CSE 484 / CSE M 584: Computer Security and Privacy

Mobile Platform Security

Fall 2016

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Thanks to Franzi Roesner, Dan Boneh, Dieter Gollmann, Dan Halperin, Yoshi Kohno, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Administrative

- Final project is out!
- An outline of your presentation is due this Friday.
- The final video is due next Friday (the last day of class).

Administrative

- My office hours moved for this week:
  - Moved to Wednesday at 12:30-1:30 pm.

- By appointment is always available.

Administrative

- There will be no lab 3.

Security Mindset Anecdote

- PGP – released in the early 1990s, when encryption with key lengths greater than 40 bits was classified as a "munition" and subject to weapons export laws.

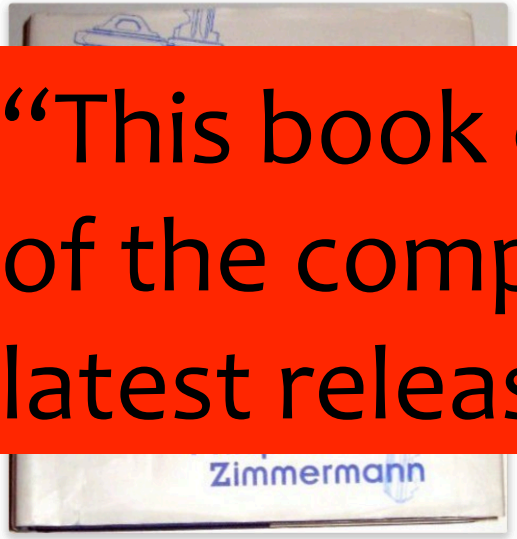
- Its creator, Phil Zimmerman was criminally investigated for "munitions export without a license"

Books › Computers & Technology › Security & Encryption

PGP: Source Code and Internals Hardcover – June 9, 1995

by Philip R. Zimmermann (Author)

★★★★★ 1 customer review



PGP (Pretty Good Privacy) is a computer program for the encryption of data and electronic mail, a powerful "envelope" that allows individuals the same privacy in their communications as enjoyed by governments and large corporations. PGP, which is freely available on the Internet, uses public-key cryptography, specifically the RSA algorithm, which is particularly well suited to the needs of computer-mediated communications. This book contains a formatted vesion of the complete source code for the latest release (2.6.2) of PGP.

See all 2 images

"This book contains a formatted version of the complete source code for the latest release (2.6.2) of PGP."

The First Amendment and Code

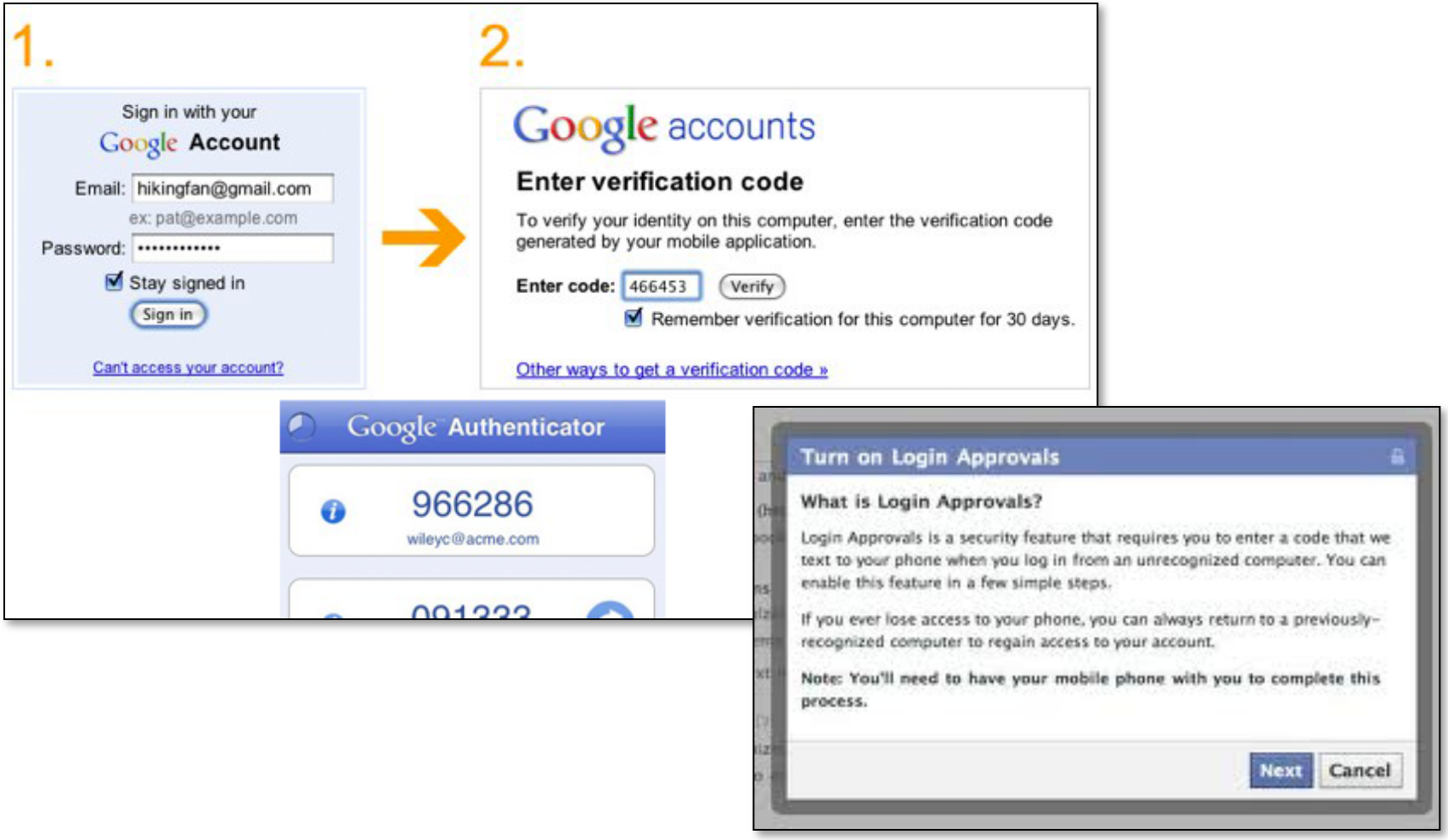
- Federal appears courts have ruled that crypto source code is speech under the First Amendment

- Export restrictions have been loosened (small list of countries are restricted – the same ones to which most US trade is prohibited)

Improving(?) Passwords

- Add biometrics
  - For example, keystroke dynamics or voiceprint
- Graphical passwords
  - Goal: easier to remember? no need to write down?
- Password managers
  - Examples: LastPass, KeePass, built into browsers
- Two-factor authentication
  - Leverage phone (or other device) for authentication

Multi-Factor Authentication



Multi-Factor Authentication

MORE ABOUT YOUR YUBIKEY

YUBIKEY 4

USB; strong crypto and touch-to-sign, plus One-Time-Password, PIV-compatible smart card, and FIDO U2F. *Read more*

YUBIKEY NEO

USB and NFC (for Android mobile); One-Time Password, PIV-compatible smart card, and FIDO U2F. *Read more*

What About Biometrics?

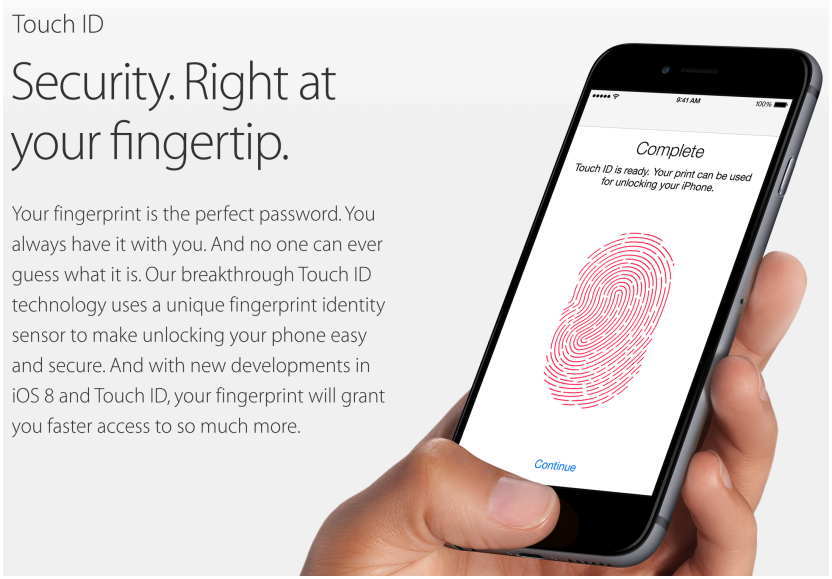
- Authentication: **What you are**
- Unique identifying characteristics to authenticate user or create credentials
  - Biological and physiological: Fingerprints, iris scan
  - Behaviors characteristics - how perform actions: Handwriting, typing, gait
- Advantages:
  - Nothing to remember
  - Passive
  - Can't share (generally)
  - With perfect accuracy, could be fairly unique

Issues with Biometrics

- Private, but not secret
  - Maybe encoded on the back of an ID card?
  - Maybe encoded on your glass, door handle, …
  - Sharing between multiple systems?
- Revocation is difficult (impossible?)
  - Sorry, your iris has been compromised, please create a new one…
- Physically identifying
  - Soda machine to cross-reference fingerprint with DMV?
- Birthday paradox
  - With false accept rate of 1 in a million, probability of false match is above 50% with only 1609 samples

Attacking Biometrics

- An adversary might try to steal biometric info
  - Malicious fingerprint reader
    - Consider when biometric is used to derive a cryptographic key
  - Residual fingerprint on a glass
- Ex: Apple's TouchID

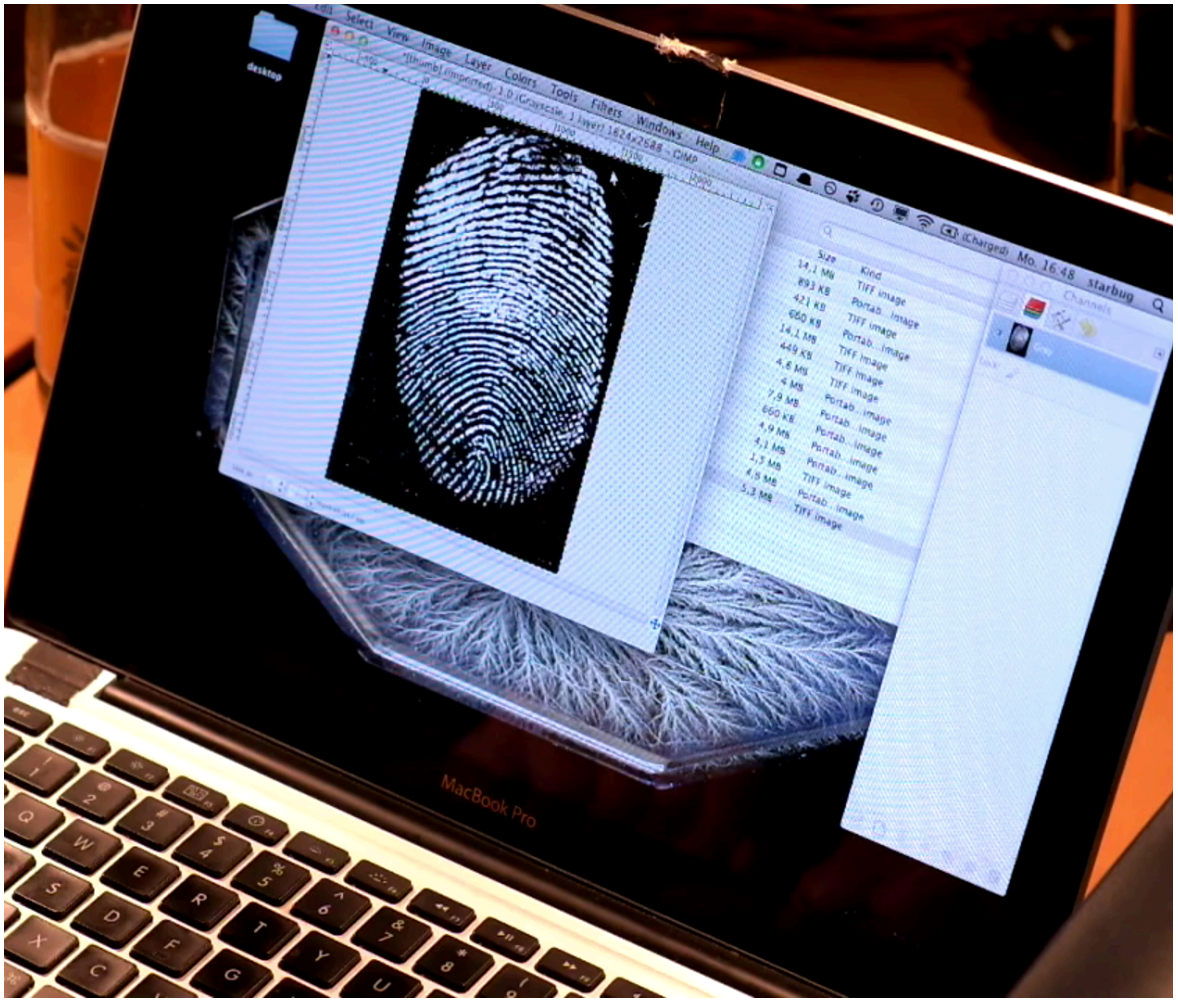


[Starbug -- http://istouchidhackedyet.com/]

Attacking Biometrics

[Starbug -- http://istouchidhackedyet.com/]

Attacking Biometrics



[Starbug -- http://istouchidhackedyet.com/]

Attacking Biometrics

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Attacking Biometrics

MOBILE PLATFORM SECURITY

Roadmap

- Mobile malware
- Mobile platforms vs. traditional platforms
- Deep dive into Android

Questions: Mobile Malware

Q1 (bottom third of the room): How might malware authors get malware onto phones?

Q2 (middle third): What are some goals that mobile device malware authors might have? What assets are present on a smartphone?

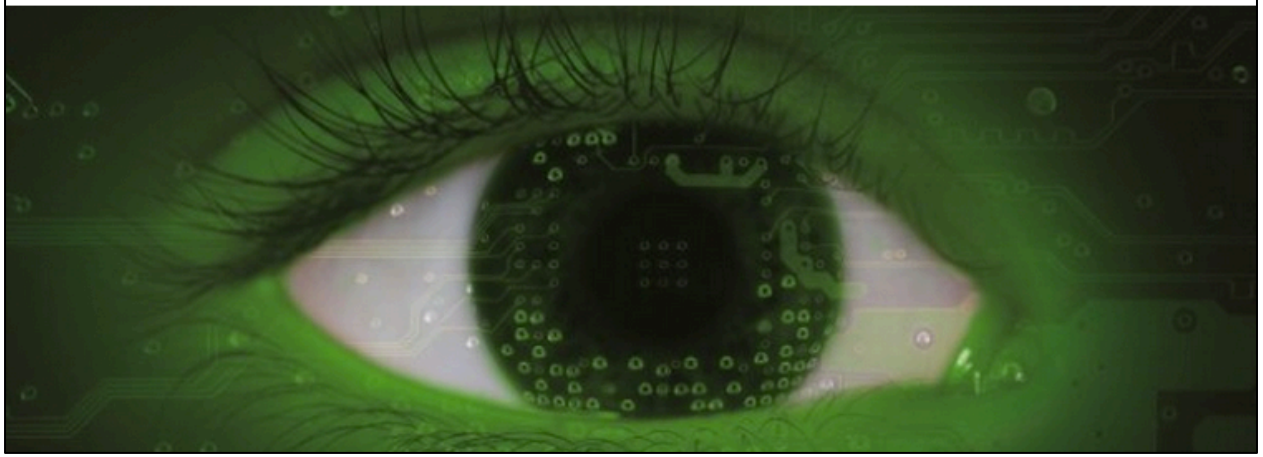
Q3 (top third): What technical things might malware authors do? What are the threats/ vulnerabilities on a smartphone?

Smartphone (In)Security

Users accidentally install malicious applications.

Over 60% of Android malware steals your money via premium SMS, hides in fake forms of popular apps

By Emil Protalinski, Friday, 5 Oct '12 , 05:50pm

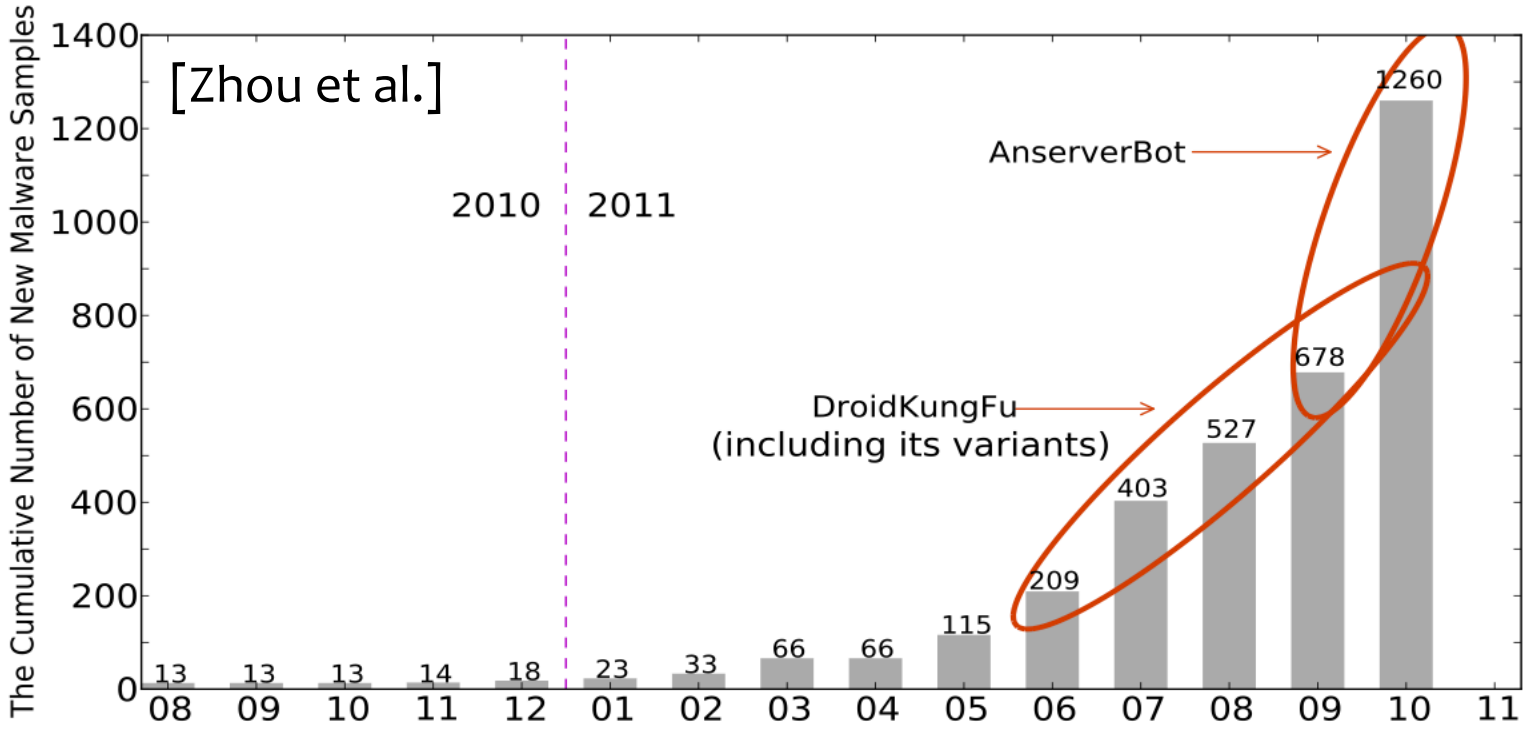


Smartphone (In)Security

Even legitimate applications exhibit questionable behavior.

Malware in the Wild

Android malware is growing.
Today (2016): millions of samples.



Mobile Malware Attack Vectors

- Unique to phones:
  - Premium SMS messages
  - Identify location
  - Record phone calls
  - Log SMS
- Similar to desktop/PCs:
  - Connects to botmasters
  - Steal data
  - Phishing
  - Malvertising

Mobile Malware Examples

- **DroidDream** (Android)
  - Over 58 apps uploaded to Google app market
  - Conducts data theft; send credentials to attackers
- **Zitmo** (Symbian,BlackBerry,Windows,Android)
  - Poses as mobile banking application
  - Captures info from SMS – steal banking 2nd factors
  - Works with Zeus botnet
- **Ikee** (iOS)
  - Worm capabilities (targeted default ssh password)
  - Worked only on jailbroken phones with ssh installed

Mobile Malware Examples

"ikee is never going to give you up"

[Zhou et al.]

(Android) Malware in the Wild

What does it do?

	Root Exploit	Remote Control		Financial Charges			Information Stealing		
		Net	SMS	Phone Call	SMS	Block SMS	SMS	Phone #	User Account
# Families	20	27	1	4	28	17	13	15	3
# Samples	1204	1171	1	256	571	315	138	563	43

Why all these problems with mobile malware?

Background: Before Mobile Platforms

Assumptions in traditional OS (e.g., Linux) design:

1. There may be multiple users who don't trust each other.
2. Once an application is installed, it's (more or less) trusted.

Background: Before Mobile Platforms

Assumptions in traditional OS (e.g., Linux) design:

1. There may be multiple users who don't trust each other.
2. **Once an application is installed, it's (more or less) trusted.**

Apps can do anything the UID they're running under can do.

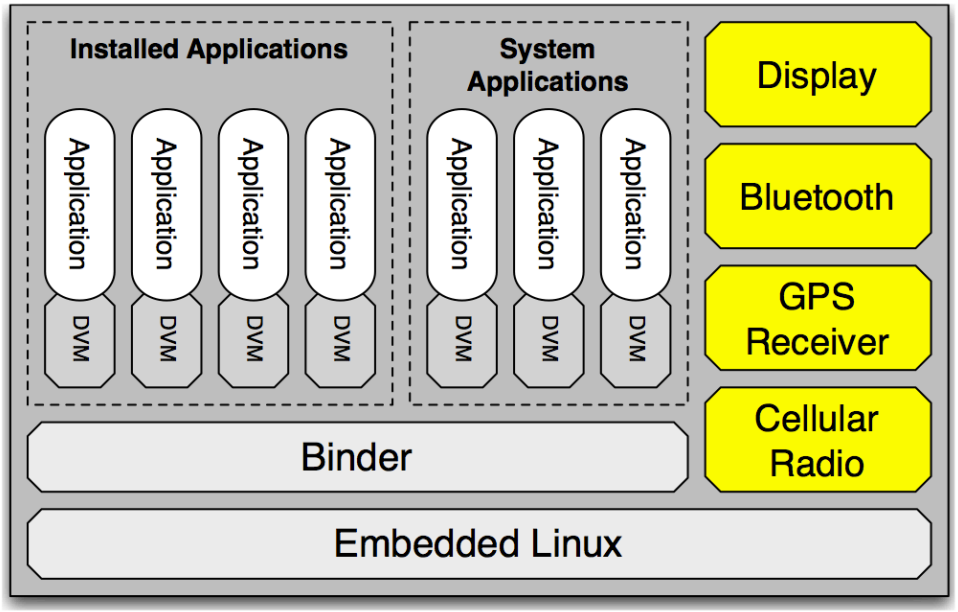
What's Different about Mobile Platforms?

- Applications are isolated
  - Each runs in a separate execution context
  - No default access to file system, devices, etc.
  - **Different than traditional OSes** where multiple applications run with the same user permissions!

- **App Store:** approval process for applications
  - Market: Vendor controlled/Open
  - App signing: Vendor-issued/self-signed
  - User approval of permissions

More Details: Android

[Enck et al.]



- Based on Linux
- Application sandboxes
  - Applications run as separate UIDs, in separate processes.
  - Memory corruption errors only lead to arbitrary code execution in the context of the **particular** application, not complete system compromise!
  - (Can still escape sandbox – but must compromise Linux kernel to do so.) ← allows rooting

Android Applications

- Activities provide user interfaces.
- Services run in the background.
- BroadcastReceivers receive messages sent to multiple applications (e.g., BOOT_COMPLETED).
- ContentProviders are databases addressable by their application-defined URIs.

- AndroidManifest.xml
  - Specifies application components
  - Specifies required permissions

Rooting and Jailbreaking

- Allows user to run applications with root privileges
  - e.g., modify/delete system files, app management, CPU management, network management, etc.
- Done by exploiting vulnerability in firmware to install `su` binary.
- Double-edged sword…

- Note: iOS is more restrictive than Android
  - Doesn't allow "side-loading" apps, etc.

Challenges with Isolated Apps

So mobile platforms isolate applications for security, but…

1. Permissions: How can applications access sensitive resources?
2. Communication: How can applications communicate with each other?

(1) Permission Granting Problem

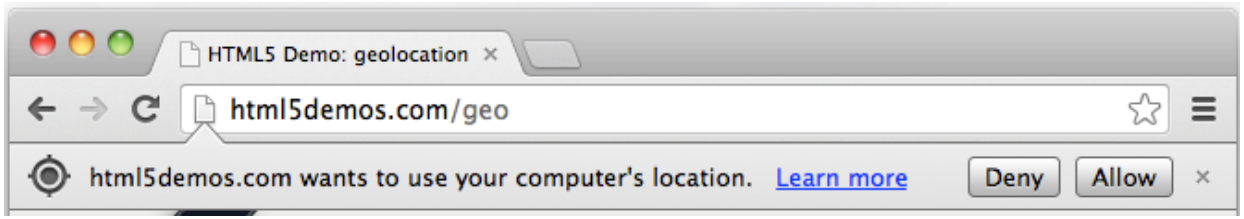
Smartphones (and other modern OSes) try to prevent such attacks by limiting applications' access to:

- System Resources (clipboard, file system).
- Devices (camera, GPS, phone, …).

How should operating system grant permissions to applications?

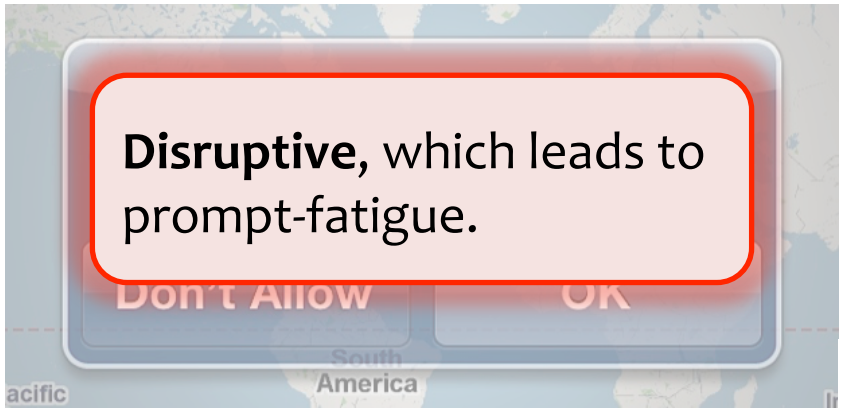
State of the Art

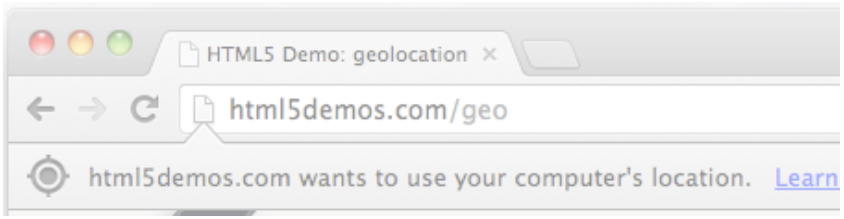
Prompts (time-of-use)



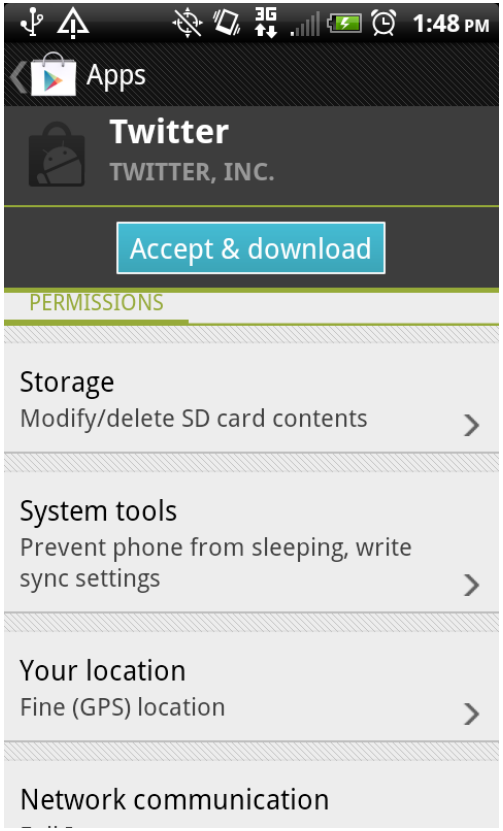
State of the Art

Prompts (time-of-use)





Manifests (install-time)



State of the Art

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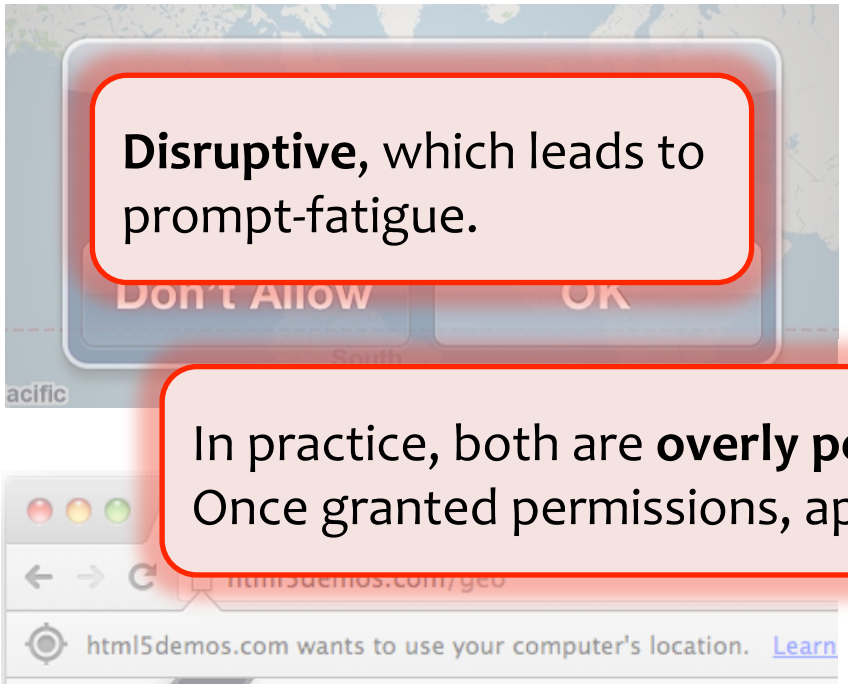
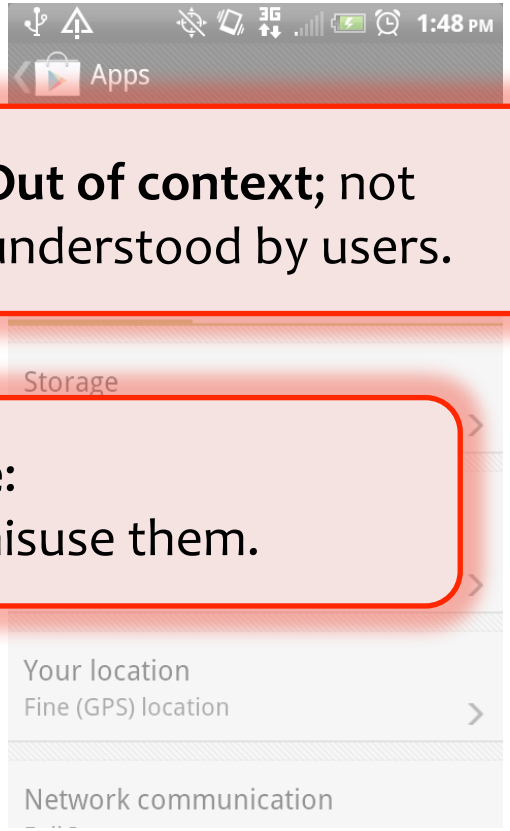


Disruptive, which leads to prompt-fatigue.

Manifests (install-time)



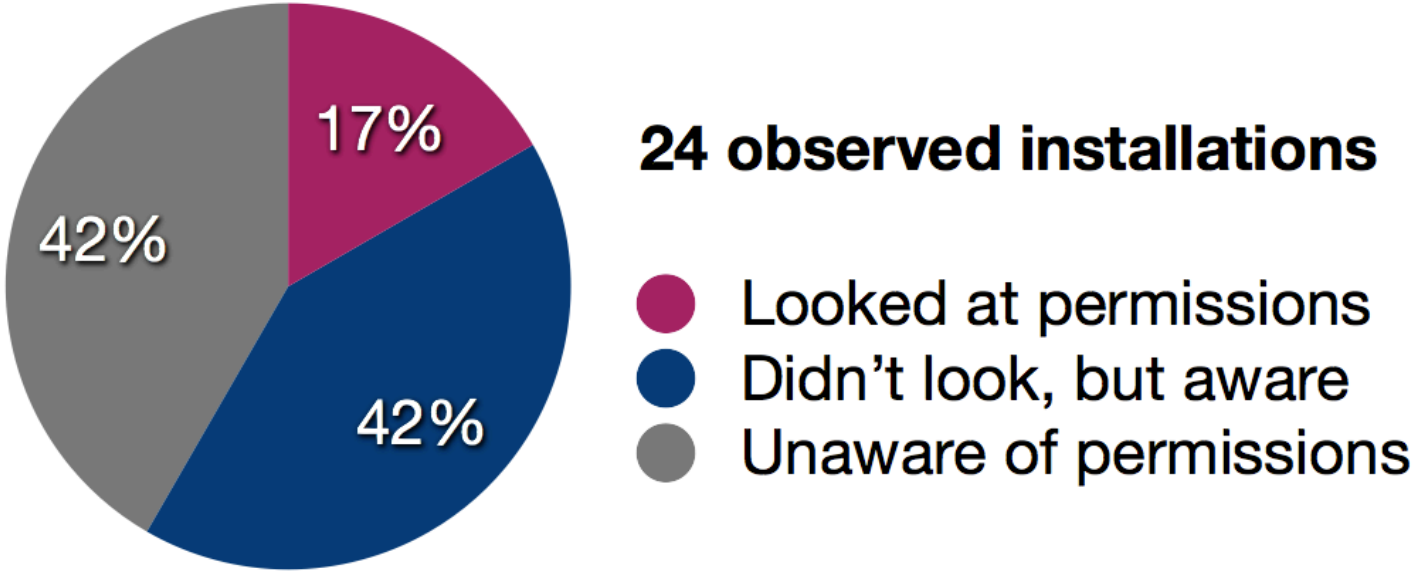
Out of context; not understood by users.

In practice, both are **overly permissive**:
Once granted permissions, apps can misuse them.

[Felt et al.]

Are Manifests Usable?

Do users pay attention to permissions?



… but 88% of users looked at reviews.

[Felt et al.]

Are Manifests Usable?

Do users understand the warnings?

	Permission	n	Correct Answers	
1 Choice	READ_CALENDAR	101	46	45.5%
	CHANGE_NETWORK_STATE	66	26	39.4%
	READ_SMS$_1$	77	24	31.2%
	CALL_PHONE	83	16	19.3%
2 Choices	WAKE_LOCK	81	27	33.3%
	WRITE_EXTERNAL_STORAGE	92	14	15.2%
	READ_CONTACTS	86	11	12.8%
	INTERNET	109	12	11.0%
	READ_PHONE_STATE	85	4	4.7%
	READ_SMS$_2$	54	12	22.2%
4	CAMERA	72	7	9.7%

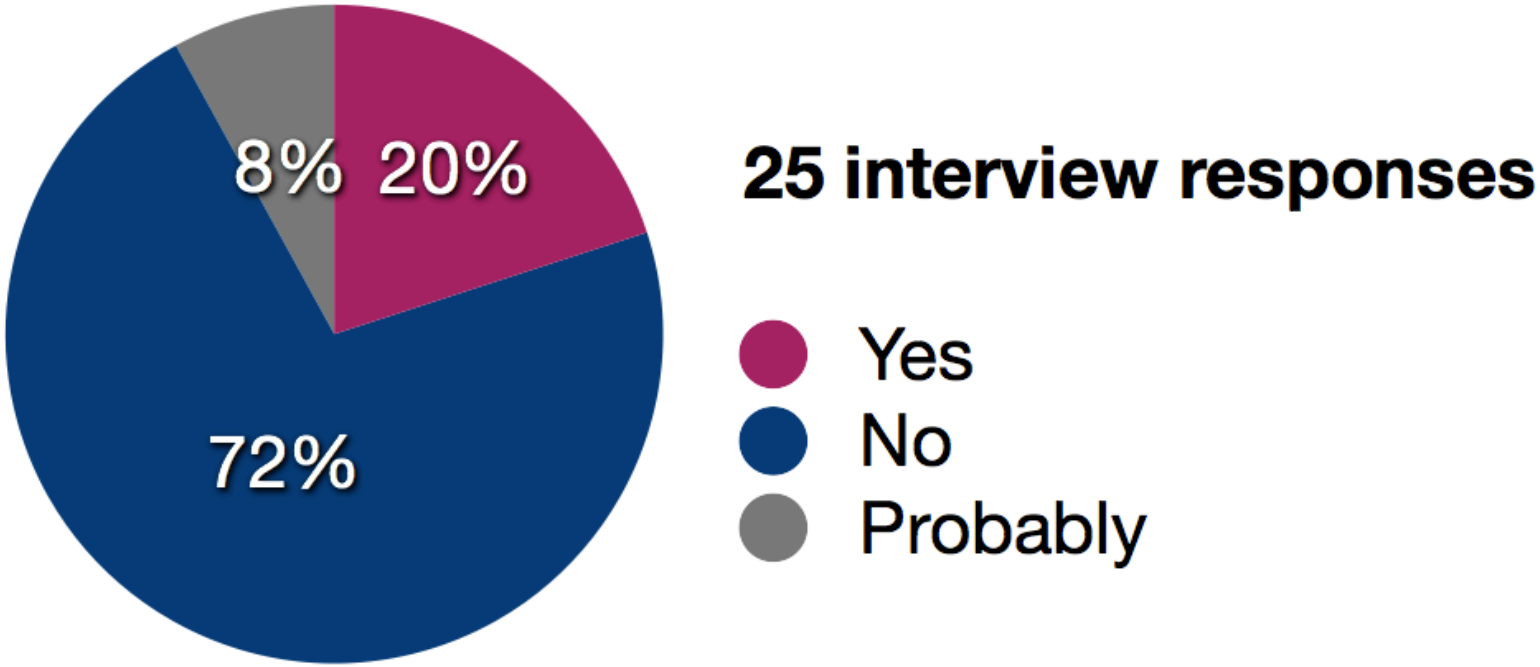
Table 4: The number of people who correctly answered a question. Questions are grouped by the number of correct choices. n is the number of respondents. (Internet Survey, $n = 302$)

[Felt et al.]

Are Manifests Usable?

Do users act on permission information?

"Have you ever not installed an app because of permissions?"

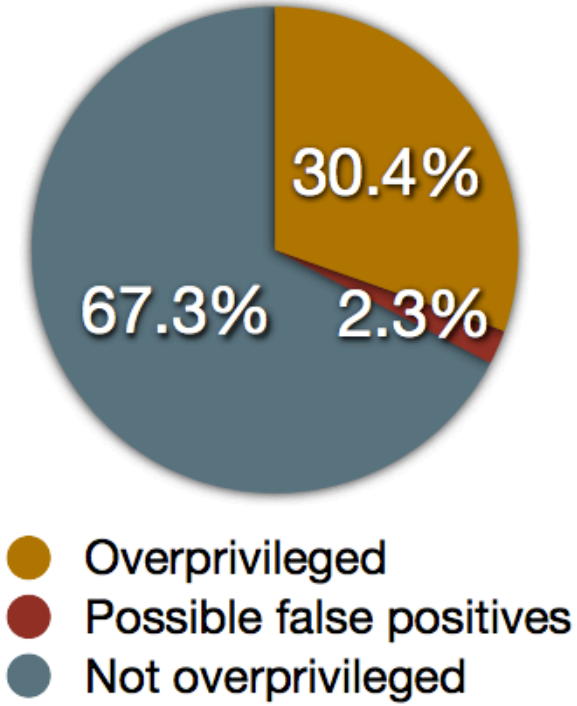


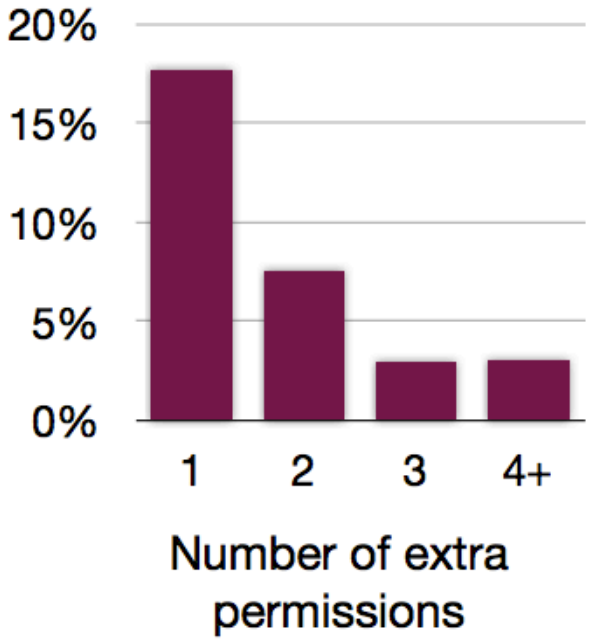
[Felt et al.]

Over-Permissioning

- Android permissions are badly documented.
- Researchers have mapped APIs → permissions.

www.android-permissions.org (Felt et al.), http://pscout.csl.toronto.edu (Au et al.)



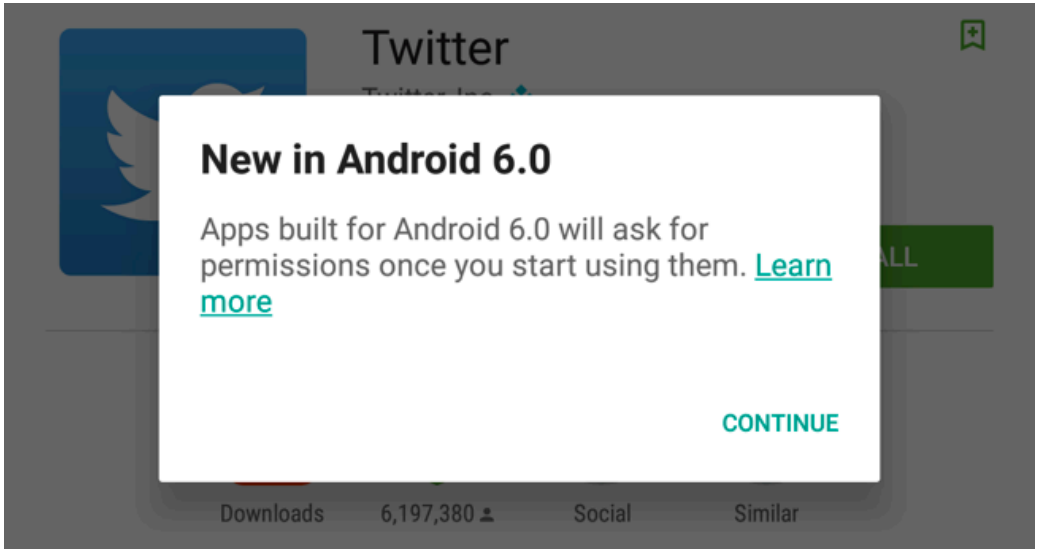


Manifests rely on the user to make good choices at install time

- It's not clear that users know how to make the right choice – or that there IS a right choice.

- I don't want ANY app to access my camera at all times. I just want apps to access my camera when they need to for legitimate purposes!

Android 6.0: Prompts!



- First-use prompts for sensitive permission (like iOS).
- Big change! Now app developers need to check for permissions or catch exceptions.

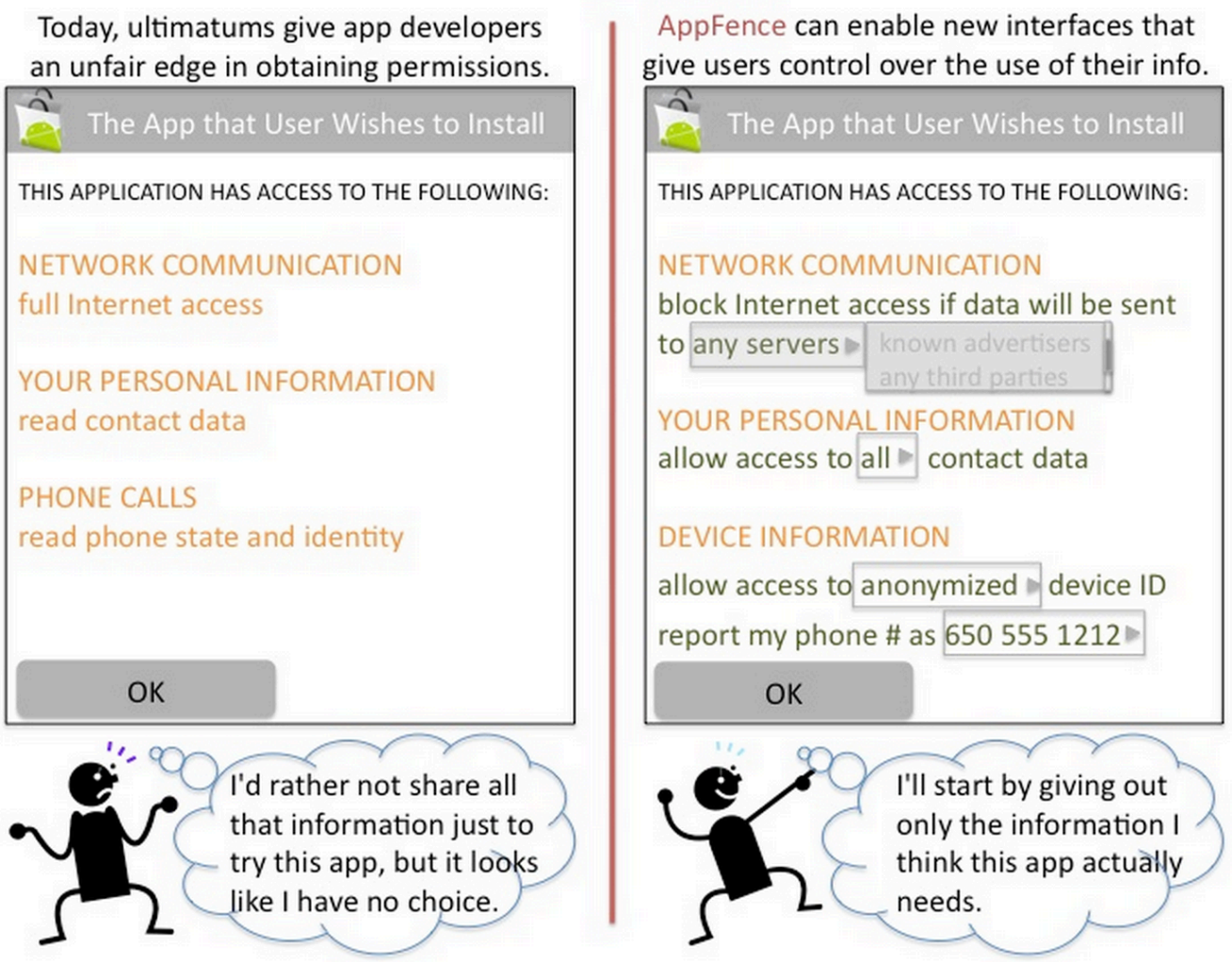
Promps rely on the user to make good choices at use time

- It's not clear that users know how to make the right choice at use time either.

- Still only checks on first use – the app can still use the resource for any reason it wants, at any time now or in the future.

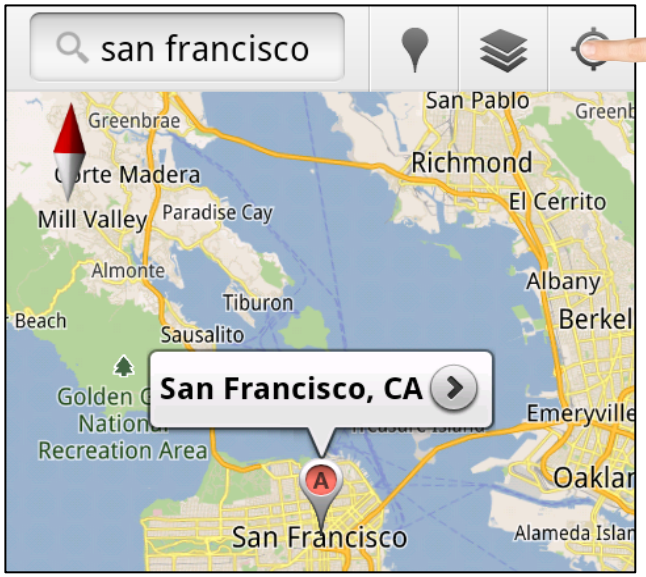
[Hornyack et al.]

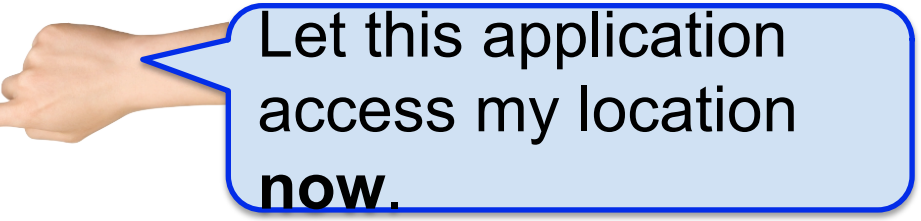
Improving Permissions: AppFence



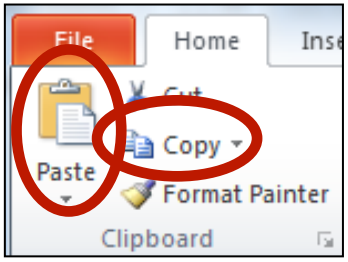
[Roesner et al.]

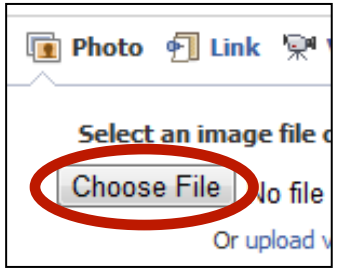
Improving Permissions: User-Driven Access Control





Insight:
A user's natural UI actions within an application implicitly carry permission-granting semantics.





[Roesner et al.]

Improving Permissions: User-Driven Access Control

Let this application access my location **now**.

Study shows:
Many users already believe (52% of 186) – and/or desire (68%) – that resource access follows the user-driven access control model.

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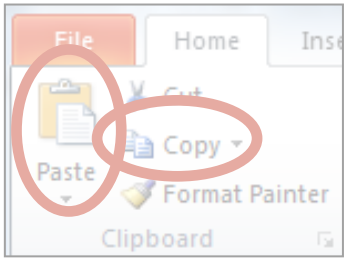
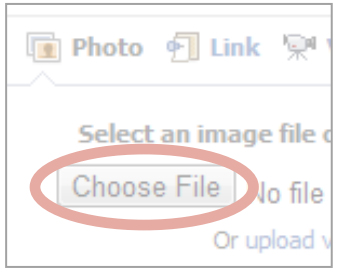
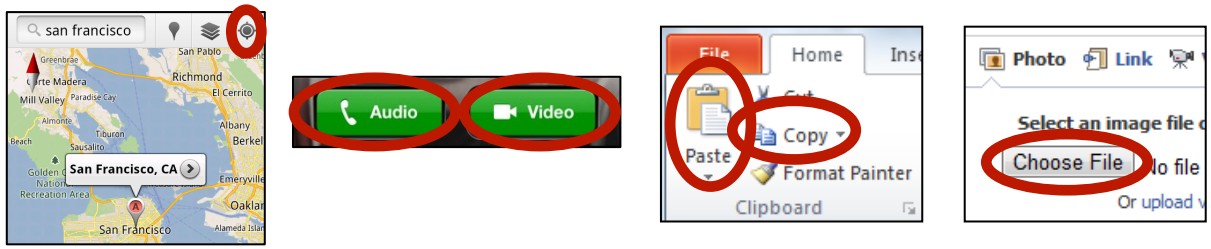




New OS Primitive: Access Control Gadgets (ACGs)



Approach: Make resource-related UI elements first-class operating system objects (access control gadgets).

- To receive resource access, applications must embed a system-provided ACG.
- ACGs allow the OS to capture the user's permission granting intent in application-agnostic way.

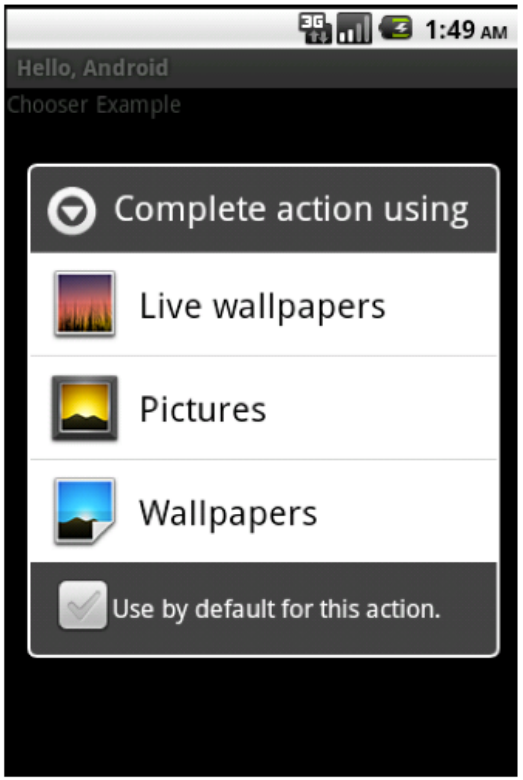
(2) Inter-Process Communication

- Primary mechanism in Android: Intents
  - Sent between application components
    - e.g., with `startActivity(intent)`
  - Explicit: specify component name
    - e.g., com.example.testApp.MainActivity
  - Implicit: specify action (e.g., ACTION_VIEW) and/or data (URI and MIME type)
    - Apps specify Intent Filters for their components.

[Chin et al.]

Unauthorized Intent Receipt

- Attack #1: Eavesdropping / Broadcast Thefts
  - Implicit intents make intra-app messages public.
- Attack #2: Activity Hijacking
  - May not always work:
- Attack #3: Service Hijacking
  - Android picks one at random upon conflict!



[Chin et al.]

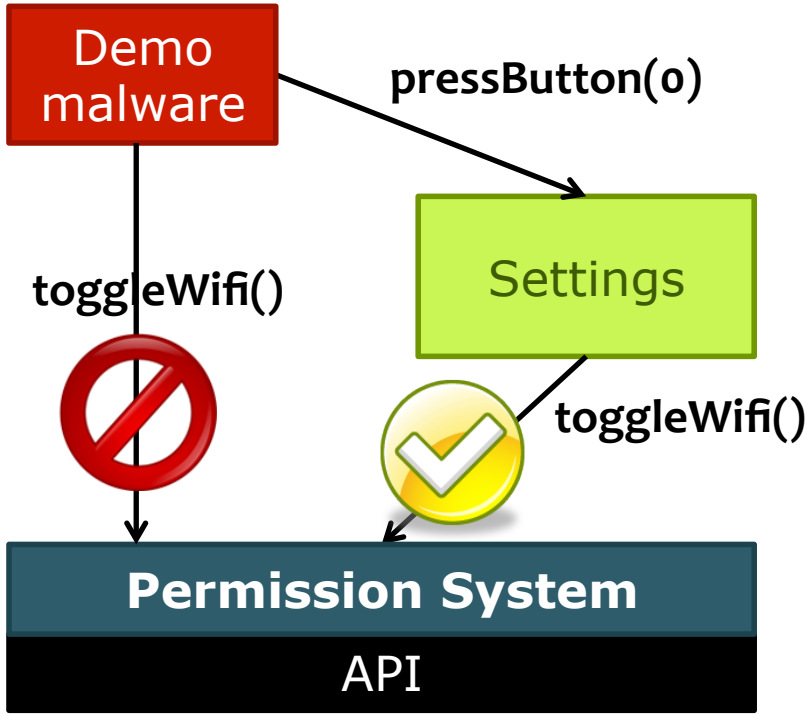
Intent Spoofing

- Attack #1: General intent spoofing
  - Receiving implicit intents makes component public.
  - Allows data injection.
- Attack #2: System intent spoofing
  - Can't directly spoof, but victim apps often don't check specific "action" in intent.

[Felt et al.]

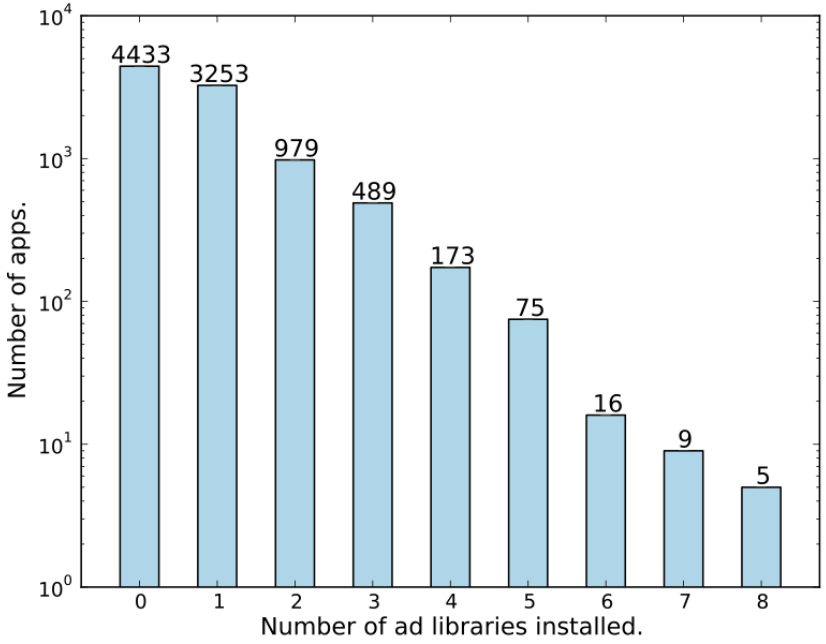
Permission Re-Delegation

- An application without a permission gains additional privileges through another application.
- Demo video
- Settings application is deputy: has permissions, and accidentally exposes APIs that use those permissions.



Aside: Incomplete Isolation

Embedded UIs and libraries always run with the host application's permissions! (No same-origin policy here…)



[Shekhar et al.]

Ad from ad library

Map from Google library

Social button from Facebook library

More on Android…

Android Application Signing

- Apps are signed
  - Often with self-signed certificates
  - Signed application certificate defines which user ID is associated with which applications
  - Different apps run under different UIDs
- Shared UID feature
  - Shared Application Sandbox possible, where two or more apps signed with same developer key can declare a shared UID in their manifest

Shared UIDs

- App 1: Requests GPS / camera access
- App 2: Requests Network capabilities

- Generally:
  - First app can't exfiltrate information
  - Second app can't exfiltrate anything interesting
- With Shared UIDs (signed with same private key)
  - Permissions are a superset of permissions for each app
  - App 1 can now exfiltrate; App 2 can now access GPS / camera

File Permissions

- Files written by one application cannot be read by other applications
  - Previously, this wasn't true for files stored on the SD card (world readable!) – Android cracked down on this
- It is possible to do full file system encryption
  - Key = Password/PIN combined with salt, hashed

Memory Management

- Address Space Layout Randomization to randomize addresses on stack
- Hardware-based No eXecute (NX) to prevent code execution on stack/heap
- Stack guard derivative
- Some defenses against double free bugs (based on OpenBSD's dmalloc() function)
- etc.

[See http://source.android.com/tech/security/index.html]

Android Fragmentation

- Many different variants of Android (unlike iOS)
  - Motorola, HTC, Samsung, …
- Less secure ecosystem
  - Inconsistent or incorrect implementations
  - Slow to propagate kernel updates and new versions

[https://developer.android.com/about/dashboards/index.html]

Version	Codename	API	Distribution
2.2	Froyo	8	0.1%
2.3.3 - 2.3.7	Gingerbread	10	2.2%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	2.0%
4.1.x	Jelly Bean	16	7.2%
4.2.x		17	10.0%
4.3		18	2.9%
4.4	KitKat	19	32.5%
5.0	Lollipop	21	16.2%
5.1		22	19.4%
6.0	Marshmallow	23	7.5%

Data collected during a 7-day period ending on May 2, 2016.
Any versions with less than 0.1% distribution are not shown.