

PentesterLab

JWAT ??

Attacking JSON WEB TOKENS…

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Agenda



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About Luke



Security Engineers:

- Pentester/Code Reviewer/Security consultant… at Elttam (https://www.elttam.com.au/
- Run one of the hardest web CTF: BitcoinCTF



BitcoinCTF:

- Challenges must be solved sequentially
- Prize is paid in Bitcoins
- @bitcoinctf on Twitter

About Louis

Security Engineers:

- Pentester/Code Reviewer/Security consultant/Security architect
- Run a website to help people learn security



PentesterLab:

- Platform to learn web security/penetration testing
- 100% Hands-on
- Available for individuals (free and PRO) and enterprises

JOSE/JWE/JWS/JWT



- JOSE:
  - Javascript Object Signing and Encryption
  - Also the name of the working group
- JWT: JSON Web Token == “jot” Token
- JWE: JSON Web Encryption
- JWS: JSON Web Signature
- JWK: JSON Web Key
- JWA: JSON Web Algorithm

Who uses JWT?



- A lot of people for OAuth
- A lot of people for sessions
- A lot of people to manage trust
- A lot of people for password reset
- A lot of people who care about being stateless and multi-datacenter architecture



THE JWT FORMAT



JavaScript Object Notation (JSON)



Human readable format to store or transmit objects

```
{
  "firstname": "John",
  "lastname": "Doe",
  "age": 30,
  "hobbies": ["security", "hacking", "lock picking"],
  "address": {
              "streetAddress": "1337 Hacker Street",
              "city": "Hacker Town",
              "country": "HackerLand"
             }
}
```

The Compact JWS Format



3 parts in a JSON Web Token:

`Header`

`Payload`

`Signature`

The Compact JWS Format



Separated by a dot



The Compact JWS Format



Separated by a dot

eyJ0eXAiOiJK
V1QiLCJhbGci
OiJIUzI1NiJ9

.

eyJsb2dpbi
I6ImFkb
WluIn0

.

FSfvCBAwypJ4abF6
jFLmR7JgZhkW674
Z8dIdAIRyt1E

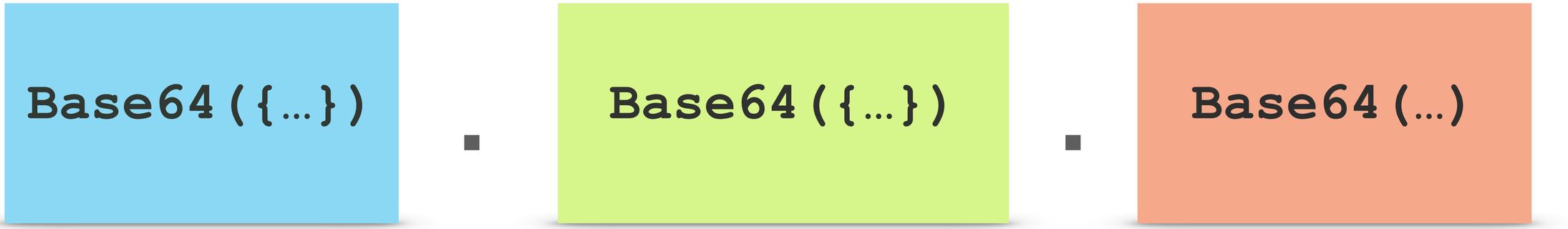
eyJ = Base64('{"')

The Compact JWS Format



Header and Payload are base64* encoded JSON

* urlsafe base64 encoding without padding



The signature is also base64 encoded



The Compact JWS Format: Encoding



Urlsafe base64 encoding without padding:

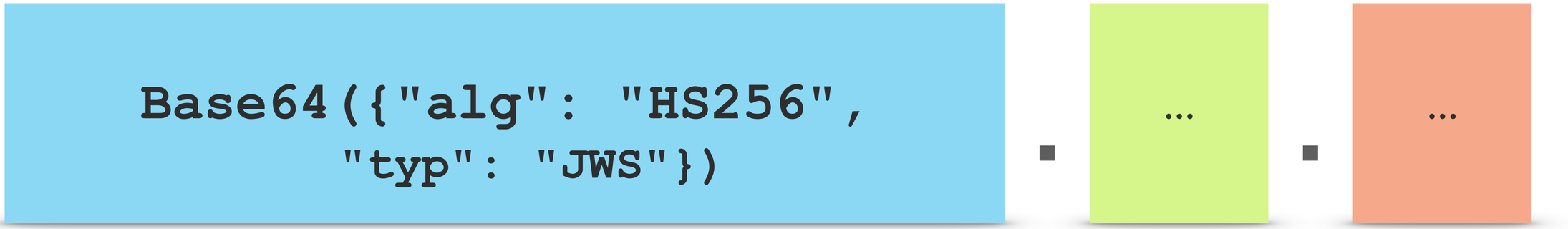
```
static string base64urlencode(byte [] arg)
  {
    string s = Convert.ToBase64String(arg); // Regular base64 encoder
    s = s.Split('=')[0]; // Remove any trailing '='s
    s = s.Replace('+', '-'); // 62nd char of encoding
    s = s.Replace('/', '_'); // 63rd char of encoding
    return s;
  }
```

*https://tools.ietf.org/html/rfc7515#appendix-C

The JWT Format: header



The header contains an algorithm “alg” attribute:



To tell how the token was signed.

In this example HMAC with SHA256 was used

The JWT Format: Algorithms



A lot of different algorithms are supported*:

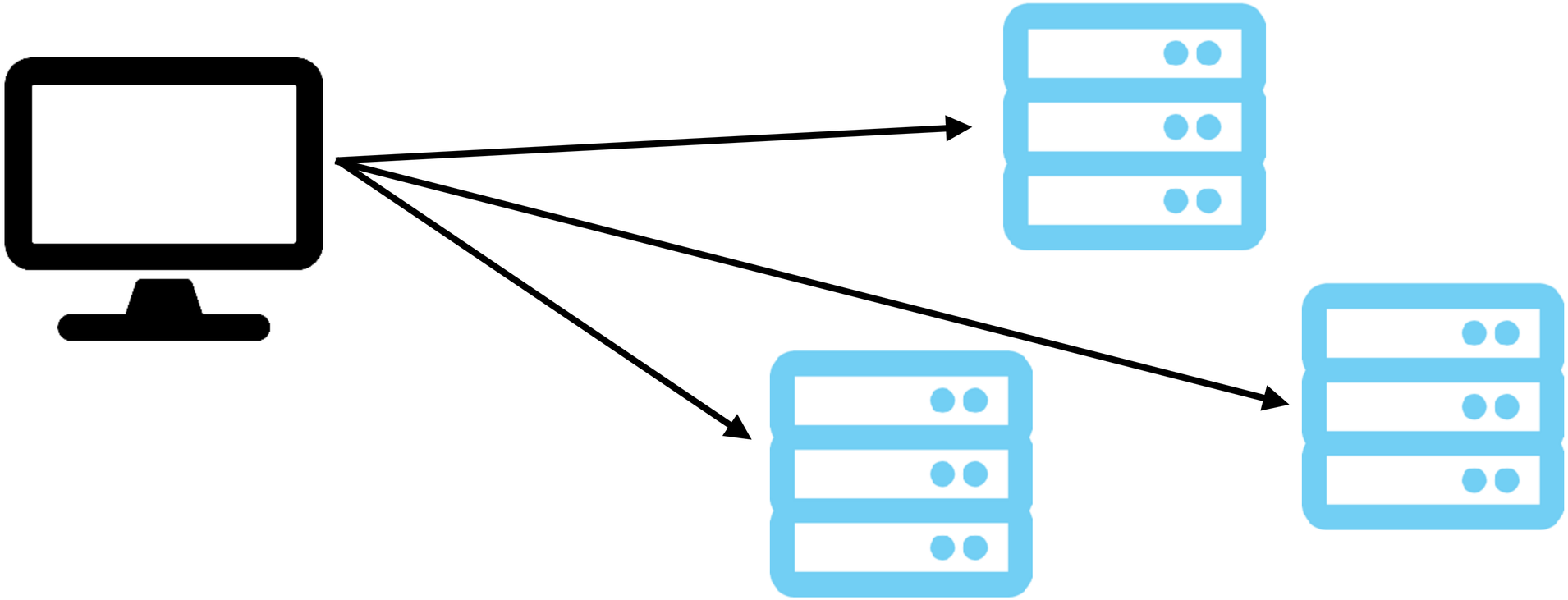
- None
- HS256
- HS384
- HS512
- RS256
- RS384
- RS512
- ES256
- ES384
- ES512
- PS256
- PS384
- PS512

* https://jwt.io/ covers most

The JWT Format: Algorithms



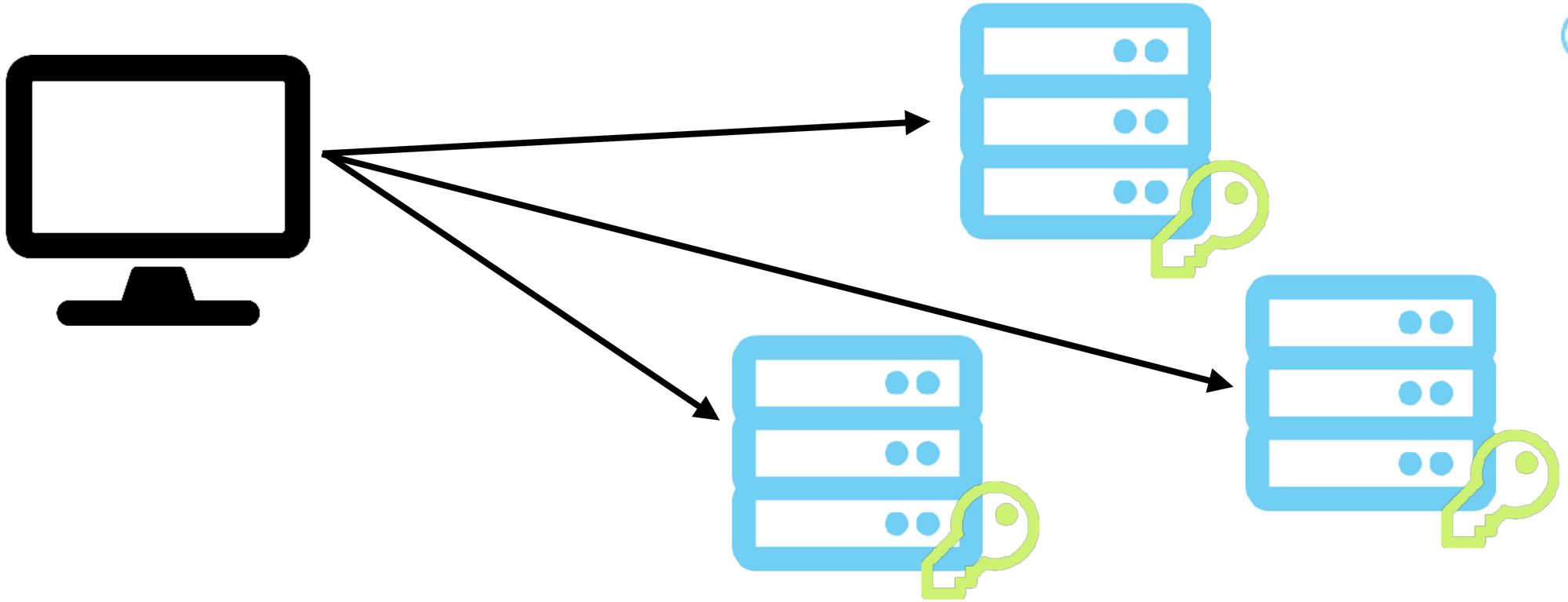
Scenario: one client talking to multiple services



The JWT Format: Algorithms

HMAC: All services need to know the secret

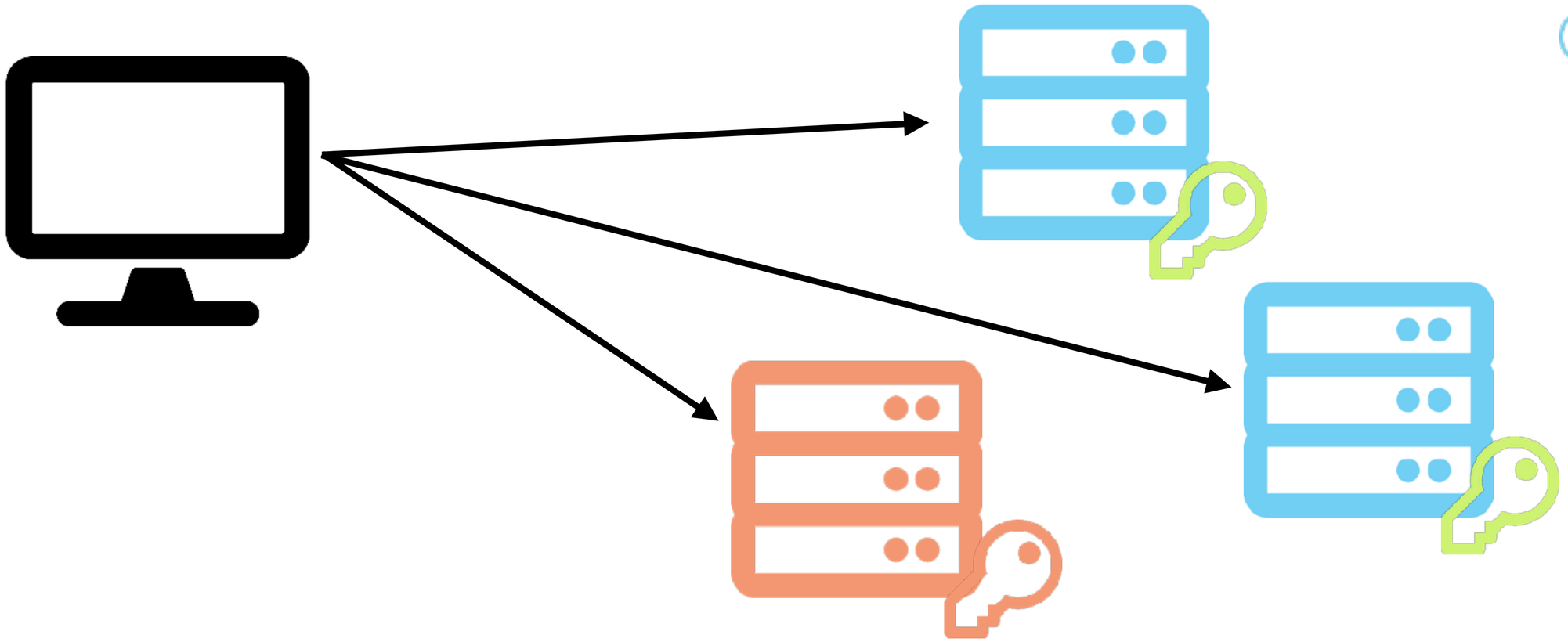
- HS256
- HS384
- HS512



The JWT Format: Algorithms

HMAC: if one service gets compromised

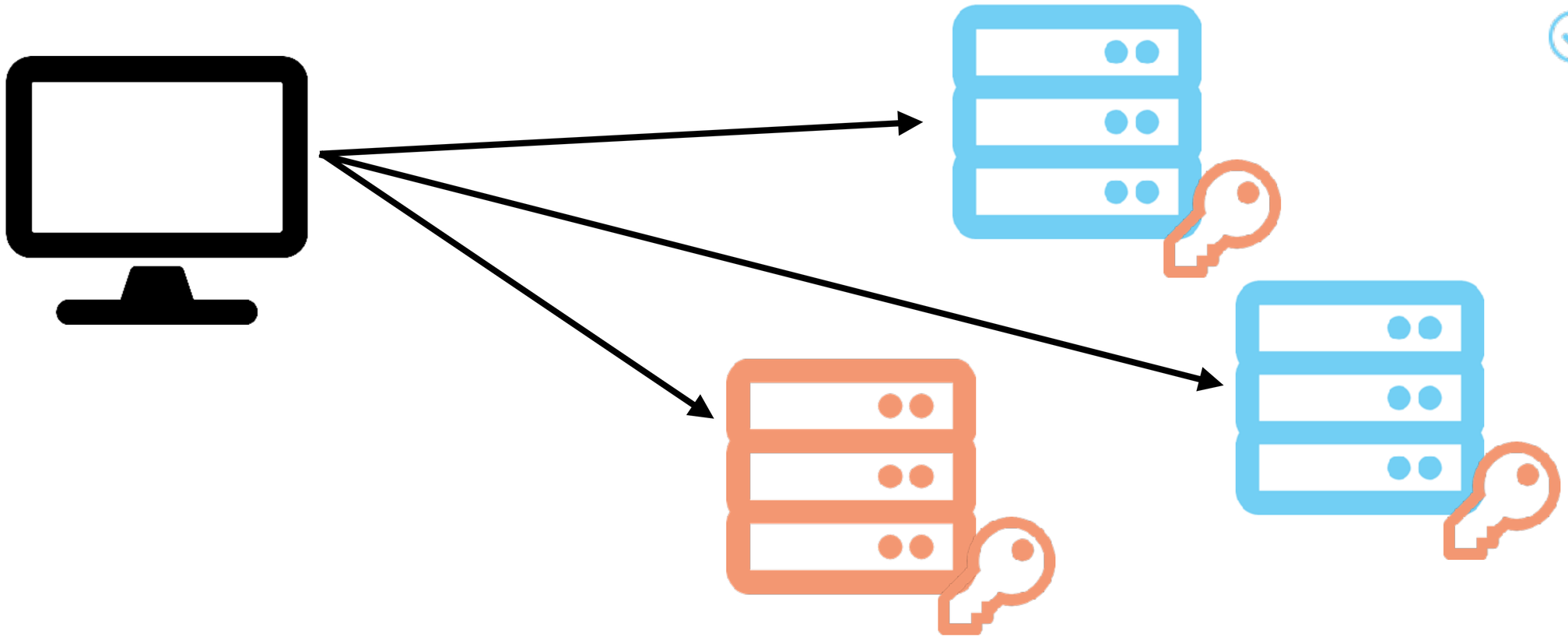
- HS256
- HS384
- HS512



The JWT Format: Algorithms

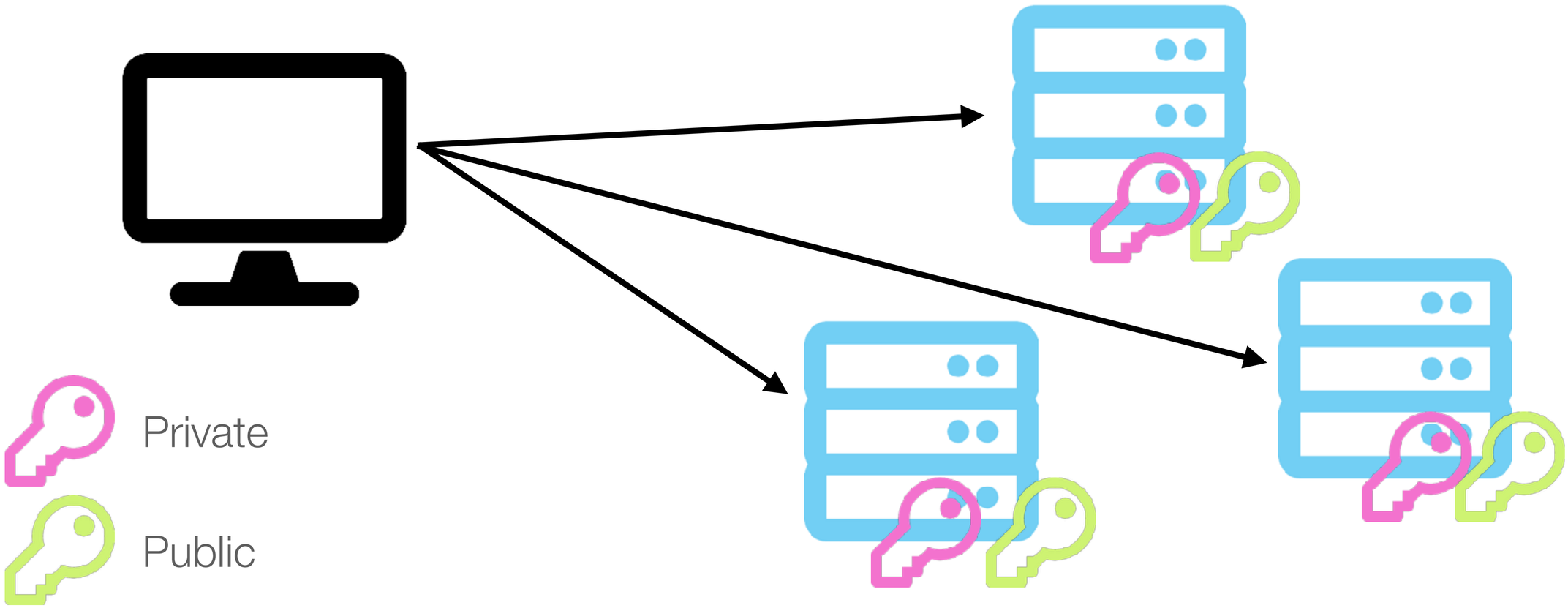
HMAC: the secret is compromised for all services

- HS256
- HS384
- HS512



The JWT Format: Asymmetric

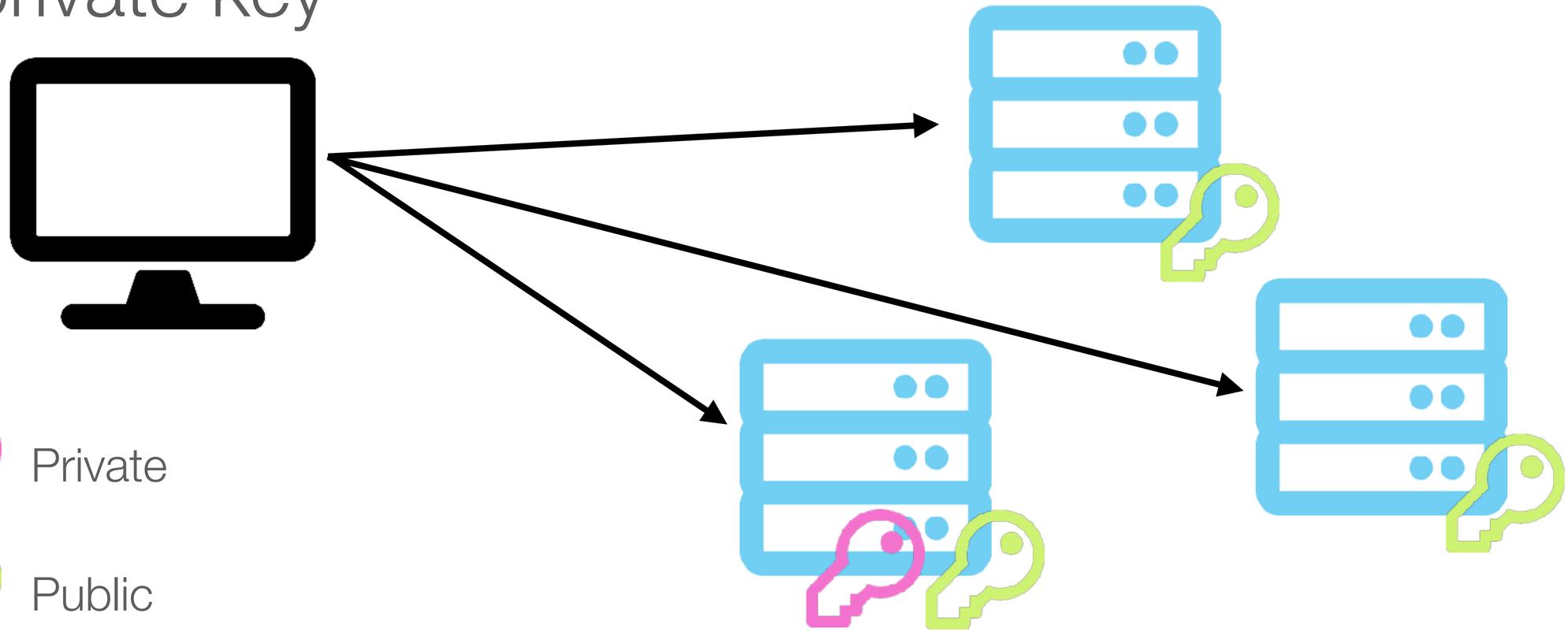
Asymmetric: sharing the key



- RS256
- RS384
- RS512
- ES256
- ES384
- ES512
- PS256
- PS384
- PS512

The JWT Format: Asymmetric

Asymmetric: Only trusted services get the private key



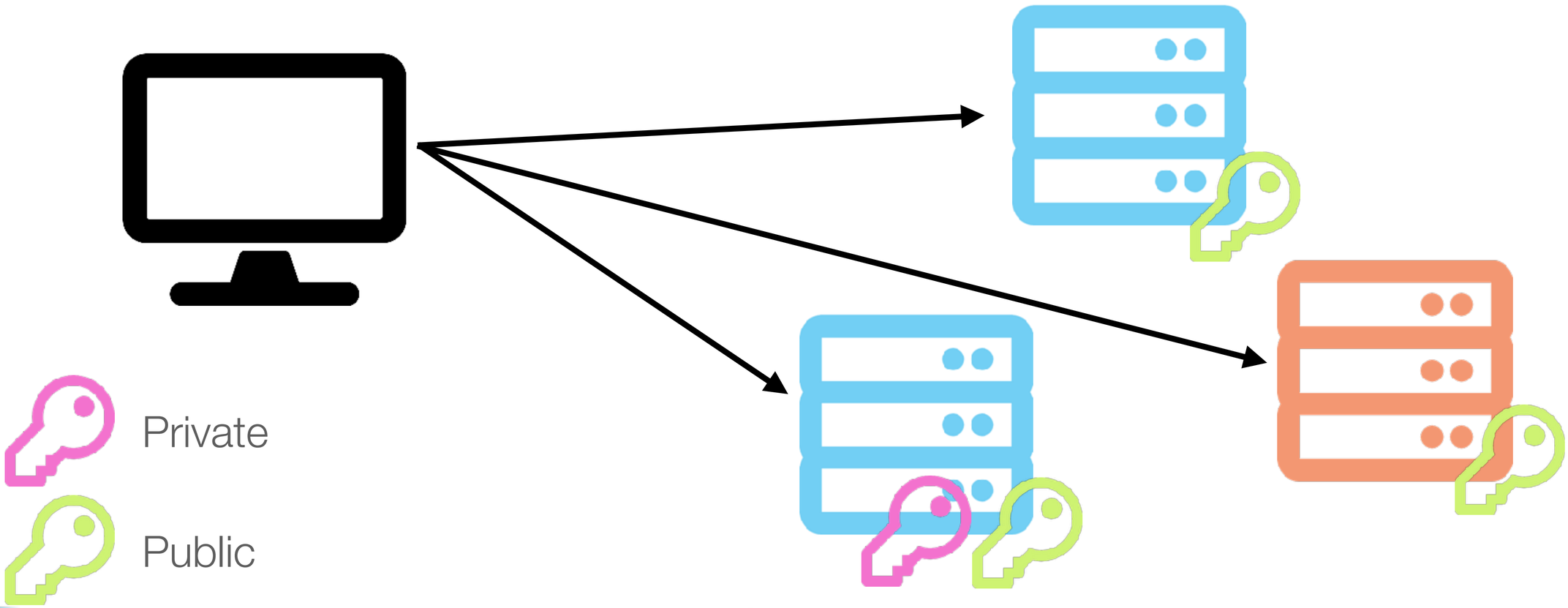
Private

Public

- RS256
- RS384
- RS512
- ES256
- ES384
- ES512
- PS256
- PS384
- PS512

The JWT Format: Asymmetric

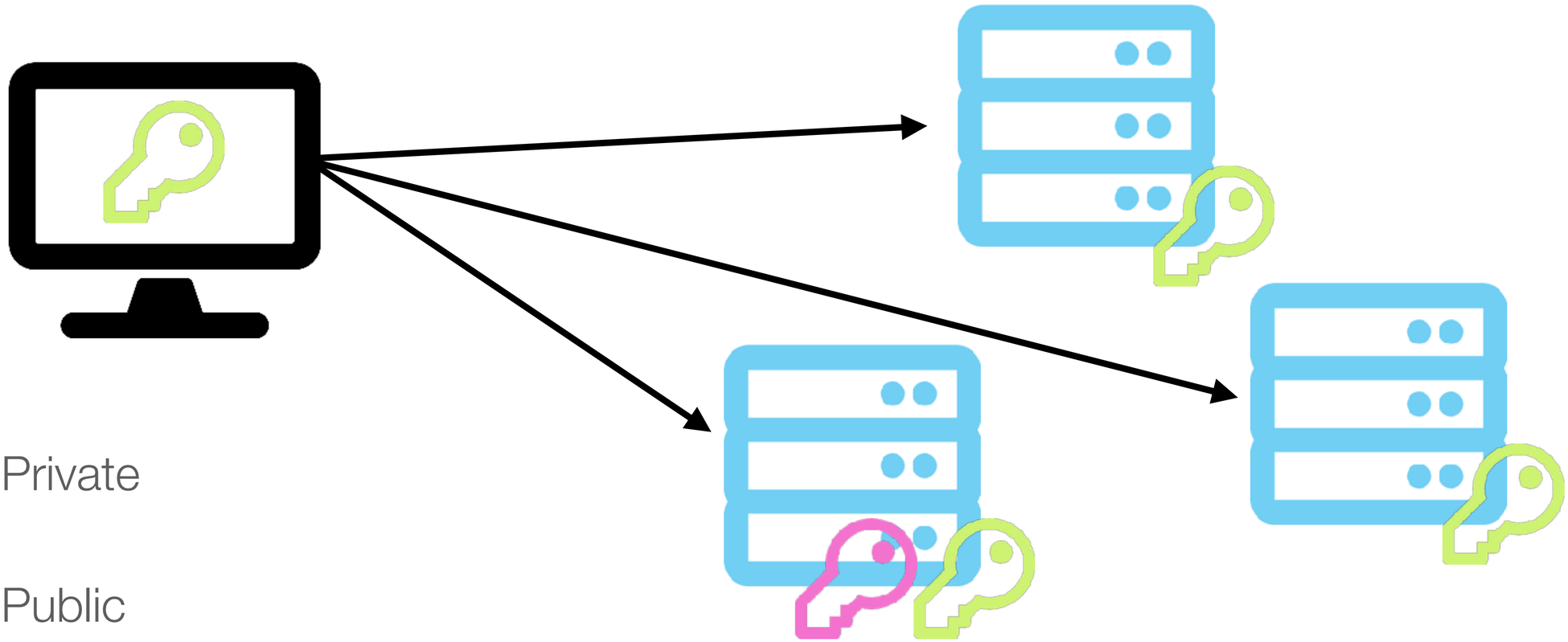
Asymmetric: If one service gets compromised…



- RS256
- RS384
- RS512
- ES256
- ES384
- ES512
- PS256
- PS384
- PS512

The JWT Format: Asymmetric

Asymmetric: Even in the browser!

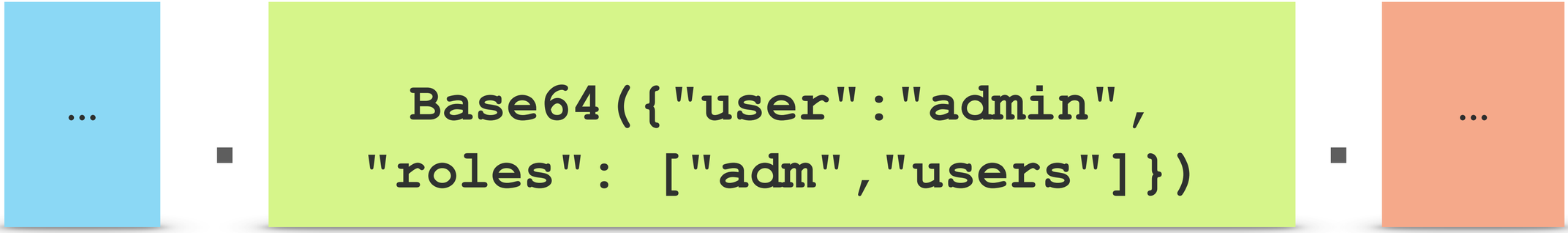


- RS256
- RS384
- RS512
- ES256
- ES384
- ES512
- PS256
- PS384
- PS512

The JWT Format: payload



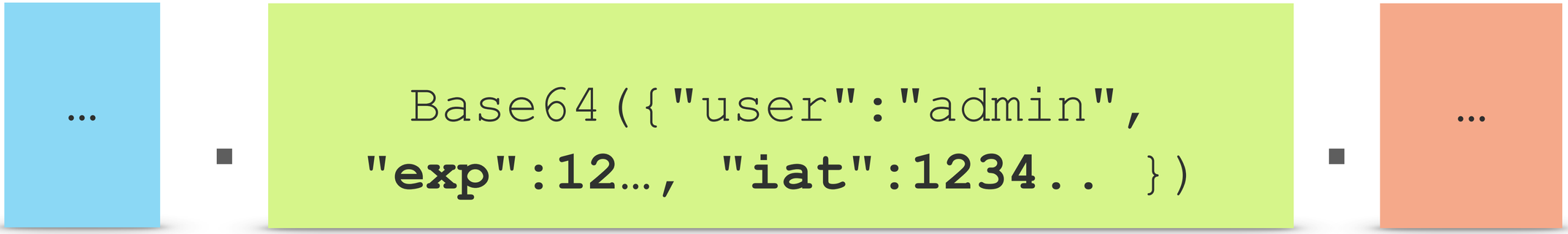
The payload may contain literally anything:



The JWT Format: payload



The payload **may** contain registered claims:



The JWT Format: payload



The payload **may** contain registered claims:

- “iss”: issuer
- “sub”: subject
- “aud”: audience
- “jti”: claim id
- “exp”: expiration time
- “nbf”: not before
- “iat”: issued at*

* useful for async processing

The JWT Format: creating a token



- Create the JSON header and base64 encode it
- Create the JSON payload and base64 encode it
- Concatenate with a dot the (encoded) header and payload
- **Sign the result (header+.+payload)**
- Base64 encode the signature
- Append a dot then the signature

The JWT Format: verifying a token



- Split the token in three parts based on the dots
- Base64 decode each part
- Parse the JSON for the header and payload
- Retrieve the algorithm from the header
- Verify the signature based on the algorithm
- Verify the claims

Keep in mind



- Multiple systems can issue tokens
- A token can be used by multiple systems
- All these systems can use different libraries



Attacking JWT



When attacking JWT, your main goal is to bypass the signature mechanism

We are going to illustrate this in the next exercises

Time for some hands-on fun!

What now?



5 Challenges

For each challenge:

- Quick introduction
- You start on your own (feel free to team up)
- We walk around the room to help you
- We do a walkthrough of the challenge

Lab 1:
None algorithm



The None algorithm



Remember that slide?

- None
- RS256
- ES256
- PS256

Basically, don’t sign the token

Used to be supported by default in few libraries



The None algorithm

Exploitation:

- Get a token
- Decode the header and change the algorithm to “none”
- Decode and tamper with the payload
- Keep or remove the signature
- Profit



Lab 2:
Trivial Secret



Trivial secret



The security of the signature relies on the strength of the secret

The secret can be cracked offline with just one valid token

Cracking is supported by hashcat





Trivial Secret

Exploitation:

- Get a token
- Brute force the secret until you get the same signature
- Tamper with the payload
- Re-sign the token using the secret



Lab 3:
Algorithm confusion



Algorithm confusion



The sender control the algorithm used

You can tell the receiver that the token has been signed using HMAC instead of RSA for example

With RSA, you sign with the private key and verify with the public key

With HMAC, you sign and verify with the same key

If you tell the receiver it's an HMAC and it verifies it with the public key (thinking it's RSA?)

Algorithm confusion



With RSA, you sign with the private key and verify with the public key

With HMAC, you sign and verify with the same key

You tell the receiver it's an HMAC (instead of RSA) and it verifies the signature using HMAC with the public key as the secret (thinking it's RSA):

You can sign the token with the public key

Algorithm confusion



How to get the public key:

- Public key accessible in the javascript code
- Public key available in a mobile client
- Public key just available in the documentation.



Algorithm confusion



Make sure:

- You write your own tool (most tools will mess this up)
- You read the key programmatically (no copy/paste)

Algorithm confusion

Exploitation:

- Get a token signed with RSA (you only have access to the public key)
- Decode the header and change the algorithm from RSA “RS256” to HMAC “HS256”
- Tamper with the payload
- Sign the token with the public RSA key



Algorithm confusion

Challenge URLs:

blue: http://fixme.fixme

green: http://fixme.fixme

red: http://fixme.fixme

yellow: http://fixme.fixme



Lab 4:
kid injection



Kid parameter



The **header** can contain a kid parameter:

- Key id (https://tools.ietf.org/html/rfc7515#section-4.1.4)
- Often used to retrieve a key from:
  - ✶The filesystem
  - ✶A Database

This is done prior to the verification of the signature

If the parameter is injectable, you can bypass the signature



Kid Injection

Exploitation:

- Get a signed token containing a kid parameter
- Decode the header and change the kid with a SQL injection payload
- Tamper with the payload
- Sign the token using the return value from the SQL injection



Lab 5:
CVE-2018-0114



Libraries: CVE-2018-0114



JWS allows you to add a “jwk” attribute (JSON Web Key) to the header to tell the receiver what key was used to sign the token:

```
  "jwk":
    { "kty":"RSA",
      "kid":"pentesterlab",
      "use":"sig",
      "n":"0wPQEuB9GAsYIFFQy54BnbpmI4oIenLYJYmLyVL8v9lDbT3NVIKWK4g4vOSOV2DoS3qVeedFOjx1CZnyr5k47D4gItocoESnJDMbZts8V
yswOMMa4bX8zxhciQ4oCdpmpNZPlAq2nhkm7j60Jjj743vwm8GS7Tj0zAv0mCXl6wjmUIUZoHngWDLGnnvZBkiPBNq_W-RXqT4Om_4s_AEYwg-bRaHp6
4TwR66i8cVkqngGx7CofvMoQOp0QmnQYwl8CNHP3d7nd12BuyIFy_dcIe3b-0PIFkCnOYPqdq7jAKdvUBUGrKeyqd99-eu6LeQ1W3jeO7Fdbne-UPkEX
ssgDQ",
      "e":"AQAB"
    }
```

Libraries: CVE-2018-0114



- Vulnerability in Cisco Node Jose
- Node-Jose uses the embedded “jwk” key to check the signature

- Integrity bypass!

Libraries: CVE-2018-0114 - Exploitation

Exploitation:

- Get a token
- Decode and tamper with the payload
- Generate a RSA key
- Add “n" & “e” to the header and use RS256
- Sign the token with your RSA key



Conclusion



Other issues we didn’t cover



Some developers don’t validate the signature:

- decode <- don’t use this one
- verify

Some developers create tokens that don’t expire:

- In too many libraries you need to opt-in to use “exp” or “iat”



Recommendations



- ✓ Use strong keys and secrets
- ✓ Review the libraries you pick (KISS library)
- ✓ Make sure you check the signature
- ✓ Make sure your tokens expire
- ✓ Enforce the algorithm

Conclusion



- JWT are complex and kind of insecure by design
- JWT libraries introduce very interesting bugs
- Make sure you test for those if you pentest or do bug bounties



THANKS

FOR YOUR TIME !

Any questions?

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