Do security tools work?

- Adwait Nadkarni

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CHARTERED 1693


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The breaches also point to a new hacking strategy that can compromise secure systems through the use of old passwords.
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ransom, you know IoT is screwed
Watch along as hacked machine grinds, beeps, and spews water.
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Hacked Nest Cam convinces family that US is being attacked by North Korea
Nest says its systems weren't breached.
Richard Nieva, Laura Hautala Jan. 22, 2019 4:27 p.m. PT
5
Security Risks Can Be
y 3, 2019
Security flaws found in popular smart home devices
Science Nov 6, 2019 12:32 PM EDT

Home automation

Home automation

trigger

1 When Alice leaves, turn the Camera ON (*for **security***)

action

trigger

2 When Alice returns, turn the Camera Off (*for **privacy***)

action

Home Automation ***routines***/ ***IoT apps***/*programs*

Security Implications of Home Automation

Bob wants to steal from Alice
without being monitored

Security Implications of Home Automation

Bob wants to steal from Alice *without being monitored*

Bob tries to directly attack the security camera, *and fails*

Security Implications of Home Automation

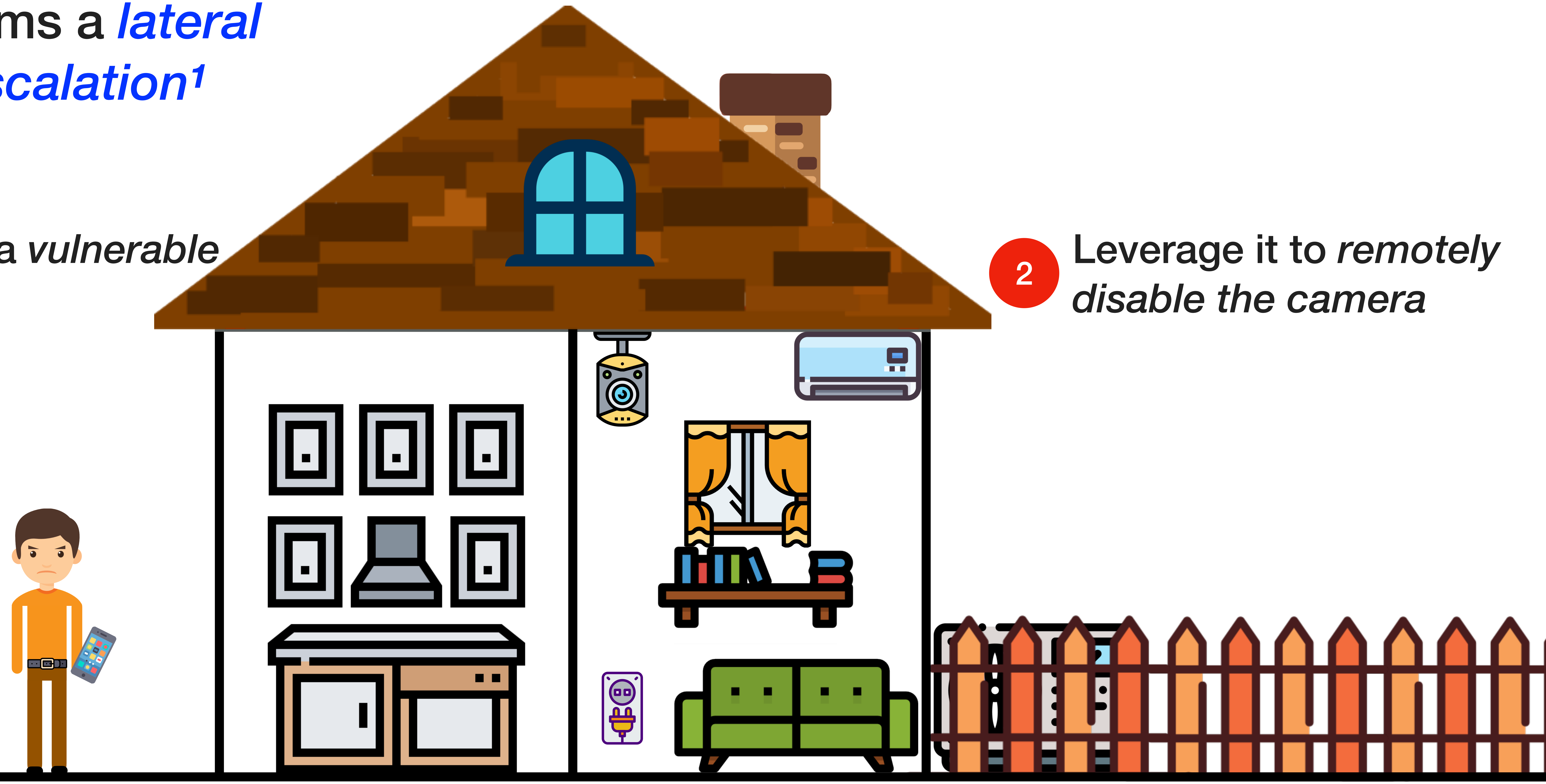
Bob wants to steal from Alice *without being monitored*

Bob tries to directly attack the security camera, *and fails*

However, **Bob** can *indirectly* attack the camera

Security Implications of Home Automation

Bob performs a *lateral privilege escalation*[1]



1. Compromise a *vulnerable* component
2. Leverage it to *remotely disable the camera*

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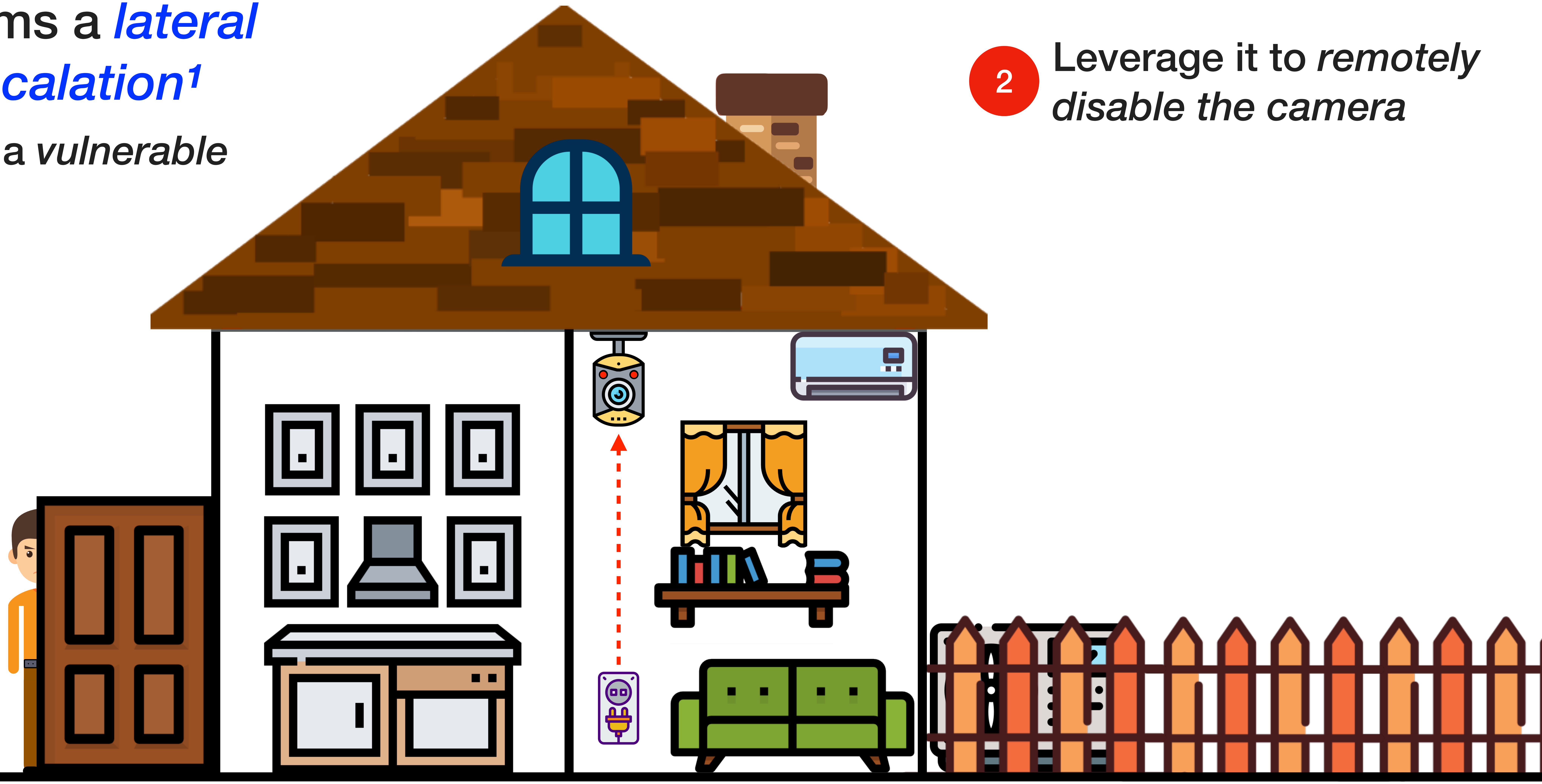

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TP Link Kasa app + MiTM Attack

Auth Token

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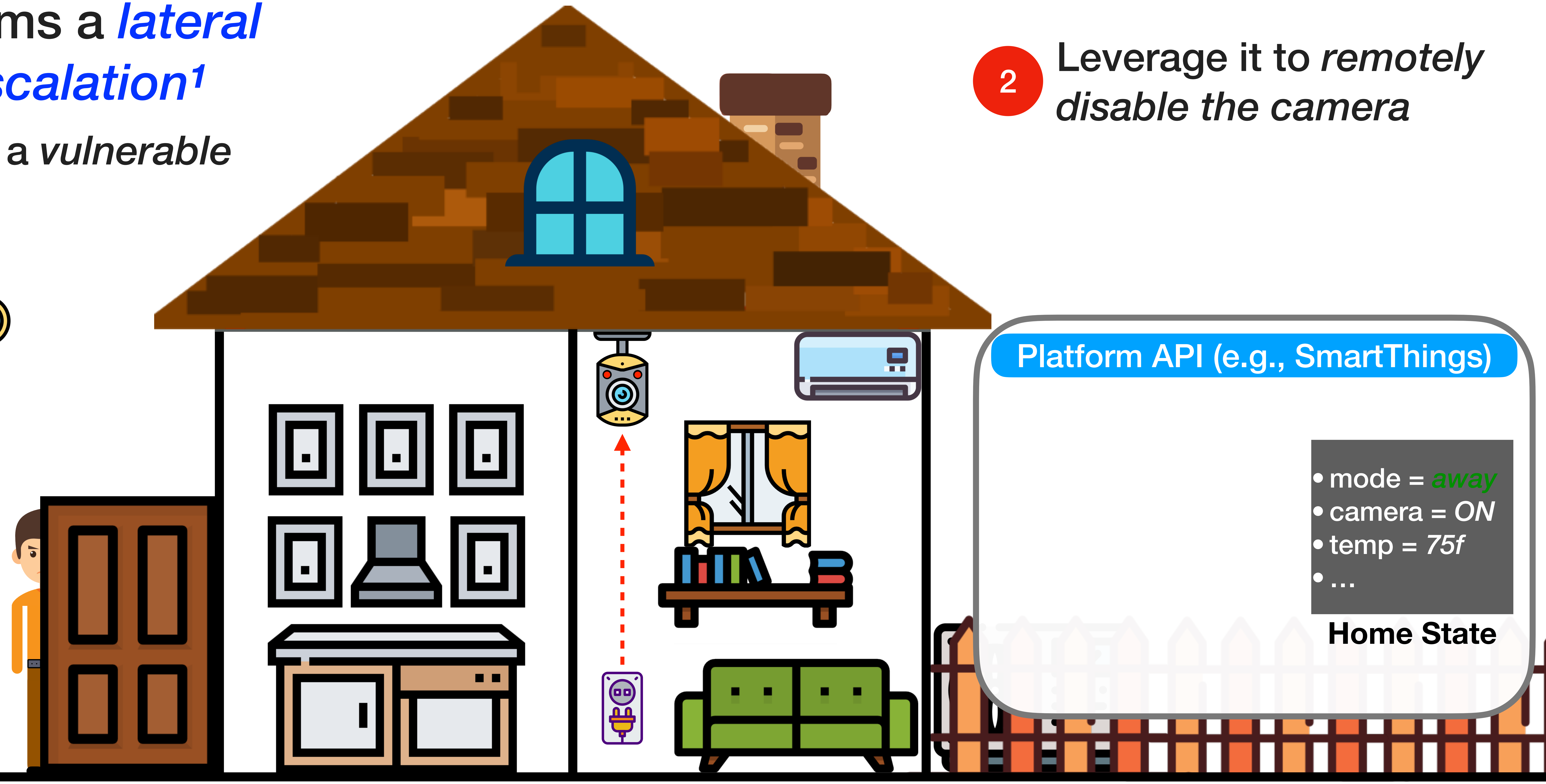

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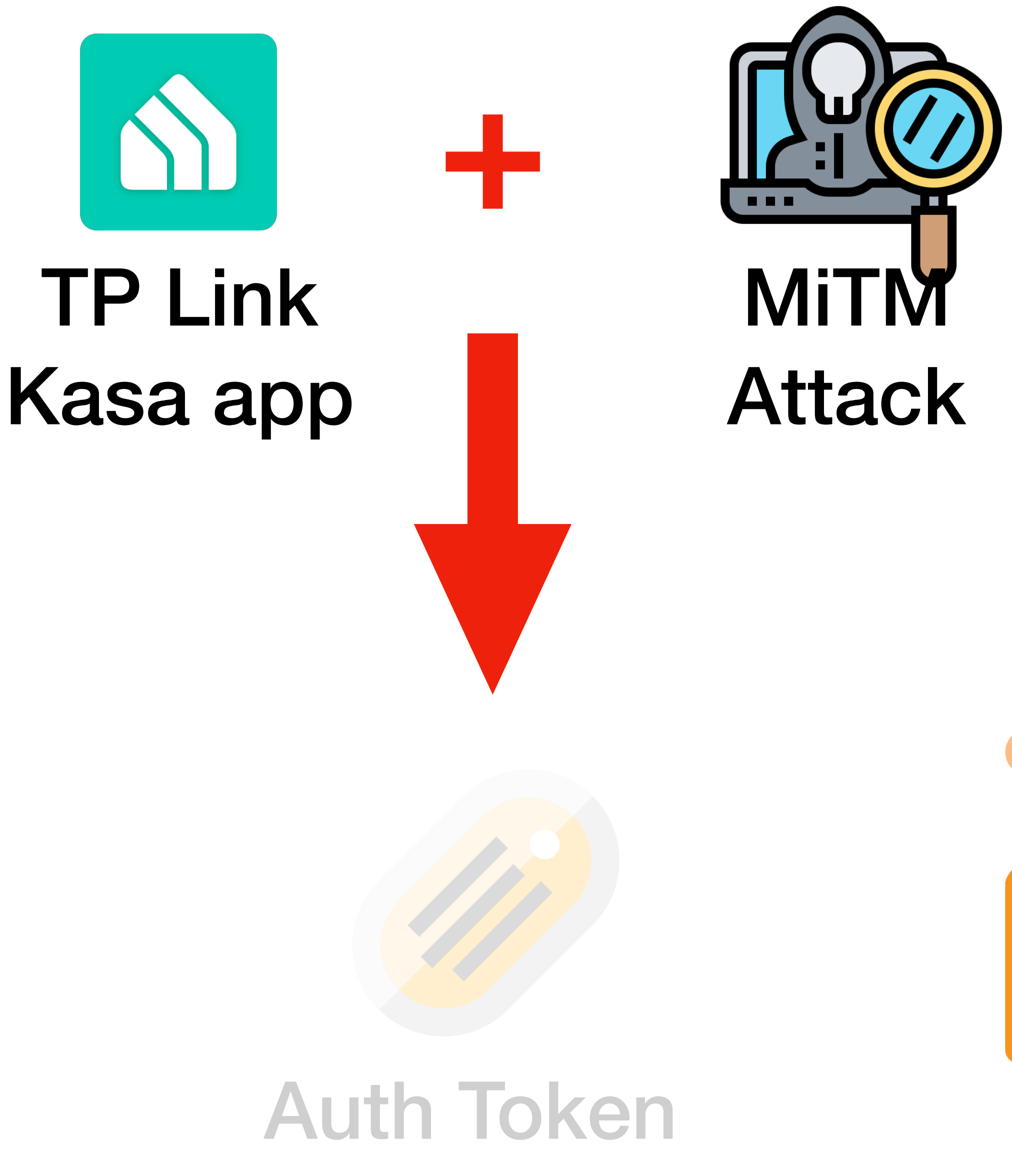

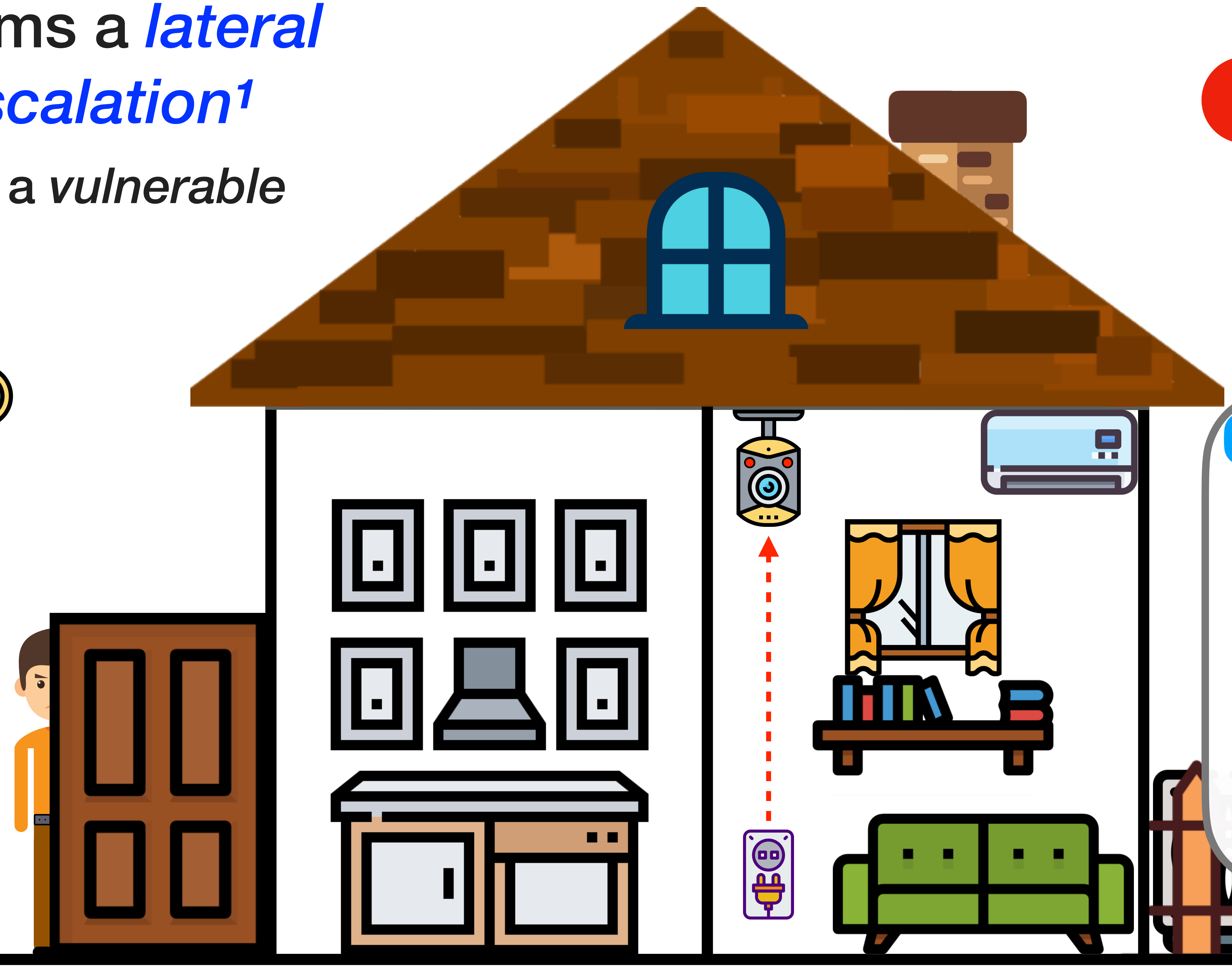

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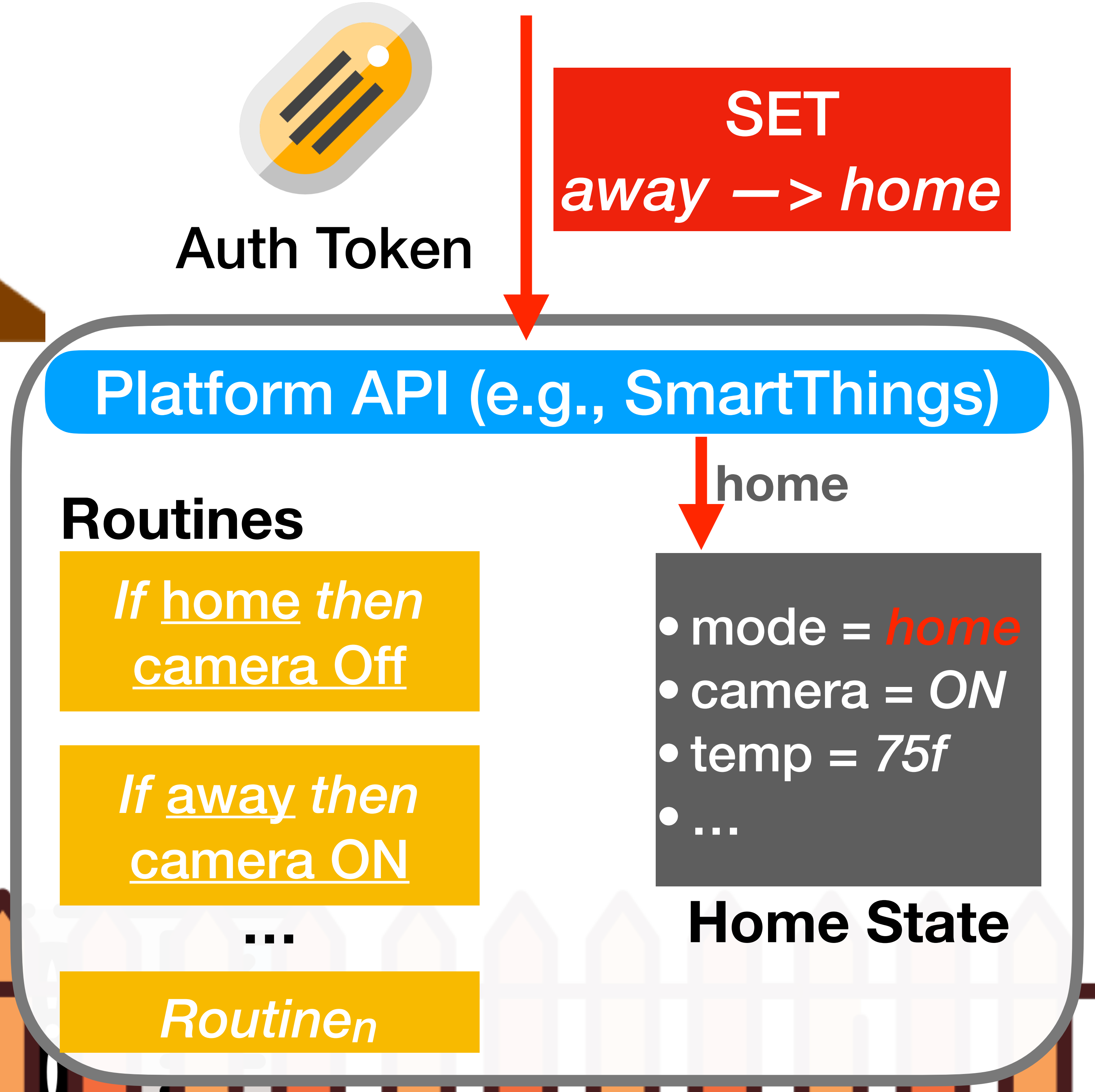

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Several popular security tools, often integrated into CI/CD pipelines (e.g., GitHub Code Scan)

CryptoGuard

CogniCrypt

ShiftLeft

SpotBugs

Coverity

QARK

sonarqube

Codiga

Checkmarx

CODACY

{/code.scan}

SYNOPSYS

VERACODE

XANITIZER
... because security matters

SECURE CODE
WARRIOR

Do Security Tools Work?

RQ$_1$ — Do security tools and techniques detect the *vulnerabilities that they claim to detect*?

[**S&P'22**, TOPS'20, USENIX'18]

RQ$_2$ — Do the tools detect vulnerabilities *as developers expect them to*?

[**S&P'24**]

Real-world implications of failures of (automated) security analysis

[**USENIX'24**, NDSS'24, CCS'22, USENIX'22]

Context: Static Analysis Security Tools (SAST) used for detecting *crypto-API misuse*

CryptoGuard, ShiftLeft, CogniCrypt, QARK, SpotBugs, Coverity, sonarqube, Xanitizer ... because security matters

Evaluating Security Tools

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Rigorously Evaluating Security Tools

RQ$_1$ — Do security tools and techniques detect the *vulnerabilities that they claim to detect*?

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*"**Variants**" of the base case*

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Research Gap: The lack of a *systematic* approach for *rigorously* and *automatically* evaluating security tools; crypto-API misuse detectors (or crypto-detectors) in particular

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Mutation Analysis for evaluating Static Crypto-API misuse detectors (*MASC*)[1]

Contextualize mutation testing to ***systematically*** generate variants, and ***rigorously*** evaluate SASTs

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What to mutate?

Crypto API Misuse Taxonomy

105 Crypto API misuse cases

Categorized to 9 Clusters based on *Semantic* Meaning

Covers last 20 years of Study from Industry & Academia

Required Over 2 person months to extract misuse cases

...ent & Server Secrecy (20)

Small Key Size
- Using RSA with < 1024 bit key (7)
- Using RSA with < 2048 bit key (3) +
- Using RSA with 2048 bit private key (1)

Weak Algorithm
- Using RSA with CBC (1)
- Using RS...
- Using R...

Weak Certi...
- Improp...
- Trustin...
- Missing...
- Improp...

Weak Hostname Management
- Allowing all hostnames (10) ✔
- Using D...

Weak SSL P...
- Using w... {SSL...
- Using S...
- Using S...
- Using S...
- HMAC for TLS with SHA1 (1)
- Using CBC for SSL/TLS with AES (1) *
- Using TLS < v 1.2 (1)
- Using TLS < v 1.1 (3)

Compromising Randomness (5)

Misuse of Randomness
- Bad derivation of IV (file/text) (4) ✔
- Low entropy in key generation/ RNG (3)
- Using static seeds for Secure Random RNG (7)
- Not using Secure Pseudo RNG (7)
- Using Setseed (3)

Compromising Non-Repudiation (3)

Key Signing Misuses
- Low entropy with DSA (1)
- Low entropy with ECDSA (1)
- Using 1024 bit DSA (2)

Unclustered (6)

- Inscure pinning with ambiguous values
- Trusting Self-signed Certificates +
- Using unencrypted server socket
- Using unencrypted socket
- Using export quality ciphers
- Using stateless encryption

API/Program Specific Misuses (17)

API/Program Specific
- Apache `HTTPClient` no host verification (1)
- `Gnutls_certificate_verify_peers2` returns 0 when self signed certificate (1)
- Constant password for android keystore (2)
- JSSE checkTrusted method does not check identify if the algorithm field is null or empty string (1) ✔
- ...droid Webview incorrect certificate verification ...
- ...va defaults to `ECB` for encryption with "`AES`"
- ...berknecht does not have host verification (1)
- ...ing `DefaultHttpClient` (due to no TLSv1.2) (1...
- ...oring `onReceivedSSLError` (3)
- ...`LSocketFactory` without verifying Hostname
- ...using counter value in encryption (2)
- Apache `HttpHost` data allows mixed schemes (1)
- Using obsolete algorithm (11) ✔
- Storing sensitive data in Java `String` (3)
- ...ing `Socket` directly for connection (1)
- ... `clearPassword` call after using `PBEKeySpec`
- ...`EKeySpec` initialized without salt (2)

...romising Secret Keys (12)

Secret Key Misuses
- Using low entropy seeds in key generation (1)
- Password Based Key Derivation Function (PBKDF) Using < SHA224 (1)
- Not using Salts while hashing password (1)
- PBKDF Using HMAC (1)
- PBKDF Using MD5 (3)
- PBKDF Using MD2 (2)
- IVs generated w/o random num generator (1) ✔
- Static IV (4) ✔
- Zeroed IV (2)
- Using hardcoded key / password (3)
- Using Constant Encryption Key (9)
- Using < 64bit salt for password (2)

Compromising Communication Secrecy with Intended Receiver (6)

Communication Secrecy Compromised
- Use of a key past its expiration date (1)
- HTTP and HTTPs mixing (3)
- Key Exchange without Entity Authentication (1)
- Improper Check for Certificate Revocation (1) ✔
- Improper Validation of Certificate with Host Mismatch (1) ✔
- Untrusted CA Signed Certificate (1) ✔

Compromising Secrecy of Cipher Text (26)

Insecure Key Size
- ECC < 224 bit (2)
- Using AES with < 128 bit key (1)
- Using RC2 with < 64 bits (1)

Insecure Number of Iterations/Cycles
- Using < 500 iterations for PBE (1)
- ...

...

- ...or
- Using AES with CBC for Encryption * (2)
- Using DESede with ECB (1)
- Using DES with CBC3 SHA (1)
- ...aining

Unsafe Algorithm Usage
- Using RC2 for symmetric encryption (4)
- Using NullCipher to encrypt plain text (1)
- Using Blowfish Algorithm for Encryption (4)
- Using ESAPI Encryptor (1)
- Using 3DES/DESEDE for encryption (4)
- Using RC4 (3)
- Using IDEA Algorithm for Encryption (3)
- Using DES for encryption (8) ✔
- Using EXP1024 for ciphers (1)
- Using Seed Cipher (1)
- Using blowfish with less than 128 bit key (1)

Compromising Integrity through Improper Checksum Use (10)

Compromised Checksums
- Hashing credentials - MD5 (5) ✔
- Hashing Credentials - MD4
- Hashing Credentials - MD2
- Digital Signature Hashes - MD4
- Obsolete Hash Algorithm (7) ✔
- Hashing Credentials - SHA1
- Digital Signature Hashes - MD5 (5) ✔
- Using a custom MessageDigest instead of relying on the SHA-224 (1)
- Digital Signature Hashes - MD2 (4)
- Digital Signature Hashes - SHA1 (5)

* CBC is insecure in TLS/client-server context; + applicable in specific situations; some misuse are newer compared to other in same cluster, # PKCS5 suggestion based

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Research Challenge 1:
What to mutate?

i.e., what vulnerabilities do we want to express?

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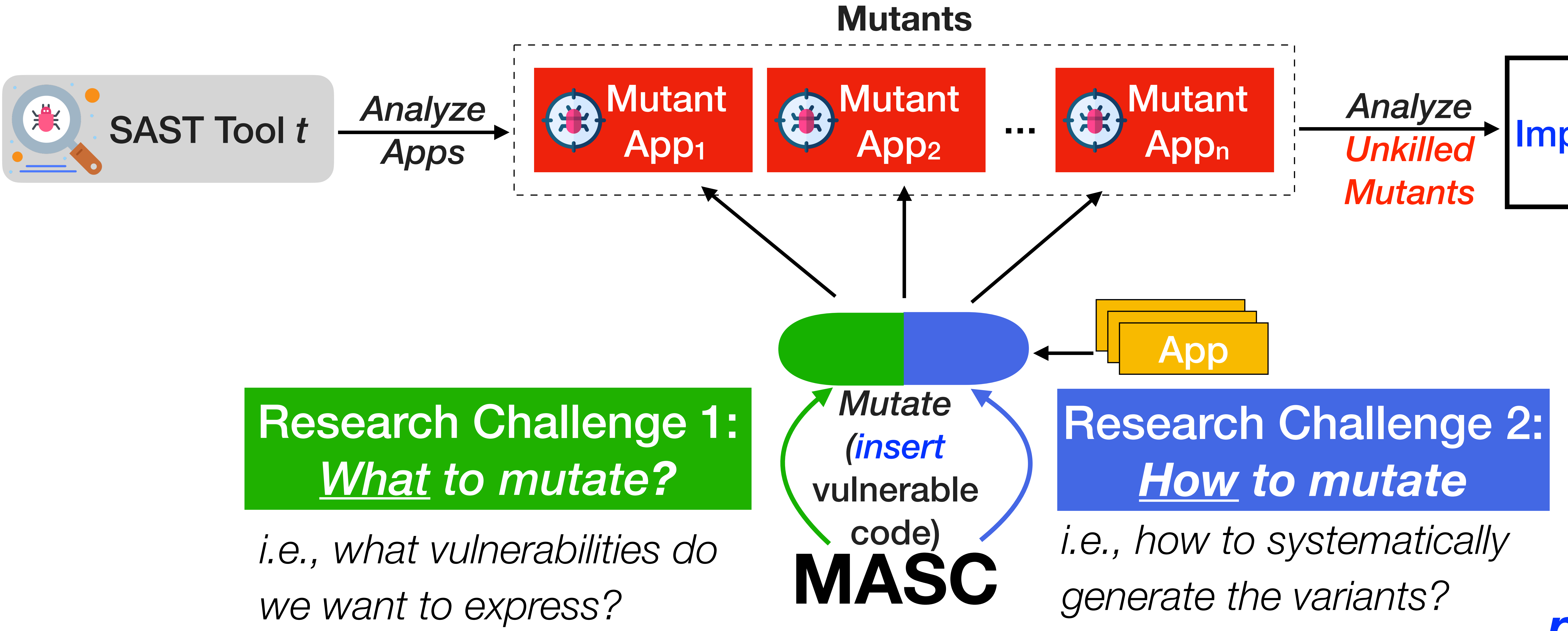

A *threat model* for Crypto-detectors

Threat-aware *mutation primitives: operators* and *scopes*

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Evaluating Crypto-Detectors [S&P 2022]

Evaluating Crypto-Detectors [S&P 2022]

19 Design/Implementation Flaws, 5 Flaw Classes

	Flaw Class (FC)	*# of flaws*	*Description*
FC1	**String Case Mishandling**	**1**	Not detecting an insecure algorithm provided in lower case *e.g., Cipher.getInstance("des");*
FC2	**Incorrect Value Resolution**	**8**	Incorrect resolution of parameters passed to Crypto-APIs, *e.g.,* String alg = "des"; Cipher.getInstance("des");
FC3	**Incorrect Resolution of Complex Inheritance & Anonymous Objects**	**4**	Inability to detect inheritance relationship among classes, *e.g., vulnerable SSL verification in anonymous inner class objects of X509ExtendedTrustManager*
FC4	**Insufficient Analysis of Generic Conditions**	**3**	Inability to identify fake/unrealistic conditions within overridden methods, *e.g., if(true ll session == null) return true; return false;*
FC5	**Insufficient Analysis of Context-Specific Conditions**	**3**	Inability to identify context-specific, fake/unrealistic conditions within overridden methods, e.g., *if(true ll session.getCipherSuite().length()>=0) return true; return false;*

Flaw Class “0” (Incomplete Analysis)

FC0 - 1. Ignore any class with “`.android`” in fully qualified name

Why? To ignore *Android libraries*

Implications: Ignores critical Android apps *and 10% of its evaluation dataset.*

- com.twitter.**android**
- com.lastpass.**lpandroid**
- com.google.**android**.gm

FC0 - 2. Not handling “`multidex`”

Android Studio automatically uses multidex for >Android 5.0

Implications: Does not completely analyze apps built after *2014, and 63% of its evaluation dataset*

- Part of the Eclipse IDE for several years
- Integrated into Oracle’s internal testing suite
- Funded by millions of federal $

19 Design/Implementation Flaws

FC1 (1 flaw) - String Case Mishandling

```
cipher.getInstance("DES");
```
DETECTS

```
cipher.getInstance("des");
```
DOES NOT DETECT

FC2 (8 flaws) - Incorrect Value Resolution

```
Cipher.getInstance("AES");
```
DETECTS

```
String alg = "AES";
Cipher.getInstance(alg);
```
DOES NOT DETECT

Industry leading tool, used in *7.5k+ open source projects*, and by *38k +developers*

```
Cipher.getInstance(
    (obj.A().B().getValue()
);
```
DOES NOT DETECT

flaw in 7/9 detectors

Repository	Stars (GitHub)
Apache Druid	10.3K stars
Exoflayer (Google)	16.8K stars
UltimateAndroid	2.1 K stars
JeeSuite	570 stars
Apache Ignite	3.5K stars

- ***Similar misuse instances were found during our impact study***

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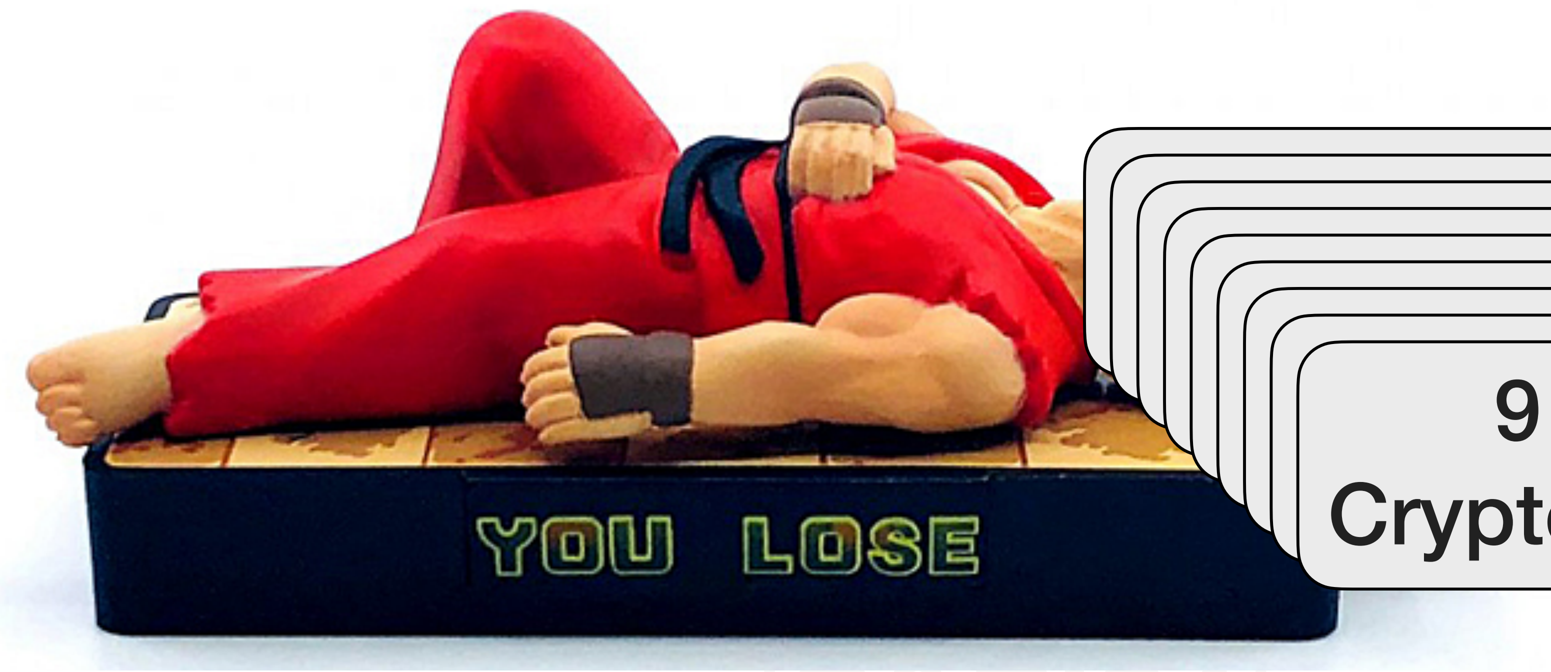

9 Popular Crypto-Detectors!

[S&P'24]

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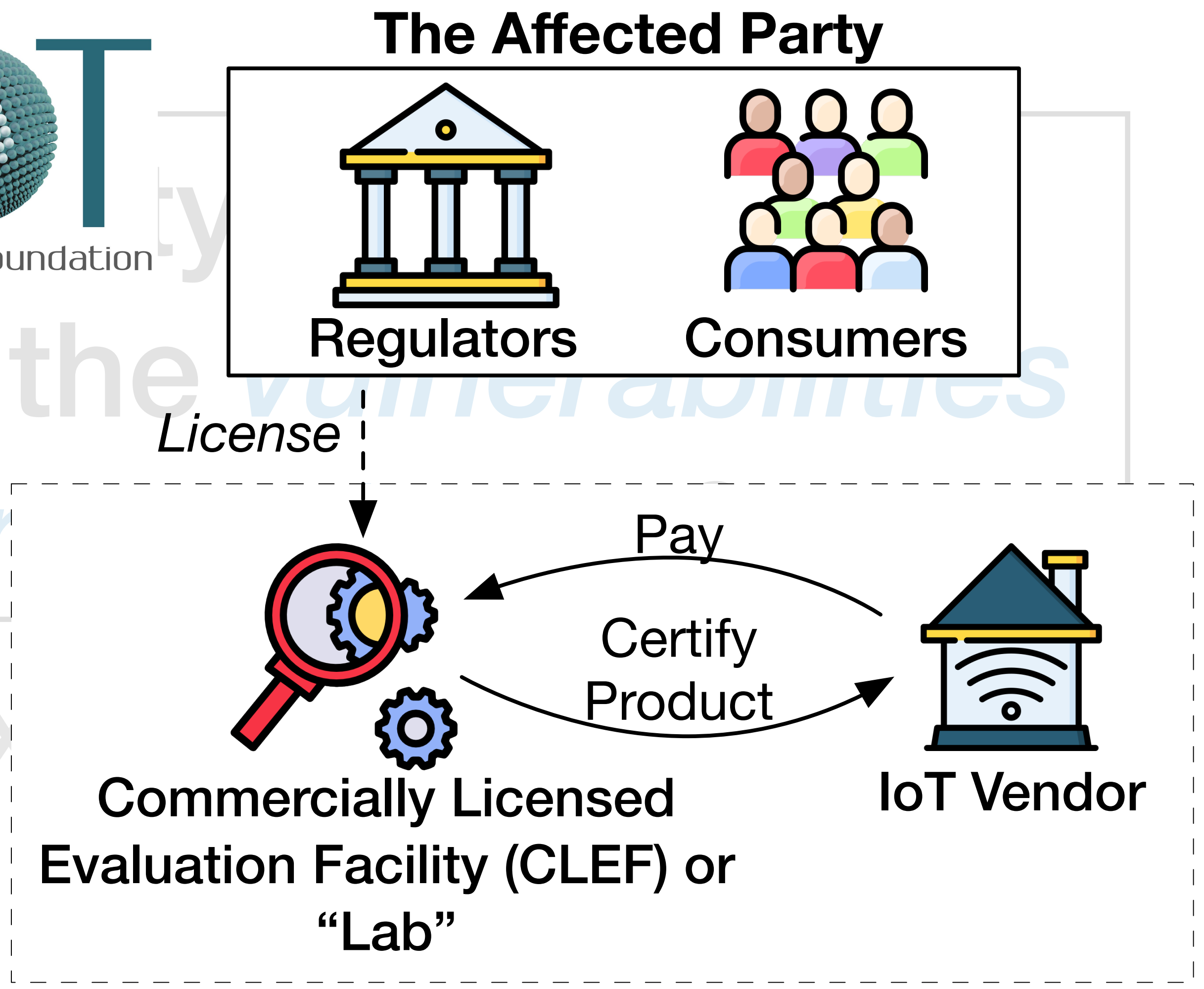
[**USENIX'24**, CCS'22, USENIX'22]

Context: Static Analysis Security Tools (SAST) used for detecting *crypto-API misuse*

CryptoGuard, ShiftLeft, CogniCrypt, QARK, SpotBugs, Coverity, sonarqube, XANITIZER ... because security matters

Investigating Early Artifacts from IoT Compliance Certification[1]



Preliminary observations from 30 CLEFs: 1) 25/30 certify mobile-IoT apps, **2)** 21/26 use SASTs (unclear for 4/30)

Real-world implications **of failures of (automated) security analysis**

[**USENIX'24**, CCS'22, USENIX'22]

[1] Mandal, Prianka, Amit Seal Ami, Victor Olaiya, Sayyed Hadi Razmjo, and Adwait Nadkarni. "***'Belt and suspenders' or 'just red tape'?*: Investigating Early Artifacts and User Perceptions of IoT App Security Certification.**" In *Proceedings of the 2024 USENIX Security Symposium (USENIX).* (To Appear)

Findings: Security Analysis of Certified Apps

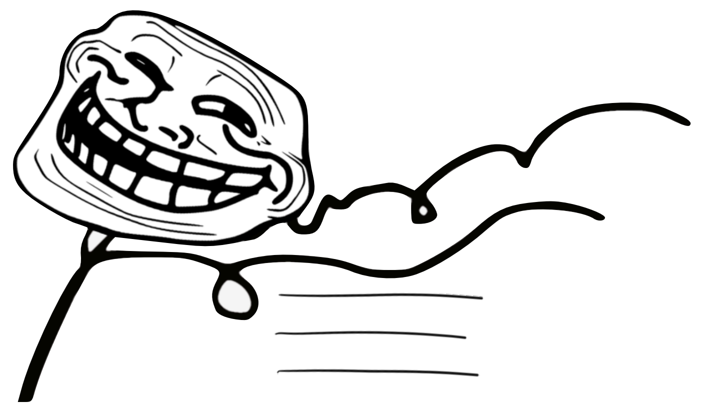
35 crypto-API vulns in 9/11 *certified* apps from ioXt internet of secure things

```
// The string operations below result in: "AES /" + "E" + "C" + "B" + "/NoPadding"
// = "AES/ECB/NoPadding"
```

```
this. ALGO = "AES/" +
            (( char) ("AES/GCM/NoPadding". charAt (4) - 2) ) +
            "AES/GCM/NoPadding". charAt (5) +
            (( char) ("AES/GCM/NoPadding". charAt (6) - 11) ) +
            "/NoPadding";

Cipher cipher = Cipher . getInstance (this. ALGO );
```

T_3: Evasive Developer



An example: Vulnerable Code in an IoT SDK/platform; used by 580k developers (app installed by >5 million users)

Security tools ***did not work!***

Finding 5: CogniCrypt, MobSF, and CryptoGuard, do not detect several of the 35 critical vulnerabilities discovered using manual reverse engineering, i.e., 33/35, 28/35, and 15/35 respectively, and ***none detect the evasive use.***

Why do Crypto-detectors fail? — Perspectives of Tool Designers [S&P 2022]

Security-Centric Evaluation *VS* *Technique-Centric* Design

*"When you really want a protection property to hold, it's vital that the design and implementation be subjected to **hostile review"***

- Security Engineering: A Guide to Building Dependable Distributed System

*"(Tools / approaches) seen so far were <u>technically</u> <u>motivated</u> - **not use-case motivated**.. (e.g.,) should we use alias analysis?"*

- CryptoGuard

*Seemingly-Unlikely/**Evasive flaws** are **within scope** as long as they are **found in the wild***

- CryptoGuard, CogniCrypt

*And should be **frequently observed**!*

- Github Code Scan/LGTM

*"the distinction should not be between 'common' and 'uncommon', but instead between 'can be (easily) **computed statically' and 'can not be computed'**."*.

- Xanitizer

Takeaway: *We need to arrive at a consensus regarding scope (specification grand challenge)*

SASTs prioritize lower FPs *for developers*, but…

Developers would **tolerate high FPs** if the tools ***find something of value***; FNs scare them the most [**S&P 2024**]

Finding 10: Nearly all the practitioners expressed a preference for fewer false negatives, i.e., *as long as the SAST is able to find valid security vulnerabilities, they would tolerate and even prefer few false negatives at the cost of many false positives*

"***I'd rather my security tool be annoying and tell me about every single possible issue*** *over it not telling me anything and* ***just letting <vulnerabilities> slide through.***" *- P14, Law Enforcement*

"*I* ***wouldn't mind wading through 100 false positives,*** *if I thought there were actually going to be genuine issues" - P02, OSS - Java App Server*

"False negative for sure. I just told you the amount of the price of the bug (in millions), so ***I don't care if there are 10 false positives. False negative - that one is going to kill you.***" *- P04, Automobile Sensors*

Re-think How We Design Security Tools

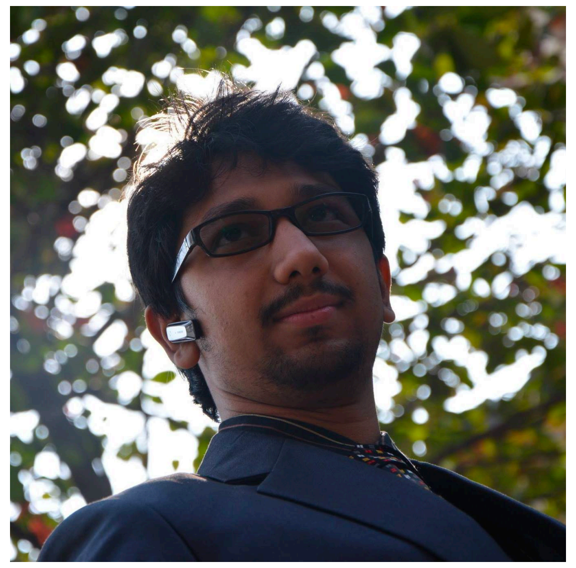
Re-think How We Design Security Tools

- Understand of *how crypto-APIs are actually misused in the wild*
- Focus on *finding something of value,* i.e., *what developers want*

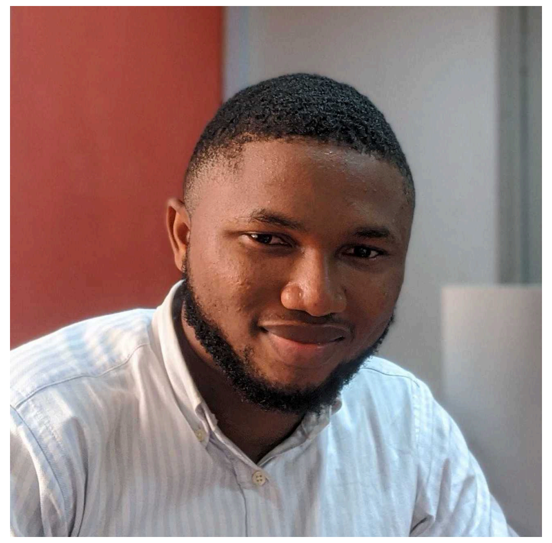
Thank You!

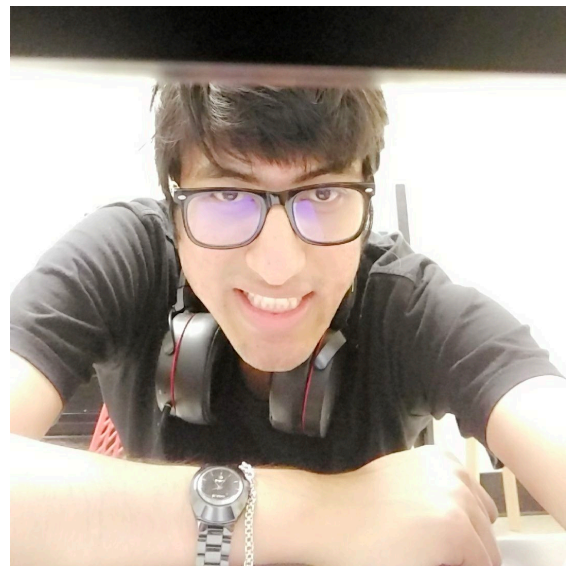
Students


Kaushal Kafle


Amit Seal Ami


Prianka Mandal


Victor Olaiya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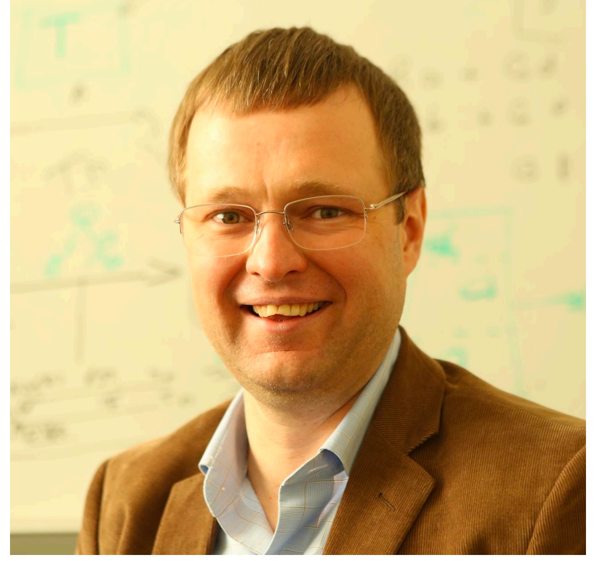
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https://spl-wm.github.io/

https://github.com/Secure-Platforms-Lab-W-M/masc-artifact