Cloak & Dagger

~~From Two Permissions~~ to Complete Control of the UI Feedback Loop

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joint work with

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Who am I?

- PhD candidate @ UC Santa Barbara
  - Graduating in a week! 
  - Shellphish Hacker 
  - Soon Assistant Professor at Eurecom, France! 
- Research focus on mobile security
  - Program analysis, rowhammer attacks (Drammer), ultrasound cross-device tracking, UI attacks
- When I don’t procrastinate, I’m on twitter [@reyammer]

What is this work about?

- A few tricks to attack Android UI
- Complete control over the UI feedback loop
- Bye bye to your device’s security

UI Feedback Loop

Cloak & Dagger Attacks

Know what is currently displayed to the user

Modify what the user sees

Output channel

Input channel

Know what the user is clicking on

Inject user input

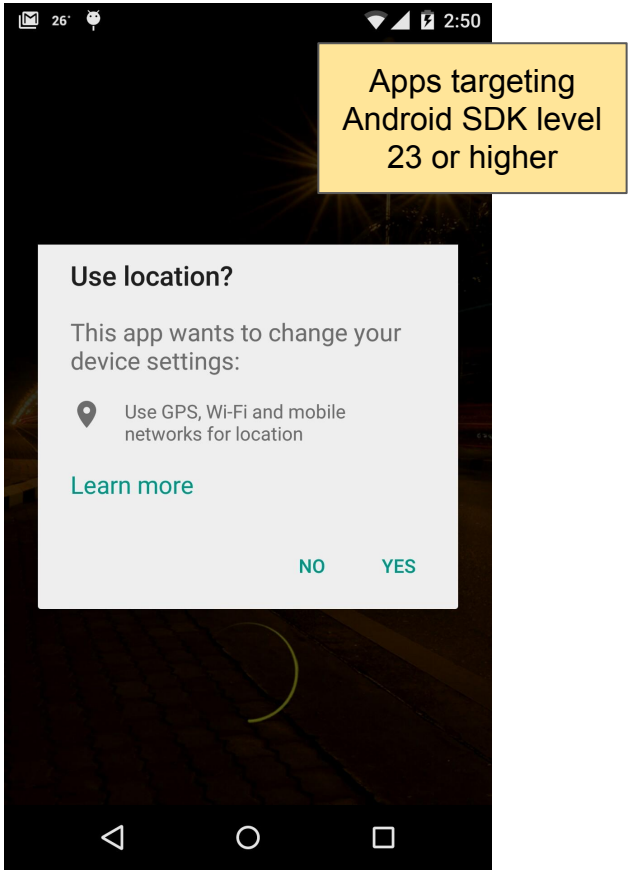
Why should I care about UI bugs? ACADEMIC BS!

- Android features tons of low-level security mechanisms
  - Sandboxing & permissions
  - Exploit mitigation techniques
  - Attack surface reduction

- Some UI bugs can bypass all low-level mechanisms
  - If you can click like a user...confused deputy!
  - “Dear Settings app, I hope this request finds you well.
    Would you mind granting me all permissions? Thx <3”

Two Permissions

Run-time Granting Permissions



SYSTEM_ALERT_WINDOW (“draw on top”)

- Draw arbitrary windows/overlays on top of the screen
  - Can be completely custom: shape, content, transparency
  - Can be clickable **xor** passthrough
- This permission is used quite often
  - 454 out of 4,455 top apps (10.2%)
- Used by Facebook, Skype, Uber, LastPass, ...

BIND_ACCESSIBILITY_SERVICE (a11y)

- Mechanism for apps to assist users with disabilities
- Many powerful capabilities
  - It is notified for each UI event
  - It can inject UI events (e.g., clicks)
- Several security mechanisms to avoid abuse
- Used by 24 top apps out of 4,455
  - Password managers (LastPass), antivirus apps, app lockers, ...

These two permissions are enough to completely compromise your device

Why would a user grant these permissions?

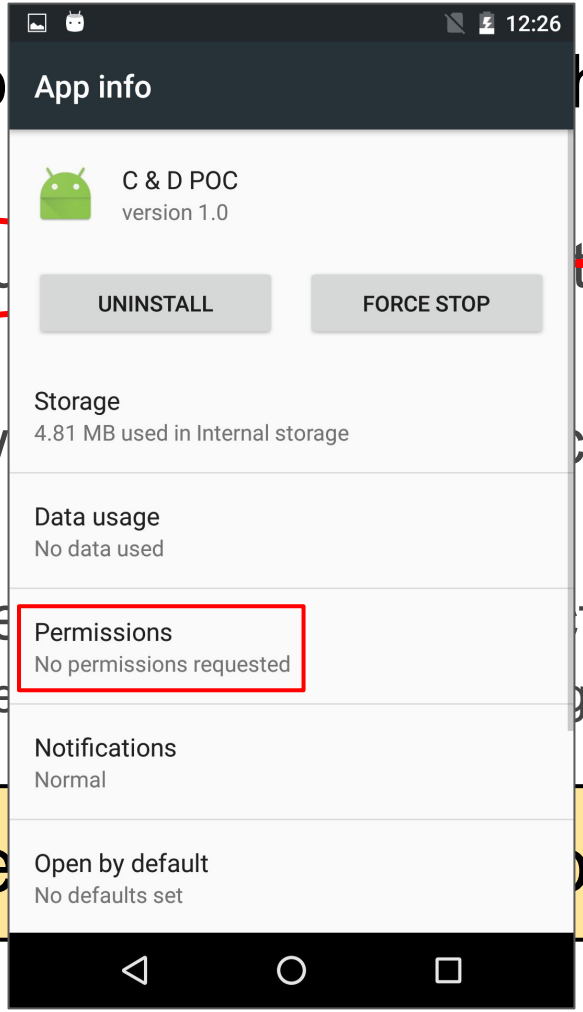
- ~~“The user needs to explicitly approve! Not stealthy!”~~
- “Draw on top” is automatically granted for Play Store apps!
- We developed a new practical clickjacking attack
  - The user is lured to unknowingly enable the a11y!

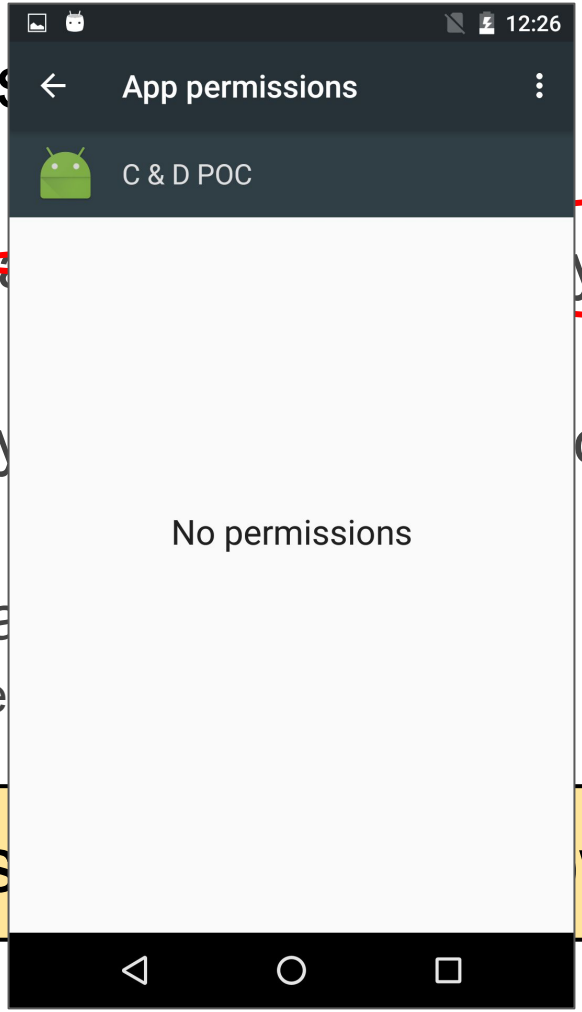
The list of permissions is not even shown!

Why wo hes

- “The u y!”
- “Draw cally ore apps!
- We de tica
  - The gly e

The ons wn!





Security Mechanisms

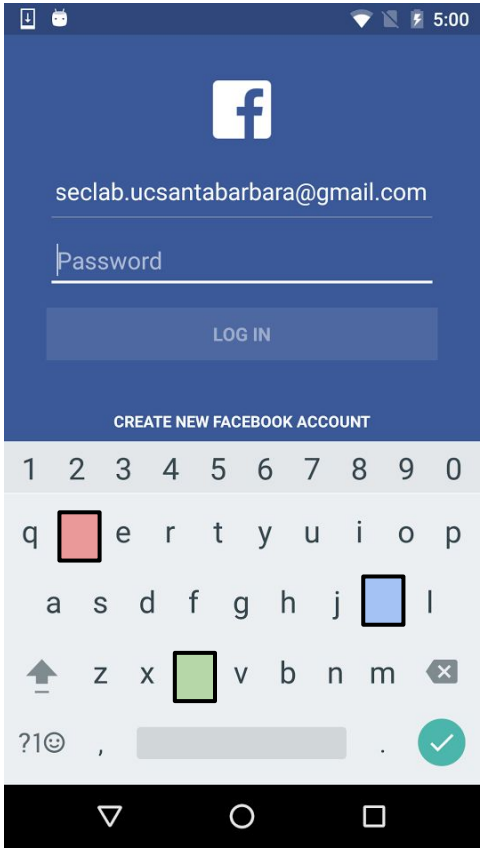
Security Mechanism #1

- For each click on an overlay, only ***one*** of these holds:
  1) The click is “captured” by the overlay
     - The overlay knows when/where the user clicked
  2) The click goes “through” the overlay
     - The click reaches what’s “behind” it
     - The overlay does ***not*** know when/where the user clicked

- No “capture & propagate” click

- Why?

Security Mechanism #1



Security Mechanism #1

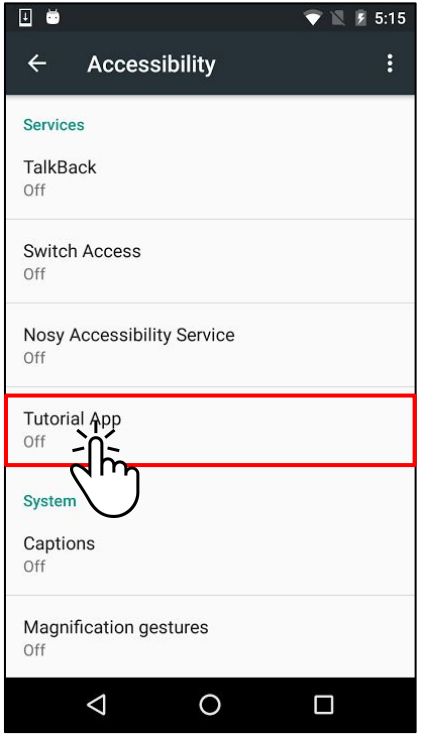
- One possible attack: FLAG_WATCH_OUTSIDE_TOUCH
  - An overlay can receive events even for clicks that land ***outside*** itself

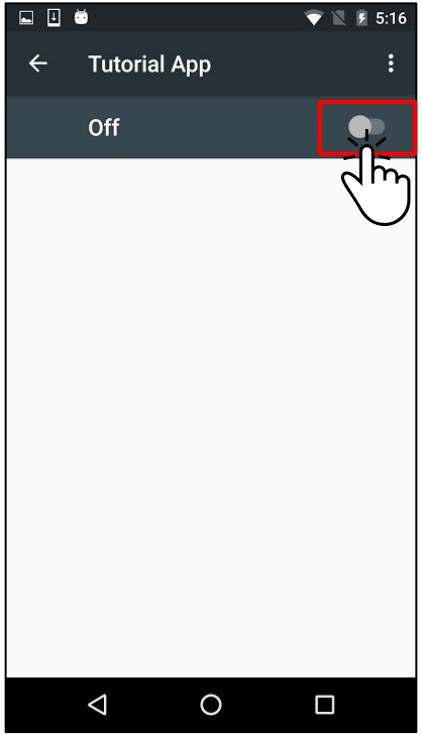
- The click coordinates are set to (0,0) if the click does not reach the app that created the overlay

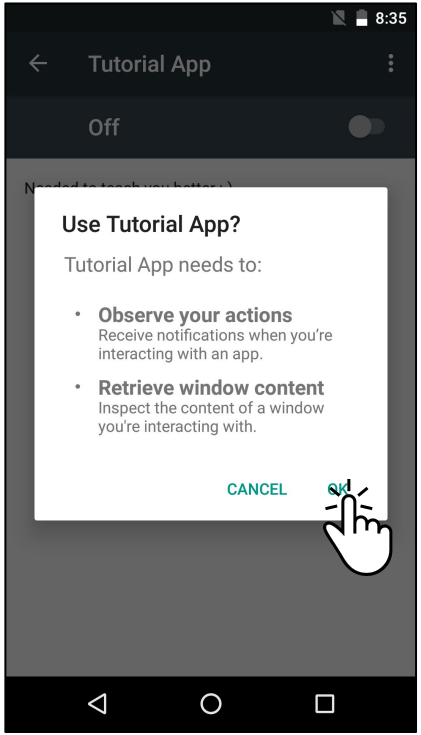
Security Mechanism #2

- Several steps are required to enable accessibility service

Security Mechanism #2



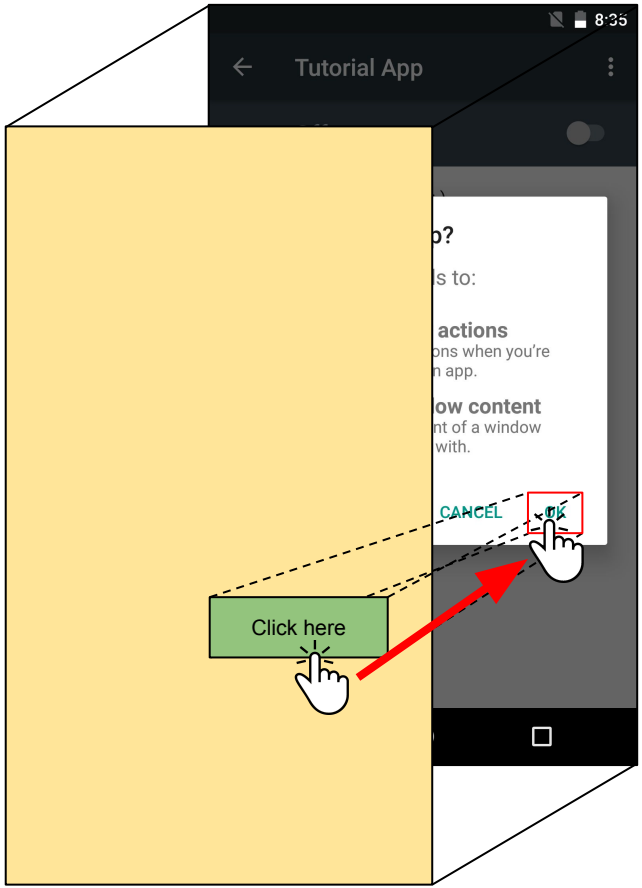




Security Mechanism #3

- Protection against clickjacking

Clickjacking 101



UI Redressing Attacks on Android Devices Revisited
Niemietz & Schwenk
BH ASIA 2014

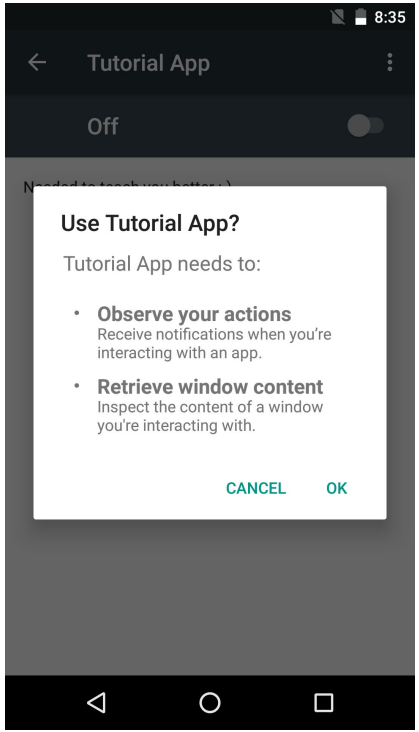
Security Mechanism #3

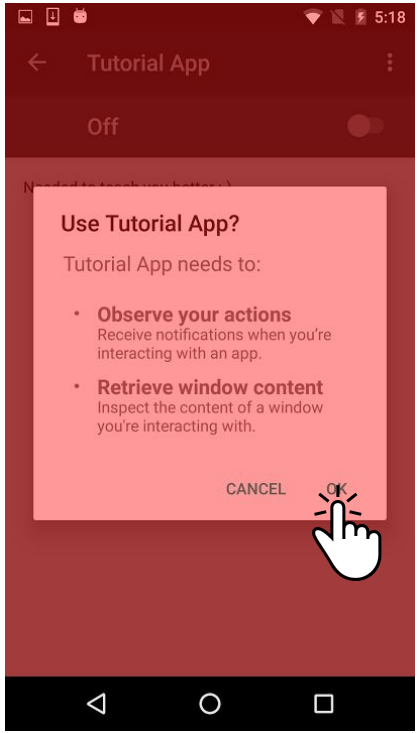
- Protection against clickjacking

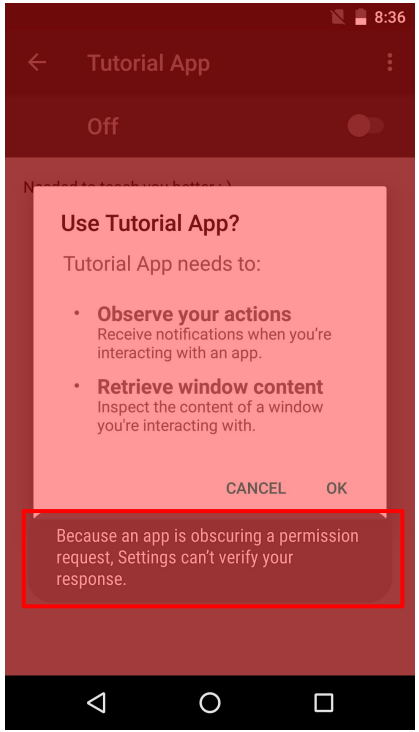
- Google introduced the “obscured” flag
  - When the user clicks on a widget, FLAG_WINDOW_IS_OBSCURED is set if “an overlay was covering the receiving widget”
  - An app can decide to “not trust” the click

- Another option: `setFilterTouchesWhenObscured()`

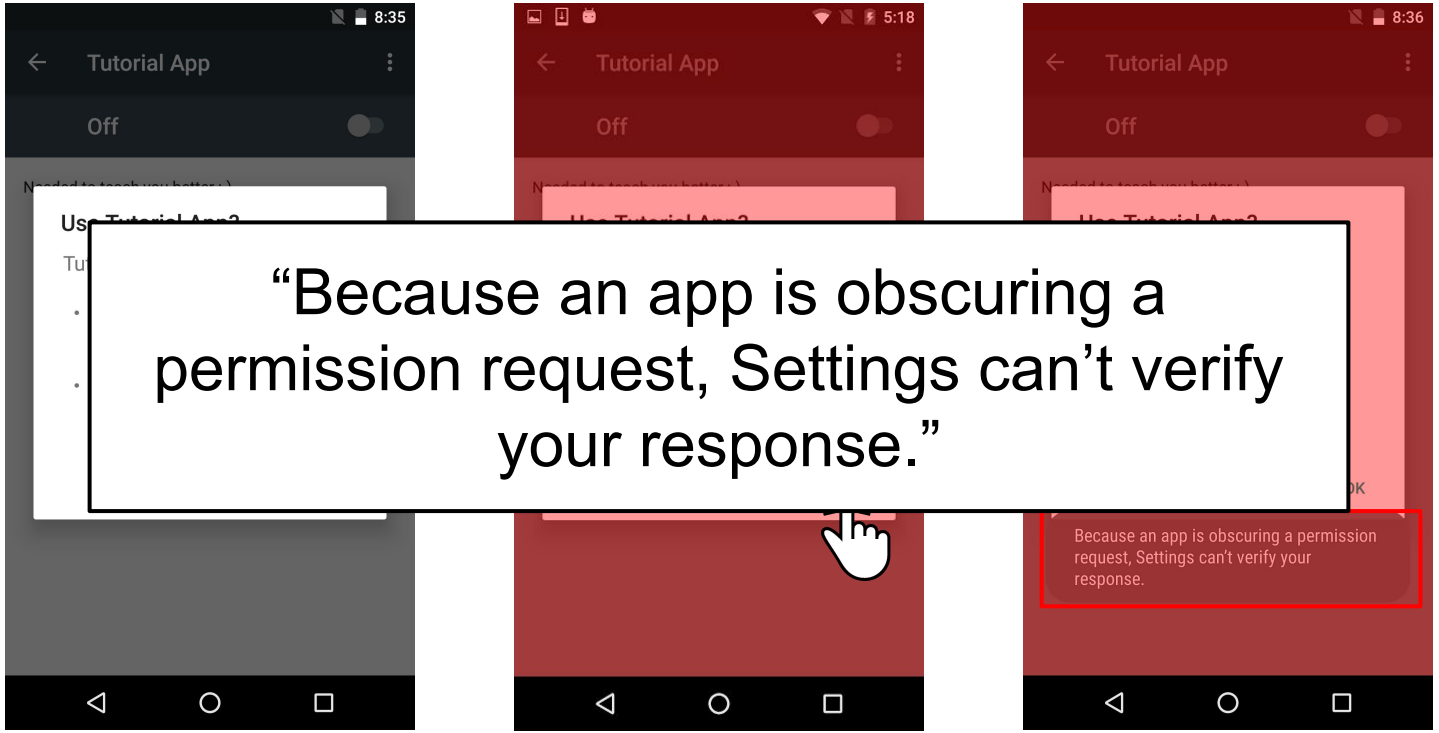
Security Mechanism #3







Security Mechanism #3



Security Mechanism #4

- Accessibility service ***cannot*** read “sensitive information” off the screen.
- Example: password fields

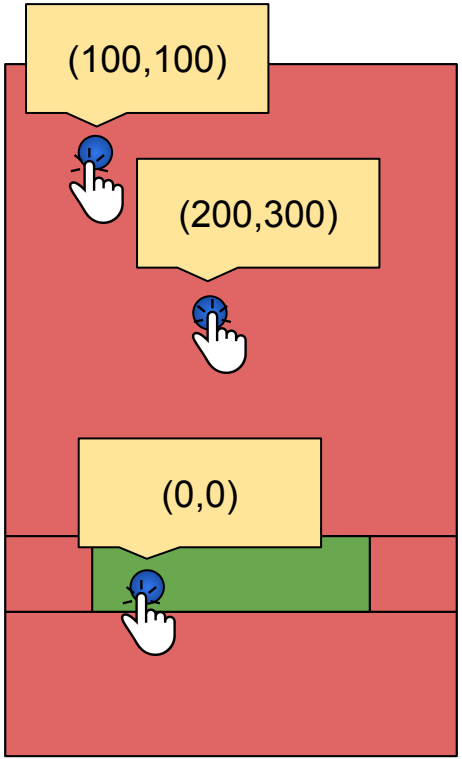
> *“Since an event contains the text of its source* ***privacy can be compromised by leaking sensitive information*** *such as passwords. To address this issue* ***any event fired in response to manipulation of a PASSWORD field does NOT CONTAIN the text of the password.***”

Unleashing Mayhem

Attack: Context-aware Clickjacking

- Multi-stage clickjacking are challenging
  - When to transition to the next stage?
  - What if the user clicks “somewhere else”?
- Security mechanisms
  - The malicious app is not notified about the clicks
  - If the FLAG_WATCH_OUTSIDE_TOUCH is used, the click’s coordinates are set to (0,0) if click lands on another app: where did the user clicked?
- What if there is only “one way” for a click to not reach the malicious app?

Attack: Context-aware Clickjacking



Clicks do **NOT** go through

Clicks go through

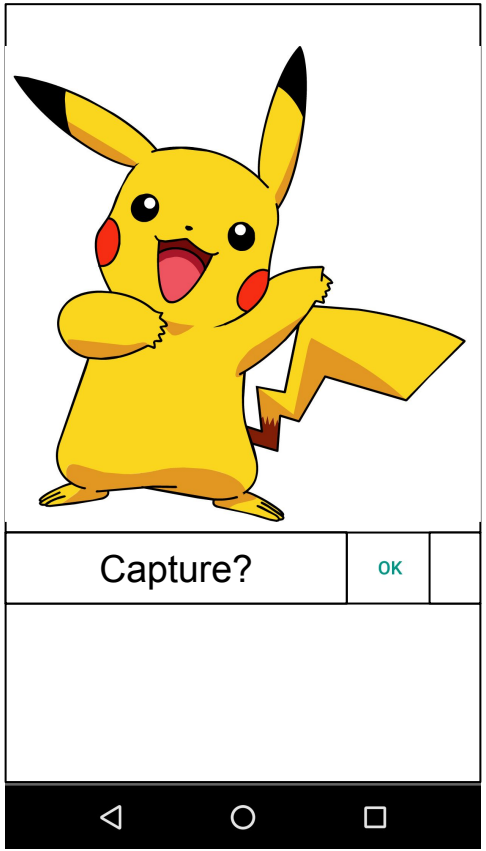
- We know the user clicked on the “target” button
- We know we need to transition to the next step

Obscured Flag Bypass

- The “obscured” flag is helpful to detect that “another overlay is on top”

- Who says that you need to cover the “target” widget?

Obscured Flag Bypass



Context-Hiding Attack

Attack: Context Hiding

- Design shortcoming: Apps do not have access to enough context information to take informed decisions
- The “obscured flag” is conceptually broken
- Difficult to fix:
  - If the full context is exposed, an attacker could (ab)use this information as side channel to mount phishing attacks

Context-aware clickjacking + Context hiding

- These two attacks are enough to lure the user to enable the accessibility service!

- We just need to hijacking three clicks
  - No guessing is involved
  - The clicks do not need to be consecutive

Back to the “obscured flag”...

- Not only it is not useful…
- ...but #1: misleading documentation

FLAG_WINDOW_IS_OBSCURED docs

*“This flag indicates that the window that received this motion event is **partly** or wholly obscured by another visible window above it.”*

FLAG_WINDOW_IS_OBSCURED docs

```
/**
 * This flag indicates that the window that received this motion event is partly
 * or wholly obscured by another visible window above it.  This flag is set to true
 * even if the event did not directly pass through the obscured area.
 * A security sensitive application can check this flag to identify situations in which
 * a malicious application may have covered up part of its content for the purpose
 * of misleading the user or hijacking touches.  An appropriate response might be
 * to drop the suspect touches or to take additional precautions to confirm the user's
 * actual intent.
 *
 * Unlike FLAG_WINDOW_IS_OBSCURED, this is actually true.
 * @hide
 */
public static final int FLAG_WINDOW_IS_PARTIALLY_OBSCURED = 0x2;
```

FLAG_WINDOW_IS_OBSCURED docs

```
/**
 * This flag indicates that the window th                    partly
 * or wholly obscured by anoth                        lag is set to true
 * even if the event                                 bscured area.
 * A securi                              this flag to identify situations in which
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 *                      or hijacking touches.  An appropriate response might be
 *               suspect touches or to take additional precautions to confirm the user's
 *    ual intent.
 *
 * Unlike
 * @hide
 */
public st
```

Same as FLAG_WINDOW_IS_OBSCURED

“Unlike FLAG_WINDOW_IS_OBSCURED, this is actually true.

Back to the “obscured flag”...

- Not only it is not useful…
- ...but #1: misleading documentation
- ...but #2: it can be abused to mount even worse attacks!

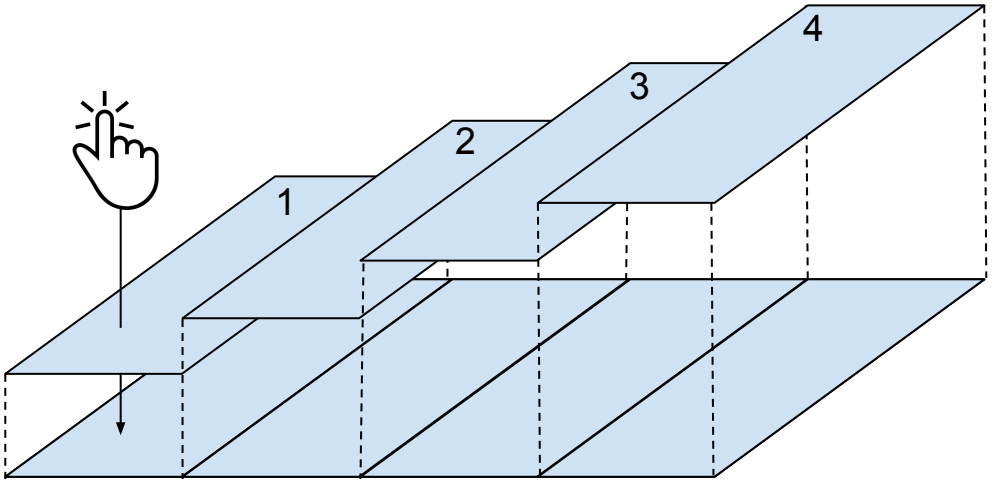
Attack: Invisible Grid Attack

- This attack can record all “keystrokes”
  - It only relies on the “draw on top” permission

- It abuses the “obscured flag” security mechanism

Attack: Invisible Grid Attack

Where did the user click?



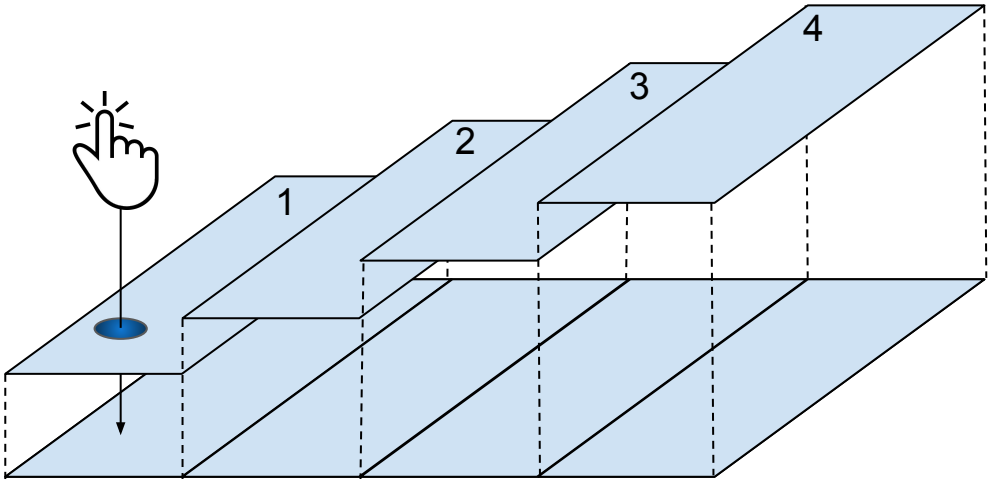
Overlays are drawn
- Invisible
- Clicks passthrough
- FLAG_WATCH_OUTSIDE_TOUCH

The “obscured” flag is set accordingly!

Overlay #	
1	MotionEvent
2	MotionEvent
3	MotionEvent
4	MotionEvent

Attack: Invisible Grid Attack

Where did the user click?



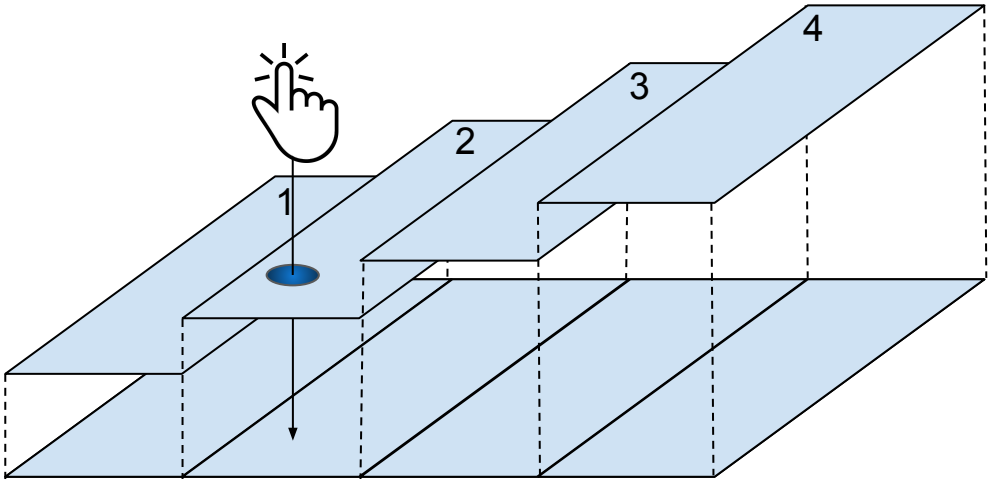
Overlays are drawn
- Invisible
- Clicks passthrough
- FLAG_WATCH_OUTSIDE_TOUCH

The “obscured” flag is set accordingly!

Overlay #		
1	MotionEvent	Not obscured
2	MotionEvent	Not obscured
3	MotionEvent	Not obscured
4	MotionEvent	Not obscured

Attack: Invisible Grid Attack

Where did the user click?



Overlays are drawn
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Overlay #		
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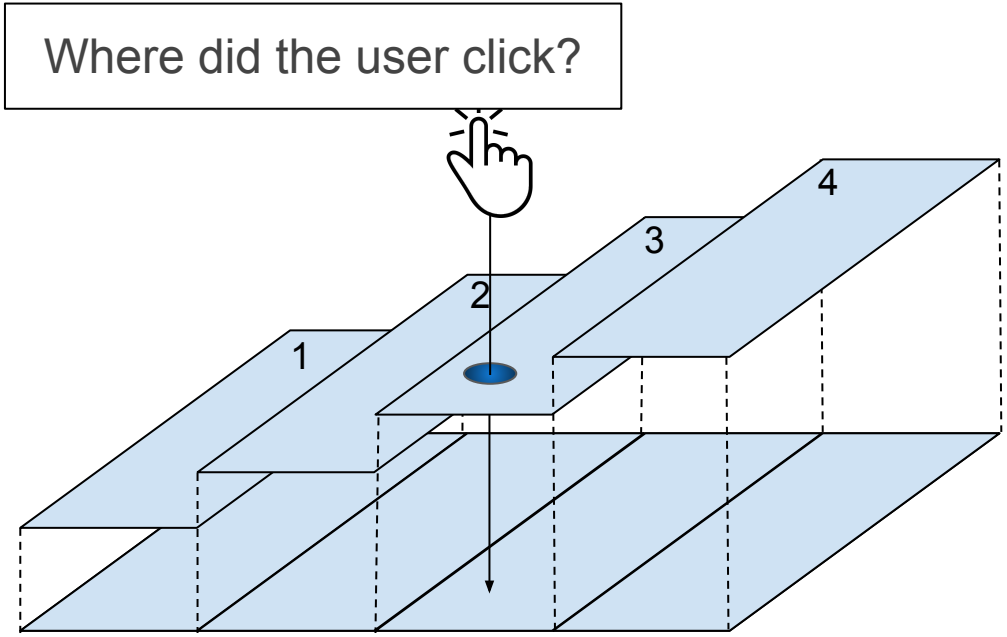
3	MotionEvent	Not obscured
4	MotionEvent	Not obscured

Attack: Invisible Grid Attack



Overlays are drawn
- Invisible
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The “obscured” flag is set accordingly!

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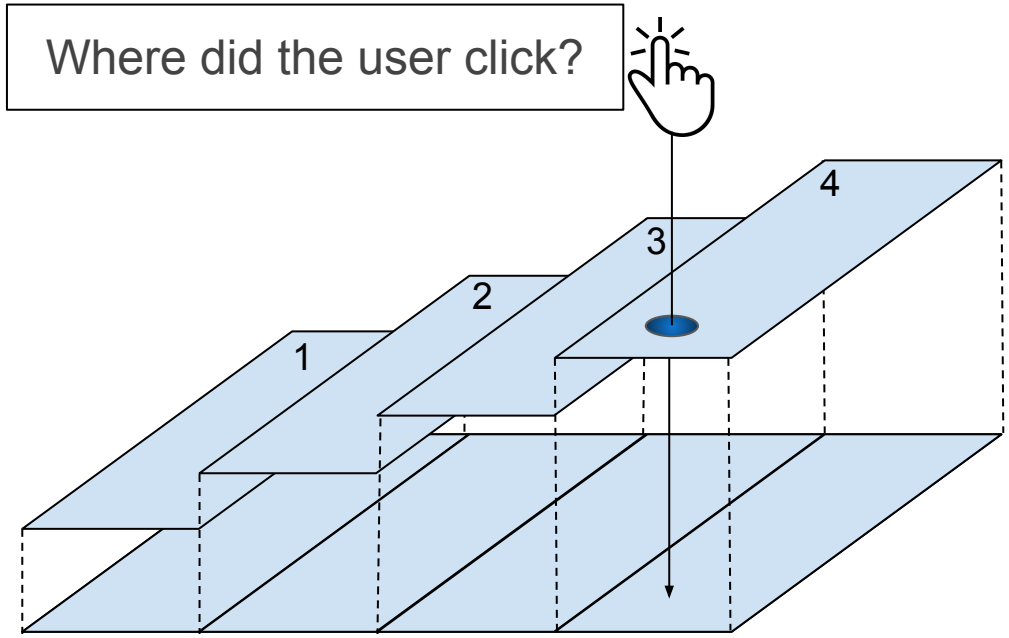
2	MotionEvent	Obscured
3	MotionEvent	Not obscured
4	MotionEvent	Not obscured

Attack: Invisible Grid Attack



Overlays are drawn
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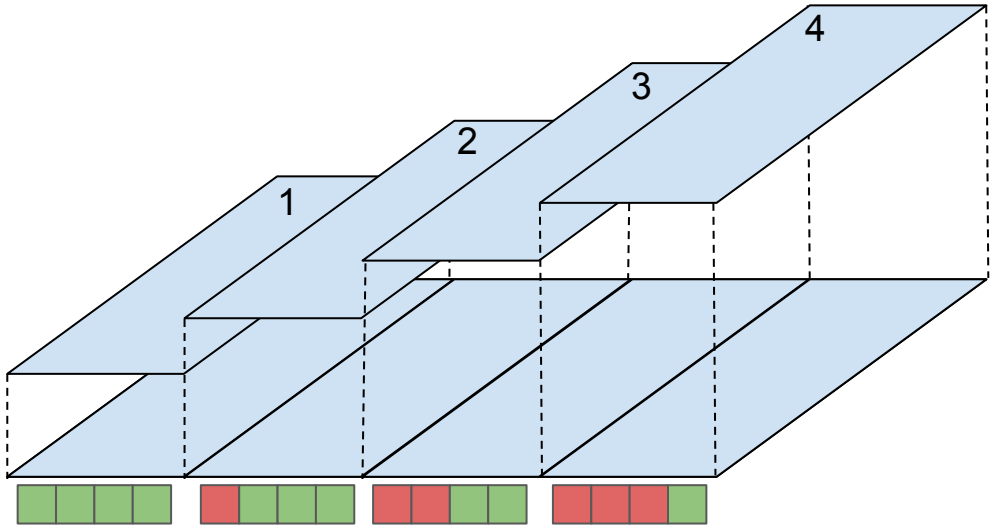
Overlay #		
1	MotionEvent	Obscured
2	MotionEvent	Obscured
3	MotionEvent	Obscured
4	MotionEvent	Not obscured

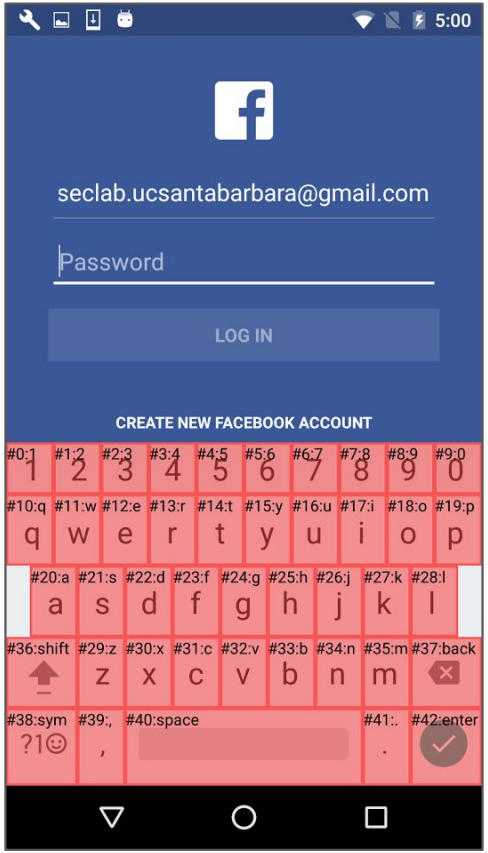
Attack: Invisible Grid Attack



Security mechanism used as side-channel!

The attacker can use these patterns to infer where the user clicked!

Attack: Invisible Grid Attack



These overlays are drawn invisible during a real attack

Design Shortcomings

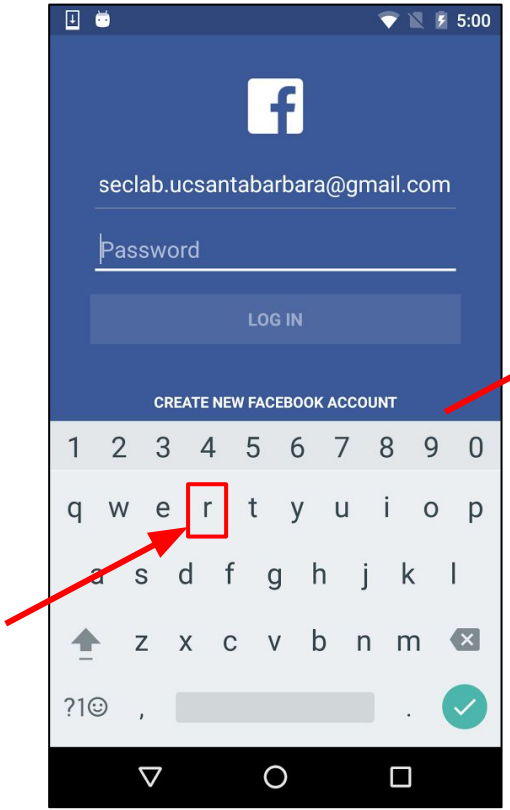
- The inherent complexity of the Android “WindowManager” leads to the creation of unexpected side channels
  - UI security as an afterthought

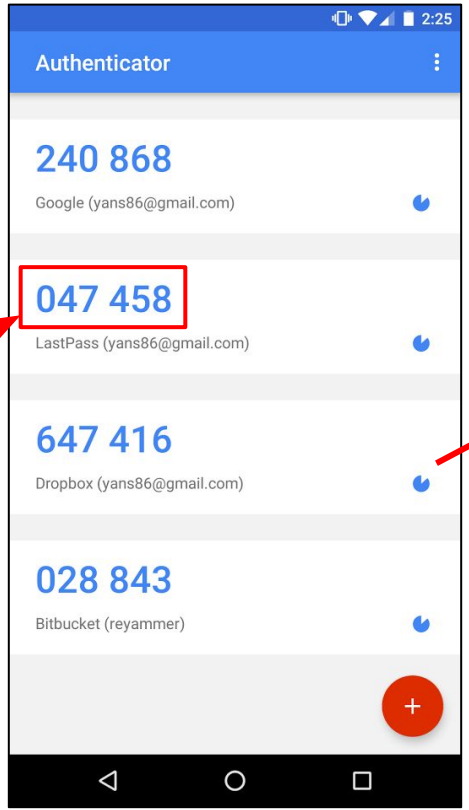
- Violation of the principle of least privilege
  - Why can an app create *invisible* overlays? *Passthrough* overlays?
  - Overlays are **completely** customizable!

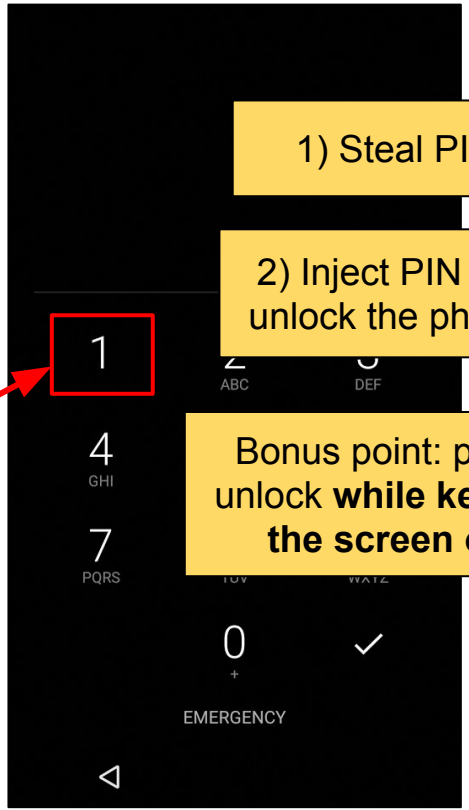
Attack: a11y on steroids

- Yet another design shortcoming:
  - By default, UI objects are all considered non-security sensitive
  - Security should be the rule, not the exception!

Attack: a11y on steroids







1) Steal PIN

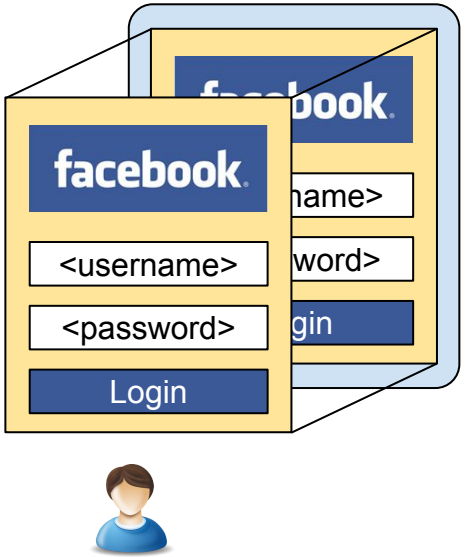
2) Inject PIN and unlock the phone!

Bonus point: phone unlock **while keeping the screen off!**

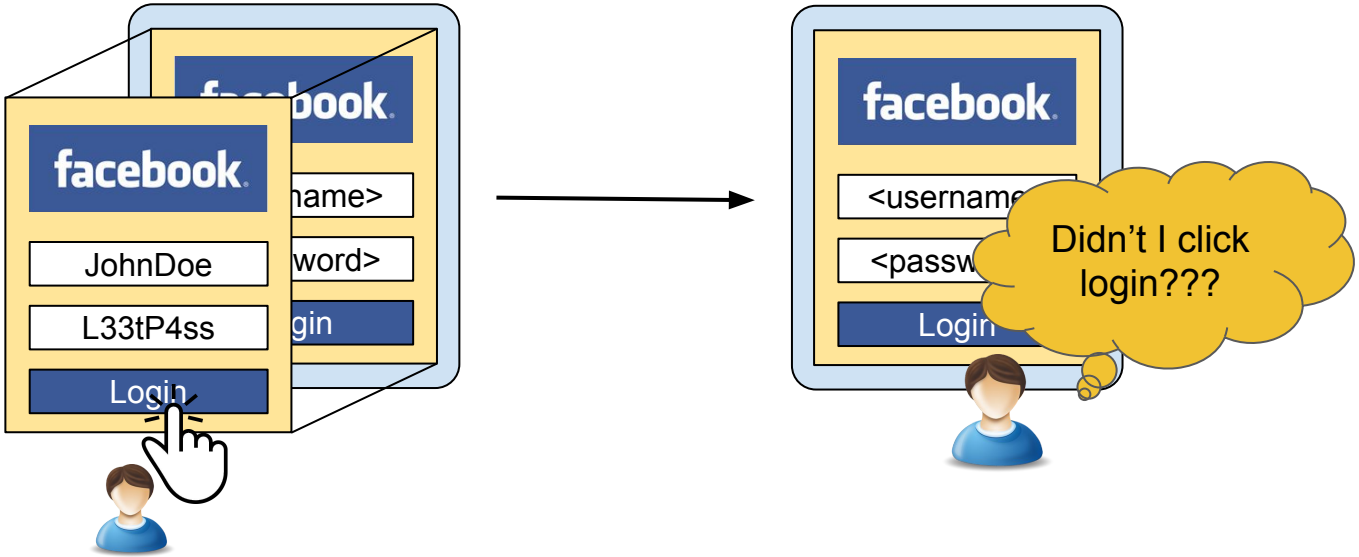
Cloak & Dagger attacks

- You can mount even nastier attacks by combining the two permissions!

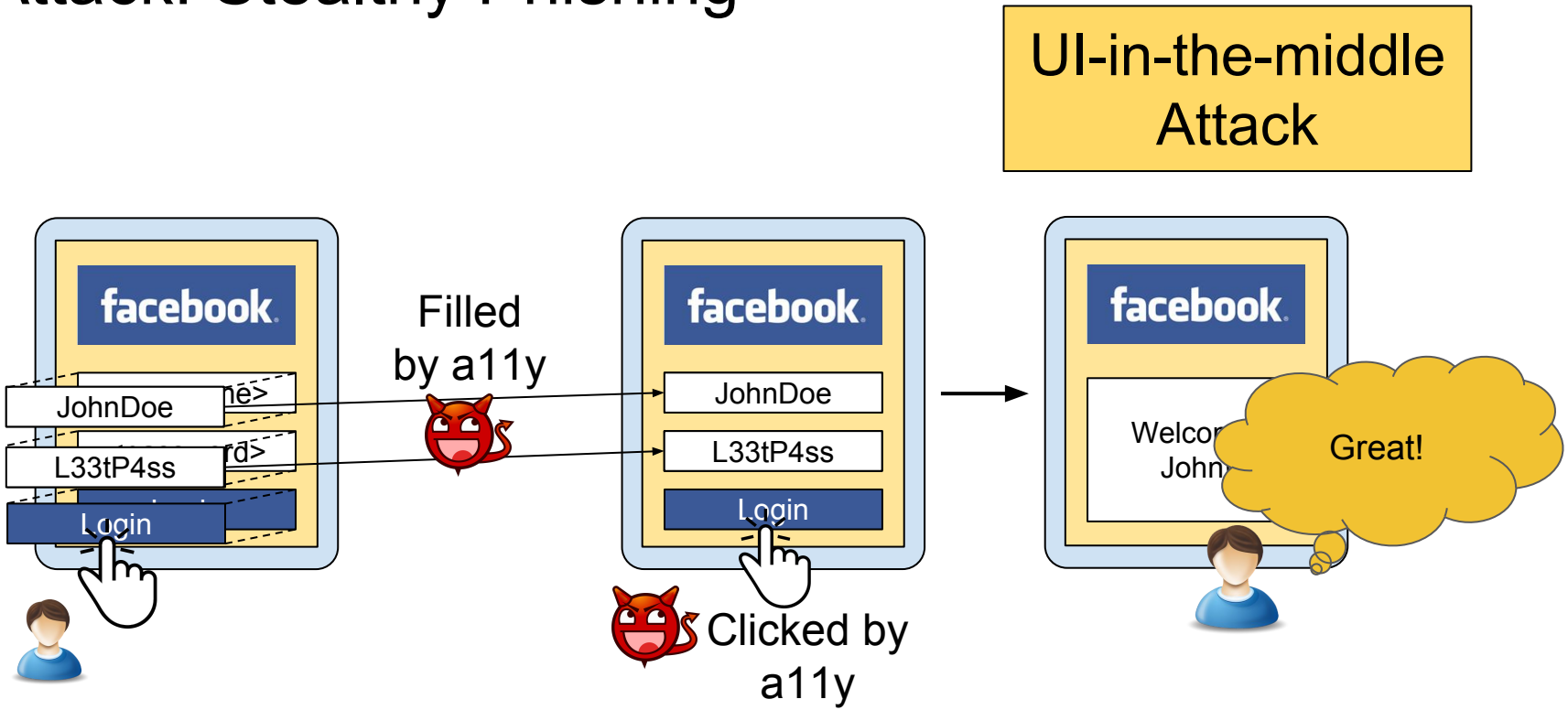
Traditional Phishing



Traditional Phishing



Attack: Stealthy Phishing



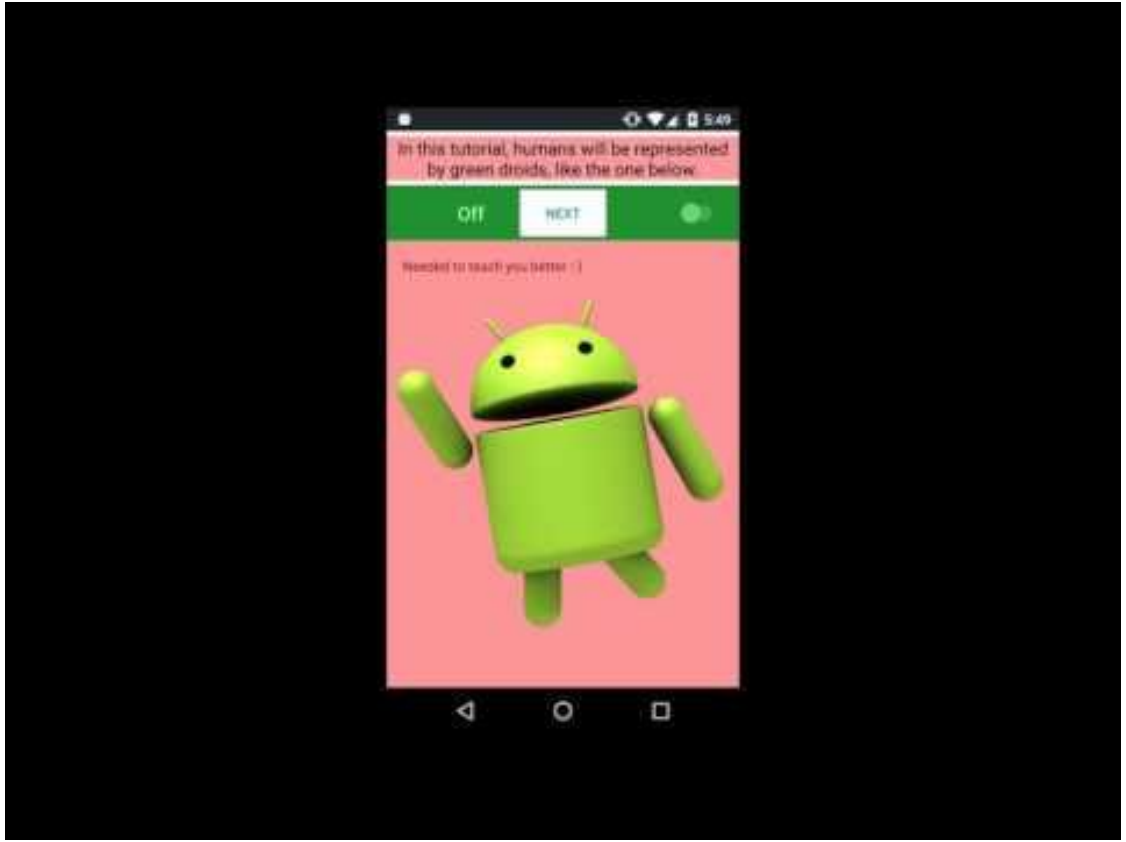
Attack: Silent God-mode App Installation

- We show a video to the user...
- ...and, behind the scene, we do nasty things via a11y
- The grand plan
  - Silent installation of super-malicious app
  - Enable all its permissions
  - Clean up steps

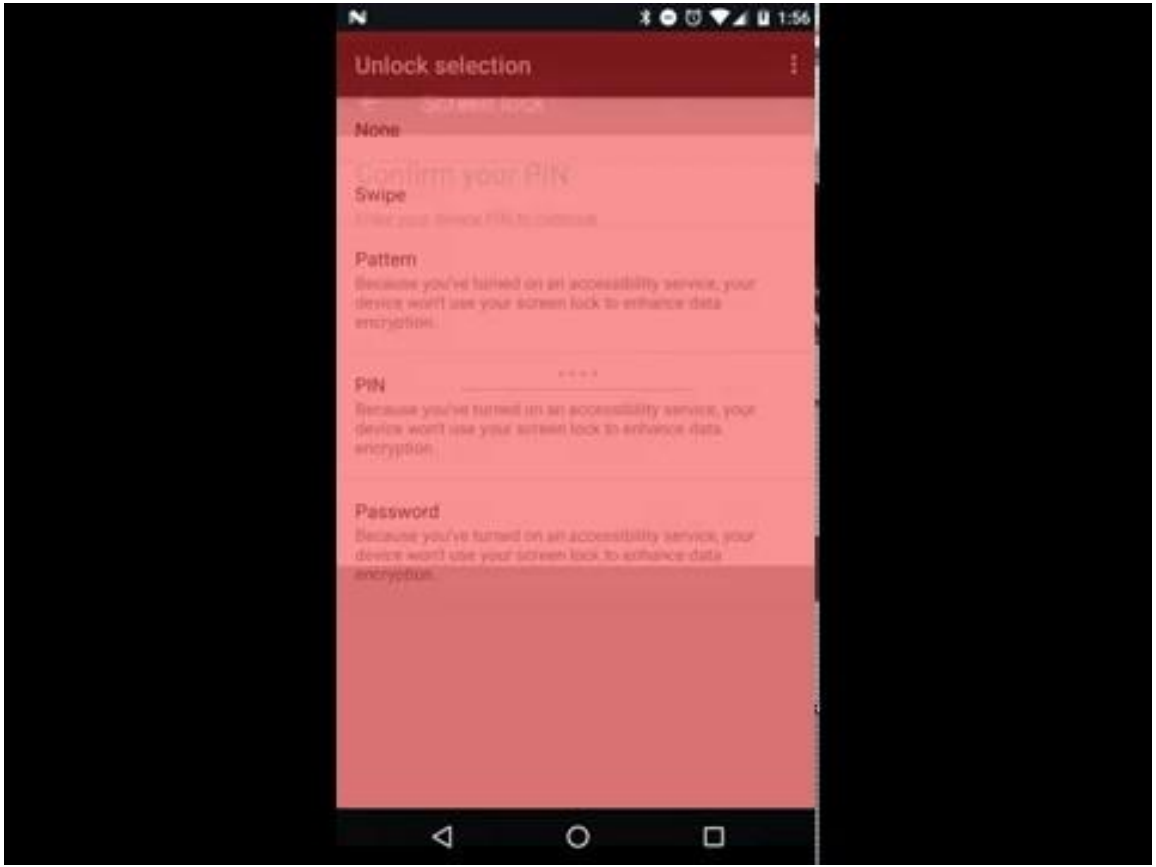
Additional Attack Scenarios

- Ransomware!
  - Block device by changing the PIN to an attacker-controlled one
- Covering and clicking around on Chrome
  - Taking over victim's Google account
  - Steal saved passwords, etc
- Note: even if Google fixes its apps, third-party apps will remain vulnerable to these attacks

Clickjacking ~> a11y & Silent God-mode App Install



Ransomware Example



Are these attacks actually practical?

User Study

- 20 human subjects (all from Georgia Tech)

- Attacks we tested
  - Clickjacking to enable a11y
  - Silent God-mode App Installation
  - Stealthy Phishing

Results

- Clickjacking to enable a11y
  - None of the subject understood what happened
- Silent God-mode App Installation
  - None of the subject understood what happened
- Stealthy Phishing
  - 18 out of 20 did not detect any difference
  - The remaining two triggered a bug in our prototype, and they reported “graphical glitches” (but they did not understand they were attacked)

Overall Awareness

- Do users know about these two permissions?

- Results are worrisome
  - Only 2 out of 20 knew about the “draw on top” permission
  - Only 5 out of 20 knew about a11y
  - ***No subject knew about both!***

- ...why should they look for them?

How can we fix this?

Responsible Disclosure

- “Simple bugs” via AOSP reports (August 22nd, 2016)
  - Invisible Grid Attack ~> Moderate severity (not fixed yet)
  - A11y on steroids ~> ???

Disclosure of “a11y on steroids” (August 22nd)

- Bug marked as “Won’t fix, work as intended” (September 30th)
- Bug marked as “High severity” (October 18th)

- Downgraded to “Won’t fix” because “limiting those services would render the device unusable” (November 28th)
- “We will update the documentation” (May 4th)
- AND THEY DID!!!11!1!

a11y documentation “patch”

- AccessibilityEvent’s “security note” is silently removed
  - June 6th version vs current version

- “Patch the documentation, not the code”

- 0day in the documentation! Where is my CVE?! :-)

Responsible Disclosure

- “Simple bugs” via AOSP reports (August 22nd, 2016)
  - Invisible Grid Attack ~> Moderate severity
  - A11y on steroids ~> ???
  - New clickjacking technique

Responsible Disclosure

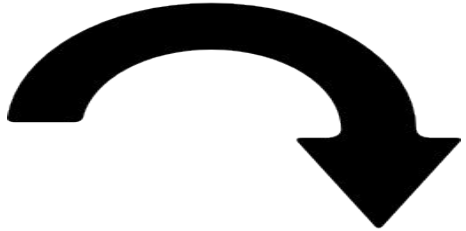
- “Simple bugs” 22nd, 2016)

Android Rewards
Qualifying Vulnerabilities

Few classes of vulnerabilities will generally not qualify for a reward:

- **Tap-jacking** and **UI-redressing** attacks that involve tricking the user into tapping a UI element


"BUT, BUT, BUT...."
memegenerator.net

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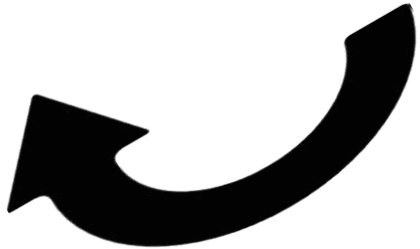

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  - Invisible Grid Attack ~> Moderate severity
  - A11y on steroids ~> ???
  - New clickjacking technique ~> :-(

- Shared the paper draft with Adrian Ludwig, head of Android security (December 19th)

Responsible Disclosure

- “Simple bugs” via AOSP reports (August 22nd, 2016)
  - Invisible Grid Attack ~> Moderate severity
  -
  -
- Sha
  Android security (December 19th)

All attacks are still working!
(Even on Android 7.1.2, with **July**’s updates)

How is the Android security team reacting?

“I’m not alone”

- UI security is not considered a “big deal”

- Check Nick Kralevich’s talk at Android Security Symposium, March 2017 (https://youtu.be/ITL6VHOFQj8?t=57m40s)
  - First question during the Q&A...

“I’m not alone”

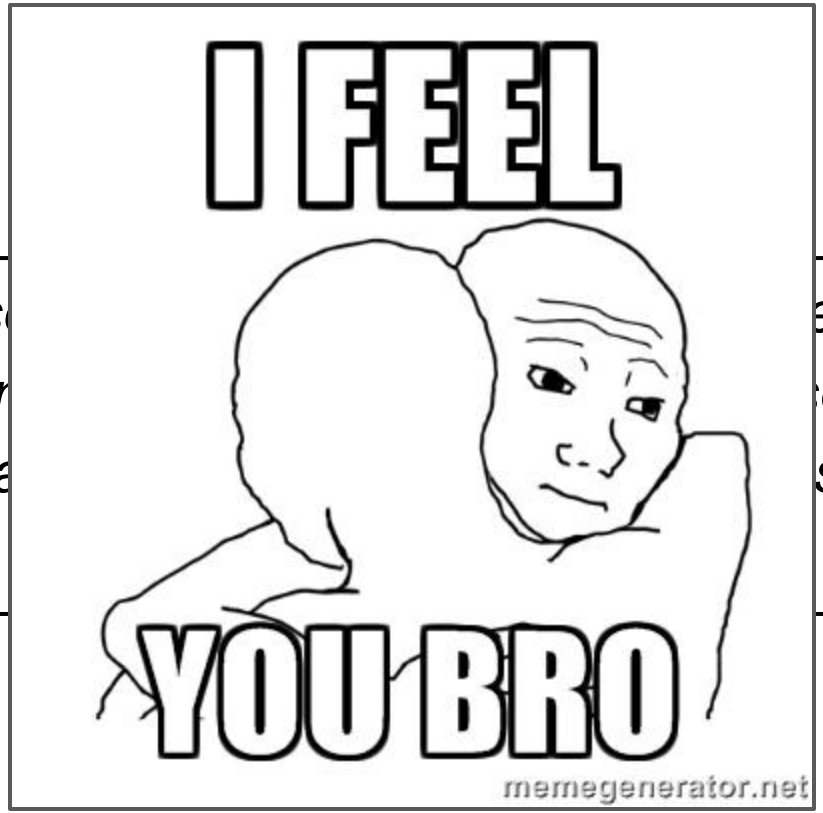
- UI security is not considered a “big deal”

> *“There are also plain boring bugs, for example in the UI [...], personally I don’t report them anymore because you just don’t care. My bugs are hanging with the ‘new’ status for years then they are just auto-closed.”*

“I’m not alone”

- UI security is

> *“There are als e in the UI [...], personally I dor e you just don’t care. My bugs a s for years then*



Securing Android UI

- Introduce the concept of “Secure Apps & Widgets”
  - Defined through a flag that is propagated across the view tree
- OS-enforced guarantee
  - No overlay will be shown on top of any secure app/widget
- System popups
  - Inspired by web popups

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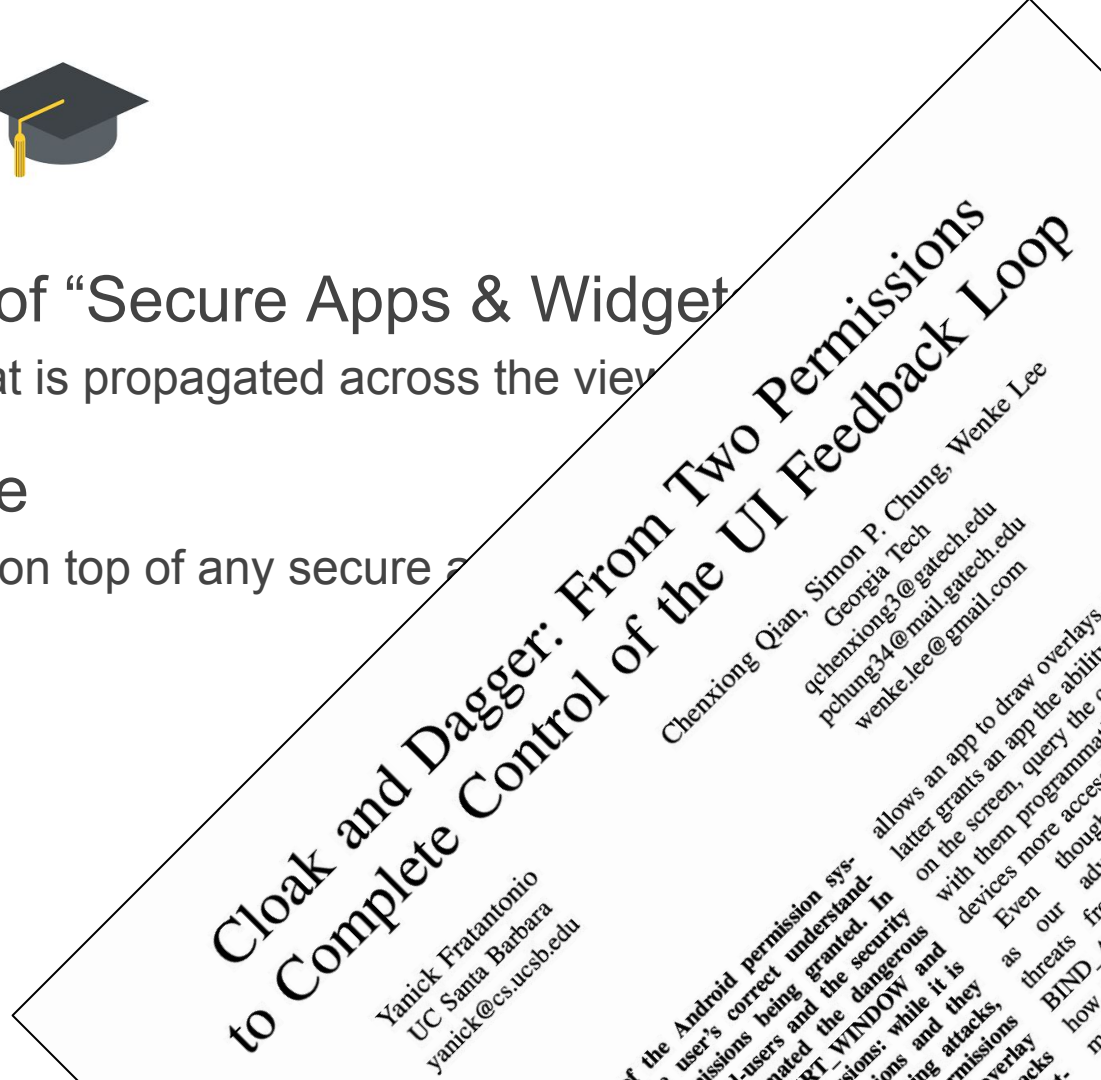


What happened next...

- Work presented at IEEE Security & Privacy 2017
  - Distinguished Practical Paper award!
- We setup a website and tweeted about it
- Crazy amount of press coverage…

Google’s official answer

“*[...] We have updated Google Play Protect — our security services on all Android devices with Google Play — to detect and prevent the installation of these apps. Prior to this report, we had already built new security protections into Android O that will further strengthen our protection from these issues moving forward.*”

Detect Cloak & Dagger

- What would I do?
  - Detect apps that combine these two permissions
- Does the attacker really need both permissions?
- Eh eh...

Bootstrap the attacks from one permission

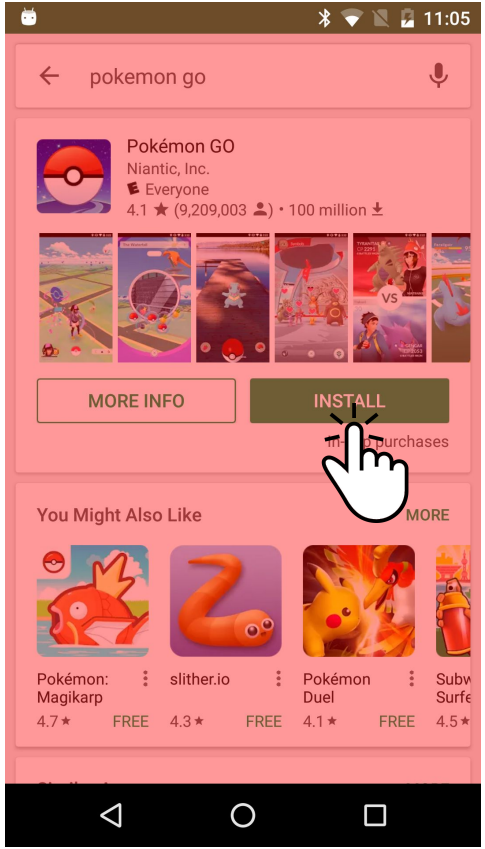
- Start with an app that only requires “SYSTEM_ALERT_WINDOW”

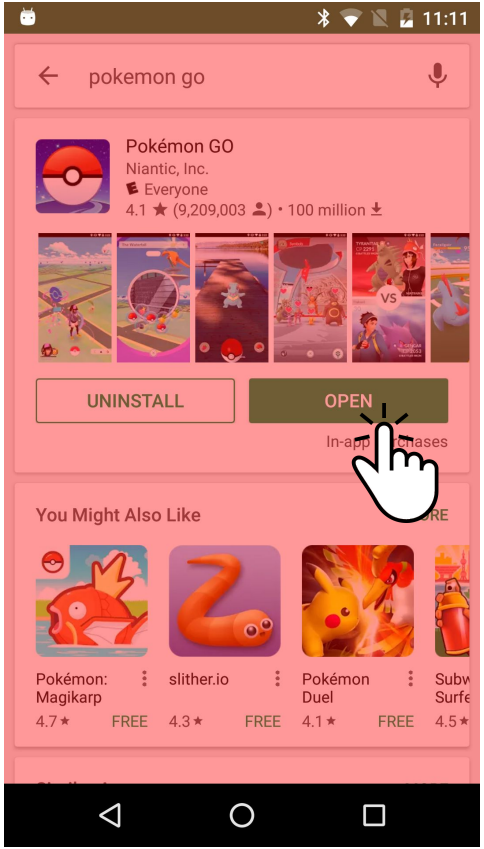
- Install a secondary malicious app that only requires a11y!

- How?


CLICKJACKING
EVERYWHERE
memegenerator.net

Clickjacking Everywhere!





Let’s go one step further...

- ...do we actually need the SYSTEM_ALERT_WINDOW?

Let’s go one step further...

- SYSTEM_ALERT WINDOW permission is needed to create windows of “TYPE_ALERT_SYSTEM”

- Realization: the attacker just needs to create windows on top of all apps’ activities
  - She does **not** need to go over “system” windows (e.g., status bar, navigation bar)
  - Any overlay’s “type” that goes on top of activities is enough

FTW!

- Toasts are usually created with this API:
  - `makeText(Context context, int resId, int duration)`
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  - Limited customization capabilities

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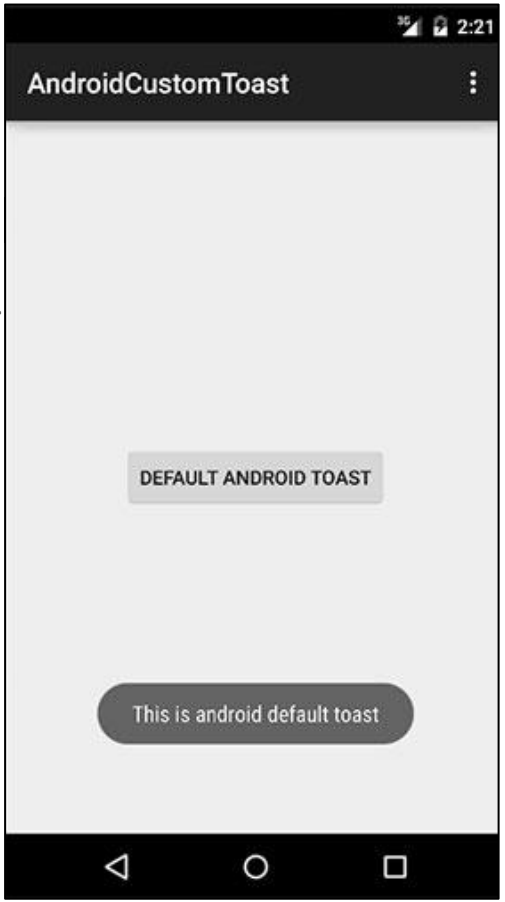

FTW!

- Toasts are usually created with this API:
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  - Limited customization capabilities

- It is possible to create arbitrarily custom “Toasts”
  - TYPE_SYSTEM_ALERT ~> TYPE_TOAST
  - “Pretty simple” to port all the attacks

FTW!

- Toasts are usually created with this API:
  - `makeText(Context context, int resId, int duration)`
  - Duration: either 2 seconds or 3.5 seconds

```
sed -i "s/TYPE_SYSTEM_ALERT/TYPE_TOAST/" *
```

  - TYPE_SYSTEM_ALERT ~> TYPE_TOAST
  - “Pretty simple” to port all the attacks

Impact & Caveats

- Android 6.0.1
  - You can bootstrap Cloak & Dagger attacks with **zero** permissions
  - Caveat: you need to hijack two more clicks to install the app with a11y

- Android 7.1.2
  - Several mechanisms against Toast abuse
    - The SYSTEM_ALERT_WINDOW permission is required
  - You can bootstrap Cloak & Dagger attacks with one permissions
    - Same caveat as above

Android O (Preview 3 developer version)

- Invisible Grid Attack is fixed! YEAH!
- Clickjacking: currently more vulnerable than before
  - The final “OK” button to enable a11y is NOT protected by the obscured flag :-(
- “A11y on steroids” attacks “work as intended” ;-)

Android O (Preview 3 developer version)

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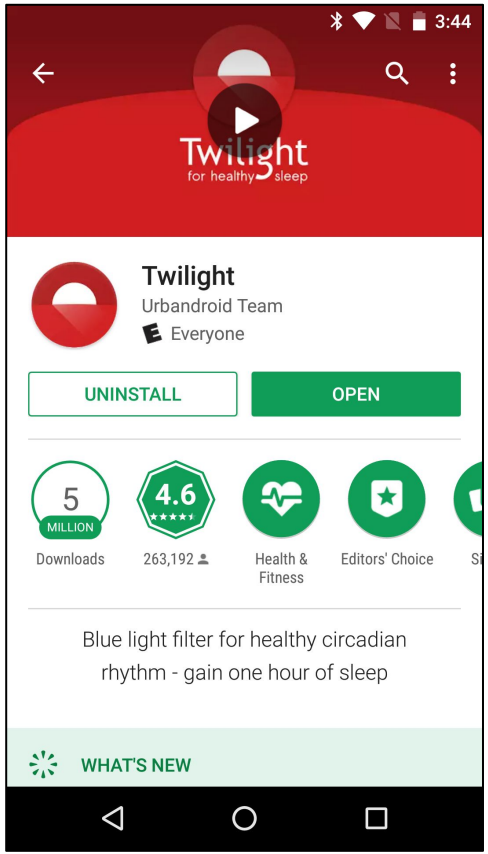
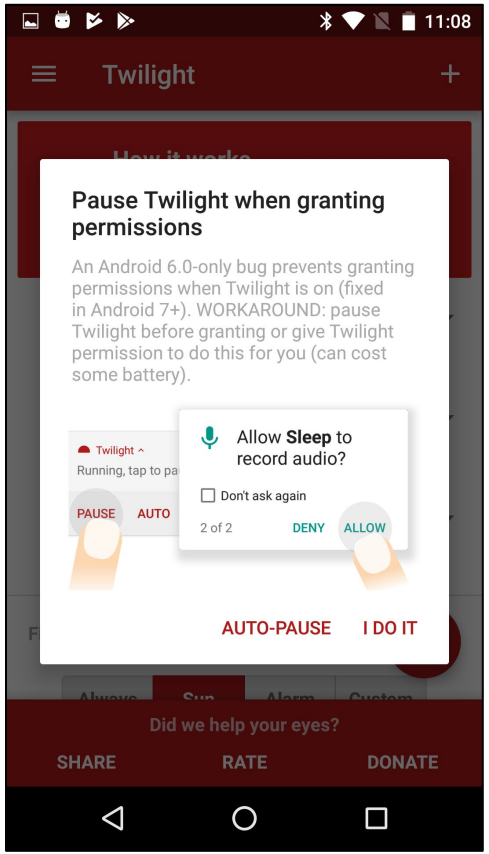
- “A11y on steroids” attacks “wo

Clickjacking ~> a11y seems fixed in Android O Preview 4!!

(released few days ago :-))

Fixing clickjacking might be trickier than expected...





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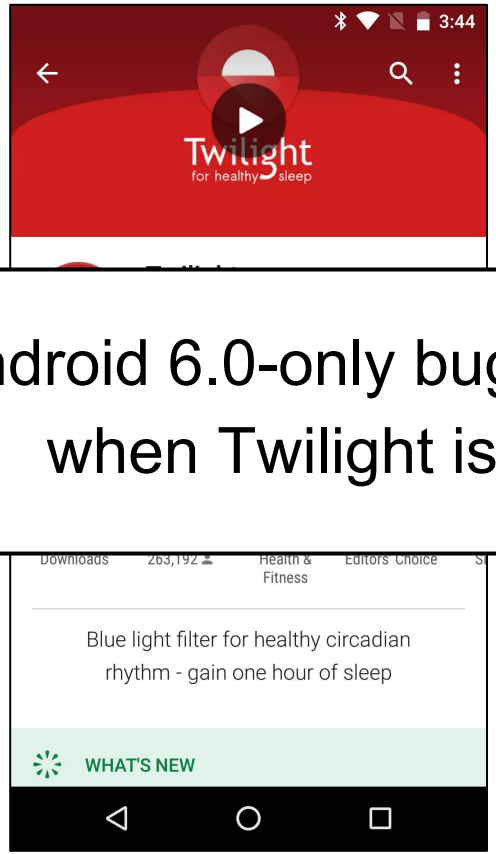

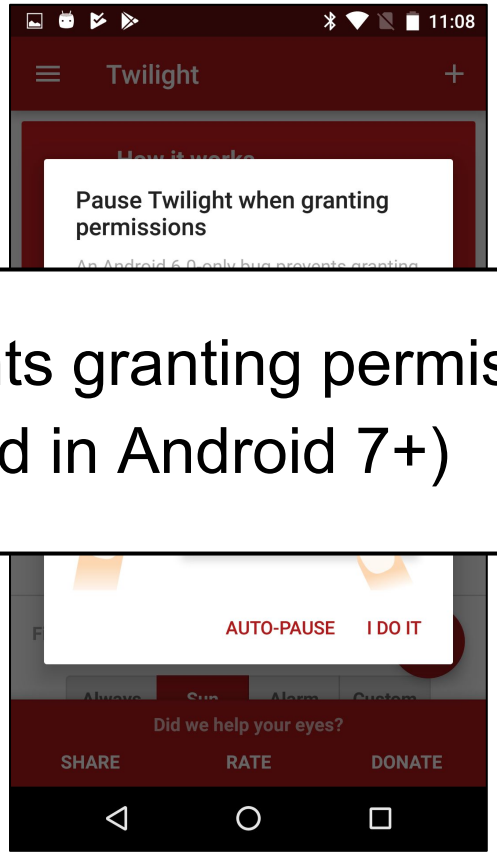

An Android 6.0-only bug prevents granting permissions when Twilight is on (fixed in Android 7+)

Current state of Android security updates

Stuck with Android 6.0.1

Minimum update & support periods

Device	No guaranteed Android version updates after	No guaranteed security updates after	No guaranteed telephone or online support after
Nexus 6P	September 2017	September 2018	September 2018
Nexus 5X	September 2017	September 2018	September 2018
Nexus 9	October 2016	October 2017	October 2017
Nexus 6	October 2016	October 2017	October 2017
Nexus 5	October 2015	October 2016	October 2016
Nexus 7 (2013)	July 2015	August 2016	August 2016
Nexus 4	November 2014	November 2015	November 2015
Nexus 10	November 2014	November 2015	November 2015
Nexus 7 (2012)	June 2014	June 2015	June 2015

Current state of Android security updates

Phone	No guaranteed Android version updates after	No guaranteed security updates after	No guaranteed telephone or online support after
Pixel XL	October 2018	October 2019	October 2019
Pixel	October 2018	October 2019	October 2019

$769

$649

Takeaways

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yanick@cs.ucsb.edu

- “Cloak & Dagger” attacks
  - UI attacks are still a thing
  - Many low-level security mechanisms are bypassed
- UI security bugs matter
  - They are the low-hanging fruits for the attackers
- More info: cloak-and-dagger.org