2550 Intro to cybersecurity

L11: Passwords

abhi shelat

Thanks Christo for slides!

Choosing Passwords

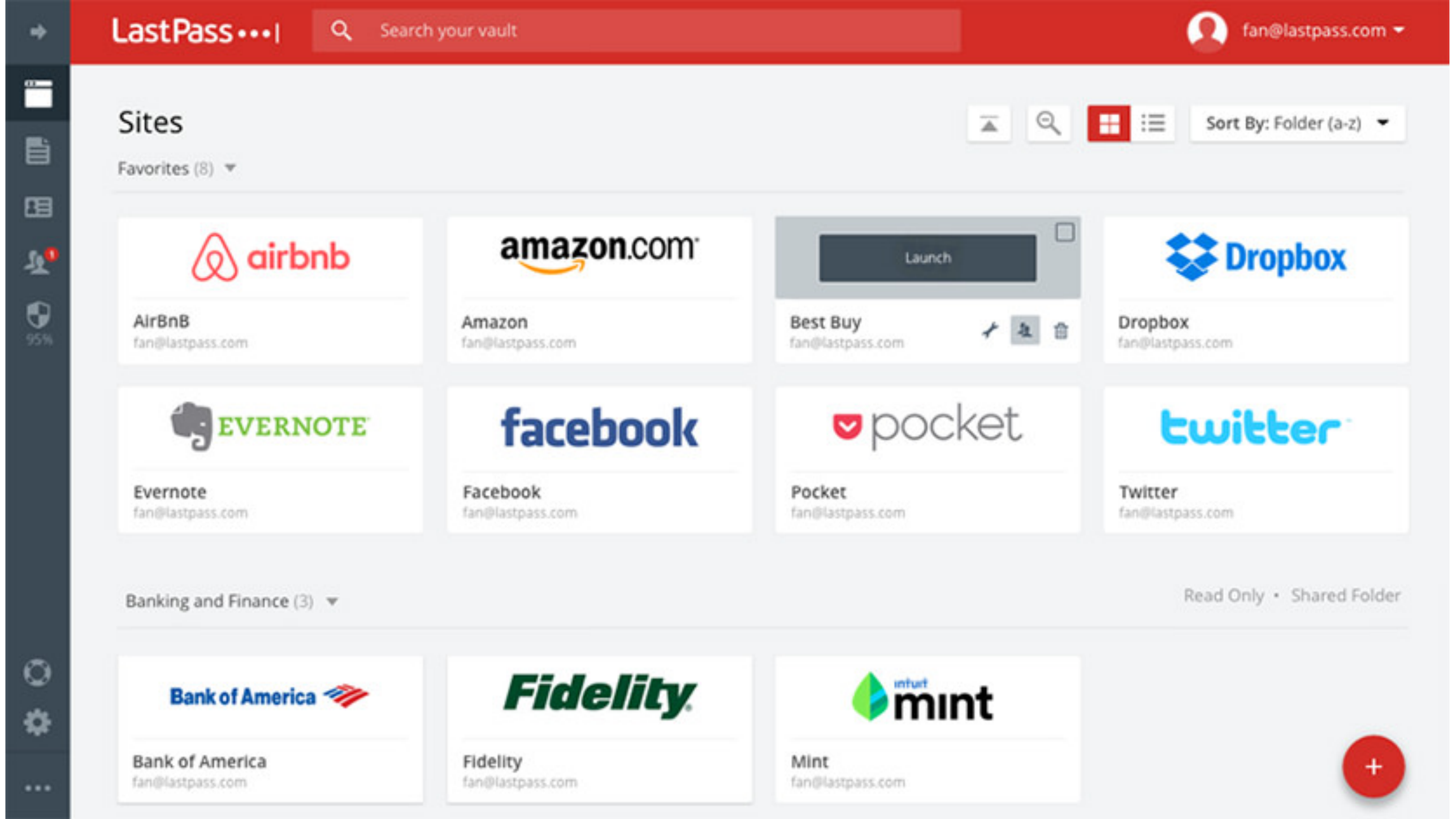
Bad Algorithms

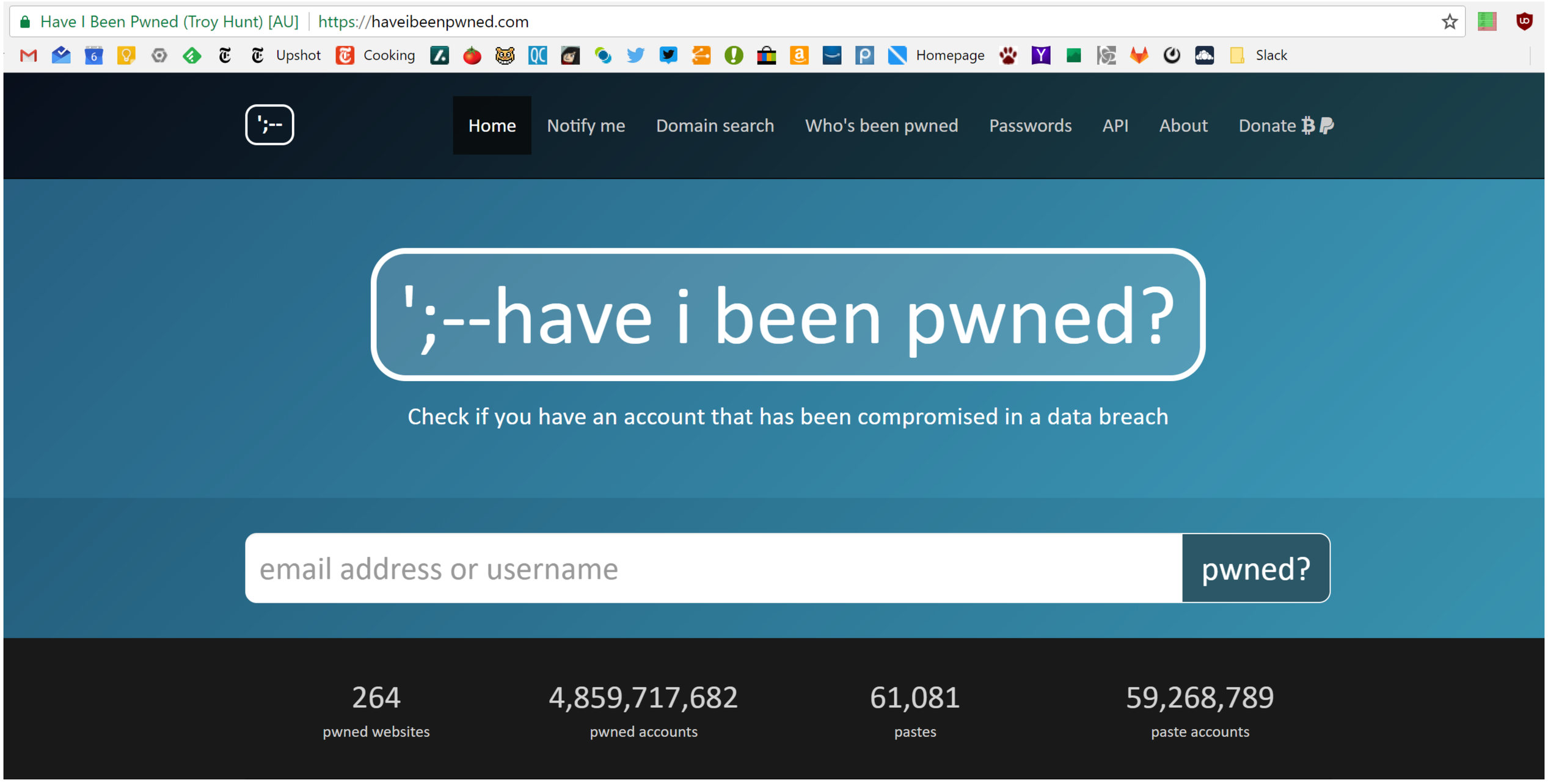
Better Heuristics

Password Reuse

Password Reuse

- People have difficulty remembering >4 passwords
  - Thus, people tend to reuse passwords across services
  - What happens if any one of these services is compromised?
- Service-specific passwords are a beneficial form of compartmentalization
  - Limits the damage when one service is inevitably breaches
- Use a password manager
- Some service providers now check for password reuse
  - Forbid users from selecting passwords that have appeared in leaks


LastPass
Search your vault
fan@lastpass.com
Sites
Sort By: Folder (a-z)
Favorites (8)
airbnb
AirBnB
fan@lastpass.com
amazon.com
Amazon
fan@lastpass.com
Launch
Best Buy
fan@lastpass.com
Dropbox
Dropbox
fan@lastpass.com
EVERNOTE
Evernote
fan@lastpass.com
facebook
Facebook
fan@lastpass.com
pocket
Pocket
fan@lastpass.com
twitter
Twitter
fan@lastpass.com
Banking and Finance (3)
Read Only • Shared Folder
Bank of America
Bank of America
fan@lastpass.com
Fidelity
Fidelity
fan@lastpass.com
intuit mint
Mint
fan@lastpass.com
95%


Have I Been Pwned (Troy Hunt) [AU]
https://haveibeenpwned.com
Upshot
Cooking
Homepage
Slack
';--
Home
Notify me
Domain search
Who's been pwned
Passwords
API
About
Donate
';--have i been pwned?
Check if you have an account that has been compromised in a data breach
email address or username
pwned?
264
pwned websites
4,859,717,682
pwned accounts
61,081
pastes
59,268,789
paste accounts

Two Factor Authentication

Biometrics

SMS

Authentication Codes

Smartcards & Hardware Tokens

Types of Secrets

- Actors provide their secret to log-in to a system
- Three classes of secrets:
  1. Something you know
     - Example: a password
  2. Something you have
     - Examples: a smart card or smart phone
  3. Something you are
     - Examples: fingerprint, voice scan, iris scan

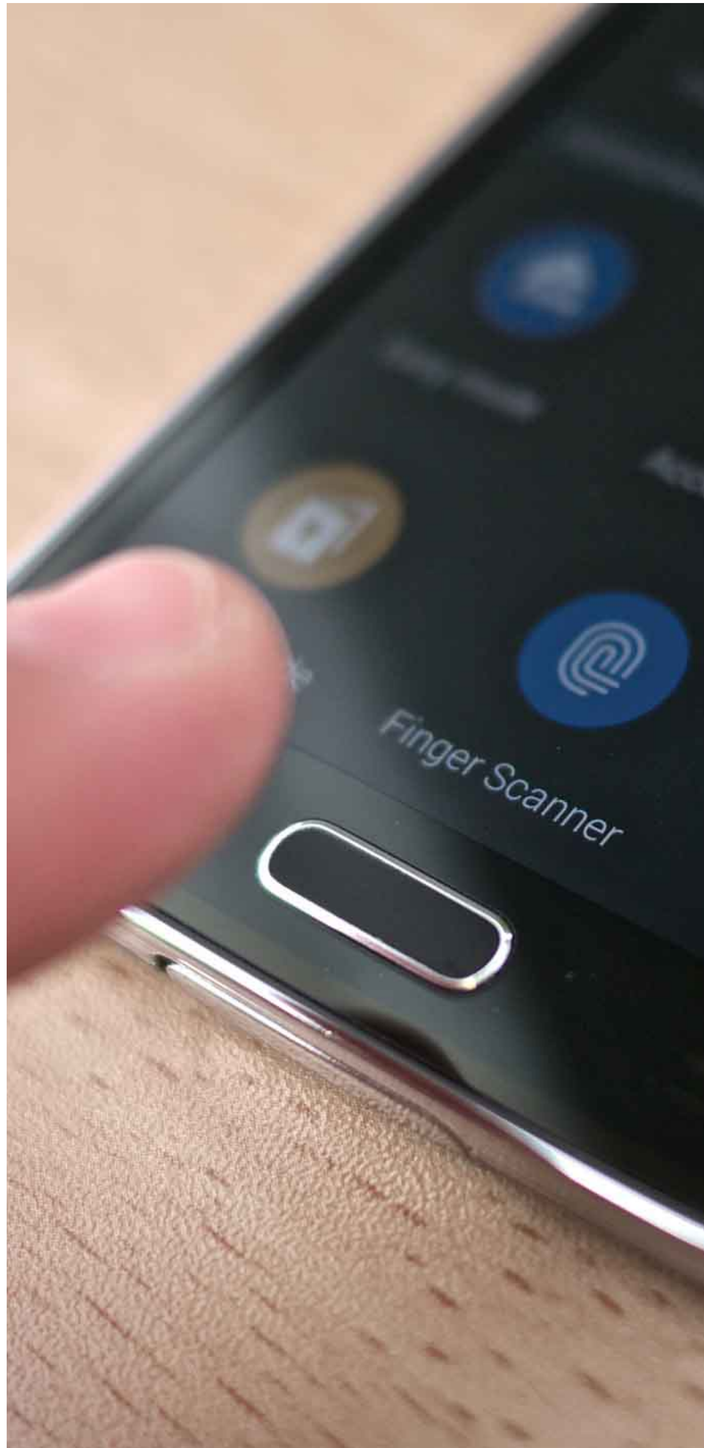
Biometrics

- ancient Greek: bios ="life", metron ="measure“
- Physical features
  - Fingerprints
  - Face recognition
  - Retinal and iris scans
  - Hand geometry
- Behavioral characteristics
  - Handwriting recognition
  - Voice recognition
  - Typing cadence
  - Gait

Fingerprints

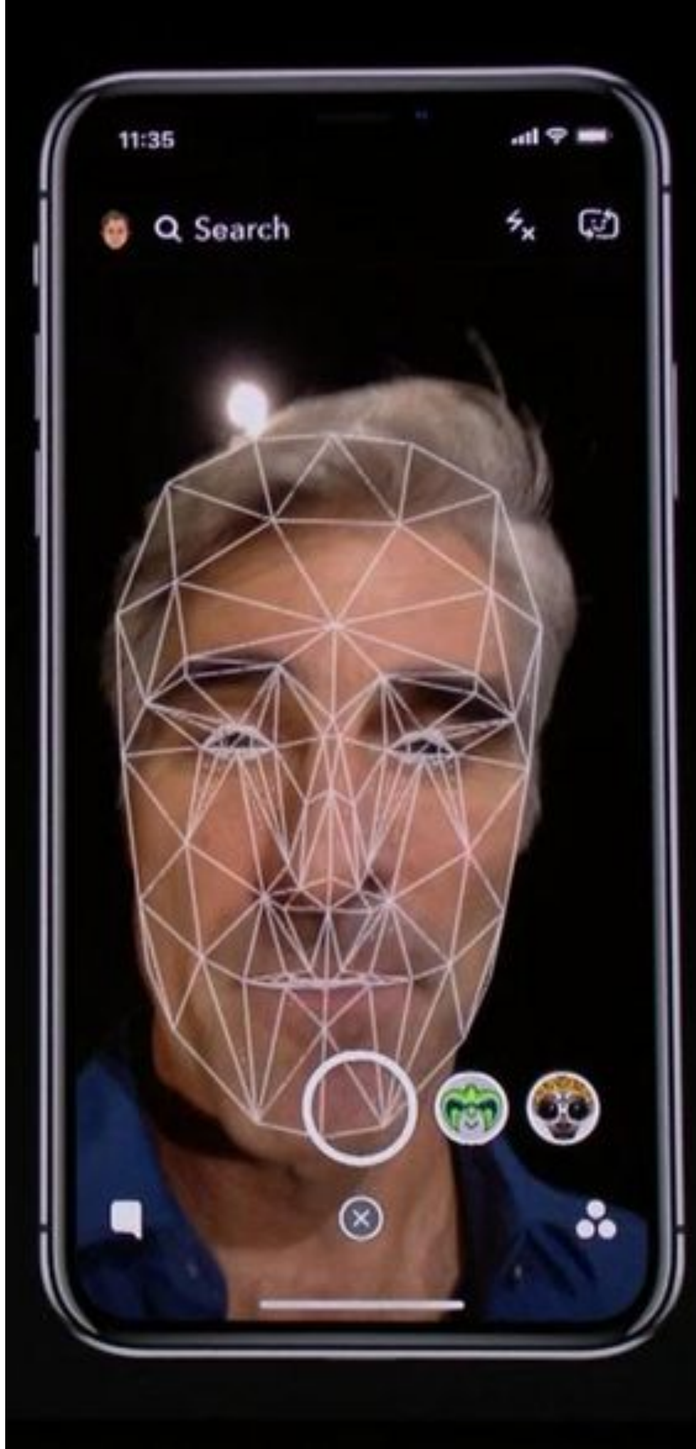
- Ubiquitous on modern smartphones, some laptops
- Secure?
  - May be subpoenaed by law enforcement
  - Relatively easy to compromise
    1. Pick up a latent fingerprint (e.g. off a glass) using tape or glue
    2. Photograph and enhance the fingerprint
    3. Etch the print into gelatin backed by a conductor
    4. Profit ;)

https://www.theregister.co.uk/2002/05/16/gummi_bears_defeat_fingerprint_sensors/



Facial Recognition

- Popularized by FaceID on the iPhone X
- Secure?



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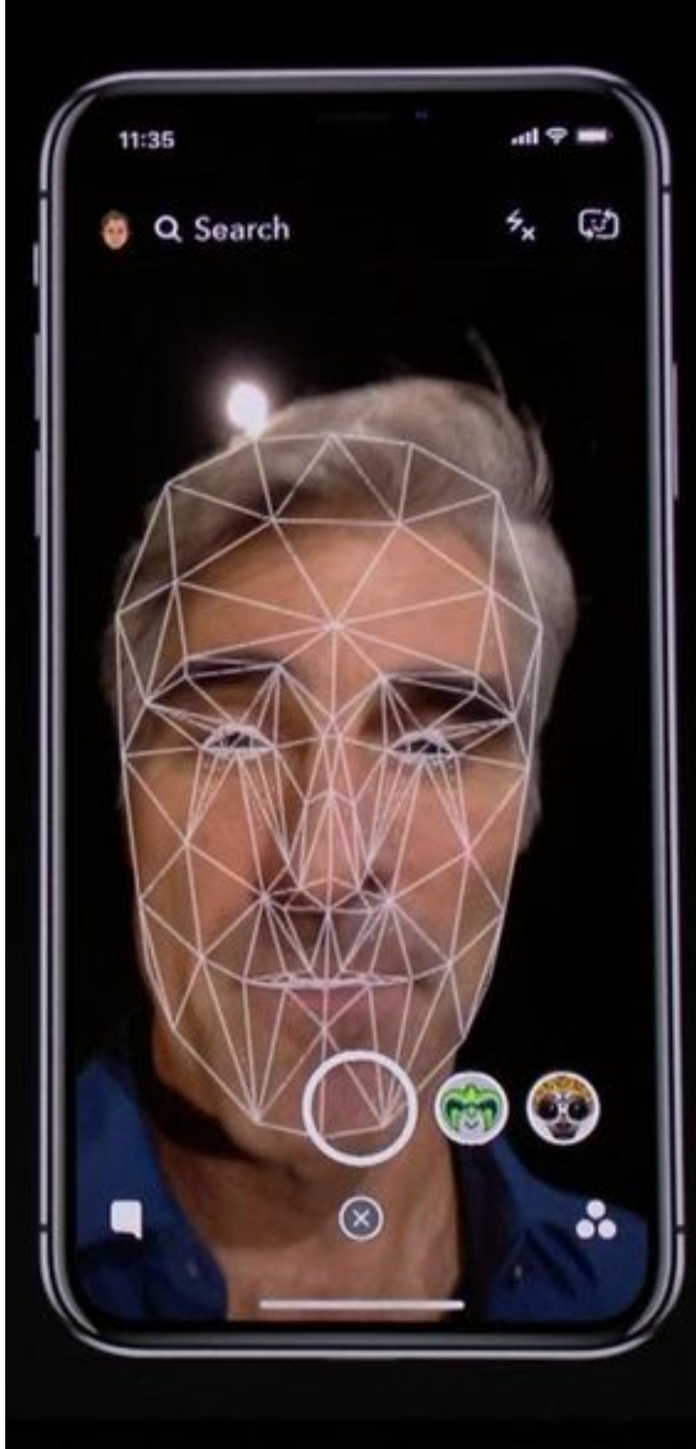

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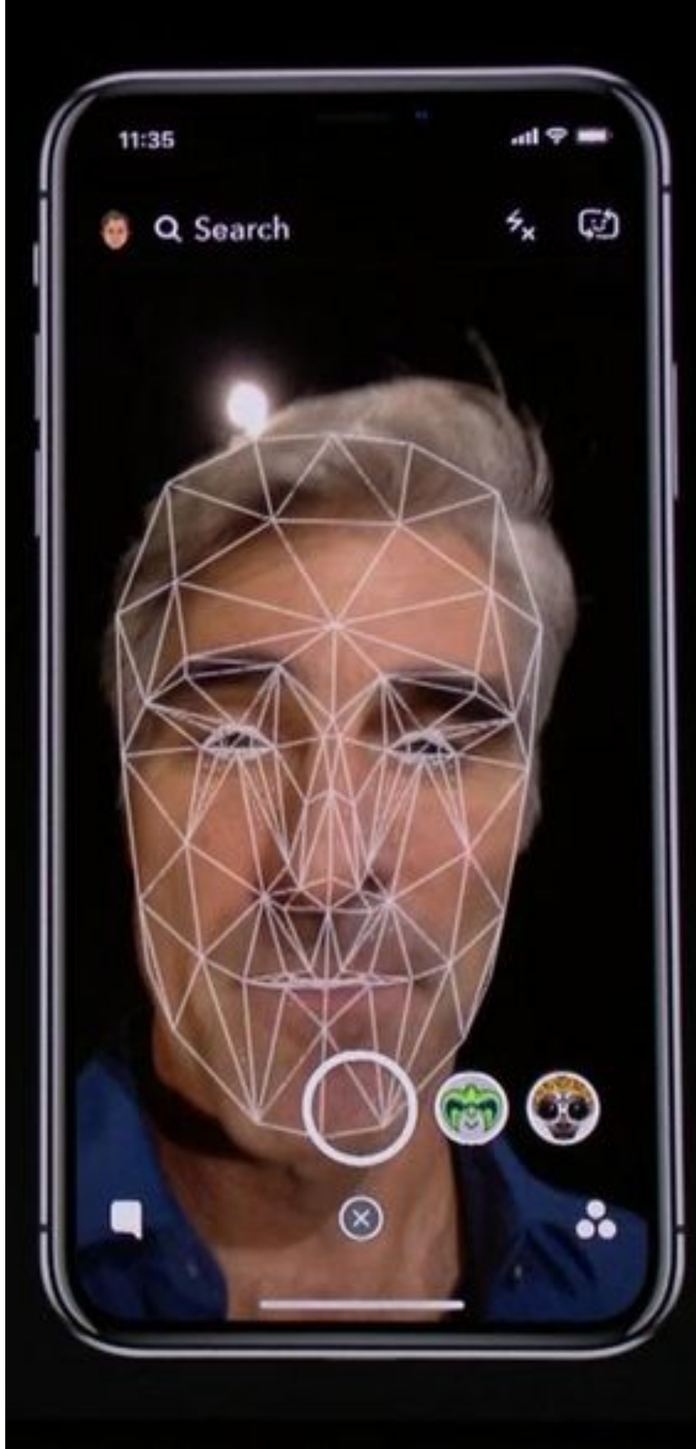
- Vulnerable to law enforcement requests
- Using 2D images?
  - Not secure
  - Trivial to break with a photo of the target’s face



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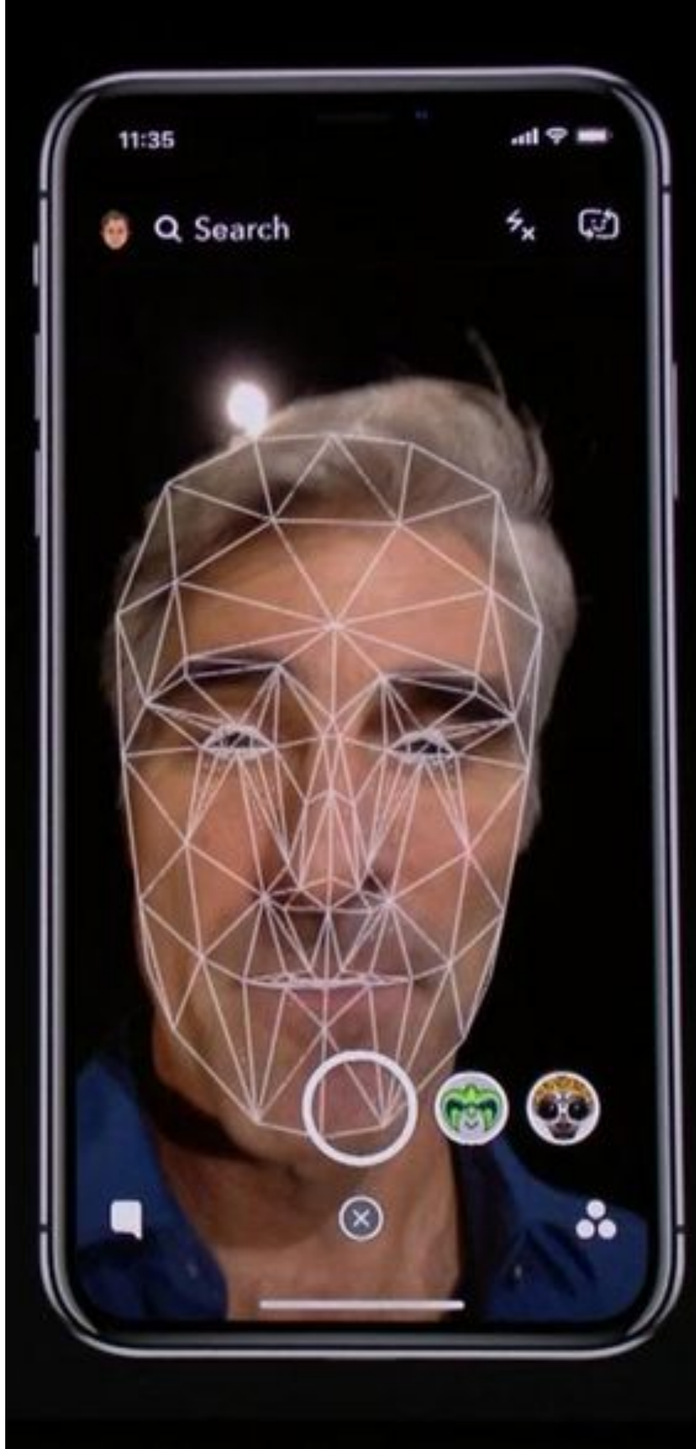
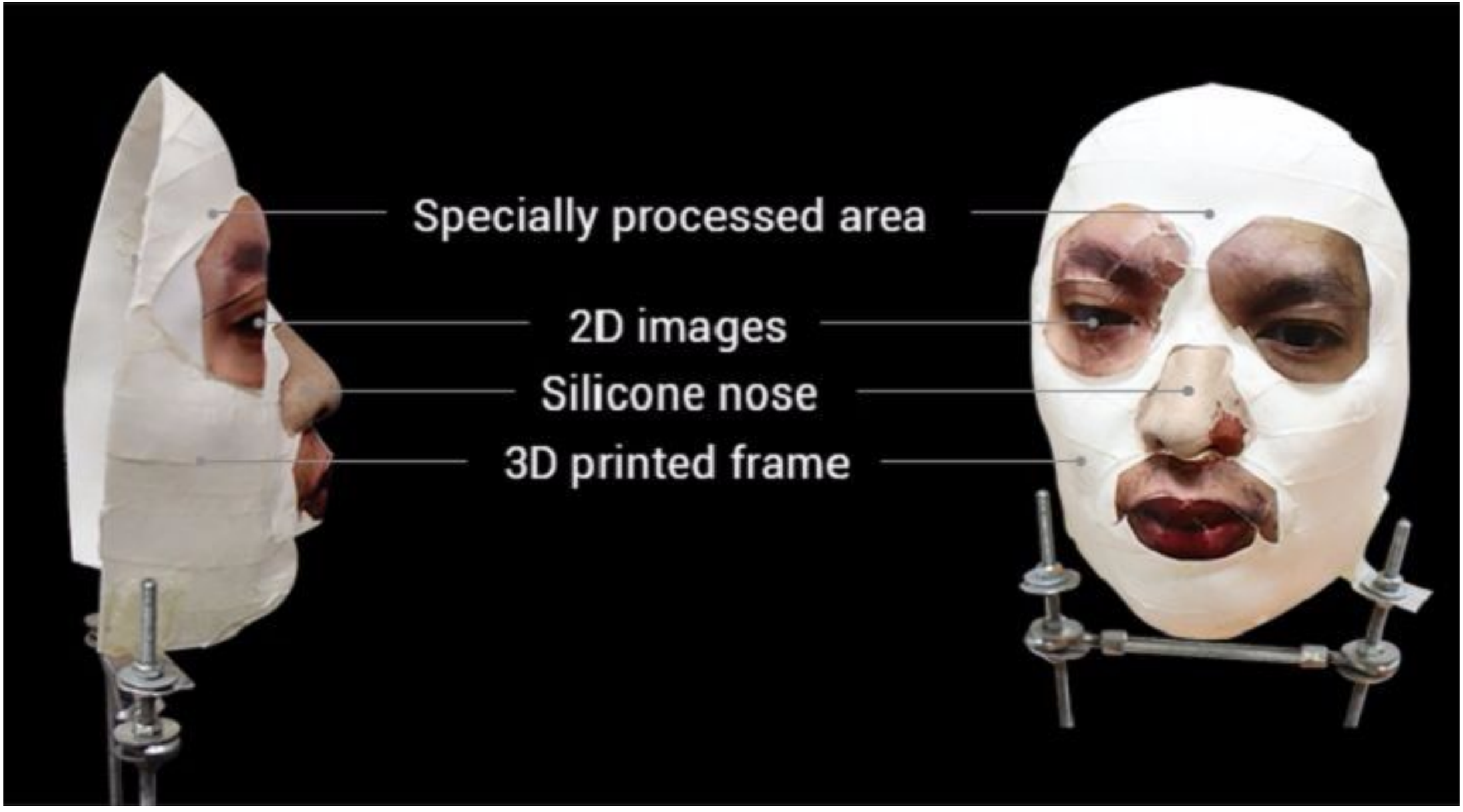
- Vulnerable to law enforcement requests
- Using 2D images?
  - Not secure
  - Trivial to break with a photo of the target’s face
- Using 2D images + 3D depth maps?
  - More secure, but not perfect
  - Can be broken by crafting a lifelike mask of the target




Specially processed area
2D images
Silicone nose
3D printed frame

By Press Association

Saturday, October 19, 2019 - 01:20 PM

Google has confirmed the Face Unlock system on its new Pixel 4 smartphone can allow access to the device even when the user has their eyes closed.

Early testers of the phone, as well as security experts, have raised concerns it could lead to unauthorised access to the device.

It has been suggested someone else could gain access to the phone by holding it in front of the face of its sleeping owner, but Google said it meets security requirements.

The technology giant unveiled the new phone earlier this week.

In a statement, Google said: “Pixel 4 Face Unlock meets the security requirements as a strong biometric and can be used for payments and app authentication, including banking apps.

“It is resilient against unlock attempts via other means, like with masks.

“If you want to temporarily disable Face Unlock, you can use lockdown mode to temporarily require a PIN/pattern/password.

Voice Recognition

- Secure?
  - Very much depends on the implementation

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- Some systems ask you to record a static phrase
  - E.g. say “unlock” to unlock
  - This is wildly insecure
    - Attacker can record and replay your voice

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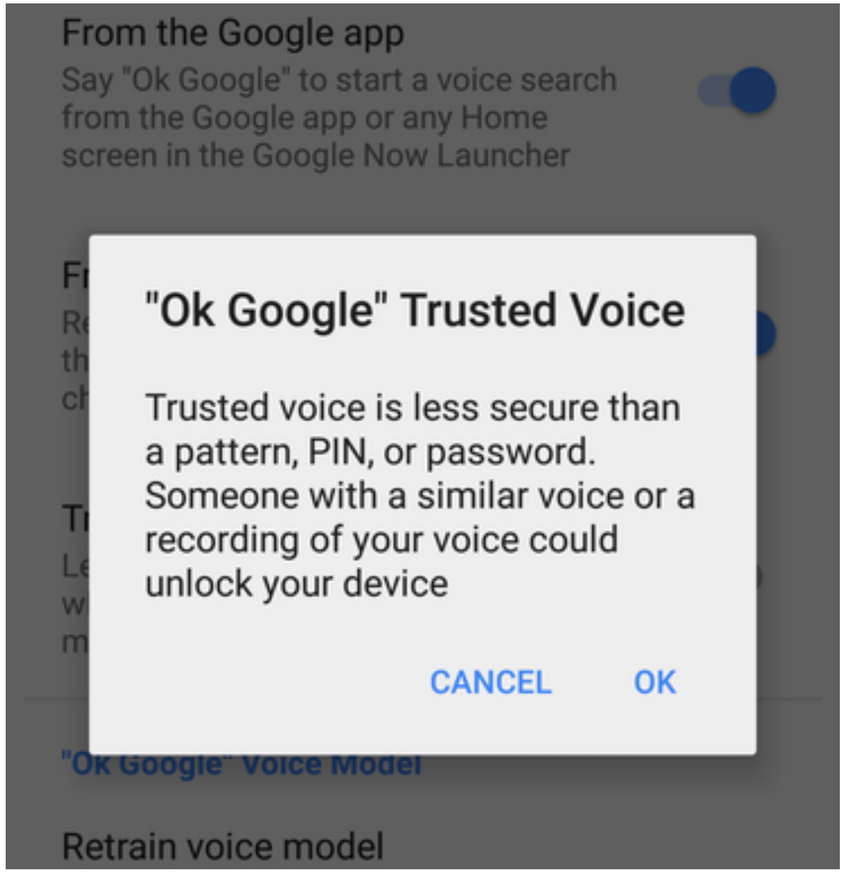
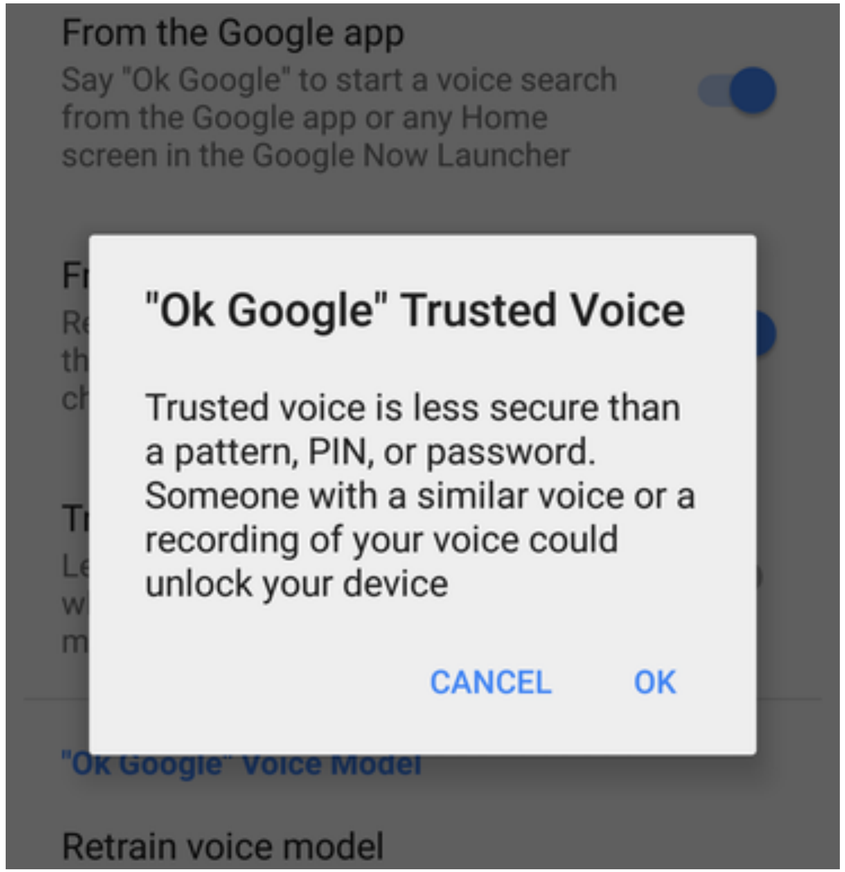


Voice Recognition

- Secure?
  - Very much depends on the implementation
- Some systems ask you to record a static phrase
  - E.g. say “unlock” to unlock
  - This is wildly insecure
    - Attacker can record and replay your voice
- Others ask you to train a model of your voice
  - Train the system by speaking several sentences
  - To authenticate, speak several randomly chosen words
  - Not vulnerable to trivial replay attacks, but still vulnerable
    - Given enough samples of your voice, an attacker can train a synthetic voice AI that sounds just like you



Fundamental Issue With Biometrics

- Biometrics are immutable
  - You are the password, and you can’t change
  - Unless you plan on undergoing plastic surgery?
- Once compromised, there is no reset
  - Passwords and tokens can be changed
- Example: the Office of Personnel Management (OPM) breach
  - US gov agency responsible for background checks
  - Had fingerprint records of all people with security clearance
  - Breached by China in 2015, all records stolen :(

Something You Have

- Two-factor authentication has become more commonplace
- Possible second factors:
  - SMS passcodes
  - Time-based one time passwords
  - Hardware tokens

SMS Two Factor

- Relies on your phone number as the second factor
  - Key assumption: only your phone should receive SMS sent to your number

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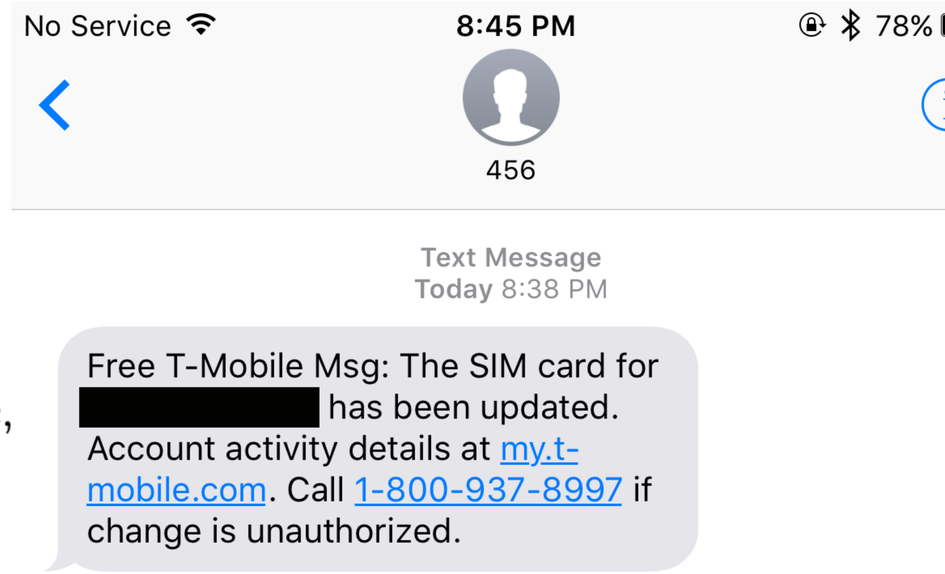
- Relies on your phone number as the second factor
  - Key assumption: only your phone should receive SMS sent to your number
- SMS two factor is deprecated. Why?
- Social engineering the phone company
  1. Call and pretend to be the victim
  2. Say “I got a new SIM, please activate it”
  3. If successful, phone calls and SMS are now sent to your SIM in your phone, instead of the victim
- Not hypothetical: successfully used against many victims

First, criminals call a cell phone carrier's tech support number pretending to be their target. They explain to the company's employee that they "lost" their SIM card, requesting their phone number be transferred, or ported, to a new SIM card that the hackers themselves already own. With a bit of social engineering—perhaps by providing the victim's Social Security Number or home address (which is often available from one of the many data breaches that have happened in the last few years)—the criminals convince the employee that they really are who they claim to be, at which point the employee ports the phone number to the new SIM card.

Game over.

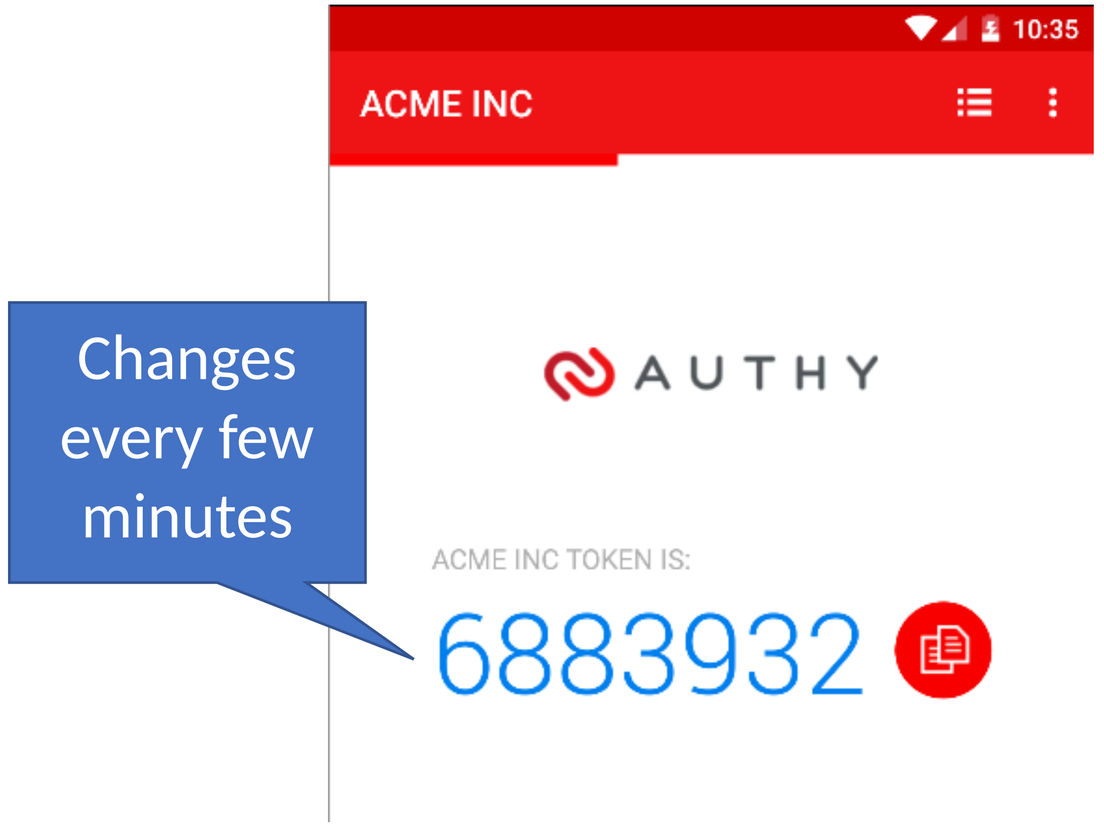
"With someone's phone number," a hacker who does SIM swapping told me, "you can get into every account they own within minutes and they can't do anything about it."



https://www.vice.com/en_us/article/vbqax3/hackers-sim-swapping-steal-phone-numbers-instagram-bitcoin

One Time Passwords

- Generate ephemeral passcodes that change over time
- To login, supply normal password and the current one time password
- Relies on a shared secret between your mobile device and the service provider
  - Shared secret allows both parties to know the current one time password



Duo Mobile

Lastpass Authenticator

Google Authenticator

Time-based One-time Password Algorithm

T0 = <the beginning of time, typically Thursday, 1 January 1970 UTC>

TI = <length of time the password should be valid>

K = <shared secret key>

d = <the desired number of digits in the password>

TC = floor((unixtime(now) − unixtime(*T0*)) / *TI*),

TOTP = HMAC(*K*, *TC*) % 10^{d}

Specially formatted SHA1-based signature

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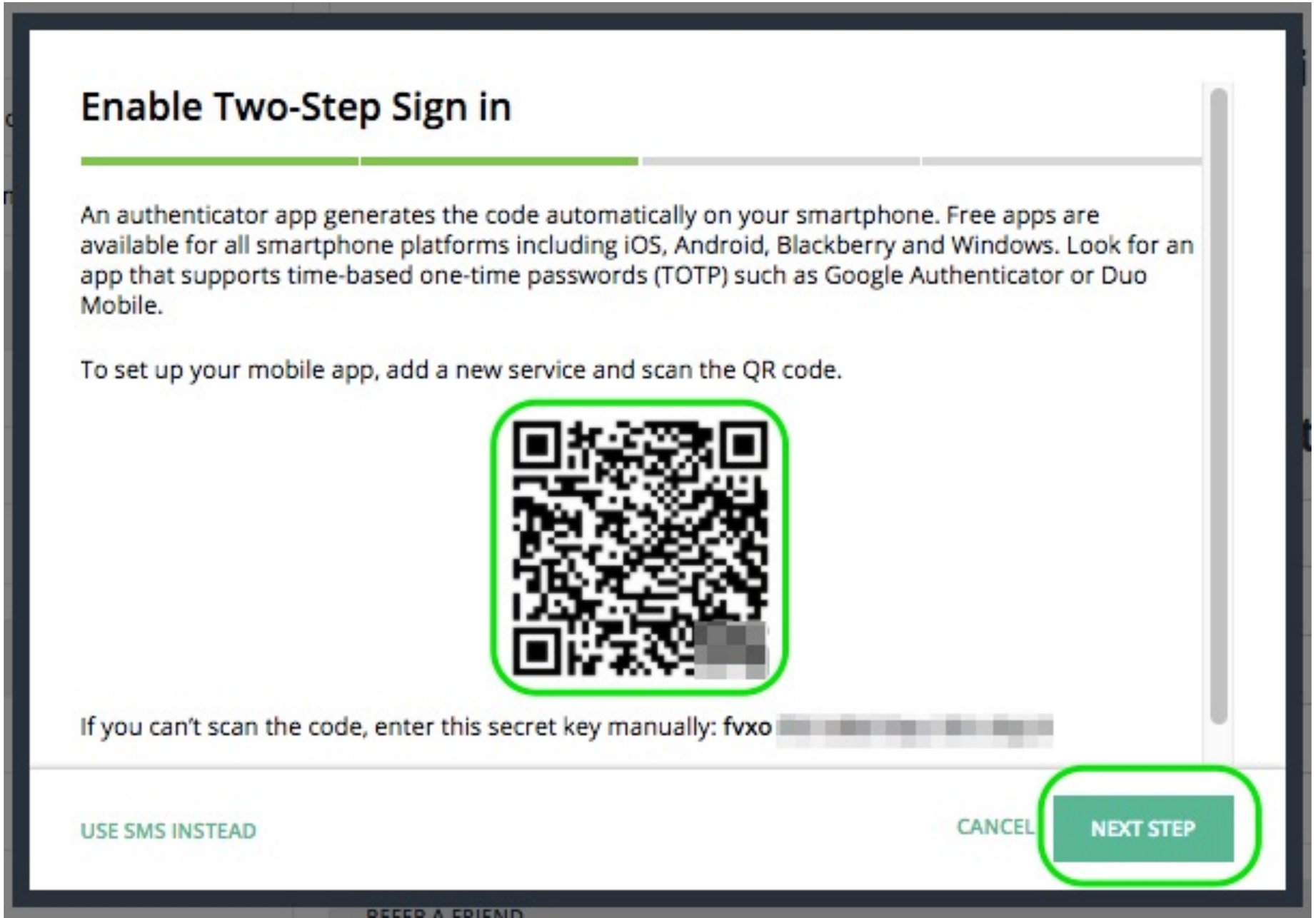
Given *K*, this algorithm can be run on your phone and by the service provider

Secret Sharing for TOTP

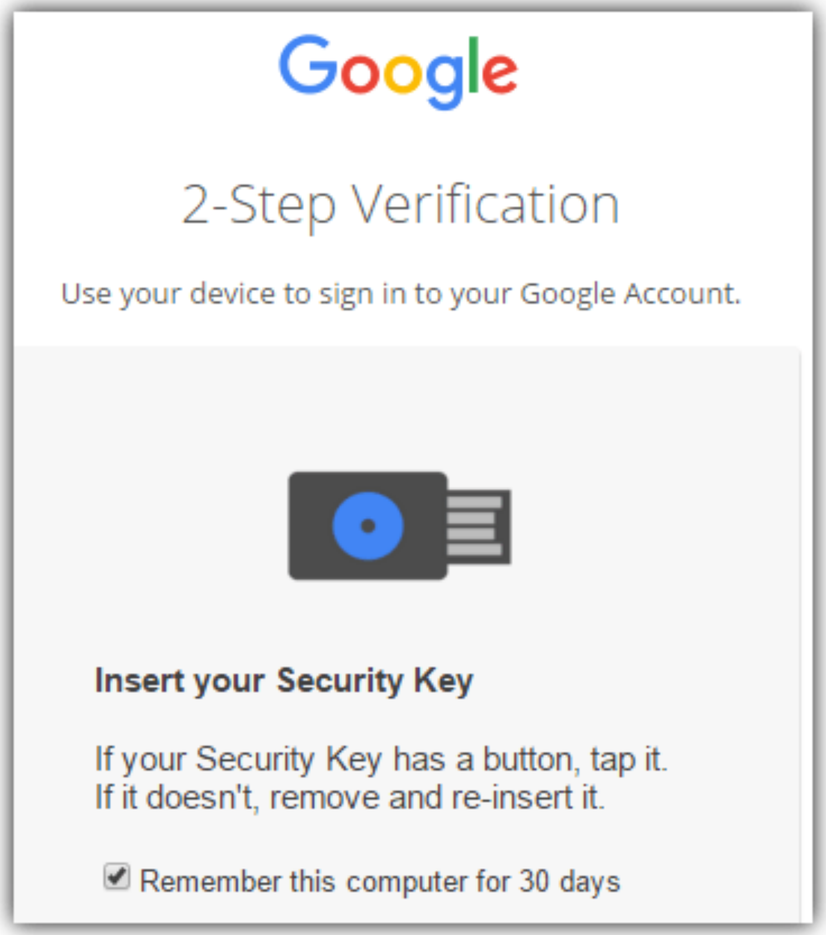


Hardware Two Factor

- Special hardware designed to hold cryptographic keys
- Physically resistant to key extraction attacks
  - E.g. scanning tunneling electron microscopes
- Uses:
  - 2nd factor for OS log-on
  - 2nd factor for some online services
  - Storage of PGP and SSH keys

Universal 2nd Factor (U2F)

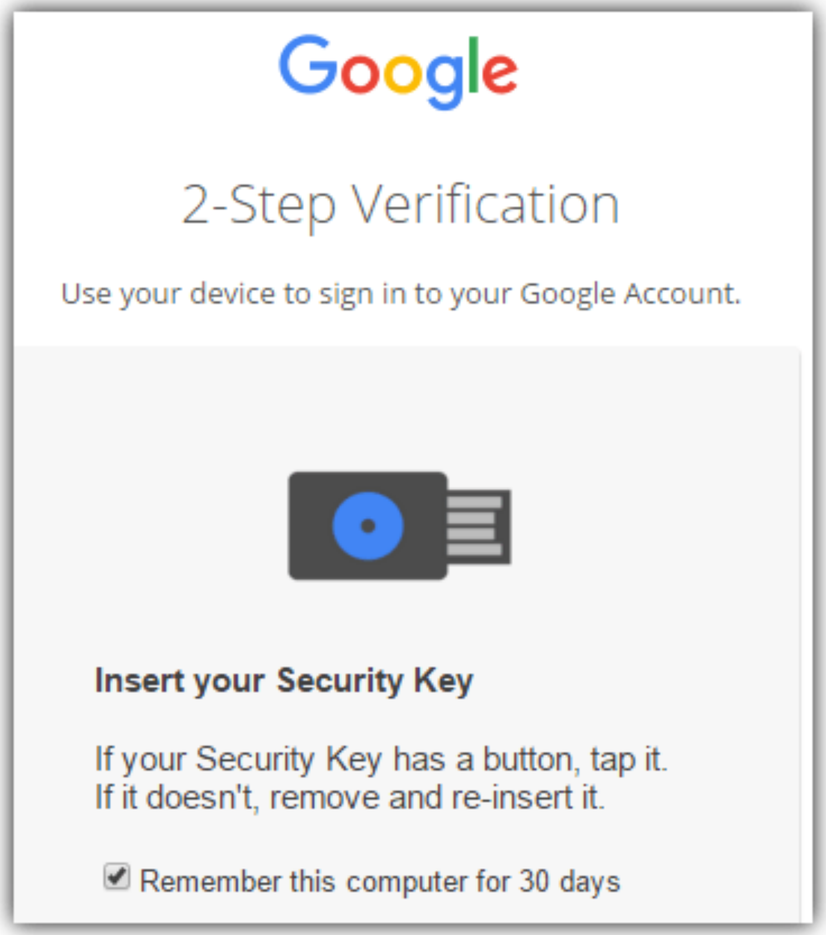
- Supported by Chrome, Opera, and Firefox (must be manually enabled)
- Works with Google, Dropbox, Facebook, Github, Gitlab, etc.



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 ;)



How does U2F work?

Website (Relying Party)

Make a signing key (sk,pk)

Init

{register}

{register}

{ pk, sign_sk(“username”) }

User, pk

Sign challenge using sk

Login

{login, ch}

{login, challenge ch}

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

{ s }

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

Vulnerable to simple attack

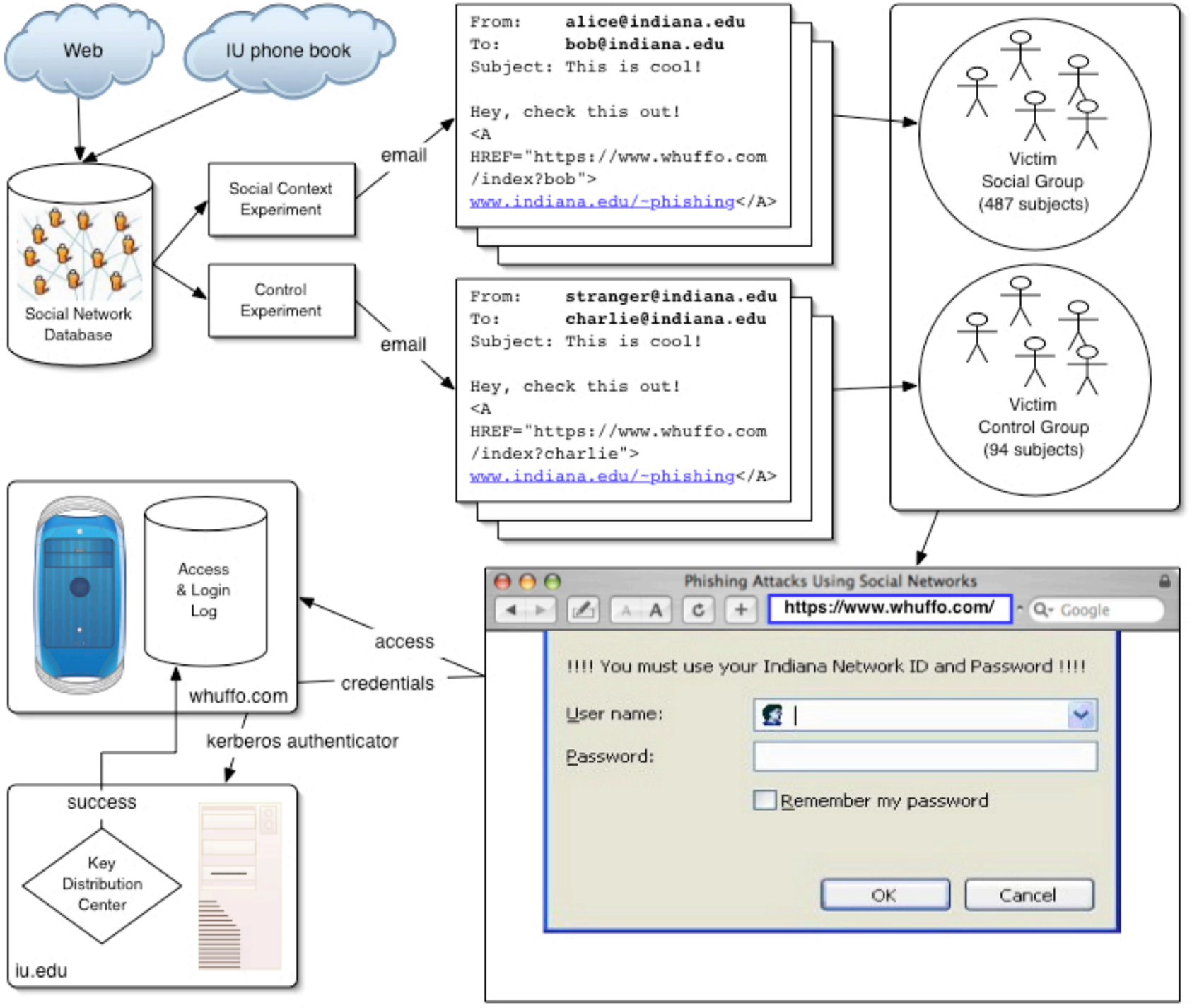
Simple Phishing

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.

Spear Phishing @ IU

Experiment by T. Jagatic, N. Johnson, M. Jakobsson, F. Menczer.


Web
IU phone book
Social Network Database
Social Context Experiment
Control Experiment
email
email
From: alice@indiana.edu
To: bob@indiana.edu
Subject: This is cool!
Hey, check this out!
<A
HREF="https://www.whuffo.com/index?bob">
www.indiana.edu/~phishing</A>
From: stranger@indiana.edu
To: charlie@indiana.edu
Subject: This is cool!
Hey, check this out!
<A
HREF="https://www.whuffo.com/index?charlie">
www.indiana.edu/~phishing</A>
Victim Social Group (487 subjects)
Victim Control Group (94 subjects)
Access & Login Log
whuffo.com
access
credentials
kerberos authenticator
success
Key Distribution Center
iu.edu
Phishing Attacks Using Social Networks
https://www.whuffo.com/
!!!! You must use your Indiana Network ID and Password !!!!
User name:
Password:
Remember my password
OK
Cancel

Control Phishing Success Rate:

9-23%

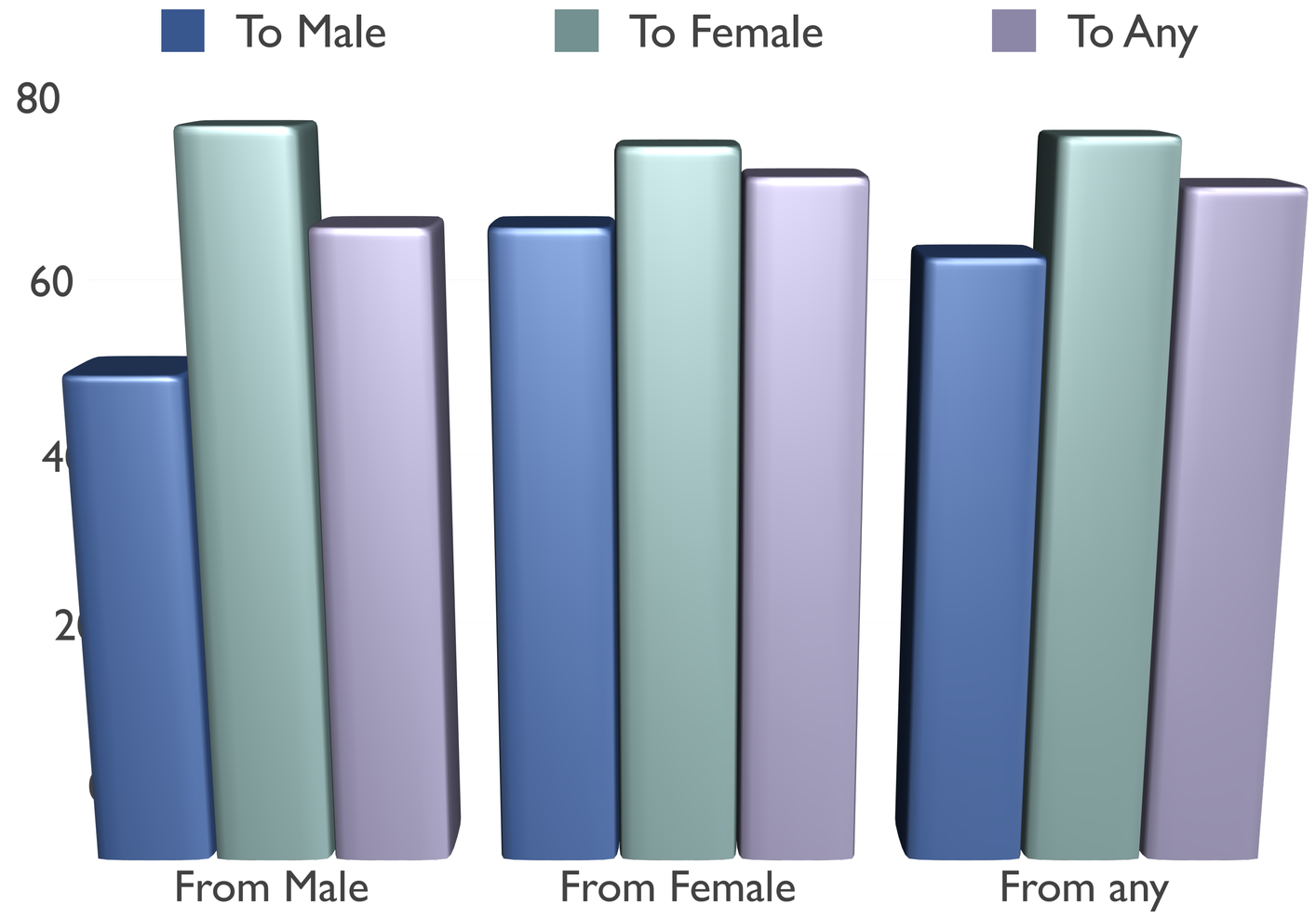
with 95% Confidence Interval

Spear Phishing Success Rate:

68-72%

with 95% Confidence Interval

Spear Phishing Success Rate by Gender



VOIP Phishing

Lure: Get victim to call a bogus 800... number about their account.

Hook: Have the human on the other end extract the victim's information.

From: FlagStar Bank <usflag60536@flagstar.com>
Date: 11 Sep 2007 10:55:21 -0400
To: <samyers@indiana.edu>
Subject: You have one new private message

Dear FlagStar Bank card holder,

You have one new private message.

Please call free 800-870-8124 to listen to your private message.

Source: Steven Myers, IU

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Source: Steven Myers, IU

Google

Someone has your password

Hi William

Someone just used your password to try to sign in to your Google Account

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

bitly TOUR ENTERPRISE RESOURCES ABOUT MY ACCOUNT

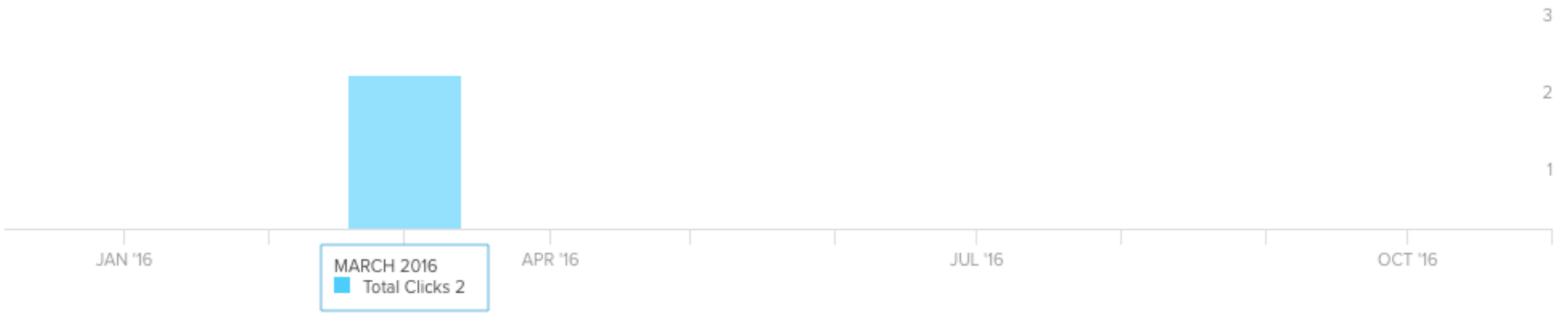
MAR 19

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



DATA IN UTC

Google

Welcome

hi.abhi@gmail.com

Enter your password

Forgot password?

Next

English (United States)

Help Privacy Terms

U2F can help prevent this attack

Website (Relying Party)

Make a signing key (sk,pk)

Init

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{register}

{ pk, sign_sk(“username”) }

User, pk

Sign challenge using sk

Login

{login, challenge ch}

{ s }

U2F can help prevent this attack

Website (Relying Party)

Init

Make a signing key (sk,pk)

{register}

{register}

{ pk, sign_sk(“username”) }

User, pk

Login

Sign challenge using sk

{login, ch, origin, tls_id}

{login, challenge ch}

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

{ s }

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

U2F can help prevent tracking

Website (Relying Party)

Init

Make a signing key (sk,pk)

{register}

{register}

{ pk, sign_sk(“username”) }

User, pk

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 (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, appid, challenge ch}

{ s,h }

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

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_0d0P0Q0e0j0
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
```

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?

Authentication in Unix/Linux

- Users authenticate with the system by interacting with *login*
  - Prompts for username and password
  - Credentials checked against locally stored credentials
- By default, password policies specified in a centralized, modular way
  - On Linux, using Pluggable Authentication Modules (PAM)
  - Authorizes users, as well as environment, shell, prints MOTD, etc.

Example PAM Configuration

```
# cat /etc/pam.d/system-auth
#%PAM-1.0

auth required pam_unix.so try_first_pa
auth optional pam_permit.so
auth required pam_env.so

account required pam_unix.so
account optional pam_permit.so
account required pam_time.so

password required pam_unix.so try_first_pass nullok sha512 shadow
password optional pam_permit.so

session required pam_limits.so
session required pam_unix.so
session optional pam_permit.so
```

- 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

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  - 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$0df/3G7iSV49nsbAa/5gSg:9479:0:10000::::
amislove:1l3RxU5F1$: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
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$<algo>$<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::::
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Distributed Authentication

- Early on, people recognized the need for authentication in distributed environments
  - Example: university lab with many workstations
  - Example: file server that accepts remote connections
- Synchronizing and managing password files on each machine is not scalable
  - Ideally, you want a centralized repository that stores policy and credentials

The Yellow Pages

- Network Information Service (NIS), a.k.a. the Yellow Pages
  - Developed by Sun to distribute network configurations
  - Central directory for users, hostnames, email aliases, etc.
  - Exposed through *yp** family of command line tools
- For instance, depending on */etc/nsswitch.conf*, hostname lookups can be resolved by using
  - */etc/hosts*
  - DNS
  - NIS
- Superseded by NIS+, LDAP,

NIS Password Hashes

- *Crypt* based password hashes
- Can easily be cracked
- Many networks still rely on insecure NIS

```
[cbw@workstation ~] ypcat passwd
afbjune:qSAH.evuYFHaM:14532:65104::/home/afbjune:/bin/bash
philowe:T.yUMej3XSNAM:13503:65104::/home/philowe:/bin/bash
bratus:2omkwsYXWiLDo:6312:65117::/home/bratus:/bin/tcsh
adkap:ZfHdSwSz9WhKU:9034:65118::/home/adkap:/bin/zsh
amitpoon:i3LjTqgU9gYSc:8198:65117::/home/amitpoon:/bin/tcsh
kcole:sgYtUsOtyk38k:14192:65104::/home/kcole:/bin/bash
david87:vA06wxjJEUgBE:13055:65101::/home/david87:/bin/bash
loch:6HgIQrVkcBeiw:13729:65104::/home/loch:/bin/bash
ppkk315:s6CTSAkqqr/nU:14061:65101::/home/ppkk315:/bin/bash
haynesma:JYWaQUARSqDQE:14287:65105::/home/haynesma:/bin/bash
ckubicek:jYpwYhqqvr3tA:10937:65117::/home/ckubicek:/bin/tcsh
mwalz:wPIa5Bv/tFVb2:9103:65118::/home/mwalz:/bin/tcsh
sushma:G6XNe18GpeQj.:13682:65104::/home/sushma:/bin/bash
guerin1:n0Da2TmO9MDBI:14512:65105::/home/guerin1:/bin/bash
```

Distributed Authentication Revisited

- Goal: a user would like to use some resource on the network
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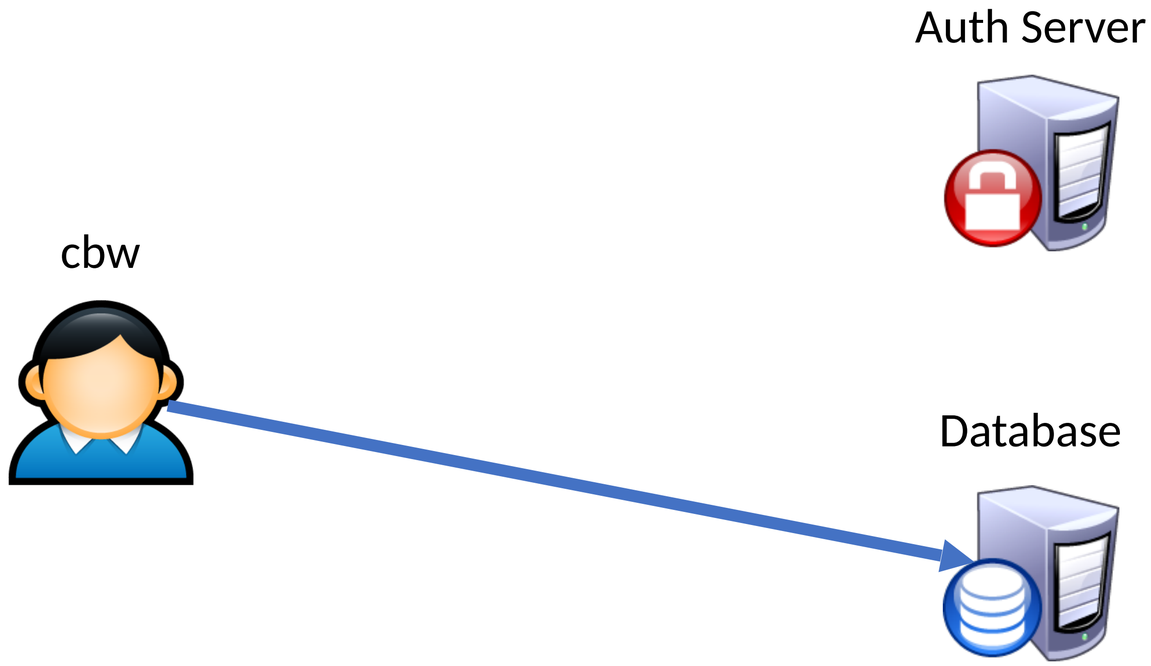
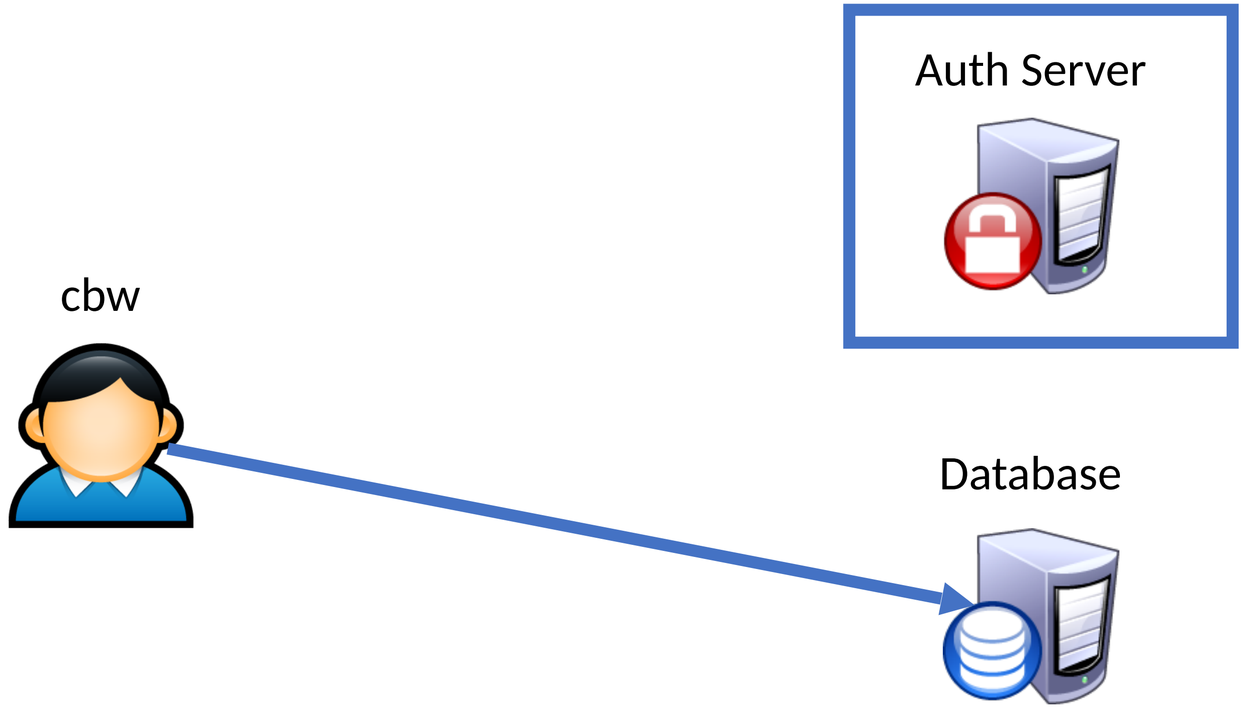


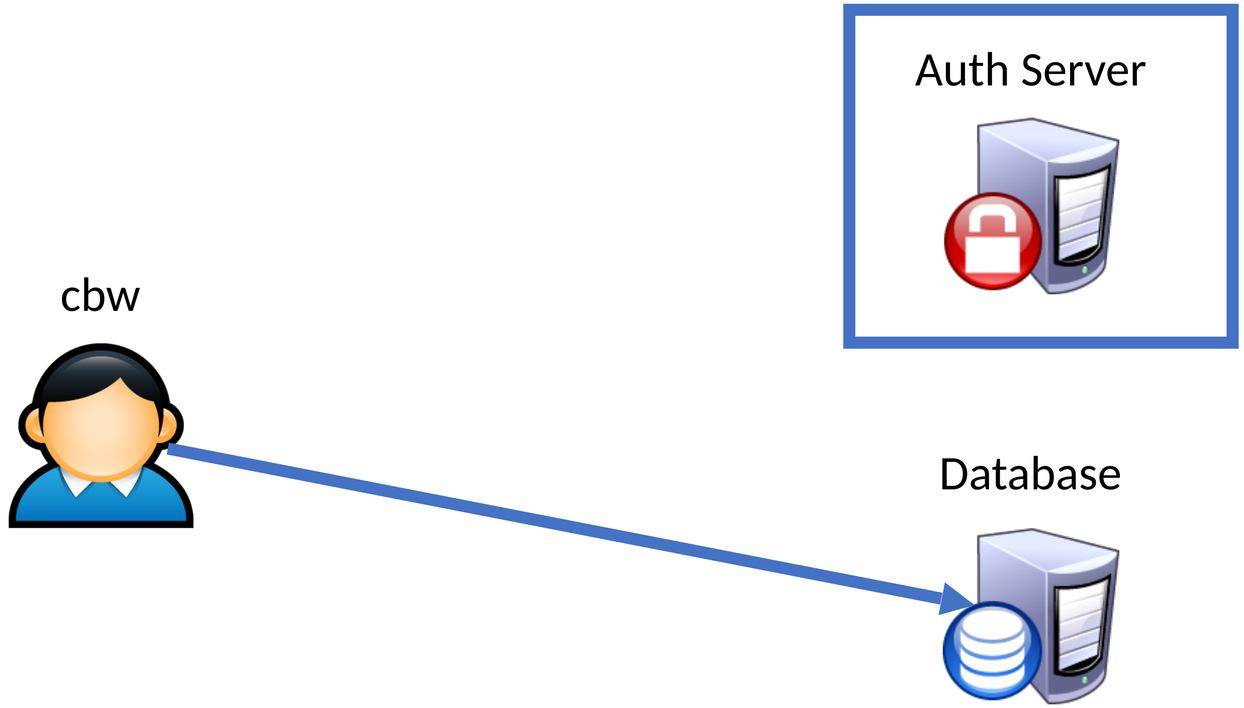
Distributed Authentication Revisited

- Goal: a user would like to use some resource on the network
  - File server, printer, database, mail server, etc.
- Problem: access to resources requires authentication
  - Auth Server contains all credential information
  - You do not want to replicate the credentials on all services



Attacker Goals and Threat Model

- Goal: steal credentials and gain access to protected resources
- Local attacker – may spy on traffic
- Active attacker – may send messages
- In some cases, may be able to steal information from users



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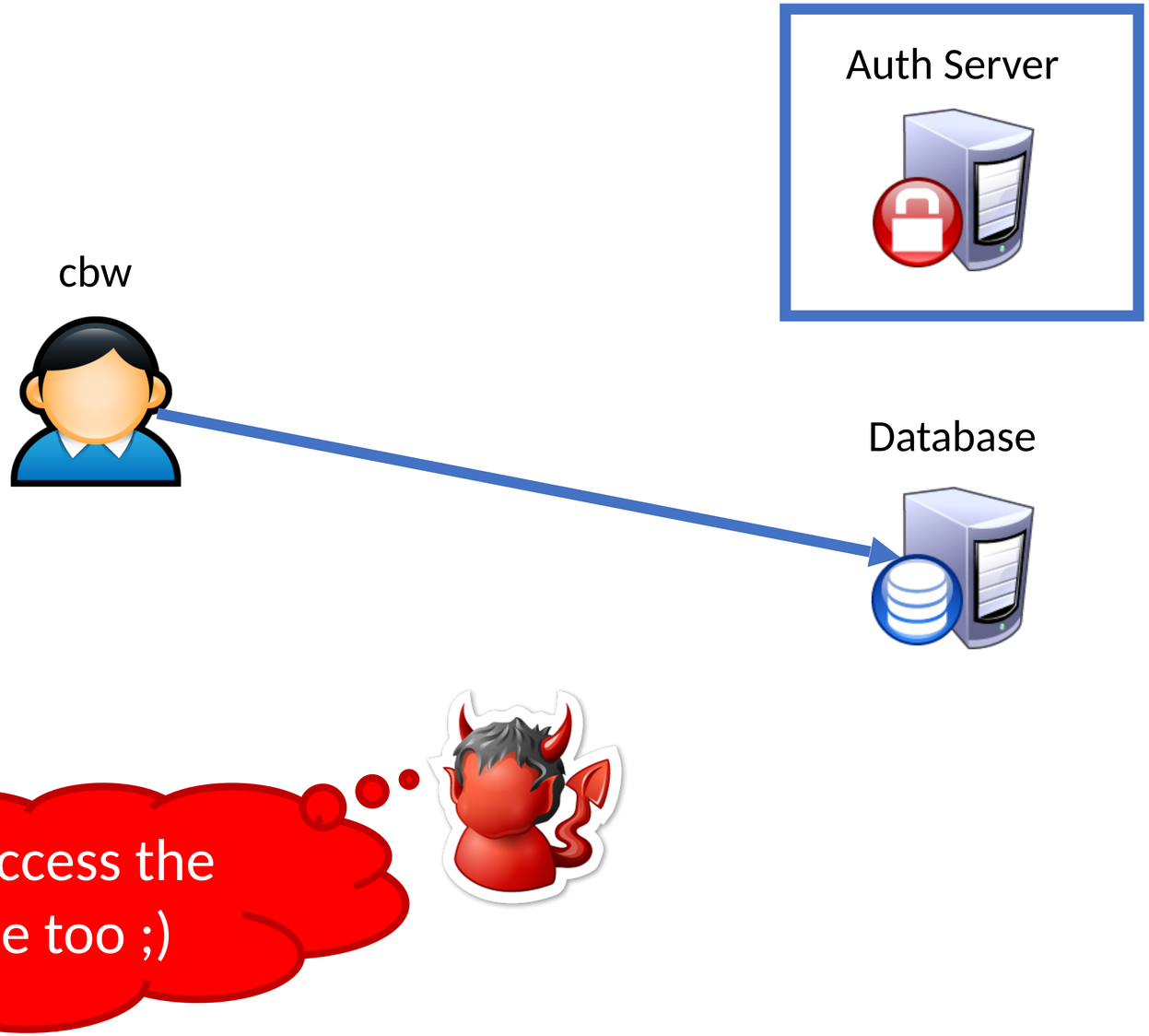

(Bad) Distributed Auth Example

- Idea: client forwards user/password to service, service queries Auth Server

Auth Server

cbw

Database

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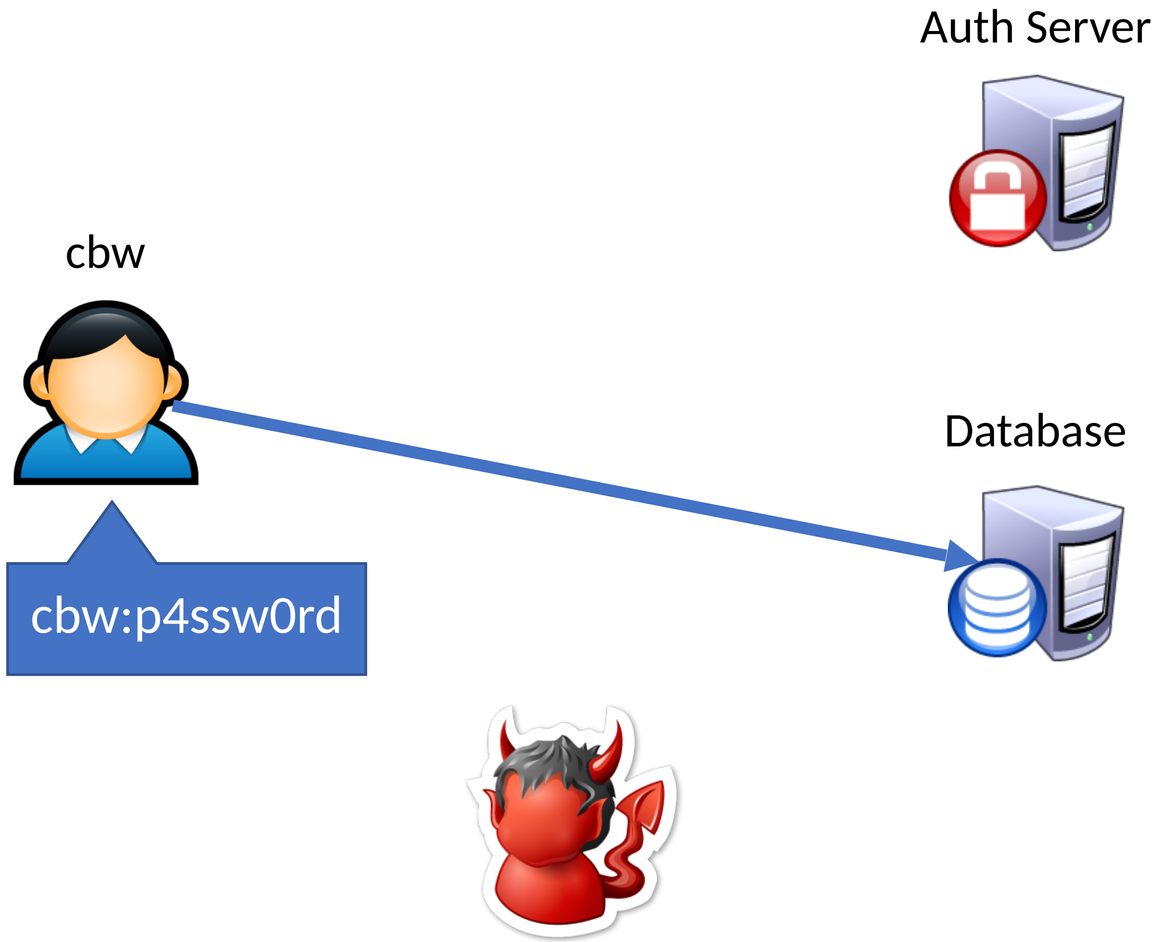

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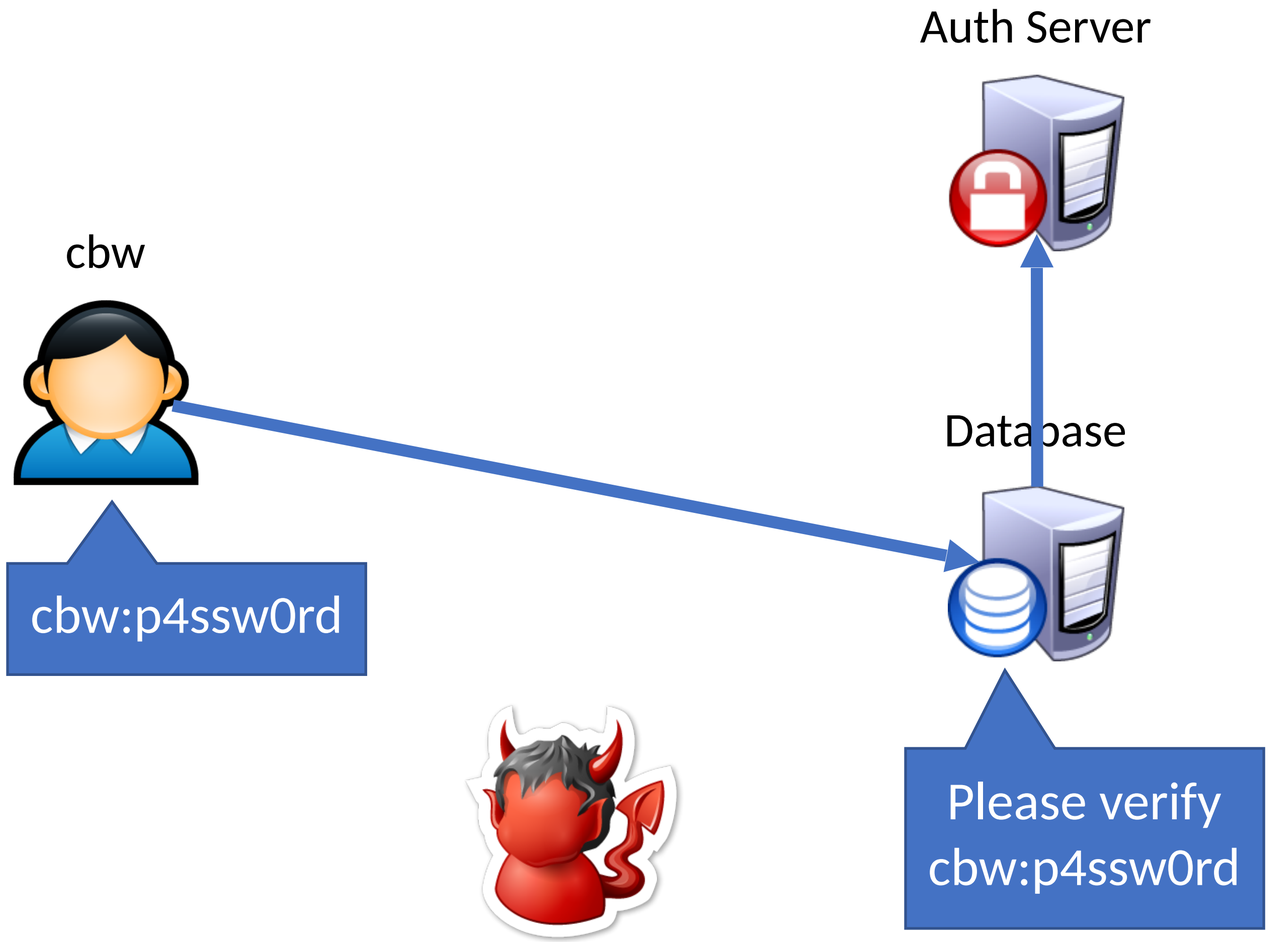

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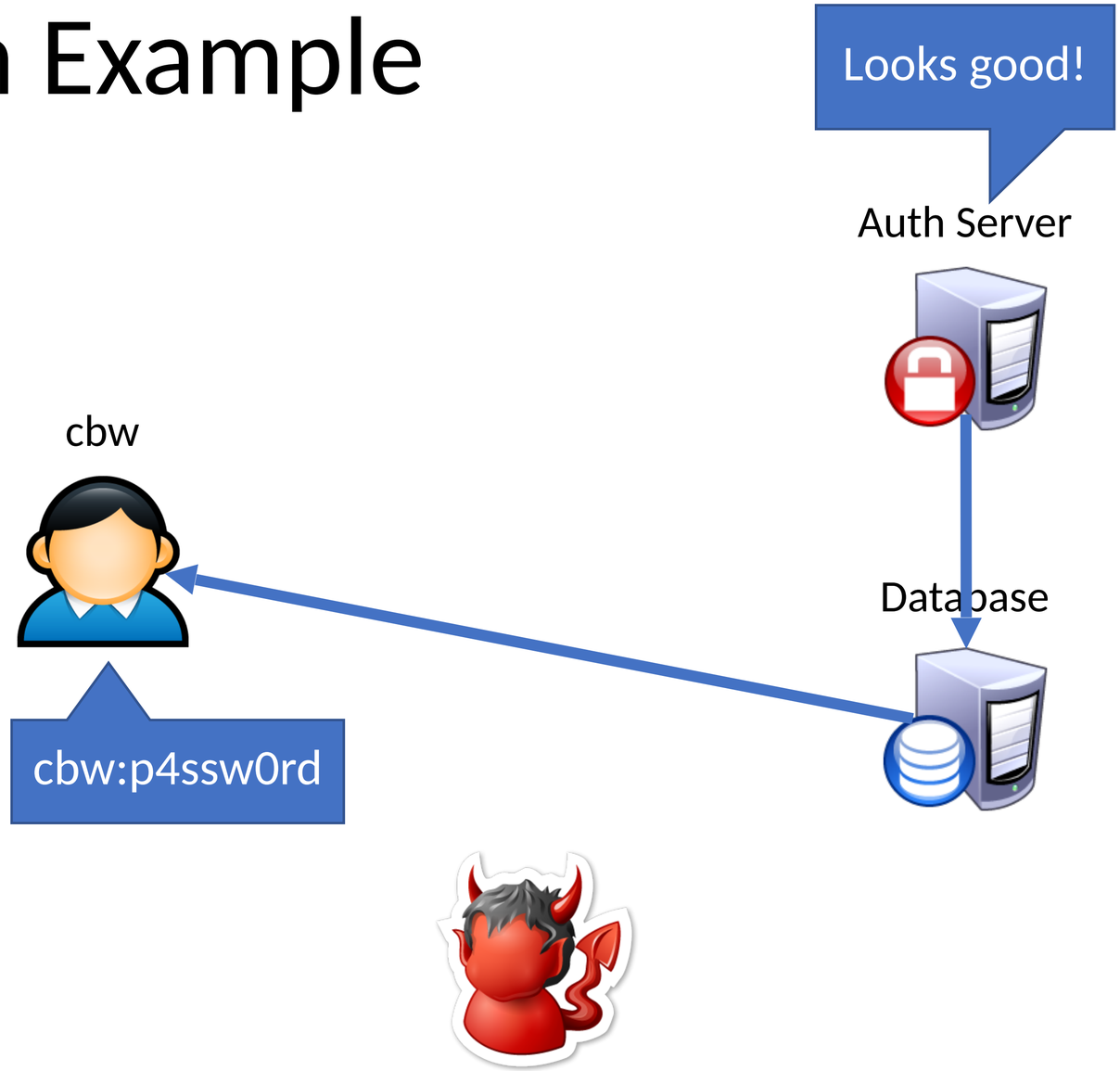

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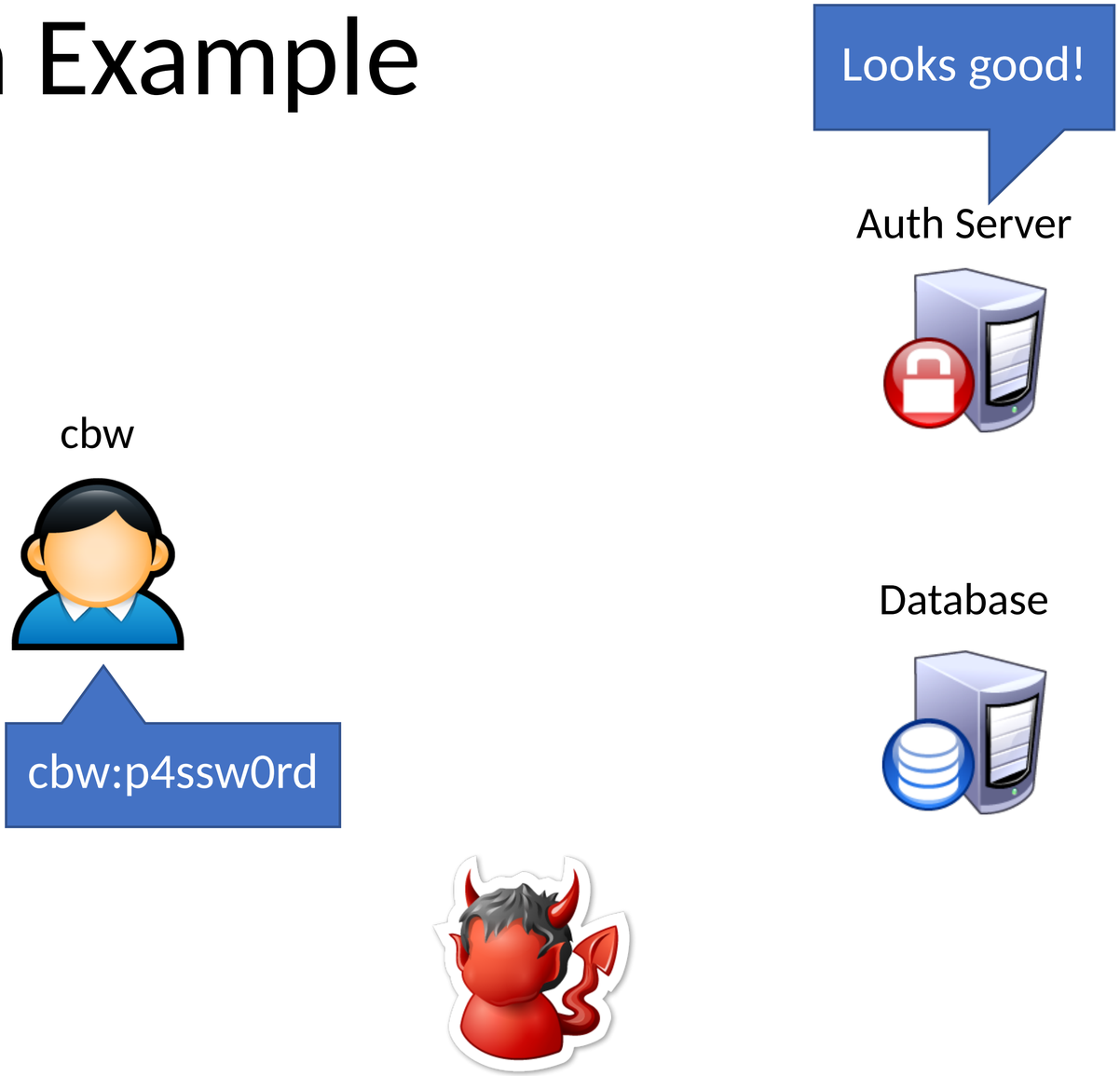

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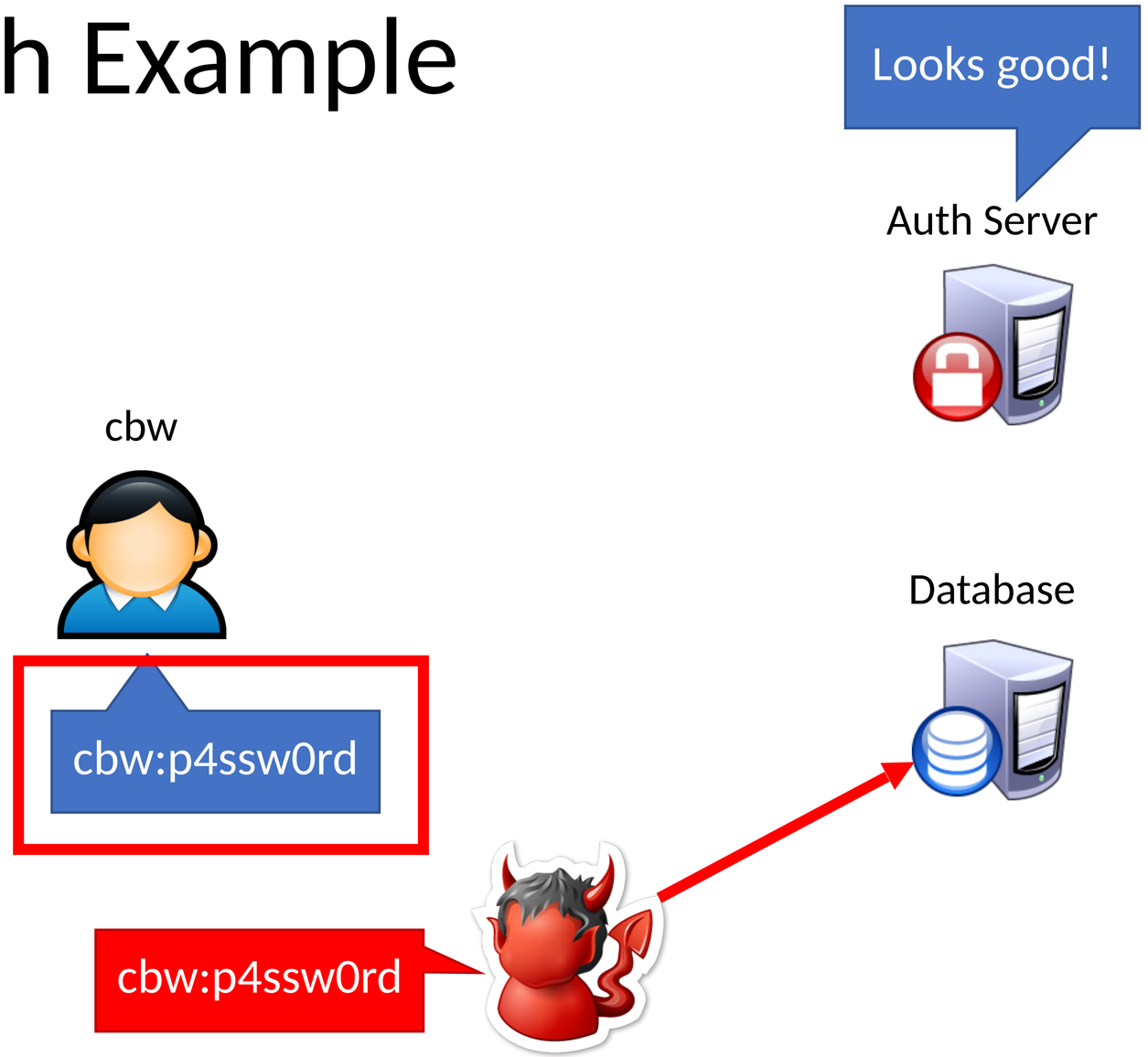

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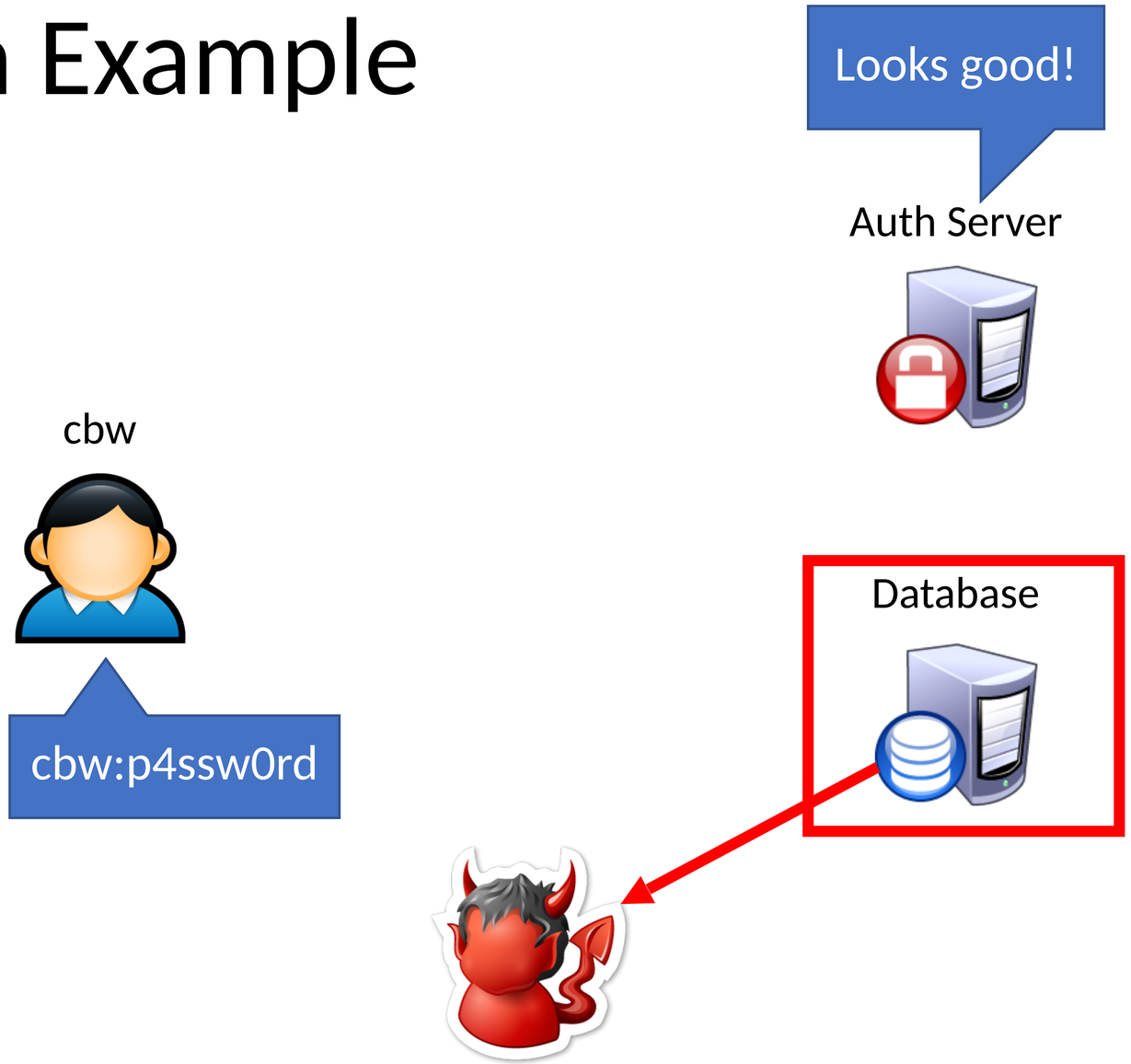
  - Database learns about passwords
    - Additional point of compromise
    - Ideally, only the user and the Auth Server should know their password



Needham-Schroeder Protocol

- Let Alice *A* and Bob *B* be two parties that trust server *S*
- K_{AS} and K_{BS} are shared secrets between [*A*, *S*] and [*B*, *S*]
- K_{AB} is a negotiated session key between [*A*, *B*]
- N_i and N_j are random nonces generated by *A* and *B*

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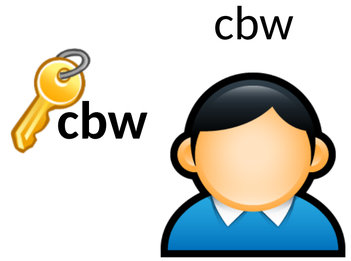

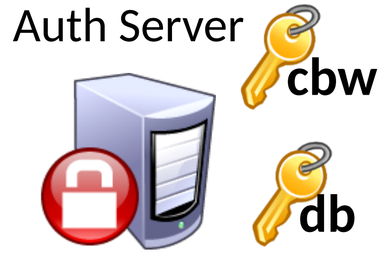

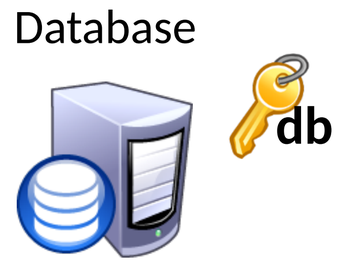

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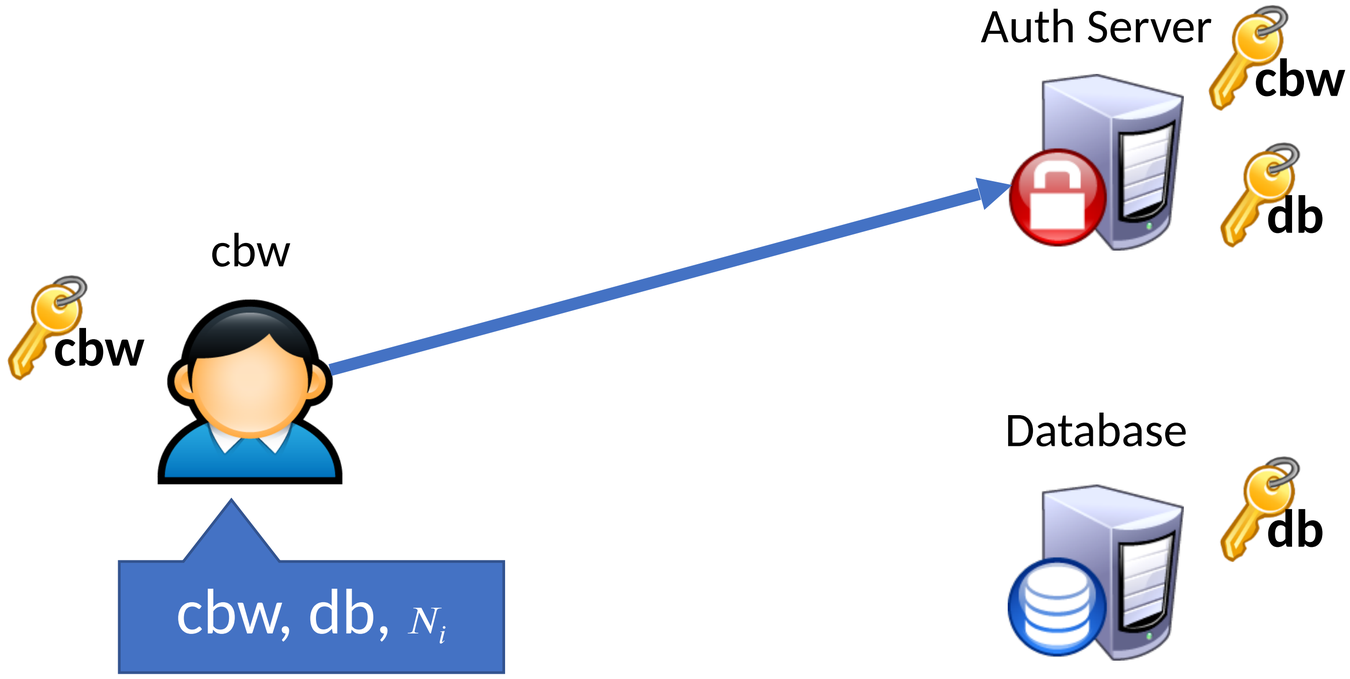

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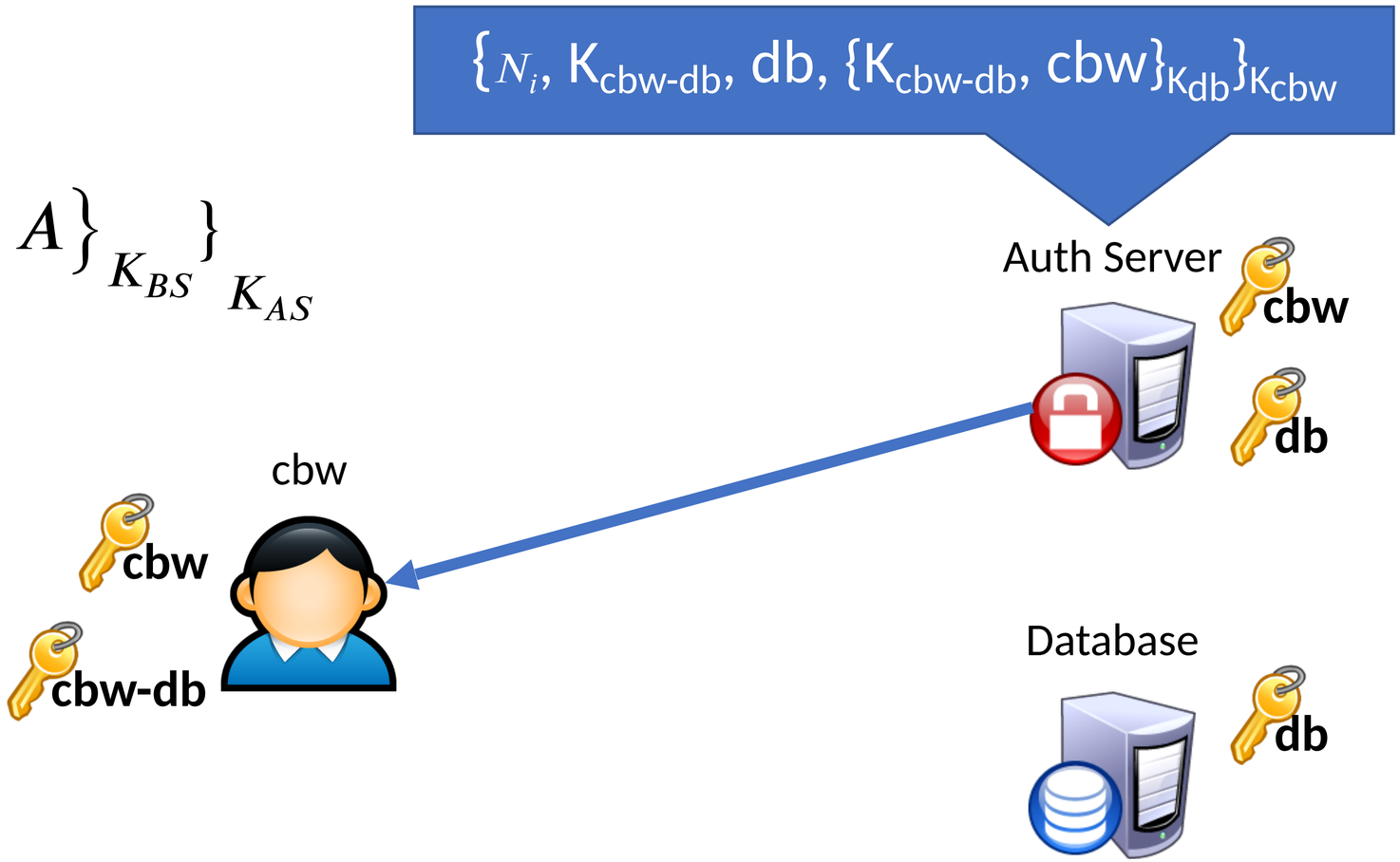

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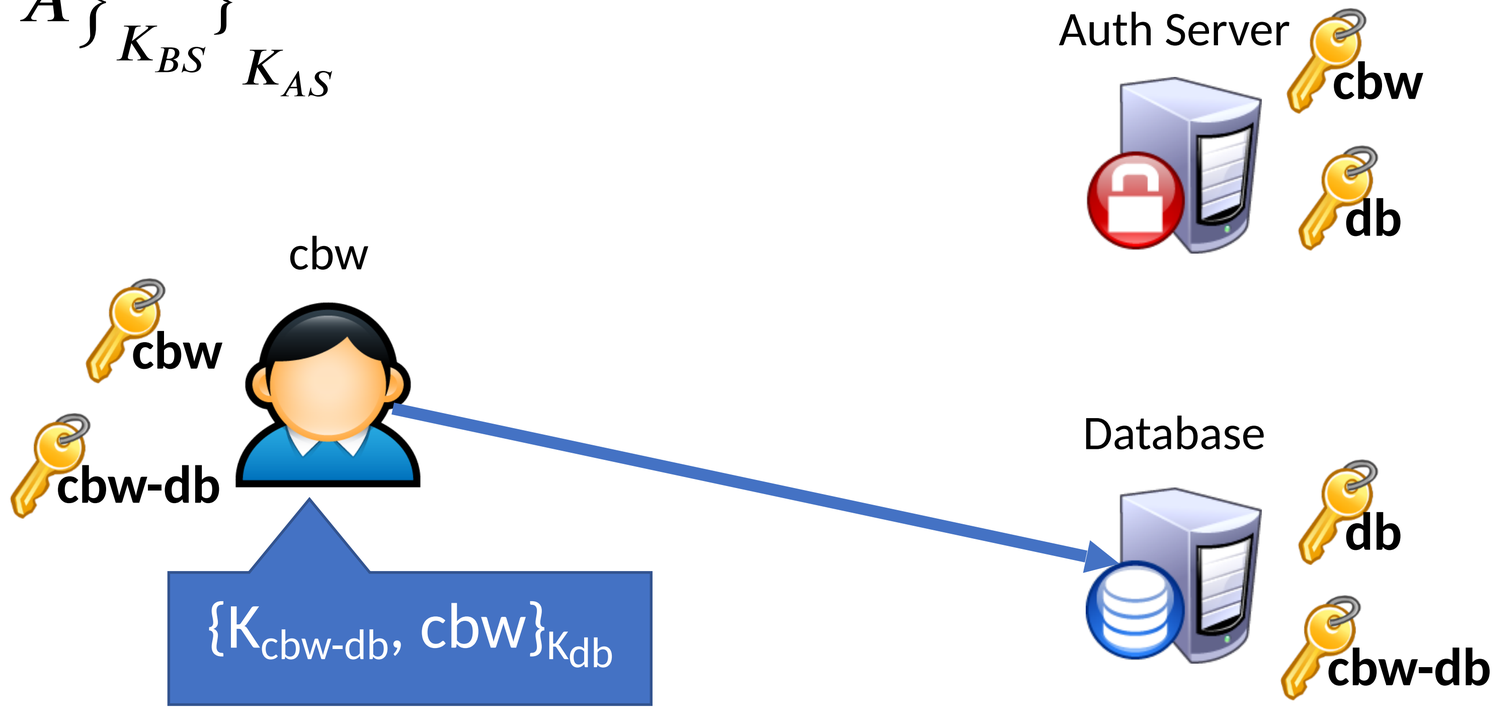

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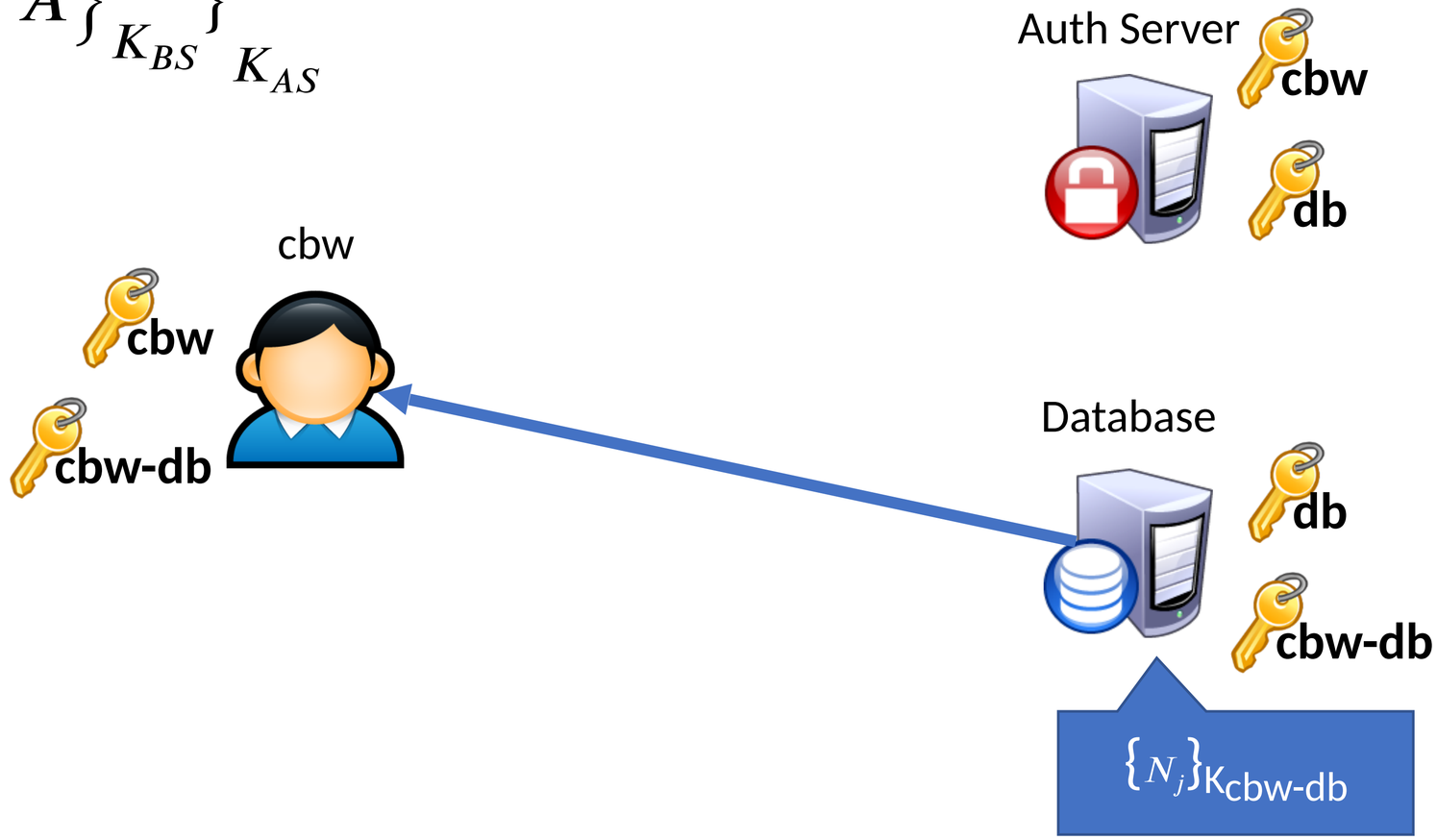

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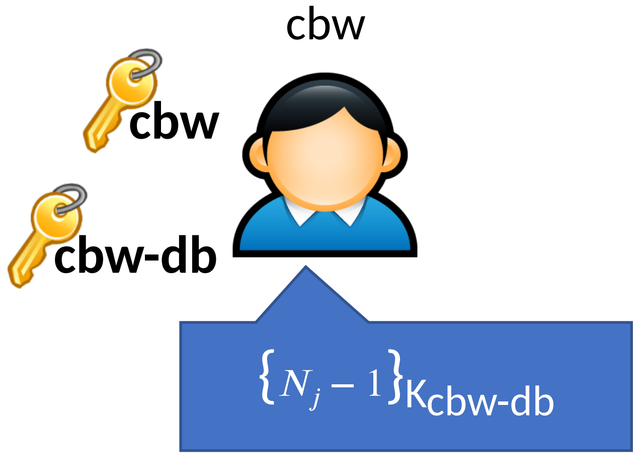
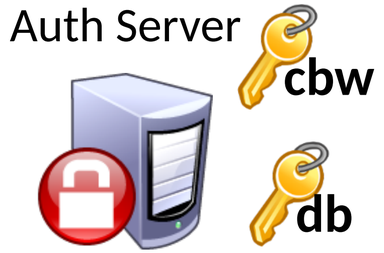
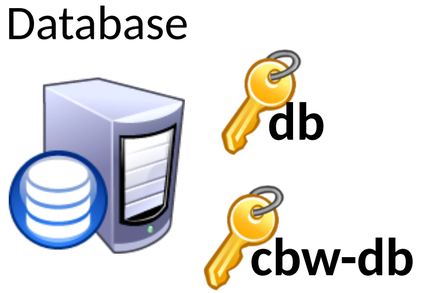
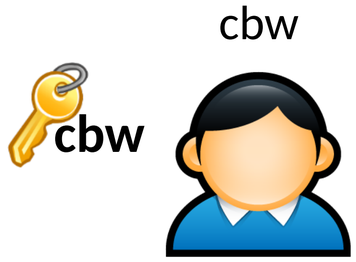
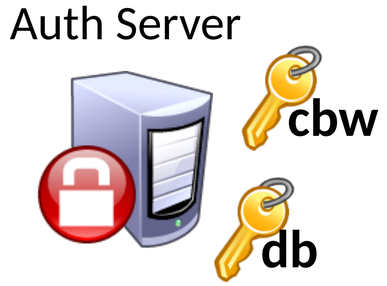


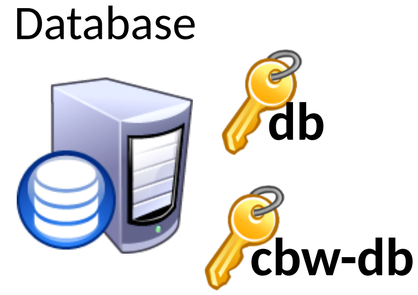




Attacking Needham-Schroeder







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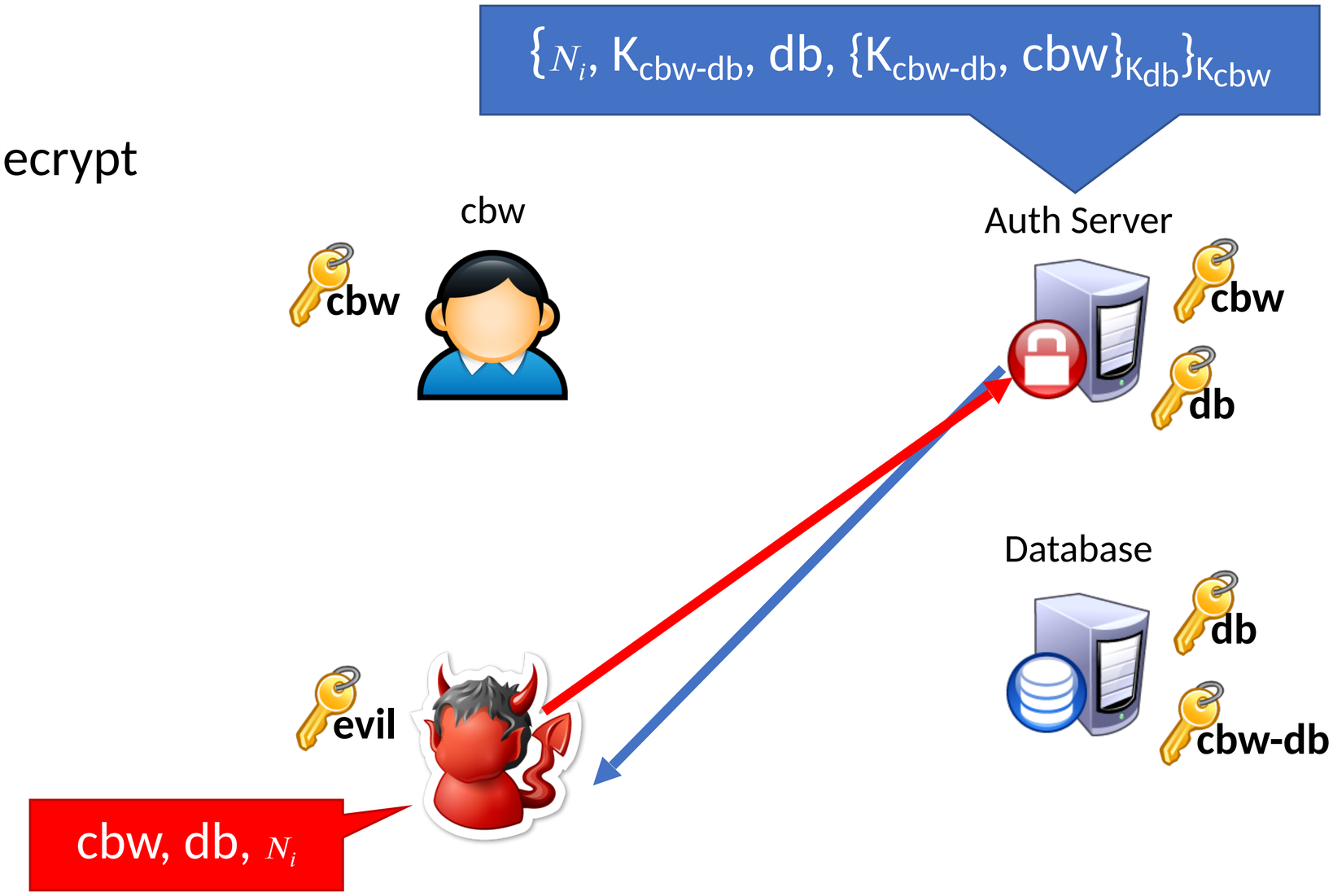

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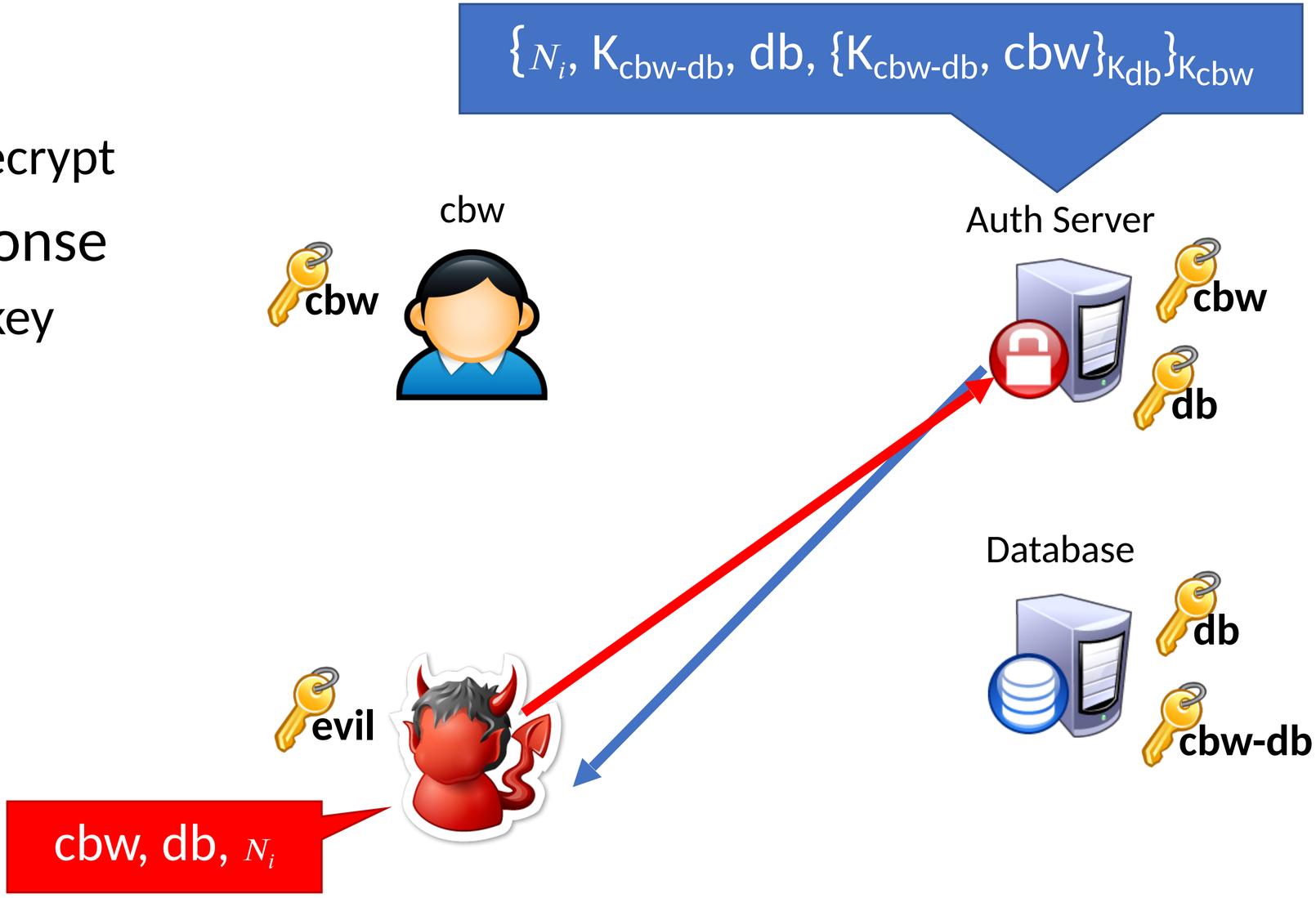

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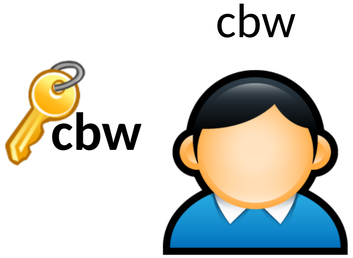

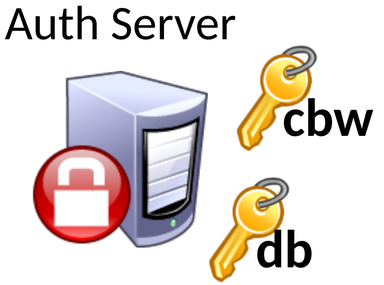

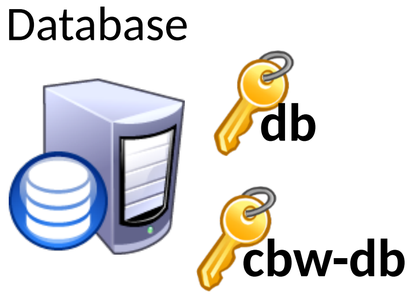

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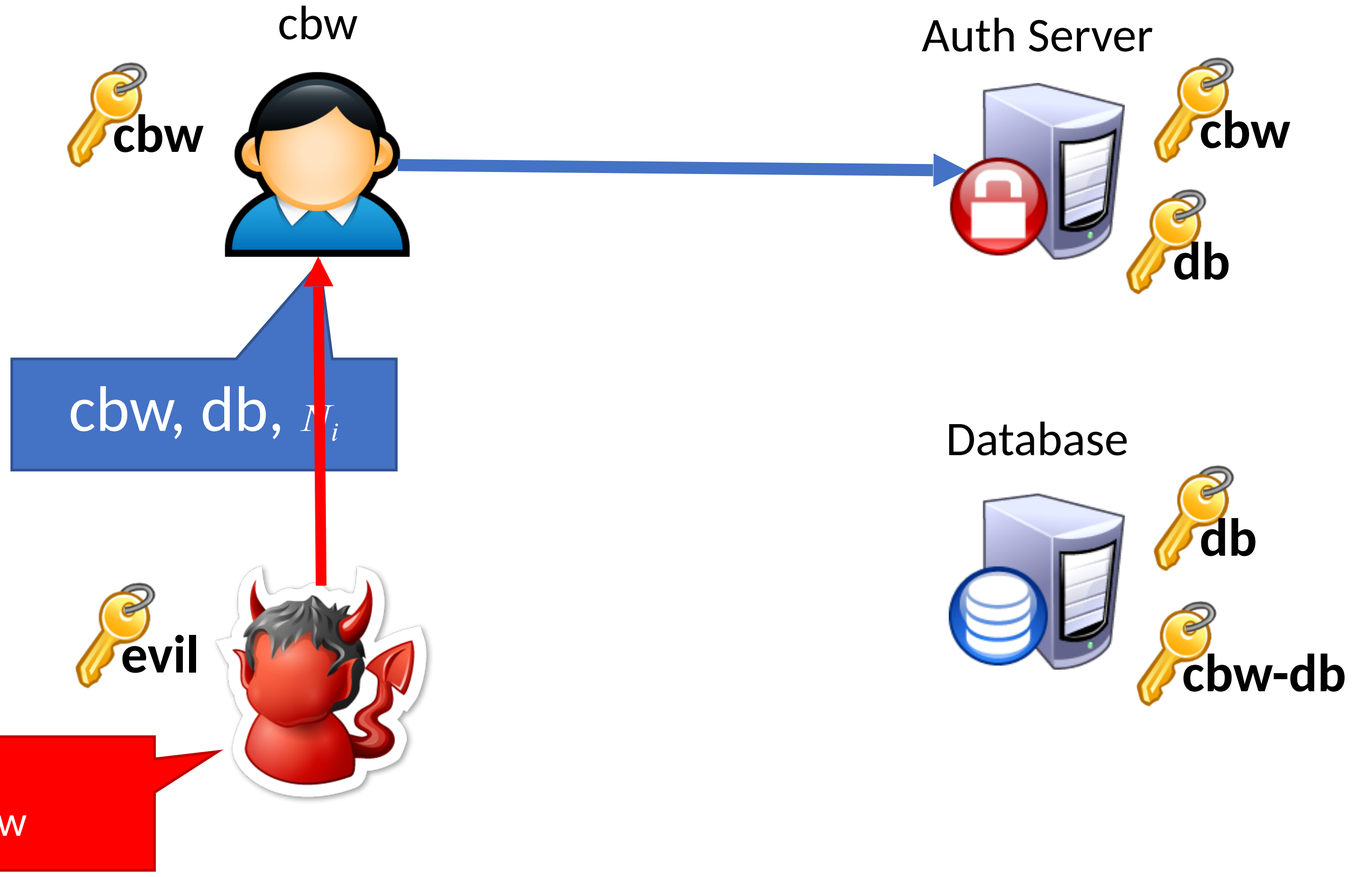

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- Replay the client-server interaction
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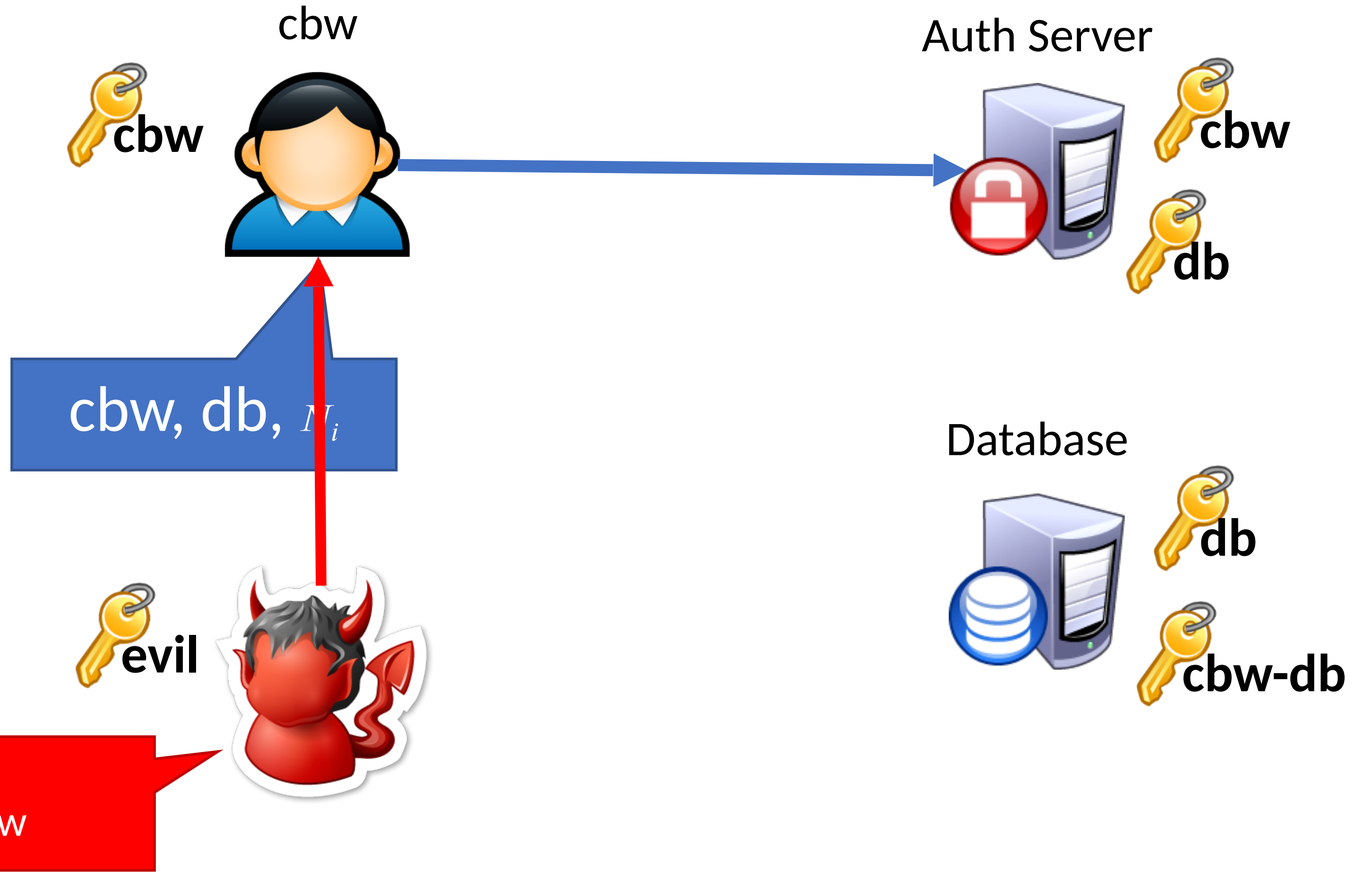

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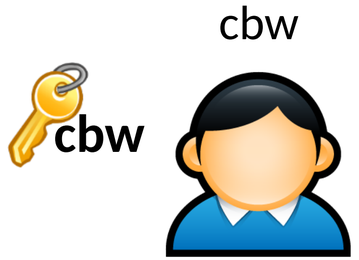

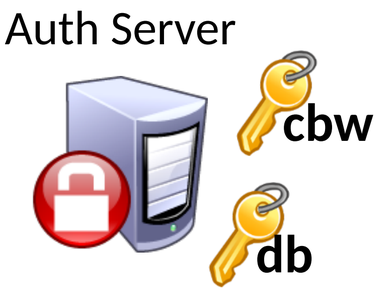

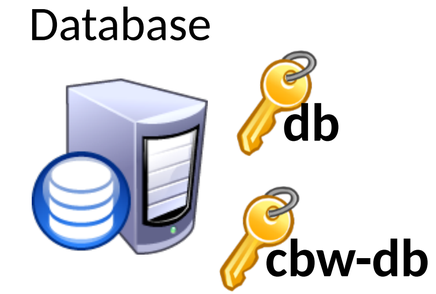

$\{K_{evil}, cbw\}_{K_{db}}$

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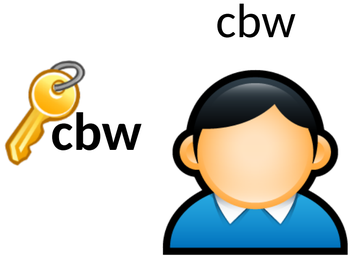
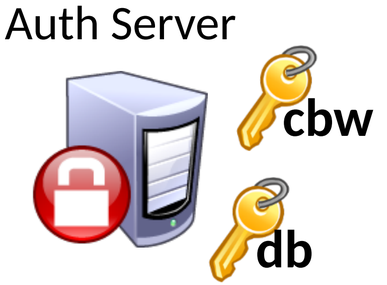
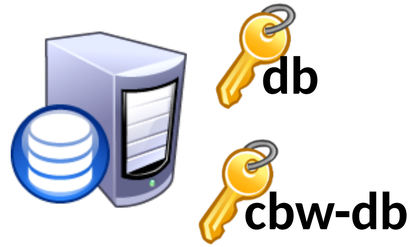
  - Fail! Need to know the database key
- Replay the client-server interaction
  - Fail! Need to know the session key

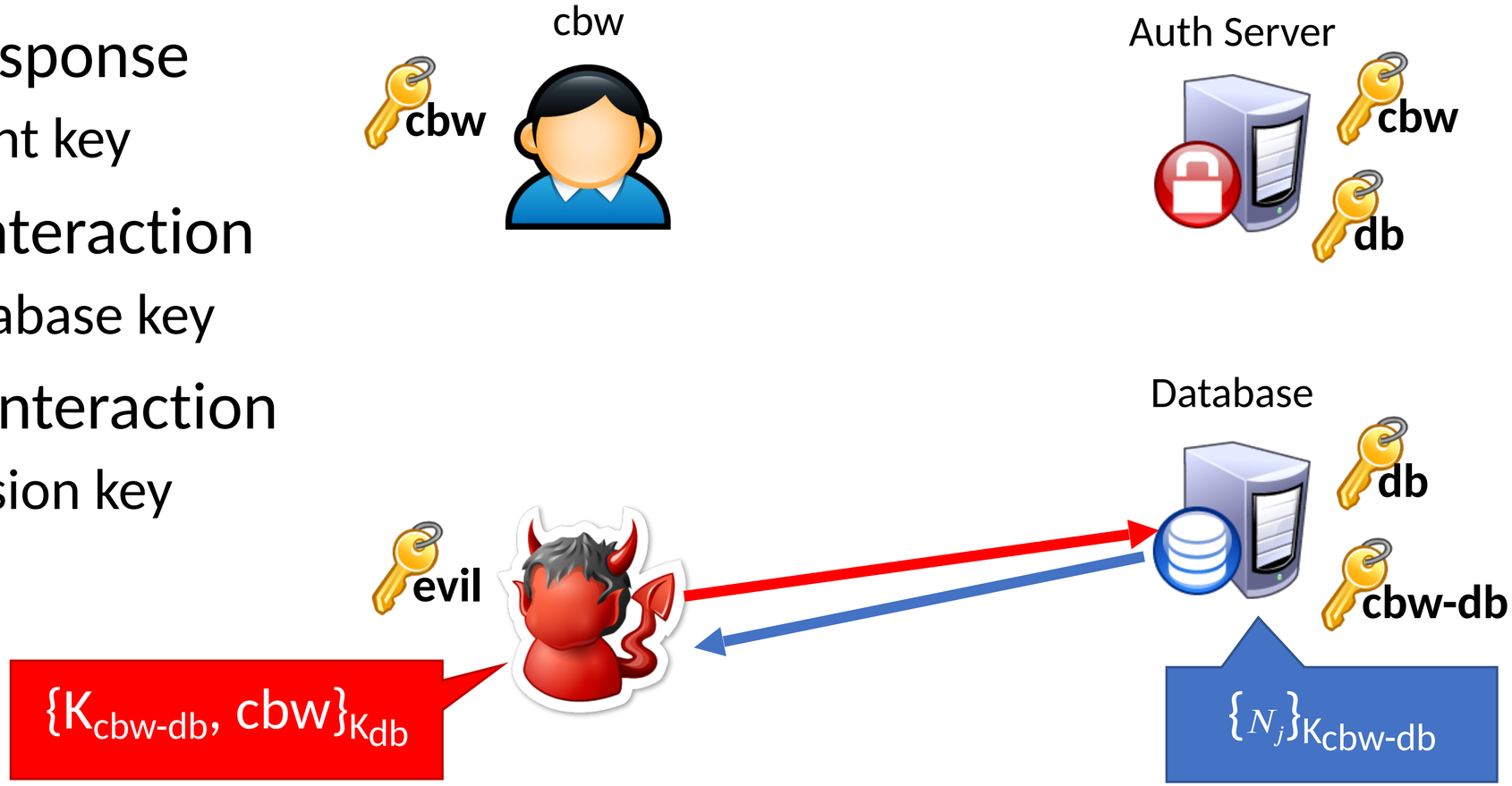






Attacking Needham-Schroeder

- Spoof the client request
  - Fail! Client key is needed to decrypt
- Spoof the Auth Server response
  - Fail! Need to know the client key
- Spoof the client-server interaction
  - Fail! Need to know the database key
- Replay the client-server interaction
  - Fail! Need to know the session key



Replay Attack

Typical, Benign Protocol

1) $A \rightarrow S: A, B, N_i$
2) $S \rightarrow A: \{N_i,\ K_{AB},\ B,\ \{K_{AB},\ A\}_{K_{BS}}\}_{K_{AS}}$
3) $A \rightarrow B: \{K_{AB},\ A\}_{K_{BS}}$
4) $B \rightarrow A: \{N_j\}_{K_{AB}}$
5) $A \rightarrow B: \{N_j - 1\}_{K_{AB}}$

Replay Attack

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Replay Attack

1) $M \rightarrow B: \{K_{AB}, A\}_{K_{BS}}$
2) $B \rightarrow M: \{N_j\}_{K_{AB}}$
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Replay Attack

Typical, Benign Protocol

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- Attacker must hack *A* to steal K_{AB}
  - So the attacker can also steal K_{AS}

Replay Attack

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- However, what happens after *A* changes K_{AS}

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Replay Attack

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- Attacker must hack *A* to steal K_{AB}
  - So the attacker can also steal K_{AS}
- However, what happens after *A* changes K_{AS}
  - Attacker can still conduct the replay attack! Only is K_{AB} necessary!

Fixed Needham-Schroeder Protocol

- Let Alice *A* and Bob *B* be two parties that trust server *S*
- K_{AS} and K_{BS} are shared secrets between [*A*, *S*] and [*B*, *S*]
- K_{AB} is a negotiated session key between [*A*, *B*]
- N_i and N_j are random nonces generated by *A* and *B*
- *T* is a timestamp chosen by *S*

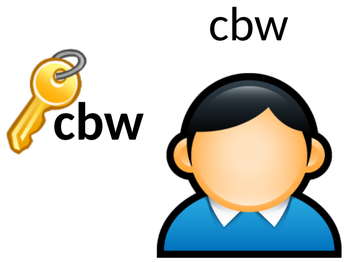
1) $A \rightarrow S: A, B, N_i$
2) $S \rightarrow A: \{N_i,\ K_{AB},\ B,\ \{K_{AB},\ A,\ T\}_{K_{BS}}\}_{K_{AS}}$
3) $A \rightarrow B: \{K_{AB},\ A,\ T\}_{K_{BS}}$
4) $B \rightarrow A: \{N_j\}_{K_{AB}}$
5) $A \rightarrow B: \{N_j - 1\}_{K_{AB}}$

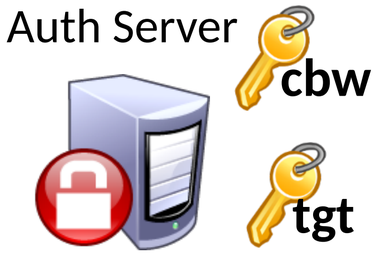
B only accepts requests with fresh timestamps

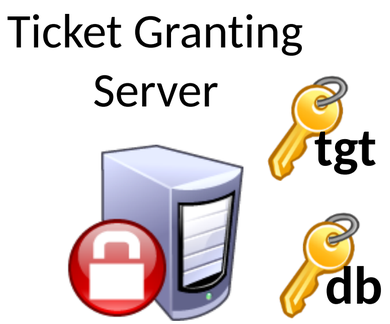
Kerberos

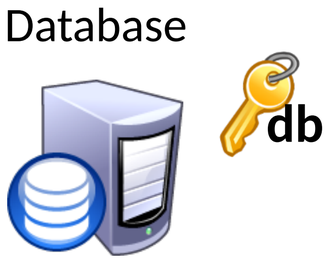
- Created as part of MIT Project Athena
  - Based on Needham-Schroeder
- Provides mutual authentication over untrusted networks
  - Tickets as assertions of authenticity, authorization
  - Forms basis of Active Directory authentication
- Principals
  - Client
  - Server
  - Key distribution center (KDC)
    - Authentication server (AS)
    - Ticket granting server (TGS)

Kerberos Example

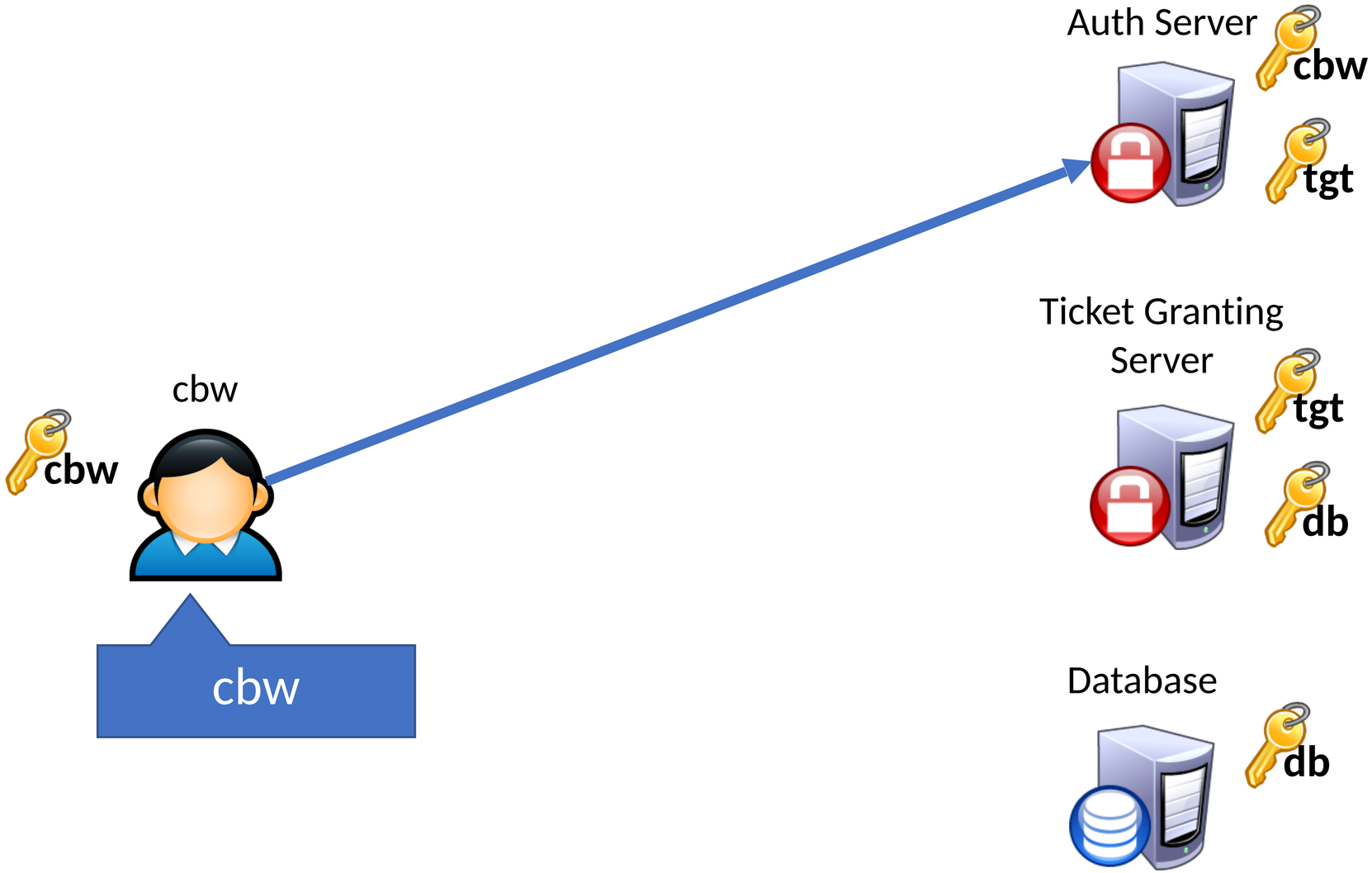




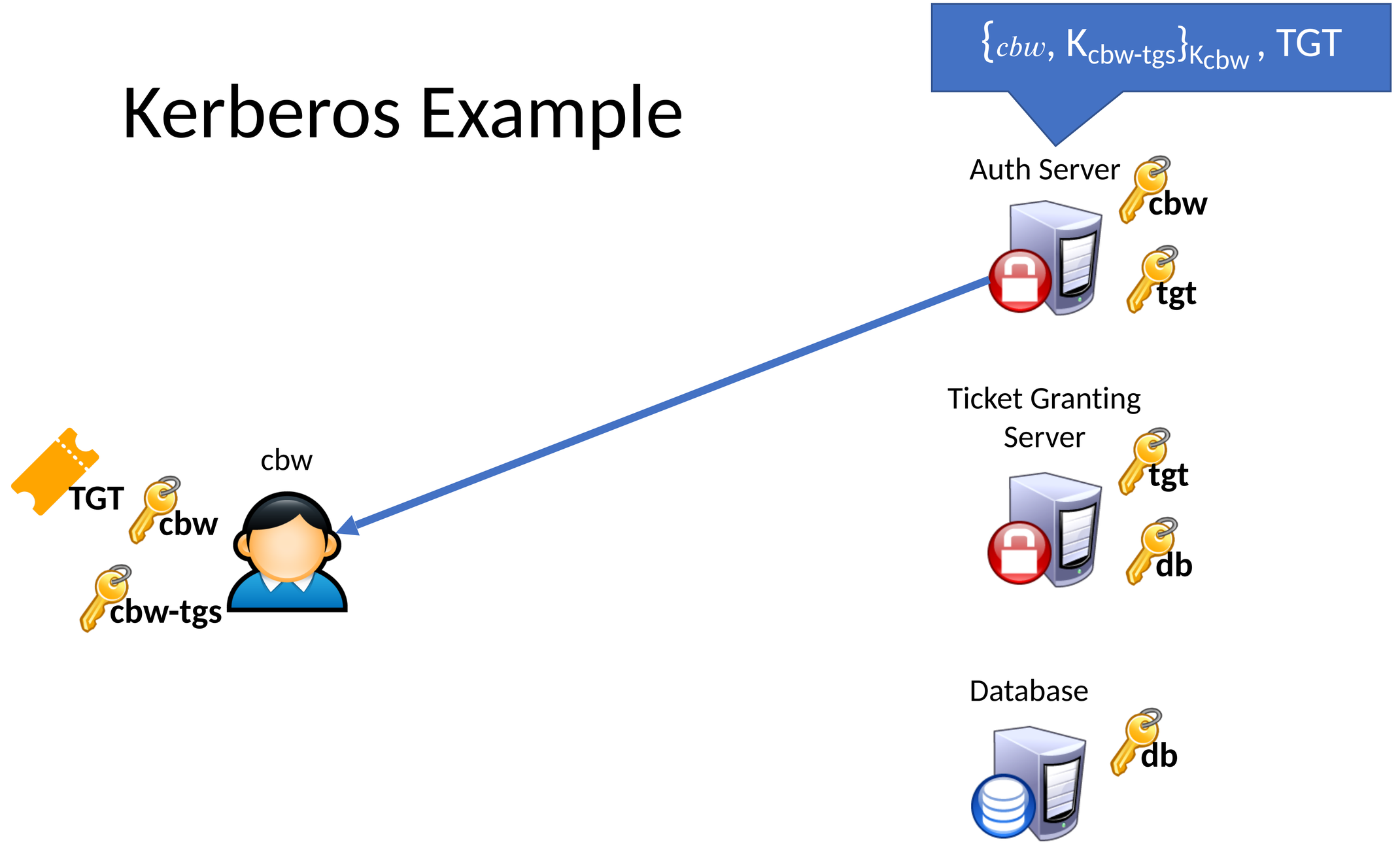




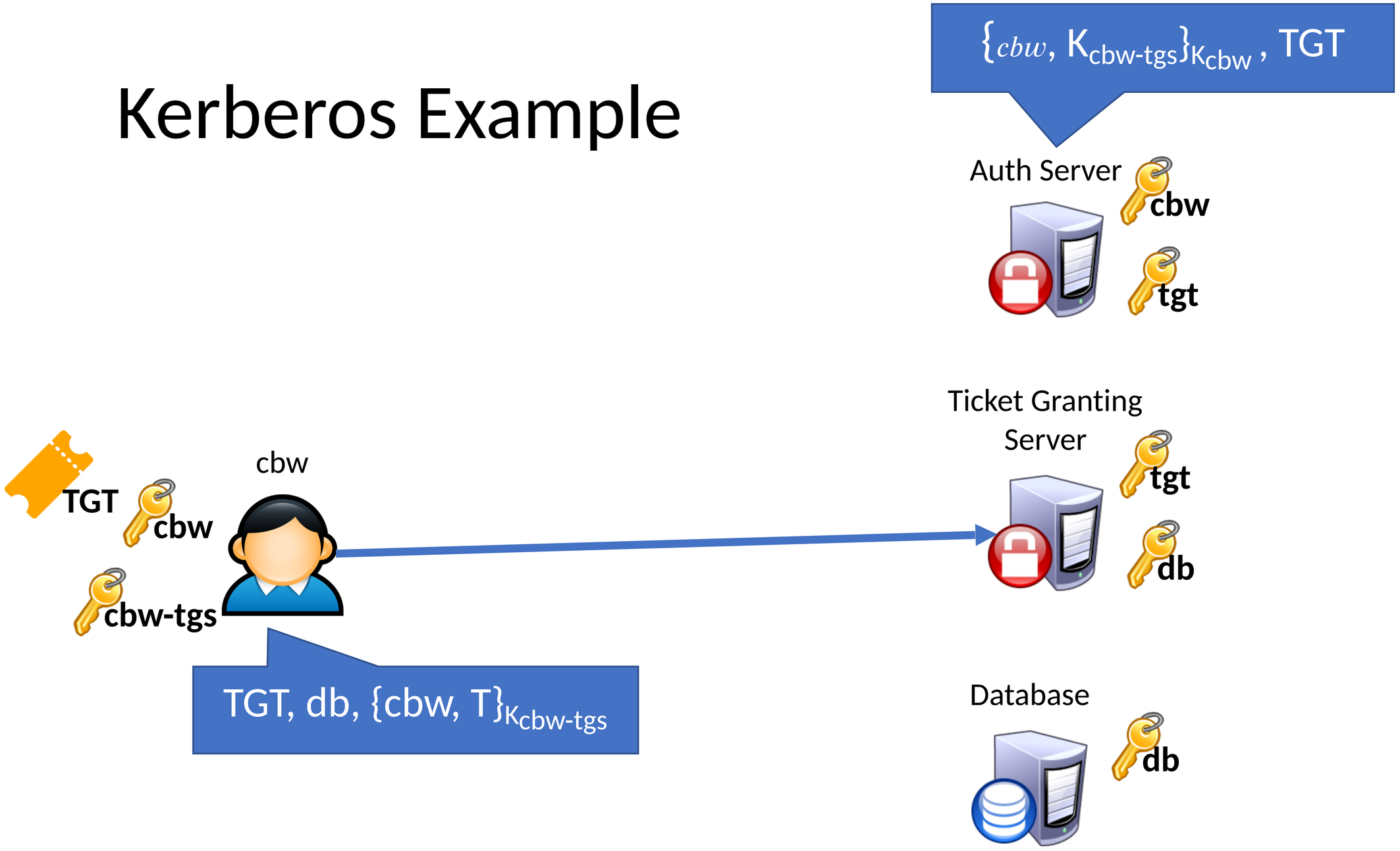
Kerberos Example



Kerberos Example



Kerberos Example



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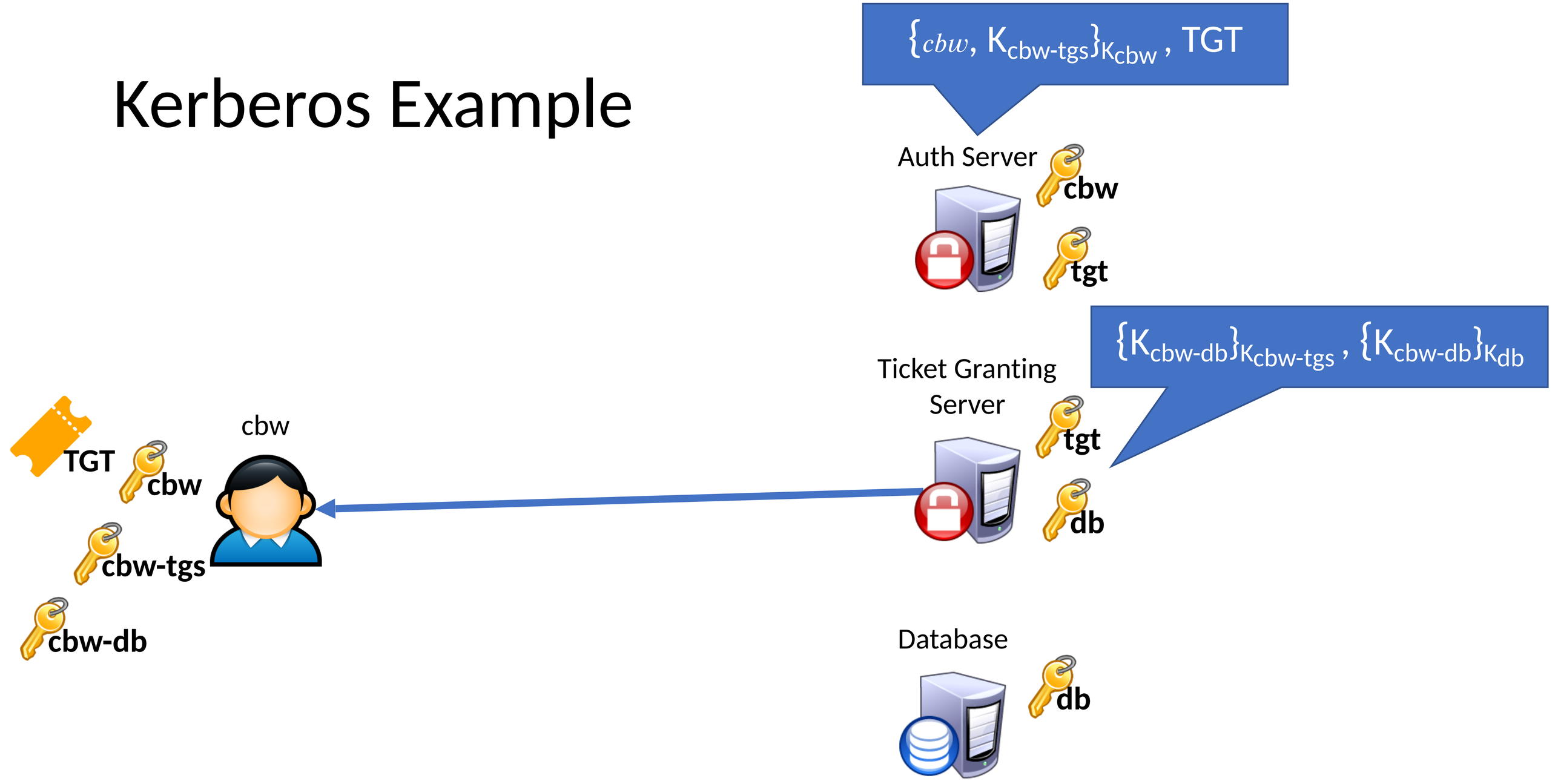
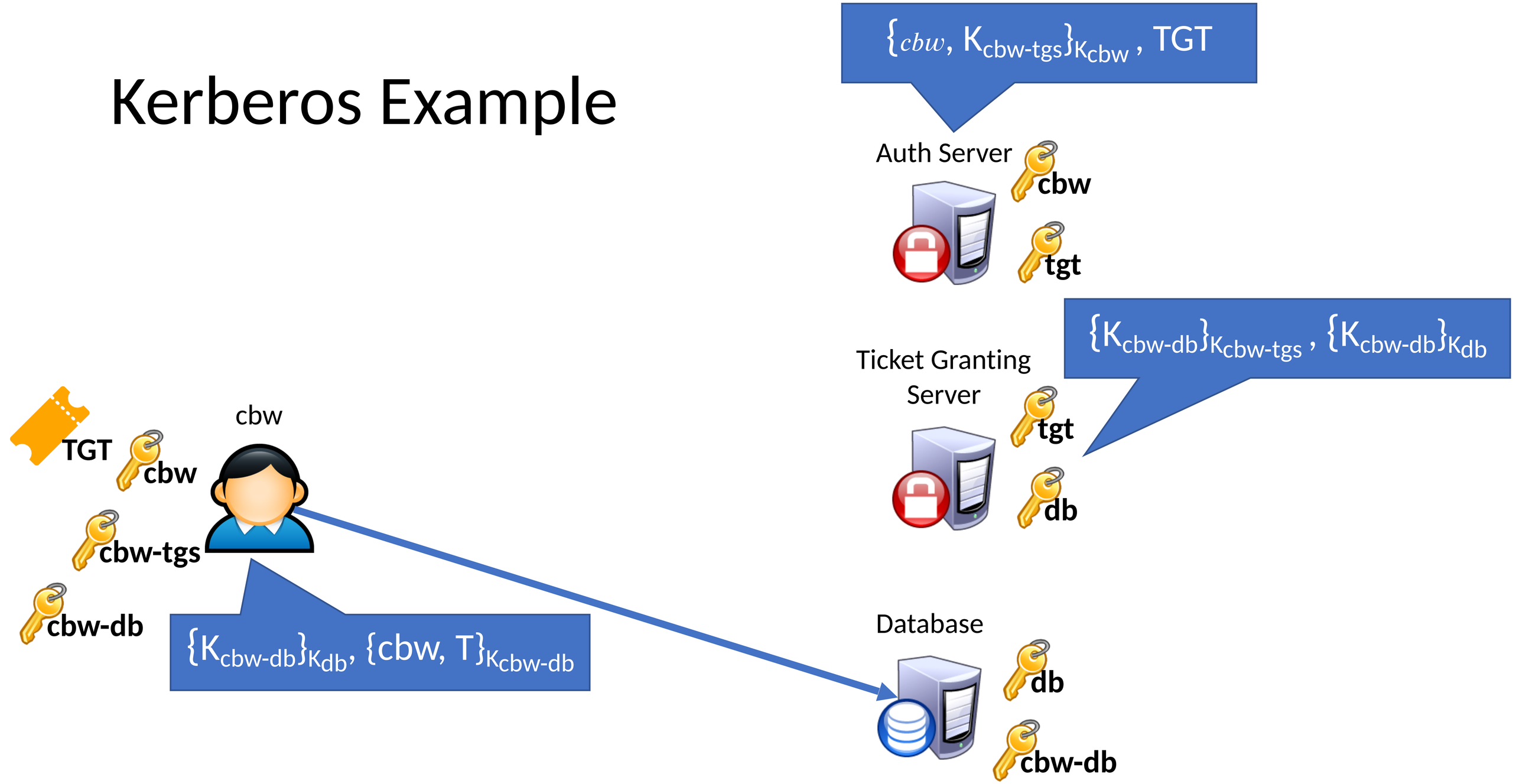
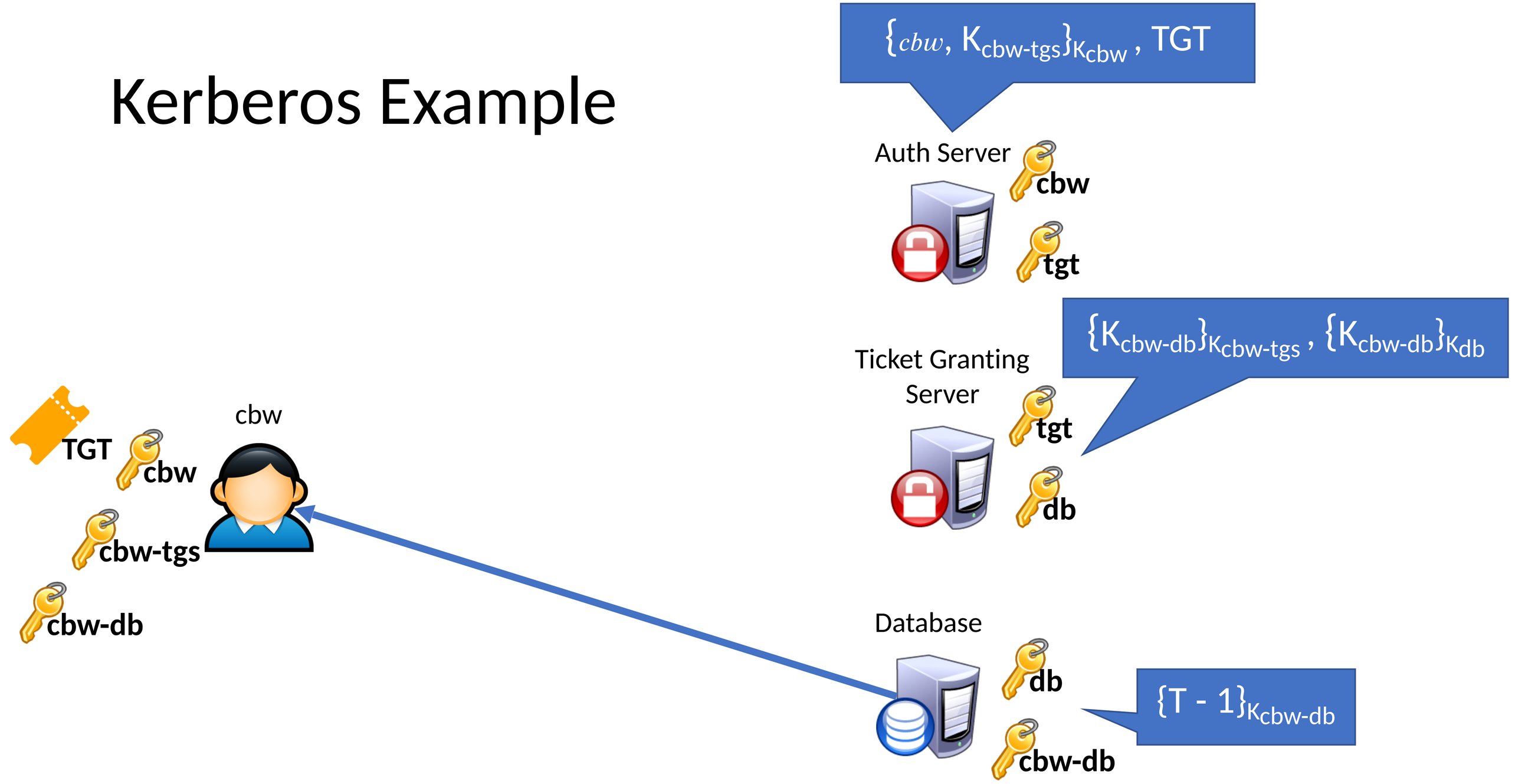


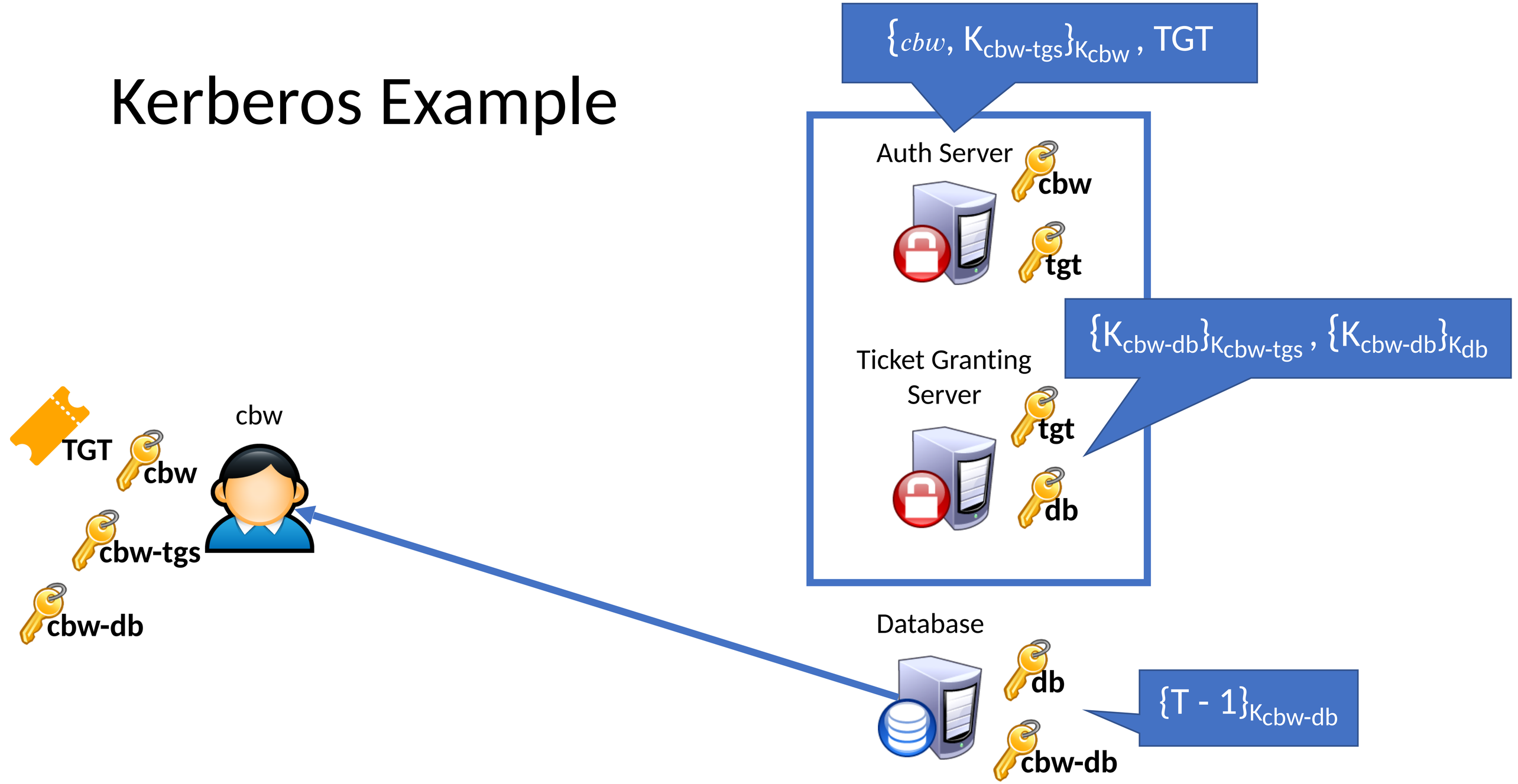
Kerberos Example



Kerberos Example



Kerberos Example



Attacking Kerberos

- Don’t put all your eggs in one basket
  - The Kerberos Key Distribution Server (KDS) is a central point of failure
  - DoS the KDS and the network ceases to function
  - Compromise the KDS leads to network-wide compromise

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- Time synchronization
  - Inaccurate clocks lead to protocol failures (due to timestamps)
  - Solution?

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- Time synchronization
  - Inaccurate clocks lead to protocol failures (due to timestamps)
  - Solution?
  - Use NTP ;)

Sources

1. Many slides courtesy of Wil Robertson: https://wkr.io
2. Honeywords, Ari Juels and Ron Rivest: http://www.arijuels.com/wp-content/uploads/2013/09/JR13.pdf

- For more on generating secure passwords, and understanding people's mental models of passwords, see the excellent work of Blas Ur: http://www.blaseur.com/pubs.htm