Security

He said “One day, you’ll leave this world behind,
so live a life you will remember”
- The Nights (Avicii ft. Nicholas Furlong)

Outline

1. Concepts
2. Attacks
3. Authentication & Authorization
    - Basic Auth
    - Session Cookie Auth
    - Token-based Auth
    - Case Studies

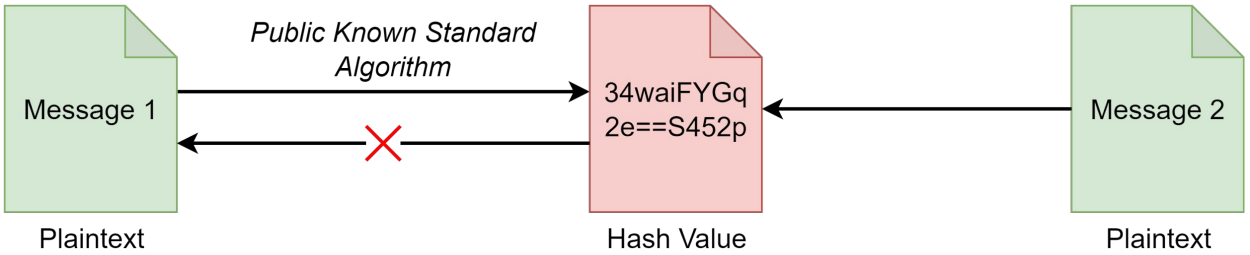
1. Concepts

1.1. Encoding

- Encoding is a technique to transform data from one format to another so that it can be consumed by different systems.
- Encoding is a **reversible process without information loss**
- Encoding has **no security purpose**
- Example:
  - Pineapple (UK) → Dứa (North of Vietnam) → Thơm (South of Vietnam)
  - Serialization: Object ←→ binary
  - URL encoding
  - JWT ← decoding/encoding → Base64

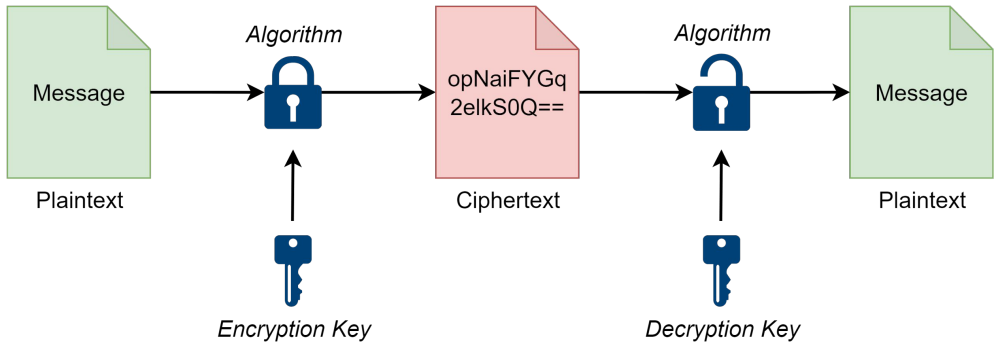
1.2. Hashing

- Hashing is the process of mapping any arbitrary size data into a **fixed-length value** using a hash function.
- Hashing is **not a reversible process**. It must not be possible to obtain the input from the output data.
- Hashing ensures data integrity. Check if data is modified?
- **Collision: two distinct input has the same hash value**
- Avoid Collision → Good Hash Function



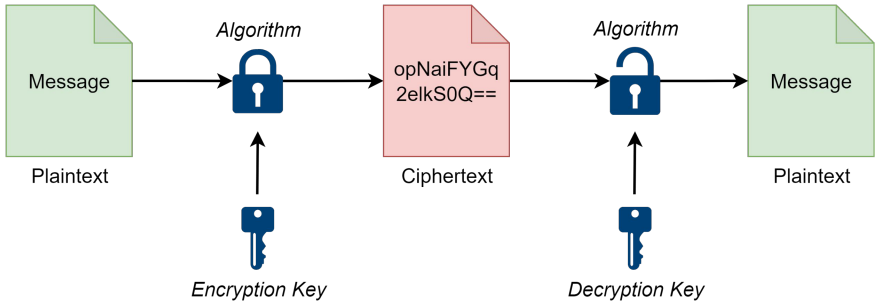
1.3. Encryption

- Encryption **secures data** using mathematical techniques (aka cryptography)
- The input plaintext is converted into a **unreadable ciphertext** using algorithm and hard to decode.
- Encryption is a reversible process as well, although just for authorized people.
- Encryption algorithms need encryption keys as input. The encryption key and decryption key may be different.



1.3. Encryption

- Two families of key-based encryption:
  - **Symmetric Encryption**:
    - Use the same key to encrypt and decrypt data
    - Ex: AES algorithm
    - **Faster but less secure**
  - **Asymmetric Encryption**:
    - The encryption key and decryption key are different.
    - Ex: RSA algorithm
    - **More secure but lower**



1.4.1. Encryption vs Hashing

- Context: Ronin Engineer integrates with a payment gateway.
- Requirement:
  - Initialize a payment request without sensitive information
  - **Integrity**: Make sure that the request is not modified while being sent
  - **Authenticity**: Make sure that requestor is Ronin Engineer
- Hash with secret key. Example: HMACSHA512

1.4.2. Encryption vs Hashing

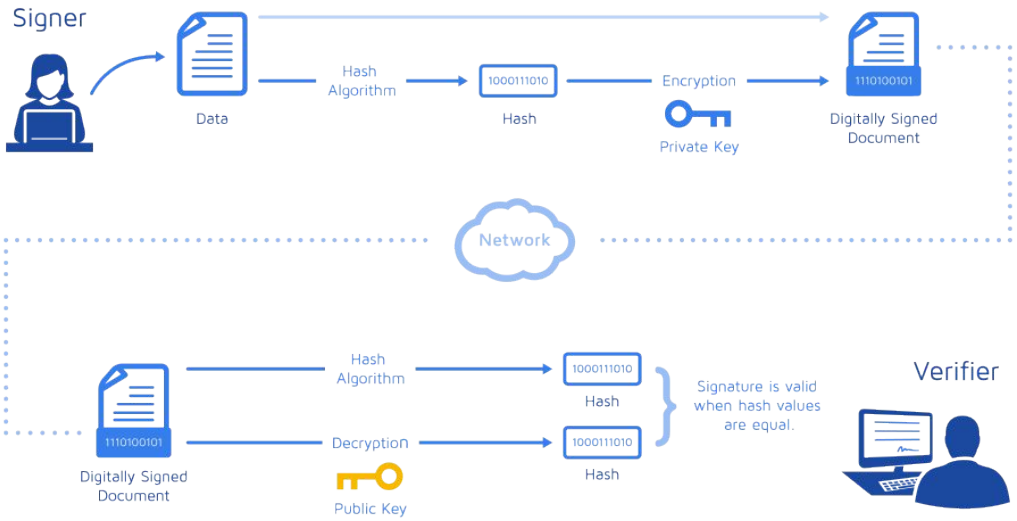
	Encryption	Hashing
Purpose	**Protect data confidentiality**	**Data integrity**
Reversibility	**Yes**	**No**
Key Usage	Yes	No
Output Length	**Variable length**	**A fixed length**
Collision	**No**	**Yes**
Cost	**Medium, high**	**Low**
Use cases	Securing data during transmission or storage, protecting sensitive information. Ex: Credit card, personal message	Data verification, data deduplication, indexing. Ex: Hash index, Password storage, Digital Signature

1.4.3. Applications of Encryption vs Hashing

- Encryption
  - AES-256: encryption for files, databases, and end-to-end communication
  - RSA: Digital signatures
  - …
- Hashing
  - BLAKE2: integrity verification
  - SHA-256: digital signatures
  - Scrypt: password hashing
  - MD5, SHA-1: Strong checksum
  - …

1.5. Digital Signature

- Purpose: Ensures that data has not been modified
- Message: Data + Digital Signature



1.6. Case Study: Password Storage

- Do not store password in plaintext
- Use hash because attacker can not obtain the original value
- MD5, SHA-1 are fast but less secure
  → Not recommended
- **Scrypt: slow but safe**
  → Make brute force attacks impossible
- Bcrypt is legacy nowaday.

- Problem: Rainbow Table

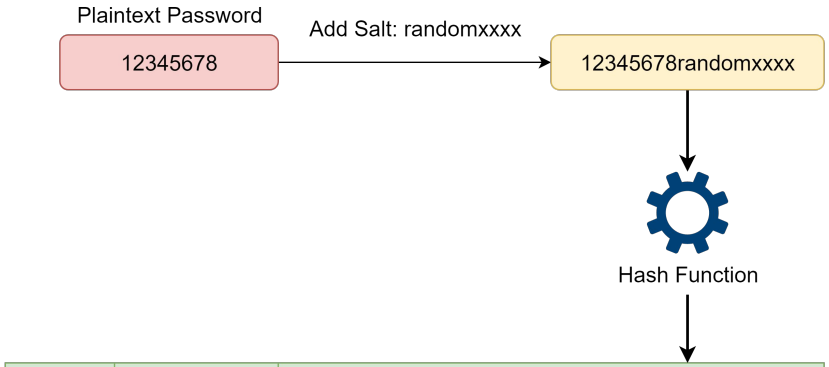
ID	Hash Password	Original Password
U1	$2y$10$PobNNUv/5xKD35XzCGtp.r2gnOageSR.1Q.	admin123

Rainbow Table

Password	Hash Password
123456	$76$7I$PobNNUv/5xKD35XzCGtp.r2gnOageSR.6Y.
babyshark	$6u$rt$PobNNUv/5xKD35XzCGtp.r2gnOagevbnfg.
admin123	$2y$10$PobNNUv/5xKD35XzCGtp.r2gnOageSR.1Q.

1.6. Case Study: Password Storage

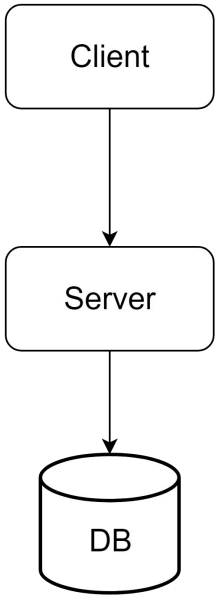
- Solution: Add random salt for each record



ID	Salt	Hash Password
U1	randomxxxx	$2y$10$PobNNUv/5xKD35XzCGtp.r2gnOageSR.1Q.
U2	34fgde345p	$xcvde$PobNNUv/5xKD35XzCGtp.r2gnOage67gh5.

1.7. Case Study: Personal Data Encryption

- Problem: Where should Encryption be performed?
  - Client Side
  - Server Side
  - DB
- Solution:
  - **Encryption in Server Side**
  - Flexible
  - Reduce workload for DB
  - Recommended Algorithm: AES-256



1.7. Case Study: Personal Data Encryption

- Problem: Should Ciphertext is stored in Binary or String (Base64)
- **Solution: Binary**
  - String:
    - Portable: supported in JSON, XML, URL, …
    - Size: Base64 String increases its size ~33%
  - Binary:
    - Direct use: Ciphertext (output) is binary, network transmission
    - More space-efficient

1.7. Case Study: Personal Data Encryption

- Problem: How to search encrypted data?
- Solution:
  - Blind Index
  - No support for fulltext search

2. Attacks

2.1. Man-In-The-Middle-Attack

- How it works?
  - An attacker intercepts and potentially alters a communication between two systems without their knowledge or consent.
- How to defend?
  - Encrypted connection (SSL/TLS)
  - Verify Certificates
    - Client-Server using CA
    - **BE-BE: using private key (HTTPS is not safe at all)**
  - Request id prevent from replay attack

2.2. SQL Injection

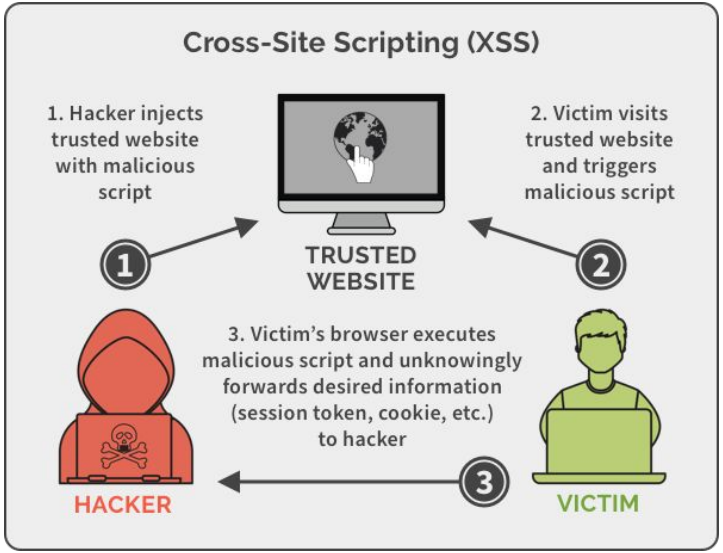
- How it works?
  - An attacker inserts malicious SQL into input fields by a web application so that attacker can manipulate the application's SQL query to execute harmful actions (retrieve, modify data)
  - Demo: OWASP Juice Shop
- Original SQL: SELECT * FROM users WHERE username = ‘?’ AND password = ‘?’;
- Attacked SQL: SELECT * FROM users WHERE username = ‘' or 1 =1 ; –’ AND password = ‘?’;

2.2. SQL Injection

- How to defend?
  - Prepared statement: These techniques separate SQL code from user input, making it harder for attackers to inject malicious code.
  - **Input validation**
    - Whitelist params
  - Minimize necessary permissions to the account that web app use

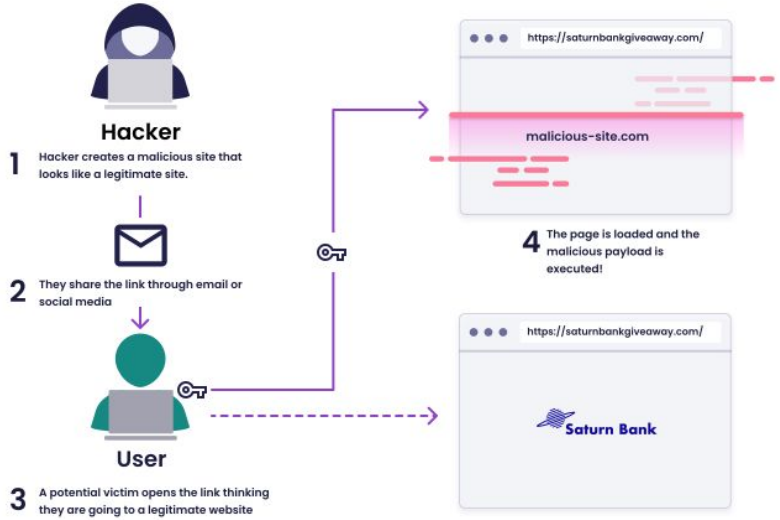
2.3. XSS (Cross-Site Scripting)

- How it works?
  - An attacker injects malicious scripts into web pages.
  - User view the web page → these scripts are executed within a user's web browser
  - Stealing sensitive data
  - Demo: Cross-site Scripting
- How to defend?
  - Input Validation
  - **Output Encoding**: Escape for specialization characters
  - Content Security Policy (CSP) allows you to **specifically whitelist URLs from which dynamic scripts can be loaded**

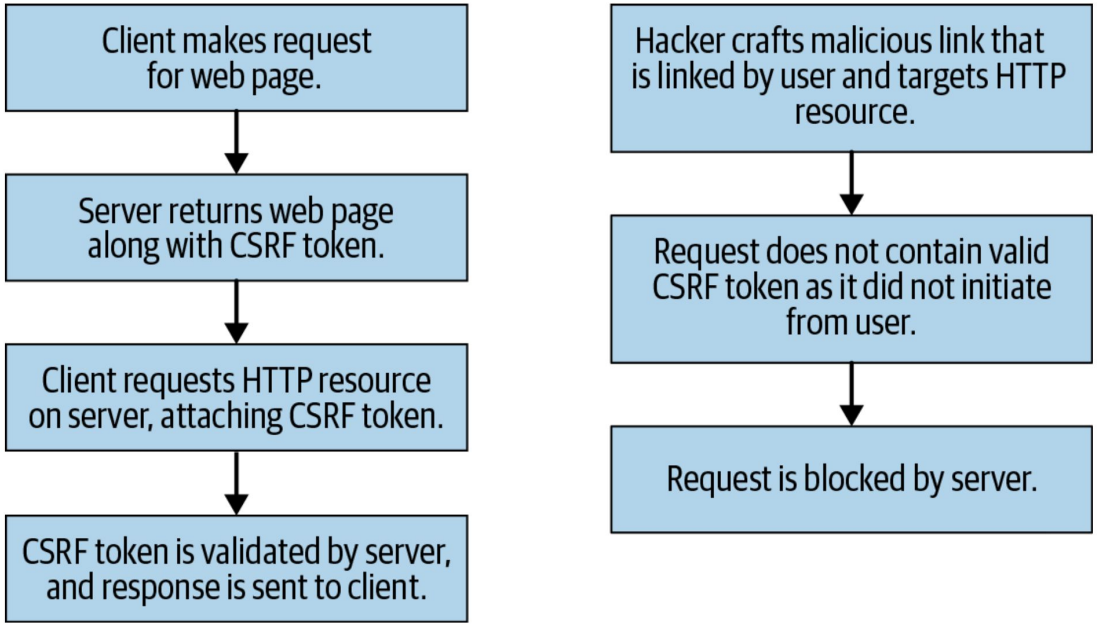


2.4. CSRF (Cross-Site Request Forgery)

- How it works?
  - An attacker tricks a user into performing actions on a website without their consent or knowledge.
  - Demo: [Cross-site Request Forgery]
- How to defend?
  - **Stateless GET Requests**
  - User Prompts: When performing sensitive actions, ask the user for confirmation, such as re-entering their password.
  - **CSRF token**

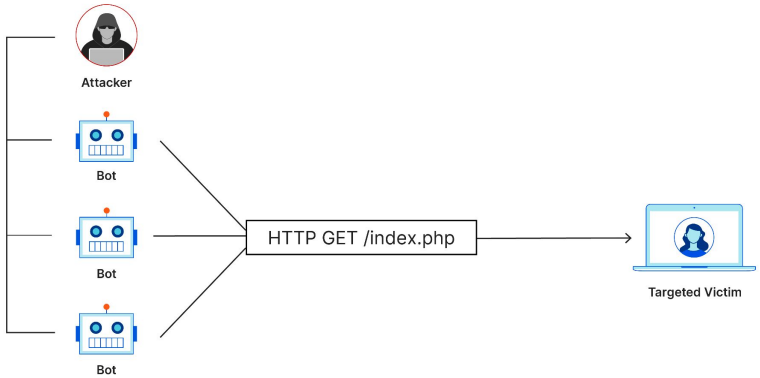


2.4. CSRF Token



2.4. DDoS (Distributed Denial-of-Service)

- How it works?
  - Botnet: pc, mobile, IoT devices, …
  - Robot + Network = Botnet
- How to defend?
  - **DDoS attacks cannot be prevented, but can be mitigated**
  - Bandwidth Management Services: many vendors on the market, but ultimately perform analysis on each packet as it passes through their servers.
  - **Rate limiting**
  - **CDN (caching)**
  - Blackhole filtering: hard to get high accuracy



3. Authentication & Authorization

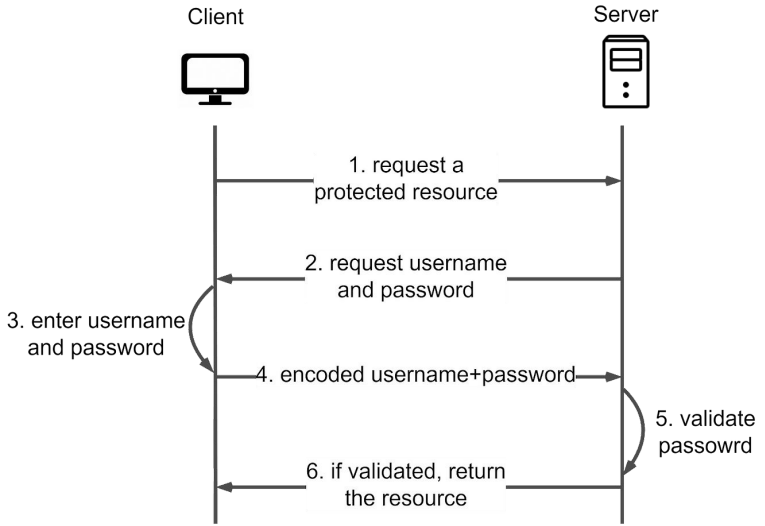
3.1. Definition

- **Identity**: Identity refers to the **unique** attributes that define an entity
- **Authentication**: the process of verifying **who a user is**
- **Authorization**: the process of verifying **what they have permission to**
- Example: a flight
  - Authentication: when you go through security gate, showing your ID card to tell who you are
  - Authorization: when you go through terminal gate, showing your flight ticket to tell you have permission to board your flight

3.2. Basic Auth

- Requires to provide a username and a password when requesting a protected resource.
- Encoded Credential = **Base64(username:password)**
- Header: “Authorization: Basic dXNlcm5hWU3d2vcmQ=”
- Alternative for BE-BE: API Key
- Limitations:
  - **Username and password can be easily decoded**
  - Authorization header is attached to each request

    → **Not track user login status → poor UX**

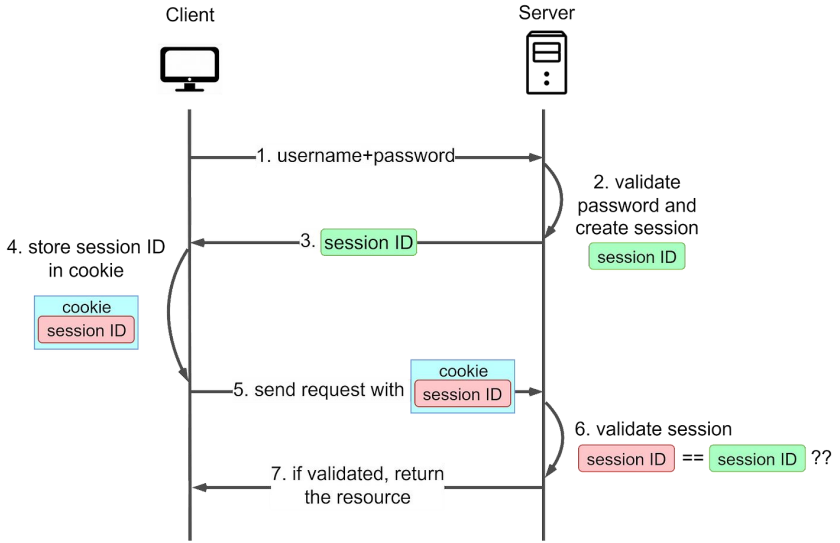


3.3. Session-Cookie Auth

	Cookies	Session Storage	Local Storage
Purpose	Typically user session, tracking user behavior	Data for a session	caching, user preferences
Storage Limit	4KB	5-10MB	5-10MB
Persistence	Server configure	Cleared when the user closes the browser or the tab	Nerver until clear manually

3.3. Session-Cookie Auth

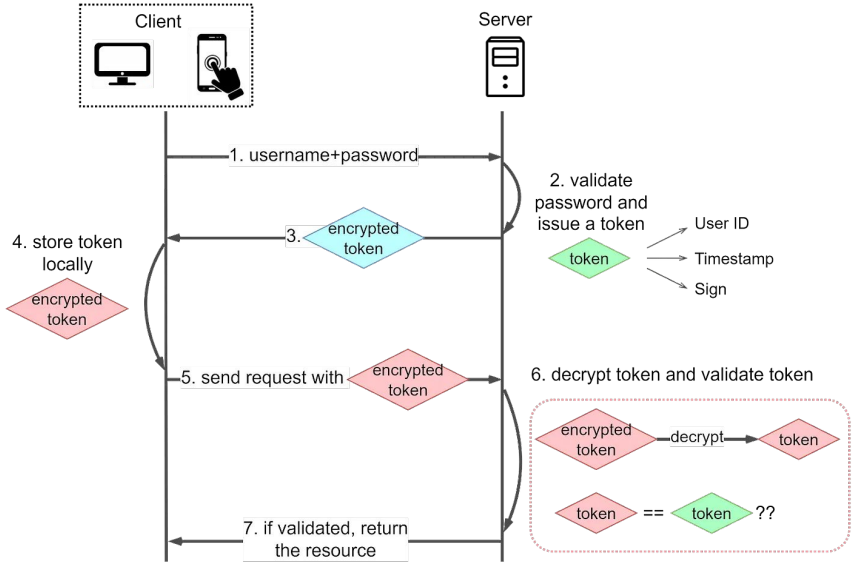
- **A session ID is generated to track the user's status during their visit.**
- This session ID is recorded both server-side and **in the client's cookie**
- Session information can be stored in the server memory or an independent session server
- Limitations:
  - Vulnerable over an unsecured network
  - Vulnerable to XSS, CSRF attacks
  - **Stateful → Difficult to scale**
  - **Not friendly to mobile native applications**



3.4. Token-Based Auth

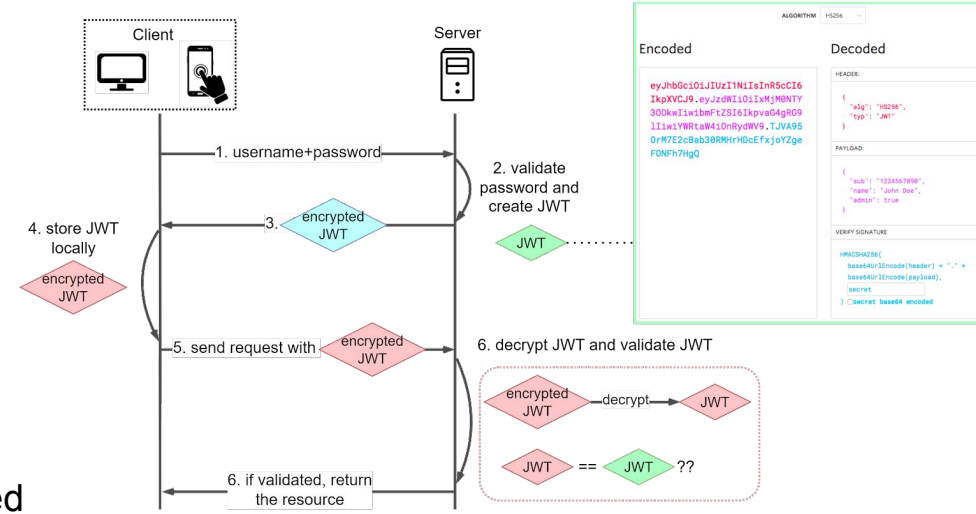
- The server issues a token and sends it to the client. The client stores the **token in the local storage**.
- Doesn't rely on cookies → friendly to mobile + web
- Typically include a user ID

  → Stateless authentication → Scalable



3.4. JWT (Json Web Token)

- A **standardized format** for token creation and validation
  → improve overall security + performance
- JWT contains 3 parts:
  - Header: token type, hash algorithm
  - Payload:
    - Seven predefined claims
    - Public claims
    - Private claims
  - Signature: sign(encoded header + encoded payload + a secret)
- JWT uses **Signature to ensure that exchange information is not modified**.
- Roles and permissions claims
  → useful to authorization processes



Recommended: AES

3.4. JWT (Json Web Token)

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  - Header: token type, hash algorithm
  - Payload:
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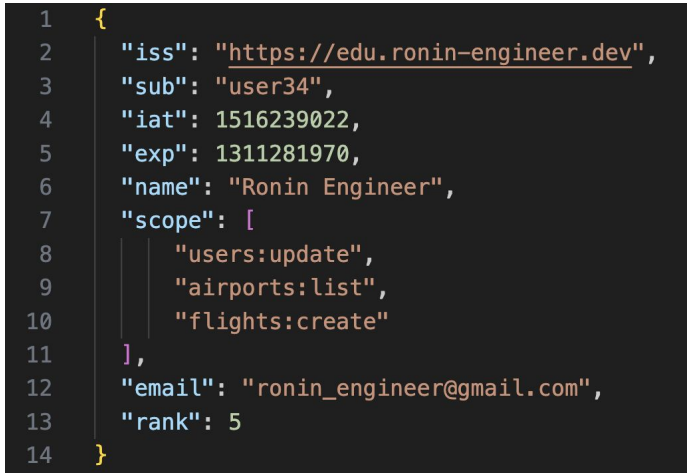


```
{
  "iss": "https://edu.ronin-engineer.dev",
  "sub": "user34",
  "iat": 1516239022,
  "exp": 1311281970,
  "name": "Ronin Engineer",
  "scope": [
      "users:update",
      "airports:list",
      "flights:create"
  ],
  "email": "ronin_engineer@gmail.com",
  "rank": 5
}
```

3.4. JWT (Json Web Token)

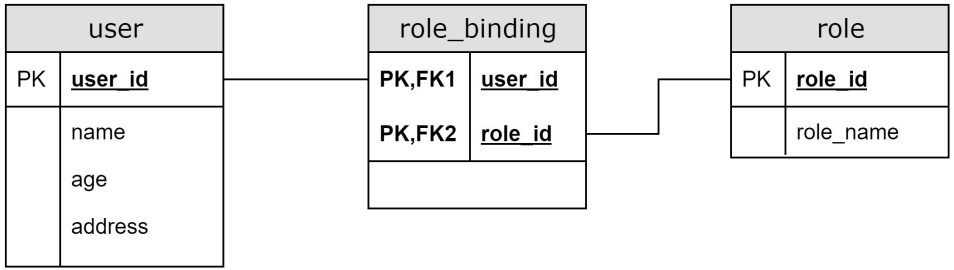
Limitations:

- Vulnerable over insecure connections
- Refresh
- **Revocation**
- JWT have **size-related issues**:
  - **Size limit**
  - Performance
  - Vulnerable if weak signing mechanism

Enhancement

- Implement a mechanism to refresh
- Embedded session into token
- Define security levels of tokens

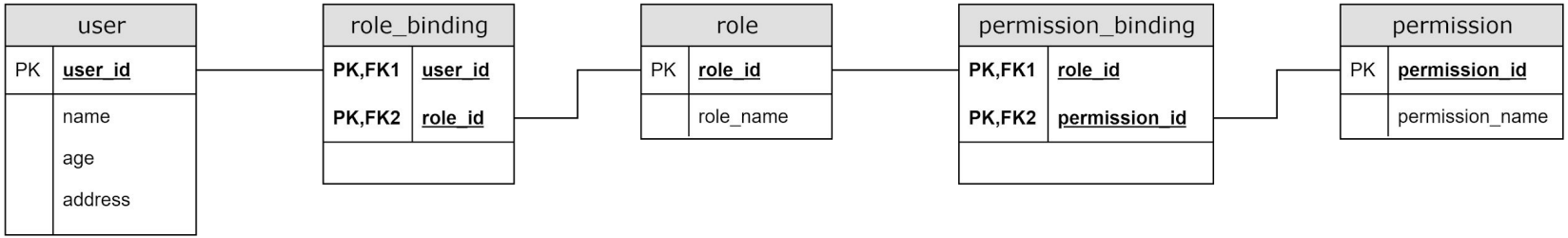
3.5. Case Study: Role Based Access Control



- Typically, each API is assigned to a set of roles in code
- Limitations:
  - **A lot of overlaps between roles**
  - Role redundancy when number of roles grows up
  - Assigning a new role to a API needs to redeploy app

```
{
  "iss": "https://edu.ronin-engineer.dev",
  "sub": "user34",
  "iat": 1516239022,
  "exp": 1311281970,
  "name": "Ronin Engineer",
  "role": "ADMIN",
  "email": "ronin_engineer@gmail.com",
  "rank": 5
}
```

3.5. Case Study: Role + Permission-Based Access Control

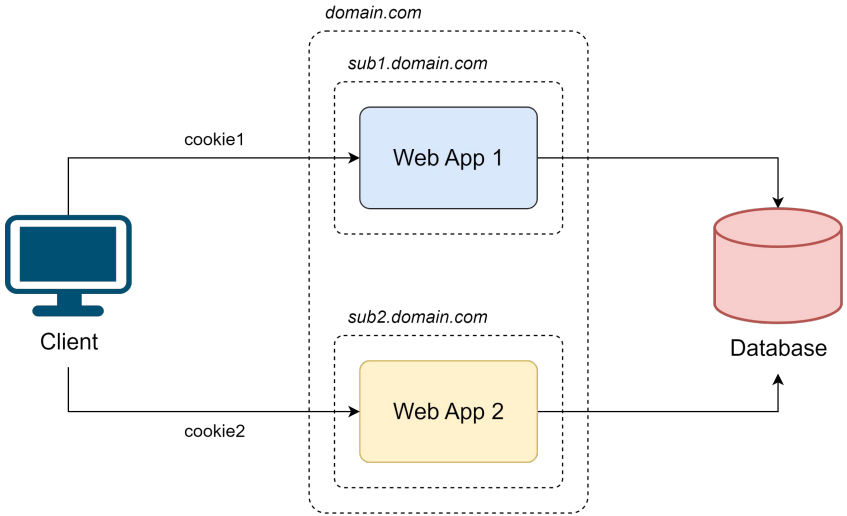


- Permission = Resource + Action
- Role = a set of Permissions
- Flexible
- Limitations:
  - Resource can be divided into many ones
    → Hard to manage Resource
  - Advanced case: access control to fields in a resource

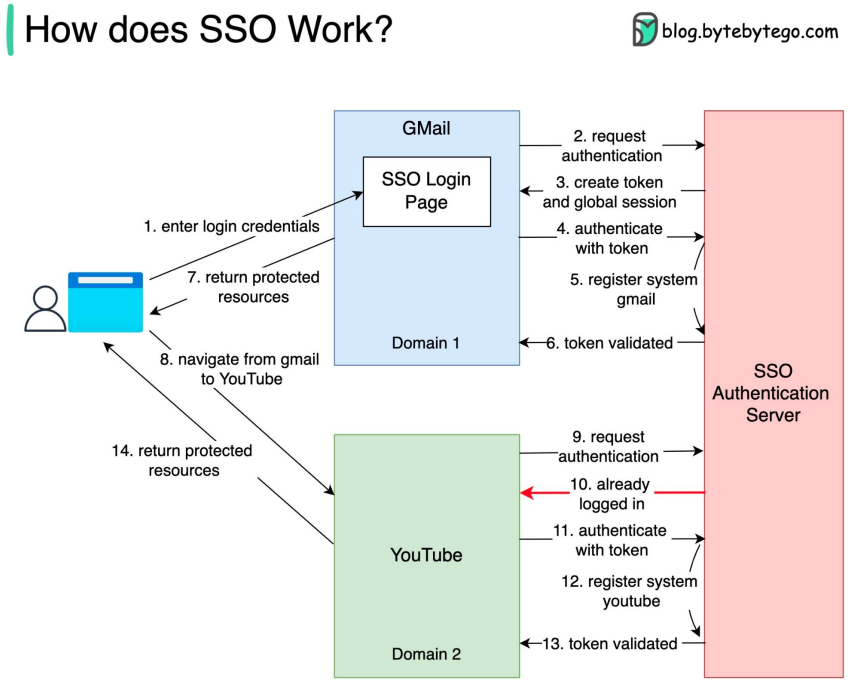
```json
{
  "iss": "https://edu.ronin-engineer.dev",
  "sub": "user34",
  "iat": 1516239022,
  "exp": 1311281970,
  "name": "Ronin Engineer",
  "scope": [
      "users:update",
      "airports:list",
      "flights:create"
  ],
  "email": "ronin_engineer@gmail.com",
  "rank": 5
}
```

3.6. Case Study: Single Sign On

- Context:
  - 2 web apps on 2 different domains in the same parent domain
  - 2 web apps use the same DB (identity)
- Requirements:
  - U1 logged in sub1 → logged in sub2
  - U1 logged in sub 1, U2 logged in sub2 at the same time



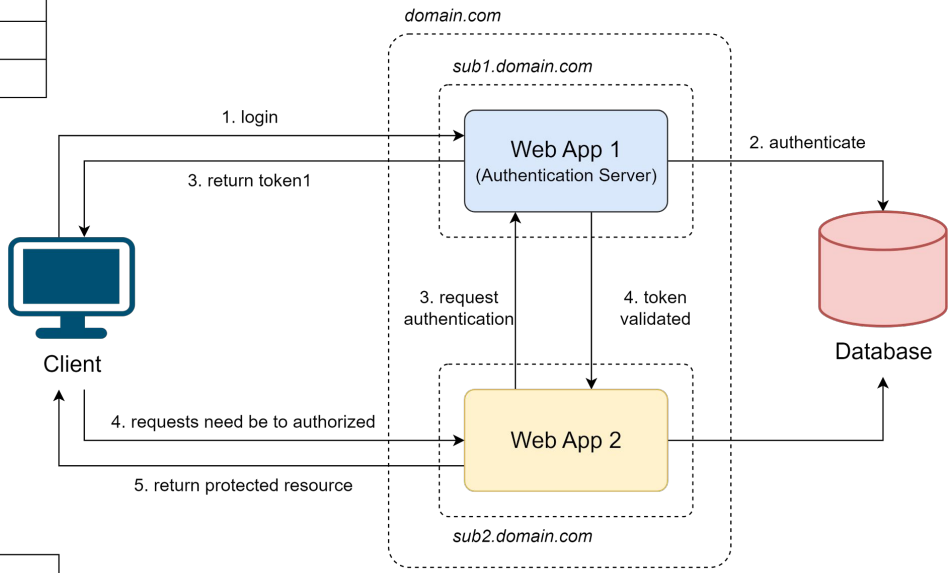
3.5. Case Study: Single Sign On



3.5. Case Study: Single Sign On

3. Cookies after authenticated

Cookies	
domain.com	token1
sub1.domain.com	token1
sub2.domain.com	null



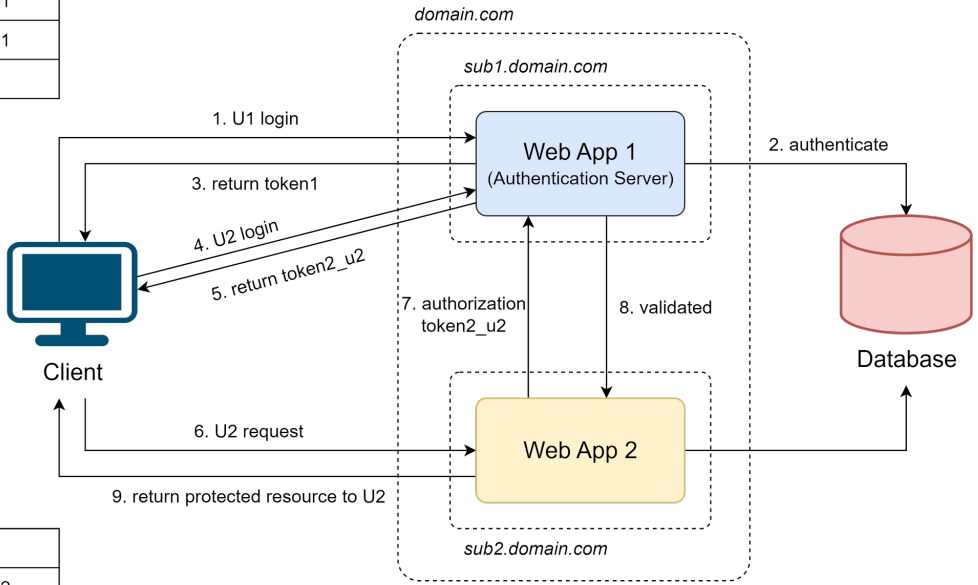
5. Cookies after authenticated

Cookies	
domain.com	token1
sub1.domain.com	token1
sub2.domain.com	null

3.5. Case Study: Single Sign On

3. Cookies after authenticated

Cookies	
domain.com	token1_u1
sub1.domain.com	token1_u1
sub2.domain.com	null



5. Cookies after authenticated

Cookies	
domain.com	token2_u2
sub1.domain.com	token1_u1
sub2.domain.com	token2_u2

Recap

- Distinguish and understand concepts:
  - Encoding
  - Hashing
  - Encryption
  - Signing
- Validate input always
- Follow standards and guidelines

Read More

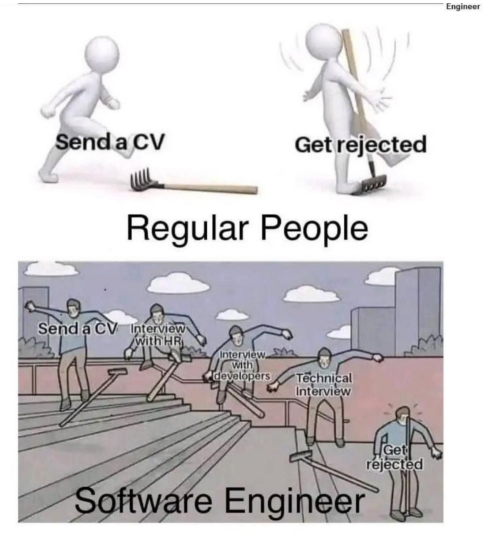
- Access Control
- **OAuth 2.0**
- OpenID Connect (OIDC)
- SAML

References

- https://owasp.org/
- https://auth0.com/blog/encoding-encryption-hashing/
- https://www.baeldung.com/cs/hashing-vs-encryption
- https://github.com/qazbnm456/awesome-web-security
- https://www.hacksplaining.com/prevention/xss-stored
- https://jwt.io/

Homework

- Requirement:
  - Authentication using JWT
  - Authorization using role + permission based access control
- Implement:
  - Hardcode: map<username, list<permission>>
  - API Login: Create JWT
    - Username
    - user_id
    - scope: list<permission>
  - API Authorize:
    - Declare the permission for this API
    - Verify token, permission



Thank you 🙏