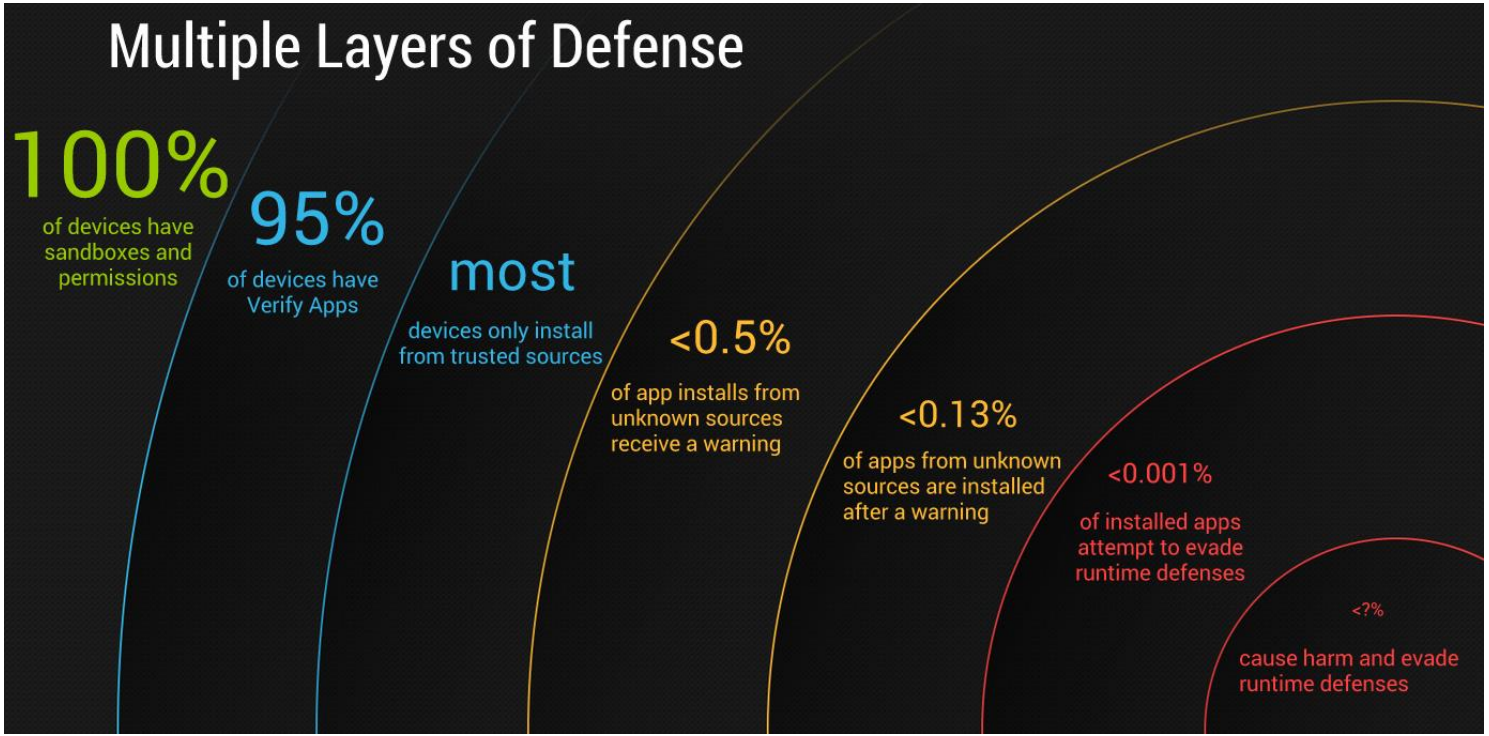
Malware

- Malware is software with a malicious intent

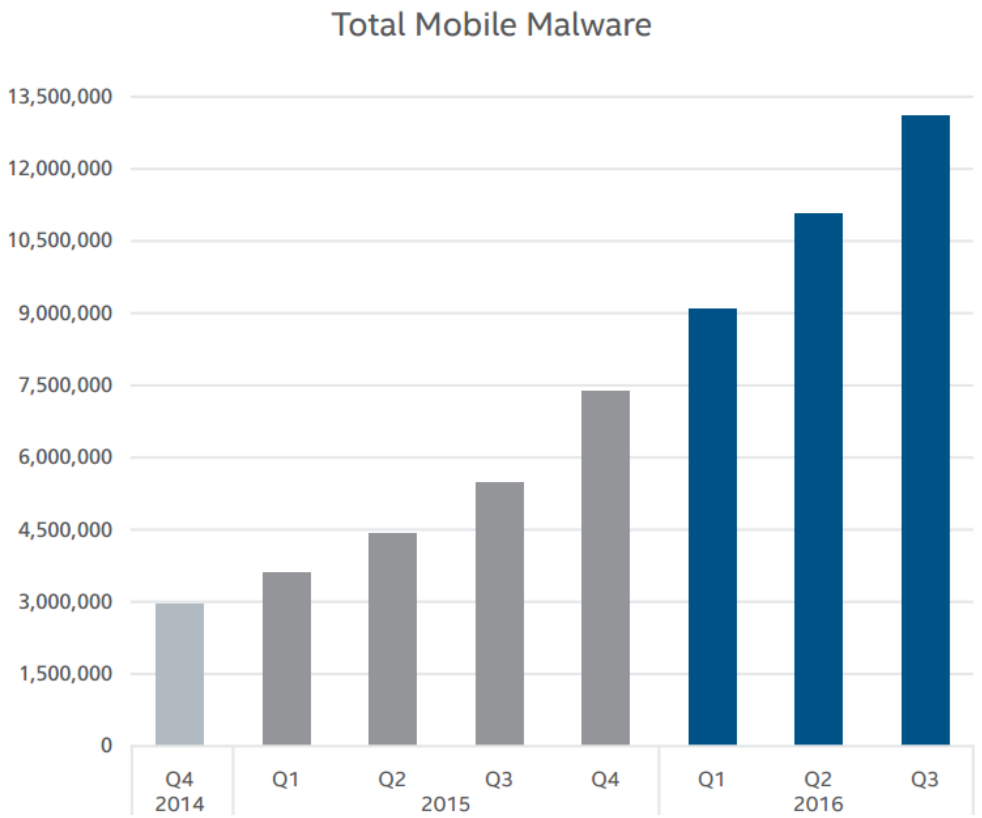
- Relation with security vulnerabilities
  - Malware may need to use/exploit security vulnerabilities to carry on its malicious actions
  - Discussion on malware will focus on the malicious behavior per se, what's the rationale behind it, various associated techniques

Does mobile malware even exist?

Mobile Malware



Resource: Google



Resource: McAfee

Why does malware exist?

Why does malware exist?

- Why would a human being spend her time writing malicious software?

- Try to always ask "why?"

- Three main thrusts
  - Just for fun / bragging rights
  - To become rich
  - Targeted attacks

Just for fun

- Just as a prank
  - "Hey, now your wallpaper is a pic of Justin Bieber ahah so funny"
- Bragging rights
  - I hacked your phone and I spammed your entire contacts list about it
- I don't like you...
  - ... and I'll post something stupid on facebook

To get money

- This is most often the case

- Monetization is one of the biggest incentives
  - Information stealing (and selling)
    - Credentials, personal data
  - Asking you to pay (ransomware)
  - Advertisement
  - Bitcoin mining
  - Send premium SMS

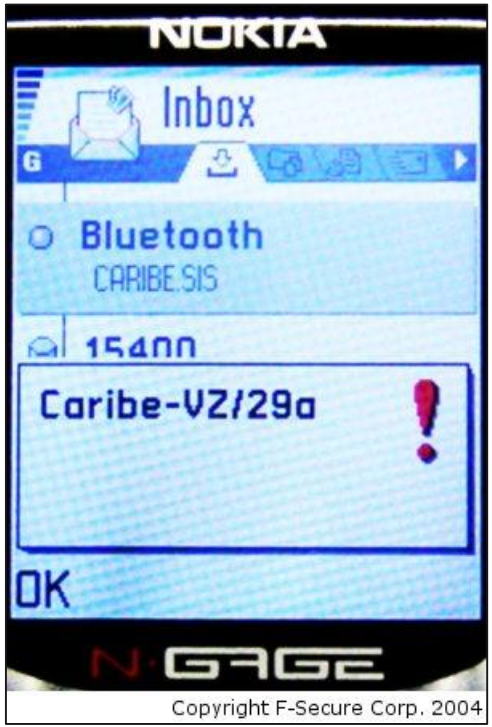
Targeted Attack

- "Targeted attacks" are those attacks meant to attack a specific, small set of individuals
  - Sometimes a specific person is targeted
- These are the most advanced, sophisticated attacks
  - People writing these (or commissioning these) have a lot of money
- Potential targets: political activists, journalists, ...

What does malware do, and why?


NOKIA
NOKIA

Cabir (2004)



- First mobile malware
- It targets Symbian OS
- The payload is a “Caribe” popup message
- Attempts propagation through bluetooth

Skull (2004)

- The payload is slightly more annoying
- It corrupts files related to critical functionalities
  - SMS / MMS
  - web browsing
  - camera
- It replaces all icons with skulls


NOKIA
Menu
Calendar
Contacts
Internet
Messaging
Download
Music
Settings
Help
Options
Phone
People
Messaging
Outlook
Pictures
Games
Internet Explorer
SAMSUNG
MOTOROLA
Google
2:55 PM
Messaging
Market
Phone
Contacts
Browser
Maps
MOTOROLA
Google
Apps
9:41 AM
Calendar
Contacts
Photos
Camera
Stocks
Maps
Weather
Utilities
iTunes
App Store
Mail
Safari
iPod
BlackBerry
12:21 PM
Friday, Oct 02
(3) Messages
SMS and MMS
Contacts
Calendar
Phone
Media
Clock

Malware Gets Real

- Plankton (2011)
  - Found on the Play Store
  - Leak user’s private information
    - contact list
    - bookmark
    - browser history

- Monetization strategy:
  - Private information is valuable, especially if it's about K/M+ users
  - Sell private information on the black market

Malware Gets Real

- DroidKungFu (2011)
  - Found on the Play Store
  - Root exploit
  - Bot-like capabilities

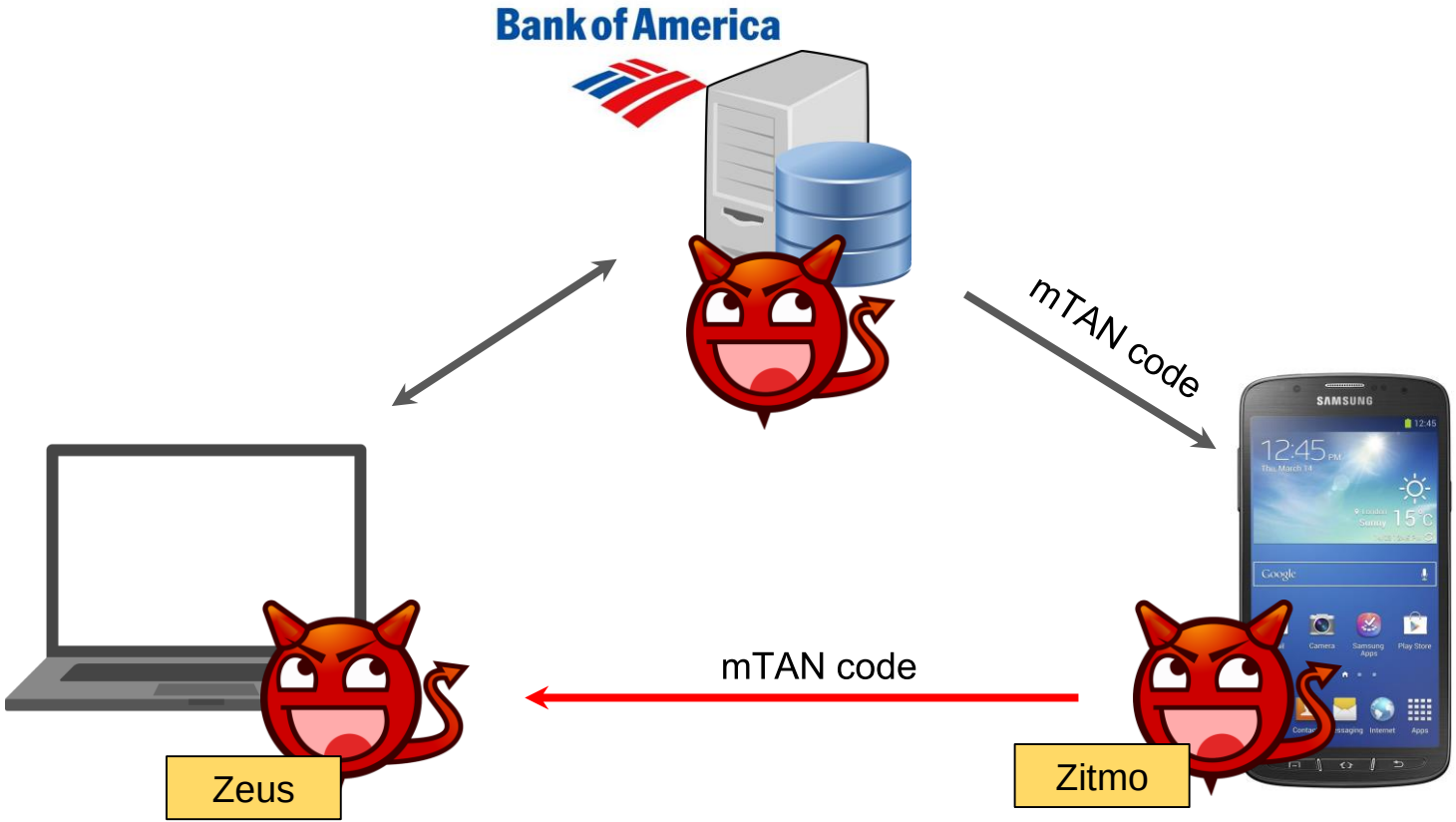
- Monetization strategy
  - Valuable: A botmaster can direct K/M+ bots to do many things
  - Examples: distributed denial-of-service attack (DDoS attack), send spam, steal data "on request", device admin and monitoring
  - Once again: these "bots" can be sold on the black market

Malware author != Malware "user"

- Different roles
  - Whoever "writes" the malicious apps ("the developer")
    - The actual coder
  - Whoever carries on the "infection"
    - Who adopts strategies to actual infect users with malware X
  - Whoever directs the malware to do XYZ ("the operator")
    - Whoever "pulls the trigger"
  - Whoever actually decides what the malware should do ("the customer")
    - "Bring website xyz.com down"

- These roles are often fulfilled by different persons

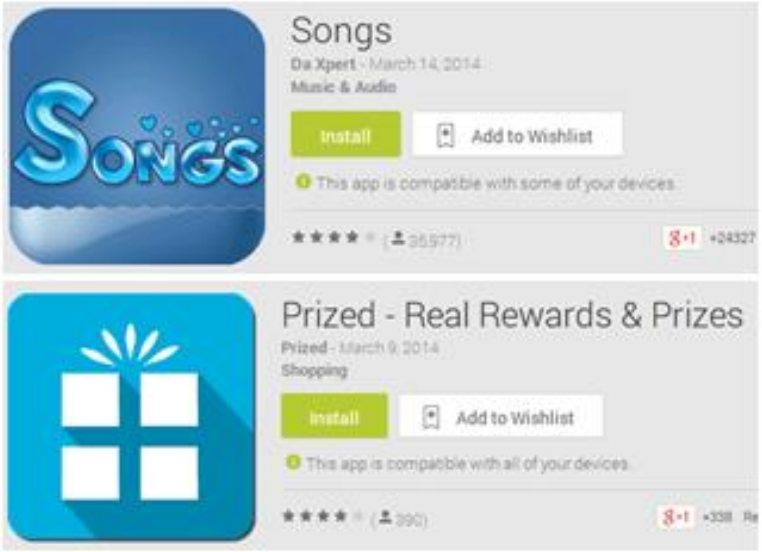
Zitmo (“Zeus In The Mobile”, 2011)



HippoSMS (2011)

- It sends SMS to premium numbers
- Stealthy: all the malware-related SMS are deleted

Bitcoin Miner (2014)



Updated	Size	Installs	Current Version
March 14, 2014	4.8M	1,000,000 - 5,000,000	41

- Legitimate apps repackaged to mine bitcoins in the background

- Is it worth it for the bad guys?
  - The main app is already written
  - The mining code is stolen from another app

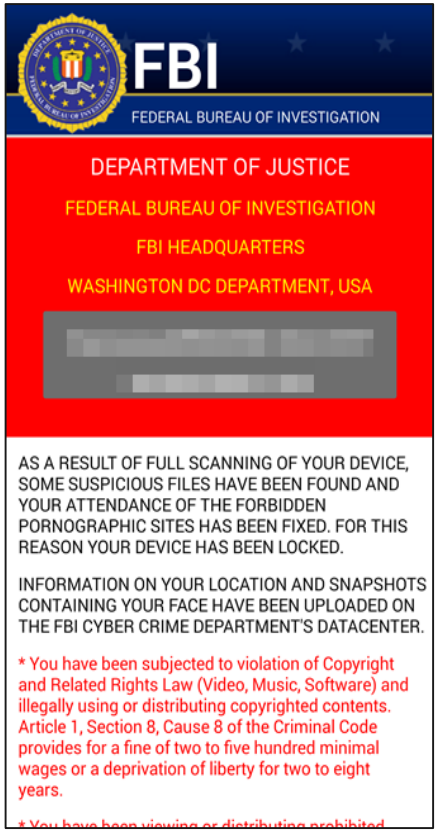
Gooligan (2016)

Gooligan malware attack hits one million Google accounts

The malware attack hijacks phones and uses them to download unauthorised apps from outside the Google Play store

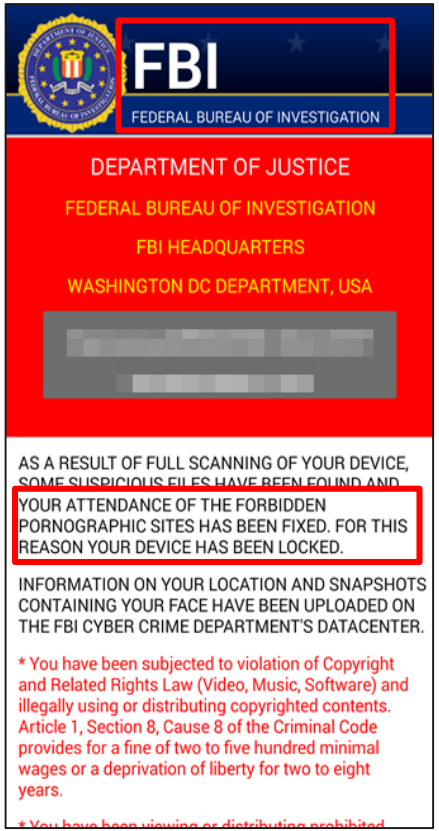
- Hijacked more than one million Google accounts
- Roots device, steals authentication tokens, download additional apps

Ransomware



- It locks your device and encrypts all your data
- It asks for money (a “ransom”) to reverse its effects

Ransomware

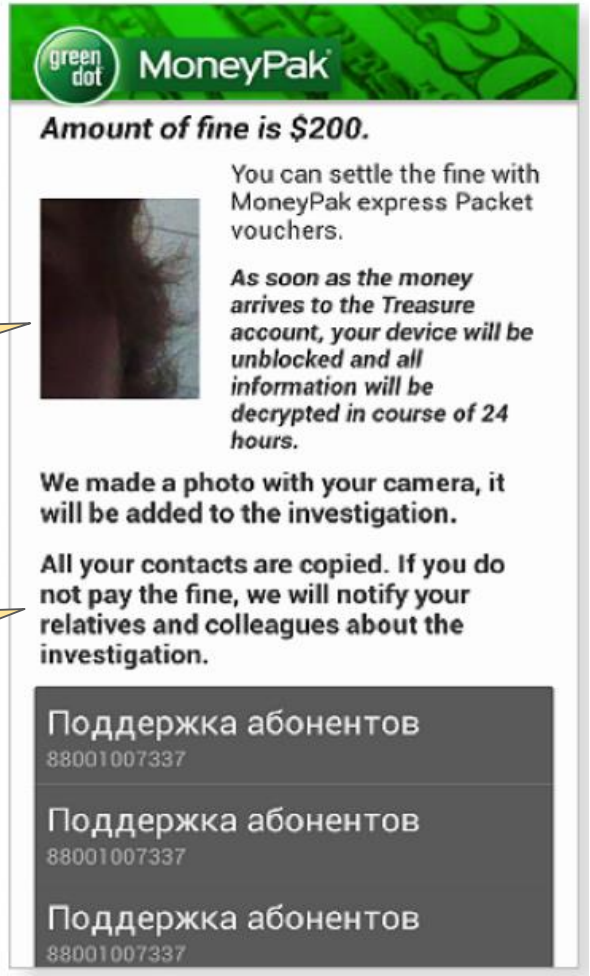


- It locks your device and encrypts all your data
- It asks for money (a “ransom”) to reverse its effects
- Puts “pressure” on the user
  - The FBI found “Forbidden pornographic sites” on your phone!

Ransomware

User's photo!

Contacts notification!



Spyware


FLEXISPY
Catch Cheaters
Is your wife or husband cheating on you? For the sake of your mental and sexual health, you have a right to know if
our partner is being responsible. Spy on their mobile
hones to reveal their secrets.
Find out more
Spy on Mobile
Phone
& Tabl
FlexiSPY is the onl
can spy on 9 instar
If you're in a committed relationship, responsible for a child, or manage an employee
YOU HAVE A RIGHT TO KNOW
Find out the truth, spy on their iPhone.
Buy Now

FlexiSPY

- Features:
  - Call logs/recordings, Facebook/WhatsApp/Skype call logs/recordings
  - Email recording, Calendar, Location tracking, SIM changed notification
  - Keylogger, Application Screenshot
  - Remote photo acquisition
- Some features require root: they provide assistance!
  - "Installation Service"
- Quite expensive:
  - Premium: $99 / 3 month
  - Extreme: $199 / 3 months

AndroidRCS

- Sophisticated malware used for "targeted attacks"
  - State-sponsored attacks, Advanced Persistent Threat (APT)
- Developed by HackingTeam
  - Italian security company, selling their products to (shady?) governments
  - Irony points: they got hacked, all private emails/info on wikileaks
- Long list of SMS-controllable “features”
  - Leak the victim’s private conversations, GPS location, and device tracking information, capture screenshots, collect information about online accounts, and capture real-time voice calls

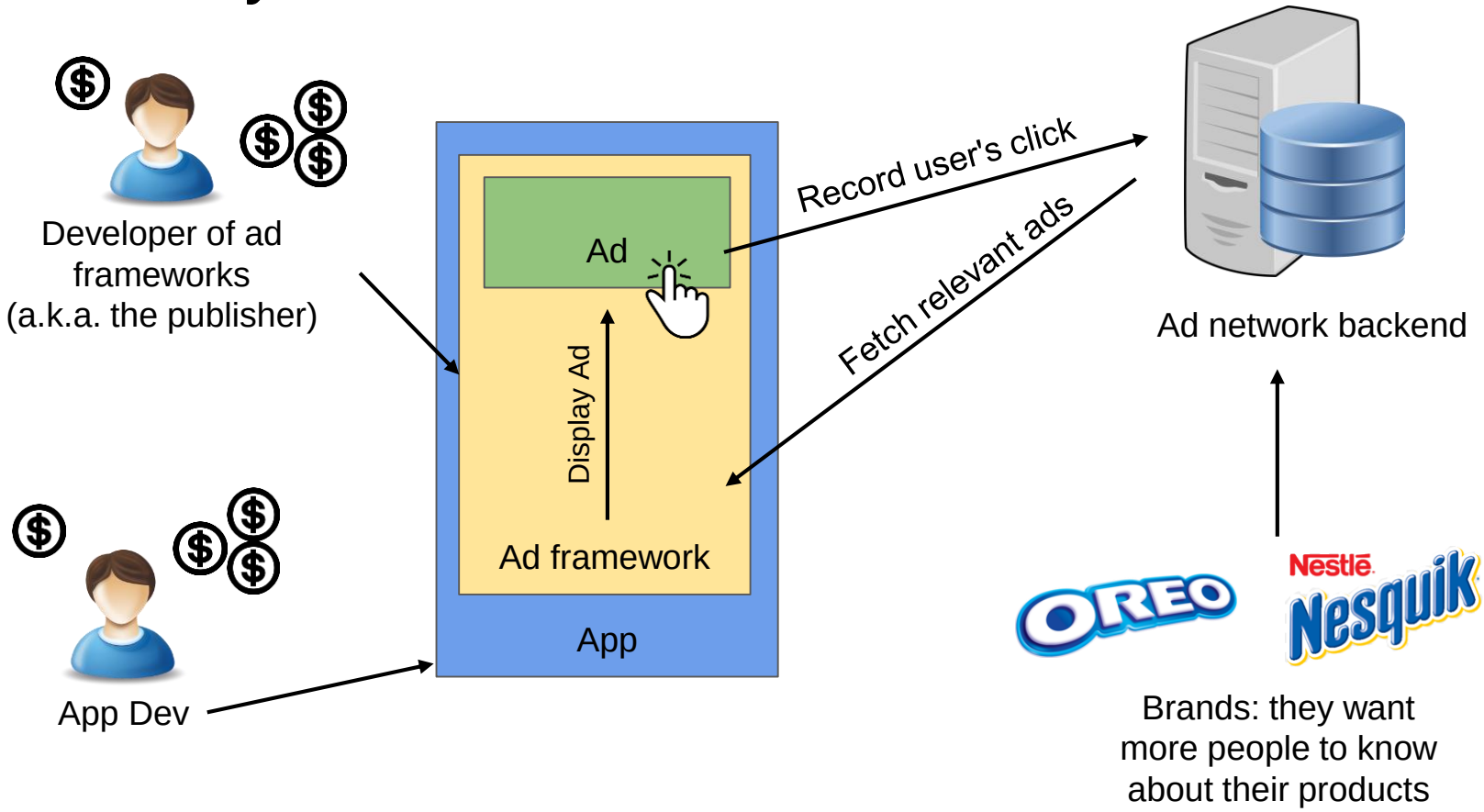
Advertisement malware & frauds

Advertisement

- Several money-related malware/frauds relate to ads

- Very complex ecosystem
  - Malware authors can abuse the system in multiple ways

Ad Ecosystem



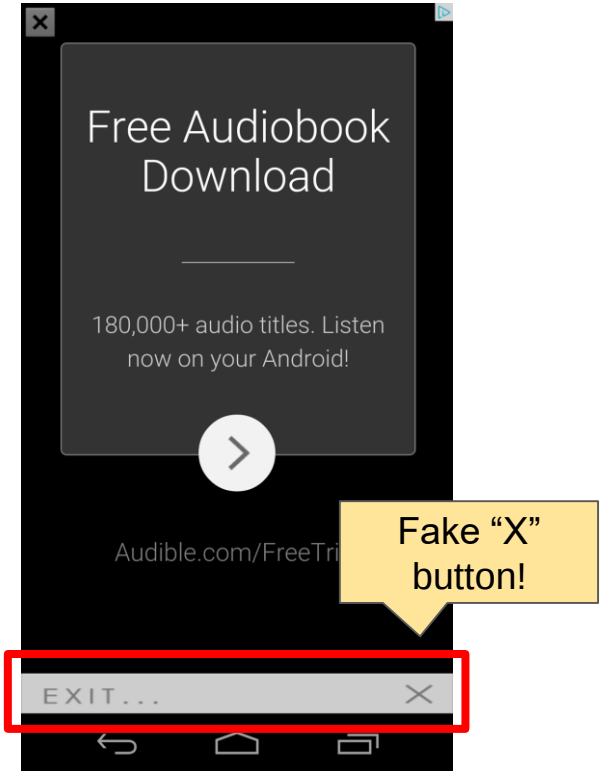
Advertisement

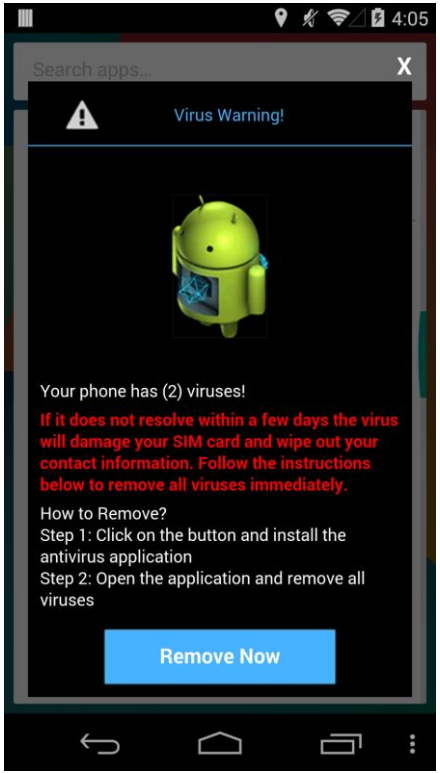
- Ad frameworks
  - Google's Admob, InMobi, Flurry, LeadBolt, AirPush, ...
- They differ from many aspects
  - money they pay to the app developer
  - the cost for the advertizer
  - how aggressively the ad is delivered (which technique?)
  - the level of "retargeting" they can offer
- Some have VERY shady/annoying practices

Adware

- Aggressive advertisement techniques
  - Notifications (sticky), shortcuts, overlays, in-app & abstract banners
  - Ads that pop out "out of nowhere" so you don't know which app is responsible for which ad
  - Ads in the "lock screen" view
- This is not technically a fraud, but it's annoying
- Net result: the user gets annoyed
  - but she is more likely to click on an ad ~> more money
  - if she is too annoyed & she finds the culprit app ~> uninstall

“Annoyware”


Free Audiobook Download
180,000+ audio titles. Listen now on your Android!
Audible.com/FreeTri
EXIT...
Fake “X” button!


4:05
Search apps...
X
Virus Warning!
Your phone has (2) viruses!
If it does not resolve within a few days the virus will damage your SIM card and wipe out your contact information. Follow the instructions below to remove all viruses immediately.
How to Remove?
Step 1: Click on the button and install the antivirus application
Step 2: Open the application and remove all viruses
Remove Now


8:11
Google
Settings
BofA
Facebook
Sexy Heels for..
Play Store
Apps
Top Apps
Apps
SuperSU
wifi万能钥匙
热卖专场
苹果6甩卖
Xposed Installer
幸运抽奖
360游戏大厅
美女色色

Ad click fraud

- An app embeds ads and it simulates user's clicks
  - App and ad views live in the same sandbox!
- To the ad network, it seems that the user clicked on ads!
- App developer gets money
  - The ad framework / the publish gets money as well!
- Net result
  - The advertizer/brand gets scammed
  - The advertizer loses trust in the publisher
    - It's in the publisher's best interest to show they detect/combat frauds!

Automatic traffic detection

- Automatic clicks are/were easy to detect
  - Very simple interactions, "easy" to distinguish user vs. bot
- Bots are now simulating real user's behavior
  - They can simulate users filling forms and watching videos
- Recent massive ad fraud: link
  - Millions of users "infected" and "tracked"
  - "By copying actual user behavior in the apps, the fraudsters were able to generate fake traffic that bypassed major fraud detection systems."

Click Farms

- "Large groups of low-paid workers whose job is to click on ads"
- We are talking about "actual humans"
- "Inside of A Chinese Click Farm (10K+ phones)"

Hiding ads

- The app uses multiple ad frameworks
- Some ads are "hidden"
  - "Ad stacking": multiple ads one on top of each other
  - "Pixel stuffing": ads fit in 1x1 pixel views
- The publisher & advertiser think "the ad was shown"

Installation referrals stealers

- Big story from a couple of weeks ago
  - Multi million dollar scam: Buzzfeed's Cheetah scandal
  - Eight apps with a total of more than 2 billion downloads
  - There is controversy:
    - Cheetah started replying to accusations with "we don't have control over ads SDKs"
    - "The Chinese company has condemned Kochava’s “misleading statements” in a press release, adding that it plans to take legal action against the firm."
    - Details on updates here

Installation referrals stealers

- App developers pay 50 cents ~> $3 to partners that help drive new installations

- Mechanism based on "Installation referrals"

- A just-installed app can "look back" and check "which device / app / ad framework" should be thanked for the installation

Installation referrals stealers

- The fraud: Click flooding and click injection

- Steps
  - The Cheetah apps listen for when a user downloads a new app
  - As soon as a new download is detected, the Cheetah app sends off clicks to ensure it gets "the last click"
  - It wins the bounty (even though it had nothing to do with the app being downloaded)
  - This is true even in cases when no ad was served and they played no role in the installation

Installation referrals stealers -- Bonus points

- It starts the just-installed app w/o the user’s knowledge
  - This helps increasing the odds that it will receive credit for the app install, as the bounty is only paid when a user opens a new app.
  - "They passed the attribution through many ad networks to hide the fact that so many attribution wins are coming from these apps"

- "Kika keyboard" app
  - It tracks keywords typed by users when they are searching for apps
  - It generates a series of clicks in an attempt to claim the bounty of potential future installations

Installation referrals stealers

- The scale of the fraud
  - Eight apps with a total of more than 2 billion downloads
  - "AppsFlyer analyzed 1 billion app installs over the past year and found 25% were fraudulent ~> an estimated $1.7 billion was stolen"

Ad targeting

- One of the main ad frameworks "feature": ad targeting
- Ad targeting: "the ability of tailoring which ads are shown to which user"
- Ad framework builds a "profile" of each user
  - Profile ⇔ "User X likes Nesquik"
  - This is one of the key feature of Facebook
    - They know everything about you from your "likes", "pages you visit", "websites you visit"
  - From Android O, "ANDROID_ID" is unique per device / per signing key

Cross-Device Tracking (XDT)

- The problem
  - Users browse the web via their laptop and via their mobile devices
  - "Chrome on laptop" profile is not linked with "Android device" profile

- Cross-Device Tracking (XDT)
  - Wouldn't it be great if users could be tracked across different devices?

- Concept: attempt to "link" users behind many devices

Cross-Device Tracking (XDT)

- XDT enables "Ad re-targeting"

- Scenario
  - User is in front of her television, and an ad about Nesquik is shown
  - The user's mobile device "detects" that Nesquik ad was just shown
  - Ad framework within mobile app pops out with a Nesquik-related ad

- Extremely creepy

Cross-Device Tracking (XDT)

- How can it be done?

- Google can track you across devices because most users are "logged in" in all of them
  - Example: users are logged in their chrome browser on their laptop and on their Android devices: Google can establish a link

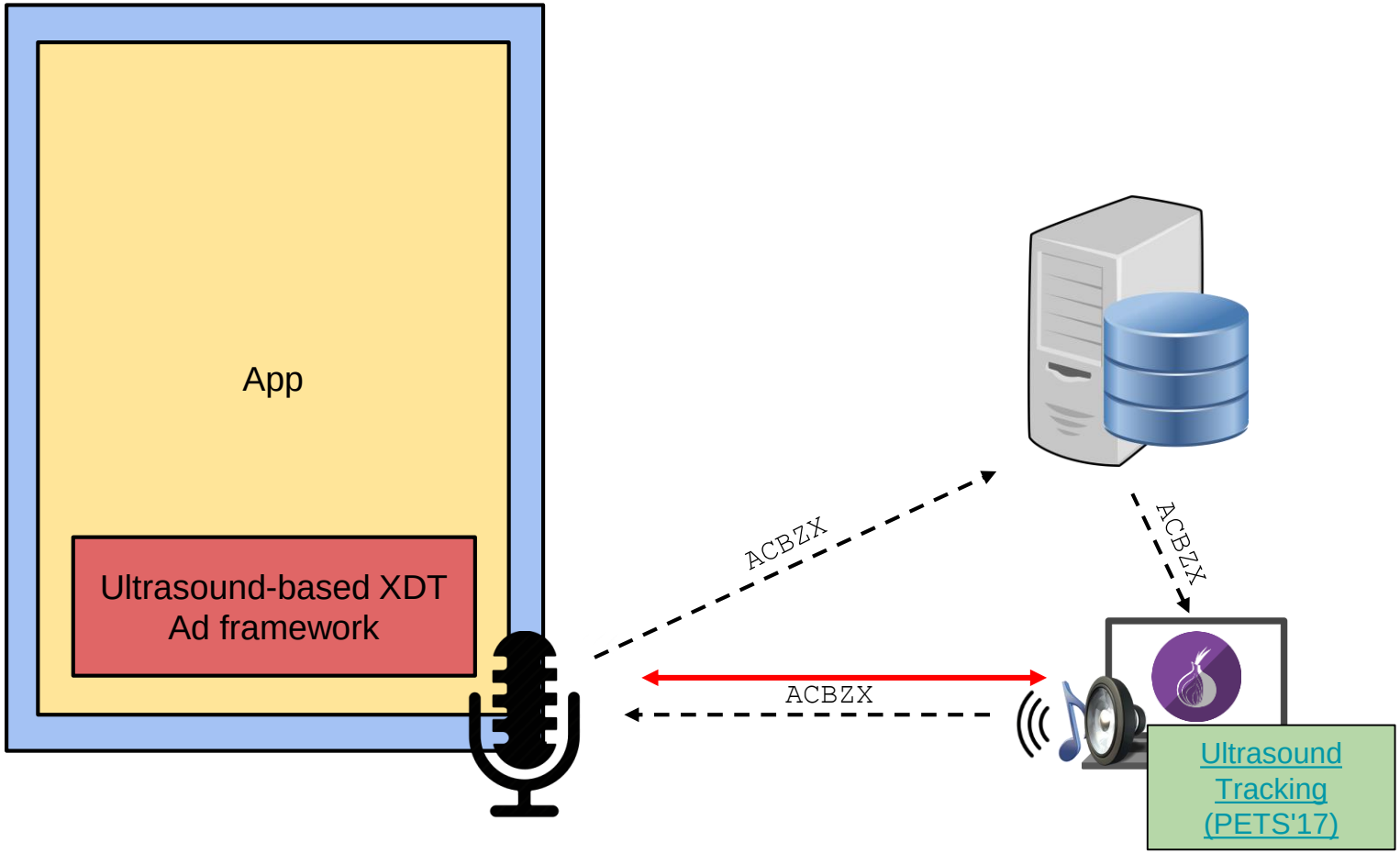
- But what about other companies? And other "devices"?

Ultrasound-based Cross-Device Tracking

- Super creepy technology to track users across multiple devices (smartphones, PCs, televisions)

- Idea: the microphone on your mobile device is used to "pick up" ultrasound-based "beacons" emitted by other devices around you (television, laptop, etc.)

- Main company: SilverPush (ArsTechnica article)
  - They now moved on and are doing different ad-related stuff


App
Ultrasound-based XDT
Ad framework
ACBZX
ACBZX
ACBZX
Ultrasound
Tracking
(PETS'17)

How does malware get on your phone?

Multiple security mechanisms to bypass

- Google Play Store’s vetting process
- Each app needs to be manually installed
  - Why would a user install these malicious apps?
- Many security mechanisms on Android
- Permission system: the user is asked for everything

Google's Vetting Process

- Google scans each APK submitted to the Play Store
- The app needs to pass security checks
- Only after the app has passed all the checks, it is accepted to the store and users can start downloading it

Google's Vetting Process Security Checks

- Static program analysis
  - It consists in trying to understand what the app is doing without running it
  - It looks for common "malicious" patterns

- Dynamic program analysis
  - Same goal, but it actually runs the app (~5 min) and logs what it does
  - They run the apps within emulators (this is my understanding)

- Analysis on metadata of the app / app developer

Bypassing Google’s Vetting Process

- Bypassing static analysis
  - Code obfuscation
  - Dynamic code loading (now "against the policy", but can be undetected)
- Bypassing dynamic analysis
  - Emulators can be detected ~> malicious functionality is not executed
  - Intentionally delayed functionality
  - Check for user's presence
- Note: Google can only control the Play Store!
  - Google can't "prevent" malware to be published on 3rd-party stores

Apps are manually installed

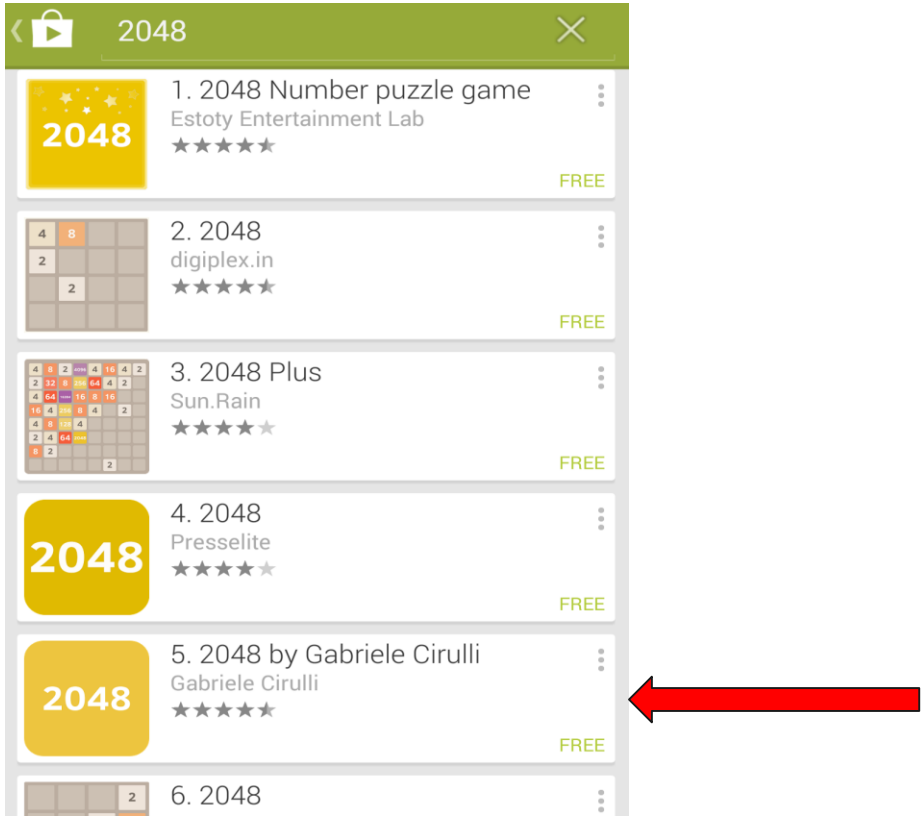
- Once Google's vetting process is bypassed...
- ... why would a user install app X?
- Several strategies
  - Social Engineering
  - Repackaging
  - Benign-becomes-malicious aka "turning bad"

Social Engineering

- Somehow convinces the user that the app she is looking for is exactly yours

- Possible techniques
  - Upload similar-looking apps on the store and hope the user is tricked
  - Malicious ads point the user to the wrong app
  - Offer the "free" version of an otherwise "paid" app
  - Offer "extra features" with respect to the "basic" version of the app

Social Engineering



Repackaging

- Repackaging steps
  - download app A
  - unpack it
  - add "feature XYZ"
  - repack it
  - upload it with slightly different name (or somewhere else)

- Very trivial from the technical standpoint!

Repackaging - Use cases

- Paid app is repackaged / re-uploaded as "free" but with
  - Advertisement ~> the 'malware' author gets ads money
  - Tracking functionality to steal user's data
  - Actual malicious functionality

- Repackaged free apps are advertised with extra features
  - These extra features may not even exist

Turning Bad

- App that is initially benign suddenly becomes malicious
  - All users will be infected at the next update (which happen automatically)

- How can this happen?
  - "Legal" change of ownership
    - The app is sold to a new "developer", who abuses the popularity of the app to start with an already big user base
  - The developer gets hacked
  - An entire software editor gets hacked (!)

XcodeGhost malware for iOS

- Xcode is a very popular code editor for Apple's macOS
- Malicious version of Xcode published on Chinese market
  - Theory: network speed is slower in China, devs looked for local copy
- All apps compiled with it are modified with malware
  - Over 4000 "benign" apps infected (including WeChat)
- Malicious behavior included
  - stealing user device information
  - read/write clipboard
  - hijack opening urls

Bypass of security mechanisms

- Even if the attacker can install an app, there are many security checks / mechanisms in place

- This is when "security vulnerabilities" kick in
  - Malware can bypass permission checks, mount privilege escalation attack, attack other user's apps, get code execution on your phone by just being on the same wifi

- We'll see more next year!