

# The Evolution of Authentication

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## Abstract

An analysis of 6 million accounts showed that 10,000 common passwords would have access to 99.8% of the accounts. When looking at passwords for banking accounts, it can be found that 73% of users shared their online banking password with at least one non-financial site, which means that when the non-banking site gets hacked, the banking account is threatened. And it's not only about security. According to a recent study conducted by the Ponemon Institute, more than 45% of the online transactions fail "Very Frequently" or "Frequently" due to authentication problems. Passwords do not work, yet no other technologies have been broadly deployed, why is that?

Current alternative technologies require their respective proprietary server technology. The current authentication architecture therefore consists of 'silos' comprising the authentication method, the related client implementation and the related server technology. Instead of having a competition for better user authentication methods, authentication companies are faced with a battle for the best server technology.

Other current challenges with Authentication include the need for flexibility. Today it is used for electronically initiating high value money transactions and for accessing the personal purchase history in an online bookshop. The security needs are different. The ongoing adoption of mobile devices and the BYOD trend lead to an increasingly heterogeneous authentication landscape. There is no one approach that can meet these diverse requirements.

The FIDO Alliance, a new industry working group, has been founded to define an open, interoperable set of mechanisms that reduce the reliance on passwords.

## 1 Motivation

**Passwords don't work:** In 2007, the average user had 25 accounts, used 6.5 passwords and performed logins 8 times a day [1]. Today, things are much worse. An analysis of 6 million accounts showed that 10,000 common passwords would have access to 99.8% of the accounts [2]. This basically means that only 0.2% of the users chose strong passwords and it means that passwords provide an effective security equivalent to 5 digit PINs. Even when looking at passwords for banking accounts only, it can be found that 73% of users shared their online banking password with at least one non-financial site [3], which means that when the non-banking site gets hacked, the banking account is threatened.

"Account or service hijacking is not new. Attack methods such as phishing, fraud, and exploitation of software vulnerabilities still achieve results. Credentials and passwords are often reused, which amplifies the impact of such attacks." [4].

The password problem seems to be an important issue to solve: “Account and service hijacking, usually with stolen credentials, remains a top threat” [4]. It’s not only about security. According to a recent study, more than 45% of the online transactions fail “Very Frequently” or “Frequently” due to authentication problems [5].

Several proposals to replace passwords have been made. A good analysis can be found in [6].

**Silos of Authentication:** Current alternative technologies require their respective proprietary server technology. The current authentication architecture therefore consists of silos comprising the authentication method, the related client implementation and the related server technology.

Innovative authentication methods proposed by the research community are not widely deployed, as in addition to the client implementation the complete server software needs to be implemented and deployed. Instead of having a competition for better user authentication methods, authentication companies are faced with a battle for the best server technology.

**Heterogeneous Authentication Needs:** Authentication is used for electronically initiating high value money transactions and for accessing the personal purchase history in an online bookshop. The security needs are different.

Users might authenticate using standalone PCs, tablets or smart phones. The employer might control some devices; others might be controlled by the user [7]. Increased adoption of mobile devices and the BYOD trend lead to an increasingly heterogeneous authentication landscape. The one authentication method satisfying all needs seems to be out of reach.

**Trustworthy Client Environment:** Client side malware could capture and disclose passwords or OTPs. It could alter transactions to be confirmed after being displayed or it could misuse authenticated communication channels to perform unintended actions. Authentication – even with username and password – needs at least one trustworthy component at the client side.

## 2 Related Work

A survey of (basic) authentication protocols can be found in [8]. The principle of hardware attestation is mentioned in [9] and it has been implemented and widely deployed by Trusted Platform Modules (TPMs).

As well as research into specific user authentication methods, the research community has tried to standardize authentication. The following standards are related:

- PKCS#15, achieving smart card profile interoperability by introducing a meta card profile;
- PKCS#11 (RSA Laboratories, 2009), achieving cryptographic token interoperability by providing a unified API;
- GSS-API (RFC 1508, RFC 2078, RFC 2743, Kitten working group), generic security service API. Achieving interoperability by allowing applications to use a shared module, i.e. effectively reducing the number of implementations;
- ISO/IEC 24727 is a set of programming interfaces for interactions between integrated circuit cards and external applications to include generic services for multi-sector use.

The aspect of supporting a variety of authentication methods for network access authentication is approached by the Extensible Authentication Protocol (EAP, RFC 3748). This protocol is de-

signed for situations in which IP layer connectivity may not be available. “Use of EAP for other purposes, such as bulk data transport, is NOT RECOMMENDED” [10].

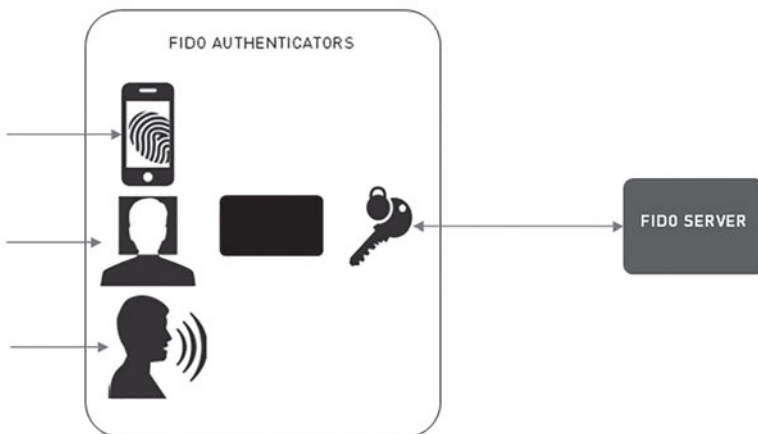
The Initiative for Open Authentication (OATH) is an industry-wide collaboration to develop an open reference architecture by leveraging existing open standards for the universal adoption of strong authentication (see [www.openauthentication.org](http://www.openauthentication.org)). Besides the OATH Reference Architecture [11], this initiative has published standards documents regarding an HMAC-Based OTP Algorithm (RFC 4226), Time-based One-time password Algorithm (RFC 6238), OATH Challenge/Response Algorithm (RFC 6287), and two pro-visioning standards (Portable Symmetric Key Container RFC 6030 and Dynamic Symmetric Key Provisioning Protocol RFC 6063).

In the case that a user has authenticated to the first relying party (typically called Identity Provider, IdP), this authentication can be federated to other relying parties (@ Federation). Popular federation protocols are SAML, OpenID, and OpenID Connect. Related to these federation protocols is the web authorization protocol OAuth. An initial authentication (of the resource owner in this case) is leveraged here as well.

The FIDO protocol is concerned with authenticating the user to the first relying party (“first-mile authentication”); federation is about leveraging this “first-mile authentication” to other relying parties (“second mile authentication”).

### 3 The FIDO Approach

We propose to (a) separate the user authentication method from the authentication protocol and (b) to define an attestation method in order to proof the FIDO Authenticator type to the relying party. Given this information, the relying party is able to infer the related assurance level (e.g. as defined in [12]). The assurance level can be fed into internal risk management systems. The relying party can then add implicit authentication methods as needed.



**Fig. 1:** Mapping Arbitrary User Authentication Methods to Cryptographic Authentication

In the FIDO approach, standardized challenge response based cryptographic authentication schemes are used between the FIDO Authenticator (controlled by the user) and the FIDO Server

(controlled by the relying party). The FIDO Authenticator can implement any user authentication method, but it has to cryptographically attest itself to the relying party. The security relevant functions are centralized into the FIDO Authenticator.

### 3.1 FIDO Protocol

Starting from this challenge response based authentication scheme, the FIDO Universal Authentication Factor protocol supports the following functionality:

- 1. Discovery
- 2. Registration
- 3. Authentication
- 4. Transaction Confirmation

The discovery enables relying parties to understand the user authentication methods (more specifically the FIDO Authenticators) supported by the FIDO User Device. The relying party can specify a policy for selecting FIDO Authenticators best suited for the specific purpose.

The Registration operation binds the FIDO Authenticator to a specific entity. This might be an existing user identity already present in the system or it might be a user identity to be created.

The Authentication operation supports a single or multiple FIDO Authenticators to be involved. Each FIDO Authenticator might be implemented to represent either simple or strong authentication / two factor authentication as defined by [13] [14]. The Authentication operation is used to establish an authenticated channel between the Browser / App and the relying party Web Server.

The Transaction Confirmation allows the user to see and authenticate a particular well-defined transaction to the relying party. It is more secure as it doesn't rely on a Web Browser / App to not misuse an authenticated channel.

This leads to the following reference architecture:

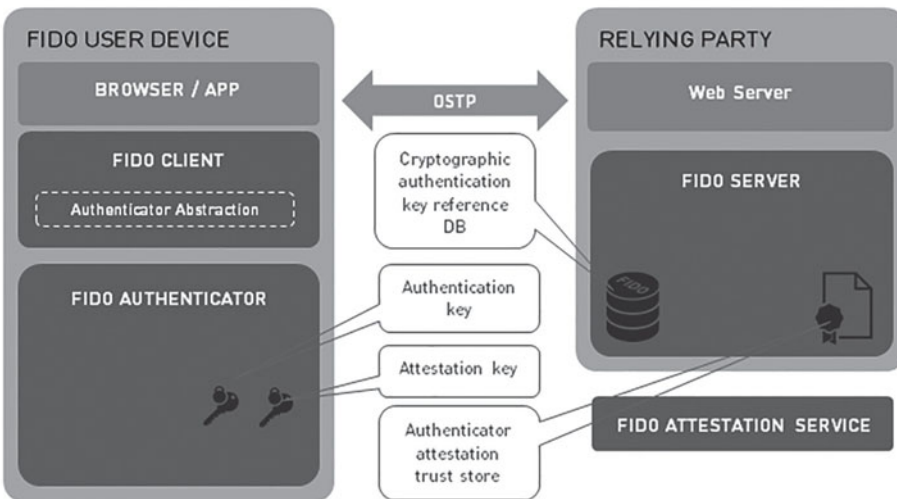


Fig. 2: FIDO Building Blocks

The FIDO Authenticator is a concept. It might be implemented as a software component running on the FIDO User Device, it might be implemented as a dedicated hard-ware token (e.g. smart card or USB crypto device), it might be implemented as software leveraging cryptographic capabilities of TPMs or Secure Elements or it might even be implemented as software running inside a Trusted Execution Environment.

The User Authentication method could leverage any hardware support available on the FIDO User Device, e.g. Microphones (® Speaker Recognition), Cameras (® Face Recognition), Fingerprint Sensors, or behavioral biometrics, see [15] [16].

## 3.2 Impact on User Experience

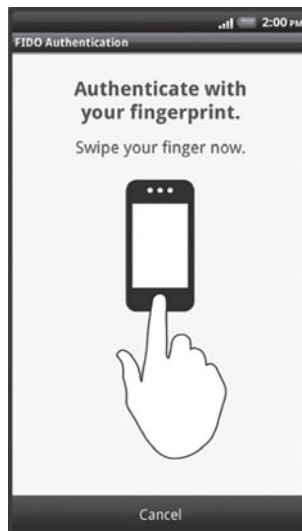


Fig 3: FIDO Authenticator

The user experience is mainly dominated by the user authentication method. For example, entering strong passwords on a smart phone leads to bad user experience [17]. Bad user experience might lead to poor security as many users opt for convenience rather than security [18].

FIDO Authenticators could implement any user authentication method. Such methods can be optimized for particular use cases and for the devices they are running on. In some situations, the user authentication method should be non-intrusive, so continuous authentication [19] [20] could be an option. In other situations a more precise user authentication method might be desirable, so the use of fingerprints or dedicated hardware tokens (such as smart cards) might be more suitable.

Due to the separation of user authentication method and authentication protocol, the change of the user method doesn't have any impact on the authentication server – as long as the assurance level is acceptable in the given context.

### 3.3 Attestation

Passwords, OTPs and other bearer tokens [21] can be submitted by legitimate users or phishing servers. For the risk of a transaction, this makes a significant difference.

The relying party is typically interested in estimating the risk of a transaction. This risk depends on the transaction volume and on the assurance level of the authentication. The assurance level depends on (a) the authentication method and (b) the certainty that the legitimate user controls the relevant portions of the client device. In the case of Transaction Confirmation (see above), this could be limited to the FIDO Authenticator. In the case of Authentication it will also include the Browser / App or User Agent in general. Risk based authentication [22] methods try to estimate (b). Authenticator attestation provides a cryptographic proof of the FIDO Authenticator being used to the relying party.

Using hardware attestation is not new, e.g. see [23]. In Public Key Infrastructures (PKIs), the hardware verification is typically being performed by the Certificate Authority before issuing the user certificate. The device policy is typically included into the user certificate as Certificate Policy OID (e.g. “id-fpki-certpcy-pivi-hardware” in the case of Federal Bridge CA, see [24]). User registration/identification and hardware attestation are combined into a single certificate. Relying parties verify such certificate policies included in the user certificate when validating the user certificates.

In non-PKI environments, hardware attestation and user registration/identification have to be separated. Trusted platform modules already support the concept of (pure) attestation [25] [26].

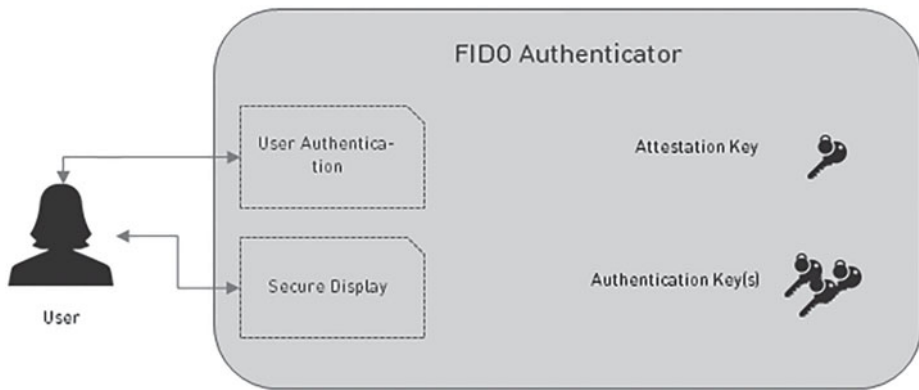
## 4 The Need for a Trusted Client Side Component

As previously mentioned, authentication requires at least one trustworthy client side component. In the case of FIDO this is the FIDO Authenticator. The security relevant functions are centralized into it. The most important security functions are:

1. Securely maintaining the attestation key and only using it for attesting newly generated authentication keys.
2. Securely maintaining the cryptographic authentication keys and
  - a. Enforcing proper user authentication before unlocking the authentication key for authentications and
  - b. Restricting its usage to cryptographic operations on defined clear-text message structures.

Use of secure hardware will significantly improve overall assurance level.

Existing secure hardware platforms include Smart Cards [27], TPMs [28], Secure Elements [29], and Trusted Execution Environments (TEEs [30]).



**Fig. 4:** Logical FIDO Authenticator Architecture

Some secure hardware can be accessed through standardized APIs e.g. PKCS#11 [31], or Microsoft Crypto API Next Generation [32]. Such APIs allow secure generation and storage of (authentication) keys (e.g. RSA keys). However, as the concept of attestation is missing by those APIs, there is no way for a relying party to be sure that a key has been generated by a specific secure hardware. Software generated keys would look the same.

Other secure hardware, e.g. ISO7816 compliant smart cards, or TPMs either support the concept of attestation by default (TPMs) or can be initialized to support that concept (e.g. by using secure messaging). For Java Cards (Oracle), applets can be implemented to provide the security related functions of an Authenticator, i.e. Attestation, Authentication and PIN based user authentication.

Implementing all aspects of the FIDO Authenticator (i.e. User Authentication, Secure Display, Authentication and Attestation) in a TEE *and* storing the keys in a Secure Element exclusively accessible by a FIDO Authenticator Trusted Application would lead to the highest assurance level.

## 5 Conclusion

We have presented a new authentication framework providing an effective separation between the local user-to-authenticator authentication and the authenticator-to-relying party authentication. It supports a broad range of authentication methods and assurance levels while still letting the relying party define the acceptable assurance level for a particular context. This framework complements federation protocols by providing a solid basis for the “first-mile authentication”.

The FIDO authentication framework is designed to support several important security and privacy properties, including non-linkability, resilience to leaks from other verifiers, resilience to phishing, no trusted third party etc. (see [6] for definition of these terms).

Based on this framework, relying parties can deploy even novel user authentication methods without changing the server side infrastructure.

Further development of this framework is driven by the FIDO Alliance ([www.fidoalliance.org](http://www.fidoalliance.org)).

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