WPSE: Fortifying Web Protocols via Browser-Side Security Monitoring

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Joint work w. Stefano Calzavara, Riccardo Focardi, Matteo Maffei,
Clara Schneidewind, Mauro Tempesta

4th OAuth Security Workshop 2019
March 21, 2019 - Stuttgart/Germany

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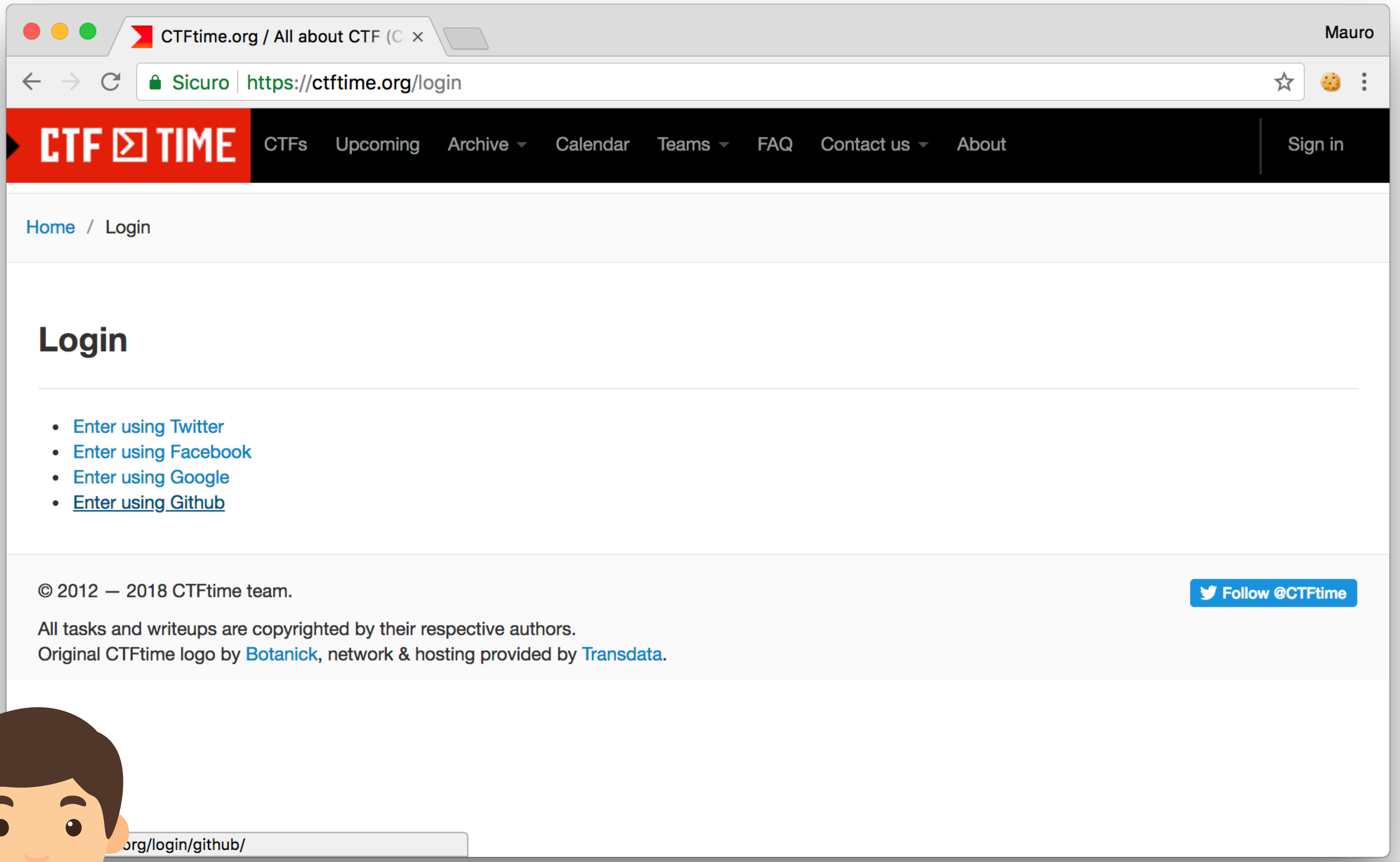
Overview of a Web Protocol



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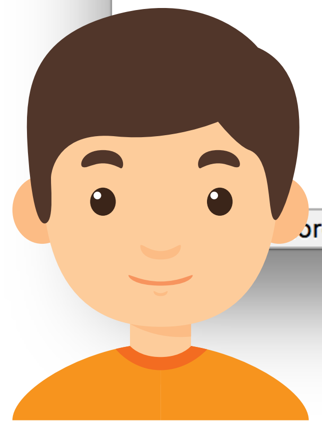

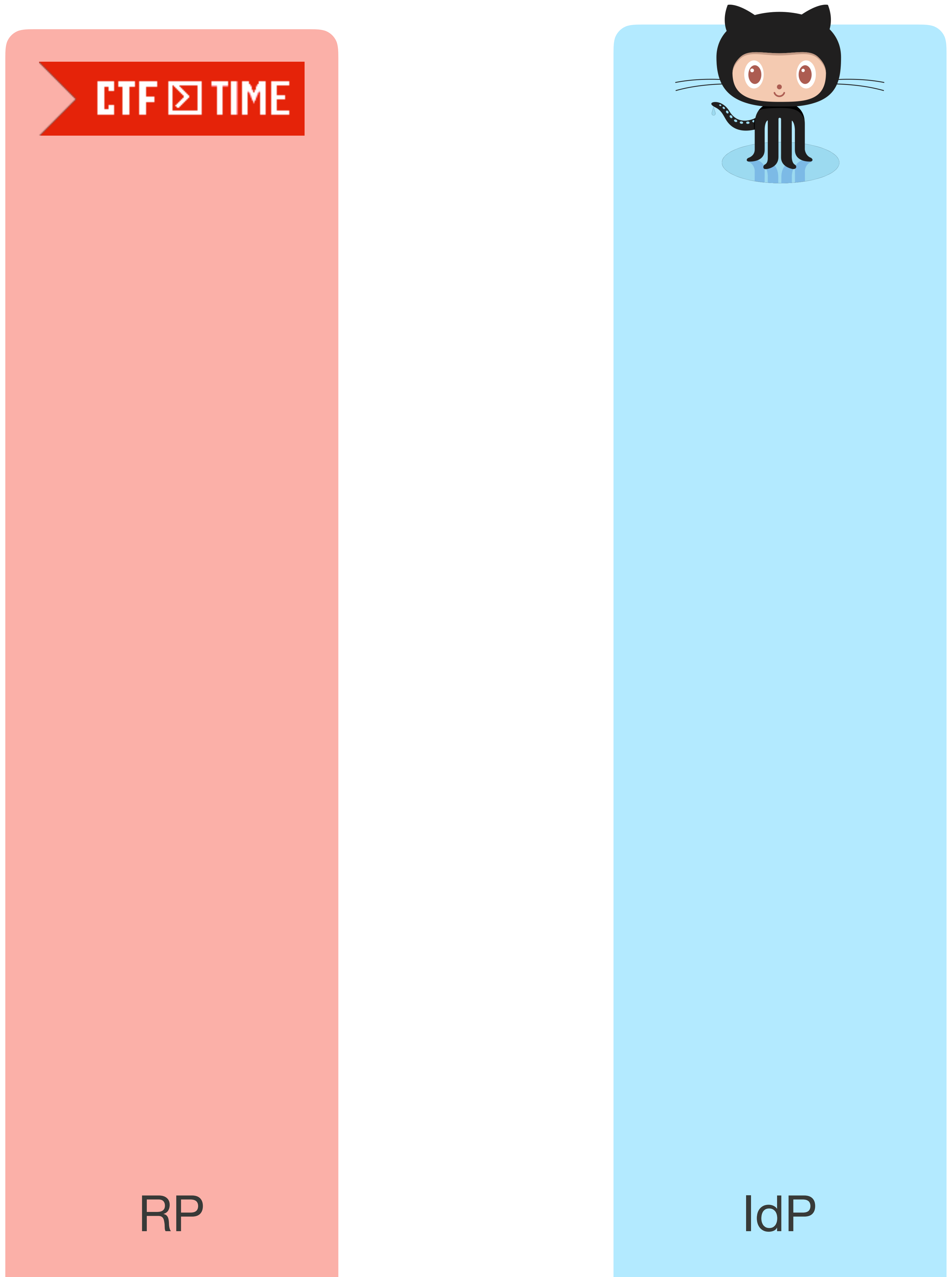

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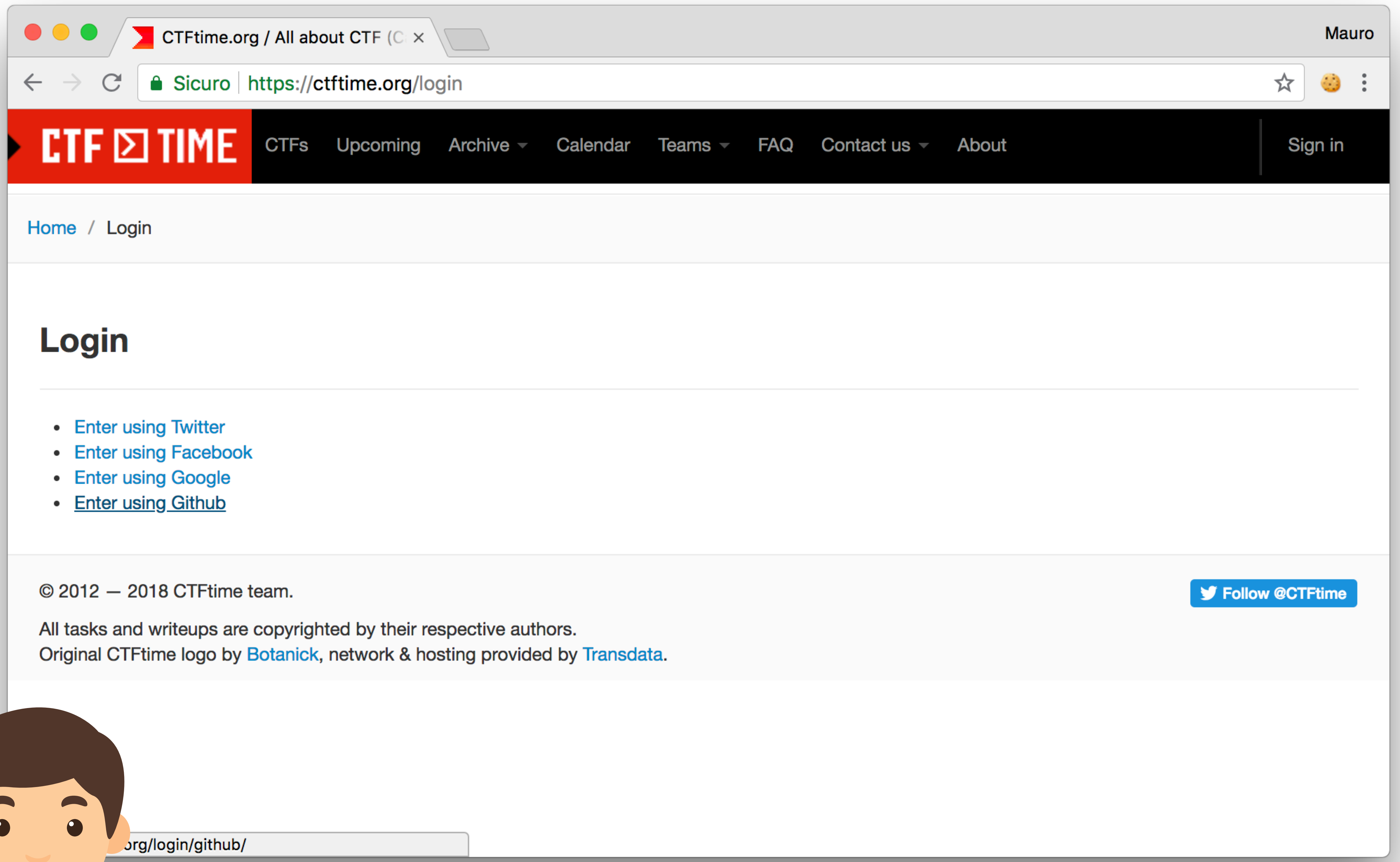
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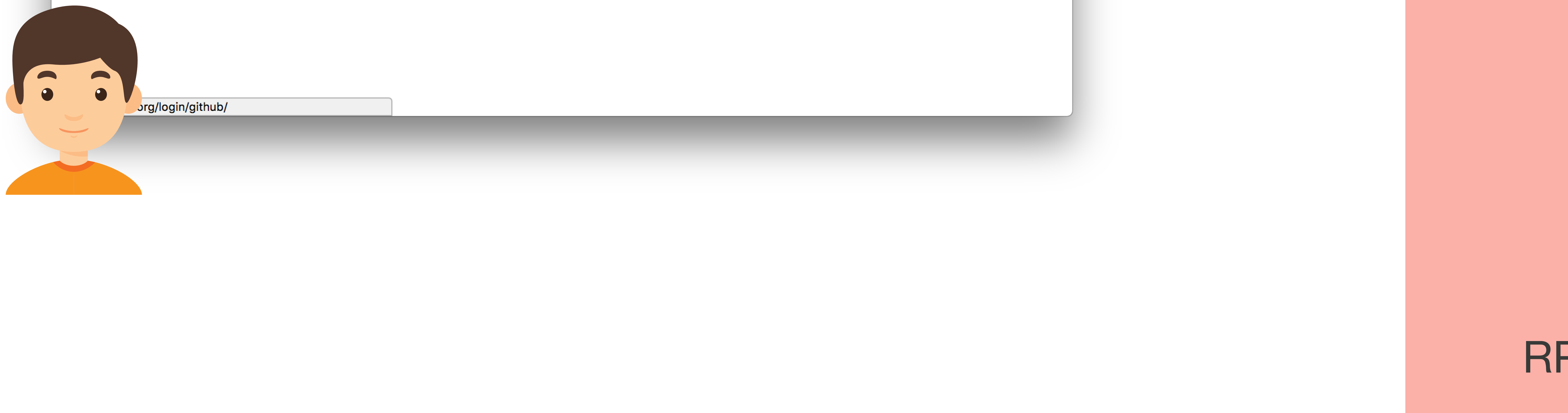

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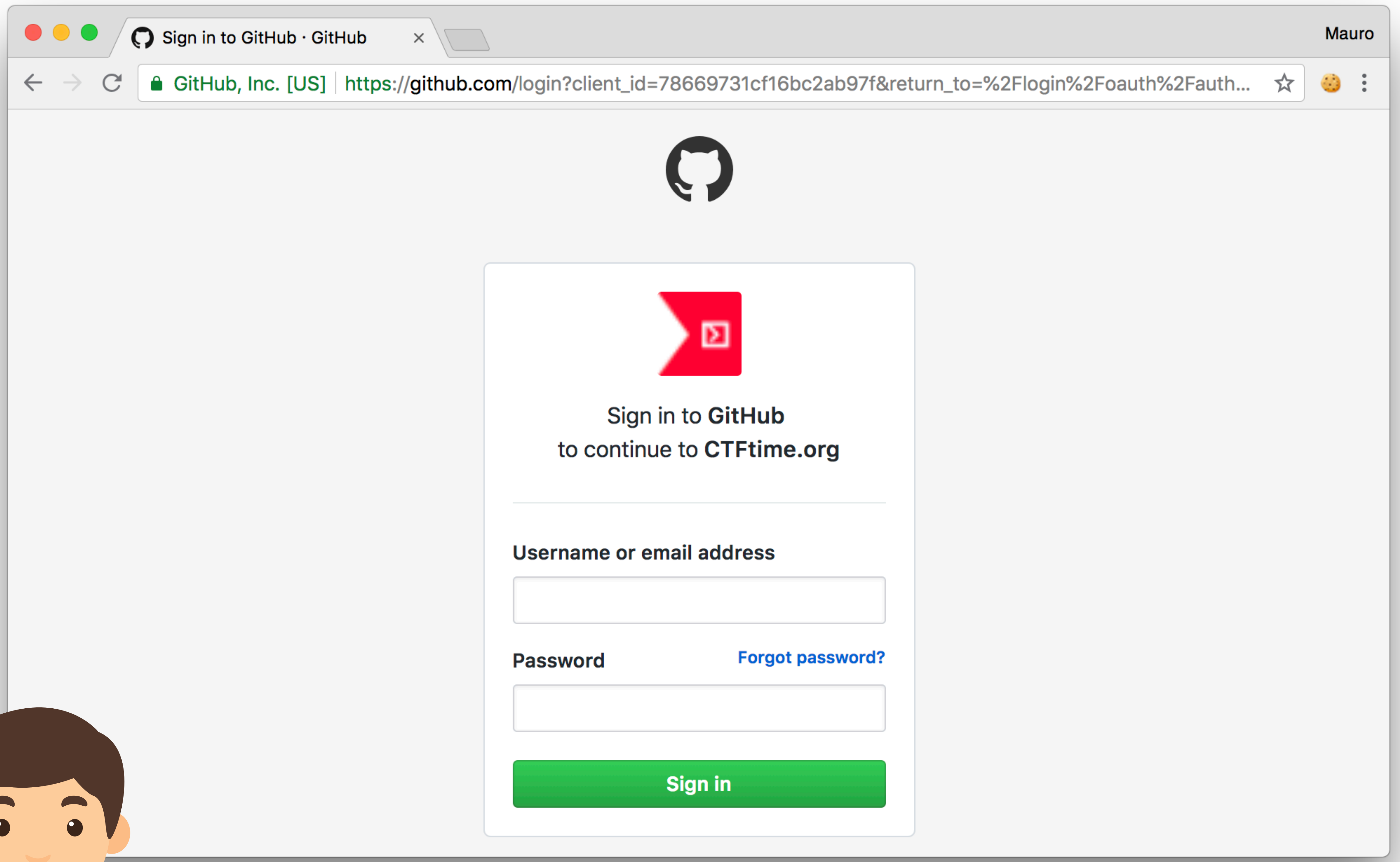
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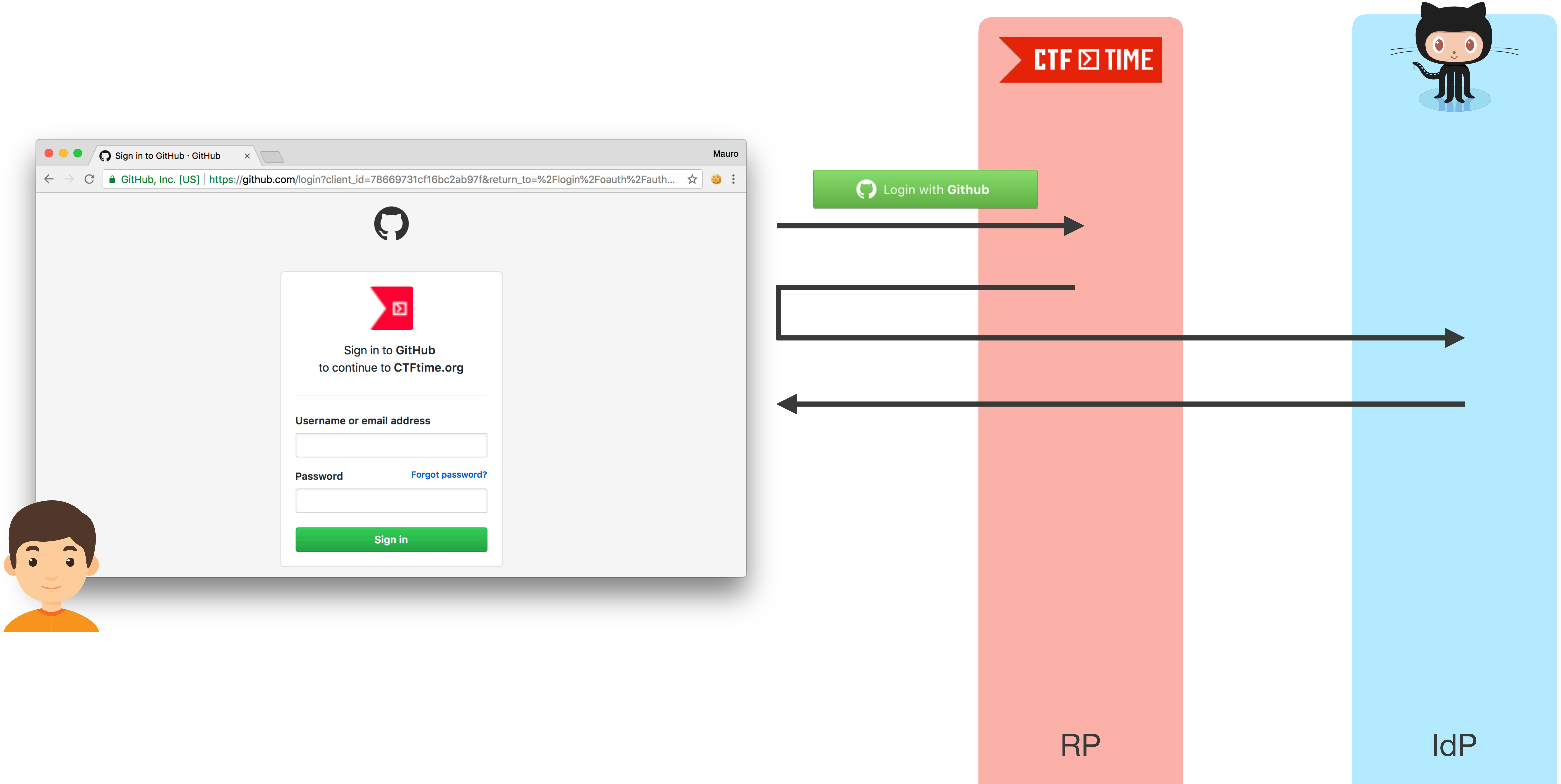

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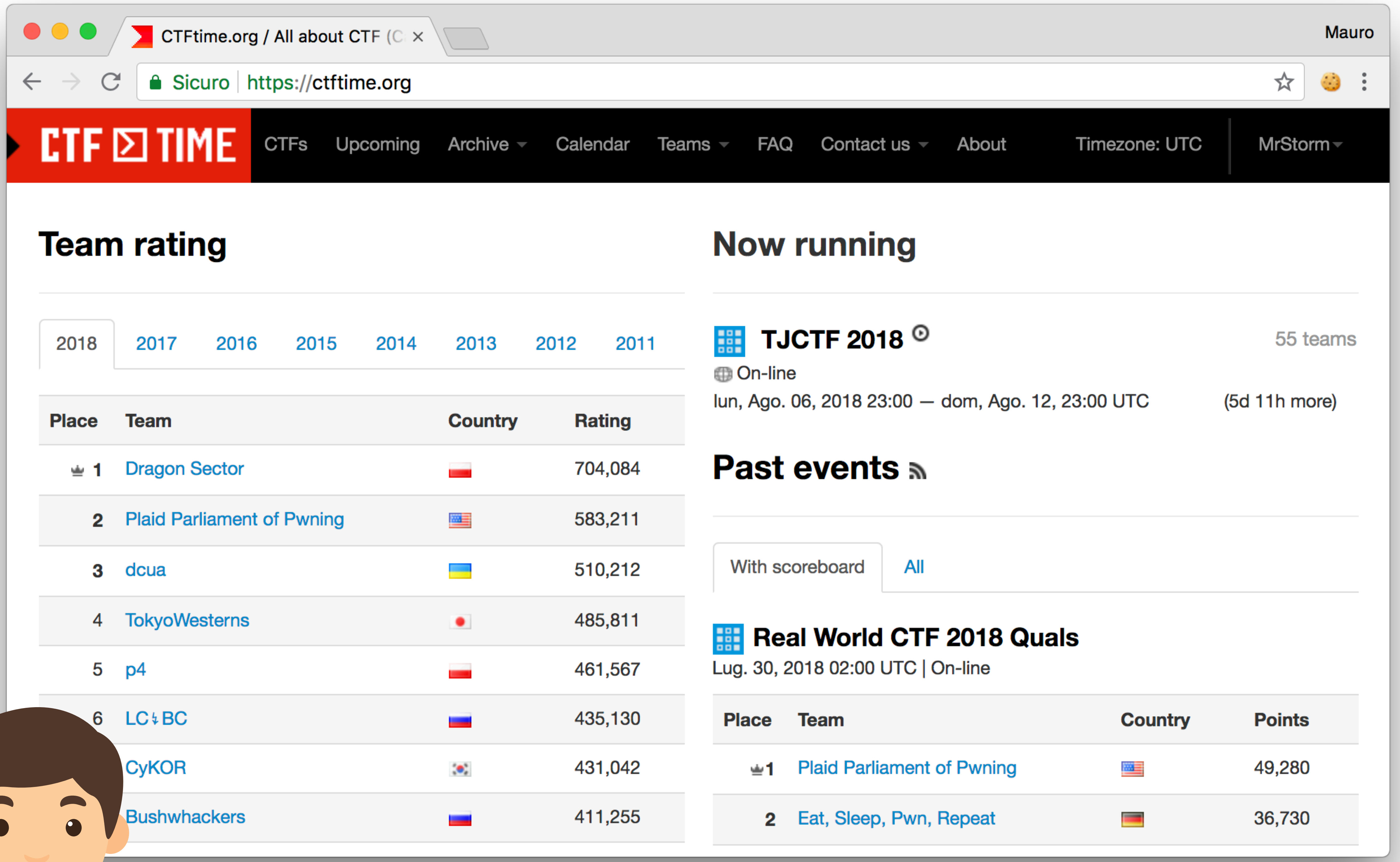

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Team rating

2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011

Place	Team	Country	Rating
1	Dragon Sector	🇵🇱	704,084
2	Plaid Parliament of Pwning	🇺🇸	583,211
3	dcua	🇺🇦	510,212
4	TokyoWesterns	🇯🇵	485,811
5	p4	🇵🇱	461,567
6	LC↯BC	🇷🇺	435,130
	CyKOR	🇰🇷	431,042
	Bushwhackers	🇷🇺	411,255

Now running

TJCTF 2018 — 55 teams

On-line

lun, Ago. 06, 2018 23:00 — dom, Ago. 12, 23:00 UTC (5d 11h more)

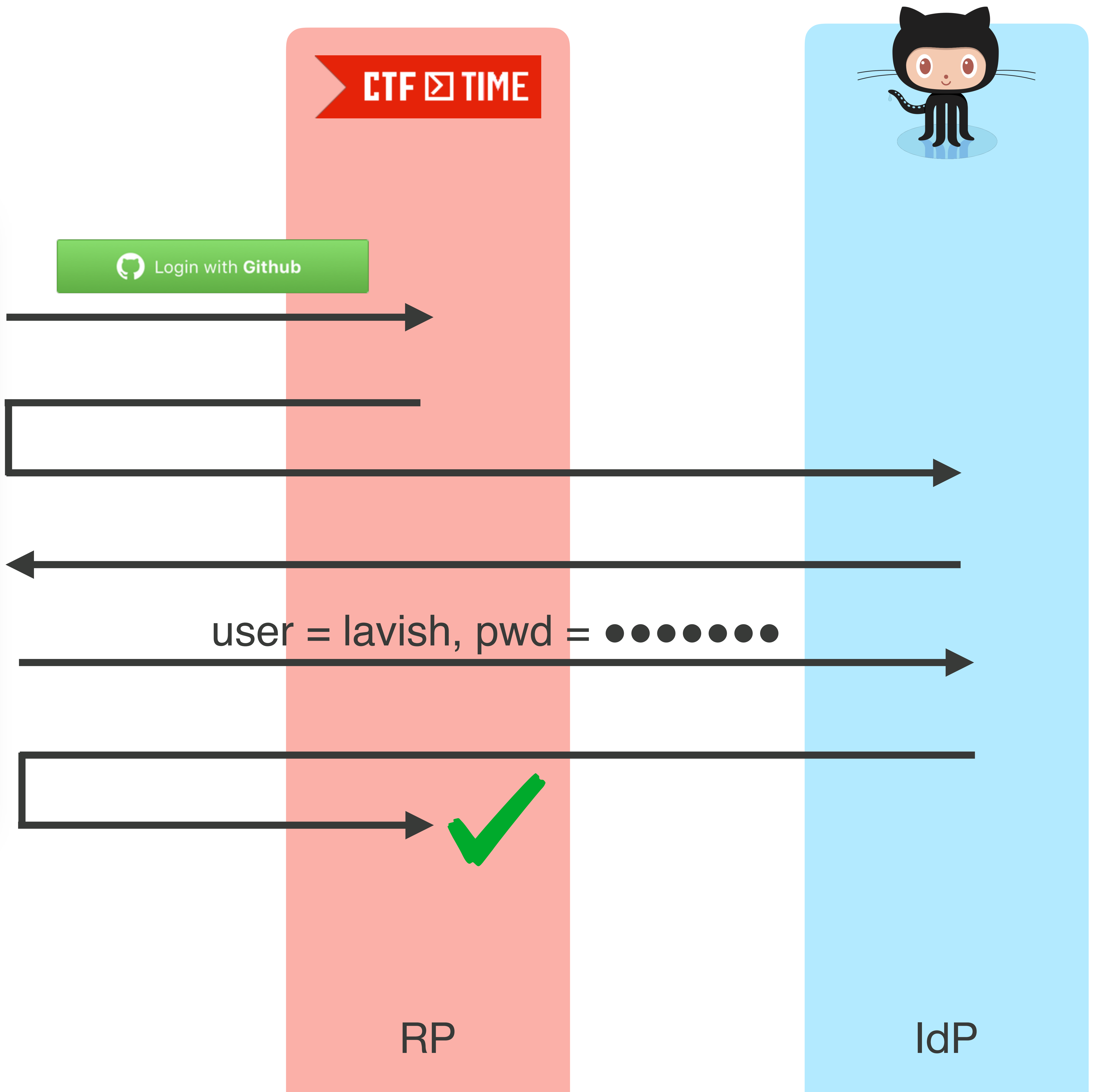
Past events

With scoreboard | All

Real World CTF 2018 Quals

Lug. 30, 2018 02:00 UTC | On-line

Place	Team	Country	Points
1	Plaid Parliament of Pwning	🇺🇸	49,280
2	Eat, Sleep, Pwn, Repeat	🇩🇪	36,730



Motivations

Designing and implementing web protocols is **HARD!**

- *Bansal et al*., Discovering Concrete Attacks on Website Authorization by Formal Analysis (**S&P '12**)
- *Wang et al.,* Signing Me onto Your Accounts through Facebook and Google: A Traffic-Guided Security Study of Commercially Deployed Single-Sign-On Web Services (**S&P'12**)
- *Sun and Beznosov,* The Devil is in the (Implementation) Details: An Empirical Analysis of OAuth SSO Systems (**CCS'12**)
- *Fett et al.,* A Comprehensive Formal Security Analysis of OAuth 2.0 (**CCS'16**)
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WHY?

MOTIVATIONS

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- …

The browser is not aware of the existence of web protocols and of their semantics!

Our Proposal - WPSE

Extend the browser with a **lightweight security monitor** that enforces the compliance of the browser behaviors with respect to the web protocol specifications

Our Proposal - WPSE

Implemented as a Google Chrome **extension**

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Advantages

1. users of vulnerable websites are **automatically protected** against a large class of attacks
2. specifications can be **written once** and **enforced on several sites**

Challenges in Web Protocols

Compliance with the protocol flow

- Preserve the intended sequence of messages exchanged by honest participants
- Perform integrity checks on the contents of protocol messages

Secrecy of message components

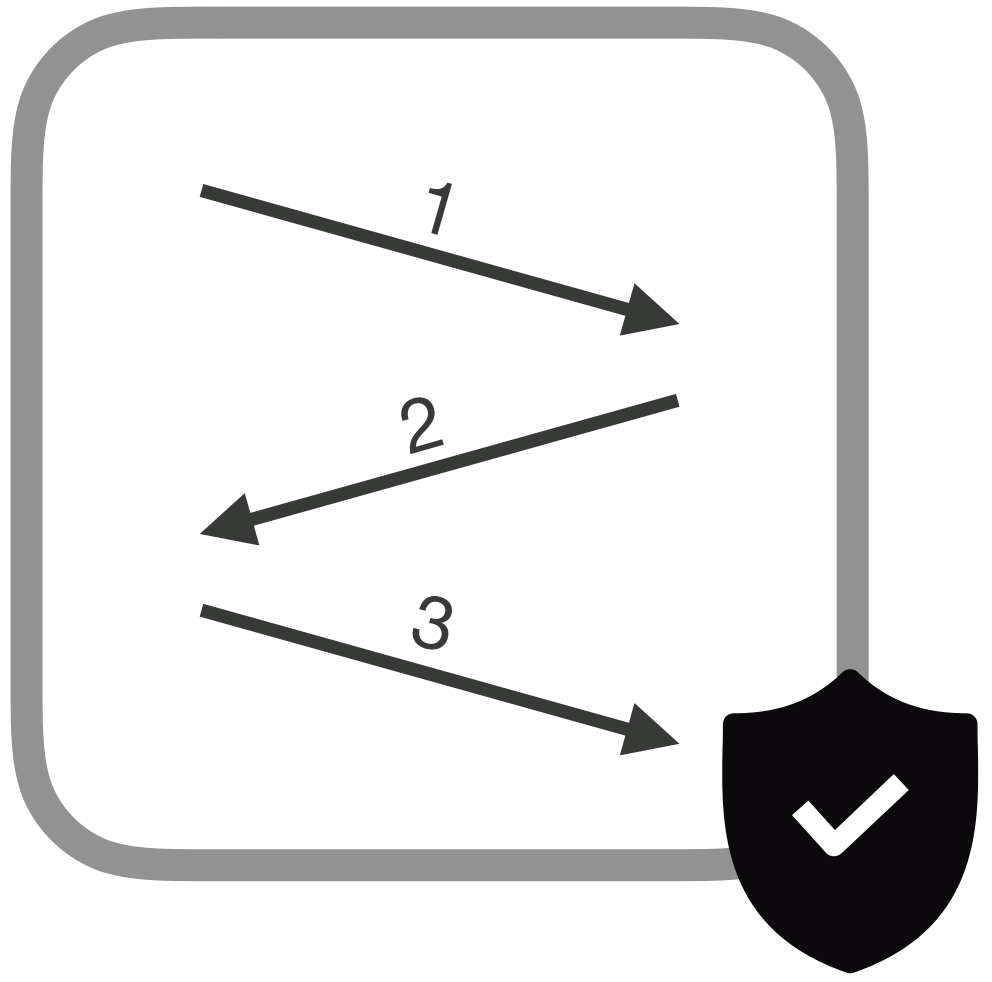
- Enforce the confidentiality of protocol secrets like tokens and credentials to avoid leaks to 3rd parties

Tackling the Challenges in WPSE

WPSE protocol specification:

- Structure and order of messages
- Desired security policies (confidentiality and integrity)

Tackling the Challenges in WPSE



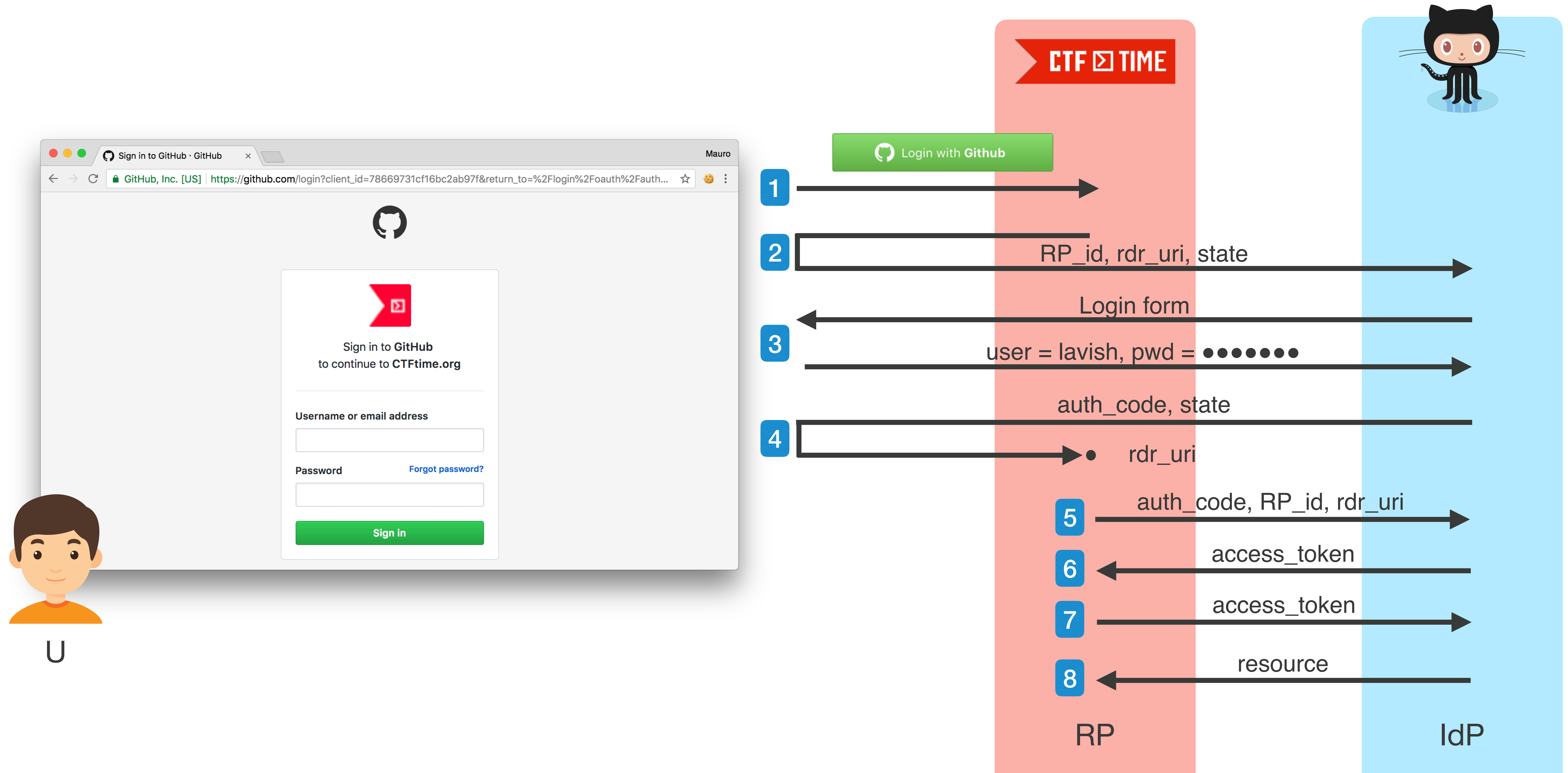
Protocol messages are **blocked** if
- not in the correct order
- integrity constraints on messages are not satisfied

Always **allow** protocol unrelated messages

Secrets in incoming messages are substituted with **random placeholders** before they enter the DOM

Placeholders in outgoing requests are replaced with secrets **only** if sent to origins entitled to learn them

Fortifying OAuth 2.0



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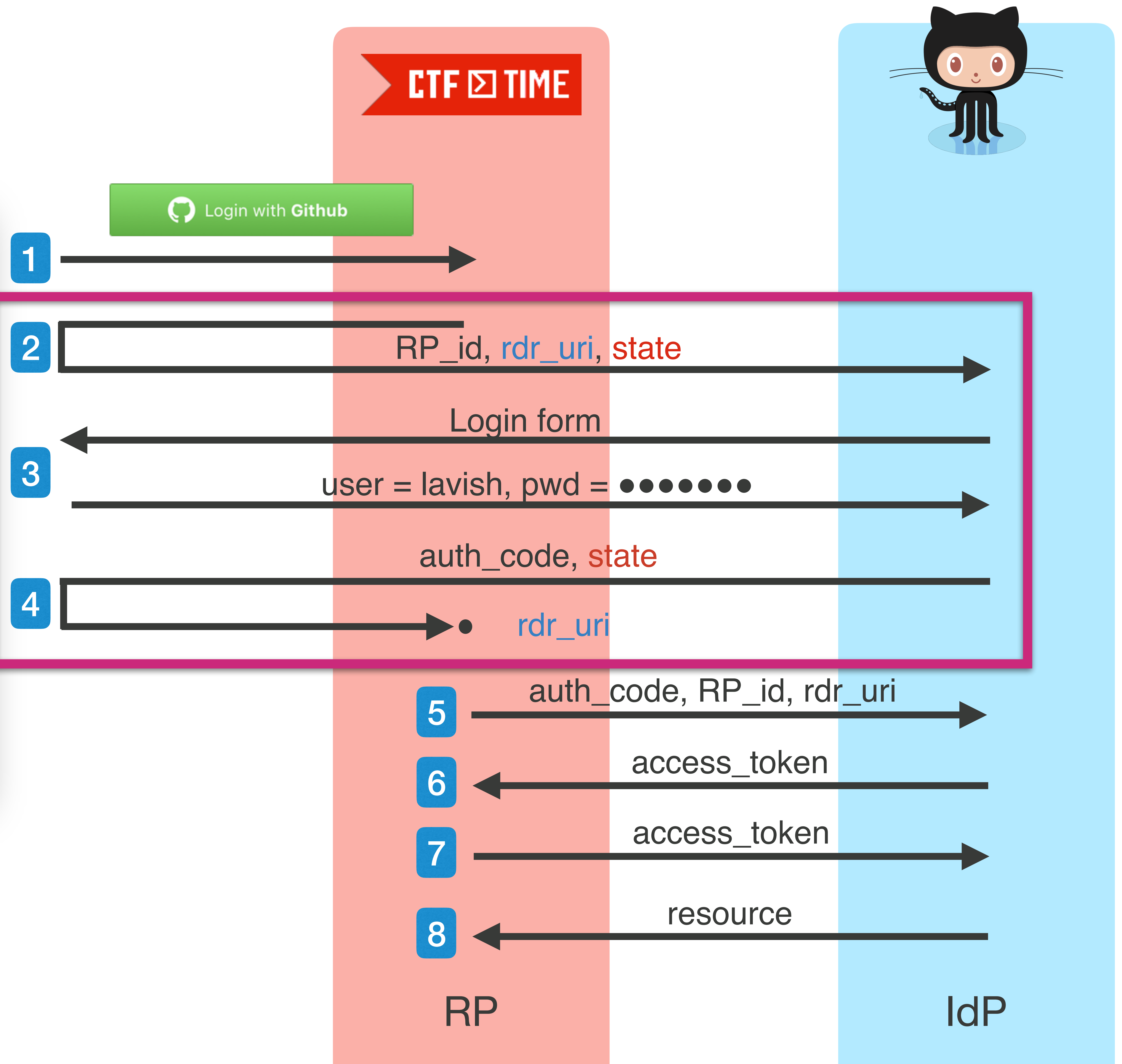

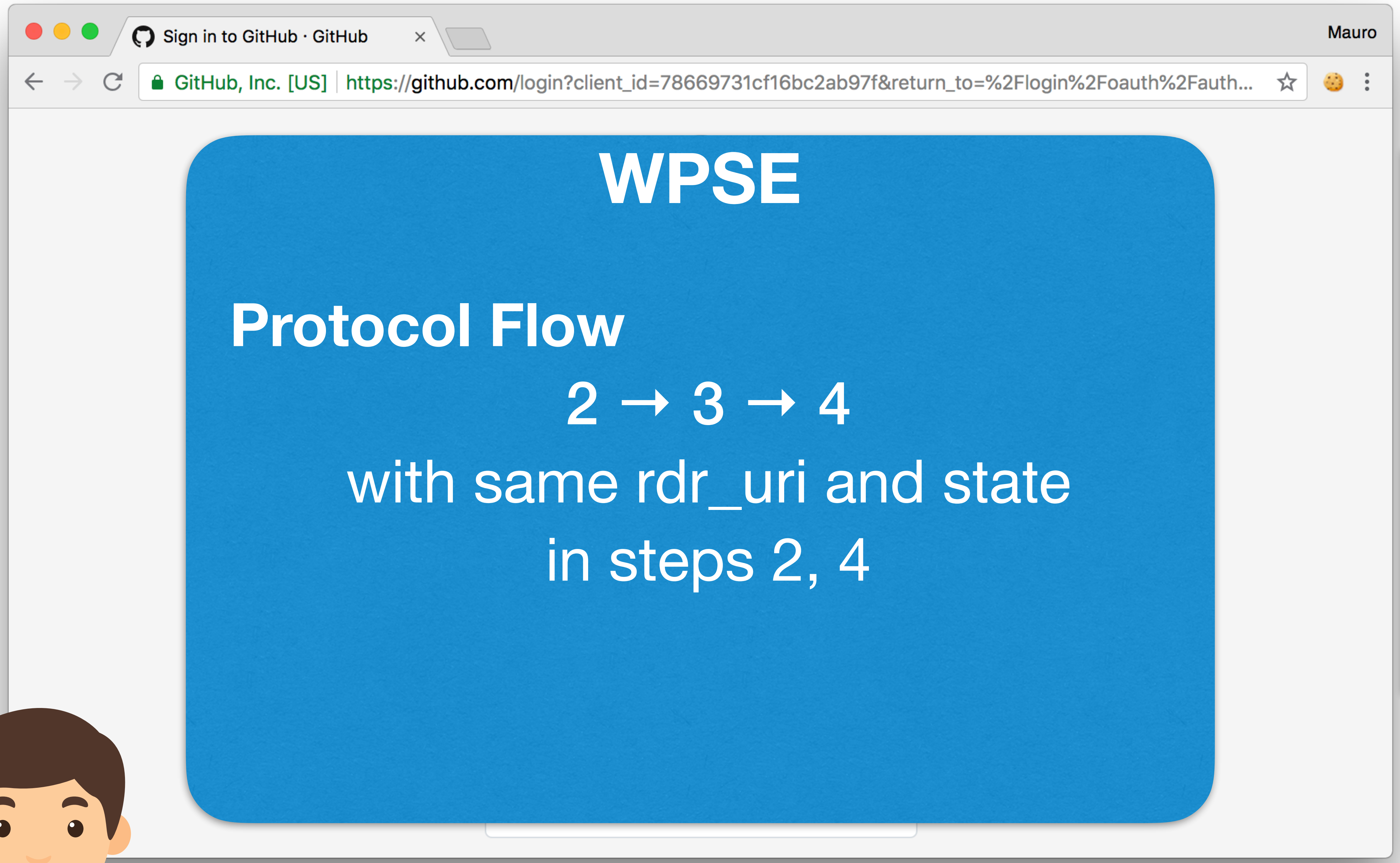
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WPSE

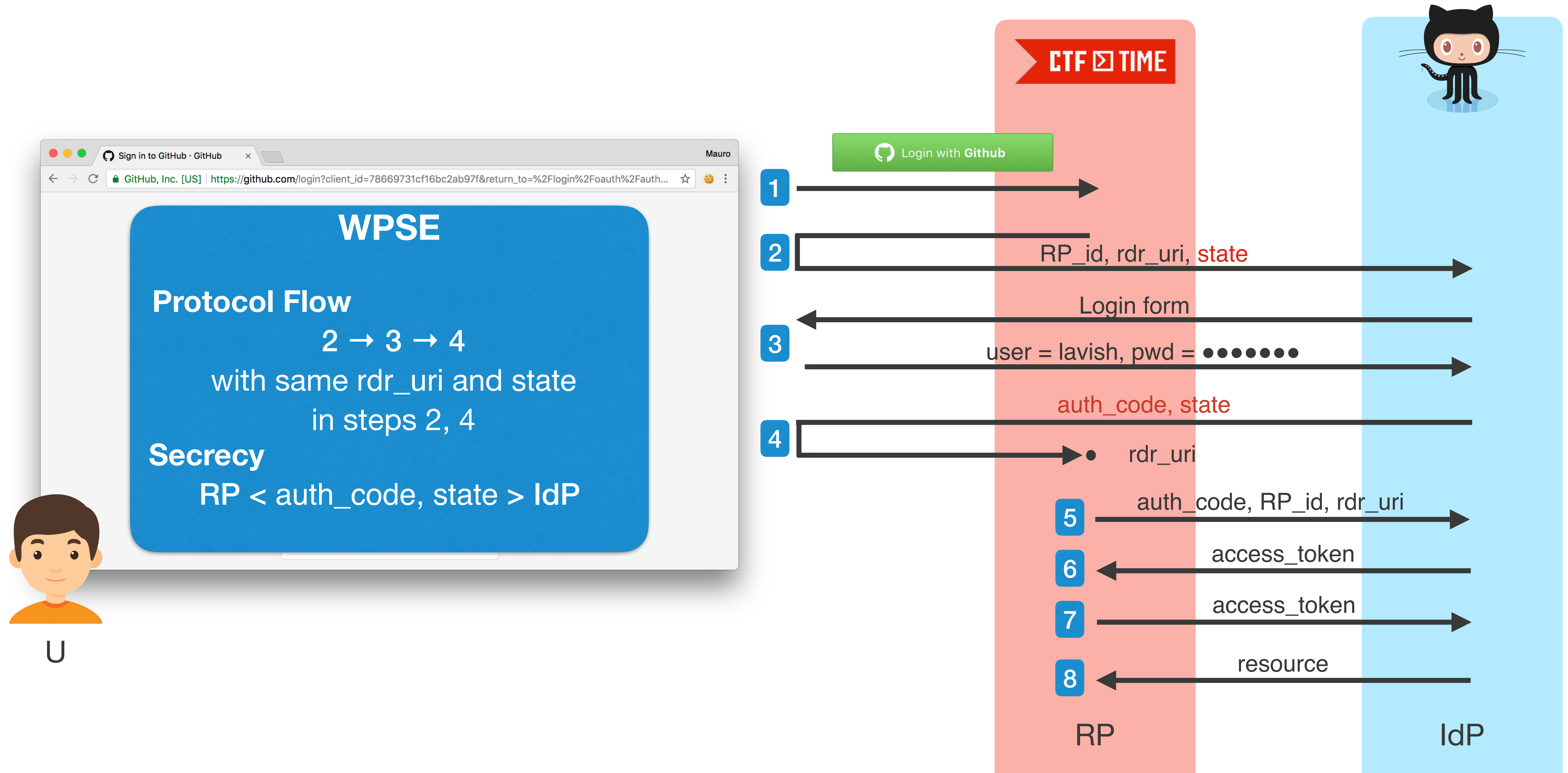
Protocol Flow

2 → 3 → 4

with same rdr_uri and state

in steps 2, 4

Fortifying OAuth 2.0



WPSE

Protocol Flow

2 → 3 → 4

with same rdr_uri and state

in steps 2, 4

Secrecy

RP < auth_code, state > IdP

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CTF TIME
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1
2
RP_id, rdr_uri, state
Login form
3
user = lavish, pwd = ●●●●●●●
auth_code, state
4
rdr_uri
5
auth_code, RP_id, rdr_uri
6
access_token
7
access_token
8
resource
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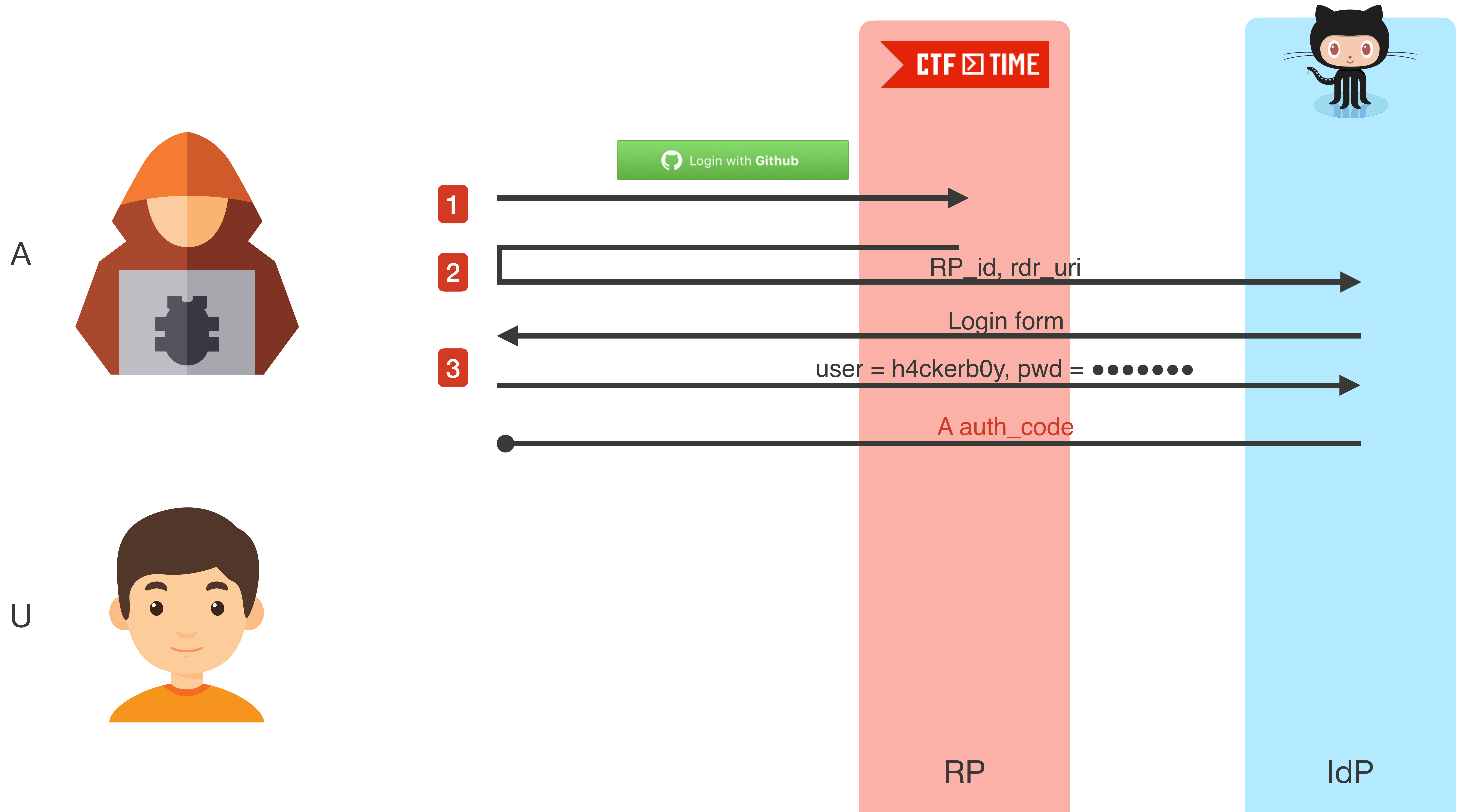
IdP

Session Swapping [SB12]



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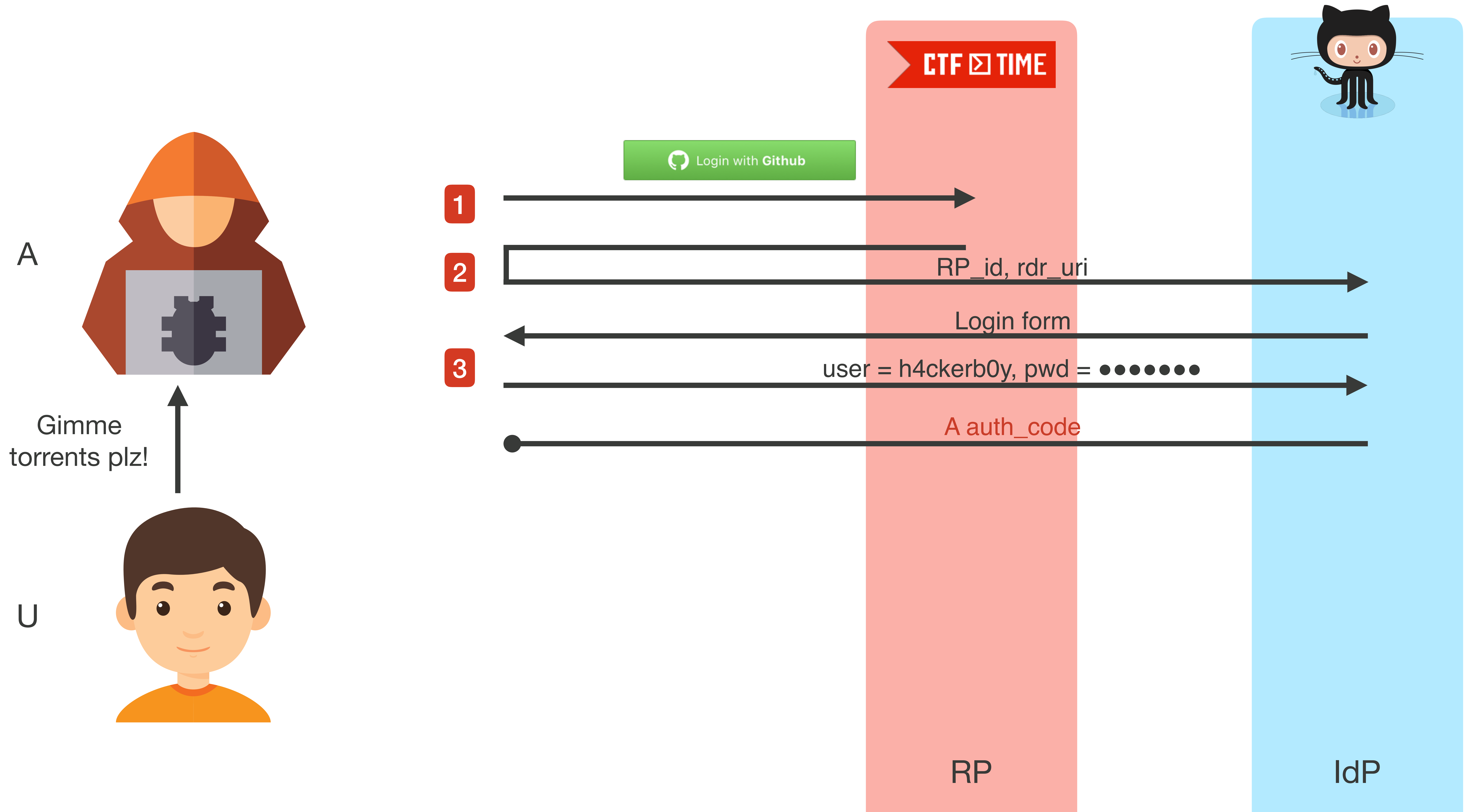

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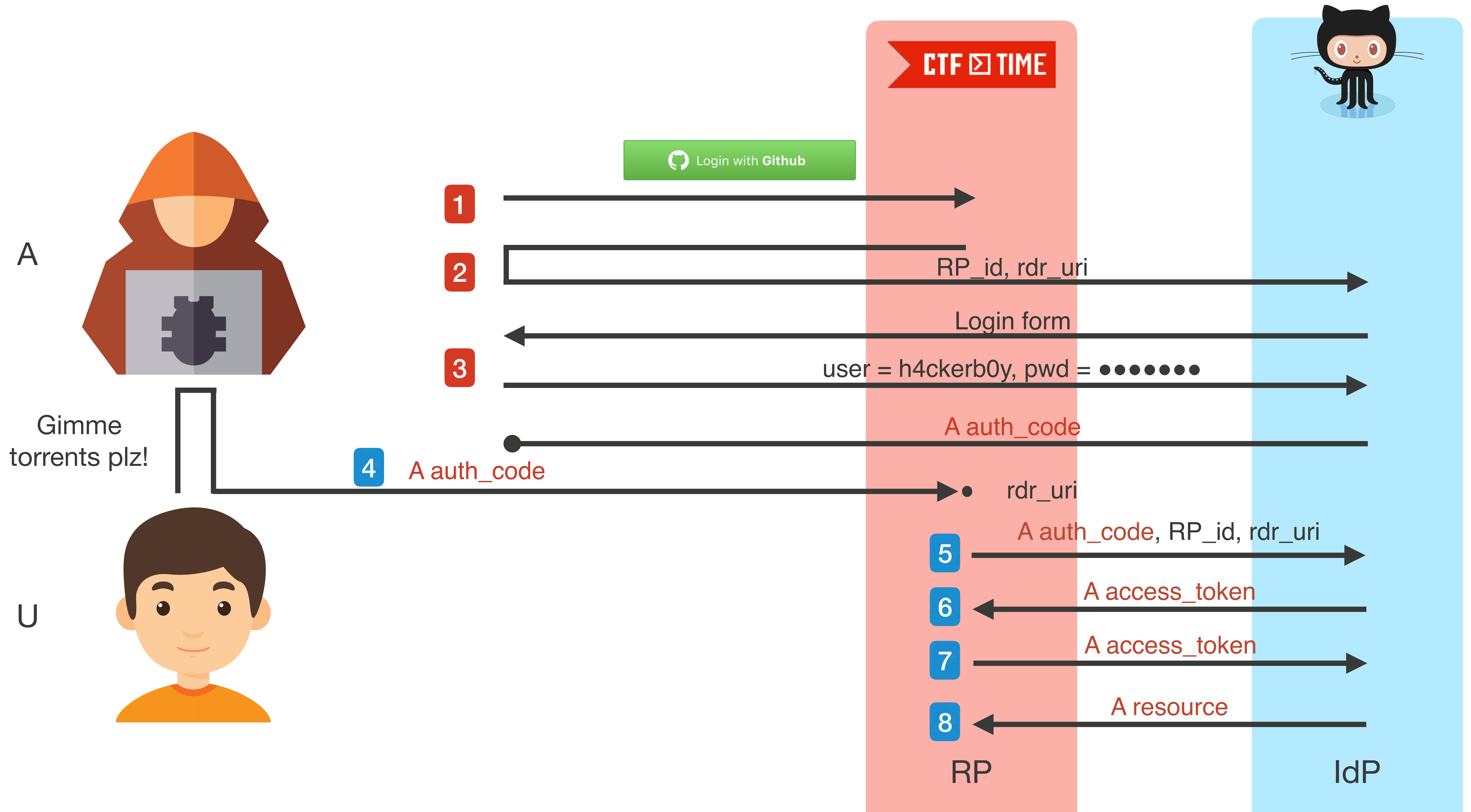

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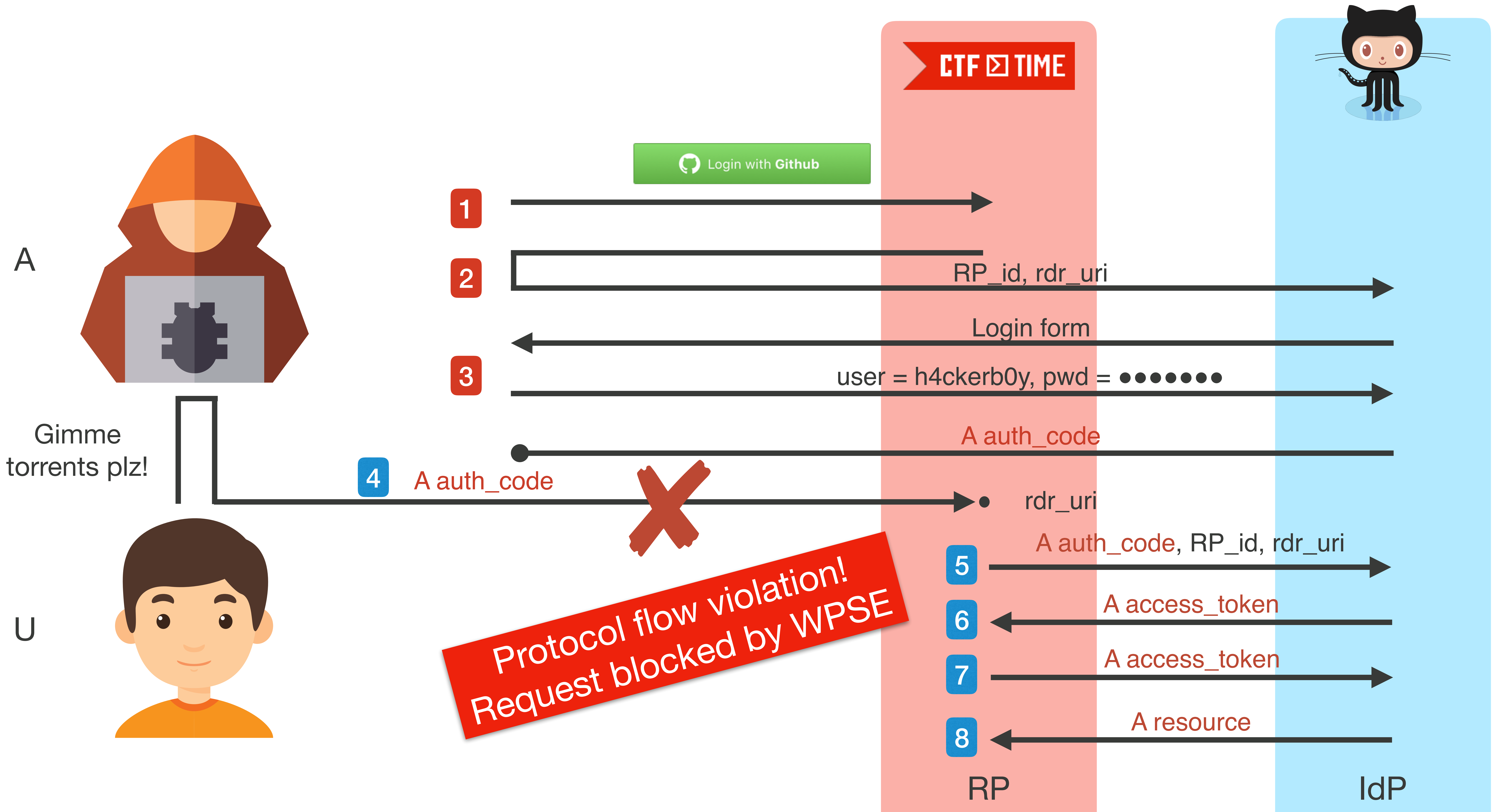
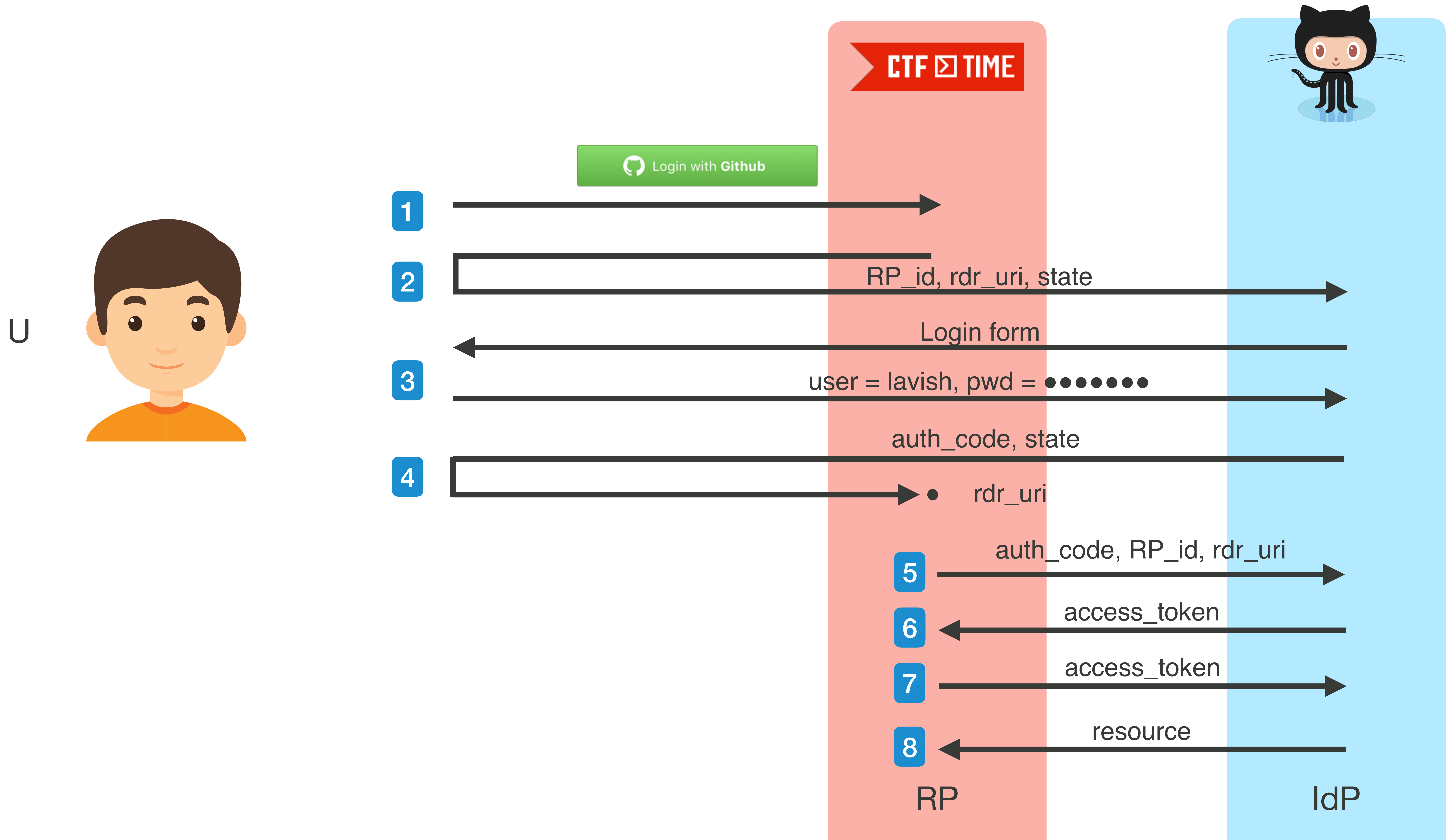


State Leak Attack [FKS16]



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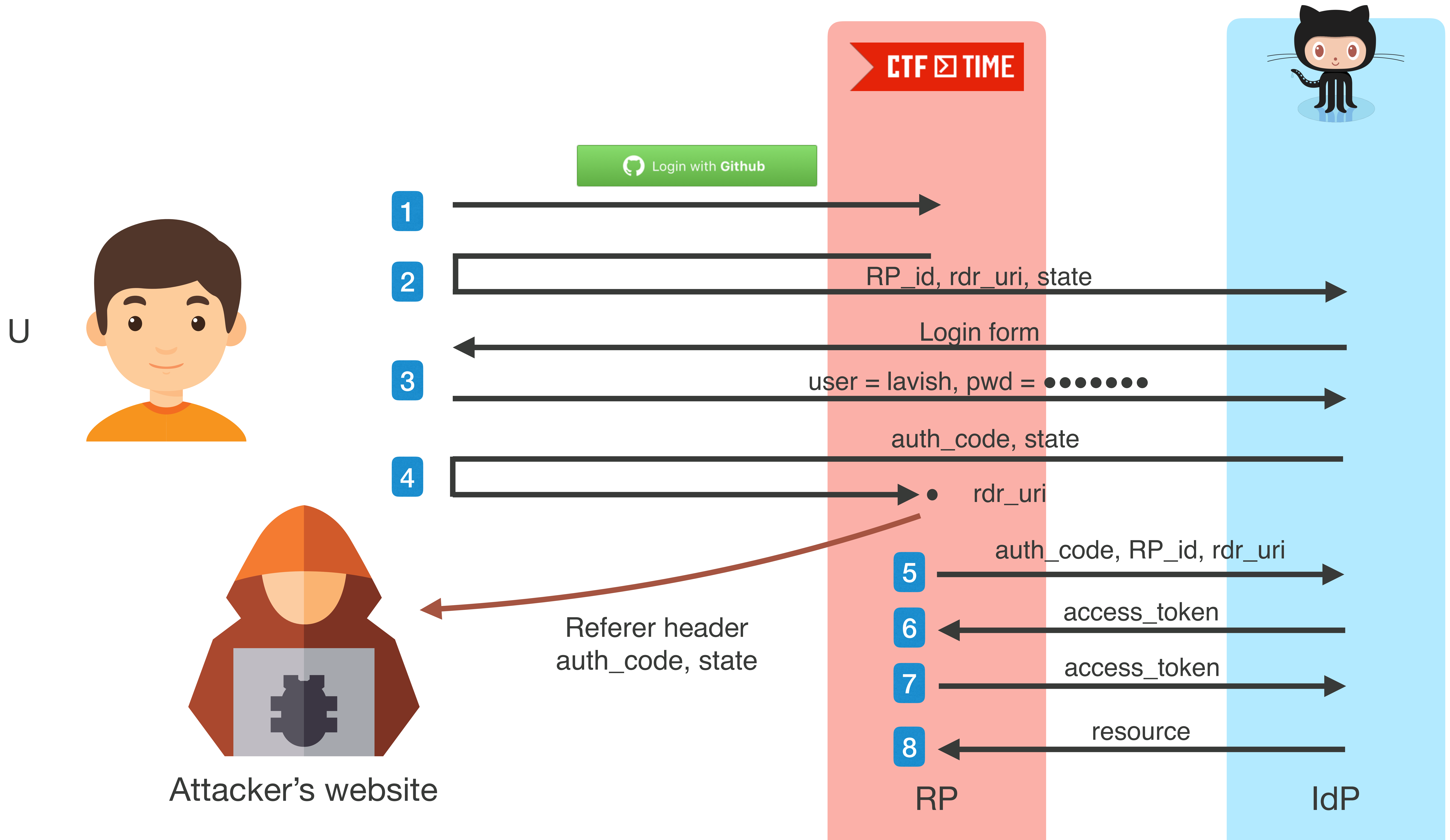

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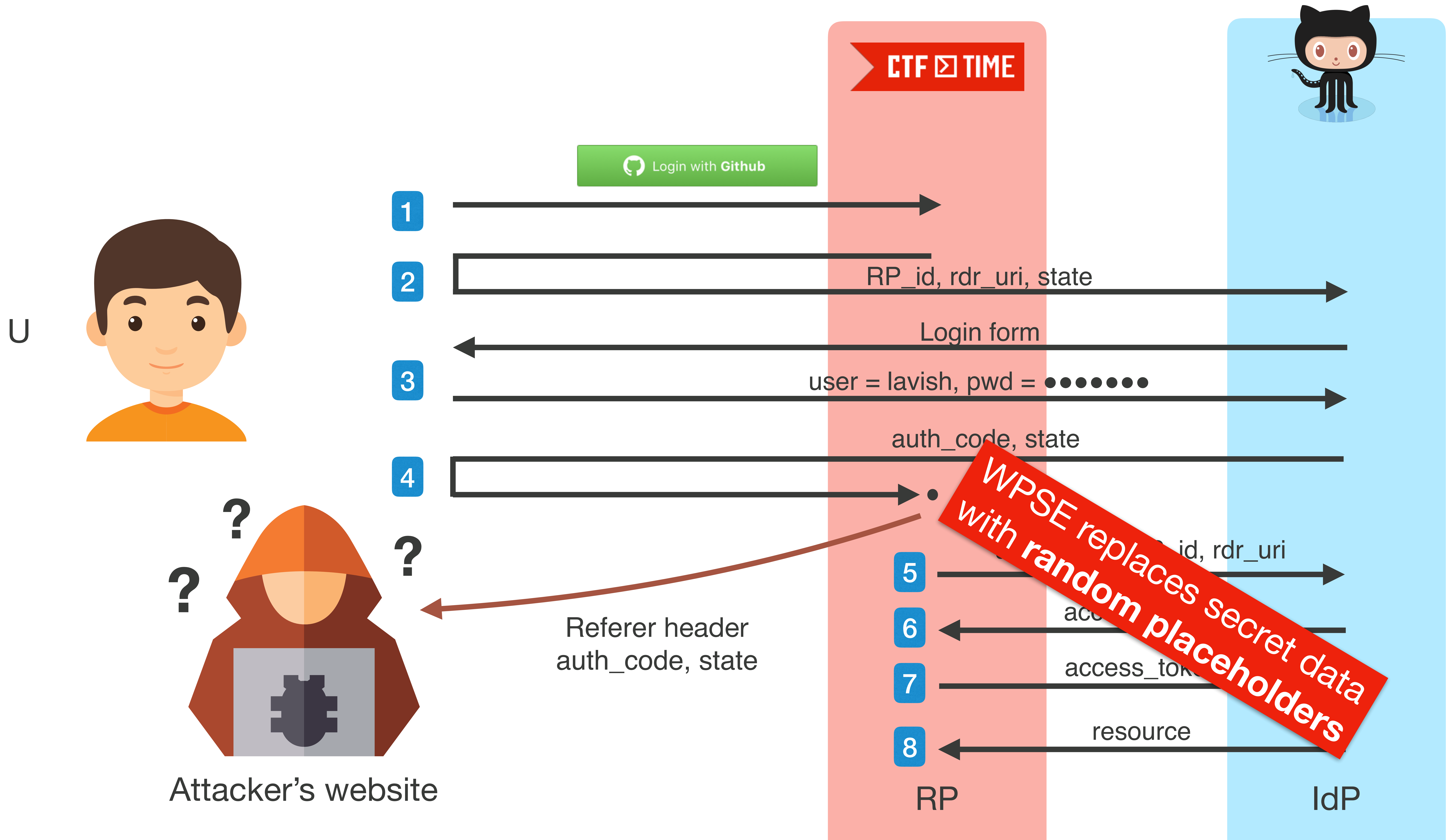


Experimental Evaluation

- Manual investigation of 30 RPs for each IdP from Alexa top 100K
- Analyzed both **authorization code mode** and **implicit mode** of OAuth 2.0

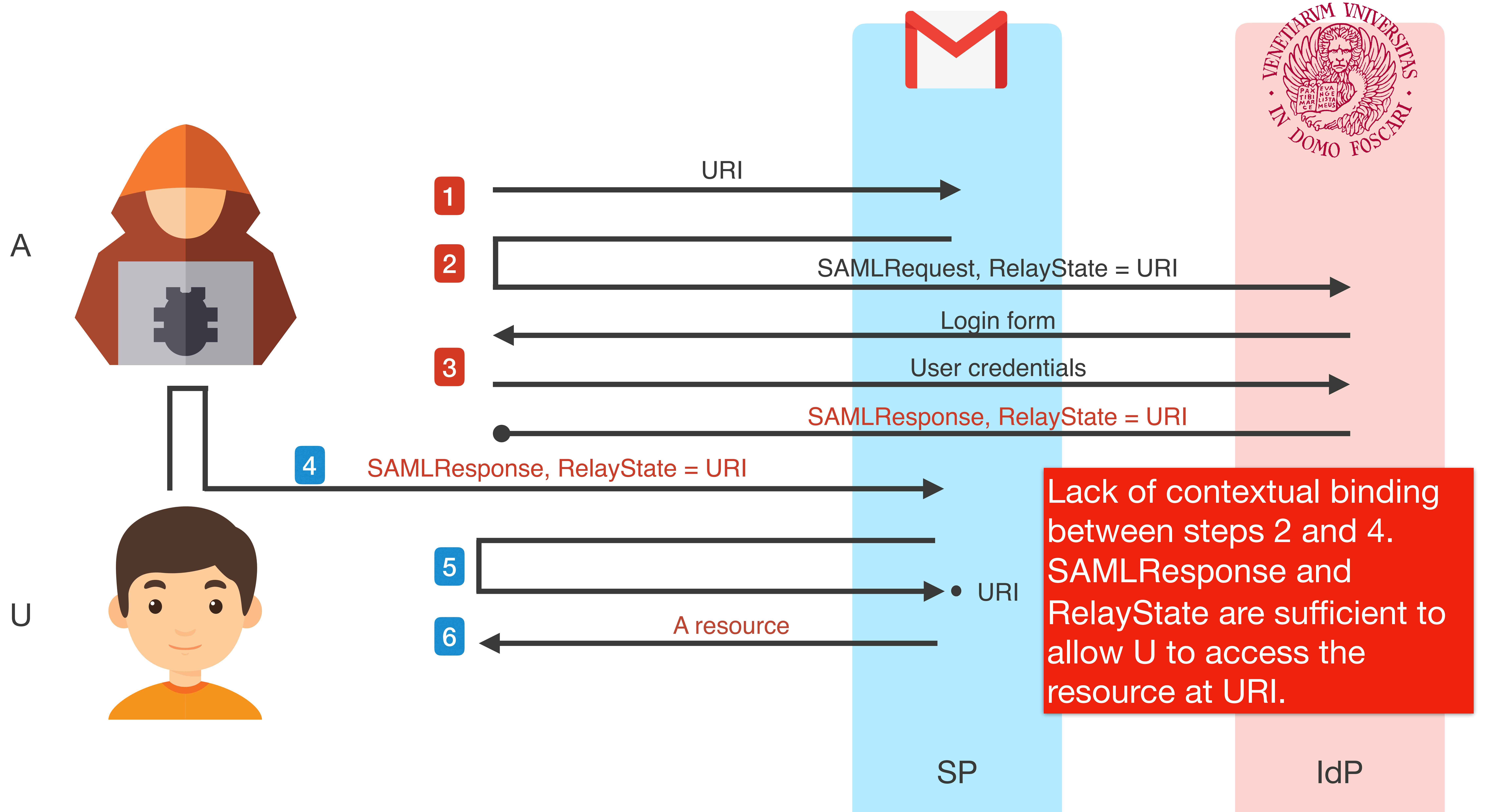
Security

- Leakage of sensitive data due to **tracking/ads libraries** (4 RPs)
- Lack or misuse of the **state parameter** (55 RPs)

Compatibility

Problems due to **security critical deviations** in the **protocol flow** (7 RPs), e.g. auth code is sent twice, second time over HTTP

Attacking Google Implementation of SAML 2.0



A
U
1
URI
2
SAMLRequest, RelayState = URI
Login form
3
User credentials
SAMLResponse, RelayState = URI
4
SAMLResponse, RelayState = URI
5
URI
6
A resource
SP
IdP
VENETIARVM UNIVERSITAS IN DOMO FOSCARI

Lack of contextual binding between steps 2 and 4. SAMLResponse and RelayState are sufficient to allow U to access the resource at URI.

New Attack Against Google SAML 2.0

- Similar to the **session swapping** attack presented before
- **Login CSRF** against Google Suite applications (Drive, Gmail, Keep, …)

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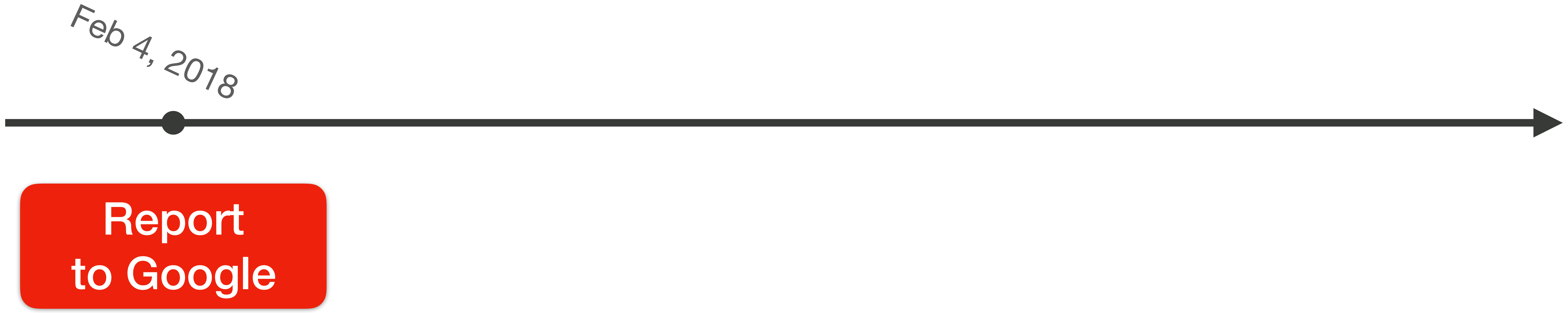

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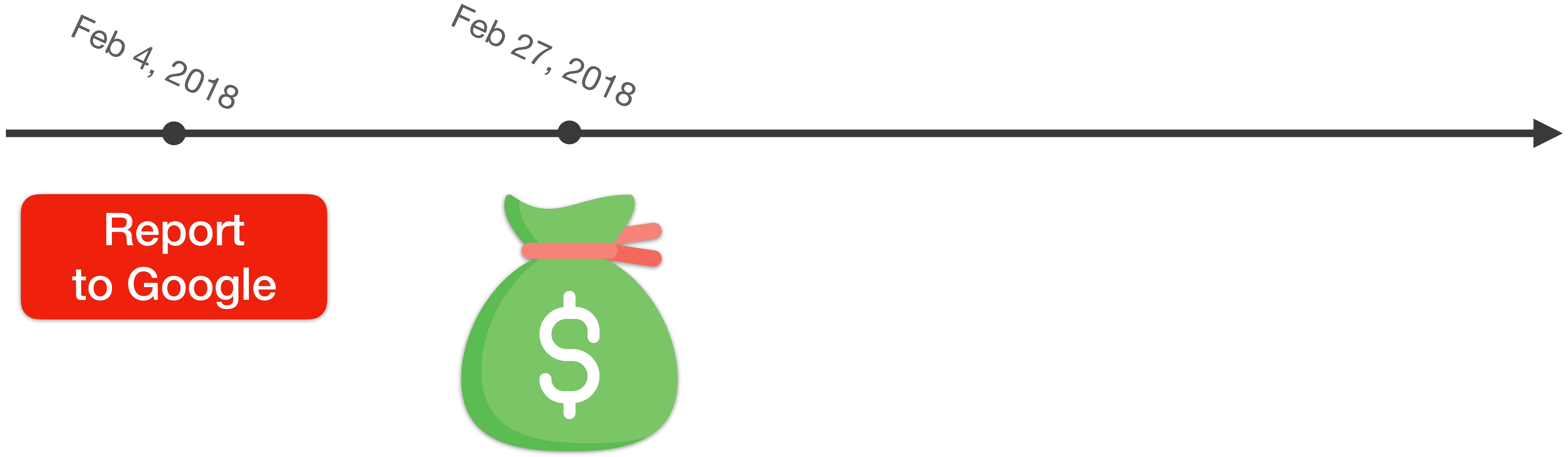

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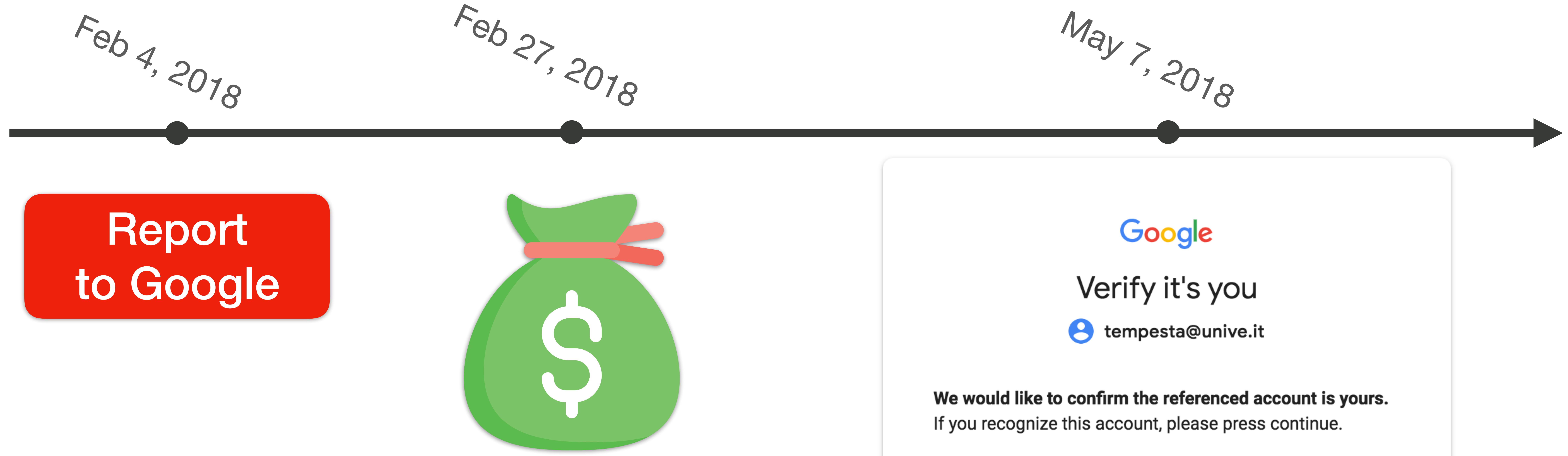

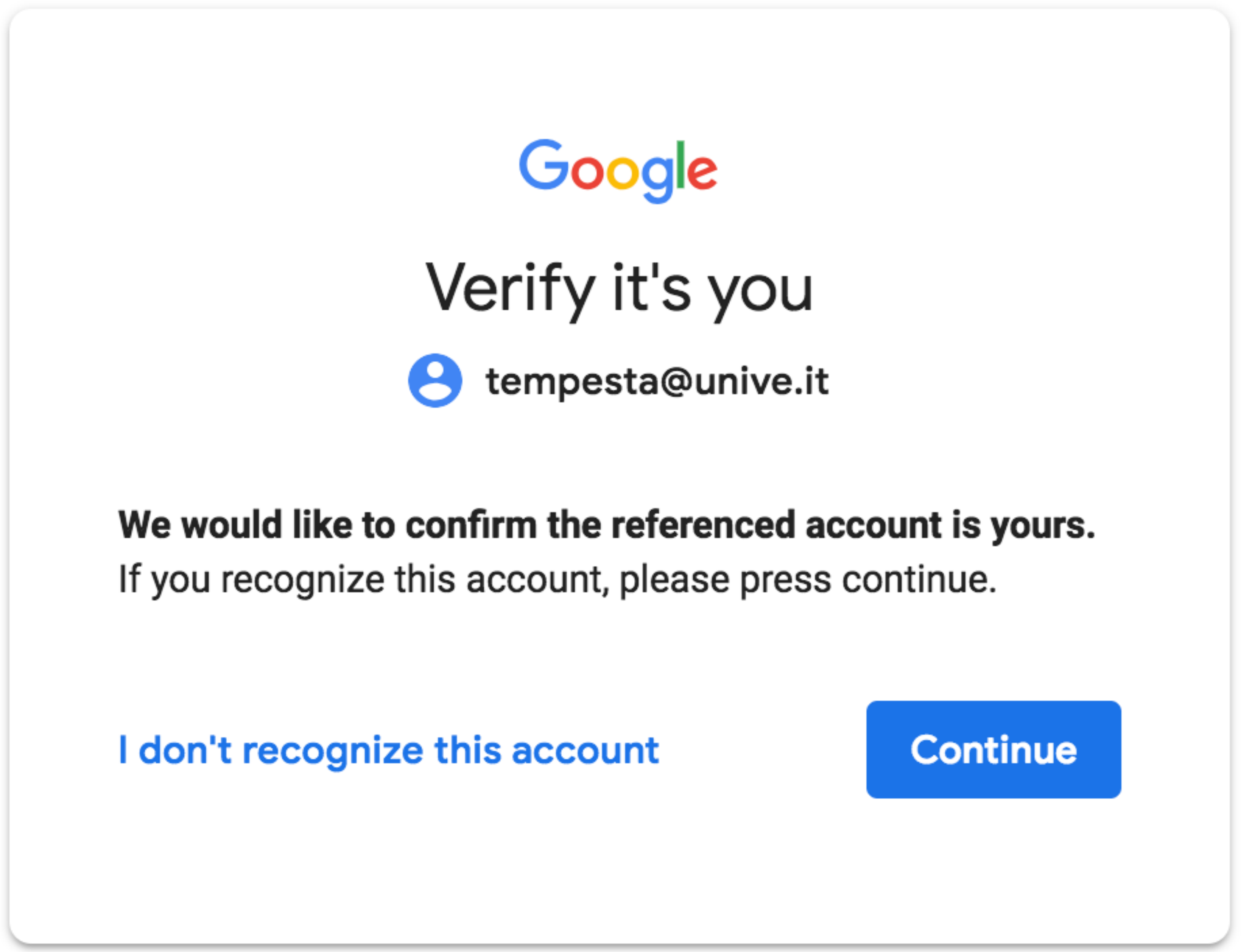
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Verify it's you

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We would like to confirm the referenced account is yours.
If you recognize this account, please press continue.

I don't recognize this account — Continue

New Attack Against Google SAML 2.0

- Similar to the **session swapping** attack presented before
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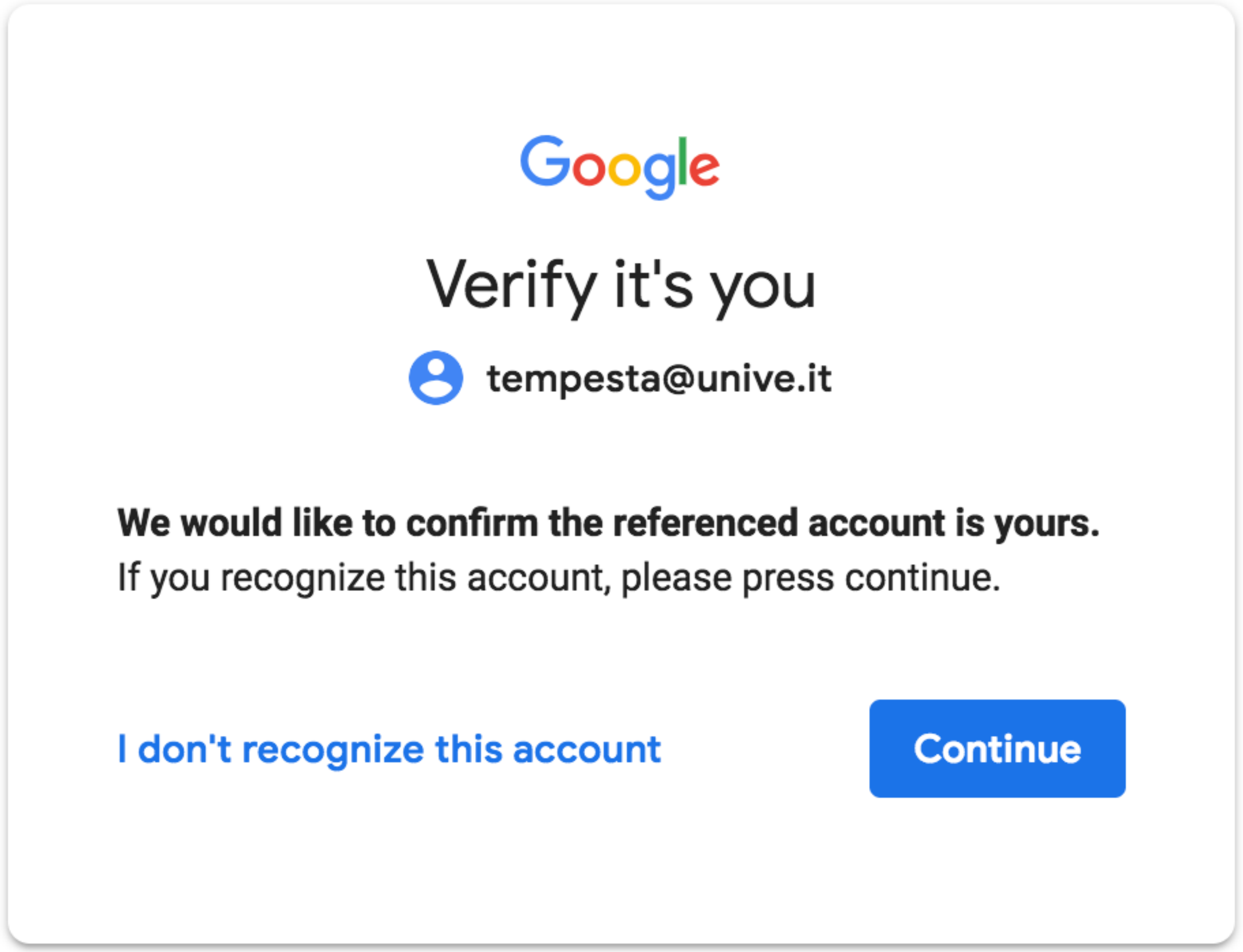
Feb 4, 2018

Feb 27, 2018

May 7, 2018

And now?

Report to Google



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Summing Up

Lightweight policies on the client-side suffice to enforce **provable security** guarantees in web protocols

SUMMING UP

Lightweight policies on the client-side suffice to enforce **provable security** guarantees in web protocols

- Support for additional protocols e.g., **e-payments**
- **Automatic** techniques to **synthesize WPSE policies** from protocol specifications / browser traffic
- Embed WPSE into real **browsers**

Thank You!

Q&A

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