<WA/>
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# API Security

## Server security issues

Enrico Masala
Antonio Servetti

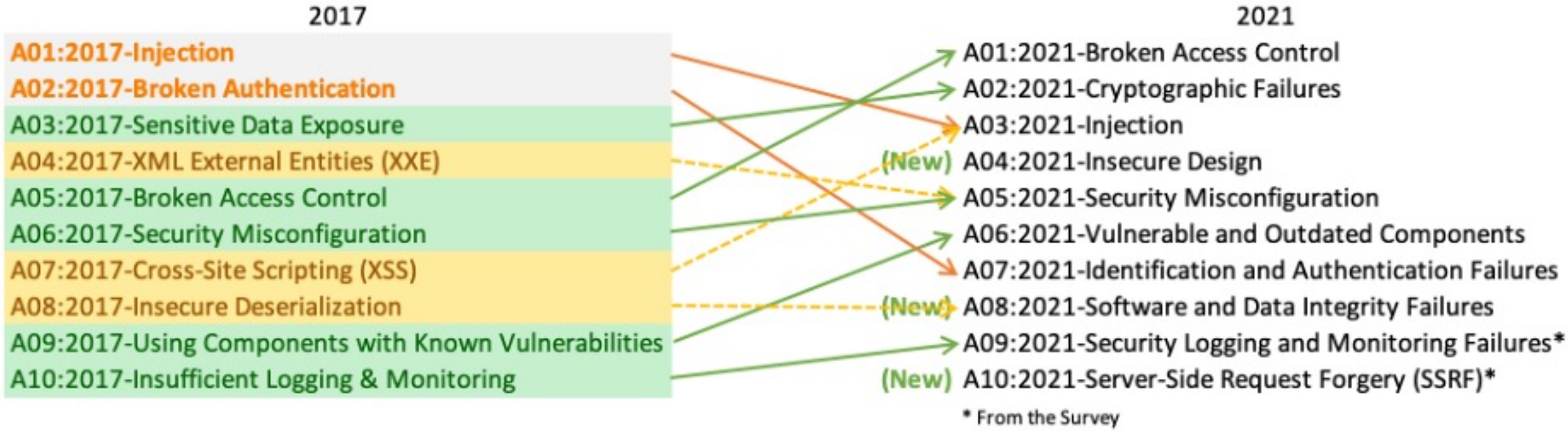
# Distributed Applications

- Web applications (client/server) are a subset of distributed applications
- Distributed applications are complex. They need to:
  - check/validate input data which comes from external (=insecure) sources
  - check permissions before performing operations
  - handle synchronization issues correctly
  - consider that communications may fail

- OWASP (Open Worldwide Application Security Project): owasp.org
  - Refer to the OWASP Foundation guidelines/initiatives for more details

    *Summary of the most important issues in the following slides*

# Top 10 Web Application Security Risks




https://owasp.org/www-project-top-ten

Some OWASP generic attack detection rules, to be included in web application firewalls, can mitigate **some** of these risks, but do NOT rely ONLY on them.

# Web Application Issues: Incoming data

- Incoming data can come from any sender
- Main checks: incoming data must be carefully checked EVERY TIME for
  - Formal correctness
    - Example: item count must be a positive number (>0), name cannot be empty
  - Consistency with application logic
    - Example: an ID must refer to something actually existing in a DB; no more than N items in a shopping cart
  - Potential to create problems
    - Example: SQL injections on free text fields: Name = “Enrico; DROP TABLE user”
- NB: This also applies to authenticated requests
  - The malicious sender could be a user who is already authenticated in the system

https://owasp.org/www-project-web-security-testing-guide/latest/4-Web_Application_Security_Testing/07-Input_Validation_Testing/README

# Web Application Issues: Security

- API must prevent requests from doing actions that the client is not authorized to do
  - Access/modify/delete data
- Rate of requests should not be excessive
  - Answering an API request sometimes is computationally demanding (involving DB, computation, etc.): rate limit
  - Anybody can send requests: Denial of Service (DoS) attacks
- APIs are the way data is managed in modern applications
  - One may want to log API requests for traceability
- Solutions exist to handle some of these problems at large scale: API gateway
  - Apache APISIX: https://apisix.apache.org/

# Web Application Issues: Synchronization

- Requests to APIs can arrive at any time
  - Web applications are **multiuser by definition**
  - Many clients can (and typically do) request operations on the same shared resource at the same time
    - Typical example: reservations
- Always think in terms of multiple users / multiple clients /concurrent requests
  - NO global variables / global states in the server to handle client requests
  - NO assumptions on the order of arrival for API requests
  - Remember that how the backend is implemented (web servers, server frameworks & languages, DB, …,
    **is independent** from how the client is developed)

Guaranteed failure at the exam

# Formal data correctness

- API specifications determine what is acceptable/expected and what is not
- Examples:
  - Number of items to buy: a positive number ( > 0, otherwise the item should not be present)
  - Exam code: alphanumeric string, 7 characters
  - Zip code (Italian): alphanumeric string, 5 characters, only ‘0’ to ‘9’ allowed
  - String must be a valid email
  - …
- Tedious to implement: middleware exists to speed up operations

# Express Validator

- https://express-validator.github.io/docs/
  - `npm install express-validator`
- Declarative validator for API parameters (either in url, query or body)

```
app.post('/user', [   // additional (2nd) parameter in app.post to pre-process request
check('username').isEmail(), // username must be an email
check('password').isLength({ min: 5 }) // password must be at least 5 chars long
], (req, res) => {
const errors = validationResult(req);
  if (!errors.isEmpty()) {
    return res.status(422).json({ errors: errors.array() });
  }
 . . . Process request
});
```

https://github.com/validatorjs/validator.js#validators

# Tips for formal data correctness

- Please **AVOID** writing your validators for non-trivial data (e.g., using regexp)
  - email, date, URLs, float number, credit card, IBAN account, etc.
- Rely on well-established libraries (express-validator or others)
- Example of valid email addresses

```
firstname+lastname@example.com
"email"@example.com
_______@example.com
1234567890@a.b.c.com
much."more\ unusual"@example.com
…
```

Did you think about all these cases?

Do you really want to spend your time to manually validate all these cases?

https://www.w3resource.com/javascript/form/email-validation.php

# Data consistency with application logic

- The way the application works determines what is acceptable and what is not
- Only the programmer/analyst/designer knows what data are correct or not for a specific API endpoint **to avoid an inconsistent DB state**
- Example #1: add a new comment to a post identified by an ID

```
POST /comments
HTTP request body: { postId: 1234, text: "Great post!" }
```

  - The API requires to insert information in a DB, with foreign key postId
  - Before/while inserting the comment, the existence of the foreign key value must be checked
    - Via code: `if (exist(postId)) insert(…); // Check with SELECT before insert`

    or
    - Force the DB to fail the INSERT query (foreign key constraint): difficult to maintain code in the API server & in the DB in the form of trigger/constraints, difficult to debug!

# Data consistency with application logic

- Example #2: cannot insert more than N items in a shopping cart

```
POST /cart
HTTP request body: { itemId: 1234 }
```

  - The API requires an INSERT into the DB, with foreign key `itemId`: all the previous considerations apply
  - In addition: before/while inserting the item in the cart, the constraint must be checked
    - Via code: `if (cartCount() < N)  insert(…);  // Test before insert`

    or

    - Via SQL: `INSERT … INTO cart WHERE (SELECT COUNT(*) FROM cart …) < N;`

# Injection: SQL injection

- Example #3: My name is "John; DROP TABLE users"

```
POST /users
HTTP request body: { name: "John; DROP TABLE users" }
```

  - The API executes an INSERT into a DB

```
db.run("INSERT INTO users(name) VALUES "+name, function(err){…});  // WRONG!

//Executed query:  INSERT INTO users(name) VALUES John; DROP TABLE users
```

!?!

```
const sql = 'INSERT INTO users(name) VALUES (?)';  // Protects from SQL injection
db.run(sql, [name], function (err) {…} );
```

NB: **Always use parametrized queries!** Do NOT construct query strings manually

https://cheatsheetseries.owasp.org/cheatsheets/SQL_Injection_Prevention_Cheat_Sheet.html

# Injection: many more cases

- Example #4: My name is “John<SCRIPT>**alert('Hacked!');**</SCRIPT>”

**HTML code says to execute JS code**

**Javascript code**

*More on this after discussing HTML and Javascript in the browser*
*(how to handle and prevent such issues, e.g., via escaping special characters)*

# Injection: what is happening

My name is “John<SCRIPT>**alert('Hacked!');**</SCRIPT>”

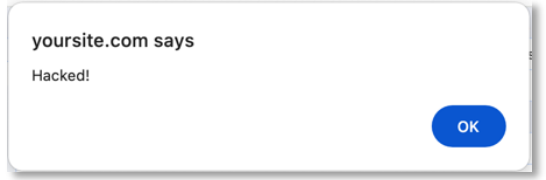
```
POST /users
HTTP request body: { name: "John<SCRIPT>alert('Hacked!');</SCRIPT>" }
```

The API executes an INSERT into the DB (with or without parametrized query)

```
// Page content
<HTML>… Hello ${name} …</HTML>
```

Render phase in the browser (creation of final page content)

```
<HTML>… Hello Enrico<SCRIPT>alert('Hacked!');</SCRIPT> …</HTML>
```




Most frameworks (including React) prevent execution of code in this way, but a more comprehensive approach is needed *(later in the course)*

# Security and permission

- Request/user should have permission to do the action *(more on this later in the course)*

```
DELETE /reservations
HTTP request body: { resId: 1234 }
```

  - The API requires a DELETE into a DB, with foreign key `resId`: can the action be performed?
  - Only the API server can determine if it is permitted or not, it cannot be told by the client
  - The server must retrieve `user` and/or its authorizations in a secure manner
    - e.g., via cookie, token etc. – more on this later in the course
  - The operation is executed by checking the authorization
    - Via code: `if (reservationOwner(resId) == user) delete(…); // Check before delete`

    or
    - Via SQL: `DELETE FROM reservations WHERE userId = user & resId = 1234;`

# Security and permission

- Request/user should have permission to do the action *(more on this later in the course)*

```
DELETE /reservations
HTTP request body: { resId: 1234 }
```

  - The API requires a DELETE into a DB, with foreign key `resId`: can the action be performed?
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  - The server must retrieve **`user`** and/or its authorizations in a secure manner
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  - The operation is executed by checking the authorization
    - Via code: `if (reservationOwner(resId) == user) delete(…); // Check before delete`

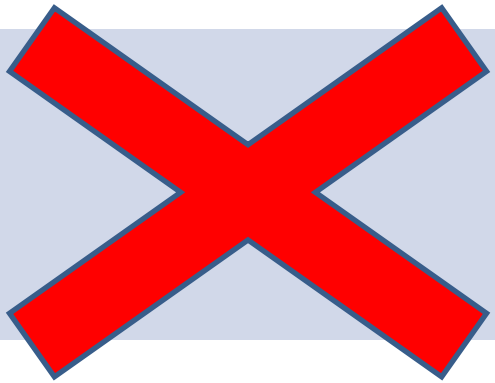
    or
    - Via SQL: `DELETE FROM reservations WHERE userId = user & resId = 1234;`

Main source of errors at exam, **big vulnerability if wrong!**

# Synchronization issues

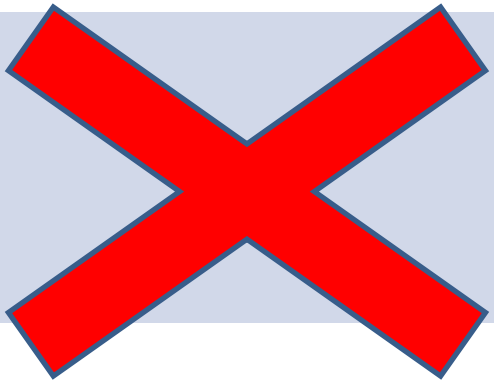
- Web applications are **multi-user and concurrent by definition**
- The backend implementation is independent from the client part
  - In can be implemented in any language, using any framework/DB/…,
    NOT ONLY node.js/express
- All actions that may change their output due to potential interference from other actions (started by us or others) should be requested using a single API call
- Example: bid in an auction

```
GET /bestOffer
HTTP response body: 100
…
PUT /bestOffer
HTTP request body: 105
```

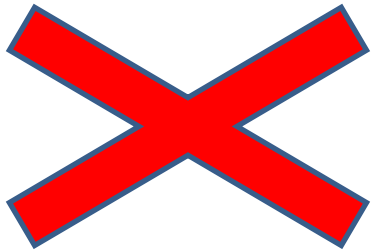


# Synchronization issues

```
GET /bestOffer
HTTP response body: 100
…
PUT /bestOffer
HTTP request body: 105
```



- The first API requires to retrieve the current best offer
- The client processes the value and decide the new price to offer
- The second API overwrites the old best offer with the new value



- What if another client do the same between the two calls? Race conditions may happen yielding wrong behavior

# Synchronization issues

- Design a single API that implement the requested operation in a single HTTP transaction, ending with either success or failure

```
POST /newOffer
HTTP request body: 105
HTTP response body: {status: 'accepted', bestOffer: 105}
```

```
POST /newOffer
HTTP request body: 105
HTTP response body: {status: 'rejected', bestOffer: 110}
```

- Note that the client does not know and SHOULD NOT know how the server implements the requested functionality

# Synchronization issues

- In this course we decided to use node.js (which serializes operations), so the operation can be implemented as follows:
  - Via a single SQL query:
    ```
    UPDATE offers SET offer=MAX(offer,newOffer) WHERE … ;
    ```
  or
  - Via code, especially when update operations are complex to code in SQL:
    ```
    let offer=bestOffer();          // Run: SELECT FROM offers WHERE …
    if (newOffer > offer)
       updateOffers(newOffer);      // Run: UPDATE offers SET price=…
    else
       returnFailure();             // Communicate that it is not possible
    ```

NB: **Only for this course, only for simplicity, the SQL queries executed in the code of the same API** will be assumed to be executed sequentially without external interference

# Synchronization issues

- Other examples
  - Increment a counter, resource reservation (places/seats), purchase operations, applying discounts (avoid applying it multiple times) ...

```
POST /addLike

POST /bookSeats
HTTP request body: [ A2, B3, B4 ]

POST /buyItems
HTTP request body: [ {itemId: 43, qty: 3}, {itemId: 88, qty: 1} ]
```

For more details, see e.g.: https://portswigger.net/web-security/race-conditions

# Web Application Security: References

- OWASP (Open Worldwide Application Security Project): owasp.org
  - OWASP **Input validation** cheat sheet
  - OWASP **SQL injection** prevention cheat sheet
    - Testing for SQL injection
  - First line of defense could also be external to your application
    - Set of OWASP generic **attack detection rules** to be included in web application firewalls
  - **Race conditions** can be used by attackers
    - https://portswigger.net/web-security/race-conditions
    - Session puzzling

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