AUTHENTICATION I: PASSWORDS & CO

Introduction to Computer and Network Security

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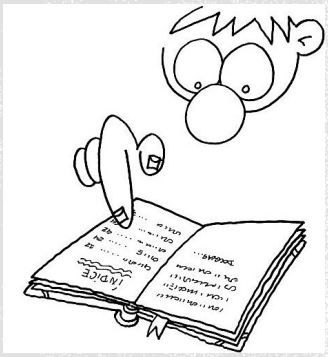
UNIVERSITÀ DI TRENTO

FONDAZIONE BRUNO KESSLER

CONTENTS

- An introduction to passwords
  - History of passwords and lessons learnt
- User authentication and digital identity lifecycle
  - Enrollment and identity assurance levels
- Passwords: attacks and mitigations
  - Protecting the password file: hashing & salting
- Extensions of passwords
- Outsourcing identity management



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AN INTRODUCTION TO PASSWORDS

PRACTICE VS RESEARCH DUALITY

- Passwords dominated human computer authentication for half a century
- Despite this, rising consensus that a **more**
  - **secure** and
  - **user friendly**

  alternative should be found
- Duality between security
  - **researchers** focusing on authentication processes
  - **practitioners** aiming to protect user accounts and sensitive data

- A secure system might have to track the identities of the users requesting its services
  - The user **identity** is recorded when **logging** security relevant events in an audit trail
  - The user **identity** is a parameter in **access control** decisions
- **Authentication**: process of verifying a user's identity

Example
- researchers recommend strict password composition policies
- in practice, little evidence that such policies are effective in reducing security issues

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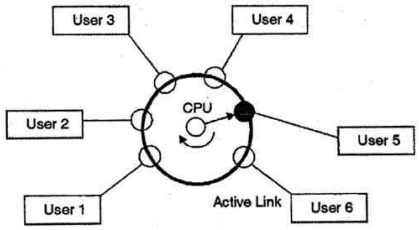
A BIT OF HISTORY



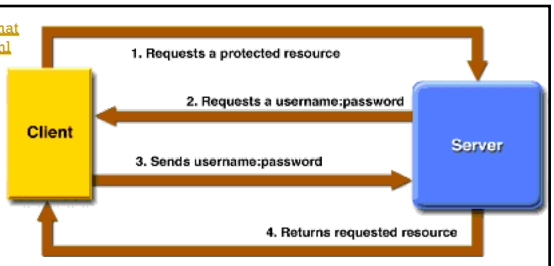
https://ecomputernotes.com/fundamental/disk-operating-system/time-sharing-operating-system

- Passwords originally used in the sixties with **time shared** mainframes
  - Quite different from today situation in the web
- Practices used today in the web are rooted in those of the original mainframes
  - Even though they are no more adequate to the current situation
  - Reasons: inertia and failure of research to come up with alternatives
- For instance, the following two models proposed by researchers are outdated
  - **Random user** drawing passwords uniformly and independently from a given set
  - **Offline attack against password files** that overemphasizes unthrottled guessing with respect to other threats including client malware, phishing, and network eavesdropping that are easier to mount

The use of these models have given rise to suggestions that are extremely difficult to put in practice by humans such as
- use long and randomly generated passwords without writing them down!

http://lia.deis.unibo.it/Courses/TecnologieWeb0708/materiale/laboratorio/guide/j2ee14tutorial7/Security5.html

CURRENT SITUATION



- In the context of **web authentication**
  - no single technology is likely to solve the authentication problem perfectly in all use cases
  - a synergistic combination of several different techniques is more likely to succeed and cope with the heterogeneous requirements arising in different use cases such as
    - social networks
    - financial services
    - healthcare services
    - …
- In practice, several different authentication processes use passwords in combination with other techniques including additional authentication factors (e.g., biometrics or One Time passwords) and Machine Learning for risk based authentication

6 HISTORY OF PASSWORDS AND LESSONS LEARNT

ORIGINALLY A BAND AID

- In the sixties, passwords were originally added to time sharing operating systems to protect against jokes or **abuse of resources**
- Security issues were immediately reported
  - cases of guessing passwords
  - leak of the master password file stored in clear
- In the seventies, passwords were used to protect both resources and sensitive data
  - passwords were protected by using **hash** functions (more on this later)
  - afterwards, not only hashing but also **salting** was used (again more on this later)
  - For a historical overview, refer to the following paper
    https://rist.tech.cornell.edu/6431papers/MorrisThompson1979.pdf

MORRIS WORM

- A **computer worm** is a standalone malware program that replicates itself in order to spread to other computers
- It often uses a computer network to spread itself, relying on security failures on the target computer to access it

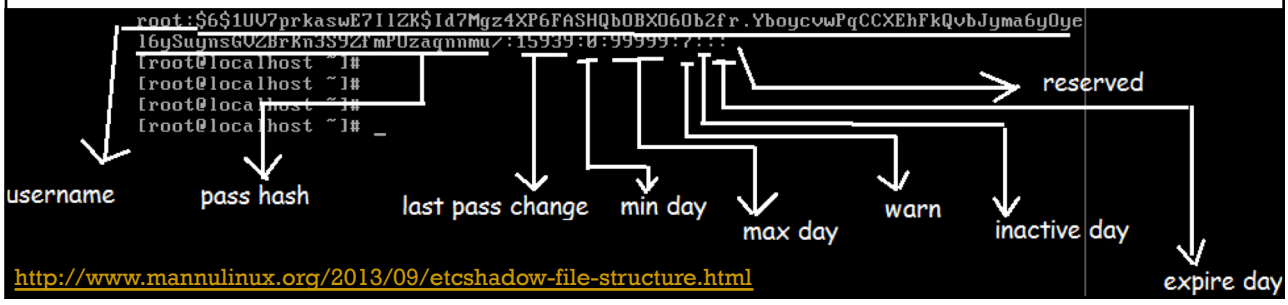
- In 1988, it was one of the first computer worms distributed via the Internet
- Among the vulnerabilities, it also **exploited easy to guess passwords** to spread
- By design, the worm was intended not to do any malicious activity but only to understand the possibility of writing such a program
- Unfortunately, **a coding error allowed the worm to infect multiple times the same computer thus potentially exhausting its resources**
  - In other words, the Morris worm was able to mount a Denial of Service attack
- As a result of the error, the **Internet was partitioned for several days**, as regional networks disconnected from the backbone and from each other to prevent recontamination whilst cleaning their own networks
- Morris was sentenced to pay a fine and some hours of community services
- For a detailed reconstruction, see the following technical report

https://spaf.cerias.purdue.edu/tech-reps/823.pdf

The U.S. General Accounting Office estimated that between $100,000 and $10 million was lost due to the internet inaccessibility that resulted from the attack.

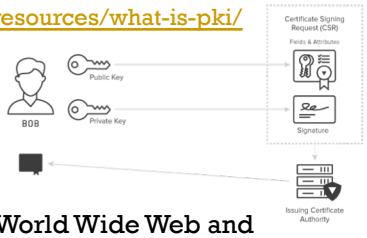
AFTER MORRIS WORM (1)

- In the first half of the nineties, passwords were stored in **shadow** files
- This means that instead of storing the (hashed and salted) passwords, they are moved to another file, called shadow, and making **this file readable only by those users who have access to the system root directory**
  - In other words, we are protecting the shadow file in which the passwords are stored by using another fundamental security mechanism called access control (we will see the details on the latter later in the course)
  - This is an example of using a combination of security mechanisms to protect a sensitive resource (the file containing the passwords) that provides for some redundancy in case of failure of one mechanism



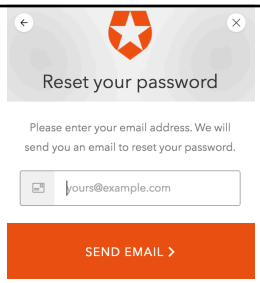
http://www.mannulinux.org/2013/09/etcshadow-file-structure.html

https://www.keyfactor.com/resources/what-is-pki/



AFTER MORRIS WORM (2)

- In the second half of the nineties, there was the advent of the World Wide Web and eCommerce
- This period has seen the first attempt to replace passwords with **certificates based on public key cryptography** (we will study this and other cryptographic techniques later in the course)
- This failed because **managing both client and server side certificates proved to be too cumbersome**
- Thus **certificates are used only by servers while users at the client side are typically asked to enter passwords or other credentials to authenticate at servers**
  - Here we are referring to the Transport Layer Security (TLS) that will also be discussed later in the course

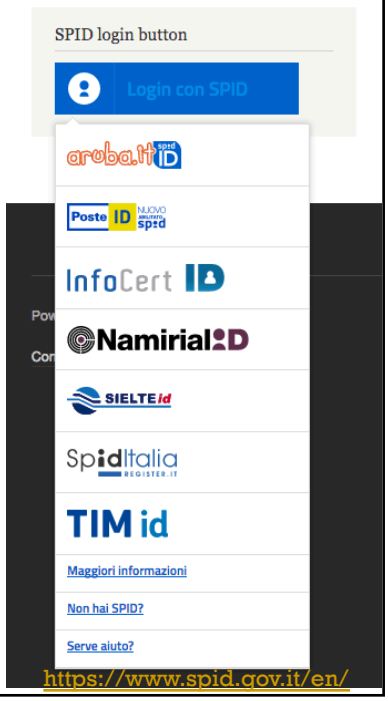


PASSWORDS AND THE WEB

- Since the second half of the nineties, web services proliferated and usability problems for passwords arose that did not exist before
- **Resetting forgotten passwords**, previously done manually by system administrators of organizations, was automated **by email** may create a security loophole for several reasons including
  - In many cases, users can click on a password reset link and get their old password delivered to their inbox. For this to work
    - the passwords are retrievable which means that they are either being stored in the site's database as plaintext or encrypted with a reversible algorithm
  - Additionally, passwords are sent without encryption so hackers sniffing network traffic could steal them
- The increased number of accounts per user stimulates the **reuse of the same password for multiple services** to help them memorize a reasonable number of passwords
- **Phishing** has emerged as a major concern with statistical approaches to mitigate it including blacklisting of known phishing site or machine learning classifiers to identify phishing messages such as those used by Google Mail

OUTSOURCING AUTHENTICATION

- Several attempts to make a business out of authentication in the consumer space without too much success
- Hardware tokens used as second factor authentication were never widely adopted because of their cost
- Smartphones may change this as they may run applications capable of computing or receiving one time passwords as second factors for authentication without the need of buying dedicated hardware
- National digital identity infrastructures sponsored by many Member States in Europe obtained different levels of success because of the not always clear business models for identity providers
  - An example of this is the *Sistema Pubblico di Identità Digitale (SPID)* in Italy that was more widely adopted only after the pandemics



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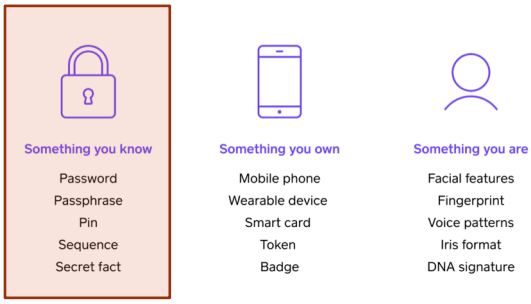
USER AUTHENTICATION & DIGITAL IDENTITY

USER AUTHN



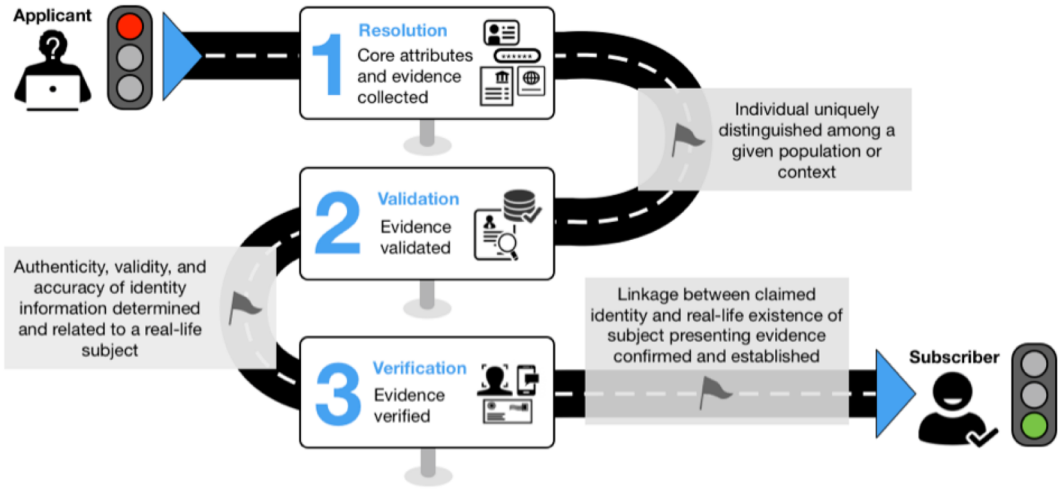
- When logging on to a computer you enter
  - **user name** and
  - **password**
- Entering user name:
  - You announce who you are
- Entering password:
  - You prove that you are who you claim to be
- This type of 'authentication' is called *user authentication*: the process of verifying a claimed user identity
- *Authentication by password* is widely accepted and not too difficult to implement (although it may be tricky)

AUTHN: BOOTSTRAPPING

Similar problems occur when resetting passwords…

- **Passwords** should be ***secrets*** *shared between the user and the system*
- How do you bootstrap a system so that the password ends up in the right hands (better head), but nowhere else?
- *In a small enterprise*, users can collect their password personally
- *Otherwise*, the password could be sent by mail, email, or phone, or entered by the user on a web page or…
  - Who might intercept the message and who might actually pick it up?
    - Ex: a letter containing the password for an online bank account might be stolen or an impersonator may phone in asking for another user's password

IDENTITY PROOFING & ENROLLMENT (1)



Identity Proofing (source NIST) https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-63a.pdf

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IDENTITY PROOFING & ENROLLMENT (2)

- **Resolution**

Individual uniquely distinguished among a given population or context

  - Collection of Personal Identifiable Information (PII) from the applicant
    - Examples: name, address, date of birth, email, and phone number
  - Collection of two forms of identity evidence
    - Example: driver's license and passport by using the camera of a laptop

Minimum set of PII:
- Full name
- Date of birth
- Home address

- **Validation**

Authenticity, validity, and accuracy of identity information determined and related to a real-life subject

  - Validation of the information supplied above by checking an authoritative source
  - Check of the images of the license and the passport for alterations, coherence of the information on the documents and compliance against standard
  - Check with the issuing sources for the license and passport and validates the information matches

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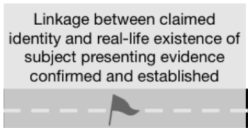
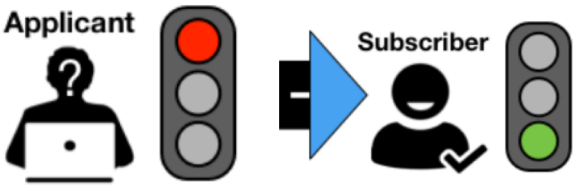
IDENTITY PROOFING & ENROLLMENT (3)



- **Verification**
  - Ask the applicant for a photo of themselves to match to the license and passport
  - Matching the pictures on the license and the passport to the applicant picture
  - Sending an enrollment code to the validated phone number of the applicant, the user provides the enrollment code, and check if they match, verifying the user is in possession and control of the validated phone number
  - The applicant has been successfully identity proofed



ENROLLMENT: IDENTITY ASSURANCE LEVELS

- Identity Assurance Levels (IALs)
  - A category that conveys the degree of confidence that the applicant's claimed identity is their real identity
- **IAL 1**: Attributes, if any, are self-asserted or should be treated as self-asserted
- **IAL 2**: Either remote or in-person identity proofing is required
- **IAL 3**: In-person identity proofing is required. Identifying attributes must be verified by an authorized respresentative through examination of physical documentation

"On the Internet, nobody knows you're a dog."

DIGITAL IDENTITY LIFECYCLE

Relationship starts

The user receives a credential or authenticator from a *Credential Service Provider* (CSP).

Enrollment/on-boarding

The process through which an applicant applies to become a subscriber of an identity system and the identity system validates the applicant's identity.

Authentication

The process of verifying the identity of a user, process, or device, often as a prerequisite to allowing access to a system's resources.

Relationship ends

Deregistration

Authorization/Access control

The process of checking user's permissions to access data, typically automated by evaluating a subject's attributes.

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PROMISES OF DIGITAL IDENTITY (1)

Unlocking the value of the digital economy globally

Today, digital identity is seen as an opportunity to drive **transformational change for citizens, businesses and public administrations**

The adoption of **mobile technology** for digital identity solutions across governments **support and enhance government performance and delivery and promote a more connected society both at national and cross-border level**

Enabled by trusted digital identity **$50bn** Global annual savings by 2020 » **$522bn** Wider economic benefits by 2020

Through digital and technology transformation **$2.5bn** annual savings in 2014-15 in the UK

https://www.gsma.com/identity/wp-content/uploads/2016/02/MWCB16-Digital-Identity-as-a-Key-Enabler-for-eGovernment-Services-Marta-Ienco.pdf

- The theme of a unique digital marketplace is particular relevant in Europe
- One of the basic enabler is to make national digital identity system interporable
- This is one of the goals of the eIDAS framework that is currently undergoing an update
  - https://digital-strategy.ec.europa.eu/en/policies/eidas-regulation

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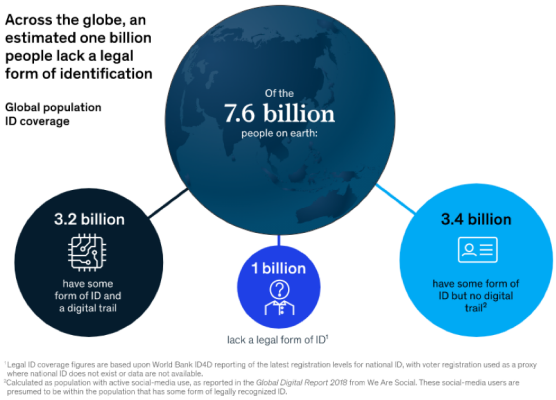
PROMISES OF DIGITAL IDENTITY (2)



[1]Legal ID coverage figures are based upon World Bank ID4D reporting of the latest registration levels for national ID, with voter registration used as a proxy where national ID does not exist or data are not available.
[2]Calculated as population with active social-media use, as reported in the *Global Digital Report 2018* from We Are Social. These social-media users are presumed to be within the population that has some form of legally recognized ID.

- A possible solution to the problem of providing 1 billion people in the world without a legal identity?
- What is the impact of not having a legal identity?
  - Difficulties in accessing basic services such as those of the public administration or financial/banking services

McKinsey & Company

https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/digital-identification-a-key-to-inclusive-growth

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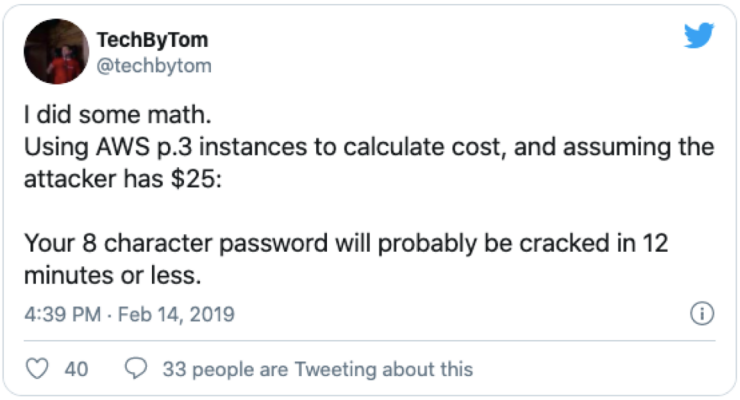
PASSWORDS: ATTACKS & MITIGATIONS

Combination	Combinations per character	Example	Password Space
Lower case only	26	pass	456,976
Lower case only	26	password	208,827,064,576
Lower+upper case	52	Password	53,459,728,531,456
Lower+upper case + digits	62	Pa55w0rd	218,340,105,584,896
Lower+upper case + digits + symbols	92 (approx.)	Pa$$w0rd	5,132,188,731,375,616



https://turingpoint.de/en/blog/how-much-does-it-cost-to-crack-your-password/

#	Numbers	Lowercase	Mixed Case	Mixed Case + Numbers	Mixed Case + Numbers + Special
1	0 $	0 $	0 $	0 $	0 $
2	0 $	0 $	0 $	0 $	0 $
3	0 $	0 $	0 $	0 $	0 $
4	0 $	0 $	0 $	0 $	0 $
5	0 $	0 $	0 $	0 $	0 $
6	0 $	0 $	0 $	0 $	0 $
7	0 $	0 $	0 $	2 $	10 $
8	0 $	0 $	6 $	155 $	965 $
9	0 $	1 $	315 $	12,118 $	94,536 $
10	0 $	16 $	16,391 $	945,165 $	9.3 M$
11	0 $	416 $	852,312 $	73.7 M$	907.9 M$
12	0 $	10,820 $	44.3 M$	6 B$	89 B$
13	1 $	281,330 $	2 B$	449 B$	8.7 T$
14	11 $	7.3 M$	120 B$	34 T$	854 T$
15	113 $	190.2 M$	6.2 T$	-	-
16	1,134 $	5 B$	324 T$	-	-
17	11,339 $	129 B$	-	-	-
18	113,387 $	3.3 T$	-	-	-
19	1,1 M$	86 T$	-	-	-
20	11.3 M$	-	-	-	-

- monetary effort required to break the given password complexity with an **offline brute force attack by simple trial and error**
- expected costs an Amazon EC2 instance (p3.16xlarge - 8xNVIDIA Tesla V100 GPUs) and SHA256 hash algorithm

GUESSING PASSWORDS

- **Brute force** (exhaustive search): try all possible combinations of valid symbols up to a certain length
- Being smarter: search through a restricted name space
  - Ex: passwords associated with a user like name, names of friends and relatives, car brand, car registration number, phone number,…, or try popular passwords
  - Typical example: **dictionary attack**, i.e. trying all passwords from an on-line dictionary
- You cannot prevent an attacker from accidentally guessing a valid password, but you can try to reduce the probability of a password compromise

DICTIONARY: AN EXAMPLE

- Trying a large number of
  1. commonly used names as possible account names and then
  2. try a large number of commonly used passwords for the account
- Commonly used account names
  - root, webmaster, admin, mysql, oracle, guest, test, sales, staff, …
- A password file embedded in the Mirai botnet (see right)
  - 61 pairs (name, password)

https://www.csoonline.com/article/3126924/here-are-the-61-passwords-that-powered-the-mirai-iot-botnet.html

USER:	PASS:	USER:	PASS:
root	xc3511	admin1	password
root	vizxv	administrator	1234
root	admin	666666	666666
admin	admin	888888	888888
root	888888	ubnt	ubnt
root	xmhdipc	root	klv1234
root	default	root	Zte521
root	juantech	root	hi3518
root	123456	root	jvbzd
root	54321	root	anko
support	support	root	zlxx.
root	(none)	root	7ujMko0vizxv
admin	password	root	7ujMko0admin
root	root	root	system
root	12345	root	ikwb
user	user	root	dreambox
admin	(none)	root	user
root	pass	root	realtek
admin	admin1234	root	00000000
root	1111	admin	1111111
admin	smcadmin	admin	1234
admin	1111	admin	12345
root	666666	admin	54321
root	password	admin	123456
root	1234	admin	7ujMko0admin
root	klv123	admin	1234
Administrator	admin	admin	pass
service	service	admin	meinsm
supervisor	supervisor	tech	tech
guest	guest	mother	fucker
guest	12345		
guest	12345		

MITIGATIONS

- Set a password!
  - if there is no password, the attacker does not even have to guess it
- Change default passwords!
  - Often passwords for system accounts have a default value (e.g., admin)
- Avoid guessable passwords:
  - Prescribe a minimal password length
  - Password format: mix upper and lower case, include numerical and other non-alphabetical symbols
  - Today **on-line dictionaries** for almost every language exist

MITIGATIONS

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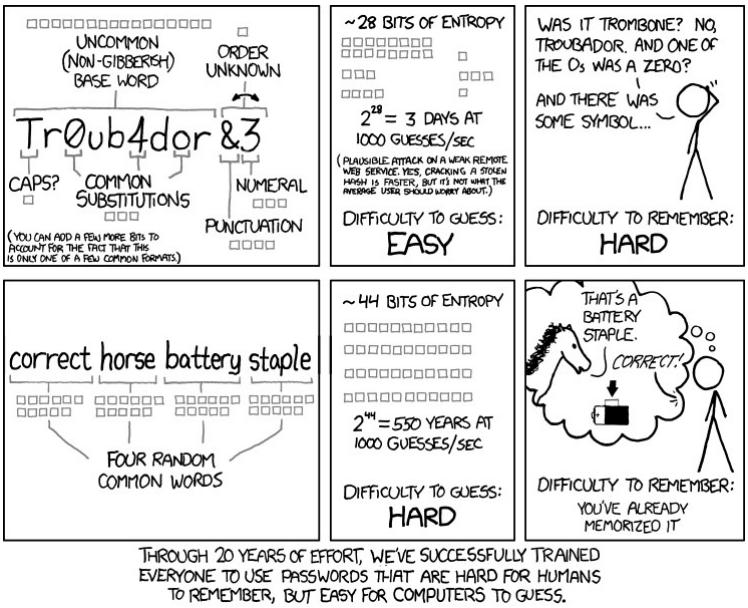
OUTDATED!!!



Old days

Future…

A-HED

The Man Who Wrote Those Password Rules Has a New Tip: N3v$r M1^d!

Bill Burr's 2003 report recommended using numbers, obscure characters and capital letters and updating regularly—he regrets the error

By *Robert McMillan*

Aug. 7, 2017 12:41 p.m. ET

The man who wrote the book on password management has a confession to make: He blew it.

NEW NIST PASSWORD LIMITATIONS

- Forbid commonly used passwords
- Don't use password hints or knowledge-based authentication
- Limit the number of password attempts

PASSWORD GENERATORS & MANAGERS

- Websites and apps offer to create randomly generated password
  - Based on **pseudo random** number **generators** (e.g., linear congruential generators) to create a random string of symbols often of **length between 10 and 16** characters
- If only generators are used, then burden of remembering passwords is on user
  - Notice that generated passwords are **typically longer than 8 characters** because it is becoming cheaper and cheaper to brute passwords of up to that length…
  - … this makes the task of remembering them even more difficult
- If managers are used, then they may be vulnerable to attacks especially if they are on-line

PHISHING AND SPOOFING

- Identification and authentication through username and password provide unilateral authentication
- Computer verifies the user's identity but the **user has no guarantees about the identity of the party that has received the password**
- In phishing and spoofing attacks a party voluntarily sends the password over a channel, but is **misled about the end point of the channel**

SPOOFING

- **Attacker starts a program that presents a fake login screen** and leaves the computer
- If the next user coming to this machine enters username and password on the fake login screen, these values are captured by the program
  - Login is then typically aborted with a (fake) error message and the spoofing program terminates
  - Control returned to operating system, which now prompts the user with a genuine login request

COUNTERMEASURES

- Display number of failed logins
  - Indicate to the user that an attack has happened
- Trusted path
  - guarantee that user communicates with the operating system and not with a spoofing program
    - Ex: Windows has a secure attention key CTRL+ALT+DEL for invoking the operating system logon screen
- Mutual authentication: user authenticated to system, system authenticated to user

PHISHING

- Attacker impersonates the system to trick a user into releasing the password to the attacker
  - Ex: a message could claim to come from a service you are using, tell you about an upgrade of the security procedures, and ask to enter username and password at the new security site that will offer stronger protection
- Take care to enter your passwords only at the "right" site (but how do you know?)
- **Social engineering**
  - Attacker impersonates the user to trick a system operator into releasing the password to the attacker

PROTECTING THE PASSWORD FILE

- Operating system maintains a file with user names and passwords
- Attacker could try to compromise the confidentiality / integrity of password file
- Options for protecting the password file:
  - cryptographic protection
  - access control enforced by the operating system
  - combination of cryptographic protection and access control, possibly with further measures to slow down dictionary attacks

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PROTECTING THE PASSWORD FILE: HASHING & SALTING

Secure storage of login and password

HASH: 1-WAY FUNCTION

- Cryptographic hash functions
- A 1-way function f is a function that is **relatively easy to compute but hard to reverse**, i.e.
  - Given an input x it is easy to compute $f(x)$, but given an output y it is hard to find x so that $y = f(x)$
- Instead of the password x, the value $f(x)$ is stored in the password file; when a user logs in entering a password x', the system applies the one-way function f and compares $f(x')$ with the expected value $f(x)$

HASH FUNCTION

- Requirements on a hash function h
  - Ease of computation: given x, it is easy to compute $h(x)$
  - Compression: h maps inputs x of arbitrary bit-length to outputs $h(x)$ of a **fixed bit-length** n
  - One-way: given a value y, it is computationally infeasible to find an input x so that $h(x) = y$
  - Weak collision resistance: given an input x and $h(x)$, it is computationally infeasible to find another input x', $x \neq x'$, with $h(x) = h(x')$
  - Strong collision resistance: it is computationally infeasible to find any two inputs x and x', $x \neq x'$, with $h(x) = h(x')$

Collision = the situation in which two inputs x and x' map to the same hash, i.e. $h(x) = h(x')$

HASHING IN PRACTICE

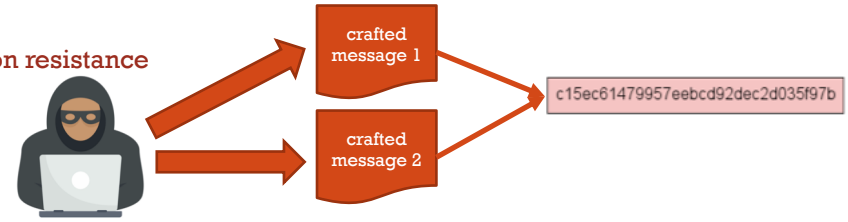
- Just changing one single letter in the input string makes the resulting hashes look very different
- This is called the **avalanche effect**, i.e. small changes to the input result in significantly different output
- This feature makes finding the input given the output much harder as the output looks "random"

Here I use *python3*

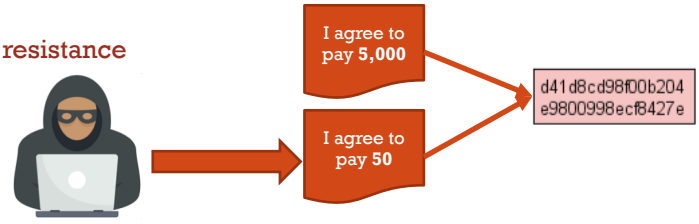
- >>> import hashlib
- >>> str1 = "**homely**"
- >>> hash1 = hashlib.sha256(str1.encode('utf-8'))
- >>> hash1.hexdigest()
  - '**423cb2dd7078b1dac9d67c89b5bb7292f263041abf60455a443664095b47f7b4**'
- >>> str2 = "**comely**"
- >>> hash2 = hashlib.**sha256**(str2.encode('utf-8'))
- >>> hash2.hexdigest()
  - '**6f804dfb2cd3a13c1cc93f6dfea34ea436dc6da85b164697a3ec1e4f135c4285**'

ON COLLISION RESISTANCE

- Strong collision resistance



- Weak collision resistance



HASH FUNCTIONS & COLLISIONS

hashing is the mathematical version of briskly stirring a pot containing 0s and 1s

- Theoretically, it is indeed **possible** to find **collisions** for any given hash function
  - This is obvious as soon as we consider the cardinality of the input set and the output set of a hash function where the former contains potentially unbounded messages and the latter only messages of size *2^n* for a given number *n* of bits
- The point that makes hash function useful in practice is that the **likelihood** that such a **collision** can **happen** should be **negligible**
  - Example
    - when n=128, we have 2^128 = 3.4 * 10^38 possible distinct hashes
    - **under the assumption that the hash function distributes uniformly the outputs among all possible distinct hashes**, it is more likely that the same person repeatedly wins the lottery…
    - For the assumption above to be satisfied, the design of the hash function should be performed in the appropriate way so that its output looks random…
    - … this is not always trivial and it was the source of attacks to widely adopted hash functions in the past…

HASH FUNCTION IMPLEMENTATIONS

- MD4: weak, it is computationally feasible to find meaningful collisions
- MD5: standard choice in Internet protocols, now broken and no longer recommended
- Secure Hash Algorithm (SHA-1): designed to operate with the US Digital Signature Standard (DSA); 160-bit hash value; collision attacks reported
- RIPEMD-160: hash function frequently used by European cryptographic service providers
- SHA-256: when longer hash values are advisable

A COLLISION ON MD5

Violation of strong collision resistance

```
d131dd02c5e6eec4 693d9a0698aff95c 2fcab58712467eab 4004583eb8fb7f89
55ad340609f4b302 83e4888325 71415a 085125e8f7cdc99f d91dbdf280373c5b
d8823e3156348f5b ae6dacd436c919c6 dd53e2b487da03fd 02396306d248cda0
e99f33420f577ee8 ce54b67080a80d1e c69821bcb6a88393 96f9652b6ff72a70
```

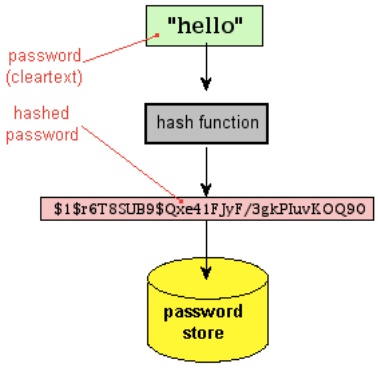
```
d131dd02c5e6eec4 693d9a0698aff95c 2fcab50712467eab 4004583eb8fb7f89
55ad340609f4b302 83e4888325 f1415a 085125e8f7cdc99f d91dbd7280373c5b
d8823e3156348f5b ae6dacd436c919c6 dd53e23487da03fd 02396306d248cda0
e99f33420f577ee8 ce54b6708028 0d1e c69821bcb6a88393 96f965ab6ff72a70
```

```
79054025255fb1a26e4bc422aef54eb4
```

Two 128 bytes block yielding the same MD5 digest differing for only 6 bits

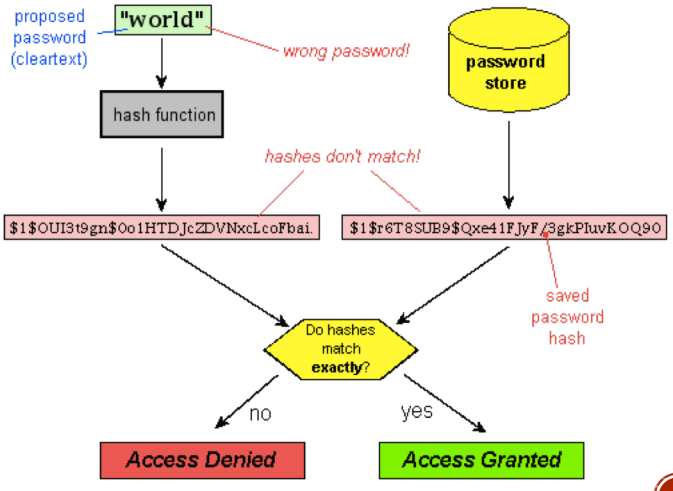
https://en.wikipedia.org/wiki/MD5

PROTECTING PASSWORD FILES PUTTING THINGS TOGETHER

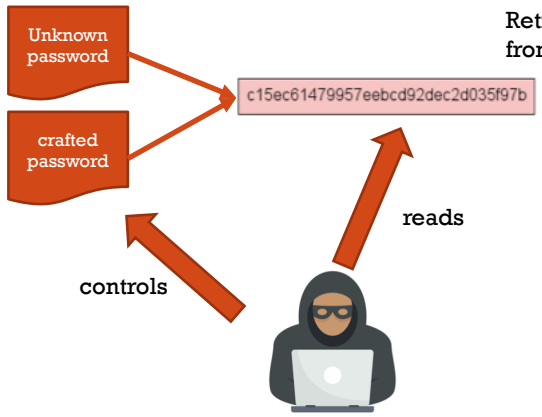


Storing

Verifying



VIOLATION OF ONE WAY PROPERTY



Retrieving a password from a password file

Notice that it is not strictly necessary to guess the password, it is "sufficient" to come up with a string yielding the same digest to authenticate as the user…

PROBLEMS WITH HASHED PASSWORDS

- Dictionary attacks
  - Use one of the many available on-line
  - Notice that hashes can be **pre-computed** and stored in databases whose key is the hash
  - Huge amount of storage space that is becoming cheaper (because of cloud services)
  - Effective when a large number of passwords are to be cracked
    - Pre-computed hashes of the content of the dictionary needs be generated only once
    - When completed, password hashes can be looked up almost instantly to find the password
- Rainbow tables
  - Data structure that aims to reduce storage requirements at the cost of slightly longer lookup-times

Have a look at the following site
https://hashtoolkit.com/
for an example of a searchable database of hash digests…

SALTING

Salt = fixed-length random value

- We refer to $f(x)$ as the hashed password, i.e. to the hash/digest of x
- To slow down dictionary attacks, a salt is appended to the password before hashing and stored with the hashed password
  - If two users have the same password, they will now have different entries in the file of hashed passwords
  - Ex: Unix uses a 12 bit salt

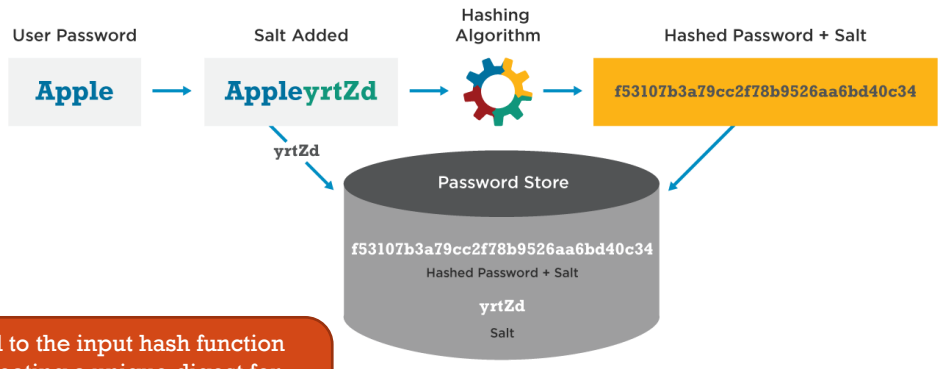
SALTING IN PRACTICE

- A UUID (Universal Unique Identifier) is a 128-bit number used to uniquely identify some object or entity on the Internet
- uuid4() creates a random UUID

Again I use *python3*

- >>> import hashlib, uuid
- >>> str = "Tyger Tyger, burning bright, In the forests of the night; What immortal hand or eye, Could frame thy fearful symmetry?"
- >>> salt = uuid.uuid4()
- >>> salt
  - UUID('f4c7d2be-59d6-45ea-a34b-81e02c88ebbb')
- >>> salt.hex
  - 'f4c7d2be59d645eaa34b81e02c88ebbb'
- salted_hash = hashlib.**sha512**(str.encode('utf-8') + salt.hex.encode('utf-8'))
- >>> salted_hash.hexdigest()
  - '96d3e17abc98249c75daadf8ffd96cb4b0719b95fd2e328c151c215b0394b750d195790f068e97a7983516d75318ba70870f82b376f15954699ff0fe9ade2b3c'

Password Hash Salting



A salt added to the input hash function allows for creating a unique digest for every password (regardless of the input not being unique as in the case of two users with the same password)

https://cyberhoot.com/cybrary/password-salting/

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SALTING AS A MITIGATION TO DICTIONARY ATTACKS

- When the salt is unique for each hash, an attacker must re-compute a rainbow table for each user hash
- This greatly reduces the capability of an attacker to crack a lot of passwords as it was the case without salting
- Notice that an attacker may still be able to crack a single password once he or she knows the salt that is not necessary to be kept secret
  - For simplifying the verification of hashes, salts are usually stored in clear with the user name and hash of the password
- Typical good sizes of salts are 32 or 64 bytes (notice the increase in the length of the password)
- **Final advice**: avoid to implement your own version of hashing and salting but use well—engineered available function such as bcrypt or scrypt

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YET ANOTHER ATTACK: CREDENTIAL STUFFING

- Attackers take millions or even billions of email addresses and corresponding cracked passwords from compromised databases and see how many of them work at other online services

- Mitigation
  - Company first extracts from leaked credential lists any email addresses that correspond to their current user base
  - Feed passwords according to standard verification process (hashing & salting) and obtain hash code C
  - Compare stored hash code with C: if they are different, then do nothing
  - If they are equal, then force password reset procedure for the user
  - More info at https://krebsonsecurity.com/2019/08/forced-password-reset-check-your-assumptions/
  - See also at https://www.troyhunt.com/ive-just-launched-pwned-passwords-version-2/ for a list of half a billion passwords to download

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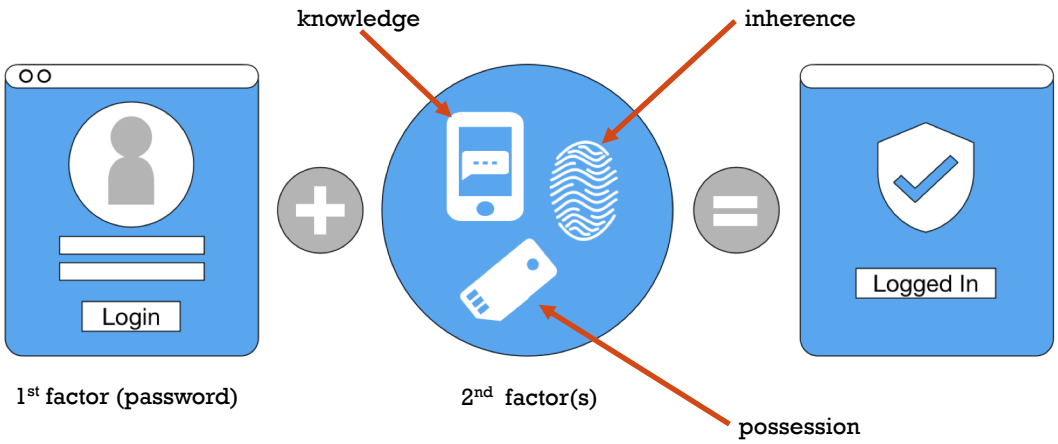
EXTENSIONS OF PASSWORD BASED AUTHENTICATION

To cope with the limitations of passwords and the difficulty of managing credentials for the web

MULTI FACTOR AUTHENTICATION (MFA)



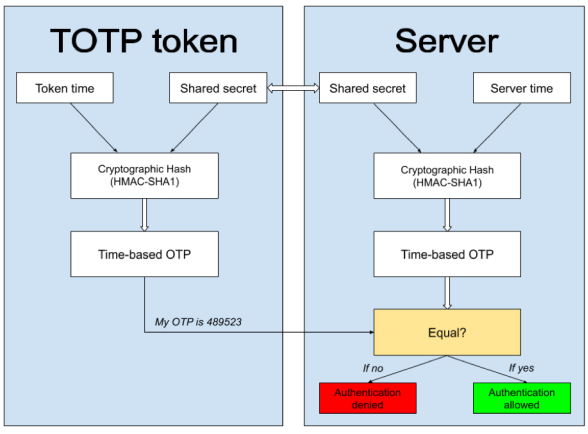
MFA: A (COMMON) SCENARIO

MULTI FACTOR AUTHENTICATION (MFA)

- MFA = authentication method in which a computer user is granted access only after successfully presenting **two or more factors** to an authentication mechanism:
  - knowledge (something the user and only the user knows)
  - possession (something the user and only the user has)
  - inherence (something the user and only the user is)
- Two-factor authentication (2FA) is a type of MFA confirming users' claimed identities by using a combination of two different factors
  - Example 1: withdrawing of money from an ATM; only the correct **combination of a bank card** (something the **user possesses**) and a **PIN** (something the **user knows**) allows the transaction to be carried out
  - Example 2: **supplement** a user-controlled **password with** a **One-Time Password** (**OTP**) or code generated or received by an authenticator (e.g., a security token or **smartphone**) that only the **user possesses**

https://datatracker.ietf.org/doc/html/rfc6238

TIME BASED ONE TIME PASSWORD



 https://protectimus.medium.com/totp-algorithm-explained-ee4934b91ee3

TIME BASED ONE TIME PASSWORD (TOTP)

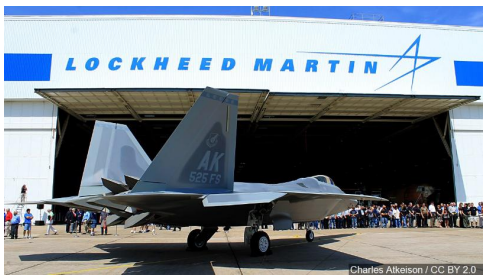
- Parameters
  - T0: Unix time from which to start counting time steps (default is 0)
  - Tx: interval which will be used to calculate the value of the counter (default is 30 seconds)
- Algorithm idea
  - Authenticator and authenticatee compute the TOTP value then the authenticator checks if the TOTP value supplied by the authenticated matches the locally-generated TOTP value
  - Some authenticators allow values that should have been generated before or after the current time in order to account for slight clock skews, network latency and user delays
- Weaknesses
  - **OTP values** can be **phished** just as passwords can and **replayed**, though they require attackers to proxy the credentials in real time rather than collect them later
  - **An attacker who steals the shared secret can generate new, valid TOTP values at will**. This can be a particular problem if the attacker breaches a large authentication database; this was the case the in the past…

ATTACK TO TOTP: LOCKHEED MARTIN

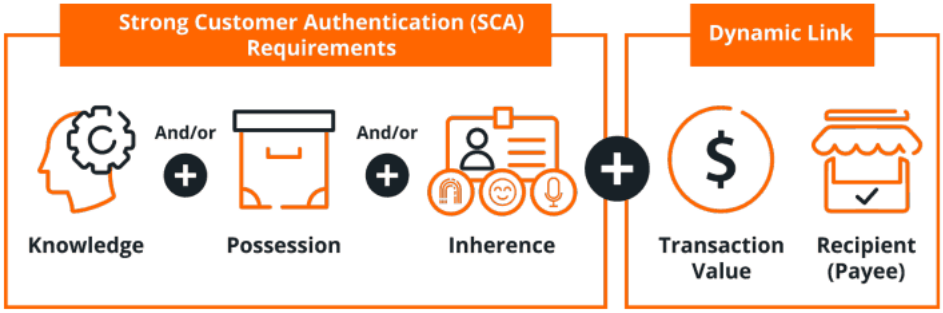
- RSA was hacked in 2007
- **Secret key for OTP tokens stolen**

- Hackers could generate OTP and spoof users
- Companies using RSA SecureID were vulnerable
- Lockheed Martin used RSA SecureID

- **Chinese attackers spoofed Lockheed Martin staff–Stole plans for F-35 fighter jet**



BEYOND TOTP: REVISED PAYMENT SERVICE DIRECTIVE (PSD2)



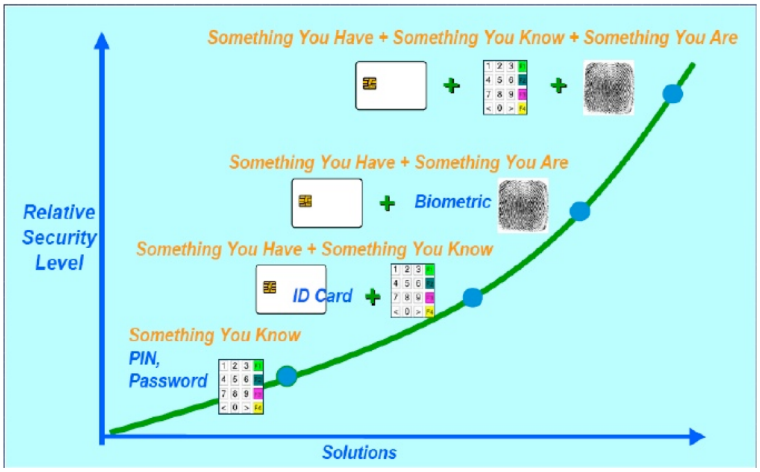
EFFECT OF PSD2: NO MORE TOTP HW TOKEN!

Can you explain why?
Do you see a way to overcome the problem?

USE OF SMARTPHONES AS PART OF MFA

- **Advantages**
  - No additional tokens are necessary
  - Dynamically generated passcodes are safer to use than fixed (static) log-in information
  - Protection to replay attacks as OTP values are uniquely associated to given transaction
- **Disadvantages**
  - A mobile phone is not always available - they can be lost, stolen have a dead battery or otherwise not working
  - Mobile phone reception is not always available - large areas, particularly outside of towns, lack coverage
  - SIM cloning gives hackers access to mobile phone connections
  - Text messages to mobile phones using SMS are insecure and can be intercepted by third parties that can steal and use the token
  - Modern smartphones are used both for receiving email and SMS. So if the phone is lost or stolen and is not protected by a password or biometric, all accounts for which the email is the key can be hacked as the phone can receive the second factor

MFA & ASSURANCE LEVELS



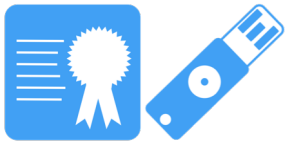
ASSURANCE LEVEL (NIST)

Authenticator = the means used to confirm the identity of a user, process, or device (e.g., user password or token)

Authentication

1. Provides some assurance that the claimant **controls** the **authenticator**; requires at least **single-factor authentication**
2. Provides high confidence that the claimant **controls authenticators**; **two different authentication factors** are required; approved cryptographic techniques are required
3. Provides very high confidence that the claimant **controls** the **authenticator**; authentication based on **proof of possession** of a key through a cryptographic protocol; requires a "hard" cryptographic authenticator

Memorized secrets such as passwords



Cryptographic software and tokens such as apps or tokens

Cryptographic hardware such as smartcards

CONTEXTUAL AUTHENTICATION

- The context (or factors) around a user's login are considered and assessed, to then decide whether the person is who they say they are
  - If there's a chance they are not, then an appropriate action is taken
- Ex: Rich arrives at his San Francisco office every morning and logs in using his desktop computer at about 8am PST. Then Rich takes his first ever business trip to Beijing (China) and he logs in at his hotel via the wifi, from his laptop that he's never used for work before, and at the equivalent of 5pm PST. A simple system might assess the context of Rich's login based on: Location, IP address, Device, Time
  - This login would present a high risk score as all factors fall outside of the behavioural profile that has been established for Rich over time. The login would immediately trigger an alert to be sent to Rich to verify his identity and/or the IT administrator at Rich's company to further investigate this potential security breach. When Rich's identity is confirmed this new data will become a part of his user profile, so the system gets smarter and smarter.

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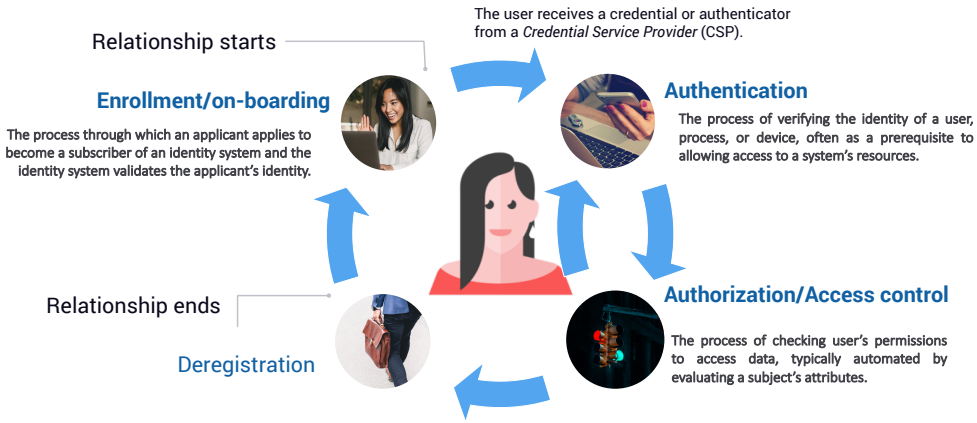
OUTSOURCING AUTHENTICATION

Identity providers: the lazy (and scalable) approach to identity management

THE PROBLEM

- Securing all the phases of the identity management lifecycle is far from being trivial
- Organizations (especially, small and medium sized ones) lack resources to devote to security and need to focus on their core business…



A SOLUTION

- Delegate authentication to a **trusted** 3rd party identity provider
- Organizations can consume authentication assertions while **assuming** it has deployed a secure identity management lifecycle
- Applications and services becomes dependable on the 3rd party identity provider

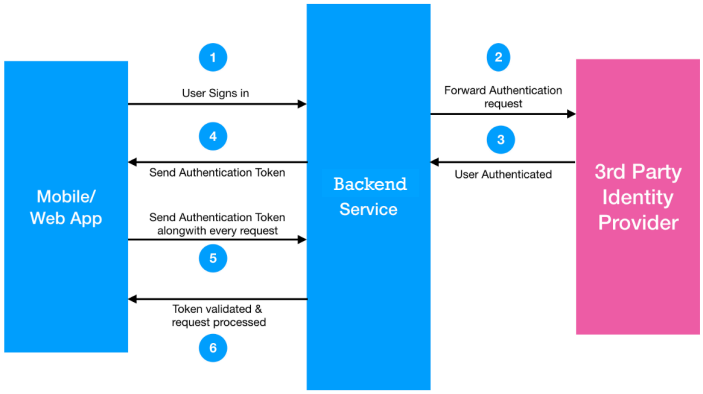


Figure adapted from
https://medium.com/humbledog/azure-app-service-custom-authentication-1b9cab20657

SINGLE-SIGN-ON (SSO)

A standard way to outsource authentication to a trusted 3rd party identity provider

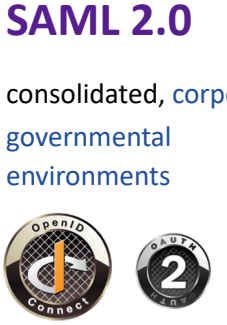
- Having to remember many passwords for different services is a nuisance
  - With SSO, you have to enter your password only once
- A simplistic single-sign on service could store your password and do the job for you whenever you have to authenticate yourself
  - Improves on user experience but raises new security concerns
- **System designers have to balance convenience and security**
  - Ease-of-use is an important factor in making systems really useful, but many practices which are convenient also introduce new vulnerabilities

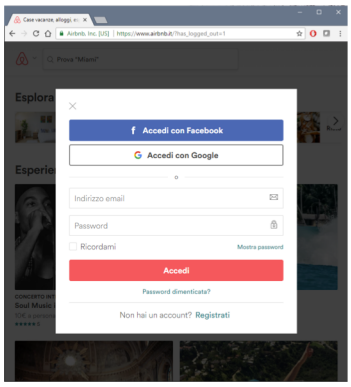
WIDESPREAD ADOPTION OF SSO

Single Sign-On (SSO) allows users to access multiple apps through a single authentication act

SAML 2.0

consolidated, corporate & governmental environments





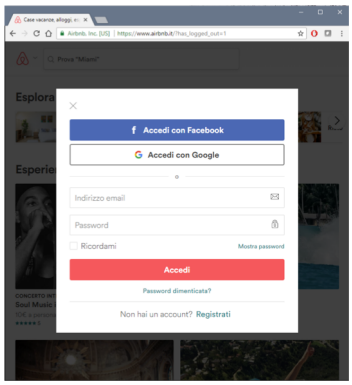
used for social network (billions of user)

PROS & CONS OF SSO

Privacy may also be problematic as the identity provider may link actions of users performed online across different services and applications that trust it

Single Sign-On (SSO) allows users to access multiple apps through a single authentication act

- *Usability*: only a password to remember for several apps
- *Security*: more complex passwords
- *Usability*: shared sessions
- *Security*: Only 1 password to compromise



→ SSO + Multi-Factor Authentication solutions

WRAP-UP

Authentication can be seen as the front door of an application, service or ICT system…

- Authentication amounts to verifying the identity of a user, process, or device, often as a prerequisite to allowing access to resources in an information system
  - Here we focused on user authentication
- Passwords are one of the most widespread and accepted method for user authentication despite their shortcomings
- Adequate security mechanisms should be put in place to protect stored passwords
  - Hashing & salting, access control, …
- Authentication is only one phase of the identity management lifecycle
  - Also other phases (e.g., identity proofing) may have weaknesses
- Given the importance and difficulty of identity management, it is frequently outsourced to trusted third parties with advantages and disadvantages also from the viewpoint of security (and privacy)