

SE507 μ Hacking Password Hashes
with Rainbow Tables

Session 1

Hash Functions and Password Storage

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Objectives

- Understand **user authentication** and how to implement it

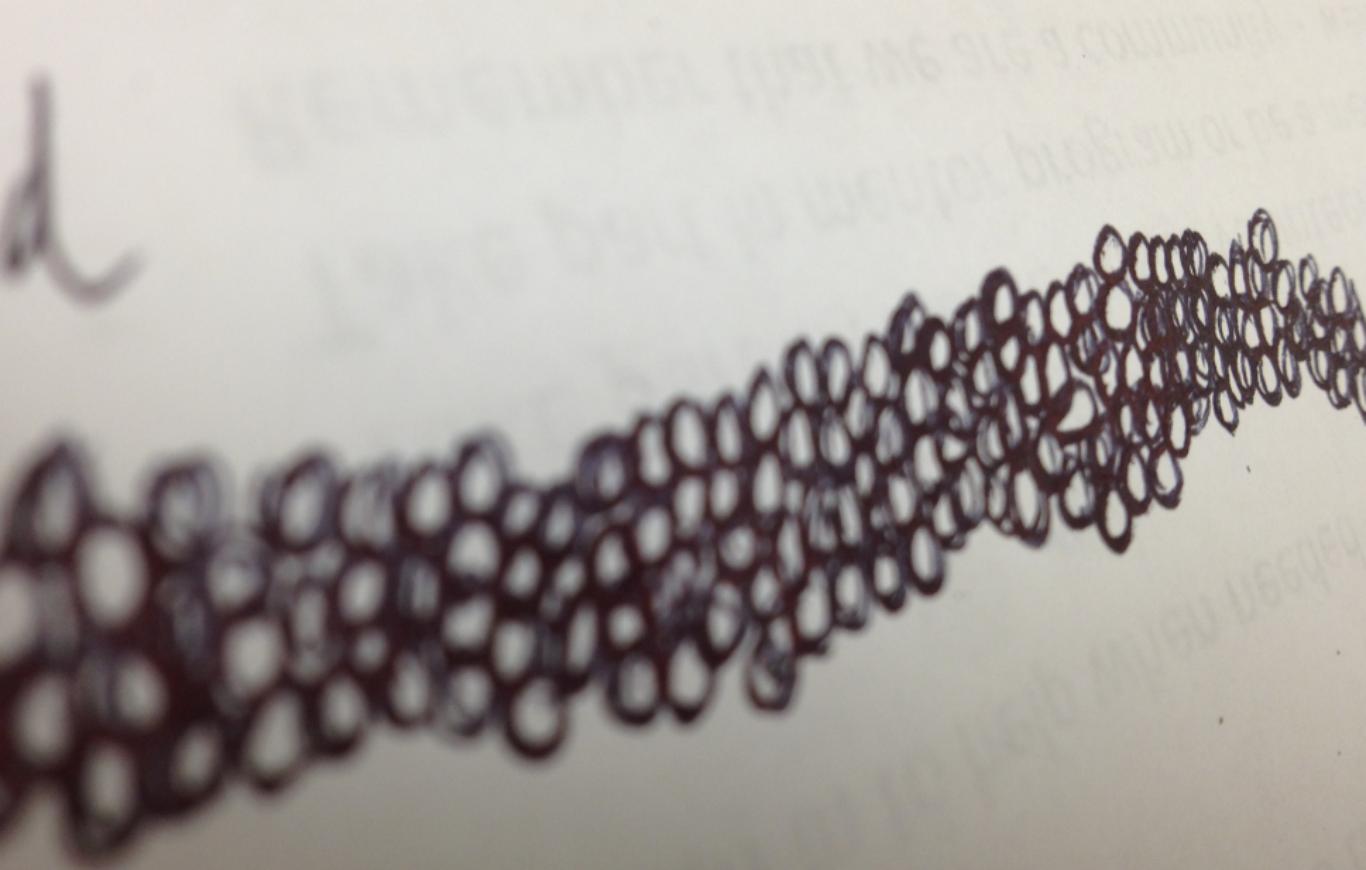
Discover how identifiers and passwords are used for that

- Understand what are (cryptographic) **hash functions**

Discover data integrity, collision and compact information storage

- Understand how to **securely store passwords** in a database

Password storage and verification to authenticate users



Password

Authentication

- Important to be able to **authenticate users** of a system

Checking that the identity of a user is authentic

- **Three possible elements** to authenticate a user

- **Possession**: a key, a card, etc.
- **Knowledge**: an identifier with a password, etc.
- **Attribute**: a fingerprint, a signature, etc.

- Authentication process consists in **two steps**

- **Identification**: presenting an identifier to the system
- **Authentication**: proving relation between entity and identifier

Password

- Authentication with a username and the **associated password**

Password compared with the one stored in the system

- Different kinds of **associations** for passwords

- One password for each object to protect
- Protecting a set of access rights with the same password

- One password should only be used for **one access**

Not a good practice to use the same password for the same user

Password Vulnerability

- Using passwords is **not secure at all**
 - Could be easy to guess, can be exposed, sniffed, etc.
 - Can be illegally transferred to an unauthorised user!
- Only 10,000 possibilities with a **four-digit pin code**

Only 5,000 attempts on average (only 5s if one test/ms)
- A password can be seen while it is **exposed**

Shoulder surfing, network sniffing, keylogger, etc.

Securing Password

- Passwords should be **secretly stored** in the system

But it must be possible to check whether a password is correct

- The storage should be **protected against theft**

Use disk encryption, physical protection, backups, etc.

- Passwords should **not be stored in clear** in the database

Typically storing them in a secured hashed form

Brute-Force Attack

- Brute-force attack tries all the possible passwords

The passwords space should be large enough

- Using botnets to make the attack legitimate

Simulate multiple users trying to access the resource

- Require an access to the system and the possibility to connect

Not always possible to do so, in particular for remote access

Dictionary Attack

- Try all the passwords from a **dictionary**

It is an improvement of brute-force attack, with fewer trials

- Most people use **common words** as passwords

Dictionary can be general or specialised for a particular target

The screenshot shows a GitHub repository page for 'combefis / SecLists'. The repository has been forked from 'danielmessier/SecLists'. It contains 8.8k forks and 0 stars. The main navigation bar includes 'Code', 'Pull requests 0', 'Projects 0', 'Wiki', 'Security', 'Insights', and 'Settings'. The current branch is 'master'. The repository path is 'SecLists / Passwords / darkweb2017-top100.txt'. A pull request by 'g0tmi1k' is visible, titled 'Close danielmessier#291 - Fix encoding issues', which was merged on May 8, 2017. The file 'darkweb2017-top100.txt' contains 100 lines (99 sloc) and 802 Bytes. The first few lines of the file are:

```
1 123456
2 123456789
3 111111
4 password
5 qerty
6 abc123
7 12345678
8 password1
9 1234567
```

Hash Function



Hash Function

- Initially used to check for **data integrity**

Computing a digital fingerprint for a given data

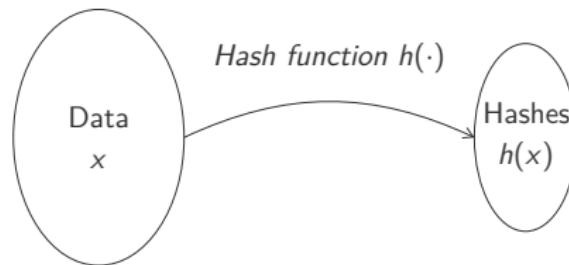
- Using a **hash function** h to get a fingerprint $y = h(x)$

For any x , a binary sequence of arbitrary length

- A **fingerprint** is a binary sequence (typically 160 bits)
 - Storing the data x and its fingerprint $h(x)$ separately
 - The fingerprint $h(x)$ should be stored in a secure place

Collision

- Hash function does some **compression** of the data
The domain of the function is larger than its image
- Two different data x and x' can result in the **same fingerprint**
This is known as collision and is expected from hash functions
- Ideally **collisions** must be minimised



Hash Function Security

- A pair (x, y) is **valid** if and only if $h(x) = y$
It means that y is a fingerprint for x
- Three problems **hard to solve** for a hash function to be good
 - **Preimage**
Given $h(\cdot)$ and y ,
find x such that $h(x) = y$ (x, y) valid
 - **Second preimage**
Given $h(\cdot)$ and x ,
find x' such that $x' \neq x$ et $h(x') = h(x)$ $(x', h(x))$ valid
 - **Collision**
Given $h(\cdot)$,
find x, x' such that $x' \neq x$ and $h(x') = h(x)$

Cryptographic Hash Function

- The only way to find $h(x)$ for x is by computing the function
Even if you already have several computed values $h(x_1), h(x_2), \dots$
- Adding a secret key as an input to the function
The key K is required in addition to the data x : $h_K(x)$
- The secret key is only known by the people communicating
Very important to store securely this secret

Hash Function Example

- MD5 only used for checksum to test data integrity

Even if it has been designed to be a cryptographic hash function

- LM Hashes used in the Windows world for passwords

Very weak hashes that can be easily reversed

- SHA-1, SHA-2, SHA-3 form the Secure Hash Algorithm family

The last one has been released on August 5, 2015



VirtualBox

Download VirtualBox

search...
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Here you will find links to VirtualBox binaries and its source code.

About

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VirtualBox binaries

By downloading, you agree to the terms and conditions of the respective license.

If you're looking for the latest VirtualBox 5.2 packages, see [VirtualBox 5.2 builds](#). Please also use version 5.2 if you still need support for 32-bit hosts, as this has been discontinued in 6.0. Version 5.2 will remain supported until July 2020.

VirtualBox 6.0.14 platform packages

- ⇒ Windows hosts
- ⇒ OS X hosts
- Linux distributions
- ⇒ Solaris hosts

The binaries are released under the terms of the GPL version 2.

See the [changelog](#) for what has changed.

You might want to compare the checksums to verify the integrity of downloaded packages. *The SHA256 checksums should be favored as the MD5 algorithm must be treated as insecure!*

- [SHA256 checksums, MD5 checksums](#)

Note: After upgrading VirtualBox it is recommended to upgrade the guest additions as well.

VirtualBox 6.0.14 Oracle VM VirtualBox Extension Pack

- ⇒ All supported platforms

Support for USB 2.0 and USB 3.0 devices, VirtualBox RDP, disk encryption, NVMe and PXE boot for Intel cards. See [this chapter from the User Manual](#) for an introduction to this Extension Pack. The Extension Pack binaries are released under the [VirtualBox Personal Use and Evaluation License \(PUEL\)](#). *Please install the same version extension pack as your installed version of VirtualBox.*

VirtualBox 6.0.14 Software Developer Kit (SDK)

- ⇒ All platforms

User Manual

The VirtualBox User Manual is included in the VirtualBox packages above. If, however, you would like to take a look at it without having to install the whole thing, you also access it here:

- ⇒ [User Manual \(HTML version\)](#)

You may also like to take a look at our [frequently asked questions list](#).

VirtualBox older builds

The binaries in this section for VirtualBox before version 4.0 are all released under the [VirtualBox Personal Use and Evaluation License \(PUEL\)](#). As of VirtualBox

c8a5cc980c9c94cdac3d94e23cf159c2433aae76b416dbfb5bla918758f21e63 *Oracle_VM_VirtualBox_Extension_Pack-6.0.14-133895.vbox-extpack
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d6a6776e42001eda5659a7f09a8c9a8aeeaced3c9ale40bd538ab0b48f1f9f37 *virtualbox-6.0_6.0.14-133895-Ubuntu-trusty_amd64.deb
a8f707caca8dbb113b9ad61504f6aa6d98009639531053646cd02ead54411904 *virtualbox-6.0_6.0.14-133895-Ubuntu-xenial_amd64.deb

Password Storage



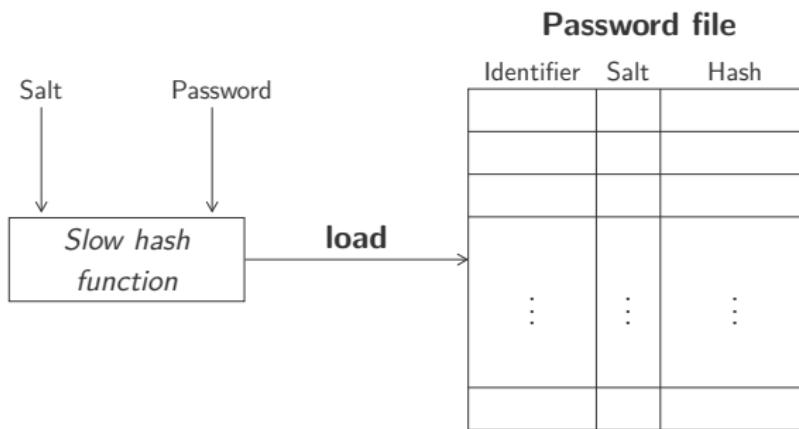
Password Hashes

- Storing **password hashes** is more secure
As it is virtually impossible to reverse them
- Only cryptographic hash functions are **practically irreversible**
Brute-force is only possible, but will take long time
- It also helps to preserve users' **confidentiality**
As the administrators do not have access to the passwords

Unix Password Scheme (1)

- Adding a **new password** in the system

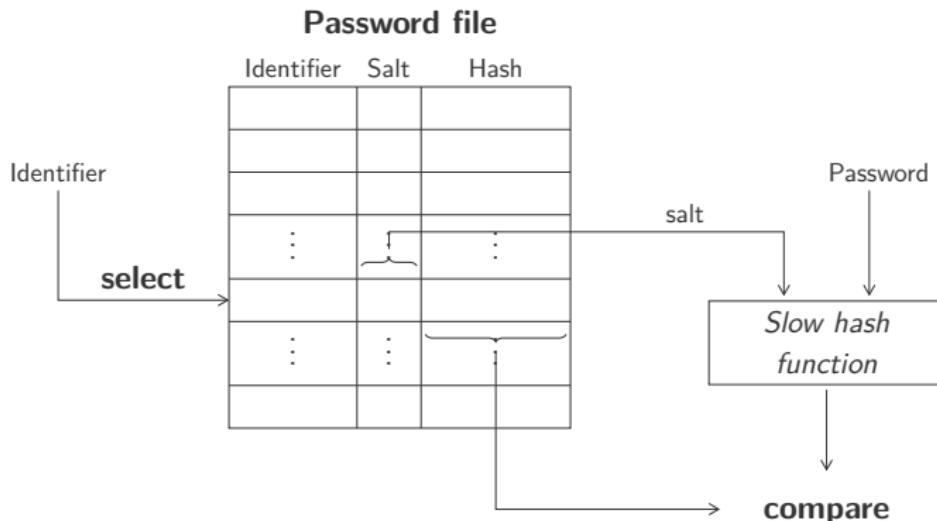
The salt is chosen by the system and used to compute the hash



Unix Password Scheme (2)

- **Checking** a password for a given identifier

The goal is to authenticate a user



Password Databases

- **Databases** used to store password hashes should be secured

Likely to have some database theft nowadays

- Password hashes can be **reversed** to guess the password

Brute-force, dictionary, rainbow tables attacks

References

- William Stallings, & Lawrie Brown (2004). *Computer Security: Principles and Practice*, Pearson, ISBN: 978-1-29222-061-1.
- Douglas R. Stinson, & Maura B. Paterson (2017). *Cryptography: Theory and Practice* (Fourth Edition), CRC Press, ISBN: 978-1-138-19701-5.
- Defuse Security (2019). *Salted Password Hashing - Doing it Right*, June 5, 2019,
<https://crackstation.net/hashing-security.htm>.
- Dan Arias (2018). *Hashing Passwords: One-Way Road to Security*, April 25, 2018,
<https://auth0.com/blog/hashing-passwords-one-way-road-to-security>.
- Danny Denenberg (2019). *A Guide to Password Hashing: How to Keep your Database Safe*, August 28, 2019,
<https://medium.com/swlh/a-guide-to-password-hashing-671c9ab923bd>.

Credits

- Jack Acecroft, March 4, 2013, <https://www.flickr.com/photos/jackace/8663584323>.
- stu_spivack, March 3, 2010, https://www.flickr.com/photos/stuart_spivack/4425612269.
- Mike Mozart, August 17, 2014, <https://www.flickr.com/photos/jeepersmedia/14764162497>.