Mobile Security: Android

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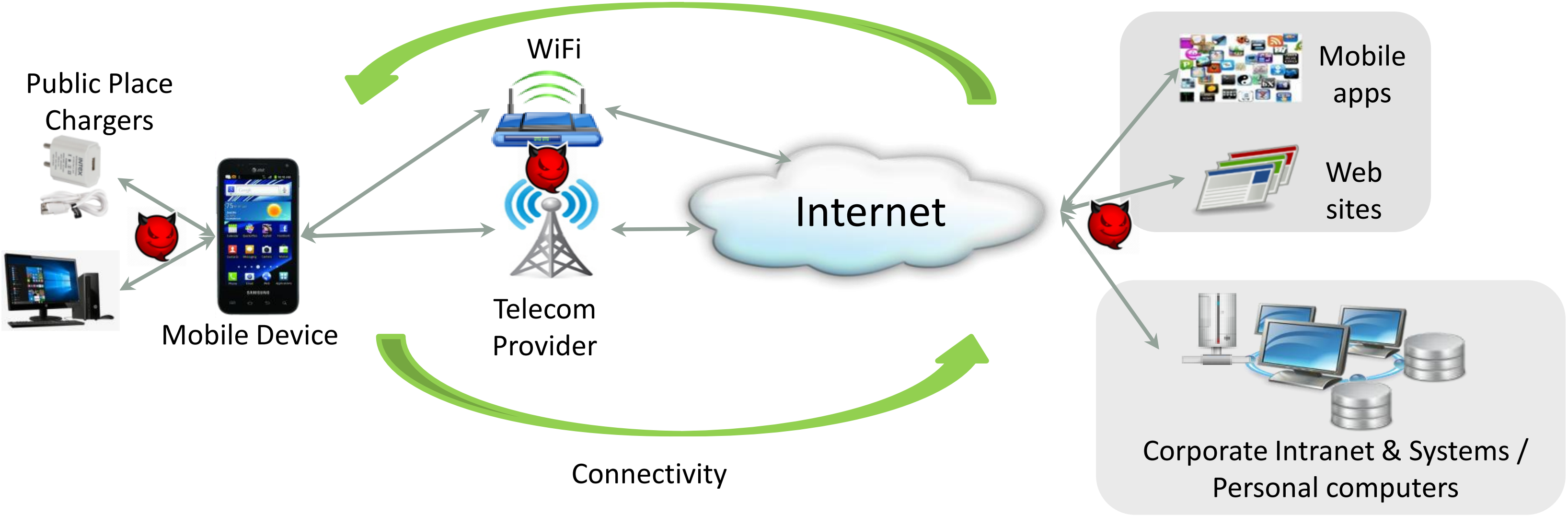
https://github.com/skmtr1/Workshop-Mobile-Forensics-And-Security

MOTIVATION

Why Mobile Security?

- ❑User activity
- ❑Valuable data
- ❑Always on
- ❑Multiple Attack Surfaces



Why Android?

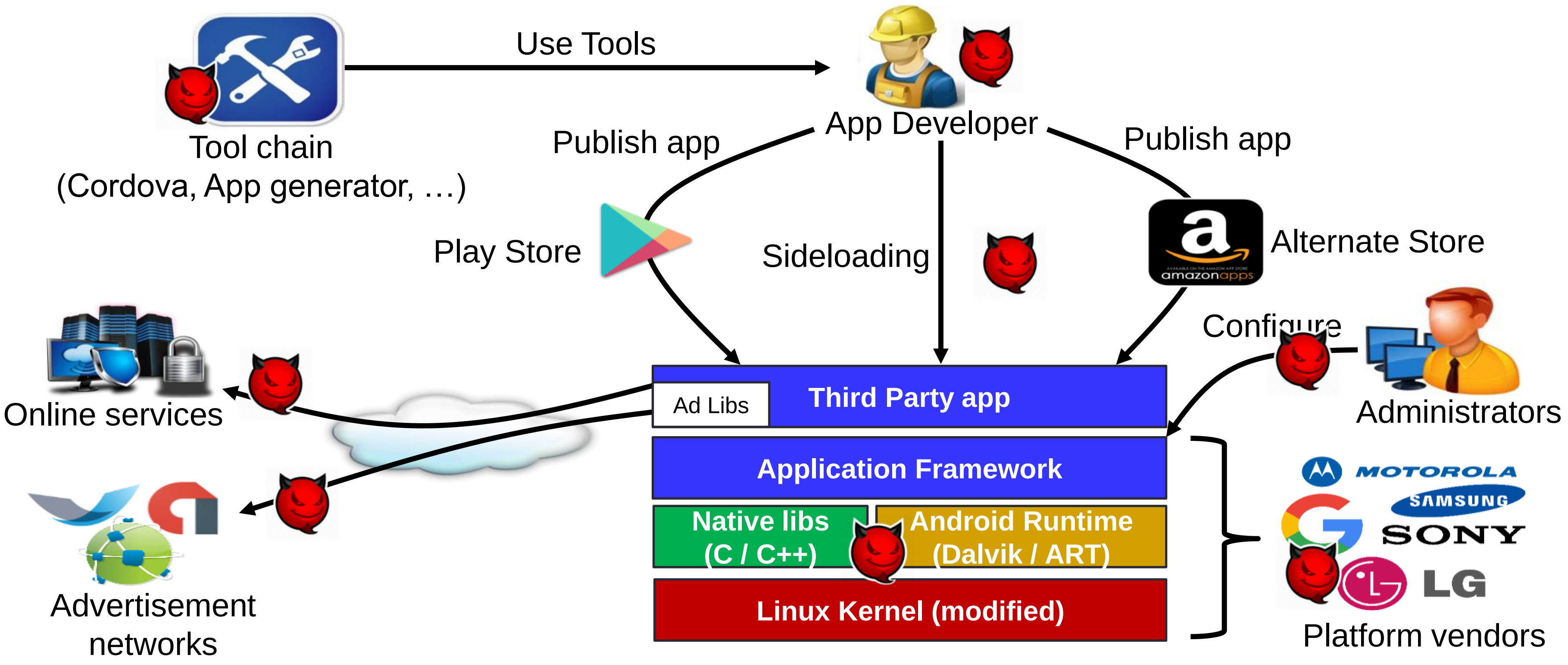
1. Almost completely open source

2. Global smartphone market share

Period	Android	iOS	Others
2020	84.1%	15.9%	0%
2021	83.8%	16.2%	0%
2022	84.1%	15.9%	0%
2023	84.4%	15.6%	0%
2024	84.7%	15.3%	0%
2025	84.9%	15.1%	0%

Source: International Data Corporation (IDC), October 2021

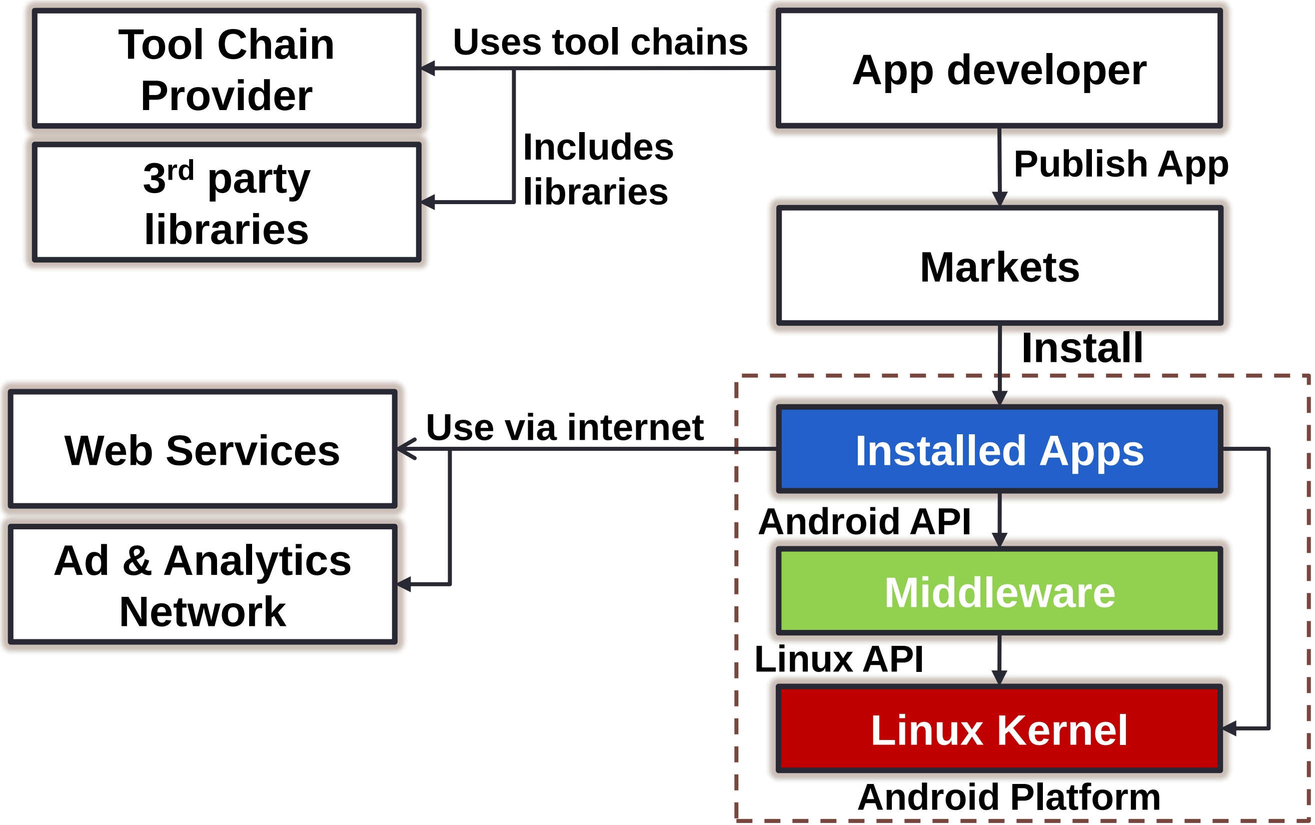
Actors in the Android Ecosystem



Security Impact of an Actor Over Others

Actor	OS Developer	H/W Vendor	Library Providers	S/W Developer	Toolchain Providers	S/W Publisher	S/W Market	End User
OS Developer	--	Partial	Full	Full	Partial	Full	Full	Full
H/W Vendor	None	--	Full	Full	None	None	None	Full
Library Provider	None	None	--	Full	None	None	None	Full
S/W Developer	None	None	Partial	--	None	None	None	Full
Toolchain Providers	None	None	None	Full	--	None	None	Partial
S/W Publisher	None	None	Partial	Partial	None	--	Partial	Full
S/W Market	None	None	Partial	Partial	None	None	--	Full
End User	None	None	None	None	None	None	None	--

Where to Improve Security?



Tool Chain Provider

Uses tool chains

App developer

3rd party libraries

Includes libraries

Publish App

Markets

Install

Web Services

Use via internet

Installed Apps

Ad & Analytics Network

Android API

Middleware

Linux API

Linux Kernel

Android Platform

Useable Security

Application Vetting

Inline reference monitors

Retrofit Android's Security

MOTIVATION: SUMMARY

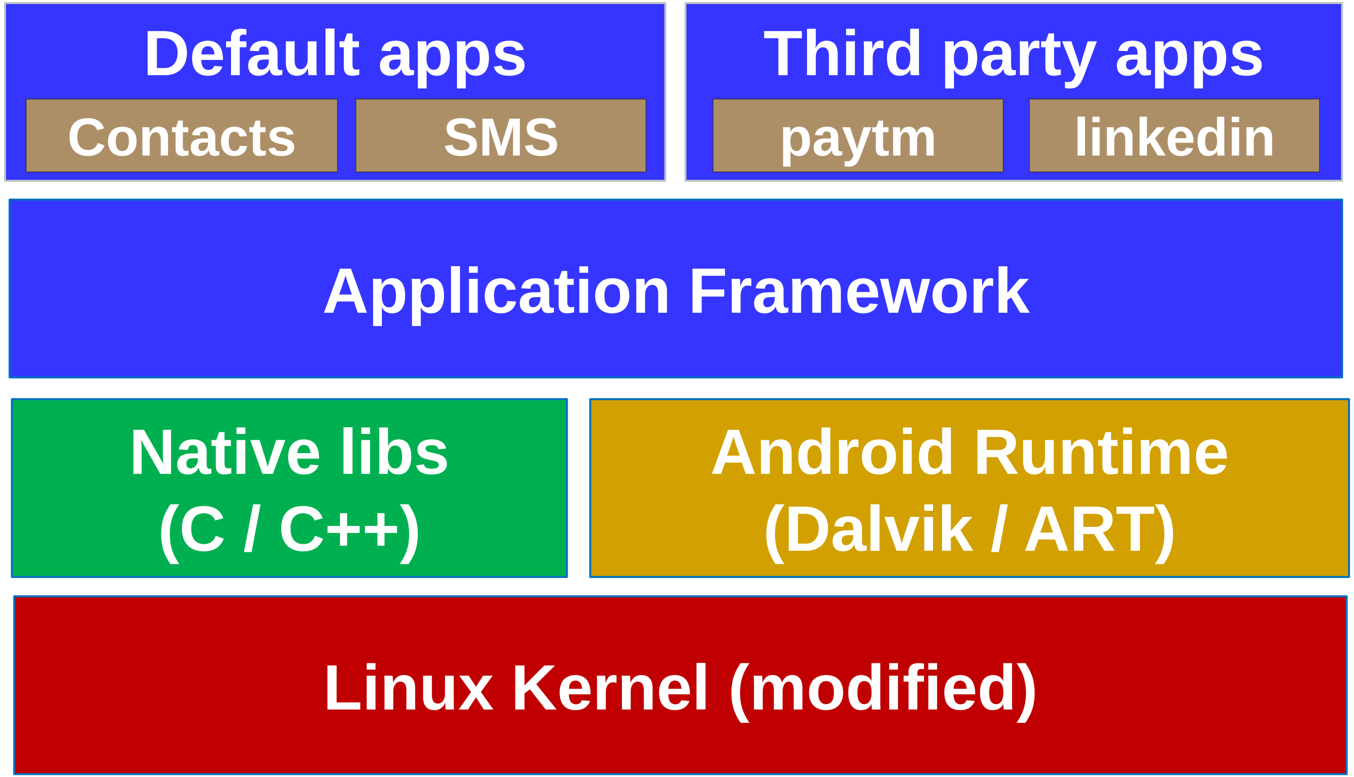
- **Feature-rich smartphones** and **appification** have induced security research on various new aspects

- Android's **market share** has made Android the **#1 target** for malware authors and makes improved security & privacy mechanisms imperative

- Various actors in the **ecosystem** with (strong) influence on **security and privacy**

ANDROID BACKGROUND

Android Software Stack



Default apps

Contacts

SMS

Third party apps

paytm

linkedin

Application Framework

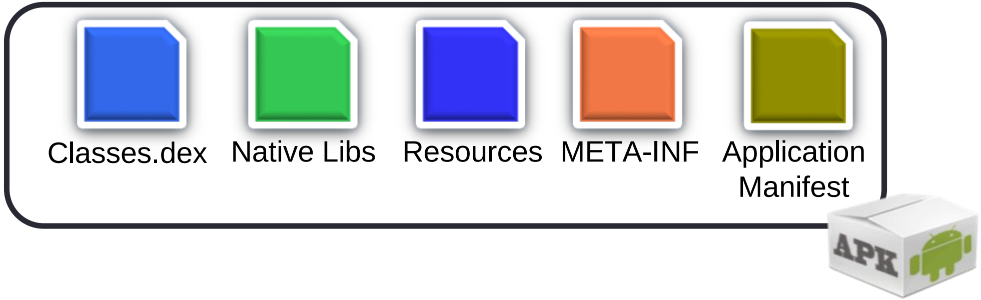
Native libs (C / C++)

Android Runtime (Dalvik / ART)

Linux Kernel (modified)

Application Packages (APK)

- APK is simply a packaging format like **JAR**, ZIP and TAR
- Component of Application
  - Activity
  - Content Provider
  - Services
  - Broadcast Receiver
- Native Code (C/C++ shared libraries)
- Resources
- META-INF
- Application Manifest

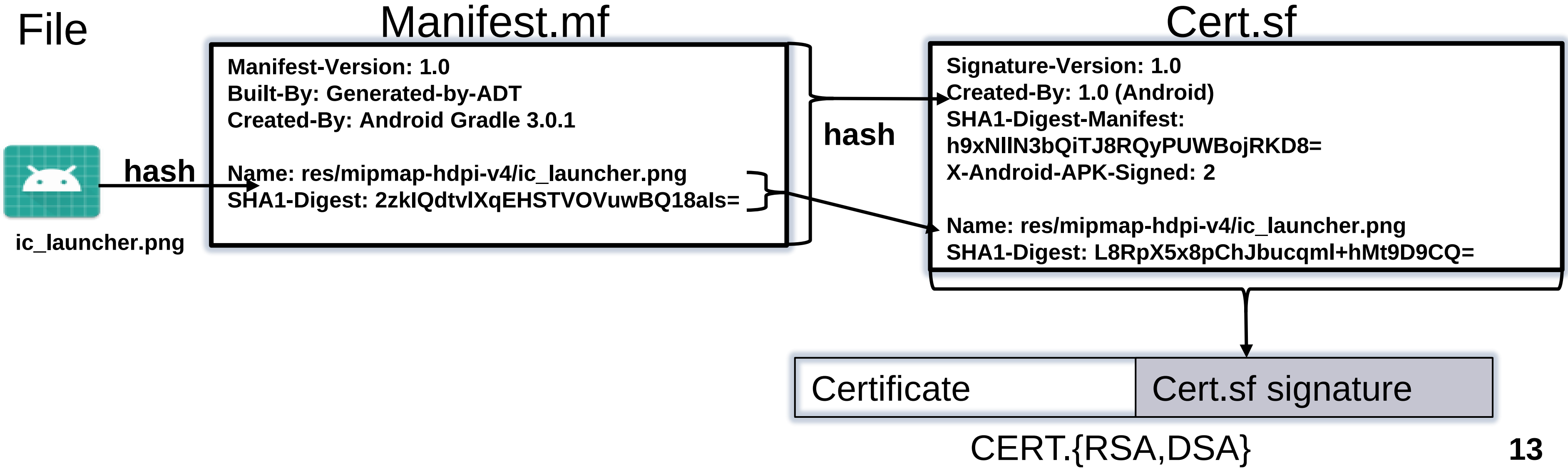


Android Security Architecture

- Package Integrity
- Sandboxing
- Permission and Least Privilege

Package Integrity: Package Manifest

- ❑ Created with **jarsigner**
- ❑ META-INF
  - ➢ Manifest.mf, Cert.sf, Cert.{RSA,DSA}



Manifest.mf

```
Manifest-Version: 1.0
Built-By: Generated-by-ADT
Created-By: Android Gradle 3.0.1

Name: res/mipmap-hdpi-v4/ic_launcher.png
SHA1-Digest: 2zkIQdtvlXqEHSTVOVuwBQ18aIs=
```

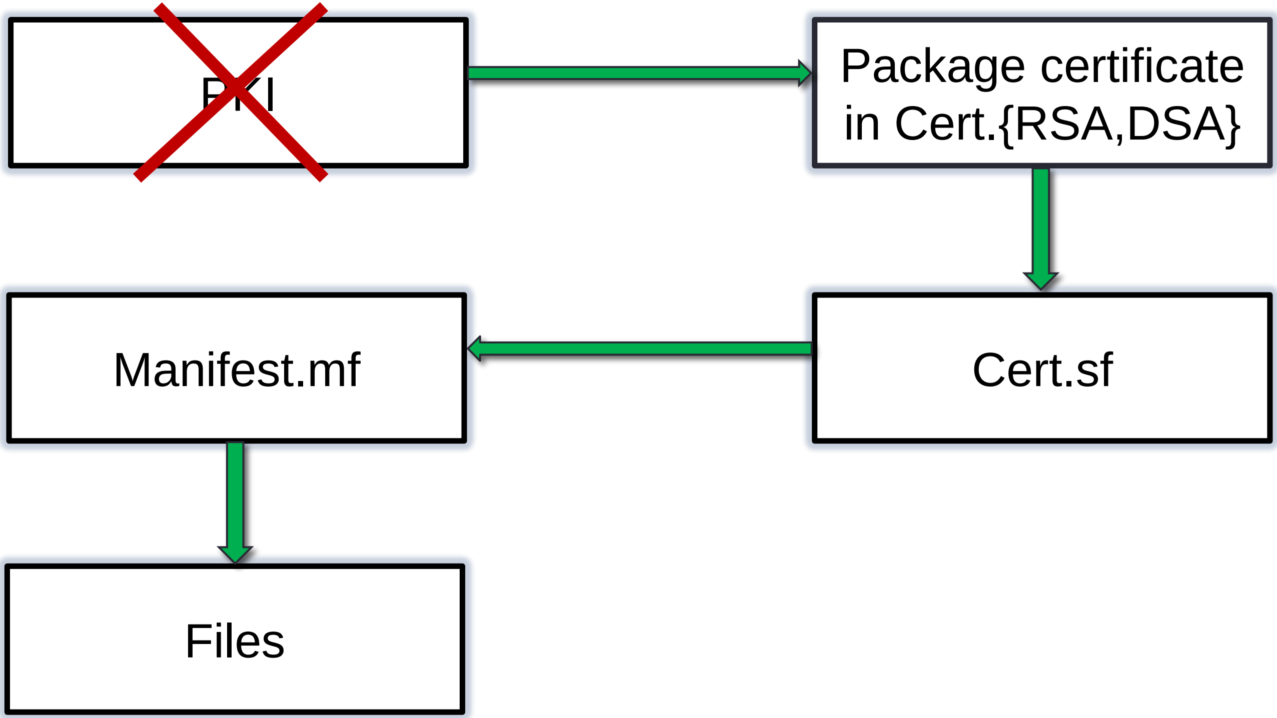
Cert.sf

```
Signature-Version: 1.0
Created-By: 1.0 (Android)
SHA1-Digest-Manifest:
h9xNlIN3bQiTJ8RQyPUWBojRKD8=
X-Android-APK-Signed: 2

Name: res/mipmap-hdpi-v4/ic_launcher.png
SHA1-Digest: L8RpX5x8pChJbucqml+hMt9D9CQ=
```

Verifying of package manifest

Chain of trust:



Android Security Architecture

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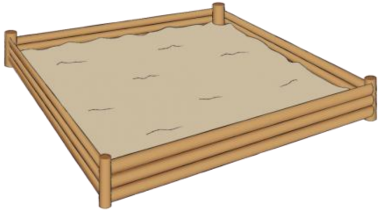
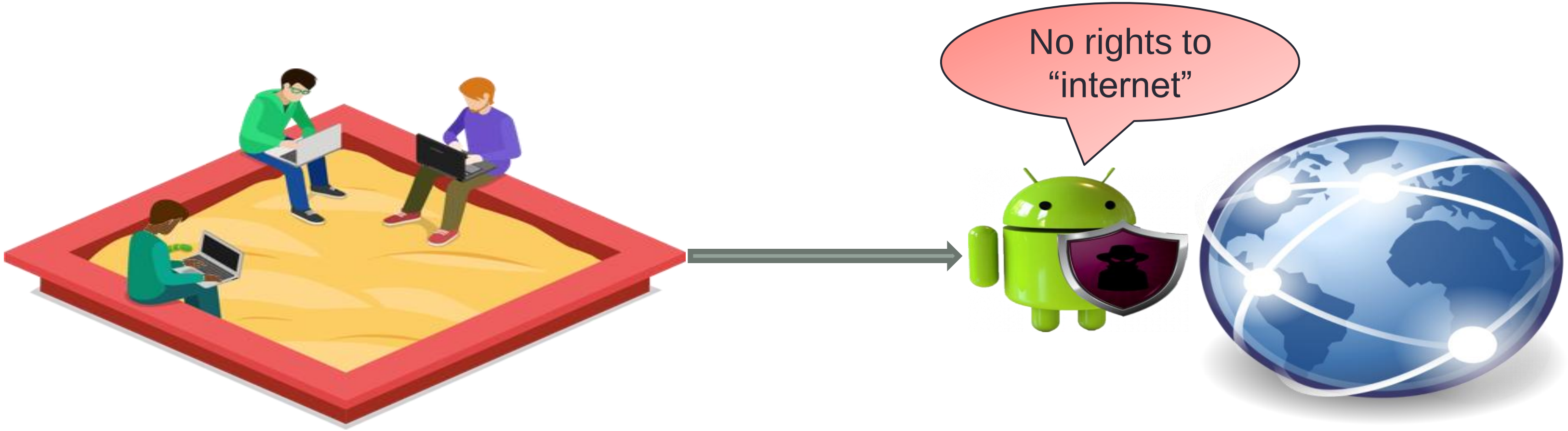
Sandboxing



- The application sandbox **specifies** which system **resources** the application is allowed to access
- An **attacker** can only perform **actions** defined in the sandbox

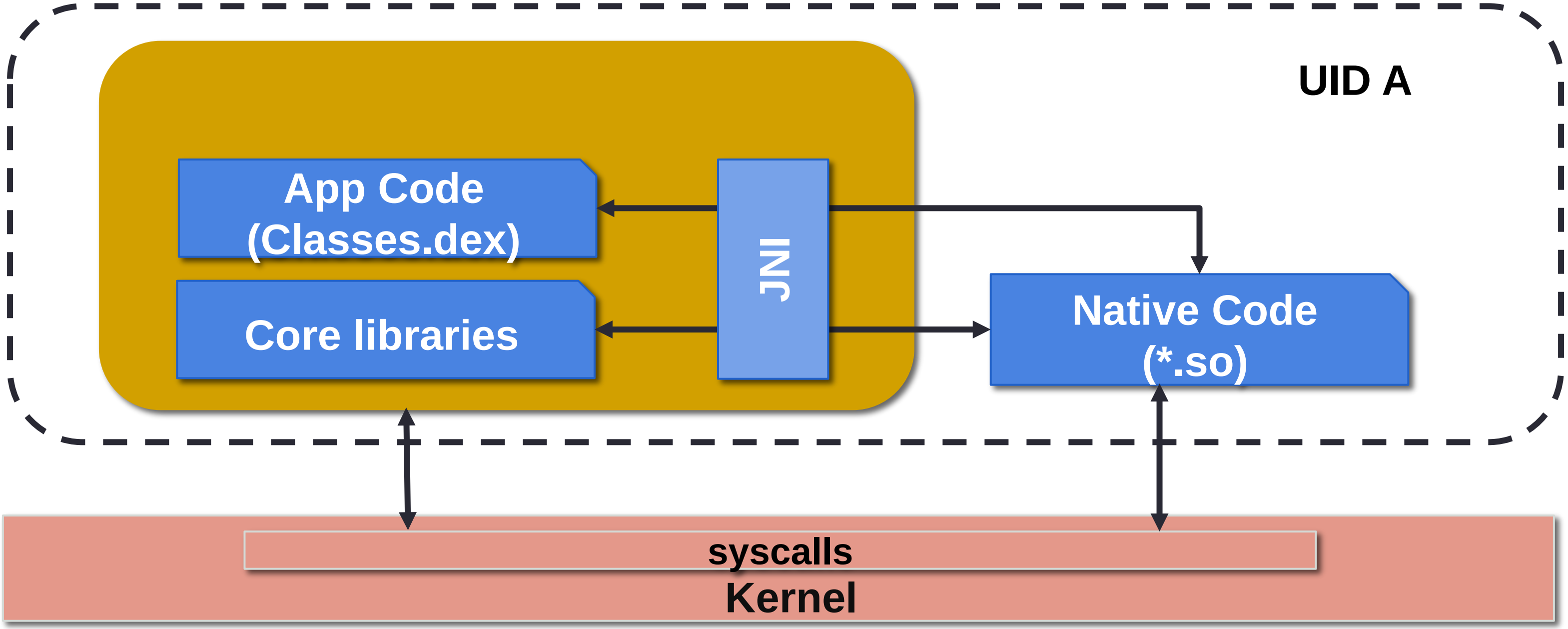
Application Isolation by Sandboxing

- ❑ Each Application is **isolated** in its own **environment**
  - ➢ **Applications** can access only its **own resources**
  - ➢ Access to **sensitive resources** depends on the **application's rights**
- ❑ **Sandboxing** is enforced by **Linux**



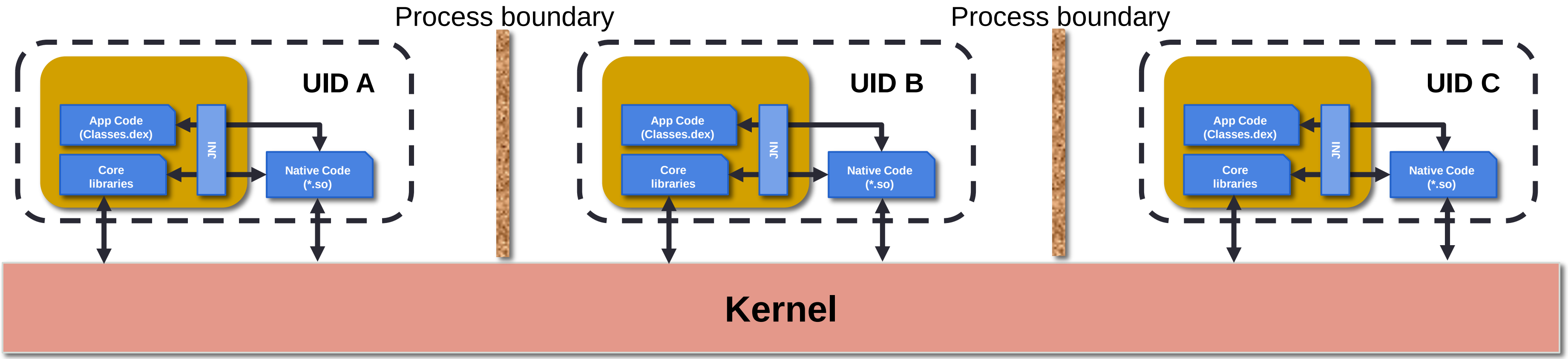
Application sandbox

- Isolation: Each installed App has a separate user ID



Application sandbox

- ❑Isolation: Each installed App has a separate user ID
  - ➢Each App lives in its own sandbox



Android Security Architecture

- Package Integrity
- Sandboxing
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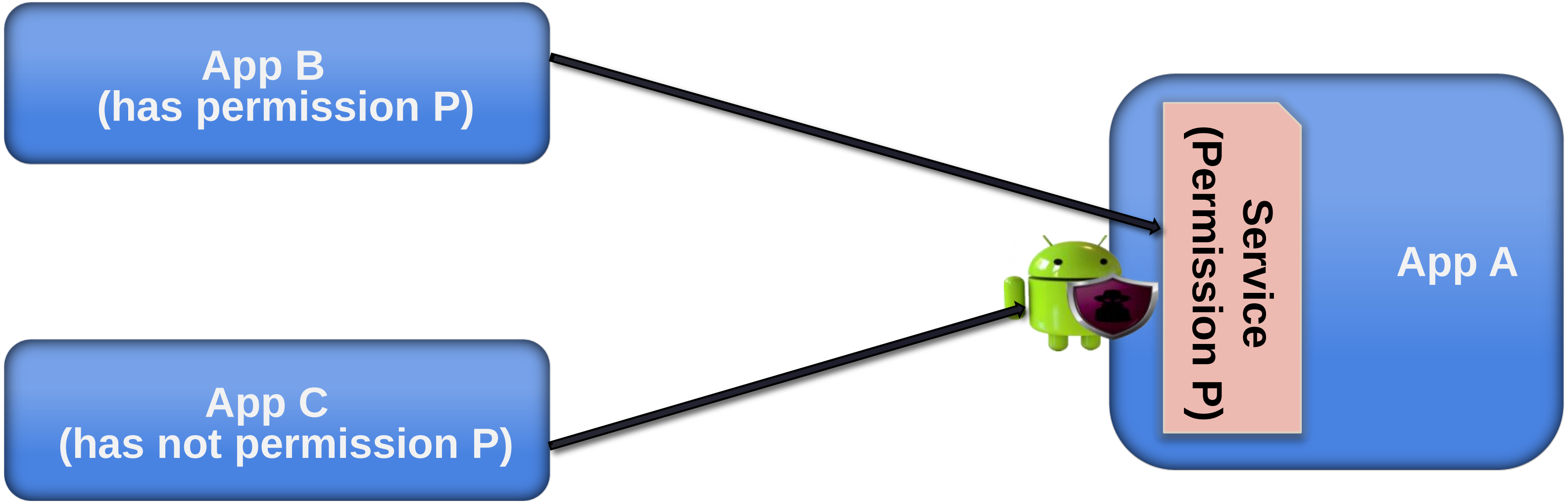
Android Permission System

- **Access rights** in Android's application framework
  - Permissions are required to **gain** access to
    - System interfaces (Internet, send SMS, etc.)
    - System resources (logs, battery, etc.)
    - Sensitive data (SMS, contacts, etc.)
  - Currently more than 140 default permissions defined in Android
- Permissions are **assigned** to sandbox
- Application developers can also **define** their **own** permissions

Android Permission: Example

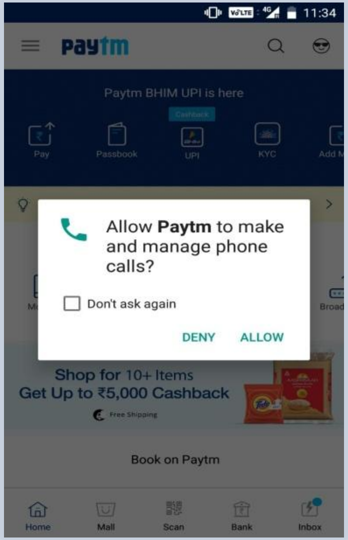


Permissions’ Protection Level

- Normal
- Dangerous
- Signature
- SignatureOrSystem

Dynamic Permissions (≥ Android 6.0)

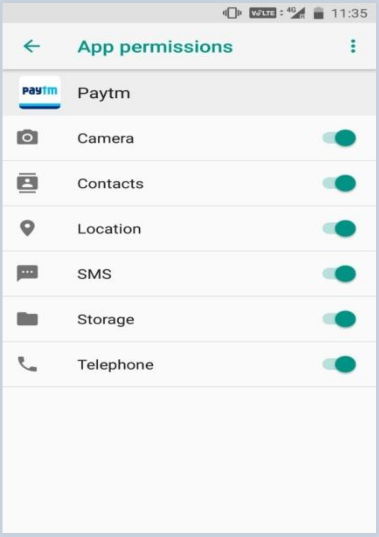
- App developers must **check** if their apps hold required **dangerous** permission, otherwise request them at runtime
- User can **grant** permissions at runtime and also **revoke** once granted permissions again



Allow **Paytm** to make and manage phone calls?

☐ Don't ask again

DENY ALLOW



11:35

App permissions

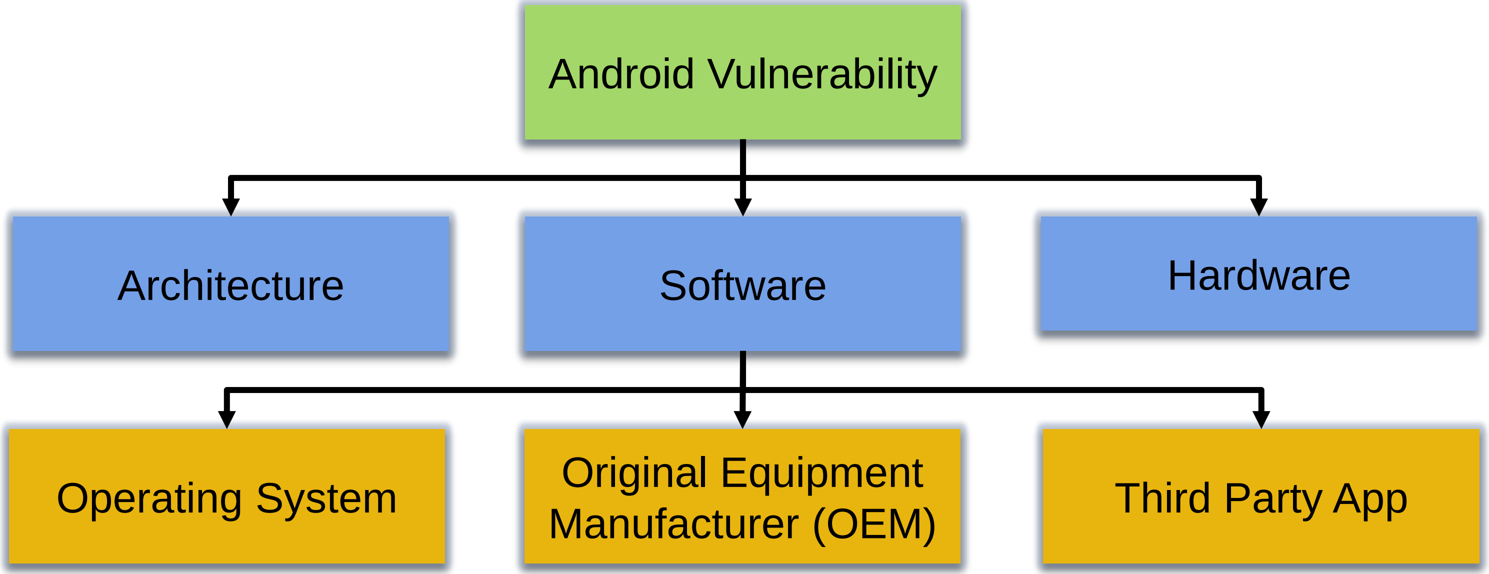
Paytm

- Camera ●
- Contacts ●
- Location ●
- SMS ●
- Storage ●
- Telephone ●

Android Vulnerabilities

- Architecture Based
- Software Based
- Hardware Based

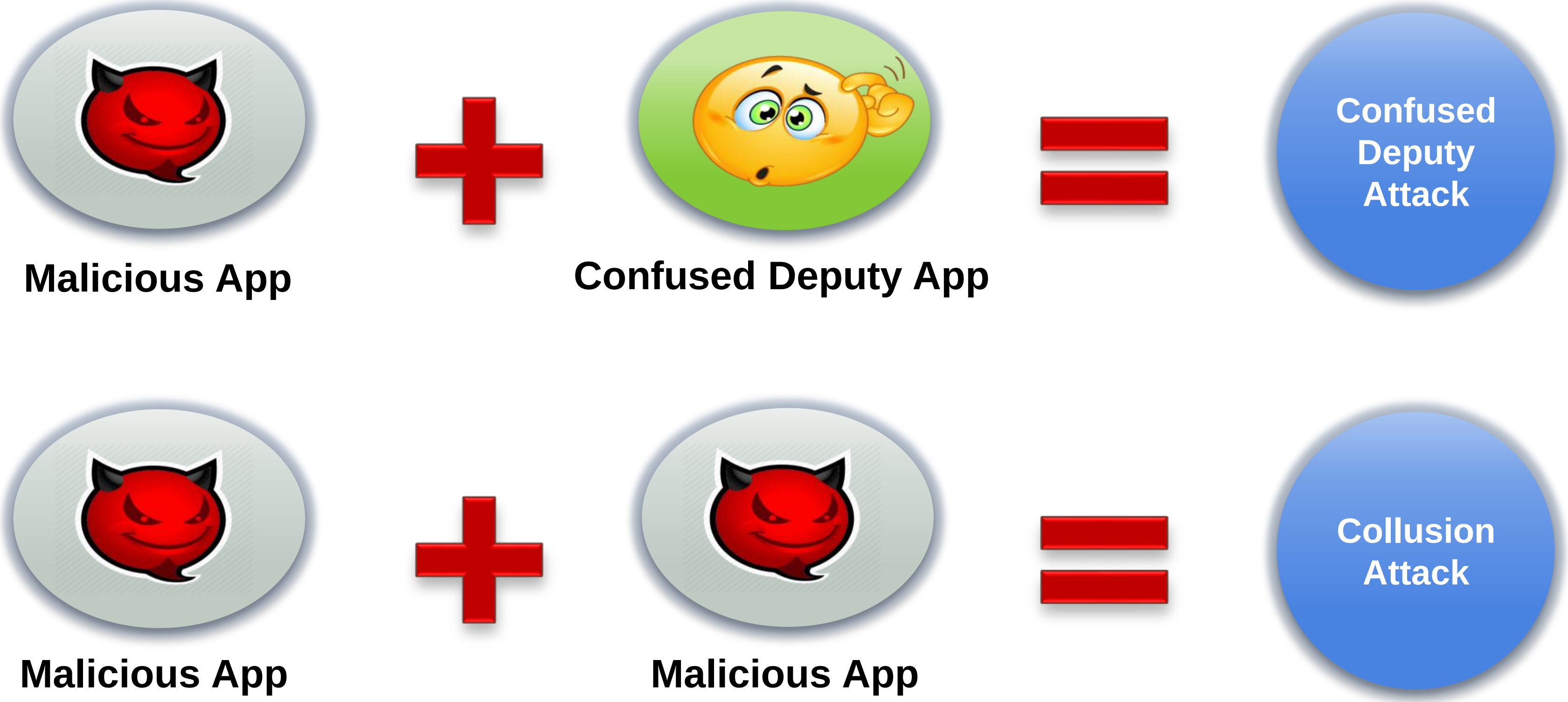
Vulnerability Classification



ANDROID VULNERABILITIES

- Architecture Based
- Software Based
- Hardware Based

Application-Level Privilege Escalation Attacks



Malicious App

Confused Deputy App

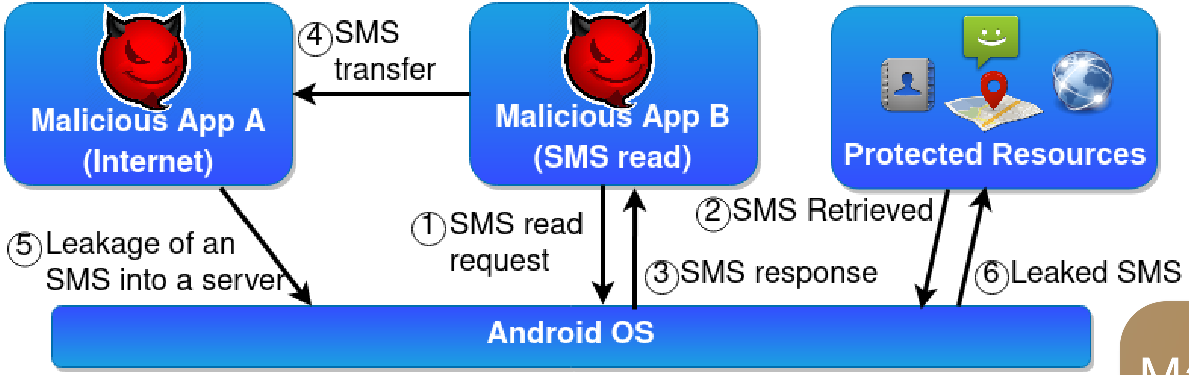
Confused Deputy Attack

Malicious App

Malicious App

Collusion Attack

Collusion Attack



Malicious apps **collude** in order to **merge** their respective **permissions**

- Variants:
  - Apps communicate directly
  - Apps communicate via covert channels in Android

ANDROID VULNERABILITIES

- Architecture Based
- Software Based
- Hardware Based

Dirty COW

- □Existed in the Linux Kernel for **9 years**
- □A **local** Privilege Escalation Vulnerability
- □Exploits a race condition in the implementation of the **copy-on-write** mechanism
- □Turns a **read-only** mapping of a file into a writable mapping

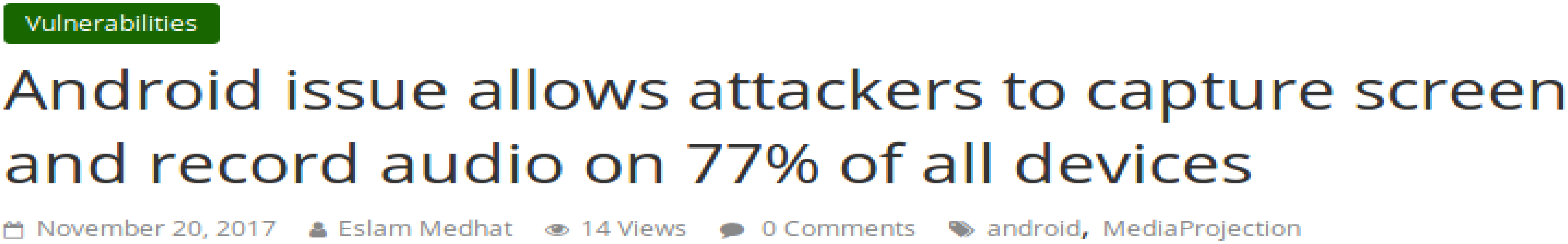
Android malware ZNIU exploits DirtyCOW vulnerability

29 SEP 2017 0

Android, Google, Malware, SophosLabs, Vulnerability

Source: https://nakedsecurity.sophos.com/2017/09/29/android-malware-zniu-exploits-dirtycow-vulnerability/

Media Projection Service Issue



Vulnerabilities

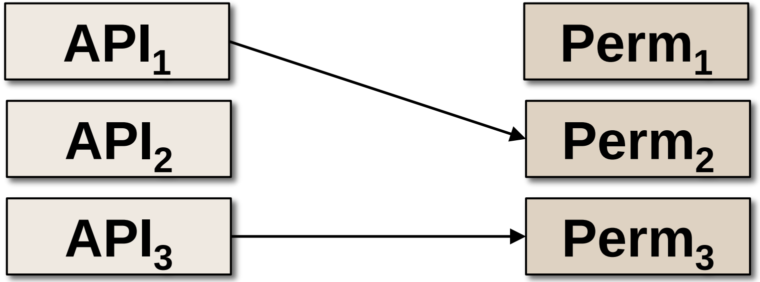
Android issue allows attackers to capture screen and record audio on 77% of all devices

November 20, 2017 Eslam Medhat 14 Views 0 Comments android, MediaProjection

Source: https://latesthackingnews.com/2017/11/20/android-issue-allows-attackers-to-capture-screen-and-record-audio-on-77-of-all-devices/

Over-privileged Apps

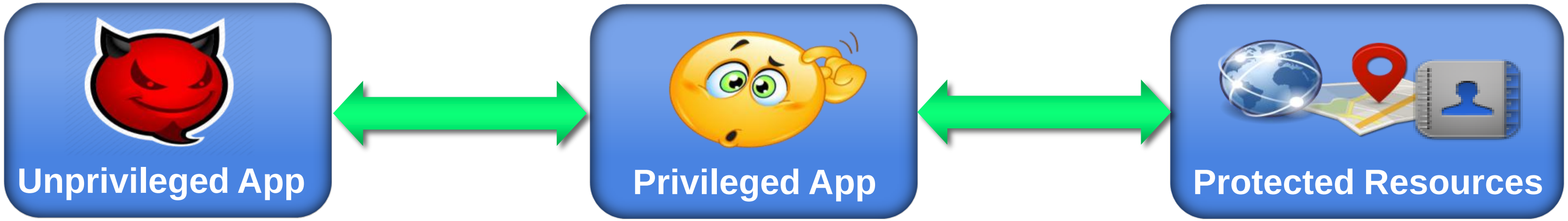
- ❑ Many apps request permissions that their **functionality** does not **require**
- ❑ Suspected root cause: API **documentation/naming** convention
  - ➢ Solution: API Permissions Maps
    - **Can be integrated into lint tools**



API$_1$ API$_2$ API$_3$

Perm$_1$ Perm$_2$ Perm$_3$

Confused Deputy Attack



Unprivileged App

Privileged App

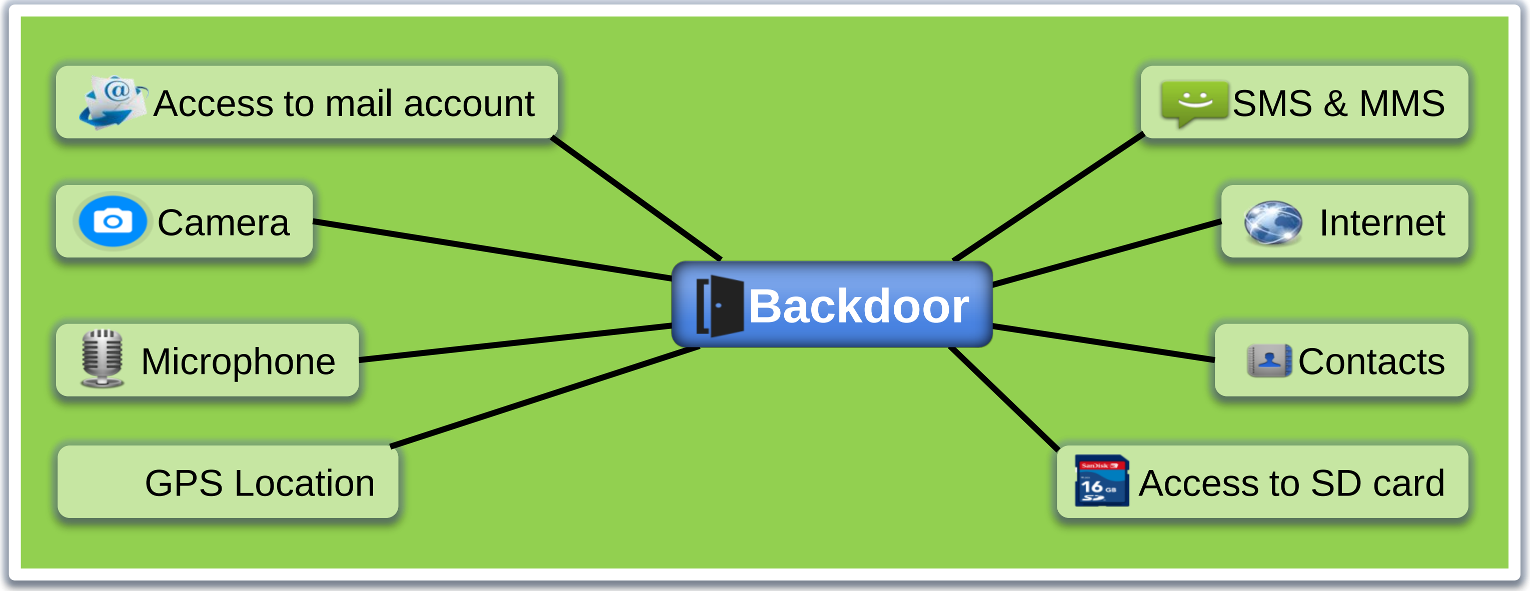
Protected Resources

- A privileged app is fooled into **misusing** its privileges on behalf of another (malicious) **unprivileged app**

- Example:
  - **Unauthorized** phone calls
  - Various confused deputies in **system apps**

Confused Deputy Introduce by OEMs

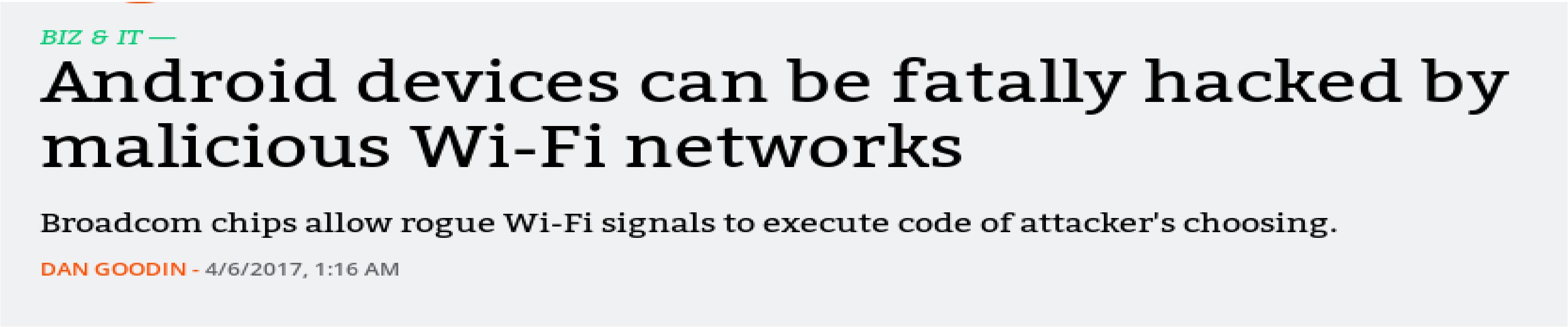
- Several **confused deputies** found in Samsung devices' **firmware**
  - One deputy running with system privileges provided **root shell service** to any app



ANDROID VULNERABILITIES

- Architecture Based
- Software Based
- Hardware Based

Broadcom Wi-Fi SoC Flaw



BIZ & IT —

Android devices can be fatally hacked by malicious Wi-Fi networks

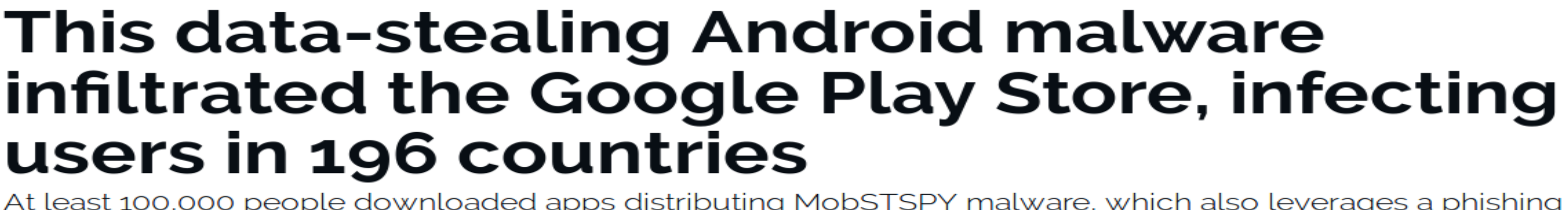
Broadcom chips allow rogue Wi-Fi signals to execute code of attacker's choosing.

DAN GOODIN - 4/6/2017, 1:16 AM

Source: https://arstechnica.com/information-technology/2017/04/wide-range-of-android-phones-vulnerable-to-device-hijacks-over-wi-fi/

MALWARE ANALYSIS

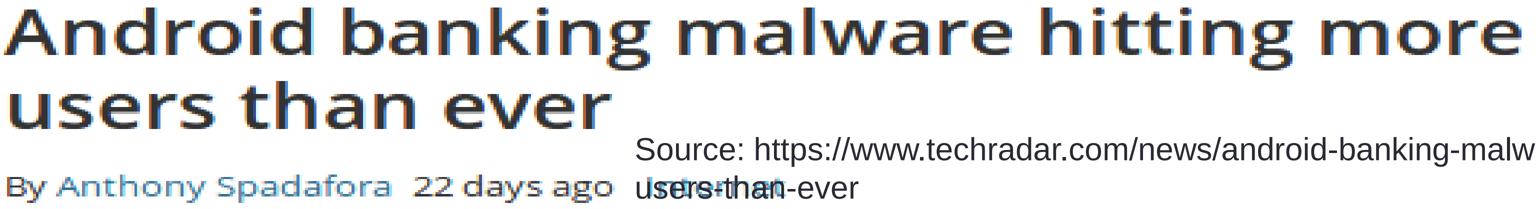
WHY MALWARE ANALYSIS?



This data-stealing Android malware infiltrated the Google Play Store, infecting users in 196 countries

At least 100,000 people downloaded apps distributing MobSTSPY malware, which also leverages a phishing

First Android Clipboard Hijacking Crypto Malware Found On Google



Android banking malware hitting more users than ever

By Anthony Spadafora 22 days ago Internet

Source: https://www.techradar.com/news/android-banking-malware-hitting-more-users-than-ever

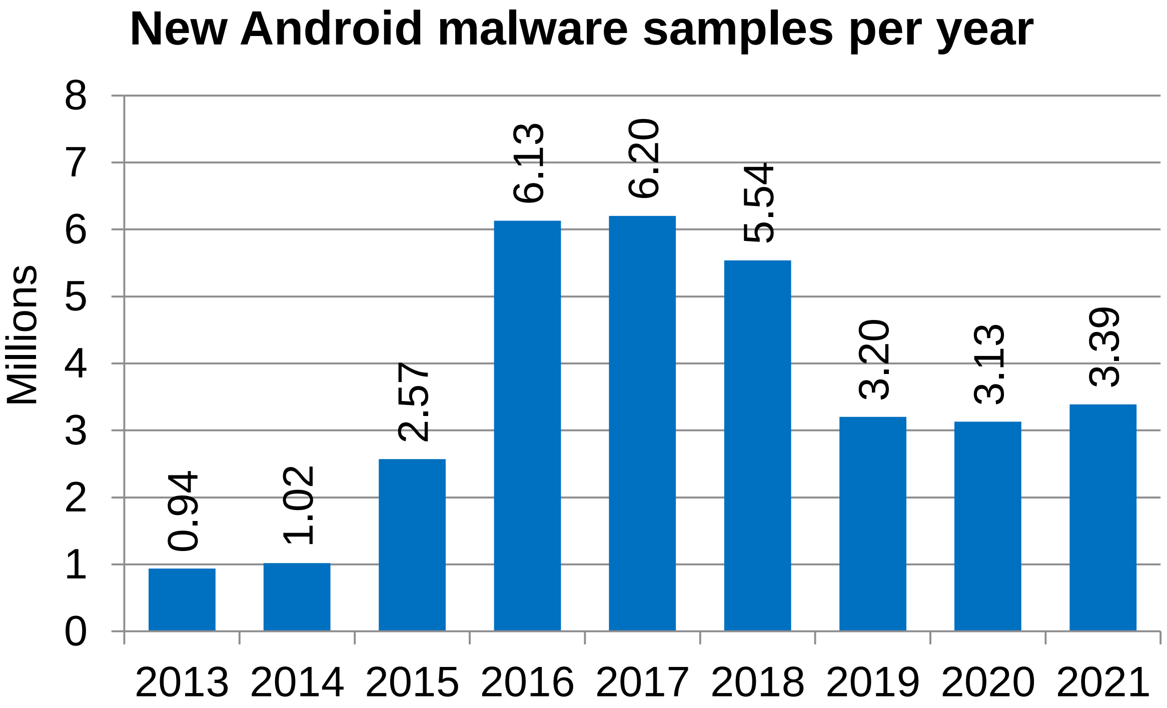
Fake banking apps could be more effective than banking Trojans

Several Popular Beauty Camera Apps Caught Stealing Users' Photos

February 04, 2019 Swati Khandelwal

Source: https://thehackernews.com/2019/02/beauty-camera-android-apps.html

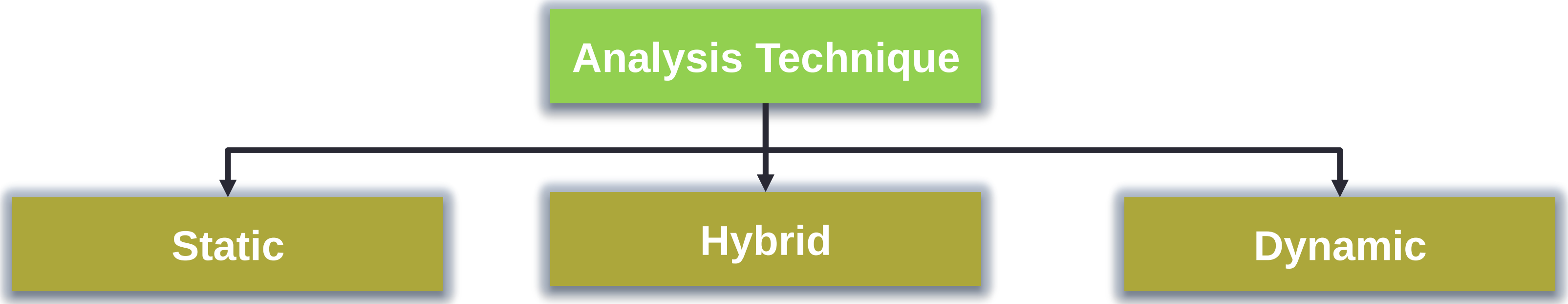
Android Malware Statistics



Source: AV-TEST malware statistics report Jan 2022

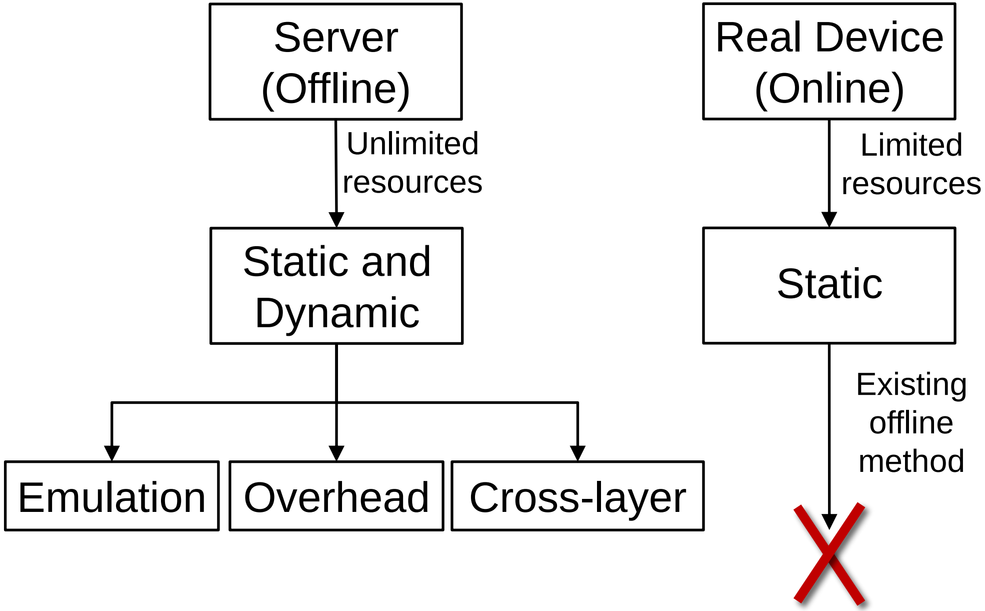
- ❑ In every 10 seconds, A new Android malware is born.

Analysis Techniques



Malware Analysis

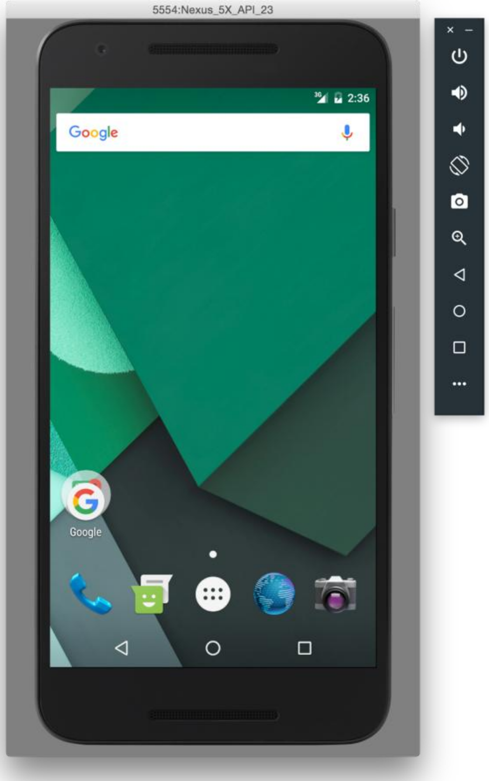
- ❑ Many work has been proposed
- ❑ Deployed on
  - ➢ Server
  - ➢ Real Device
- ❑ Offline analysis can be bypassed
- ❑ On a real device, existing offline method cannot be used
  - ➢ High resources requirement



Challenges: Dynamic Analysis

Android Emulator

- ❑ A virtual mobile device
- ❑ Use Case:
  - ➢ Prototype, develop and test an application
  - ➢ Dynamic Analysis of malware
    - ▪ Used by security companies



Emulation-Detection

- Detection methods are classified in 5 category
  - Unique Device Information (basic and **smart**)
  - Sensors Reading
  - GPS Information
  - Device State Information
  - Distributed Detection

Unique Device Information

❑ Basic

- ➢ Unrealistic/null value for IMEI, Phone No. etc.

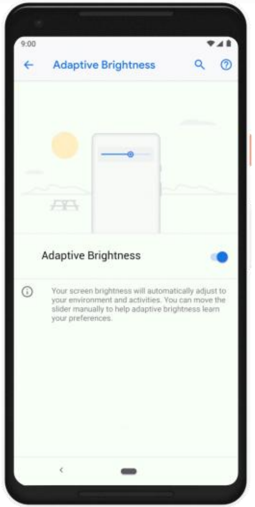
❑ Smart

- ➢ Realistic but fixed values

	IMEI	Phone No.	ICCID
	123456XXXXX2347	901XXXXX36	89XXXXX5611117910720
	null/00000000000	155XXXXX554	89XXXXX3211118510720
cuckoo DROiD	3514XXXXX401216	972XXXXX243	89XXXXX0082067415160
cuckoo DROiD	3514XXXXX401216	972XXXXX243	89XXXXX0082067415160

Sensors

- ❑ Different sensors in a smart phone
  - ➢ Motion Sensors: accelerometer, gyroscope
  - ➢ Environmental Sensors: illumination (light), humidity
- ❑ Detection:
  - ➢ Count: At least 6-7 or more sensors in a smartphone
  - ➢ Reading: No change in sensors reading


9:00

Adaptive Brightness

Adaptive Brightness ●

Your screen brightness will automatically adjust to your environment and activities. You can move the slider manually to help adaptive brightness learn your preferences.

GPS Information

- No change in GPS location

- Use of mock location API to provide fake location

- No correlation with BTS geo-location

Device State Information

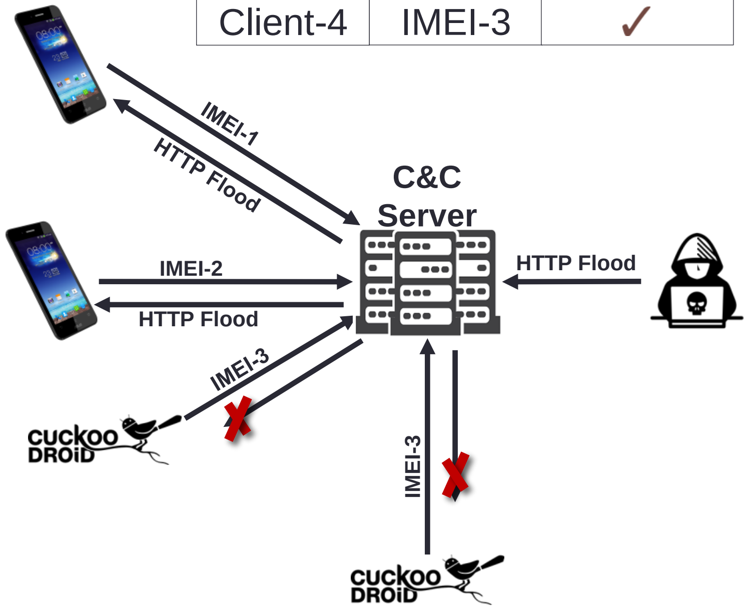
- ❑ Smartphone state may change due to:
  - ➢ Battery power
  - ➢ Signal Strength
  - ➢ SMS
  - ➢ Call
- ❑ No state change in emulated platform

Distributed Detection

- ❑ Detection on server
  - ➢ App communicates with server
  - ➢ Observing identical information for multiple device like IMEI

- ❑ Example:
  - ➢ Botnet analysis

Client No.	IMEI	Emulated?
Client-1	IMEI-1	✗
Client-2	IMEI-2	✗
Client-3	IMEI-3	✗
Client-4	IMEI-3	✓



Existing Frameworks Evaluation

Detection Type	Emulator	DroidBox	CuckooDroid	MobSF
Unique ID (Basic)	✓	✗	✗	✗
Unique ID (Smart)	✓	✓	✓	✓
Sensors reading	✓	✓	✓	✓
Device State	✓	✓	✓	✓
GPS	✓	✓	✓	✓
Distributed Detection	✓	✓	✓	✓

Every framework fails to defend against all the detection method except for basic unique ID

Summary: Emulation Detection

- Existing framework fails to defend against detection method:
  - Smart unique device information
  - Sensors and GPS information
  - Device state
  - Distributed detection

- Need a robust anti-emulation-detection system:
  - Hides underline emulated platform
  - Remain undetected when attack is performed from any layer

Reference for More Details

❑ Robust Anti-Emulation-Detection

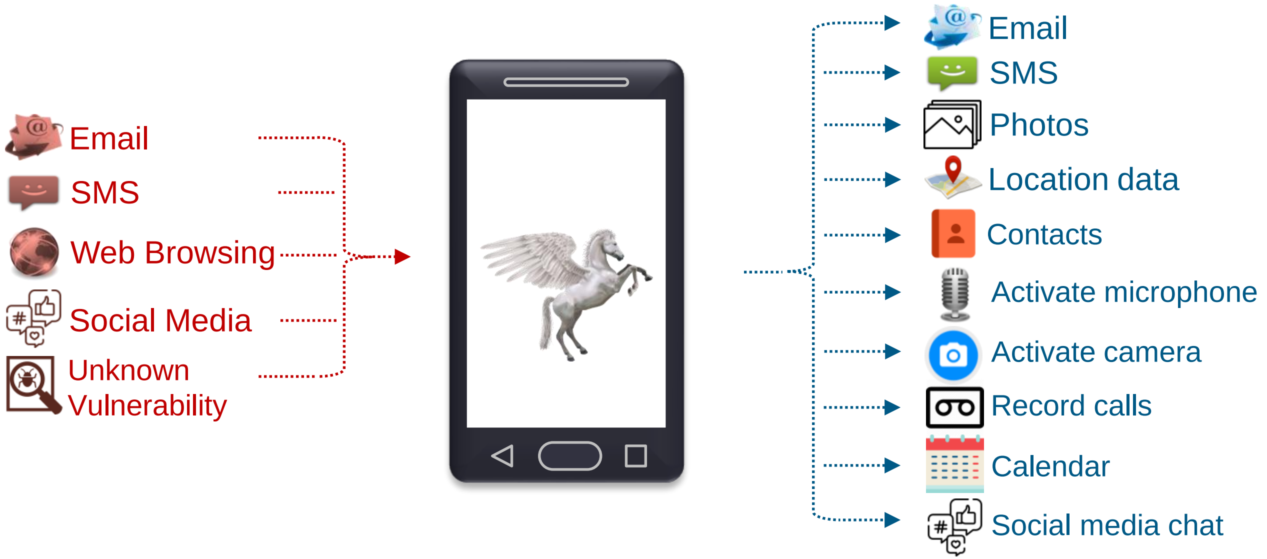
https://www.youtube.com/watch?v=ahAgW4Wj3qc

❑ On-Device Android Malware Detection

https://www.youtube.com/watch?v=ziwIJGttkYg

Case Study: Analysis of Pegasus Malware

Pegasus: Attack Vector and Capabiliteis



Attack Vector.

Capabilities

Data Collection

- ❑ Samples were collected from CloudSek
- ❑ Total 5 Apps
- ❑ App-1 and App-3 are same only file name is different

App ID	File Name
App-1	9fae5d148b89001555132c896879652fe1ca633d35271db34622248e048c78ae.apk
App-2	144778790d4a43a1d93dff6b660a6acb3a6d37a19e6a6f0a6bf1ef47e919648e.apk
App-3	cc9517aafb58279091ac17533293edc1.apk
App-4	d257cfde7599f4e20ee08a62053e6b3b936c87d373e6805f0e0c65f1d39ec320.apk
App-5	bd8cda80aaee3e4a17e9967a1c062ac5c8e4aefd7eaa3362f54044c2c94db52a.apk

Analysis Type and Environment

- Static
  - Androguard
- Dynamic
  - STDNeut: Neutralizing Sensor, Telephony System and Device State Information on Emulated Android Environments
  - Xposed framework to monitor API calls
  - SysCallMon: A system call monitoring Kernel module

Analysis Result

App-1 and App-3

Meta Information

- Package Name: com.binary.sms.receiver
- Modification Date: 2 June, 2014
- Hash: 9fae5d148b89001555132c896879652fe1ca633d35271db34622248e048c78ae

Server Communication

IP/URLs	Port	Geo Location
142.XXX.27.188	443	Mountain View, California, USA
	5228	

App-1 and App-3 cont..

System Command

- chmod, mount, su

Capability

- Install new applications
- Make a call, listen or record incoming/outgoing call
- Read/Write contacts, bookmark,
- Many more…

App-1 and App-3 cont..

Observation:

- Tries to get root privilege
- Change file permissions
- Mount system partition as R/W
- Intercept incoming/outgoing SMS and Calls
- Obtain information about installed and running apps
- Can install new apps
- Read other information like contacts, history bookmarks,
- Read/write system settings,
- Process outgoing calls and send new SMS
- Delete call logs and many more.

App-2

Meta Information

- Package Name: com.lenovo.safecenter
- Modification Date: 16 Dec, 2010
- Hash: 144778790d4a43a1d93dff6b660a6acb3a6d37a19e6a6f0a6bf1ef47e919648e

Server Communication

IP/URLs	Port	Geo Location
142.XXX.102.188	443	Mountain View, California, USA
	5228	
142.XXX.5.188	443	Mountain View, California, USA
	5228	

App-2 cont..

System Command

- app_process, bind, cat, chmod, chown, close, connect, date, dumpsys, echo, exit, gzip, id, iptables, kill, log, logcat, ls, mkdir, mount, mv, notify, open, pm, ps, pwd, read, reboot, sdcard, select, service, sh, socket, start, su, system_server, times, uptime, write

Capability

- Make a call, send new SMS
- Read/Write contacts, system settings,
- Process outgoing calls
- Access location data
- Kill background processes
- Many more…

App-2 cont..

Observation:

- Capable to bypass dynamic analysis using device information
- Tries to get root privilege
- Can change files permission
- Mount system partitions as RW
- Open network sockets
- Get running process information and kill any process
- Dynamically load code, end an incoming call, kill background processes
- Remove any app
- Register a broadcast receiver to intercept incoming SMS

App-4

Meta Information

- Package Name: com.xxGameAssistant.pao
- Modification Date: 15 Nov, 2013
- Hash: d257cfde7599f4e20ee08a62053e6b3b936c87d373e6805f0e0c65f1d39ec320

System Command

- Chmod, dd, ln, mkdir, mount, stop, su

Capability

- Read Phone state
- Access location data
- Listen to boot complete event
- Read/Write to external storage

App-4

Server Communication

IP/URLs	Port/Protocol	Geo Location
http://tdcv3.talkingdata.net/g/d	HTTP	Kansas City, Missouri, USA
http://tdcv3.talkingdata.net	DNS	
35.XXX.63.213	--	
142.XXX.188.196	--	Mountain View, California, USA
142.XXX.102.188	--	
142.XXX.27.188	--	
142.XXX.5.188	--	

App-4 cont..

Observation:

- Tries to get root privilege
- Can change files permission
- Mount system partitions as R/W
- Capable to bypass dynamic analysis using device & CPU information
- Can install apps,
- Get information about the currently installed/running App, processes and tasks
- Track location and steal sensitive information like device Ids, phone numbers and others
- Listen to BOOT COMPLETE event so that it can run a code or background process when a phone restarts.

App-5

Only static analysis

- Dex file is tempered, hence no dynamic analysis

Meta Information

- Package Name: sec.dujmehn.qdtheyt
- Modification Date: 10 Nov, 2018 based on last modified content
- Hash: bd8cda80aaee3e4a17e9967a1c062ac5c8e4aefd7eaa3362f54044c2c94db52a

App-5 cont..

Capability

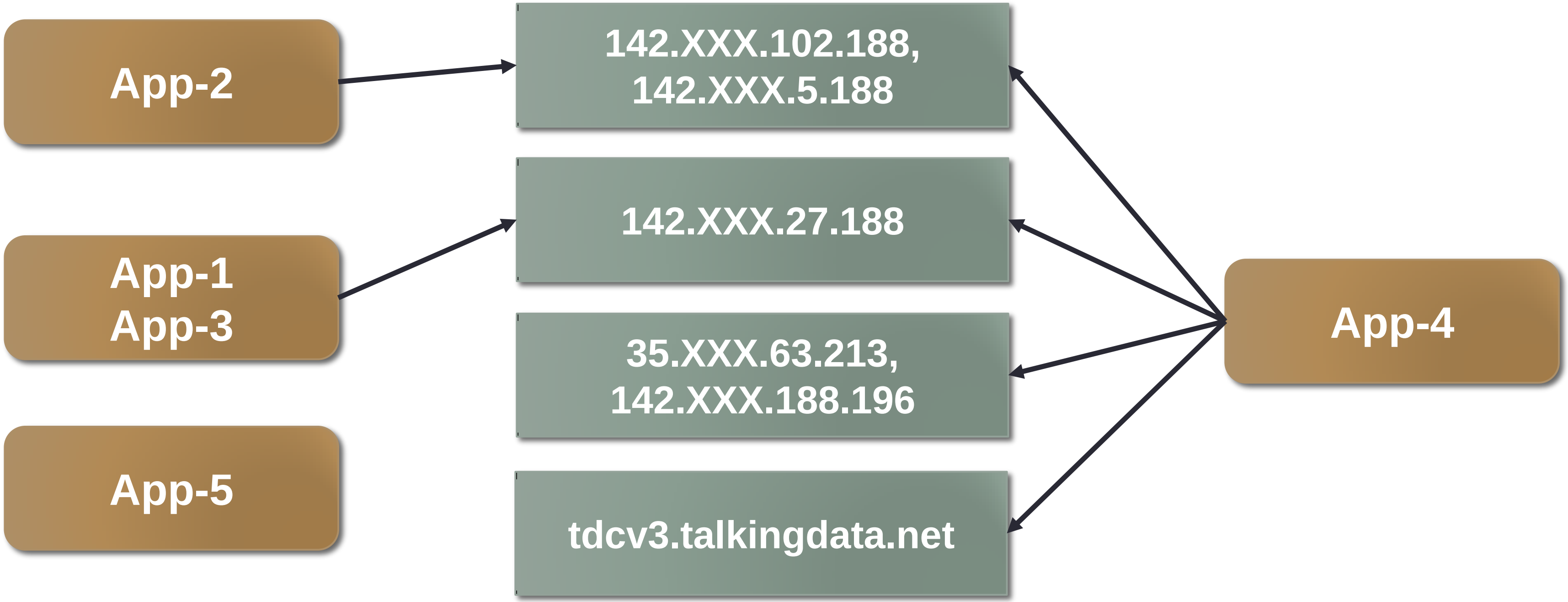
- Install new applications
- Make a call, listen or record incoming/outgoing call
- Read/Write contacts, bookmark,
- Access to location data
- Send and read SMS
- Kill background process
- Set fake location information
- Many more…

App-5 cont..

Observation:

- Can change files permissions
- Mount system partitions as R/W.
- Can get information about currently installed/running apps, processes and tasks
- Track location and steal sensitive information like device Ids, phone numbers and others.
- Listen to BOOT COMPLETE, NEW SMS, OUTGOING CALLS, BATTERY STATUS CHANGED, and many other events
  - Can run a code or background process when any of such event occurs
- Ability to change system configuration, R/W contacts, bookmark history,
- Record audio in background, install apps

Connection Between Apps



App-2

App-1
App-3

App-5

142.XXX.102.188,
142.XXX.5.188

142.XXX.27.188

35.XXX.63.213,
142.XXX.188.196

tdcv3.talkingdata.net

App-4

Detection of Pegasus

- ❑Used DeepDetect, machine learning based Android malware detector
- ❑Static features from Manifest File and Dex code
- ❑Results

App ID	Detection Result
App-1	✓
App-2	✓
App-3	✓
App-4	✓
App-5	✓ **(Only based on Android Manifest file)**

https://github.com/skmtr1/Workshop-Mobile-Forensics-And-Security

Thank You