# #6 – Broken Authentication

# OWASP A2 – Broken Authentication

- Application functions related to **authentication** and **session management** are often implemented incorrectly

- Allow attackers to **compromise passwords, keys, or session tokens**, or to **exploit other implementation flaws**

- Attackers may **assume other users' identities** temporarily or permanently.

# OWASP A2 – Broken Authentication

- Prevalence is widespread
  - due to the operation of most identity and access controls.

- Session management is the bedrock of authentication and access controls
  - present in **all stateful applications**

- Attackers can detect broken authentication using **manual means**

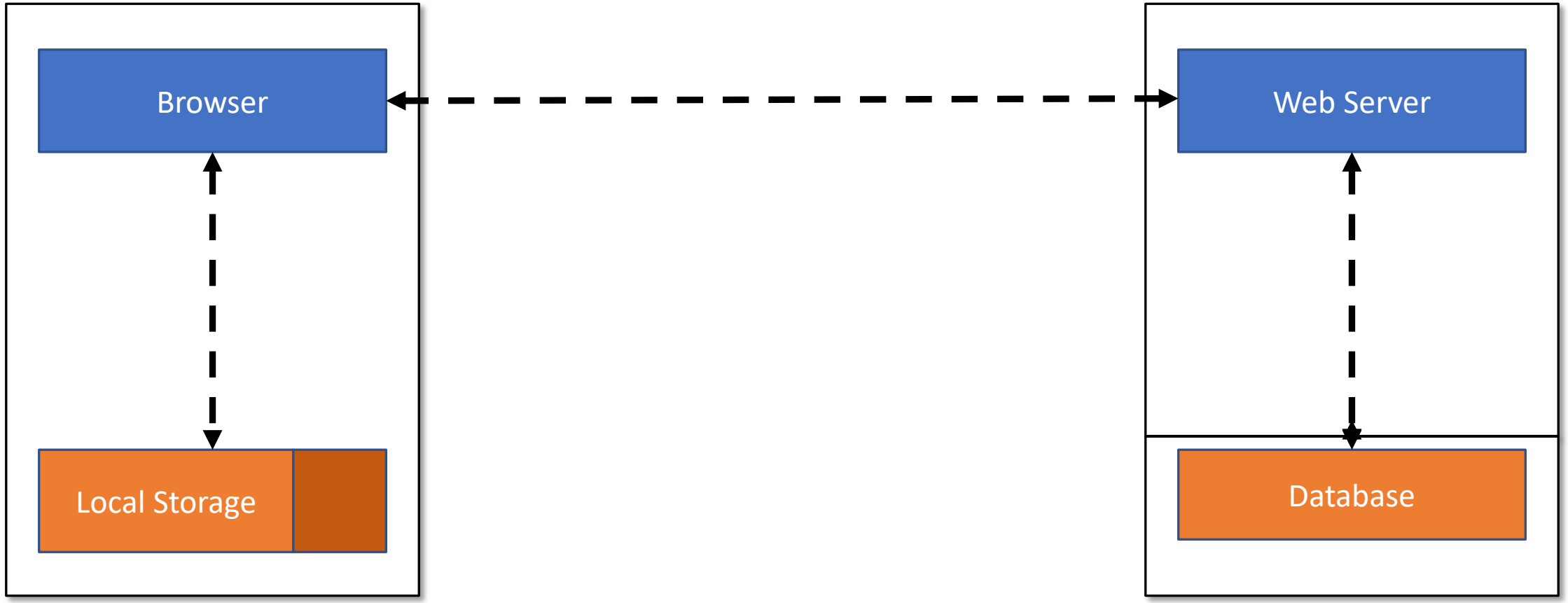
- Attackers can exploit them using automated tools
  - **There are extensive password lists and dictionary attack tools**

# Changes in the OWASP ranking

- Services evolving from monolithic server applications to microservices
  - Proliferation of HTTP and REST to implement APIs
- Applications are evolving to Progressing Web Applications
  - Single HTML page for entire application
  - Lots of Javascript based logic
  - Resources provided through REST APIs
  - Services exposed to the Internet, used directly by clients
- Impact
  - Logic is moving towards clients
  - State anchors are kept in the clients

# HTTP Basics

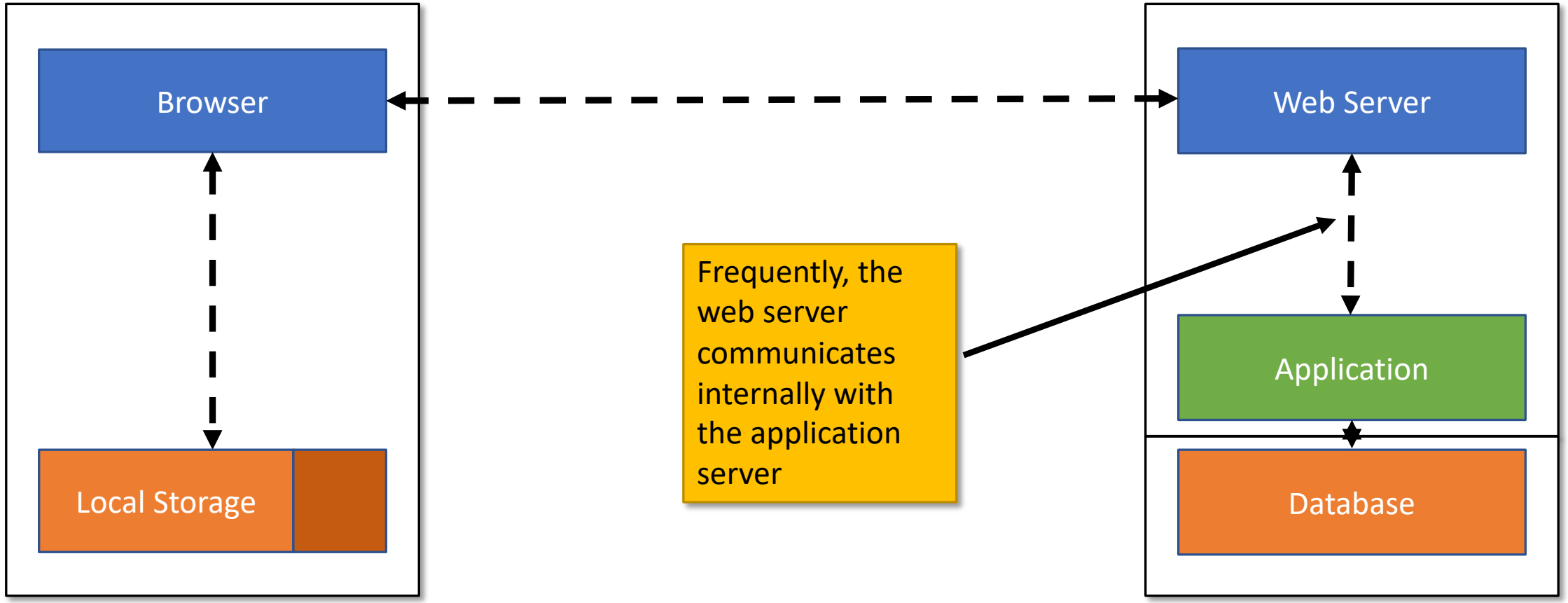
# The Web



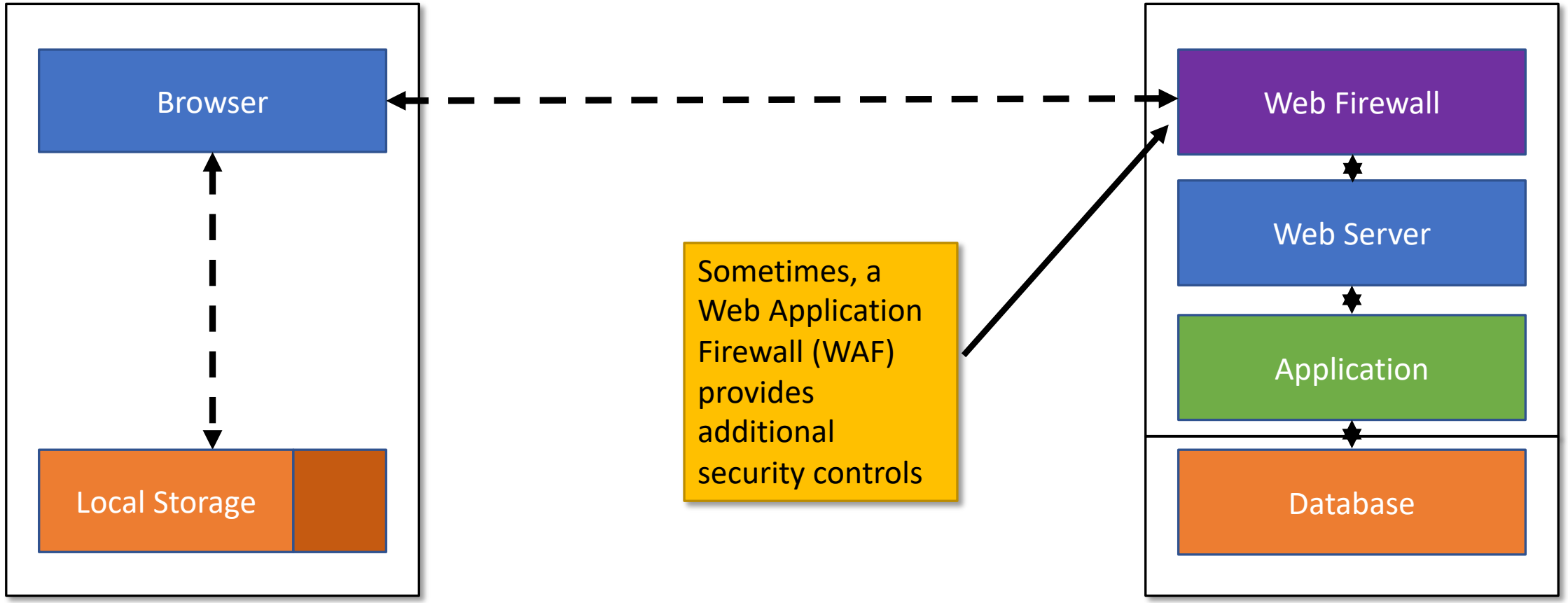

Local storage contains user data inside and outside the browser

Database frequently is on a different host

# The Web


Browser
Local Storage
Web Server
Application
Database
Frequently, the web server communicates internally with the application server

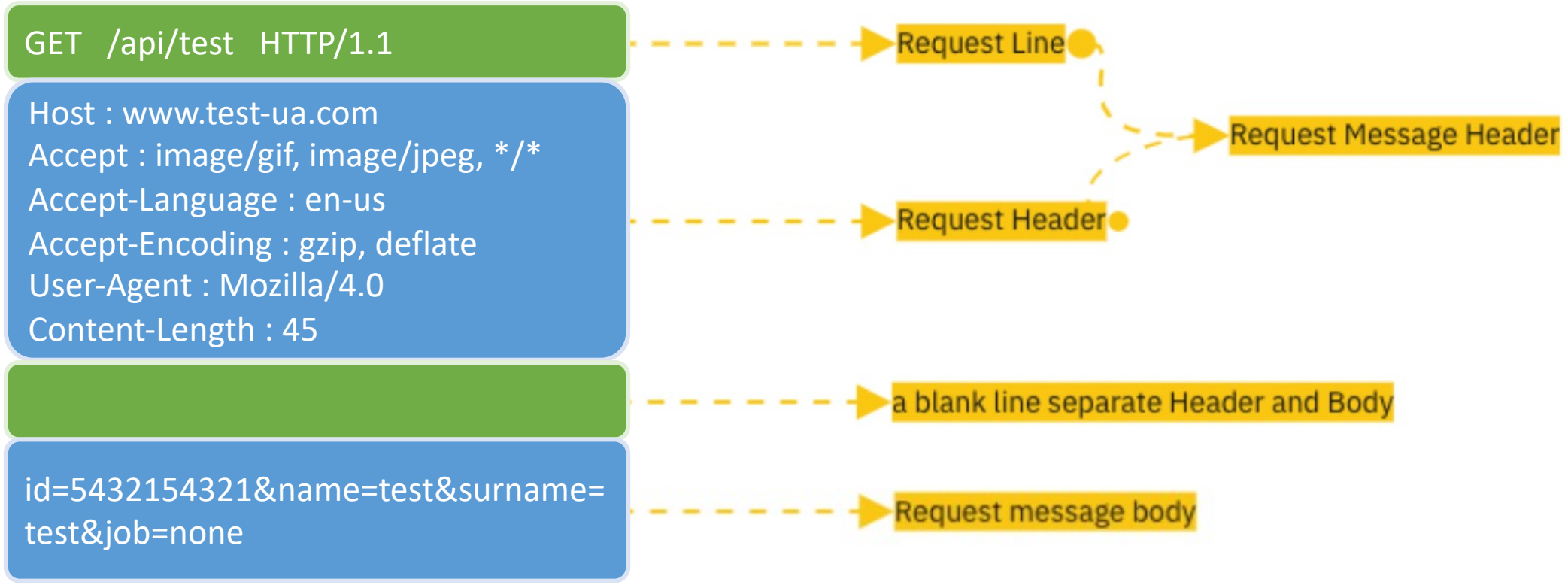
# The Web


Browser
Local Storage
Sometimes, a Web Application Firewall (WAF) provides additional security controls
Web Firewall
Web Server
Application
Database

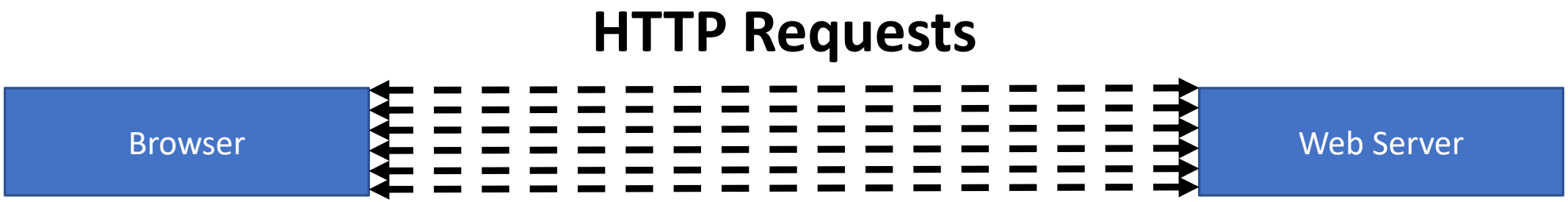
# A Web Request


1. Browser asks DNS for the IP address of server.com
2. Browser connects to TCP port 80/443 of server.com
3. Browser sends a request with:
    1. Action: GET, POST, PUT, DELETE
    2. URL: http://server.com
    3. Headers: language, compression, user-agent…

# HTTP Structure



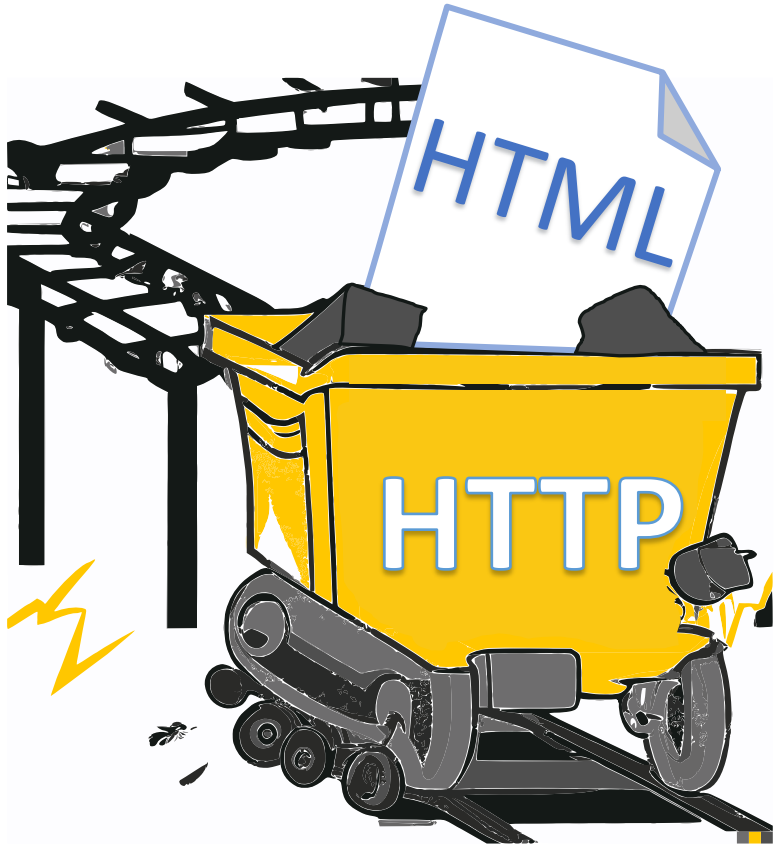
# Multiple Web Request




- HTTP is stateless by design
- HTTP Requests are independent of each other
  - Each triggering an individual action
  - Usually **tokens** or **cookies** are included in requests/responses to keep state

# HTTP and HTML

- HTTP is not related with HTML
  - You can have HTTP without HTML, and vice versa
- HTTP is a generic transport protocol
  - Usually operated over TCP on port 80 or 8080
- HTML is a language
  - used to define the structure of a web page



# HTTP Communication

- HTTP is a standard Client-Server protocol
  1. Client establishes a TCP connection with the server on port 80
  2. Client sends a HTTP request over that TCP connection
  3. Server replies
     - Sends a response
     - HTTP 1.0: Closes the connection
     - HTTP 1.1/2: May keep it *persistent* for some time

- Server only issues replies to requests
  - It may never contact clients directly

image: https://ruslanspivak.com/

# HTTP Communication

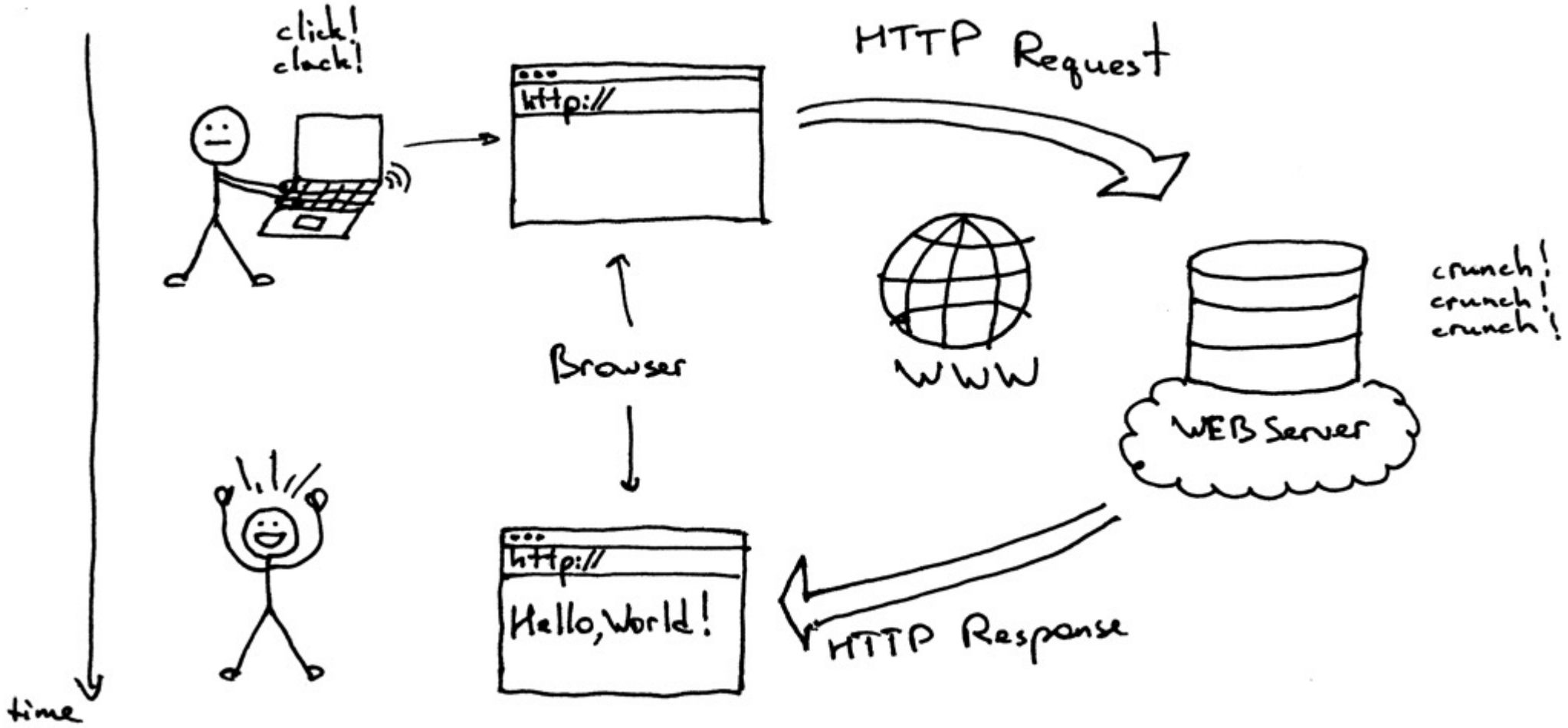
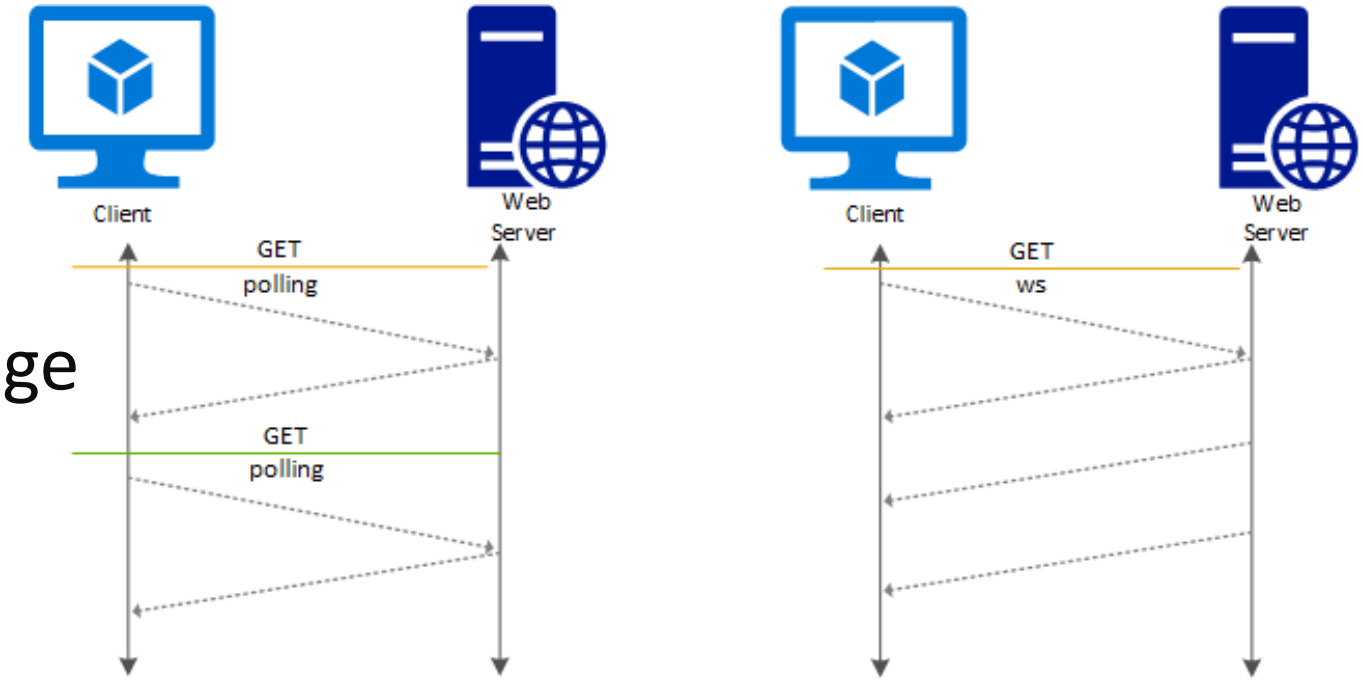


image: Microsoft.com

# HTTP Communication

- Actually… servers can contact clients directly with WebSockets
  - Great for low latency asynchronous communications (e.g. VoIP, telemetry)
  - Nightmare for security!
- Client upgrades connection to a WebSocket
- Any participant can send message
  - No polling is required
    Usually no log is done
  - Client and server must know the message format



# HTTP Request

```
$ curl https://elearning.ua.pt  -D - -v


GET / HTTP/1.1
Host: elearning.ua.pt
User-Agent: curl/7.68.0
Accept: */*
```

HTTP Request

# HTTP Response

```
$ curl https://elearning.ua.pt  -D - -v

HTTP/1.1 200 OK
Date: Thu, 12 Nov 2020 17:01:16 GMT
Server: Apache
Set-Cookie: MoodleSession=qvnej3ar6u28ndar312jhg1veh; path=/
Expires: Mon, 20 Aug 1969 09:23:00 GMT
Cache-Control: no-store, no-cache, must-revalidate
Pragma: no-cache
Cache-Control: post-check=0, pre-check=0, no-transform
Last-Modified: Thu, 12 Nov 2020 17:01:16 GMT
Accept-Ranges: none
```

**HTTP Response**

With server timestamp
Cookie, Cache control

# Anything can be a client

```
$ echo -ne 'GET / HTTP/1.1\r\nHost: elearning.ua.pt\r\nUser-Agent: Android
10\r\n\r\n' | ncat --ssl elearning.ua.pt 443

HTTP/1.1 200 OK
Date: Thu, 12 Nov 2020 17:20:12 GMT
Server: Apache
Set-Cookie: MoodleSession=ooma3far88iqh9nvssn598nsuu; path=/
Expires: Mon, 20 Aug 1969 09:23:00 GMT
Cache-Control: no-store, no-cache, must-revalidate
Pragma: no-cache
Cache-Control: post-check=0, pre-check=0, no-transform
Last-Modified: Thu, 12 Nov 2020 17:20:12 GMT
Accept-Ranges: none
```

# Anything can be a client

- Many programs can communicate with HTTP servers
  - A socket is all that is required

- Even Bash can do it

```
$ exec 5<>/dev/tcp/193.136.173.58/80
$ echo -e "GET / HTTP/1.1\r\nHost: www.ua.pt\r\n\r\n" >&5
$ cat <&5

HTTP/1.1 301 Moved Permanently
Server: nginx/1.18.0
Date: Thu, 12 Nov 2020 17:26:58 GMT
Content-Type: text/html
Content-Length: 169
Connection: keep-alive
Location: https://www.ua.pt/
```

Open TCP to 193.136.173.58:80 into FD5
Write to FD 5
Read from FD 5

# Anything can be a client

- There is no client-side security model

- All parts of a request can be crafted
  - HTTP Headers, Methods, URLs
  - POST content can be manipulated freely

- Control must reside in the server-side context
  - Remember that developers are pushing content to the client? ☺

- There are no input validation processes in the server
  - As long as the HTTP protocol is “generally” observed

# Authentication

# Authentication - Recap

- Authentication aims to determine the identity of an entity
  - Entity may be user, system, software

- The basic process relies in the verification of some property of the authenticated entity by the authenticator
  - Something that he has
  - Something that he knows
  - Something that he is

# Authentication - Recap

- What else can be used?

# Authentication - Recap

- Somewhere where he is (location)
- Someone that is close by (neighborhood)
- Something that he has done (past behavior)

- A combination of several
  - 2FA – Two Factor Authentication (e.g. Secret + Cookie)
  - MFA – Multiple Factor Authentication (e.g. Secret + Cookie + Smartphone)

# Base HTTP methods

- Makes use of the Authorization header
  - Header is passed to applications as well as user
  - May require password to be in clear text
  - Presents no configurable user interface

- Basic authentication through direct presentation of credentials
  - `Authorization: Basic base64(login:password)`

# Base HTTP methods

- Digest authentication
  - Server replies with the authentication arguments in the WWW-Authenticate

```
Authorization: Digest username="Mufasa",
                      realm="testrealm@host.com",
                      nonce="dcd98b7102dd2f0e8b11d0f600bfb0c093",
                      uri="/dir/index.html",
                      qop=auth,
                      nc=00000001,
                      cnonce="0a4f113b",
                      response="6629fae49393a05397450978507c4ef1",
                      opaque="5ccc069c403ebaf9f0171e9517f40e41"
```

# Authentication Flow state

# Sessions

- HTTP is stateless and provides no way of keeping state
  - Besides WebSockets in HTML5
- Most applications over HTTP need state for good purposes
  - User preferences
  - Navigation history
  - Authentication state
- Some use it for less noble purposes, usually compromising privacy
  - Track users across multiple sites for advertising purposes
  - Profile user behavior

# Flow State keeping mechanisms

- Referer header
- SESSION_ID, or SID or other custom headers
- Cookie
- JSON Web Token (jwt)

# Use of the URL

```
GET /internal/private.html?pass=secret&sid=234234 HTTP/1.1
Host: www.company.com
```

- Input encoded as part of the URL as Request Arguments
- GET request is expected to have side effects
  - Arguments control language, authentication, authorization

# Use of the URL

**Should be avoided at all cost to transport state**

- Arguments are visible in the browser
  - A use problem if your browser is visible: public presentation, remote lecture, over the shoulder eavesdropping
- Arguments may be logged by the webserver
  - Enable compromise if logs are accessed by an attacker
- SEO is broken: different users will have a different URL for the same resource
- Cache may be impacted: unique URLs limit the use of caches

# Use of a POST request

```
POST /doLogin HTTP/1.1
Host: company.com
Pragma: no-cache
Cache-Control: no-cache
User-Agent: Mozilla/5.0 (Windows 10)
Referer: http://company.com/login
Content-Length: 34

username=john&password=supersecret
```

- URL visible on the browser: http://company.com/doLogin

# GET vs POST

- **GET** is used to REQUEST information
  - Can be resent by browsers
  - May be logged, cached, bookmarked, kept in the browser history
  - Should not change server-side state (no side-effects)
    - Frequently it will change state, or create logs
- **POST** is used to UPDATE information
  - Will not be cached, bookmarked, kept in browser history
  - May not be logged
  - Is not visible to users
  - Is expected to change server-side state (has side effects)

# Referer Header

- The Referer request header contains the address of the page making the request.

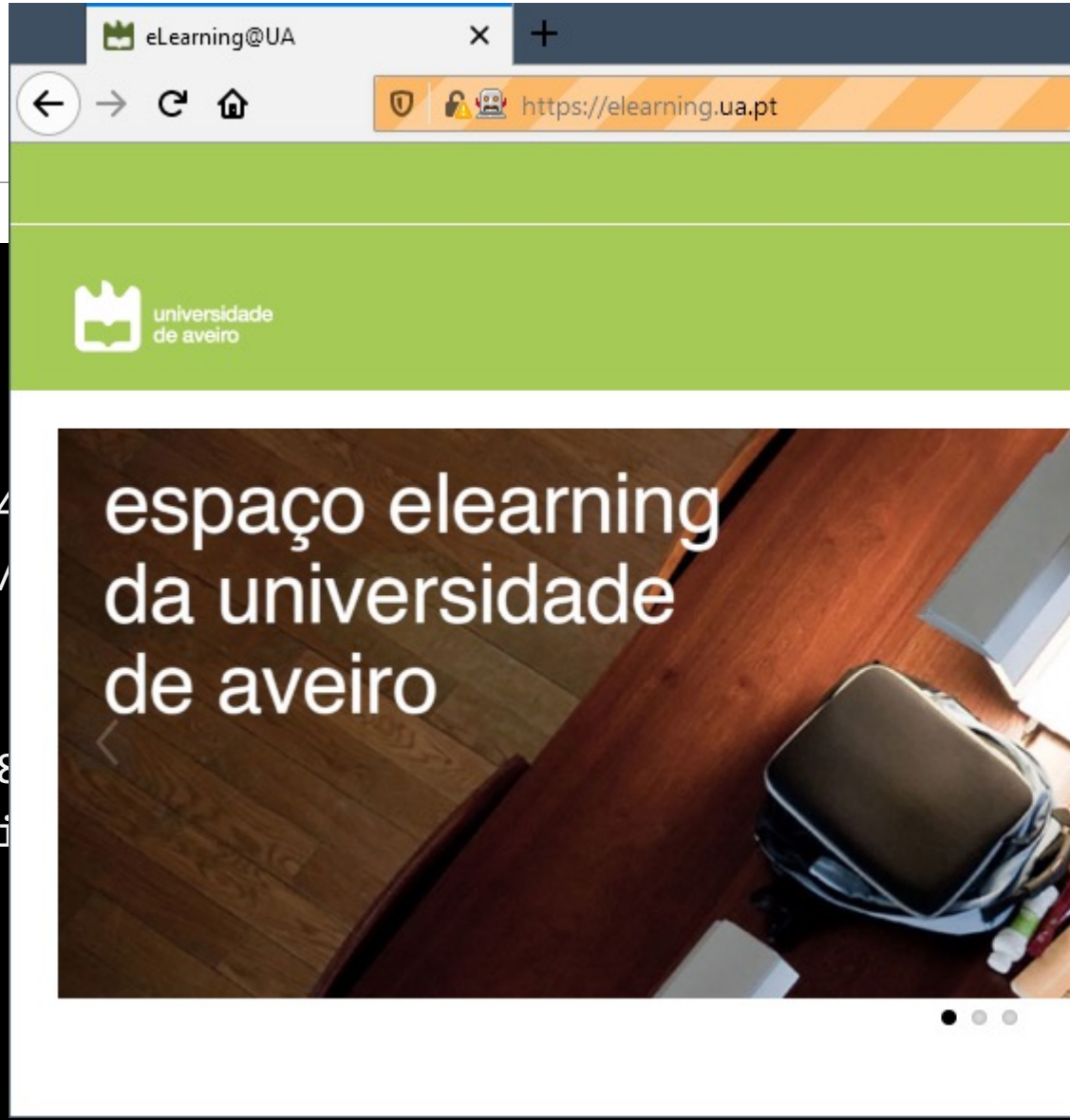
- The Referer header allows servers to identify where people are visiting them from
  - may use that data for analytics, logging, or optimized caching
  - Sometimes used for access control

- Fully user controllable

# Referer Header

- First hit: No Referer

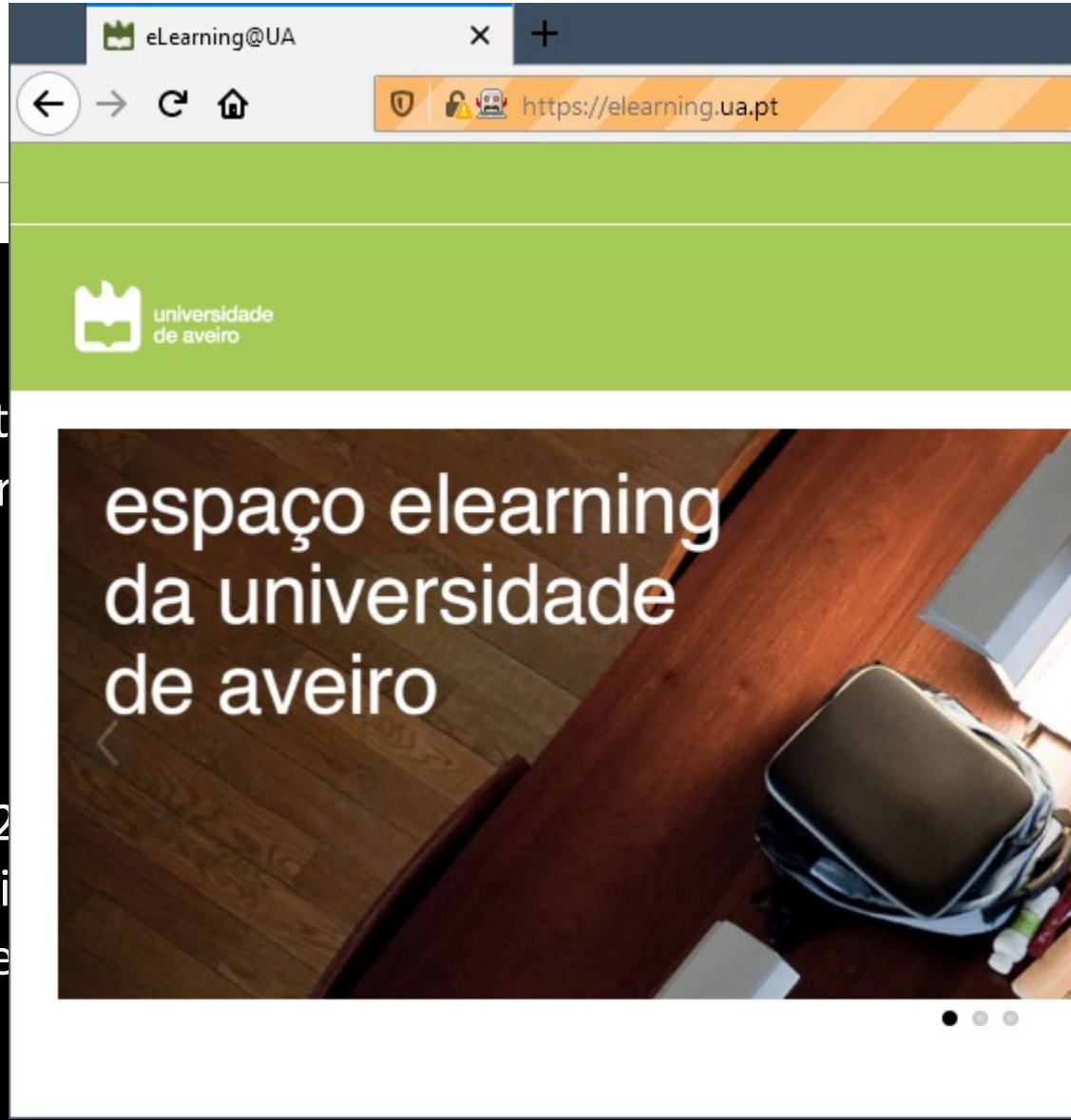
```
GET https://elearning.ua.pt/ HTTP/1.1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64
Accept: text/html,application/xhtml+xml,application/
Accept-Language: en-US,en;q=0.5
Connection: keep-alive
Cookie: _ga_RWZB1HRVYE=GS1.1.1605202432.1.1.16052028
_gid=GA1.2.1334581424.1605202436; _hjTLDTest=1; _hji
_hjFirstSeen=1; _hjAbsoluteSessionInProgress=0
Upgrade-Insecure-Requests: 1
Host: elearning.ua.pt
```



# Referer Header

- Subsequent request

```
GET https://elearning.ua.pt/theme/adaptable/style/print
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; r
Accept: text/css,*/*;q=0.1
Accept-Language: en-US,en;q=0.5
Connection: keep-alive
Referer: https://elearning.ua.pt/
Cookie: _ga_RWZB1HRVYE=GS1.1.1605202432.1.1.16052
_gid=GA1.2.1334581424.1605202436; _hjTLDTest=1; _hji
_hjFirstSeen=1; _hjAbsoluteSessionInProgress=0; Moodle
Host: elearning.ua.pt
```



# Referer Header

```
GET /internal/private.html HTTP/1.1
Host: www.company.com
Referer: http://www.company.com/loggedin/
```

- Expected meaning: User accessing `/internal/private.html`, and came from `/loggedin` therefore it was authenticated
- In reality
  - Referer header MAY be set by the browser
  - Was meant for origin authentication, is used for authorization
  - Falls in the TOCTOU: Time-of-check time-of-use

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# SESSION ID

- A value, set by the server in the HTML/Javascript
  - Kept manually by the HTML/JS logic
  - Browser is unaware of it
- URLs in the HTML include the SESSION ID

```
<a href=http://company.com?PHPSESSION=value>resource</a>
```

- SESSION ID added to requests
  - Header or explicit argument in GET actions
  - Header or body in POST actions

# Cookies (RFC 6265)

- ASCII text created by the server and sent to the client
  - HTTP Header - Set-Cookie: VALUE
- Stored in the clients' cookie jar
  - A file or simple database
  - The client may freely delete (or edit) cookies
- Client resends the **`Cookie`** header to servers
  - in every request made for which there is a compatible cookie
  - Format is: **`Cookie: VALUE`**

# Cookies (RFC 6265)

- Server can keep context using the cookie provided
  1. Receives a Cookie from the client
     - Cookie can contain the session identifier
  2. Fetches context (session)
  3. Provides a customized answer

- Cookies are used as a token enabling authorization
  - When set as the result of an authentication process
  - Allow obtaining the identity associated with the request

- Loosing a Cookie opens the door to *impersonation*

# Cookies (RFC 6265)

- Cookie scope and lifetime are set by the server in the client response

```
Set-Cookie: <nome-cookie>=<valor-cookie>
Set-Cookie: <nome-cookie>=<valor-cookie>; Expires=<date>
Set-Cookie: <nome-cookie>=<valor-cookie>; Max-Age=<non-zero-digit>
Set-Cookie: <nome-cookie>=<valor-cookie>; Domain=<domain-value>
Set-Cookie: <nome-cookie>=<valor-cookie>; Path=<path-value>
Set-Cookie: <nome-cookie>=<valor-cookie>; Secure
Set-Cookie: <nome-cookie>=<valor-cookie>; HttpOnly
Set-Cookie: <nome-cookie>=<valor-cookie>; SameSite=Strict
Set-Cookie: <nome-cookie>=<valor-cookie>; SameSite=Lax
```

# Cookies (RFC 6265)

- Client -> Server
  No cookie sent

- Server -> Client

```
Set-Cookie: MoodleSession=0r6mroovg98o338clahfd177g0; path=/
```

- Client -> Server

```
Cookie: MoodleSession=0r6mroovg98o338clahfd177g0
```

# JWT - JSON Web Tokens

- Concatenation of 3 texts
  - base64(header) + '.' + base64(payload) + '.' + base64(signature)
  - signed with a HMAC or Asymmetric crypto (RSA)

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

payload = {"loggedInAs" : "admin","iat" : 1422779638}

signature=HMAC-SHA256(secret,base64(header)+'.'+base64(payload))
```

# JWT - JSON Web Tokens


1 Header

```
{
      “alg”: “HS256”,
      “typ”: “JWT”
}
```

2 Payload

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

3 Signature

HMACSHA256(
BASE64URL(header)
.
BASE64URL(payload),
secret)

# JWT - JSON Web Tokens

- Provide mechanisms for token refresh, limiting impact due to a lost token
- Access Token – JWT Token that authorizes the user – very limited lifespan
  - Is used in every request and has higher exposition
- Refresh Token – Random Token only to refresh Access Token
  - Only used to refresh the Access Token
  - Longer lifetime
- After all tokens expire, the authentication process must be restarted

```
payload = {"loggedInAs" : "admin","iat" : 1422779638}
```