Cybersecurity Revisited: Honeytokens meet Google Authenticator

Vasilis Papaspirou\textsuperscript{a,*}, Maria Papathanasaki\textsuperscript{b}, Leandros Maglaras\textsuperscript{c}, Ioanna Kantzavelou\textsuperscript{a}, Christos Douligeris\textsuperscript{d}, Mohamed Amine Ferrag\textsuperscript{e}, Helge Janicke\textsuperscript{f}

\textsuperscript{a}Department of Informatics and Computer Engineering, University of West Attica, Athens, Greece
\textsuperscript{b}Department of CS and Telecommunications, University of Thessaly, Lamia, Greece
\textsuperscript{c}Cyber Technology Institute, De Montfort University, Leicester, UK
\textsuperscript{d}Department of Informatics, University of Piraeus, Piraeus, Greece
\textsuperscript{e}Department of Computer Science, Guelma University, Guelma, Algeria
\textsuperscript{f}Cyber Security CRC and Edith Cowan University, Perth, Australia 6027

Abstract

Although sufficient authentication mechanisms were enhanced by the use of two or more factors that resulted in new multi factor authentication schemes, more sophisticated and targeted attacks have shown they are also vulnerable. This research work proposes a novel two factor authentication system that incorporates honeytokens into the two factor authentication process. The current implementation collaborates with Google authenticator. The novelty and simplicity of the presented approach aims at providing additional layers of security and protection into a system and thus making it more secure through a stronger and more efficient authentication mechanism.

© 2011 Published by Elsevier Ltd.

Keywords: Honeytoken, Authentication, Security, honeywords, 2FA

1. Introduction

Communication systems rapidly evolved to meet the cutting edge technologies in the last decade. Remote services, procedures, and tasks have greatly replaced in person ones. Consequently, remote access has proven the use of just one password to protect an online account currently inadequate and insufficient for our needs. Higher level requirements leads us to the development of more sophisticated mechanisms to identify a user, and confront new challenges in nowadays threat landscape [1].

Password mechanisms fail to protect a user and the system she uses to an acceptable security level for any number of reasons, two the most important, a) the user is unaware and unable to choose a strong password against brute force and dictionary attacks, if the system will not guide her to do so, and b) password storage, even encrypted in hash format, becomes problematic and improper for the size of the liability it sustains. Passwords act as guards and operating systems establish their protection on passwords. But furthermore, users share without hesitation their passwords to facilitate cooperation, to help friends, colleagues or teammates, and do not realize the consequences of such a practice. In other cases, a user might fall victim to a phishing attack.

*Corresponding Author
Email addresses: vpapaspyrou@uniwa.gr (Vasilis Papaspirou), mpapathanasaki@auth.gr (Maria Papathanasaki), leandros.maglaras@dmu.ac.uk (Leandros Maglaras), i.kantz@uniwa.gr (Ioanna Kantzavelou), cdoulig@uniipi.gr (Christos Douligeris), ferrag.mohamedamine@univ-guelma.dz (Mohamed Amine Ferrag), helge.janicke@cybersecuritycrc.org.au (Helge Janicke)
and unintentionally discloses her credentials.

In most of the aforementioned cases, a really high risk threat for any computing device takes place, the impersonation of a user, the well known masquerade attack. The rationale behind this is that a single password does not guarantee any more the security of an online account and does not protect the system of unauthorized access. Nevertheless, user authentication remains at the first line of defense against such threats, and it is the central component of any security infrastructure. Therefore, enhanced security requires several levels of protection towards an in depth security and defense. In case the first line of defense fails, there is always a way to avoid a possible attack, through a multi-factor authentication (MFA) mechanism.

Multi Factor Authentication (MFA) is achieved by using two or more different factors related to the user. Such factors may refer to something the user knows, as a password or a PIN. Another factor is connected with something the user has in his possession, as an identity or a smart card. Finally, another group of factors might be something the user is, any physical feature as a fingerprint, the iris, or the voice, etc. can be used as a method of identification. A prerequisite for a secure two factor authentication mechanism (2FA) is the use of two separate devices for entering at least two factors. Unfortunately, this is not always the practice used, which generates one of source of problems in 2FAs. Other problems on the functioning of a 2FA scheme, instead of securing more a users’ account, create additional security concerns and makes it even more vulnerable. SIM Swapping, one of the major recent threats, has been proven to be very difficult to be stopped. Mobile Network Operators (MNOs), banks and authorities have started collaborating to mitigate fraudulent SIM swapping through the use of Application Programming Interface (API) provided by the MNOs to check whether a SIM swap has been recently performed. Even though this solution could be effective against SIM Swapping it is not yet used by all banks and it is not efficient against another family of attacks. The apps a user downloads may not be the only things which are on his/her phone. Hidden spyware that allows people to monitor activity, access information and even eavesdrop on user’s chats can also be installed. These malware are called 'Stalkerware' and pose a major threat to mobile devices.

In this paper, we use the state-of-the-art solutions and propose a novel system that integrates honeytokens in a two factor authentication scheme that is embedded into google authenticator. The novel approach aims at providing additional layers of defense into the system and thus making it more secure through a stronger and enhanced authentication mechanism.

The contributions of the proposed research work include:

- The incorporation of the honeywords technique used as an additional factor on a different computing device to enhance security,
- The use of the very popular QR-code system to accelerate the identification procedure,
- The integration and harmonization with the main-stream authentication technology that is widespread today,
- The proposal of new integrated mechanism entitled 'Two Factor Honeytoken Authentication Mechanism'
- The use of any authenticator, with the Google authenticator used for the pilot system presented in this article.
- The low complexity, the simplicity and the user friendliness of the proposed system, even to the elderly.
- The security evaluation of the proposed system that is proven to be robust against many serious attacks like SIM swapping, stalkerware and side channel attack among others.

The paper is organized as follows. Section 2 gives details on Authenticators along with a comparative analysis. In Section 3 we thoroughly describe the proposed system. In Section 4 we perform a security analysis of the proposed 2FHA mechanism. In Section 5 we present other research works related to user authentication and 2FA. Finally, in Section 6 we summarize the findings of our work by writing up conclusions and present possible work extensions that will expand the research outcomes.

2. Authenticators Comparison

There is a growing range of Authenticators. Among the Authenticators that are flooding the Internet, there are some that have stood out for the simplicity and efficiency they offer. Google Authenticator (GA) is the most popular as it offers a large number of advantages. It is free and very easy to use. It does not require an Internet connection and supports Time-based One-Time Password (TOTP) and HMAC-based One-Time
Password (HOTP). There is a small number of disadvantages including the inability to create a backup and the lack of a variety of features [6].

Authy 2Factor Authenticator (Authy 2FA) is a widely used Authentication method that has a lot in common with Google Authenticator. It is free and easy to use, with many features and supports crypto-wallets and backup creation. Despite the many benefits it offers, the Multi-device synchronization feature raises security risks since the use of a password in the App is not mandatory, making it difficult to maintain control on all devices. Also, Authy continues to use SMS as an Authentication method while it is generally considered obsolete in 2FA systems. It is worth noting that users of other Authentication applications who wish to transfer all their tokens to Authy will need to have a rooted phone, exposing the overall security of the device to major risks [7].

As for Microsoft Authenticator (MA), it is especially useful for users of Microsoft Services, those who have a Microsoft account or have the Windows 10 Operating System on their mobile phone. A great advantage of using this application, is that it notifies the user in case the application is used in an unknown environment and supports passwordless authentication with Microsoft apps. The relatively difficult user interface of the application reduces its popularity, and the fact that it lacks features to make it appealing [7].

All the above characteristics are summarized in the following table (Table 1), where ✓ represents the existence of a feature in the authenticator and the ✗ represents its absence.

| FEATURES                  | GA   | Authy 2FA | MA   |
|---------------------------|------|-----------|------|
| Open source               | ✗    | ✓         | ✓    |
| Free                      | ✓    | ✓         | ✓    |
| Widely adopted            | ✓    | ✓         | ✗    |
| Lack of features          | ✗    | ✓         | ✓    |
| Easy to use               | ✓    | ✓         | ✓    |
| Data backup               | ✓    | ✓         | ✓    |
| Network connection needed | ✗    | ✓         | ✓    |
| Multiple account support  | ✓    | ✓         | ✗    |
| Cryptocurrency securing   | ✓    | ✓         | ✓    |
| Microsoft services compatible | ✗   | ✗         | ✓    |
| TOTP and HOTP use         | ✓    | ✓         | ✓    |

Table 1: Most used authenticators comparison

Authentication mechanisms use cryptographic algorithms to protect user credentials; however, many users have a tendency to choose weak passwords, i.e., common words that can easily be guessed by a dictionary attack [8]. The hash value of a frequent password (i.e., a word in a dictionary) may be cracked rapidly thanks to advances in GPU technology. An adversary may be able to get user credentials as a result of these assaults.

2.1. Honeywords

Juels and Rivest [9] advocated the use of "honey-words". The general idea of honeywords is to alter the location where the passwords are stored in a way that each user has a password and some phonies passwords. Honeywords are the passwords that are fake and the sum of all the Honeywords and the password are named Sweetwords. When a honeyword is send by the login phase, there will be an alert that the password database has been infringed. A set of false passwords is mixed with the user’s genuine password, and the hash values of these passwords (real password and honeywords) are kept in the password file to identify whether the password file has been stolen or not. Even if this file has been hacked and all of its hash values have been broken, the adversary still has no idea which one is the real password.

3. Proposed System

In this paper, we suggest the use of an alternative method, the ‘Two Factor HoneyToken Authentication (2FHA)’ mechanism. We propose the combination Honeywords and two factor authentication in a novel mechanism. The mechanism collaborates with Google authenticator.

This mechanism agrees with a new user two factors, a password and the right position of a honeyword it will provide to him at log in on a different device (eg. a mobile phone). This covers the 2FA concept and upon login the user has to enter two pieces of information, the password and the correct honeyword. The user knows where the correct honeyword has been placed in the sequence of honeywords an authenticator sends to him on the second device. Then, he enters it to complete his login to the system.

A new user first has to get registered through a simple registration form During this procedure, the user is prompted to enter a number from a specific range (i.e. 1 to 3). This number is agreed between the mechanism and the user and indicates the correct position where the genuine OTP number will be placed, among a sequence of fake OTP passwords, during the login phase. A new sequence of fake OTP passwords will be produced each time the user attempts to login, and will include the genuine OTP number at the right position. The length of
this sequence has been chosen to be 3 for the pilot implementation. Detailed operational descriptions on the registration and login phases are provided in the following sections.

Registration phase

A user must enter first some information into the proposed mechanism, in order to get registered. He has to fill the required fields (username, password, first-name, last-name, phone) to be identified at the login phase later. The phone field requires the phone number, which is the device where the OTP codes will be sent at the login phase. Afterwards, the user has to choose the position of the right OTP code, a number from a predetermined range of numbers available to him (1, 2, 3). The number the user selects will be the place the correct OTP code will appear in the sequence of the three OTP codes. For instance, if he chooses number 2, then from the three OTP codes he will receive in the login phase, number 2 will be the correct one. The username must be unique.

When the user is registered, the system will produce three keys, which are not the same in length. These keys will generate the OTP codes for the user. If the registration is successful, the user will receive three QR-images that must be scanned with the Google Authenticator. The QR-images are compatible with other authenticators as well, like Authy. The database of the system will not save any OTP codes. The OTP number the user chooses, will not be stored in the same database with the rest of the information. For security reasons they will be saved in another database.

Login phase

At the login phase, a user will have to complete the username and the password fields, and this is the first layer of security in our system. If the user enters three times a wrong password in a row, his account will be locked. When the user successfully enters these credentials into the system, he will receive an SMS with three OTP codes. In addition, the user is authorized to access the OTP codes via the Google authenticator. When the user receives the three OTP codes from the authenticator or via SMS, he knows which one to select because he has chosen the correct one during the registration phase. By picking the correct number, he will be able to fill the OTP edit box in successfully. If the user selects any other OTP code, then the account will be locked and the user will be informed that an attempt of breach occurred.

4. Security Analysis

In this model we focus our research at the security of the user authentication mechanism using honeywords. Without increasing login complexity and without loss of the general idea of the honeywords, the same key factors remain in our system. In this section we discuss several attacks and how our system is robust to them.

Stalkerware

The apps a user downloads may not be the only things which are on his/her phone. Hidden spyware that allows people to monitor activity, access information and even eavesdrop on user’s chats can also be installed. 2FHA mechanism is robust to stalkerware since even the attacker manages to read the OTPs that are sent to the mobile phone of the user he will not be able to know which is one is the valid one among the fake ones.

SIM Swapping

Since 2017 there have been several media reports about SIM swapping attacks, targeting people within the cryptocurrency community, but also bank accounts and social media and email accounts. SIM Swapping can be used to bypass 2FA security but our proposed 2FHA mechanism is robust against this attack, since only the legitimate user knows the position of the valid OTP among the fake ones.

Video recording Attack

This attack is using a video recording device as an external tool for the attack. At most cases it is very difficult to make this attack without the user’s noticing it. On the one hand, the use of username and password, and on the other hand the inability of the attacker to scan the QR-images that would grant him access to Google Authenticator, make our proposed system robust to such attack.

Guessing Attack

The success of the guessing attack depends on the length of the password. The larger the length, the lower the chance of a successful attack. In our system the
that they do not just detect, but continue to gather information about the malicious intruder, tracking the source of the problem in the system.

Finally, in [18] the authors conclude that some standard, present authentication schemes intended to authenticate that are based on IoT, do not meet all the security requirements set by modern era. For this reason, they created a new authentication scheme, much more powerful than the existing ones, which adopts the honeypots technique. This scheme suggests a way for effective detection and thwart node capture attack.

The proposed work presented in this article attempts to enhance a traditional 2FA mechanism in order to overcome security problems related to password authentication mechanisms, 2FA mechanisms, and users’ problemmatic practices and behaviors that finally endanger heavily computing systems. The selected approach aims at protecting a system and its users from unauthorized access to resources, from data leakage and disclosure of private information, and provides secure and uninterruptible services to the next possible level. The Honeywords principles are used to detect corrupted or stolen tokens. By introducing also QR codes, the integration of this mechanism into any platform or web application and gain access via a mobile phone can be eas-
ily accomplished. This work has been developed over the previously published one, which outlines the main concept [19].

6. Conclusions and future work

We have analyzed the mix of Honeywords with a two factor authentication mechanism in our system that is entitled 2FHA. Our proposed mechanism increases the complexity for the attacker, is robust to SIM Swapping attacks as long as to a number of other well known attacks.

The mix system we propose, has the advantage that it goes hand by hand with the mainstream authentication technology, most users have nowadays. Moreover, Google authenticator is compatible with the systems of many companies that use already for security reasons. On the other hand, all these security requirements impose additional cost to the users. In order for a user to access Google authenticator, he must own a smartphone which is not affordable by everyone. Also, due to the fact that the elderly are less familiar with the use of smart applications, the proposed 2FHA mechanism supports the option of sending simple SMSs in order to facilitate them.

For the future we will try to upgrade the defense system and to make it platform agnostic. We plan to test the proof of concept by integrating the 2FHA mechanism to banking or health organizations. These are the main targets of recent cyber-attacks and since they are already using OTP systems for online transactions the proposed 2FHA could enhance their security.

7. Acknowledgement

This work has received funding from the European Union’s Horizon 2020 research and innovation programme: projects CyberSec4Europe (Grant Agreement no. 830929), and LOCARD (Grant Agreement no. 832735)

References

[1] L. Maglaras, M. A. Ferrag, A. Derhab, M. Mukherjee, H. Janicke, S. Rallis, Threats, protection and attribution of cyber attacks on critical infrastructures, arXiv preprint arXiv:1901.03899.
[2] NIST. Back to basics: Multi-factor authentication (MFA) (2021). URL https://www.nist.gov/itl/applied-cybersecurity/tig/back-basics-multi-factor-authentication
[3] C. Rathgeb, A. Uhl, Two-factor authentication or how to potentially counterfeit experimental results in biometric systems, in: International Conference Image Analysis and Recognition, Springer, 2010, pp. 296–305.
[4] S. Ćerić, Two-factor authentication vulnerabilities (2018). URL https://hal.archives-ouvertes.fr/hal-01759198/file/two-factor-vulnerabilities.pdf
[5] N. Aggrawal, Authentication methods: A review, Productivity 52 (4) (2012) 243.
[6] E. De Cristofaro, H. Du, J. Freudiger, G. Norcie, A comparative usability study of two-factor authentication, arXiv preprint arXiv:1309.5344.
[7] P. Pollet, M. Sprietzenbarth, Defeating the secrets of otp apps, in: 2018 11th International Conference on IF Security Incident Management & IT Forensics (IMF), IEEE, 2018, pp. 76–88.
[8] Z. A. Genç, S. Kardaş, M. S. Kiraz, Examination of a new defense mechanism: Honeywords, in: IFIP International Conference on Information Security Theory and Practice, Springer, 2017, pp. 130–139.
[9] A. Juels, R. L. Rivest, Honeywords: Making password-cracking detectable, in: Proceedings of the 2013 ACM SIGSAC conference on Computer & communications security, 2013, pp. 145–160.
[10] M. H. Almeshekah, C. N. Gutierrez, M. J. Atallah, E. H. Spafford, Ersatzpasswords: Ending password cracking and detecting password leakage, in: Proceedings of the 31st Annual Computer Security Applications Conference, 2015, pp. 311–320.
[11] J. Camenisch, A. Lehmann, G. Neven, Optimal distributed password verification, in: Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security, 2015, pp. 182–194.
[12] R. W. Lai, C. Egger, D. Schröder, S. S. Chow, Phoenix: Rebirth of a cryptographic password-hardening service, in: 26th (USENIX) Security Symposium (USENIX) Security 17, 2017, pp. 899–916.
[13] D. Fiorencio, C. Herley, A large-scale study of web password habits, in: Proceedings of the 16th international conference on World Wide Web, 2007, pp. 657–666.
[14] S. M. Furnell, P. Dowland, H. Illingworth, P. L. Reynolds, Authentication and supervision: A survey of user attitudes, Computers & Security 19 (6) (2000) 529–539.
[15] D. Wang, P. Wang, Two birds with one stone: Two-factor authentication with security beyond conventional bound, IEEE transactions on dependable and secure computing 15 (4) (2016) 708–722.
[16] Z. A. Genç, S. Kardaş, M. S. Kiraz, Examination of a new defense mechanism: Honeywords, in: G. H. Hancke, E. Damiani (Eds.), Information Security Theory and Practice, Springer International Publishing, Cham, 2018, pp. 130–139.
[17] S. Palaniappan, V. Parthipan, S. Stewart kirbakaran, R. Johnson, Secure user authentication using honeywords, in: A. Pandian, T. Senju, S. M. S. Islam, H. Wang (Eds.), Proceeding of the International Conference on Computer Networks, Big Data and IoT (ICCB - 2018), Springer International Publishing, Cham, 2020, pp. 896–903.
[18] W. Li, P. Wang, Two-factor authentication in industrial internet-of-things: Attacks, evaluation and new construction, Future Generation Computer Systems 101 (2019) 694–708.
[19] V. Papaspirou, L. Maglaras, M. A. Ferrag, I. Kantzavelou, H. Janicke, C. Doulgeris, A novel two-factor honeytoken authentication mechanism, in: 2021 International Conference on Computer Communications and Networks (ICCCN), IEEE, 2021, pp. 1–7.