<WA1/>

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Authentication

For some, but not for all

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Outline

- The need for authentication
- HTTP sessions
- The JWT approach
- Implementation in React

https://flaviocopes.com/cookies/

Who are you?

AUTHENTICATION IN WEB APPLICATIONS

Authentication vs authorization

- Authentication
  - Verify you are who you say you are (identity)
  - Typically done with credentials (e.g., username, password)
  - Allows a personalized user experience

- Authorization
  - Decide if you have permission to access a resource
  - Granted authorization rights depends on the identity as established during authentication

Both are often used in conjunction to protect access to a system

Authentication and authorization

- Developing authentication and authorization mechanisms:
  - is complicated
  - is time-consuming
  - is prone to errors
  - may require interacting with third-party systems (log-in with google, facebook, …)
- Involve both client and server
- Rely on advice by security experts!

HTTP sessions

- Because **HTTP is stateless**, each HTTP request is independent and must be self-contained
- While communication, it is often desirable that information about previous interactions is maintained
- A **session** is an established communication between entities that may involve one or more messages in each direction, and typically at least one party keep some state information
- Example: client authenticates with the server, the server establish a session in which the client is considered authenticated

Session ID

- Basic mechanism to maintain session
- Upon authentication, the client receives from the authentication server a session ID that allows to recognize subsequent HTTP requests as authenticated
- Such information must be stored on the client side
- Such information must be sent by the client every time it sends a request which is part of the session
- Typical implementation in HTTP: **cookie**

https://en.wikipedia.org/wiki/HTTP_cookie
https://tools.ietf.org/html/rfc6265

Cookie

- RFC 6265
- Automatically handled by the browser. Uses HTTP headers:
  - `SetCookie:` server → client; the browser stores the cookie locally
  - `Cookie:` client → server
- Properties
  - name, value, domain (including port), path, secure, httpOnly, expiration date (optional)
- Stored by the browser in its cookie storage
- Always sent automatically by the browser when sending requests to the **domain** and **path** to which the cookie belong

Security of the session ID

- Any session ID must always travel on encrypted connections (HTTPS) to avoid being intercepted
- By stealing session ID, one can impersonate an authenticated client

- Several attack mechanisms are possible in a web application
  - XSS: Cross-site scripting: malicious JS code stealing the session ID
  - CSRF: Cross-site request forgery: make the browser perform an unwanted action by inducing the user to click on links (phishing email, social media post)
    `<a href="https://api.bank.com/sendMoney">Go to homepage</a>`

Mitigation techniques for XSS and CSRF

- XSS: Prevent any JS code (legit or not) from accessing the session ID
  - Use cookie with the httpOnly attribute

- CSRF: Do not rely only on cookie to authenticate requests on server side
  - Use additional headers derived by a shared secret and added via JS
  - Specific libraries exist for this purpose
  - Some web frameworks incorporate CSRF protection by default

- Rely on advice by security experts!

Alternatives to cookies

- From client to server
  - Separate Custom HTTP header
  - Hidden query parameters
- From server to client
  - Request body
  - Separate Custom HTTP header
- Handling by JS code in the browser, specific code on the server side
- Store in HTML5 `localStorage` or `sessionStorage`
  - Values accessible by JS but only from the same origin (schema, domain, port)

Cookies vs alternative approach: pros and cons

	Cookies	Other approaches
Pros	• Automatically handled by the browser • Can be made inaccessible to JS code (httpOnly option) to prevent access from malicious JS code (XSS) • Can be sent on secure connections only (secure option)	• More flexibility (not restricted to cookie APIs) • Sent only when required by JS
Cons	• Cannot be sent by third parties • Always sent for any request: expose to CSRF attack	• Need to explicitly manage storage (localStorage, sessionStorage) • Can be accessed by any (malicious) script in the page (XSS)

https://flaviocopes.com/jwt/

https://stackabuse.com/authentication-and-authorization-with-jwts-in-express-js/

Can you do the requested operation?

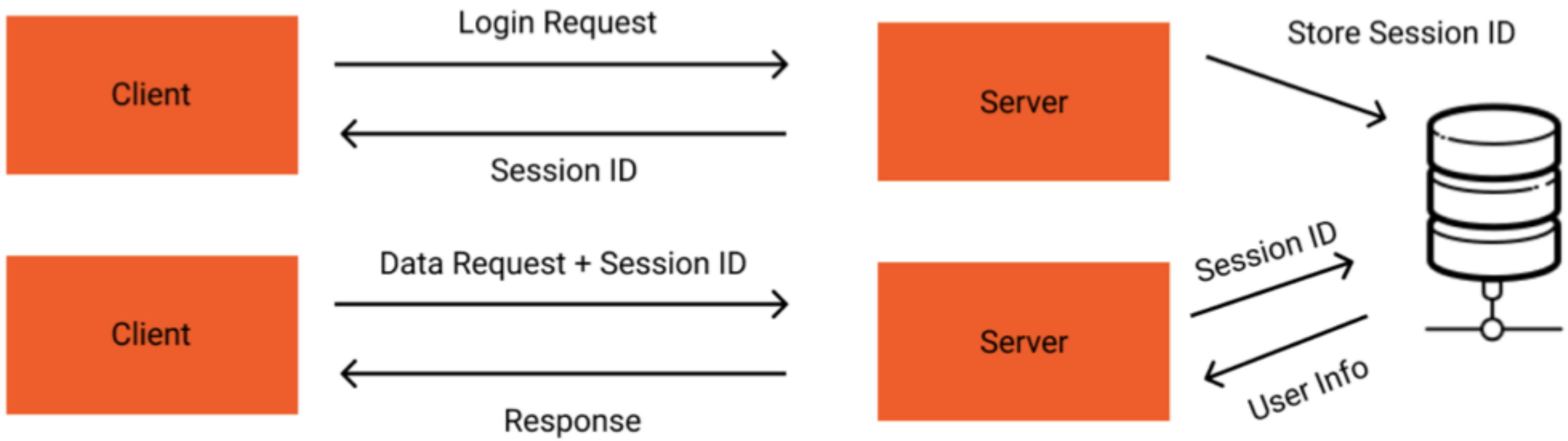
AUTHORIZATION IN WEB APPLICATIONS

Authorization after authentication

- Two approaches to handle authorization after authentication:
  - Stateful server
  - Stateless server

Stateful server

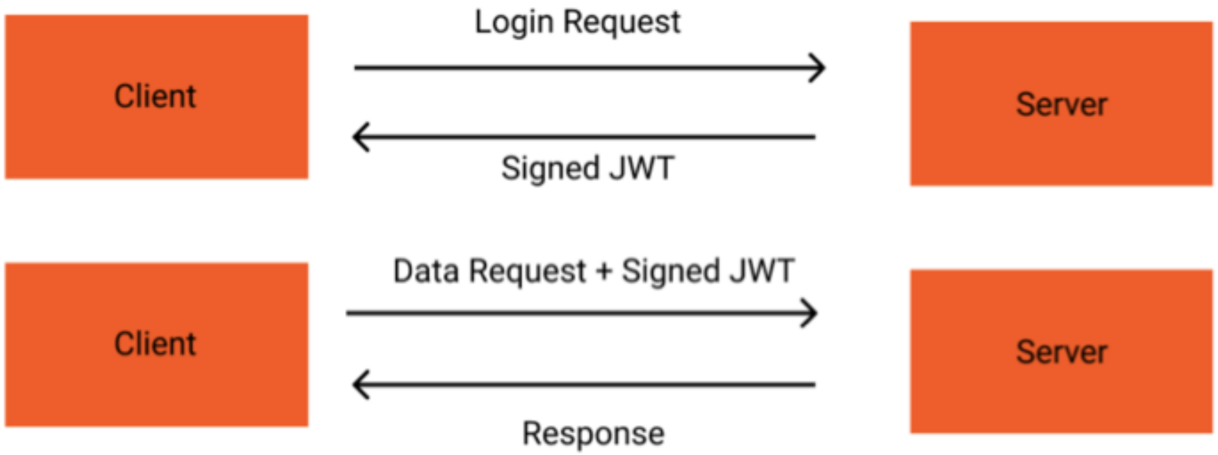
- The server actively **remembers** the still valid session IDs and the associated user info
- Such information cannot be maliciously altered since it **never leaves the server**
- Each time a request arrives for a restricted resource, the server **retrieves** the info associated with the session and decides if the user is allowed or not
- Works best with a single server that manages everything



https://stackabuse.com/authentication-and-authorization-with-jwts-in-express-js/

Stateless server

- The **server signs a payload** which contains information about user info, what can be accessed, and when the authorization expires
- The server **sends** the signed payload to the client, that **stores** it
- Each time a request arrives for a restricted resource, the receiving **server verifies the signature**, extracts and uses the information
- Works best where there are multiple servers which cannot easily share session information, often employed for REST API servers in single page applications (SPA)



https://stackabuse.com/authentication-and-authorization-with-jwts-in-express-js/

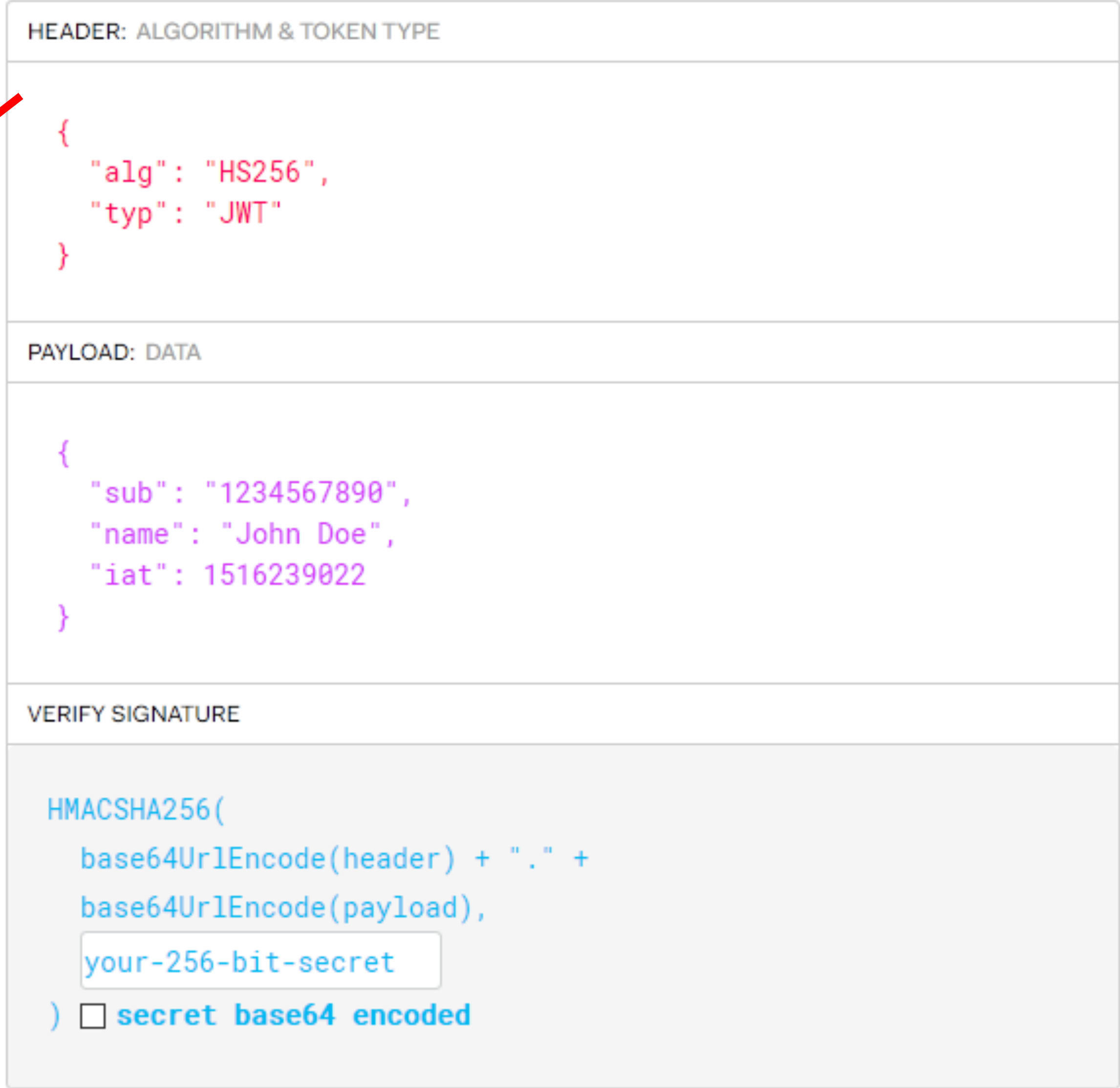
JSON Web Token: a mechanism for authorization

- Standardized in RFC 7519
- In short, JSON Web Tokens (JWTs) are digitally signed JSON payloads, encoded in a URL-friendly string format
- A JWT can contain any payload in general, but the most common use case is to use the payload to define a user session
- JWTs used for authentication should contain at least:
  - a user ID
  - an expiration timestamp

https://blog.angular-university.io/angular-jwt-authentication/
https://tools.ietf.org/html/rfc7519

JWT Example

```
eyJhbGciOiJIUzI1NiIsInR5cCI6
IkpXVCJ9.
eyJzdWIiOiIzNTM0NTQzNTQzNTQz
NTM0NTMiLCJleHAiOjE1MDQ2OTky
NTZ9.
zG-2FvGegujxoLWwIQfNB5IT46D-
xC4e8dEDYwi6aRM
```



HEADER: ALGORITHM & TOKEN TYPE

```
{
  "alg": "HS256",
  "typ": "JWT"
}
```

PAYLOAD: DATA

```
{
  "sub": "1234567890",
  "name": "John Doe",
  "iat": 1516239022
}
```

VERIFY SIGNATURE

```
HMACSHA256(
  base64UrlEncode(header) + "." +
  base64UrlEncode(payload),
  your-256-bit-secret
) □ secret base64 encoded
```

https://blog.angular-university.io/angular-jwt-authentication/

https://jwt.io/

JWT Pros and Cons

- To confirm JWT validity, **validating the signature is enough**
- No need to contact the authentication server that provided the JWT
- No need to keep the token in server memory nor server storage (files, DBs etc.) between HTTP requests

- Difficult to make JWT invalid sooner than the expiration time
  - Change secret (invalidates all tokens), list of blacklisted/whitelisted token (requires stateful server)
- For this reason, better to have a short expiration time
  - Requires generating a new JWT token while the old is still valid

JWT in practice

- As any other authentication token, it must be kept secret
  - sent over HTTPS only
- Must be sent with each request to the server (e.g., REST API server)
- The server receiving the token (e.g., REST API server) must have a method to validate the legitimacy of the JWT
  - Depends on how the signature is implemented

JWT signing algorithms

- Many
- Two important categories
  - Single secret key (Hash-based)
  - Public / private key (RSA, ECDSA)

- HMAC + SHA256
- RSASSA-PKCS1-v1_5 + SHA256
- ECDSA + P-256 + SHA256
- …

https://auth0.com/blog/json-web-token-signing-algorithms-overview/

Keys for signing

Single key

- Key is the same between authentication server and verifying server
- Key must be long enough (at least as the hash length, i.e. 256 bits = 32 bytes/characters)
- Key must be duly protected
  - Can be used to forge JWT tokens

Public/private keys

- Private key is used **only** by the authentication server to initially sign the JWT token
- API servers can be many and only need the public key: better security
  - Public keys cannot be used to forge JWT tokens

https://medium.com/@ryanchenkie_40935/react-authentication-how-to-store-jwt-in-a-cookie-346519310e81

https://stackabuse.com/authentication-and-authorization-with-jwts-in-express-js/

JWT in practice

JWT IN PRACTICE

Our recommendations

- Create a login page which collects username/password and sends a POST request to the authentication server
- Receive the signed JWT from the authentication server
  - As a **cookie, invisible to JS ("http only" option)** to protect from XSS
- The browser will always send the JWT in the HTTP cookie header to any API that requires authentication
  - Use proxy mechanism for API server: cookie cannot be sent to other domains/ports
- Protect the system from CSRF using a standard library
  - Necessary due to the use of cookie

Client login form: use standard practice

- Create it as React component, with local state, and validation if required

```
<LoginForm userLogin={this.userLogin}/>

class LoginForm extends React.Component {
    constructor(props) {
        super(props);
        this.state = { username: '', password: '' };
    }
    doLogin = (event) => {
        event.preventDefault();
        if (this.form.checkValidity()) {
            this.props.userLogin(this.state.username, this.state.password);  // Make POST request to authentication server
        } else {
            this.form.reportValidity();
        }
    }
...
```

Server

- Decide a sufficiently long *random secret*
  - Keep it secret (don’t commit to GitHub…)
- Decide where to keep the JWT (recommended: cookie)
- Develop an authentication server which receives credentials (username/password), and upon successful authentication it sends the JWT as response body
  - For instance, add `POST /login` route in API server
- Verify the JWT signature for each API call for which authorization is needed
  - Typically through a middleware that does it automatically

JWT in express.js

- Several libraries are available
- Most frequently adopted ones:
  - `express-jwt` https://github.com/auth0/express-jwt
  - `jsonwebtoken` https://github.com/auth0/node-jsonwebtoken/

- `npm install express-jwt` (*middleware*)
- `npm install jsonwebtoken` (*utilities to encode info and sign JWTs*)

express-jwt

https://github.com/auth0/express-jwt

- Configuration through an object `jwt( { … config props … } );`
- Most important properties are:
  - `secret`: sufficiently long random string needed to verify signature
  - `getToken()`: extract token from the request (req => req.cookies.token)
  - `credentialsRequired`: if false, allow access to unauthorized users for logging or other purposes

Protecting REST APIs

```
app.use(cookieParser());

app.use(
  jwt({
    secret: jwtSecret,
    getToken: req => req.cookies.token
  })
);

// All the following APIs will require authentication
...
//REST APIs
//app.post('/api/exam', ...
...
```

Unauthorized requests

https://github.com/auth0/express-jwt

- The JWT middleware throws an exception if not authorized
- To handle the error, you may provide an custom middleware function

```
app.use(function (err, req, res, next) {
  if (err.name === 'UnauthorizedError') {
    res.status(401).json(authErrorObj);
  }
});
```

jsonwebtoken

https://github.com/auth0/node-jsonwebtoken/

- Used to **create the JWT** with a specified sign method
- `jwt.sign(payload, secretOrPrivateKey, [options, callback])`
  - Can be used synchronously or asynchronously (providing a callback)
  - Main options:
    - `expiresIn`: seconds from now when the token will expire
    - `algorithm`: the algorithm to be used for signature
    - `noTimestamp`: used not to include, in the payload, the timestamp when the token is issued
    - … others to include standard fields in the payload (issuer, audience, subject, etc.)
- Other methods (verify, decode) are present but directly used by the previous middleware

Import and headers

```
const jwt = require('express-jwt');
const jsonwebtoken = require('jsonwebtoken');
const cookieParser = require('cookie-parser');

const jwtSecret =
'6xvL4xkAAbG49hcXf5GIYSvkDICiUAR6EdR5dLdwW7hMzUjjMUe9t6M5kSAYxsvX';
```

Login route

```
const expireTime = 1800; //seconds

app.post('/api/login', (req, res) => {
    dao.checkUserPwd(req.body.username, req.body.password)
    .then((userID) => {
      const token = jsonwebtoken.sign({ user: userID }, jwtSecret, {expiresIn: expireTime});
      res.cookie('token', token, { httpOnly: true, sameSite: true, maxAge: 1000*expireTime });
      res.end()
    }).catch(
      // Delay response when wrong user/pass is sent to avoid fast guessing attempts
      () => new Promise((resolve) => { setTimeout(resolve, 1000) }).then(
           () => res.status(401).end()
      )
    );
});
```

Password storage and check

- **Never** save plaintext passwords anywhere (e.g., DB)
- Save the result of a strong hash function applied to the plaintext password
  - So that even if hashed passwords are leaked, they cannot be used directly
  - Note: passwords cannot be recovered, but users can set a new password if needed
- When checking authentication, compare password hashes
- Use well-established libraries, for instance `bcrypt`
  - Provides methods to create and check hashes
  - `bcrypt.hash(myPlaintextPassword, saltRounds, function(err, hash) { /* store hash */ }`
  - `bcrypt.compare(myPlaintextPassword, hash, function(err, result) { /* result == true? */ }`

https://www.npmjs.com/package/bcrypt

Password hash check

```
exports.checkUserPass = function (user, pass) {
    return new Promise((resolve, reject) => {
        const sql = 'SELECT username, passwordhash, name FROM user WHERE username = ?';
        db.all(sql, [user], (err, rows) => {
            if (err) { reject(err); return; }
            if (rows.length === 0) { reject(null); return; }

            // bcrypt.compare might be computationally heavy
            // thus the compare method provides a callback function which is called when computation ends
            bcrypt.compare(pass, rows[0].passwordhash, function (err, res) {
                if (err) { reject(err); }
                if (!res) { reject(null); }
                else { resolve({
                        userID: rows[0].username,
                        name: rows[0].name,
                    }); return;
                }
            });
        });
    });
}
```

Accessing the JWT payload

- For authenticated requests, the JWT payload is accessible via `req.user`

```
// ... const token = jsonwebtoken.sign({ userID: id}, jwtSecret, {expiresIn: expireTime});
// ...

// GET /exams
app.get('/api/exams', (req, res) => {
  // Extract userID from JWT payload
  // check if req.user is present, in case the API is used without authentication
  const userID = req.user && req.user.userID;
  dao.listExams(userID)   // e.g., userID is a parameter of the DB query
    .then((exams) => res.json(exams))
    .catch((err) => res.status(503).json(dbErrorObj));
});
```

Logout route

- To logout, simply delete the cookie containing the JWT from the browser
- Need to be done via server SetCookie since it is not directly accessible from the client JS code
  - NB: This does not make the token expire before its deadline, if it is stolen it can still be used until its expiration timestamp

```
app.post('/api/logout', (req, res) => {
  res.clearCookie('token').end();
});
```

CSRF protection for the cookie case

- Express.js does not contain support by default
- Libraries available
- The most frequently adopted one is `csurf`

- `npm install csurf`

CSRF: server side

```
const csrf = require('csurf');
...
const csrfProtection = csrf({
  cookie: true
});
...
app.get('/api/csrf-token', csrfProtection, (req, res) => {
  res.json({ csrfToken: req.csrfToken() });
});
...
// Any non-GET API to be protected with middleware call
app.put('/api/exams/:code', csrfProtection, ...)
```

CSRF: client side

```
// In main App, upon successful authentication:
API.getCSRFToken().then( (response) => this.setState({csrfToken:
response.csrfToken}));


// In API.js
async function getCSRFToken() {
    return new Promise((resolve, reject) => {
        fetch(BASEURL + '/csrf-token').then((response) => {
            if (response.ok) {
                response.json()
                    .then((obj) => { resolve(obj); })

...
```

CSRF: client side: send additional header

```
// In main App, when needed, call API functions
API.updateExam(exam, this.state.csrfToken).then( ...

// In APIs
async function updateExam(exam, csrfToken) {
    return new Promise((resolve, reject) => {
        fetch(BASEURL + '/exams/' + exam.coursecode, {
            method: 'PUT',
            headers: {
                'Content-Type': 'application/json',
                'X-CSRF-Token': csrfToken,
            },
            body: JSON.stringify(exam),
        }).then(
 ...
```

Tip: authentication is a complex problem

- Much more than “simple” JWT + Cookies + CSRF
- Third party authentication (google, facebook, etc.)
  - More complex, but similar principles
  - Oauth2, …
- Many possible attack approaches (XSS, CSRF, …)

- Never invent your own mechanism! Use standardized, well tested, ones!

- **Consult a security expert** before deployment in real world applications!

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