Identification

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Introduction

Identification is the task of correctly identifying a user or entity

It is typically **required** for enforcing other security properties

Any time the **access to a resource** needs to be regulated, some form of identification is necessary

Examples:

- Users identify into a system when they **login**
- Users identify to mobile network providers through the **SIM card**
- Users identify to the SIM card through a **PIN**
- Users identify to **ATMs** with cards and PINs

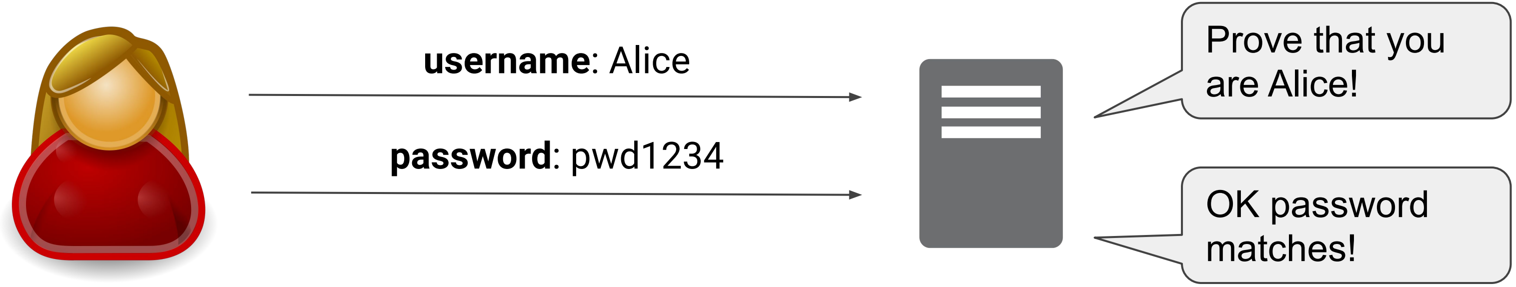
Entity authentication

Identification can be thought as **authenticating a user** or, more generally, an **entity**

- Allow a **verifier** to check **claimant's** identity

Example: login-password scheme

- The user **claims** her identity by inserting the **username**
- The system **verifies** the identity by asking for a **secret password**



username: Alice

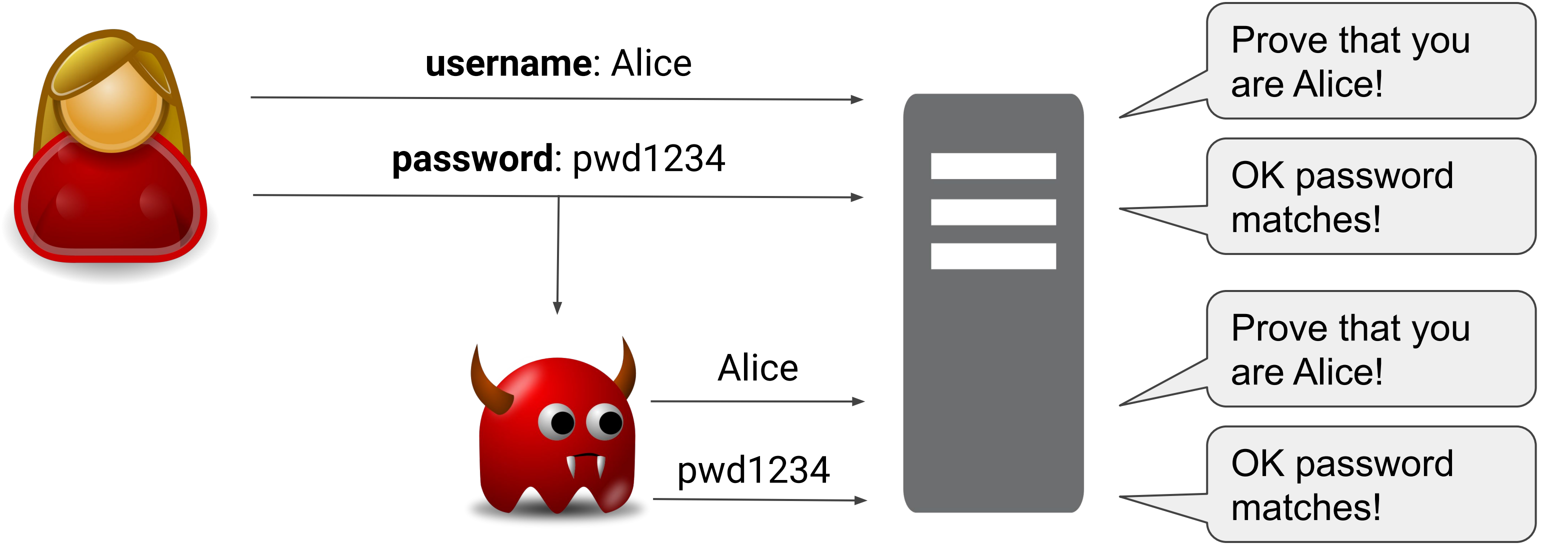
password: pwd1234

Prove that you are Alice!

OK password matches!

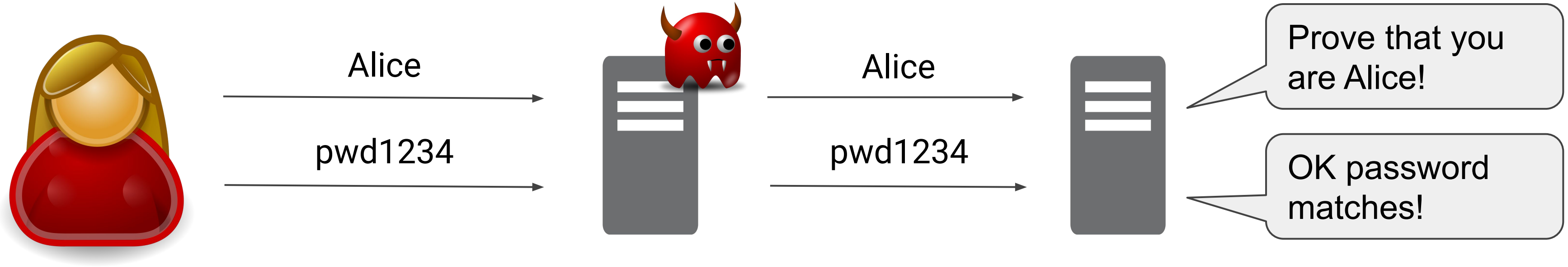
Impersonation

An identification scheme should prevent **impersonation**, even observing previous identifications



Transferability

The verifier should not **reuse** a previous identification to impersonate the claimant with a different verifier, unless **authorized**



NOTE: The verifier has more information available than an attacker, e.g., when the communication is **encrypted**

⇒ Passwords shouldn't be reused!

Classes of identification schemes

Something known. Check the **knowledge** of a secret

- passwords, passphrases, Personal Identification Numbers (PINs), cryptographic keys

Something possessed. Check the **possession** of a device

- ATM cards, credit cards, smartcards, One Time Password (OTP) generators, USB crypto-tokens, smartphones, …

Something inherent. Check **biometric** features of users

- Paper signatures, fingerprints, voice and face recognition, retinal patterns

Passwords

The identity claimed through the **login** information is checked by asking for a corresponding **secret password**

Problem 1: What if the password is *sniffed*?

⇒ stolen passwords allow for **impersonation** (*weak authentication*: secret is exhibited)

Problem 2: What if password is *guessed*?

⇒ guessed passwords allow for **impersonation**

Problem 3: How are password **stored** on the server?

⇒ an attacker getting into the server might steal all the passwords (might be reused for other servers)

Preventing leakage and guess

Problem 1: What if the password is *sniffed*?

Solution: only use password over encrypted channels

Example 1: passwords and card numbers sent over **`https`**

Example 2: `telnet` was an **insecure** remote terminal client sending passwords in the clear

Problem 2: What if password is *guessed*?

Solution 1: Disable the service after MAX attempts

Example: lock SIM after 3 attempts

Solution 2: Use strong passwords

⇒ useful in offline attacks when the service cannot be disabled

“Encrypted” passwords

Problem 3: How are password **stored** on the server?

IDEA: The server stores a *one-way hash* of passwords

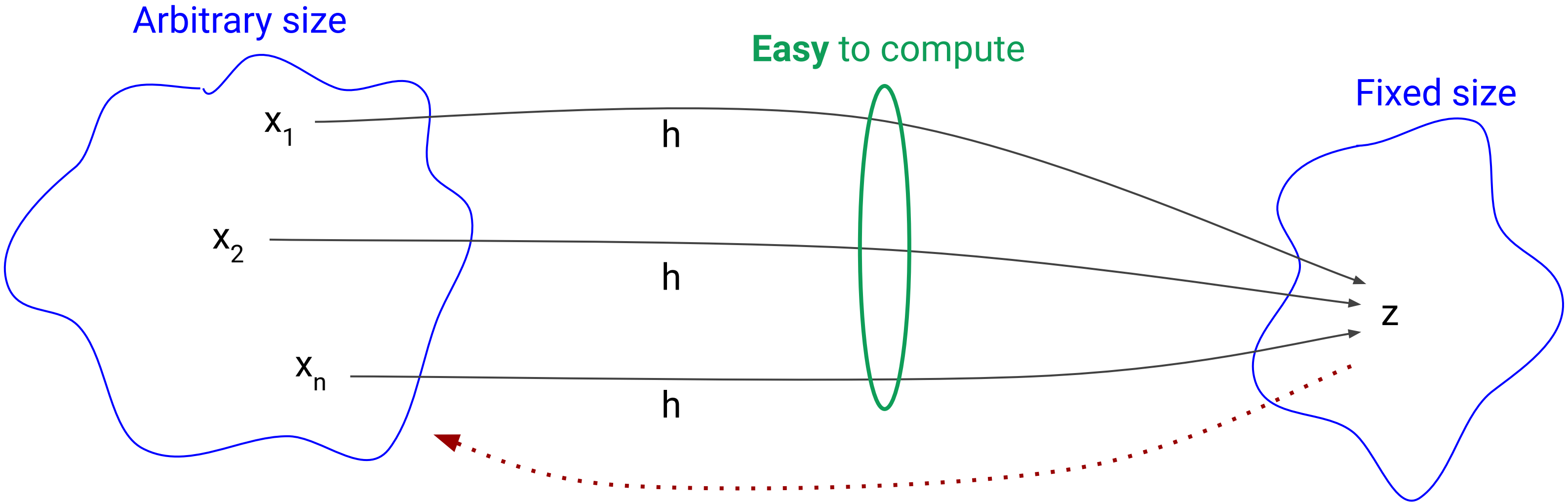
Definition (***hash function***). A hash function h computes efficiently a **fixed length** value h(x)=z called **digest**, from an x of **arbitrary size**.

NOTE: **Collisions** are possible: h(x1) = h(x2)

Definition (***one-way hash function***). A hash function h is **one-way** if given a digest z, it is ***infeasible* to compute a preimage** x’ such that h(x’)=z

⇒ **Finding** a pre-image is computationally infeasible

One-way hash function



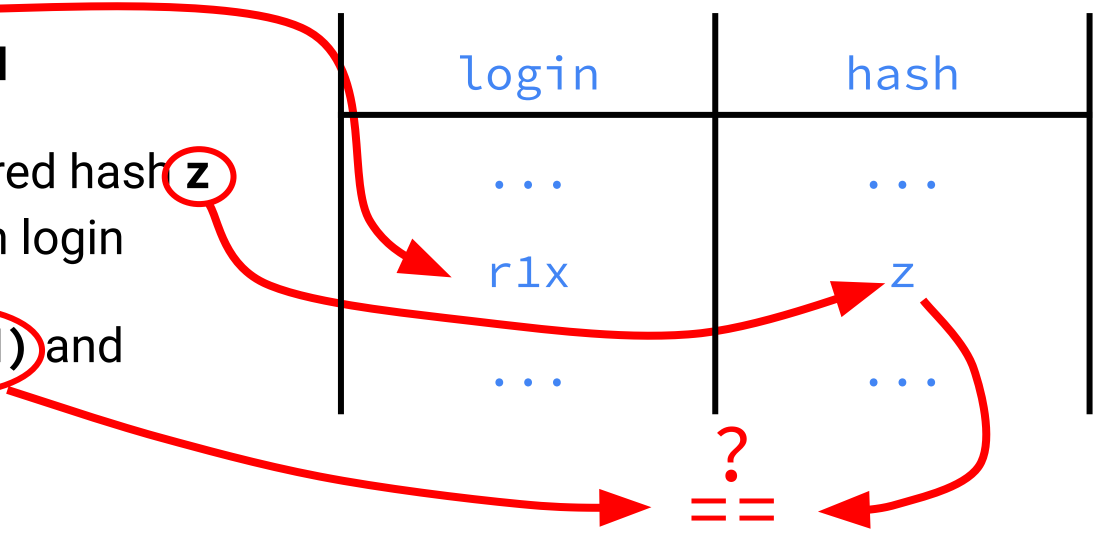
Hard to invert: computing any of x_1, x_2, …, x_n is **infeasible**

Verification of hashed passwords

User is asked for **`login`**, **`pwd`**

The system retrieves the stored hash **`z`** of the password for the given login

The system computes **`h(pwd)`** and checks it is the same as z



login	hash
...	...
r1x	z
...	...

⇒ Since h is one-way, in principle, **no password can be recovered from its hash z**

One-way hash functions

MD5 (Message-Digest algorithm 5) produces 128-bit (16-byte) hash

SHA-1 (Secure Hash Algorithm 1) produces a 160-bit (20-byte) hash

Collision attacks: it is possible to find collisions in MD5 and SHA-1: finding x1 and x2 such that h(x1) = h(x2)

⇒ No efficient attack to compute a valid preimage (still **one-way**!)

SHA-2 (Secure Hash Algorithm 2) produces 224, 256, 384 or 512 bits hashes (28, 32, 48, 64 bytes)

SHA-3 (Secure Hash Algorithm 3) is the result of a NIST competition to establish the new cryptographic hash function standard

SHA-2 is the **most used one**, no reason to switch to SHA-3 yet ...

Examples

Dash ‘-’ stands for stdin (see next slide)

```
$ echo -n "mypassword" | md5sum
34819d7beeabb9260a5c854bc85b3e44  -

$ echo -n "mypassword" | sha1sum
91dfd9ddb4198affc5c194cd8ce6d338fde470e2  -

$ echo -n "mypassword" | sha224sum
9b1cdbab8c8410d63ca8700b12d03b9f0bf93d33b793653cc0983ef3  -

$ echo -n "mypassword" | sha256sum
89e01536ac207279409d4de1e5253e01f4a1769e696db0d6062ca9b8f56767c8  -

$ echo -n "mypassword" | sha384sum
95b2d3b2ad7c2759bf3daa53424e2a472bc932798dae30b982621833a449492883b7ae9d31d30d32372f98abdbb256ae  -

$ echo -n "mypassword" | sha512sum
a336f671080fbf4f2a230f313560ddf0d0c12dfcf1741e49e8722a234673037dc493caa8d291d8025f71089d63cea809cc8
ae53e5b17054806837dbe4099c4ca  -
```

File integrity (never use MD5 and SHA-1)

```
$ sha256sum Assembly/*
23b21ab11641c6bfc3ec3599bcc85a61414fa9b8316002112ff164231efc0fea  Assembly/checkPassword
6ad802b2b45b229abffdf1433df949b526db07b10543b0bd38c56deb65d34820  Assembly/count
034e1535a391e2a3cdf404fc144e124af457155a5a3d2782b122c5d1dae8be2a  Assembly/count.c
$ sha256sum Assembly/* > checksum
```

Digest are computed and stored in checksum

```
$ sha256sum -c checksum
Assembly/checkPassword: OK
Assembly/count: OK
Assembly/count.c: OK
```

Hashes are recomputed and compared with the ones in file checksum

```
$ nano Assembly/count.c

$ sha256sum -c checksum
Assembly/checkPassword: OK
Assembly/count: OK
Assembly/count.c: FAILED
sha256sum: WARNING: 1 computed checksum did NOT match
```

Any modification is detected! Note that for **MD5** and **SHA-1** it is possible to find collisions so **NEVER** use them for file integrity!

Offline attacks

Attacker model: we assume the attacker has access to the password file and tries to recover passwords from their hashes

⇒ **offline** attack!

One-way hashes protect passwords stored on the server, but ...

Problem 2: What if password is *guessed*?

Solution 1 was: disable the service after MAX attempts

The attacker has the password file and can try to hash **any password** of her choice!

⇒ useless for offline attacks!

Solution 2: use strong passwords

⇒ protects from offline attacks

Dictionary attacks

Brute force: even if one-way hashes cannot be inverted, an attacker can try to compute hashes of *easy passwords* and see if the hashes match

Note: It is possible to **precompute** the hashes of a dictionary and just search for z into it

Example:

```
$ echo -n "mypassword" | sha256sum
89e01536ac207279409d4de1e5253e01f4a
1769e696db0d6062ca9b8f56767c8  -
```

Password `"mypassword"` is clearly weak, we can search for the hash directly in search engines or using existing online services

Salting passwords

Precomputation of password hashes is prevented by adding a ***random salt***, different for each user, which is stored together with the hashes

login	hash	**salt**
...	...	...
r1x	z	**s**
...	...	...

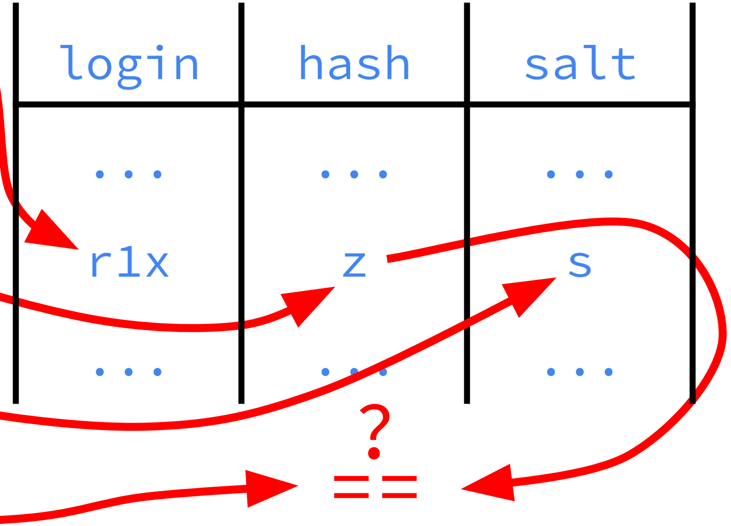
Verification of “salted” passwords

User is asked for **`login`**, **`pwd`**

The system retrieves the stored hash **`z`** of the password for the given login

The system retrieves the stored salt **`s`**

The system computes **`h(pwd,s)`** and checks it is the same as z



login	hash	salt
...	...	...
r1x	z	s
...	...	...

The salt s is **different for each user** and is **stored** in the password file

⇒ Precomputing hashes for each possible salt would require **too much space**

Example

```
$ echo -n "mypassword54otdf84" | sha256sum
3181527671d5dd6b3c1a990ed7b47f3afd69bdfa7794757451639f2b4aa7d65e
```

Password `"mypassword"` is clearly weak

We add “random” salt `"54otdf84"`

Searching for the hash directly in search engines or using existing online services will fail!

⇒ since salt is stored in the file, an attacker can still **bruteforce** easy passwords computing, on-the-fly, the hashes (slower but feasible!)

“Slow” hashes

Instead of using a single hash, hashes are usually iterated so to slow down brute-force

Example: Linux passwords

```
goofy:$6$Lc5mF7Mm$03IT.AXVhC3Vl4/rLAdomffgv5feOlKBzNGtpEei
2dBgK9z/4QBqM3ZMRK4qcbbYJhkAE.2KscEZx0Am/y50: .....
```

- `6`: SHA512-based hashing, iterated **5000** times, by default
- `Lc5mF7Mm`: salt
- `03IT.AXVhC3...Zx0Am/y50`: digest

Example ctd.

Linux passwords in python:

```
>>> import crypt
>>> crypt.crypt("donald","$6$Lc5mF7Mm$")
'$6$Lc5mF7Mm$03IT.AXVhC3Vl4/rLAdomffgv5feOlKBzNGtpEei2dBgK9z8B/4QB
qM3ZMRK4qcbbYJhkAE.2KscEZx0Am/y50'
```

Command line tool (provided by `whois` package in ubuntu):

```
$ mkpasswd donald -m sha-512 -S Lc5mF7Mm
$6$Lc5mF7Mm$03IT.AXVhC3Vl4/rLAdomffgv5feOlKBzNGtpEei2dBgK9z8B/4QBq
M3ZMRK4qcbbYJhkAE.2KscEZx0Am/y50
```

Increasing the iterations

```
$ time mkpasswd donald -m sha-512 -S Lc5mF7Mm
$6$Lc5mF7Mm$03IT.AXVhC3Vl4/rLAdomffgv5feOlKBzNGtpEei2dBgK9z8B/4QBqM3ZMRK4qc
bbYJhkAE.2KscEZx0Am/y50
real	0m0.005s
user	0m0.003s
sys 0m0.002s

$ time mkpasswd donald -m sha-512 -S Lc5mF7Mm -R 5000000
$6$rounds=5000000$Lc5mF7Mm$FWm/GeTLTryHa0Nt/WfrbLqjVOsipSBNP3IUgwbNP7H95eR8
lhKj.6Pc7YczhupXjHXA9QBirkmmaxh3oqt4v.

real	0m1.926s
user	0m1.925s
sys 0m0.001s
```

Default number of iterations is 5000

We raise the number of iterations to 5000000

Salt examples

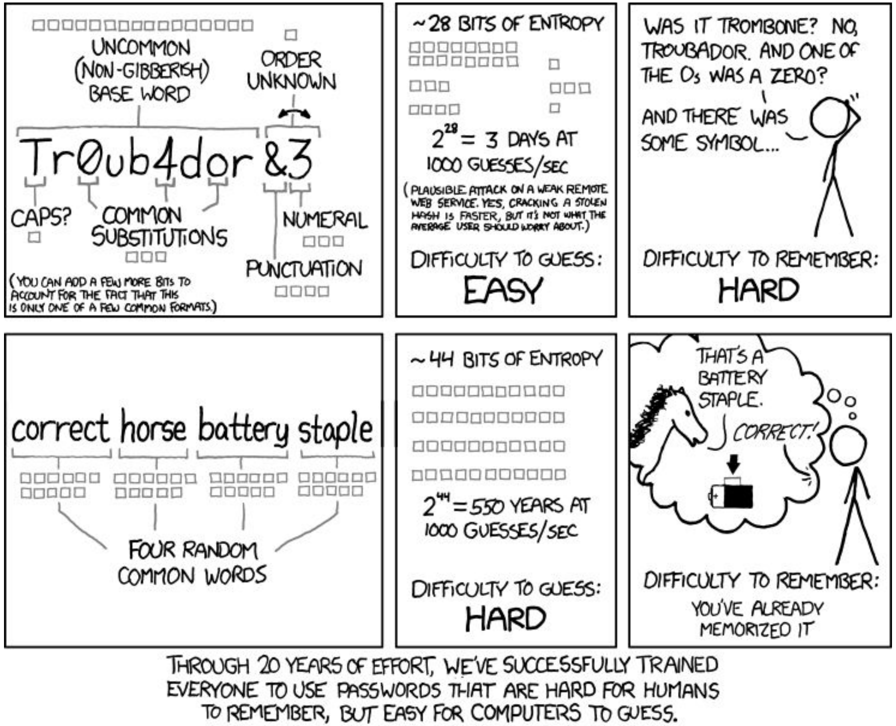
Up to 16 random chars from [a-zA-Z0-9./]

```
$ mkpasswd donald -m sha-512
$6$XGX3asxc$srRtplHNT0Itr44D/xyYbxBNQoPPsYYb6gVNxP372PL0hw9Toit9DQ
KVMtg9/I9DR9UGaZF1sCclcYRscJgDm1

$ mkpasswd donald -m sha-512
$6$zLm12FS6w/Dr$LBUDF9J.uneghlepBGi.OGrWJ9NCdzro5O.j8iq3gJQLt7A2mj
WavWYw7PkISKYHdy63pVI9zLDmkXU2L2Vex.

$ mkpasswd donald -m sha-512
$6$uTOR38Mo16$PLjldovzZAuu6eRVZtbL2HwUeB.VIQ.hQiwhmxmnggDy5EZZufKK
CjrMbXS3rM.2S6oKWK.aEoVFtAFsPJaPP0
```

Password policies

NIST SP 800-63-2 suggests the following alternative rules:

- Password must have at least sixteen characters (**basic16**)
- Password must have at least eight characters including an uppercase and lowercase letter, a symbol, and a digit. It may not contain a dictionary word (**comprehensive8**)


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.

xkcd.com

Diceware

Passphrase of N words picked at random from a fixed list, by rolling 5 dice

- 5 dice gives $6^5 = 7776$ possible words
- Entropy for each word is $\log_2 7776 \sim 12.9$ bits

The **whole entropy** is thus 12.9 N

- for N=4 entropy is ~**52** bits
- for N=5 entropy is ~**64** bits
- for N=6 entropy is ~**77** bits

Word list: http://world.std.com/~reinhold/dicewarewordlist.pdf

Token-based authentication

Something possessed. Check the **possession** of a device

- ATM cards, credit cards, smartcards, One Time Password (OTP) generators, USB crypto-tokens

Memory cards

Passive card with a memory

Examples:

- Old ATM cards with magnetic stripe
- Hotel cards to open doors

When **paired with a PIN** the attacker needs to steal/duplicate both

Problems:

- Passive cards are usually simple to clone

Example:

- Old ATM cards were cloned by putting a fake reader and a camera (to also steal the PIN)

Smart cards

Smart token with embedded chip

Various devices:

- Standard smartcard
- USB token
- Small portable objects
- Bigger objects with display and/or keyboard

⇒ **One time passwords** (OTPs) and **Challenge-response**

Biometrics

Something inherent. Check **biometric** features of users

- Signatures, fingerprints, voice, face, hand geometry, retinal patterns, iris, ...

Biometrics

1. **Enrollment**: features are extracted and stored in database
2. **Verification**: features are extracted and compared with the stored ones

A delicate balance:

No impersonation (no false positives) but correct user should be identified most of the times (no false negatives)

Problems:

A breach in the biometric database has **high impact**:

- biometric data is unique, belongs to users
- differently from passwords it cannot be changed if leaked

New attacks: *adversarial machine learning*