Authentication systems in IT solutions based on web architectures

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1. Abstract

The web over the years has spread to all areas of our lives, from the most basic to the most complex thus being more and more connected to the Internet. This led to the necessity of having a secure and reliable authentication system to protect users and the system itself. In this article will be presented the most common authentication techniques used in web applications and the advantages and disadvantages of each one, followed by real-world study cases. The main goal is to present the most common authentication systems and their respective characteristics, so that the reader can have a better understanding of the subject and be able to choose the best authentication system for their project.

Keywords: *json web tokens; oauth2; saml*

2. Introduction

Authentication systems are one of the most important parts of a web application. This system is responsible for identifying the user and granting access to the system. This process comprises a series of steps that are performed in order to verify the identity of the user. It is usually divided into two phases: the first phase is the authentication itself, and the second phase is the client authorization.

Authentication is the process of verifying the identity of a user. It is the first step of the authorization process, which is the process of verifying that the user has the rights to perform the action they are trying to perform. The authentication process is performed by a system or service, which in the case of web applications is the web server. A user can authenticate on a web server by entering a username and password, which is the most common method, but there are other methods that will be presented later in this article. The web server receives the username and password and then verifies them, and if they are correct, the user is authenticated and the server returns an authentication token to the client.

The authentication process is usually performed by the user, but in some cases, the system can perform the authentication process automatically, for example, when the user is already logged in.

Authorization is the process of verifying that the user has the rights to perform the action they are trying to perform. The authorization process is performed by a system or service, which in the case of web applications is the web server. The web server receives an authenticated session signature and verifies if the user has the rights to perform the action they are trying to perform. Usually, if the user is authorized to perform a certain action, the server returns the operation result to the client, and in the other hand, if the user is not authorized, the server returns an error to the client and the operation is not performed.

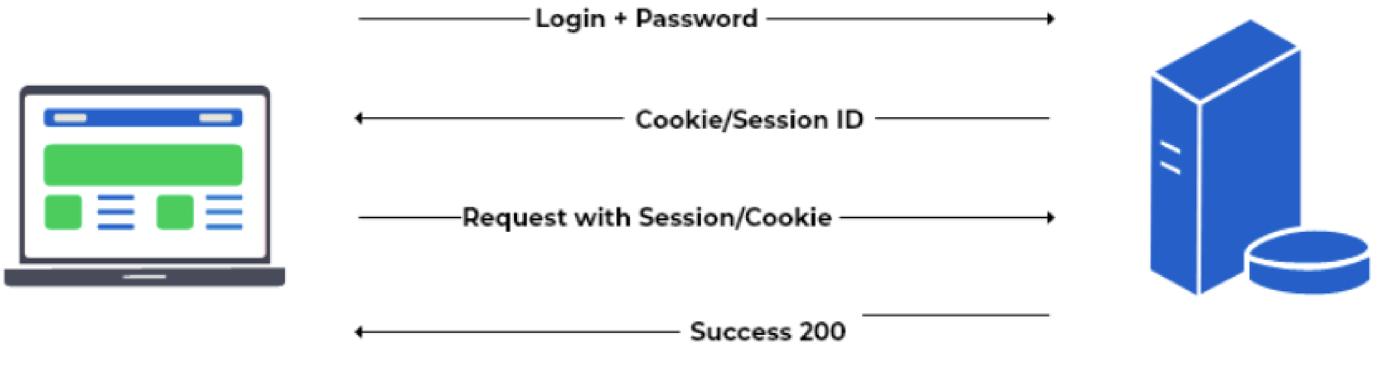
3. Authentication systems in web applications

3.1. Different kinds of authentication systems

Authentication systems for web-based IT solutions can be categorized into two main groups: session-based and token-based.

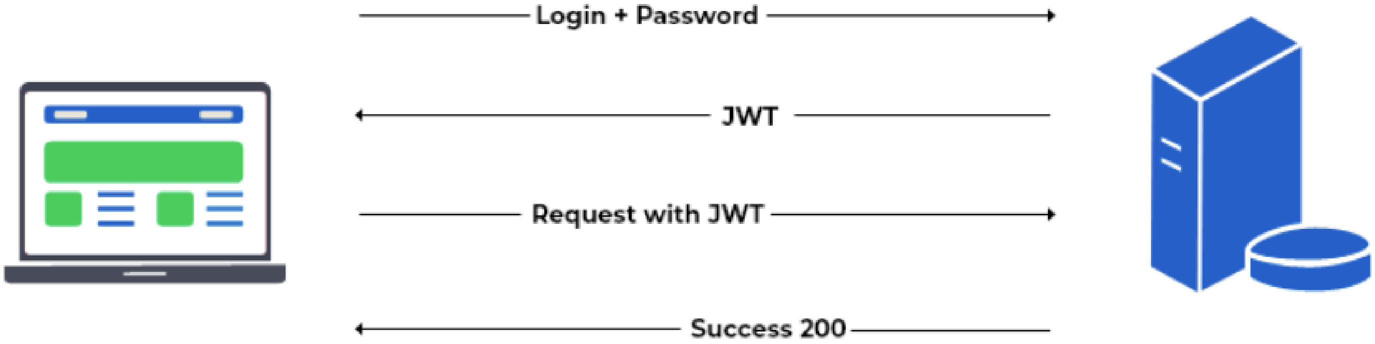
Session-based authentication is a method of stateful-authentication **[1]** that uses a session identifier to identify the user. After a successful user authentication, the server creates a session and shares its unique identifier (referred as *session ID*) with the related user. This identifier is later stored in the client-side (usually through the use of cookies) and used to access protected API routes.

The two main drawbacks of this method are that the server must store the session data in memory, which can lead to scalability issues and, since the session ID is stored in the client-side, is prone to XSS (*Cross-site scripting*) and CSRF (*Cross-site request forgery, also known as one-click attack*) attacks.



> Source: https://beaglesecurity.com/blog/article/session-security.html

Token-based authentication is a method of stateless-authentication **[2]** that uses a token to identify the user. After the user logs in, the server generates a token that is signed with a secret key or a key pair and returns it to the user. The user must then send this token in the header of every request to access protected API routes.



> Source: https://beaglesecurity.com/blog/article/session-security.html

[1]: Stateful Authentication is a way to verify users by having the server or backend store much of the session information, such as user properties.

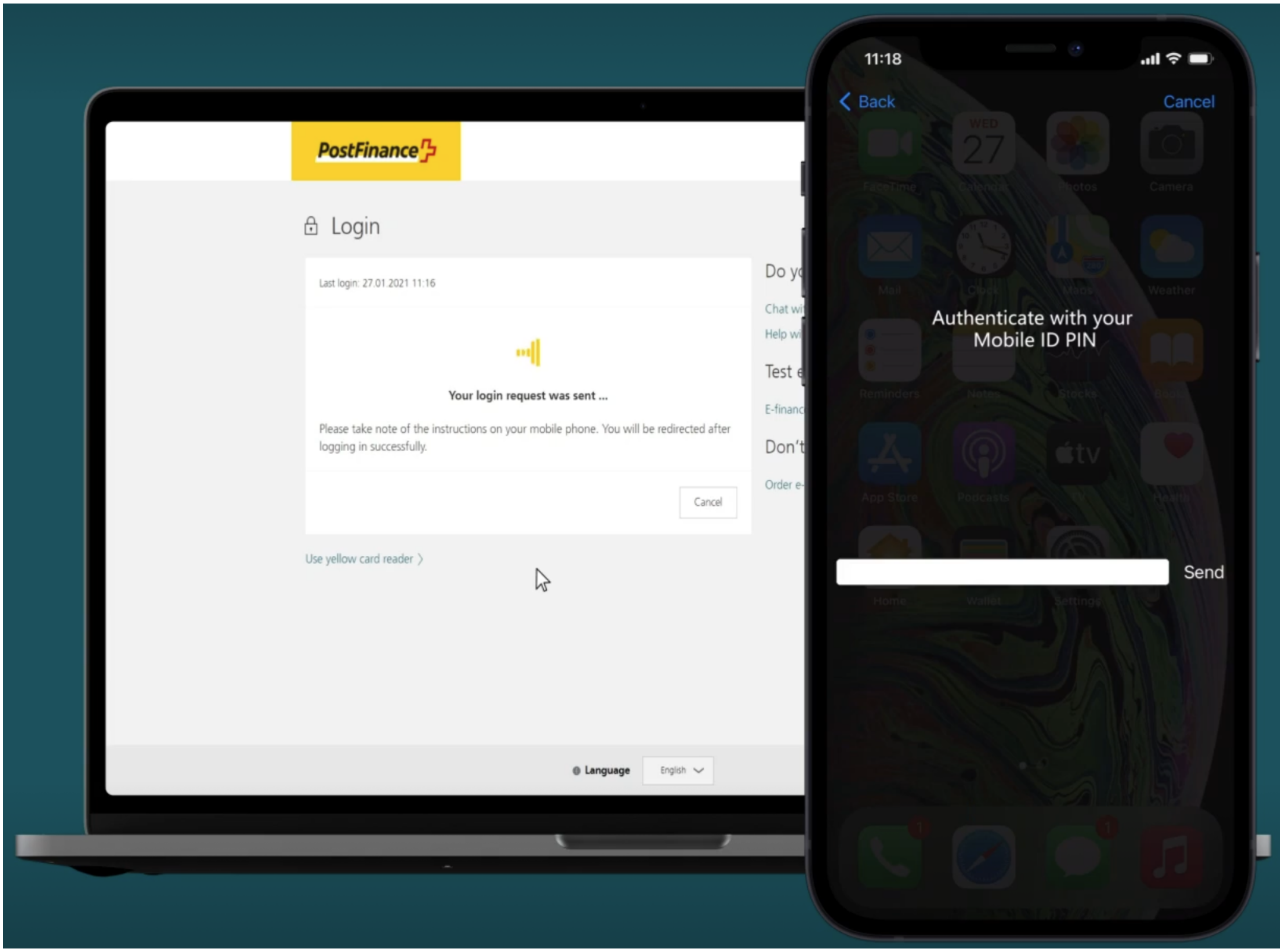
[2]: It is commonly referred to as stateless authentication since the token can be a self-contained entity that transmits all the necessary information for authenticating the request.

3.2. Study cases

3.2.1. PostFinance - Mobile ID

PostFinance is a Swiss bank that offers a wide range of financial services, including banking, insurance, and asset management. It is a subsidiary of the Swiss Post, which is the Swiss postal service.

User can access the online banking service using the PostFinance Mobile App (which is available for both Android and iOS) or using the web portal. If Mobile ID two-factor authentication is enabled, after the user enters their username and password they will be asked to confirm the login attempt using the Mobile ID. On the mobile app, the user will be asked to confirm the login attempt by entering the MobileID PIN code set during two-factor authentication setup. If the PIN code is correct, the user is authenticated and can access the online banking service.



Login

Last login: 27.01.2021 11:16

Your login request was sent ...

Please take note of the instructions on your mobile phone. You will be redirected after logging in successfully.

Cancel

Authenticate with your Mobile ID PIN

> Source: https://www.postfinance.ch/en/private/products/digital-banking/mobile-id.html

Mobile ID in depth

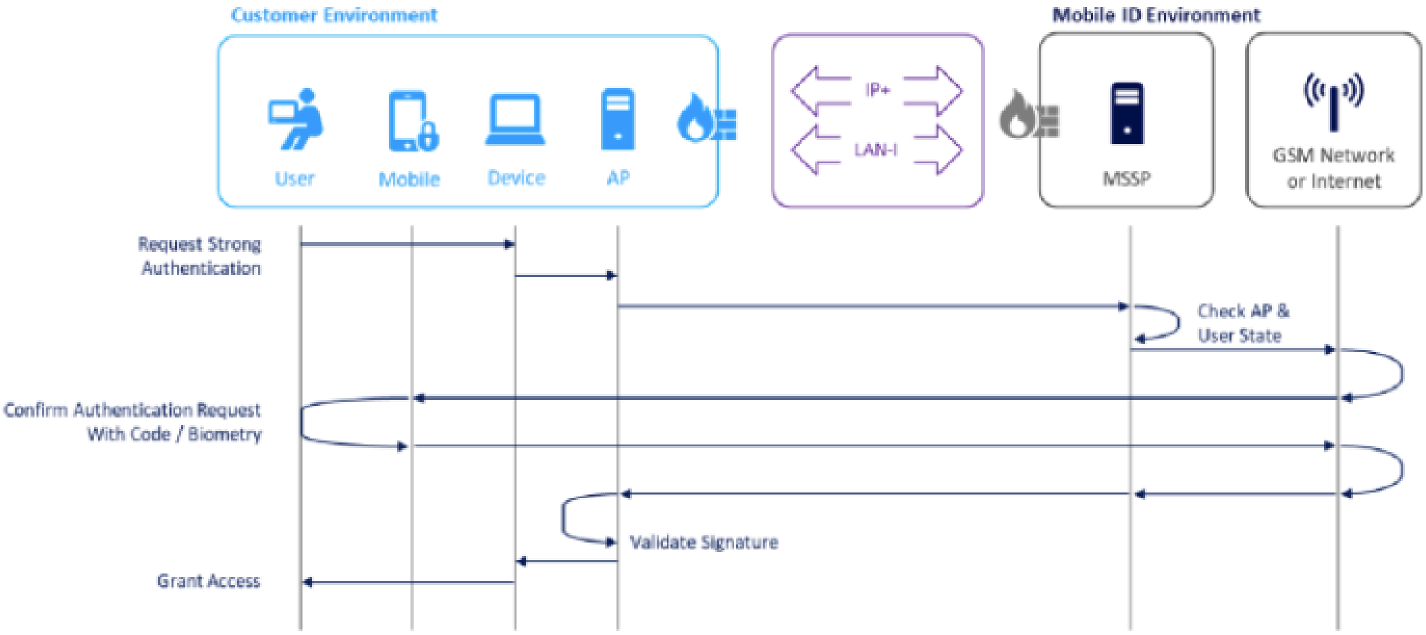
Mobile ID is a managed authentication service from Swisscom (Swiss telecomunication company) based on a secure handware tokens. The token can be either the user Mobile ID compliant SIM/eSIM or the mobile device running the Mobile ID app (available on both iOS and Android, used when SIM/eSIM not supported). An account could have either the eSIM/SIM method, the MobileID app method, or both at the same time.

This is an example of Mobile ID authentication flow:

Mobile ID (e-)SIM: An application provider (in this study case *PostFinance*) can request SIM Toolkit (STK) based authentication. To use this method, the user must have a Mobile ID compliant SIM/eSIM.

Data exchange between the Mobile ID server and the STK application is done with SMS messaged using data packets which are not visible to the user. Since the Mobile ID SIM Toolkit runs on SIM card environment, the Mobile ID SIM/eSIM authentication availability does not depend on the mobile device.

This is an example of a Mobile ID SIM/eSIM authentication:



> Source https://github.com/MobileID-Strong-Authentication/mobileid-api/blob/main/doc/mobile-id-reference-guide-v-3-9.pdf

The Mobile ID authentication flow is the following:

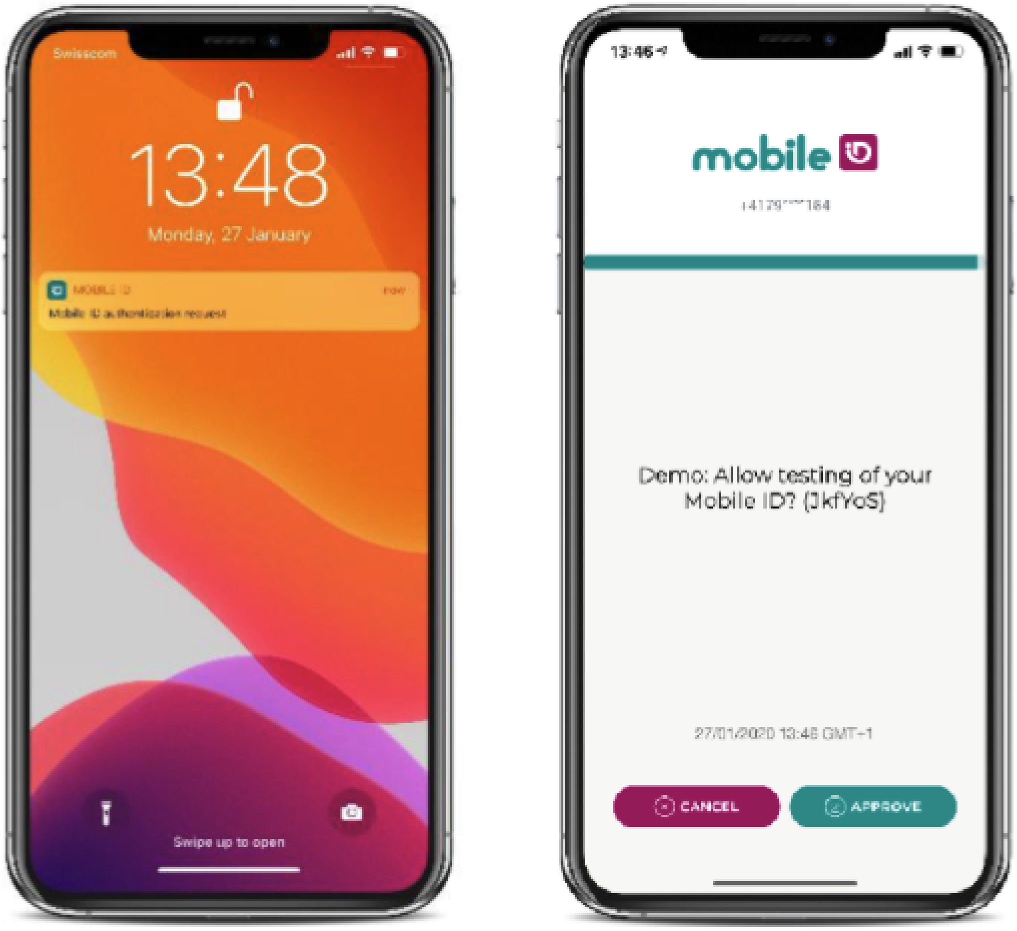
1. The end-user uses any application relying on Mobile ID authentication, which sends a mobile signature request through the dedicated web interface (hosted by the application provider) that includes the personal identification number (MSISDN, a number that uniquely identifies a mobile phone subscription, commonly called *phone number*)
2. The application provider receives the end-user request, forms the contents to be signed, and sends the request to the Mobile ID server providing the mobile signature service.
3. The mobile signature server receives the signature request and validate the application provider in accordance with the service agreement.
4. The mobile signature server ensures that the end-user signature request is allowed and forwards it to the end-user mobile device.
5. The end-user geets a message on his mobile phone to sign the mobile signature request. The end-user confirms the authentication request either by providing the Mobile ID PIN (only if SIM/eSIM method is used) or using a passcode / biometric authentication (if Mobile ID app is used).
6. After the application provider has received a valid response, the end-user will be granted access to the corporate application.

> Source: https://github.com/MobileID-Strong-Authentication/mobileid-api/blob/main/doc/mobile-id-reference-guide-v-3-9.pdf

Main advantages of this method are:

- Strong two-factor authentication
  - You have physical access to the SIM/eSIM (*possession factor*)
  - You need to enter a personal Mobile ID PIN (*knowledge factor*)
- Hight security level
  - Authentication is dome through a secure and isolated (encrypted) channel
  - Tamper-proof key storage based on EAL5+ and Evaluation level 3 certified hardware
- Mobile ID STK application is preinstalled on the SIM/eSIM
- Supported by most Swiss Mobile network operators: Swisscom, Salt, Sunrisem, M-Budget

Mobile ID app: An application provider (in this study case *PostFinance*) can request App-based authentication.
The user must first install the Mobile ID app on their mobile devices (available on both Google Play Store and Apple App Store) and the proceed by linking the Mobile ID app with the mobile device by accessing the official Mobile ID web portal (available at https://www.mobileid.ch/) and scanning a QR code.



Mobile ID authentication request

Demo: Allow testing of your Mobile ID? (JkfYoS)

27/01/2020 13:46 GMT+1

Main advantages of this method are:

- Strong two-factor authentication
  - You need physical access to the mobile device (*possession factor*)
  - In order to get access to the device you need to know the phone passcode (*knowledge factor*) or use biometric authentication such as FaceID, fingerprint, etc. (*Inherence factor*)

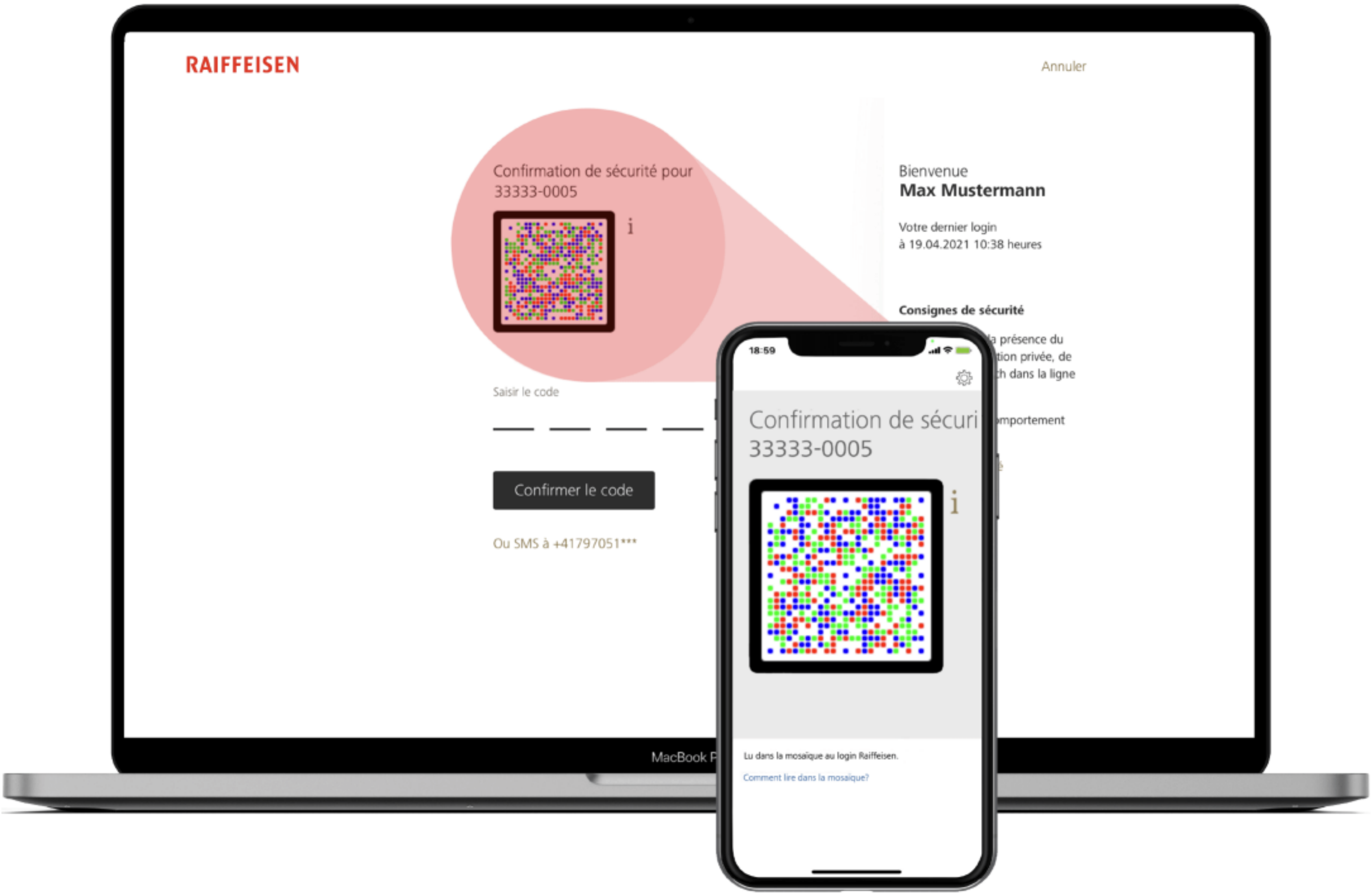
Learn more about MobileID API and certificates: https://github.com/MobileID-Strong-Authentication/mobileid-api]

3.2.2. Raiffeisen - PhotoTAN

Raiffeisen is another Swiss bank that offers a wide range of financial services, including banking, insurance, and asset management. It is a subsidiary of Raiffeisen Schweiz, which is the Swiss Raiffeisen banking group.

User can access the online banking service using the Raiffeisen Mobile App (which is available for both Android and iOS) or using the web portal. If PhotoTAN two-factor authentication is enabled, after the user enters their username and password they will be asked to confirm the login attempt by scanning a PhotoTAN mosaic image using the official Raiffeisen PhotoTAN mobile app (available on both Google Play Store and Apple App Store). After the user scans the PhotoTAN mosaic image, the app will generate a 9-digit code that the user must enter in the web portal to confirm the login attempt.

This is an example using the Raiffeisen PhotoTAN mobile app:



Confirmation de sécurité pour 33333-0005

Bienvenue
Max Mustermann

Votre dernier login
à 19.04.2021 10:38 heures

Consignes de sécurité

la présence du
tion privée, de
h dans la ligne

mportement

Confirmation de sécuri
33333-0005

Lu dans la mosaïque au login Raiffeisen.

Comment lire dans la mosaïque?

> Source: https://www.raiffeisen.ch/rch/fr/outils-calculateurs/aide-login/login-avec-phototan.html

If the user does not have a smartphone, they can use a PhotoTAN reader to scan the mosaic image. The PhotoTAN reader is a small device that can be purchased from Raiffeisen bank branches.

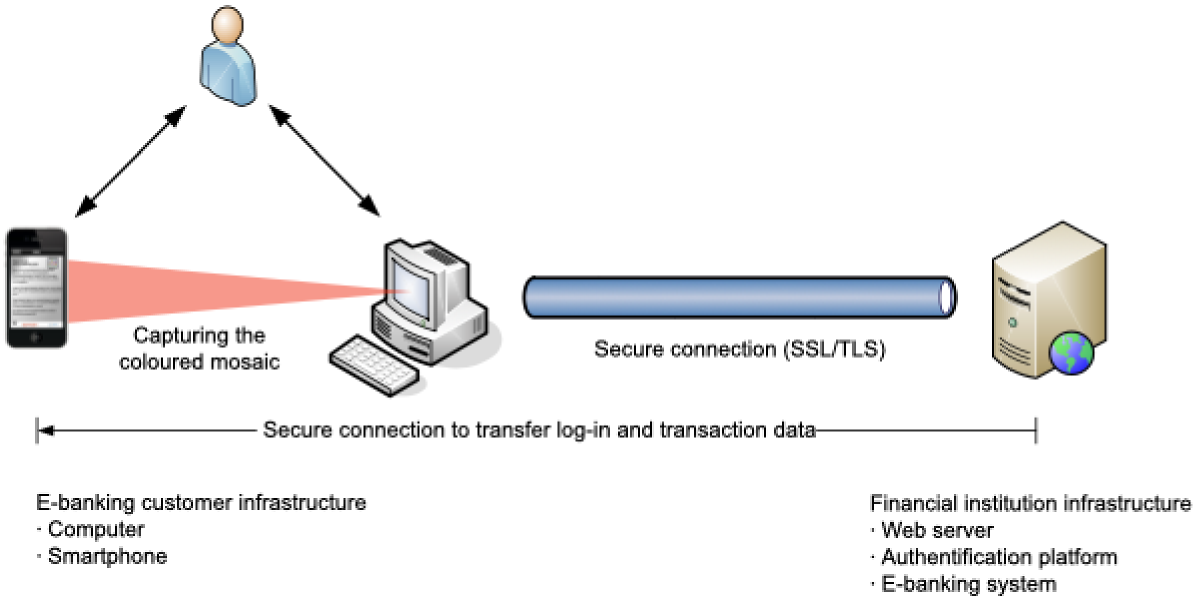
> Source: https://www.raiffeisen.ch/rch/fr/outils-calculateurs/aide-login/login-avec-phototan.html

If you have not yet activated your e-banking contract for PhotoTAN, log in to e-banking and choose the option "Log in" in your profile under "Security", then activate PhotoTAN. A mail will be sent to you by post within two to three working days.
Inside the mail can be found a PhotoTAN mosaic image needed to link a photoTAN reader (reader device or smartphone) to the user's e-banking contract.

> Source: https://github.com/MobileID-Strong-Authentication/mobileid-api/blob/main/doc/mobile-id-reference-guide-v-3-9.pdf

PhotoTAN in depth

This is an example of PhotoTAN authentication flow:


Capturing the coloured mosaic
Secure connection (SSL/TLS)
Secure connection to transfer log-in and transaction data
E-banking customer infrastructure
· Computer
· Smartphone
Financial institution infrastructure
· Web server
· Authentification platform
· E-banking system

Unfortunately, there is any technical documentation available to understand how PhotoTAN works. We can only guess that the mosaic image is a QR code that contains the user's username and a random N-digit code. The PhotoTAN mobile app or reader scans the QR code and with an algorithm calibrated agains on the user's "first mosaic image" (Sent by mail, needed to link the PhotoTAN reader to the user's E-Banking account) computes the N-digit code that the user must enter in the web portal to confirm the login attempt.

The main advantages of this method are:

- You need physical access to the smartphone or PhotoTAN reader (*possession factor*)
- You need to know the smartphone passcode or use biometric authentication (*knowledge factor*)

The main disadvantages of this method are:

- Since a physical PhotoTAN reader does offer any kind of authentication method, a linked device can be stolen and used by an attacker to login to the user's account. In fact, raiffeisen has a FAQ page where they explain how to handle this situation:

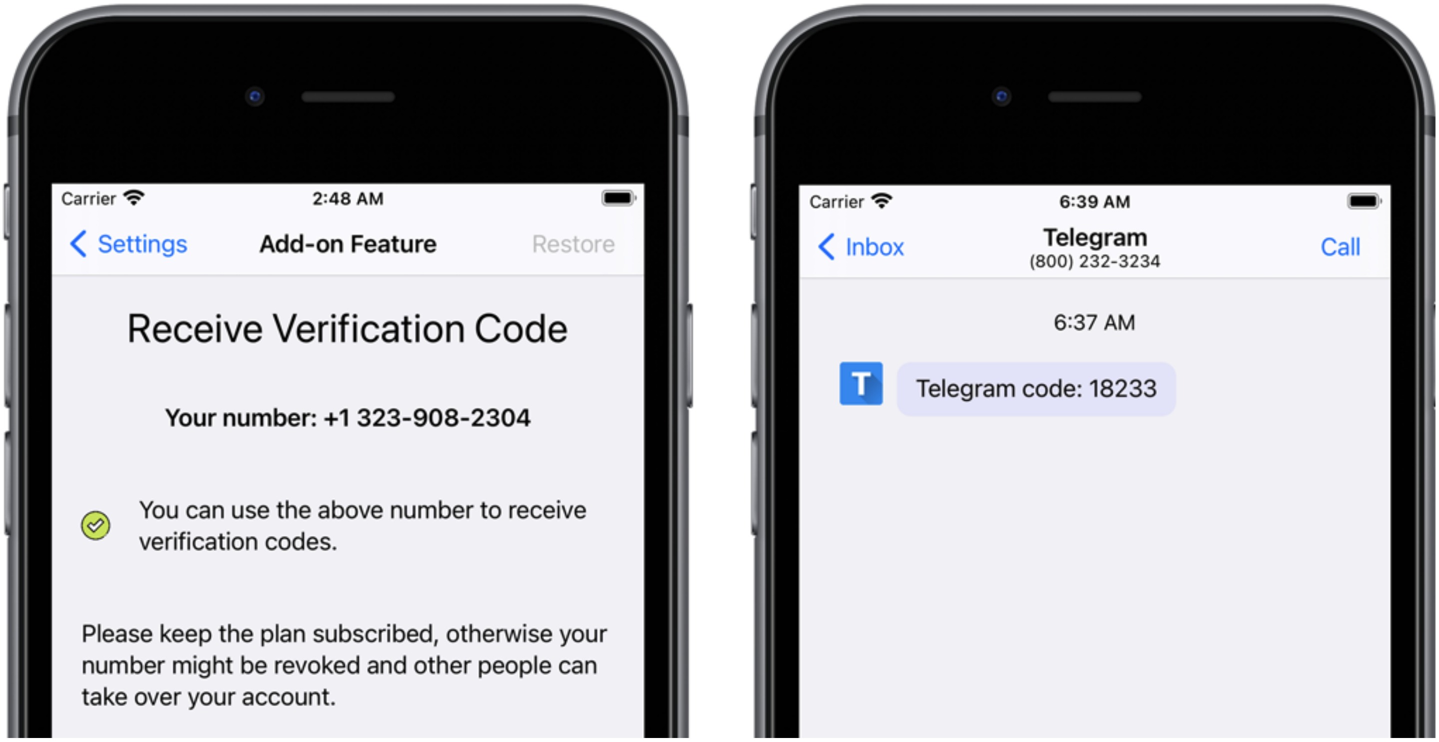
> Sources:
>
> - https://www.raiffeisen.ch/rch/de/privatkunden/e-banking/mobile-banking-zahlungen-scannen.html
> - https://www.raiffeisen.ch/content/dam/www/rch/pdf/e-banking/broschueren/de/phototan-geraet-raiffeisen.pdf
> - https://www.raiffeisen.ch/rch/fr/outils-calculateurs/aide-login/login-avec-phototan.html

3.2.3. Telegram - mTAN

Telegram is a cloud-based instant messaging service that allows users to send text messages, voice messages, images, videos, and other files. It is available on both Android and iOS.

User can access the Telegram service using the Telegram Mobile App (which is available for both Android and iOS) or using the web portal. If two-factor authentication is enabled, after the user enters their username and password they will be asked to confirm the login attempt by entering a 6-digit code sent via SMS to the user's mobile phone.

This is an example using the Telegram Mobile App:



Receive Verification Code

Your number: +1 323-908-2304

You can use the above number to receive verification codes.

Please keep the plan subscribed, otherwise your number might be revoked and other people can take over your account.

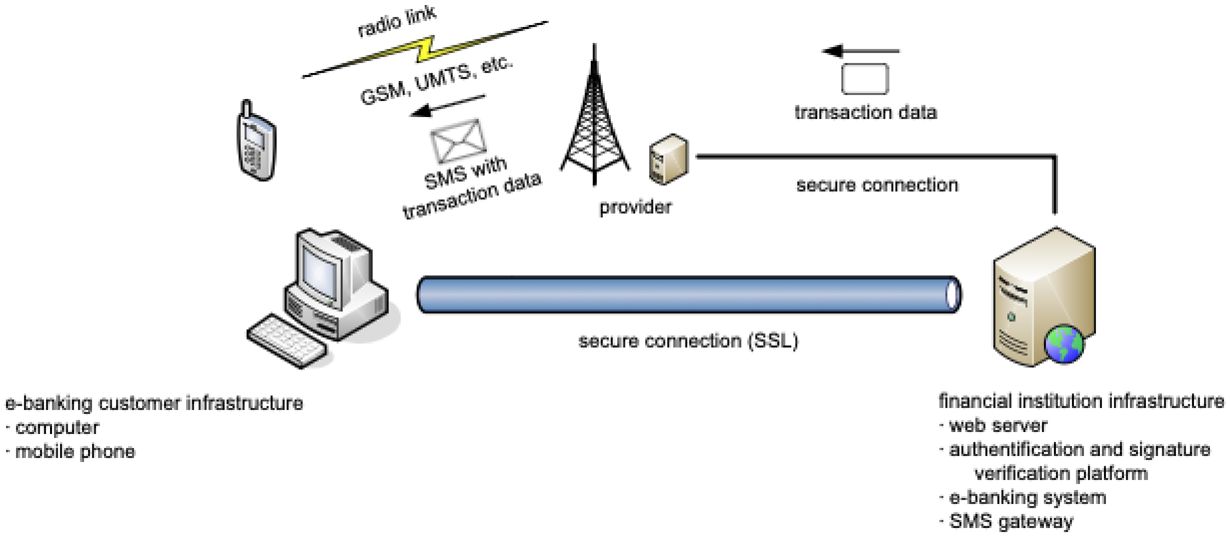
Telegram code: 18233

> Source: https://autobizline.com

mTAN in depth

mTAN (*Mobile Transaction Authentication Number*, known also as Mobile-TAN or SMS-TAN) is a one-time password sent via SMS to the user's mobile phone to confirm an operation. It is a common method used by banks and other financial institutions to confirm a transaction but also used by many other services such as social networks, cloud providers, messaging services, etc.

This is an example of mTAN authentication flow:



The main advantages of this method are:

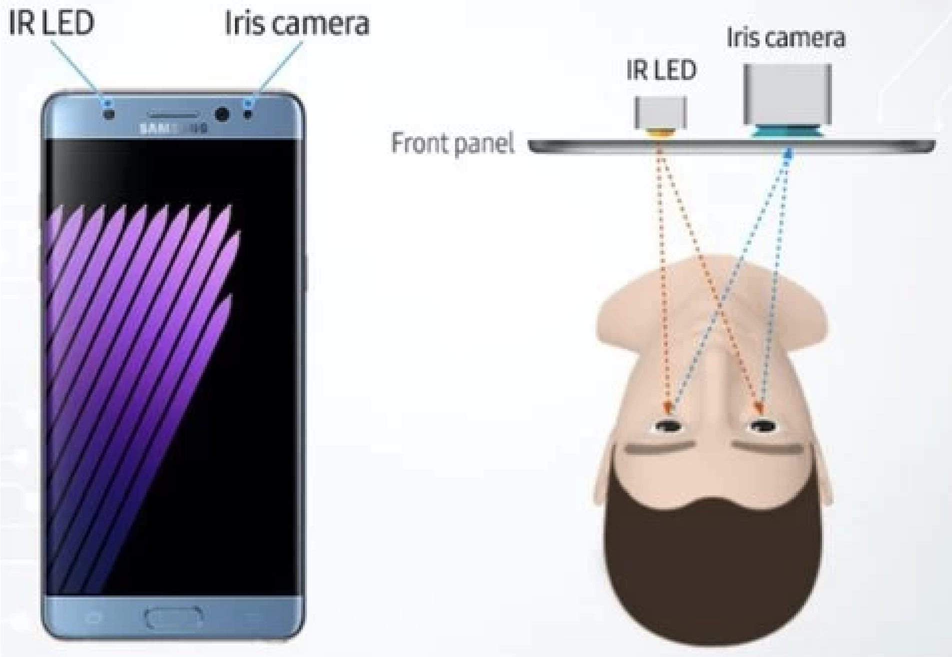
- Strong two-factor authentication
  - You need physical access to the mobile device (*possession factor*)
  - In order to get access to the device you need to know the phone passcode (*knowledge factor*) or use biometric authentication such as FaceID, fingerprint, etc. (*Inherence factor*)
- No need to install any additional software

> Source: https://www.ebas.ch/en/mobile-tan-mtan-sms-tan/

3.2.4. Samsung - Biometric authentication

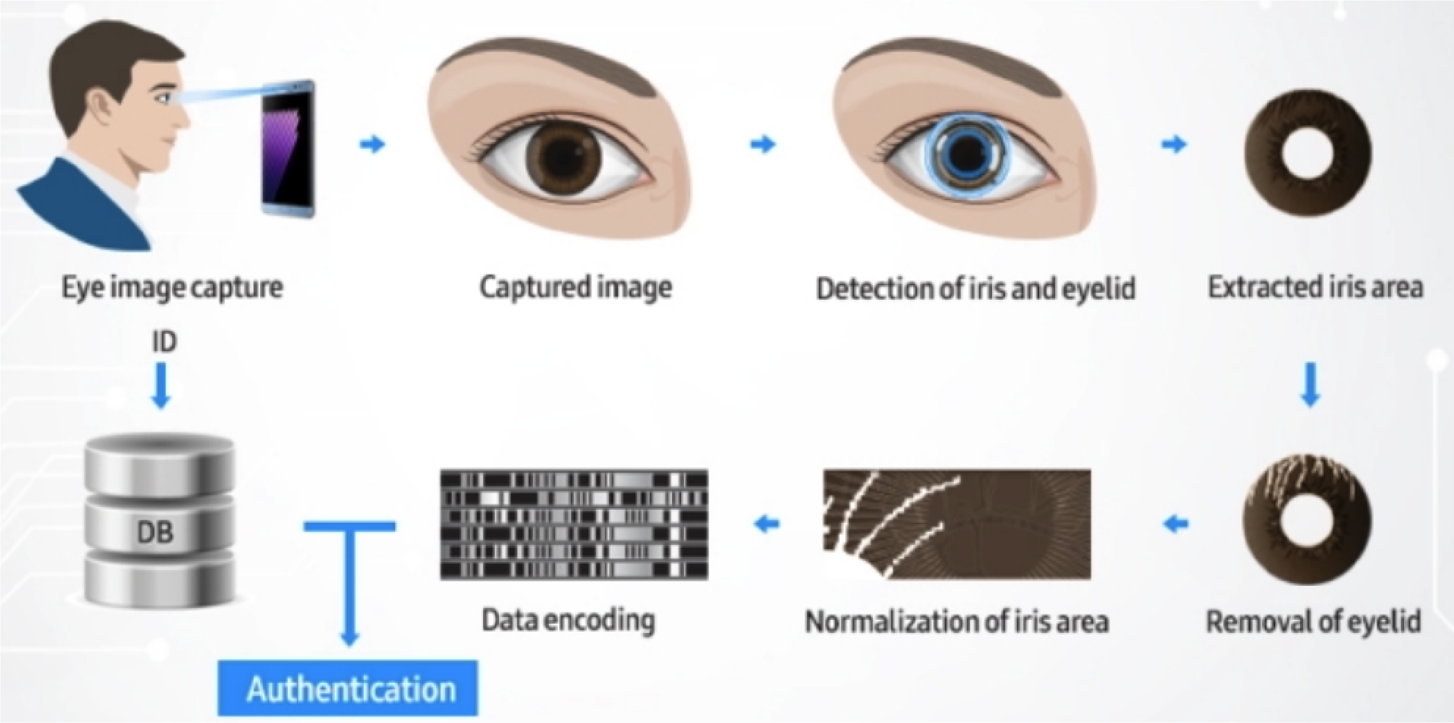
Samsung is a South Korean multinational conglomerate headquartered in Samsung Town, Seoul. It is the largest South Korean chaebol (business conglomerate). Samsung is the world's largest manufacturer of smartphones, smartphones, and memory chips. It is also the world's largest manufacturer of televisions and washing machines.

Samsung in 2017 introduced in the Samsung Note 7 an iris scanner based authentication to unlock the device. The iris scanner is a biometric sensor that recognizes the user's iris pattern, which is unique for each person and virtually impossible do replicate, and allows the user to unlock the device just by looking at it. The iris scanner is located on the front of the device, at the top of the screen next to the camera:



> Source: https://www.pocket-lint.com/phones/news/samsung/138335-samsung-galaxy-note-7-iris-scanner-what-is-it-and-how-does-it-work

This is the iris scanner based authentication flow on Samsung Note 7:



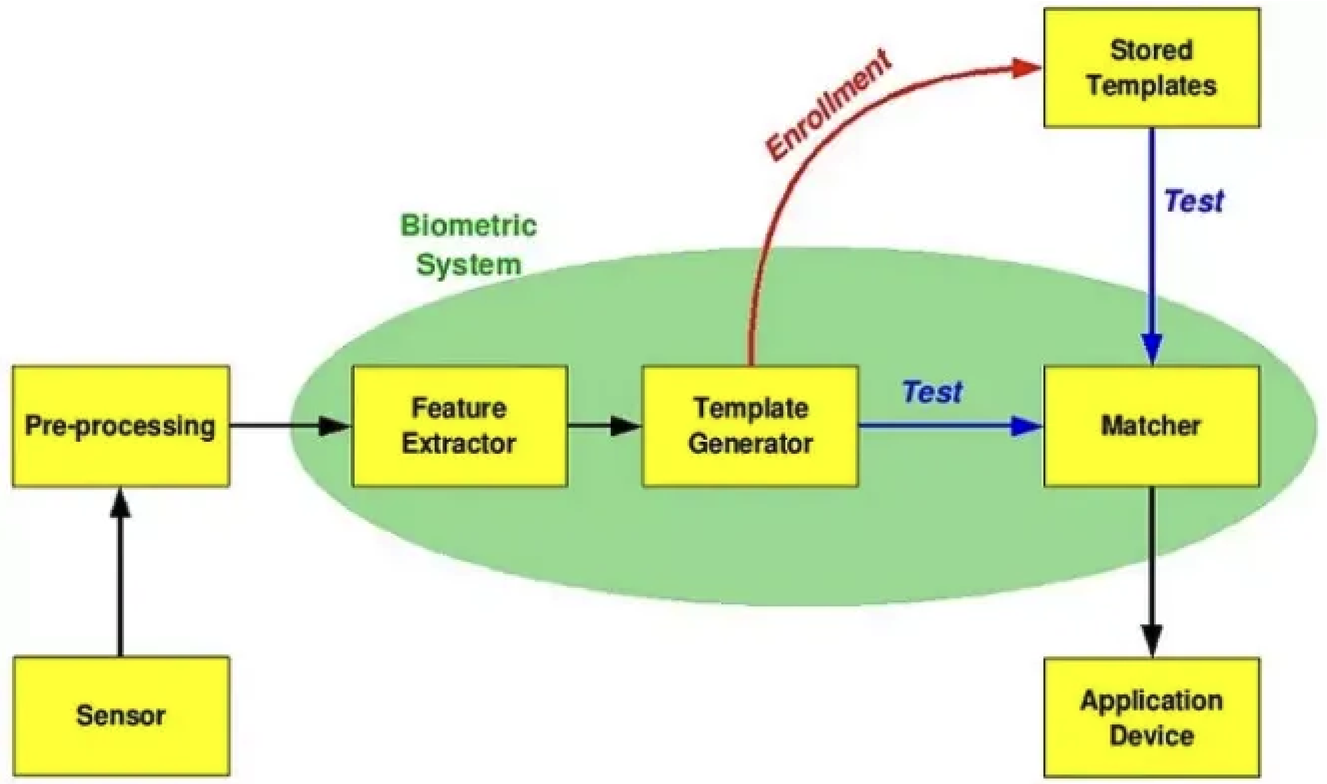
> Source: https://news.samsung.com/global/in-depth-look-keeping-an-eye-on-security-the-iris-scanner-of-the-galaxy-note7

Biometric authentication in depth

Biometric authentication is a method of authentication that uses the user's physical characteristics to confirm the identity of the user. The most common biometric authentication methods are fingerprint, face recognition, and iris recognition. Biometric authentication is one of the most secure authentication methods available today.

To be able to use biometric authentication, the user must first enroll their biometric data to be used to compare against the fresh collected biometric data during the authentication proces. The biometric data is stored in a secure enclave on the sytems and is never shared.

This is an generic example of biometric authentication flow:



The main advantages of biometric authentication are:

- It is very easy to use, the user does not need to remember any password or PIN code.
- It is very secure, the biometric data is unique for each person and virtually impossible to replicate.

The main disadvantages of biometric authentication are:

- It is not available on all devices, only on devices that have a biometric sensor.
- It is not available on all services or platforms, only on services that support biometric authentication.
- Could be expensive to implement, the biometric sensor must be integrated into the device.

> Source: https://krazytech.com/technical-papers/biometric-technology

4. Authentication in APIs and Web Services

In this section will be presented the most common authentication methods used in APIs and Web Services: JSON Web Tokens (JWT), OAuth 2.0 and SAML.

4.1. JSON Web Tokens (JWT)

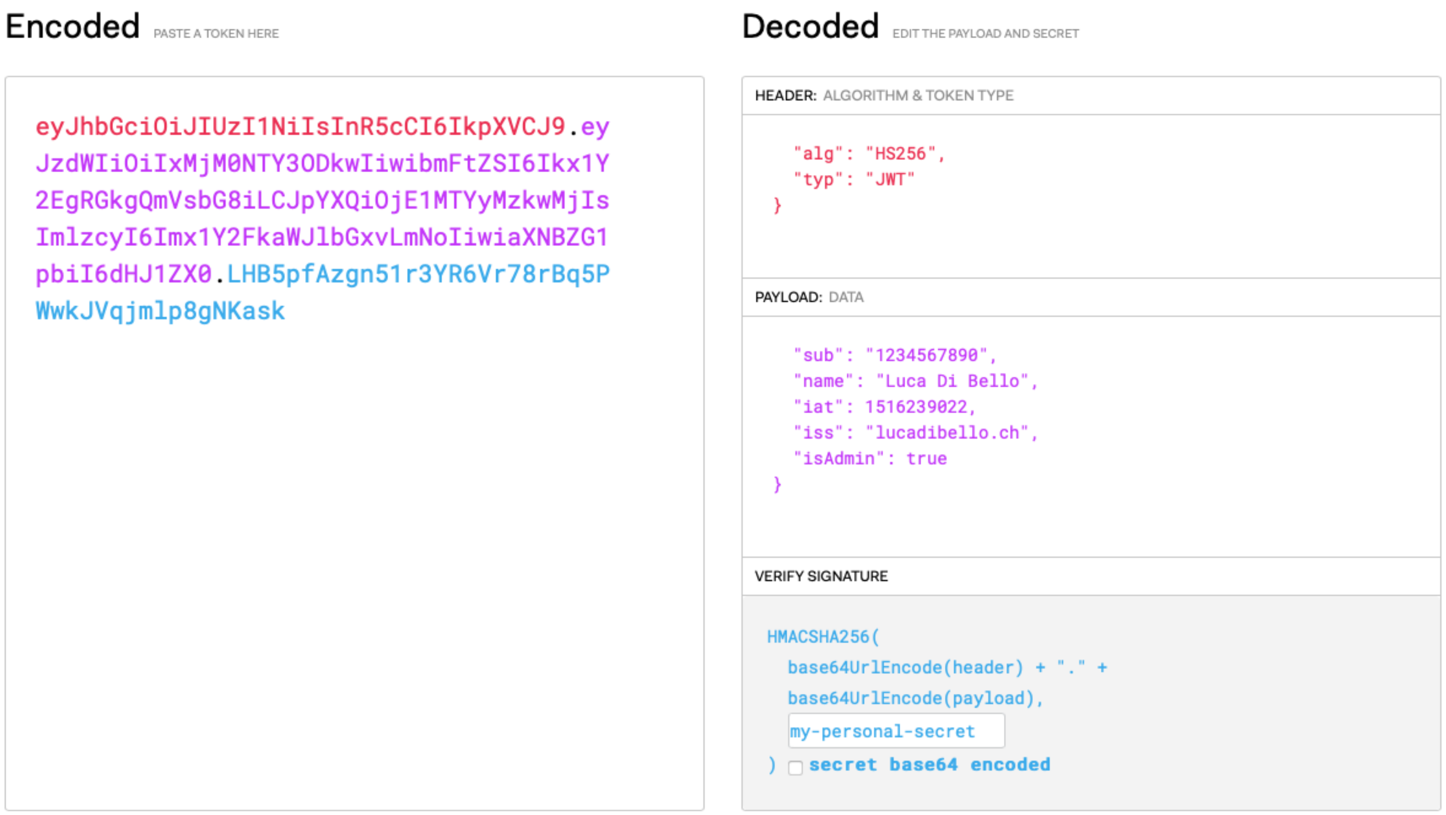
JSON Web Tokens (JWT) is an open standard (RFC 7519) that defines a compact and self-contained way for securely transmitting information between parties as a JSON object. This information can be verified and trusted because it is digitally signed. JWTs can be signed using a secret (with the HMAC algorithm) or a public/private key pair using RSA, needed to be able to verify a token signature later during the authentication proess.

The token consist of three parts separated by dots (.), which are:

- **Header** - The header typically consists of two parts: the type of the token, which is JWT, and the signing algorithm being used, such as HMAC SHA256 or RSA.
- **Payload** - The second part of the token is the payload (also called *claim set*), which contains the claims. Claims are statements about an entity (typically, the user) and additional data. There are three types of claims: registered, public, and private claims, which are explained in the next section.
- **Signature** - To create the signature part you have to take the encoded header, the encoded payload, a secret, the algorithm specified in the header, and sign that.

JWT tokens are used to authenticate users in APIs and Web Services. The user is authenticated by sending the JWT token in the HTTP request header. The server will validate the token and if it is valid, the user will be authenticated. To be able to send the JWT token inside HTTP requests, the token is *base64url* (view more: https://www.rfc-editor.org/rfc/rfc4648#section-5) encoded.

This is an example of a JWT token in both encoded and decoded format:



```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.ey
JzdWIiOiIxMjM0NTY3ODkwIiwibmFtZSI6Ikx1Y
2EgRGkgQmVsbG8iLCJpYXQiOjE1MTYyMzkwMjIs
ImlzcyI6Imx1Y2FkaWJlbGxvLmNoIiwiaXNBZG1
pbiI6dHJ1ZX0.LHB5pfAzgn51r3YR6Vr78rBq5P
WwkJVqjmlp8gNKask
```

```
    "alg": "HS256",
    "typ": "JWT"
  }
```

```
    "sub": "1234567890",
    "name": "Luca Di Bello",
    "iat": 1516239022,
    "iss": "lucadibello.ch",
    "isAdmin": true
  }
```

```
HMACSHA256(
  base64UrlEncode(header) + "." +
  base64UrlEncode(payload),
  my-personal-secret
) □ secret base64 encoded
```

> Source: https://jwt.io

4.1.1. JWT claims

JWT claims are statements about an entity (typically, the user) and additional data. There are three types of claims: registered, public, and private claims.

Registered claims:

These are a set of predefined claims which are not mandatory but recommended, to provide a set of useful, interoperable claims. Some of the most common registered claims are:

- **iss** (issuer) - The issuer of the token (the server that generated the token).
  - Example: `iss: "https://example.com"`
- **sub** (subject) - The subject of the token, which usually is the user ID.
  - Example: `sub: "1234567890"`
- **aud** (audience) - The audience of the token (the server that will validate the token).
  - Example: `aud: "https://example.com"`
- **exp** (expiration time) - The expiration time of the token (the date and time when the token will expire).
  - Example: `exp: "2019-10-31T23:59:59.999Z"`
- **nbf** (not before) - The date and time before which the token must not be accepted for processing.

    - Example: `nbf: "2019-10-31T23:59:59.999Z"`
- **iat** (issued at) - The date and time in which the token was issued.
    - Example: `iat: "2019-10-31T23:59:59.999Z"`
- **jti** (JWT ID) - The unique identifier of the token (used to prevent the JWT from being replayed).
    - Example: `jti: "1234567890"`

> Source: https://www.rfc-editor.org/rfc/rfc7519#section-3

Public claims:

These are the custom claims created to share information between parties that agree on using them and are neither registered or private claims.

This kind of claims are defined as public since defined in the IANA JSON Web Token Registry and can be used without collisions.

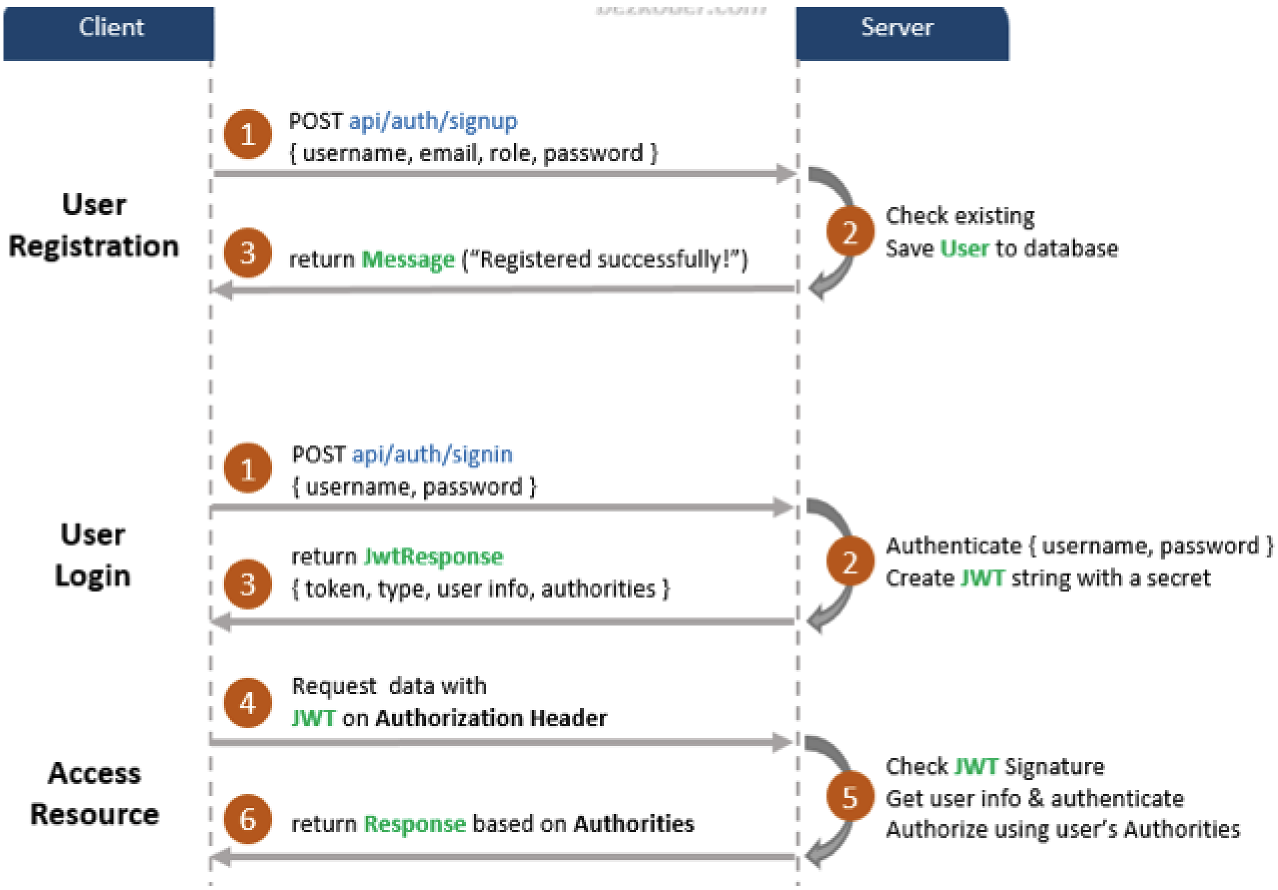
Private claims:

These are the custom claims created to share information between parties that agree on using them and are neither registered or public claims.

This kind of claims are primarily used to share information between parties, such as the user ID, the user role, the user permissions, etc.

4.1.2. JWT authentication flow

This is an example of a JWT authentication flow inside classic web applications:


Client
bezkoder.com
Server
User Registration
1
POST api/auth/signup
{ username, email, role, password }
2
Check existing
Save User to database
3
return Message ("Registered successfully!")
User Login
1
POST api/auth/signin
{ username, password }
2
Authenticate { username, password }
Create JWT string with a secret
3
return JwtResponse
{ token, type, user info, authorities }
Access Resource
4
Request data with
JWT on Authorization Header
5
Check JWT Signature
Get user info & authenticate
Authorize using user's Authorities
6
return Response based on Authorities

> Source: https://www.bezkoder.com/spring-boot-jwt-authentication/

4.1.3. JWT advantages and disadvantages

The main advantages of JWT are:

- JWT tokens are stateless, which means that the server does not need to store any session data for JWT authentication. This makes the server scale easily
- It is very secure, the token is digitally signed and can be verified by the server
- Simple and fast to implement

The main disadvantages of JWT are:

- Very difficult to revoke a token, since the token is stateless, the server does not have any session data to revoke the token
- The token is sent in every request, which could be a security risk if the token is intercepted
- The token payload is not encrypted, which means that the token payload can be read by anyone. This affects privacy and the overall security of the application

> Source: https://jwt.io/introduction/

4.1.4. JWT privacy considerations

JWT tokens might contain sensitive information about the user, such as the user ID, the user role, the user permissions, etc. This information must be protected and never shared with third parties, since it could be used to as an attack vector.
To prevent privacy issues some of the most common practices are:

- Use an encrypted JWT and authenticate the recipient
- Ensure that JWTs containing unencrypted privacy-sensitive information
  are only transmitted using protocols utilizing encryption that
  support endpoint authentication, such as Transport Layer Security
  (TLS)
- Omitting privacy-sensitive information from a JWT (simplest and most effective solution)

This could negatively affect the user experience, since the user will not be able to access the information that is stored in the JWT token.

> Source: https://tools.ietf.org/html/rfc7523#section-3

4.2 OAuth 2.0

OAuth 2.0 is an industry-standard (**RFC6749**) authorization framework that enables applications to obtain limited access to user accounts on an HTTP service, such as Facebook, GitHub, and DigitalOcean. This framework is used to provide client applications a "secure delegated access" to server resources on behalf of a resource owner. OAuth 2.0 provides authorization flows for web and desktop applications, and mobile devices.

To allow limited access to user account data OAuth 2.0, instead of using the resource owner's credentials to access protected resources, uses access tokens. An access token is a string opaque to the user (not visible) that represents an authorization issued to a client, and identifies the user, the client, and the scopes and duration of the access granted. Access tokens are issued to third-party clients by an authorization server with the approval of the resource owner and must be used to access protected resources hosted by the resource server.

4.2.1. OAuth 2.0 roles

OAuth 2.0 defines four roles:

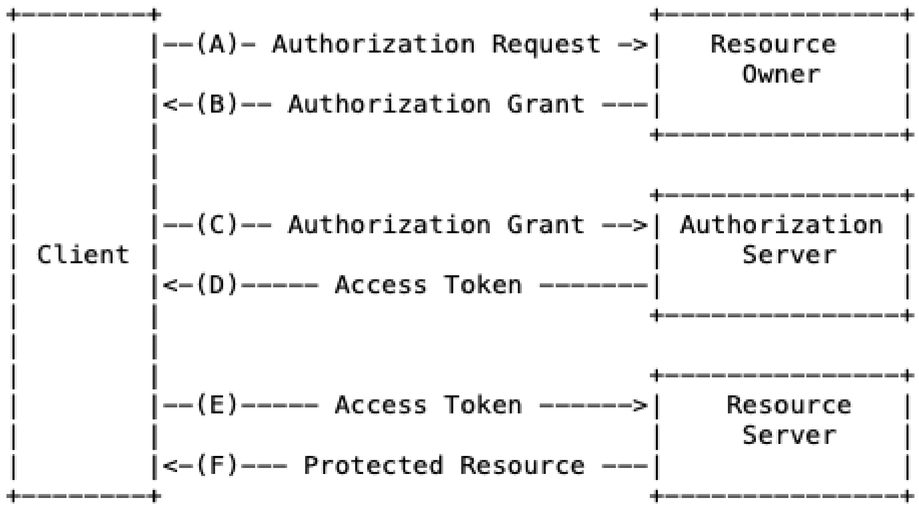
- **Resource owner** - The entity that can grant access to a protected resource. When the resource owner is a person, it is referred to as an end-user.
- **Resource server** - The server hosting the protected resources, capable of accepting and responding to protected resource requests using access tokens.

- **Client** - An application making protected resource requests on behalf of the resource owner and with its authorization.
- **Authorization server** - The server issuing access tokens to the client after successfully authenticating the resource owner and obtaining authorization.

> Source: https://www.rfc-editor.org/rfc/rfc6749#section-1.1

4.2.2. OAuth 2.0 authentication flow

OAuth 2.0 defines four authorization flows:



```
+--------+                               +---------------+
|        |--(A)- Authorization Request ->|   Resource    |
|        |                               |     Owner     |
|        |<-(B)-- Authorization Grant ---|               |
|        |                               +---------------+
|        |
|        |                               +---------------+
|        |--(C)-- Authorization Grant -->| Authorization |
| Client |                               |     Server    |
|        |<-(D)----- Access Token -------|               |
|        |                               +---------------+
|        |
|        |                               +---------------+
|        |--(E)----- Access Token ------>|    Resource   |
|        |                               |     Server    |
|        |<-(F)--- Protected Resource ---|               |
+--------+                               +---------------+
```

Figure 1: Abstract Protocol Flow

> Source: https://www.rfc-editor.org/rfc/rfc6749#section-1.2

Steps:

A: The client requests authorization from the resource owner. The authorization request can be made directly to the resource owner, or indirectly via an authorization server as an intermediary (preferable, to learn more see RFC7649 Section 3.1). The client sends the following parameters:

- **response_type** - The type of the response. The value must be `code`.
- **client_id** - The client identifier as described in RFC6749 Section 2.2.
- **redirect_uri** - The redirection URI to which the response will be sent. This URI must exactly match one of the redirection URIs registered for the client, as described in RFC6749 Section 3.1.2.
- **scope** - The scope of the access request as described by RFC6749 Section 3.3.
- **state** - An opaque value used by the client to maintain state between the request and callback. The authorization server includes this value when redirecting the user-agent back to the client.

The parameter SHOULD be used for preventing cross-site request forgery as described in RFC6749 Section 10.12.

B: The resource owner grants or denies the access request and sends the client an authorization grant. The grant is a credential representing the resource owner's authorization (to learn more see RFC6749 Section 1.3). The response can be sent directly to the client, or indirectly via an authorization server as an intermediary (preferable, to learn more see RFC6749 Section 3.1).

C: The client requests an access token from the authorization server and authenticates by presenting the authorization grant (to learn more see RFC6749 Section 4.1.3).

D: The authorization server authenticates the client and validates the authorization grant, and if valid, issues an access token (to learn more see RFC6749 Section 5.1). If the authorization grant is invalid, expired, or revoked, the authorization server returns an error response (to learn more see RFC6749 Section 5.2). This is a sample HTTP response with a valid authorization grant:

```
HTTP/1.1 200 OK
Content-Type: application/json;charset=UTF-8
Cache-Control: no-store
Pragma: no-cache

{
  "access_token":"mF_9.B5f-4.1JqM",
  "token_type":"Bearer",
  "expires_in":3600,
  "refresh_token":"tGzv3JOkF0XG5Qx2TlKWIA"
}
```

We can see that the response contains both access and refresh token. The access token is used to access the protected resources, while the refresh token is used to obtain a new access token when the current access token expires. Learn more in chapter **4.2.4. Refresh token**.

> Source: https://www.rfc-editor.org/rfc/rfc6750#section-4

E: The client requests the protected resource from the resource server and authenticates by presenting the access token (to learn more see RFC6749 Section 7.1). The token is sent in the HTTP Authorization header using the Bearer authentication scheme (to learn more see RFC6750 - Bearer Token Usage).

4.2.3. JWT Bearer Token

The JWT Bearer Token is a security token that is used to access an OAuth 2.0 protected resource. The token is a JSON Web Token (JWT) that is signed using a private key. The token is sent in the

HTTP Authorization header using the Bearer authentication scheme (to learn more see RFC6750 - JWT Access tokens).

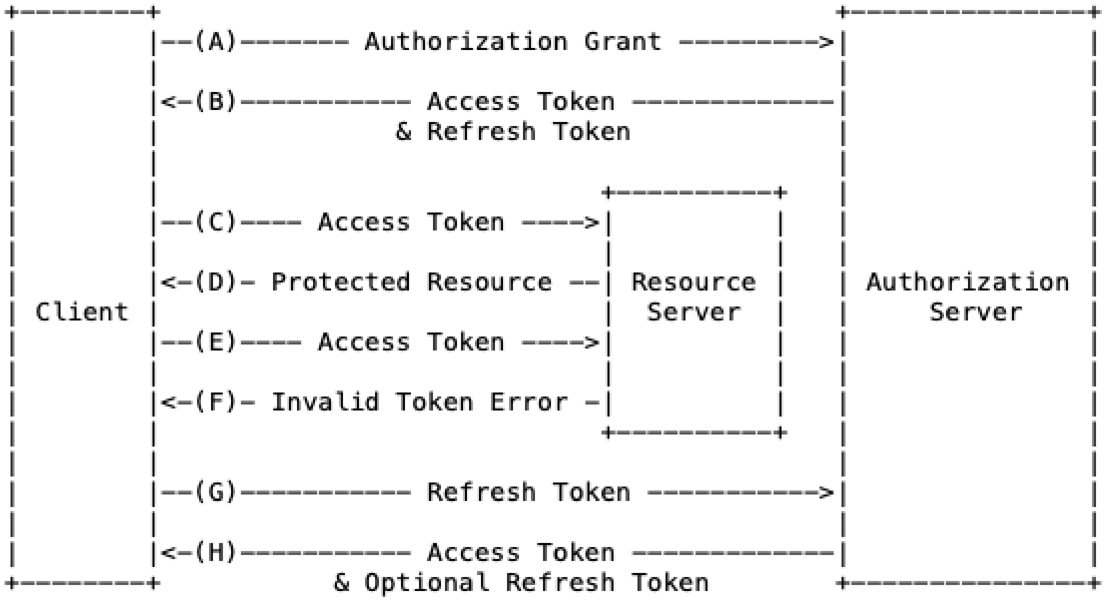
> Source: https://www.rfc-editor.org/rfc/rfc6749#section-1.5

4.2.4. Refresh token

OAuth 2.0 defines a refresh token, which is a credential used to obtain fresh access token. The refresh token is issued to the client by the authorization server and is used to obtain a new access token when the current access token becomes invalid or expires, or to obtain additional access tokens with identical or narrower scope (access tokens may have a shorter lifetime and fewer permissions than authorized by the resource owner). The refresh token is issued only if the authorization server supports the use of refresh tokens and only if the client has provided the appropriate authorization. The authorization server issues a new refresh token, and invalidates the old refresh token after issuing a new access token.

This tokens are meant to be used only with authorization servers, should not be shared with other parties, and should be stored securely on the device.

This is the refresh token flow:



```
+--------+                                           +---------------+
|        |--(A)------- Authorization Grant --------->|               |
|        |                                           |               |
|        |<-(B)----------- Access Token -------------|               |
|        |               & Refresh Token             |               |
|        |                                           |               |
|        |                            +----------+   |               |
|        |--(C)---- Access Token ---->|          |   |               |
|        |                            |          |   |               |
|        |<-(D)- Protected Resource --| Resource |   | Authorization |
| Client |                            |  Server  |   |     Server    |
|        |--(E)---- Access Token ---->|          |   |               |
|        |                            |          |   |               |
|        |<-(F)- Invalid Token Error -|          |   |               |
|        |                            +----------+   |               |
|        |                                           |               |
|        |--(G)----------- Refresh Token ----------->|               |
|        |                                           |               |
|        |<-(H)----------- Access Token -------------|               |
+--------+           & Optional Refresh Token        +---------------+
```

Figure 2: Refreshing an Expired Access Token

> Source: https://www.rfc-editor.org/rfc/rfc6749#section-1.5

We can see that the refresh token is only used to obtain a new access token when it becomes invalid or expires. To obtain a new access token, the client sends the refresh token to the authorization server, which validates the refresh token and issues a new access token and (optionally) also a new refresh token.

4.3. SAML

The Security Assertion Markup Language (SAML) is an XML-based standard for exchanging authentication and authorization data between parties, in particular, between an identity provider and a service provider. SAML is an open standard (OASIS commitee draft) that is maintained by the Organization for the Advancement of Structured Information Standards (OASIS).

The SAML authentication protocol is used to authenticate users to a service provider (SP) using a trusted identity provider (IdP). The IdP authenticates the user and sends an authentication assertion to the SP. The SP then uses the assertion to establish the user's identity. It exchanges authentication and authorization data between multiple parties (example: multiple websites) in the form of XML documents. The XML documents are digitally signed and encrypted to ensure the integrity and confidentiality of the data.

Currently, SAML is at version 2.0 (**SAML 2.0**).

> Source: https://www.cloudflare.com/en-gb/learning/access-management/what-is-saml/

4.3.1 SAML assertions

A SAML assertio is a statement that contains information about a subject, where the subject is typically an end user. The assertion is digitally signed and encrypted to ensure the integrity and confidentiality of the data. It contains all the necessary information for a service provider to confirm the user's identity, such as source of assertion, issued time, expiration time, user's identity, etc.

4.3.2. How a typical SAML SSO authentication works

A typical SSO authentication process using SAML involves the following three parties:

- **Principal** - The user who is trying to access a resource. (human in most cases)
- **Identity Provider (IdP)** - The entity that authenticates the principal and provides the principal's identity information to the service provider. (example: Google, Facebook, Twitter, etc.)
- **Service Provider (SP)** - The entity that provides the resource to the principal. (example: website, application, etc.)

The principal makes a request to the SP. The SP then redirects the principal to the IdP for authentication. The IdP authenticates the principal and sends an authentication assertion to the SP. The SP then uses the assertion to establish the principal's identity. The SP then provides the principal with access to the resource.

This is an example of SAML assertion, which contains proof that a certain user has been authorized to access a specific service and/or resource:

```
<saml:Assertion xmlns:saml="urn:oasis:names:tc:SAML:1.0:assertion"
    xmlns:ds="http://www.w3.org/2000/09/xmldsig#"
    MajorVersion="1" MinorVersion="0"
    AssertionID="192.168.0.131.1010924615489"
    Issuer="AA" IssueInstant="2002-03-26 16:23:35">
  <saml:Conditions NotBefore="2002-04-18T09:19:00Z"
        NotOnOrAfter="2003-06-28T09:21:00Z"/>
  <saml:AuthorizationDecisionStatement
    Resource="http://www.abc.org/services/getPrice"
    Decision="Permit">
      <saml:Action>Read</saml:Action>
  </saml:AuthorizationDecisionStatement>
</saml:Assertion>
```

> Source: https://docs.oracle.com/cd/E27515_01/common/tutorials/authz_saml_assertion.html

4.3.1. Benefits

- **Single sign-on (SSO)** - SAML enables a user to log in once and access multiple applications. To learn more, see official CloudFlare guide: What is SSO?
- **Identity federation** - SAML enables users to log in to a service provider using their credentials from a third-party identity provider.
- **Delegation** - SAML enables a user to log in to a service provider using their credentials from a third-party identity provider.
- **Attribute exchange** - SAML enables a service provider to request attributes about the user from an identity provider.
- **Assertion encryption** - SAML enables a service provider to encrypt assertions sent to it by an identity provider.
- **Assertion signing** - SAML enables a service provider to verify that assertions sent to it by an identity provider are valid.

> Source: https://auth0.com/blog/how-saml-authentication-works/

4.3.2. SAML in OAuth 2.0

The SAML 2.0 Profile for OAuth 2.0 Client Authentication and Authorization Grants defines a SAML 2.0 bearer assertion as an OAuth 2.0 access token. The assertion is sent in the HTTP Authorization header using the Bearer authentication scheme (to learn more see RFC 7522 - (SAML) 2.0 Profile for OAuth 2.0 Client Authentication and Authorization Grants).

> Source: https://www.rfc-editor.org/rfc/rfc7522

5. Demo

To showcase a practical example of a token-based authentication system, will be presented a NextJS 13 application that uses JWT tokens (access token and related refresh token) for authentication and authorization, with a two-factor authentication via E-Mail. This application is a boilerplate that can be used as a starting point to implement custom JWT-based authentication for any NextJS >= 13 application.

In this demo, users can downvote and upvote posts from a list of posts loaded dynamically through an API call. Users can also see the number of upvotes and downvotes for each post. Only admin users have access to a button that allows them to delete all the votes for a post.
In the dashboard users can also see their session information, including user information and the JWT access and refresh tokens.

The demo comprehends also a login page and a two-factor authentication page that are used to authenticate users. The login page is used to authenticate users with username and password, while the two-factor authentication page is used to authenticate users with token (linked to the user) used as OTP sent via E-Mail.

5.1. Main features

- Fully-typed with TypeScript
- Login with email and password (hashed with bcrypt)
- Role-based access control (by default: *User*, *Admin*)
- Automatic JWT access token refresh
- Two-factor authentication via email
- Front-end `useAuth` hook to easily manage the user session
- User session persistence via cookies and local storage
- New flexible back-end middleware management system
- Protected routes and pages

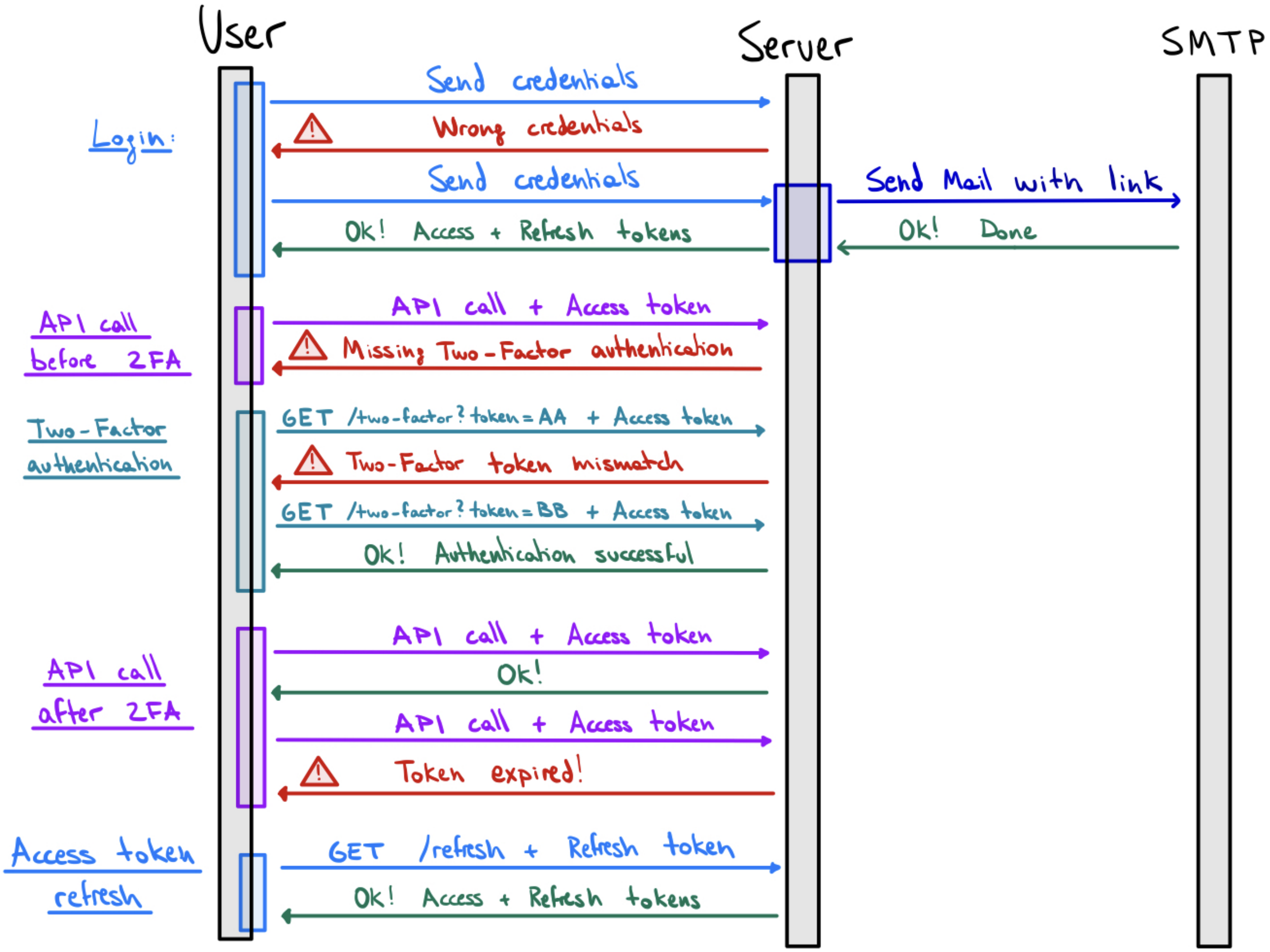
5.2. Tech stack

- NextJS v13
- TypeScript
- Chakra UI
- React Hook Form

- SWR (stale-while-revalidate)
- Prisma ORM
- jsonwebtoken

5.3. Authentication flow

The authentication flow is the following:


User
Server
SMTP
Login:
Send credentials
⚠ Wrong credentials
Send credentials
Send Mail with link
Ok! Done
Ok! Access + Refresh tokens
API call before 2FA
API call + Access token
⚠ Missing Two-Factor authentication
Two-Factor authentication
GET /two-factor?token=AA + Access token
⚠ Two-Factor token mismatch
GET /two-factor?token=BB + Access token
Ok! Authentication successful
API call after 2FA
API call + Access token
Ok!
API call + Access token
⚠ Token expired!
Access token refresh
GET /refresh + Refresh token
Ok! Access + Refresh tokens

The chart is self-explanatory, but to better understand the flow, we can see the following steps:

1. The user sends a request to the `/api/login` endpoint, submitting the E-Mail address and password of the user in the request body. The server then validates the user credentials and, if valid, generates a JWT access token and a JWT refresh token. The access token is used to access the protected resources, while the refresh token is used to obtain a new access token when the current access token expires. The access token is sent in the response body, while the refresh token is sent in the response cookies. After that, the server sends an E-Mail to the user with a token used as OTP (one-time password) for the two-factor authentication.

2. The user cannot access the protected resources until the two-factor authentication in completed.
3. The user sends a GET request to `/api/two-factor` passing the two-factor authentication code sent via E-Mail in the request query with name `token`. The server validates the token and, if valid, the is authenticated and can access the protected resources using the access token generated in step 1. This is a sample two-factor authentication URL:

```
https://my-awesome-app.com/two-factor?token=eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJpZCI
```

4. The user can now access the protected resources using the access token generated in step 1. The access token is sent in the HTTP Authorization header using the Bearer authentication scheme.
5. When the access token expires, the user can obtain a new access token by sending a a request to the `/api/refresh` endpoint with a cookie containing the refresh token. The server validates the refresh token and, if valid, generates a new access token and sends it in the response body. This process is done automatically inside the NextJS application by the `useAuth` hook.

1.5.4. The `useAuth` hook

The `useAuth` hook is a React hook that can be used to easily manage the user session. It is used to authenticate users, to get the user session information, to refresh the access token, to logout users, and to check if the user is authenticated.

The `useAuth` hook is defined in the `providers/auth/AuthProvider.tsx` file and is used in the `pages/_app.tsx` file to wrap the entire application. This is the list of the features provided by the `useAuth` hook:

- `currentUser` : The current user session information, such as the user ID, E-Mail address, name, surname and role
- `accessToken` : The JWT access token used to access the protected resources
- `refreshToken` : The JWT refresh token used to obtain a new access token when the current access token expires
- `isAuthenticated` : A boolean value that indicates if the user is authenticated
- `login(username: string, password: string)` : A function that can be used to authenticate users
- `logOut()` : A function that can be used to logout the user
- `refreshSession()` : A function that can be used to refresh the user session

5.5 Route protection

To protect access to the protected resources, have been used two different approaches:

- Middleware (**/middleware.ts**) that check if the user has set the access token in the cookies and, if not, redirects the user to the login page
- Server-side rendering (SSR) function that checks the user's access token validity and, if not valid, redirects the user to the login page

5.6 JWT tokens

The JWT access token and the JWT refresh token have the following payload:

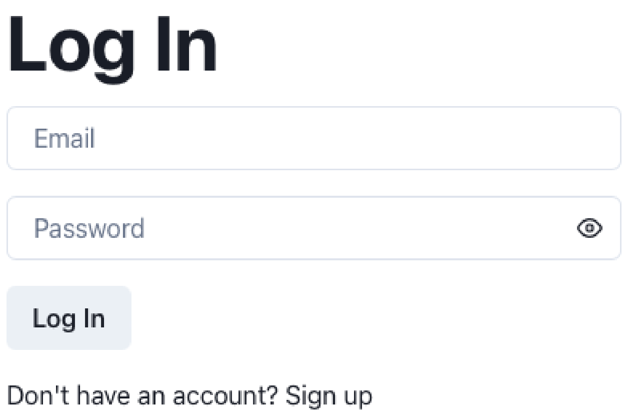
```
{
  "sub": <user id>,
  "email": <user email>,
  "name": <user first name>,
  "surname": <user last name>,
  "role": <user role: ADMIN or USER>,
  "iat": <issued at timestamp>,
  "exp": <expire at timestamp>,
  "iss": "${APP_URL}", // ENVIRONMENT VARIABLE
}
```

The JWT access token expires after 15 minutes, while the JWT refresh token expires after 30 days. Both tokens are signed using different secret keys to increase security.

Both tokens shares the same payload structure to permit the server to do extra checks on the token validity. If the user saved in the database is not the same user that is present in the token payload, the token is not valid. This has been done to prevent the user from using a token with old / invalid user information.

1.5.5. Screenshots and short demo

Login page:

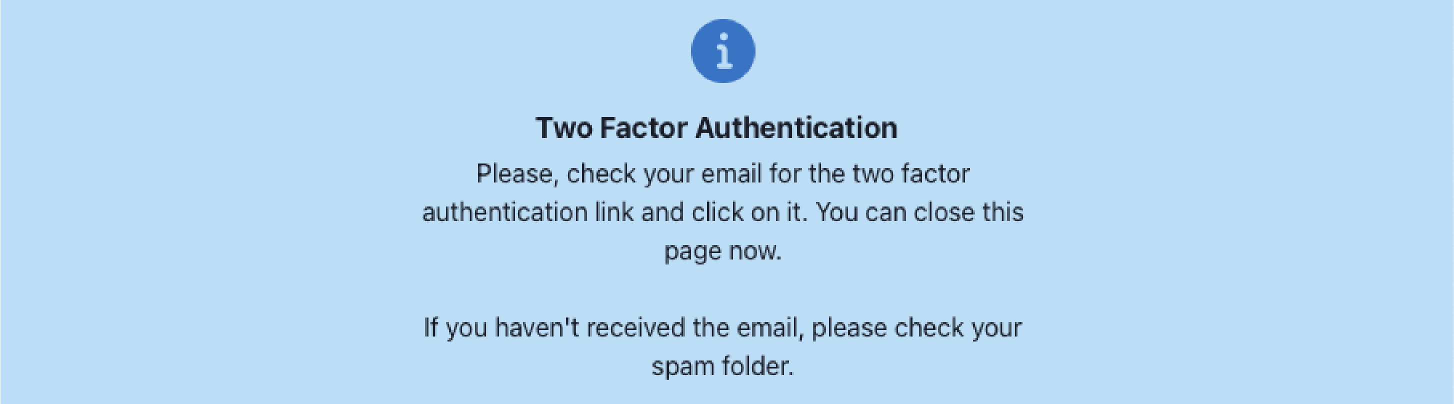


Log In

Don't have an account? Sign up

Two-factor authentication pages:

Two-Factor authentication landing page:

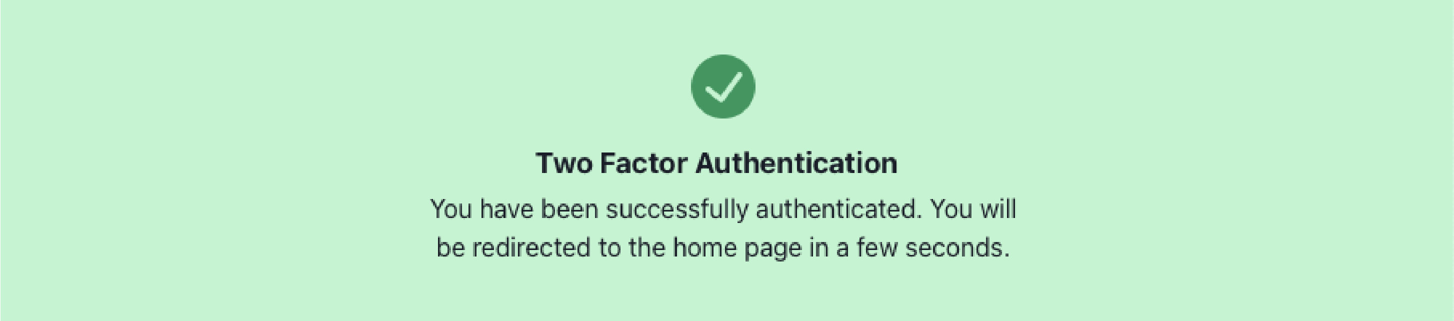


Two Factor Authentication

Please, check your email for the two factor authentication link and click on it. You can close this page now.

If you haven't received the email, please check your spam folder.

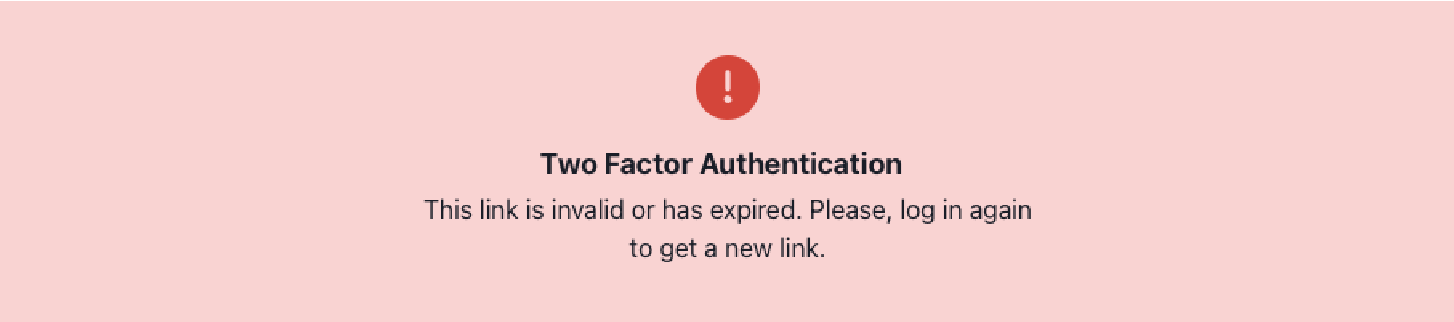
Two-Factor authentication success page:



Two Factor Authentication

You have been successfully authenticated. You will be redirected to the home page in a few seconds.

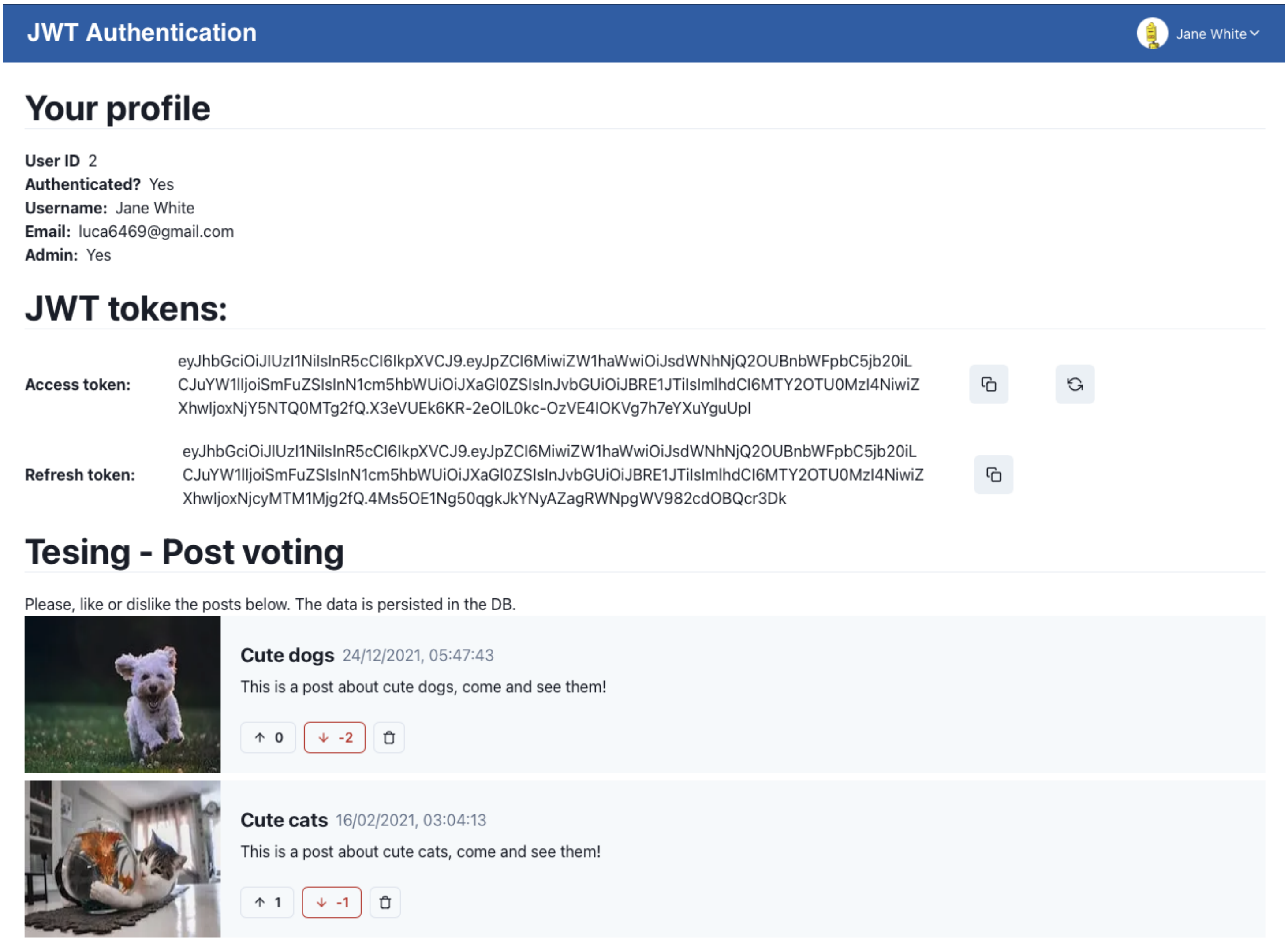
Two-Factor authentication error page:



Two Factor Authentication

This link is invalid or has expired. Please, log in again to get a new link.

Dashboard page:



Your profile

User ID 2
Authenticated? Yes
Username: Jane White
Email: luca6469@gmail.com
Admin: Yes

JWT tokens:

Access token:

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJpZCI6MiwiZW1haWwiOiJsdWNhNjQ2OUBnbWFpbC5jb20iL
CJuYW1lIjoiSmFuZSIsInN1cm5hbWUiOiJXaGl0ZSIsInJvbGUiOiJBRE1JTiIsImlhdCI6MTY2OTU0MzI4NiwiZ
XhwIjoxNjY5NTQ0MTg2fQ.X3eVUEk6KR-2eOlL0kc-OzVE4IOKVg7h7eYXuYguUpI
```

Refresh token:

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJpZCI6MiwiZW1haWwiOiJsdWNhNjQ2OUBnbWFpbC5jb20iL
CJuYW1lIjoiSmFuZSIsInN1cm5hbWUiOiJXaGl0ZSIsInJvbGUiOiJBRE1JTiIsImlhdCI6MTY2OTU0MzI4NiwiZ
XhwIjoxNjcyMTM1Mjg2fQ.4Ms5OE1Ng50qgkJkYNyAZagRWNpgWV982cdOBQcr3Dk
```

Tesing - Post voting

Please, like or dislike the posts below. The data is persisted in the DB.

Cute dogs 24/12/2021, 05:47:43

This is a post about cute dogs, come and see them!

Cute cats 16/02/2021, 03:04:13

This is a post about cute cats, come and see them!

Demo video using two accounts concurrently:

Showcase video