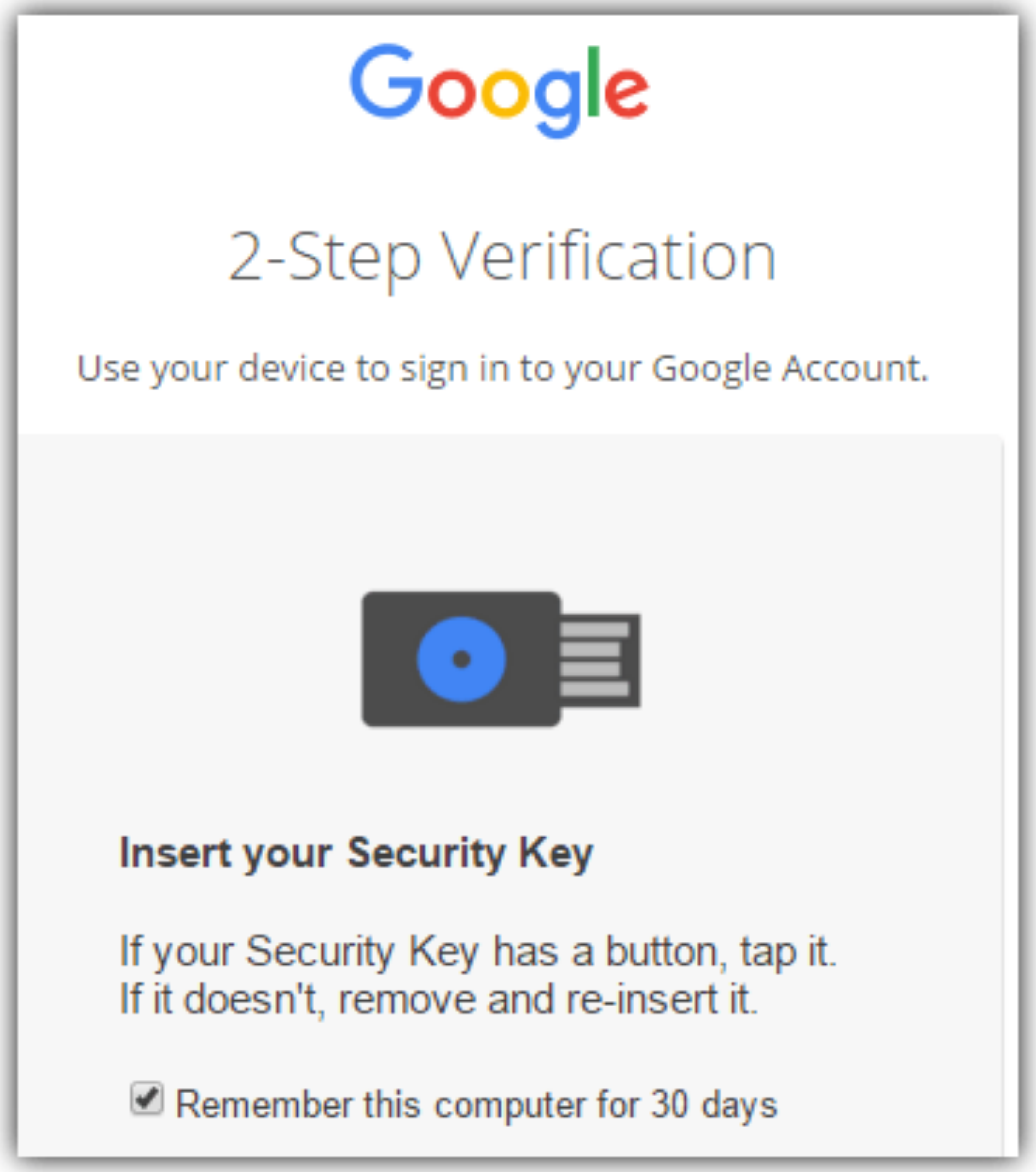
2550 Intro to cybersecurity

L5

abhi shelat

Universal 2nd Factor (U2F)

- Supported by Chrome, Opera, and Firefox (must be manually enabled)
- Works with Google, Dropbox, Facebook, Github, Gitlab, etc.



2-Step Verification

Use your device to sign in to your Google Account.

Insert your Security Key

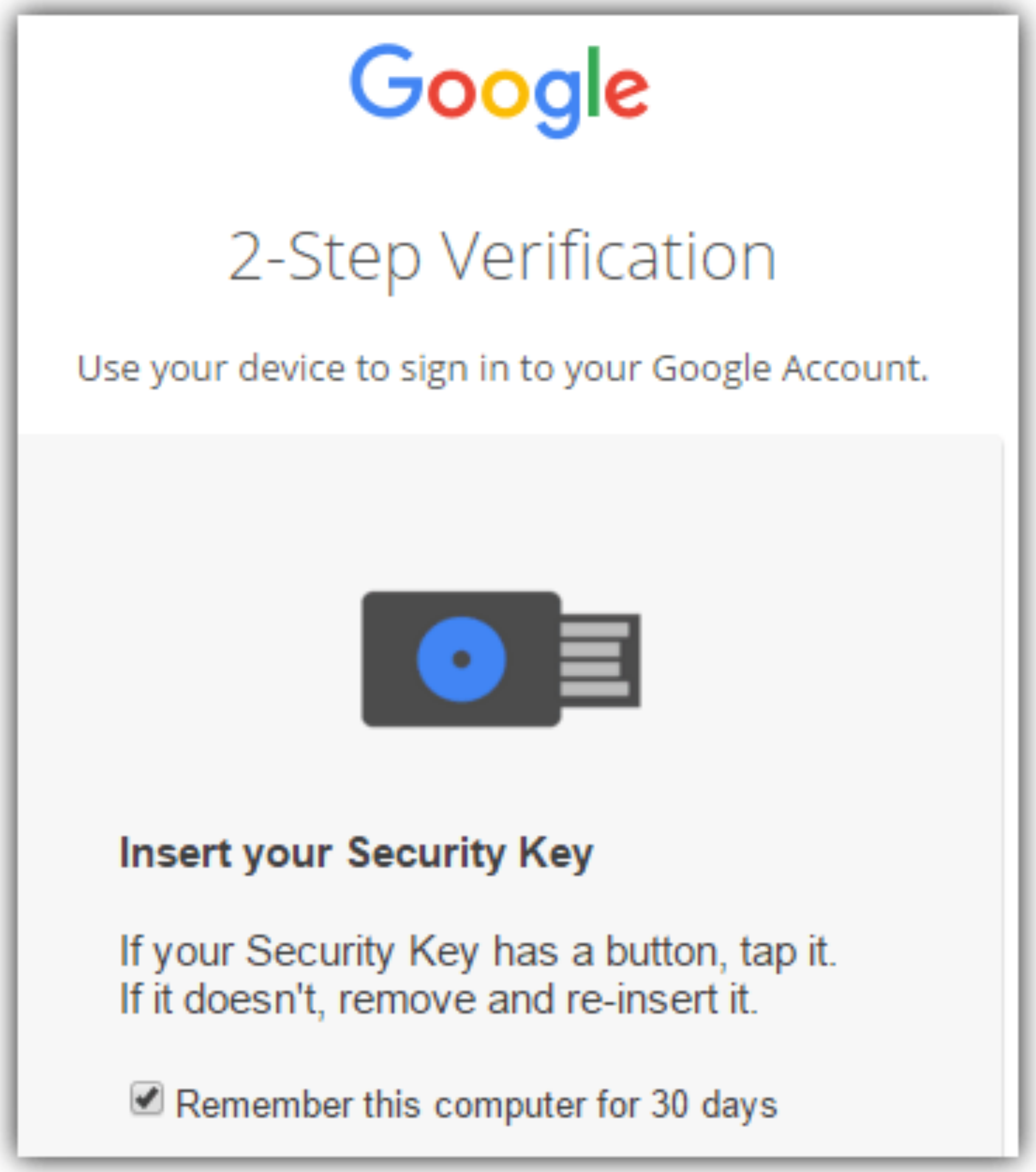
If your Security Key has a button, tap it.
If it doesn't, remove and re-insert it.

☑ Remember this computer for 30 days

Universal 2nd Factor (U2F)

- Supported by Chrome, Opera, and Firefox (must be manually enabled)
- Works with Google, Dropbox, Facebook, Github, Gitlab, etc.

- Pro tip: always buy 2 security keys
  - Associate both with your accounts
  - Keep one locked in a safe, in case you lose your primary key ;)



Google

2-Step Verification

Use your device to sign in to your Google Account.

Insert your Security Key

If your Security Key has a button, tap it.
If it doesn't, remove and re-insert it.

✓ Remember this computer for 30 days

How does U2F work?

Website (Relying Party)

Init

Make a signing key (sk,pk)

$\xleftarrow{\text{\{register\}}}$ $\xleftarrow{\text{\{register\}}}$

$\xrightarrow{\text{\{ pk, sign\_sk(“username”) \}}}$

User, pk

Login

Sign challenge using sk

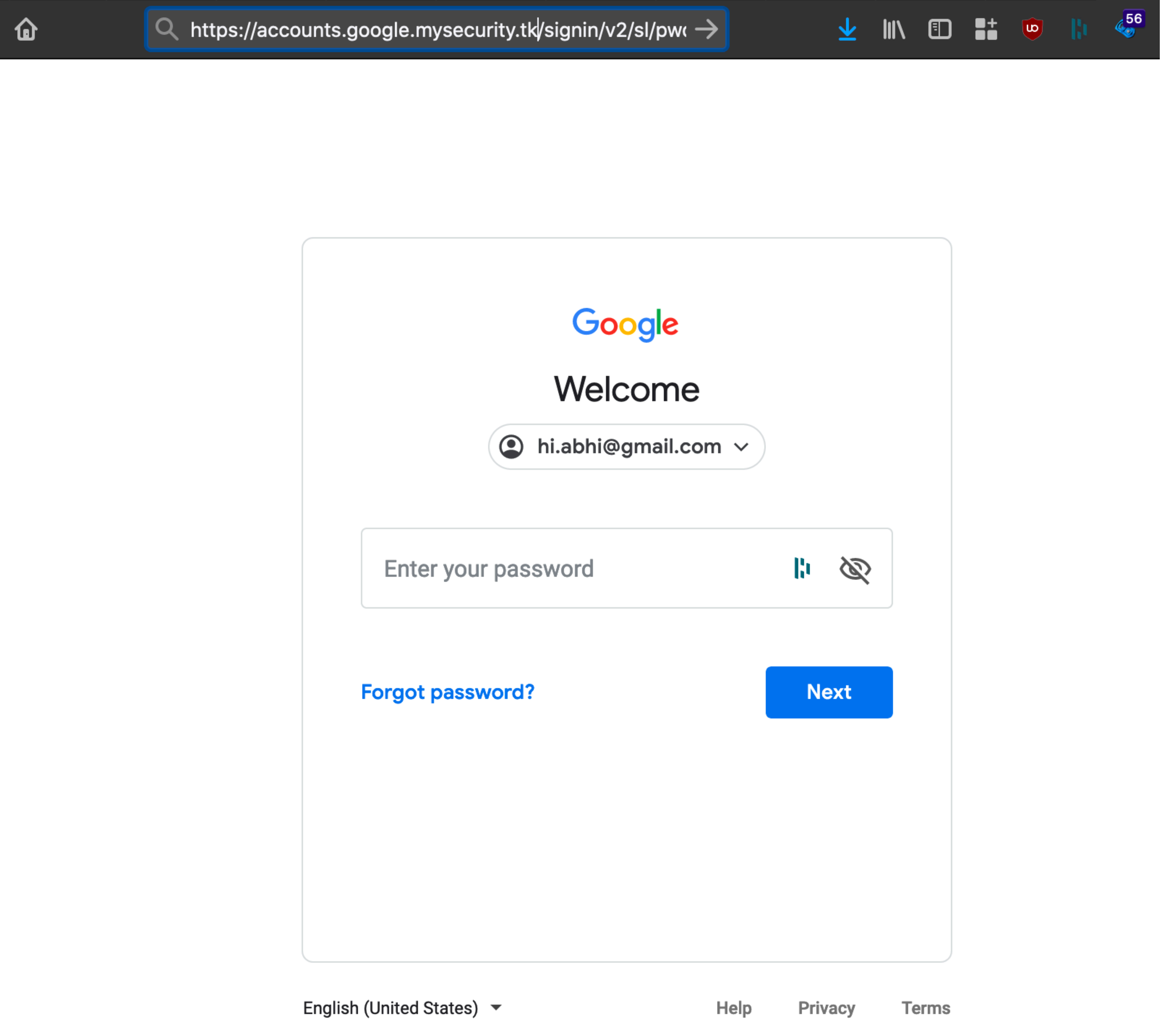
$s \leftarrow \text{Sign}_{sk}(ch)$

$\xleftarrow{\text{\{login, ch\}}}$ $\xleftarrow{\text{\{login, challenge ch\}}}$

$\xrightarrow{\text{\{ s \}}}$

$\text{Verify}_{pk}(ch)$

Vulnerable to simple attack



https://accounts.google.mysecurity.tk/signin/v2/sl/pwd

Google

Welcome

hi.abhi@gmail.com

Enter your password

Forgot password?

Next

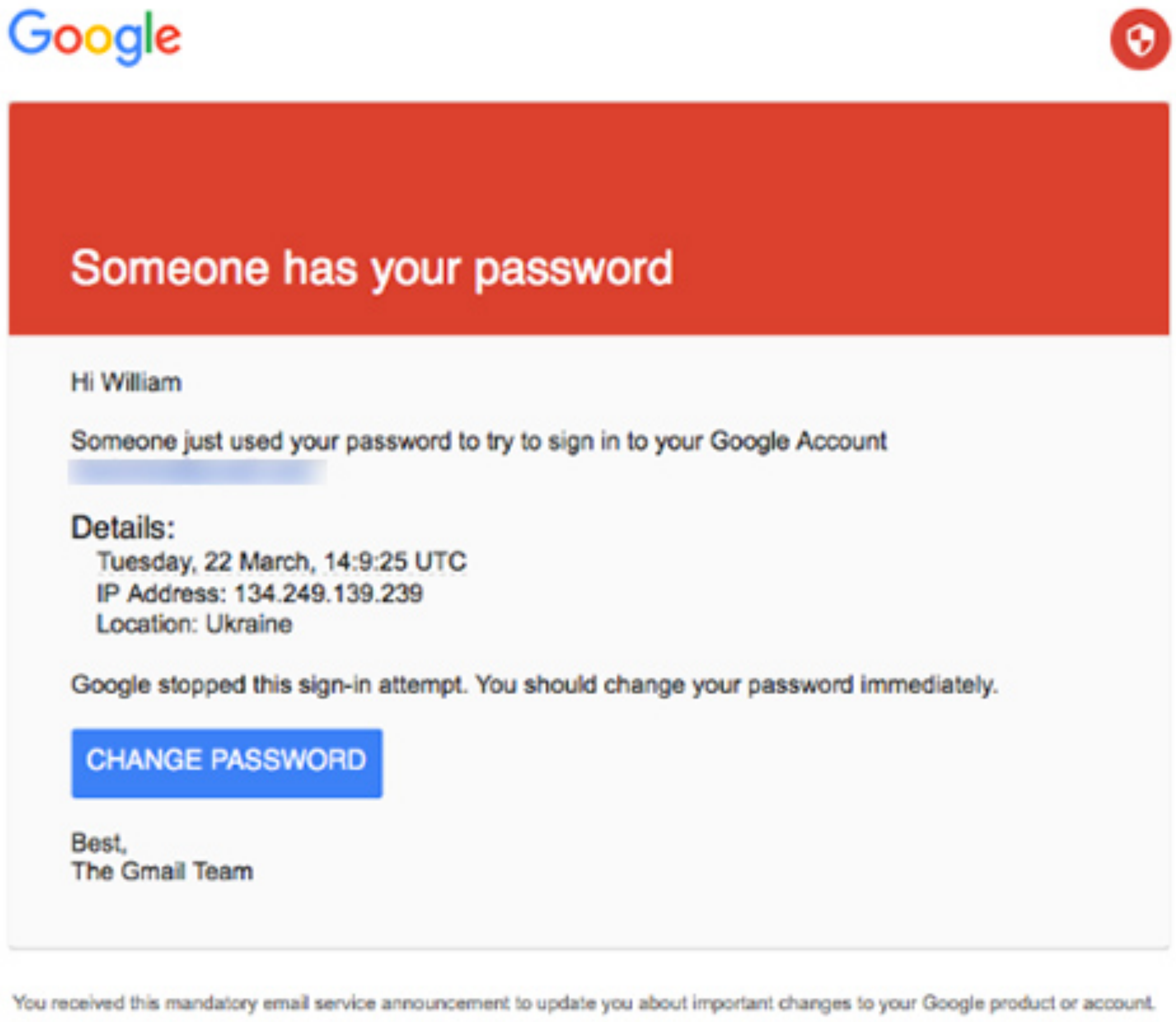
English (United States)

Help Privacy Terms

Simple Phishing

Lure: A spammed email with a call to action from a seemingly legitimate source encouraging the user to visit a hook website.

Hook: A website designed to mimic legitimate site and collect confidential information.



Google

Someone has your password

Hi William

Someone just used your password to try to sign in to your Google Account
[redacted]

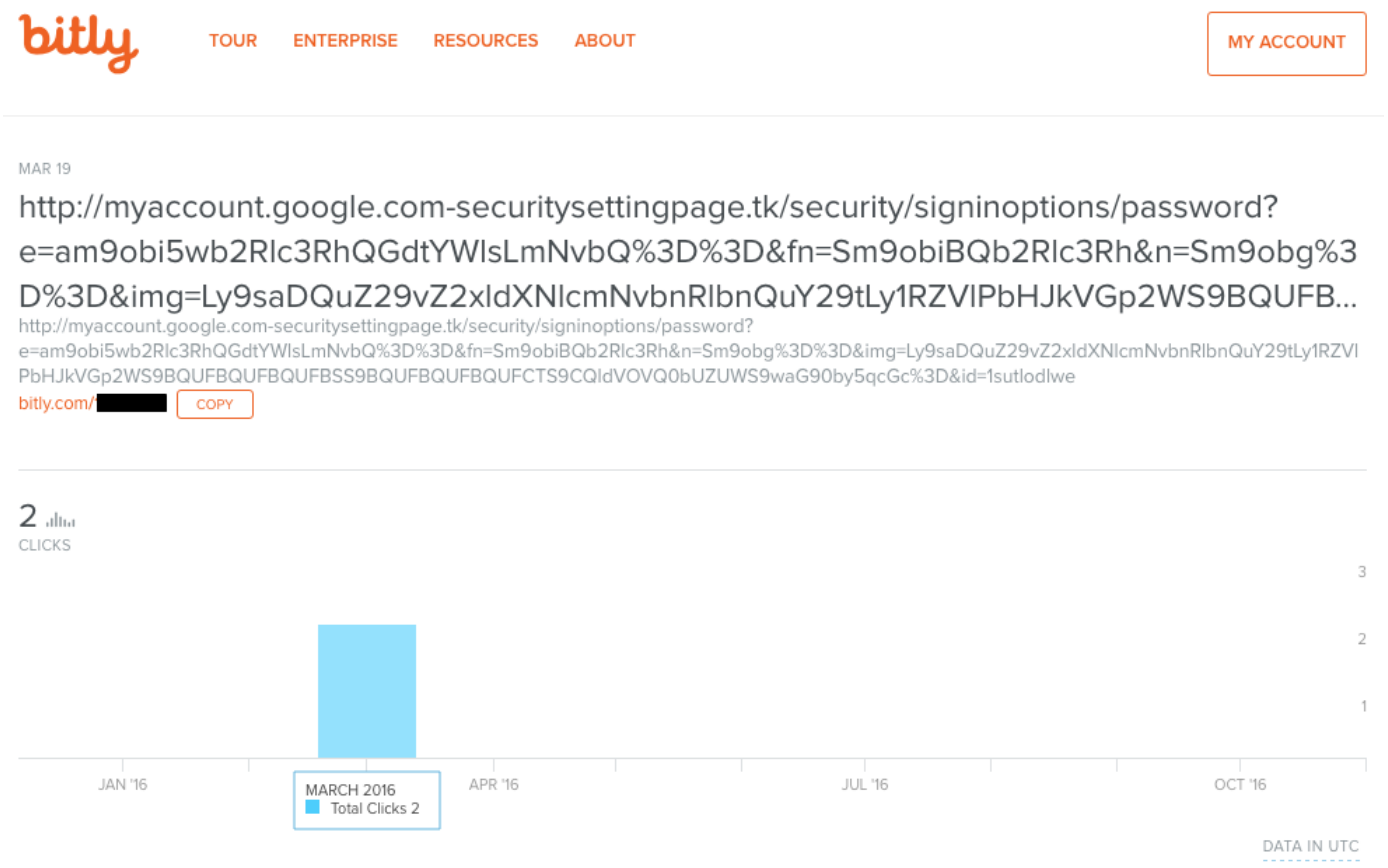
Details:
Tuesday, 22 March, 14:9:25 UTC
IP Address: 134.249.139.239
Location: Ukraine

Google stopped this sign-in attempt. You should change your password immediately.

CHANGE PASSWORD

Best,
The Gmail Team

You received this mandatory email service announcement to update you about important changes to your Google product or account.



MAR 19

http://myaccount.google.com-securitysettingpage.tk/security/signinoptions/password?e=am9obi5wb2Rlc3RhQGdtYWlsLmNvbQ%3D%3D&fn=Sm9obiBQb2Rlc3Rh&n=Sm9obg%3D%3D&img=Ly9saDQuZ29vZ2xldXNlcmNvbnRlbnQuY29tLy1RZVlPbHJkVGp2WS9BQUFB...

http://myaccount.google.com-securitysettingpage.tk/security/signinoptions/password?e=am9obi5wb2Rlc3RhQGdtYWlsLmNvbQ%3D%3D&fn=Sm9obiBQb2Rlc3Rh&n=Sm9obg%3D%3D&img=Ly9saDQuZ29vZ2xldXNlcmNvbnRlbnQuY29tLy1RZVlPbHJkVGp2WS9BQUFBQUFBQUFBSS9BQUFBQUFBQUFCTS9CQldVOVQ0bUZUWS9waG90by5qcGc%3D&id=1sutlodlwe

bitly.com/[redacted] COPY

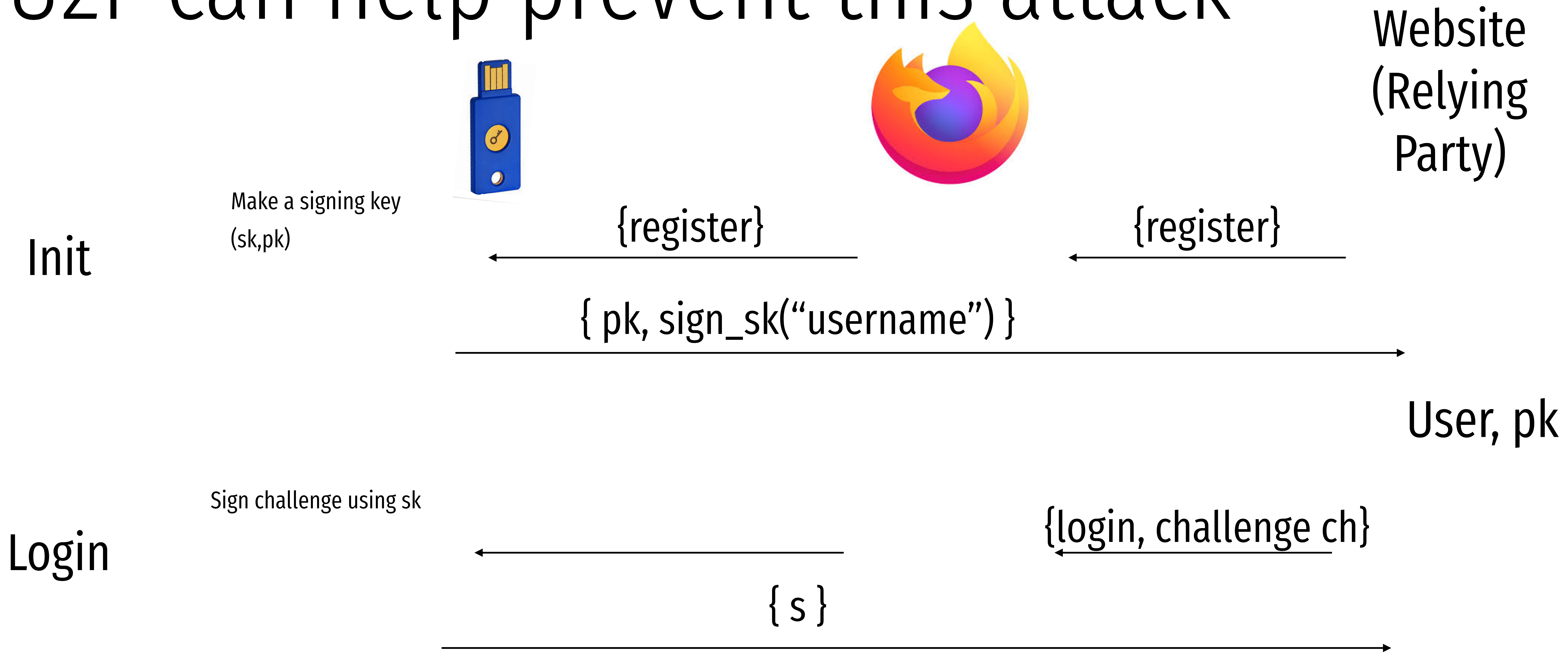
2

CLICKS

MARCH 2016
🟦 Total Clicks 2

DATA IN UTC

U2F can help prevent this attack



U2F can help prevent this attack

Website (Relying Party)

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Make a signing key (sk,pk)

{register} $\longleftarrow$

{register} $\longleftarrow$

{ pk, sign_sk("username") } $\longrightarrow$

User, pk

Login

Sign challenge using sk

{login, ch, origin, tls_id} $\longleftarrow$

{login, challenge ch} $\longleftarrow$

$s \leftarrow \text{Sign}_{sk}(ch, \text{url}, \text{tls}_{id})$

{ s } $\longrightarrow$

$\text{Verify}_{pk}(ch, s, \text{url}, \text{tls}_{id})$

How U2F foils phishing

User,sk

My browser

1. In the beginning, I register with G and setup 2FA.

User,pk

How U2F foils phishing

2. I am tricked into clicking on fake G login, who tries a PITM attack.

User,sk

My browser

Fake Website

Com-settingssecurity.tk

User,pk

How U2F foils phishing

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Fake Website

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User,pk

{login, challenge ch}

$\longleftarrow$

How U2F foils phishing

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User,sk

My browser

Fake Website

Com-settingssecurity.tk

User,pk

$$\begin{tikzcd}
\text{My browser} & \text{Fake Website} \arrow[l, "{\{login, challenge\ ch\}}"'] & \text{User,pk} \arrow[l, "{\{login, challenge\ ch\}}"']
\end{tikzcd}$$

How U2F foils phishing

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User,sk

My browser

Fake Website

`Com-settingssecurity.tk`

User,pk

{login, ch, url, tls_id} ←

{login, challenge ch} ←

{login, challenge ch} ←

My browser knows the origin is "com-settingssecurity.tk" instead of google.com, and passes this string as url.

How U2F foils phishing

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User,sk

My browser

Fake Website

Com-settingssecurity.tk

User,pk

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My browser knows the origin is "com-settingssecurity.tk" instead of google.com, and passes this string as url.

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Sign challenge using sk

The 2FA key signs this with url=com-settings...

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Fake Website

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Sign challenge using sk

$\xrightarrow{\{\ s\ \}}$

$\text{Verify}_{pk}(ch, s, \text{url}, \text{tls}_{id})$

The 2FA key signs this with url=com-settings...

Google reject the authentication and detects the attack!

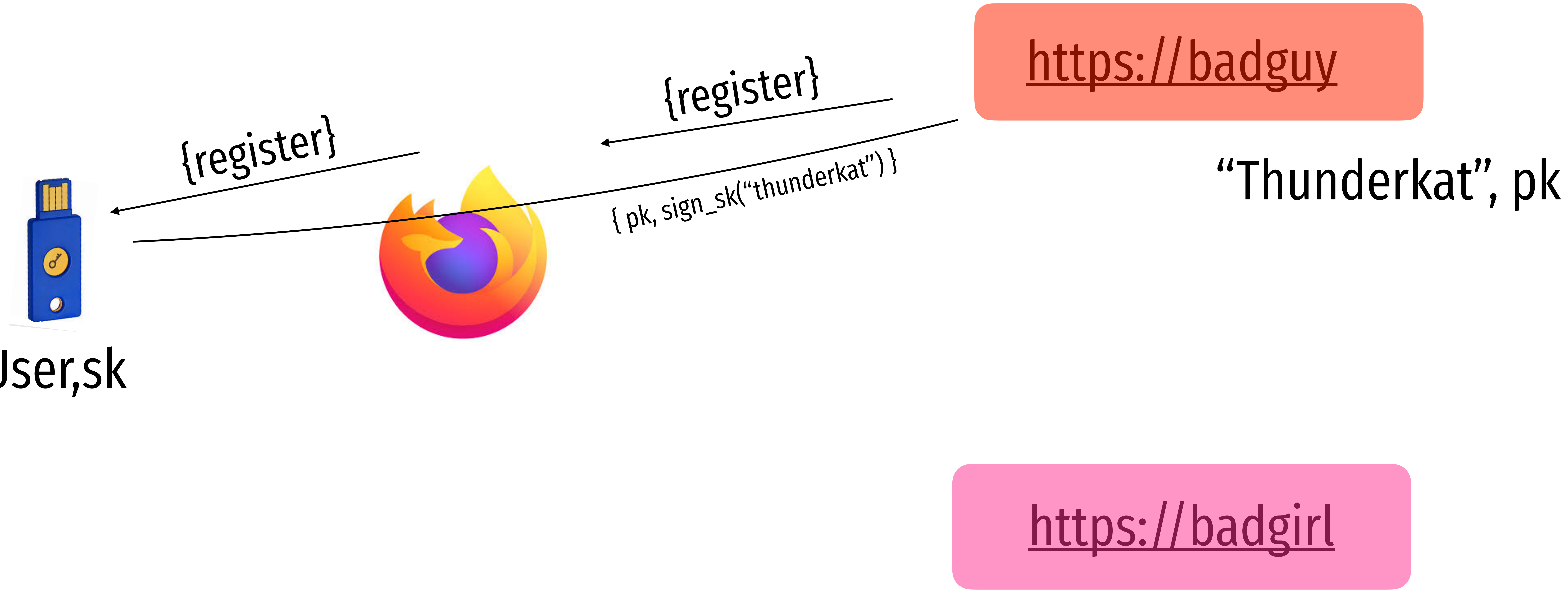
The Tracking problem

https://badguy

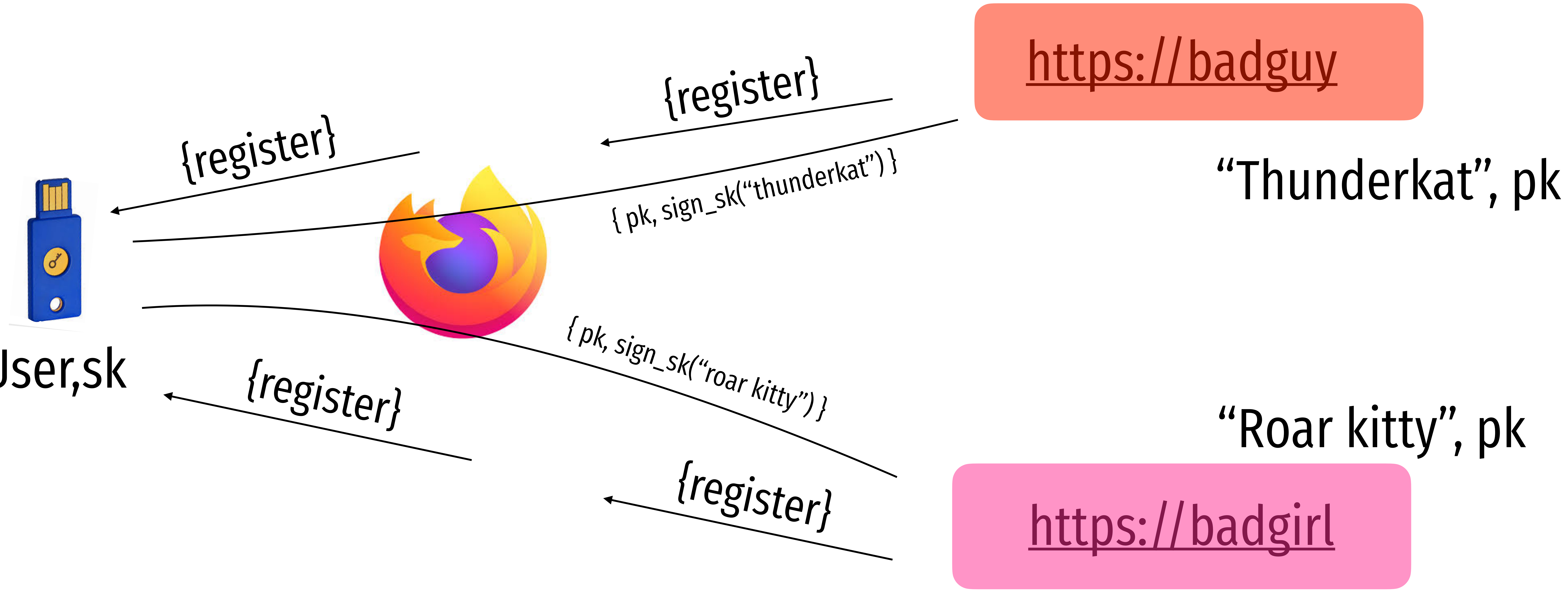
User,sk

https://badgirl

The Tracking problem



The Tracking problem



U2F can help prevent tracking

Website (Relying Party)

Init

Make a signing key (sk,pk)

And link it with appid, and create A token “h”

{appid, register} ←

{appid, register} ←

{ h, pk, sign_sk(“username”) } →

User, h, pk

U2F can help prevent tracking

Website (Relying Party)

Init

Make a signing key with aphid

(sk,pk)

And link it with appid, and create A token “h”

{appid, register} ←

{appid, register} ←

{ h, pk, sign_sk(“username”) } →

User, h, pk

Login

Lookup sk using h
Sign challenge using sk

$s \leftarrow \text{Sign}_{sk}(ch, \text{url}, \text{tls}_{id})$

{login, h, ch, origin, tls_id} ←

{login, h, challenge ch} ←

{ s,h } →

$\text{Verify}_{pk}(ch, s, \text{url}, \text{tls}_{id})$

Check h

```
Sending request with appId: https://u2f.bin.coffee
{
  "version": "U2F_V2",
  "challenge": "uQnl3M4Rj3FZgs6WjyLaZAfwRh4"
}

Got response:
{
  "clientData": "eyJjaGFsbGVuZ2UiOiJ1UW5sM000UmozRlpnczZXanlMYVpBZndSaDQiLCJvcmlnaW4iOiJodHRwczovL3UyZi5iaW4uY29mZmVlIiwidHlwIjoibmF2
  "errorCode": 0,
  "registrationData": “BQRSuRLPv0p5udQ55vVhucf3N50q6…”,
  "version": "U2F_V2"
}

Key Handle: 0r0Z0p0F0E0-0d0W0c0Q0b0X0i020C0w0-0E0v0h0t0T0T0P0_0-090_0a050P0e030u0b0z0l0K0Q0r0O0f0u030_0P020B0J0M0x0D050J0_0d0P0Q0e0j
Certificate: 3082021c3082…
Attestation Cert
Subject: Yubico U2F EE Serial 14803321578
Issuer: Yubico U2F Root CA Serial 457200631
Validity (in millis): 1136332800000
Attestation Signature
R: 00b11e3efe5ae5ac7ca0e0d4fe2c5b5cf18a2531c0f4f70b11c30b72b5f946a9a3
S: 0f37ab2d4f93ebcdaed0a51b4b17fb93403db9873f0e9cce36f17b1502734bb2
[PASS] Signature buffer has no unnecessary bytes.: 71 == 71
[PASS] navigator.id.finishEnrollment == navigator.id.finishEnrollment
[PASS] uQnl3M4Rj3FZgs6WjyLaZAfwRh4 == uQnl3M4Rj3FZgs6WjyLaZAfwRh4
[PASS] https://u2f.bin.coffee == https://u2f.bin.coffee
[PASS] Verified certificate attestation signature
[PASS] Imported credential public key
Failures: 0 TODOs: 0
```

Future without passwords?

Authentication Protocols

Unix, PAM, and crypt

Network Information Service (NIS, aka Yellow Pages)

Needham-Schroeder and Kerberos

Status Check

- At this point, we have discussed:
  - How to securely store passwords
  - Techniques used by attackers to crack passwords
  - Biometrics and 2nd factors

Status Check

- At this point, we have discussed:
  - How to securely store passwords
  - Techniques used by attackers to crack passwords
  - Biometrics and 2nd factors
- Next topic: building authentication systems
  - Given a user and password, how does the system authenticate the user?
  - How can we perform efficient, secure authentication in a distributed system?

Building authentication systems

Example PAM Configuration

```
abhi@l2:~$ cat /etc/pam.d/common-password
#
# /etc/pam.d/common-password - password-related modules common to all services
#
# This file is included from other service-specific PAM config files,
# and should contain a list of modules that define the services to be
# used to change user passwords.  The default is pam_unix.

# Explanation of pam_unix options:
#
# The "sha512" option enables salted SHA512 passwords.  Without this option
# the default is Unix crypt.  Prior releases used the
#
# The "obscure" option replaces the old `OBSCURE_CHECK
# login.defs.
#
# See the pam_unix manpage for other options.

# As of pam 1.0.1-6, this file is managed by pam-auth-
# To take advantage of this, it is recommended that yo
# local modules either before or after the default block, and us
# pam-auth-update to manage selection of other modules.  See
# pam-auth-update(8) for details.

# here are the per-package modules (the "Primary" block)
password [success=1 default=ignore]pam_unix.so obscure sha512
# here's the fallback if no module succeeds
password requisite     pam_deny.so
# prime the stack with a positive return value if there isn't one already;
# this avoids us returning an error just because nothing sets a success code
# since the modules above will each just jump around
password required      pam_permit.so
# and here are more per-package modules (the "Additional" block)
# end of pam-auth-update config
```

- Use SHA512 as the hash function
- Use /etc/shadow for storage

Unix Passwords

- Traditional method: *crypt*
  - 25 iterations of DES on a zeroed vector
  - First eight bytes of password used as key (additional bytes are ignored)
  - 12-bit salt
- Modern version of *crypt* are more extensible
  - Support for additional hash functions like MD5, SHA256, and SHA512
  - Key lengthening: defaults to 5000 iterations, up to $10^8 - 1$
  - Full password used
  - Up to 16 bytes of salt

Password Files

- Password hashes used to be in */etc/passwd*
  - World readable, contained usernames, password hashes, config information
  - Many programs read config info from the file…
  - But very few (only one?) need the password hashes

Password Files

- Password hashes used to be in */etc/passwd*
  - World readable, contained usernames, password hashes, config information
  - Many programs read config info from the file…
  - But very few (only one?) need the password hashes
- Turns out, world-readable hashes are **Bad Idea**
- Hashes now located in */etc/shadow*
  - Also includes account metadata like expiration
  - Only visible to root

Password Storage on Linux

/etc/passwd

username:x:UID:GID:full_name:home_directory:shell

```
cbw:x:1001:1000:Christo Wilson:/home/cbw/:/bin/bash
amislove:1002:2000:Alan Mislove:/home/amislove/:/bin/sh
```

/etc/shadow

username:password:last:may:must:warn:expire:disable:reserved

```
cbw:$1$0nSd5ewF$0df/3G7iSV49nsbAa/5gSg:9479:0:10000::::
amislove:$1$l3RxU5F1$:8172:0:10000::::
```

Password Storage on Linux

/etc/passwd

username:x:UID:GID:full_name:home_directory:shell

```
cbw:x:1001:1000:Christo Wilson:/home/cbw/:/bin/bash
n Mislove:/home/amislove/:/bin/sh
```

$<algo>$<salt>$<hash>

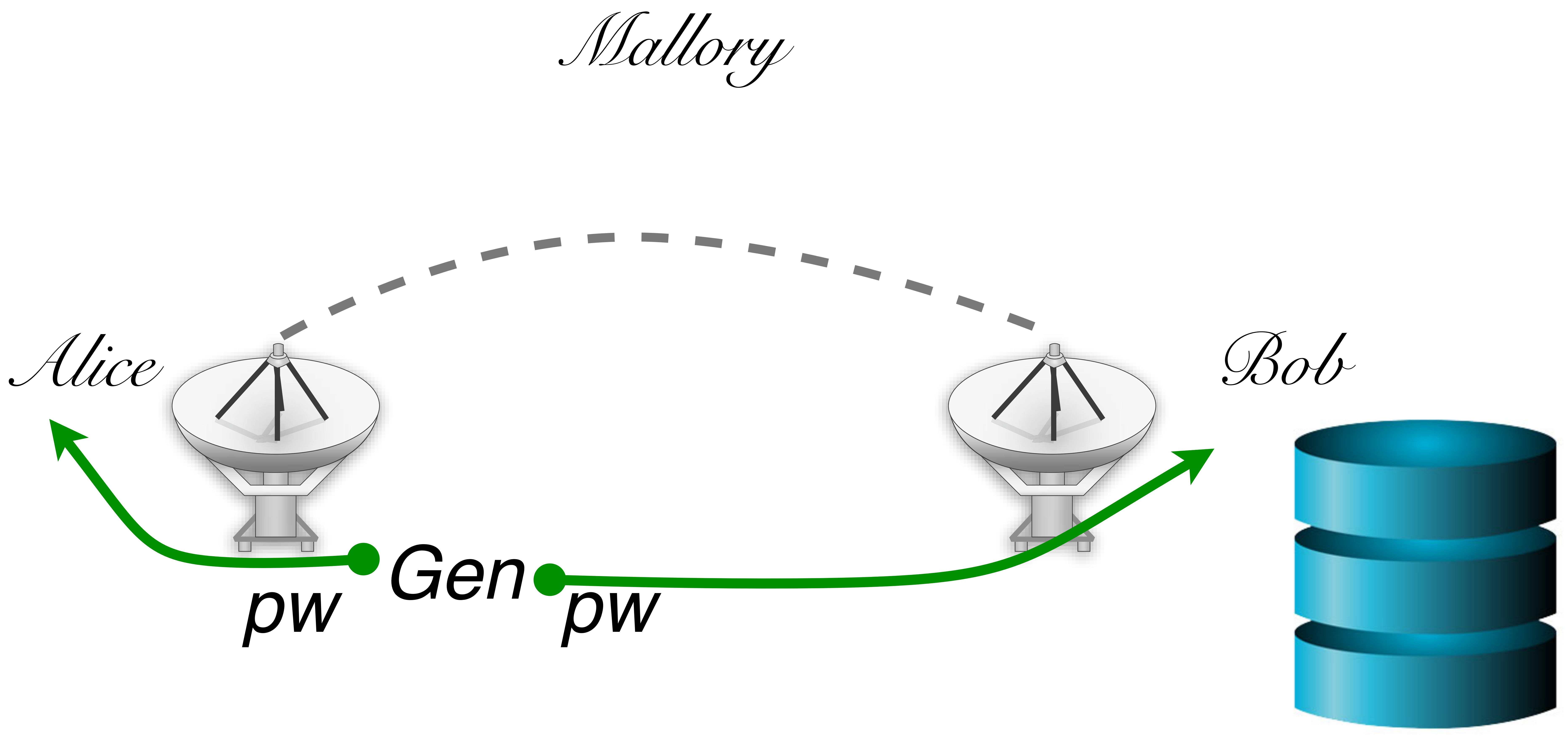
Algo: 1 = MD5, 5 = SHA256, 6 = SHA512

/etc/shadow

ername:password:last:may:must:warn:expire:disable:reserved

```
cbw:$1$0nSd5ewF$0df/3G7iSV49nsbAa/5gSg:9479:0:10000::::
amislove:$1$l3RxU5F1$:8172:0:10000::::
```

Password Security game



More realistic picture of the world

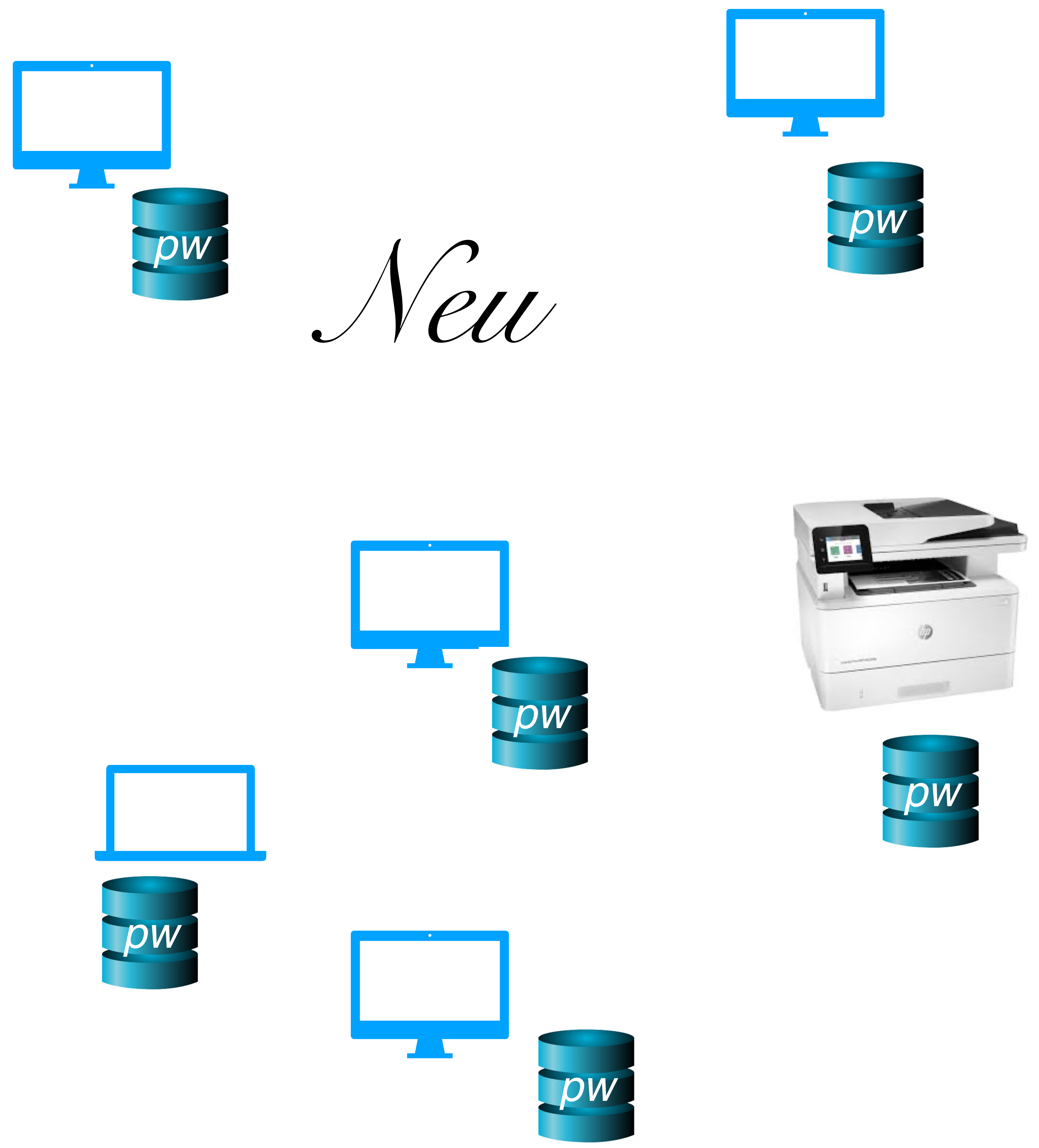
Neu

Alice
pw

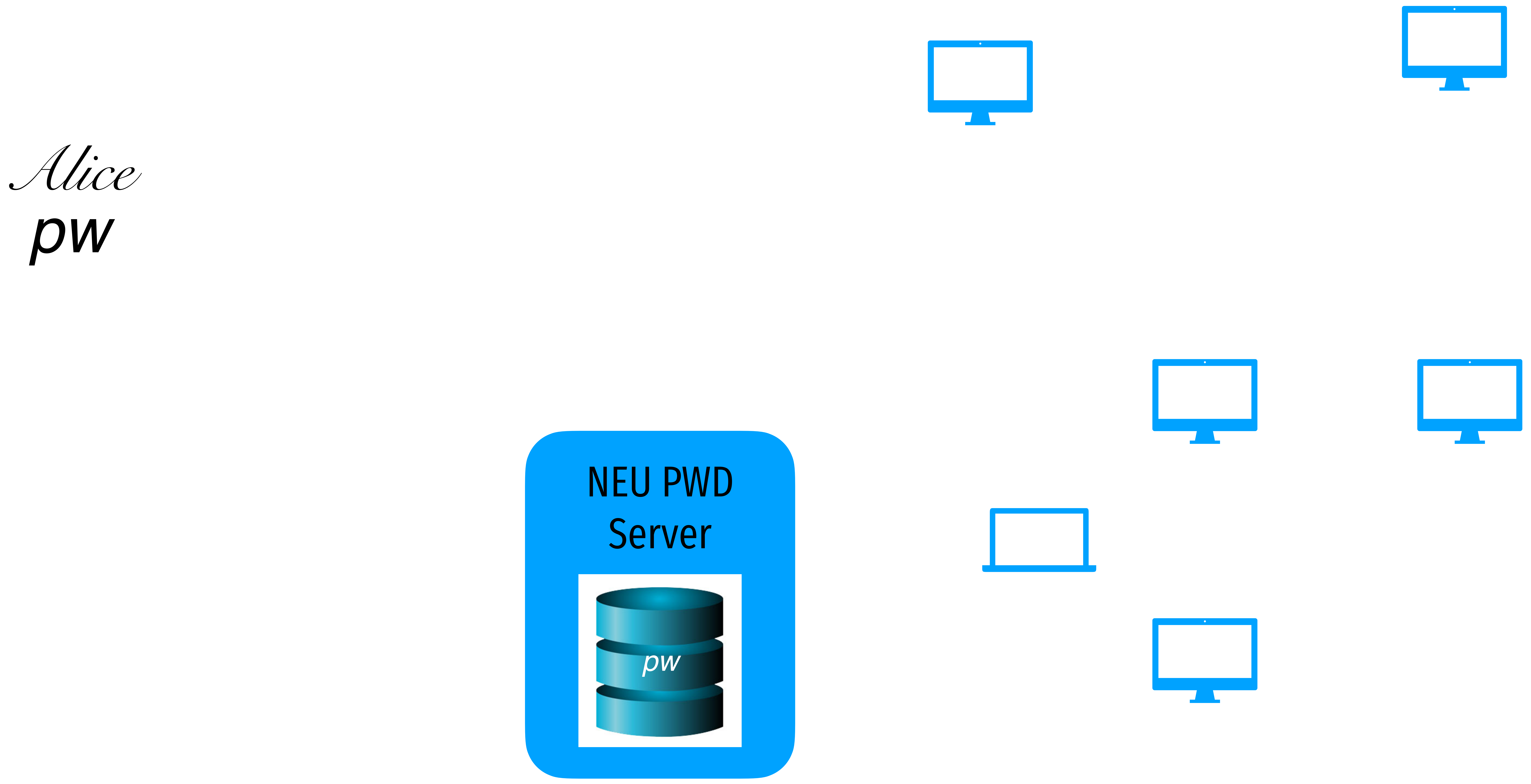
More realistic picture of the world

What are the problems with this solution?

Alice
pw

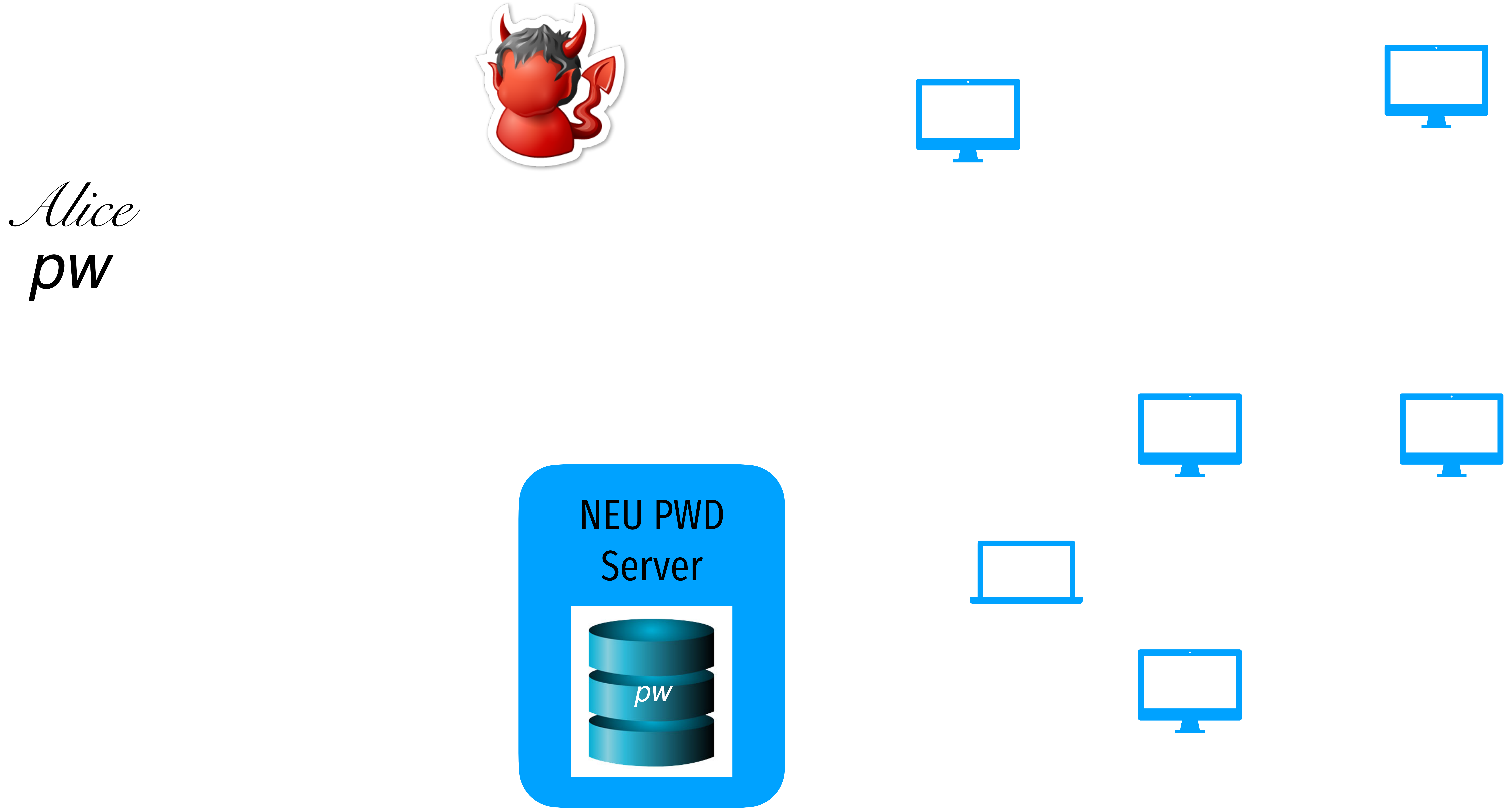


The problem of distributed authentication



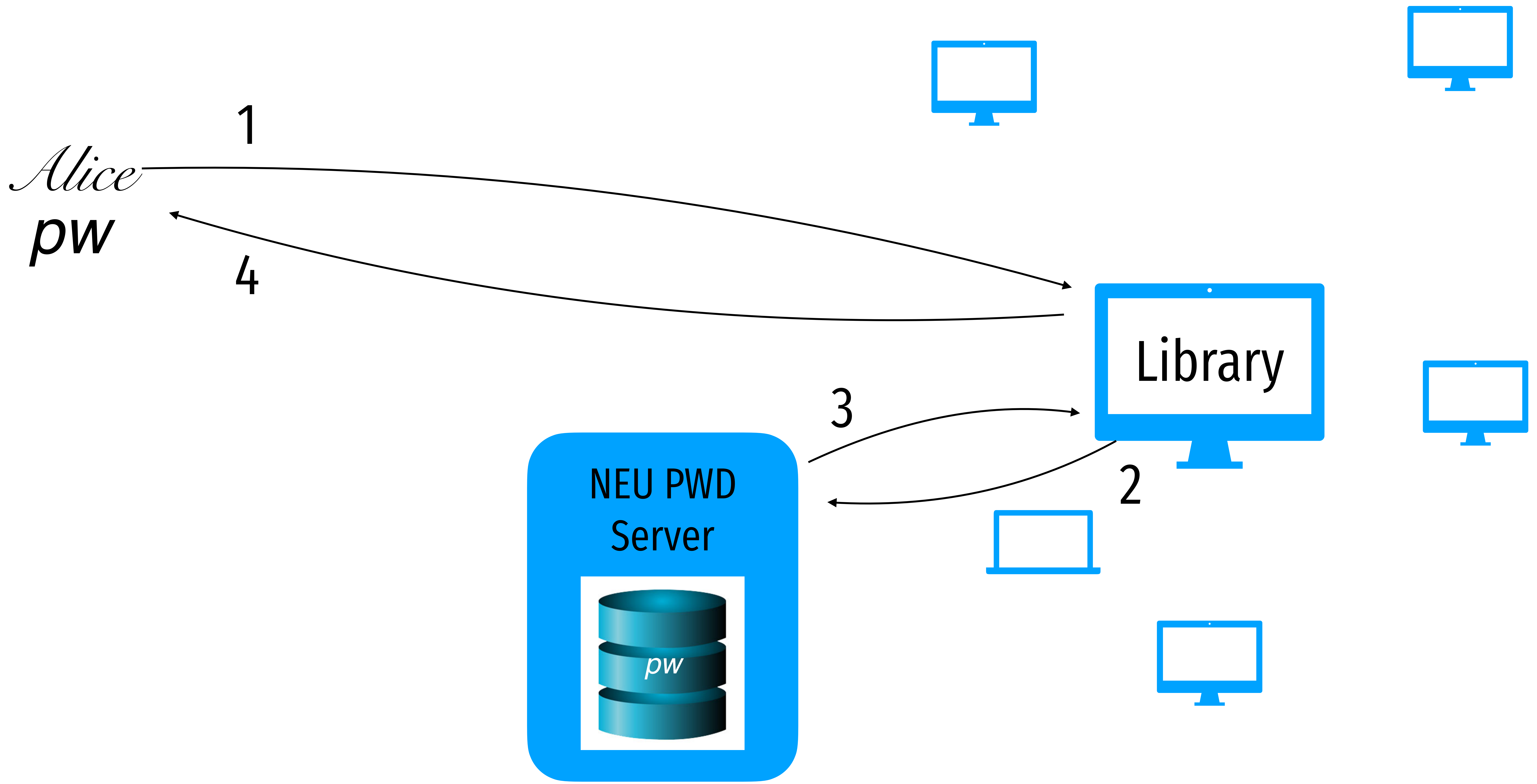
Distributed authentication: Attacker model

What can attacker do?

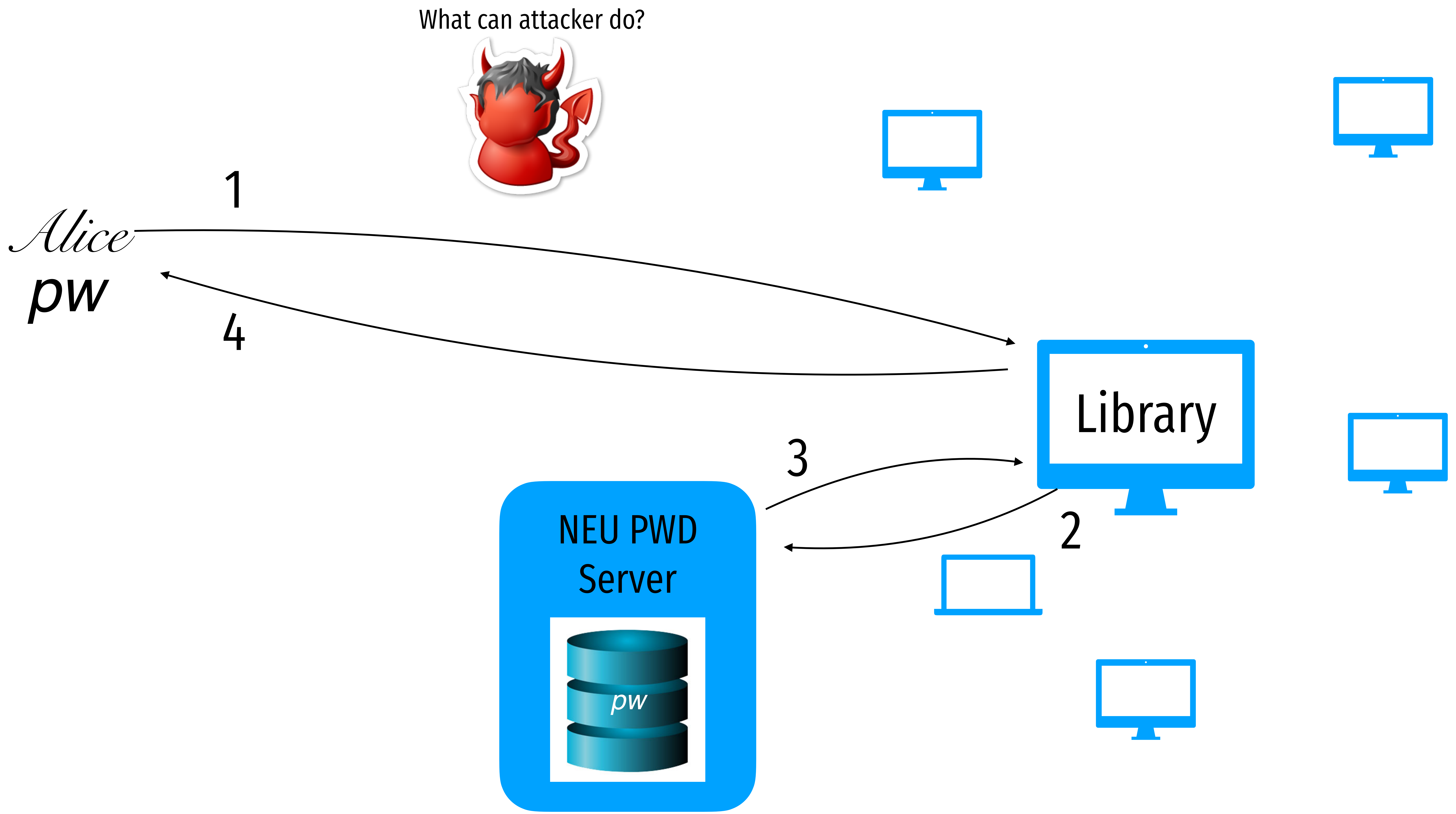


Distributed authentication: Bad Solution

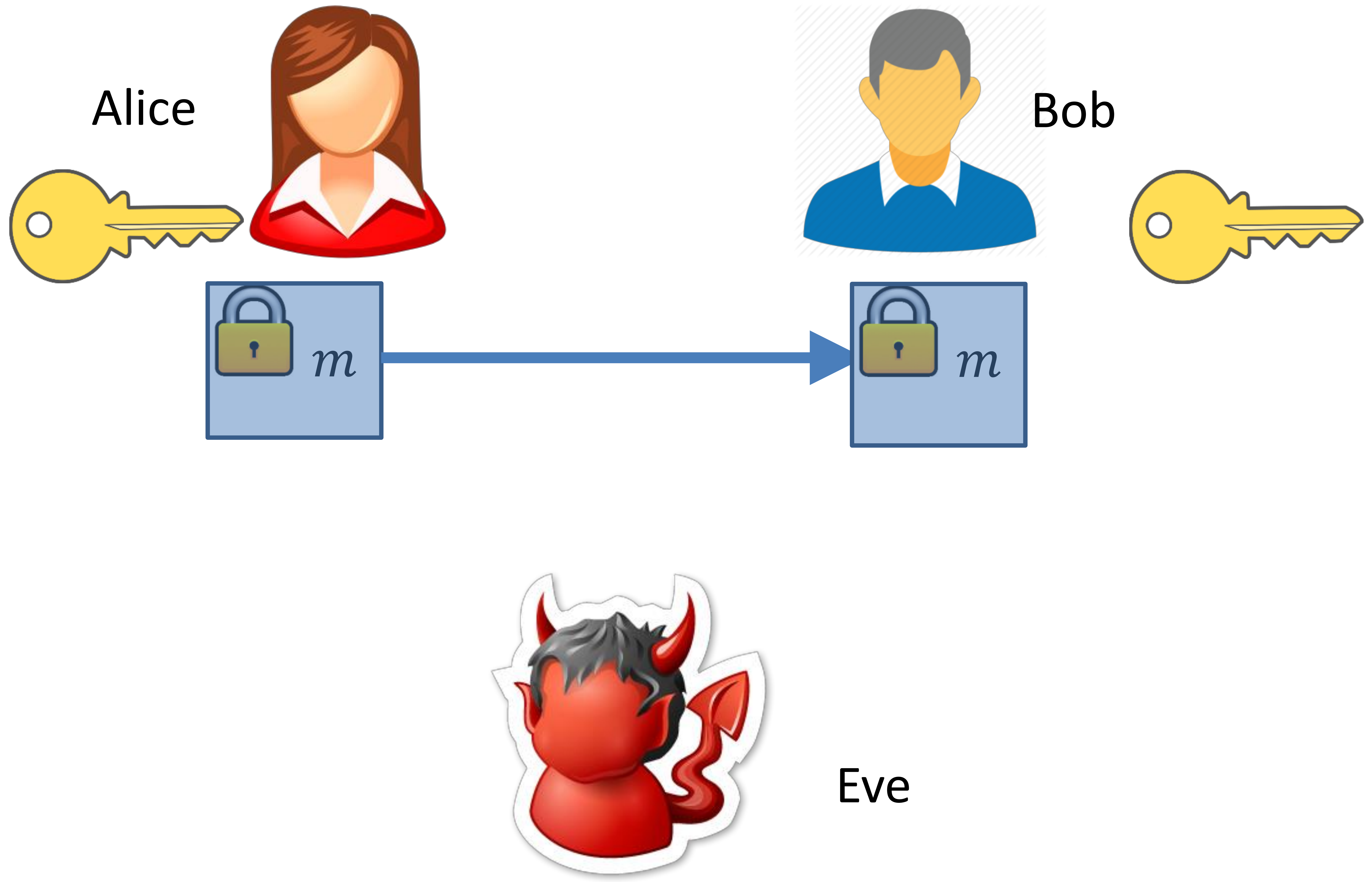
What can attacker do?



Distributed authentication: Bad Solution

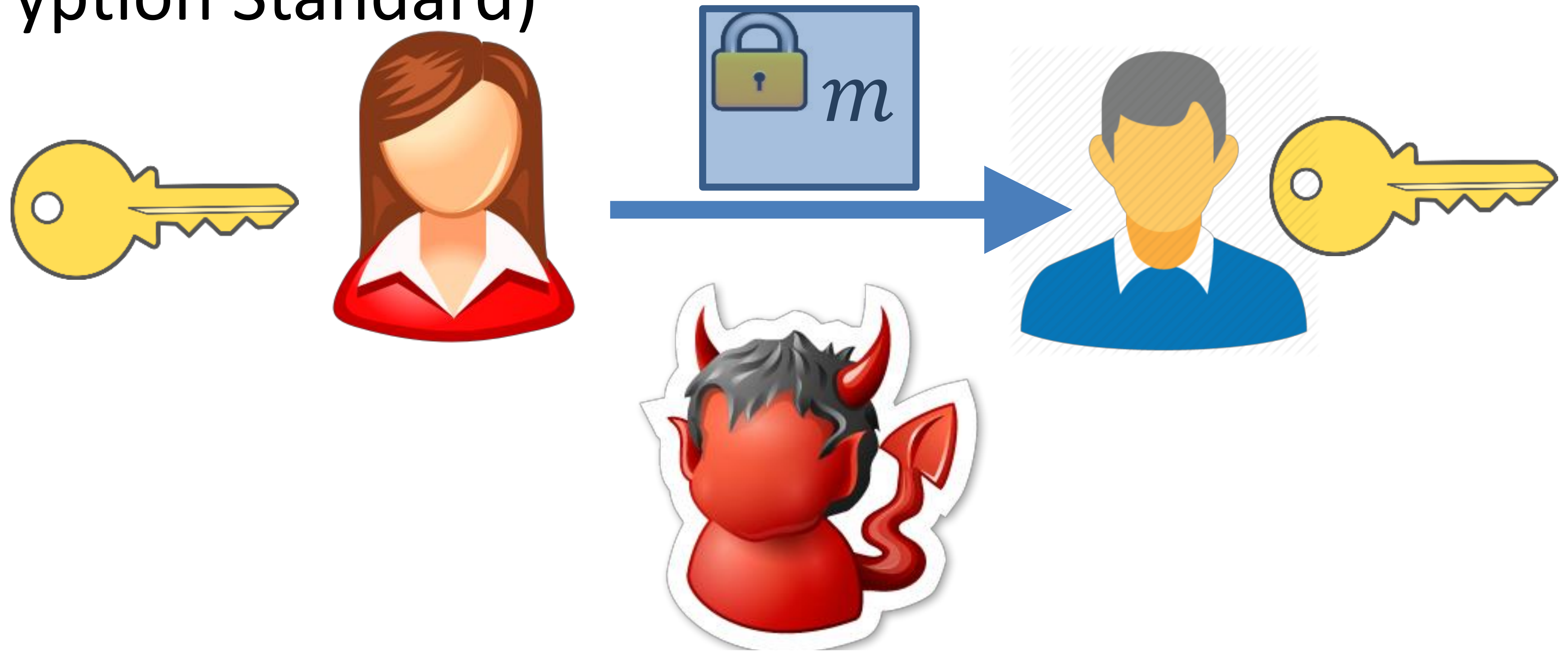


Basic tool: symmetric encryption



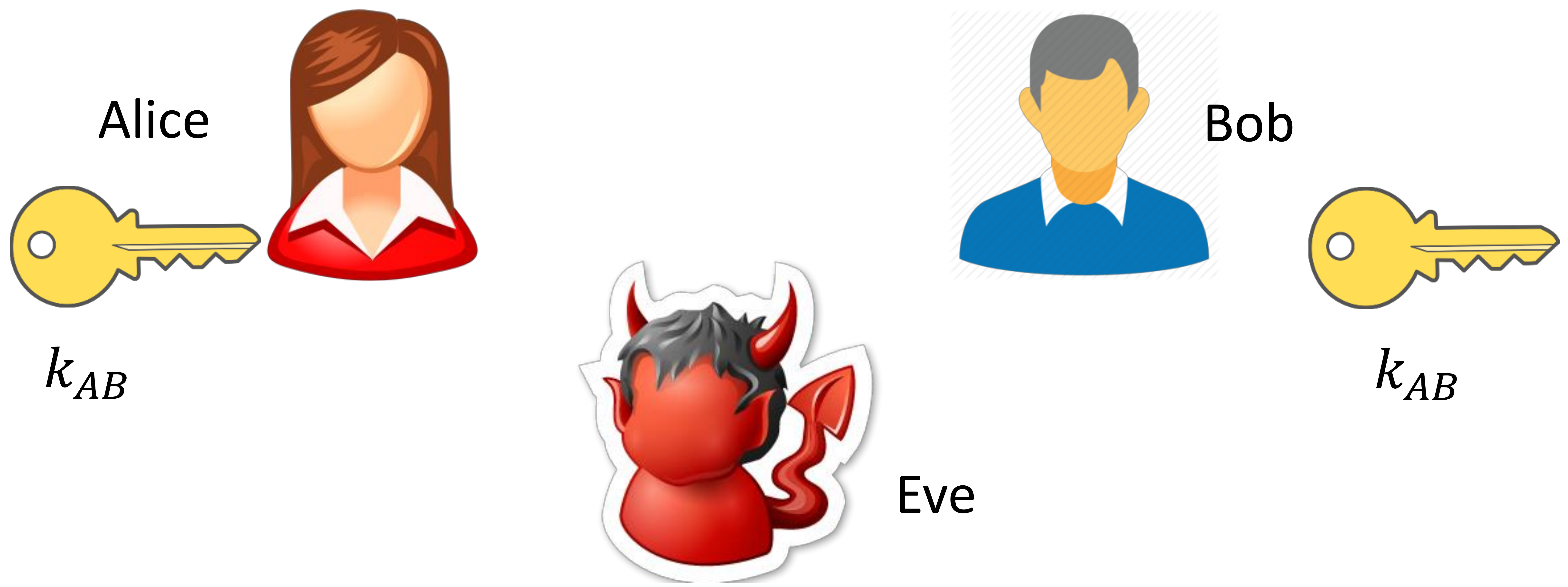
Basic tool: symmetric encryption

- Gen: generates secret key k
- Enc: given k and m output a ciphertext c
  Denote $Enc_k(m)$, $E_k(m)$, $\{m\}_k$
- Dec: given k and c output a message m
- Security (informal):
  Whatever Eve can learn on m given c can be learned without c
- Examples:
  - DES (Data Encryption Standard)
  - AES (Advanced Encryption Standard)

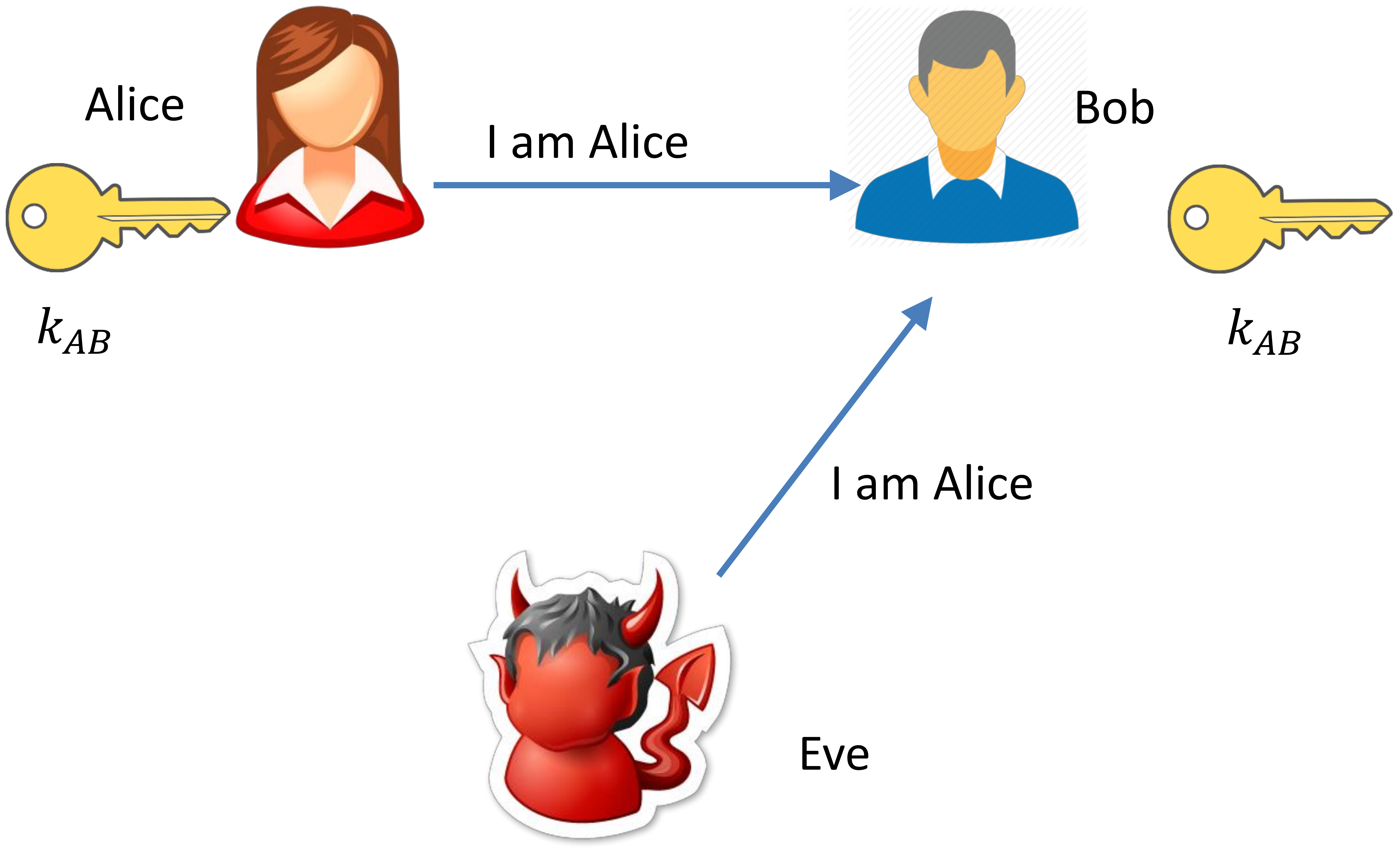


Authentication from Encryption

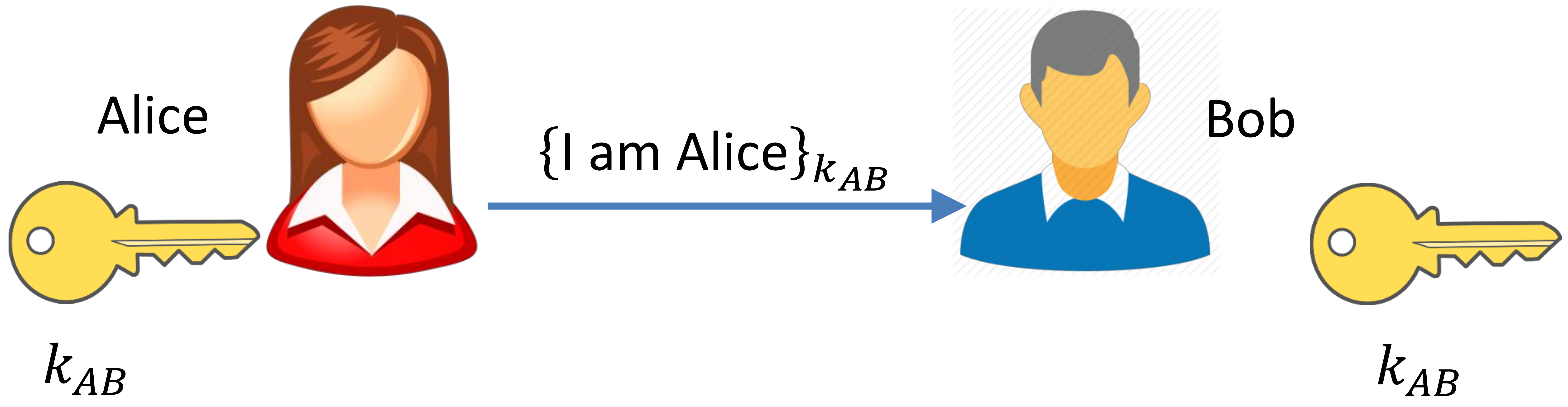
- Alice and Bob share a key
- They communicate over an insecure channel
- Alice wants to prove her identity to Bob
- Eve's goal: impersonate Alice



Attempt #1



Attempt #2: use the key



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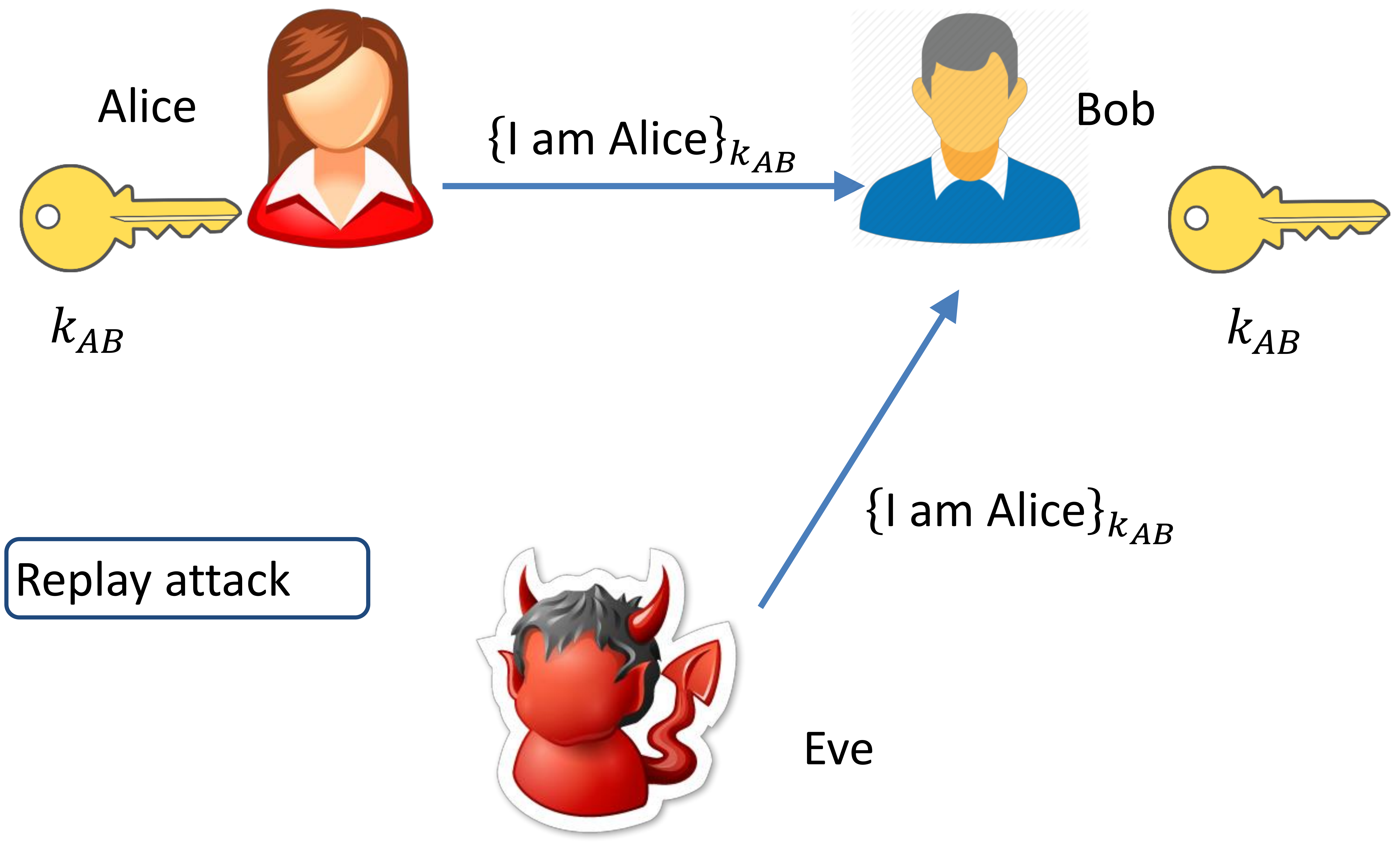
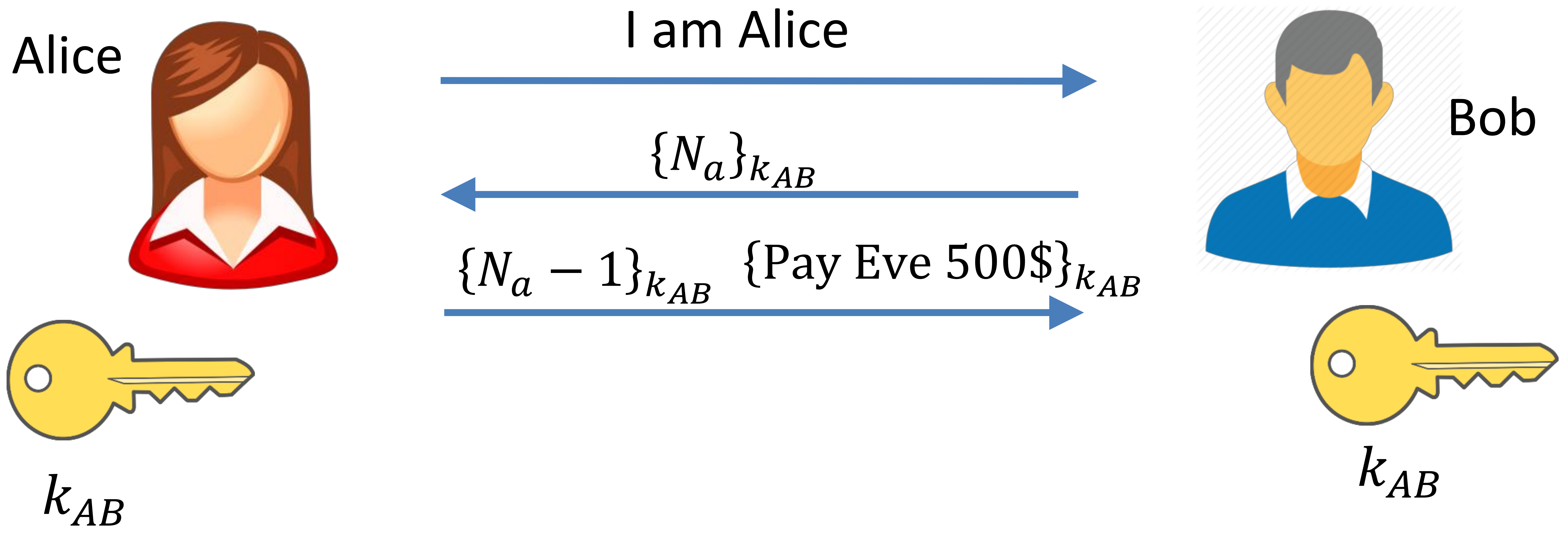
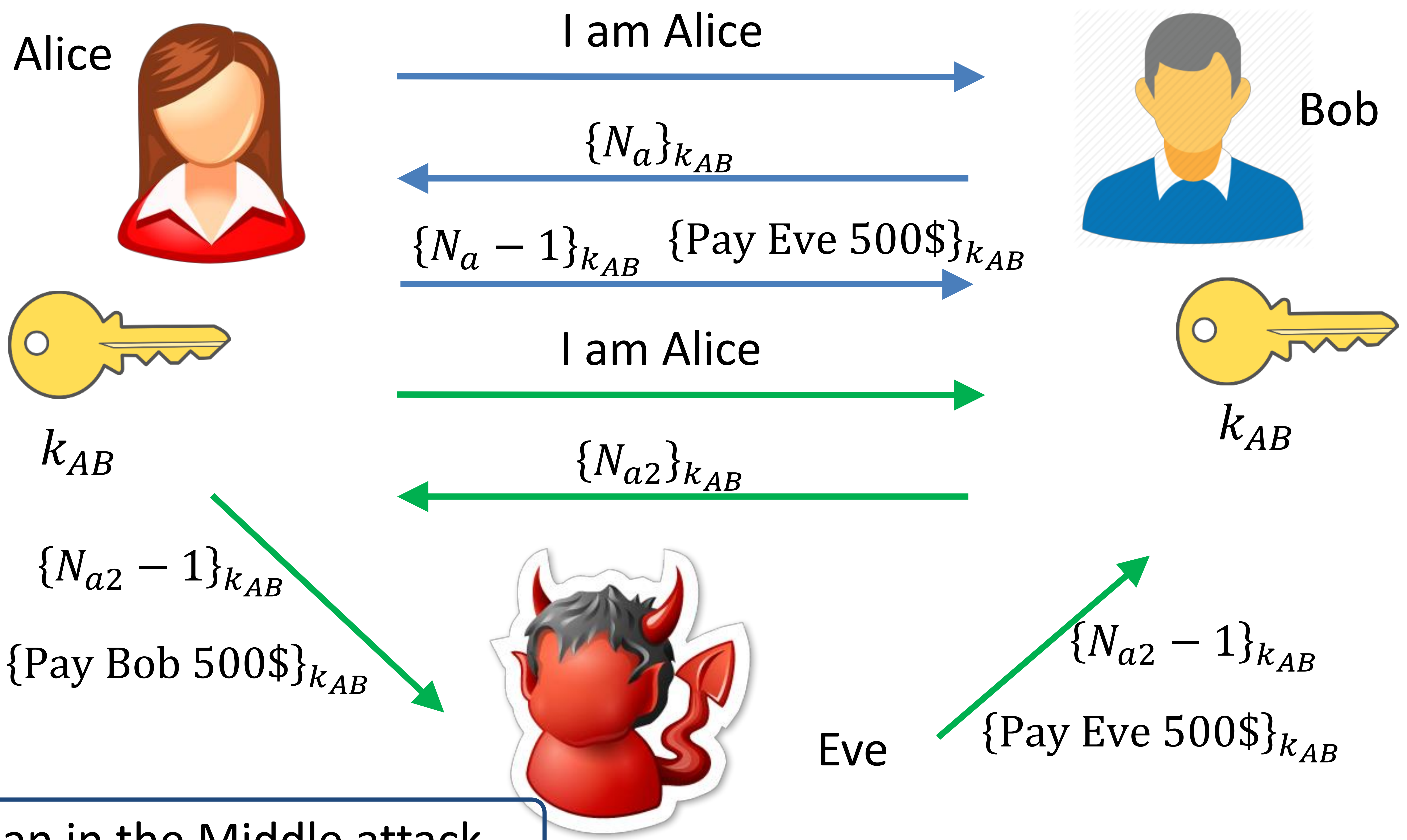

Alice
$\{\text{I am Alice}\}_{k_{AB}}$
Bob
k_{AB}
k_{AB}
$\{\text{I am Alice}\}_{k_{AB}}$
Eve

Replay attack

Attempt #3: use nonce

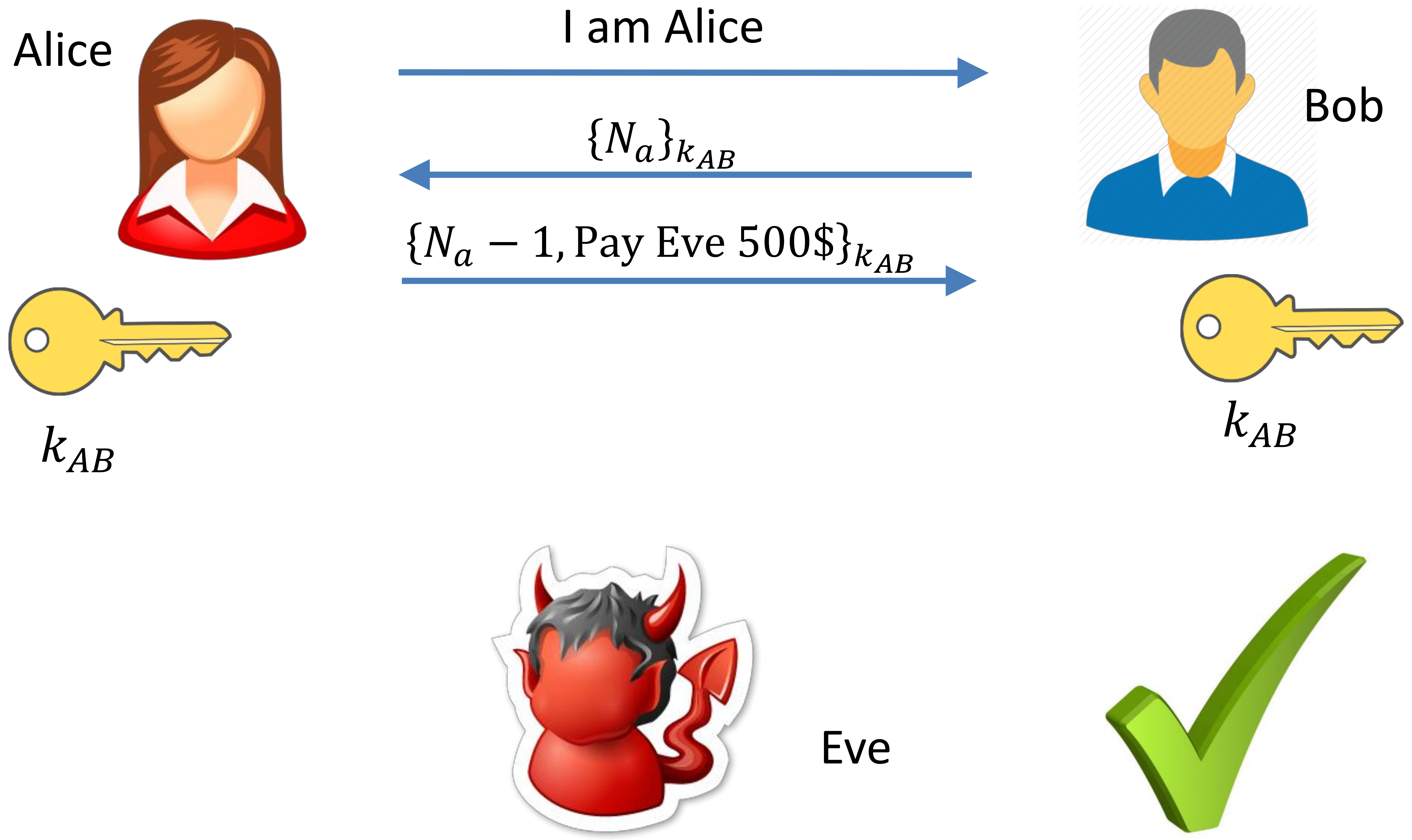


Attempt #3: use nonce


Alice
Bob
I am Alice
$\{N_a\}_{k_{AB}}$
$\{N_a - 1\}_{k_{AB}}$ $\{\text{Pay Eve } 500\$\}_{k_{AB}}$
I am Alice
$\{N_{a2}\}_{k_{AB}}$
k_{AB}
k_{AB}
$\{N_{a2} - 1\}_{k_{AB}}$
$\{\text{Pay Bob } 500\$\}_{k_{AB}}$
Eve
$\{N_{a2} - 1\}_{k_{AB}}$
$\{\text{Pay Eve } 500\$\}_{k_{AB}}$

Man in the Middle attack

Attempt #4

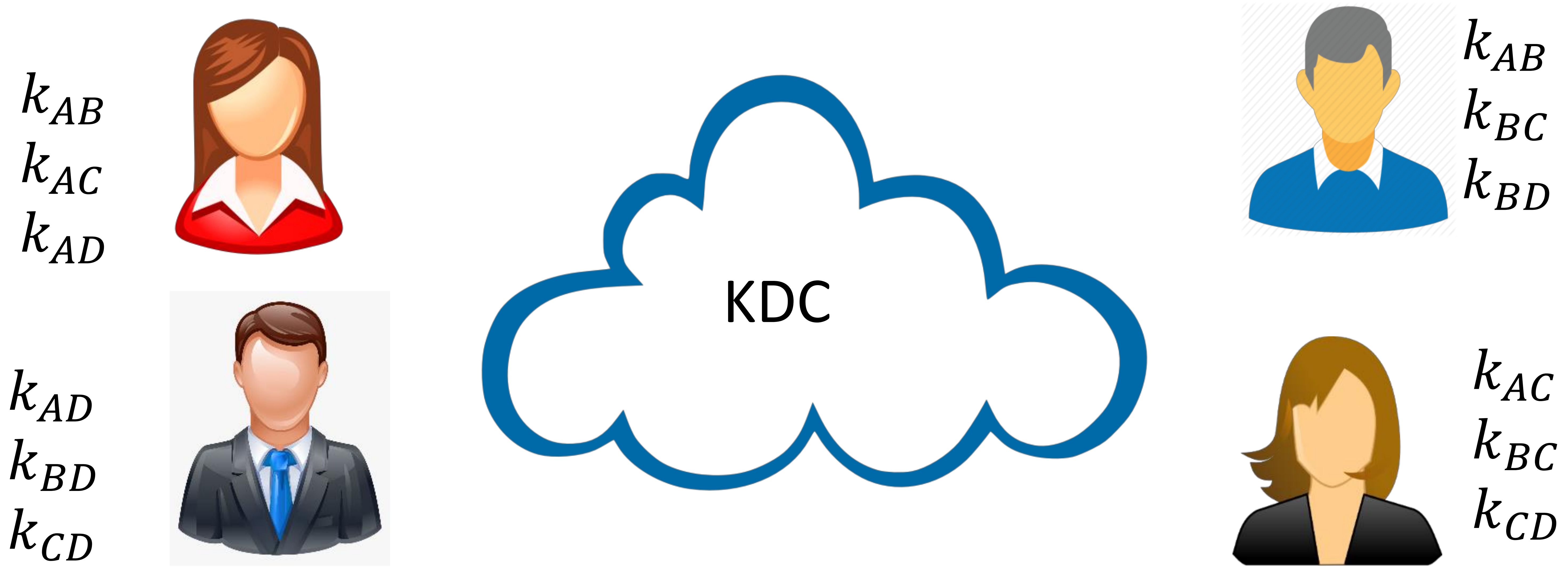


Key establishment

- The protocol worked because Alice and Bob shared a key
- How do parties agree on a key?
  - Run a key agreement protocol (later in the semester)
  - Use a trusted third party (this lecture)
- Key distribution center (KDC):
  - Shares a key with each entity
  - Single point of failure
  - Reasonable assumption for organizations
  - Not useful for open environments (e.g. the Internet)

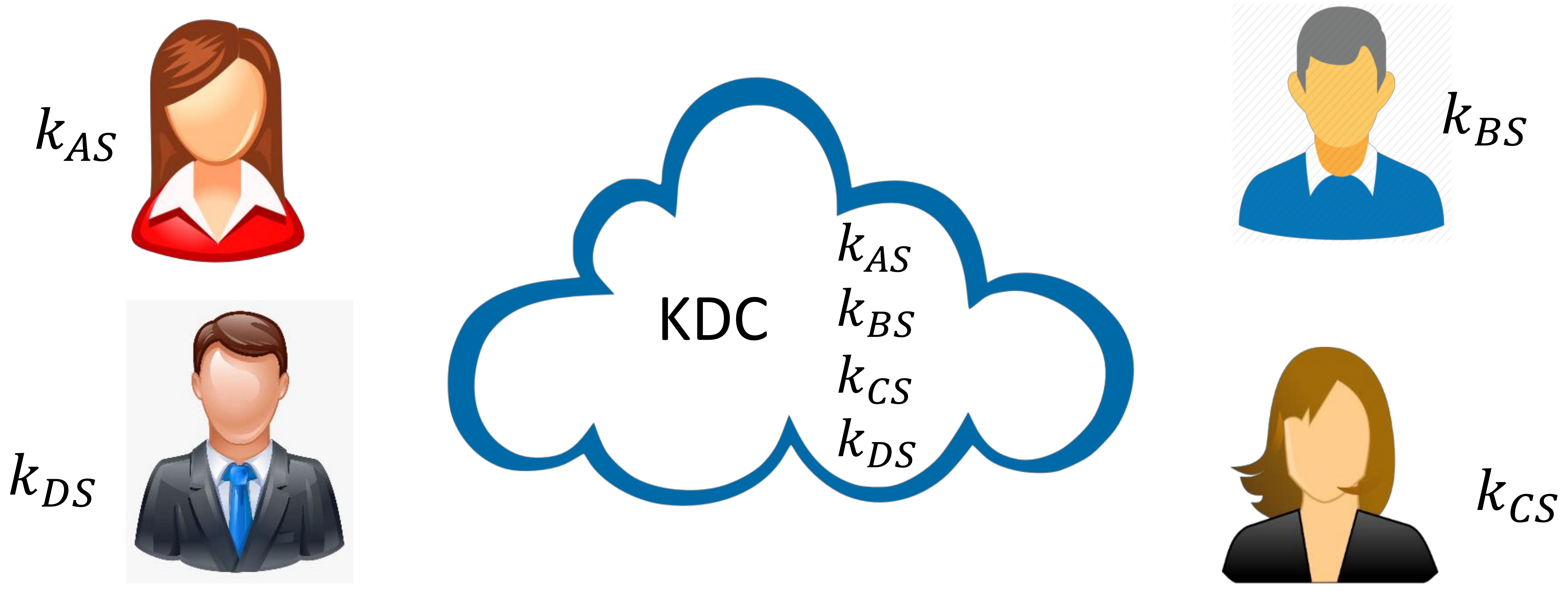
Naïve solution

- KDC generates a key for each pair
- Number of keys $n(n-1)$, number of key pairs $\frac{n(n-1)}{2} = \binom{n}{2}$
- Drawbacks:
  - Quadratic number of keys
  - Adding new users is complex
- May be useful for static small networks

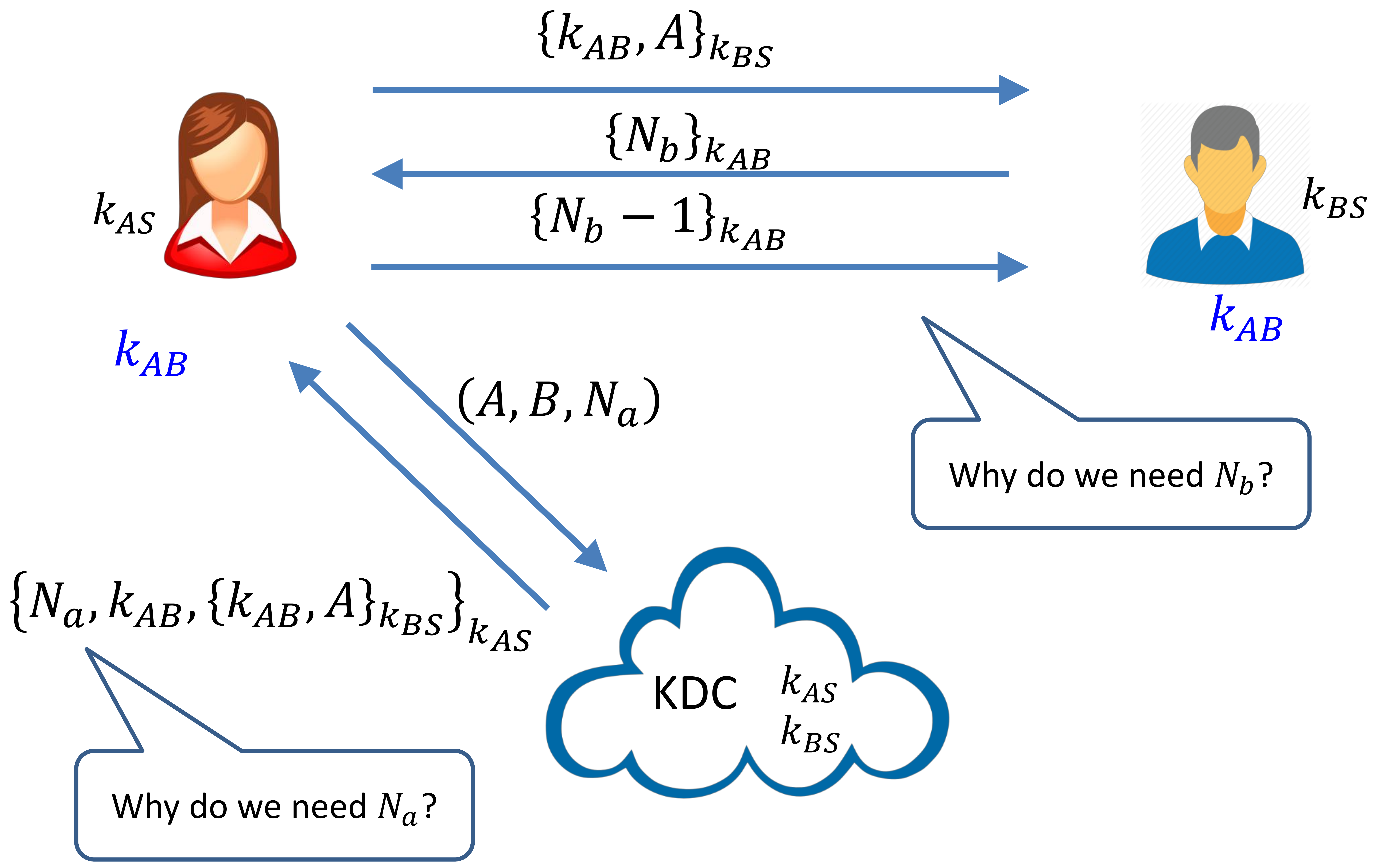


Desire: solution with linear keys

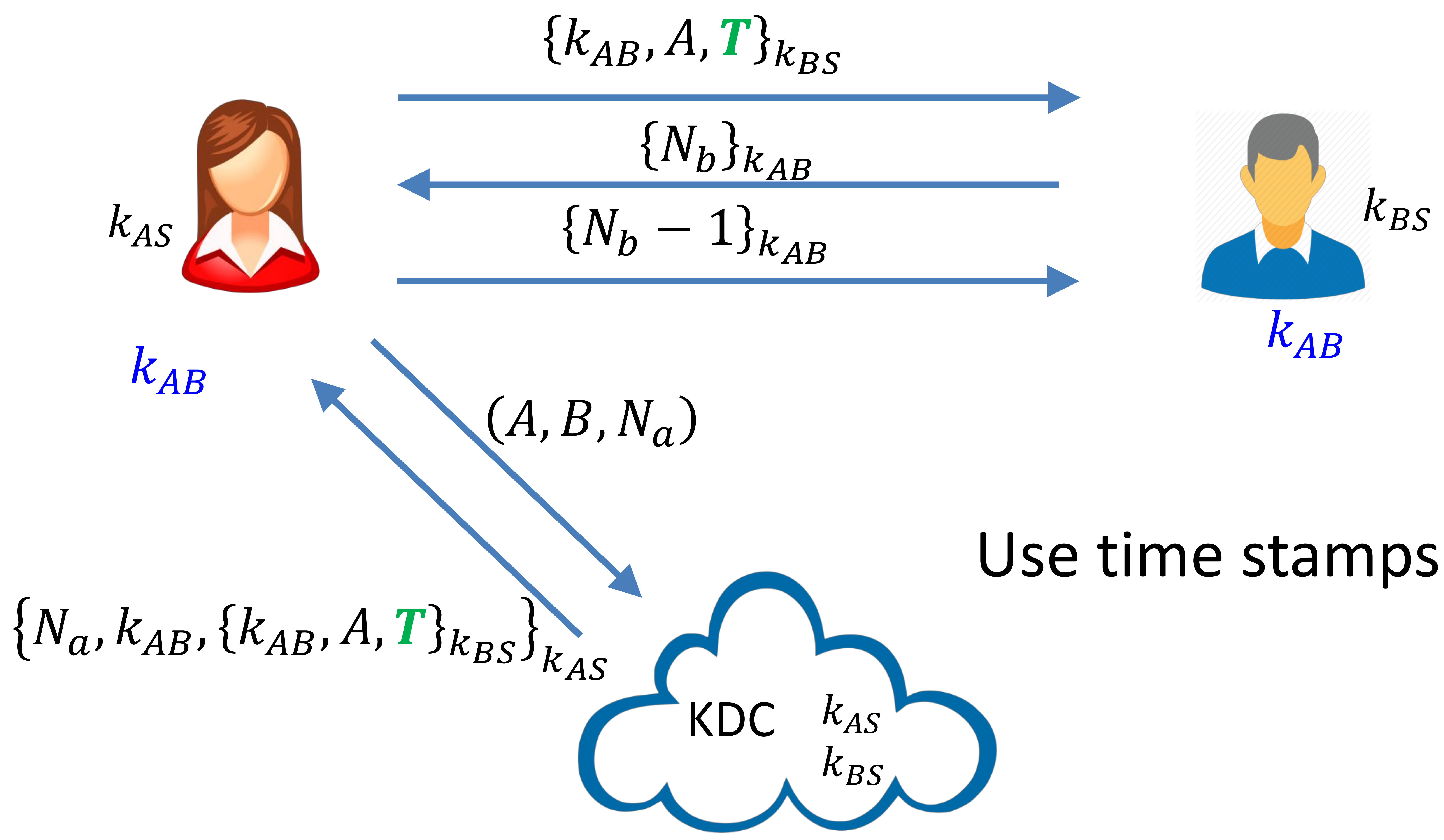
- KDC shares a key with each user
- Number of keys $2n$
- Number of key pairs n
- These are long-term keys
- Alice and Bob establish a fresh session key



Needham-Schroeder Protocol (1978)



Fixed Needham-Schroeder

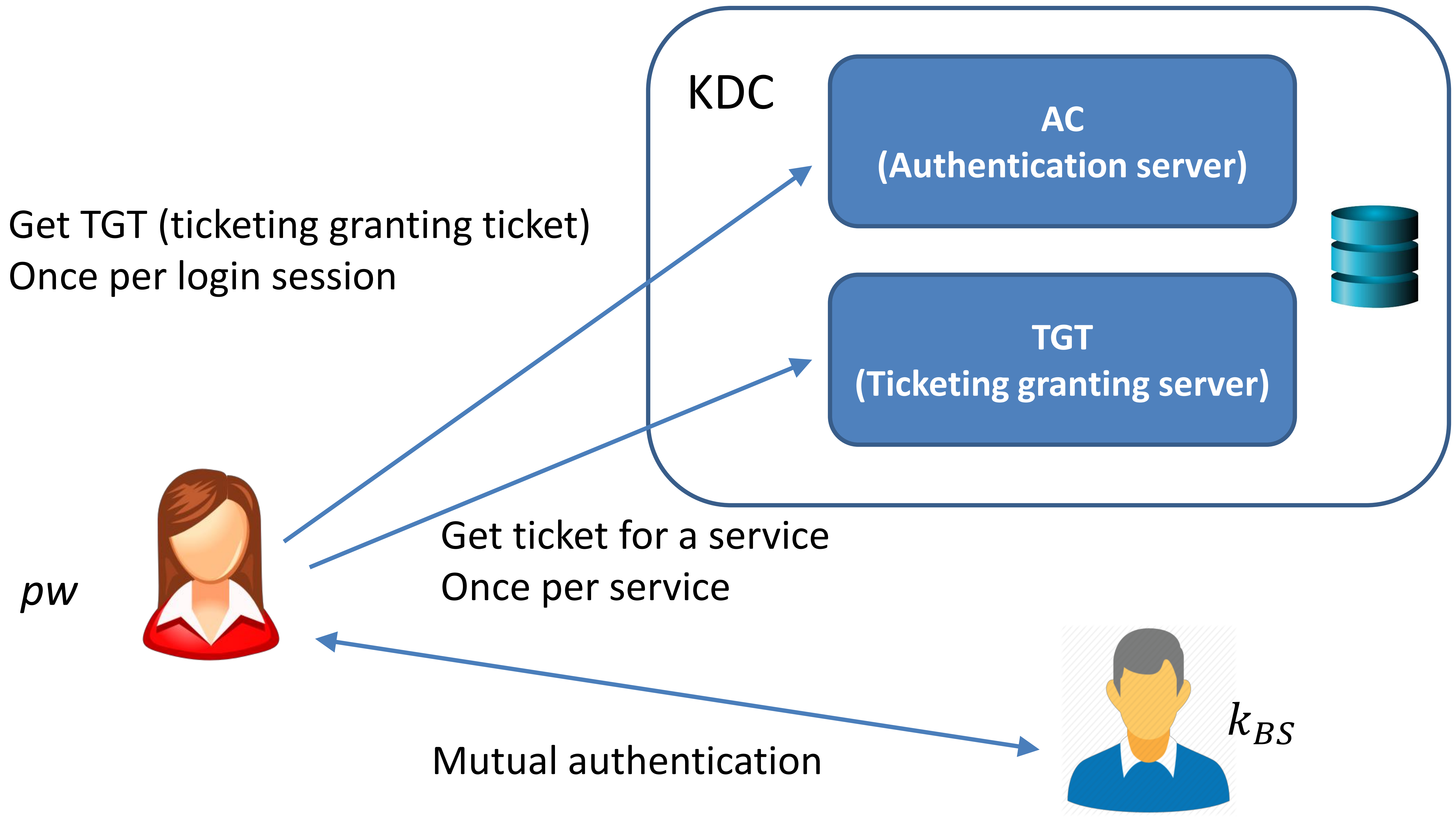


Use time stamps

Kerberos

- Developed in MIT in the ‘80s
- Based on Needham-Schroeder
  - Versions 1-3 not published
  - Version 4 not secure
  - Version 5 published in 1993
- Widely used nowadays:
  - The basis of Microsoft’s active directory
  - Many Unix versions

Kerberos

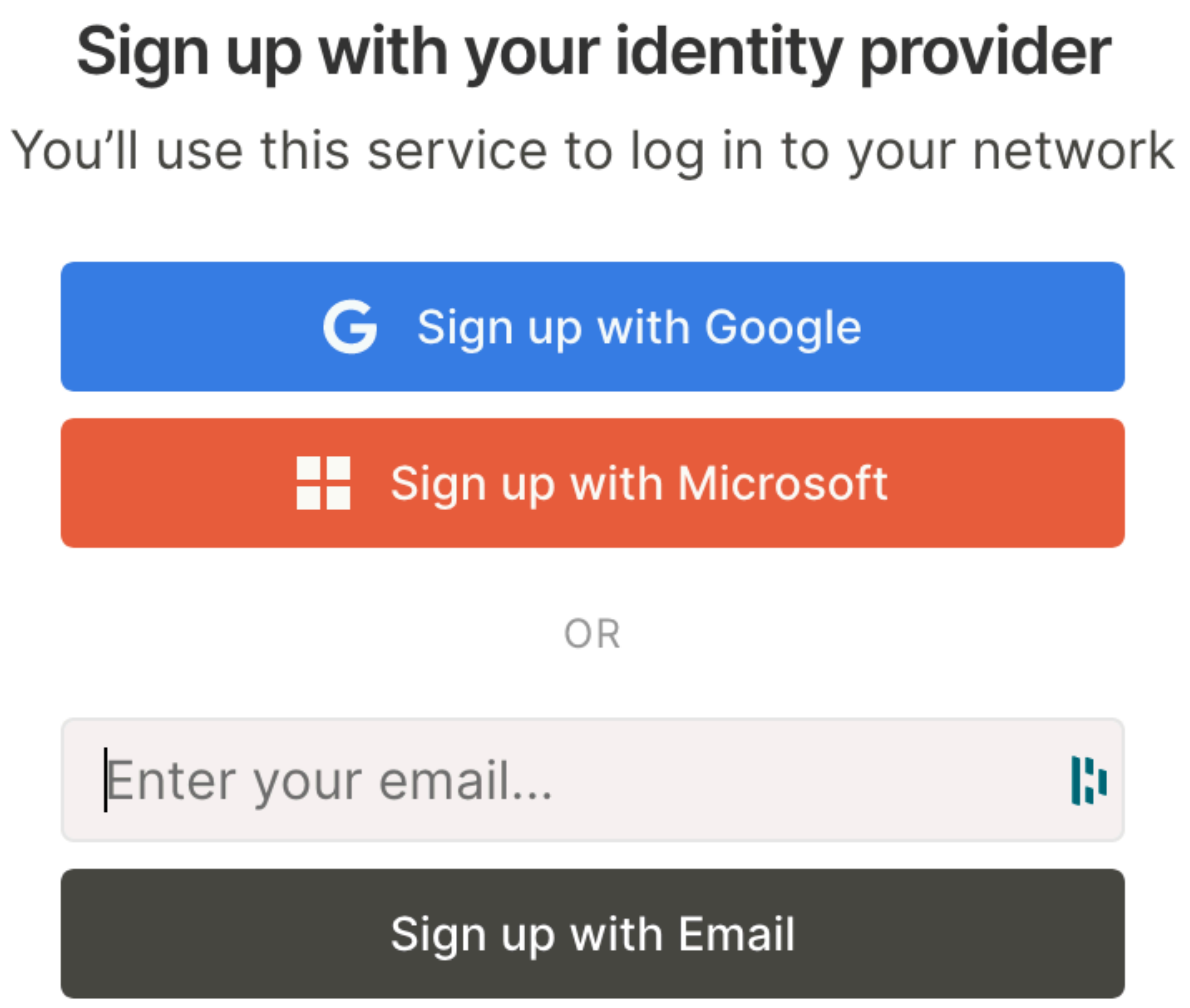

KDC
AC
(Authentication server)
TGT
(Ticketing granting server)
Get TGT (ticketing granting ticket)
Once per login session
Get ticket for a service
Once per service
pw
Mutual authentication
k_{BS}

Kerberos

- Passwords are not sent over the network
- Alice's key k_{AS} is a hash of her password

- Kerberos weaknesses:
  - KDC is a single point of failure
  - DoS the KDC and the network ceases to function
  - Compromise the KDC leads to network-wide compromise
  - Time synchronization is a very hard problem

“Single Sign on”

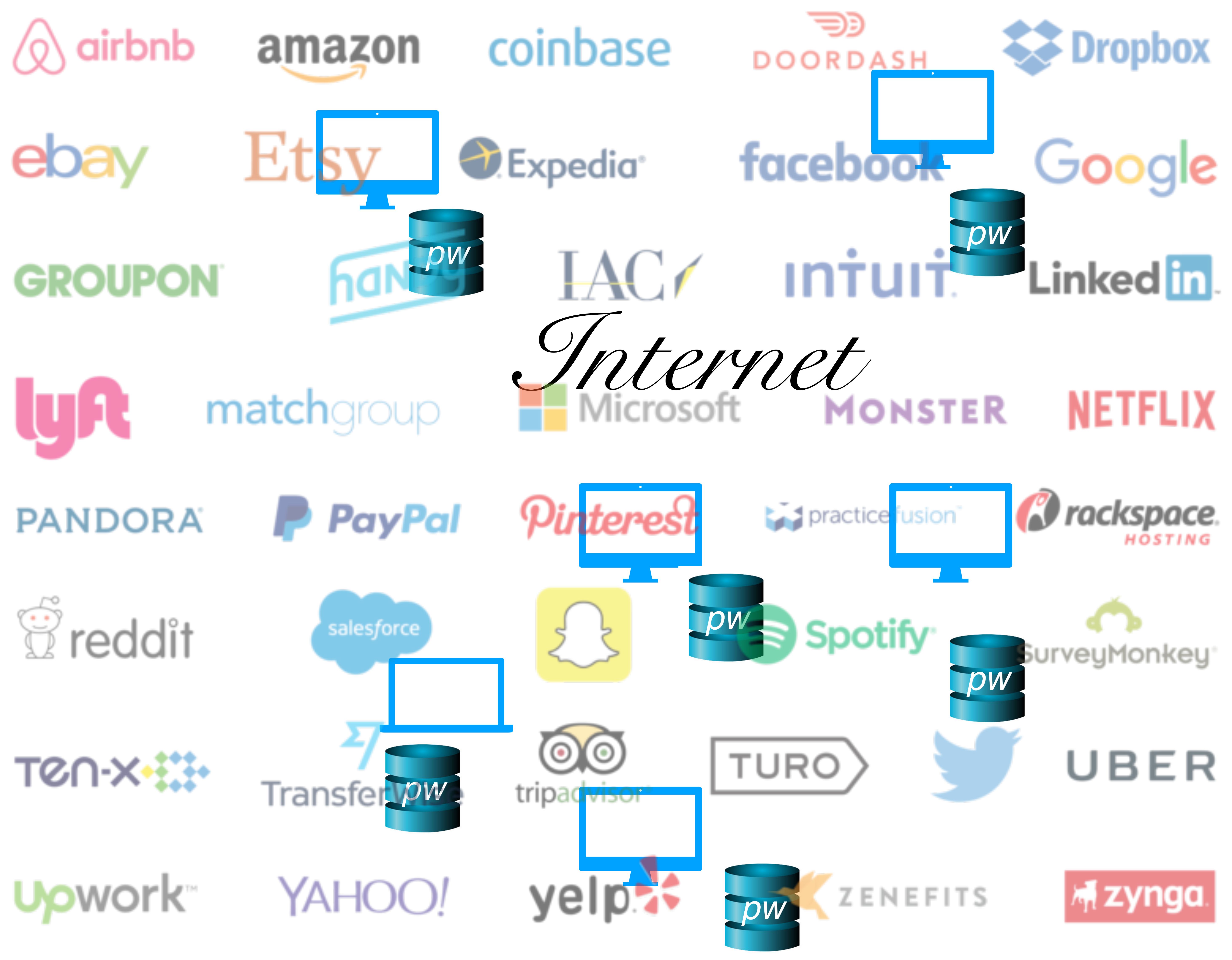


Sign up with your identity provider

You’ll use this service to log in to your network

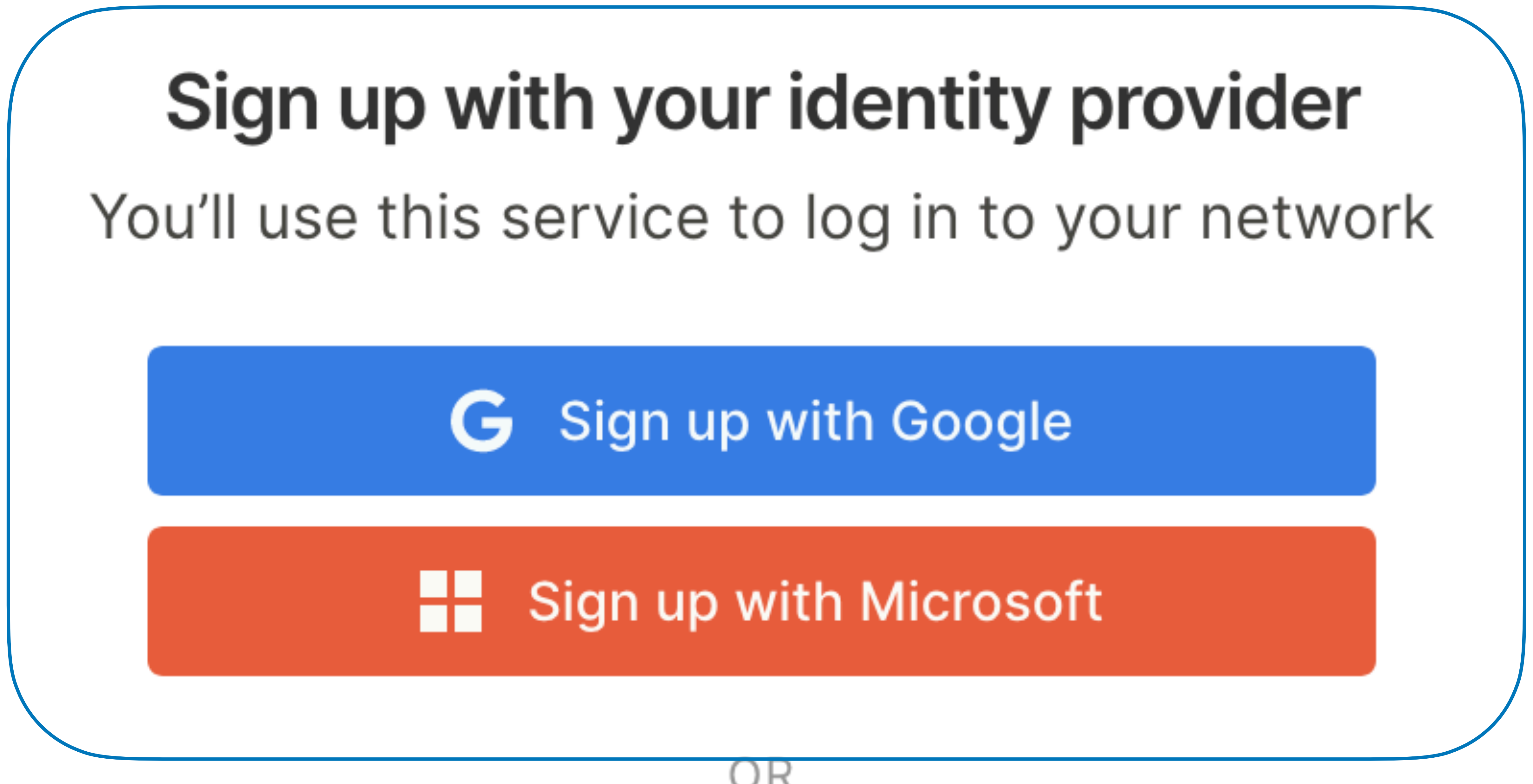
Same problem as before

Alice
pw



“Single Sign on”

Alice
pw


Sign up with your identity provider

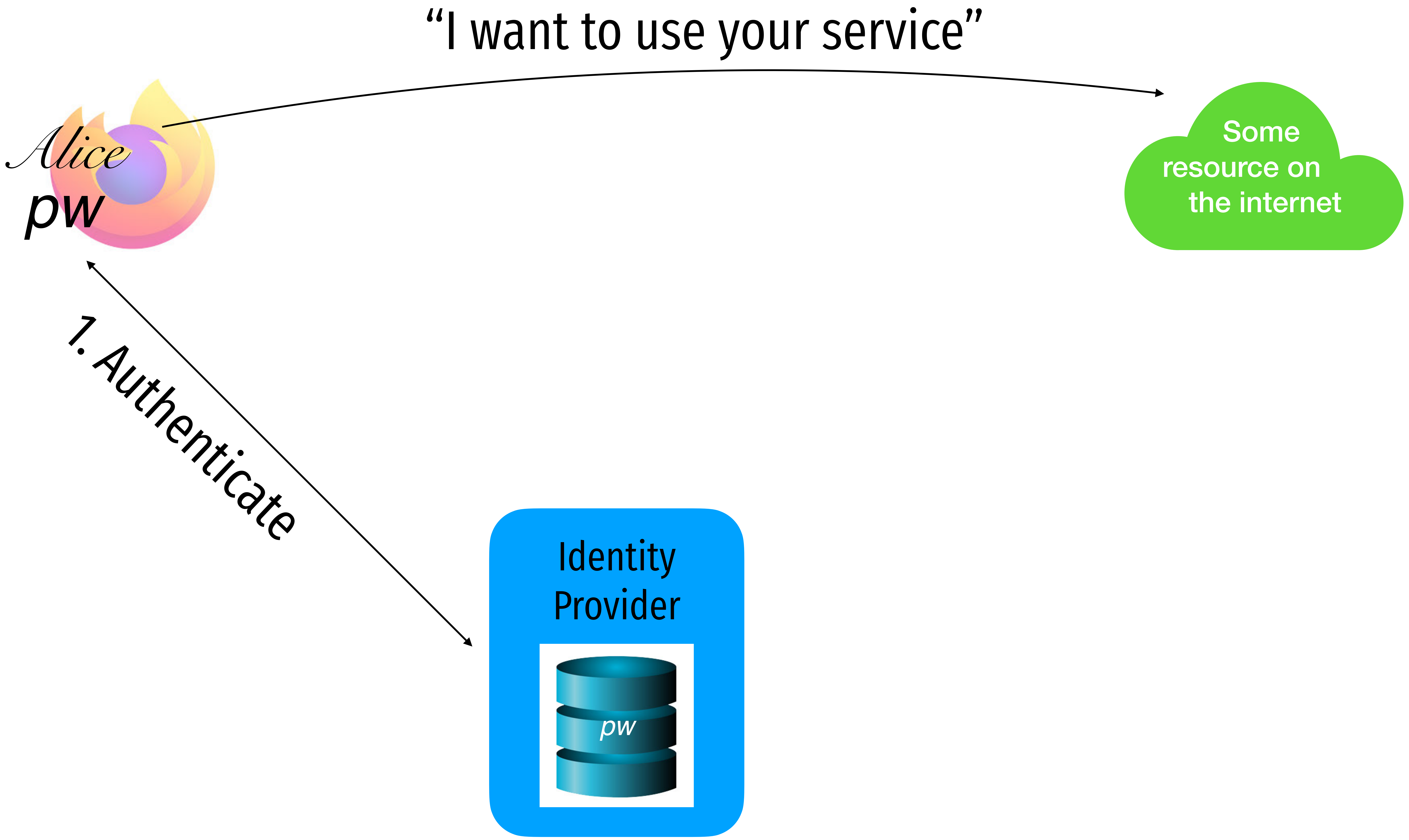
You’ll use this service to log in to your network

Sign up with Google

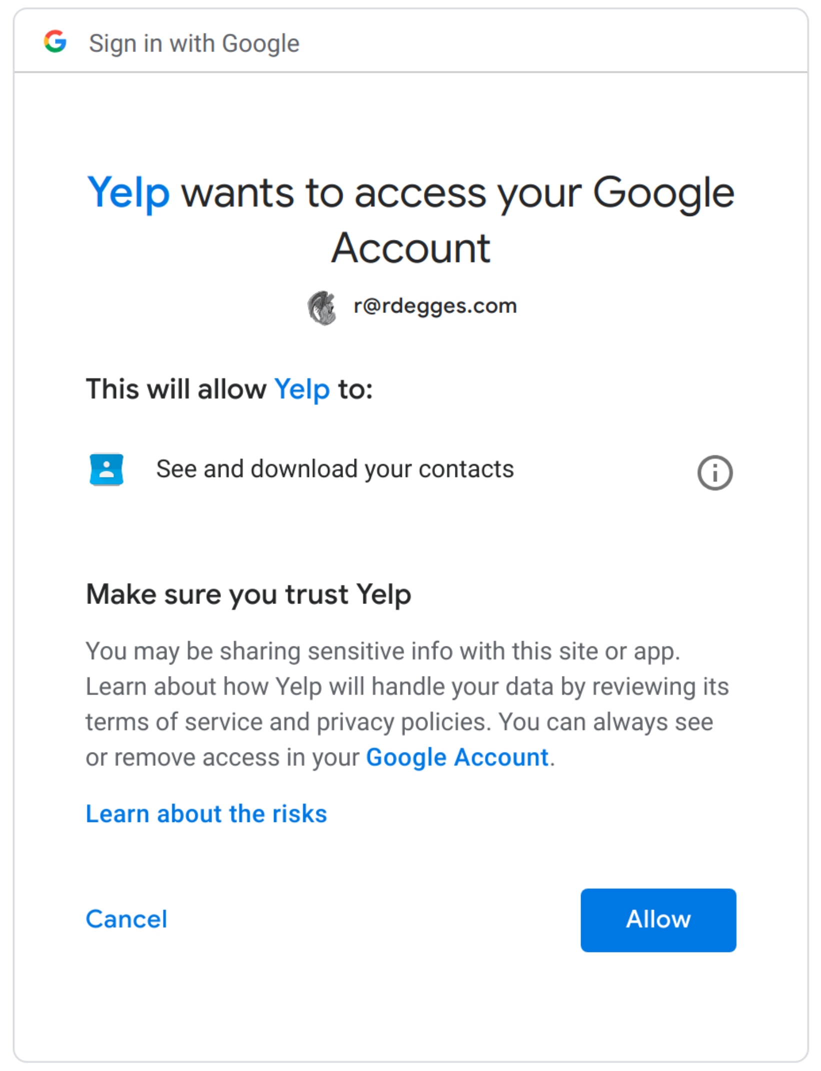
Sign up with Microsoft

OR

Oauth


"I want to use your service"
Alice
pw
Some resource on the internet
1. Authenticate
Identity Provider
pw

Oauth



Sign in with Google

Yelp wants to access your Google Account

r@rdegges.com

This will allow Yelp to:

See and download your contacts

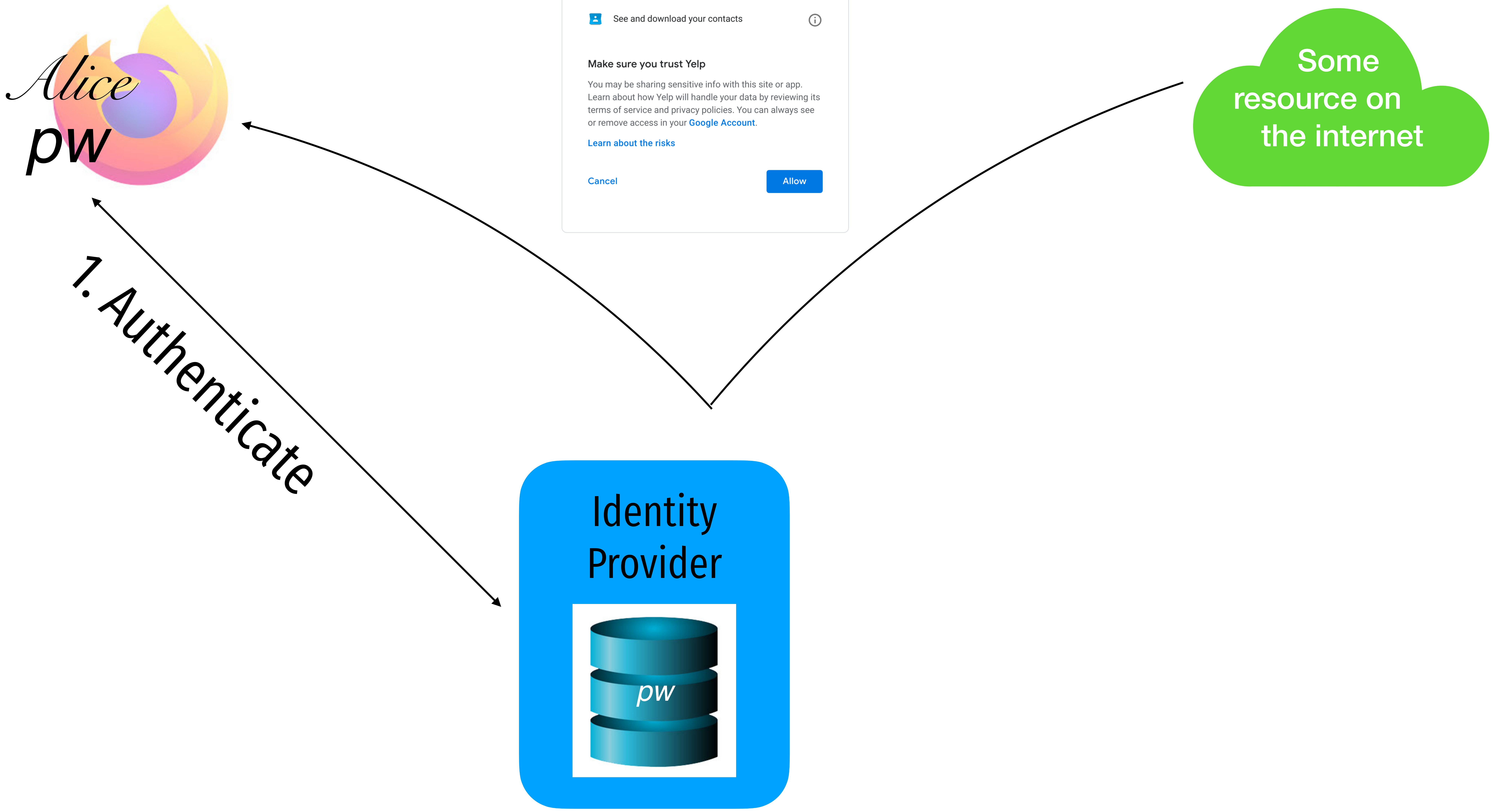
Make sure you trust Yelp

You may be sharing sensitive info with this site or app. Learn about how Yelp will handle your data by reviewing its terms of service and privacy policies. You can always see or remove access in your Google Account.

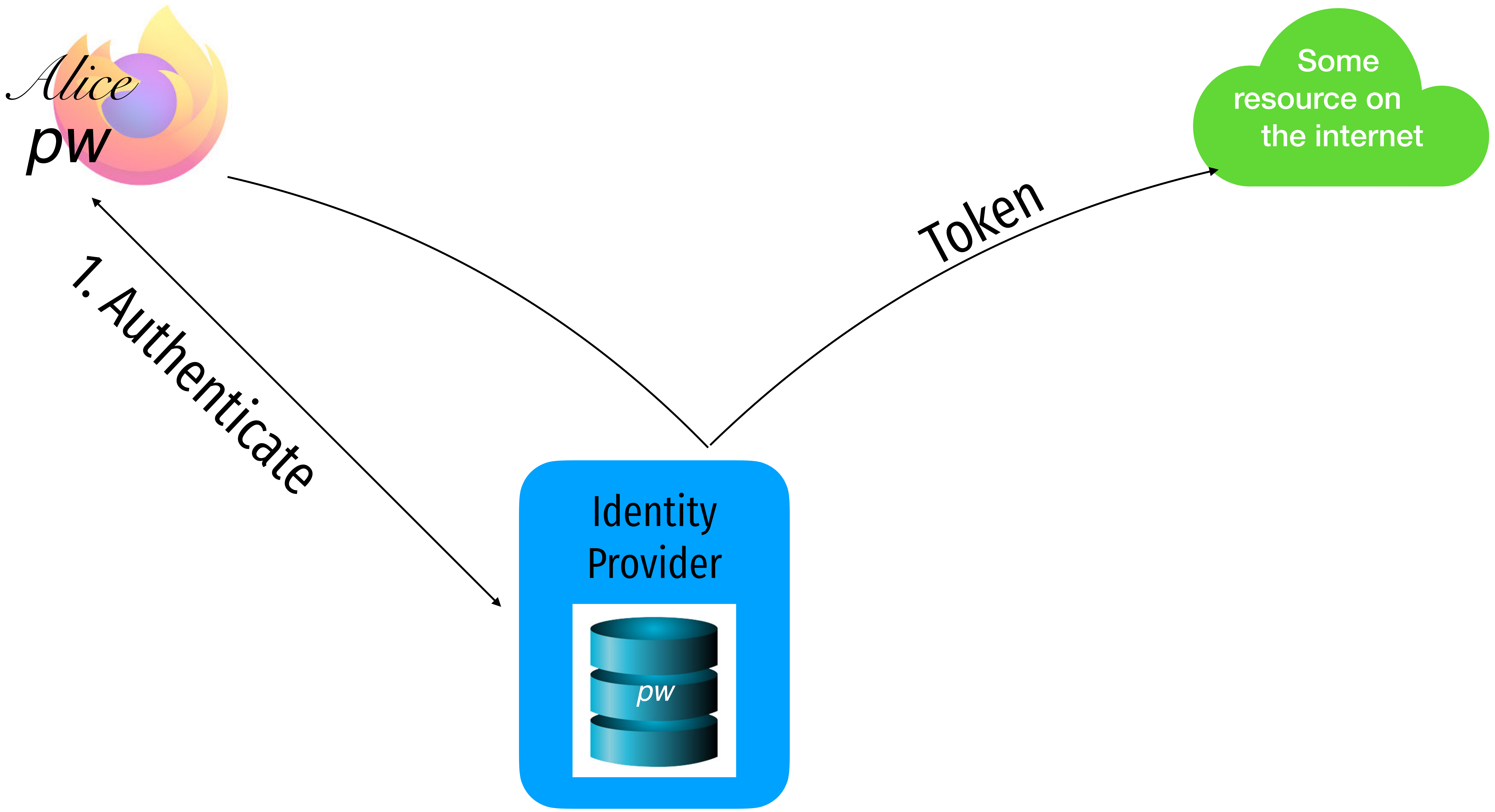
Learn about the risks

Cancel

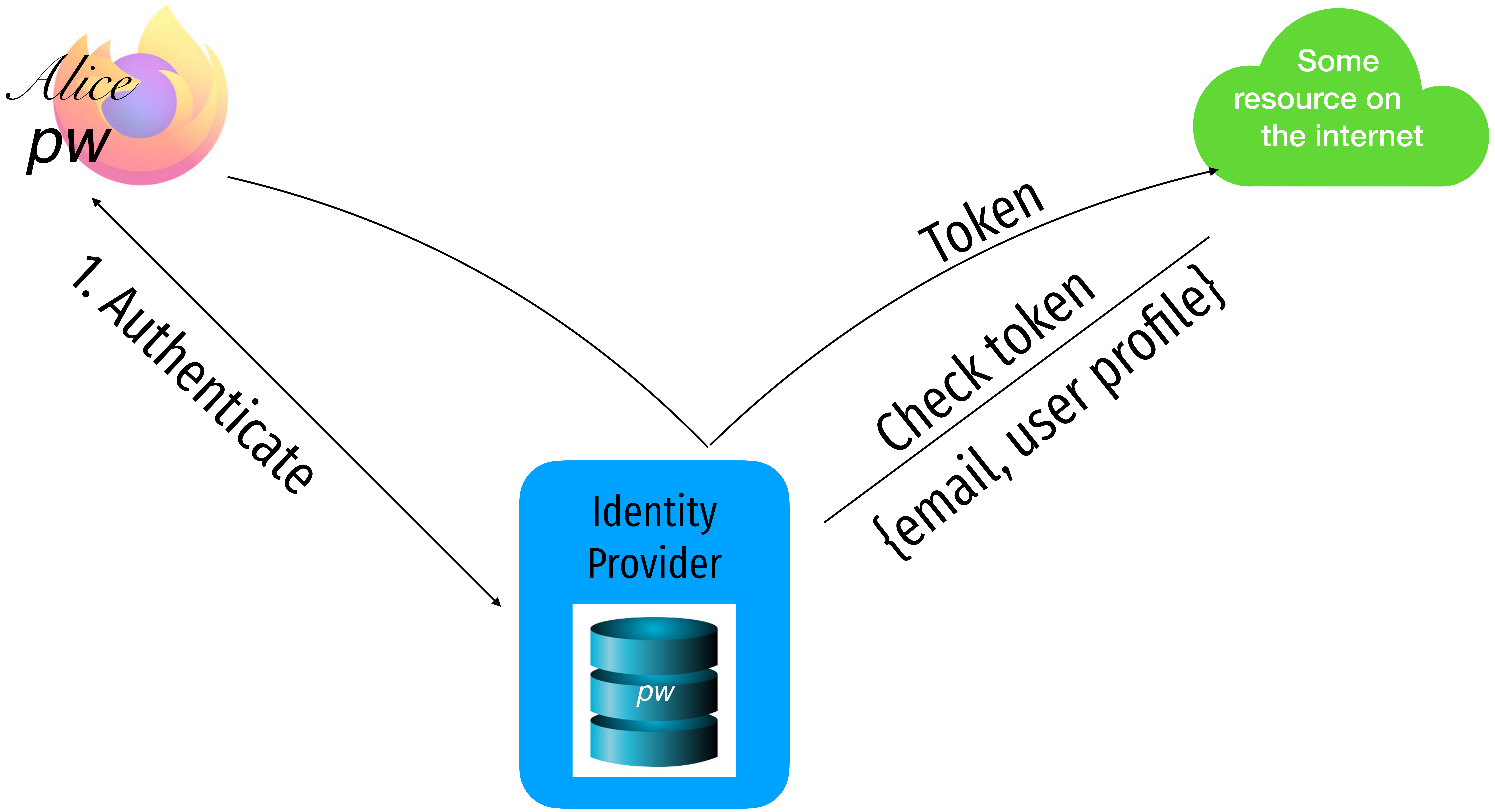
Allow



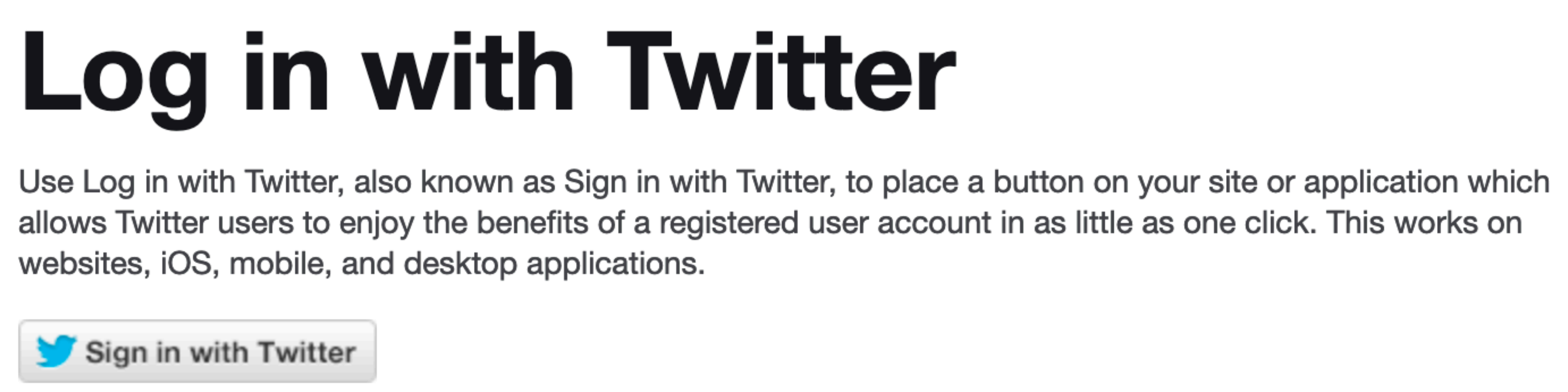
Oauth


Alice
pw
1. Authenticate
Token
Some resource on the internet
Identity Provider
pw

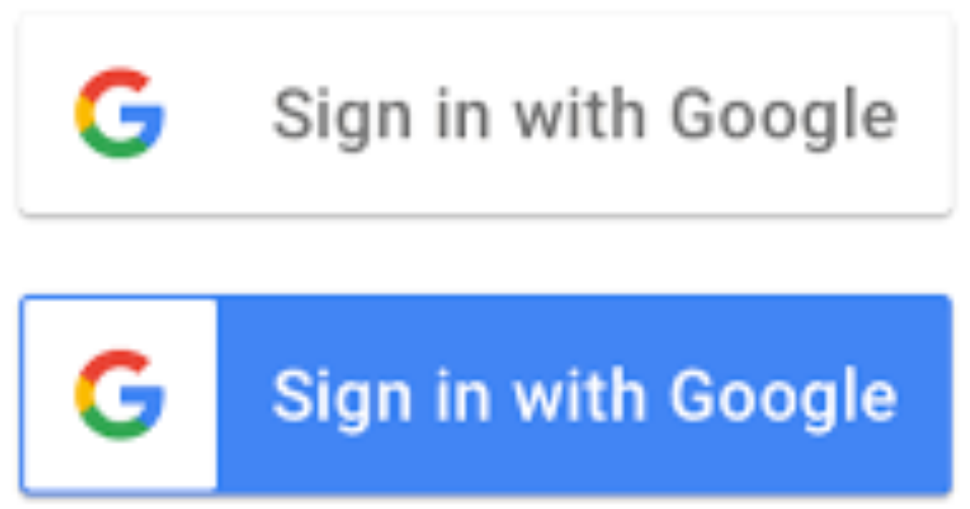
Oauth


Alice
pw
1. Authenticate
Identity Provider
pw
Token
Check token
{email, user profile}
Some resource on the internet

Attacks against “Login with…” services


Log in with Twitter

Use Log in with Twitter, also known as Sign in with Twitter, to place a button on your site or application which allows Twitter users to enjoy the benefits of a registered user account in as little as one click. This works on websites, iOS, mobile, and desktop applications.



Use Sign in with Apple on your Apple device

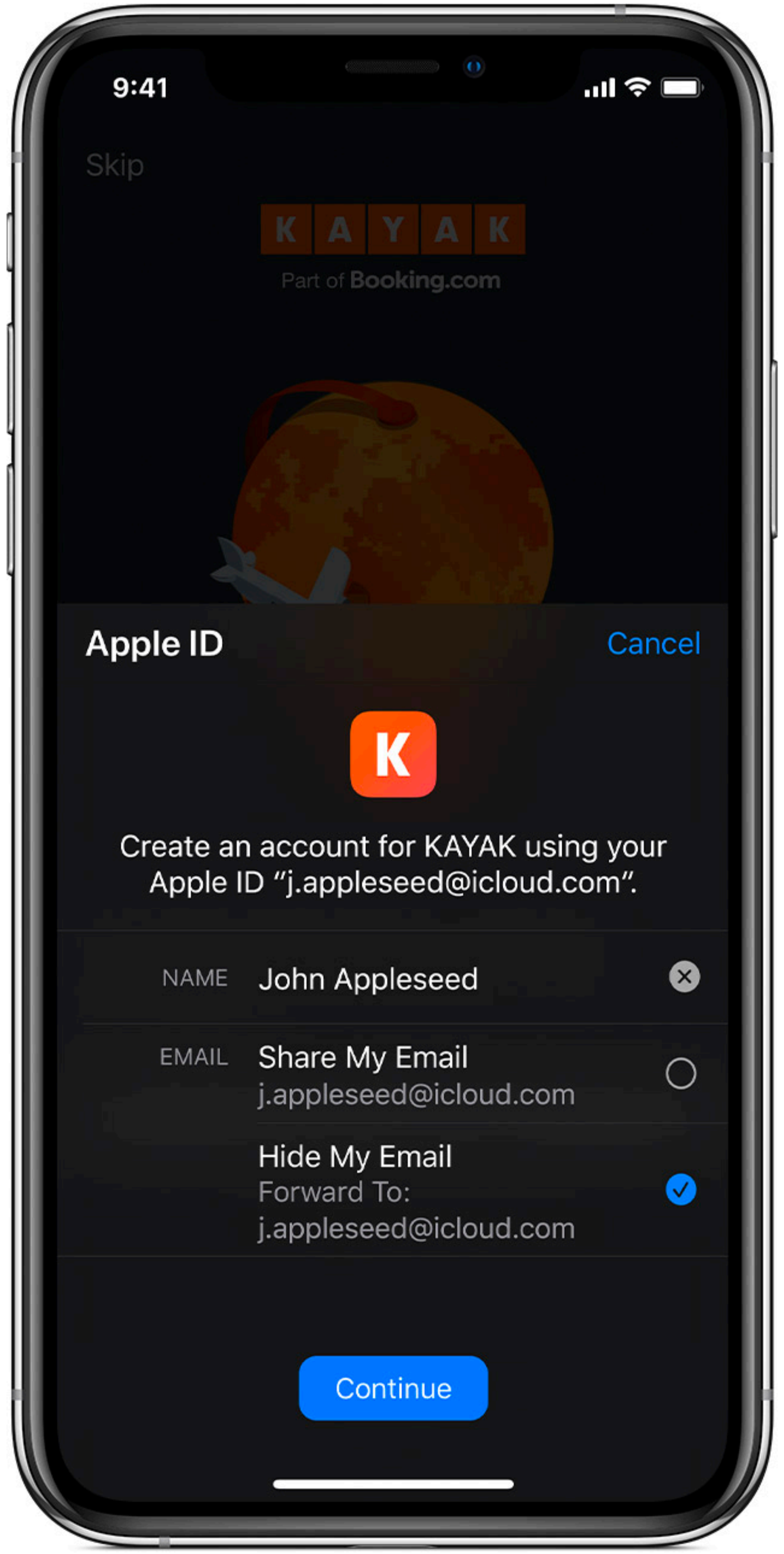
Using Sign in with Apple is quick and easy on any Apple device with the latest software. Make sure you're signed in with your Apple ID on your device.

1. Tap the Sign in with Apple button on the participating app or website.

   If the app or site has not requested any information to set up your account, check that your Apple ID is correct and go to Step 4.

   If you're asked to provide your name and email address, Sign in with Apple automatically fills in the information from your Apple ID. You can edit your name if you like and choose Share My Email or Hide My Email.

   Tap Continue and confirm with a quick Face ID, Touch ID, or device passcode to sign in. If you don't have Face ID, Touch ID, or a passcode set up, enter your Apple ID password.



Create an account for KAYAK using your Apple ID "j.appleseed@icloud.com".

NAME John Appleseed

EMAIL Share My Email j.appleseed@icloud.com

Hide My Email Forward To: j.appleseed@icloud.com ✓

Sources

1. Many slides courtesy of Wil Robertson: https://wkr.io
2. Many slides courtesy of Ran Cohen