ETH zürich

Sound-Proof: Usable Two-Factor Authentication Based on Ambient Sound

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ETH Zurich

USENIX Security 2015

Supplementing passwords

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- Passwords are used everywhere
  - Password reuse, leakage, guessing, phishing…

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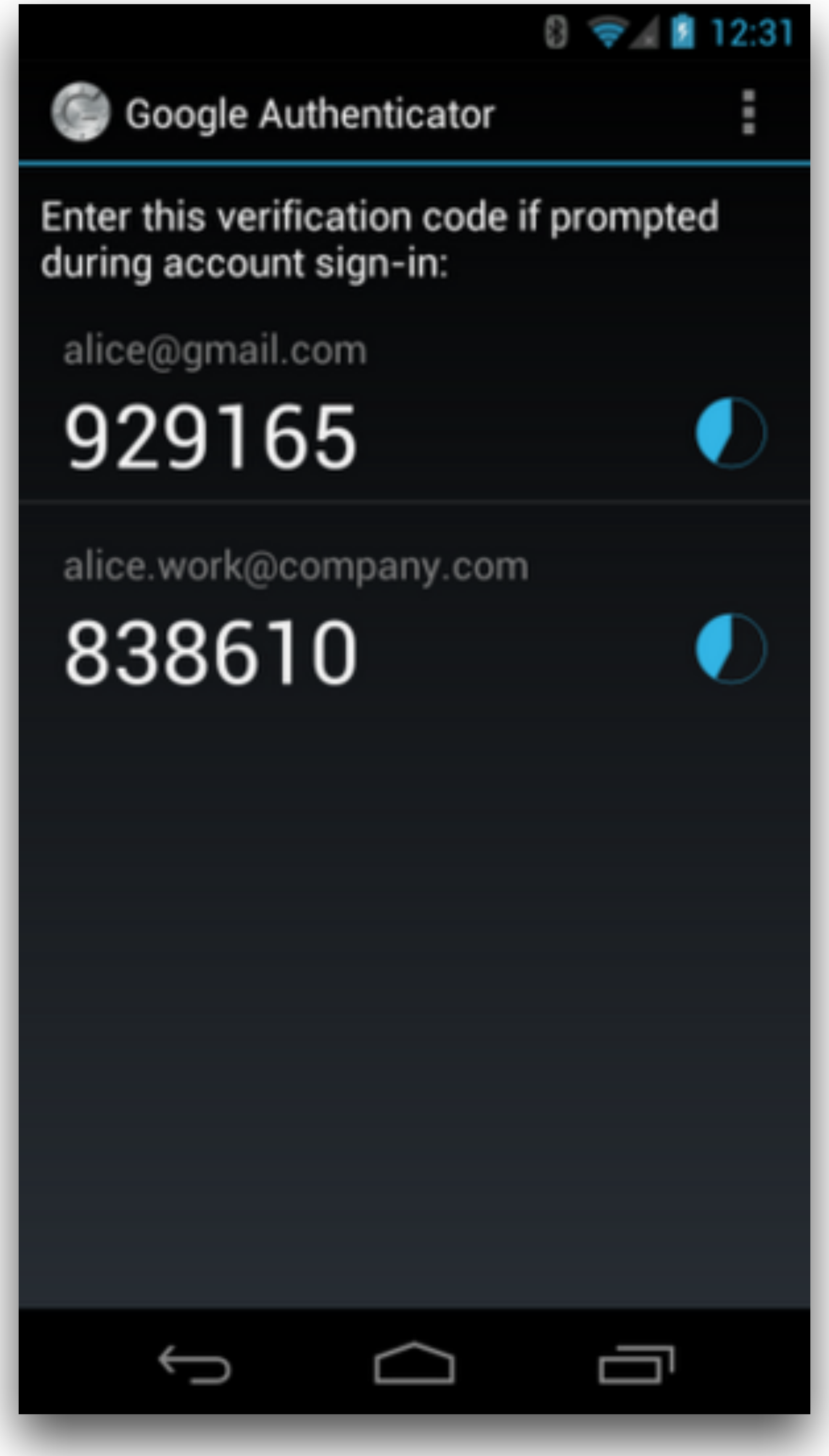
- Two-factor authentication to the rescue
- Password + Token (one-time code)
  - Typically smartphones are used as tokens



Enter this verification code if prompted during account sign-in:

alice@gmail.com
929165

alice.work@company.com
838610

Web 2FA Adoption

Is 2FA used in practice on the web?

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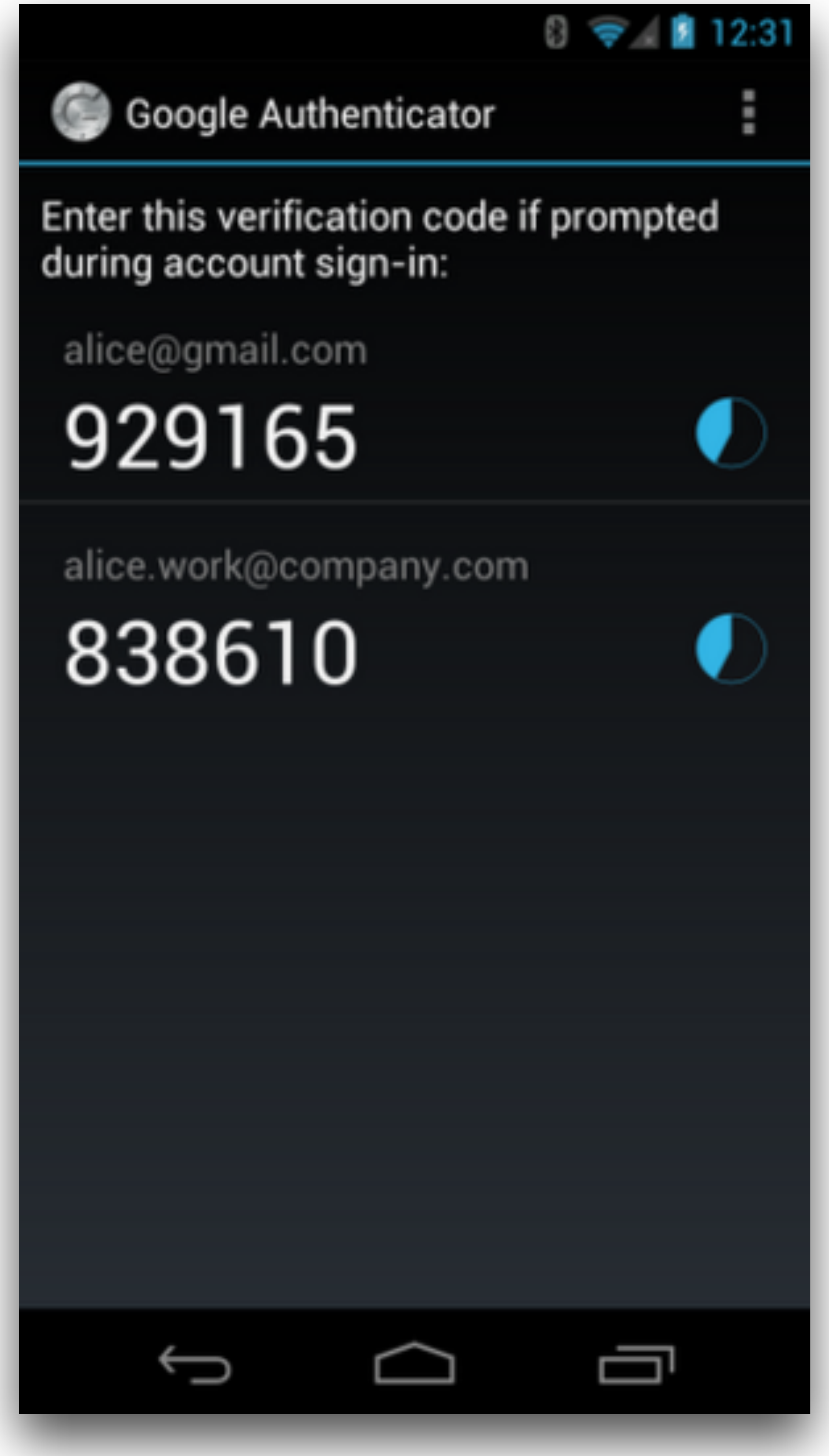
- Most popular 2FA: Code-based (App or SMS)
  - Google, Facebook, Apple, Microsoft, Twitter…



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Web 2FA Adoption

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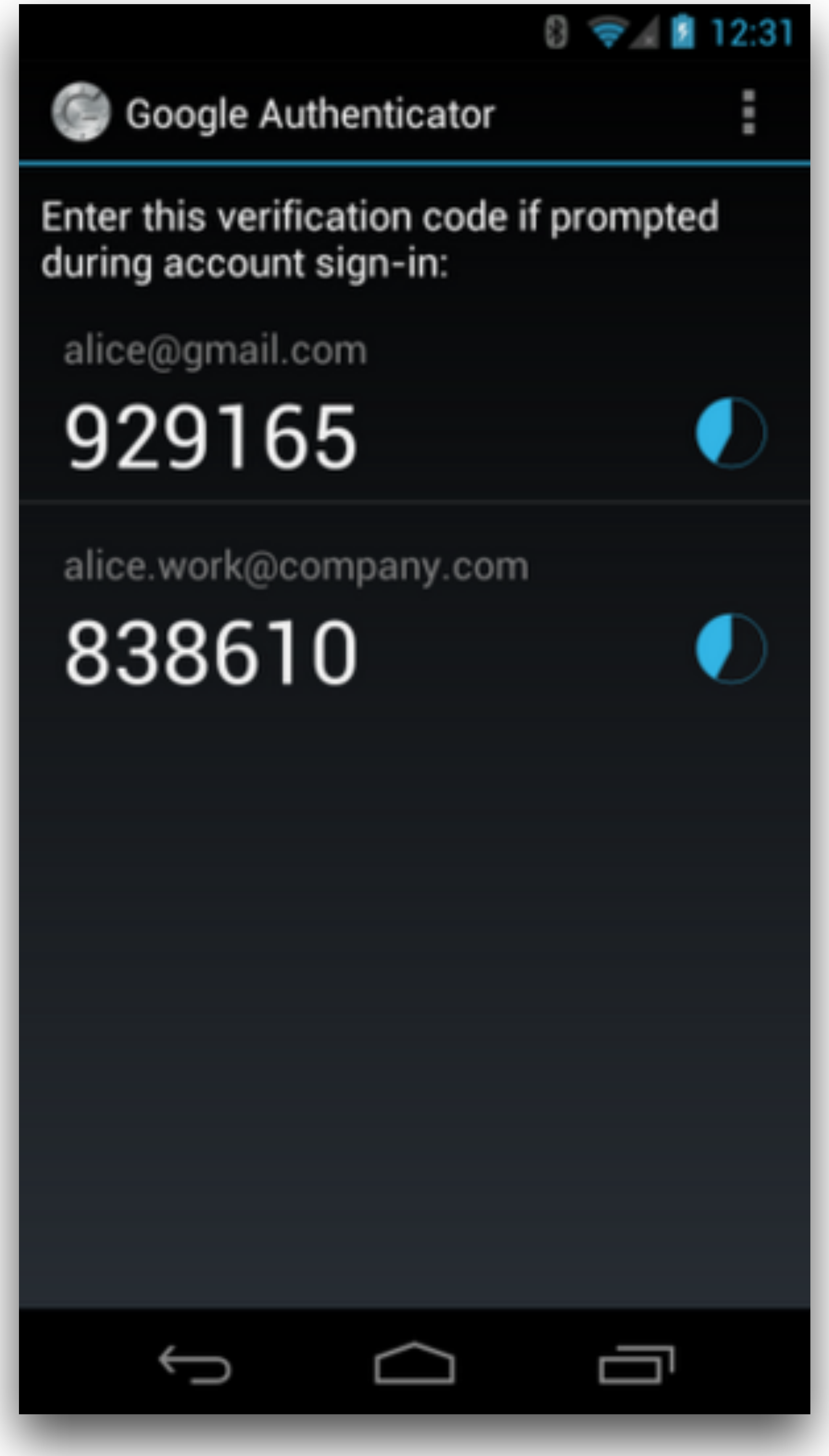
- Most popular 2FA: Code-based (App or SMS)
  - Google, Facebook, Apple, Microsoft, Twitter…

- **Small** user adoption (**if 2FA optional**)
  - Only 25% of Americans use 2FA[1]
  - Only 6% of 100k Gmail accounts have 2FA enabled[2]



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[1] Study by Impermium, 2013 (BusinessWire article, http://goo.gl/NsUCL7)
[2] Petsas et al., EuroSec 2015

Improving 2FA Usability

Reduce user actions

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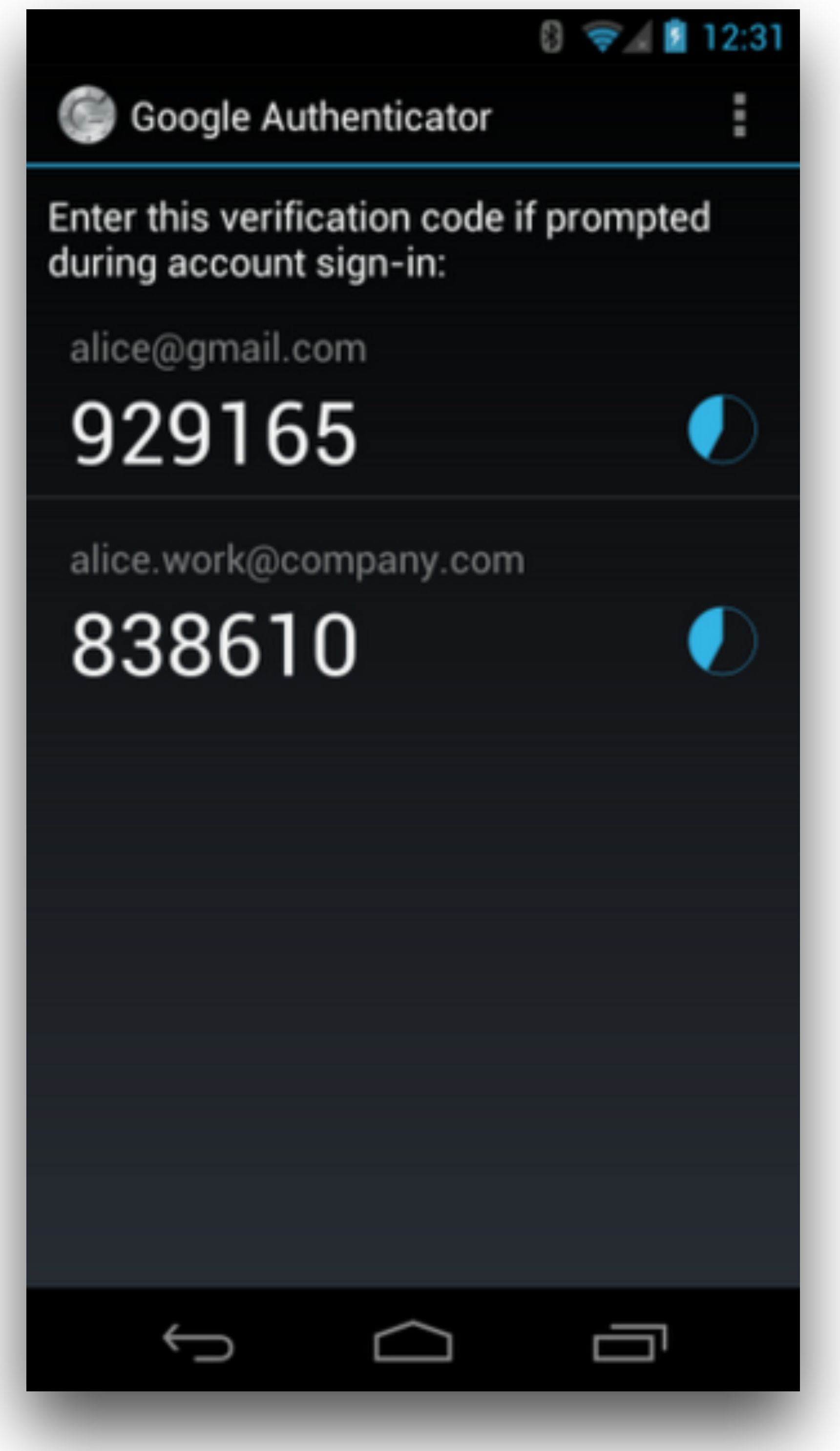

12:31

Google Authenticator

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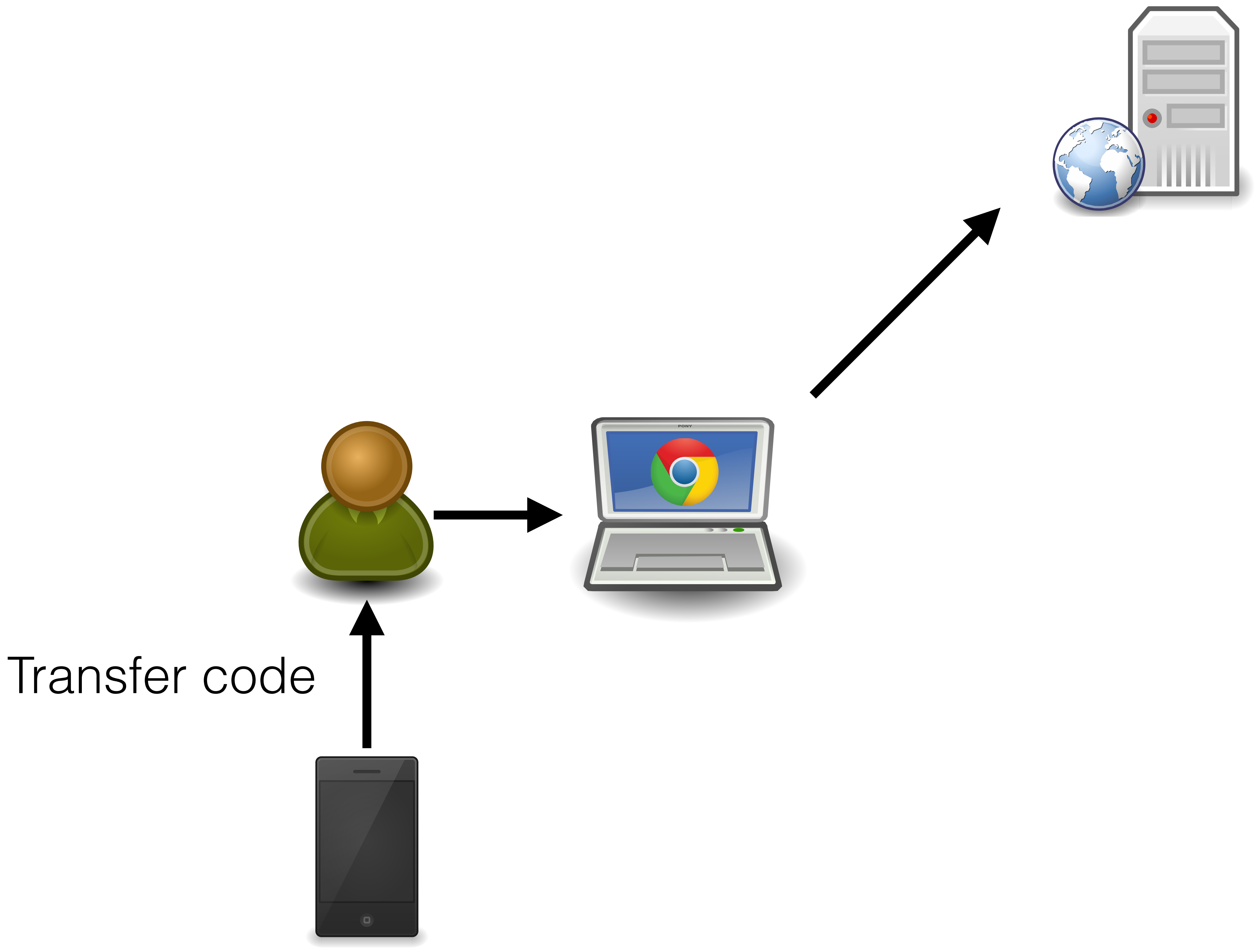


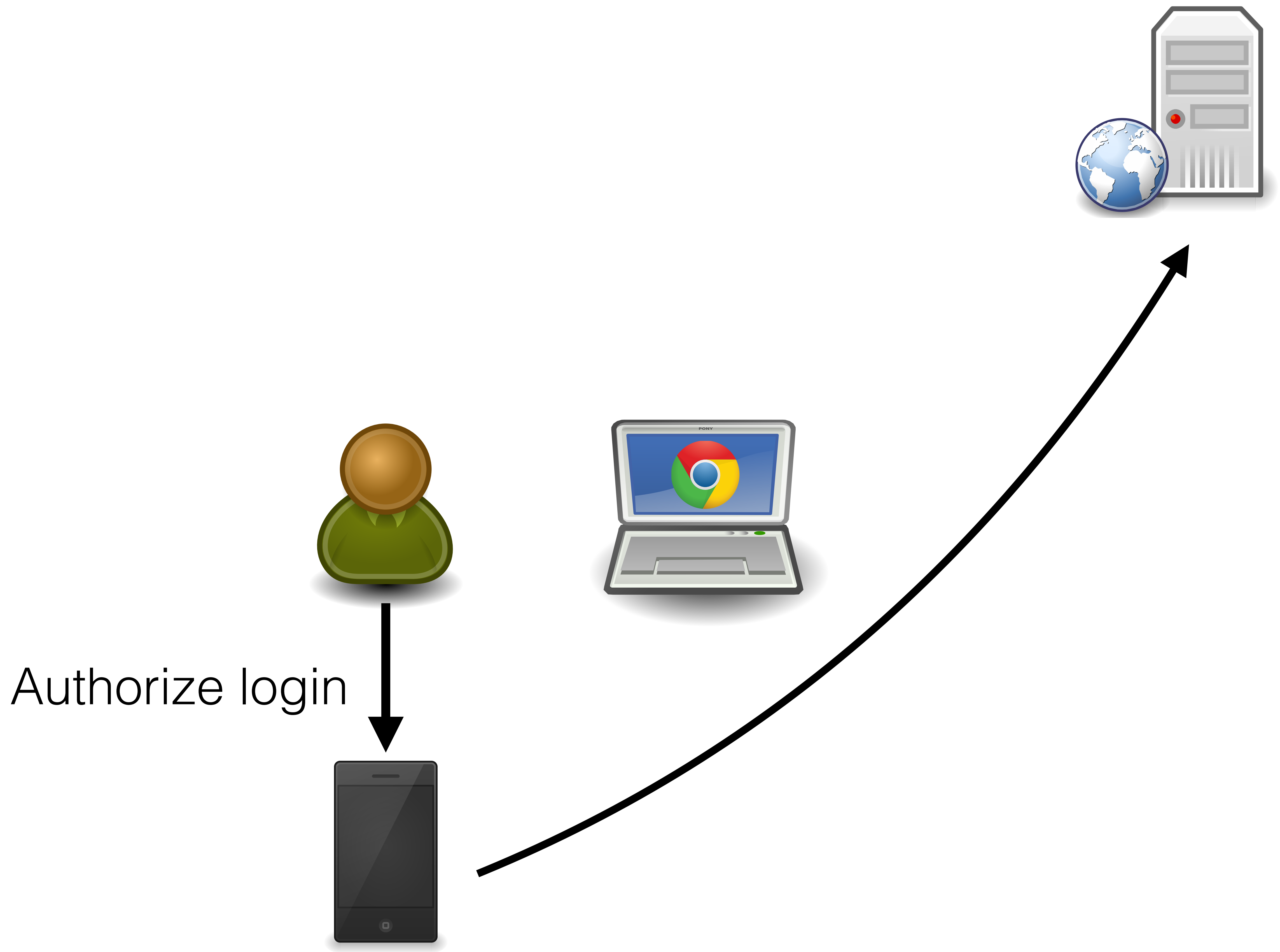
Improving 2FA Usability

Reduce user actions

- Minimize user-phone interaction
  - Just tap a button instead of copying a code

ENCAP® SECURITY

DUO



Authorize login

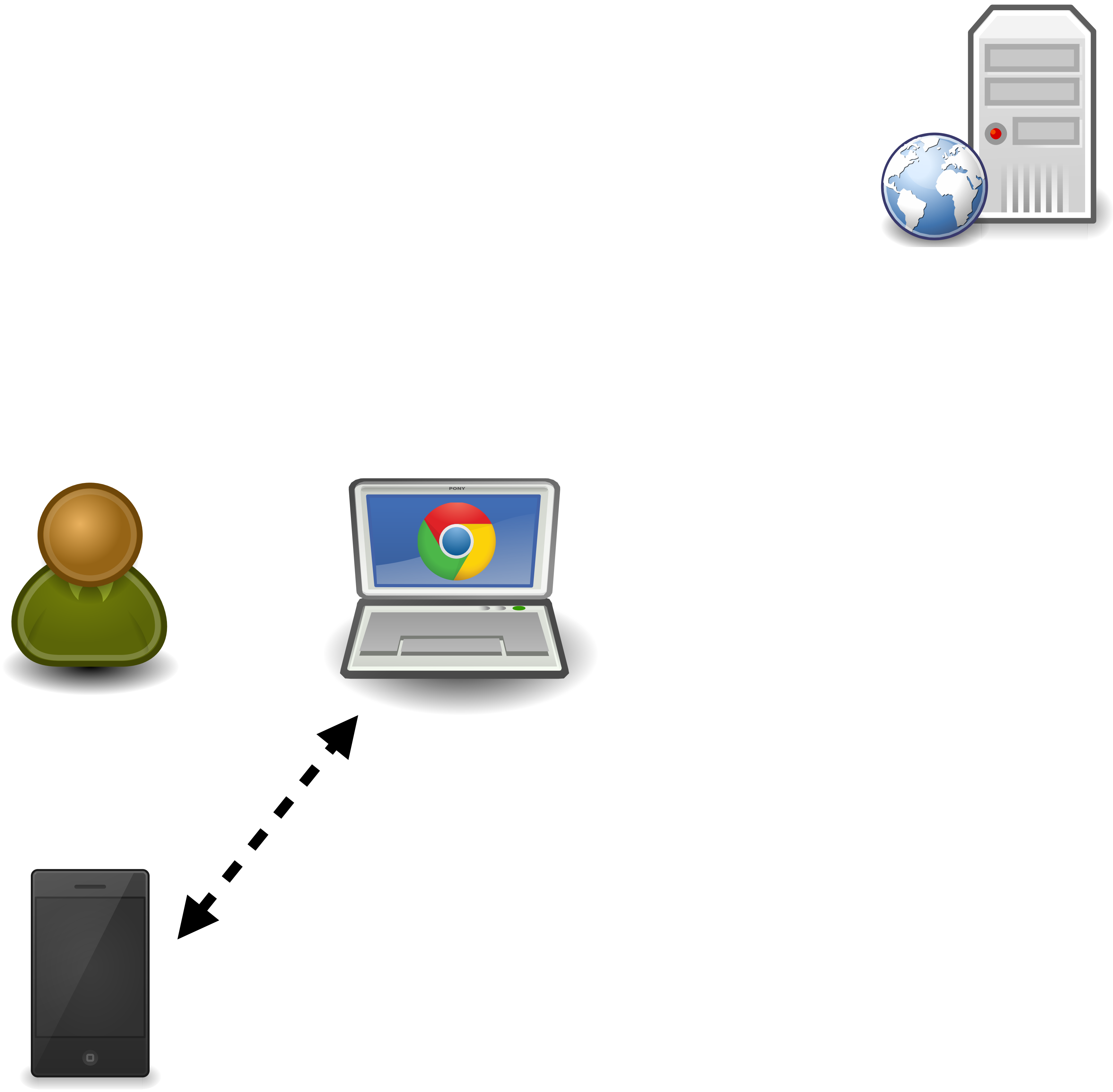
Eliminate user-phone interaction

How can it be achieved?

Eliminate user-phone interaction

How can it be achieved?

- Leverage the **proximity** between user's phone and computer as the **second factor**



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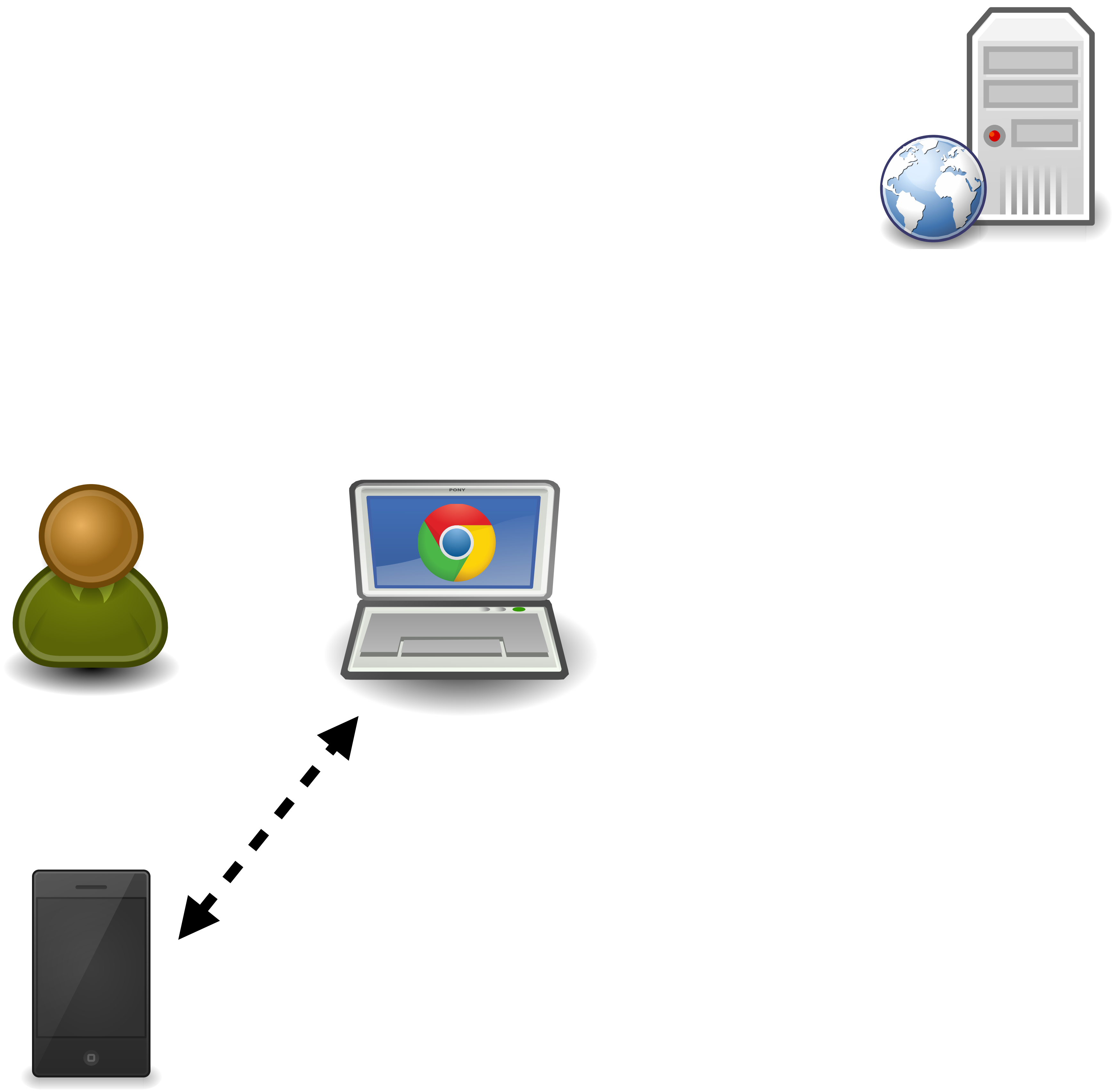

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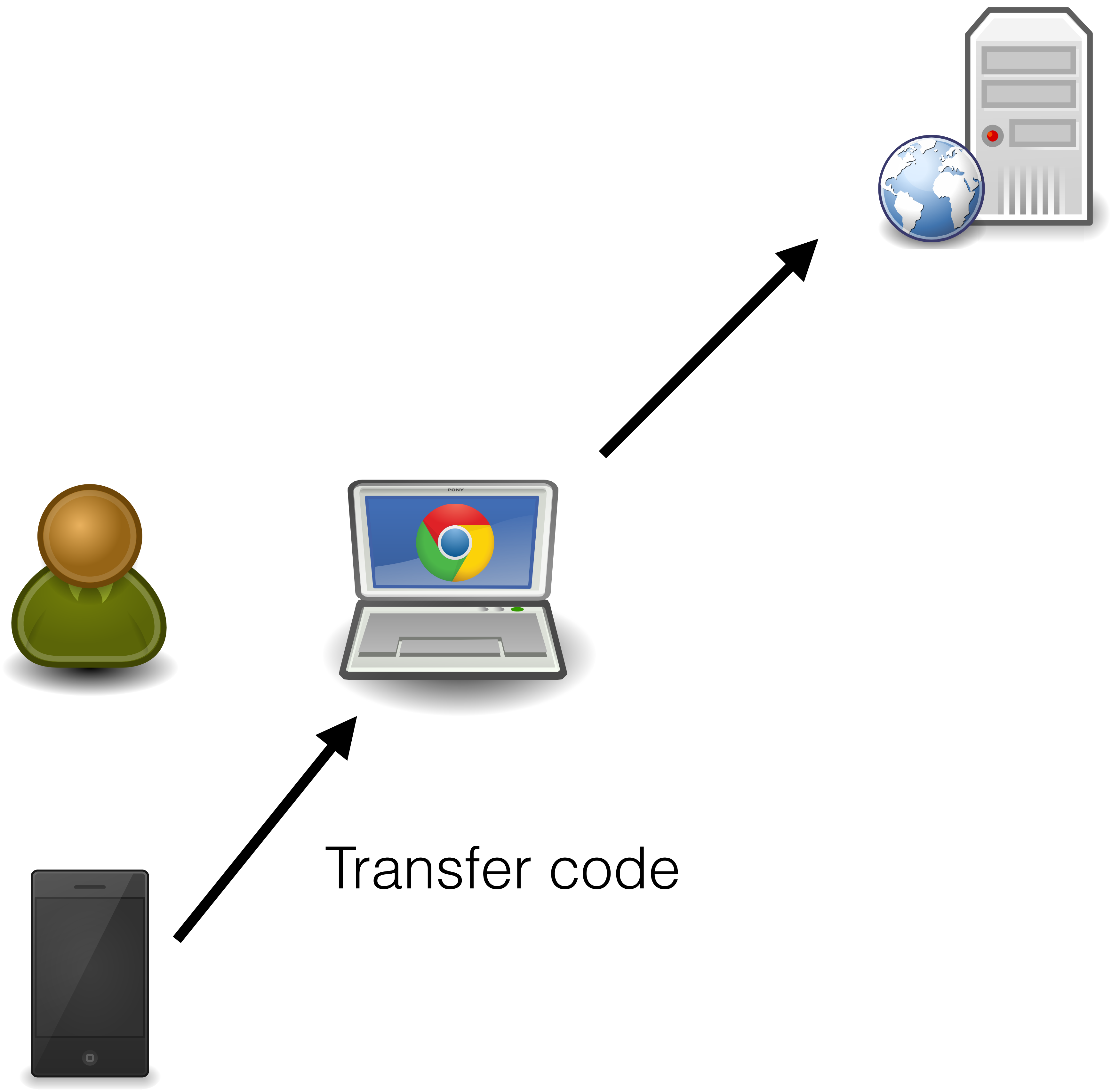

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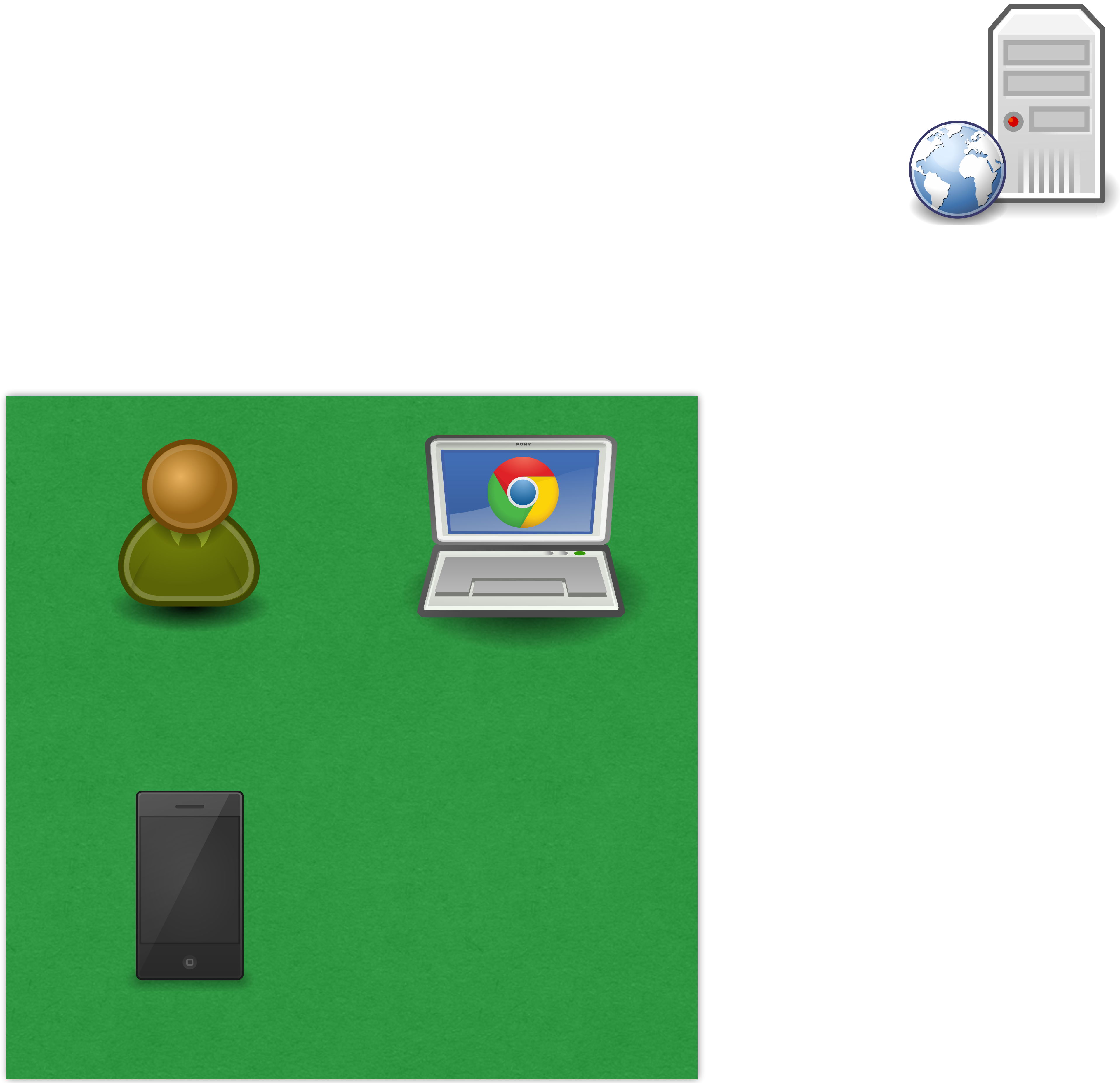
How can it be achieved?

- Leverage the **proximity** between user’s phone and computer as the **second factor**
- Proximity can be verified by:
  - Using local communication channels (phone-computer communication)
  - Sensing the environment



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What are the available options?

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Phone-computer communication

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(PhoneAuth, Czeskis et al., CCS '12)

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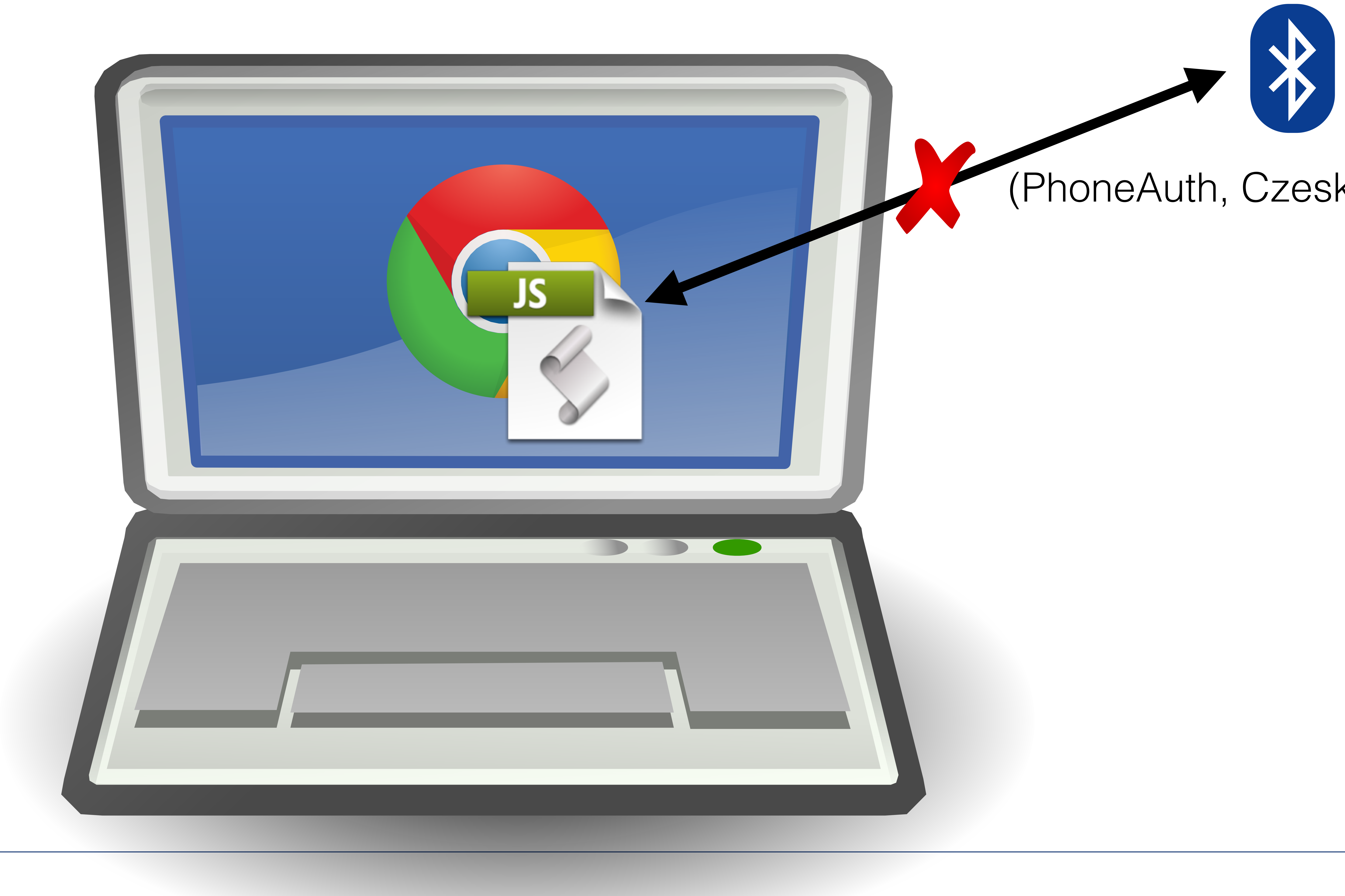

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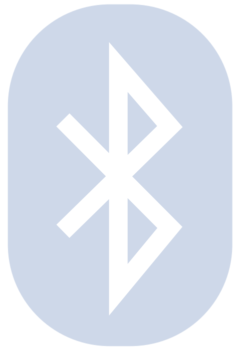

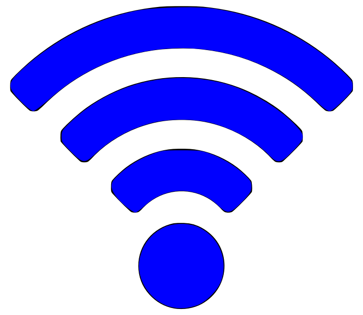

(Shirvanian et al., NDSS ’14)

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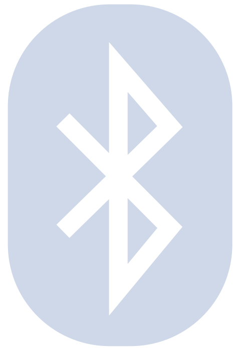

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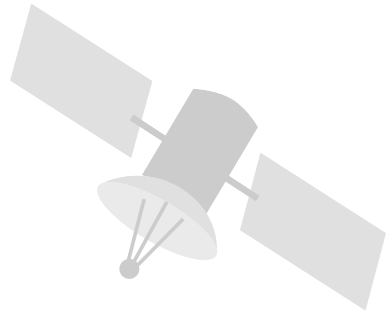

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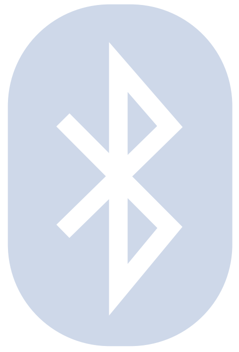

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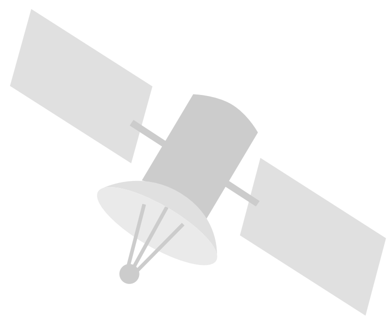

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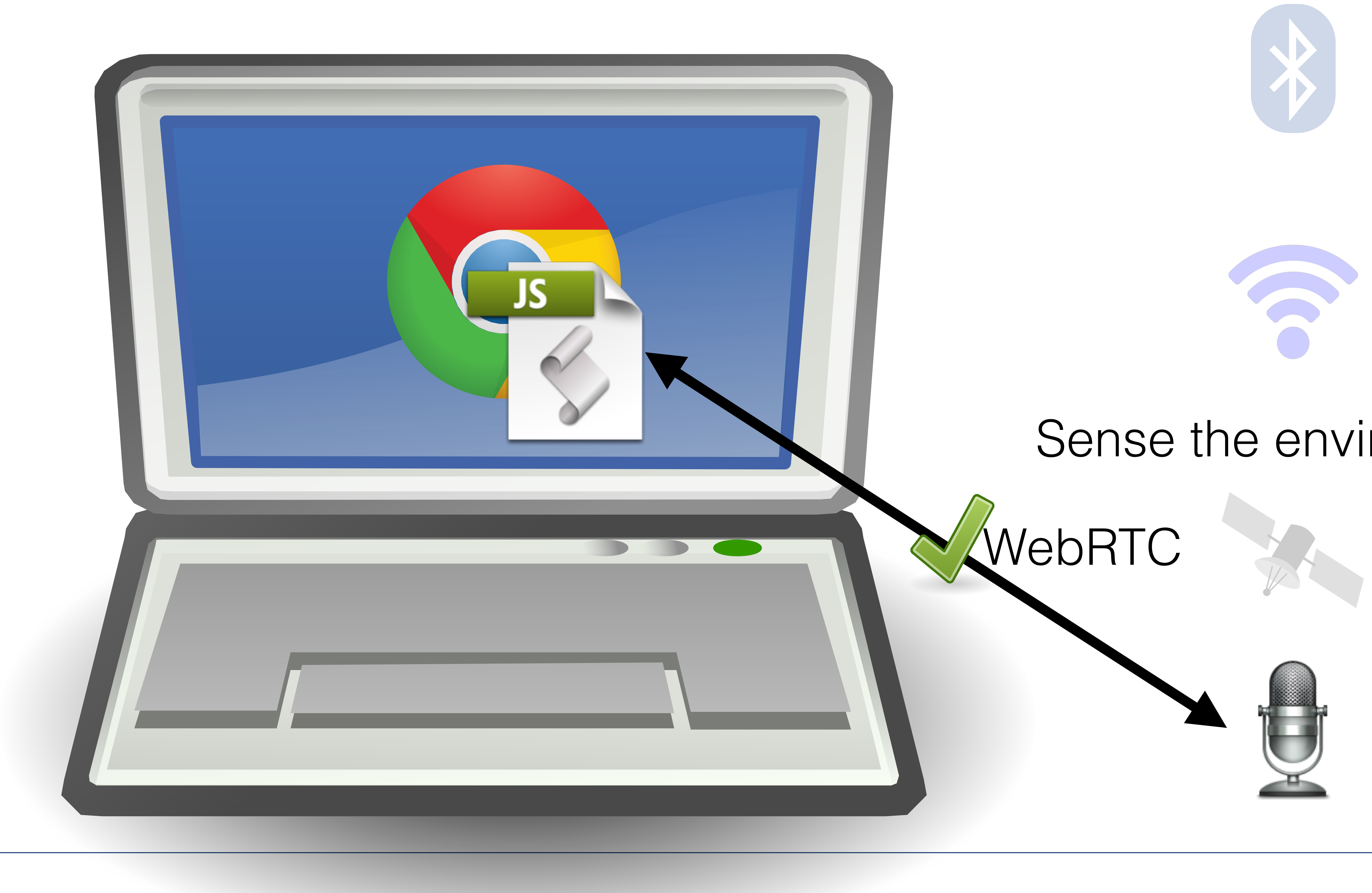

✓ WebRTC

Contributions

Sound-Proof

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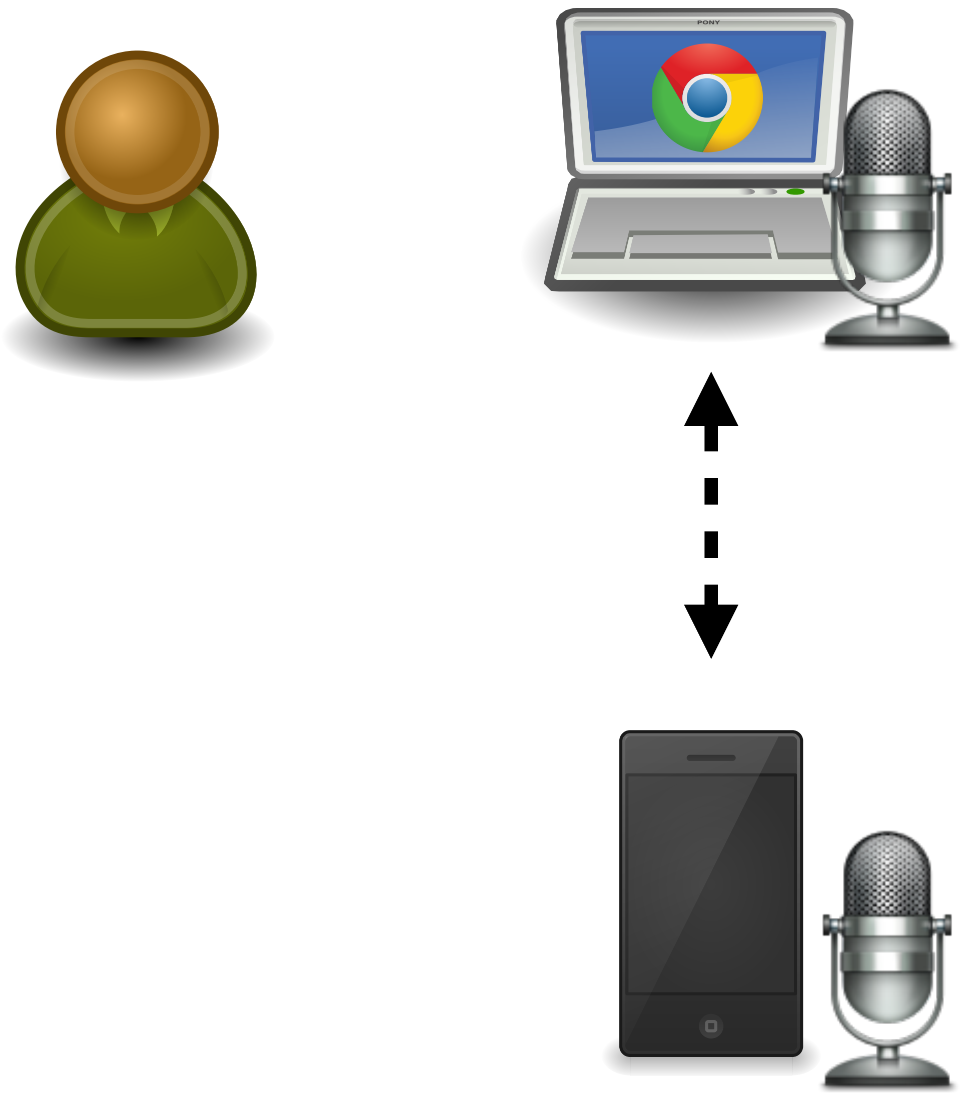
- Novel 2FA mechanism
  - Sense ambient audio to verify proximity



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Sound-Proof

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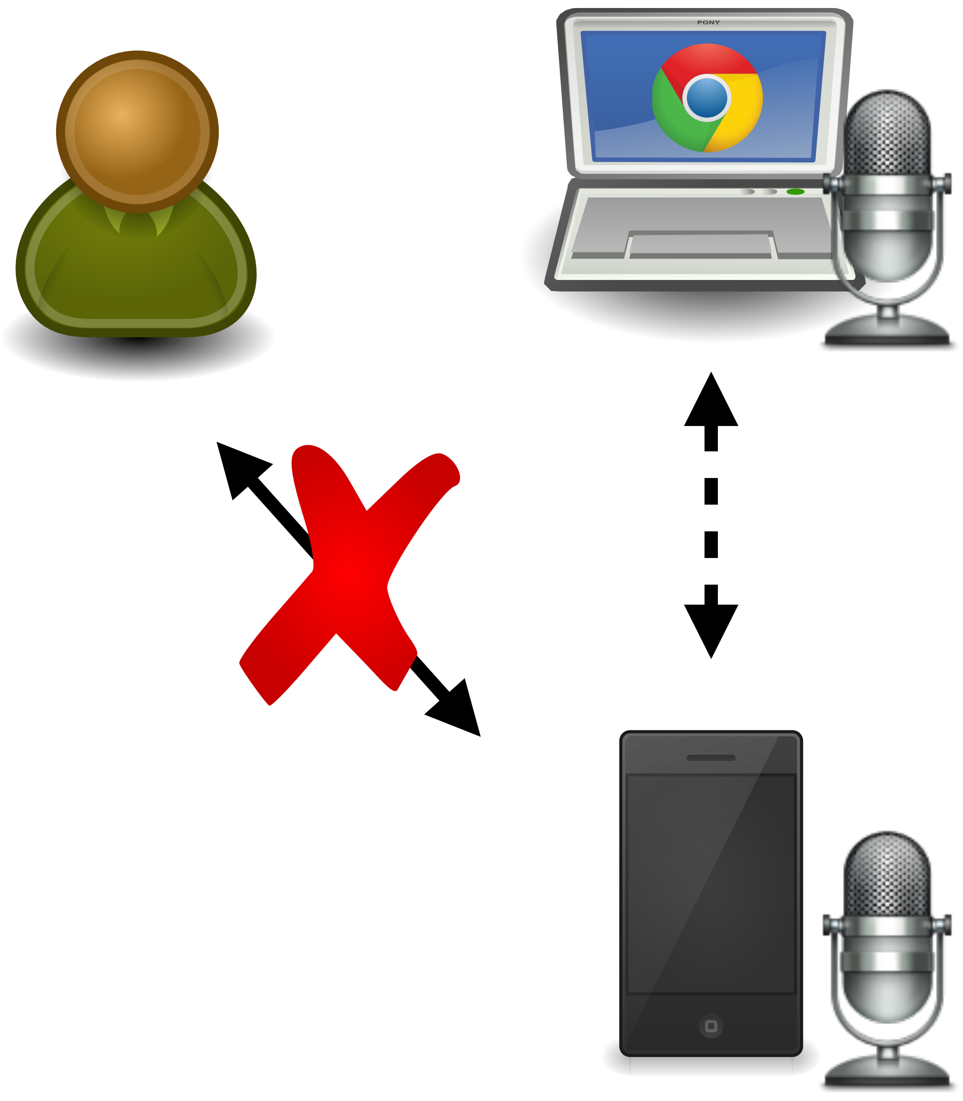
  - **Usable**: No user-phone interaction



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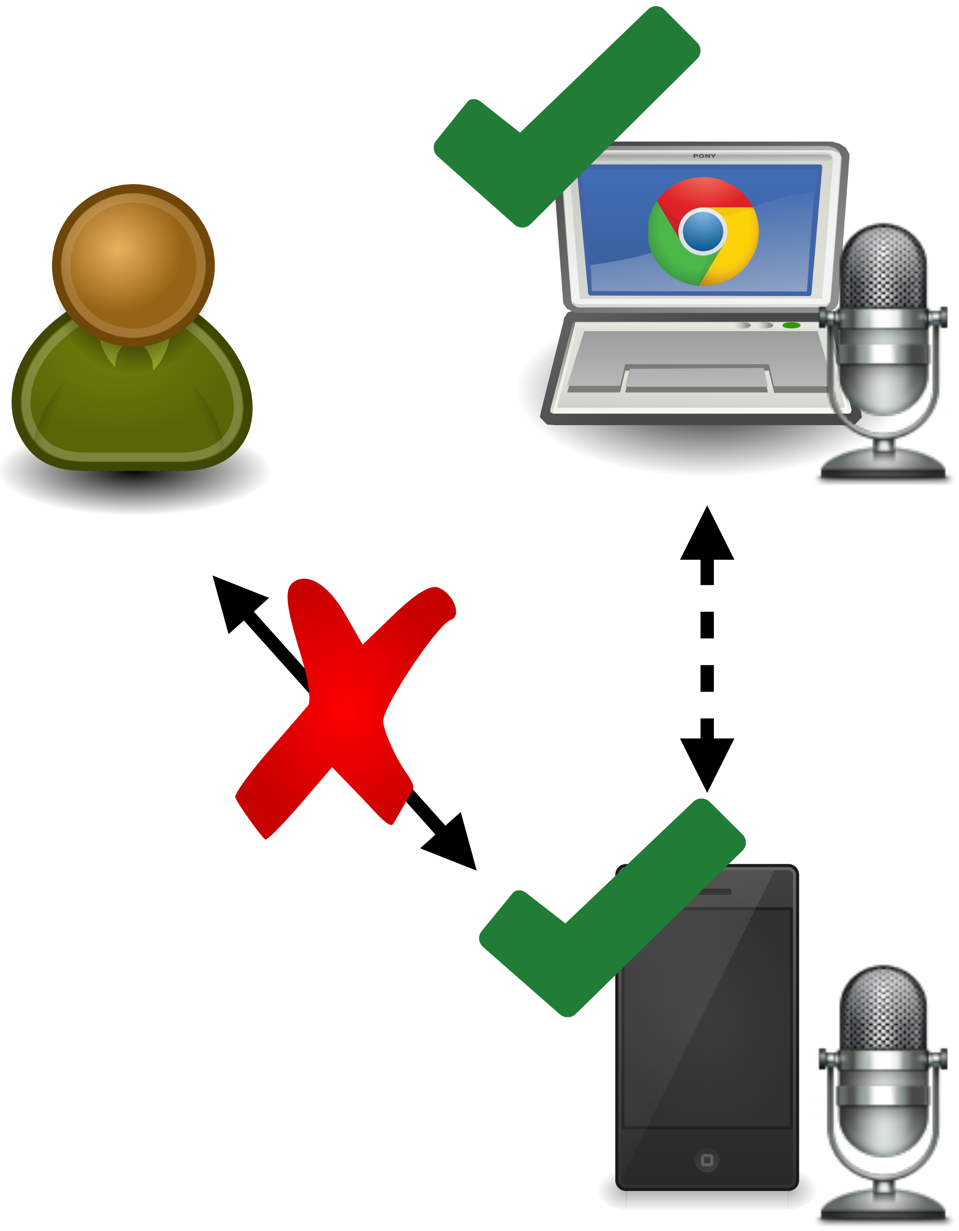

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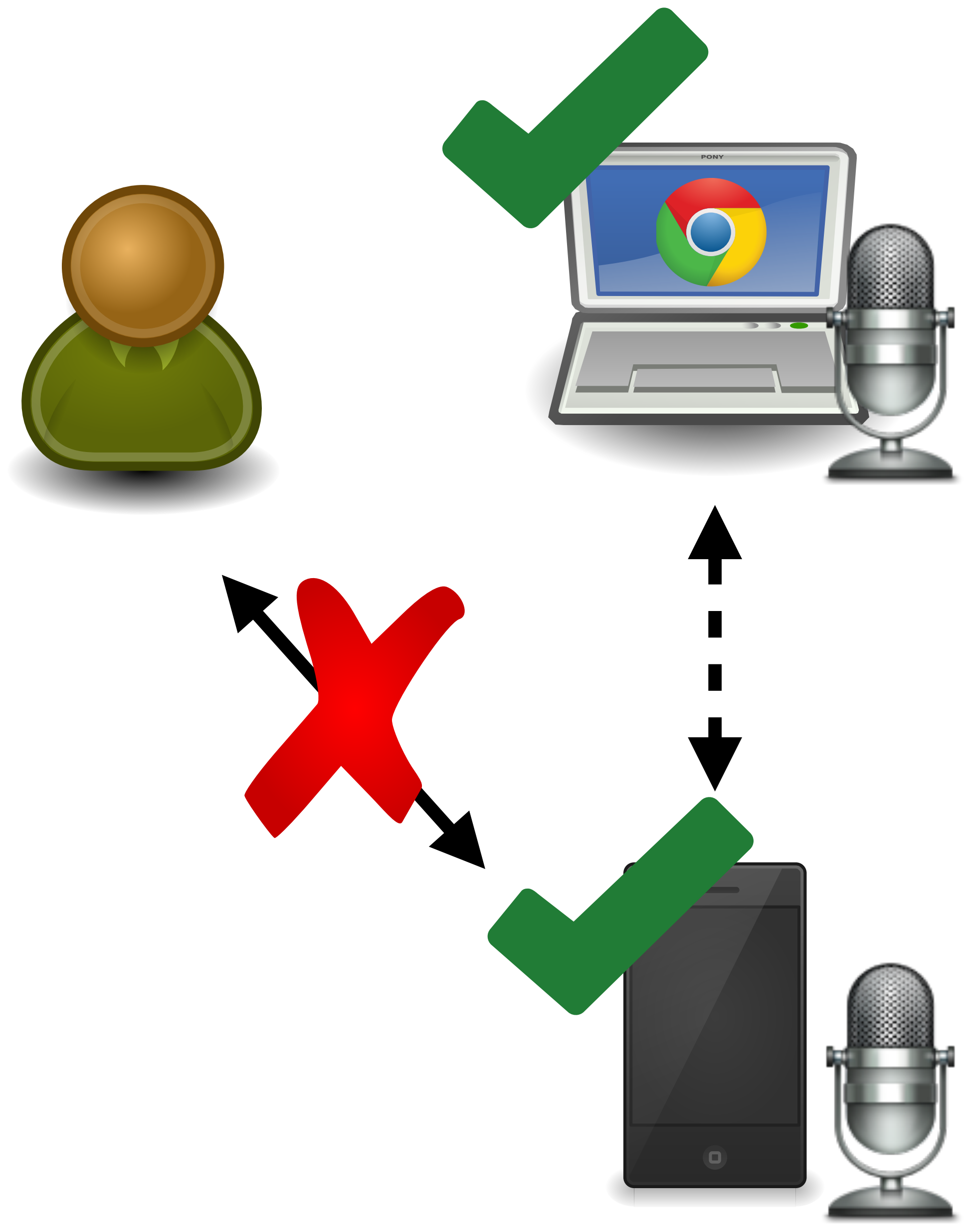
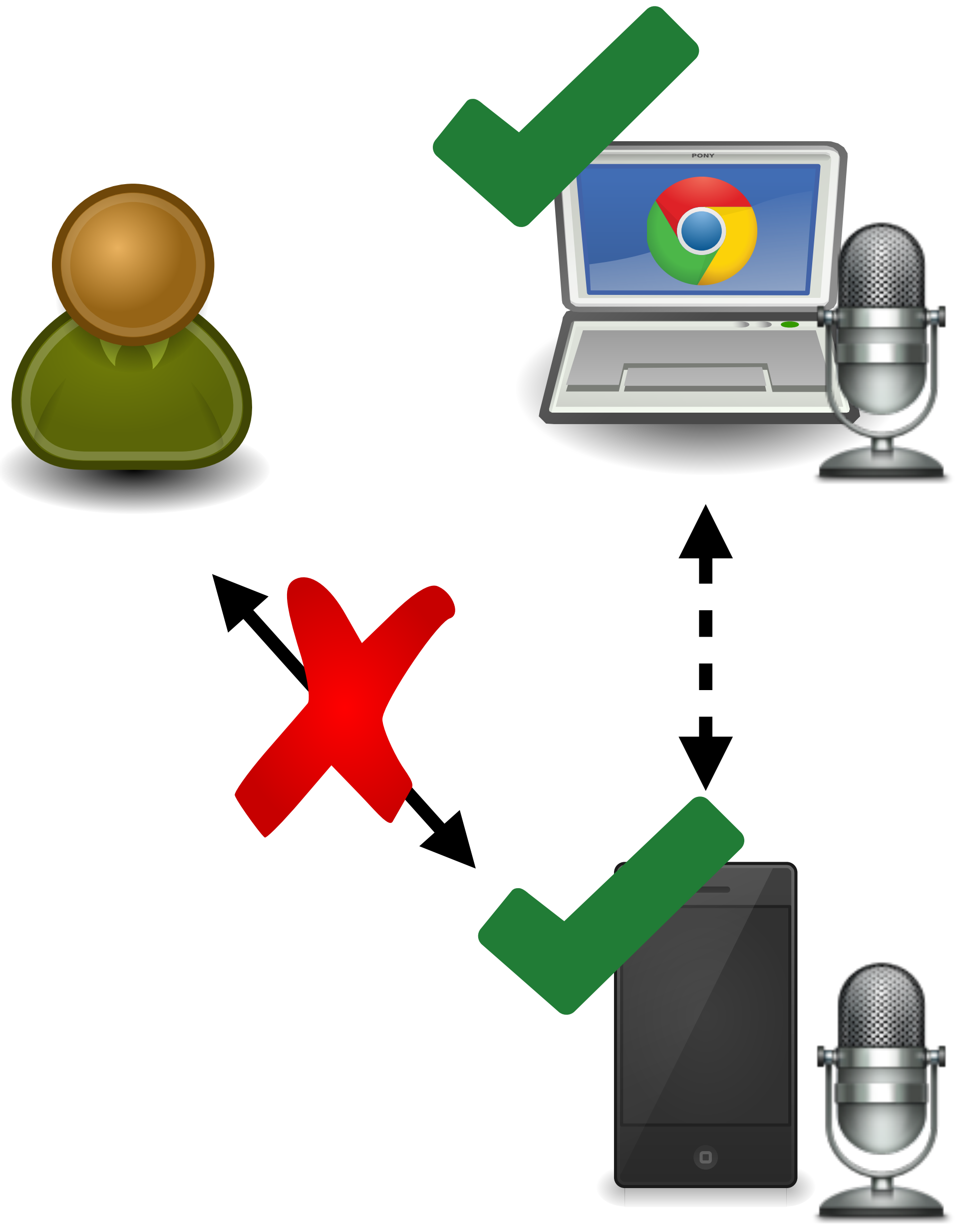


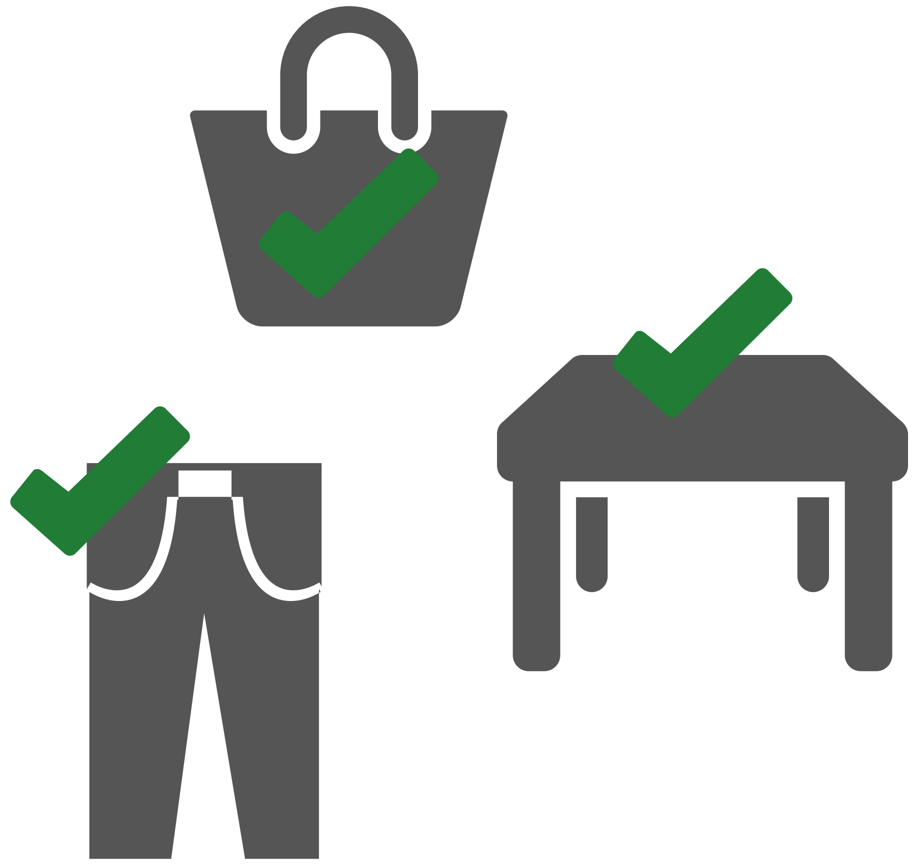
- Prototype implementation on Android and iOS

Contributions

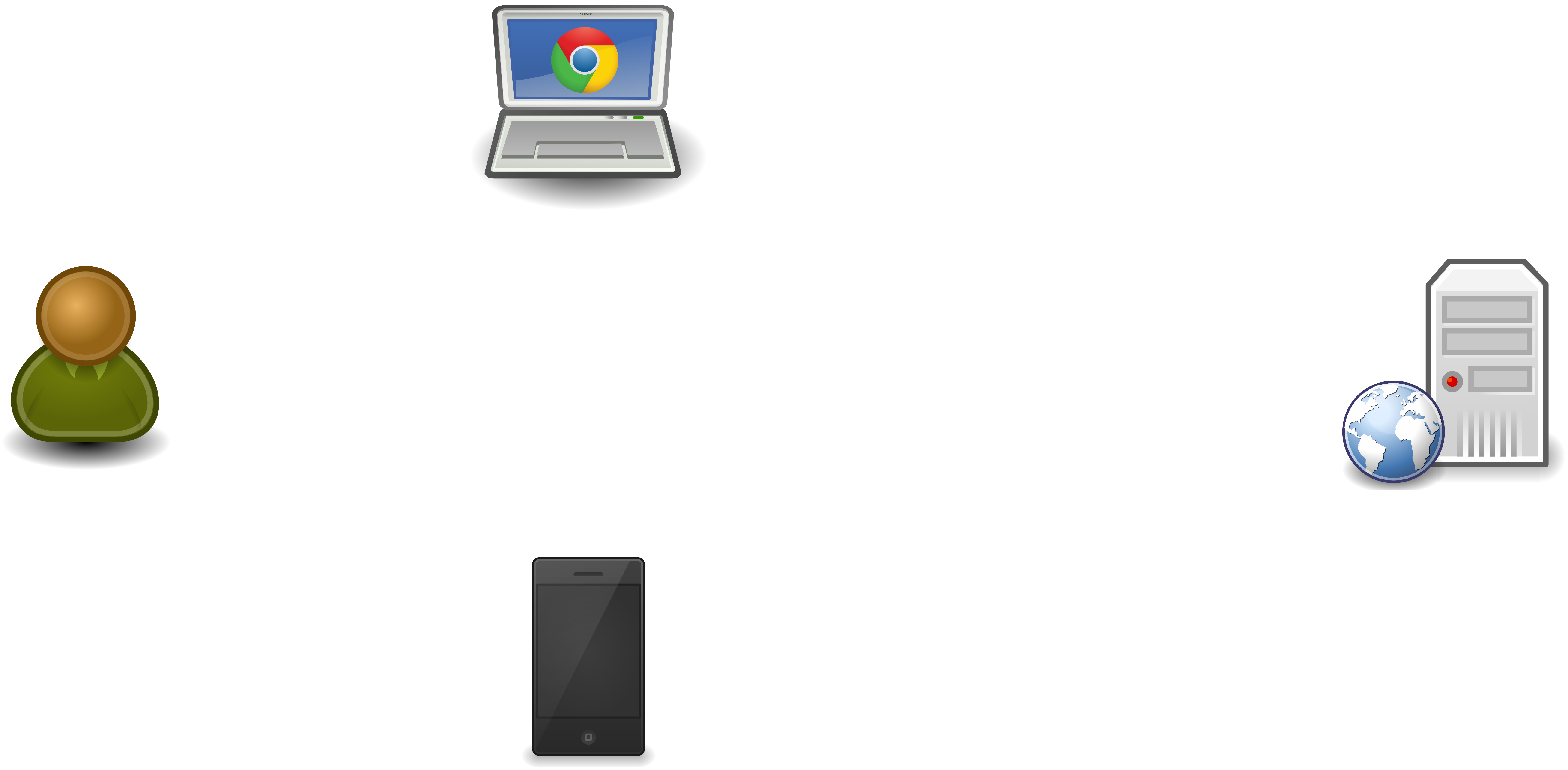
Sound-Proof

- Novel 2FA mechanism
  - Sense ambient audio to verify proximity
  - **Usable**: No user-phone interaction
  - **Deployable**: Compatible with smartphones and major browsers without plugins
- Prototype implementation on Android and iOS
- Evaluation
  - Sound-Proof works in a **variety of environments**, even if the phone is in a pocket or purse





Architecture overview



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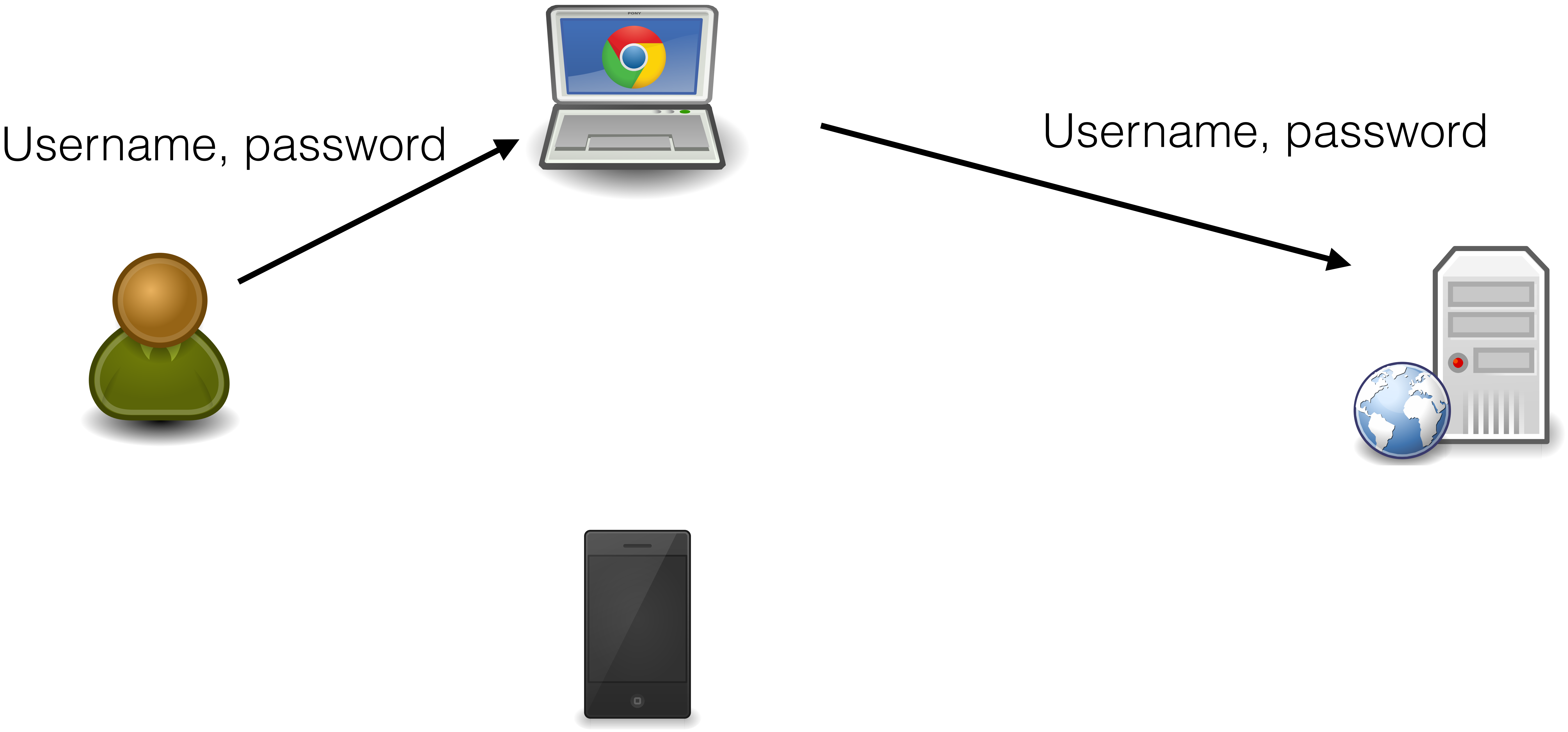

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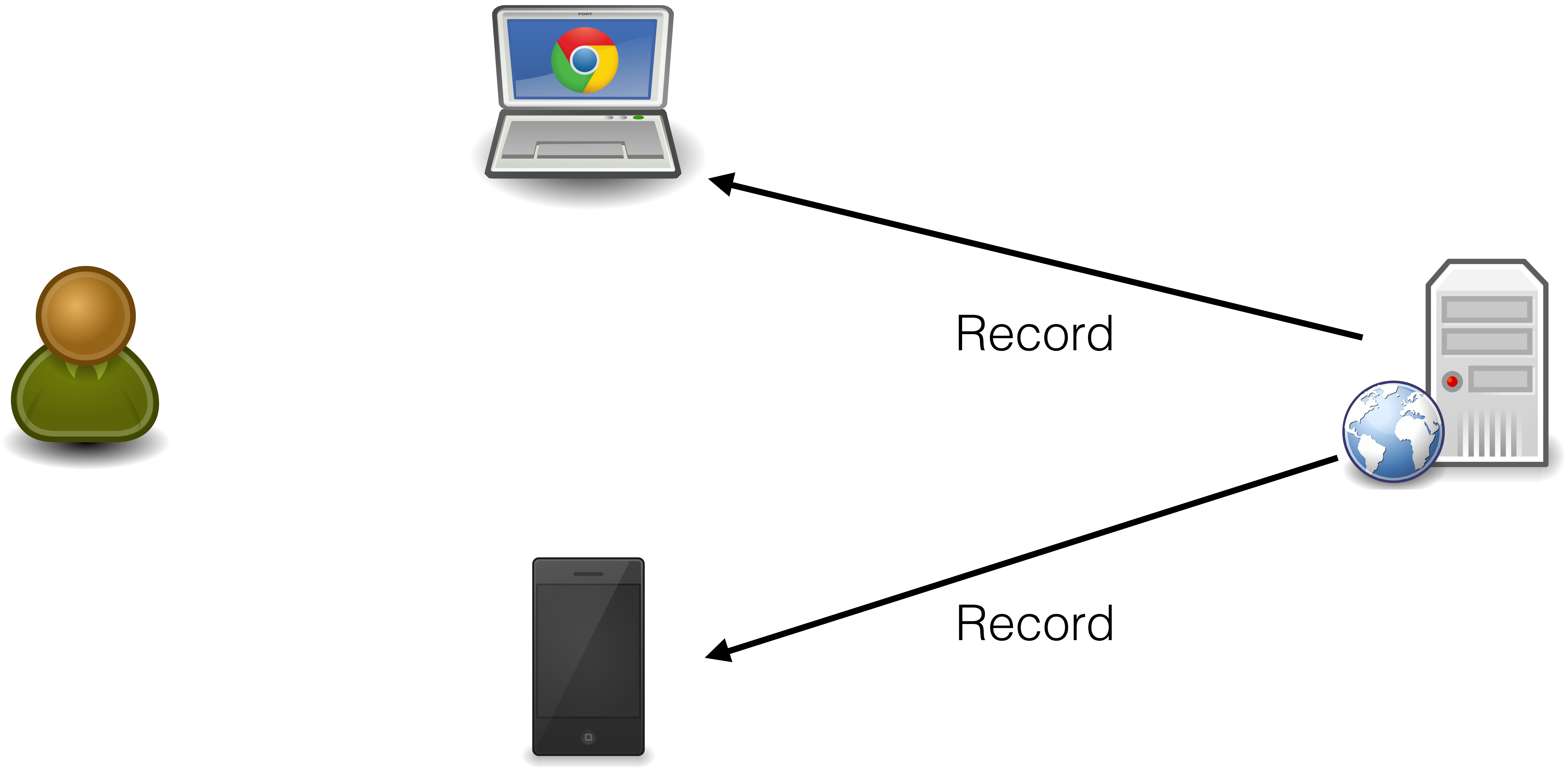

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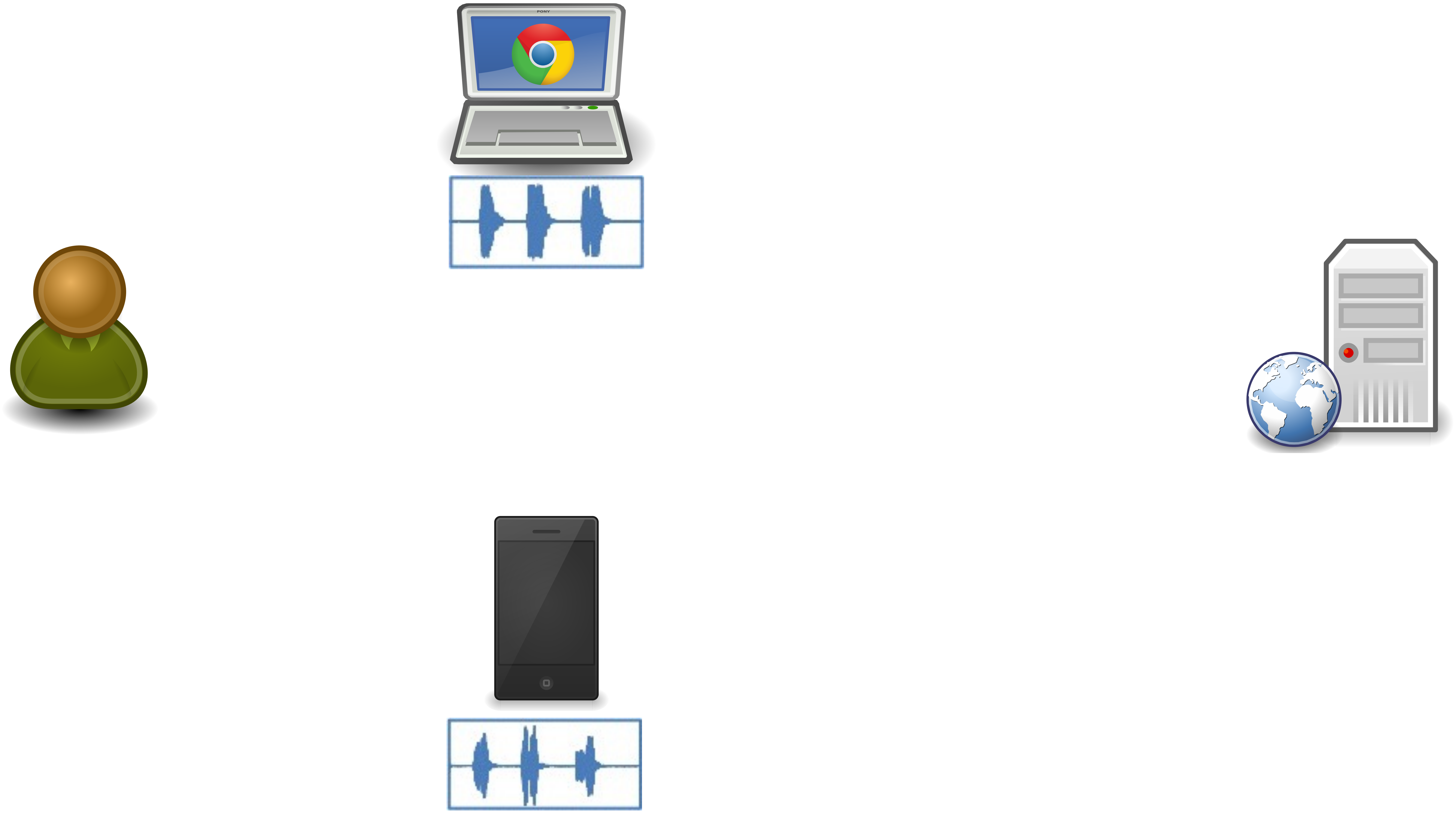

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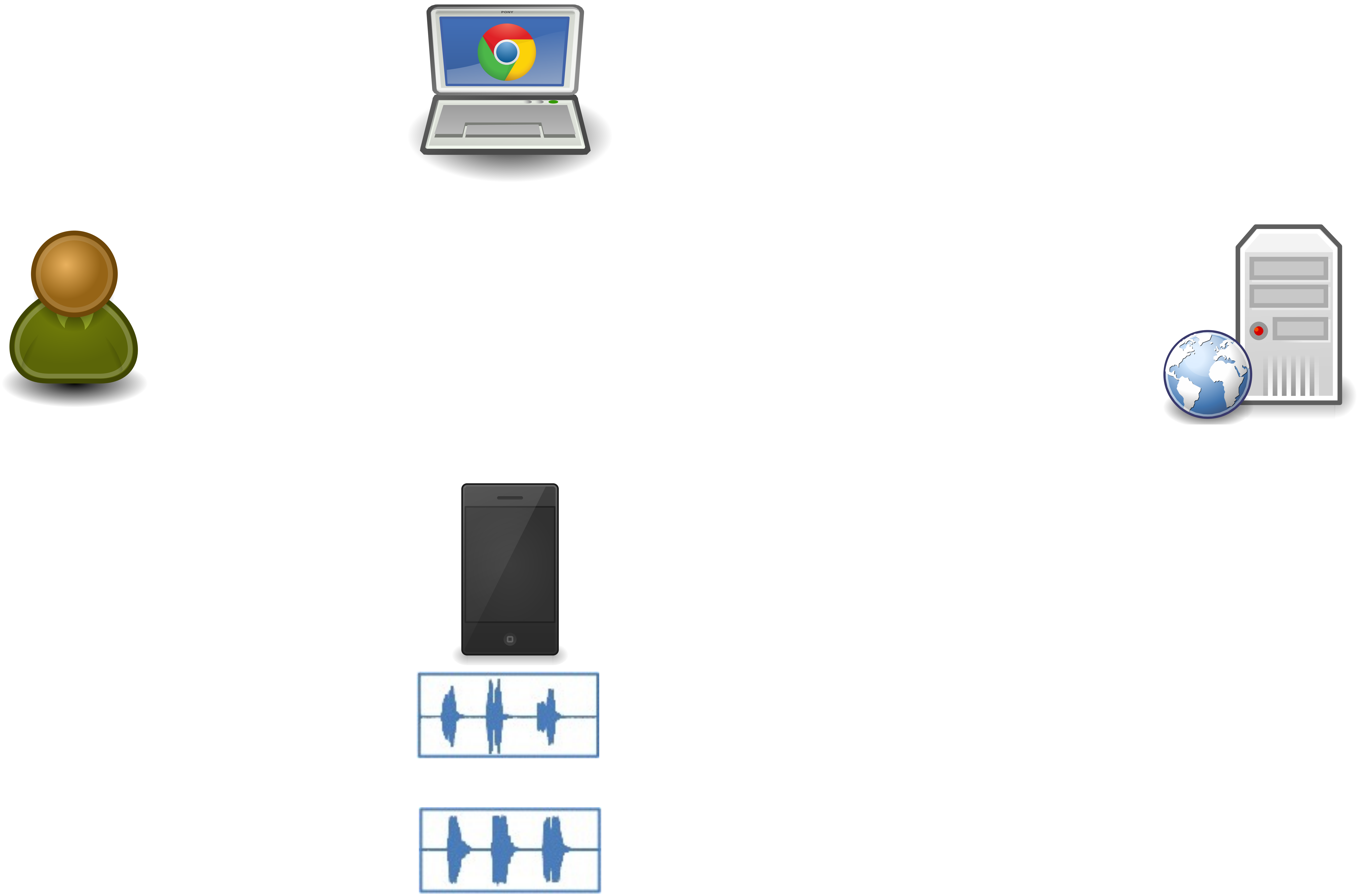

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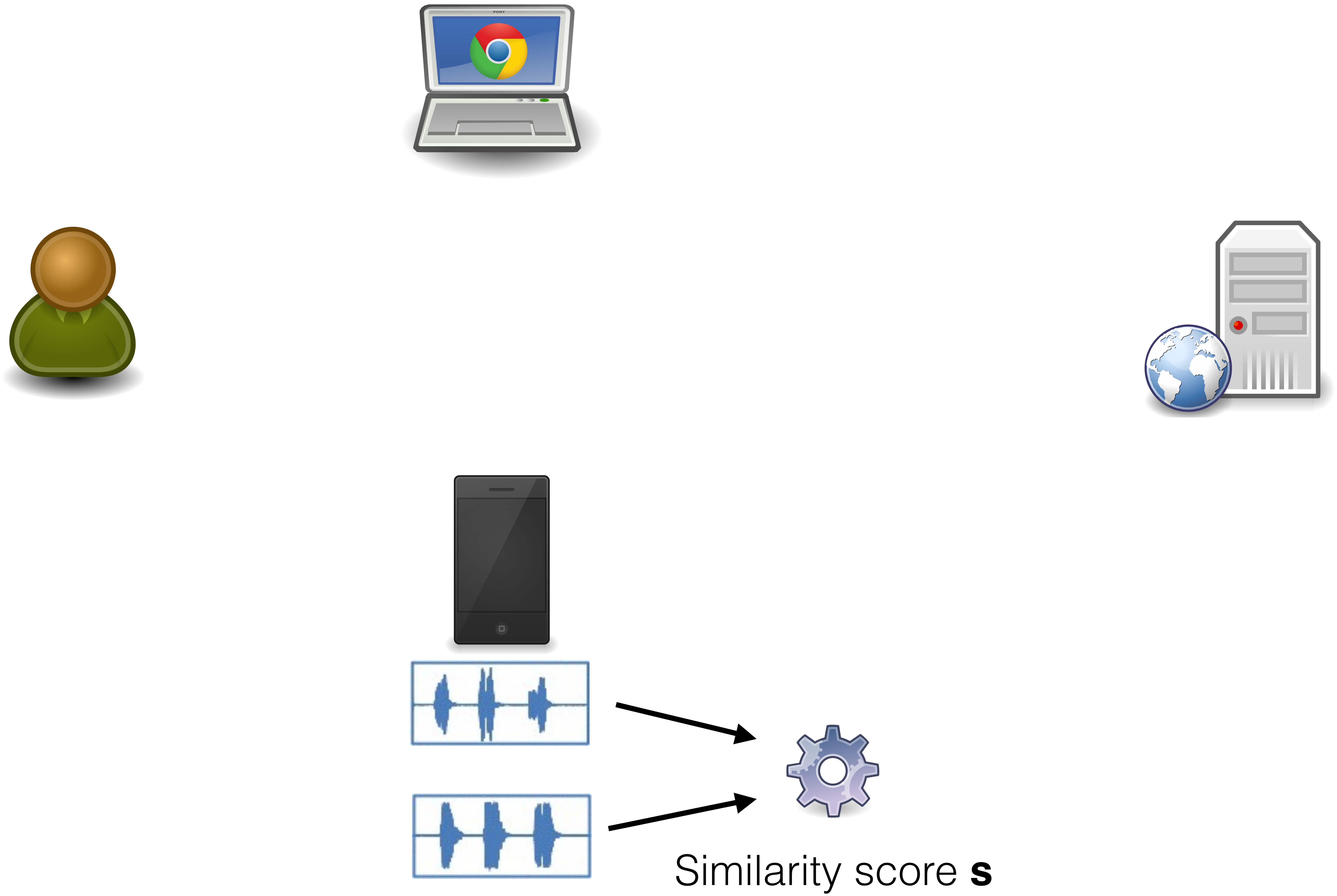

Similarity score **s**

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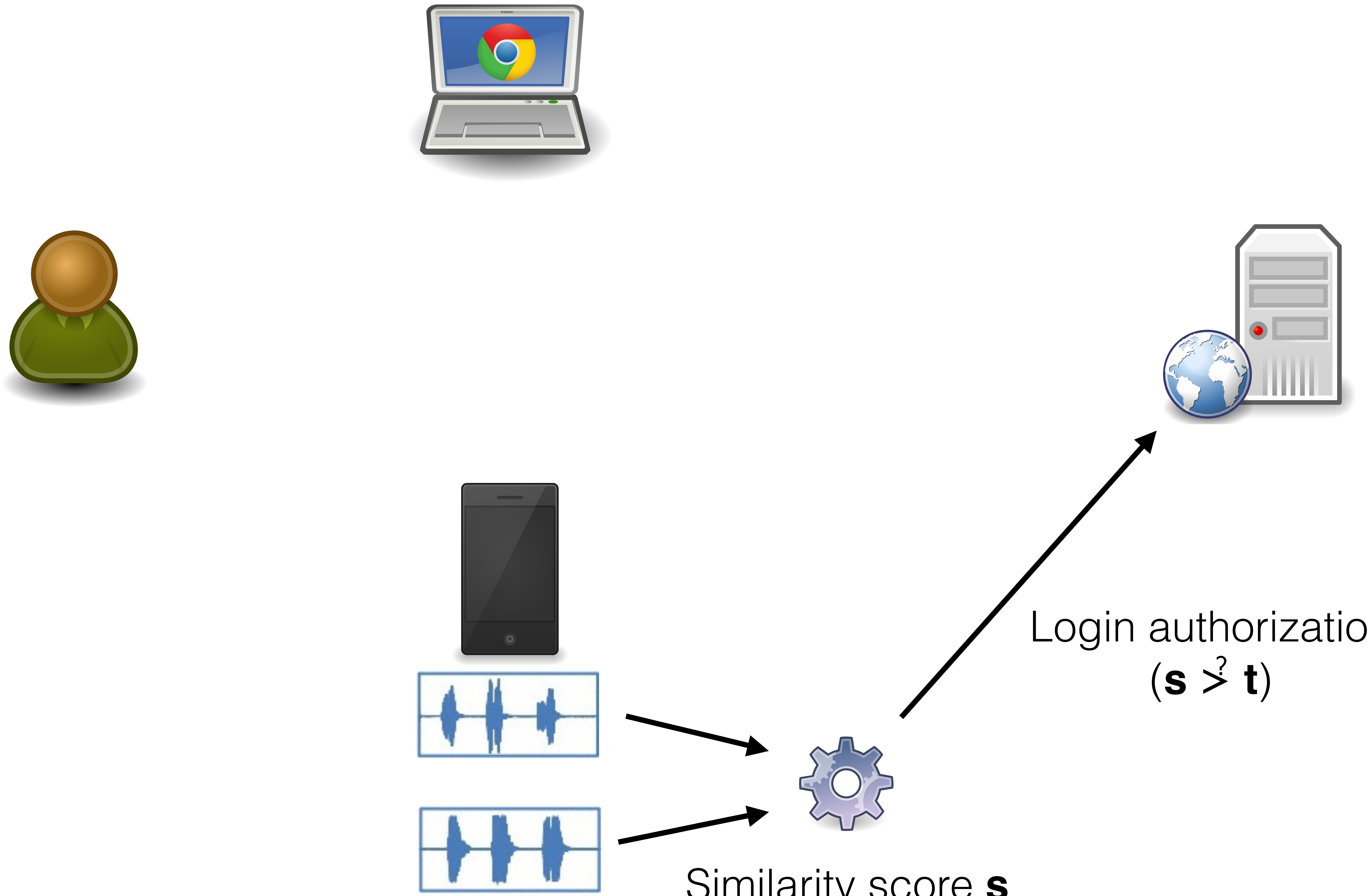
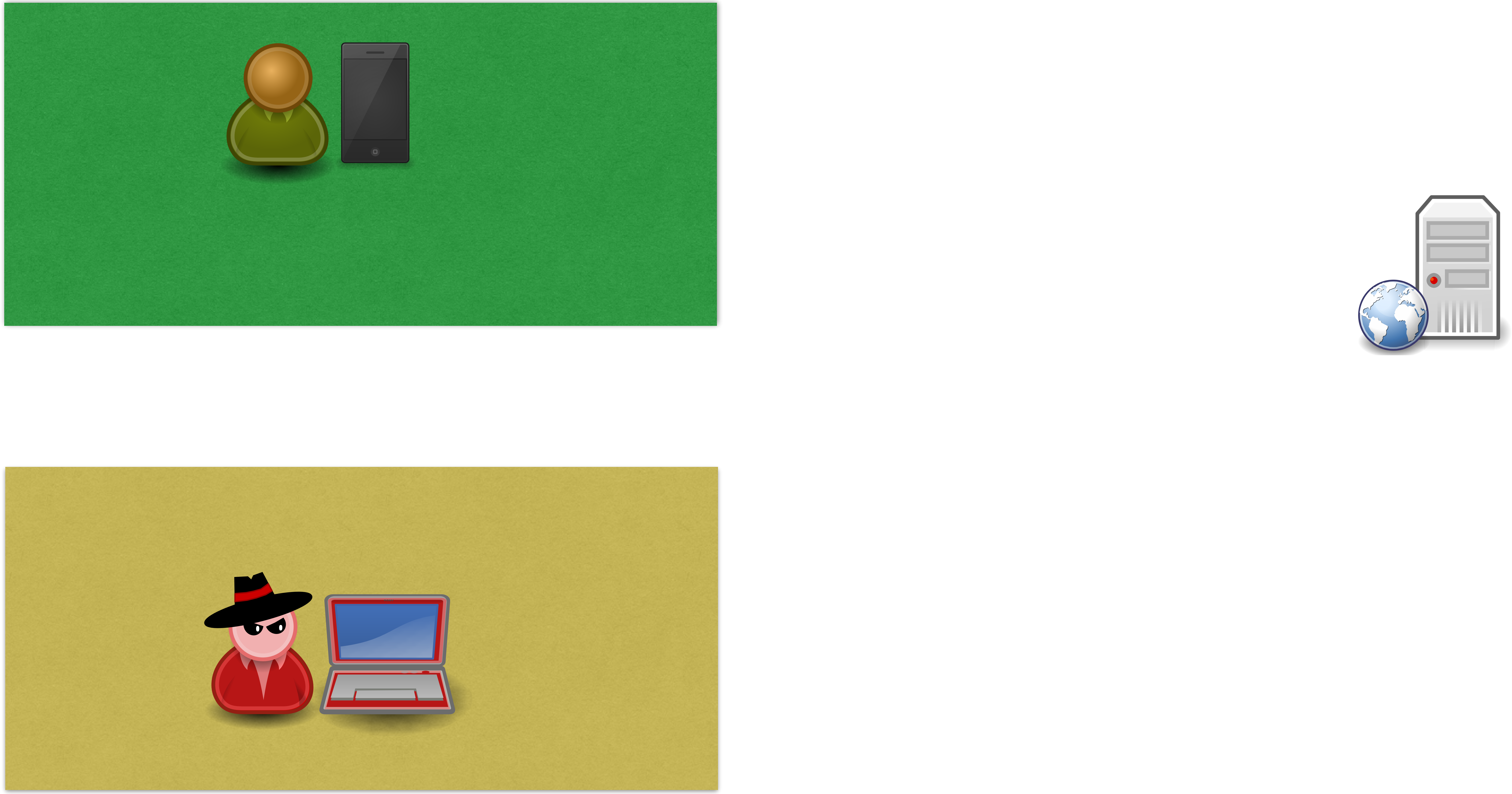


Login authorization
$(\mathbf{s} \overset{?}{>} \mathbf{t})$

Similarity score **s**

Attacker Model

Remote attacker



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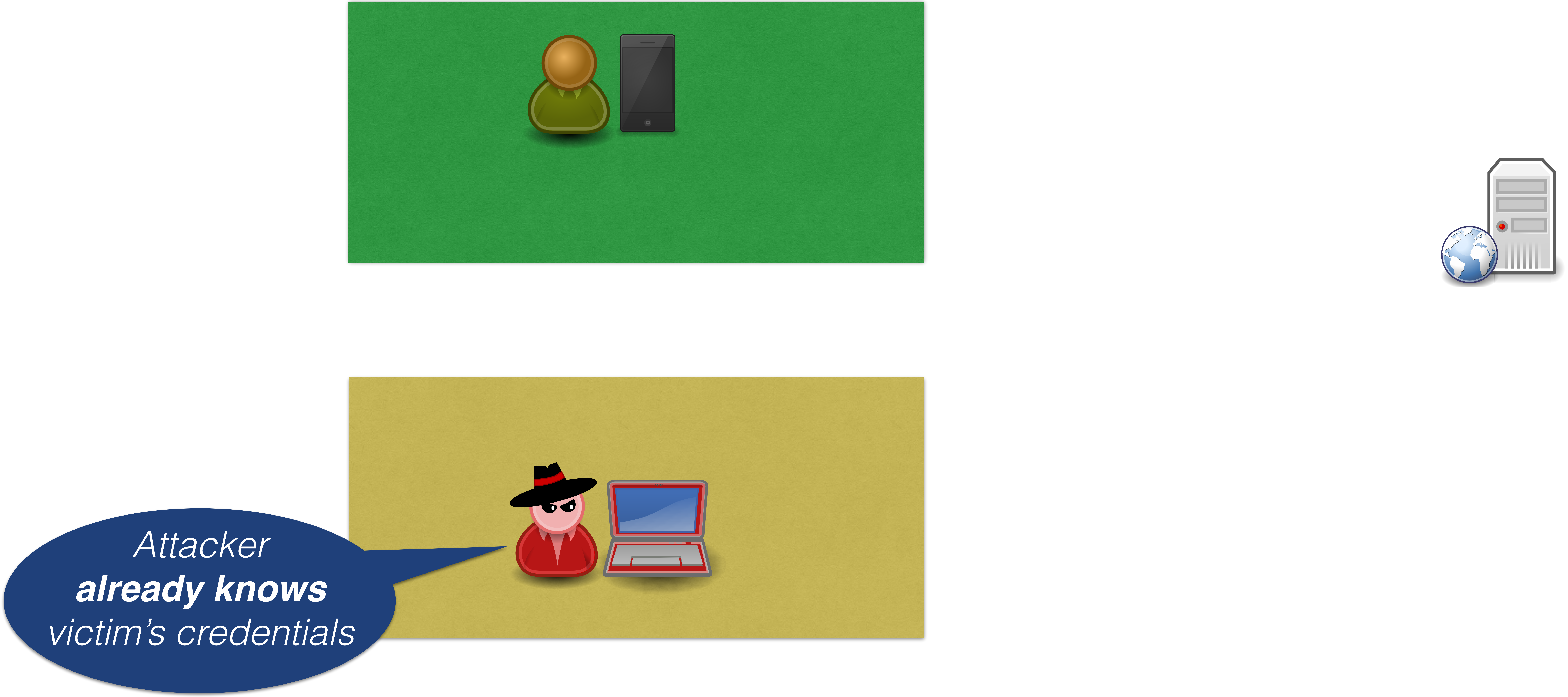
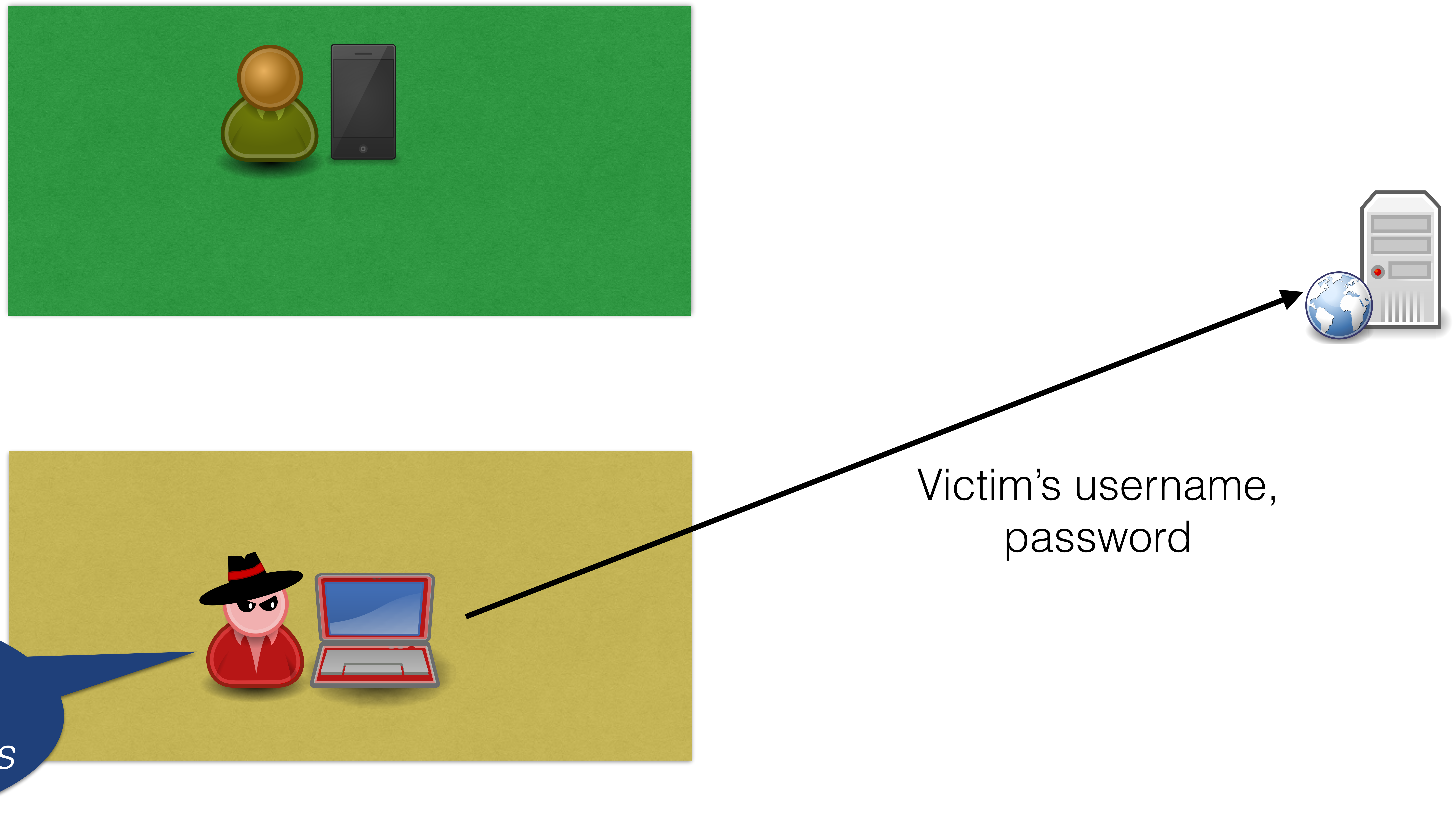


Attacker *already knows* victim's credentials

Remote attacker


Victim's username, password
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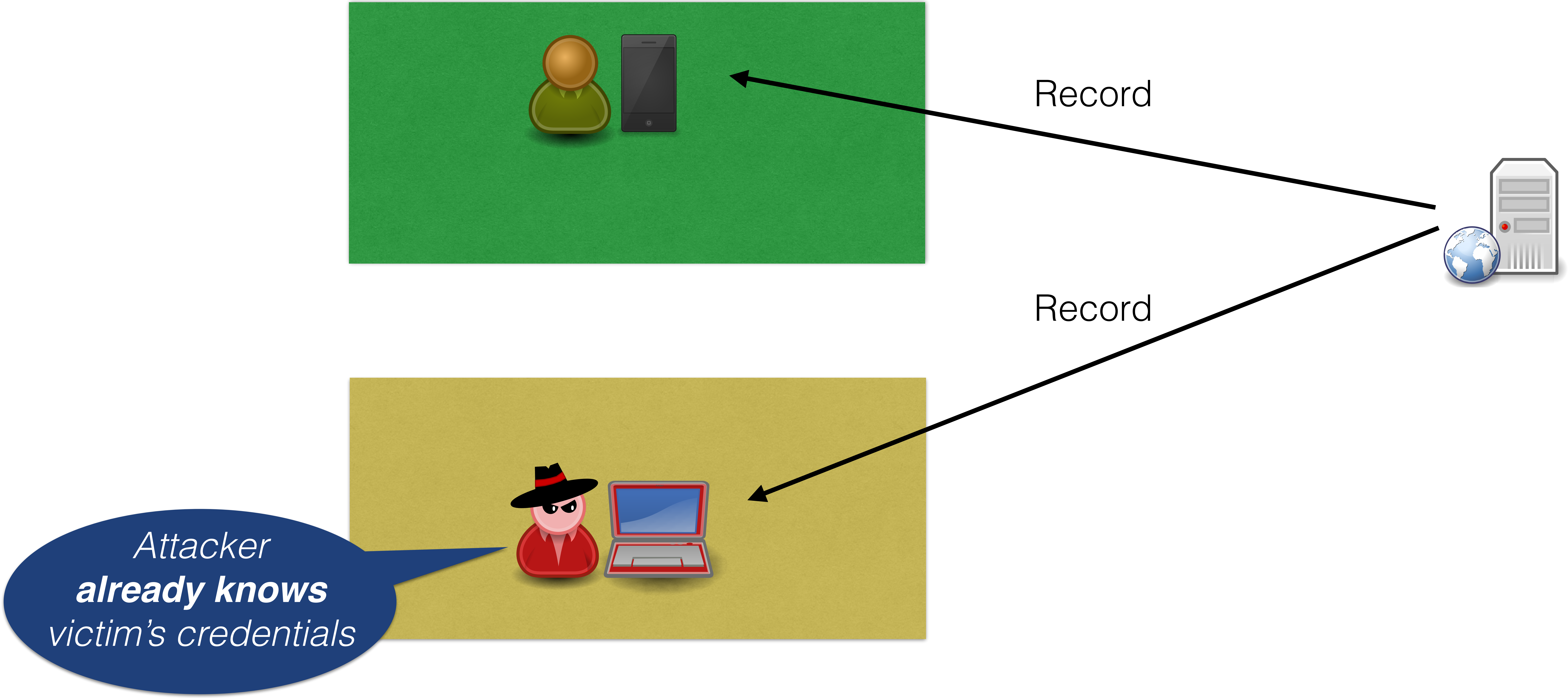

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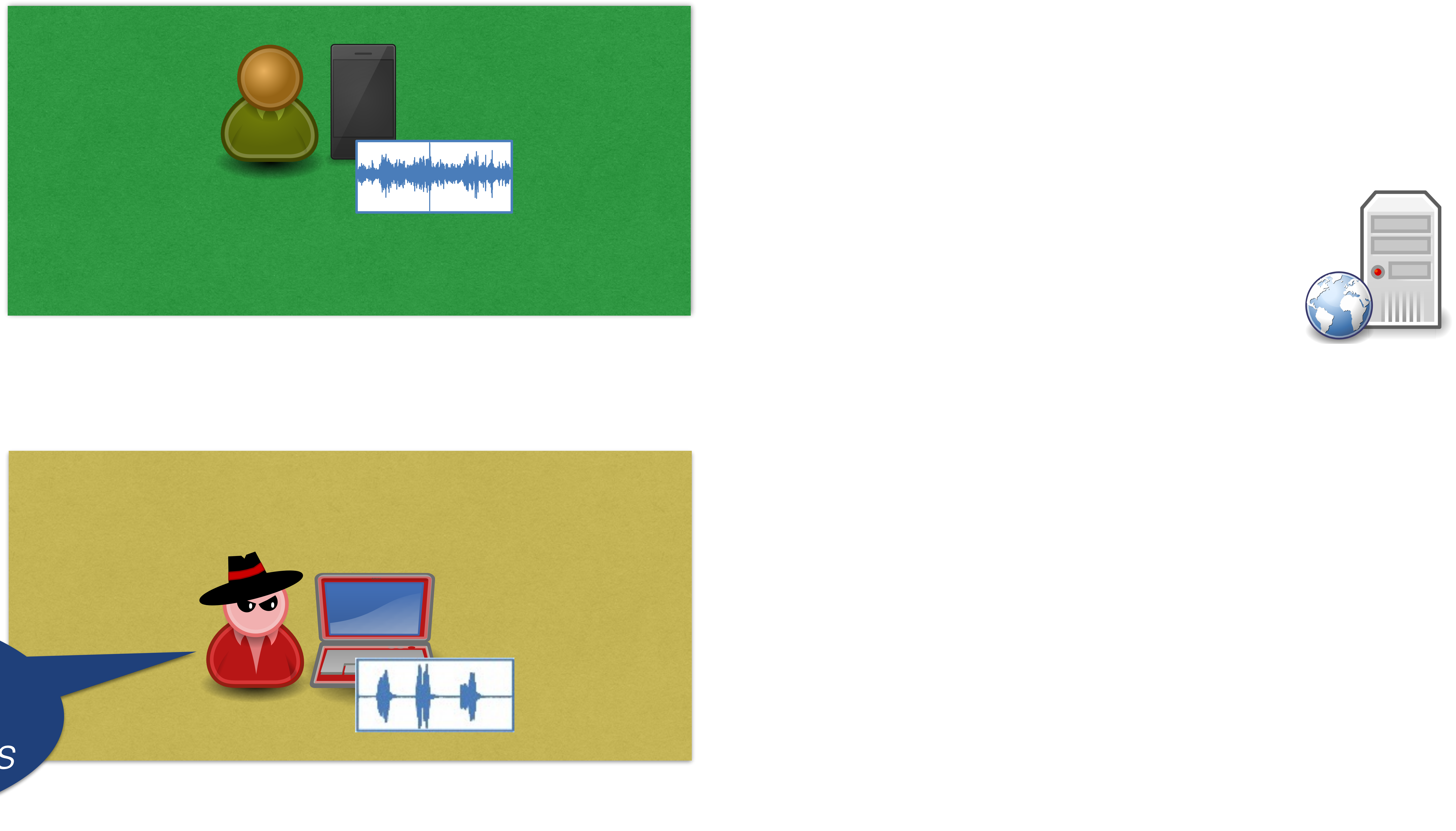

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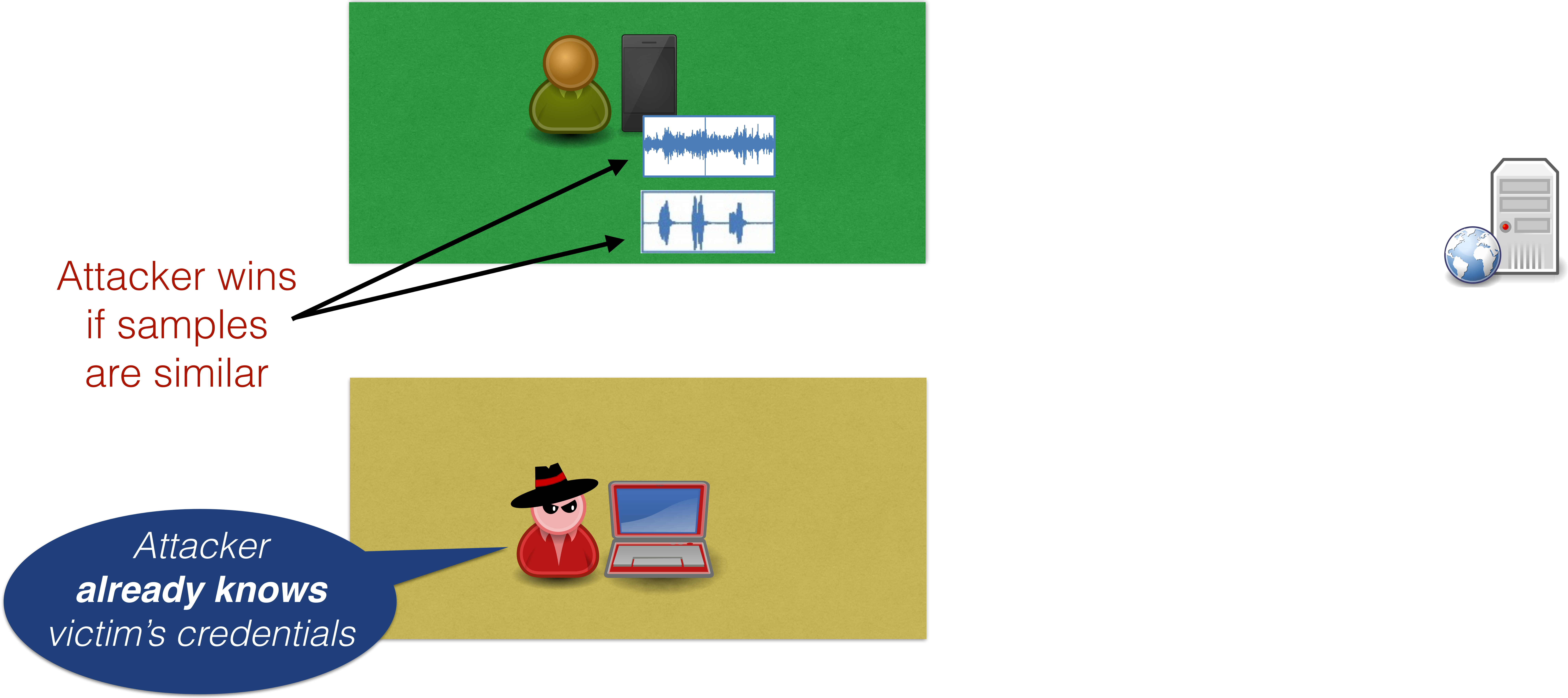
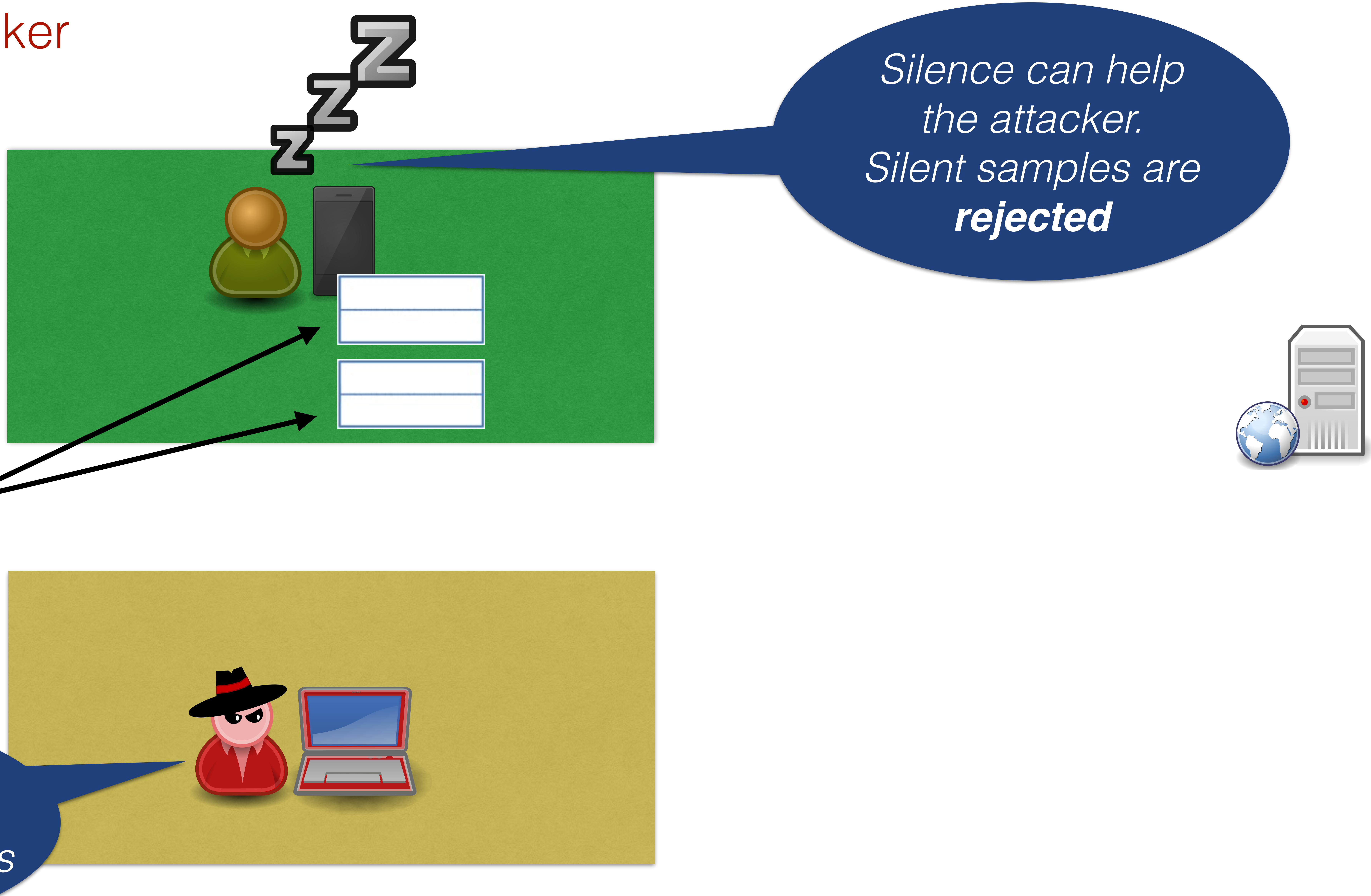


Attacker wins if samples are similar

Attacker ***already knows*** *victim's credentials*

Attacker Model

Remote attacker



*Silence can help the attacker. Silent samples are **rejected***

Attacker wins if samples are similar

*Attacker **already knows** victim's credentials*

Sound-Proof Evaluation

ETHzürich

Performance

Sound-Proof Evaluation

Performance

- Total time: User clicks “login” —> browser refresh to log the user in
  - Recording time: 3 seconds

Sound-Proof Evaluation

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	Total Time (mean)
WiFi	4677ms (±181ms)
Cellular	4944ms (±233ms)

Phone network connectivity

Sound-Proof Evaluation

Performance

- Total time: User clicks “login” —> browser refresh to log the user in
  - Recording time: 3 seconds
- Room for **improvement**
  - Compress and/or stream browser recording

	Total Time (mean)
WiFi	4677ms (±181ms)
Cellular	4944ms (±233ms)

Phone network connectivity

Audio Collection Campaign (2 subjects over 4 weeks)

- **Environment**
  - office, office-music, home-TV, lecture room, train station, café
- **Laptop**
  - MacBook Pro Mid 2012, Dell E6510 (using Google Chrome)
- **Phone**
  - iPhone 5, Google Nexus 4
- **Phone position**
  - outside, in pocket, in purse
- **User activity**
  - being silent, talking, coughing, whistling

4014 audio samples (2007 login attempts)

Sound-Proof Evaluation

Parameter Tuning

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- Frequency bands
  - ≥ 50Hz (low frequency noise)
  - ≤ 4kHz (fading, directionality)

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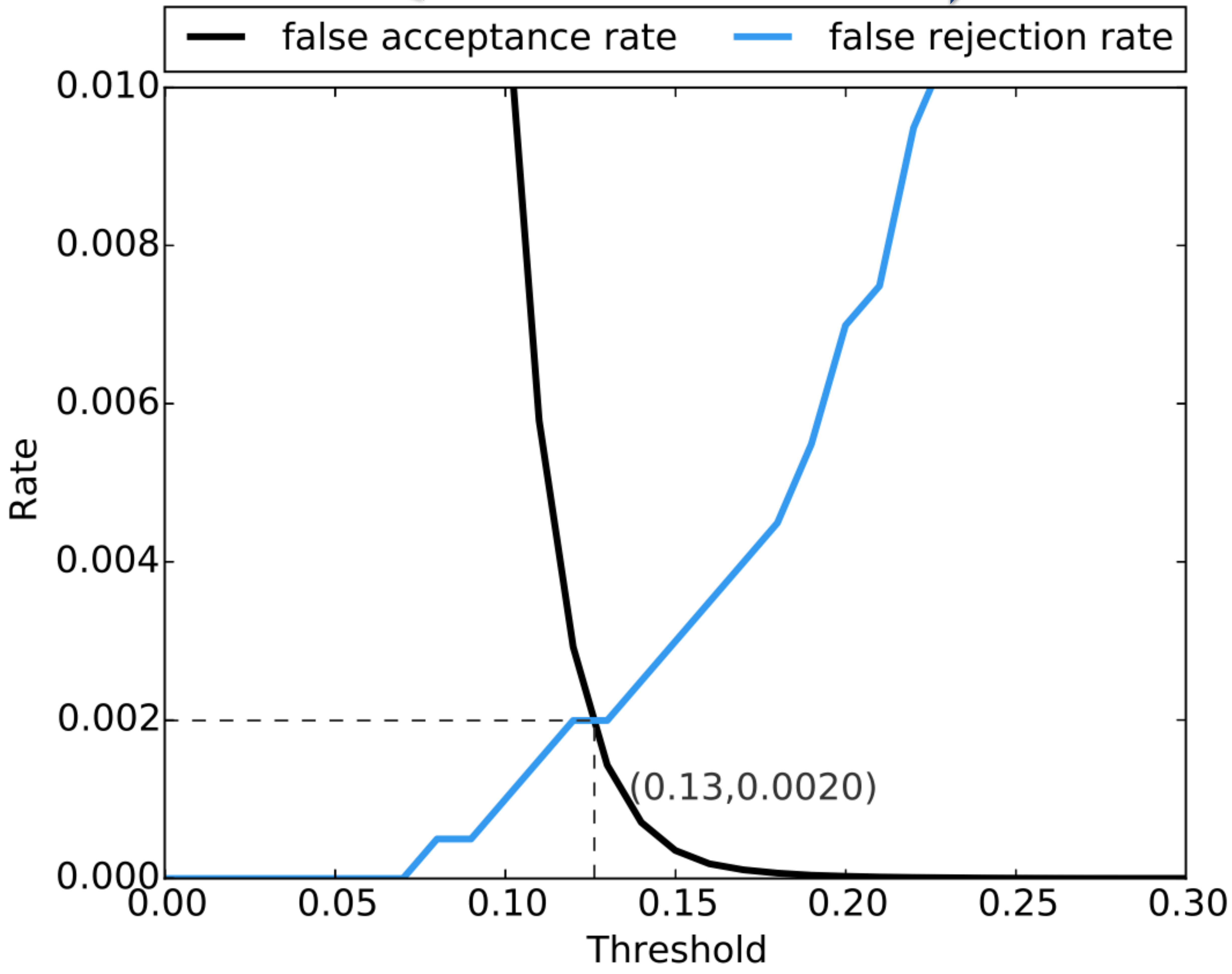
Fraudulent logins not detected

Legitimate logins rejected



Sound-Proof Evaluation

Parameter Tuning

- Frequency bands
  - ≥ 50Hz (low frequency noise)
  - ≤ 4kHz (fading, directionality)

- Similarity score threshold t = 0.13
  - **Equal Error Rate = 0.002**

0.2%

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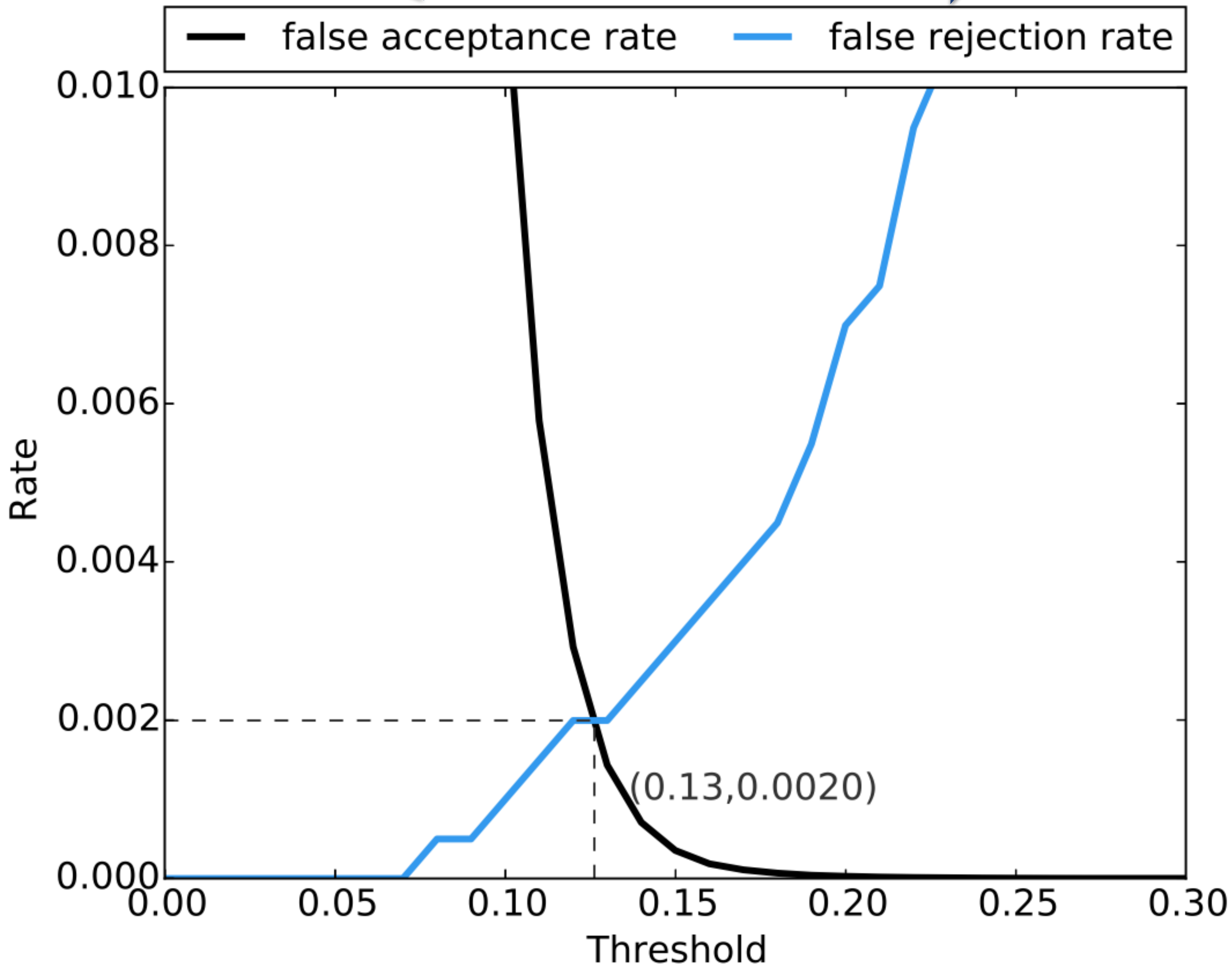
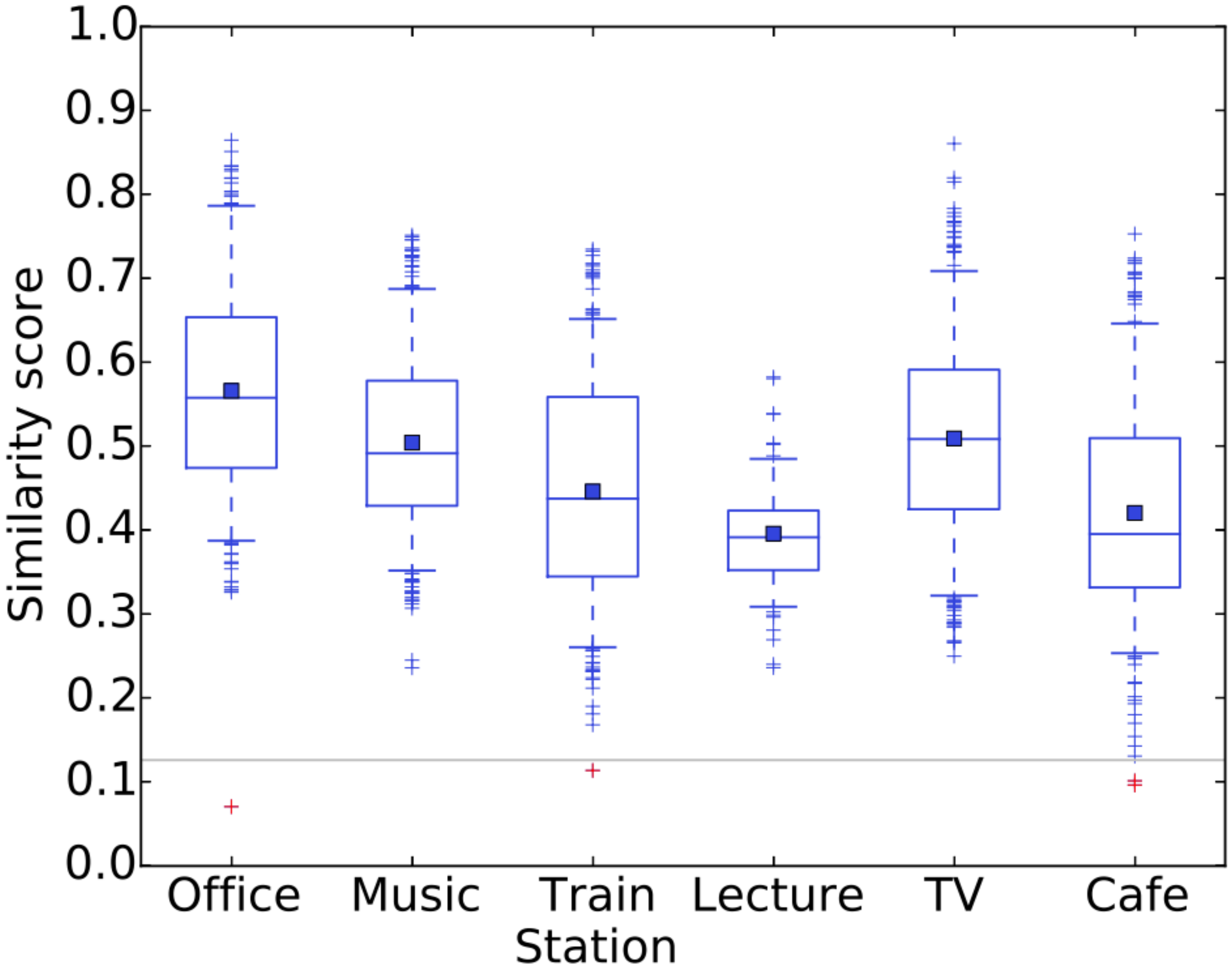


Impact of environment



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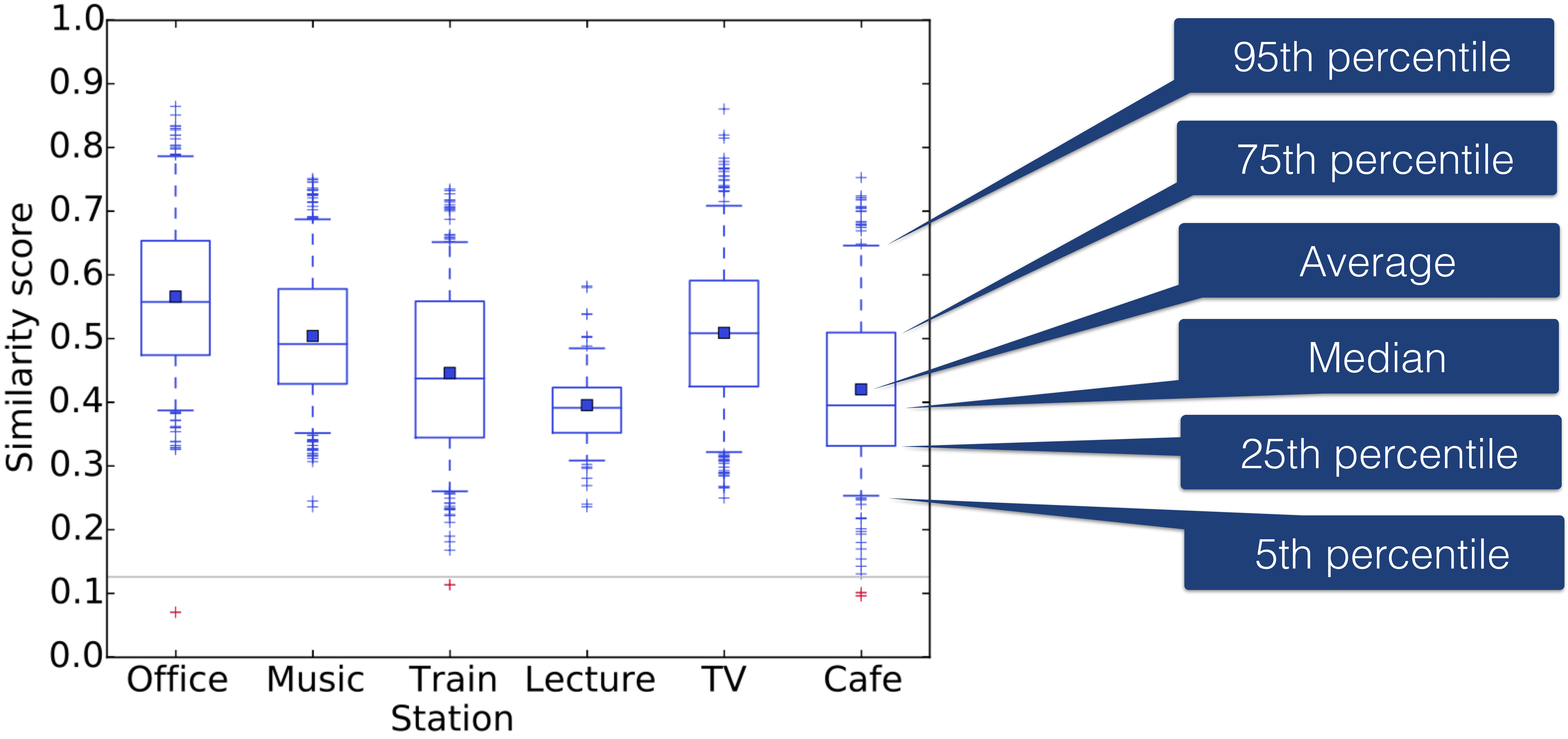


95th percentile

75th percentile

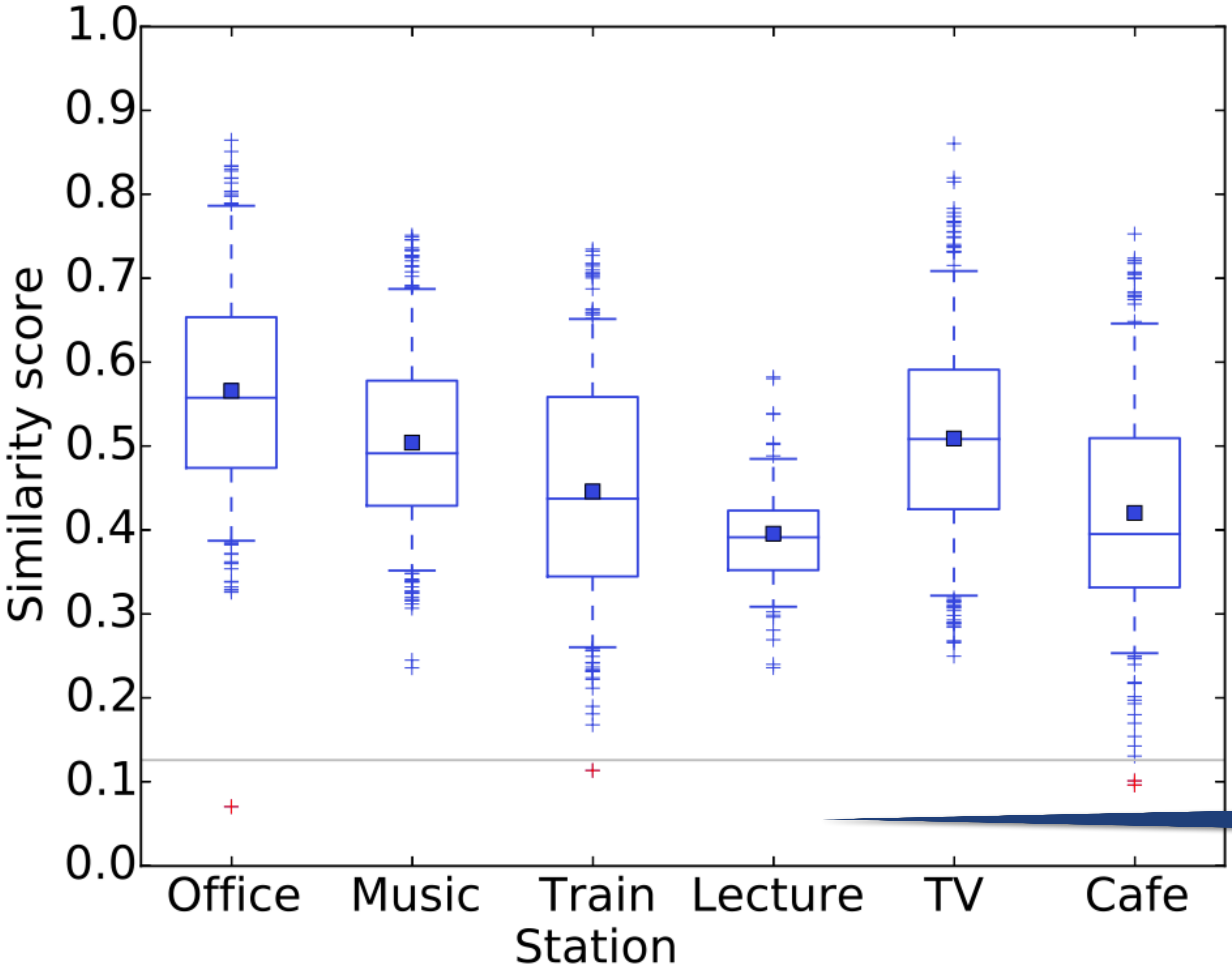
Average

Median

25th percentile

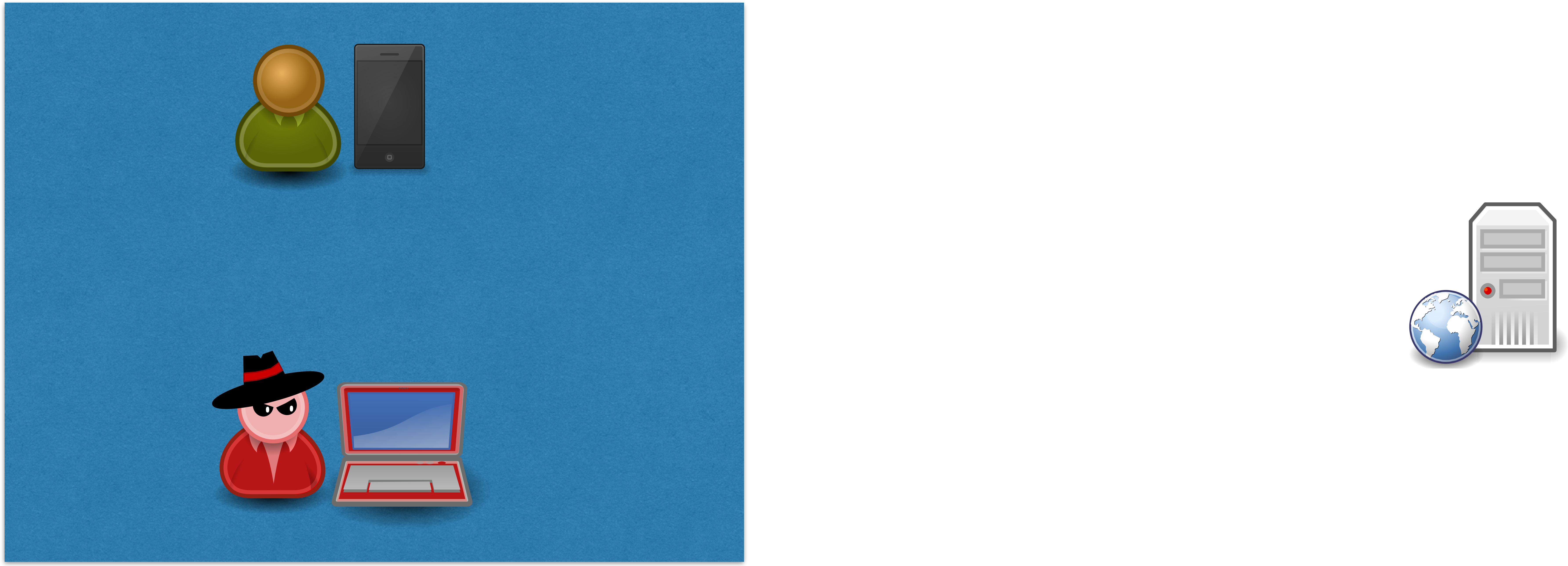
5th percentile

Impact of environment



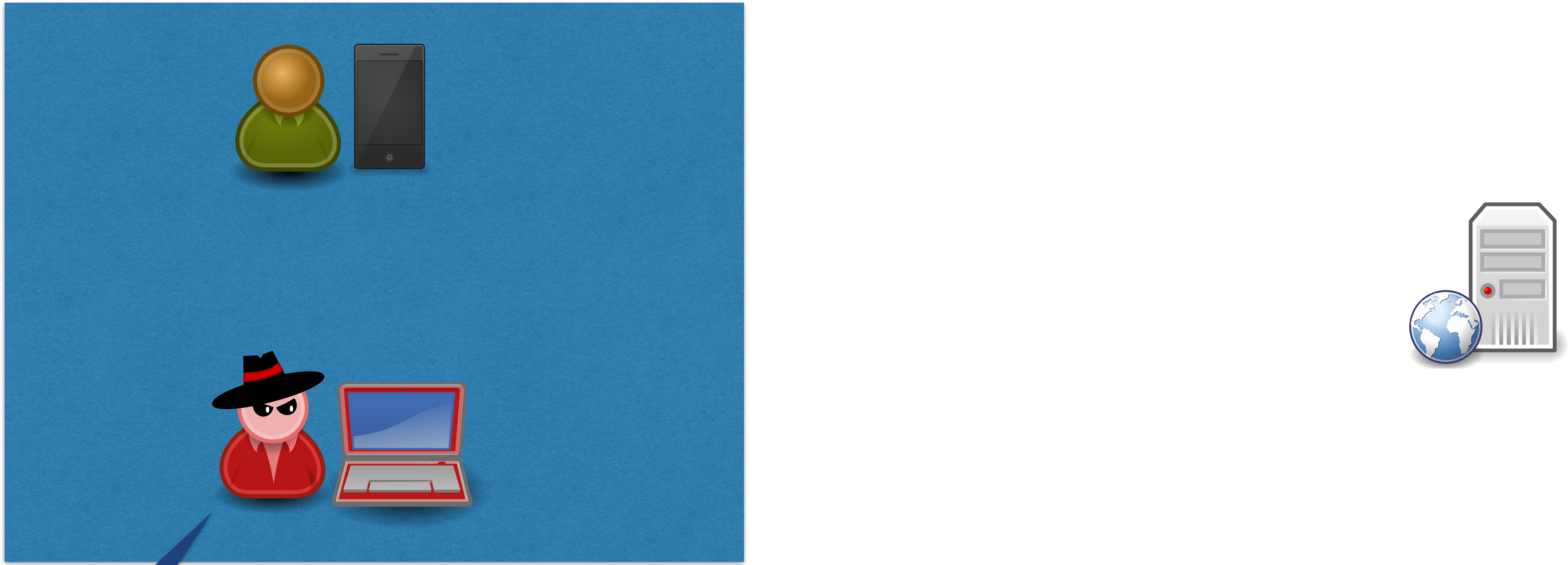
4 false rejections out of **2007**

Co-located attackers



Security Evaluation

Co-located attackers



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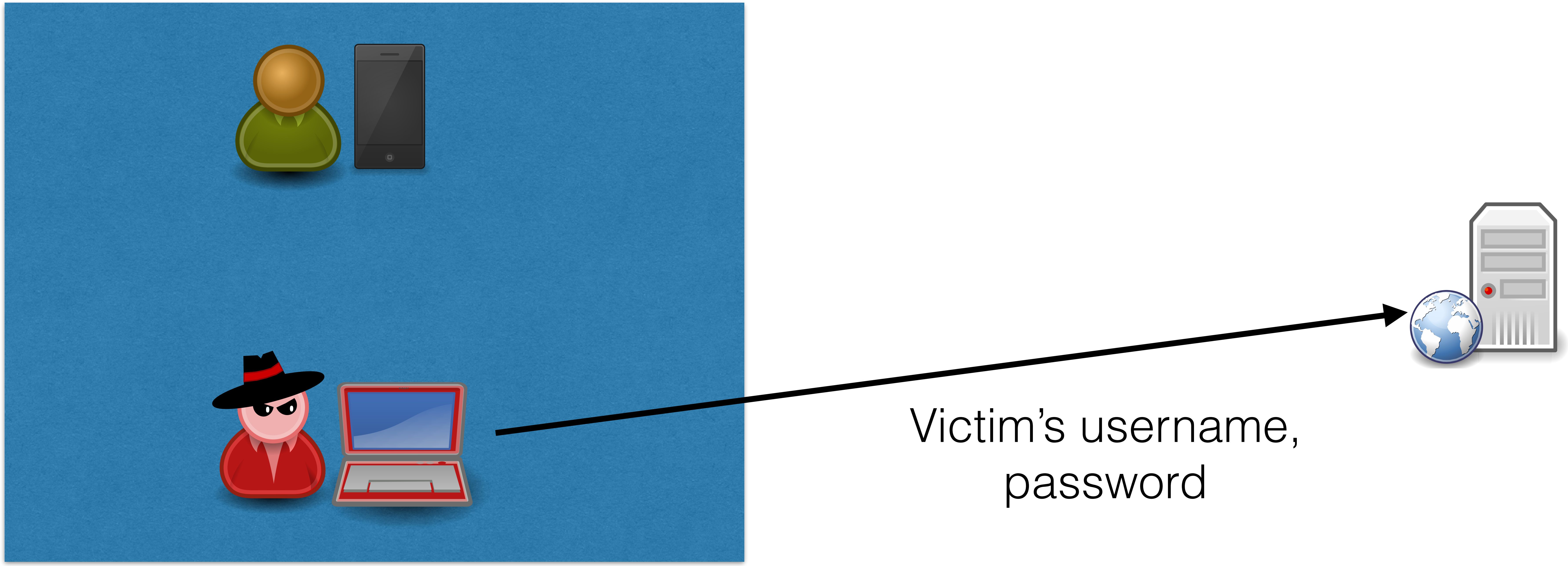

Victim’s username, password

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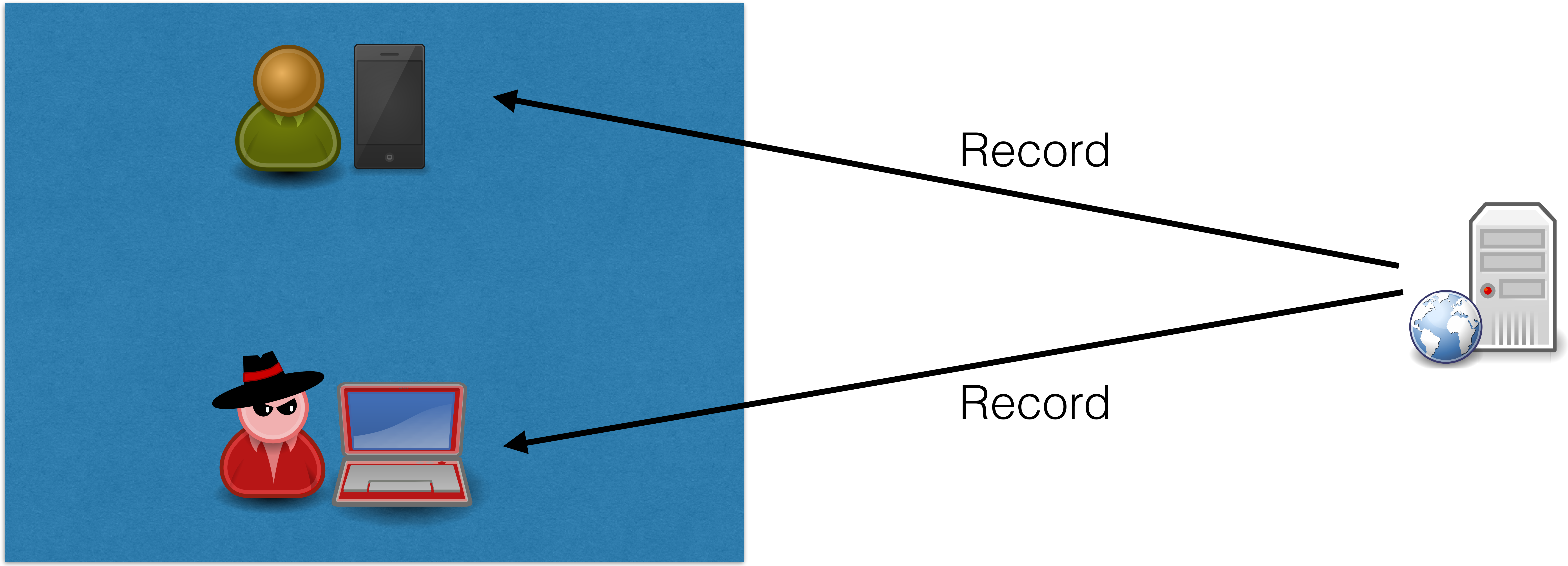

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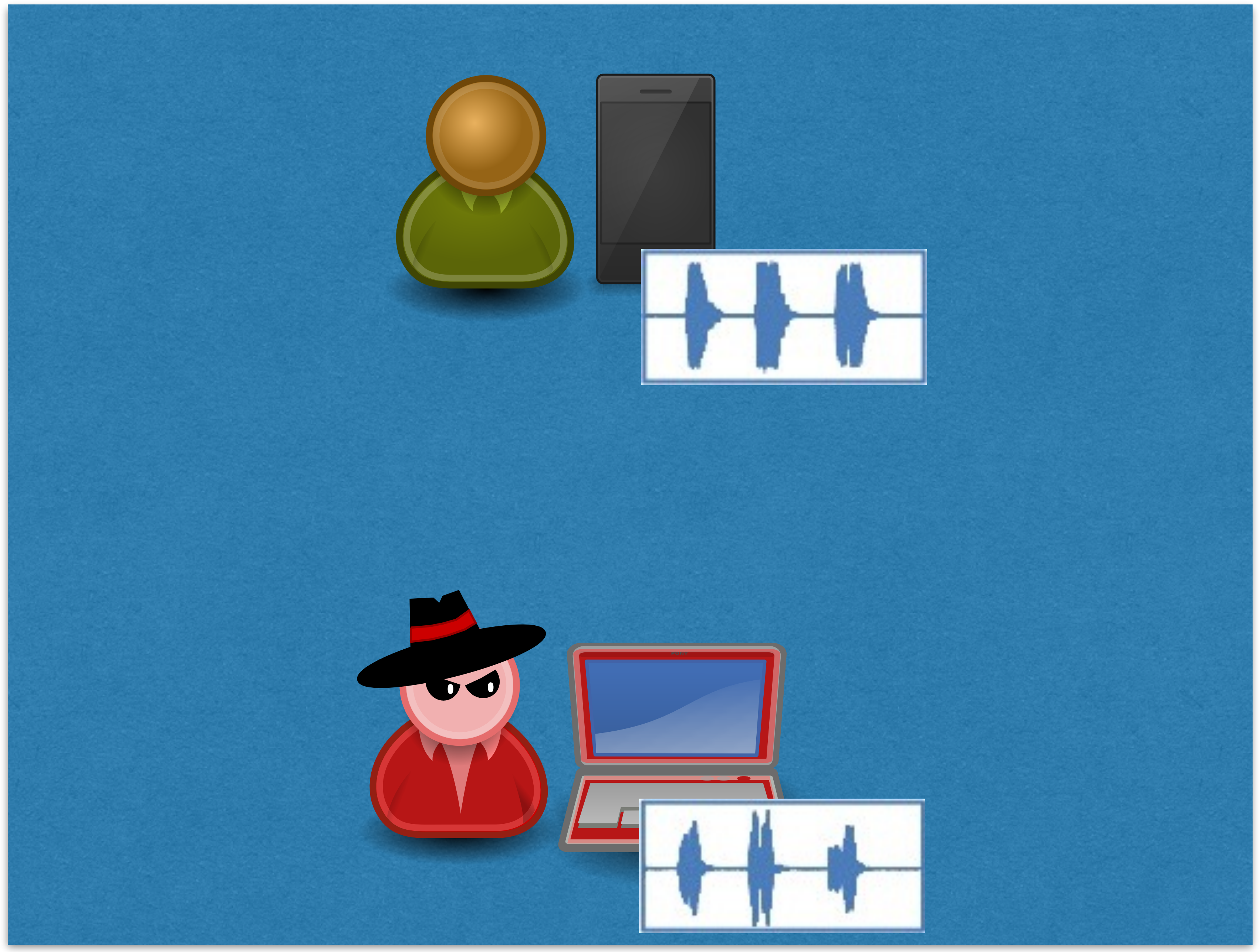

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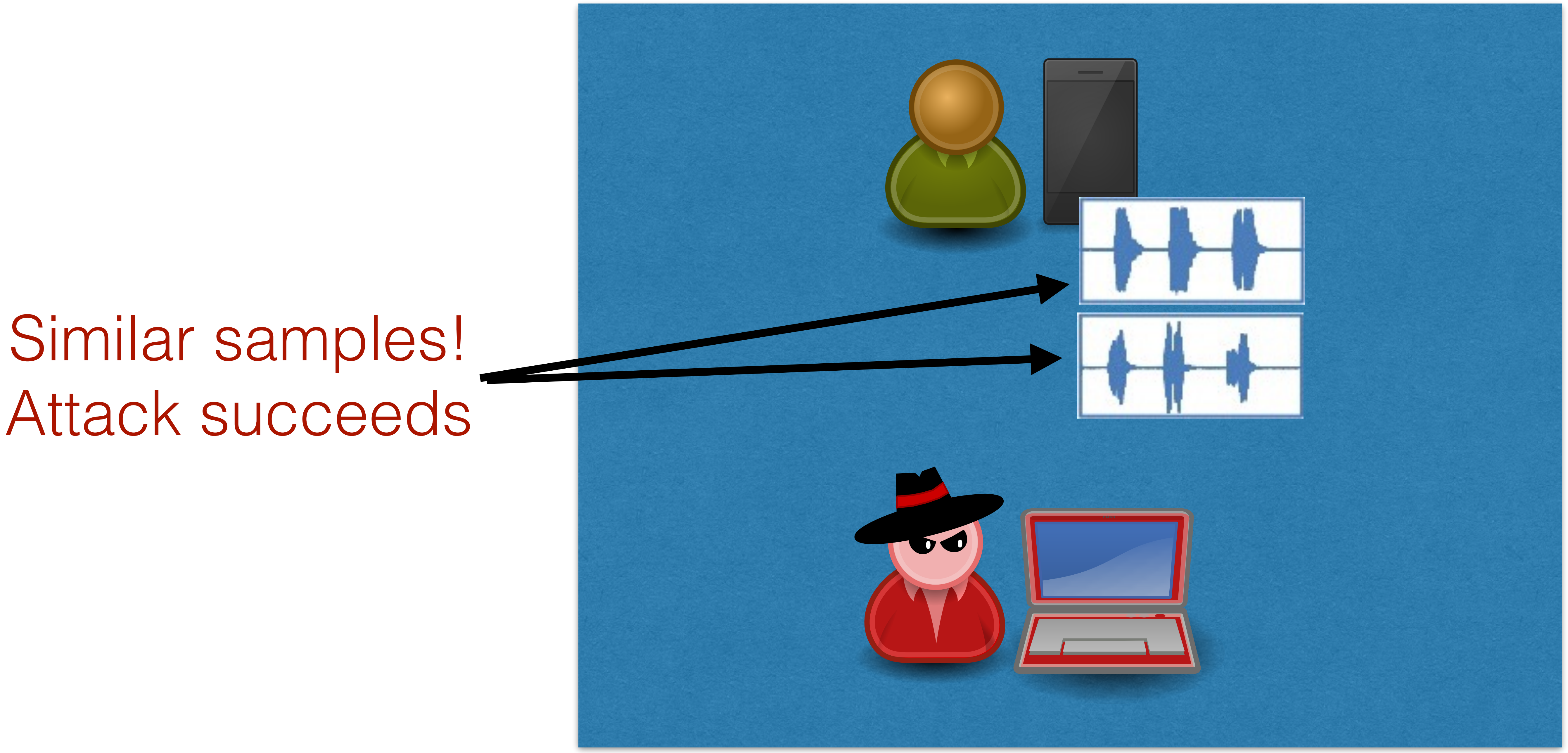
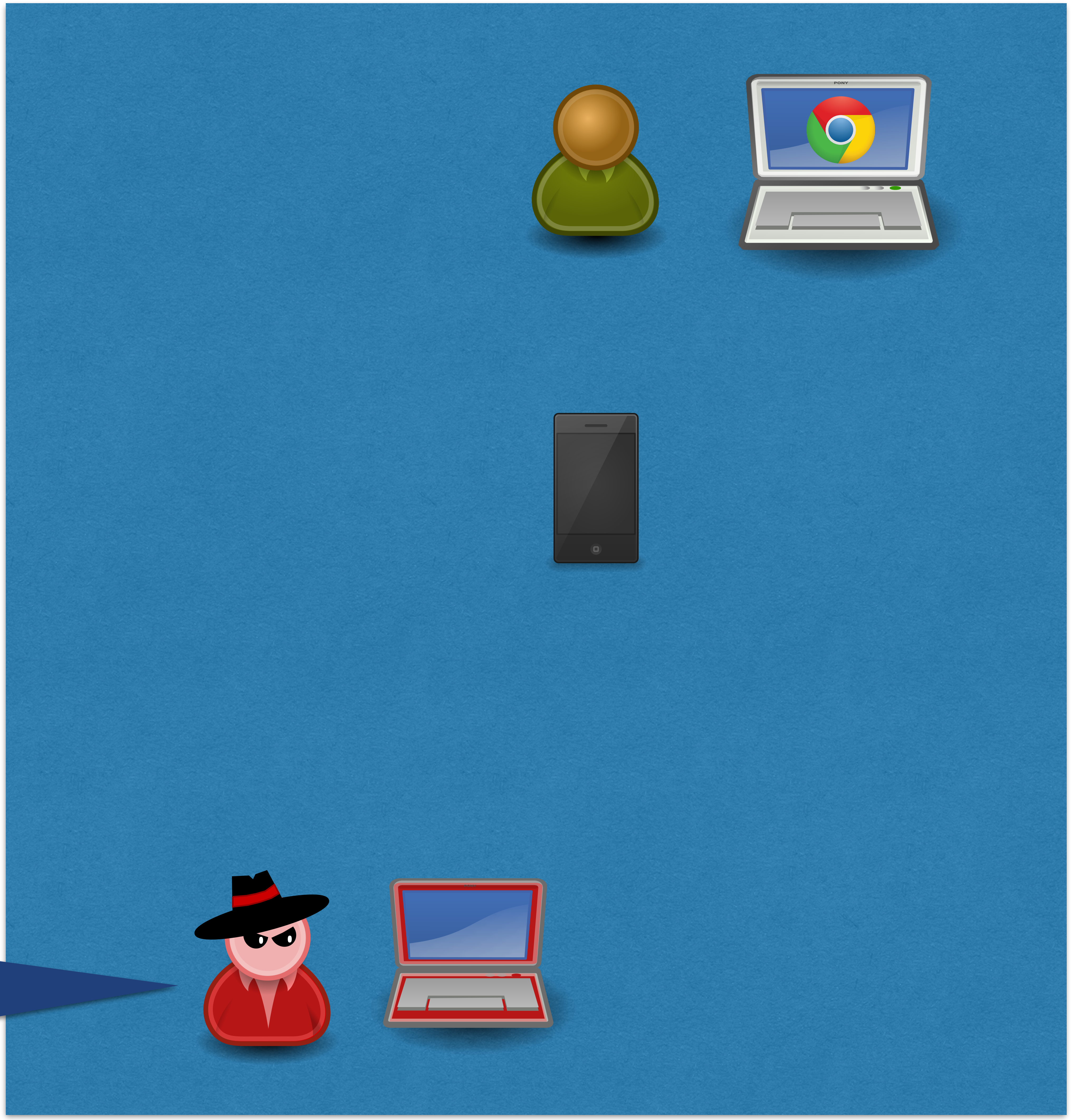


Co-located Attacks

Hard to defeat



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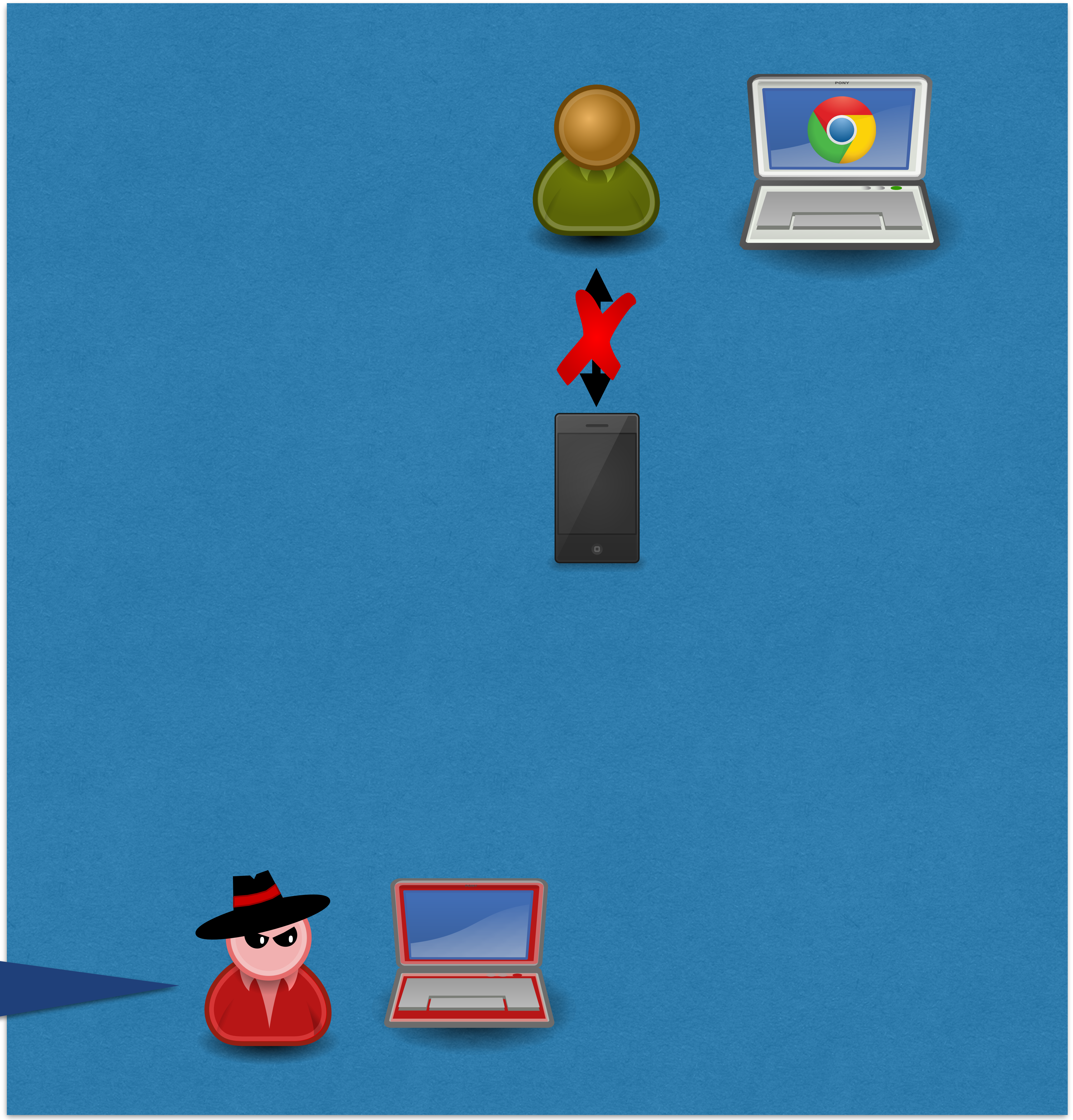

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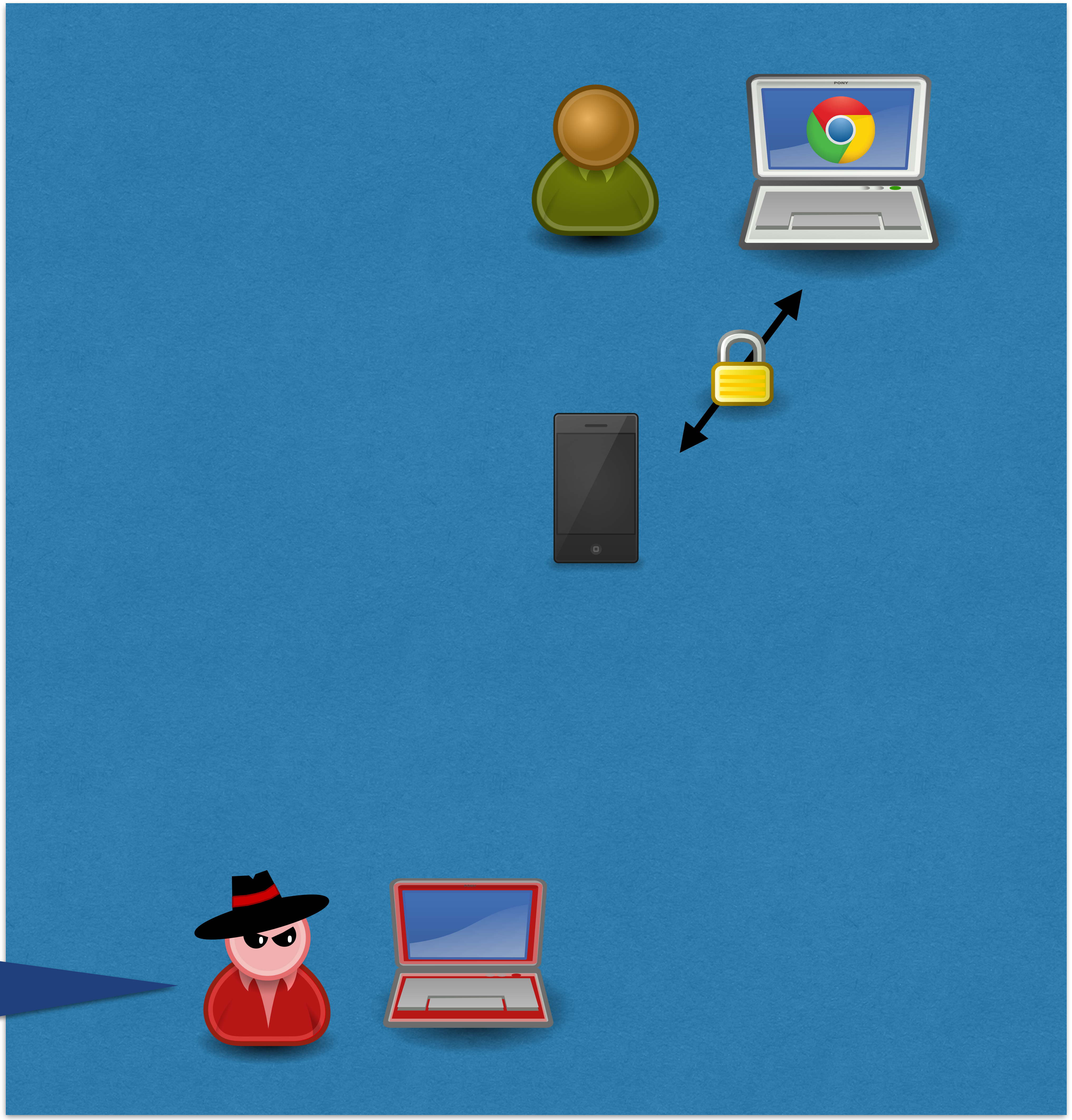

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Hard to defeat

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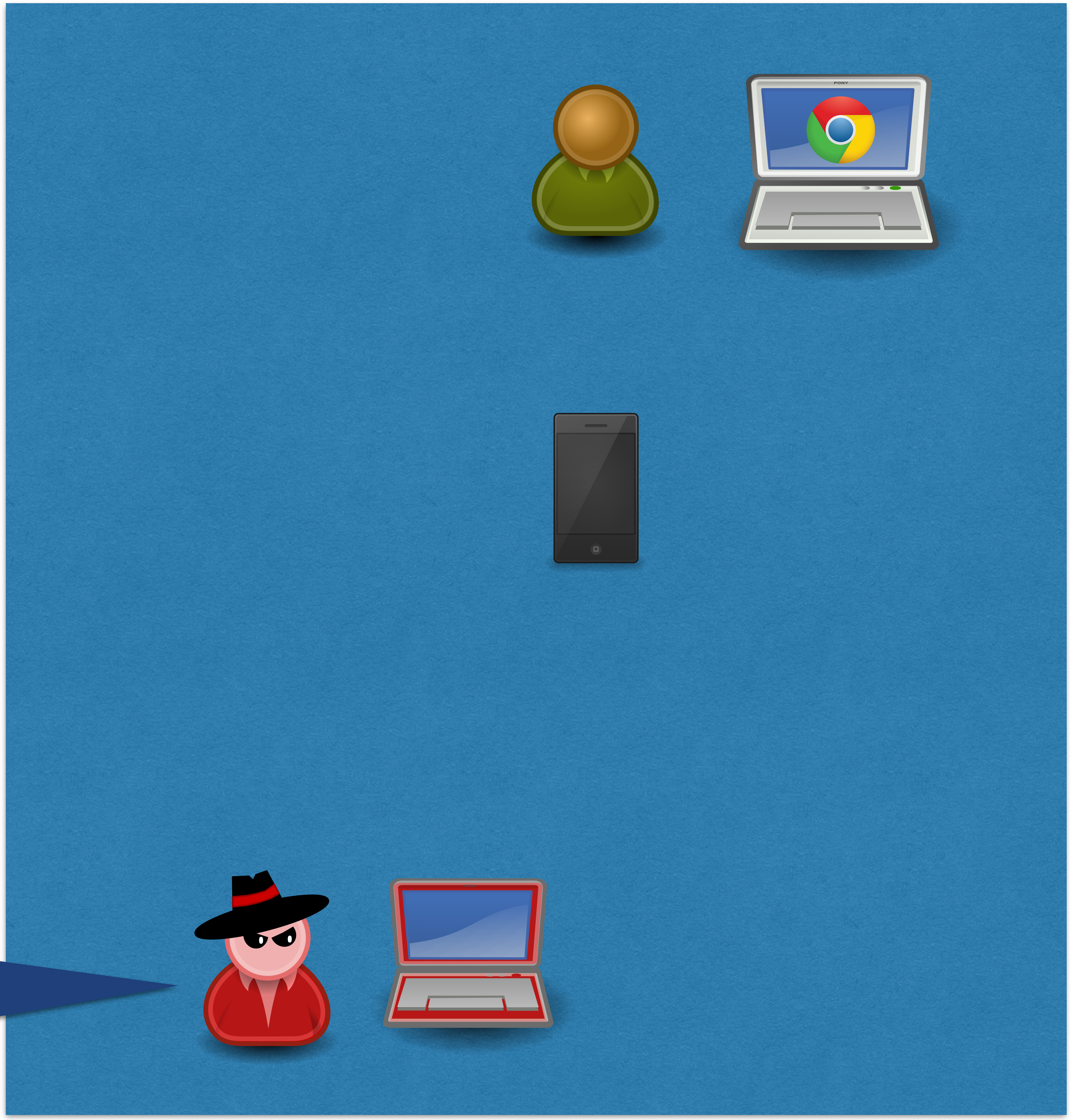
  - Unless phone-computer pairing is required (affects usability)

- Even when 2FA requires user-phone interaction, a determined, co-located attacker might be hard to defeat...



Attacker already knows victim's credentials

User Study

Do people find Sound-Proof usable?

User Study

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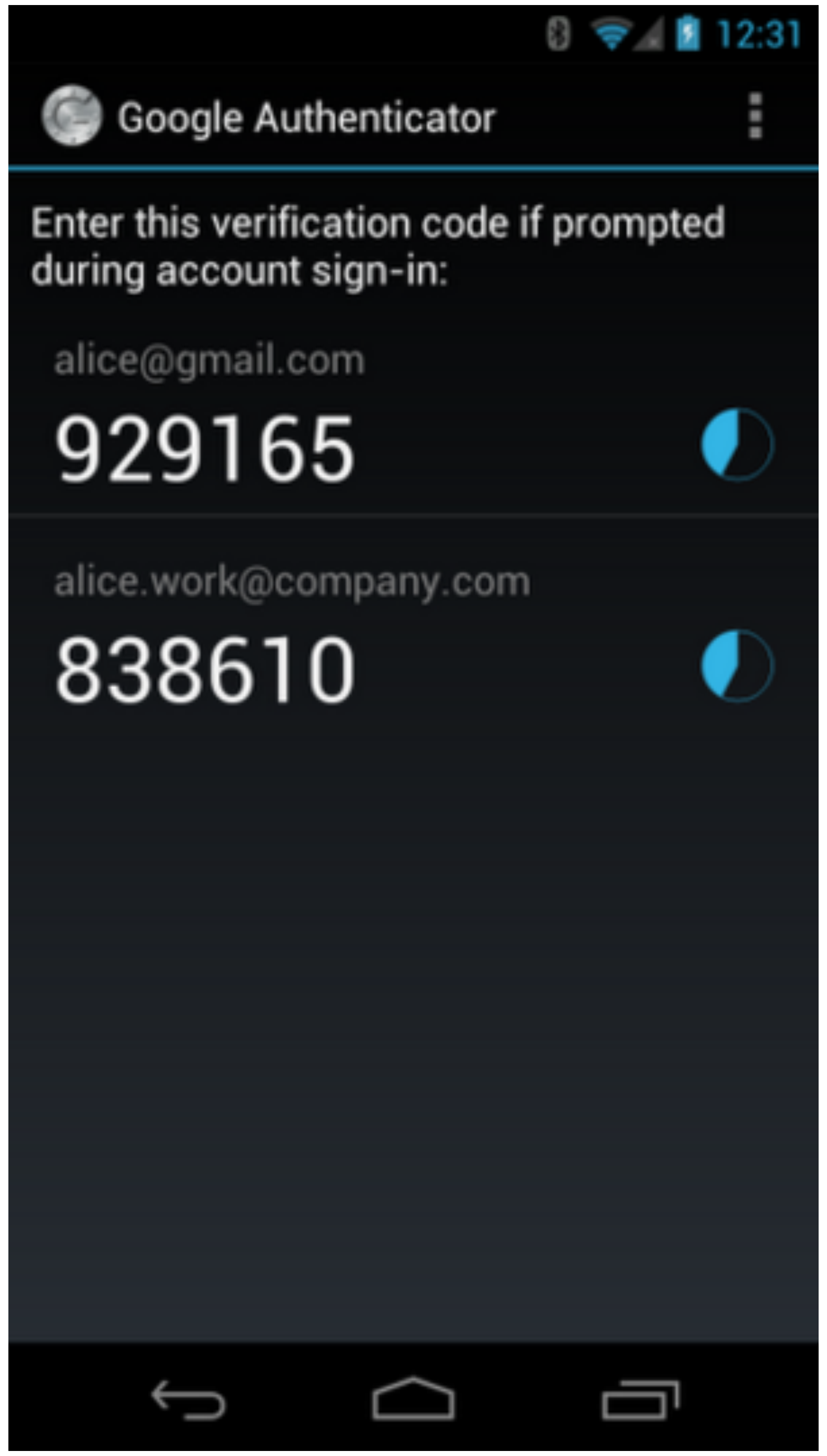
32 participants (no security experts) in a controlled environment

Do people find Sound-Proof usable?

32 participants (no security experts) in a controlled environment



Enter this verification code if prompted during account sign-in:

alice@gmail.com
929165

alice.work@company.com
838610

Google 2SV

Do people find Sound-Proof usable?

32 participants (no security experts) in a controlled environment

Google 2SV **vs** **Sound-Proof**

User Study

Do people find Sound-Proof usable?

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Google 2SV **vs** **Sound-Proof**

Preferred method ✓

User Study

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Google 2SV	vs	Sound-Proof
		Preferred method ✓
> 10s		< 5s ✓

User Study

Do people find Sound-Proof usable?

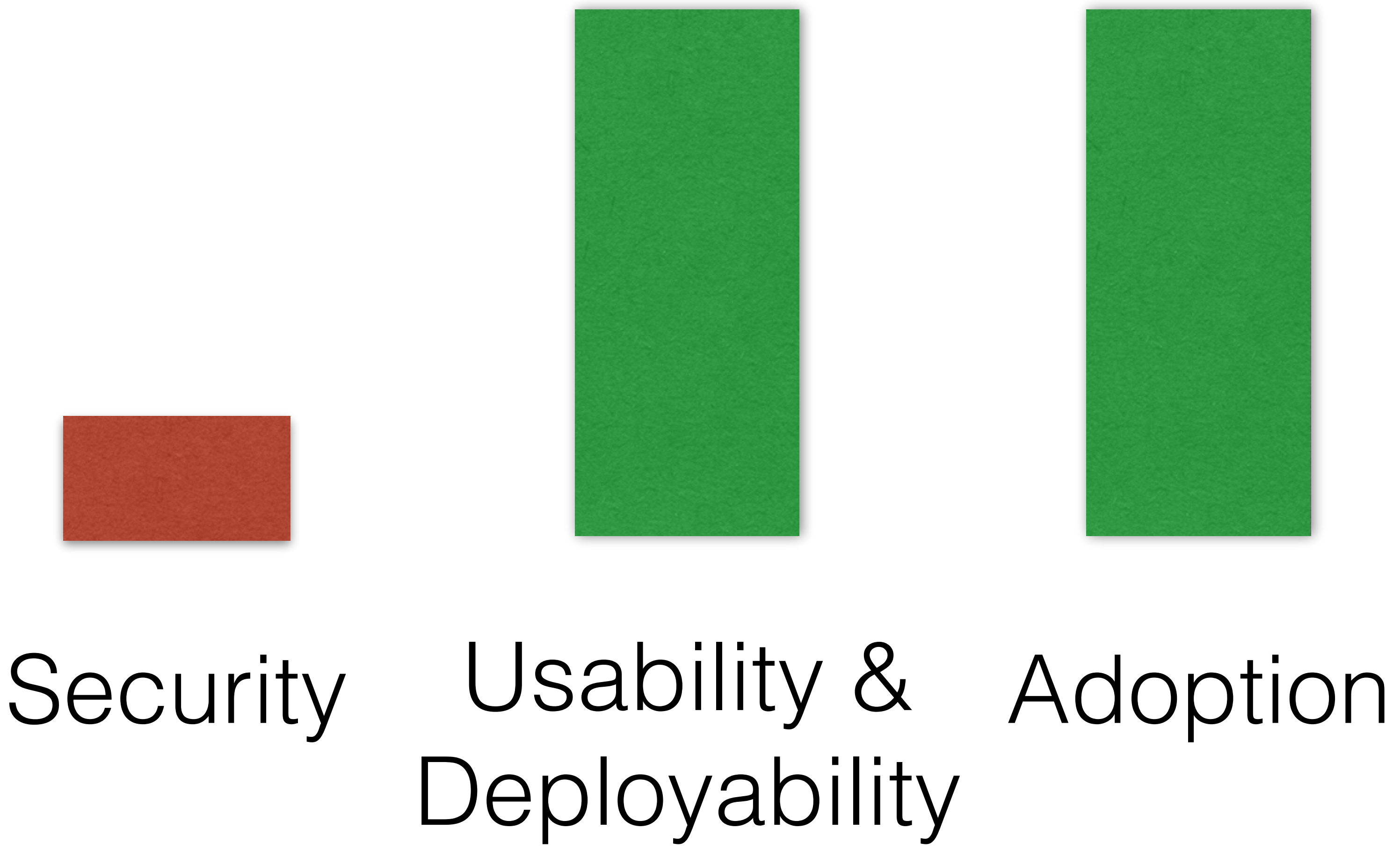
32 participants (no security experts) in a controlled environment

Google 2SV	vs	Sound-Proof
		Preferred method ✓
> 10s		< 5s ✓
		More likely to opt-in ✓

Takeaway

Attempt to foster 2FA adoption on the web

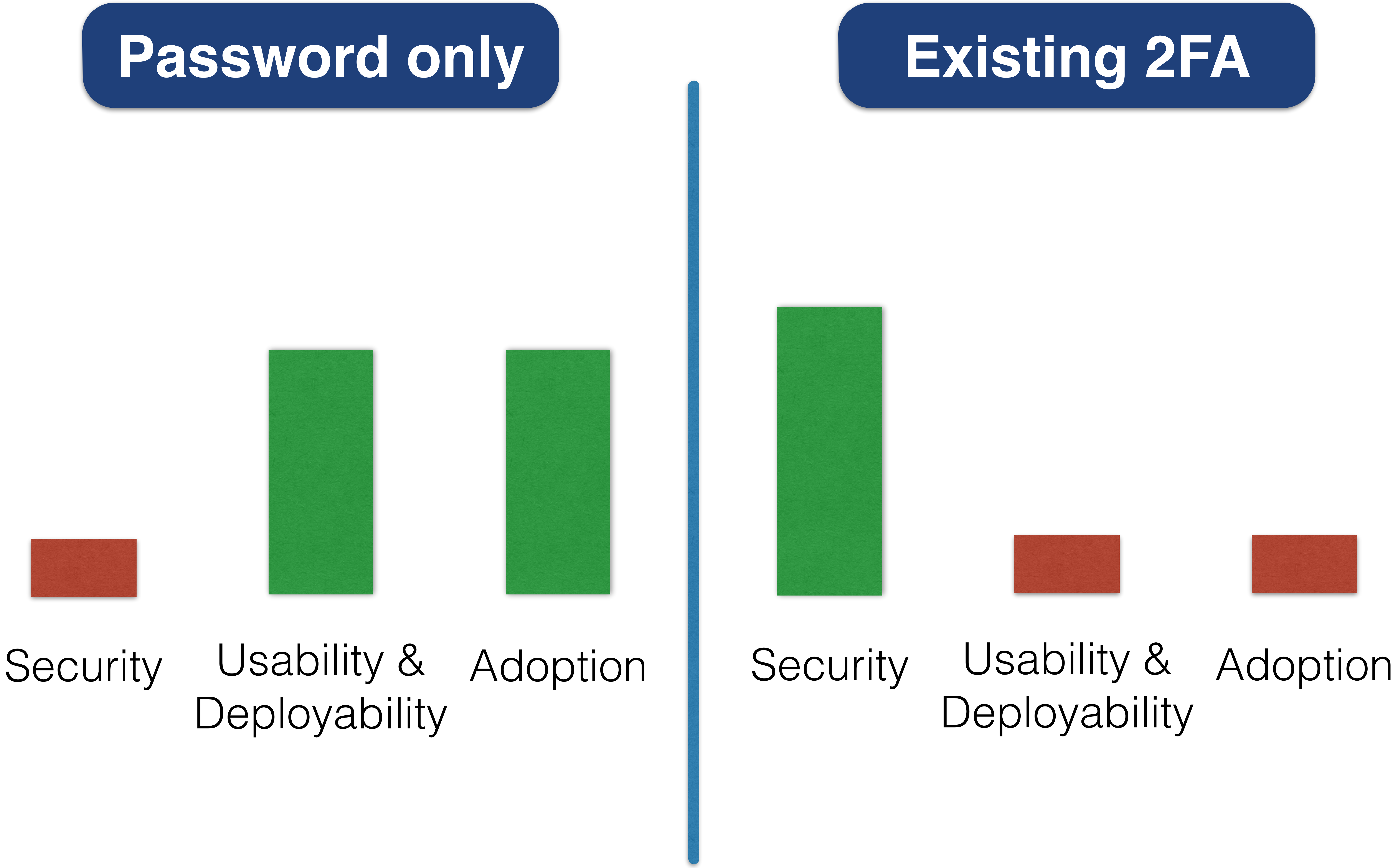
Password only



Sizes are purely qualitative!

Takeaway

Attempt to foster 2FA adoption on the web



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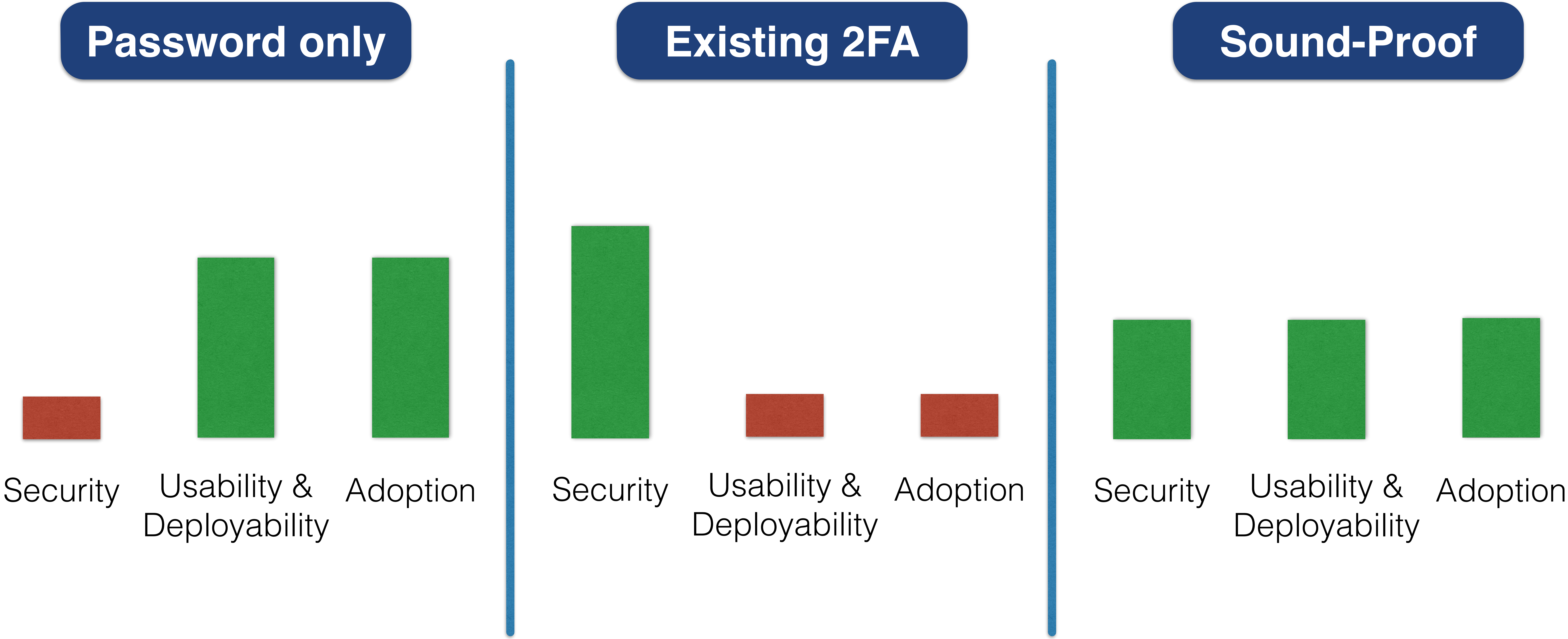
Takeaway

Attempt to foster 2FA adoption on the web



Sizes are purely qualitative!

Thank you for your attention!
Any Questions?

http://sound-proof.ch/

knikos@inf.ethz.ch

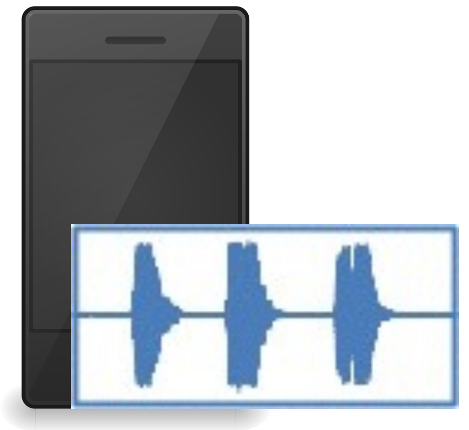
Some of the icons used in this presentation were taken and adapted from opensecurityarchitecture.org

User Privacy

Prying service provider has to actively cheat

Prying service provider has to actively cheat

- Phone sample never leaves the phone
  - Service provider cannot use phone to spy on user



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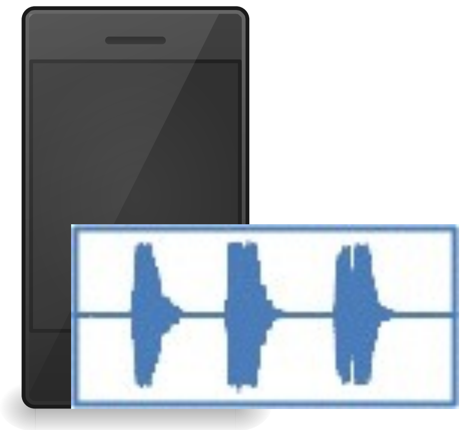
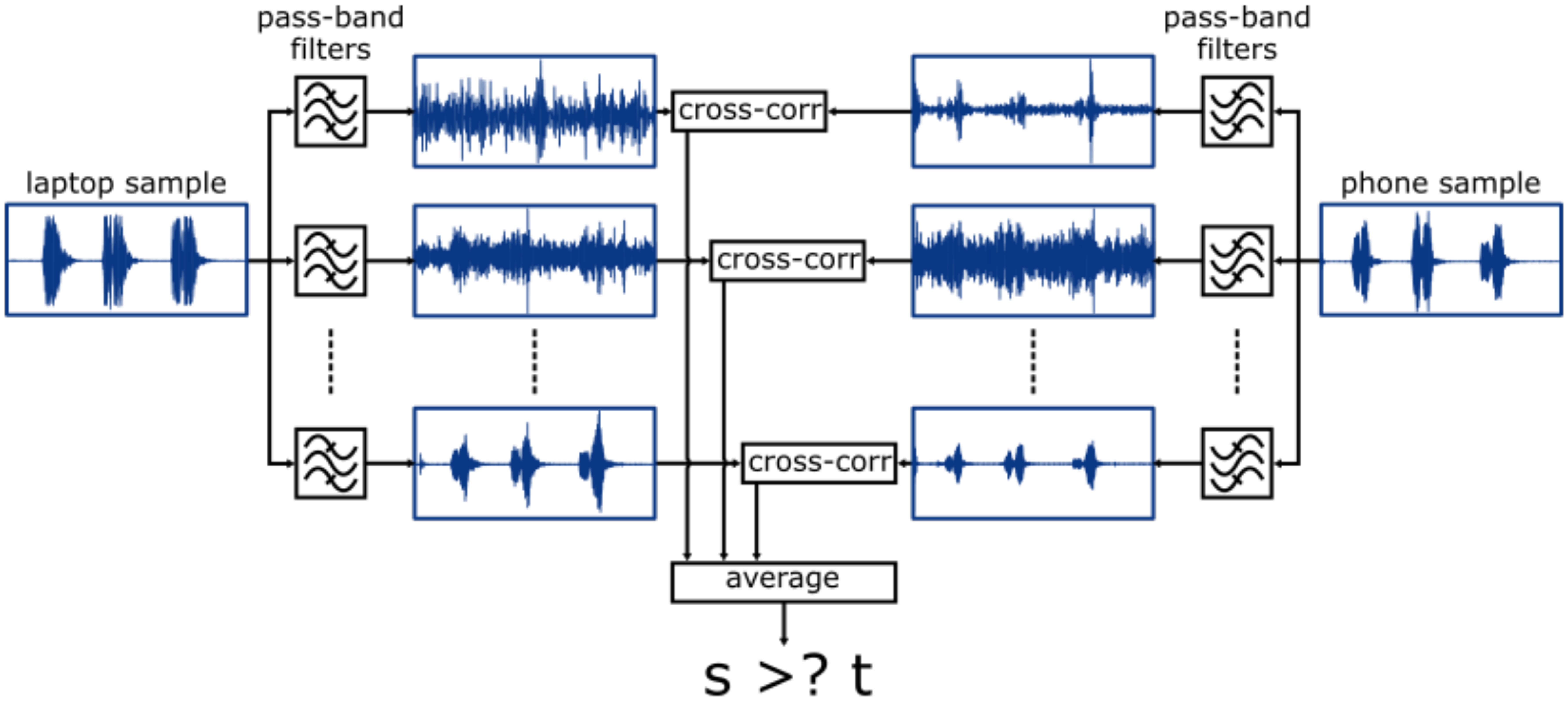


- Browser sample encrypted under phone's public key
  - Service provider has to actively play Man-In-The-Middle or supply malicious Javascript
  - Can only be abused, while the user is browsing the site

- Browser indicators whenever web site is recording
- Service provider risks detection —> reputation

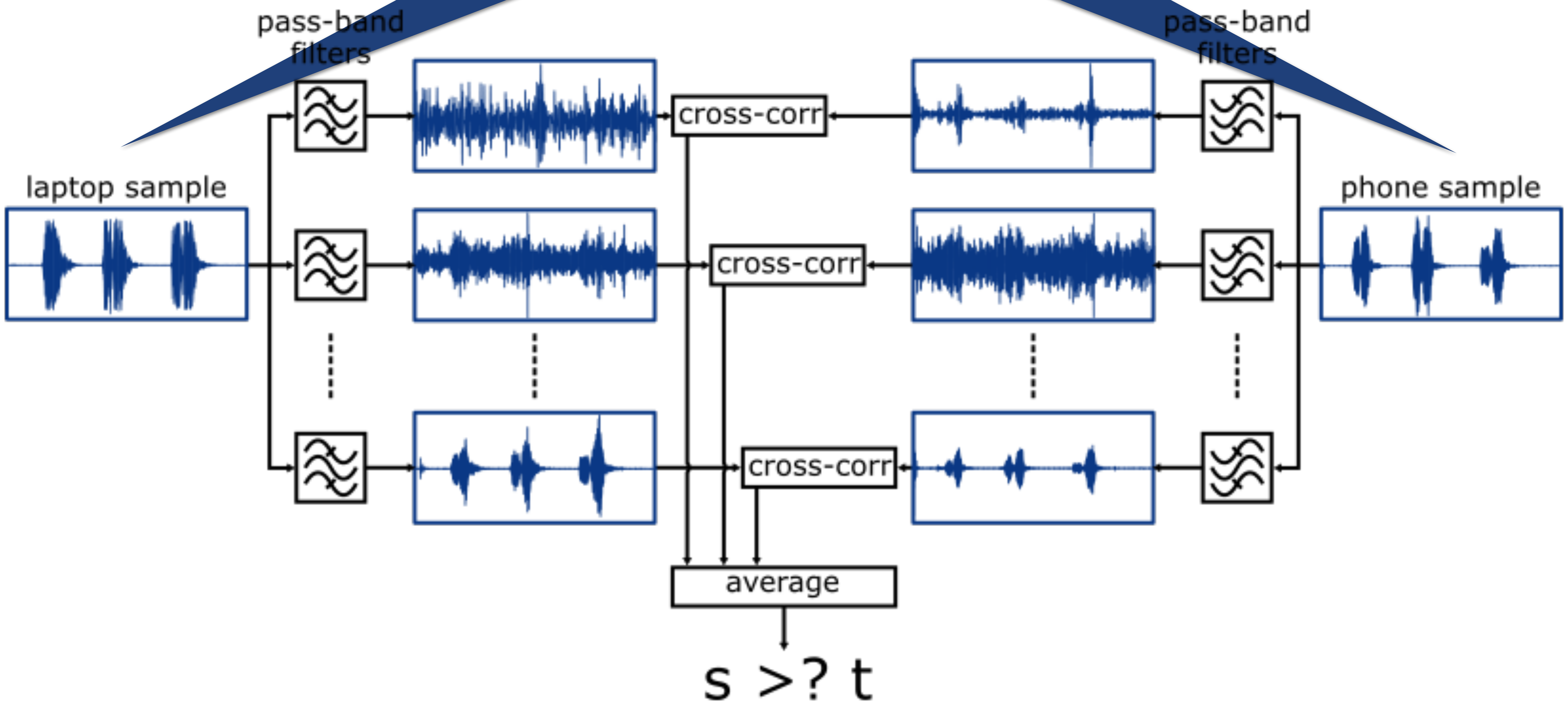
Similarity score computation



Audio Comparison

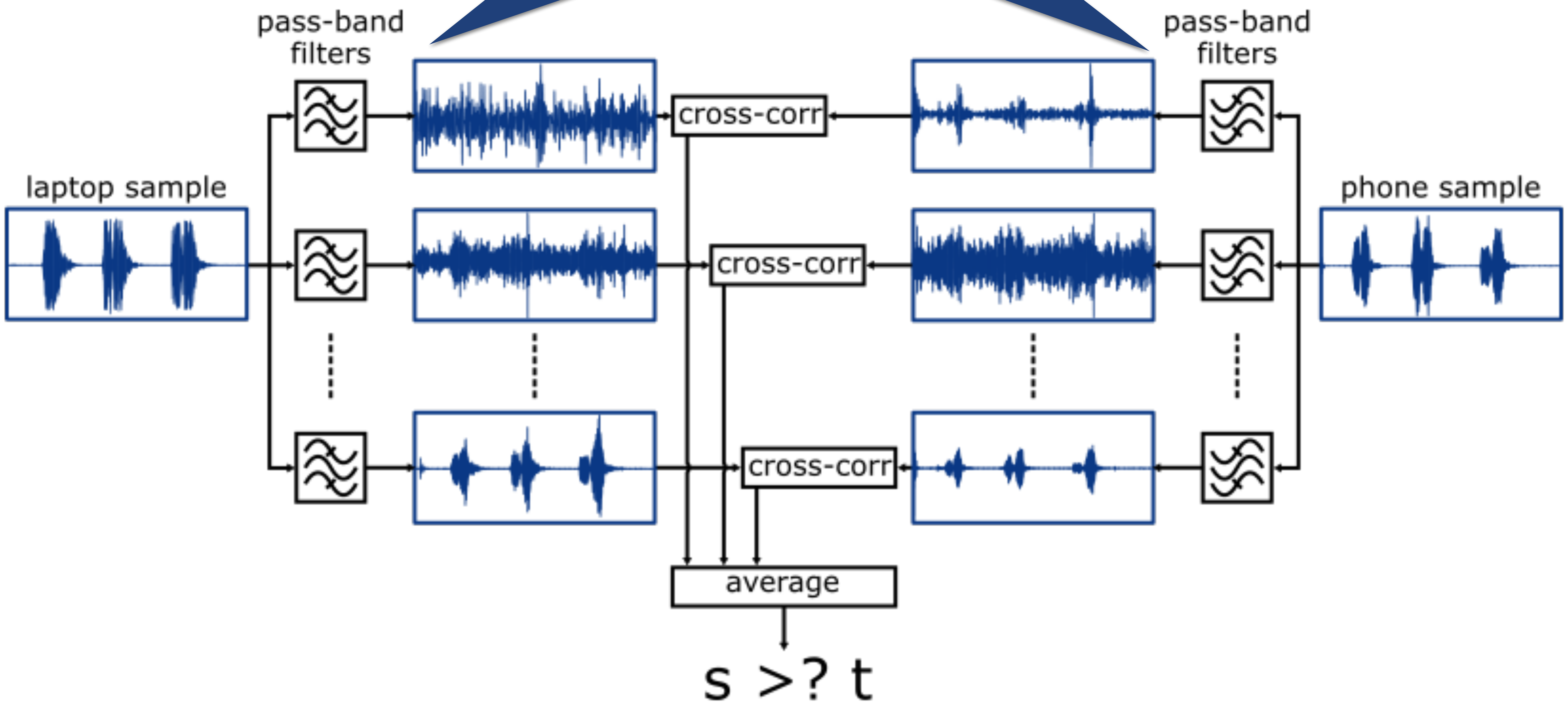
Similarity score computation

Reject silent recordings



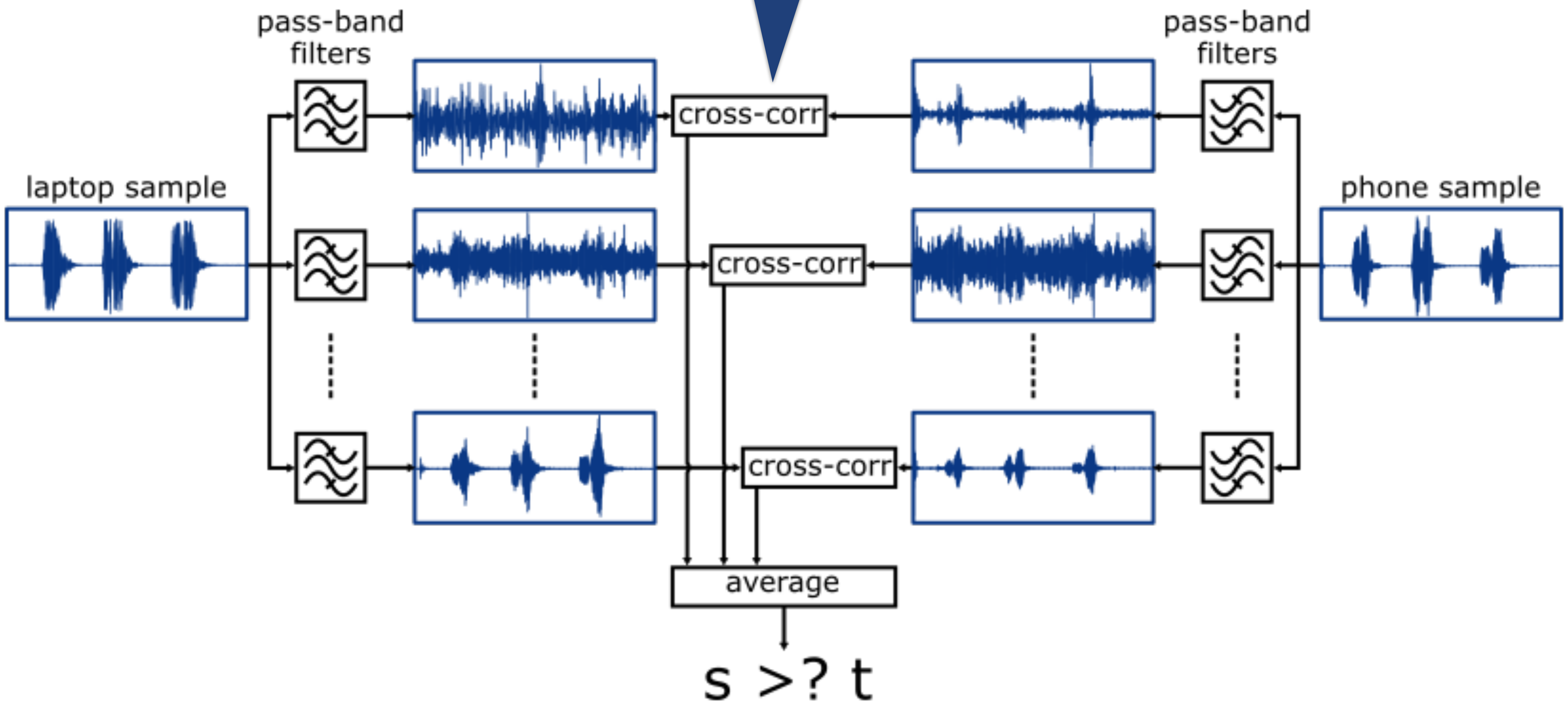
Similarity score computation

Split signal in 1/3 octave-bands

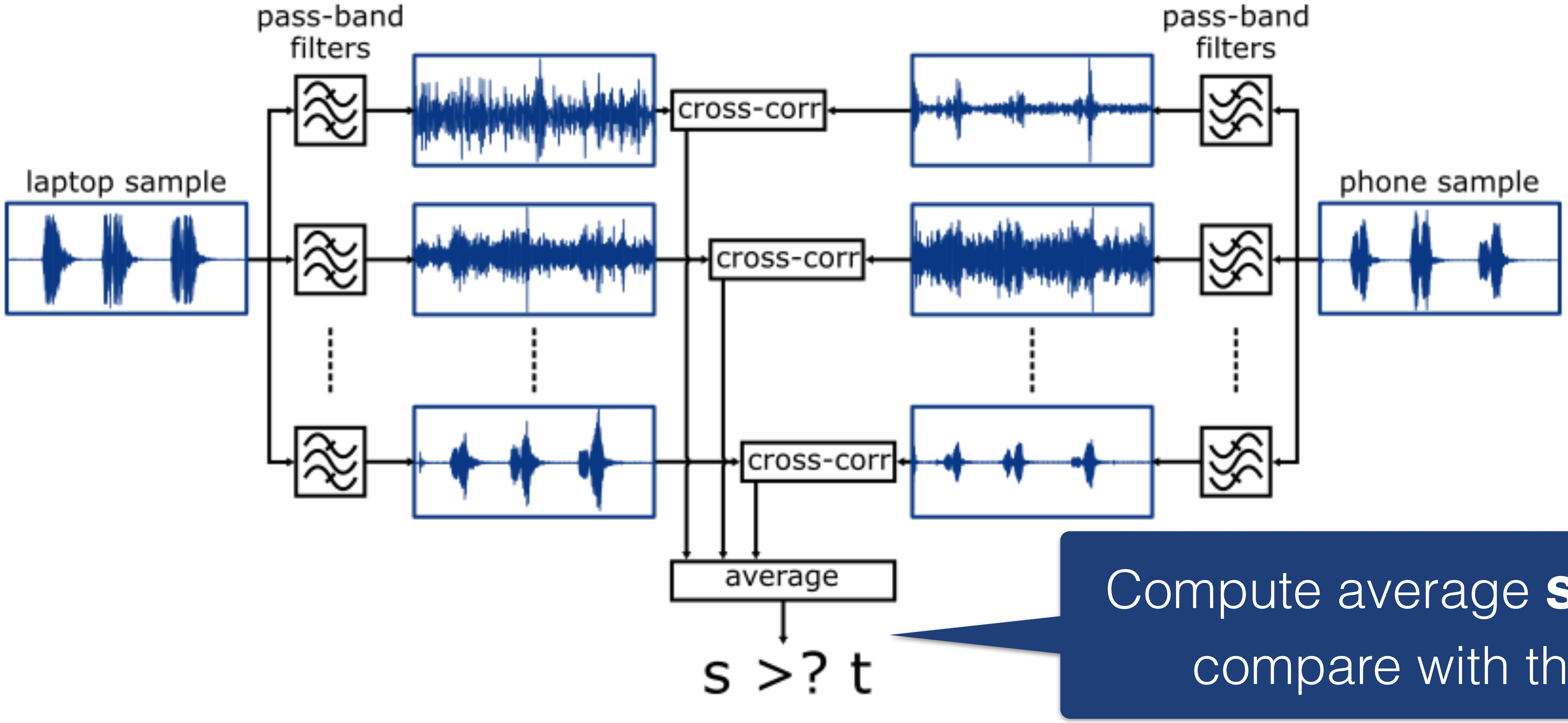


Similarity score computation

Pair-wise cross-correlation
(0 ≤ xcorr ≤ 1)



Similarity score computation



Compute average **s** (0 ≤ **s** ≤ 1), compare with threshold **t**