Dashlane Security Whitepaper

November 2017

Contents

1. General Security Principles

a. Protection of User Data in Dashlane

Protection of User Data in Dashlane relies on 3 separate secrets:

- The **User Master Password**
  - It is never stored on Dashlane Servers, neither is any of its derivative (including hashes)
  - By default, it is not stored locally on disk on any of the user devices: we simply use it to (de)cipher the local files containing the user data
  - It is stored locally upon user request when enabling the feature "remember my Master Password"
  - In addition, the user Master Password never transits over the Internet, neither any of its derivatives (including hashes)
- A unique **User Device Key** for each device enabled by a user
  Auto generated for each device.
  Used for authentication
- A **Dashlane Secret Key**
  Used to secure communication between the Dashlane application and the browser plugins.

b. Local access to User Data

Access to the user's data requires using the **User Master Password** which is only known by the user. It is used to generate the symmetric AES 256 bits key for ciphering and deciphering the user's personal data on the user's device.

The user's data ciphering and deciphering is performed using *OpenSSL*:

- A 32 bytes salt is generated using the *OpenSSL* RAND_bytes function (ciphering) or reading it from the AES file (deciphering)
- The User Master Password is used, with the salt, to generate the AES 256 bit key that will be used for (de)ciphering. This generation is performed using the *OpenSSL* PKCS5_PBKDF2_HMAC_SHA1 function, using more than 10000 iterations
- The 32 bytes initialization vector is generated with *OpenSSL* EVP_BytesToKey function using SHA1
- Then, the data is (de)ciphered using CBC mode.
- When ciphering, the salt is written in the AES file

c. Local Data Usage after deciphering

Once the user has input his Master Password locally in Dashlane and his user's data has been deciphered, data is loaded in memory.

The Dashlane client operates within significant constraints to use deciphered user data effectively and securely:

- Dashlane processes decipher and access individual passwords to autofill them on websites or to save credentials without having to ask the user for master password each time
- Users require that these actions are performed quickly
- The passwords are sent from different processes through named pipes or web sockets from core to plugins (but are encrypted using AES first).
- The 10000 iterations PKBDF2 derivation used to compute the AES keys adds significant latency (on purpose to protect from brute force attacks)

See in §2.f for more on Memory management.

d. Use of 2FA Applications to increase user's data safety

At any time, a user can link his account to a 2FA application on his mobile (an example among others is Google Authenticator). All of his data, both the data stored locally, and the data sent to Dashlane servers for synchronization purposes are then ciphered with a new key, which is generated by a combination of the **User Master Password** and a randomly generated key called **User Secondary Key** stored on Dashlane server, as described in the following steps:

- The user links his Dashlane account with his 2FA application
- Dashlane servers generate and store a **User Secondary Key**, which is sent to the user's client application
- All personal data are ciphered with a new symmetric AES 256 bits generated client side with both the **User Master Password** and the **User Secondary Key**.
- The **User Secondary Key** is never stored locally
- The next time the user tries to log into Dashlane, he will be asked by Dashlane servers to provide a One-Time Password generated by the 2FA application. Upon receiving and verifying this One-Time Password, Dashlane servers will send the **User Secondary Key** to the client application, allowing the user to decipher his data

Doing so, user's data can be deciphered only by having in the same time the **User Master Password**, and the **2FA** application linked to the user's account.

e. Authentication

As some of Dashlane's services are cloud based (data synchronization between multiple devices for instance) there is a need to authenticate the user on Dashlane servers.

Authentication of the user on Dashlane servers is based on the **User Device Key** and has **no relationship with the User Master Password**.

When a user creates an account or adds a new device to synchronize his data, a new User Device Key is generated. The User Device Key is composed of two parts:

- A first part, which is a predictable part based on some Hardware and Software characteristics of the user's device
- A second part, of 38 characters (lower letters, capital letters, and numbers) generated using the *OpenSSL* RAND_byte function.

This User Device Key is then stored locally in the user data, ciphered as all other user data as explained earlier, and sent to our servers. When a user has gained access to his data using his Master Password, Dashlane is able to access his User Device Key to authenticate him on our servers without any user interaction.

As a result, Dashlane does not have to store the user Master Password to perform authentication.

f. Communication

All communications between the Dashlane Application and the Dashlane servers are secured with HTTPS. HTTPS connections on the client side are performed using *OpenSSL*. On the server side, we use a *DigiCert* High Assurance CA-3 certificate[1].

The HTTPS communications between Dashlane application and Dashlane's servers are using SSL/TLS connections.

TLS protocol main steps are as follows:

- The client and the server negotiate to choose the best cipher and hash algorithm available on both side
- The server sends his digital certificate
- The client verifies the certificate by contacting a Certificate Authority
- The client encrypts a random number with the server's public key, and sends it to the server.
- The server decrypts this number, and both sides use this number to generate a symmetric key, used to encrypt and decrypt data

Finally, communication between the Dashlane Browser Plugin and the Dashlane Application is secured using with AES 256 with the *OpenSSL* library:

- A 32 bytes salt is generated using the *OpenSSL* RAND_bytes function (ciphering) or reading it from the inter process message (deciphering)
- The **Dashlane Private Key** is used, with the salt, to generate the AES 256 bit key that will be used for (de)ciphering. This generation is performed using the *OpenSSL* EVP_BytesToKey, using SHA1, with 5 iterations

[1] Key Length: 2048 bit, Signature algorithm = SHA1 + RSA

- The 32 bytes initialization vector is generated with the *OpenSSL* EVP_BytesToKey function, using SHA1
- Then, the data is (de)ciphered using CBC mode.
- When ciphering, the salt is written on inter process message

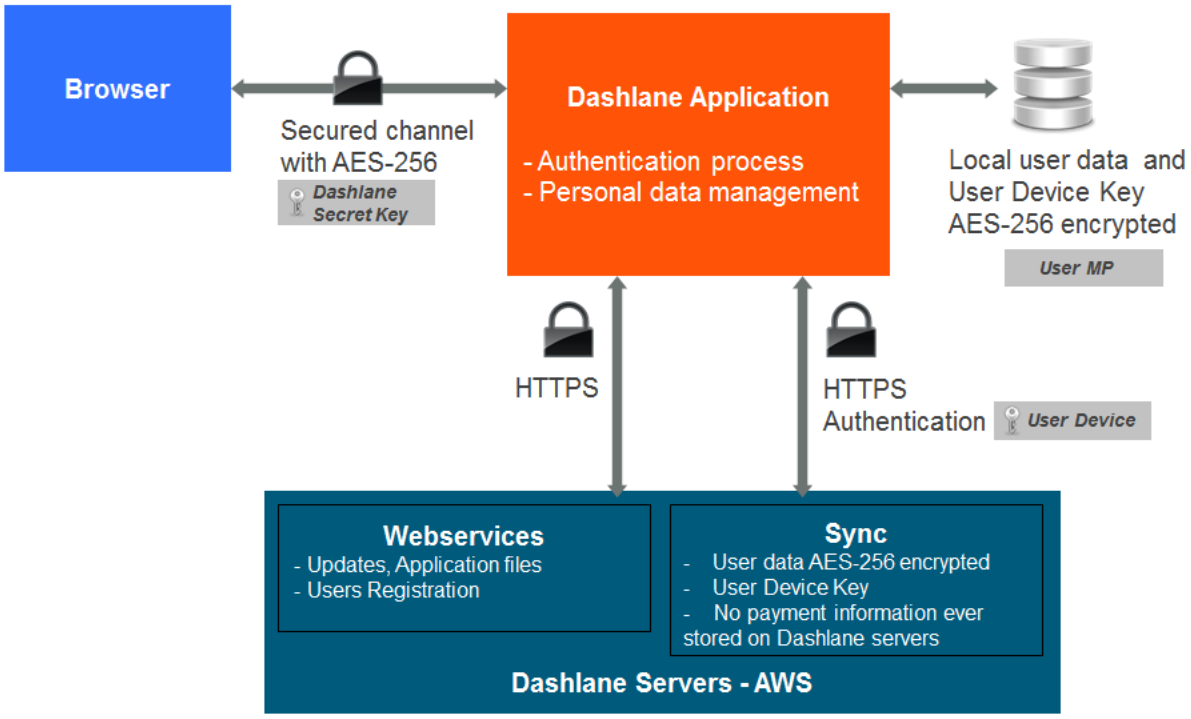


Figure 1: Use of Authentication Mechanisms in Dashlane

g. Details on Authentication Flow

The initial registration for a user follows the flow described in Figure 2: *Authentication flow during registration*.

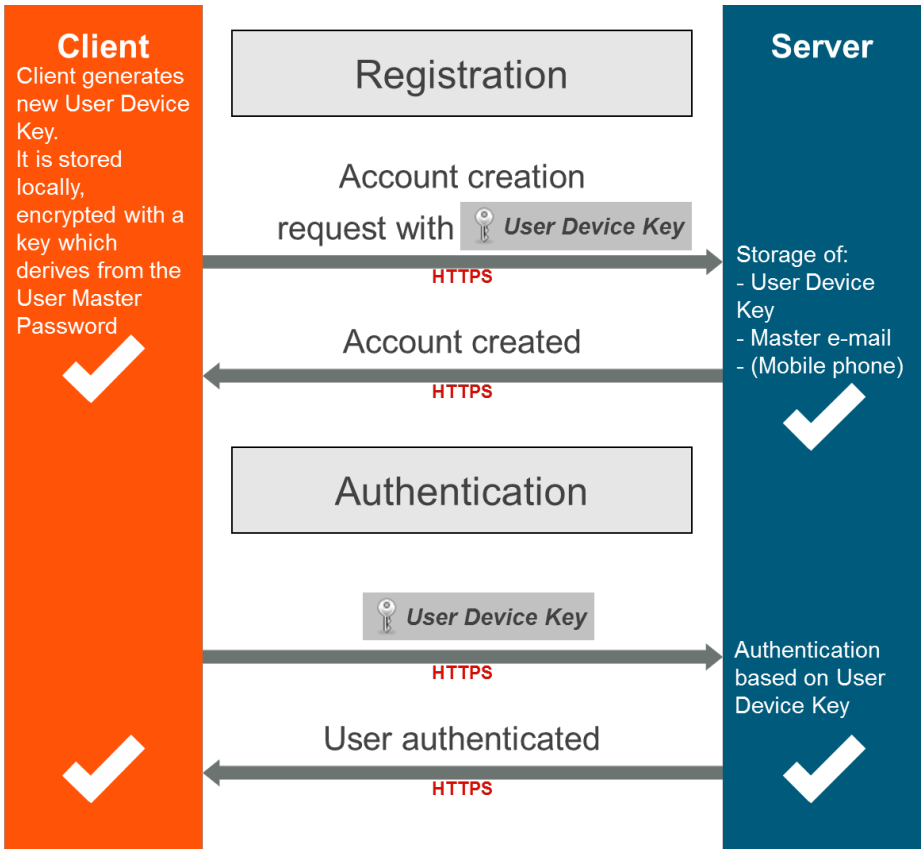


Figure 2: Authentication flow during registration

As was seen in Figure 2, the User Master Password is never used to perform Server Authentication, and the only keys stored on our servers are the User Device keys.

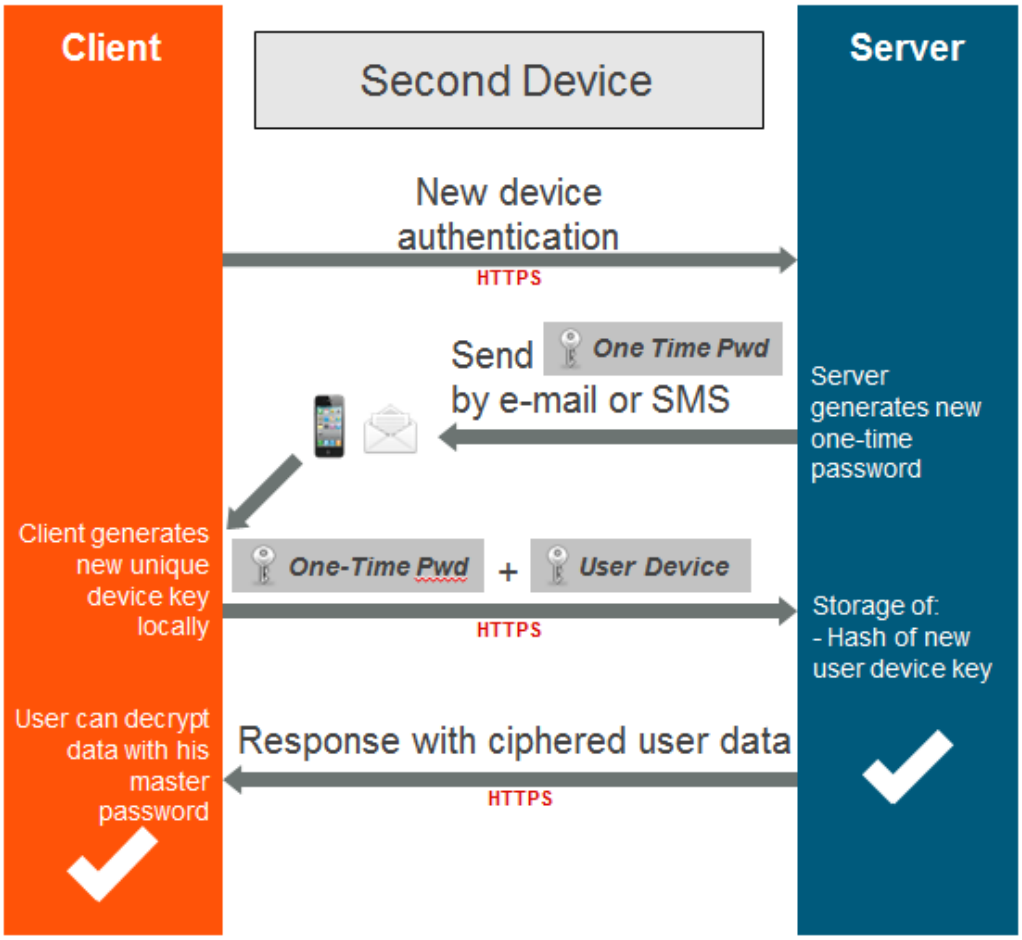


Figure 3: Authentication when adding a new device

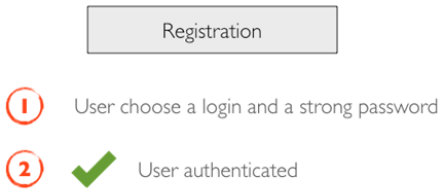
When adding a second device, the important point is that Dashlane needs to make sure the user adding the additional device is indeed the legitimate owner of the account. This is to gain additional protection in the event the user Master Password has been compromised and an attacker who does not have access to his already enabled device is trying to access the account from another device.

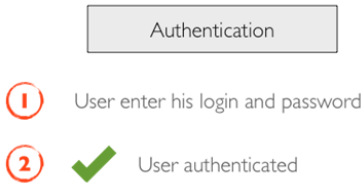
As shown on Figure 3, when a user is attempting to connect to a Dashlane account on a device that has not yet been authorized for this account, Dashlane generates a One-Time Password (a Token) that is being sent to the user either to the email address used to create the Dashlane account initially, or by text message to the user's mobile phone if the user has chosen to provide his mobile phone number.

In order to enable the new device, the user has to enter both his Master Password and the Token. Only once this Two-Factor authentication has been performed will Dashlane servers start synchronizing the user data on the new device. All communication is handled with HTTPS and the user data only travels in AES-256 encrypted form. Please note again that the user Master Password never transits on the Internet.

h. Keeping the User Experience simple

All along, our goal is to keep the user experience simple and to hide all the complexity from the user. Security is growing more and more important for users of Cloud services but they are not necessarily ready to sacrifice convenience for more security.





Even though what goes on in the background during the initial registration steps is complex (See Figure 2) and highly secure, the perception by the user could not be simpler. All he has to do is to pick as (strong) Master Password, all the other keys are generated by the application without user intervention.

When adding an additional device, the process is equally simple, while remaining highly secure through the use of two-factor authentication described in Figure 3.

i. Use of 2FA Application to secure the connection to a new device

At any time, a user can link his Dashlane account to a 2FA application on his mobile. When he attempts to connect into a new device, instead of sending him a One-Time Password by email, Dashlane asks the user to provide a One-Time password generated by the 2FA application.

After receiving and verifying the One-Time Password provided by the user, Dashlane servers will store the **User Device Key** generated by the client application, as described in Figure 3.

j. 2 Factor Authentication

Dashlane offers 2 Factor Authentication, that can be activated from the Security settings in the desktop application, to force the usage of a second factor each time the user logs into Dashlane.

Supported 2 Factor methods include 2FA Applications such as Google Authenticator or U2F compatible devices such as Yubikeys. U2F is an open protocol from the FIDO Alliance (https://fidoalliance.org). Dashlane is a member of the FIDO Alliance.

k. Sharing data between users

Dashlane allows users to share credentials and secure notes with other users, or with groups of users, in such a way that Dashlane never directly accesses a user's data at any point. In fact, Dashlane's servers never have access to the content of shared data.

Dashlane sharing relies on asymmetric encryption; upon account creation, a unique pair of public and private RSA keys is created by the Dashlane application for each user. The private key is stored in the user's personal data, and the public key is sent to Dashlane's servers. RSA public and private keys are generated using the OpenSSL function RSA_generate_key_ex, using a key length of 2048 bits, with 3 as a public exponent.

Here is the process for a user, Alice, to share a credential with another user, Bob:

- Alice asks Dashlane's servers for Bob's public key
- Alice generates a 256-bit AES key, using cryptographically secure random on each platform. This key is unique for each shared item, and is called an ObjectKey.
- Alice encrypts the ObjectKey using Bob's public key, creating a BobEncryptedObjectKey
- Alice sends the BobEncryptedObjectKey to Dashlane's servers
- Alice encrypts her credential with the ObjectKey, using AES-CBC and HMAC-SHA2 creating an EncryptedCredential
- Alice sends the EncryptedCredential to Dashlane's servers
- When Bob logs in, Dashlane's servers inform him that Alice wants to share a credential with him. Bob must manually accept the item, in his Dashlane application, and sign his acceptance using his private key
- Upon acceptance, Dashlane's servers send Bob the BobEncryptedObjectKey, and the EncryptedCredential
- Bob decrypts the BobEncryptedObjectKey with his private key, and gets the ObjectKey
- Bob decrypts the EncryptedCredential with the ObjectKey and adds Alice's plain text credential to his own personal data

Sharing data with a group of users follows the same security principle: use a user's RSA public and private keys to send protected AES keys, and sign a user's action, and use intermediary AES keys to exchange data.

To summarize:

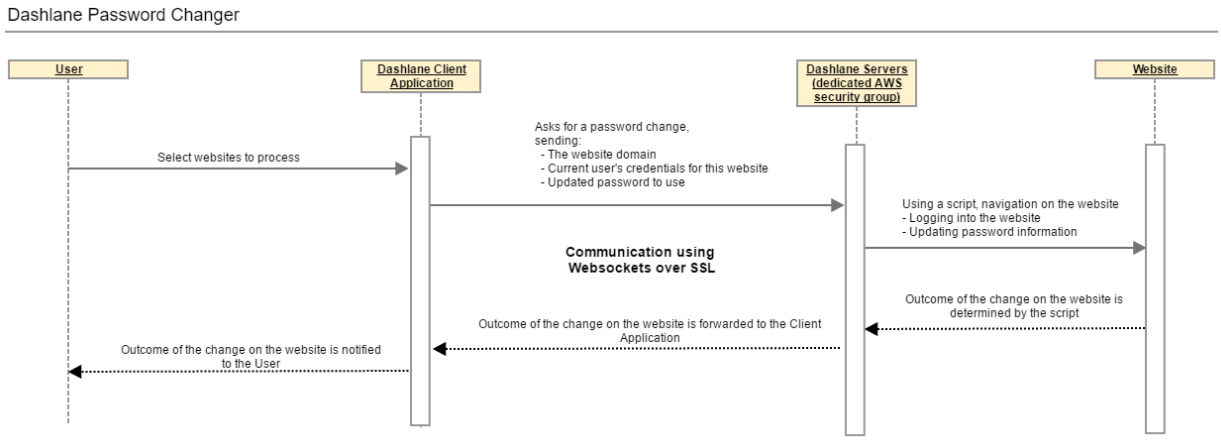
- Each user has a pair of public and private RSA 2048-bit keys
  - Public keys are used to encrypt information only a specific user can decrypt
  - Private keys are used to sign actions users are performing
- For each credential or secure note shared, an intermediary AES 256-bit key is created and used to perform data encryption and decryption

l. Using Password Changer to further increase the User security

The “Password Changer” feature of Dashlane offers a 1-click experience to change a password for a particular website. This makes changing passwords for compromised websites easier. Furthermore, it provides users a convenient way to regularly update their passwords without going through the hassle of manually updating passwords for websites they have. Password Changer makes such a very important security practice, which is rarely followed, a lot easier.

To change a password for a particular website, a Dashlane’s client sends current saved password to Dashlane's servers along with a new strong password generated on the client. This communication is done using secure websockets (Websockets over SSL/TLS – the SSL termination is done using AWS Elastic Load Balancers as for any other Dashlane webservices) to prevent Man-in-The-Middle attacks. The servers try to login to the targeted website and change the user’s password using either a browser navigation or a call to an API depending on the website. Dashlane prompts the user for additional information if needed (e.g. security question) using the same secure websocket connection. At the end of the operation, it notifies the user with the result. In case of success, the client updates the password locally.

The servers (AWS EC2 instances) that are used to provide Password Changer are separated from the rest of the Dashlane's server infrastructure (dedicated instances and distinct AWS security groups). Additionally, on the server side, sensitive information (e.g. logins and passwords) is stored in RAM only. It’s removed from RAM right after the result is sent back to the client (the password change takes 45 seconds in average), or after five minutes in case of a client disconnection.

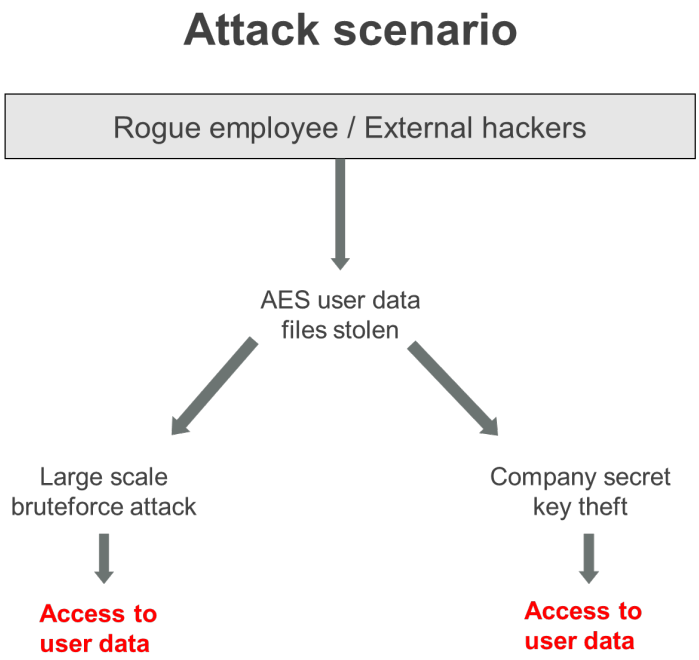


2. Impact on Potential Attack Scenarios

Today, cloud based services make various choices to encrypt their user data. These choices have certain important consequences in terms of security.

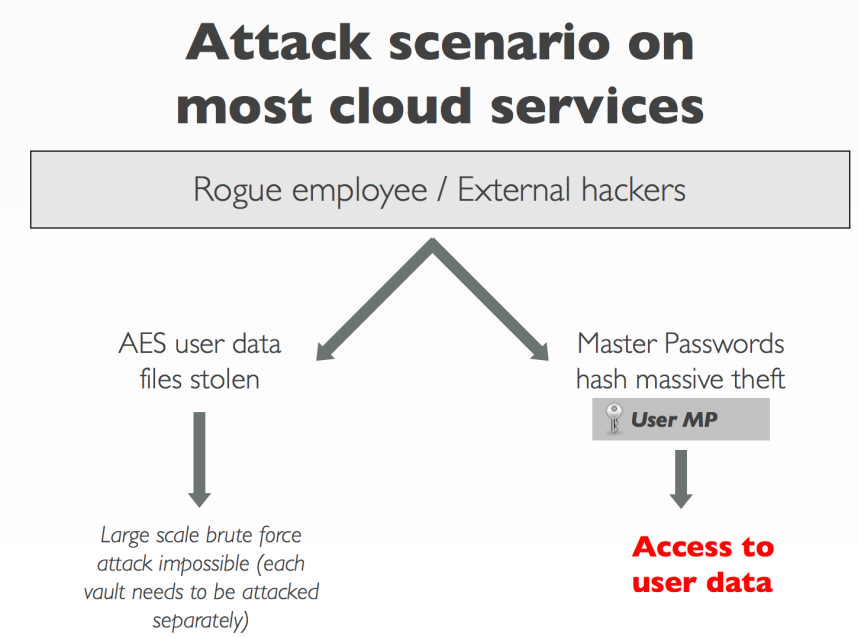
a. Minimal Security Architecture

Cloud Services can use a **single private secret**, usually under their control, **to encrypt all user data**. This is obviously a simpler choice from an implementation standpoint, plus it offers the advantage of facilitating *deduplication* of data which can provide important economic benefits when the user data volume is important. Obviously, this this not an optimal scenario from a security standpoint since if the key is compromised (hacker attack or rogue employee), all user data is exposed.



b. Most Common Security Architecture

A better alternative is to use a different key for each user. The most common practice is to ask the user to provide a (strong) Master Password and to derive the encryption key for each user from his Master Password. However, to keep things simple for the user, many services or applications tend to also use the user's Master Password as an authentication key for the connection to their services. This implies that an attacker could access a user's vault by just knowing is master password. It could also easily lead to implementation errors (missing salt/rainbow tables attacks, wrong/weak hashing, etc.).



c. Dashlane Security Architecture

In order to make this attack scenario impossible, we have made the decision to separate the key used for user data Encryption and the key used for server based authentication (See Figure 4: *Limits on Attack potential with Dashlane's security Architecture*). The user data is encrypted with a key which is a derivative of the User Master Password. A separate User Device Key (unique to each couple device-user is used to perform authentication on Dashlane Servers. This User Device Key is automatically generated by Dashlane. As a result:

- Encryption keys for User Data is not stored anywhere
- No Dashlane Employee can ever access User Data
- User Data is protected by its master password even if Dashlane Servers are compromised

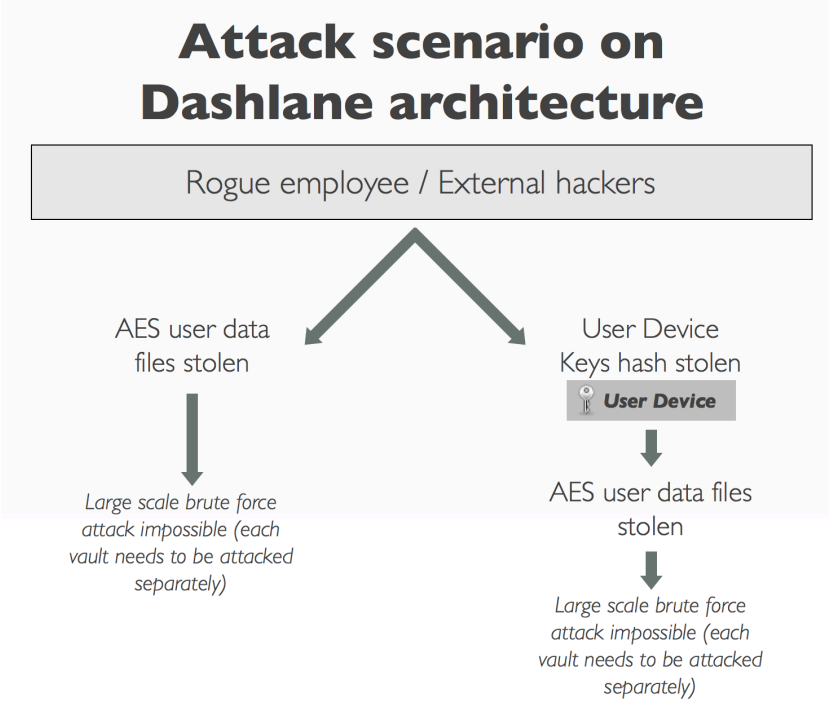


Figure 4: Limits on Attack potential with Dashlane's security Architecture

Even if this scenario happens, a rogue employee or an external hacker would have a very hard time executing a brute force or a dictionary attack on the AES user data files, as we use the PBKDF2 algorithm with more than 10,000 iterations. As the user data are encrypted using a salted key which is a derivate of their User Master Password, no rainbow attacks are possible.

As an example, this is a benchmark of attempts to decipher AES files using a Xeon 1.87GHz (4 cores):

	Time to get the password on a Xeon 1.87 GHz (4 cores)	
Type of brute force attack	**AES 256**	**AES 256 with PBKDF2-SHA1 with 10000 iterations**
4 million terms dictionary	2,8 seconds	**21 hours**
Alphanumerical(small caps + digits) password of 7 characters	15,7 hours	**48,6 years**
Alphanumerical(small caps + digits) password of 8 characters	23,6 days	**1751,3 years**

This table represents the time it would take on a Xeon 1.87 GHz (4 cores) to break a password used to protect Dashlane user data. Without using PBKDF2, those numbers show that even with a strong password, an attacker would be able to crack the user password within less than a month.

Using PBKDF2, and given that Dashlane enforces reasonably strong password requirements[2] (and so user Master Passwords are not contained in a dictionary), an attack would be impractical

Obviously there is a limit to any security architecture. If the user's computer is physically compromised and an attacker is able to install a keylogger allowing him to capture all keystrokes, then no password based security system will prevent data theft or piracy. This is why the end user still remains responsible for physically protecting his computer from non-authorized access and for making sure he is not installing potentially infected software. Our point is that in any event, a Dashlane user is significantly more secure than if he stores sensitive personal data in Word or Excel documents, uses his memory or a system that necessitates weak password patterns, or stores passwords in the cache of his browsers.

[2] At least one upper case, one lower case, 1 digit and at least 8 characters

d. Anti-Click Jacking Provisions

In order to protect Dashlane users from rogue websites that would attempt to use Click Jacking tactics or other JavaScript based attacks to extract data from the Dashlane Application, we have made sure none of the webpage-based interactions involving user data unrelated to this website use JavaScript.

Instead, all the interactions[3] involving user data have been written in C++ and this compiled code has seen the use of various packing and protection methods to further complicate reverse engineering attempts and make Click-Jacking and others Javascript attacks extremely difficult to perform. This of course won't be relevant if the user's computer has been compromised by a rogue program.

For example, the popups used to trigger form-filling on a webpage are C++ popup and are external from the Javascript. As a result, a Rogue Website cannot trigger a click that would cause Dashlane to believe that the user has actually clicked, and therefore, cannot extract information unless the user explicitly clicks in the field.

e. Same-origin policy

Dashlane automatically logs users into websites. In order to avoid providing user's information to rogue websites, the same-origin policy is always respected.

First, a credential saved by Dashlane when it has been used on a website with a Url of the form mysubdomain.mydomain.com will not be automatically filled on another website with a Url of the form myothersubdomain.mydomain.com. This prevents a credential of a specific website from being provided to another website which would share the same top level domain name.

Also, a credential saved by Dashlane when it has been used on a website with a Url beginning with https will not be automatically filled on another website with a Url beginning with http.

f. Memory protection

A problem can arise if an attacker takes control of the client device of the user. In that scenario, the attacker could retrieve from the memory the deciphered user data.

This is an extreme scenario as, in that case, the attacker can take control of many parts, including adding a key logger to capture the Master Password.

- Mobile Operating Systems (Android, IOS) ensure that no process can ever access the memory of another process and *are not directly affected.*
- Sandboxed process: Windows store or Mac App store apps *can't access other process memory, either.*

[3] The only exception being interactions where data specific to the website is provided like the automatic login where we do not create any additional risk by using JavaScript

- Non Sandboxed Desktop Apps are an issue. They can access memory with classic system API (CreateRemoteThread, ReadProcessMemory, WriteProcessMemory on windows) or classic debugging tools.
- On Windows, Dashlane binaries are compiled with ASLR enabled.

Dashlane is working on adding additional memory protections (add intermediate cipher keys, wipe chunks of memory before releasing, etc.), but we also need to take into account that if the attacker had control over the process memory, he can already cause a lot of harm and can bypass such countermeasures:

- Hook process decryption functions
- Add a Keylogger
- Hook ssl http functions and retrieve passwords
- Tamper certificates authorities
- Debug, trace, add watches and bypass added security

Finally, we believe the system integrity and security between processes is a system function and Dashlane cannot (and should not) reinvent the wheel and add useless complexity (that could lead to other vulnerabilities and have negative side-effects on antivirus).

g. SHA1 usage

Dashlane uses SHA1 only as the Pseudo Random function of our Key Derivation (done with PBKDF2) to generate a suitable 32 bytes AES Derivated Key from the user Master Password.

There is a known issue in SHA1 that allows attackers to find collisions. Collisions are two different preimages (the clear text) that will give the same hash.

This attacks requires to know both the preimage and the computed hash which is the case when SHA1 is used as an integrity control mechanism and especially in digital signatures.

In the Dashlane case it only means that someone in possession of the Master Password can process a Derivated Key and will be able to compute a second Master Password that will provide the same Derivated Key which is useless.

In other words: this vulnerability in SHA1 does not affect the security of Dashlane.

h. Intel SGX

Dashlane Windows Application supports the Intel SGX protocol, that adds another layer of security for Dashlane customers using Intel CPU compatible with SGX instructions.

When a SGX compatible hardware is detected by Dashlane, it enables the use of the secure enclave to further protect the encryption key. When this feature is enabled, the key is derived two times:

- One time using the classic Dashlane derivation function (today PBKDF2)
- A second time using the SGX enclave to do another derivation. The salt of the derivation is confined in the enclave and can't be read by anyone. The encryption is also done in the enclave so an attacker can never access this key.