Screenmilker:
How to Milk Your Android Screen for Secrets

Chia-Chi Lin, Hongyang Li[1],

Xiaoyong Zhou[2], and XiaoFeng Wang[2]

[1]*University of Illinois at Urbana-Champaign*
[2]*Indiana University at Bloomington*

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

INDIANA UNIVERSITY
Bloomington

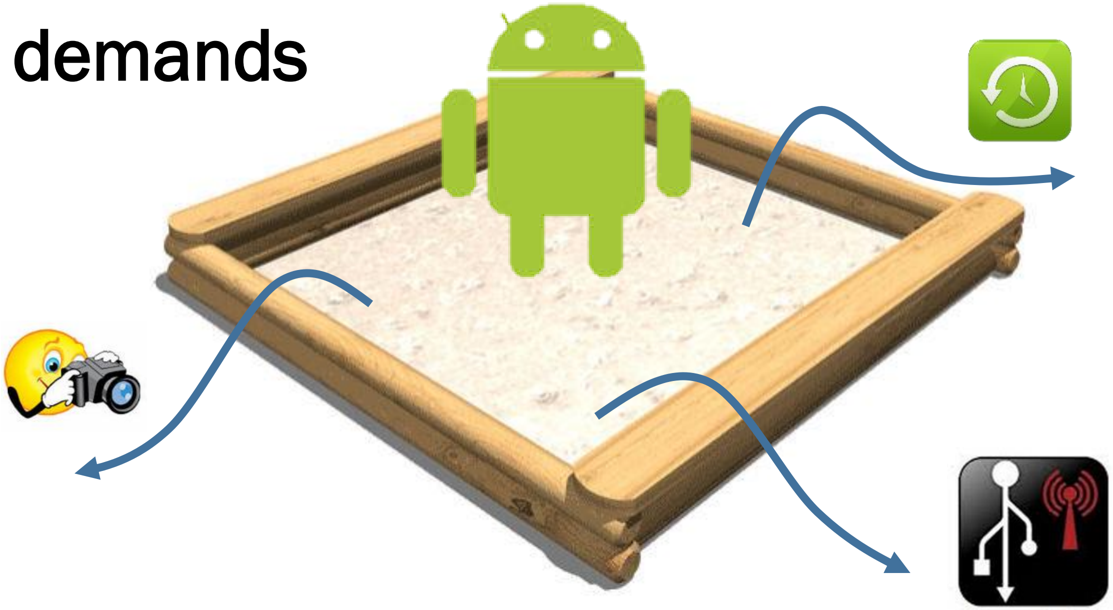
Android Security VS. App Demands

Android security design

- **No** Direct access system resources
- **No** Reading/Writing outside it's own directory
- **No** installing/uninstalling other apps

User's/developer's demands

- Capture screen
- Backup
- USB Tethering



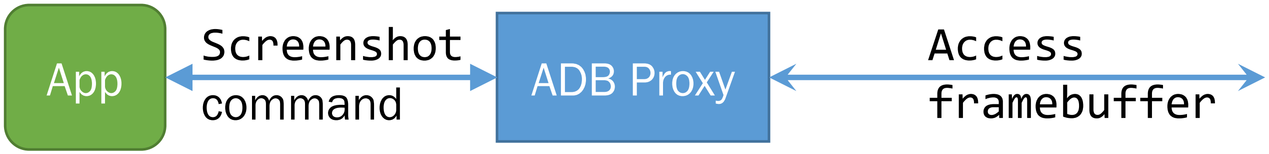
One Solution: Root the phone

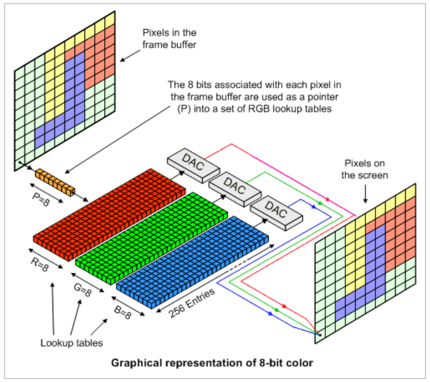
An Legitimate Alternative: ADB Proxy

- Android Debug Bridge (ADB)
  - A versatile command line tool that lets user communicate with his device
  - A set of capabilities
    - Install/Uninstall
    - Pull/Push data
    - Take screenshots / Record screen
    - …
- How app can use ADB? -- proxy

ADB Proxy

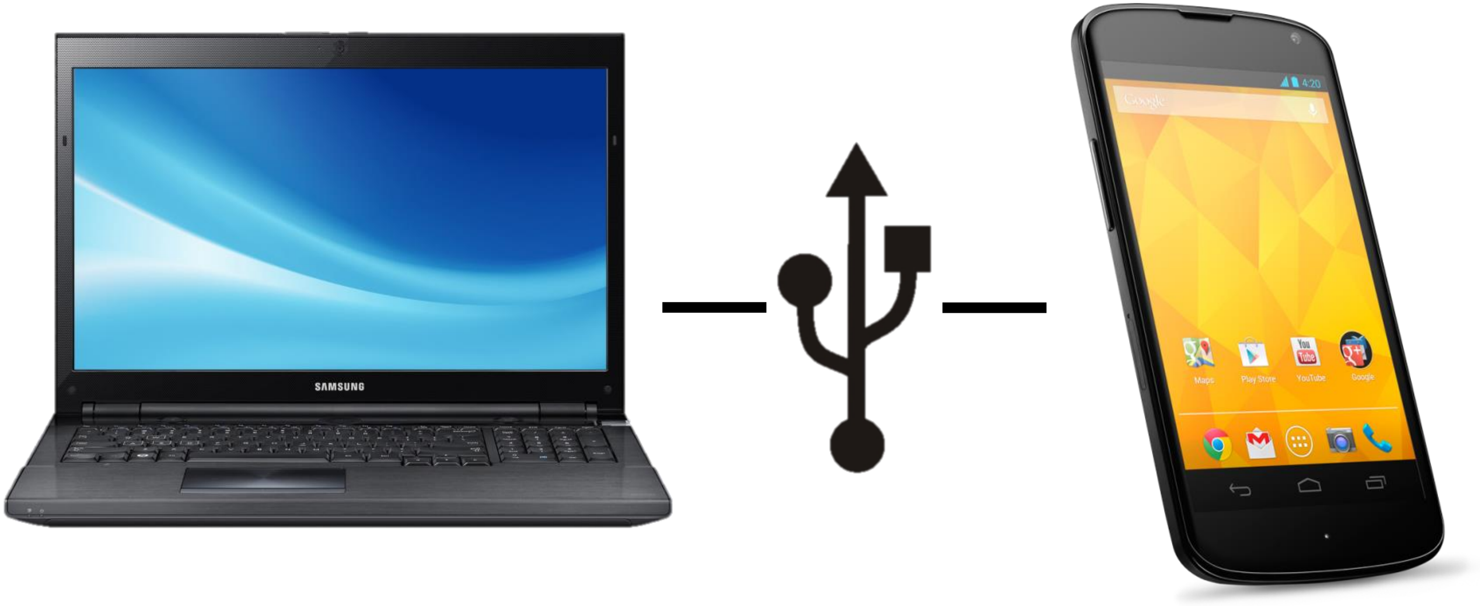
- An native executable implemented by developer
- Runs on the phone as shell user to provide privileged services to other apps
- ADB proxy is legitimate
  - Apps using this approach have tens of millions of downloads
  - No objections from Google



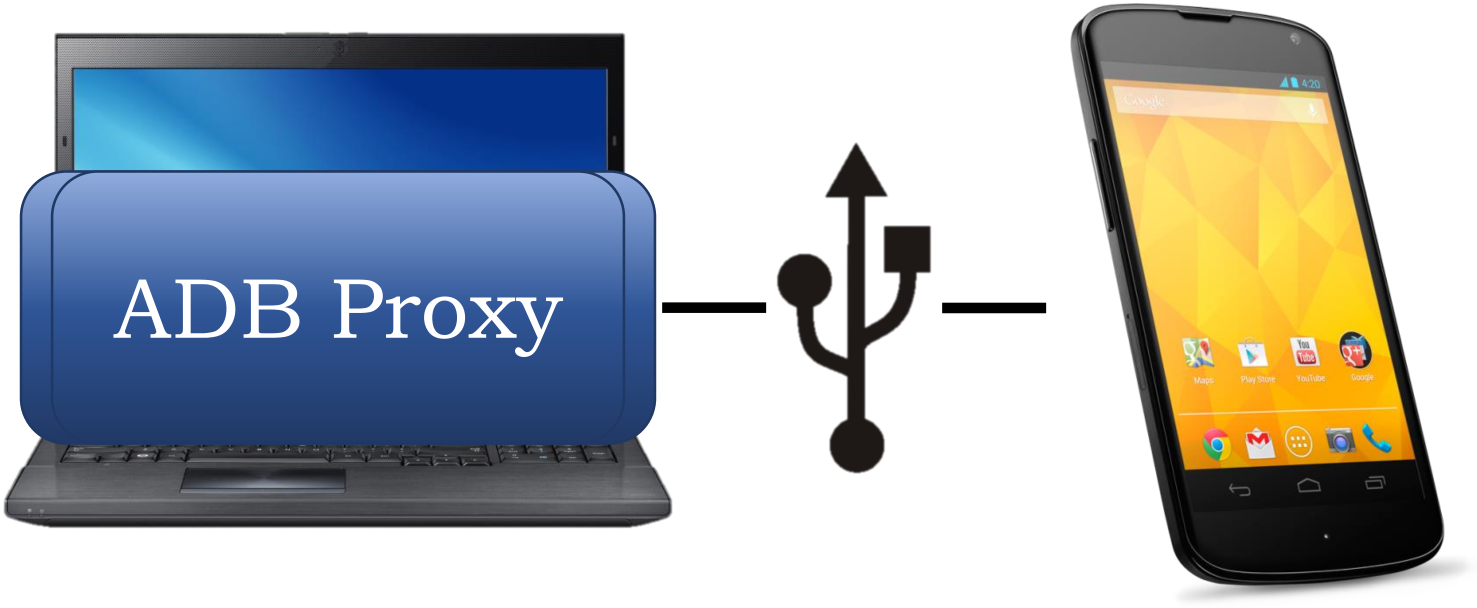

Pixels in the frame buffer
The 8 bits associated with each pixel in the frame buffer are used as a pointer (P) into a set of RGB lookup tables
DAC
DAC
DAC
Pixels on the screen
P=8
R=8
G=8
B=8
256 Entries
Lookup tables

Graphical representation of 8-bit color

1. Turn on USB Debugging and Connect Android to a PC

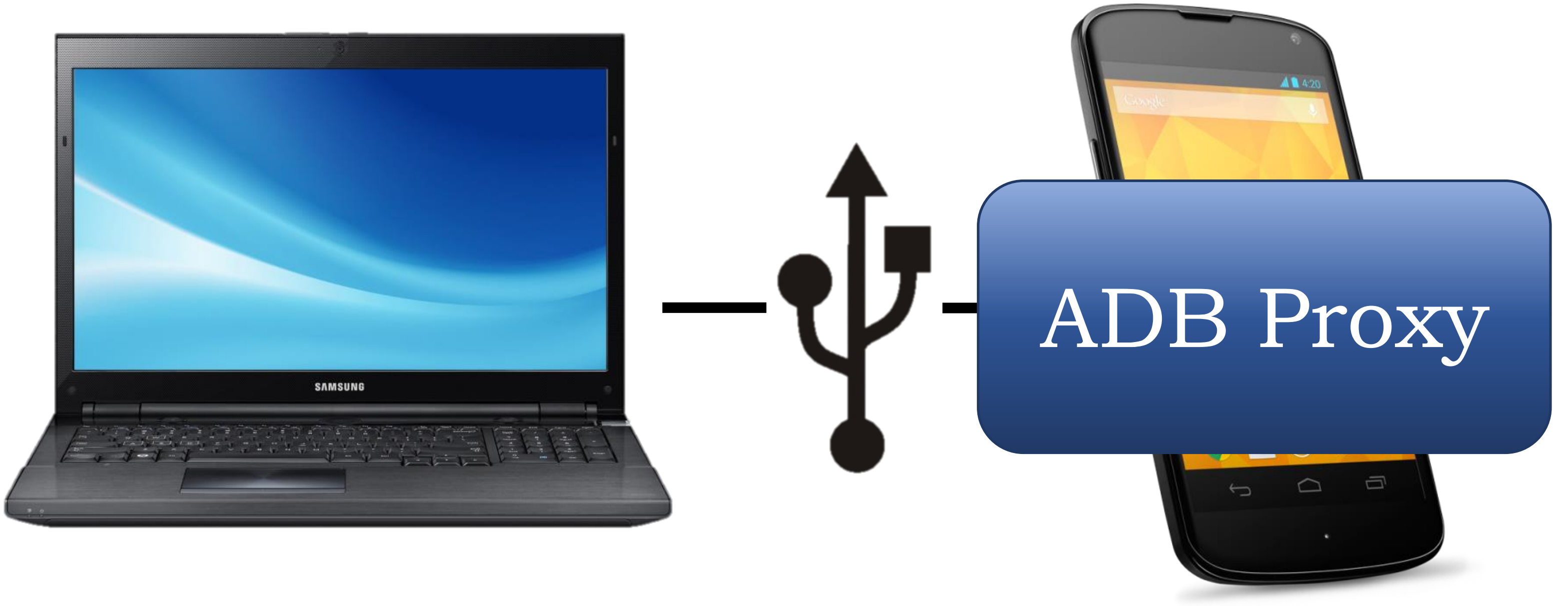


2. Run a Script on the PC to Install a ADB Proxy on Android



- ADB Proxy has the same capabilities as ADB

3. Disconnect Android from the PC



ADB Proxy

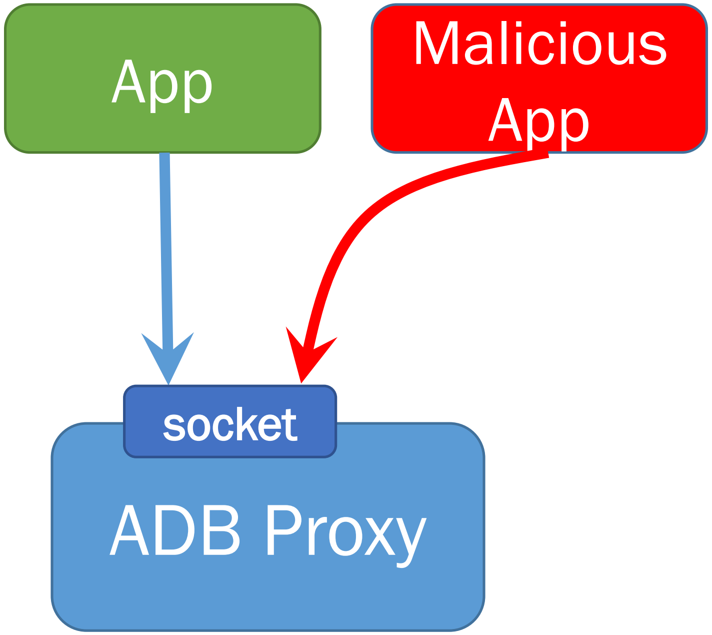
Apps Using ADB proxy

- Screenshot apps
  - Very popular on Google Play
- USB Tethering Apps
- Sync and Backup Apps

App Name	Total Installs
Screen Capture – No Rooting 2.2	1,000,000 – 5,000,000
Screenshot Free	1,000,000 – 5,000,000
Screenshot UX Trail	1,000,000 – 5,000,000
No Root Screenshot It	100,000 – 500,000
Screenshot and Draw Trail	100,000 – 500,000
Screenshot Ultimate	100,000 – 500,000
ShakeShot Trail	100,000 – 500,000
NoRoot Screenshot Lite	50,000 – 100,000

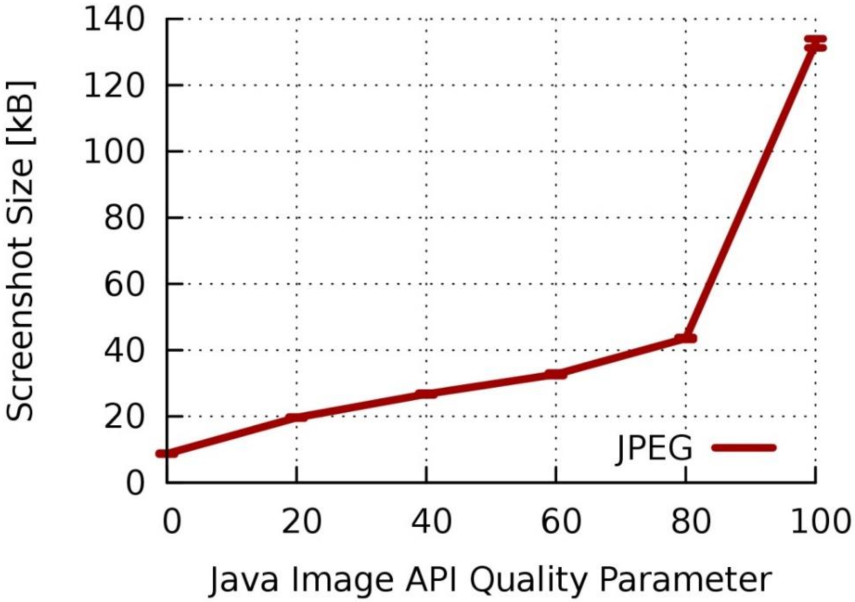
Security Implications

- No Access Control
  - Local socket
  - Any apps with the INTERNET permission can connect to ADB proxy
- A malicious app could command ADB proxy to
  - Take screenshots
  - Install applications



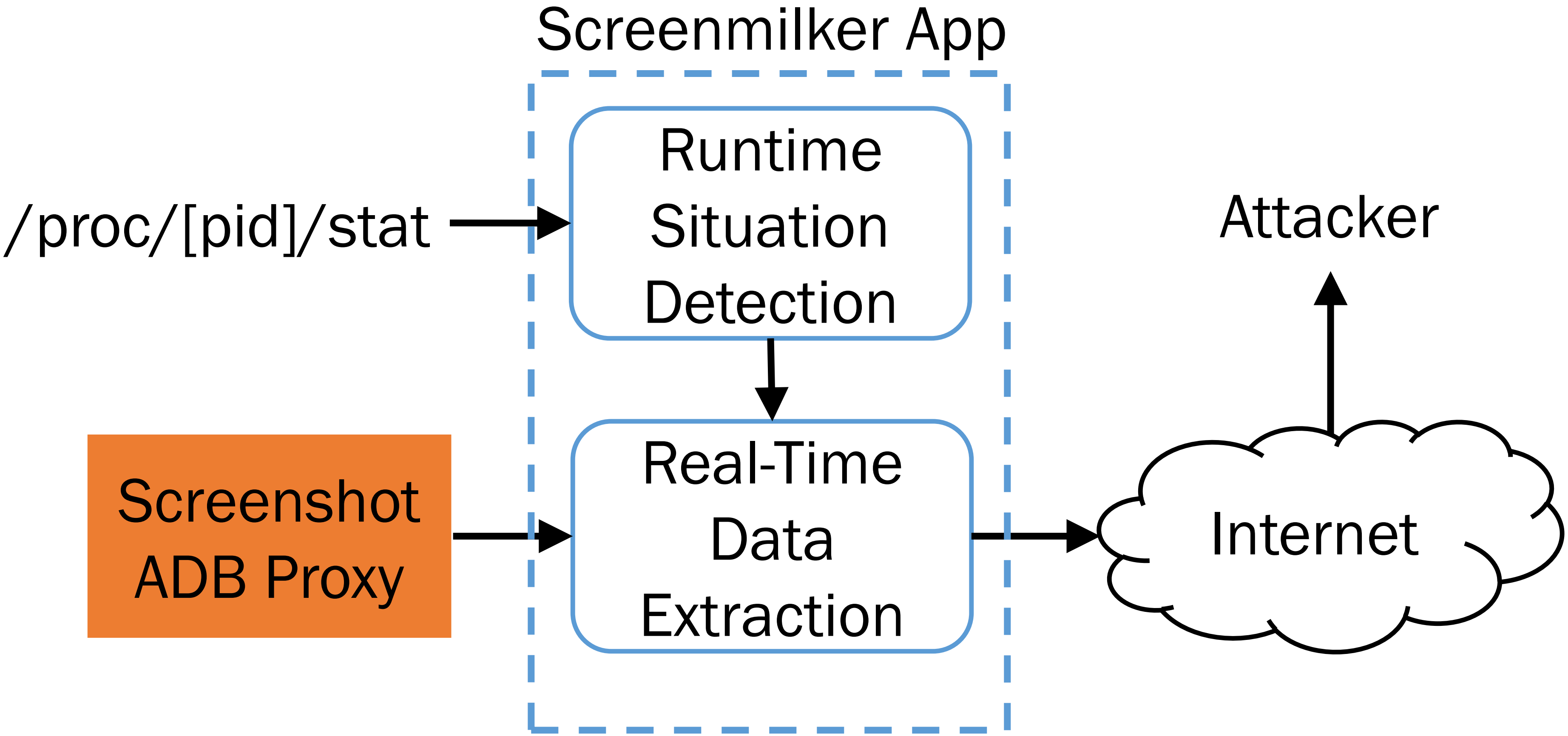
Naïve attacks are not stealthy

- Streaming pictures to adversary consumes too much bandwidth
- Running OCR locally uses too much CPU and memory



For a 2-Mbps Upload Bandwidth, Only 2 Screenshots Can Be Sent Out Every Second

Our Attack


Screenmilker App
/proc/[pid]/stat
Runtime Situation Detection
Attacker
Screenshot ADB Proxy
Real-Time Data Extraction
Internet

Detect Screenshot Proxy

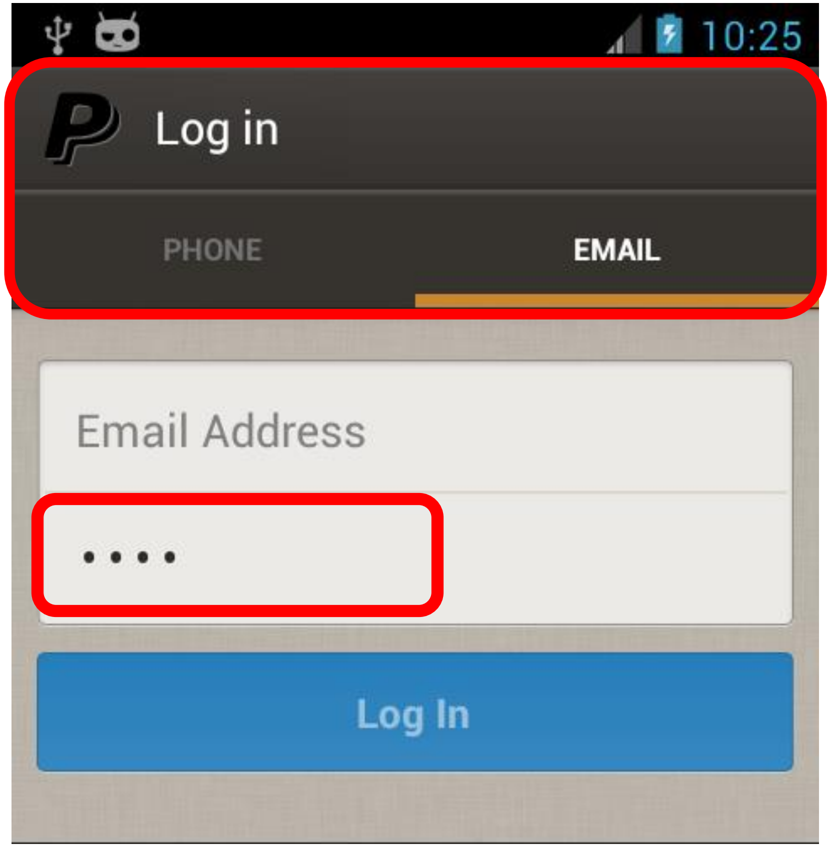
- Build a database of screenshot apps
- Use call *PackageManager* to get the list of apps on the device
- Alternatively, scan TCP ports ADB proxies use

Runtime Situation Detection

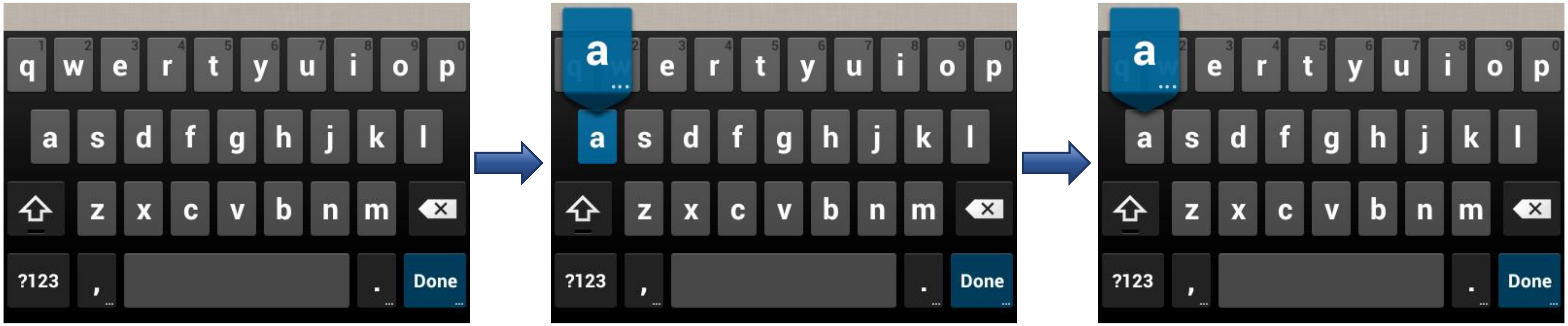
- Detect target apps (e.g., banking apps) through `PackageManager`
- Probe */proc/[pid]/stat* to monitor apps' activities
  - Check the cpu `utime` change of target app
- Monitor the soft keyboard app to identify whether user is typing on the soft keyboard
  - com.google.android.inputmethod.latin

Detecting Application States

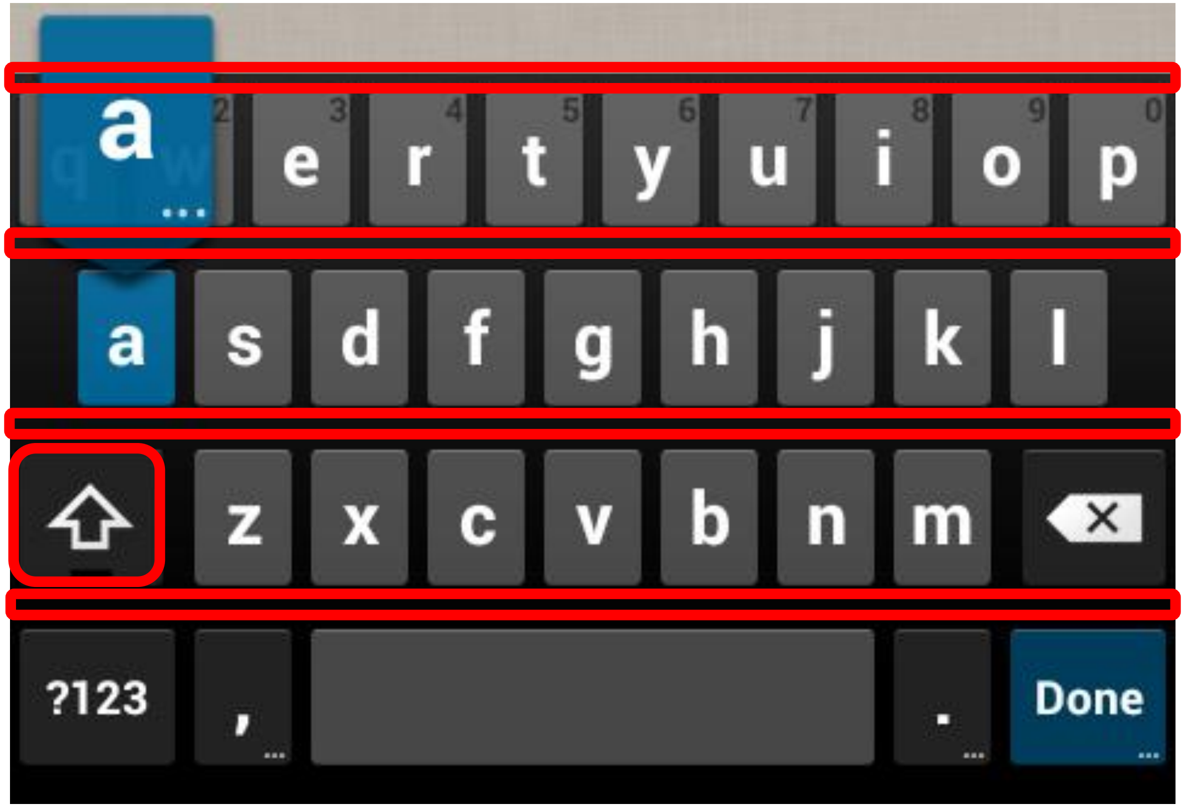
1. Get Screen Orientation
2. Take screenshots
3. Extract title bar
4. Match the title bar against app state database



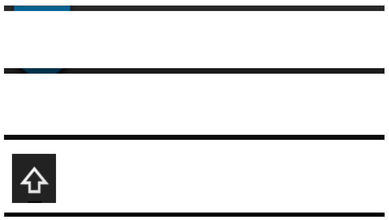
Real-Time Keystroke Analysis



Fingerprinting the Soft Keyboard



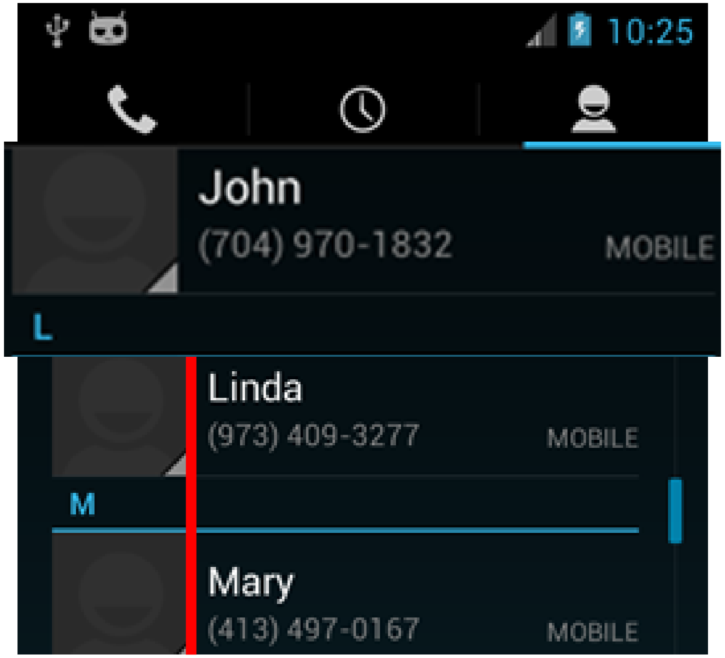
Determining the Keystroke



222054093

CRC32 Value	Keystroke
222054093	a
8599545	b
4181574192	c
…	…

Real-Time Contact Collection



10:25

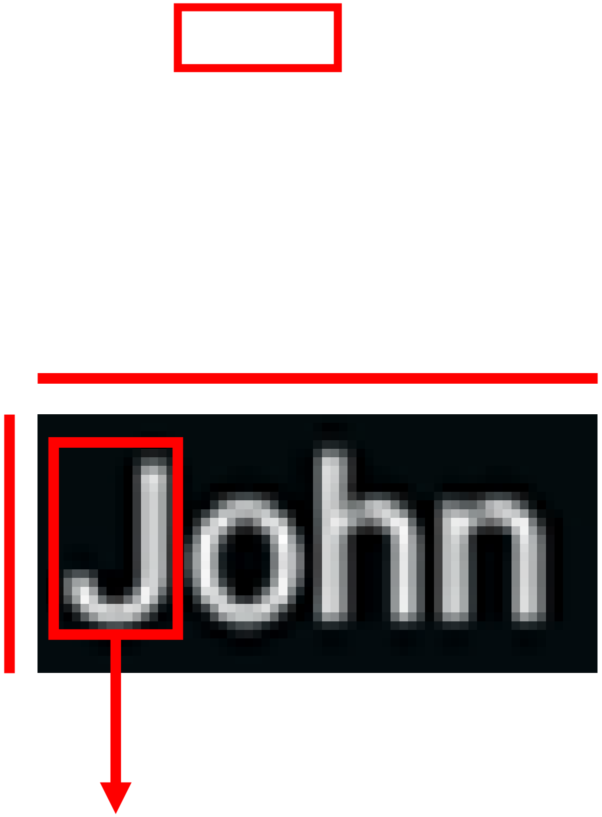
John
(704) 970-1832 MOBILE

L

Linda
(973) 409-3277 MOBILE

M

Mary
(413) 497-0167 MOBILE

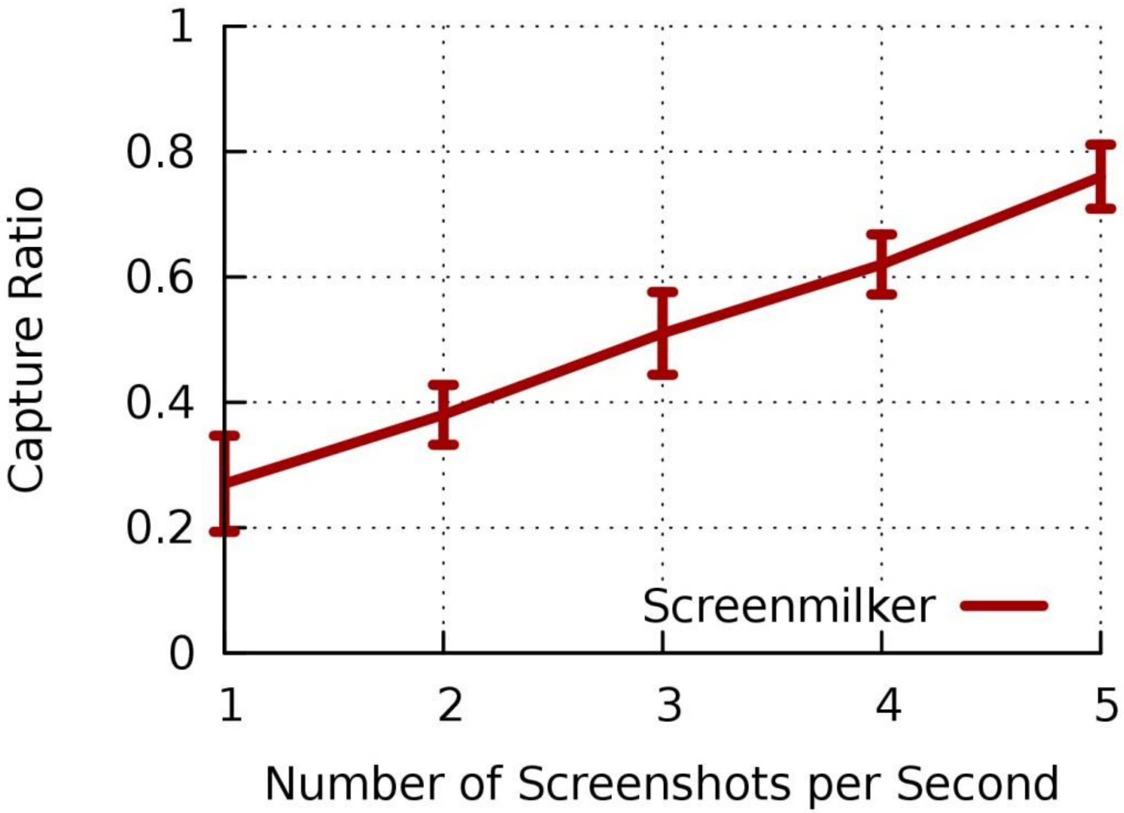


CRC

Evaluations

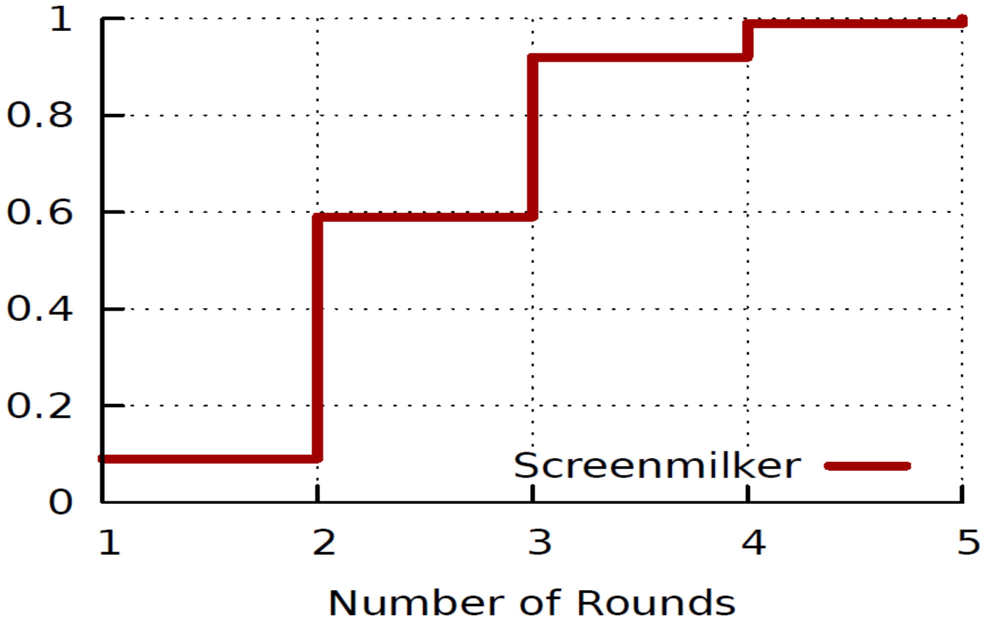
Effectiveness: Single Key Stroke Capture Ratio

Capture Ratio Increases From 27% to 76% as the Screenshot Rate Increases



Password Extraction

- Experiment setup
  - 10-character passwords
  - 5 banking apps [American Express, Chase, Citi, PayPal and Wells Fargo]
  - 40 password entering for each app
- How many rounds to recover a password?
  - Screenmilker may miss the moment for some keystrokes



Rounds to Extract Entire Password

App	Average Number of Rounds
American Express US	2.625
Citi Mobile	2.525
Chase Mobile	2.325
PayPal	2.75
Wells Fargo Mobile	2.45

CPU run time

	Extraction Function	Time [ms]
General	**Initialize Hash Table [one time]**	1.389
	Take a Screenshot [not controllable by Screenmilker]	161.314
Keystroke Extraction	**Fingerprint the Image Features**	0.388
	Lookup Hash Table	0.220
Contact Collection	**Obtain Position of Text**	3.018
	Segment and Map Text	2.916

Memory Consumption

App	Memory [Kbytes]
Screenmilker [situation detection]	286.308
Clock	294.072
Screenmilker [contact collection]	295.279
Screenmilker [keystroke extraction]	295.364
Calculator	295.464
Google Talk	310.844
Instagram	326.244
Pandora Internet Radio	356.332
Facebook	365.384
Browser	391.912
Temple Run 2	436.712

Power Consumption

App	Power [mW]
Screenmilker [situation detection]	4.1
Screenmilker [contact collection]	8.3
Google Talk	47.8
Clock	52.1
Calculator	91.8
Screenmilker [keystroke extraction]	101.6
Instagram	155.8
Pandora Internet Radio	213.5
Facebook	252.1
Browser	374.8
Temple Run 2	529.2

Mitigations: Access Control on ADB Proxy

- Utilize *iptables* to control local-socket communication
- Users need to explicitly grant apps permission to communicate with local servers
- We build a service to add *iptables* rules accordingly

Conclusions

- ADB proxy is a popular workarounds that grant privileged capabilities to 3rd party apps

- Without proper protection, ADB proxy could be exploited by malicious apps to extract sensitive information from the phone as demonstrated by Screenmilker

- From our evaluation, we show that malicious app can effectively and stealthily extract information from screenshots

Thank You! Questions?