Web Development and API Design

Lesson 06: Async Calls to Web Services

Prof. Andrea Arcuri

Goals

- Understand how a SPA can communicate with a backend using **AJAX**, retrieving data in JSON format
- Introduction to the “*event-loop*” model in JS, and how **async/await** can be used to simplify the code dealing with asynchronous behavior
  - e.g., calls to a remote web service, like *REST* and *GraphQL*

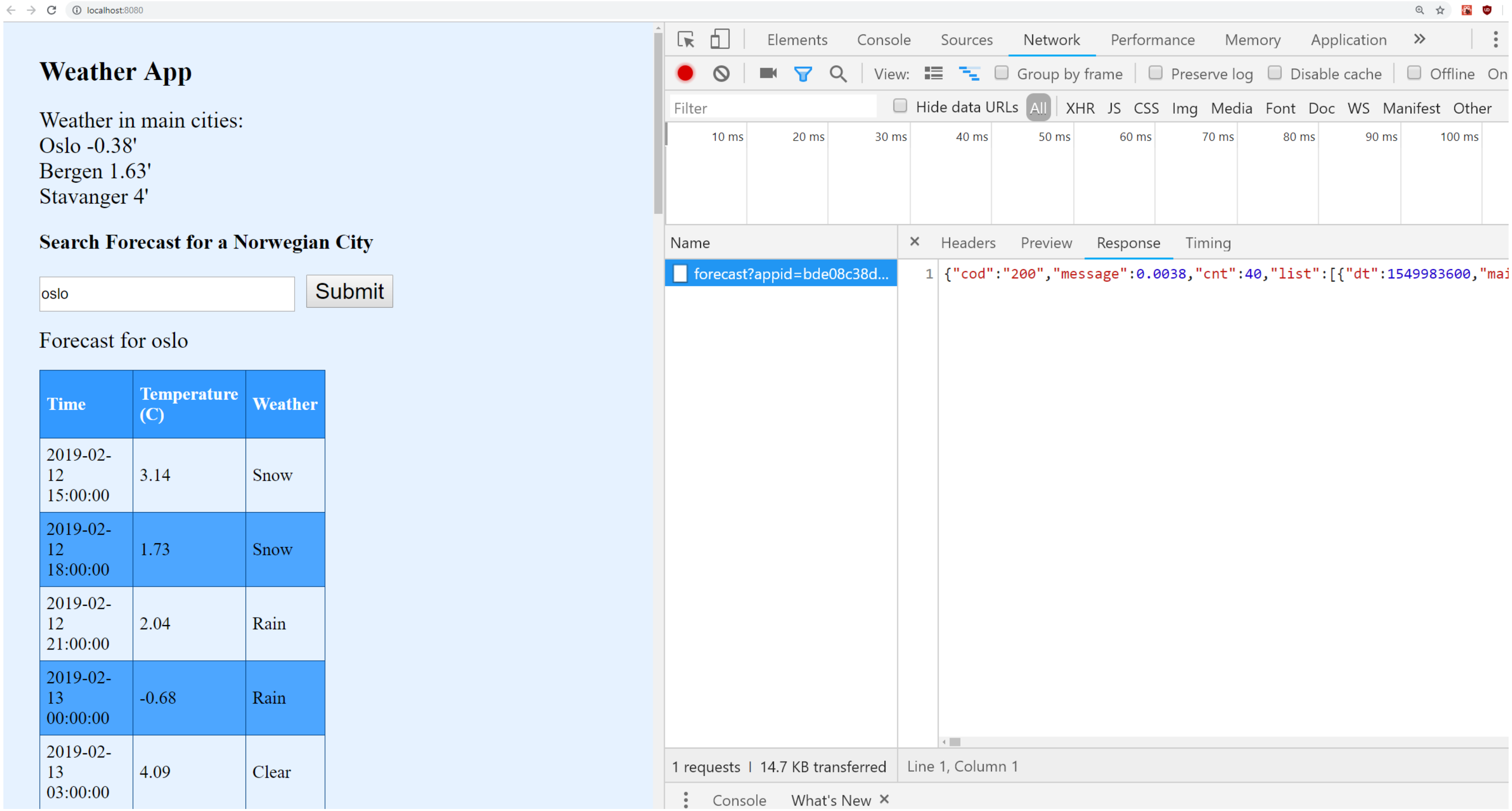
Browser-Server Communications

- Usually based on HTTP over TCP
- Address bar in browser: download that resource, e.g., typically starting from *index.html*
- Then download all other resources used in that HTML file
  - eg, CSS, images and JS files
- User interactions with server: clicking on **<a>** links and submitting **<form>**
  - after such actions, usually would get a new HTML page back from server

AJAX (Asynchronous JavaScript and XML)

- Ability for JS code to start HTTP communications to server
- XML in the name is just for historical reasons… nowadays the main data format is **JSON** (JavaScript Object Notation)
- A SPA can use AJAX to retrieve the data it needs (in JSON), without getting whole new HTML pages
- Once getting JSON data, update HTML in the browser (eg with React)

Example: just fetch data of forecast in JSON, and not a whole HTML page displaying it



Weather App

Weather in main cities:
Oslo -0.38'
Bergen 1.63'
Stavanger 4'

Search Forecast for a Norwegian City

oslo

Submit

Forecast for oslo

Time	Temperature (C)	Weather
2019-02-12 15:00:00	3.14	Snow
2019-02-12 18:00:00	1.73	Snow
2019-02-12 21:00:00	2.04	Rain
2019-02-13 00:00:00	-0.68	Rain
2019-02-13 03:00:00	4.09	Clear

forecast?appid=bde08c38d...

```
{"cod":"200","message":0.0038,"cnt":40,"list":[{"dt":1549983600,"mai
```

1 requests | 14.7 KB transferred

Line 1, Column 1

Using AJAX

- For JS in the browser, there are 2 main ways to do HTTP calls
- **XMLHttpRequest**: *old* approach using **Callbacks**
  - same as AJAX, the XML in the name is only for historical reasons… you can use it to send/receive any kind of data besides XML, eg JSON
- **fetch()**: more *modern* approach using **Promises**

Issues with AJAX

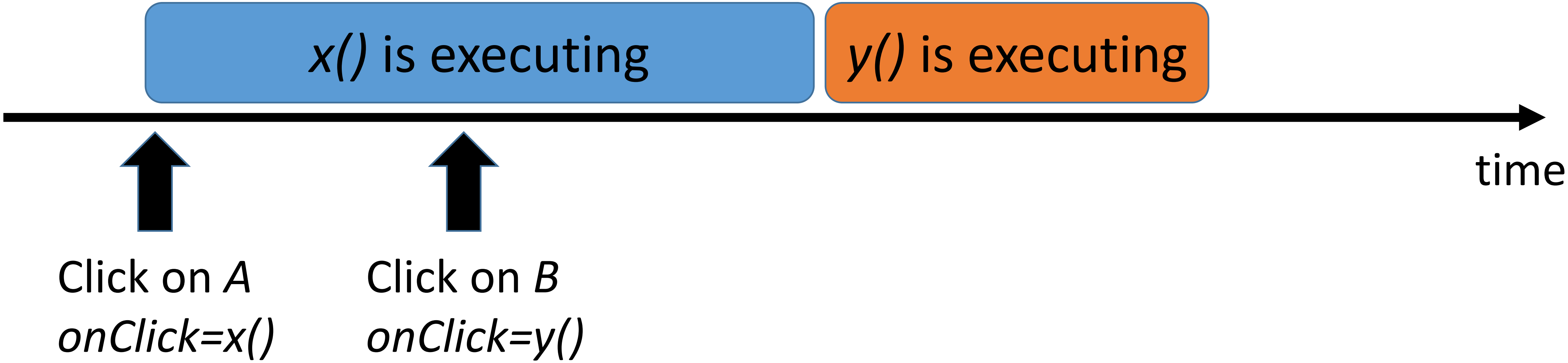
- You make an HTTP call over TCP with AJAX
- Such call could take few milliseconds, or seconds, BEFORE you get a reply from the server
- Even if just 1 ms, might need to do many HTTP calls to render current page (eg fetch data from different servers)
- You do NOT want your app to **freeze** and be unresponsive till server replies
- This is a problem due to how threading is handled in JS

JS Event-Loop Thread

- Following is a very *high-level*, *simplified* story of how the *event-loop* works in JS
  - eg, not going to discuss things like *Service Workers* or the *Job Queue*
- For what concerns you, your JS code is going to be executed on a **single thread**
- Your functions will **run to completion**
  - These are the functions executed when intercepting events like *onClick* and *onMouseOver*

Run To Completion

- Assume a user clicks on 2 buttons (*A* and *B*), executing *x()* and then *y()*, which are registered as *onClick* handlers
- As long as *x()* is running, *y()* cannot start, as there is only 1 thread executing your code for the event handlers



Run To Completion Problems

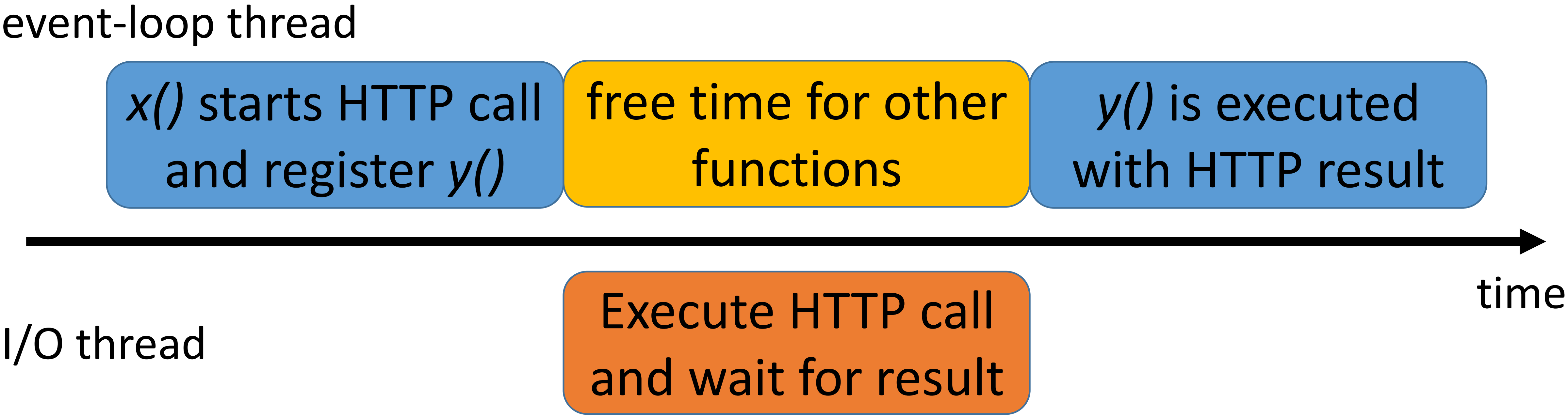
- **while(true){}**
- Code above could completely freeze your app, as no other code could run, as that is an infinite loop and will never end
  - note, you can end up in infinite loops due to bugs…
- Expensive CPU computations in JS can slow down the responsiveness of your app, making it feeling sluggish

AJAX and Run to Completion

- AJAX: (1) execute a HTTP Request; (2) do something when you get the HTTP Response
- Might take many ms before getting back the response
- **Cannot wait on event-loop thread for the response**, otherwise the app would freeze in that period of time
  - i.e., no other code could be executed meanwhile
- 2 solutions: **Callbacks** and **async/await** on **Promises**

Callback

- AJAX call in function *x()* will register a callback function *y()* which will be executed on the event-loop thread when getting results from server
- The HTTP call will be made by an I/O thread, which will schedule *y()*



event-loop thread

x() starts HTTP call and register *y()*

free time for other functions

y() is executed with HTTP result

time

I/O thread

Execute HTTP call and wait for result

```
const ajax = new XMLHttpRequest();

//register the "callback" to handle the server's response
ajax.onreadystatechange = () => {
    const payload = JSON.parse(ajax.response);
    //do something with response
};

ajax.open("GET", url);
ajax.send();
```

- Here, the **onreadystatechange** is the **callback** that is going to be executed once we get back the result
- Note: such callback has to be registered BEFORE we **send()** the HTTP request, but will be executed AFTER

Callback Issues

- Callbacks are fine when you make a single request
- When you have many asynchronous communications, each one depending on the others, it can get *very difficult* to see what is going on and the order in which functions are executed
- Often called **Callback Hell**

Promise

- A **Promise** is a JavaScript object
- *“The Promise object represents the eventual completion (or failure) of an asynchronous operation, and its resulting value”*
    - https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Promise
- A Promise will eventually return the value of the asynchronous computation, and we can **await** until such value is available
- The **fetch()** method making an AJAX request does return a Promise

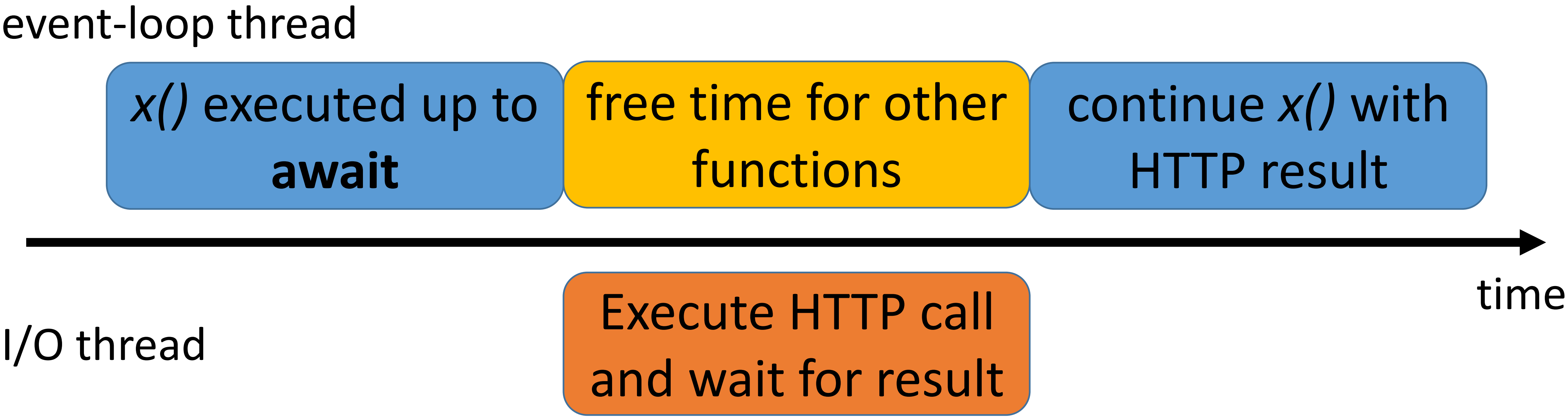
```
async doHttpFetch(url) {

    response = await fetch(url);
    payload = response.json();
    //do something with response
```

- Here there is no callback… we execute operation (*fetch*) and **await** for the results
- Then we continue with the rest of the function
- But what about “**Run to Completion**” in JS???
  - note: the function is declared as **async**

async/await

- **async** functions are split in *execution blocks*, around the **await** commands
  - note, there can be many **await**s inside the same **async** function
- The event-loop thread will execute the functions blocks, and not the whole function
- When I/O thread will get the HTTP response, it will schedule the execution of the second block after the **await**
- The *event-loop thread* is **NOT** waiting during an **await**



event-loop thread

x() executed up to **await**

free time for other functions

continue *x()* with HTTP result

time

I/O thread

Execute HTTP call and wait for result

Benefits of **async/await**

- It makes code much easier to read, as now the flow of execution looks *sequential*
  - this is particularly true when you have many asynchronous operations in the same function
- No major performance drawback: the event-loop thread is not waiting, and can execute other commands meanwhile we wait for I/O
- Recall that *thread waiting* and *thread-context switches* are **expensive**, because OS operations

Non-Blocking I/O

- This model of a single event-loop thread running your code in blocks is often referred as **Non-Blocking I/O**
- Such model was popularized by *NodeJS*
  - however, most other languages can do the same, e.g., Java, Kotlin and C#
- Very good for CRUD web applications:
  - most operations are CPU cheap, where bottlenecks are in I/O on database
  - can serve many different users without thread-context switches
- However, it is bad for CPU-bound applications
  - as you only have a single execution thread…
  - you could though replicate your app in many running instances, behind a load-balanced gateway (but this is not something we will see in this course…)

Creating a Promise

- For this course, we deal with **Promise**s mainly when we **await** on **fetch()** calls
- But we can create our own **Promise**s
  - we will need to do it for testing purposes
- A Promise requires as input a function, which itself takes as input two functions:
  - *resolve(someValue)*: we will call it when we want to state the Promise is resolved, ie successfully finished. The value we will be what returned to who is **await**ing on such Promise
  - *reject()*: specify that the Promise has failed
  - note: if "*your code*" in the example below is "*resolve(5)*", then the Promise would resolve immediately, giving the value 5 as output

```
new Promise( (resolve, reject) => {/* your code */});
```