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An Empirical Study on Fingerprint API Misuse with Lifecycle Analysis in Real-world Android Apps

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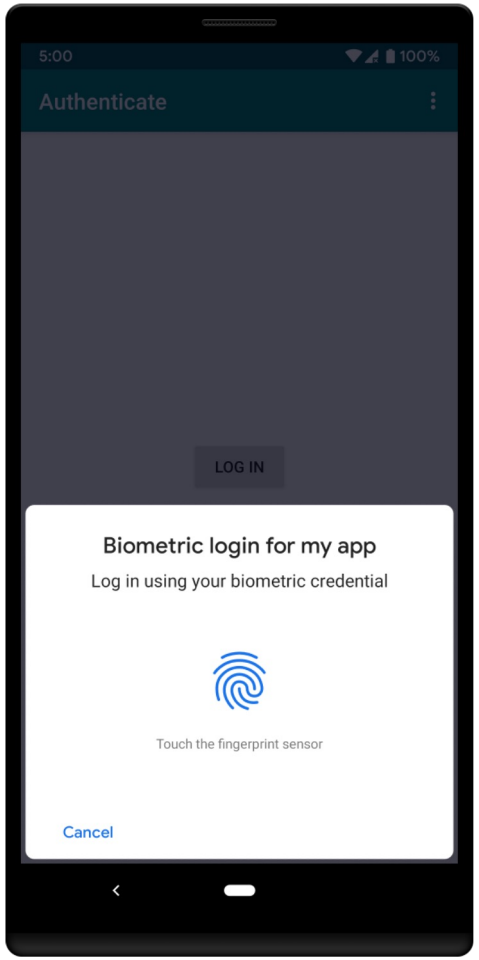
Fudan University

Fingerprint-based Authentication (FpAuth)

- Used commonly by mobile apps

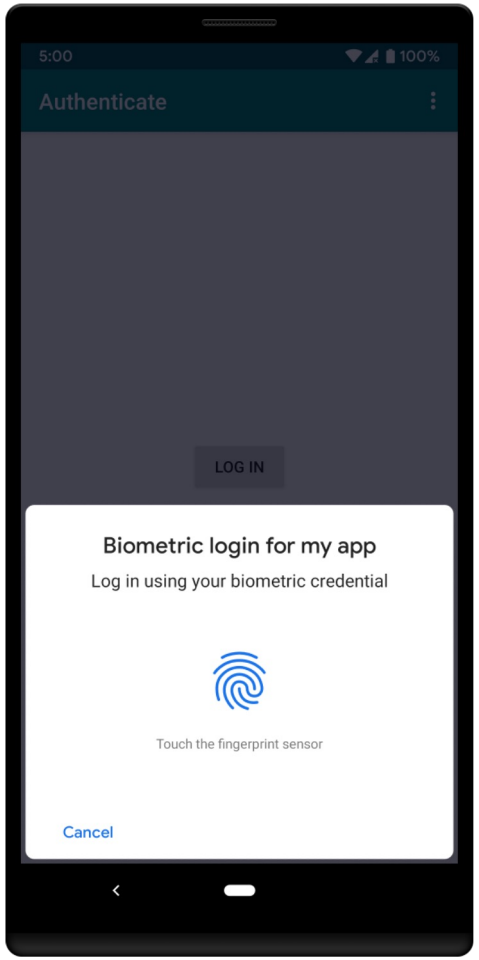
- Used in sensitive scenarios

FpAuth in Android Apps



What happens when performing FpAuth?

FpAuth in Android Apps



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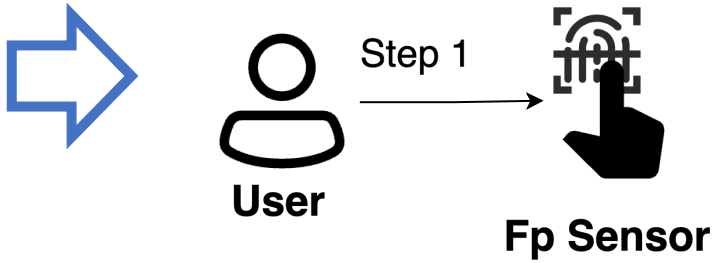

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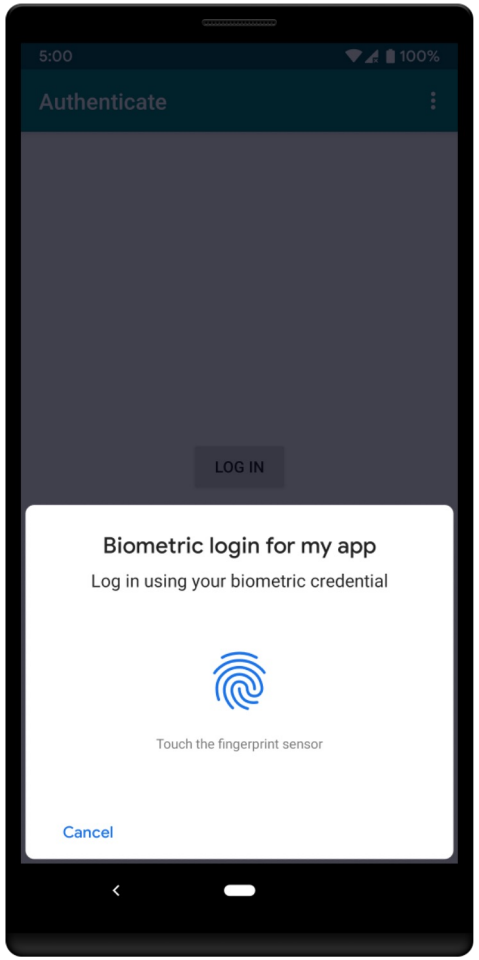

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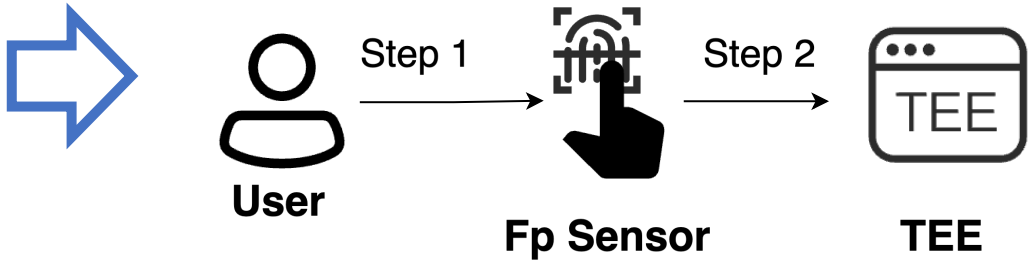

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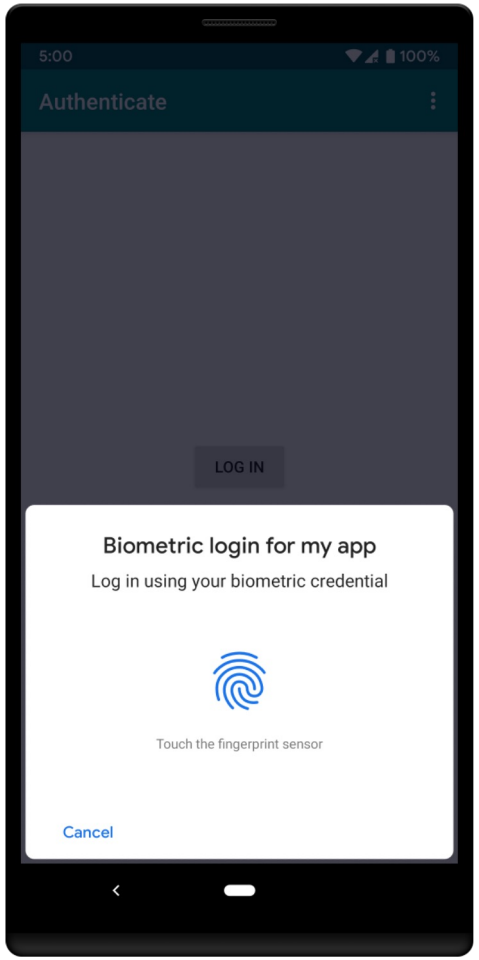

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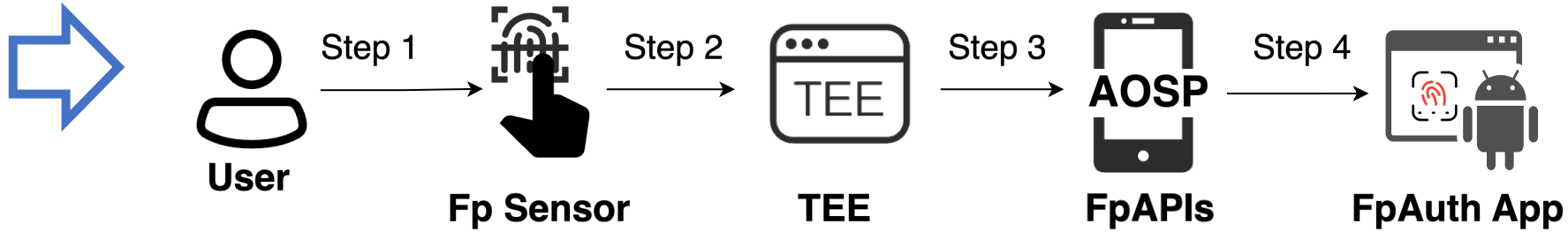

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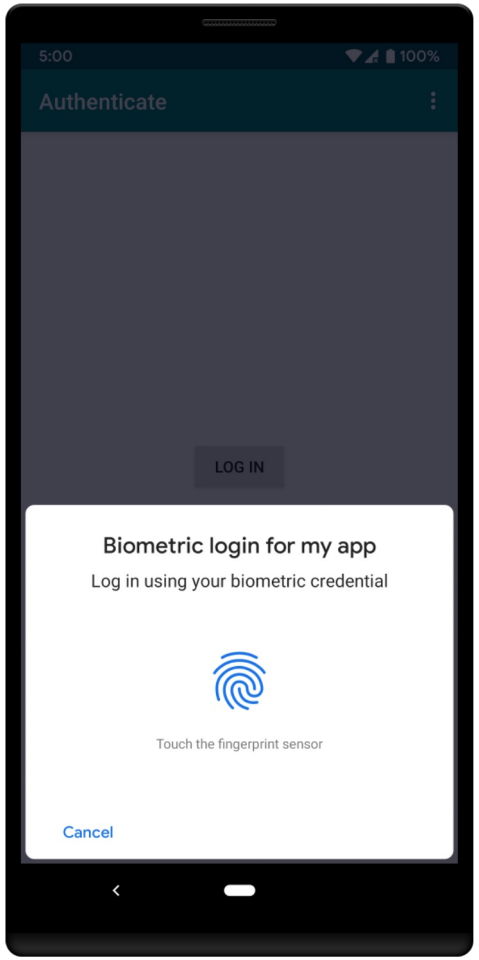

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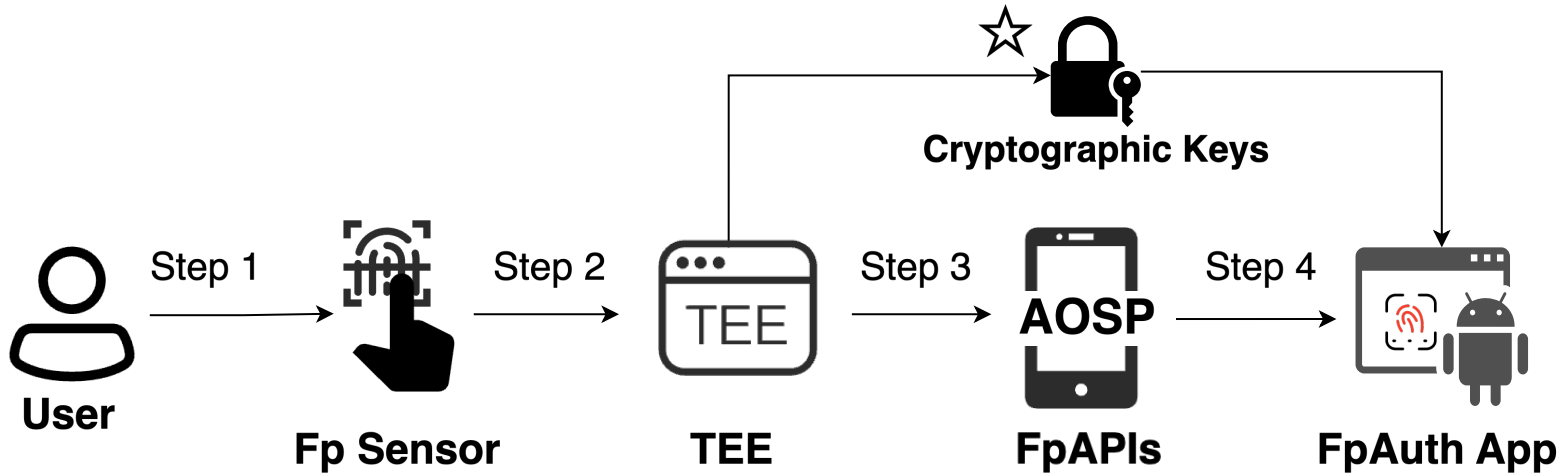
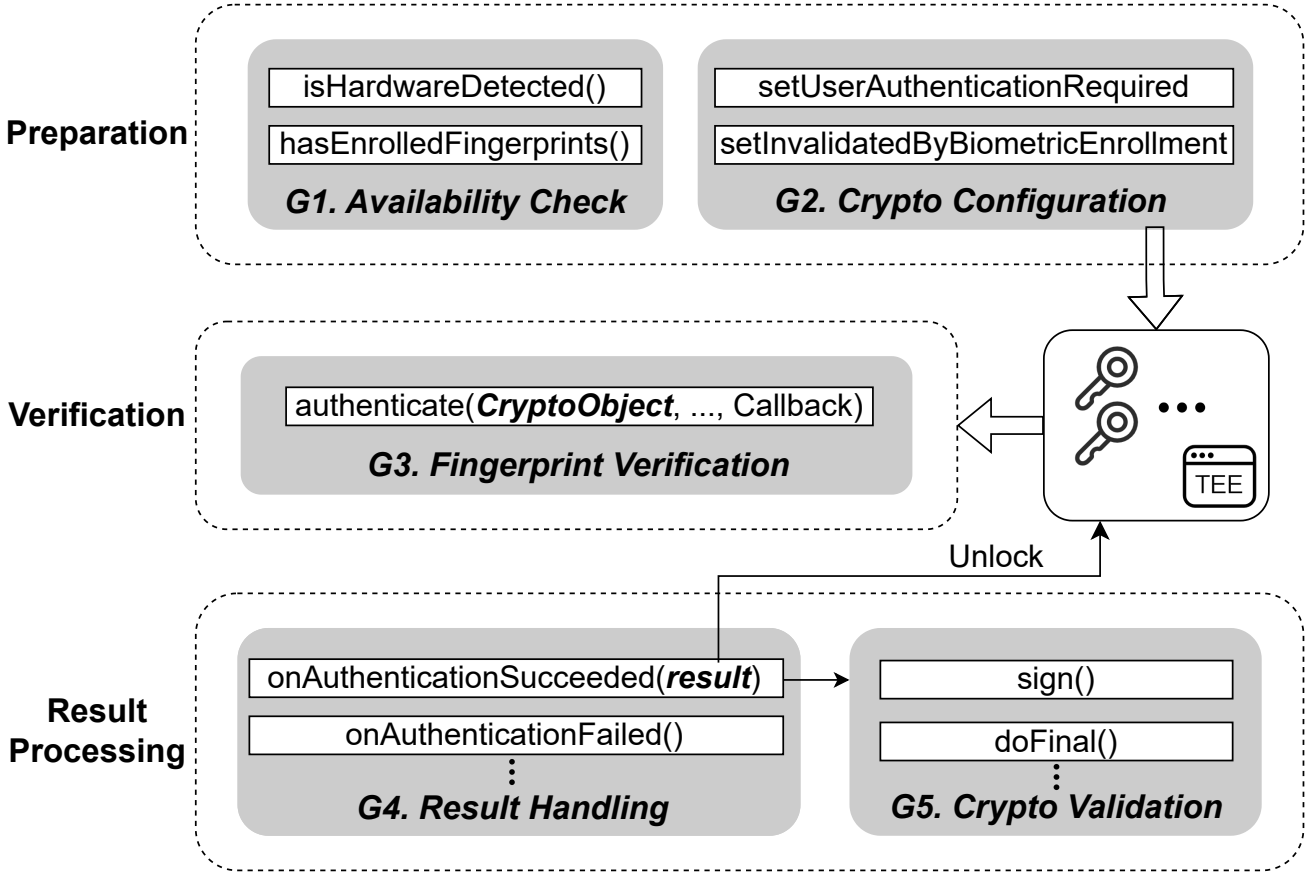


FpAuth in Android Apps

For developers, how to implement?

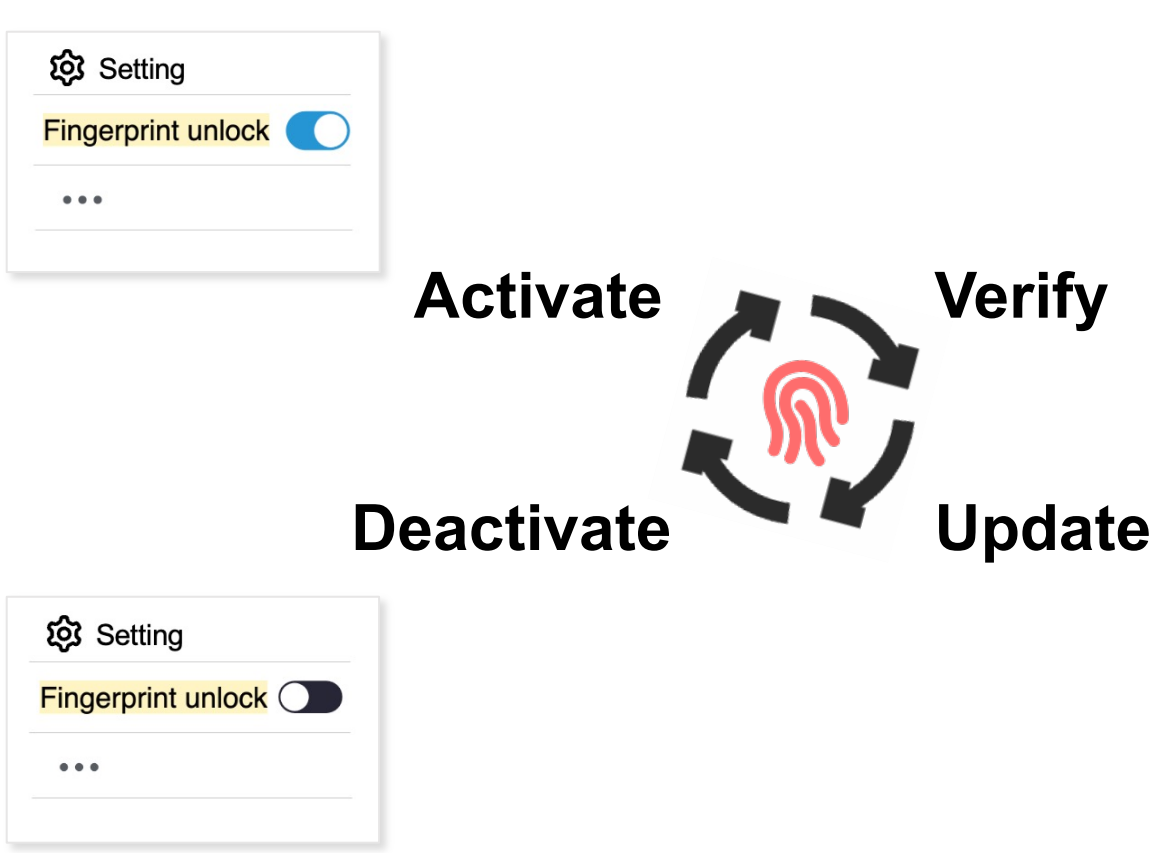


- Android APIs for FpAuth
  - ***Complicated***
    - 5 groups of related APIs
    - Combined with crypto
  - ***Evolving***
    - Issued in 2015
    - Migrated in 2018

Developers are prone to misuse

FpAuth Lifecycle Analysis

- Systematic analysis from a new perspective – FpAuth lifecycle



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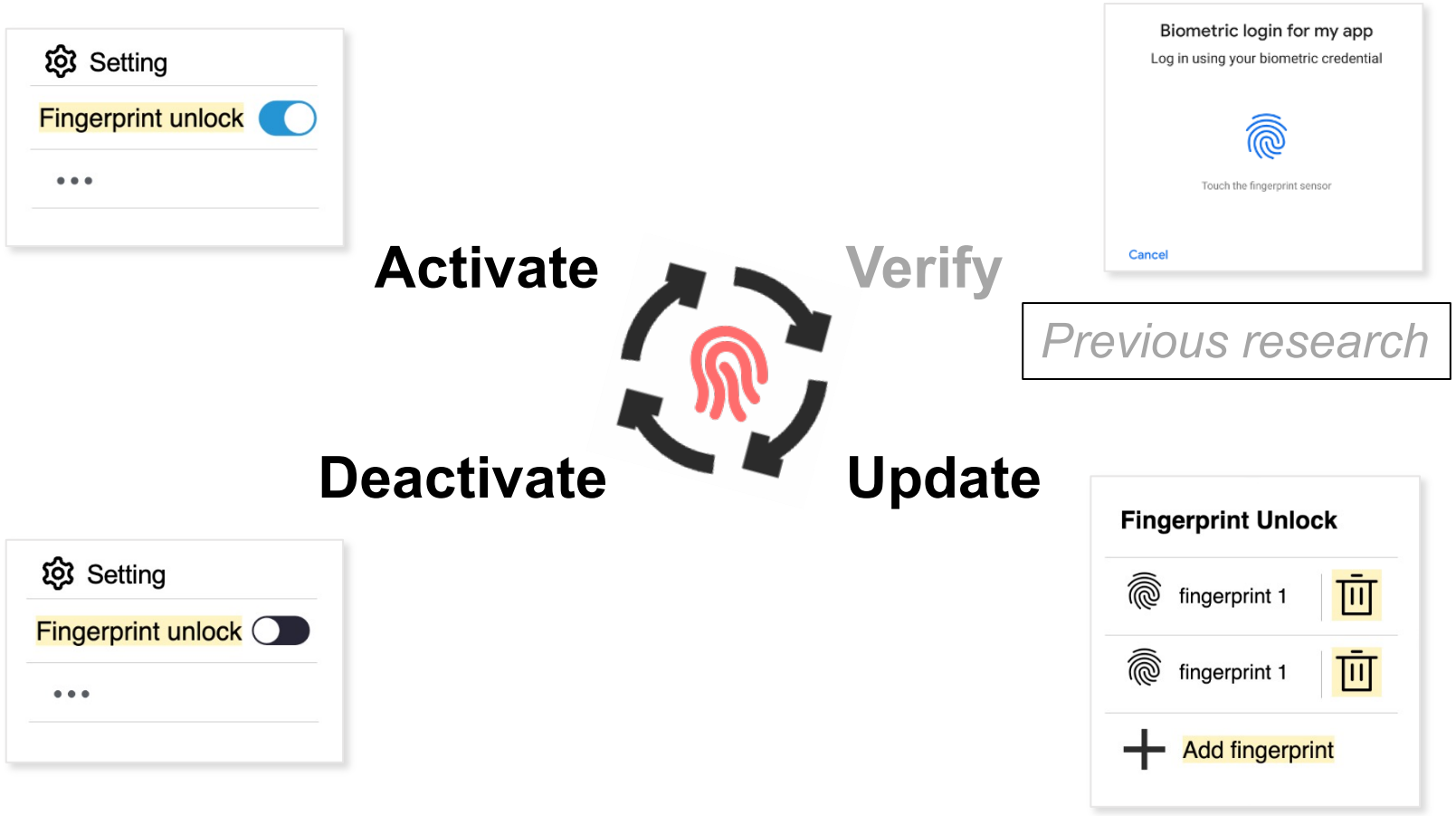

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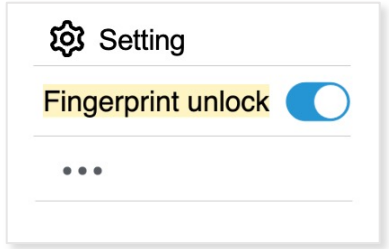
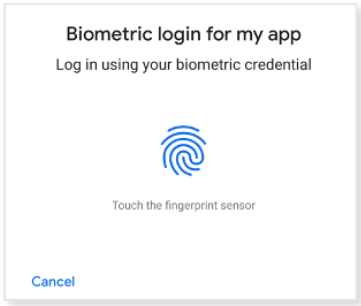




Activate

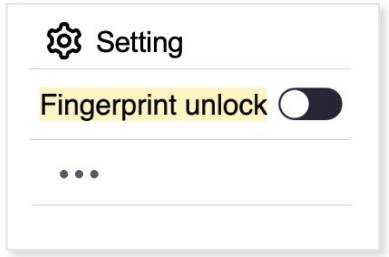
Verify

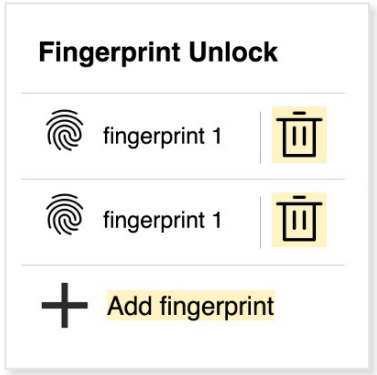
Deactivate

Update

Previous research

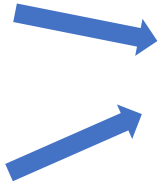
New issues!





Four Types of Misuses

- Misuse #1: Obsolete API Usage
- Misuse #2: Inadequate Cryptographic Validation



Verification

- Misuse #3: Unauthorized Fingerprint Deactivation

Deactivation

- Misuse #4: Mishandled Fingerprint Updates

Update

Fingerprint API Misuse

- **Misuse #1: Obsolete API Usage**
  - Local software-level attacker
  - Using obsolete FpAPI makes it vulnerable to UI attack [PHYjacking-NDSS'22]

[PHYjacking-NDSS'22] Wang, Xianbo, et al. "PHYjacking: Physical Input Hijacking for Zero-Permission Authorization Attacks on Android." NDSS. 2022.
[Broken Fingers-NDSS'18] Bianchi, Antonio, et al. "Broken Fingers: On the Usage of the Fingerprint API in Android." NDSS. 2018.

Fingerprint API Misuse

- **Misuse #1: Obsolete API Usage**
  - Local software-level attacker
  - Using obsolete FpAPI makes it vulnerable to UI attack [PHYjacking-NDSS'22]

- **Misuse #2: Inadequate Cryptographic Validation**
  - Local OS-level attacker
  - Failing to correctly bind crypto → unreliable verification result [Broken Fingers-NDSS'18]

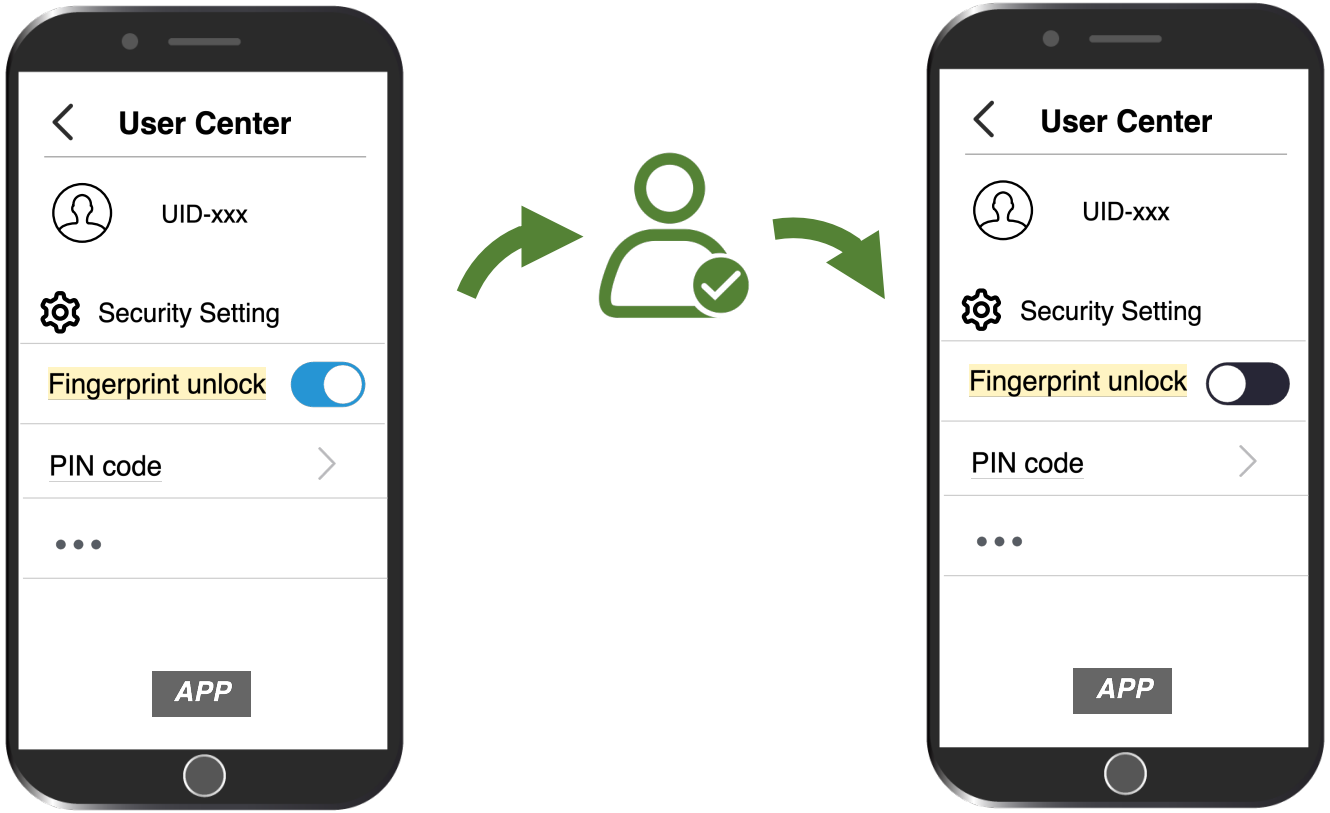
```
    // Pattern 2: Null Cryptographic Object
1   fingerprintmanager.authenticate(null);  // Misuse: Setting parameter crypto to
    null causes FpAuth is not protected by cryptographic key

    // Pattern 3: Failed Key Binding
2   keyGenerator.init(KEY_NAME)
3       ...
4       .setUserAuthenticationRequired(false);  // Misuse: Not explicitly setting this
    API to true causes failure to bind FpAuth with cryptographic key
5   fingerprintmanager.authenticate(CryptoObject(cipher.init(KEY_NAME)), ...);

    // Pattern 4: Failed Result Validation
6   keyGenerator.init(KEY_NAME)
7       ...
8       .setUserAuthenticationRequired(true);
9   fingerprintmanager.authenticate(CryptoObject(cipher.init(KEY_NAME)), ...);

10  public void onAuthenticationSucceeded(result) {
11      log.info("FpAuth succeeded!");  // Misuse: Not validating the result using
    cryptographic key causes the result can be forged
12  }
```

Code example of M2

[PHYjacking-NDSS'22] Wang, Xianbo, et al. "PHYjacking: Physical Input Hijacking for Zero-Permission Authorization Attacks on Android." NDSS. 2022.
[Broken Fingers-NDSS'18] Bianchi, Antonio, et al. "Broken Fingers: On the Usage of the Fingerprint API in Android." NDSS. 2018.

Fingerprint API Misuse

- **Misuse #3: Unauthorized Fingerprint Deactivation**



Threat Model

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  - Has a one-time opportunity to access
  - Aims for permanent access

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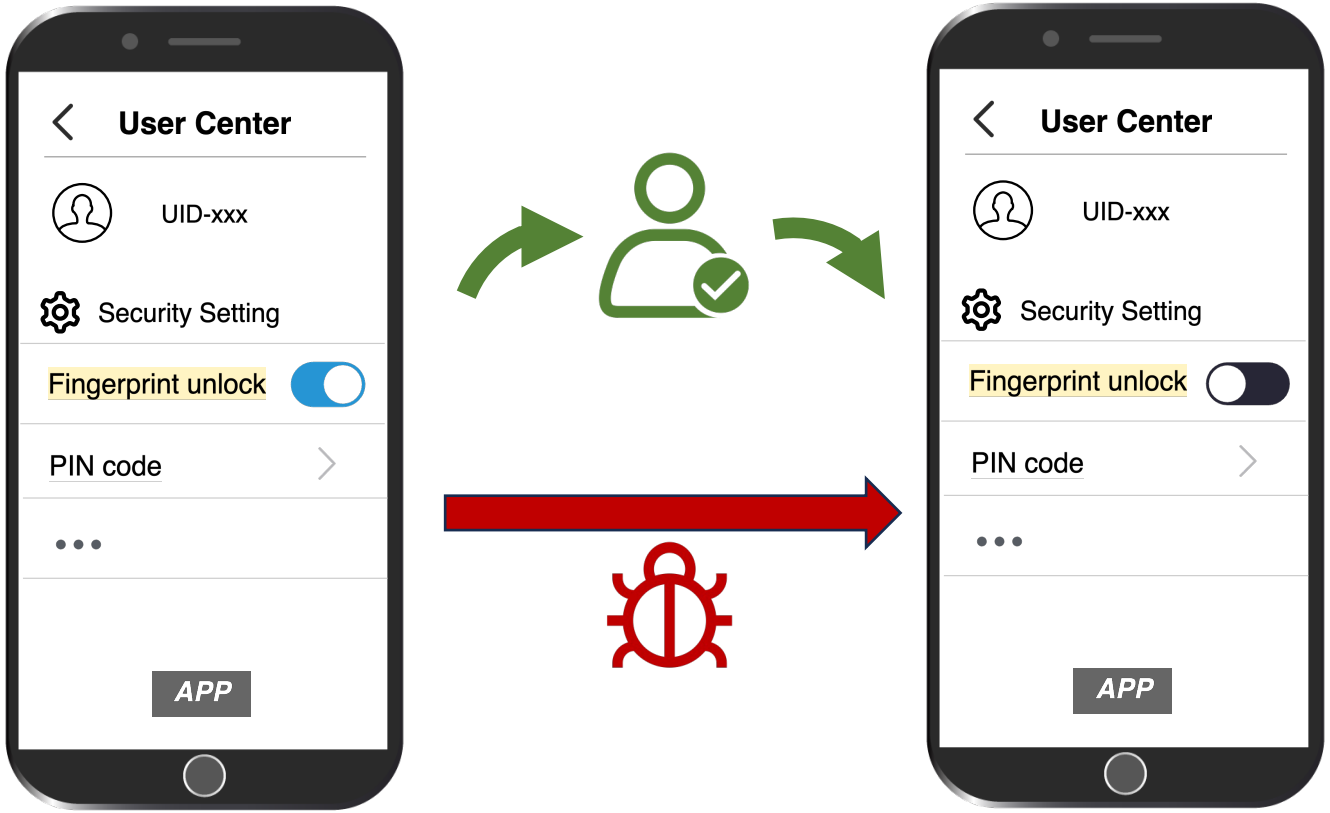

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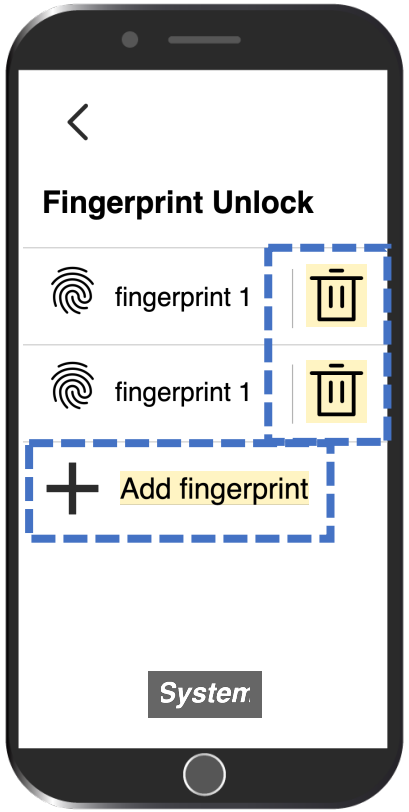
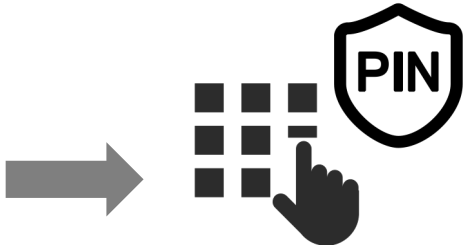
FpAuth protection can be disabled, allowing unauthorized access

Fingerprint API Misuse

- **Misuse #4: Mishandled Fingerprint Updates**





Add a new/remove all fingerprint by verifying PIN code

Fingerprint API Misuse

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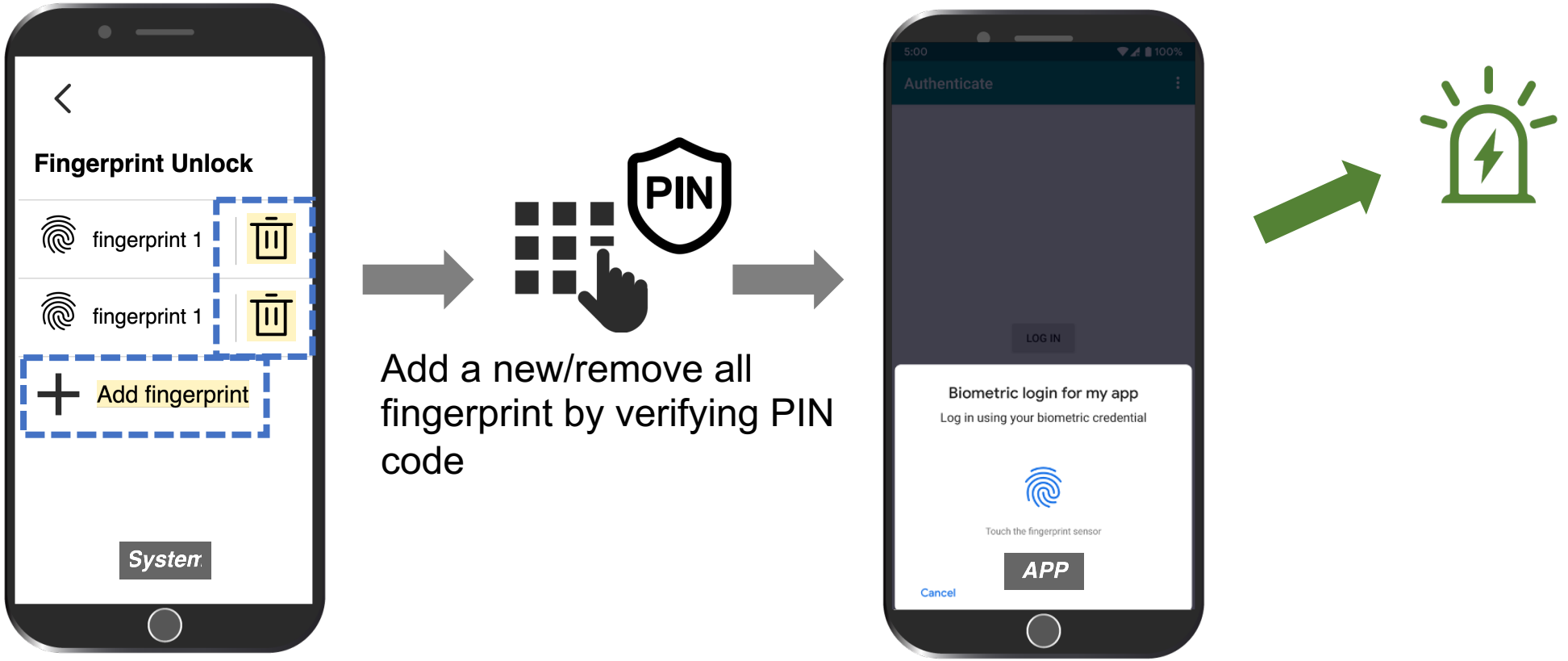

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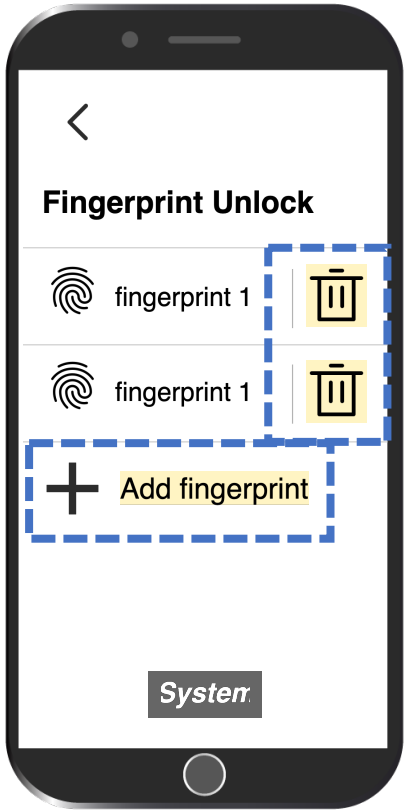

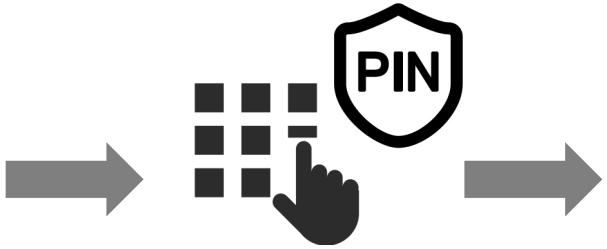

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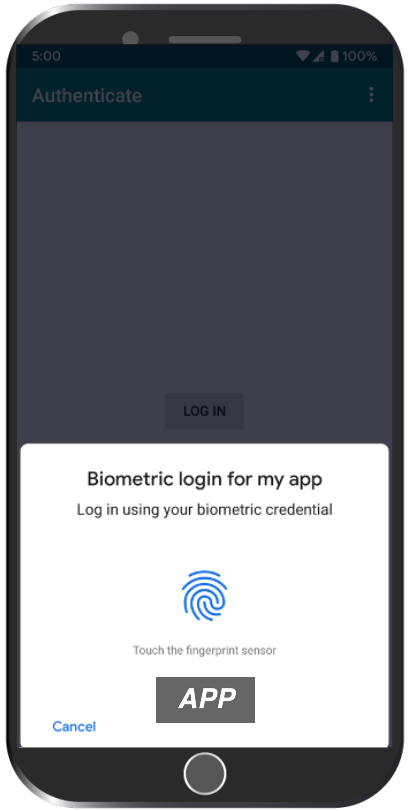

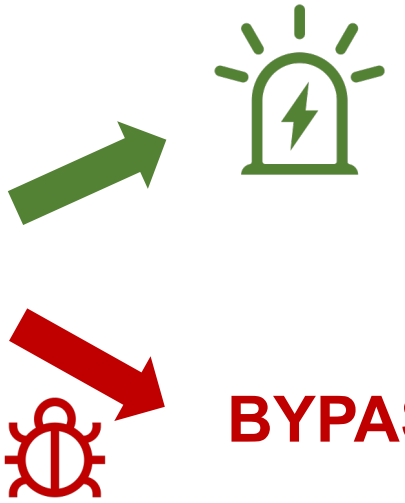

BYPASS

Degrade dual protection to single, lowering security level

Fingerprint API Misuse

- **Misuse #4: Mishandled Fingerprint Updates**

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  - Knows locking PIN
  - Aims to bypassing FpAuth

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PIN is weak!

- Shoulder surfing
- Guessing attacks
- ……

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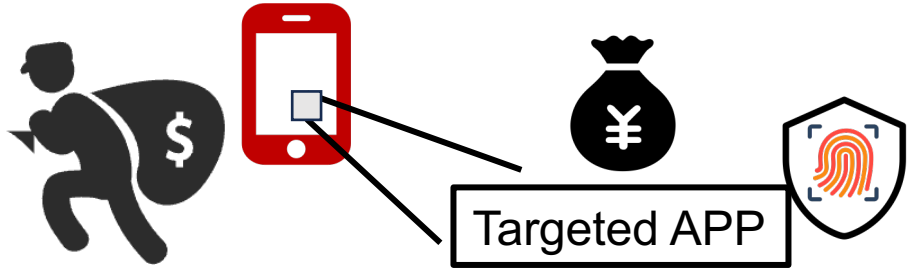

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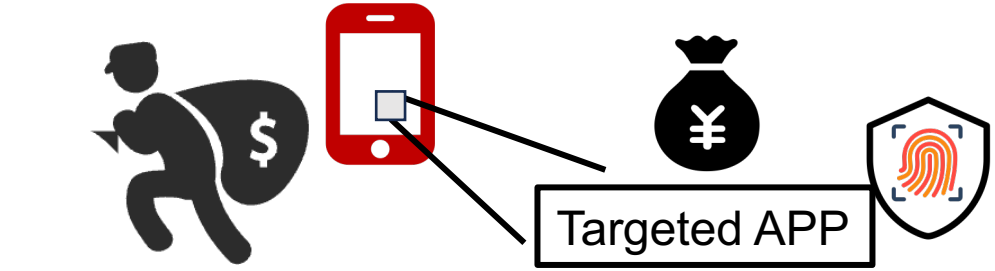

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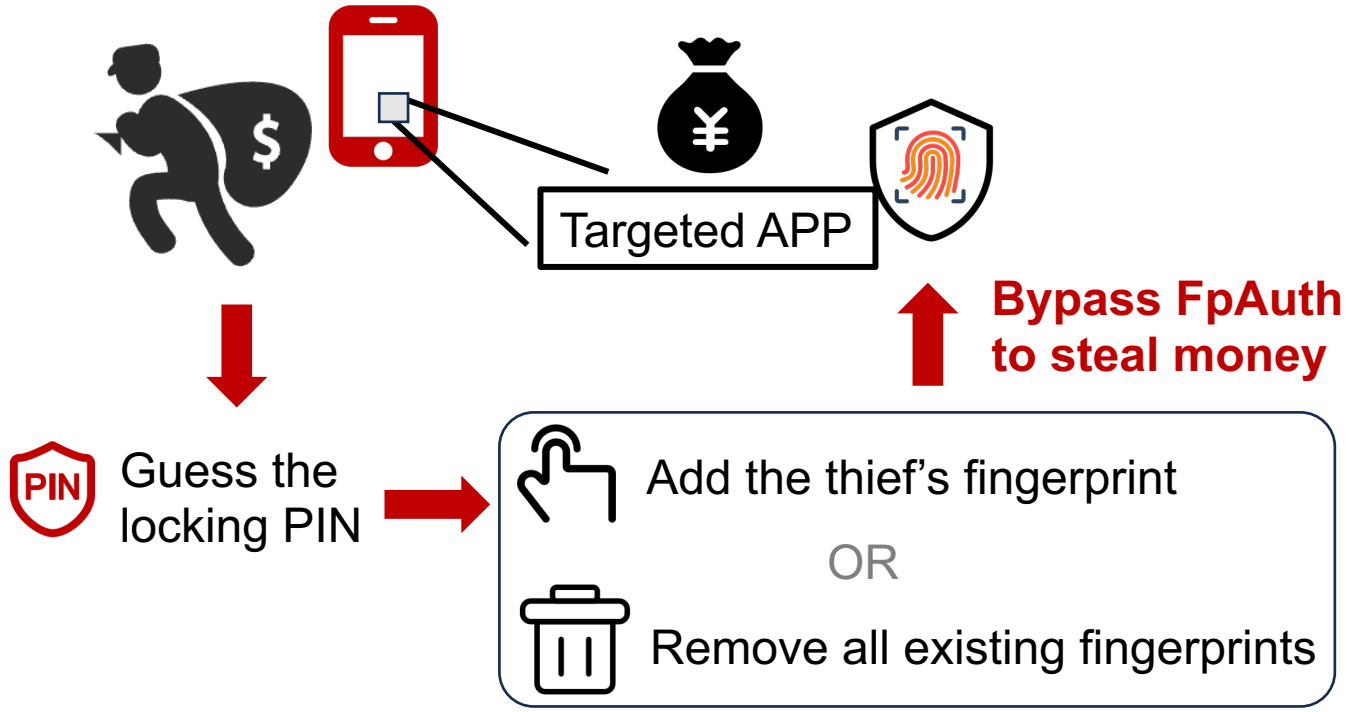
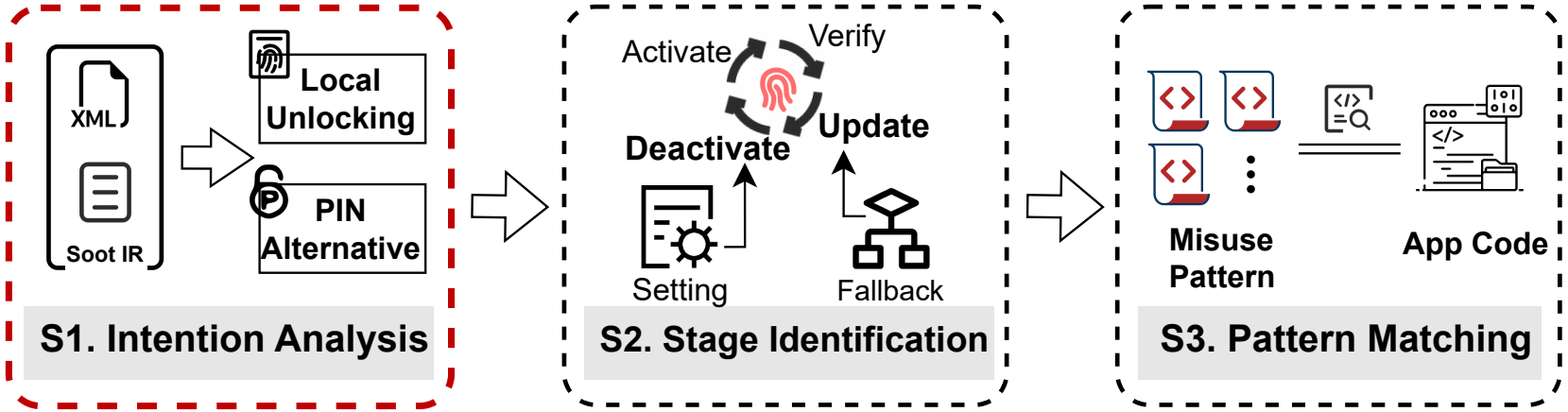


Misuse Detection

- Step 1. Intention Analysis



Considering two special app intentions

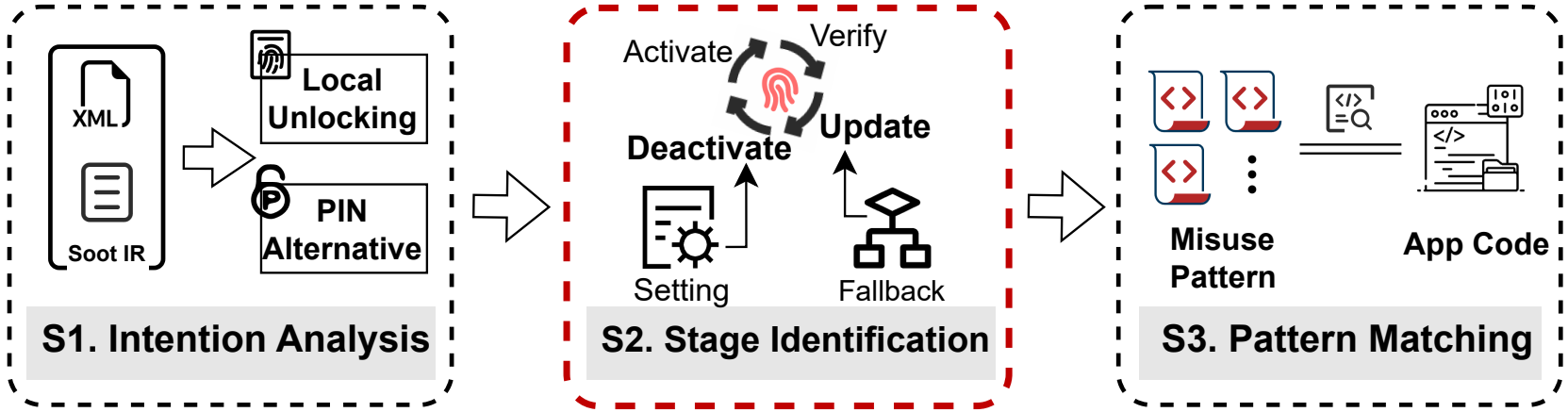
Local Unlocking → Not considering M2. *Inadequate Cryptographic Validation*

PIN Alternative → Not considering M4. *Mishandled Fingerprint Updates*

- Detection
  - UI semantics
  - Code semantics

Misuse Detection

- Step 2. Stage Identification



Identify two special stages

Deactivation

Fingerprint unlock

"Switch" component

Authenticate API

Call chain

onCheckedChanged

Update

Add

setInvalidatedByBiometricEnrollment

Remove

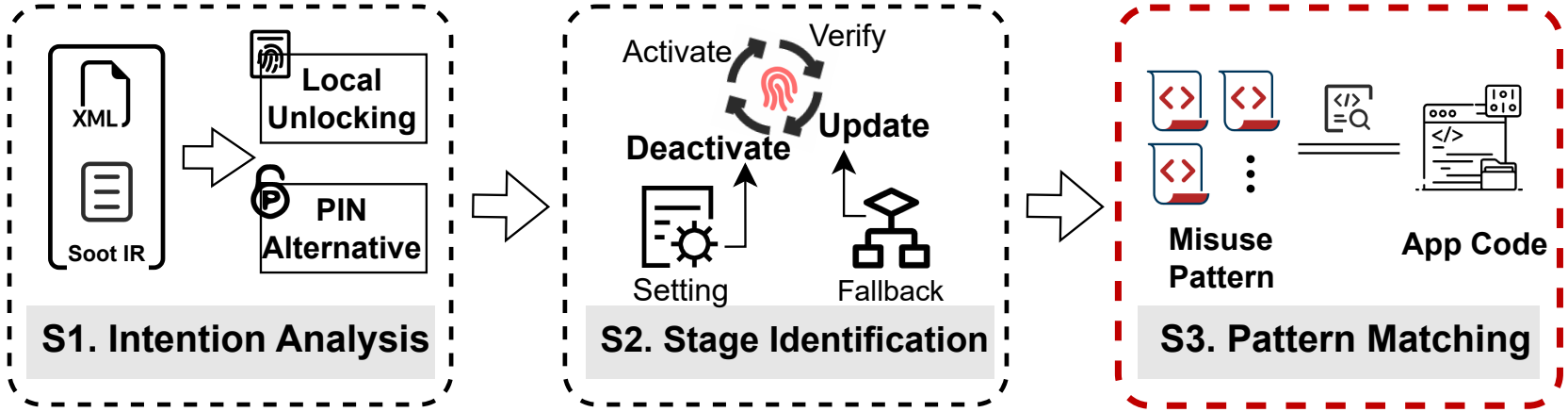
hasEnrolledFingerprints

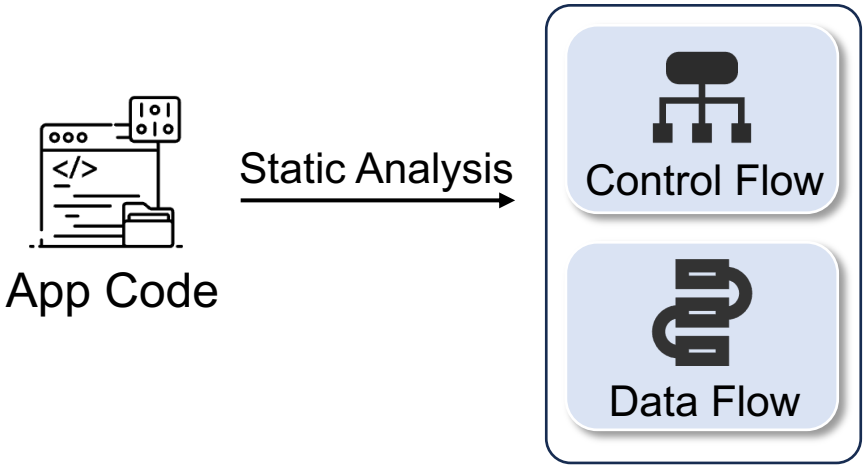
FpAuth

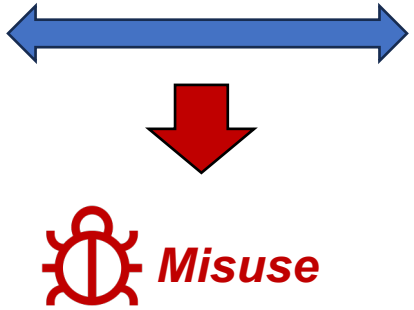
No Auth

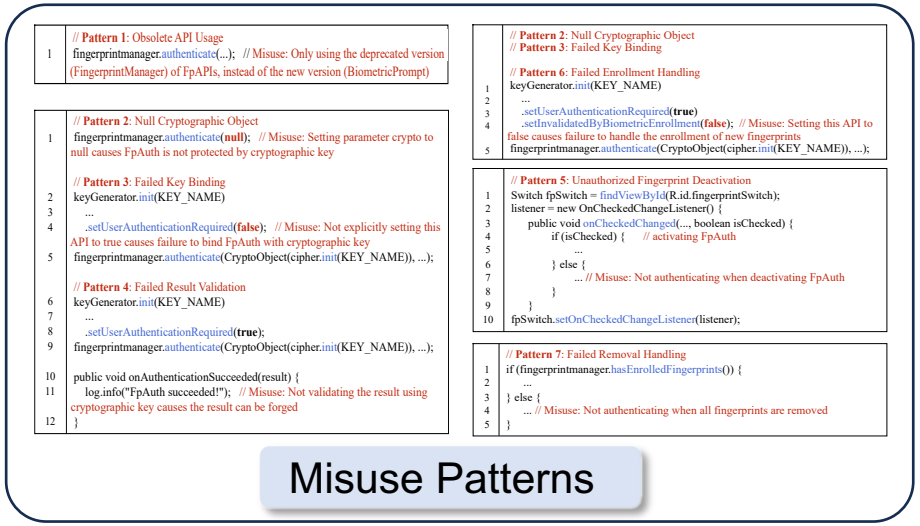
Misuse Detection

- Step 3. Pattern Matching









FpAPI Misuses in Real-world Apps

- Dataset

# Apps	Market	# Categories
29,848	Google Play	37
35,238	Huawei Market	16

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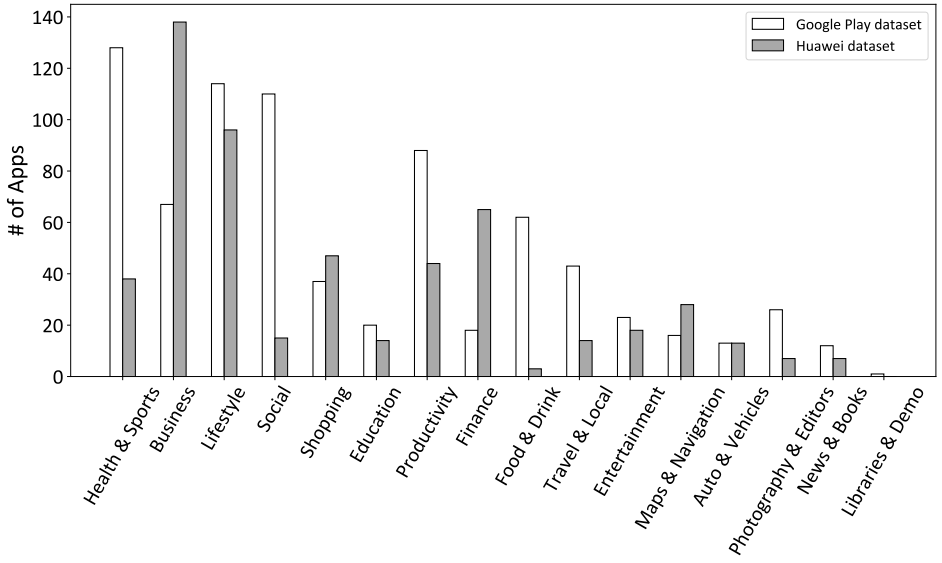
- Identifies *1,333* FpAuth apps
  - Sensitive categories
  - Collectively over 218 billion installations

FpAuth exhibits significant impact!



FpAPI Misuses in Real-world Apps

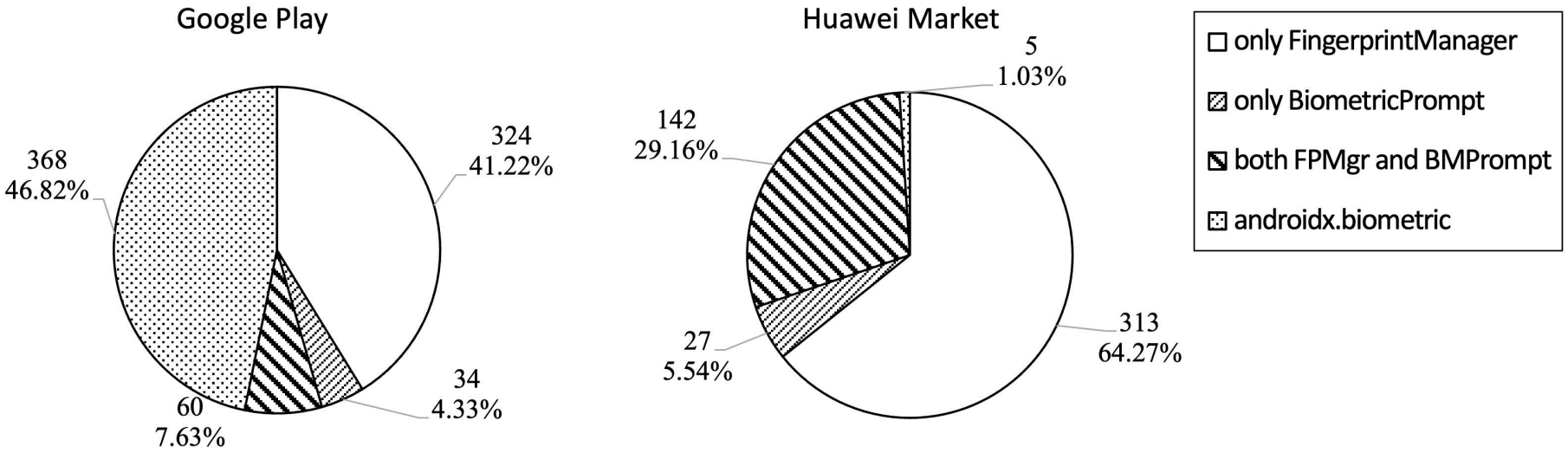
- Overall Result
  - Nearly all FpAuth apps (97.15%) have at least one misuse
  - Each type of misuses are present in nearly or over half of FpAuth apps

Four types of misuses in 1,333 FpAuth apps

Misuse	# Apps (Proportion)	# Misuse	# Apps (Proportion)
M1. Obsolete API	637 (47.79%)	1	179 (13.43%)
M2. Weak Crypto	999 (74.94%)	2	377 (28.28%)
M3. Unauthorized Deactivation	871 (65.34%)	3	488 (36.61%)
M4. Mishandled Updates	894 (67.07%)	4	251 (18.83%)
# Apps without Misuse			38 (2.85%)

FpAPI Misuses in Real-world Apps

- Findings – *Obsolete use of FpAPI (M1)*
  - **Five years after the release of the new secure FpAPI, 47.79% still use the obsolete FpAPI (M1)**



  - *Androidx.biometric* library is recommended but underutilized

FpAPI Misuses in Real-world Apps

- Findings – *Ineffective protection (M3)*

Verification practices when activating/deactivating FpAuth (M3)

	Verified Deactivation	Verified Activation Only	Verified None
# Apps	462 (34.66%)	120 (9.00%)	751 (56.34%)

  - 120 (9%) apps authenticate when activating FpAuth but fail to authenticate when deactivating it ⇨ cannot guarantee the integrity of FpAuth protection

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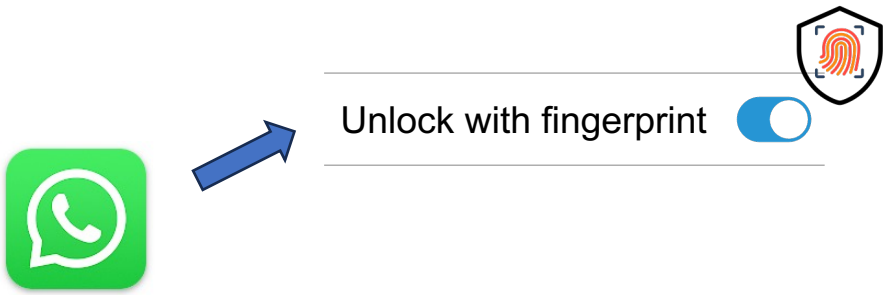

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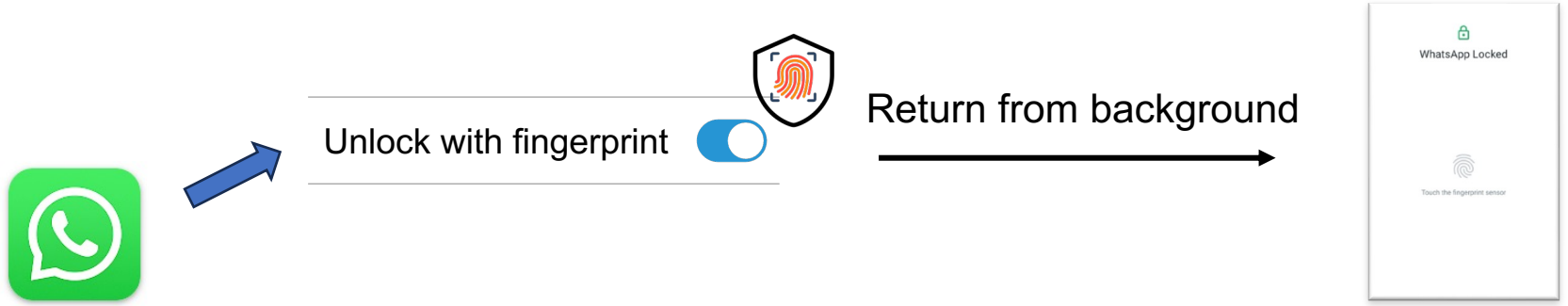

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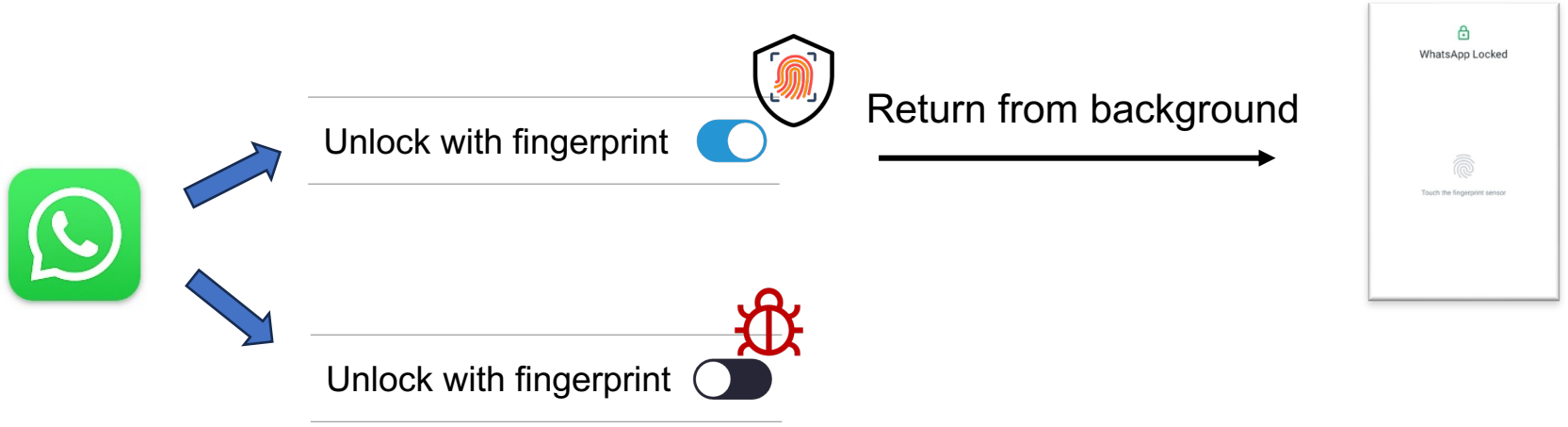

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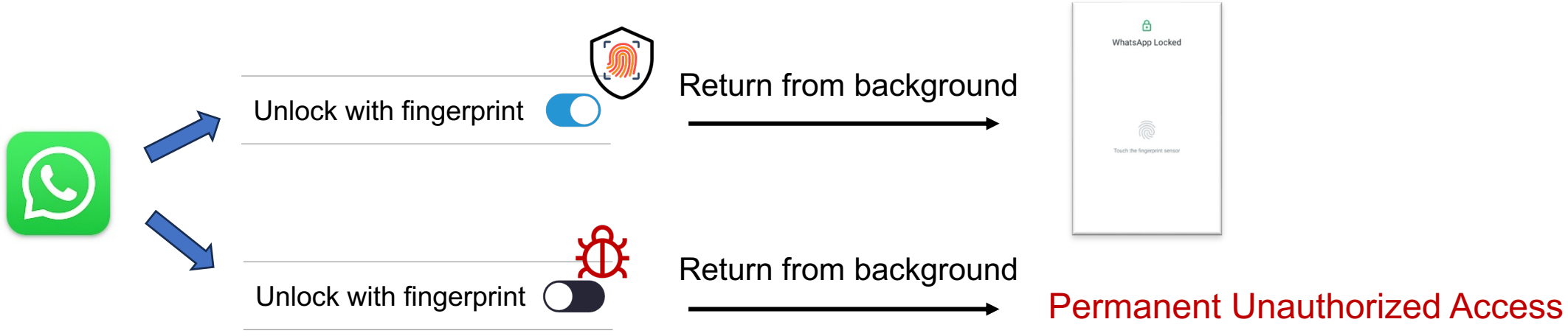

FpAPI Misuses in Real-world Apps

- Findings – *Insufficient security awareness / knowledge (M4)*

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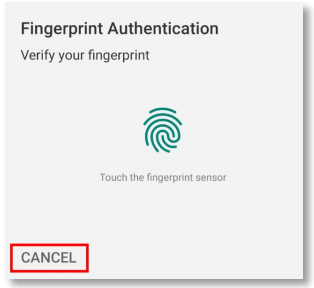

➢ disallow PIN as alternative

Prioritizing functionality over security

setInvalidatedByBiometric Enrollment → False

➢ configure to ignore fingerprint updates

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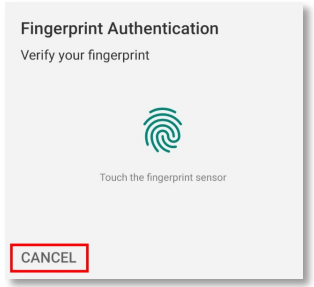

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Prioritizing functionality over security

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➢ configure to ignore fingerprint updates

5 apps – Insufficient security knowledge

setInvalidatedByBiometricEnrollment → True ✓

setUserAuthenticationRequired → False ✗

Nullify the security intention

Responsible Disclosure

- Report the issues to vulnerability repositories and developers
  - Apps from Google Play – CVE
  - Apps from Huawei Market – CNVD (Chinese)

	CVE ID	CNVD ID	Developer
Number	184	19	15

Summary

- Comprehensive study from the new perspective – lifecycle of FpAuth in apps
  - New threat models
  - Four common FpAPI misuse types
- Effective static tool to detect FpAPI misuses
- Large-scale measurement on real-world apps to reveal the significant security breaches

Thanks!

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