Introduction to Macaroons

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Dr. Neil Madden

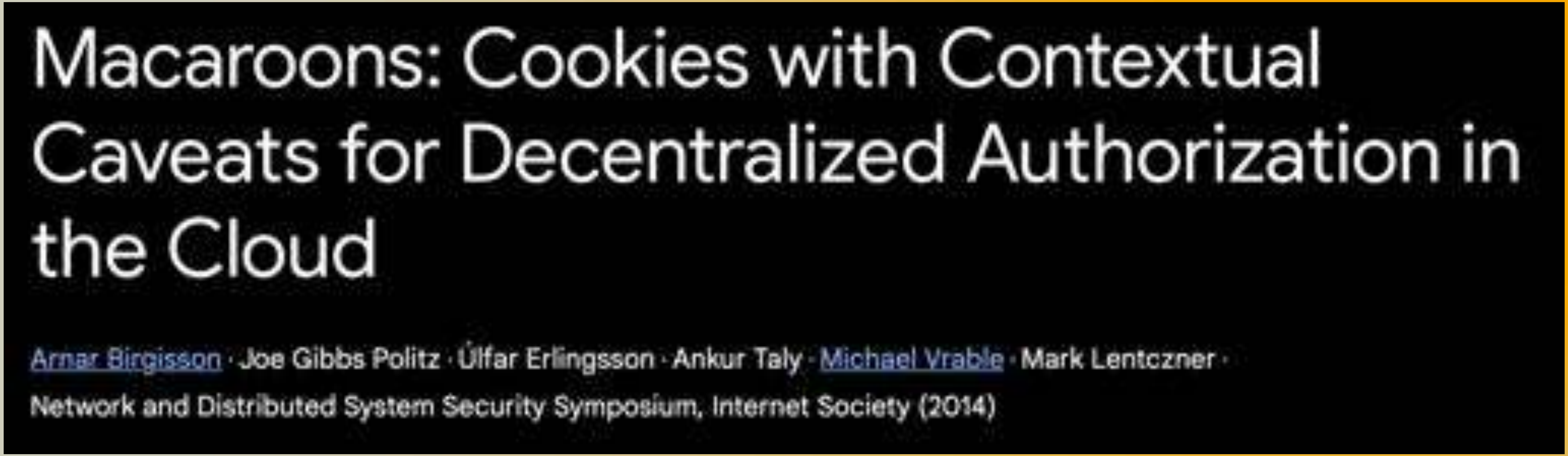
Author *API Security in Action*

Found “Psychic Signatures” vulnerability in Java ECDSA

AppSec and applied crypto specialist

Contributor to OAuth and JOSE working groups

Macaroons



Macaroons: Cookies with Contextual Caveats for Decentralized Authorization in the Cloud

Arnar Birgisson · Joe Gibbs Politz · Úlfar Erlingsson · Ankur Taly · Michael Vrable · Mark Lentczner ·

Network and Distributed System Security Symposium, Internet Society (2014)

Cookies & authentication tokens

Database token storage

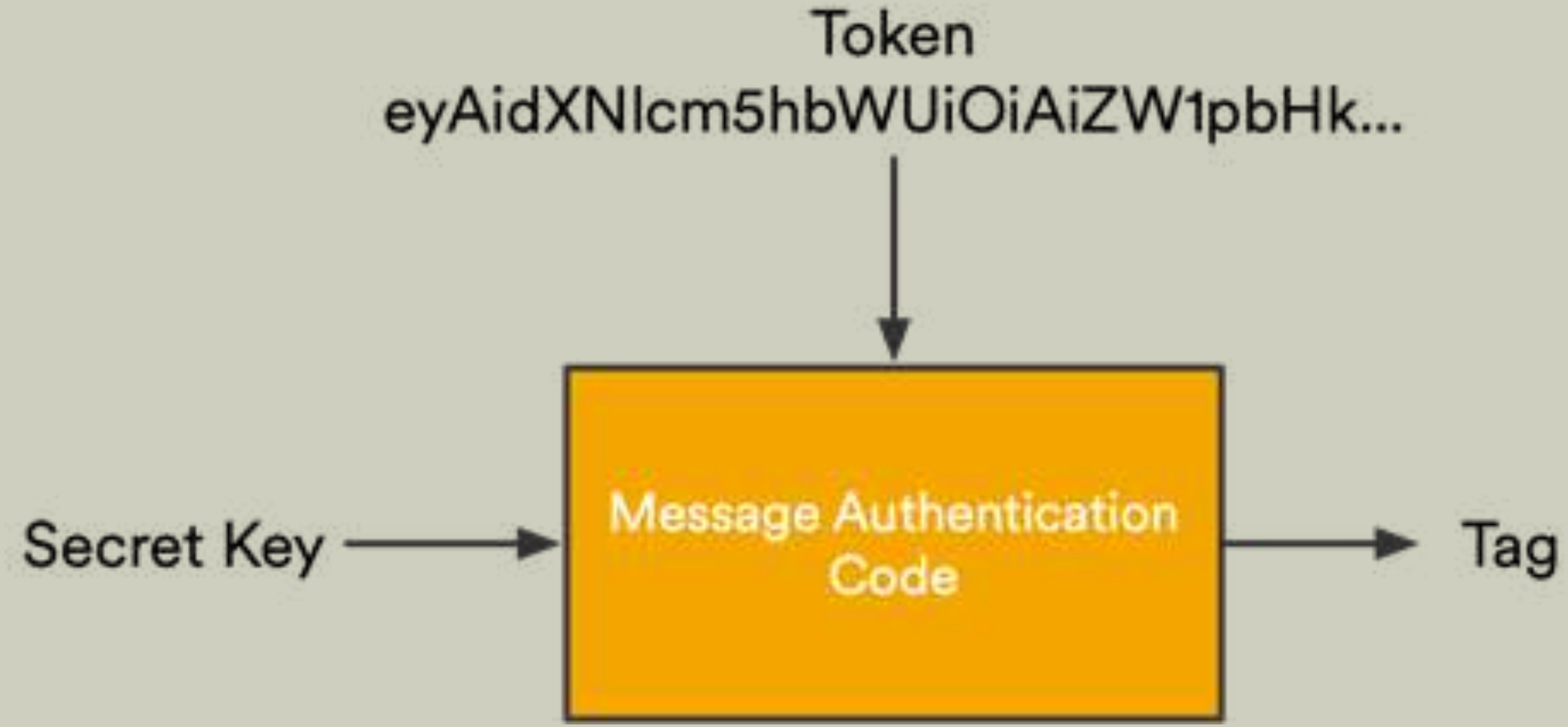
Token	Username	Login Time	Login Method
xyz...	emily.p	1234567	Password
abc...	peter.f	4561234	MFA
...	...	...	...

```
var json = {
    "username": "emily.p",
    "logintime": 1234567,
    "authmethod": "password",
    "fullname": "Emily Peacock",
    ...
}
var cookie = base64url(json);
```

⇓

```
eyAidXNlcm5hbWUiOiAiZW1pbHk...
```

Message Authentication Codes



Token
eyAidXNlcm5hbWUiOiAiZW1pbHk...

Secret Key

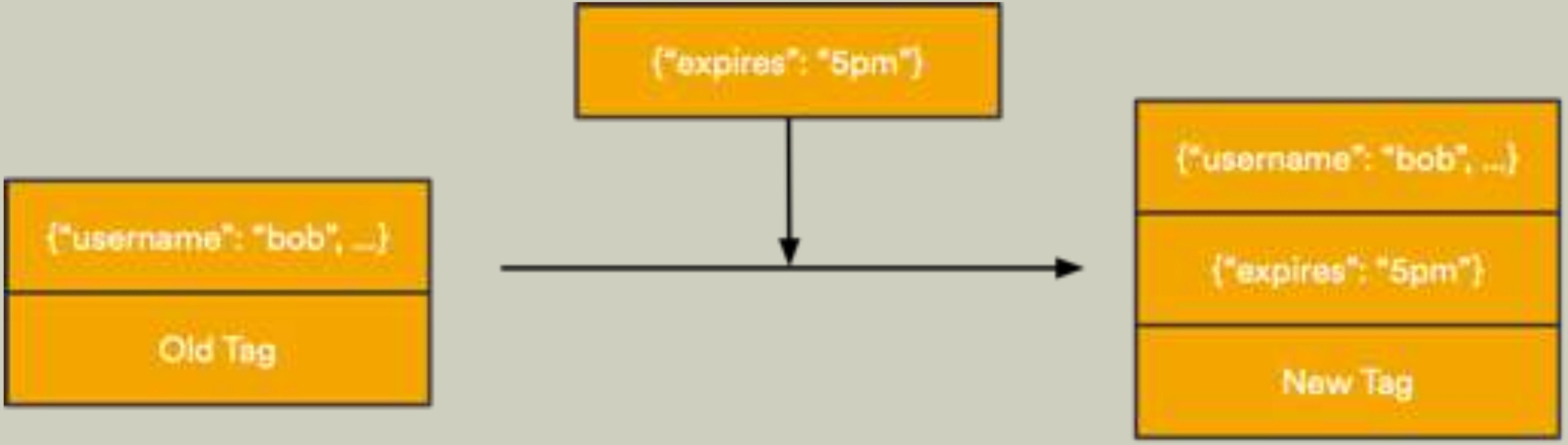
Message Authentication Code

Tag

Macaroons

```
var claims = {
    "username": ...
    ...
}
var encoded = base64url(claims);
var tag = hmac(key, encoded);
var macaroon = encoded + ':' +
base64url(tag);
```

Caveats



{"expires": "5pm"}

{"username": "bob", ...}

Old Tag

{"username": "bob", ...}

{"expires": "5pm"}

New Tag

Caveats should only ever *restrict*

Bearer tokens

and API clients

Proof of Possession

Cryptography to the rescue?

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> “Cryptography is a tool for turning lots of different problems into key management problems.”
>
> — Lea Kissner

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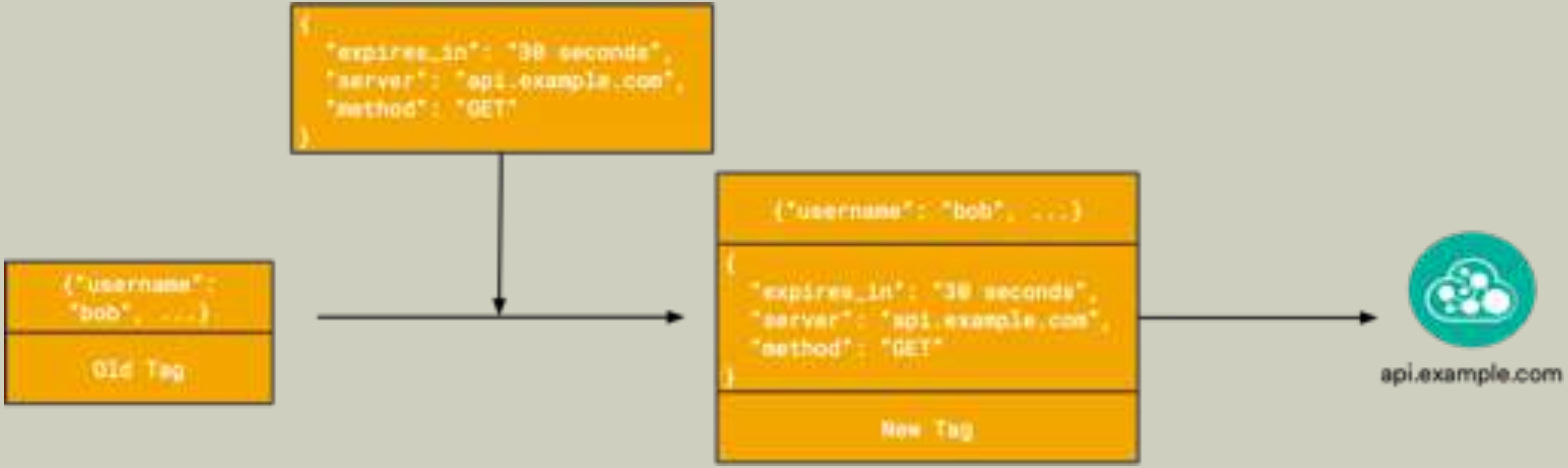
Contextual caveats

Least privilege with less effort

Contextual caveats



```
{
  "expires_in": "30 seconds",
  "server": "api.example.com",
  "method": "GET"
}
```

```
{"username":
"bob", ...}
```

Old Tag

```
{"username": "bob", ...}
```

```
{
  "expires_in": "30 seconds",
  "server": "api.example.com",
  "method": "GET"
}
```

New Tag

Contextual caveats are added to a copy of the token, but the client still retains access to the original, unrestricted, macaroon.

How caveats work

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Pseudorandom Functions

$$\mathrm{PRF} : K \times M \to T$$

where $K = \{0,1\}^k, M = \{0,1\}^*, T = \{0,1\}^t$.

If you don't know the key, k, then $\mathrm{PRF}(k,\cdot)$ looks indistinguishable from a random function $f : M \to T$.

Macaroon PRF

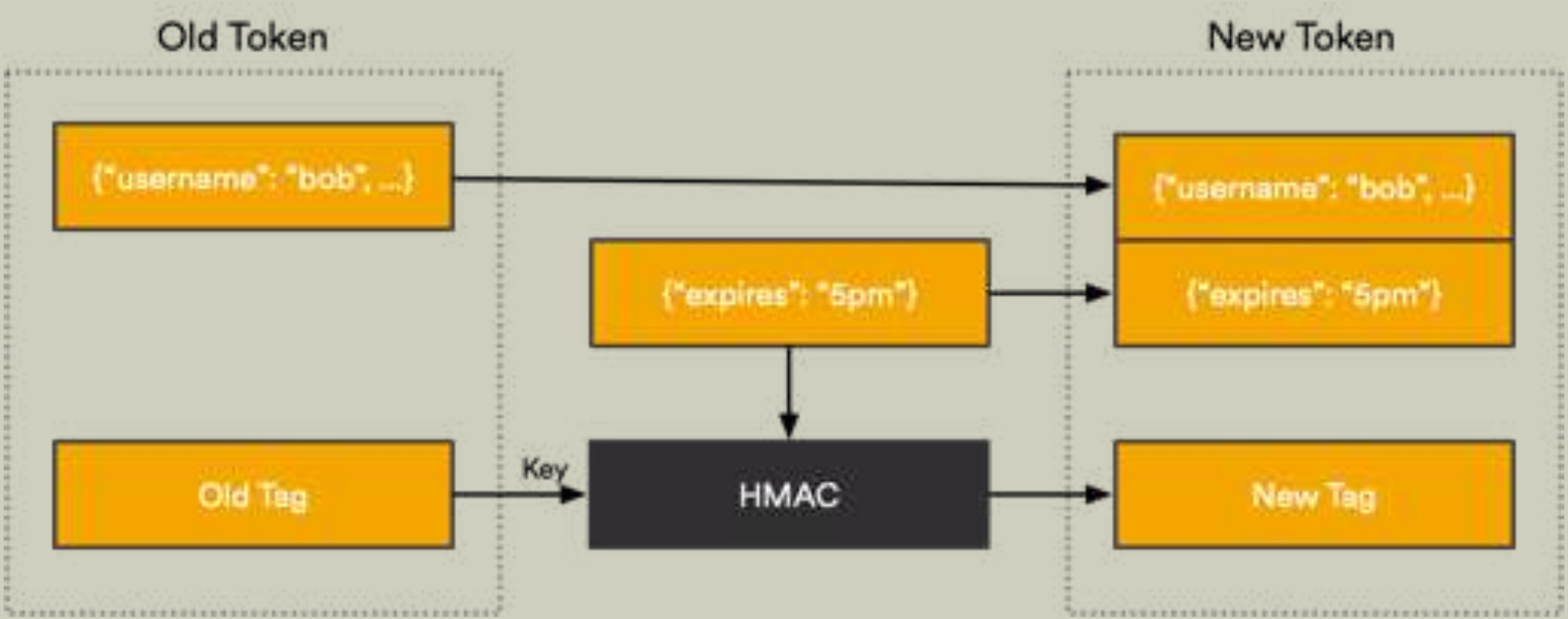
For HMAC:

$$T = K$$

$$\mathrm{HMAC} : K \times M \rightarrow K$$

Use old tag as the key to compute a new tag.

Appending a caveat



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Just-in-time contextual caveats

```
function restrict(macaroon, newCaveat) {
  var old = decode(macaroon);
  var newTag = hmac(old.tag, newCaveat);
  return encode(old.claims,
    old.caveats + newCaveat, newTag);
}
```

```
fetch('https://api.example', {
    headers: {
      'Authorization': 'Bearer ' +
        restrict(macaroon, {exp: now()+30})
    }
});
```

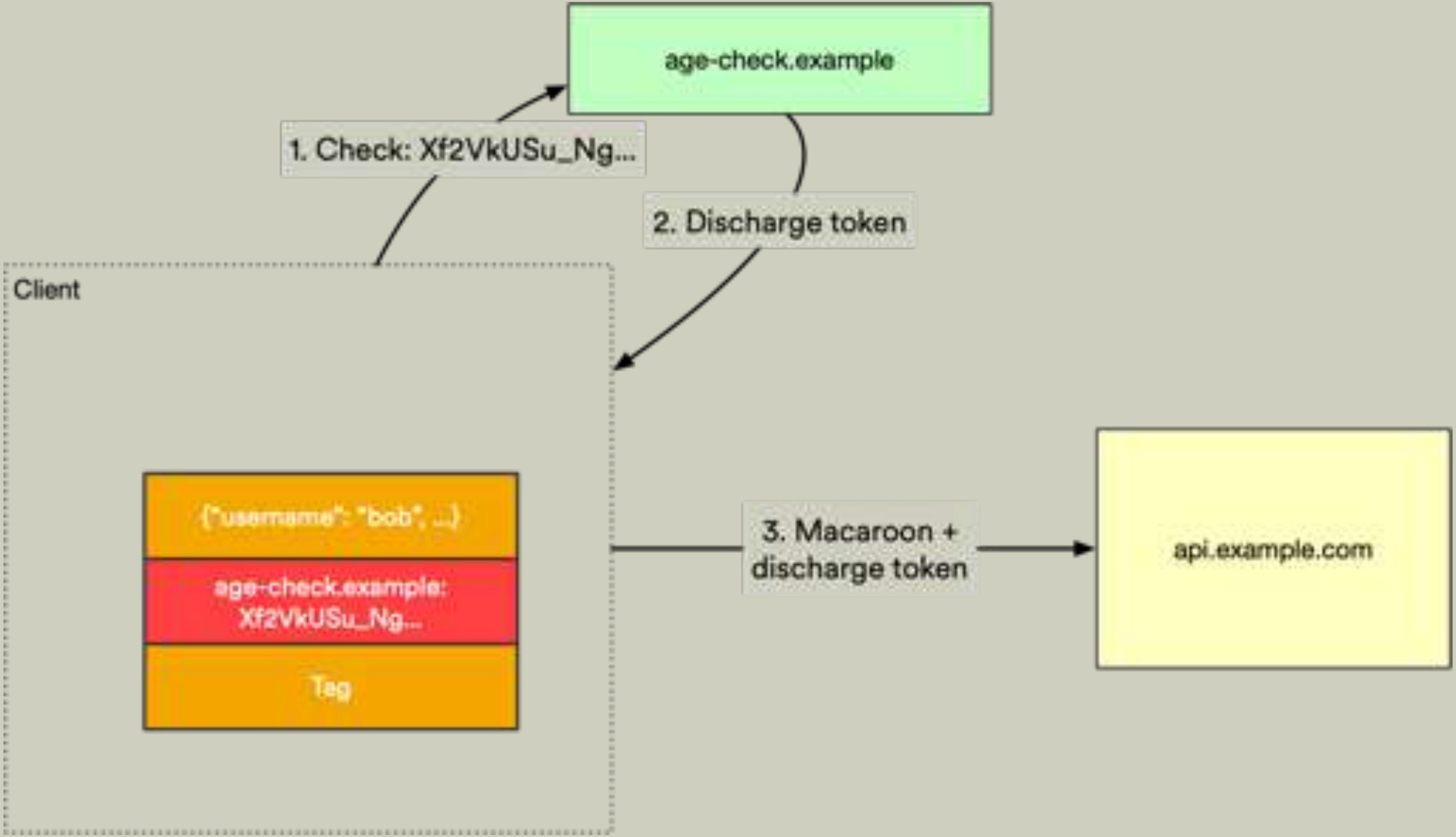
Verifying a Macaroon

```
var { claims, caveats, providedTag } =
    decode(macaroon);

var computedTag = hmac(key, claims);
for (var caveat in caveats) {
    computedTag = hmac(computedTag, caveat);
}

var sigOk = macEquals(providedTag,
computedTag);
return sigOk && checkAll(caveats, request);
```

3rd-party caveats



age-check.example

1. Check: Xf2VkUSu_Ng...

2. Discharge token

Client

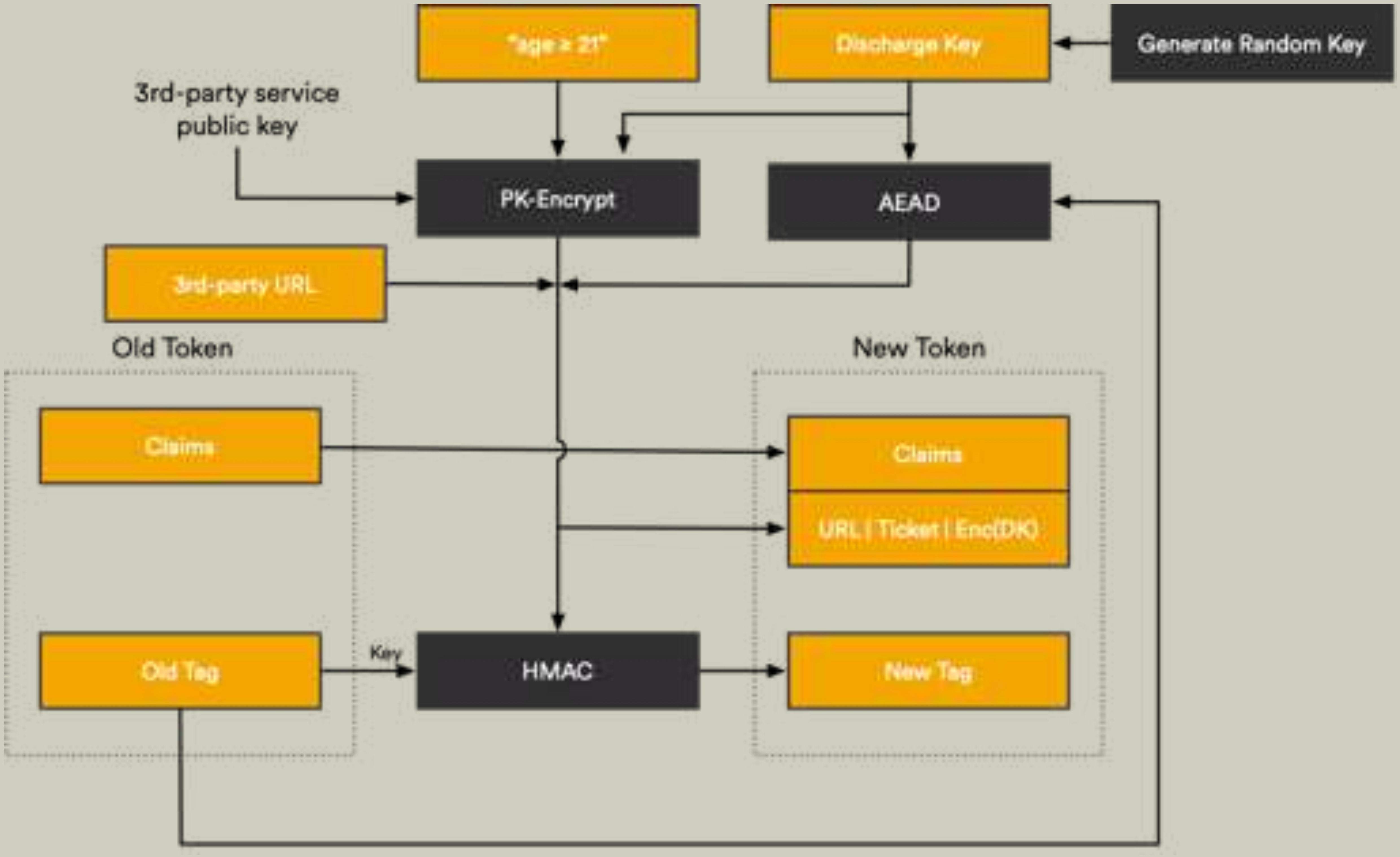
{"username": "bob", ...}

age-check.example: Xf2VkUSu_Ng...

Tag

3. Macaroon + discharge token

api.example.com


"age ≥ 21"
Discharge Key
Generate Random Key
3rd-party service public key
PK-Encrypt
AEAD
3rd-party URL
Old Token
New Token
Claims
Claims
URL | Ticket | Enc(DK)
Old Tag
Key
HMAC
New Tag

What can you do with 3rd-party caveats?

- Require login via SSO
- Add revocation checks
- Implement anti-CSRF tokens
- Authorize payments & other transactions

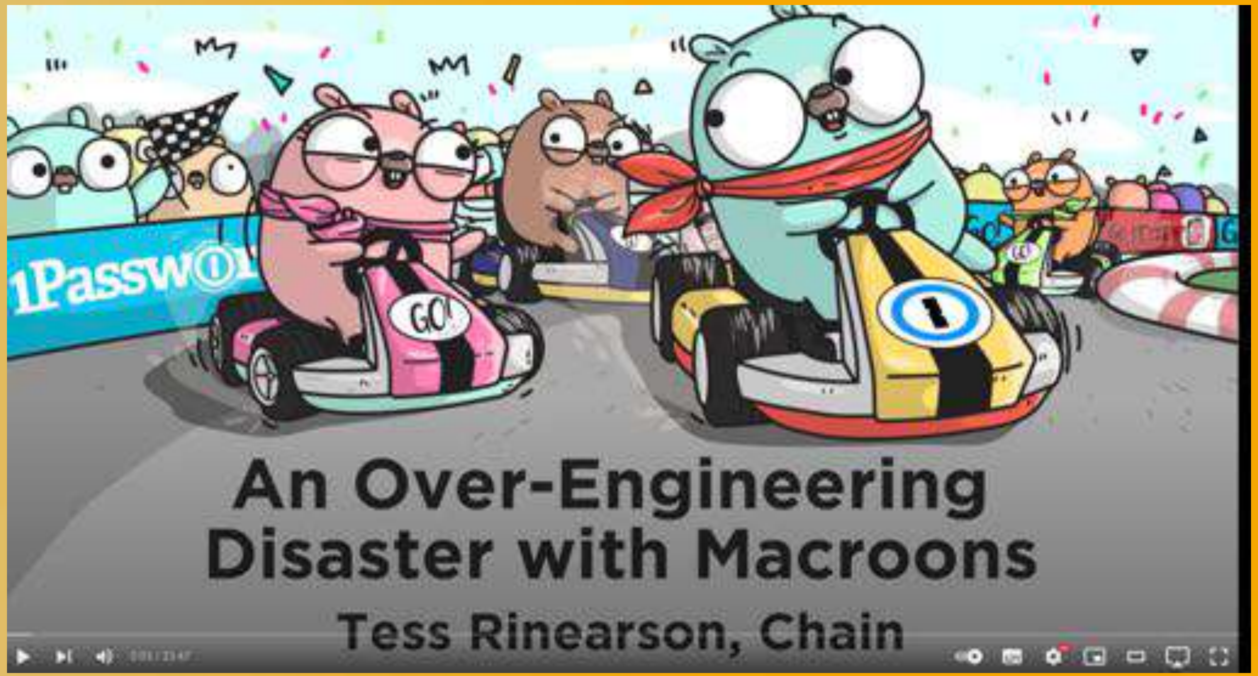
A word of caution

Easy to over-use 3rd-party caveats

Can make the system fragile

Case study: Tess Rinearson, Chain, GopherCon 2018[1]

Self-DoS via 3rd-party caveat that was discharged by an underpowered Rails app



[1] https://www.youtube.com/watch?v=MZFv62qz8RU

Deployment topics

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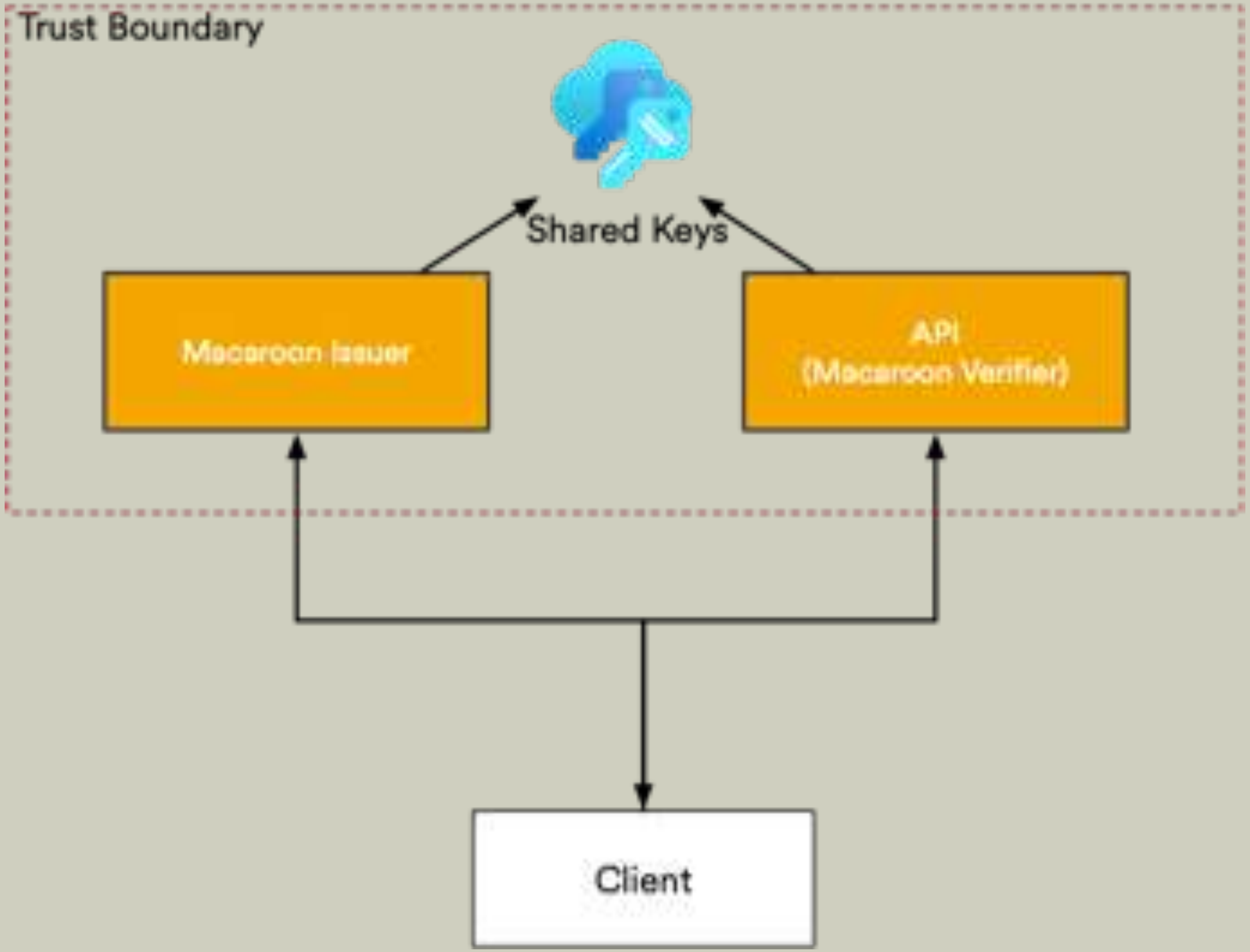
Trust model



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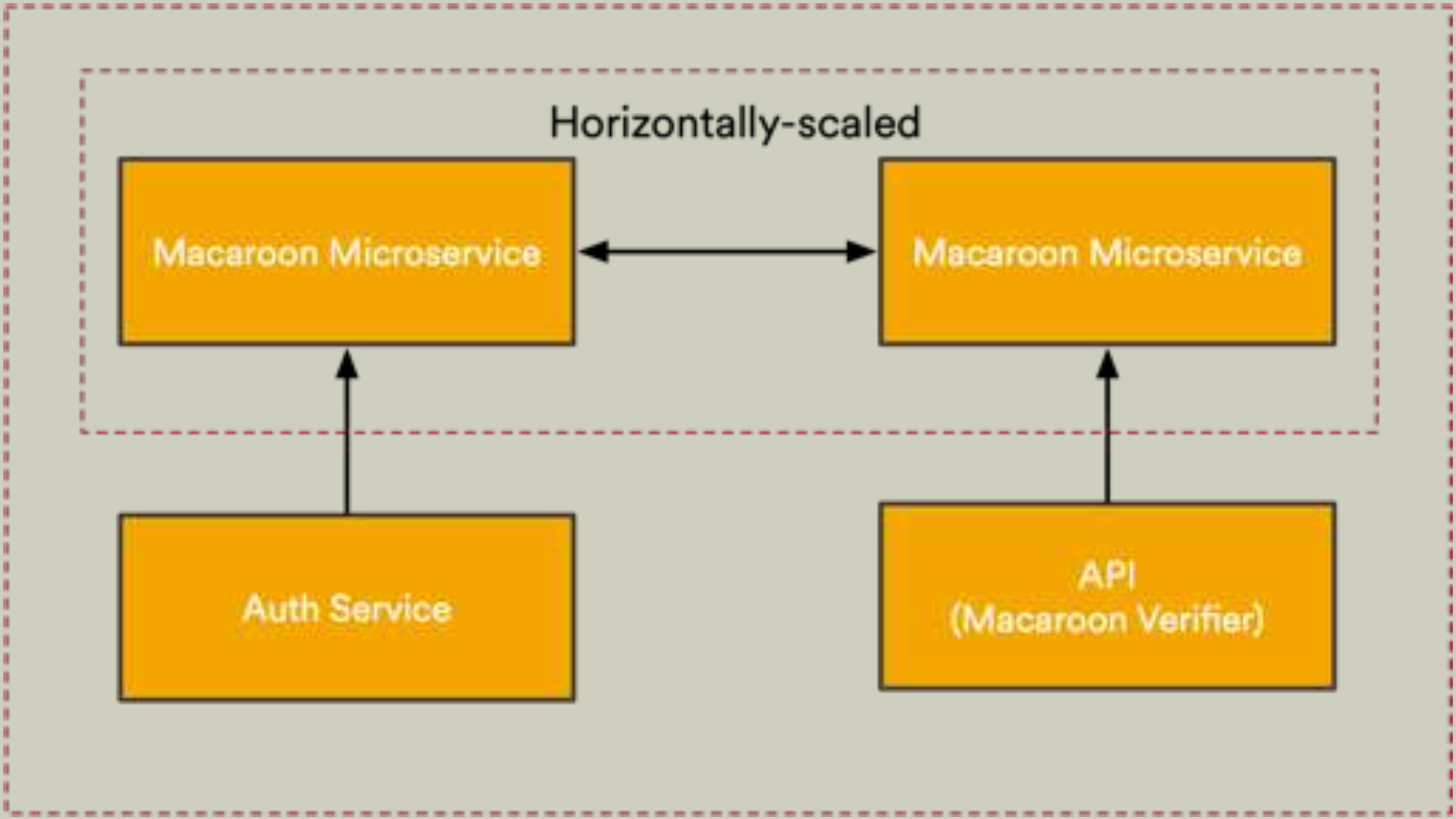


Horizontally-scaled

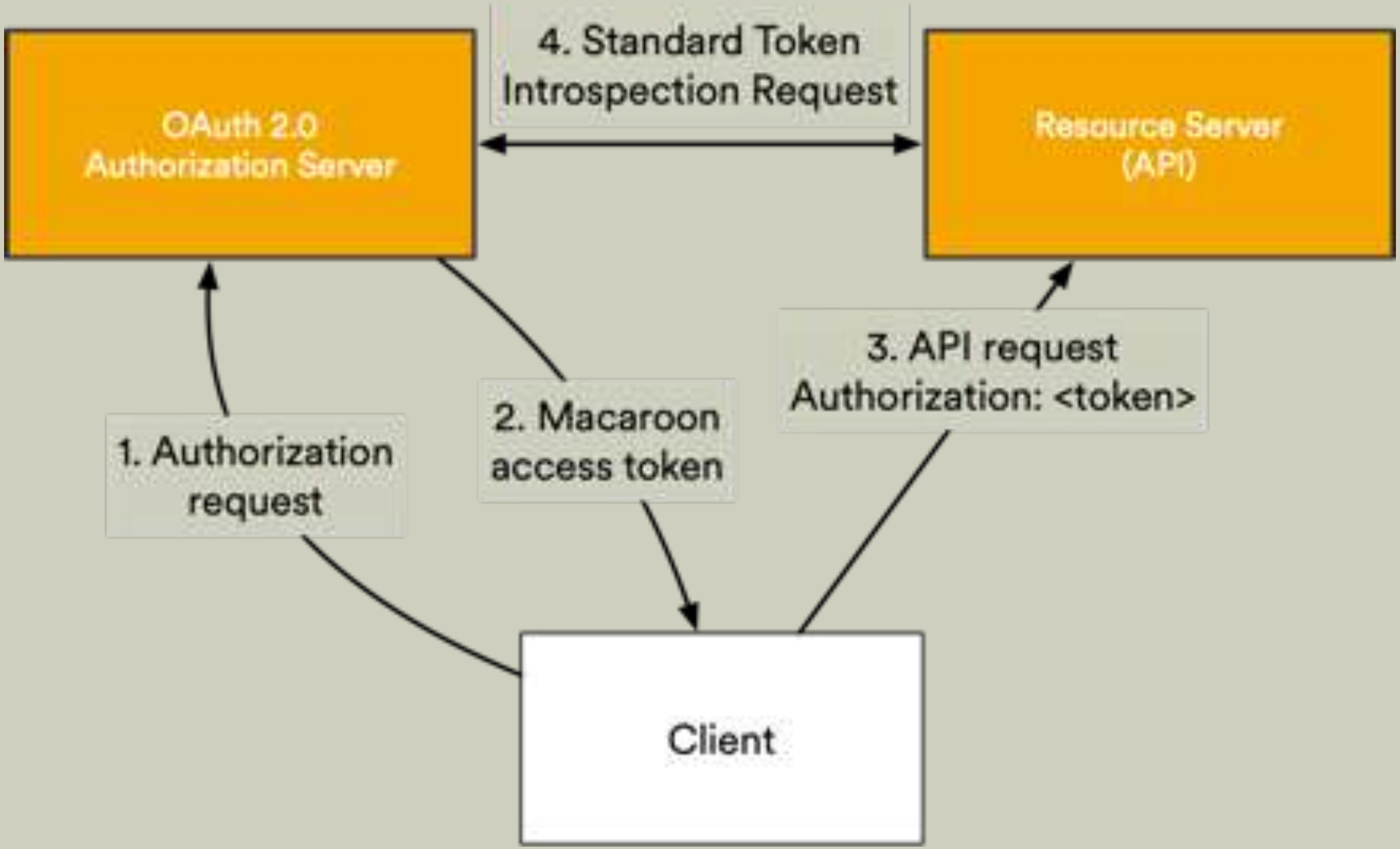
Macaroon Microservice

Macaroon Microservice

Auth Service

API
(Macaroon Verifier)

Macaroons and OAuth



4. Standard Token Introspection Request
OAuth 2.0 Authorization Server
Resource Server (API)
1. Authorization request
2. Macaroon access token
3. API request Authorization: <token>
Client

Macaroons and OAuth

Supports standard OAuth/JWT fields as caveats:

```
scope, aud, exp, nbf, cnf
```

Token introspection respects caveats—example: expiry time is minimum of original expiry and any `exp` caveats

Handles discharge macaroons too

Scan for more details

Public Key Macaroons?

florentines

Why *shouldn't* you use Macaroons?

No standard

De facto “standard” libmacaroons quirky, not widely liked

Not “boring”: burn innovation tokens?

Further reading:

https://research.google/pubs/macaroons-cookies-with-contextual-caveats-for-decentralized-authorization-in-the-cloud/

https://fly.io/blog/macaroons-escalated-quickly/

https://github.com/superfly/macaroon/blob/main/macaroon-thought.md

https://neilmadden.blog/2020/09/09/macaroon-access-tokens-for-oauth-part-2-transactional-auth/

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