Software Engineering II: **Web API Design**

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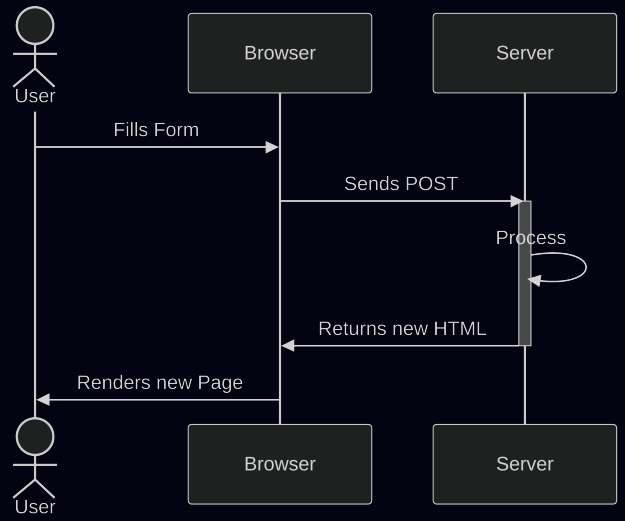
Web Application Structure

Traditional Web Applications

- Browser ⇄ Server ⇄ Database
- Server Side Rendering (SSR)
  - No **J**ava**S**cript (JS) required
  - Example: PHP, Django
- Full page reload every time
- State lives on server session
- Limited interactivity
  - Hard to support mobile apps
- UI tightly coupled to backend
- Modernization: jQuery, alpine.js, HTMX



Web Application Structure

Modern SPA Architecture

- SPA = **S**ingle **P**age **A**pplication
- Initial HTML loads once
  - Afterwards: Dynamic updates using JS
- Frontend framework handles "routing"
  - Often using page anchor (`https://my.app/#/mypage`)
- Stateless API calls
- Often Token-based auth (JWT, OAuth)
- Decoupled frontend/backend
  - Often different development teams

New Problems

- **S**earch **E**ngine **O**ptimization (SEO) issues
- Slow first page load
  - Large JS bundles
    - More client-side computation
- Complex state management
  - More state on client, but only server state is really persistent
- API overfetching

Web Application Structure

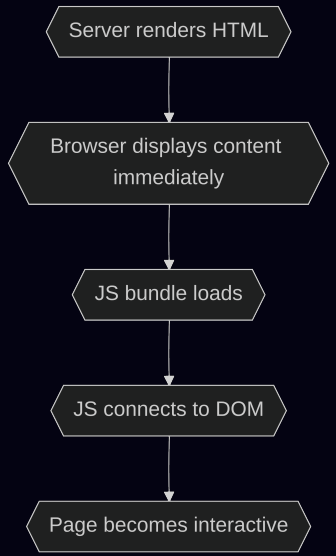
Modern Full-Stack Frameworks

- Combine SSR with interactivity
- Examples: Next.js/Nuxt/Remix/SvelteKit
- Enables Hydration
  - Fast first paint
  - Rich interactivity

Advantages:

- SEO-friendly
- Fast initial load
- API routes built-in
- Reduced boilerplate
- Shared types

Hydration Flow



API Styles

What is an API Style?

An API style defines:

- How clients communicate
- How data is structured
- How operations are modeled
- How contracts are defined

Why This Matters

Architecture decisions here:

- affect scalability
- affect performance
- affect developer experience
- live for years

Today

REST (main focus) | GraphQL | gRPC | WebSockets | SOAP (briefly)

REST

Representational **S**tate **T**ransfer

Architectural style defined by Roy Fielding

⚠ Not just "HTTP + JSON"

> https://roy.gbiv.com/pubs/dissertation/fielding_dissertation.pdf

Further reading (more descriptive):

> O'Reilly REST API Design Rulebook

REST Constraints

True REST requires:

1. Client-Server
2. Stateless
3. Cacheable
4. Uniform Interface
5. Layered System
6. (Optional) Code on Demand

If you break these -> HTTP API, not REST.

HTTP Methods

Method	Description	Safe	Idempotent	Cacheable
HEAD	Same as GET but returns headers only (no body).	Yes	Yes	Yes
OPTIONS	Returns supported HTTP methods for a resource (CORS).	Yes	Yes	No
GET	Retrieves data from the server without modifying it.	Yes	Yes	Yes
POST	Sends data to the server to create a new resource.	No	No	Yes
PUT	Replaces an existing resource with new data.	No	Yes	No
PATCH	Partially updates an existing resource.	No	No	Depends
DELETE	Removes a resource from the server.	No	Yes	No
TRACE	Performs a message loop-back test for diagnostics.	Yes	Yes	No
CONNECT	Establishes a tunnel to the server (often for HTTPS).	No	No	No

https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Methods

Uniform Interface

In REST HTTP verbs have meaning.

- GET → safe, idempotent
- POST → create (or run controller)
- PUT → replace
- PATCH → partial update
- DELETE → idempotent delete

CRUD = **C**reate (POST) **R**ead (GET) **U**pdate (PUT/PATCH) **D**elete (DELETE)

⚠ not just GET/POST as traditional HTML forms

Resource-Oriented Design

Resources are nouns. Nouns are always in plural form.

Good:

```
GET /orders/123

POST /orders

DELETE /orders/123
```

Bad:

```
POST /createOrder

POST /deleteOrder
```

Naming Conventions

Identifiers

- Use singular nouns for identifiers: `GET /users/philipp`
- Use some other kind of identifier (not noun):
  - `/users/1337`
  - `/users/cafe1234-coff-ee00-bean-123456789abc`

Collections and Controllers

- Use plural nouns for collections: `GET /users`
- Use verbs for controllers: `POST /emails/42/resend`

URI Structure

Longer paths separated by `/` indicate a hierarchical relationship

`https://api.example.com/electronics/computers/laptops`

Use hyphens for more readable URLs, avoid underscores

`https://api.example.com/philipp/lectures/introduction-to-linux/`

Use lowercase letters and avoid file extensions

E.g. `Content-type: application/json` header instead of api.example.com/users.json

Query Design

Filtering

Queries can be used to filter certain resources:

- `GET /users` returns all users
- `GET /users?firstname=Philipp` filters the users by first name

Pagination

Our APIs often serve lots of data. Use pagination for more responsiveness:

- `GET /students?pageSize=50&page=3`

Partial Responses

- Imagine a user selection field
- We send a `GET /users` request
- Now we get all Users
  - First name/Last name
  - Date of birth
  - Address & Email
- But we only need name and ID!

⚠ Overfetching

Up to own implementation, e.g.

`GET /users?fields=id,name`

HTTP Status Codes

Status Codes Matter!

Q: Which status codes do you know?

Not just 200 or 500

- Clients want to rely on status codes

Never return 200 with content like

```
{"error": "Unexected error"}
```

Status	Description
200	OK
201	Created
204	No Content
400	Bad Request
401	Unauthorized
403	Forbidden
404	Not Found
405	Method Not Allowed
409	Conflict
418	I'm a teapot

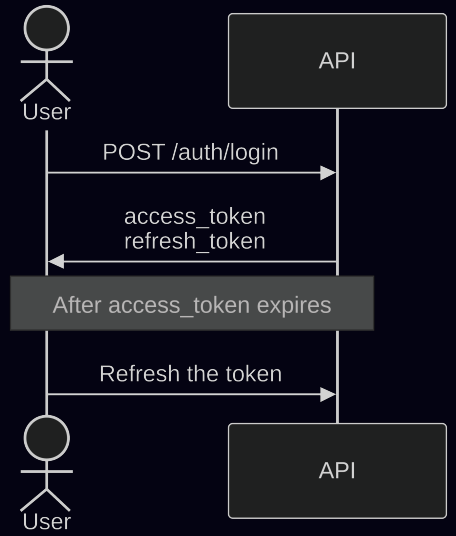
https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Status

Authentication

REST uses token based authentication

- Authenticate against API (Username/Password)
- Or use identity provider (OAuth)
- User retrieves token(s)
  - Access + Refresh token is possible
  - Can be string-token or JWT
- Authenticate against API

```
GET /api/data
Authorization: Bearer <access_token>
```



REST Attributes

Statelessness

Each request contains:

- Authentication
- Context
- All required data

Server stores no client session.

Benefits:

- Horizontal scaling
- Simpler infrastructure

Maturity Model after Richardson

Level	Description
Level 0	HTTP as transport
Level 1	Resources
Level 2	HTTP verbs
Level 3	Hypermedia

Most APIs stop at Level 2

HATEOAS

Hypermedia **A**s **T**he **E**ngine **O**f **A**pplication **S**tate

Example response:

```
{
  "id": 123,
  "status": "shipped",
  "_links": {
    "self": "/orders/123",
    "cancel": "/orders/123/cancel"
  }
}
```

Almost nobody fully implements this...

Though e.g. AWX gets pretty close

Versioning Strategies

Why should we use versioning?

- APIs evolve
- Clients stay static or lack behind
  - Web Apps can be distributed together
  - What if "old" SPA contact new backend?
    - Page reload required
  - What about native clients?
- How can old and new clients use the same API?

Common approaches

- URI versioning:
  - api.example.com/v1/orders
  - v1.example.com/orders
- Header versioning
  - `Header: "X-API-Version: 1"`
- Content negotiation
  - `Accept: application/vnd.company.v1+json`

> Pragmatism > purity.

OpenAPI

What

Machine-readable REST contract.

Describes:

- Endpoints
- Schemas
- Authentication
- Responses

YAML or JSON.

> All JSON is valid YAML

Why

Enables:

- Client code generation
- Server stub generation
- Mock servers
- Documentation
- Contract-first development

Single source of truth.

OpenAPI Code Generation

Which direction

From one spec we can generate:

- API Clients/SDKs
- Server Stubs

The spec can also be generated!

- See e.g. FastAPI/Django REST Framework
  - Also available for every other relevant language/framework

Which version

- OpenAPI v2 ("Swagger")
- OpenAPI v3.X
- Be as modern as possible :)
  - Limitation: Codegen Tooling

OpenAPI Codegen Tools

Viewers

Can be bundled with your application or used standalone to view the OpenAPI spec

- **Swagger UI** (https://github.com/swagger-api/swagger-ui)
- **Swagger Editor** (https://editor.swagger.io)
- **Redoc** (https://github.com/Redocly/redoc)
- **Stoplight Tools** (https://github.com/stoplightio)

Mock Servers

Generate static responses (no logic)

- **PRISM** (https://github.com/stoplightio/prism)

Generators

OpenAPI Generator (https://openapi-generator.tech)

- Most popular
- Clients/Servers/Docs

Swagger Codegen (https://swagger.io/tools/swagger-codegen)

- "Original" OpenAPI codegen tool
- Less maintenance, not community driven

AutoRest (https://github.com/Azure/autorest)

- From Microsoft, Azure SDK Style

And more depending on Language/Framework

Events

REST APIs are focused on HTTP Polling

Use GET or HEAD to retrieve resource

But what if we want to get notified by the server?

WebSockets

- Persistent connection – Stays open, unlike HTTP request/response.
- Bidirectional – Server can push data anytime; client can send anytime.
- Low latency – Ideal for real-time apps.
- Protocol – Starts as HTTP/HTTPS handshake, then “upgrades” to WebSocket.

1. Client opens socket

```
wss://example.com/socket
```

2. Server sends message when required

```
{ "type": "message", "content": "Hello!" }
```

Other API Types

brief summary

GraphQL

Different philosophy

Single endpoint/method:

- `POST /graphql`

Client defines the shape of the response

Supports subscriptions -> Push Events

Characteristics

- Strongly typed schema
- No overfetching
- No underfetching
- Typically no versioning
- Evolving schema

GraphQL Example

Example Query body:

```
query {
    order(id: 123) {
        id
        status
        items {
            name
            price
        }
    }
}
```

Client controls data selection -> Like SQL for the frontend

- Avoids complicated backend logic when filtering/joining data
- Avoids overfetching of data

GraphQL Contract

Schema Definition Language (SDL):

```
type Order {
    id: ID!
    status: String!
}
```

From schema you can generate:

- Typed clients
- Models/Interfaces for different programming languages

Very strong tooling ecosystem.

Low effort to try out! For Postgres: Try `pg_graphql` / `graphile` / `hasura`

- Instantly make your database a GraphQL server
  - ⚠ Only expose the tables you want, don't leak data!

gRPC

- High-Performance Remote Procedure Call (RPC) interface
- Protocol Buffers (Protobuf) – compact binary serialization format
- HTTP/2 – supports multiplexing, bidirectional streaming, and low latency
- Strongly typed contracts via `.proto` files

```
service UserService {
    rpc GetUser (UserRequest) returns (UserResponse);
}
```

- More for Server-Side API queries
- Browsers need gRPC-Web (cannot open raw HTTP/2 streams)
- `.proto` files can be used for codegen

SOAP (Simple Object Access Protocol)

- XML-based protocol. Not just HTTP; can run over SMTP, TCP, etc
- Uses WSDL (Web Services Description Language) contracts
- Uses RPCs based on dynamic XML content:

```xml
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope">
  <soap:Header>
    <!-- Optional metadata -->
  </soap:Header>
  <soap:Body>
    <m:GetUser xmlns:m="http://example.com/users">
      <m:UserId>123</m:UserId>
    </m:GetUser>
  </soap:Body>
</soap:Envelope>
```

- TL;DR: Not as simple as the name implies, rather complex and bloated

TL;DR

Use REST when:

- Public APIs
- External consumers
- Simplicity matters
- Browser-first

Use GraphQL when:

- Many frontend variants
- Complex data graphs
- Avoiding overfetching is critical

Use gRPC when:

- Internal microservices
- Performance critical
- Strong contracts required

Use SOAP when: The application already exists, and you don't have a choice

Thank you for your attention!

Don't forget the feedback