CSE331 Computer Security Fundamentals

10/3/2017

Authentication

Michalis Polychronakis

Stony Brook University

Authentication

The process of reliably verifying the identity or role of someone (or something)

What is identity?

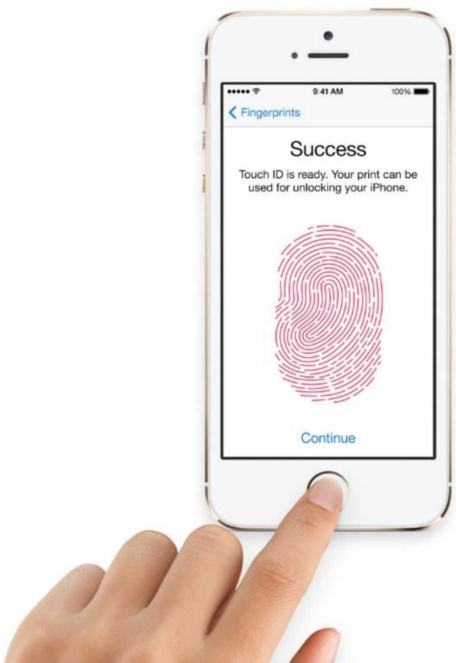
- Which characteristics uniquely identify an entity?

Authentication is a critical service, as many other security mechanisms are based on it

- Entity authentication is the security service that enables communicating parties to verify the identity of their peers

Two main types

- Human to computer
- Computer to computer



Credentials

Evidence used to prove an identity

User Authentication: credentials supplied by the user

- Something you know
- Something you have
- Something you are

Computer authentication: crypto, location

- Computers (in contrast to humans) can "remember" large secrets (keys) and perform complex cryptographic operations
- Location: evidence that an entity is at a specific place (e.g., IP address/subnet)

Authentication can be delegated

- The verifying entity accepts that a trusted third party has already established authentication

Something You Know: Password-based Authentication

Passwords, passphrases, pins, key-phrases, access codes, …

- Say the magic word

Good passwords are easy to remember and hard to guess

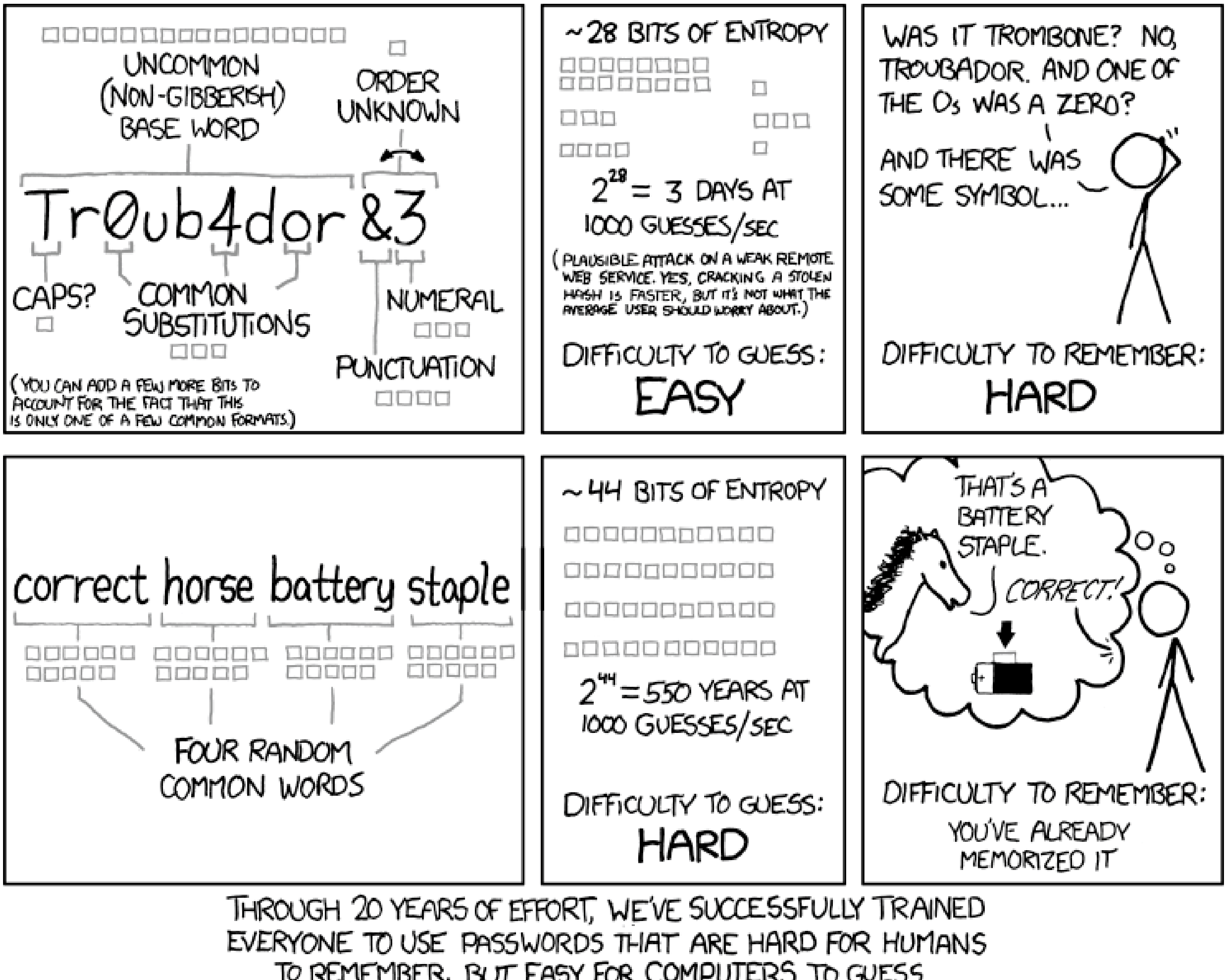
- Easy to remember → easy to guess
- Hard to guess → hard to remember
- Bad ideas: DOB, SSN, zip code, favorite team name, …

Password space (bits) depends on:

- Password length
- Character set

Better way to think about strong passwords

- **Long passphrases**, combined with custom variations, symbols, numbers, capitalization, …


UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor&3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)
~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS: EASY
WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER: HARD
correct horse battery staple
FOUR RANDOM COMMON WORDS
~44 BITS OF ENTROPY
2^44 = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS: HARD
THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER: YOU'VE ALREADY MEMORIZED IT
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

Password Policies (often have the opposite effect)

Password rules

"At least one special character"

"Minimum/Maximum length of 8/12 characters"

"Must contain at least one number"

"Must contain at least one capital letter"

Hard to remember! ➔ encourage password reuse, writing down passwords insecurely, …

Periodic password changing

"You haven't changed your password in the last 90 days"

Probably too late anyway if password has been stolen

Makes remembering passwords harder ➔ more passwords resets

What users do: `password1` ➔ `password2` ➔ `password1` ➔ …

Attacking Passwords

Offline cracking
Online guessing
} *Brute force attacks*

Eavesdropping

Capturing

Password Storage

Storing passwords as plaintext is disastrous

Better way: store a cryptographic hash of the password

Even better: store a "salted" version of the password

- Defend against *dictionary attacks*: prevent precomputation of hash values (wordlists of popular passwords, rainbow tables, …)
- Even if two users have the same password, their hash values will be different ➔ need to be cracked separately
- Salting *does not* make brute-force guessing a given password harder!

Username	Salt	Password hash
Bobbie	4238	h(4238, $uperman)
Tony	2918	h(2918, 63%TaeFF)
Mitsos	6902	h(6902, zour1da)
Mark	1694	h(1694, Rockybrook#1)

Still, password databases are getting leaked…

Password Cracking

Exhaustive search ➔ infeasible for large password spaces

Dictionary attacks

- Language words
- Lists of previously leaked real user passwords

Variations, common patterns, structure rules

- Prepend/append symbols/numbers/dates, weird capitalization, l33tspeak, visually similar characters, intended misspellings, …

Target-specific information

- DOB, family names, favorite team, pets, hobbies, anniversaries, language, slang, …
- Easy to acquire from social networking services and other public sites
- **Particularly effective against "security questions"**

Advanced techniques

- Probabilistic context-free grammars, Markov models, …

Combination of all the above

Example hashes

Table of Contents

If you get a "line length exception" error in hashcat, it is often because the hash mode that you have requested does not match the hash. To verify, you can test your commands against example hashes.

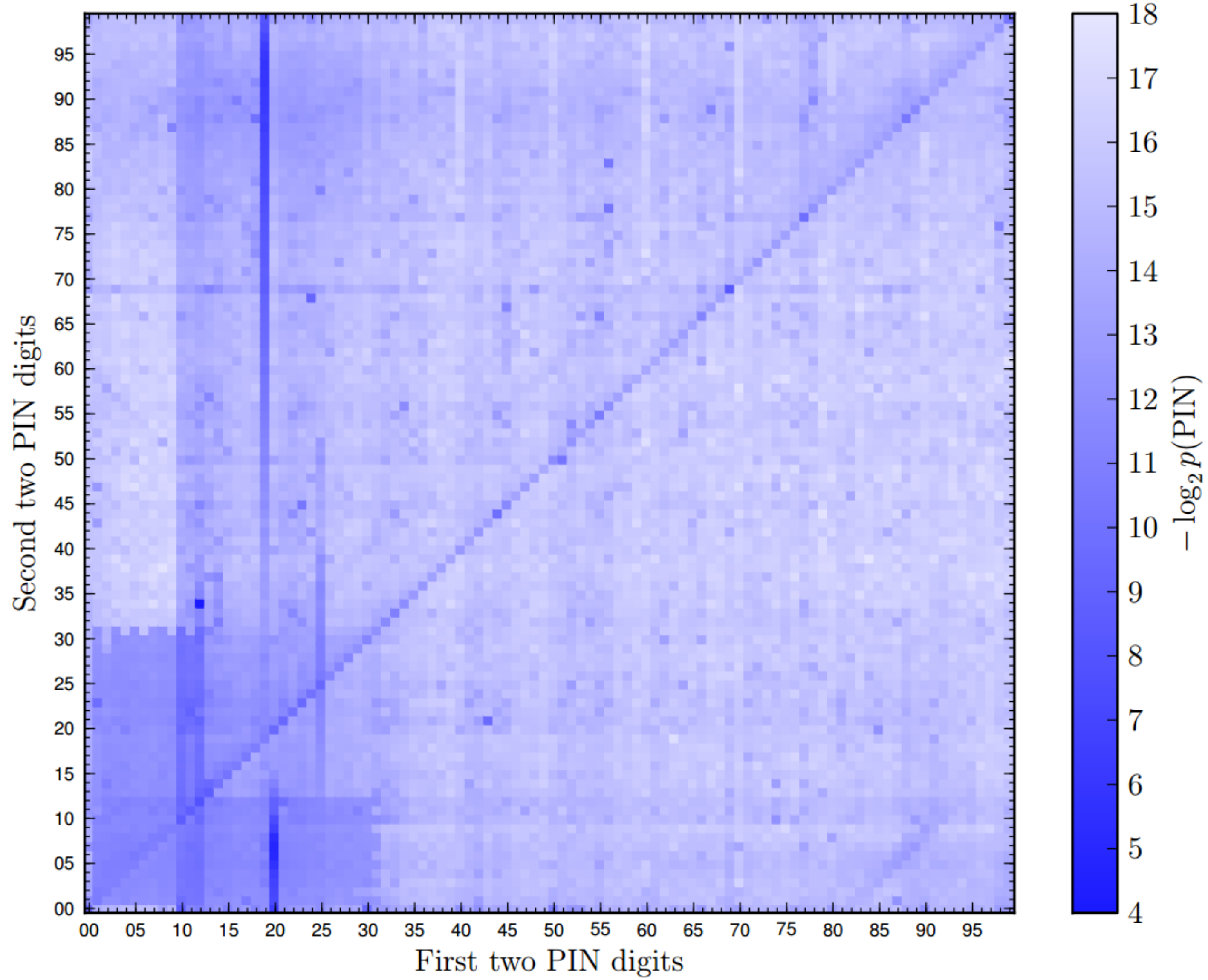
Unless otherwise noted, the password for all example hashes is **hashcat**.

Generic hash types

Hash-Mode	Hash-Name	Example
0	MD5	8743b52063cd84097a65d1633f5c74f5
10	md5($pass.$salt)	01dfae6e5d4d90d9892622325959afbe:7050461
20	md5($salt.$pass)	f0fda58630310a6dd91a7d8f0a4ceda2:4225637426
30	md5(utf16le($pass).$salt)	b31d032cfdcf47a399990a71e43c5d2a:144816
40	md5($salt.utf16le($pass))	d63d0e21fdc05f618d55ef306c54af82:13288442151473
50	HMAC-MD5 (key = $pass)	fc741db0a2968c39d9c2a5cc75b05370:1234
60	HMAC-MD5 (key = $salt)	bfd280436f45fa38eaacac3b00518f29:1234
100	SHA1	b89eaac7e61417341b710b727768294d0e6a277b
110	sha1($pass.$salt)	2fc5a684737ce1bf7b3b239df432416e0dd07357:2014
120	sha1($salt.$pass)	cac35ec206d868b7d7cb0b55f31d9425b075082b:5363620024
130	sha1(utf16le($pass).$salt)	c57f6ac1b71f45a07dbd91a59fa47c23abcd87c2:631225
140	sha1($salt.utf16le($pass))	5db61e4cd8776c7969cfd62456da639a4c87683a:8763434884872
150	HMAC-SHA1 (key = $pass)	c898896f3f70f61bc3fb19bef222aa860e5ea717:1234
160	HMAC-SHA1 (key = $salt)	d89c92b4400b15c39e462a8caa939ab40c3aeeea:1234
200	MySQL323	7196759210defdc0
300	MySQL4.1/MySQL5	fcf7c1b8749cf99d88e5f34271d636178fb5d130

25 Most-used (Worse) Passwords

password
123456
12345678
1234
qwerty
12345
dragon
pussy
baseball
football
letmein
monkey
696969
abc123
mustang
michael
shadow
master
jennifer
111111
2000
jordan
superman
harley
1234567



Distribution of 4-digit sequences within RockYou passwords

Wordlists

ce#ebc.dk
goddess5
20071002
271075711
zs3cu7za
scoopn
frygas1411
SL123456sl
12345687ee123
xuexi2010
daigoro
12345614
DICK4080
567891234
tilg80
6z08c861
:zark:
ravishsneha
150571611369
661189
passme
trolovinasveta
abdulkhaleque
007816
xLDSX
Florida2011
037037
WestC0untry
hitsugaiya
955998126
3n3rmax
4637324
bugger825
marmaris
jinjin111
170383gp
3484427
fl33321
zwqrfg
67070857
432106969
6856
704870704870
pv041886
20060814
512881535
milanimilani
472619
dbyxw888
85717221
cc841215
ariana19321
bbbnnn
ang34hehiu
wj112358
Brenda85
786525pb
shi461988
pingu
yeybozip
71477nak
stokurew
gea8mw4yz
kukumbike
260888
jordi10
lexusis
kj011a039
c84bwlrb
priyanka05
loveneverdies
u8Aqebj576
FGYfgy77
659397
327296
74748585
19720919
050769585
nicopa
2232566
bearss
n0tpublic
isitreal00
ashraf19760
48144
22471015
antyzhou115
0167005246
ec13kag
226226226226
6767537/33
mimilebrock
gueis8850
fujinshan
counter
N8mr0n
520057
adc123
bmaster
qbjh04zg
ueldaa79
EMANUELLI
yanjing
assynt
62157173
0704224950753
6903293
axaaxa
hilall
30091983
2510618981
soukuokpan
tosecondlife
p4os8m6q
015614117
acw71790
lsyljm2
2xgialdl
gaybar9
88203009
MKltyh87
quiggle
2063775206
fr3iH3it
masich
pengaiwei
coalesce
56402768
thesis
aabbcc894
marion&maxime
614850
ydz220105
584521584521
txudecp
84410545
pietro.chiara
jman1514
heryarma
39joinmam
timelapse
mwinkar
251422
willrock
YHrtfgDK
xys96exq
mercadotecnia
8s5sBEx7
0125040344
margitka
omaopa
dfTi6nh
1314520521
pixma760
pearpear
gothpunksk8er
rftaeo48
8d7R0K
5172032
aics07
34mariah
dongqinwei
samarica
cap10l4
0167387943
AE86Trueno
19700913
mcsuap
bu56mpbu
danbee
passw<>
money521
conan83
nxfjpl
rateg143
kojyihen
058336257
sarah4444
7363437
freindship
JytmvWO848
sb inbau
30907891
0515043111
1973@ati
wlxgjf
20081010
leelou44
8UfjeGbO
200358808
dellede
liang123.
captainettekt
kwiki-mart
mdovydas
tigmys2001
denial
678ad5251
woaiwuai
1591591591212
hNbDGN
cardcap
13985039393
001104
desare11
412724198
nibh1kab
asferg
hqb555
xgames7
muckerlee
choqui67
12130911
lierwei120
skytdvn
milena1995
kambala11

Hashes.org - Leaked Lists

Secure | https://hashes.org/public.php#

LEAKED LISTS

Complete left lists from public leaks

ID	Name	Last Update	Num of Hashes	Progress	Left Hashes	Found
6505	H4v3 1 b33n pwn3d (SHA1)	02.10.2017 - 02:03:24	320'294'464	319'837'535 (99.86%)	Get	Get
5638	P4y4sUGym (MD5)	02.10.2017 - 02:04:19	241'266	221'152 (91.66%)	Get	Get
4920	L1nk3d1n (SHA1)	02.10.2017 - 03:24:58	61'829'262	60'147'825 (97.28%)	Get	Get
3282	4mzr3v13w7r4d3r.c0m (MYSQL5)	02.10.2017 - 03:25:32	41'823	39'166 (93.65%)	Get	Get
3186	X5pl17 (SHA1)	02.10.2017 - 03:32:38	2'227'254	2'162'101 (97.07%)	Get	Get
2499	Hashkiller 32-hex left total	02.10.2017 - 11:48:14	9'976'651	1'723'709 (17.28%)	Get	Get
2498	Hashkiller 40-hex left total	02.10.2017 - 13:22:34	1'739'204	350'788 (20.17%)	Get	Get
1619	4m4t3urc0mmuni7y.c0m	02.10.2017 - 13:33:26	197'302	57'407 (29.1%)	Get	Get
1535	b73r.c0m (MD5)	02.10.2017 - 13:34:43	63'070	32'543 (51.6%)	Get	Get
1427	4v17r0n.fr	02.10.2017 - 13:34:43	2'405	2'334 (97.05%)	Get	Get
1366	v0d4f0n3 (MD5($pass."s+(_a*)")	02.10.2017 - 13:34:44	322	307 (95.34%)	Get	Get

Password Hashing Functions

Problem: hash functions are very fast to evaluate ➔ facilitate fast password cracking

Solution: slow down guessing process (password “stretching”)

- Benefit: cracking becomes very inefficient (e.g., 10-100ms per check)
- Drawback: increased cost for the server if it must handle many users

Make heavy use of available resources

- Computation should be fast enough to validate honest users, but render password guessing infeasible
- Adaptable: flexible cost (time/memory complexity) parameters

Bcrypt [Provos and Mazières, 1999]

- Cost-parameterized, modified version of the Blowfish encryption algorithm
- Tunable cost parameter (exponential number of loop iterations)

Alternatives: Scrypt (memory-hard), PBKDF2 (PKCS standard)

Online Guessing

Similar strategy to offline guessing, but rate-limited

- Connect, try a few passwords, get disconnected, repeat…

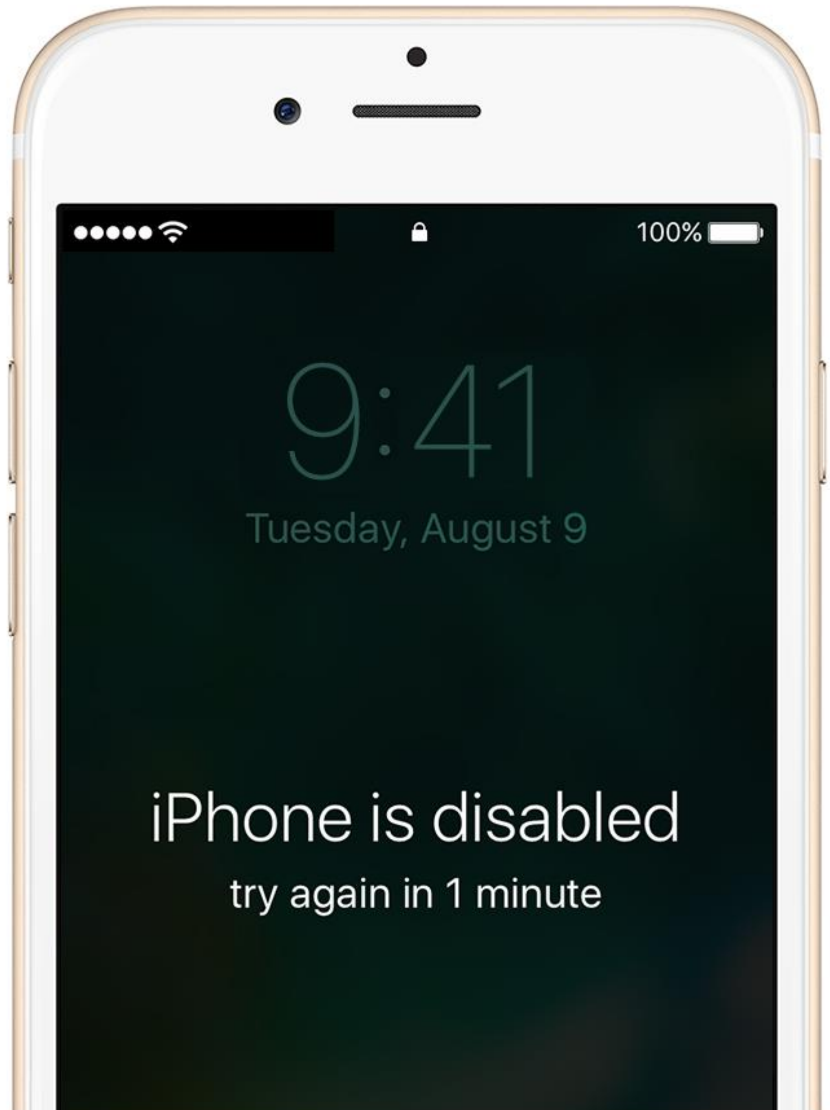
Prerequisite: know a valid user name

Many failed attempts can lead to a system reaction

- Introduce delay before accepting future attempts (exponential backoff)
- Shut off completely (e.g., ATM capturing/disabling a card after 3 tries)
- Ask user to solve a CAPTCHA

Very common against publicly accessible SSH, VPN, RDP, and other servers

- Main reason people move sshd to a non-default port
- Fail2Ban: block IP address after many failed attempts → may allow an attacker to lock you out of the server (!)
- Better: disable password auth and use a key pair → cumbersome if having to log in from many/others' computers


100%
9:41
Tuesday, August 9
iPhone is disabled
try again in 1 minute

LOGIN: mitch
PASSWORD: FooBar!-7
SUCCESSFUL LOGIN

(a)

LOGIN: carol
INVALID LOGIN NAME
LOGIN:

(b)

LOGIN: carol
PASSWORD: Idunno
INVALID LOGIN
LOGIN:

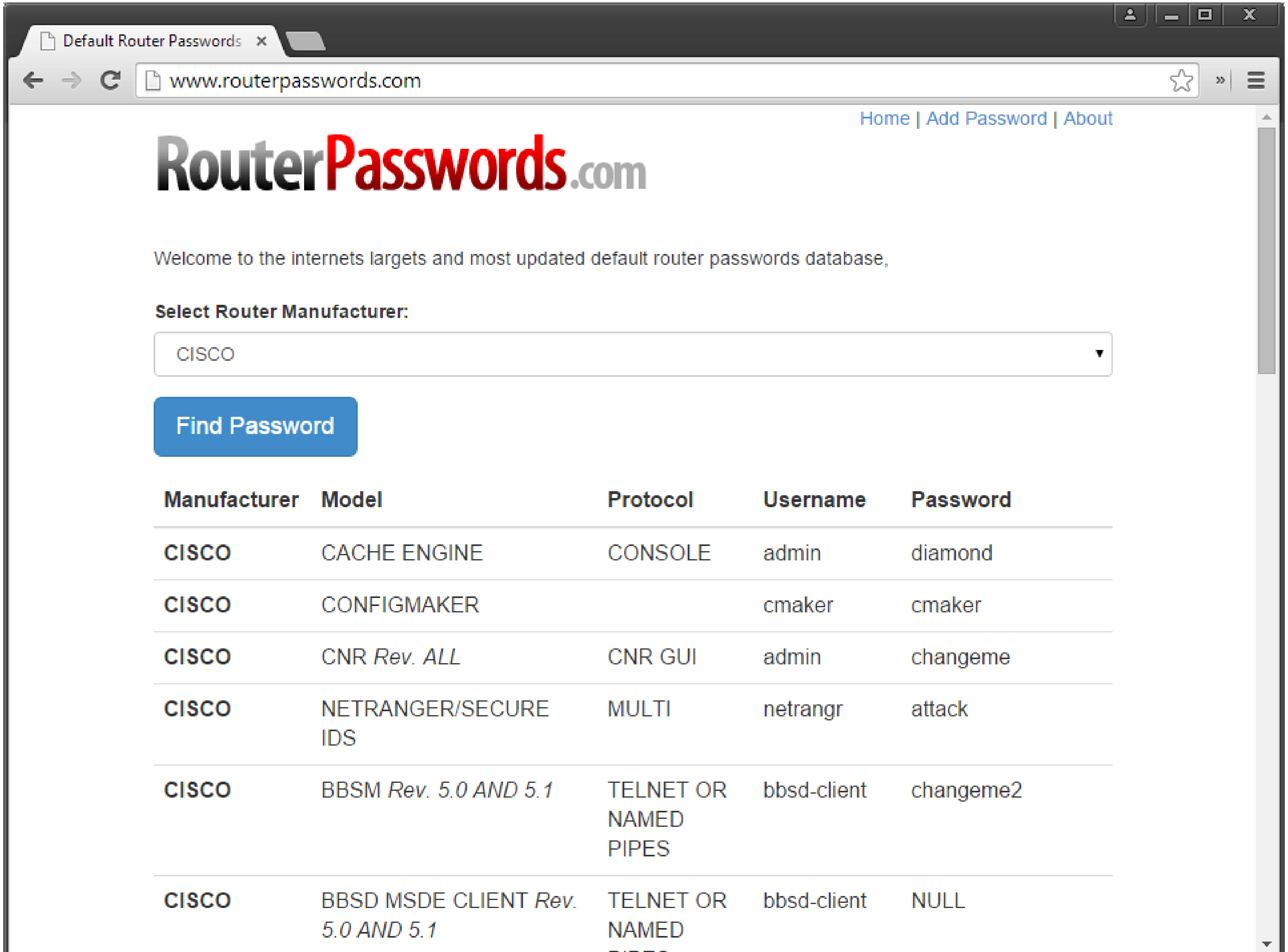
(c)

(a) A successful login

(b) Login rejected after name is entered

(c) Login rejected after name and password are typed ➔ less information makes guessing harder

Try the Default First



Eavesdropping and Replay

Physical world

- Watch user type password (shoulder surfing)
- Cameras (ATMs skimmers)
- Lift fingerprints (iPhone)
- Post-it notes

Network makes things easier

- Sniffing (LAN, WiFi, …)
- Man-in-the-Middle attacks

Defenses

- Encryption
- One-time password schemes

Kerberos

Long-lived vs. session keys

- Use long-lived key for authentication and negotiating session keys
- Use "fresh," ephemeral session keys (prevent replay, cryptanalysis, old compromised keys) for encrypted communication, MACs, …

Kerberos: most widely used (non-web) single sign-on system

- Originally developed at MIT, now used in Unix, Windows, …

Authenticate users to services: using their password as the initial key, without having to retype it for every interaction

- A Key Distribution Center (KDC) acts as a trusted third party for key distribution
- Online authentication: Variant of Needham-Schroeder protocol
- Assumes a non-trusted network: prevents eavesdropping
- Assumes that the Kerberos server and user workstations are secure…

Use cases: workstation login, remote share access, printers, …

Password Capture

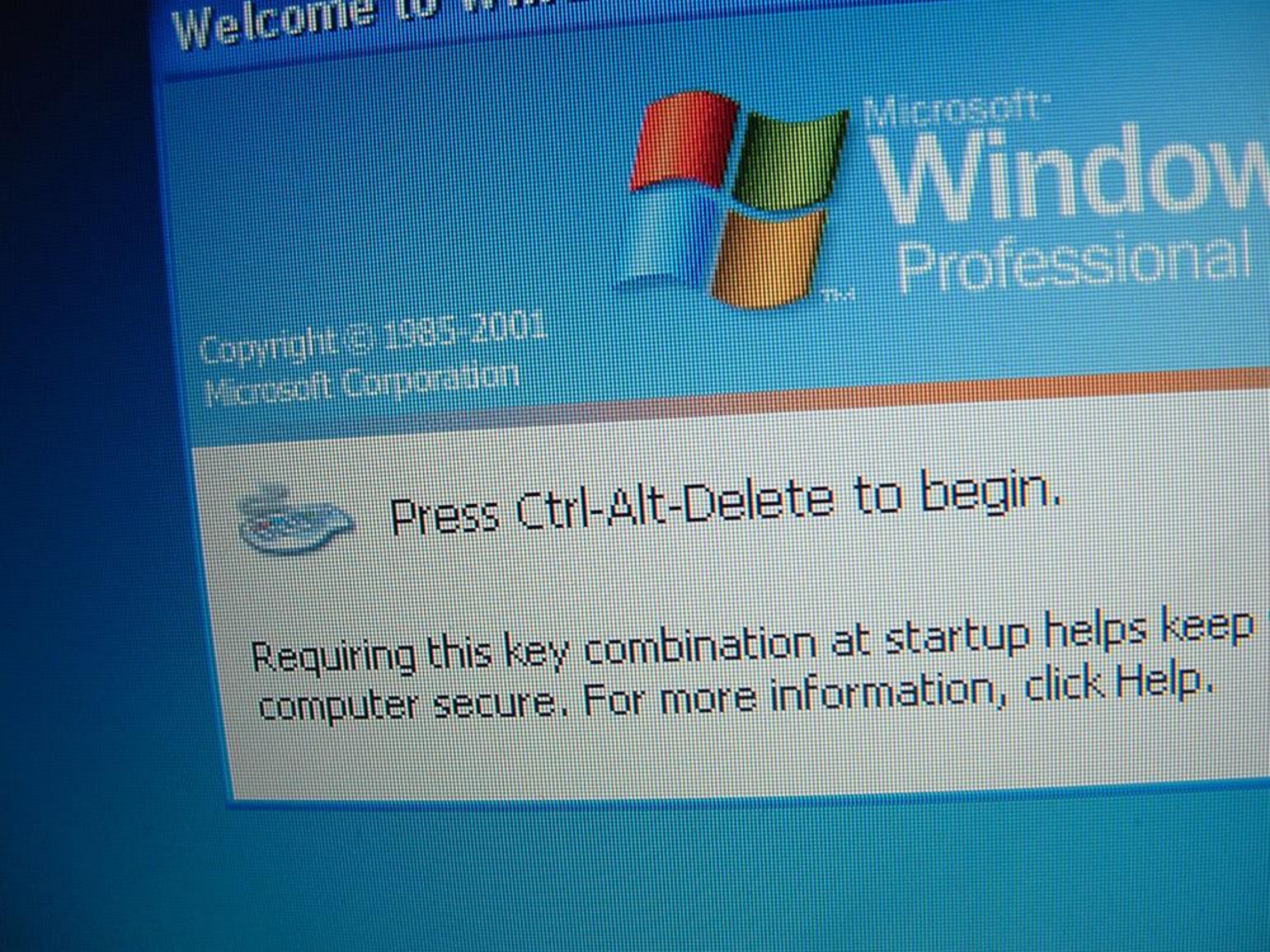
Hardware bugs/keyloggers

Software keyloggers/malware

Cameras

Phishing

Social engineering


Welcome to
Microsoft
Professional
Copyright © 1985-2001
Microsoft Corporation
Press Ctrl-Alt-Delete to begin.
Requiring this key combination at startup helps keep
computer secure. For more information, click Help.

(a) Correct login screen

(b) Phony login screen

Something You Have: Authentication Tokens

One-time passcode tokens

- Time-based
- Counter-based

Other authentication tokens: store certificates, encryption keys, challenge-response, …

Smartcards (contact or contactless)

- Identification, authentication, data storage, limited processing
- Magnetic stripe cards, EMV (chip-n-pin credit cards), SIM cards, RFID tags, …

USB/NFC tokens, mobile phones, watches, …

- Can be used as authentication devices

Multi-factor Authentication

Present several separate credentials of different types

Most common: *two-factor authentication (2FA)*

- Example: Password + hardware token, mobile phone, …
- Example: ATM card + PIN

Motivation: a lost/guessed password is not enough anymore for attackers ➔ not always true

- *Man-in-the-Middle:* set up fake banking website, relay password to real website, let the user deal with the second factor…
- *Man-in-the-Browser:* hijack/manipulate an established session after authentication has completed (banking Trojans)
- *Dual infection:* compromise both PC and mobile device

Implementation-dependent usability issues

- Token may be lost, in-flight WiFi but cannot receive SMS, …
- Fallback: backup one-time-use passcodes (where to keep them?)

SMS Is Not a Secure 2nd Factor

(but still better than no 2nd factor)

Social engineering

Call victim's mobile operator and hijack the phone number

SIM swap, message/call forwarding, …

Message interception

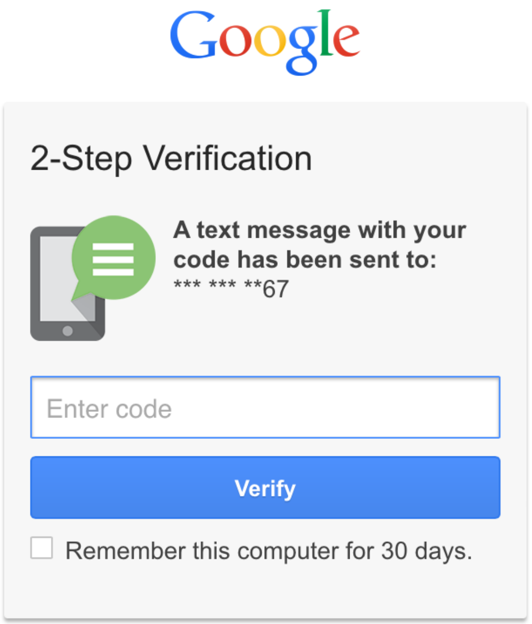
Rogue cell towers: IMSI catchers, StingRays,…

Some phones even display text messages on the lock screen (!)

SS7 attacks

The protocol used for inter-provider signaling is severely outdated and vulnerable

Allows attackers to spoof change requests to users' phone numbers and intercept calls or text messages



'Sim swap' gives fraudste ×

Secure | https://www.theguardian.com/money/2015/sep/26/sim-swap-fraud-mobile-phone-vodafone-customer

Scams

'Sim swap' gives fraudsters access-all-areas via your mobile phone

There's a new, little-known scam designed to empty your bank account, as one Vodafone customer found to her cost

Anna Tims

Saturday 26 September 2015 02.00 EDT

Most popular in US

Las Vegas shooting: death toll rises to 58 as police name suspect - latest updates

Confusion follows reports of Tom Petty death after heart attack

Las Vegas gunman may have used special device to fire faster, expert says

Better Alternative: Authenticator App

Six/eight digit code provided after successful password validation

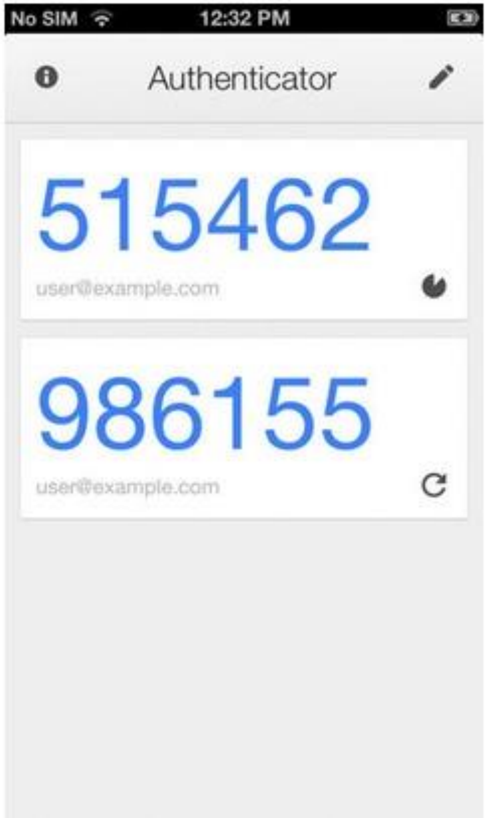
Time-based one-time password (TOTP)

Code computed from a shared secret key and the current time (using HMAC)

The key is negotiated during registration

Requires "rough" synchronization between client and server

Code constantly changes in 30-second intervals



Phishing is still possible!

The attacker needs to proxy the captured credentials in real time (rather than collecting them for later use)

Session hijacking and Man-in-the-Middle are still possible!

After the user has successfully logged in

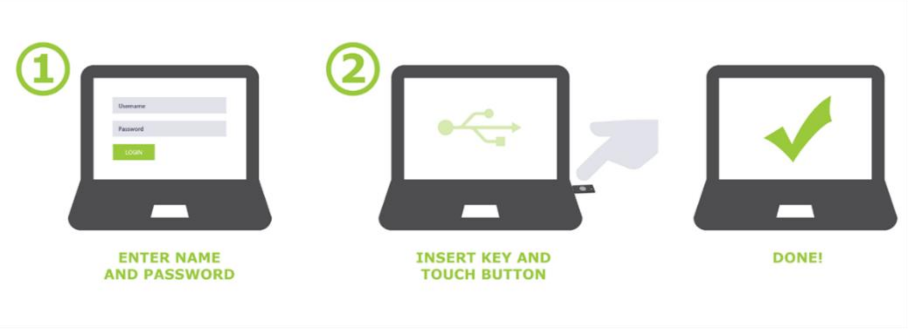
Even Better Alternative: U2F Tokens

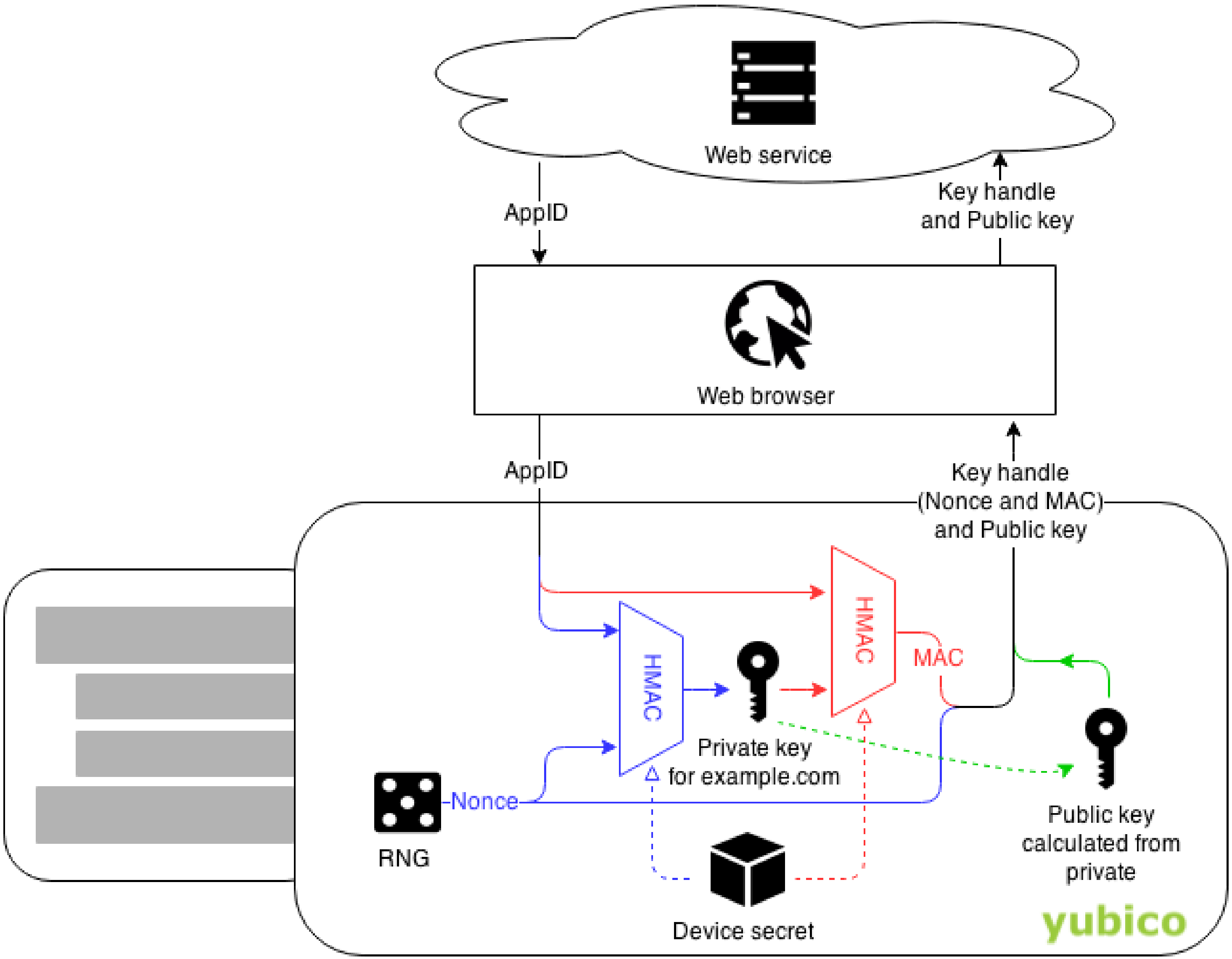
Universal Second Factor (U2F)

- FIDO (Fast IDentity Online) alliance: Google, Yubico, …
- Supported by many popular online services
- Supported by Chrome and Opera (and soon Mozilla and Microsoft)

A different key pair is generated for each origin during registration

- Origin = <protocol, hostname, port>
- Private key stored on device
- Public key sent to server




Web service
AppID
Key handle
and Public key
Web browser
AppID
Key handle
(Nonce and MAC)
and Public key
HMAC
HMAC
MAC
Private key
for example.com
Nonce
RNG
Device secret
Public key
calculated from
private
yubico

U2F tokens

Benefits

- Easy: just tap the button (no typing)
- Works out of the box (no drivers to install)
- USB, NFC, Bluetooth communication
- No shared secret between client and server
- Origin checking → effective against phishing!

Drawbacks

- Can be lost → a fallback is needed (e.g., Authenticator App)
- Still a bit cumbersome: have to pull keychain out of pocket and plug token in (or have an always pugged-in token per device)
- Cost ($7 – $60)
- *Man-in-the-Browser is still possible!*

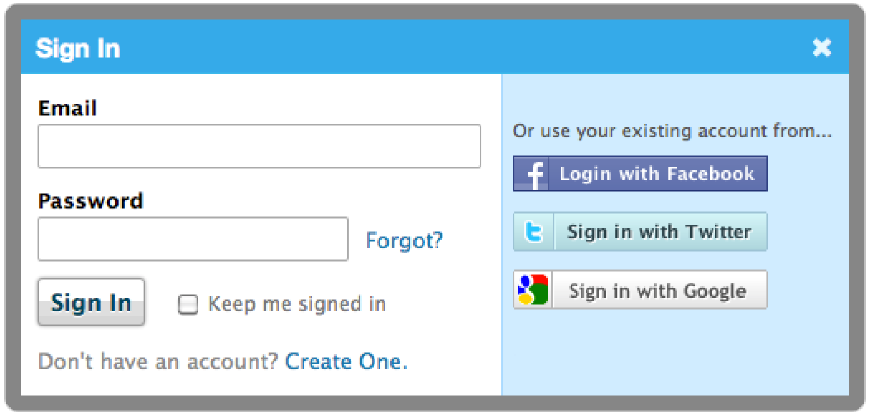
Single Sign-on/Social Login

Pros

- Convenience: fewer passwords to remember
- Rich experience through social features
- Easier development: outsource user registration/management

Cons

- Same credentials for multiple sites: single point of failure
- Access to user's profile
- User tracking



Biometrics

Fingerprint reader

Face recognition

- Depth sensing, “liveness” detection (pulse, thermal), etc. to foil simple picture attack

Retina/iris scanner

Voice recognition

…

Continuous authentication

- Keystroke timing, usage patterns, …

Crypto-based Authentication

Rely on a cryptographic key to prove a user's identity

User performs a requested cryptographic operation on a value (challenge) that the verifier supplies

- Usually based on knowledge of a key (secret key or private key)
- Can use symmetric (e.g., Kerberos) or public key schemes

How can we trust a key? Why is it authentic?

- Need to establish a level of trust

Different approaches: **TOFU**, **PKI**, **web of trust**

- Emerging approach: blockchain/ledger-based PKI

Trust on First Use (aka Key Continuity)

Use case: SSH

- Performs *mutual authentication*

Server *always* authenticates the client

- password, key pair, …

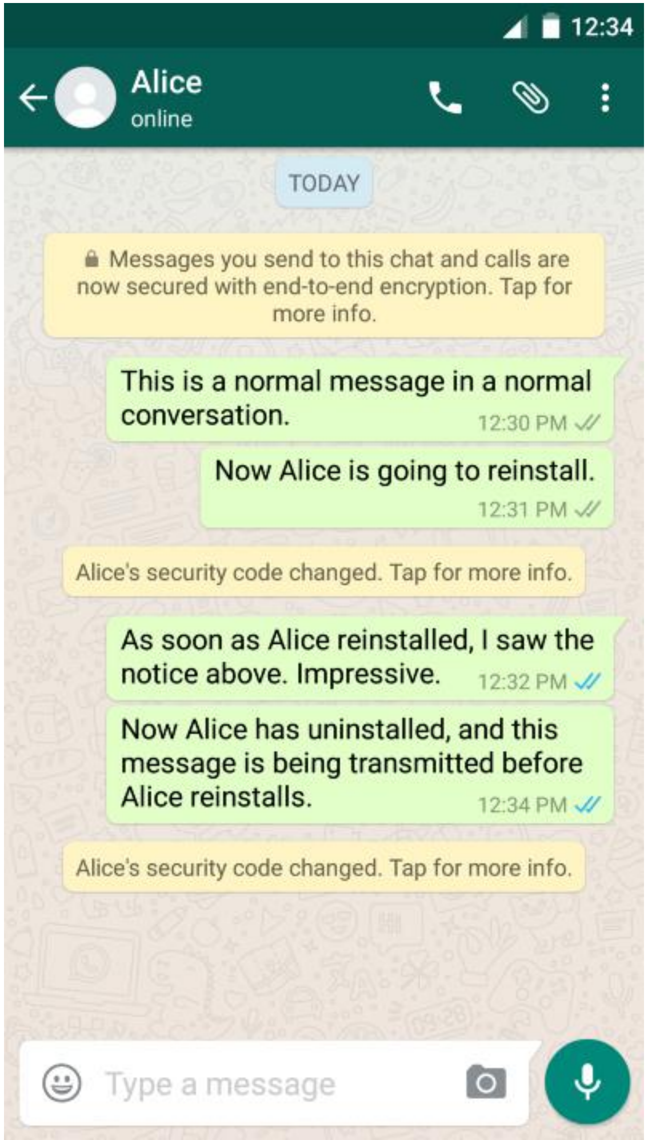
Client almost always authenticates the server – *except the first time!*

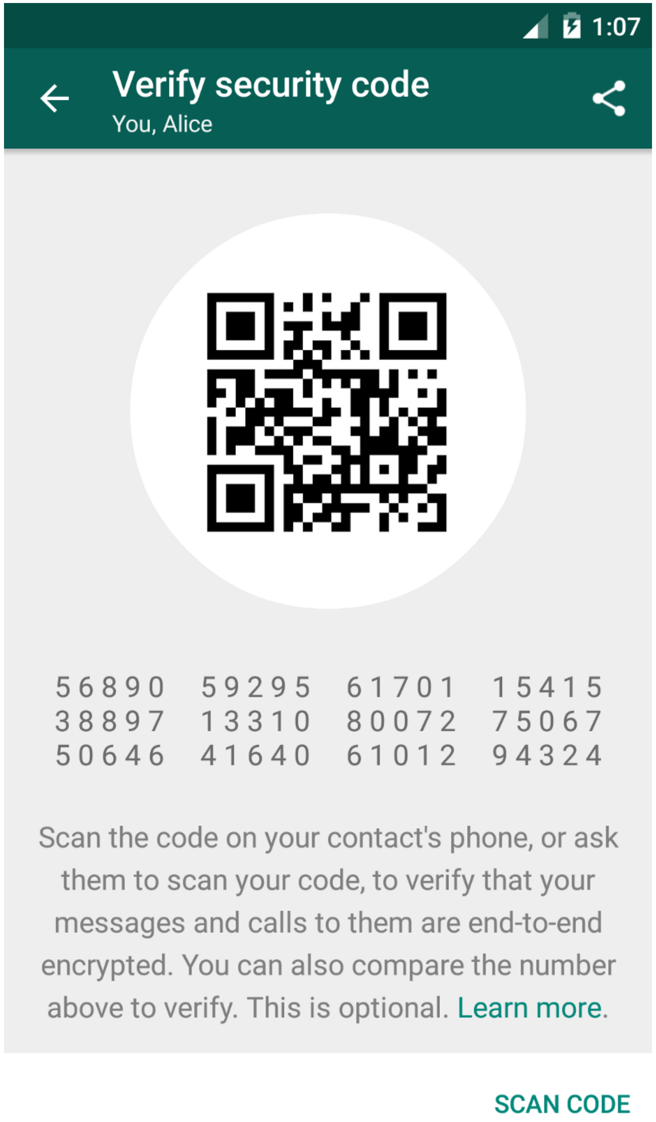
- First connection: server presents its public key
- No other option for the user but to accept it: MitM opportunity
- Subsequent connections: client remembers server's key, and triggers an alert on key mismatch

Pragmatic solution, but shifts the burden to users

- Users must determine the validity of the presented key
- Assuming a key change is valid without verifying the new key offers no protection against MitM (unfortunately, that's what most users do)

```
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
It is also possible that the RSA host key has just been changed.
The fingerprint for the RSA key sent by the remote host is
df:c8:52:aa:cd:e3:da:8c:ec:50:46:db:4d:21:d9:c7.
Please contact your system administrator.
Add correct host key in /root/.ssh/known_hosts to get rid of this message.
Offending key in /root/.ssh/known_hosts:1
RSA host key for 192.168.2.5 has changed and you have requested strict checking.
Host key verification failed.
```


12:34
Alice
online
TODAY
Messages you send to this chat and calls are now secured with end-to-end encryption. Tap for more info.
This is a normal message in a normal conversation. 12:30 PM
Now Alice is going to reinstall. 12:31 PM
Alice's security code changed. Tap for more info.
As soon as Alice reinstalled, I saw the notice above. Impressive. 12:32 PM
Now Alice has uninstalled, and this message is being transmitted before Alice reinstalls. 12:34 PM
Alice's security code changed. Tap for more info.
Type a message


1:07
Verify security code
You, Alice
56890 59295 61701 15415
38897 13310 80072 75067
50646 41640 61012 94324
Scan the code on your contact's phone, or ask them to scan your code, to verify that your messages and calls to them are end-to-end encrypted. You can also compare the number above to verify. This is optional. Learn more.
SCAN CODE

Certificates

How can we distribute "trusted" public keys?

- Public directory → risk of forgery and tampering
- More practical solution: "certified" public keys

A certificate is a digitally signed message containing an identity and a public key

- Makes an association between a user/entity and a private key
- Valid until a certain period

Why trust a certificate?

- Because it is signed by an "authority"
- Third party's signature prevents tampering

Public Key Infrastructures (PKI)

Facilitate the authentication and distribution of public keys based on identities

- Set of roles, policies, and procedures to create, mange, distribute, use, store, and revoke certificates

An issuer signs certificates for subjects

- Trust anchor

Methods of certification

- **Certificate authorities** (hierarchical structure – root of trust)
- **Web of trust** (decentralized, peer-to-peer structure)

Certificate Authorities

Trusted third-parties responsible for certifying public keys

- Most CAs are tree-structured
- Single point of failure: CAs can be compromised!

Why should we trust an authority?

- How do you know the public key of the Certificate Authority (CA)?

CA's public key (trust anchor) must somehow be provided out of band

- Trust has to start somewhere

Operating systems and browsers are pre-configured with ~200 trusted root certificates

- A public key for any website in the world will be accepted without warning if certified by any of these CAs (more in the TLS lecture)

KIM ZETTER SECURITY 09.20.11 03:05 PM

DIGINOTAR FILES FOR BANKRUPTCY IN WAKE OF DEVASTATING HACK

A Dutch certificate authority that suffered a major hack attack this summer has been unable to recover from the blow and filed for bankruptcy this week.

Web of Trust

Entirely decentralized authentication

- No single point of failure
- No need to buy certs from CAs
- Used in PGP

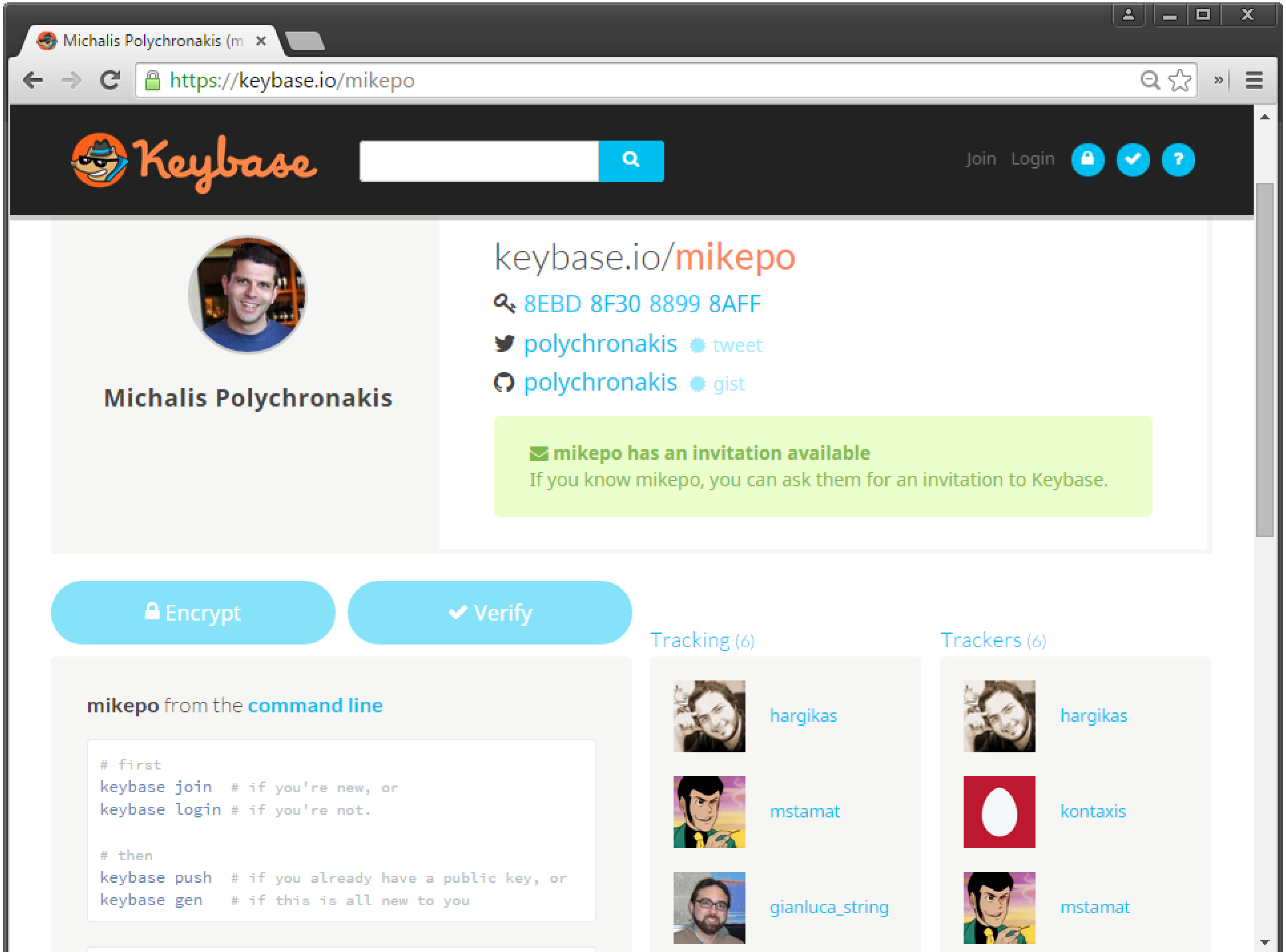
Users sign other users' keys

- Only if they deem them trustworthy
- Certificate signings can form an arbitrarily complex graph
- Users can verify path to as many trust anchors as they wish

Drawbacks

- Hard to use, requires in-person verification – key signing parties!
- Hard to know what trust level to assign transitively

WoT Alternative: Online Social "Tracking"



Keybase.io

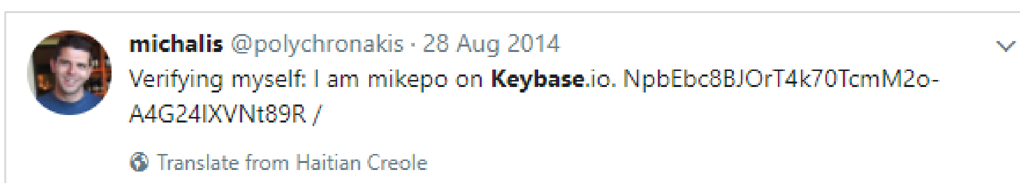
In essence, a directory associating public keys with names

Identity established through *public signatures*

- **Identity proofs**: *"I am Joe on Keybase and MrJoe on Twitter"*
- **Follower statements**: *"I am Joe on Keybase and I just looked at Chris's identity"*
- **Key ownership**: *"I am Joe on Keybase and here's my public key"*
- **Revocations**: *"I take back what I said earlier"*

Keybase identity = sum of other public identities

- Twitter, Facebook, Github, Reddit, domain ownership, …
- Example:



An attacker has to compromise all connected identities

- The more connected identities, the harder to impersonate a user

Best Practices

Pick long passwords (passphrases)

Never reuse the same password on different services

Never share passwords

Use SSH keys instead of passwords

Use two-factor authentication when available

Use Authenticator App or U2F instead of SMS

- Disassociate phone number from account after initial setup

Use a password manager

- Not only for passwords! Also for “security” questions…