# Security analysis of the Wi-Fi Easy Connect

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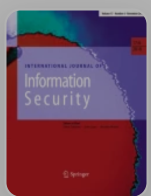

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## Abstract

future connections, highlighting the risks when implementations do not fully adhere to the protocol's design specifications. Our analysis illustrates the danger of introducing security and privacy vulnerabilities in protocols, when protocol design favors usability versus security.

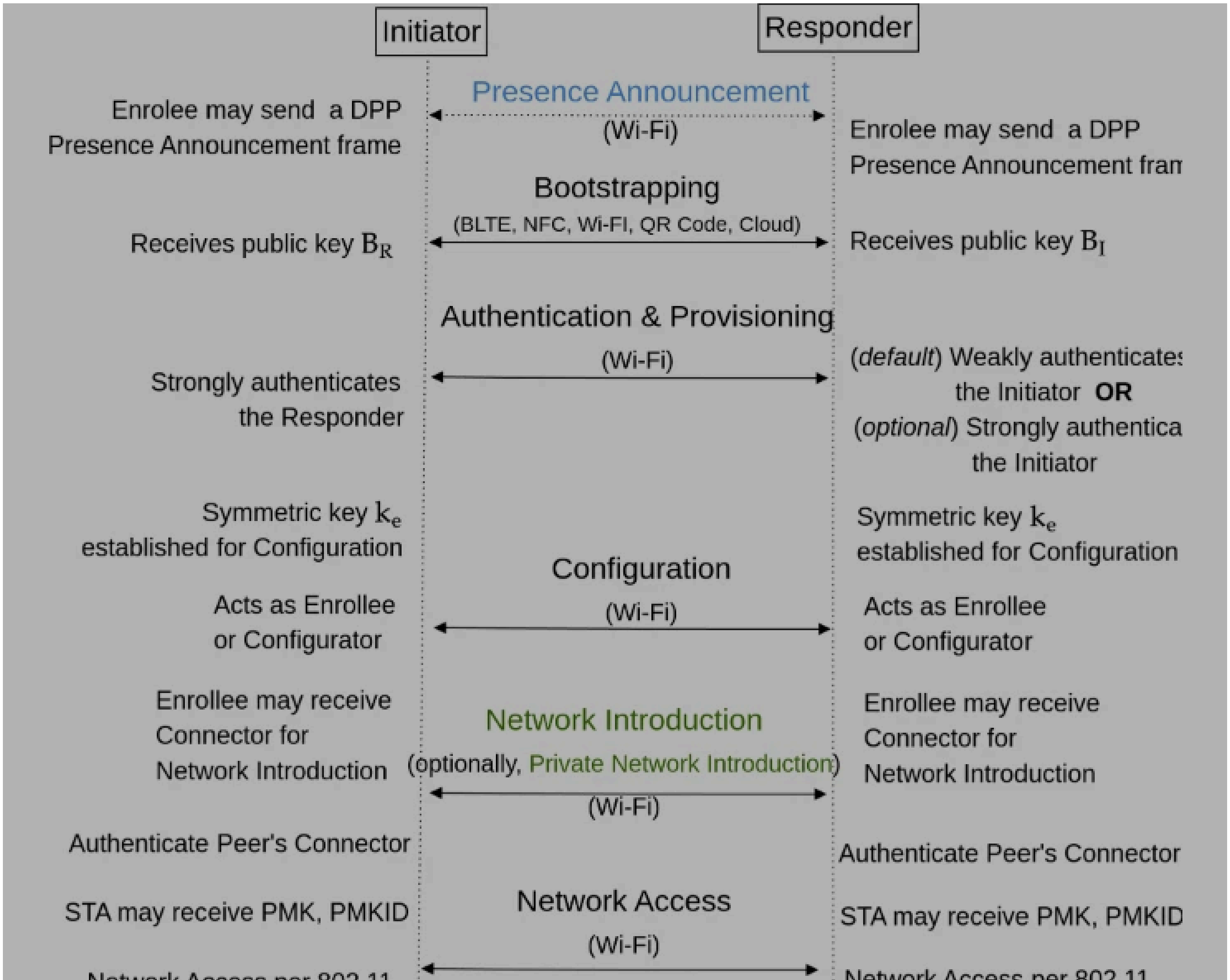


## 1 Introduction

The widespread adoption and utilization of wireless technology led to a significant increase in the use of Wi-Fi networks. Wi-Fi, adheres to the IEEE 802.11[1] specification, offering a a few hours through a brute-force attack. Once the WPS PIN is recovered, the attacker also has access to the network's WPA/WPA2 pre-shared key (PSK). As a result of this vulnerability, users have been advised to turn off the WPS PIN feature, although this may not be possible on some router models.

*Wi-Fi Easy Connect* was introduced by the Wi-Fi Alliance in June 2018 along with WPA-3, as the core replacement for the WPS protocol. Being the replacement of WPS, it is expected to see extensive deployment across millions of devices globally in the coming years. The underlying protocol of Wi-Fi Easy Connect, named Device Provisioning Protocol [3] (DPP),[2] aims to facilitate user-friendly Wi-Fi provisioning methods. In DPP, bootstrapping and authentication can be configured in various user-friendly ways including among others, scanning a quick response (QR) code, short-range wireless protocols like Near-Field Communication (NFC) and Bluetooth Low Energy (BLE).

**Fig. 1**


Initiator
Responder
Presence Announcement
(Wi-Fi)
Enrolee may send a DPP Presence Announcement frame
Enrolee may send a DPP Presence Announcement fram
Bootstrapping
(BLTE, NFC, Wi-Fi, QR Code, Cloud)
Receives public key $B_R$
Receives public key $B_I$
Authentication & Provisioning
(Wi-Fi)
Strongly authenticates the Responder
(*default*) Weakly authenticate the Initiator **OR**
(*optional*) Strongly authentica the Initiator
Symmetric key $k_e$ established for Configuration
Symmetric key $k_e$ established for Configuration
Configuration
(Wi-Fi)
Acts as Enrollee or Configurator
Acts as Enrollee or Configurator
Enrollee may receive Connector for Network Introduction
Network Introduction
(optionally, Private Network Introduction)
(Wi-Fi)
Enrollee may receive Connector for Network Introduction
Authenticate Peer's Connector
Authenticate Peer's Connector
STA may receive PMK, PMKID
Network Access
(Wi-Fi)
STA may receive PMK, PMKID

High level overview of DPP

At the time of writing this paper, there is a growing trend of vendors implementing the DPP protocol annually. According to the Wi-Fi Alliance's Product Finder [4], there are currently 23 Wi-Fi Easy Connect\(^\textrm{TM}\) certified devices in the market from 6 different vendors, including major ones such as MediaTek, Sagemcom and Qualcomm. Additionally, some vendors have implemented part of the Wi-Fi Easy Connect specification. For example, Android only supports DPP in Initiator mode. Also, popular open-source software such as hostapd, wpa_supplicant, and iwd have already implemented a majority of the Wi-Fi Easy Connect specification. The DPP specification is subject to ongoing development, having undergone three releases since its initial deployment, with the present iteration being version 3.0. Each successive release incorporates substantial enhancements to the specification, while also ensuring compatibility with previous versions.

*Motivation.* To the best of our knowledge, no thorough security analysis of the Wi-Fi Easy Connect protocol has been conducted prior to this study. Considering that this protocol is specifically designed to streamline the provisioning of devices in contemporary networks and is anticipated to become a widely accepted standard, conducting a thorough security assessment is critical. Detecting and mitigating potential vulnerabilities in its early stages vulnerabilities and challenges that were not relevant in the previous WPS protocol.

- Besides the protocol specification itself, protocol implementation may also affect security. In this context, we performed code auditing of the hostapd implementation of DPP, revealing an implementation issue that allows attackers who successfully associate using DPP to manipulate future connections. We provide the technical details into this issue to aid other implementations in avoiding similar pitfalls.

The discovered attacks target various sub-protocols or security features within the Wi-Fi Easy Connect specification, which were introduced in different versions of the DPP protocol. However, all the discovered security issues are applicable as of the latest released version 3.0. Our findings demonstrate the danger of introducing novel security and privacy vulnerabilities in modern protocols when usability is over-prioritized in contrast to security.

As part of our responsible disclosure process, we communicated our findings on vulnerabilities within the DPP to the Wi-Fi Alliance. Several conclusions emerged from this interaction. The Wi-Fi Alliance acknowledged certain issues, such as the Configurator Impersonation Attack (described in Sect. 3.2) and the Group Downgrade Attack (see Sect. 3.3), for further discussion and potential mitigation strategies. However, other vulnerabilities, including the Private Introduction Protocol Downgrade (see Sect. 3.4), were considered by Wi-Fi Alliance as acceptable risks. Our disclosure helped highlight areas of

## 2.1 Protocol notation

We will follow the symbols and notation of the Wi-Fi Easy Connect specification [3]. Following the terminology of the specification, the two main entities of the IEEE 802.11 protocol are the *Station* (STA) that represents a device with Wi-Fi access capabilities, and the *Access Point* (AP), that represents the device that provides Wi-Fi connectivity. As shown in Table 1 STA and AP may also obtain additional authentication roles regarding the DPP sub-protocols. A *Configurator* is a logical entity with capabilities to enroll and provision devices for device-to-device communication or Infrastructure communication. Usually the AP has the role of the Configurator. In contrast, an *Enrollee* is a device that is enrolled in a Wi-Fi network via a Configurator.

## 2.2 Phases of the DPP

**Table 1 Main entities and roles in DPP**

As shown in Table 1, based on the initiation capabilities of the devices, they may act as *Initiator* or *Responder*. A device acts as an Initiator if it initiates the DPP Authentication protocol, while it acts as a Responder if it responds to the initiation of the DPP

Let $\mathrm {(B_I,b_I)}$ (resp. $\mathrm {(B_R,b_R)}$) denote the long-term identity public/private key pair of the Initiator (resp. of the Responder), called the *bootstrapping keys*. As defined in the protocol specification, a bootstrapping key is a public key that is obtained through a bootstrapping method. From a high-level view DPP involves the following phases or sub-protocols (see Fig. 1).

During the *Bootstrapping phase*, the Initiator obtains the public key of the Responder $\mathrm {B_R}$; in cases when mutual authentication is performed, the Responder may also obtain the public key of the Initiator $\mathrm {B_I}$. DPP supports various methods of transferring a public key, such as: (a) scanning a QR code that contains an encoded version of the key, (b) exchanging the key wirelessly using the Public Key Exchange (PKEX) protocol [3], (c) using another short-range communication protocol, such as NFC and BLE, or (d) utilizing other proprietary methods, such as those that utilize the cloud. Regardless of the chosen method, the bootstrapping phase results in the Initiator, and optionally the Responder, obtaining the public key of a supposed trusted device. It is worth mentioning that these methods are not without their limitations. The physical security constraints in BLTE and NFC, such as proximity and line-of-sight, have been shown to be weak in the past against relay attacks and skimming [5]. The security level desired by a user may vary depending on the selected bootstrapping method for DPP, however, this flexibility can be difficult for less experienced users to navigate, potentially leaving them vulnerable to attacks.

bootstrapping. Alternatively, mutual authentication can be enabled, allowing the Initiator to prove ownership of $\mathrm{b_I}$ and provide strong authentication to the Responder. According to the specification, by enabling strong mutual authentication both entities can be certain that the authenticated connection they established in the bootstrapping can be carried over in later phases of the protocol (e.g., the Configuration and Network Access phases). In some cases, depending on the bootstrapping method used, this means carrying over the authentication they performed in a different communication channel (i.e., from BLTE to Wi-Fi). For example, a mobile phone (Initiator) uses the BLTE method to exchange keys with another phone (Responder). After finishing with the bootstraping phase, the two devices wish to proceed with the authentication phase which occurs over Wi-Fi. The goal of mutual authentication is for both devices to ensure that the other endpoint is the entity they trusted over BLTE.

The outcome of this phase is the exchange of a symmetric key $\mathrm{k_e}$, which is utilized in the next phase, the *Configuration phase*, to establish the actual communication keys, known as the connector keys (Connector-I and Connector-R respectively). The connectors are then utilized in the *Network Access phase*, to establish the actual network keys through Elliptic Curve Diffie-Hellman (ECDH) exchange, creating a Pairwise Master Key $\mathrm{(PMK)}$ for normal network access.

In version 3 of the Wi-Fi Easy Connect specification, additional enhancements have been introduced to further augment the protocol's functionality and security. The *Network Introduction Protocol* and the *Private Introduction Protocol* facilitate communication between the provisioned Enrolles within the DPP network controlled by the Configurator, offering options for network introduction with or without privacy considerations. Moreover, a novel protocol has been incorporated to enable the backup and restoration of configuration information for DPP Configurators. This protocol, named *Configuration Backup and Restore*, mandates the storage of a DPP digital envelope, with storage and retrieval methods being vendor-specific. It places the onus on the owner to manage the password safeguarding the content-encryption key, ensuring the integrity and confidentiality of the configuration data. In essence, the protocol facilitates the distribution of the privacy protection key (Ppk, ppk), an authentication credential that is possessed only by authorized Configurators within the network.

## 3 Security analysis of DPP

We conducted a comprehensive security analysis of the DPP protocol, identifying three notable security vulnerabilities exploitable by attackers:

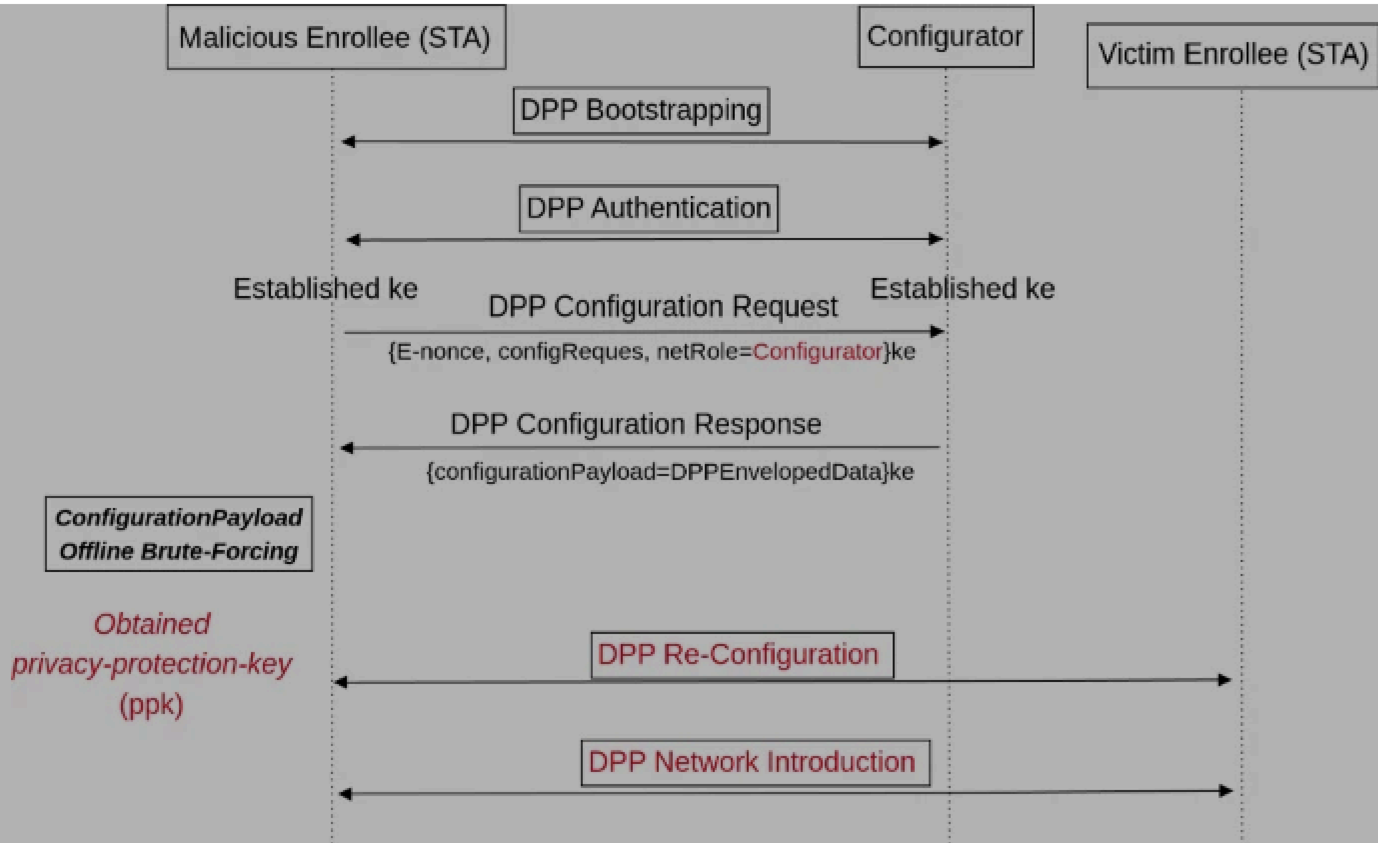
**Configurator Impersonation**: A vulnerability in the *DPP Re-Configuration Protocol* model.

### 3.1 Threat model

The threat model defined in the Wi-Fi Easy Connect specification, considers three types of attackers: (i) passive adversaries capable of intercepting transmitted information during provisioning or subsequent operations, (ii) active adversaries with the ability to conduct association attacks and divert devices to unauthorized networks, and (iii) active adversaries capable of disrupting provisioning services without user notification [6]. In addition, it is assumed that the attacker consistently remains within the wireless proximity of the target and in some instances, is able to respond to wireless frames faster than the original recipient.

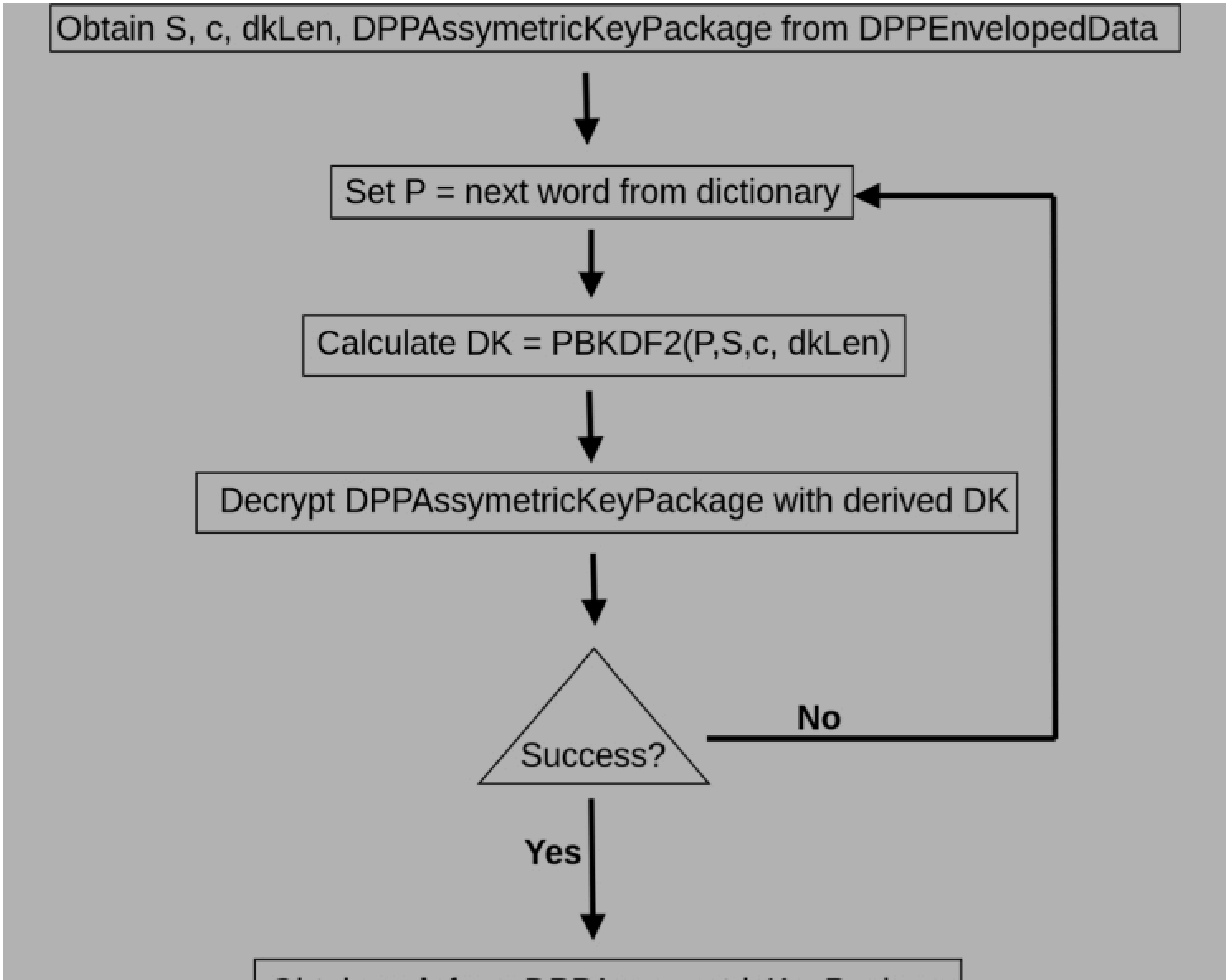
The attacks presented in this section conform to the above threat model. To clarify the particular prerequisites for each attack, the ‘Exploitability’ subsection presented within each attack further elucidates the necessary conditions for a successful attack, covering the specific parameters and constraints under which the discussed vulnerabilities can be effectively exploited.

### 3.2 Configurator impersonation attack in the DPP re-configuration phase




Configurator impersonation attack

**Fig. 3**


Obtain S, c, dkLen, DPPAssymetricKeyPackage from DPPEnvelopedData
Set P = next word from dictionary
Calculate DK = PBKDF2(P,S,c, dkLen)
Decrypt DPPAssymetricKeyPackage with derived DK
Success?
No
Yes

Reliance on a password represents a common pitfall in the design of wireless protocols, as passwords are inherently susceptible to brute-force attacks. By using a password-based approach for protecting the `ppk`, the protocol inadvertently introduces a significant weakness, enabling malicious actors to systematically attempt all possible combinations of characters until the correct password is discovered.

According to the specification, a new Configurator can be enabled and configured during the *DPP Configuration protocol* (as described in Sect. 2), where the new Configurator acts as an Enrollee and sets the `netRole` to "Configurator" in the DPP Configuration Request frame (see Fig. 2). Additionally, if the parameter `netRole` in the DPP Configuration request has the value "Configurator", the `configurationPayload` shall consist of one instance of `DPPEnvelopedData`.

While the protocol effectively authenticates Enrollees and verifies their possession of the proper bootstrapping key, it lacks provisions for authorizing the Enrollee's request. This oversight allows malicious Enrollees to potentially exploit the system by requesting to become a new Configurator, thereby assuming the role of a malicious Configurator capable of hijacking future connections. Upon receiving a request from an Enrollee, the Configurator merely acknowledges the Enrollee's request *without evaluating its legitimacy* or verifying whether the Enrollee's intention aligns with the network's security policies. Consequently, a

Note that the password attack can be performed *offline*, giving the attacker a significant advantage to successfully reveal the password. With each derived key `DK` (see Fig. 3), the attacker attempts to decrypt the captured `DPPEnvelopedData` using the underlying encryption scheme. If the decryption operation fails, the attacker moves on to the next password guess. If decryption is successful, the attacker has recovered the `DPPAsymmetricKeyPackage`, indicating a successful compromise of the encrypted data.

Upon attaining the role of a Configurator, a malicious actor gains the ability to disseminate unauthorized configurations. These configurations can instruct network stations to associate with the malicious actor's device posing as an AP serving the desired SSID. This manipulation allows the malicious actor to intercept and potentially manipulate network traffic. Such actions could lead to data interception, or the insertion of malicious payloads into the network traffic flow.

*Exploitability.* The attacker needs access to the DPP network as a valid Enrollee. Achieving this heavily depends on the bootstrapping methods used by the network administrators, as well as the distribution of bootstrapping keys. Furthermore, the success of the attack is strongly influenced by the entropy of the password. High-entropy passwords substantially elevate computational complexity, making brute-force attempts impractical.

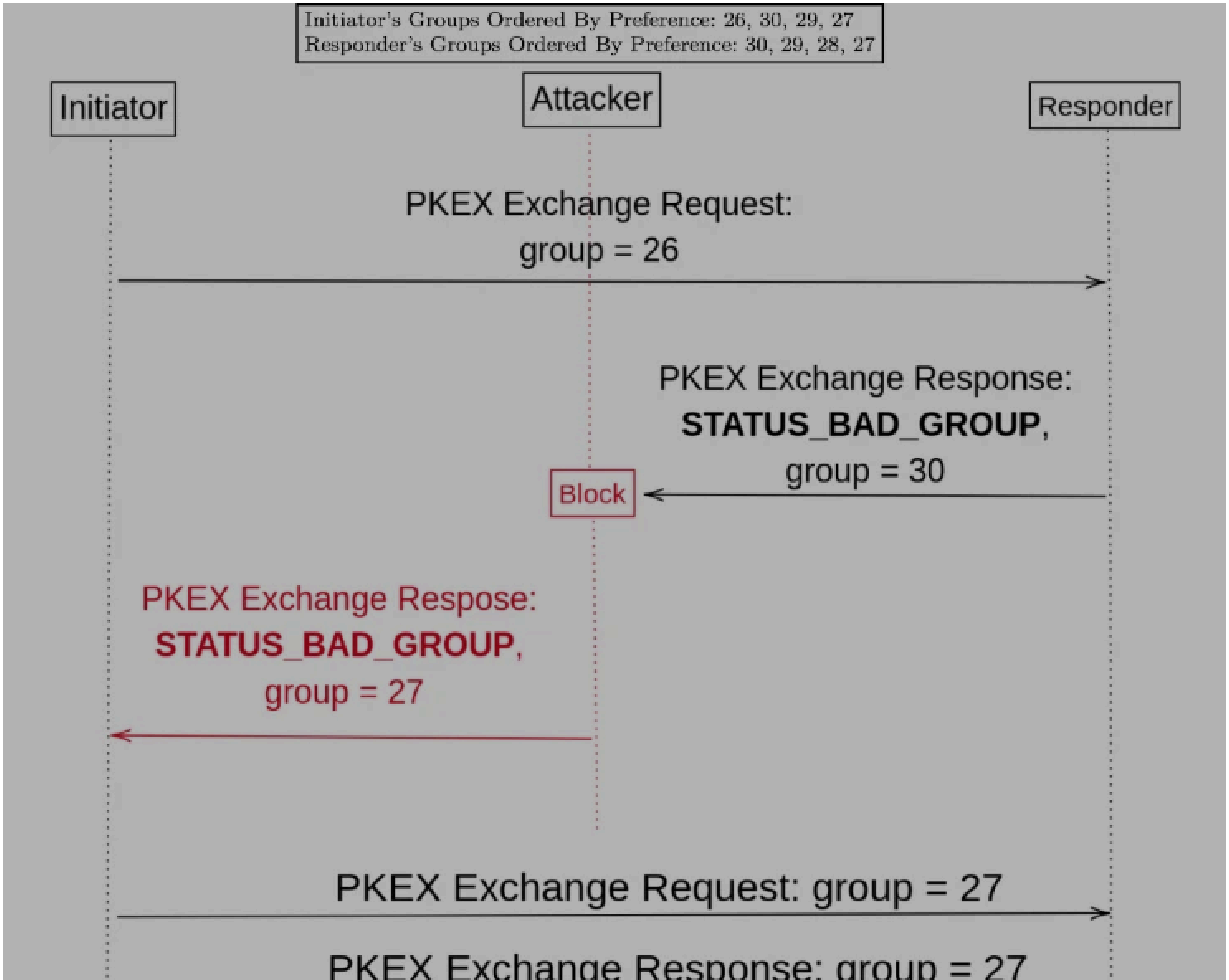
protecting DPPEnvelopedData may still be vulnerable to other attacks. To address this flaw in the protocol, several remediation measures can be implemented:

a. Introduction of authorization checks for the Configurators: This would involve the implementation of robust authorization checks within the DPP Configuration protocol to evaluate the legitimacy of Enrollees' requests to become Configurators. In this way the Enrollee's identity would be verified against predefined security policies before granting Configurator privileges.

b. Unique Key per Configurator: Another possible solution would be to use a cryptographic key that is unique to each Configurator, rather than using a single shared key for all Configurators. This ensures that even if one Configurator's key is compromised, the security of other Configurators remains intact. Employing individualized keys for each Configurator enhances the overall resilience of the system against attacks targeting Configurator credentials.

## 3.3 Lack of cryptographic verification in PKEX bootstrapping group negotiation

As explained in Sect. 2, PKEX is one of the bootstrapping methods supported by DPP. As per the 802.11 standard, stations have the ability to prioritize ECDH groups in a user-configurable order. For example, a user may avoid certain ECDH groups because they may


Initiator's Groups Ordered By Preference: 26, 30, 29, 27
Responder's Groups Ordered By Preference: 30, 29, 28, 27
Initiator
Attacker
Responder
PKEX Exchange Request:
group = 26
PKEX Exchange Response:
STATUS_BAD_GROUP,
group = 30
Block
PKEX Exchange Respose:
STATUS_BAD_GROUP,
group = 27
PKEX Exchange Request: group = 27
PKEX Exchange Response: group = 27

the PKEX Exchange Response frame and sends a PKEX Exchange Request frame proposing group 27 (`ECC_BRAINPOOLP224R1`) instead. The Initiator accepts group 27, which is weaker than the group originally offered by the Responder. Since this negotiation process is not cryptographically validated, it is vulnerable to this type of attack.

It's important to note that while the established group (group 27) is "stronger" than what was originally requested (group 26), a user's choice of elliptic curve groups may involve factors beyond just the prime length. For example, a cautious user might avoid certain groups and their associated parameters due to concerns about possible vulnerabilities or backdoors, as seen for example with Curve1174 [7].

*Exploitability.* The attack is applicable in cases where the Initiator requests for a group that is not supported by the Responder. Since group's preference for elliptic curves might involve considerations beyond just the length of the prime, the group the Initiator is requesting must be lower than the Responder's proposed alternative. In addition, The attacker must be within the wireless range of both the Initiator and Responder and have the ability to intercept the communication between the two. The attacker also needs knowledge of the supported groups of both endpoints in order to determine which groups can be agreed upon by both entities (this information can easily be obtained by intercepting traffic from the two entities, even in other associations with other clients). Finally, an attacker can use readily likelihood of successful attacks on the connection. This attack is similar to the group downgrade attack identified in the WPA3 specification [8, 9].

*Wi-Fi Alliance Response.* "Wi-Fi Alliance will take this matter under discussion and decide a course of action regarding cryptographic protection of group negotiation."

*Possible Remediation.* An easy way to mitigate the attack is by adding cryptographic verification of the groups that were originally sent in the PKEX Exchange phase of the protocol. During the Commit-Reveal phase, the Responder should also include their supported groups in the commitment that they sign and send to the Initiator. The Initiator will calculate its own version of the commitment, which includes the Responder's MAC address, public bootstrapping key, ephemeral keys, and supported groups. If the commitment received from the Responder does not match the one calculated by the Initiator, it indicates that the information used to calculate the hash was tampered with, which could be due to a group downgrade attack. In this case, the Initiator should abort the connection. This approach ensures that the groups that were agreed upon in the PKEX Exchange phase are cryptographically verified before proceeding with the rest of the protocol.

### 3.4 Private introduction protocol downgrade

The *Private Introduction Protocol* was introduced in the third version of the WiFi Easy Connect

A privacy issue arises from the potential jamming or destruction of the `Private Peer Introduction` message by adversaries. If disrupted, the affected device is forced to abandon the secure Private Introduction Protocol and resort to the less secure Network Introduction Protocol.

*Impact.* An attacker may gain insight into the DPP device's attempts to connect to a specific network, including its SSID. This exposure affects the device owner's privacy and potentially facilitates the execution of association attacks [10].

*WiFi Alliance Response.* "Wi-Fi Alliance considers the attack an acceptable risk. Inducing the abandonment of the Private Introduction Protocol and forcing the use of Network Introduction Protocol is merely privacy-exposing as it will expose the non-AP STA's connector to a passive attacker. There is no compromise of confidentiality or integrity of communication by using the Network Introduction Protocol."

*Possible Remediation.* To address this kind of privacy risk, future iterations of the specification should implement countermeasures to validate the STA's preferences from the AP in subsequent exchanges. By verifying the legitimacy and integrity of the STA's preferences during ongoing communication sessions, the AP can detect and mitigate potential attacks aimed at disrupting the Private Introduction Protocol.

vectors and management complexities that are discussed below. Specifically, we highlight two security concerns regarding mixed authentication modes and key management, as well as recommendations that may reduce the attack surface associated with these areas.

### 4.1 Mixed authentication modes

Not all devices fully support the DPP, as many vendors implement only certain aspects of it. For example, some may support only QR code provisioning. As a result, network administrators must maintain multiple provisioning methods, creating a mixed authentication mode. For instance, in a DPP network that needs to accommodate various devices, regardless of their specific DPP implementation, it may support both PKEX and QR code provisioning methods simultaneously. However, this flexibility introduces a potential security issue: the system could default to the weaker of the two methods-in this case, the QR code method, which relies on single-factor authentication as opposed to mutual authentication. This allows devices to bypass the stronger mutual authentication by opting for the weaker provisioning method, if enabled.

*Wi-Fi Alliance Response.* "The DPP protocol certification requires an Enrollee to be able to do mutual authentication as well as non-mutual authentication but it is not required to perform non-mutual in the event that mutual is not available. This is a policy decision for the deployed Enrollee."

retains ongoing control over network access, even when network credentials such as WPA2 or WPA3 are changed. This is because it operates through the Privacy-Protected Keypair (Ppk/ppk), which is independent of those credentials.

However, the DPP specification lacks mechanisms for revoking or updating this crucial keypair. This contradicts security policies that may require regular rotation of sensitive cryptographic keys. Since the ppk allows continuous access to the network even if the network settings are modified, a compromised ppk could grant an attacker permanent access.

The vulnerability described in 3.2 serves as an example of an attack that allows attackers to gain access to the critical keypair, with recovery being exceptionally difficult as it require restarting the entire protocol and invalidating all distributed bootstrapping keys.

*Proposed security enhancement* To revoke access for compromised Configurators or PPK keypairs, revocation mechanisms must be put in place to update the sensitive keypair [11]. A similar approach is employed in Enterprise Wi-Fi networks utilizing the EAP-TLS protocol that rely on the Certificate Revocation List (CRL) or Online Certificate Status Protocol (OCSP) to invalidate compromised certificates, preventing unauthorized access to the network [12].

protocol-wide weaknessess and not to serve as an exhaustive code analysis of DDP implementations.

*Re-using the PKEX code.* According to the Wi-Fi Easy Connect specification [3], the PKEX protocol utilized in DPP, is vulnerable to threats if public keys and codes (passwords) are reused. For example, if an entity has successfully bootstrapped public keys in the past and uses the same code with multiple keys, they could potentially subvert a future bootstrapping by passively observing the keys. To mitigate this risk, once the PKEX protocol is completed successfully and both the device and peer have each other's trusted public key, the code should be irreversibly deleted. However, our code audit of the PKEX implementation in hostapd revealed that the dpp_pkex_build_exchange_req function found in the file "./src/common/dpp_pkex.c" generates a new public key for every exchange request transmitted, and the pkex code remains active even after a successful PKEX association. This can potentially lead to an automatic association attack, as the attacker can impersonate a Configurator and use the same code, to trick new Enrollees into connecting to the attacker instead of the legitimate Configurator. Following responsible disclosure, we immediately notified the hostapd developers, who were able to address the issue. A Common Vulnerability and Exposure identifier (CVE-2022-37660) was assigned to the vulnerability [13]. The identified vulnerability serves as an example of an implementation mistake that can lead to severe impact, highlighting the importance for vendors to conduct thorough code audits when implementing the specification.

channel leaks and downgrade attacks, termed "Dragonblood" [9]. More recently [16] they demonstrated a time-memory trade-off attack on the Simultaneous Authentication of Equals authentication and key exchange method of WPA3 (WPA3-SAE), highlighting that even modern protocol designs can remain vulnerable to sophisticated attacks.

Some works examine the use of fuzzing techniques against the authentication process of WPA2 and WPA3. Marais et al. [17] proposed a fuzzing strategy called WPA3Fuzz, based on which three vulnerabilities that may be exploited to DoS attacks are discovered. In addition, Kambourakis et al. [18] proposed an extensible open-source Wi-Fi fuzzer tool, which covers the IEEE 802.11 management and control frame types, as well as the WPA3-SAE. The fuzzer can be used to detect vulnerabilities potentially existing in wireless Access Points under WPA3 and WPA2.

Chatzoglou et al. [18, 19] demonstrated the feasibility of Denial-of-Service (DoS) attacks on WPA3-SAE, emphasizing the susceptibility of the protocol to resource exhaustion and de-authentication techniques, as well as the need for comprehensive security mechanisms that may ensure the reliability and robustness of the respective protocols.

Other works on Wi-Fi security focus on Wi-Fi association attacks [10, 20], through which attackers may gain man-in-the-middle position, by tricking unsuspecting clients into

In summary, the related work highlights the importance of identifying and addressing security flaws in Wi-Fi protocols at the earliest stage possible, as timely mitigation is crucial for protecting millions of devices. Although existing works have revealed various attacks and vulnerabilities in WPA2/WPA3 handshake and authentication[9, 15, 16, 18], DoS attacks on WPA3 [18, 19], attacks on the WPS provisioning protocol [21] and Wi-Fi association attacks [10, 20], to the best of our knowledge an analysis of the Wi-Fi Easy Connect specification has not been conducted prior to this study. Despite the different protocols or security fields of Wi-Fi security examined in the related work, a common ground is that Wi-Fi protocols and specifications should prioritize security from the outset and include thorough peer reviews before they are widely deployed. This work aims to assist in this direction, concerning the Wi-Fi Easy Connect specification.

## 7 Discussion and conclusions

Wi-Fi Easy Connect is a powerful technology that aims to streamline the process of connecting devices to Wi-Fi networks. However, as our analysis has shown, several weaknesses in DPP can be exploited by attackers. The protocol design-specific attacks that we described cannot be solved without updating the protocol itself. The impact of these attacks can be particularly severe given the huge number of expected users of DPP.

impersonating the Configurator and distributing malicious files to other devices.

The identified weaknesses serve as additional evidence, of the need to carefully consider the security implications of user-friendliness features in new protocols (such as the use of mixed authentication modes or reconfiguration capabilities).

The results highlight the importance of thoroughly analyzing new Wi-Fi protocols that are anticipated to be widely adopted. It is a call for rigorous scrutiny and evaluation to ensure the robust and secure integration of these advanced technologies into our digital infrastructure.

## Notes

1. https://www.ieee802.org/11/.

2. The terms "Device Provisioning Protocol", "DPP" and "Wi-Fi Easy Connect" are used interchangeably throughout this paper.

4. Wi-Fi Alliance. Wi-Fi Alliance product finder. https://www.wi-fi.org/product-finder. Accessed 07 Jan 2023

5. Group, N.: Ble proximity authentication vulnerable to relay attacks. Available: https://www.nccgroup.com/us/research-blog/technical-advisory-ble-proximity-authentication-vulnerable-to-relay-attacks/ (2023). Accessed 02 Jan 2025

6. Nobles, P.: Vulnerability of IEEE802.11 WLANs to MAC layer DoS attacks. In: IET Conference Proceedings, pp. 14–14(1). https://digital-library.theiet.org/content/conferences/10.1049/ic.2004.0670 (2004)

7. Bernstein D.J., Hamburg, M., Krasnova, A., Lange, T.: Elligator: elliptic-curve points indistinguishable from uniform random strings. In: Proceedings of the 2013 ACM SIGSAC conference on Computer & Communications Security, pp. 967–980 (2013)

8. WiFi Alliance: WPA3 specification version 1.0. Available: https://www.wi-fi.org/file/wpa3-specifica- tion-v10

11. National Institute of Standards and Technology (NIST): A closer look at revocation and key compromise in public key infrastructures. National Institute of Standards and Technology, Tech. Rep. https://www.nist.gov/publications/closer-look-revocation-and-key-compromise-public-key-infrastructures (2023). Accessed 02 Jan 2025

12. IEEE Standard for Local and Metropolitan Area Networks—Port-Based Network Access Control, IEEE Std. 802.1X-2010. https://standards.ieee.org/standard/802_1X-2010.html (2010)

13. Common Vulnerability and Exposure database: CVE-2022-37660. https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2022-37660 (2022)

14. Rondon, L.P., Babun, L., Aris, A., Akkaya, K., Uluagac, A.S.: Survey on enterprise internet-of-things systems (e-iot): a security perspective. Ad Hoc Networks, vol. 125, p. 102728. https://www.sciencedirect.com/science/article/pii/S1570870521002171 (2022)

15. Vanhoef, M., Piessens, F.: Key reinstallation attacks: Forcing nonce reuse in wpa2. In: Proceedings of the 2017 ACM SIGSAC Conference on Computer and Communications

17. Marais, S., Coetzee, M., Blauw, F.: Simultaneous deauthentication of equals attack. In: Wang, G., Chen, B., Li, W., Di Pietro, R., Yan, X., Han, H. (eds.) Security, Privacy, and Anonymity in Computation, Communication, and Storage, pp. 545–556. Springer, Cham (2021)

18. Kampourakis, V., Chatzoglou, E., Kambourakis, G., Dolmes, A., Zaroliagis, C.: Wpaxfuzz: sniffing out vulnerabilities in wi-fi implementations. In: Cryptography, vol. 6, no. 4. https://www.mdpi.com/2410-387X/6/4/53 (2022)

19. Chatzoglou, E., Kambourakis, G., Kolias, C.: How is your WiFi connection today? DoS attacks on WPA3-SAE. J. Inf. Secur. Appl. **64**, 103058 (2022)

20. Chatzisofroniou, G., Kotzanikolaou, P.: Exploiting WiFi usability features for association attacks in IEEE 802.11: attack analysis and mitigation controls. J. Comput. Secur. **30**(3), 357–380 (2022)

21. Bongard, D.: Offline bruteforce attack on WPS: The pixie dust attack. Presentation at Hack.lu 2014.

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## Ethics declarations

### Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

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