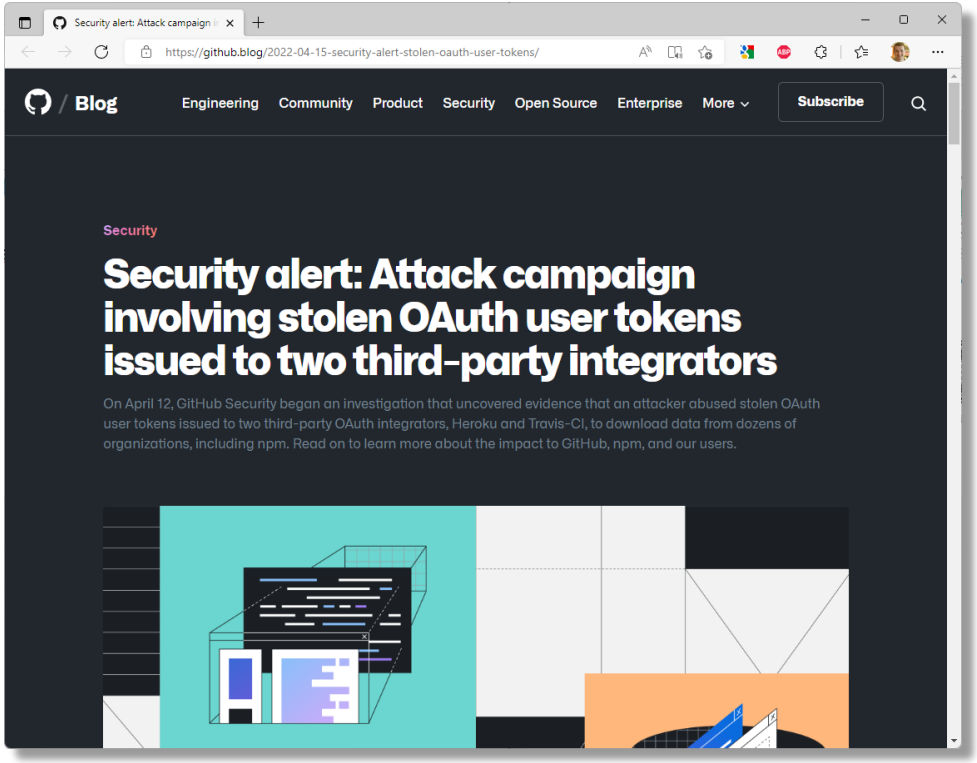
Analyzing the Compliance of OAuth 2.0 Implementations

Pieter Philippaerts

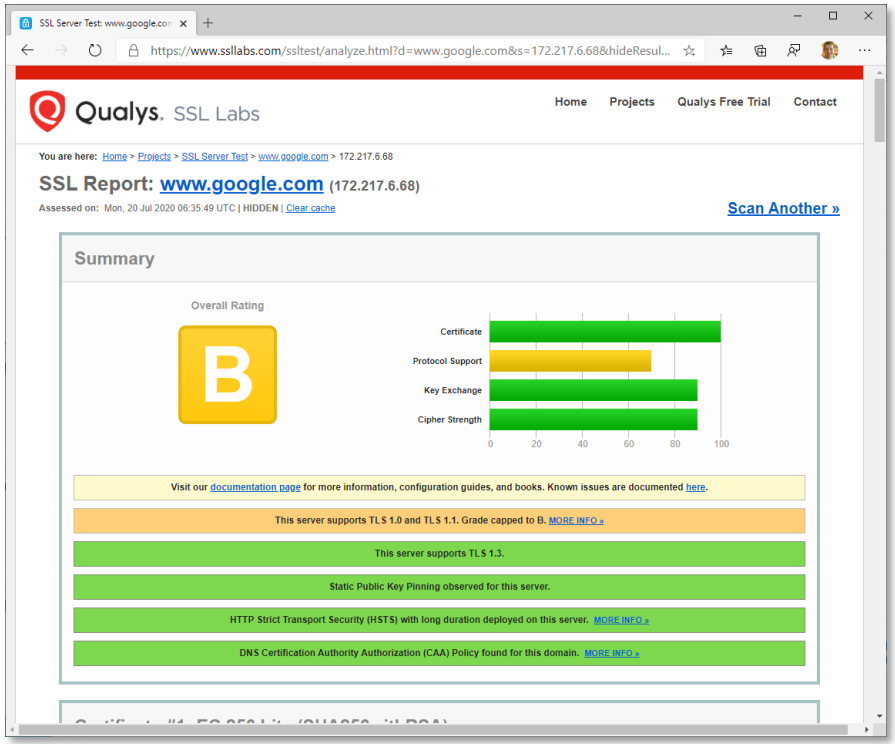
KU LEUVEN DistriNet

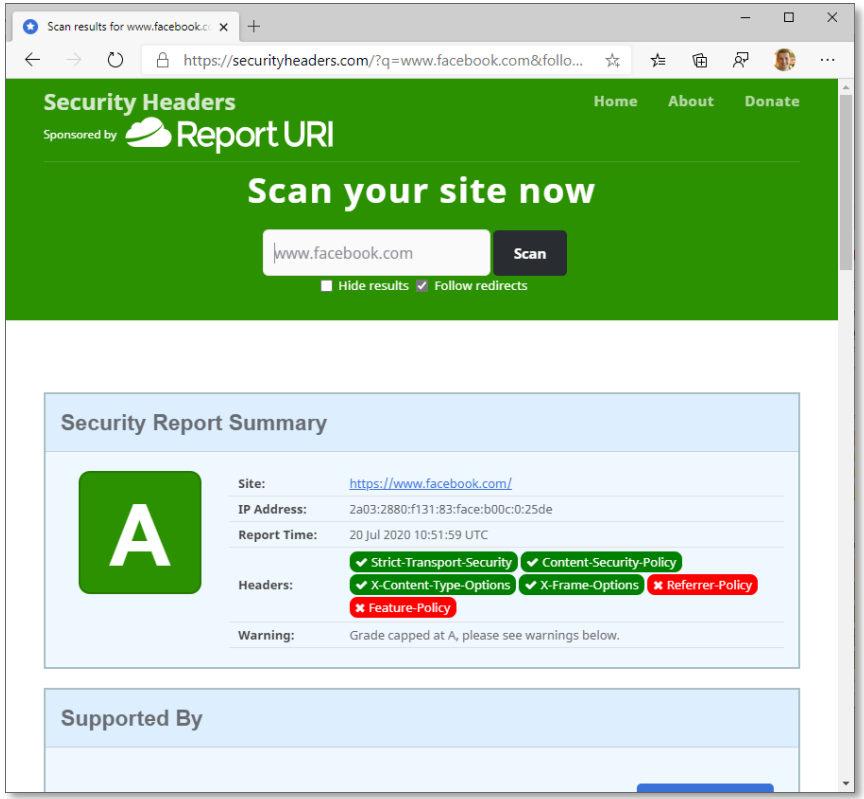


"We do not believe the attacker obtained these tokens via a compromise of GitHub [..] because the tokens in question are not stored by GitHub in their original, usable formats"

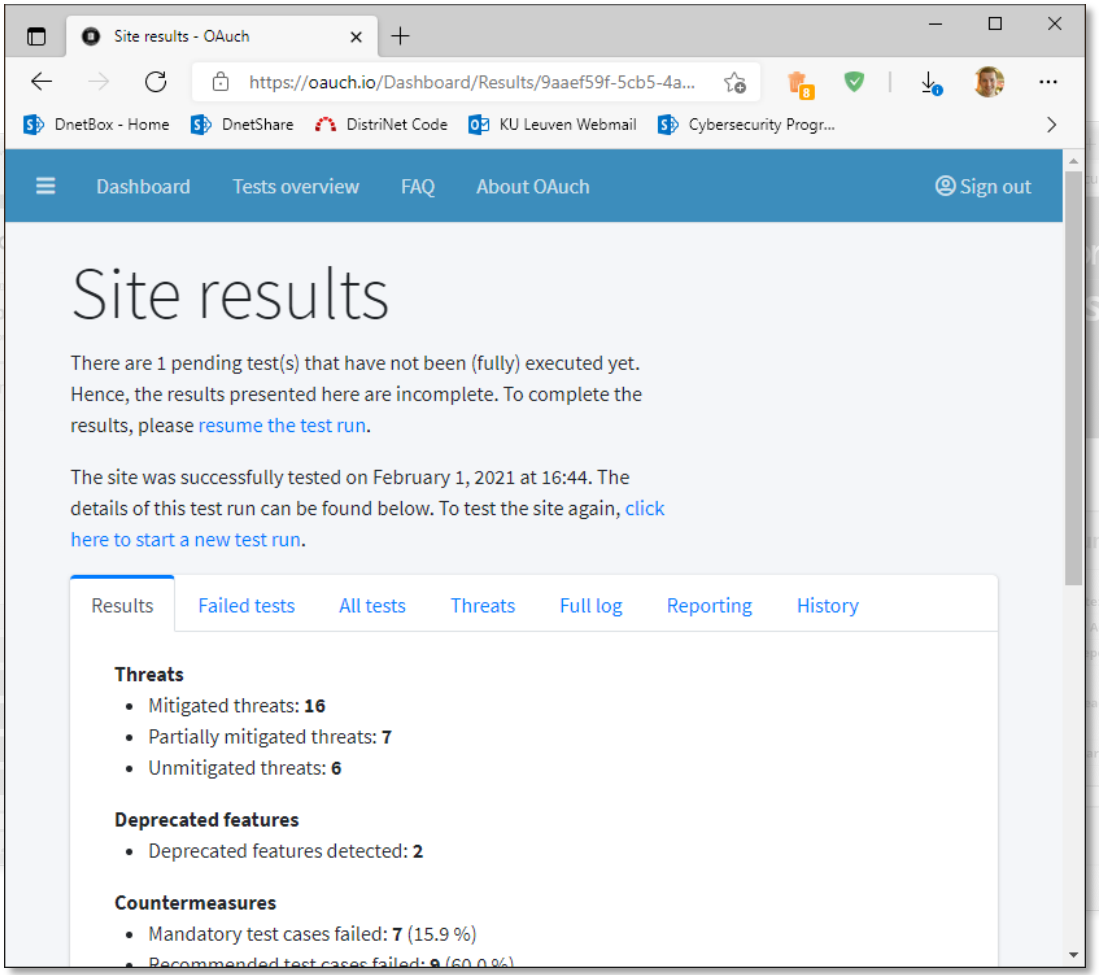
- Mike Hanley, chief security officer, GitHub

"Once you have implemented OAuth2, how do you know you have implemented it correctly?"





KU LEUVEN DistriNet



KU LEUVEN DistriNet

The OAuch Tool

Internet Engineering Task Force (IETF)
Request for Comments: 6749
Obsoletes: 5849
Category: Standards Track
ISSN: 2070-1721

D. Hardt, Ed.
Microsoft

October 2012

The OAuth 2.0 Authorization Framework

Abstract

The OAuth 2.0 authorization framework enables a third-party application to obtain limited access to an HTTP service, either on behalf of a resource owner by orchestrating an approval interaction between the resource owner and the HTTP service, or by allowing the third-party application to obtain access on its own behalf. This specification replaces and obsoletes the OAuth 1.0 protocol described in RFC 5849.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc6749.

Copyright Notice

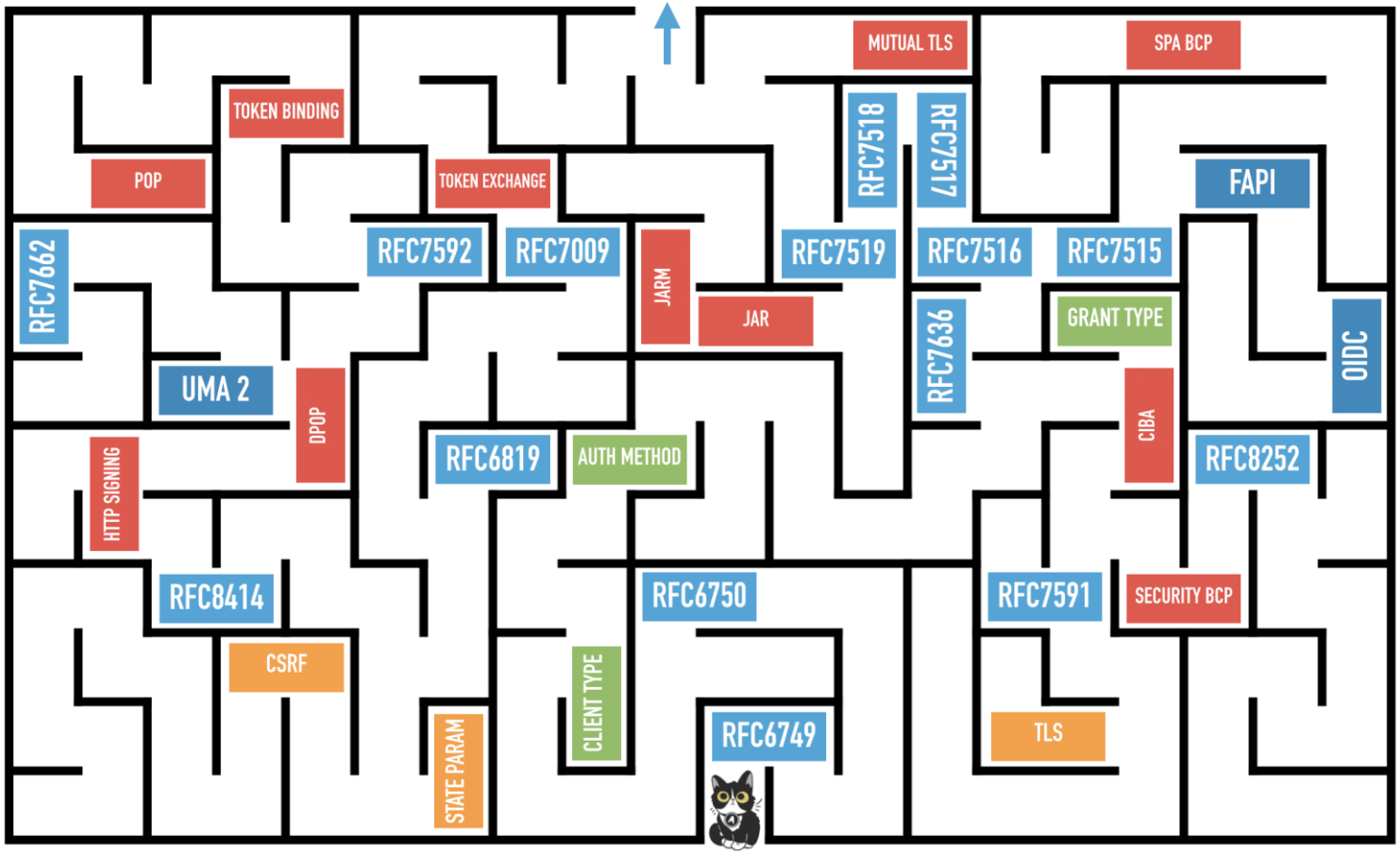
Authorization servers MAY issue re
clients and native application cli

Refresh tokens MUST be kept confid
shared only among the authorizatio
refresh tokens were issued. The a
the binding between a refresh toke
issued. Refresh tokens MUST only
described in Section 1.6 with serv
[RFC2818].

The authorization server MUST veri
token and client identity whenever
authenticated. When client authen
authorization server SHOULD deploy
token abuse.

KU LEUVEN DistriNet

BUILDING YOUR APPLICATION



KU LEUVEN DistriNet

Building a test case

The client MUST NOT use the authorization code more than once.

- OAuch tries to use the same authorization code two times and keeps track of the server's response

Test case coverage

- OAuch implements 112 unique test cases from 10 documents
  - Many documents contain the same requirements
  - If a requirement has varying requirement levels, OAuch picks the strictest one
- Not all security requirements can be converted to test cases

Testing Process

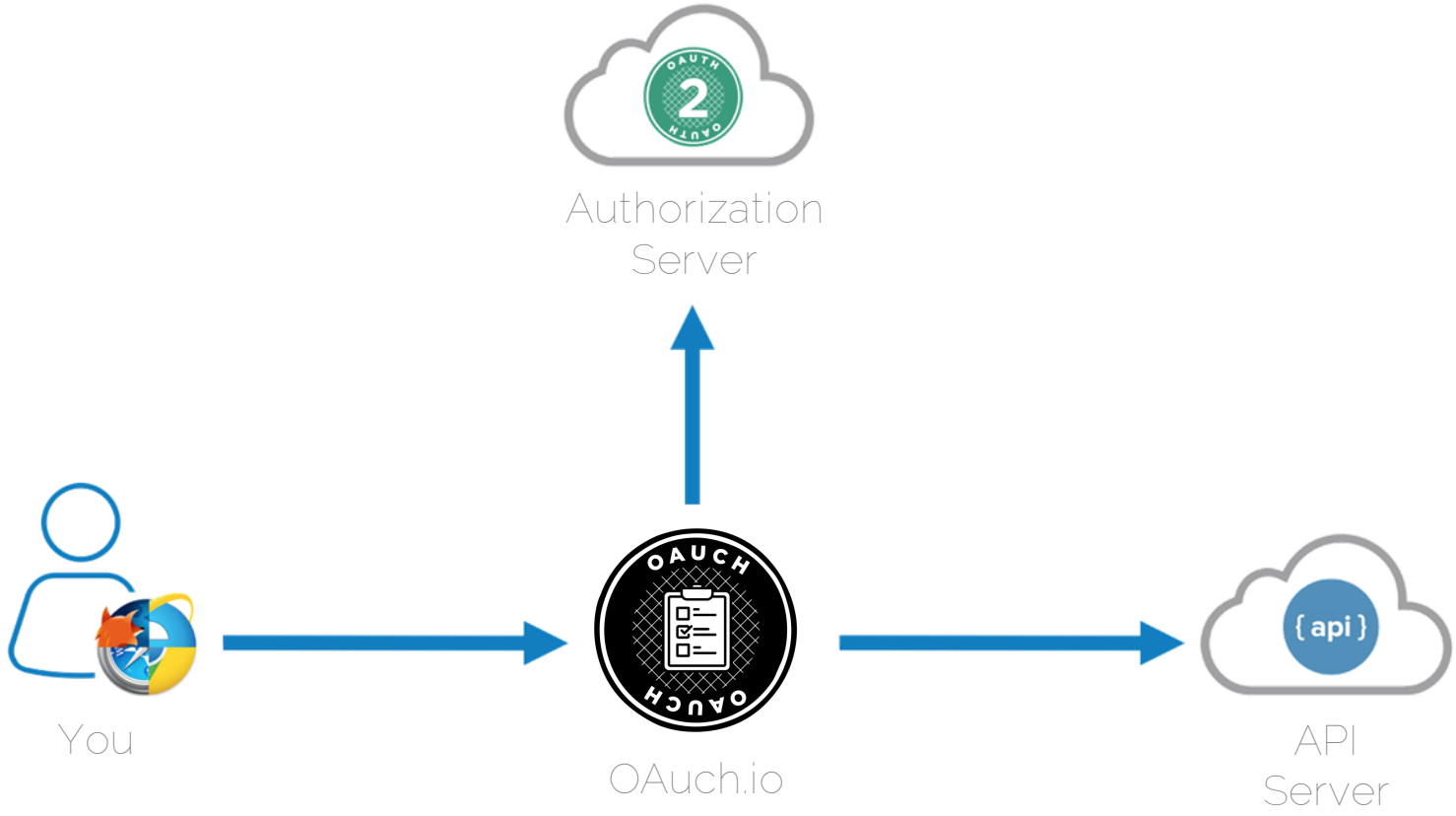
- OAuch is set up like any other client
  - … but acts like a malicious client!

- Access token validation requires an API endpoint
  - **`HTTP 2xx`** → access token is valid
  - **`HTTP 4xx/5xx`** → access token is invalid

Testing Process

- OAuch detects which features are enabled on the server
  - The relevant test cases are selected and run
  - OAuch keeps a detailed log, that can be inspected by the user
- Result: a full overview of which countermeasures are enabled on the server

DEMO: OAuch



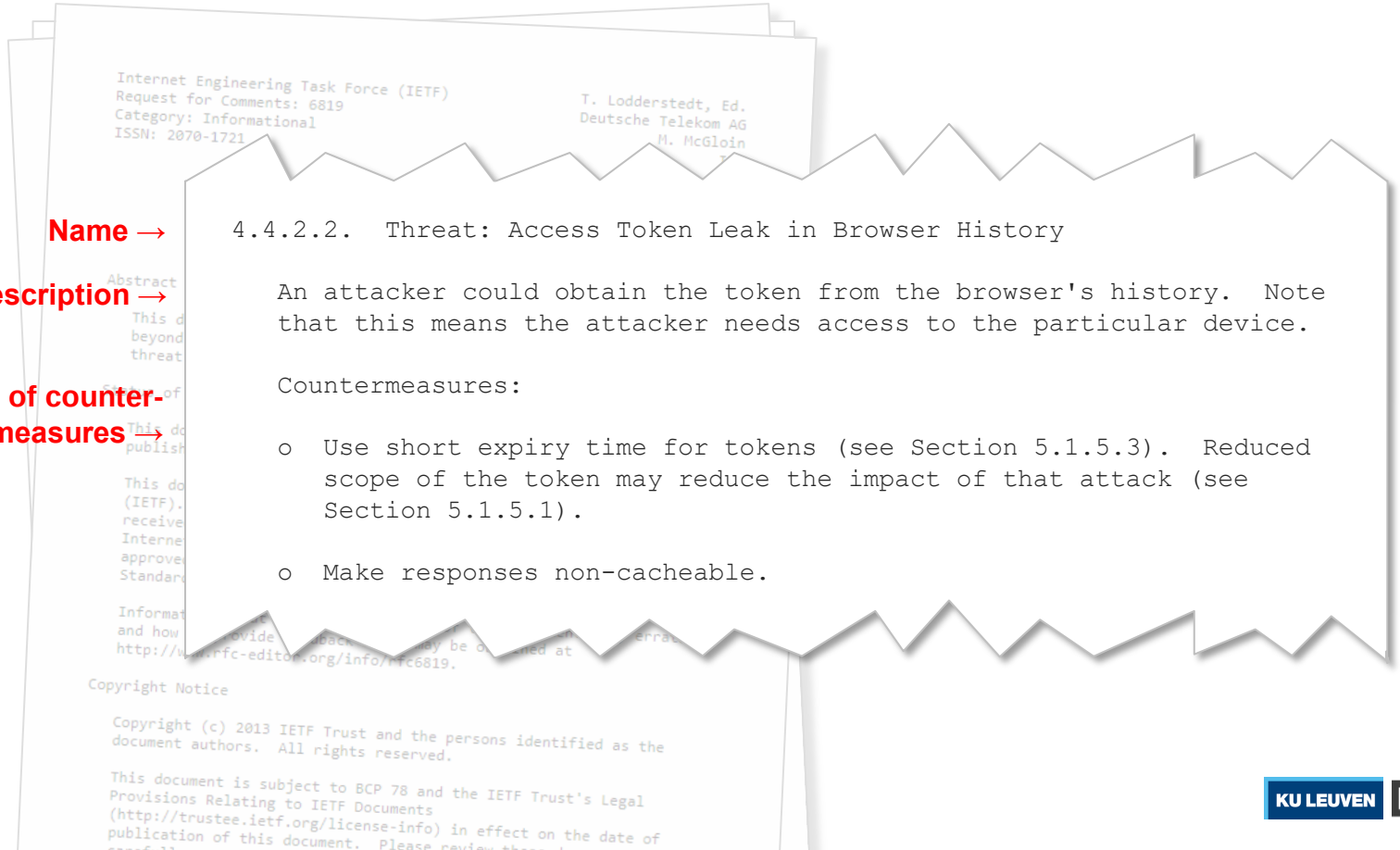
https://developer.okta.com/blog/2017/06/21/what-the-heck-is-oauth

Testing Process

- OAuch detects which features are enabled on the server
  - The relevant test cases are selected and run
  - OAuch keeps a detailed log, that can be inspected by the user
- Result: a full overview of which countermeasures are enabled on the server

But what does that mean?

OAuth Threat Model



Name →

Description →

List of counter-measures →

4.4.2.2. Threat: Access Token Leak in Browser History

An attacker could obtain the token from the browser's history. Note that this means the attacker needs access to the particular device.

Countermeasures:

- Use short expiry time for tokens (see Section 5.1.5.3). Reduced scope of the token may reduce the impact of that attack (see Section 5.1.5.1).

- Make responses non-cacheable.

KU LEUVEN DistriNet

OAuth Threat Model

- OAuch integrates this threat model (+BCP) into the analysis
  - 42 server-side threats are evaluated
  - A threat can be full mitigated, partially mitigate or not mitigated
- OAuch gives clear advice to a site owner
  - Which threats your site might be vulnerable to
  - Which countermeasures must be implemented to mitigate them

DEMO: The Threat Model

Limitations of OAuch

- Only tests the authorization server
  - Assumes no client-side mitigations
- Only unintrusive tests
  - No validation of DDoS countermeasures
- The threat model assumes a powerful attacker
  - Nation-state attackers

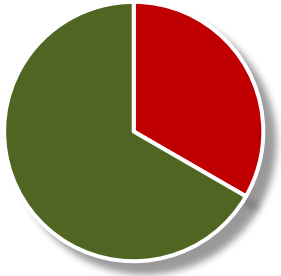
Analyzing the OAuth 2.0 Ecosystem

What we did

- We tested 100 OAuth implementations
  - 80 API providers, 20 OIDC providers
  - 75 sites from Top 10000
  - All publicly available (so they *should* be secure)

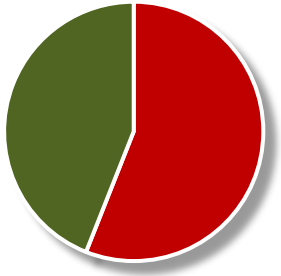
- We drew statistics over the sites and over the individual countermeasures/threats

Results – Failure Rates

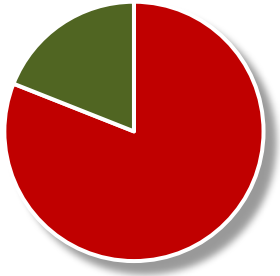


Overall: **33% FR**

Must: **20% FR**

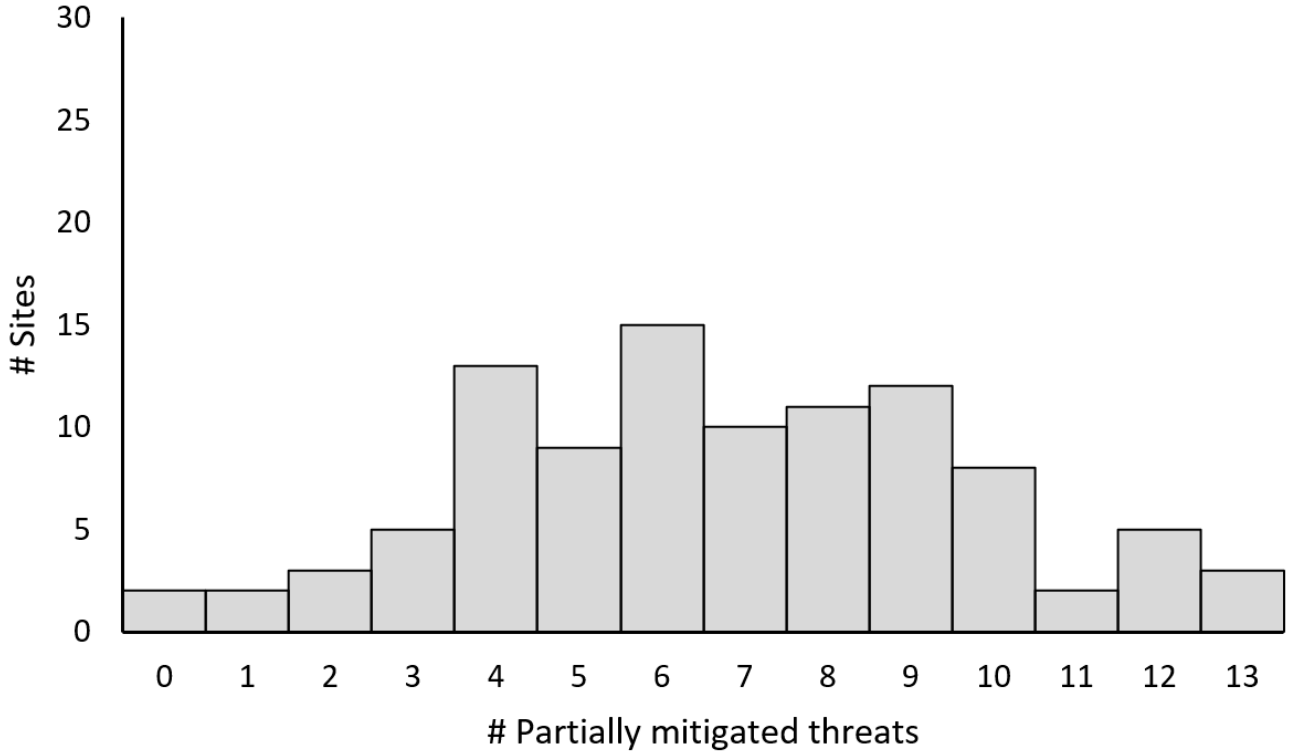


Should: **56% FR**

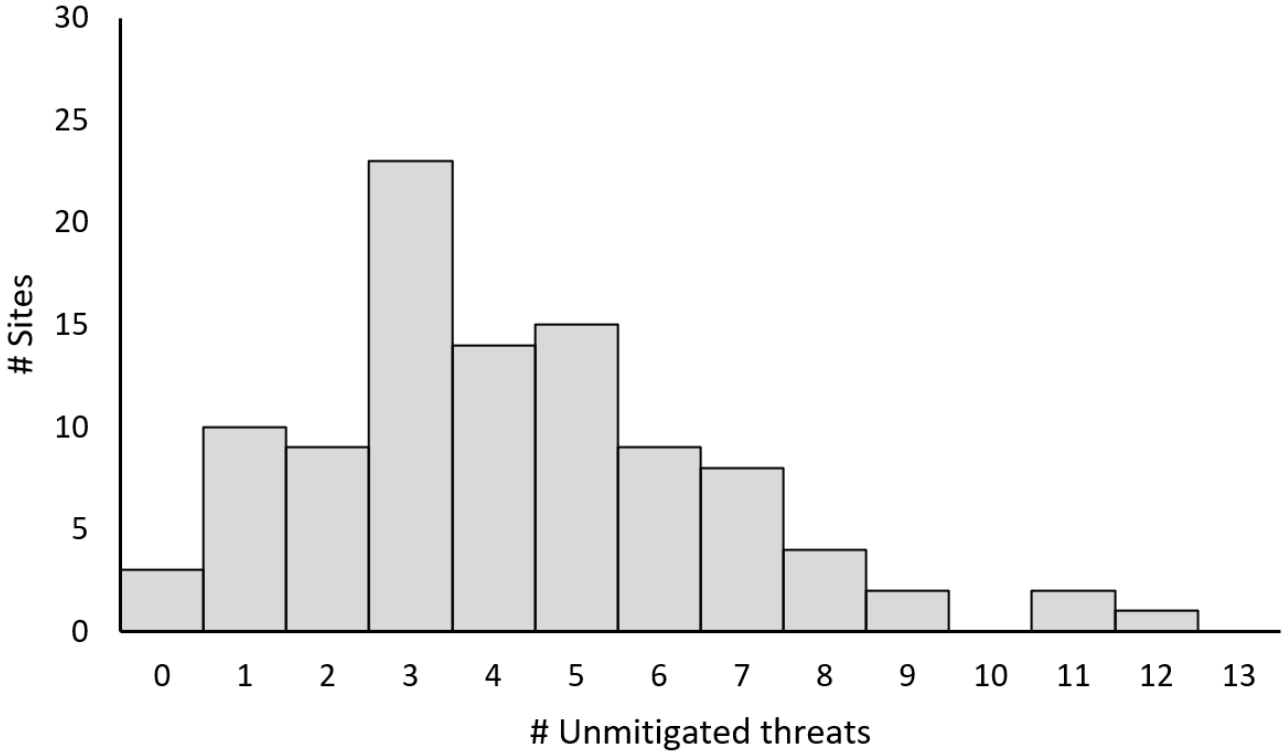


May: **81% FR**

Results – Partially Mitigated Threats



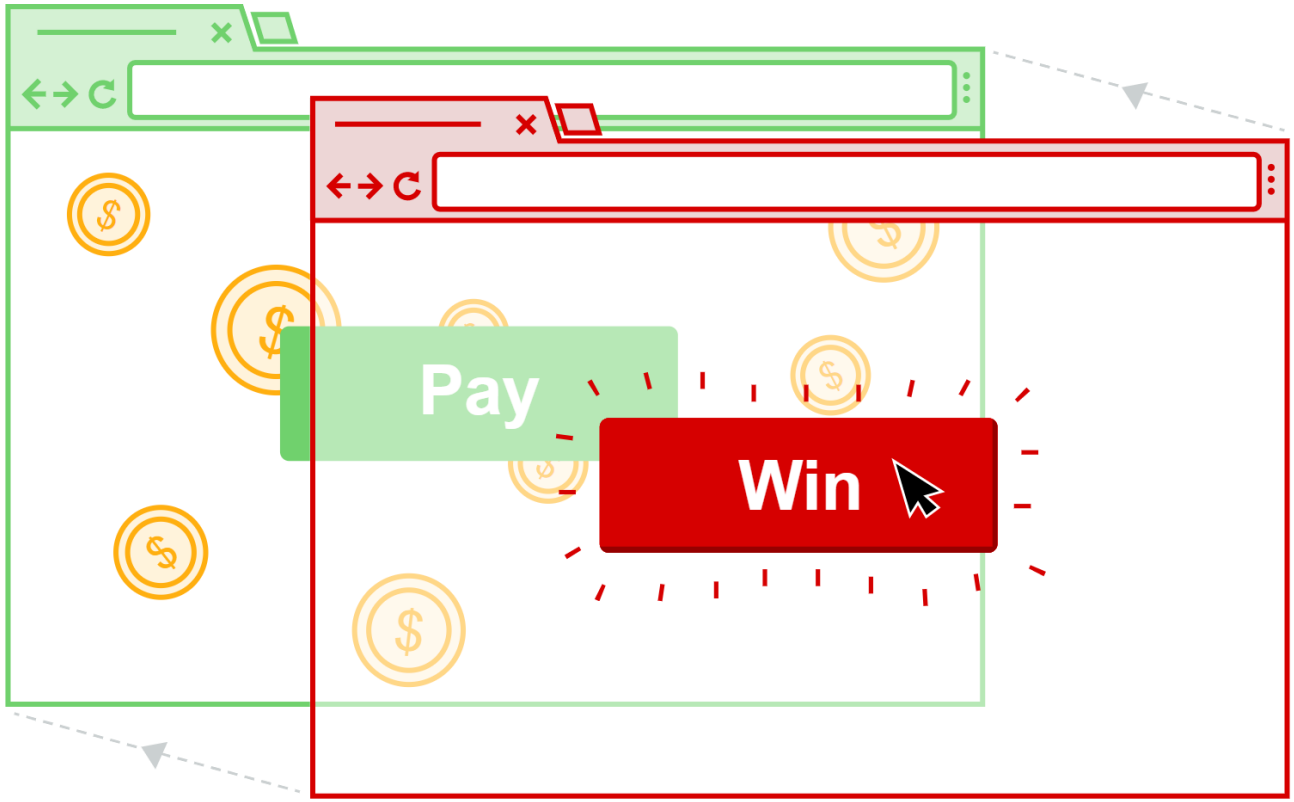
Results – Unmitigated Threats



Confirming the Results

- To validate the results, we used OAuch as an offensive tool
  1. Choose an attack vector
  2. Use OAuch to list all vulnerable sites
  3. Try to write a proof-of-concept exploit

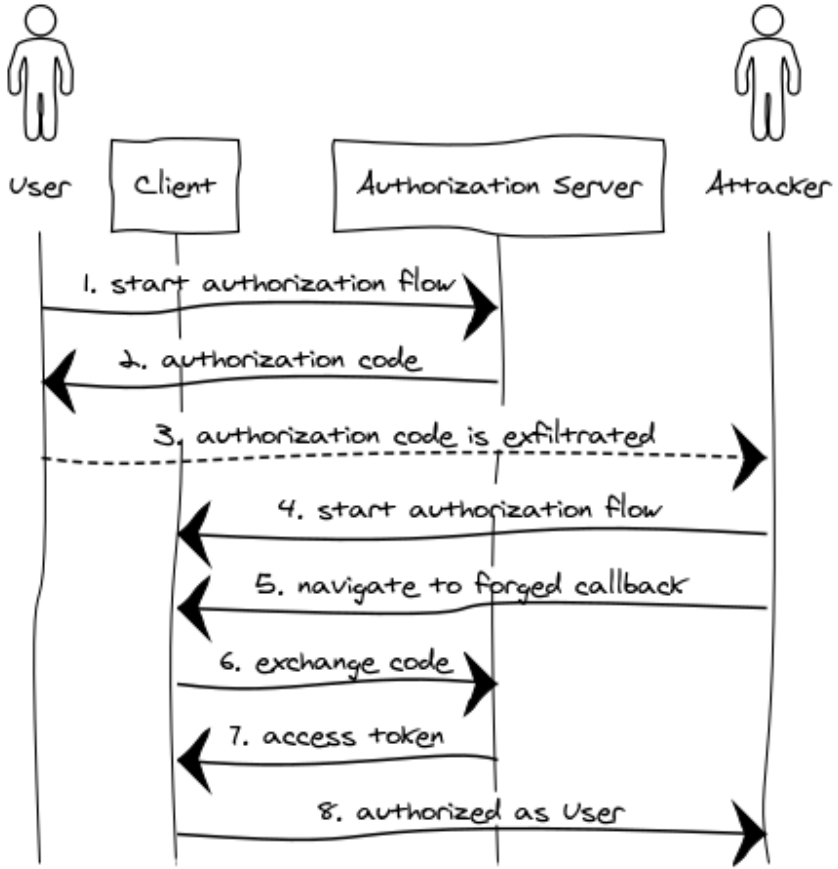
Confirming the Results – Clickjacking Attack



Confirming the Results – Clickjacking Attack

- OAuch identified 22 sites that could be vulnerable to this threat
  - After manual verification, 19 could be exploited (86% success rate)
  - 2 sites used JavaScript to redirect to a secure page
  - 1 site used frame-busting JavaScript

Confirming the Results – Authorization Code Injection



Confirming the Results – Authorization Code Injection

- Focus on the OIDC providers
  - Found clients for 12 OIDC providers
  - These clients were tested for this vulnerability
    - Most clients were vulnerable
    - For each provider, at least one vulnerable client was found (100% success rate)

“Is it really that bad?”

Is it really that bad?

- Yes and no.
  - Yes, the servers do not (fully) mitigate certain threats
  - No, the threat model assumes a powerful attacker
    - Often complex exploitability
  - No, OAuch assumes no client mitigations

“Why are OAuth implementations lacking so many counter-measures?”

Why are implementations non-compliant?

- The provider knows about it, but…
  - … wants to maintain backward compatibility
  - … some countermeasures cannot be efficiently implemented
  - … they have other development priorities
  - … doesn't care, because "it can be mitigated on the client side"

Why are implementations non-compliant?

- The provider may not know about it, because…
  - … the original OAuth standard is outdated
  - … they make invalid assumptions
  - … they assume the OAuth library handles everything
  - … OAuth looks deceptively easy to implement

Concluding Thoughts

Lessons Learned?

- It's hard to use these results to create generally applicable advice
  - Everyone makes different mistakes
  - OAuch gives tailor-made advice per site

Lessons Learned

- Do not assume that a library is safe. Verify that it is.
- Update your packages regularly. Security protocols evolve.
- Do not rely on clients making great security decisions. Enforce them.

Lessons Learned

- Having a formal verification of the OAuth2 protocol is great
  - … but we also need tools to verify practical implementations

- A lot of sites can benefit from implementing missing countermeasures

Try it!

- The tool is available on https://oauch.io/
  - Let us know if we can improve something

Thank you!

https://distrinet.cs.kuleuven.be/

Pieter.Philippaerts@kuleuven.be