

Programmer friendly communication framework

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Abstract—This document will focus on an important topic of cybersecurity: Passwords. It will have a look on the indispensable role of passwords now and in the future. Additionally it will cover the role of passwords in robotics and will provide a best practice guide for working with password safes and how to create a secure and easy to remember master passphrase.

I. INTRODUCTION

The present paper concentrates on the wide use of passwords or passphrases in IT-security, with a special consideration of robotics. It focuses on the security aspect of passwords, especially on weak passwords due to user (human) laziness, which in some cases can lead to major problems. Further, it covers state of the art password technologies (2 factor authentication with passkeys) and possible future technologies.

In addition the review highlights alternatives for effective password management and it introduces a choice of selected password managing software.

Finally the paper includes a best practice guide to:

- check if user's passwords have already been breached
- create an easy to remember but secure master password for a password managing software

II. IMPLICATIONS OF WEAK PASSWORDS

In today's digital world many aspects of our daily lives rely on remote services, like online banking, social media and smart home devices to name just a few of them. The majority of those services require the user to authenticate him- or herself via username and password. A weak or re-used password could become a major security issue, if an account gets breached it can have devastating affects on the account owner's life.

But not only humans can be negatively affected. Many robots in today's world are controlled or maintained remotely. To regulate access, users will need a high security password. Especially in robotics, using a weak one can cause major problems, because users don't want anybody to have access to their robots.

A. How weak passwords can cause problems in robotics

- **Robot vacuum cleaner:** A harmless example to point out is the case of Mister Greg. The computer scientist took part in a program where he was gifted a robot vacuum cleaner with an additional camera for orientation. What

he didn't know was that a picture of him, sitting on the toilet, would somehow find it's way onto Facebook. [10] These days, many people already got themselves a robot vacuum cleaner with a camera. In most cases it communicates with the docking station or a device of its owner (e.g.: smart phone) remotely. Because it's accessed remotely the connections have to be secured with a strong password. If not the user could undergo a similar experience as Mister Greg.

- **Military drones:** High risk or even danger of weak passwords lies in the area of military applications. Remote controlled spying and attack drones are already an important part there and will become even more significant in the future. The major problem is that these drones have to communicate with some kind of wireless radio signal. These signals are very vulnerable for hacking attacks. If somebody gains access to enemy robots, they can do a lot of damage, like destroying military bases. So even if it's not known for sure, there is a high probability that remote access to those drones will require a password at some point, and it should definitely be a strong and secure one.
- **In the future:** Boston Dynamics is a company which focuses on developing robots for the world of tomorrow. Robots are developing so fast that it is possible that in the near future many people will have an own personal assistant robot. [12]

In a futuristic world it could become common to own a robotic dog that looks after a user's house when they aren't home or asleep. Or a robotic nanny which helps in the house and becomes part of the family. If the password to such a robot gets hacked or leaked, it could do all sorts of damage. For example spying on the family or robbing their home could get a lot easier, if one would have access to such a household assistant.

III. STATE OF THE ART

Sensitive information or access to hardware must be protected in some way. Nowadays this is likely to happen with a username, which is normally easy to guess, and a password, which should be complex and secure. Also the data traffic should be encrypted, so nobody can read along and possibly gain access to it.

For example users need to key in a username and password

before they can access any network device over SSH. This is also the case if a client wants to access the Raspberry Pi inside the Wombat controller remotely. Over SSH the data traffic is encrypted and protected with a password.

A. The problem with passwords

As mentioned above, a password protects sensitive information or access to hardware like a robot. That's why it's so important to have a good, secure password. However users often are too lazy to create a strong password for every account they own. This is understandable, because as often cited study from NordPass shows, the average user has around 100 accounts that require a unique password. Remembering a hundred unique passwords or more is really beyond a users capability. In a matter of that, users often use the same password for all programs and devices. For example if a user owns 150 robots and all of them have the same password a hacker only needs to find out one and already has access to all of his or her robots. If a user is using 150 different password, a successful hacker will just be able to control one robot by one hack. [1] [2]

Beside laziness as the main cause there are many other reasons why users tend to create weak passphrases such as lack of risk awareness or the fear of forgetting it.

Every year long records get published by different providers revealing the most used passwords. Here are the top ten used passwords of last year (2022): [3]

- 1) 123456
- 2) 123456789
- 3) qwerty
- 4) password
- 5) 12345
- 6) 12345678
- 7) 111111
- 8) 1234567
- 9) 123123
- 10) 1234567890

Other common passwords are locations, names, birthdays, etc.

But how quickly can a password really be hacked? The following graph shows that it is important to choose long passphrases with different types of characters (such as numbers, upper-case and lower-case letters and symbols). The user should always consider that names, common words etc. are still easily hackable with a rainbow list attack (brute force attacks with lists of often used passwords). Users also shouldn't use personal information as a password.

Figure 1 shows the time it takes to crack a password in a brute force attack depending on its length and the use of different character sets.

Number of Characters	Numbers Only	Lowercase Letters	Upper and Lowercase Letters	Numbers, Upper and Lowercase Letters	Numbers, Upper and Lowercase Letters, Symbols
4	Instantly	Instantly	Instantly	Instantly	Instantly
5	Instantly	Instantly	Instantly	Instantly	Instantly
6	Instantly	Instantly	Instantly	1 sec	5 secs
7	Instantly	Instantly	25 secs	1 min	6 mins
8	Instantly	5 secs	22 mins	1 hour	8 hours
9	Instantly	2 mins	19 hours	3 days	3 weeks
10	Instantly	58 mins	1 month	7 months	5 years
11	2 secs	1 day	5 years	41 years	400 years
12	25 secs	3 weeks	300 years	2k years	34k years
13	4 mins	1 year	16k years	100k years	2m years
14	41 mins	51 years	800k years	9m years	200m years
15	6 hours	1k years	43m years	600m years	15 bn years
16	2 days	34k years	2bn years	37bn years	1tn years
17	4 weeks	800k years	100bn years	2tn years	93tn years
18	9 months	23m years	6tn years	100 tn years	7qd years

Fig. 1: How secure is a password depending on its length?

Now if a user is not really sure if his or her password is secure, he or she can use a website like PasswordMonster to check how long it would take a hacker to crack his or her password. [9]

The screenshot shows the PasswordMonster interface. At the top, it says 'Take the Password Test' and 'Tip: Try to make your passwords at least 15 characters long'. Below this, a password input field contains 'lkomm@u5d@5tadtWi3n'. A green bar below the input field indicates the password is 'Very Strong'. Below the bar, it says '19 characters containing: Lower case, Upper case, Numbers, Symbols'. At the bottom, it says 'Time to crack your password: 785 billion years'.

Fig. 2: Example in PasswordMonster

B. Current state of the art

In recent years there was a massive increase in cybercrime. To prevent data-leaks, companies started integrating 2-factor-authentication. [4]

2-factor-authentication adds an extra layer of security to passwords. First the user has to fill in the username and the password like always. Then the user has to pass an additional login-method to verify it's really him or her.

The second factor is usually divided into one of the following categories:

- **Something only the user knows.** This might be a personal question the user had to configure beforehand, a personal identification number (PIN), etc.
- **Something only the user possesses.** This could be a small hardware token or smart-phone.
- **Something physical unique to the user.** This might be a biometric pattern like a fingerprint, an iris scan, or a voice print.

The most common type of the 2-factor-authentication is a smartphone. Another good - but less common - option is a hardware key. (Something only the user possesses.) A leading company in this market is yubico. They are providing a security key named YubiKey for devices with USB-A, USB-C, Lightning and NFC. Users that have a YubiKey should be

aware that they have to carry it with them at all times and be careful not to lose it. [11]

Another widely used method is the SMS Text-Message. (Something only the user knows.) After entering the password and username the user receives a unique one time passcode (OTP) via text message. The user needs to key in the passcode during a limited time (for example one minute).

After both the first factor and the second factor are correct the user gains access.

C. Future state of the art

In the future passwords will likely be entirely replaced by passkeys because they are easier to use, securer, faster and still work on almost every device.

A passkey is similar to the 2-factor-authentication but without the first factor. The second and only factor is the user's device's security method such as a PIN or a biometric sensor (fingerprint, face scan).

The passkey is hardware specific, which means the user always needs to carry a second device (that the passkey is installed on). If the user wants to use a passkey on the laptop he or she needs to verify the identity with an additional smartphone. This eliminates phishing, credential stuffing and other remote attacks.

In conclusion when a user is asked to sign-in to an app or website, he or she approves the sign-in with the same biometric or PIN that he or she uses to unlock the device (phone, computer or security key). The app or website can use this mechanism instead of the traditional (and insecure) username and password. [5]

D. Solutions to password managing

If users don't want to or are not able to use passkeys there are different options how they could protect their sensitive information. Users can write their passwords with their account information into a booklet. Thus, the passwords can be unique and strong. It's a really simple idea but also has a lot of drawbacks. For example:

- Users need to always carry the booklet with them. Without it they are not able to access their accounts.
- Users can lose the booklet. Depending on the security restrictions they can't gain access to some of their accounts anymore.
- It's not a really clear way of organizing passwords. Once something is written down it cannot change the position in the booklet. So users would have to search for each password for indefinite time before they find it.

The other and better option is a password safe.

E. Password Safe

1) *Explanation:* A password safe, also known as password manager, is a piece of software that allows saving a list of usernames and passwords for all accounts. It has one master password or passphrase that unlocks the safe. Now users only have to recall one single master passphrase instead of a huge amount of passwords.

2) Examples:

• KeePassXC

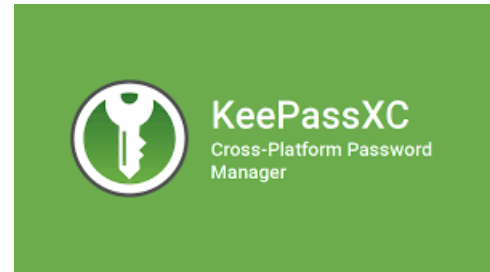


Fig. 3: KeePassXC Logo

This software is developed for users with extremely high demands of secure personal data management.

KeePassXC uses Advanced Encryption Standard (AES) encryption algorithm with a 256-bit key to secure the password database.

The biggest difference to other password safes is that the data (password, account information and additional data such as URLs, attachments and notes) is stored in an offline, encrypted file that can be stored locally. This prevents user's data from getting leaked when a server gets hacked or breached.

The XC stands for Cross-Plattform. It is possible to use it on Linux, Windows, macOS and Android.

The program is also customizable. It allows the user to customize literally everything to their needs. [6]

• 1Password



Fig. 4: 1Password Logo

This password safe is known for its easy to use interface and its high security encryption.

1Password uses an uncommon encryption known as dual-key encryption. If the server gets breached it's impossible for the hacker to decrypt the user's sensitive information because of the two required keys. The first key is the user's master-key. The second key is a secret key, which is a 128-bit, machine-generated code. The secret key is generated on every device the user logs into. It will only be saved on the user's devices and will never be saved together with the second PINs.

Depending on the account type the data is stored differently, but there is only one account type saving the

users' data locally. In every other option the user's data gets saved in a cloud-based vault.

The interface is known as user-friendly and generates strong passwords for accounts that are newly created. [7]

3) Benefits and drawbacks of password safe software:

Benefits:

- **Security:** Password safes use advanced encryption algorithms to protect the user's passwords. This makes it extremely difficult for hackers to steal the passwords and gain access to the user's online accounts.
- **Convenience:** Password safes store all of the user's passwords in one place, which makes it easy for them to access their accounts without remembering multiple passwords.
- **Auto-fill feature:** Many password safes have an auto-fill feature that automatically enters the username and the password of the user, saving time and reducing the risk of typing errors.
- **Multi-device access:** Many password safes allow the user to access their passwords from multiple devices, including smartphones, tablets, and computers.
- **Password strength:** Password safes often include a password generator feature, which creates strong passwords. This helps to ensure that the passwords are not easily guessable.

Drawbacks:

- **Single point of failure:** If a user's password safe is hacked or compromised, all of their passwords are at risk. It is important to choose a password safe that has a strong encryption algorithm and to use a strong master password.
- **Dependency:** Using a password safe can make a user dependent on it for remembering passwords, which may make it difficult to remember passwords if the user is not able to access their password safe for some reason.
- **Learning curve:** Some password safes have a steep learning curve, and it can take some time to get used to the application.
- **Cost:** Some password safes charge a fee for their services, which can be a disadvantage if the user is looking for a free solution.
- **Compatibility:** Some password safes may not be compatible with all websites or devices, which can limit their usefulness.

Sources used to find the benefits and drawbacks: [8]

4) *Scientific Studies regarding password managers:* A thoughtful scientific study by Peter Mayer et al. shows, that even for highly educated people, which definitely know about the risk of bad or reused passwords, the adoption of password manager software depends largely on how easy it is to use. Mayer and his colleagues show, that browser based password managers are more widely used than standalone password saves, mainly because they are easier to use. [13]

IV. CONCEPT AND IMPLEMENTATION FOR BEST PRACTICE

It can be very overwhelming to start with a secure option to manage passwords. So here is a best practice guide everyone can follow.

- 1) First you should check if your password has already been breached. There is a website that makes it easy to check it out. It's called **"haveibeenpwned.com"**. Haveibeenpwned is open source and secure. If someone searches for a breach it doesn't store the data that was typed in (an email address or phone number). It only ever retrieves the data from storage then returns the data.

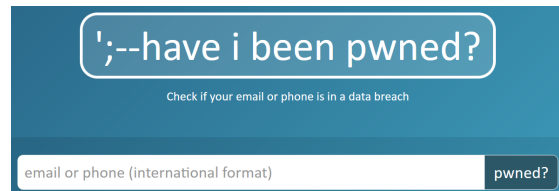


Fig. 5: Have I been pwned? Homepage

If you have already been pwned, change the present password. If not you can rest assured.

- 2) Pick a password safe that fits best for your needs. You can choose one of the ones mentioned above or do your own research.
 - 3) Create a good master password or even better a master passphrase. Here is a easy way to to design it:
 - First think of something which is easy to remember. For example "I love apples and bananas" or "Ich komme aus der Stadt Wien" if you want to use your native language.
 - The second step is to transform the sentence in dialect or slang form. For example "I luv appls and bananas" or "I komm aus da Stadt Wien".
 - Third, you can change letters into numbers and remove spaces. A "s" gets changes into a "5", an "e" gets changed into a "3" and an "o" gets changed into a "0". For example "Iluvappl5andbanana5" or "Ik0mmau5da5tadtWi3n".
 - The fourth step is to add symbols to your password. Change characters that look like a symbol into one such as "a" to "@" or "s" to "?". For example "Iluv@ppl5@ndb@n@n@5" or "Ikomm@u5d@5tadtWi3n".
 - The fifth step is to make all words start with a capital letter. This is only useful if the language you choose does not have a grammar rule for that (It's needed in English but not in German for example).
- Finally you would end up with a passphrase like "ILuv@ppl5@ndB@n@n@5" or "Ikomm@u5d@5tadtWi3n". This is a really secure passphrase because it compromises numbers, upper case and lower case letters, symbols and more than 8 characters. This would make a strong master password that is nearly impossible to crack.

V. CONCLUSION

Passwords remain a widely used and convenient method of authentication, but they have significant weaknesses that make them vulnerable when attacked. While there are emerging alternatives to passwords, such as biometric authentication and passkeys, there are also challenges associated with their adoption, such as cost, compatibility, and user experience. As the cybersecurity landscape continues to evolve, it is important to explore new, innovative and equally trustworthy approaches to authentication and access control, that are both secure and user-friendly.

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