CS 4530: Fundamentals of Software Engineering

# Module 11.3 Communication Patterns

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# Learning Goals for this Lesson

- At the end of this lesson you should be able to
  - Explain the basic principles of the REST and WebSocket communication patterns
  - Compare the tradeoffs between REST and WebSockets
  - Construct a simple REST server using TSOA

Protocol Design Follows Requirements

PULL	PUSH
The Client knows about the Server	Server knows about the Client(s)
The Server must have a method that the Client can call	The Client must have a method that Server can use to notify it
The Client asks the Server for the data	Server notifies the Client whenever the data is updated
Better when updates are more frequent than requests	Better when updates are rarer than requests
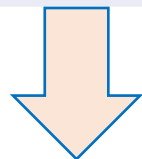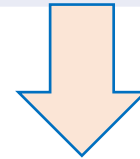
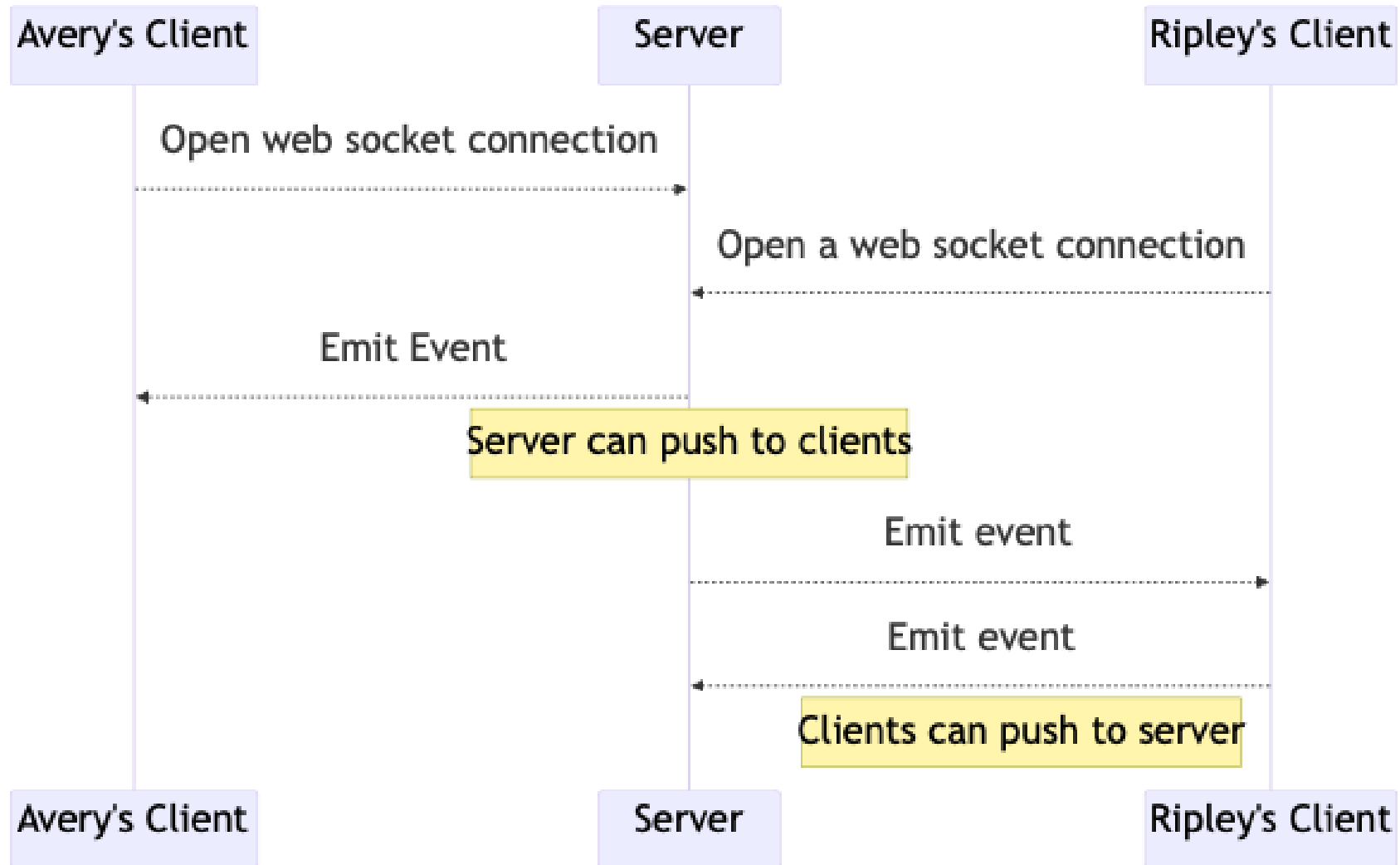**REST**   **Web Sockets**

WebSockets Follow Push Pattern

WebSocket Principles

- Event-based model. Not a request/response model
- Server maintains stateful connections to all clients
- Clients only know about the server, not other clients
- Server can broadcast to all clients, or push to a single one
- Client can push to server, server can push to client

Socket.io is a popular websocket library

- "WebSocket" is a low-level standard protocol
- [Socket.io](#) provides: automatic reconnection, broadcast rooms, typed emitters
- Hello world example with Socket.io (creating client and server not shown):

```javascript
// Server side - when a connection comes in, we are passed a pointer to our side of the  client's socket
io.on('connection', (socket) => {
  // Register an event listener when we receive a "hello" event from this client
  socket.on('hello', (arg) => {
    console.log(arg); // Will print 'world'
  });
});


// Client side – Once establishing a connection to the server, emit a "hello" event with the argument "world"
socket.emit('hello', 'world');
```

Socket.IO uses the Typed Emitter Pattern

```typescript
export type CoveyTownSocket = Socket<ServerToClientEvents, ClientToServerEvents>;
export interface ServerToClientEvents {
  playerMoved: (movedPlayer: Player) => void;
  playerDisconnect: (disconnectedPlayer: Player) => void;
  playerJoined: (newPlayer: Player) => void;
  initialize: (initialData: TownJoinResponse) => void;
  townSettingsUpdated: (update: TownSettingsUpdate) => void;
  townClosing: () => void;
  chatMessage: (message: ChatMessage) => void;
  interactableUpdate: (interactable: Interactable) => void;
  commandResponse: (response: InteractableCommandResponse) => void;
}

export interface ClientToServerEvents {
  chatMessage: (message: ChatMessage) => void;
  playerMovement: (movementData: PlayerLocation) => void;
  interactableUpdate: (update: Interactable) => void;
  interactableCommand: (command: InteractableCommand & InteractableCommandBase) => void;
}
```

Listen for and emit events on client and server

```
//Client-side: register a listener for a "playerDisconnect" event
this._socket.on('playerDisconnect', disconnectedPlayer => {
  this._players = this.players.filter(eachPlayer => eachPlayer.id !== disconnectedPlayer.id);
});
```

```
//Client-side: emit a chat message
public emitChatMessage(message: ChatMessage) {
  this._socket.emit('chatMessage', message);
}
```

frontend/.../TownController.ts

```
// Server-side, register a listener for "chatMessage" from a single player's socket.
// After receiving it, emit a chat message to every player in the town
socket.on('chatMessage', (message: ChatMessage) => {
  this._broadcastEmitter.emit('chatMessage', message);
  this._chatMessages.push(message);
  if (this._chatMessages.length > 200) {
    this._chatMessages.shift();
  }
});
```
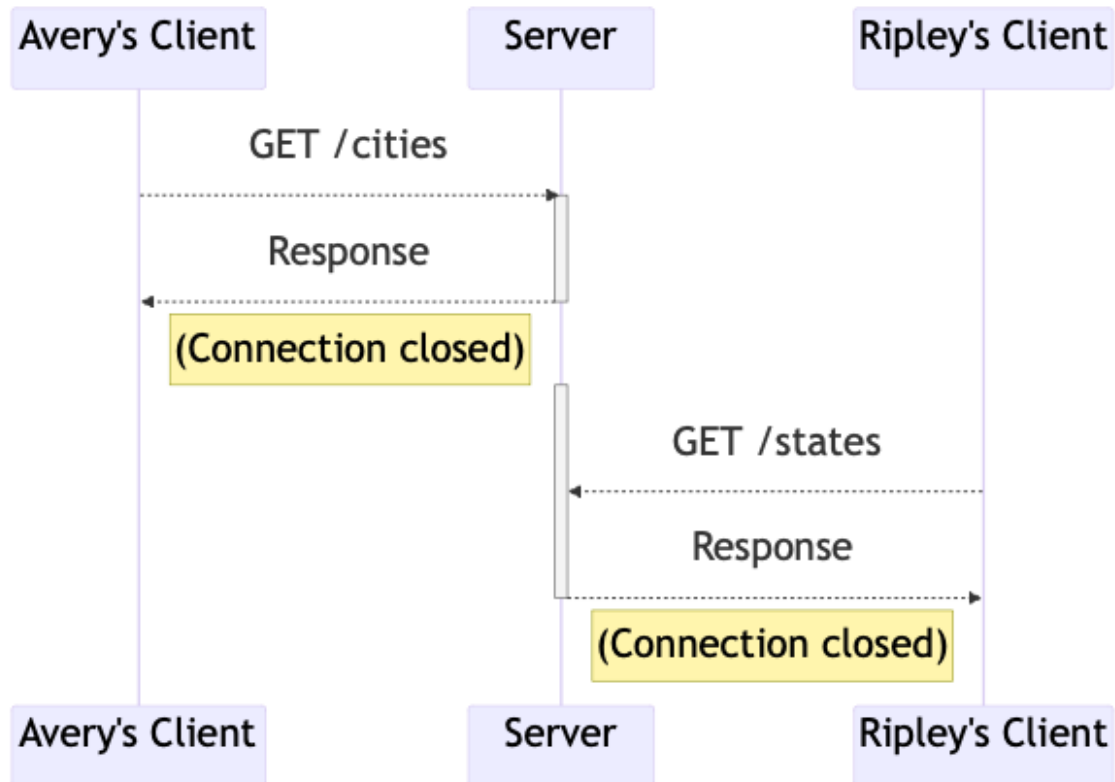
townService/.../ Towns.ts
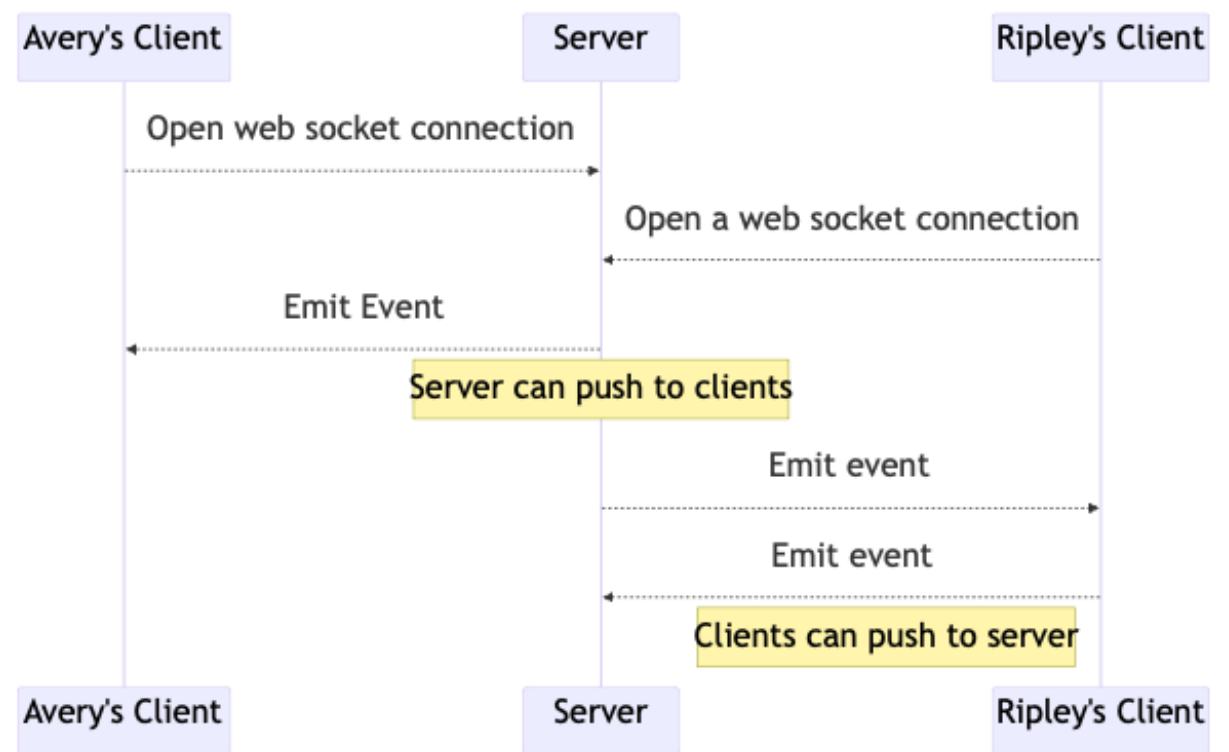
REST Follows Pull Pattern
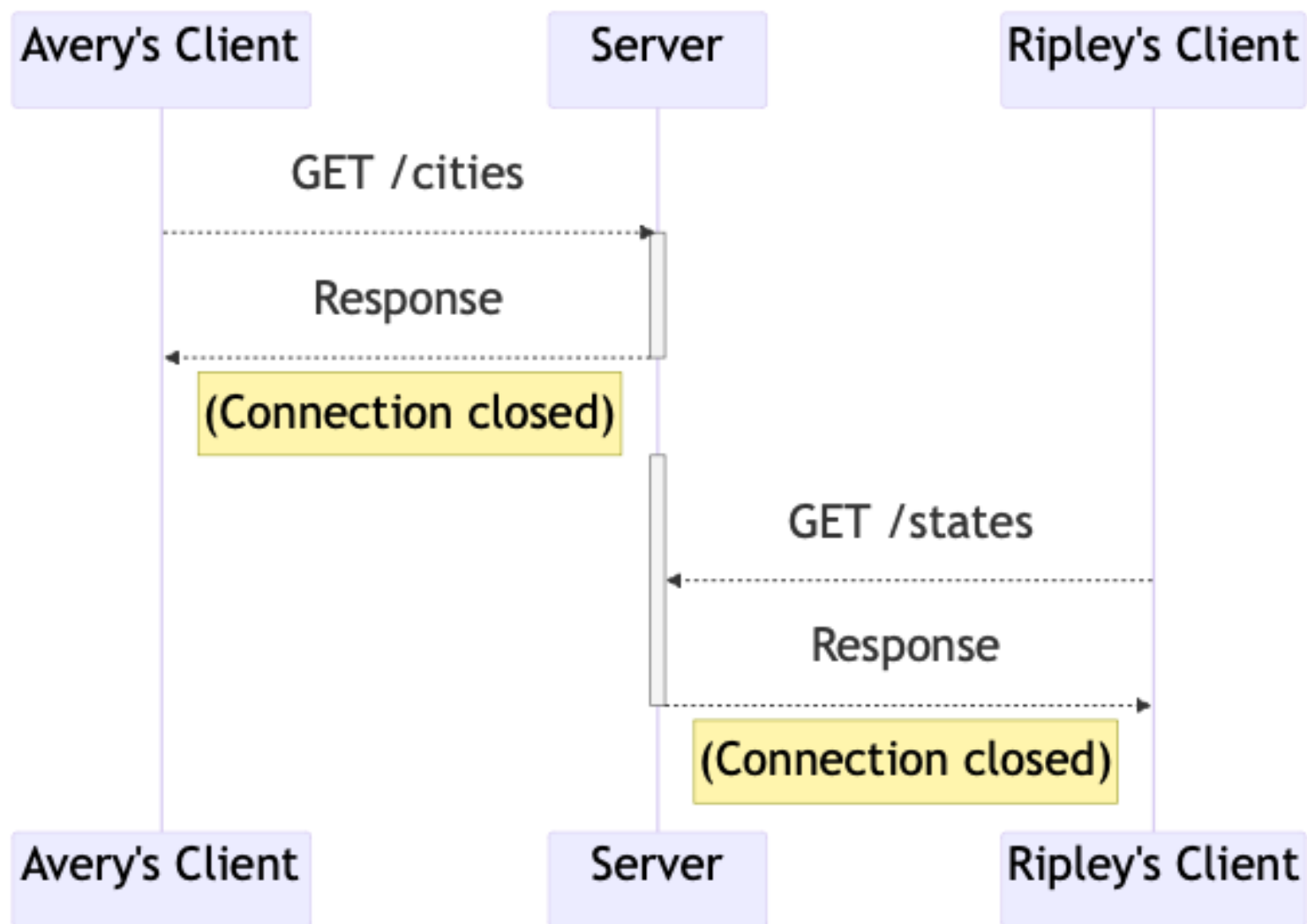
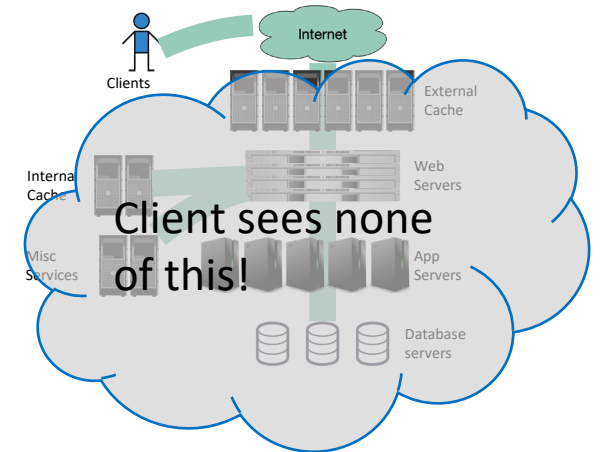# Compare REST and Web Sockets

REST

Web Sockets

REST Principles

- Single Server - As far as the client knows, there's just one

- Stateless - Each request contains enough information that a different server could process it

- Uniform Cacheability - Each request is identified as cacheable or not.

- Uniform Interface - Standard way to specify interface

Uniform Interface: URIs are nouns

- In a RESTful system, the server is visualized as a store of named resources (nouns), each of which has some data associated with it.

- A URI is a name for such a resource.

Examples

- Examples:
  - /cities/losangeles
  - /transcripts/00345/graduate (student 00345 has several transcripts in the system; this is the graduate one)
- Anti-examples:
  - /getCity/losangeles
  - /getCitybyID/50654
  - /Cities.php?id=50654

We prefer plural nouns for toplevel resources, as you see here.

Useful heuristic: if you were keeping this data in a bunch of files, what would the directory structure look like? But you don't have to actually keep the data in that way.

Path parameters specify portions of the path to the resource

For example, your REST protocol might allow a path like

`/transcripts/00345/graduate`

In a REST protocol, this API might be described as

`/transcripts/:studentid/graduate`

`:studentid` is a path parameter, which is replaced by the value of the parameter

Query parameters allow named parameters

Example:

/transcripts/graduate?lastname=covey&firstname=avery

These are typically used to specify more flexible queries, or to embed information about the sender's state, eg

https://calendar.google.com/calendar/u/0/r/month/2023/2/1?tab=mc&pli=1

This URI combines path parameters for the month and date, and query parameters for the format (tab and pli).

You can also put parameters in the body.

- You can put additional parameters or information in the body, using any coding that you like. (We'll usually use JSON)

- You can also put parameters in the headers.

- TSOA gives tools for extracting all of these parameters

- Choose where to put parameters based on readability/copyability:
  - Path parameters provide a link to a resource
  - Query parameters modify how that resource is viewed/acted upon
  - Headers are transparent to users
  - Body parameters have unrestricted length

Uniform Interface:
Verbs are represented as http methods

- In REST, there are exactly four things you can do with a resource

- POST: requests that the server create a resource with a given value.

- GET: requests that the server respond with a representation of the resource

- PUT: requests that the server replace the value of the resource by the given value

- DELETE: requests that the server delete the resource

Example interface #1: a todo-list manager

- Resource: /todos
  - GET /todos   - get list all of my todo items
  - POST /todos - create a new todo item (data in body; returns ID number of the new item)
- Resource: /todos/:todoItemID
  - :todoItemID is a path parameter
  - GET /todos/:todoItemID - fetch a single item by id
  - PUT /todos/:todoItemID - update a single item (new data in body)
  - DELETE /todos/:todoItemID - delete a single item

Example interface #2: the transcript database

```
POST /transcripts
  -- adds a new student to the database,
  -- returns an ID for this student.
  -- requires a body parameter 'name', url-encoded (eg name=avery)
  -- Multiple students may have the same name.
GET  /transcripts/:ID
  -- returns transcript for student with given ID.  Fails if no such student
DELETE /transcripts/:ID
  -- deletes transcript for student with the given ID, fails if no such student
POST /transcripts/:studentID/:courseNumber
  -- adds an entry in this student's transcript with given name and course.
  -- Requires a body parameter 'grade'.
  -- Fails if there is already an entry for this course in the student's transcript
GET  /transcripts/:studentID/:courseNumber
  -- returns the student's grade in the specified course.
  -- Fails if student or course is missing.
GET  /studentids?name=string
  -- returns list of IDs for student with the given name
```

Remember the heuristic: if you were keeping this data in a bunch of files, what would the directory structure look like?

Didn't seem to fit the model, sorry

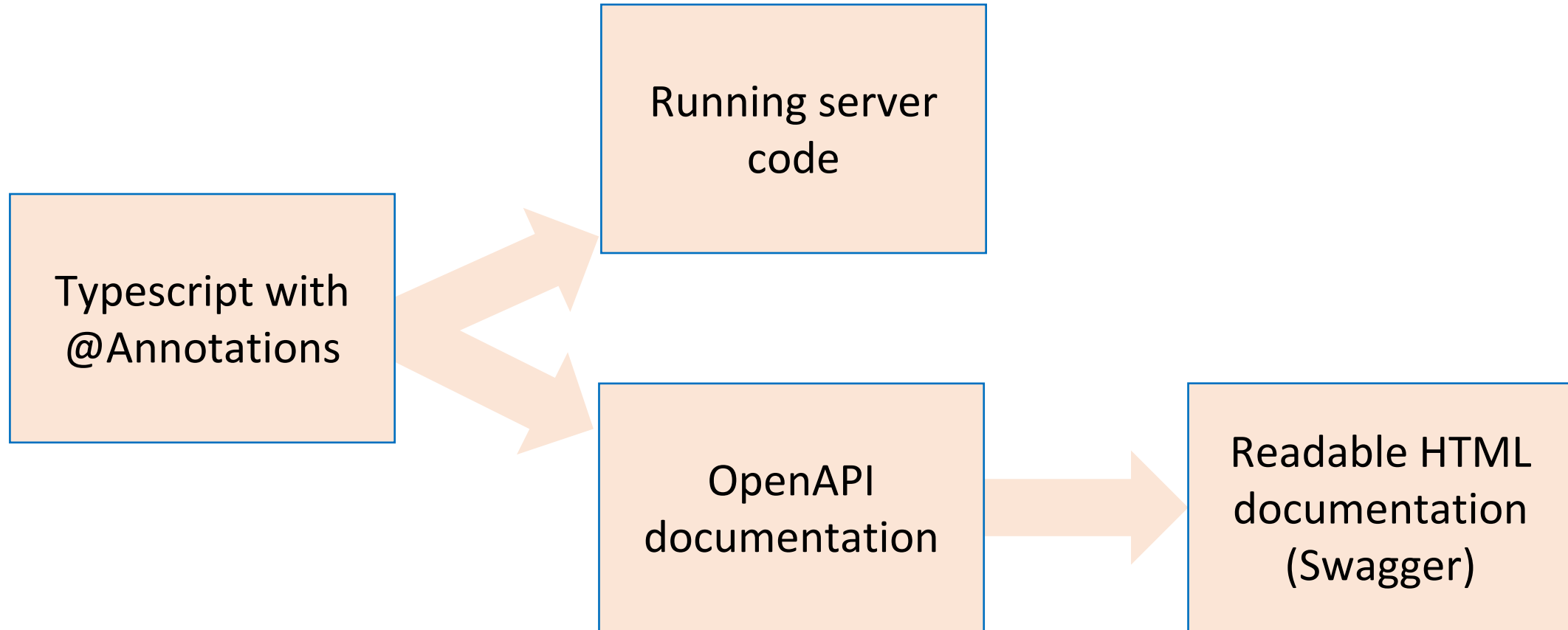# It would be better to have a machine-readable specification

- The specification of the transcript API on the last slide is RESTful, but is not machine-readable

- A machine-readable specification is useful for:
  - Automatically generating client and server boilerplate, documentation, examples
  - Tracking how an API evolves over time
  - Ensuring that there are no misunderstandings

OpenAPI is a machine-readable specification language for REST

- Written in YAML

- Not really convenient for human use

- Better: use a tool!

```yaml
/towns/{townID}/viewingArea:
post:
  operationId: CreateViewingArea
responses:
  '204':
description: No content
'400':
description: Invalid values specified
content:
  application/json:
schema:
  $ref: '#/components/schemas/InvalidParametersError'
description: Creates a viewing area in a given town
tags:
  - towns
security: []
parameters:
  - description: ID of the town in which to create the new viewing area
in: path
name: townID
required: true
schema:
  type: string
  - description: |-
  session token of the player making the request, must
match the session token returned when the player joined the town
in: header
name: X-Session-Token
required: true
schema:
  type: string
requestBody:
  description: The new viewing area to create
required: true
content:
  application/json:
schema:
  $ref: '#/components/schemas/ViewingArea'
description: The new viewing area to create
```

TSOA uses TS annotations to generate all the needed pieces

Typescript with @Annotations → Running server code

Typescript with @Annotations → OpenAPI documentation → Readable HTML documentation (Swagger)

Sample annotated typescript (1)

```
@Route('towns')
export class TownsController exten

/**
 * Creates a viewing area in a given town
 *
 * @param townID ID of the town in whi
 * @param sessionToken session token
 *      match the session token retu
 * @param requestBody The new viewing
 *
 * @throws InvalidParametersError if t
 *      viewing area could not be
 */
@Post('{townID}/viewingArea')
@Response<InvalidParametersError>(400, 'Invalid values specified')
public async createViewingArea(
    @Path() townID: string,
    @Header('X-Session-Token') sessionToken: string,
    @Body() requestBody: ViewingArea,
){ /** method body goes here */ }
```

This class defines methods that can be invoked on the base route /towns

This method can be invoked by making a POST request to /towns/{townID}/viewingArea - where /towns was the base route for the class. {townID} is a path parameter

In the event of an InvalidParametersError, the HTTP response will have the error status code "400"

Sample annotated typescript (2)

```
@Route('towns')
export class TownsController exte

/**
 * Creates a viewing area in a given town
 *
 * @param townID ID of the town in whi
 * @param sessionToken session token
 *        match the session token retu
 * @param requestBody The new viewing
 *
 * @throws InvalidParametersError if t
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 */
@Post('{townID}/viewingArea')
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public async createViewingArea(
    @Path() townID: string,
    @Header('X-Session-Token') sessionToken: string,
    @Body() requestBody: ViewingArea,
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```

This class defines methods that can be invoked on the base route /towns

This method can be invoked by making a POST request to /towns/{townID}/viewingArea - where /towns was the base route for th {townID} is a path paramet

The townID parameter to the method will come from the corresponding Path parameter of the URI.

The "sessionToken" parameter will come from an HTTP header called "X-Session-Token"

The requestBody parameter will come from the body of the HTTP request

Sample generated HTML ("Swagger")

POST /towns/{townID}/viewingArea

Creates a viewing area in a given town

Parameters   Try it out

Name	Description
townID * required string (path)	ID of the town in which to create the new viewing area townID
X-Session-Token * required string (header)	session token of the player making the request, must match the session token returned when the player joined the town X-Session-Token

Request body required   application/json

The new viewing area to create

Example Value | Schema

```
{
  "id": "string",
  "video": "string",
  "isPlaying": true,
  "elapsedTimeSec": 0
}
```

Swagger in the wild

National Park Service

[Base URL: developer.nps.gov/api/v1]

This API is designed to provide authoritative National Park Service (NPS) data and content about parks and their facilities, events, news, alerts, and more. Explore the NPS API below and even try to make API calls. In order to try an API call, you'll need to click on the "Authorize" button below and add your API key. If you don't have an API key yet, visit our **Get Started page**.

Schemes

HTTPS ⌄

Authorize 🔓

activities   Retrieve categories of activities (astronomy, hiking, wildlife watching, etc.) possible in national parks. ⌄

GET /activities 🔒

activities/parks   Retrieve national parks that are related to particular categories of activity (astronomy, hiking, wildlife watching, etc.). ⌄

GET /activities/parks 🔒

alerts   Retrieve alerts (danger, closure, caution, and information) posted by parks. ⌄

GET /alerts 🔒

Activity: Build the Transcript REST API

```
@Route('transcripts')
export class TranscriptsController extends
Controller {

    @Get()
    public getAll() {
        return db.getAll();
    }
}
```

Open API Specification

Learning Goals for this Lesson

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  - Explain the basic principles of the REST and WebSocket communication patterns
  - Compare the tradeoffs between REST and WebSockets
  - Construct a simple REST server using TSOA