CSCI 4140 – Tutorial 7

Learning the basics of Node.js

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SHB 118

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Outline

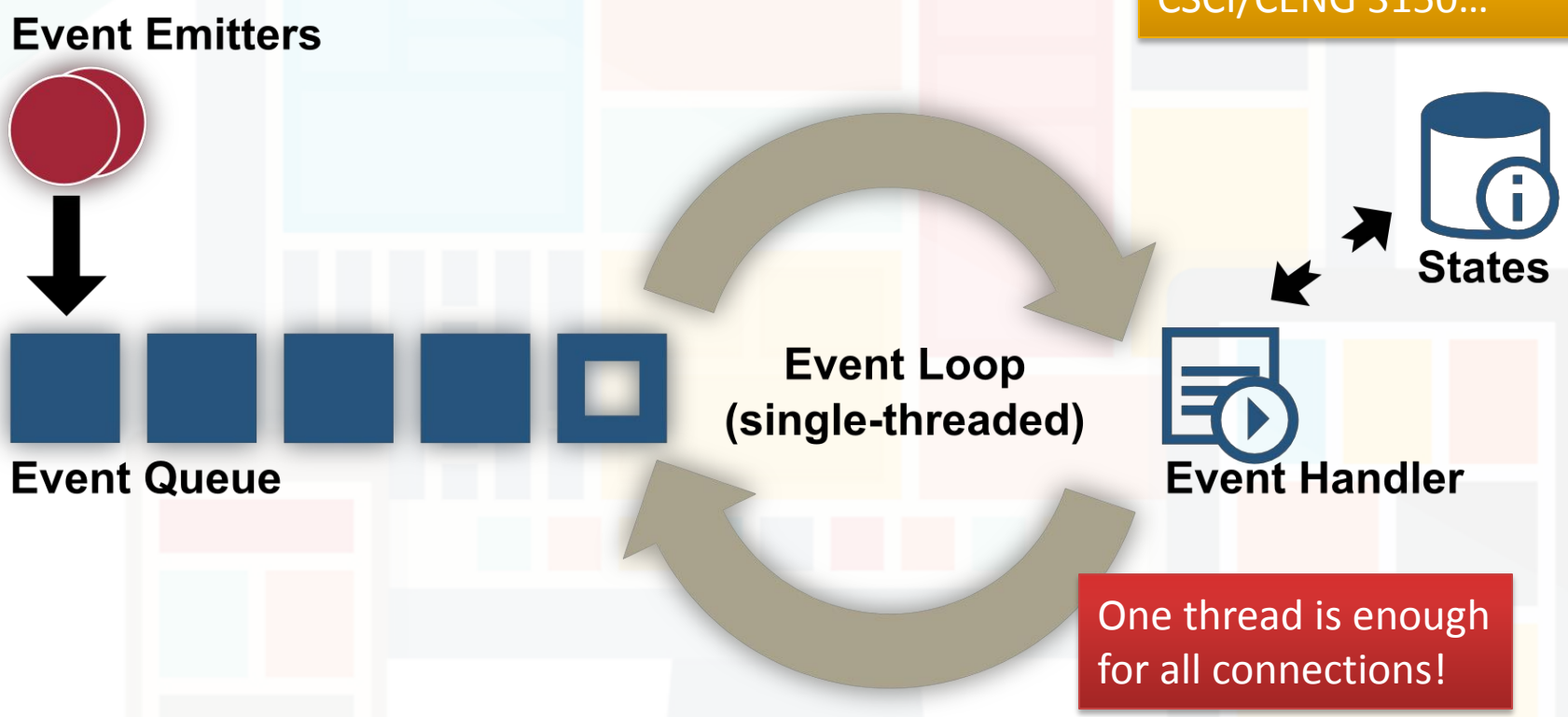
- What is Node.js?
- Learning the basics of Node.js: Non-blocking I/O, HTTP
  - Exercises adapted from **`learnyounode`**: https://github.com/rvagg/learnyounode

What is Node.js?

- An **open-source**, **cross-platform** runtime environment for **server-side** and **networking applications**
- Applications are written in **JavaScript**
  - Node.js uses **Google V8 JavaScript engine** to execute code
- Provide an **event-driven architecture** and a **non-blocking I/O** API
  - One process for all **concurrent connections**
  - Optimizes an application's **throughput** and **scalability**
  - For your information, Apache uses **process-/thread-based architecture**, which is relatively inefficient
    - A new process / thread is created per connection

What is Node.js: Event-driven architecture

For those who have taken CSCI/CENG 3150…



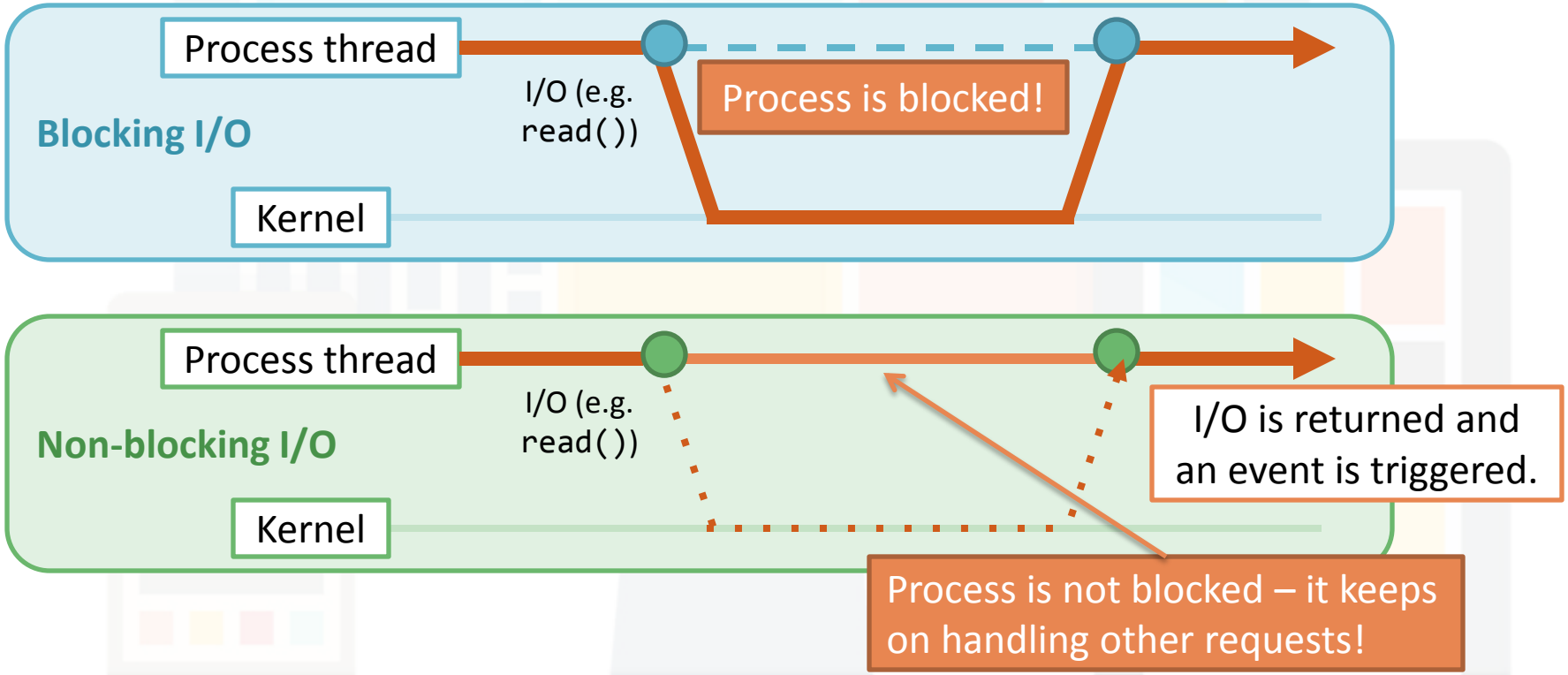
One thread is enough for all connections!

Reference: http://berb.github.io/diploma-thesis/original/042_serverarch.html

What is Node.js: Non-blocking I/O

For those who have taken CSCI/CENG 3150…

- Also called **Asynchronous I/O**
- You are familiar with **blocking I/O** already…



Node.js HTTP server

- HTTP is a **first class citizen** in Node
  - Forget about Apache / IIS / Nginx
- Say "Hello World!" with Node.js HTTP server:
  - Execute "**`node nodejs/server.js`**" in your terminal and visit **http://127.0.0.1:4140/** in your browser

```
var http = require( 'http' );
http.createServer( function( request, response ) {
    response.writeHead( 200, { 'Content-Type' : 'text/plain' } );
    response.end( 'Hello World!\n' );
} ).listen( 4140, '127.0.0.1' );

console.log( 'Server running at http://127.0.0.1:4140/' );
```

nodejs/server.js

Learning the basics of Node.js: Non-blocking I/O, HTTP

Exercises adapted from https://github.com/rvagg/learnyounode

Exercise 1: Hello World

- *Let's learn Node.js by doing exercises!*
- **Problem:** Write a program that prints the text "HELLO WORLD" to the console (stdout)
- Use the **console** API: http://nodejs.org/api/console.html

```
console.log( "HELLO WORLD" );
```

nodejs/ex1-hello.js

```
$ node nodejs/ex1-hello.js
```

Terminal

- Useful for debugging
  - Obviously you cannot call "alert()"…

Exercise 2: Baby steps

- **Problem:** Write a program that accepts one or more numbers as command-line arguments and prints the sum of those numbers to the console (`stdout`)
- Access **command-line arguments** from the **`argv`** property of the global **`process`** object
  - For example, executing "**`node program.js 1 2 3`**"

program.js
```
console.log(process.argv);
```

Output
```
[ 'node', '/home/mtyiu/program.js', '1', '2', '3' ]
```

- Note that the command-line arguments are strings
  - Convert the string into number with "**`Number( <string> )`**"

Exercise 3: My first I/O

- **Problem:** Write a program that uses a single **synchronous** filesystem operation to read a file and print the **number of newlines** it contains to the console (`stdout`), similar to running **`cat file | wc -l`**.
- We need the **`fs`** module from the Node core library
  - http://nodejs.org/api/fs.html
  - Load the `fs` module into a **variable**: `var fs = require( 'fs' );`
- All synchronous (or blocking) filesystem methods end with "Sync", e.g., "**`fs.readFileSync(`** *`<file path>`* **`)`**"
  - This method returns a **`Buffer`** object containing the complete contents of the file

Exercise 3: My first I/O

- **`Buffer`** objects are Node's way of efficiently representing arbitrary arrays of data
  - To convert them to strings, call "**`toString()`**" method on them, e.g., **`var str = buf.toString()`**
- To count the number of newlines in a string, you can split it using the "**`split()`**" method with the "**`\n`**" character as the delimiter
- Remember that the last line of the input file does not contain a newline

Exercise 4: My first asynchronous I/O

- **Problem:** Write a program that uses a single **asynchronous** filesystem operation to read a file and print the number of **newlines** it contains to the console (`stdout`), similar to running `cat file | wc -l`.
- `fs.readFile()` is the asynchronous version of `fs.readFileSync()`
  - This method returns **without blocking**
  - To read the file contents, you need to pass a **callback function** which will be called when the I/O completes
    - This concept is **extremely important** in **JavaScript** programming!

Exercise 4: My first asynchronous I/O

- The callback functions should have the following signatures:

```
function callback ( err, data ) { /* ... */ }
```

Represent an error

The Buffer object / string containing the file contents

OR

```
function callback ( err, options, data ) { /* ... */ }
```

Pass "utf8" for the options argument to get a string instead of an Buffer object

Exercise 5: Filtered `ls`

- **Problem:** Create a program that prints a list of files in a given directory to the console using **asynchronous I/O**, filtered by the **extension** of the files
  - ***1st argument***: A directory name
  - ***2nd argument***: A file extension to filter by
- Similar to Exercise 4, but with **`fs.readdir()`**
  - http://nodejs.org/api/fs.html#fs_fs_readdir_path_callback
- You will also need **`path.extname()`** in the **`path`** module
  - http://nodejs.org/api/path.html#path_path_extname_p

Exercise 6: Make it modular

- **Problem:** Same as Exercise 5, but you need to make it **modular**
- Write a **module file** to do most of the work
  - The module should **export a function** which takes 3 arguments:
    1. The directory name
    2. The filename extension string (identical to the corresponding command-line argument)
    3. A callback function
  - The callback function should use the idiomatic node `(err, data)` convention
    - `err` is `null` if there is no errors; return the errors from `fs.readdir()` otherwise
    - `data` is the filtered list of files, as an Array
  - Nothing should be printed from your module file
    - Only print from the original program

Exercise 6: Make it modular

- From the problem statement, we induce the four requirements of a module:
  - **Export** a single function that takes exactly the **arguments** described
  - Call the **callback** exactly **once** with an error or some data as described
  - **Don't change anything** else, like global variables or `stdout`
  - Handle all the **errors** that may occur and pass them to the callback
    - Do **early-returns** within callback functions if there is an error
- A good Node.js developer should follow these rules!

Exercise 6: Make it modular

- In the module file (e.g., `module.js`), assign a function to the **`module.exports`** object to define a **single function export**:

```
module.exports = function (args) { /* ... */ }
```

- In your program, load the module (`module.js`) using the **`require()`** call ("`./`" indicates that it is a local module):

```
var module = require( './module' );
```

  - **Note:** "`.js`" can be omitted
- The `require()` call returns what you export in the module file
  - In this example, it returns a function that you can call directly!

Exercise 7: HTTP client

- **Problem:** Write a program that performs an **HTTP GET request** to a URL provided to you as the first command-line argument. Write the `String` contents of each "`data`" event from the response to a new line on the console (`stdout`).
  - **Note:** There is a sample scenario in Assignment 2 – retrieving video title from YouTube server using an HTTP GET request
- Use the **`http.get()`** method in the **`http`** module
  - http://nodejs.org/api/http.html#http_http_get_options_callback
  - ***1st argument***: The URL you want to GET
  - ***2nd argument***: A callback with the following signature:

```
function callback ( response ) { /* ... */ }
```

Exercise 7: HTTP client

- The `response` object is a **Node Stream** object
  - It is an object that emits events
  - Register an **event listener** (`.on(*, callback)`) to handle the event
    - This is the core of "**event-driven architecture**"
  - For `http.get()`, the three events that are of most interests are: "**`data`**", "**`error`**" and "**`end`**"
    - See http://nodejs.org/api/http.html#http_http_incomingmessage and http://nodejs.org/api/stream.html#stream_class_stream_readable
- The `response` object has a **`setEncoding()`** method
  - If you call this method with "`utf8`", the **`data`** events emit `Strings` instead of the standard Node **`Buffer`** objects

Exercise 8: HTTP collect

- **Problem:** Write a program that performs an HTTP GET request to a URL provided to you as the first command-line argument. Collect **all data** from the server (not just the first "`data`" event) and then write two lines to the console (`stdout`).
  - ***1st line***: The **number of characters** received from the server
  - ***2nd line***: The **complete `String` of characters** sent by the server
- Two approaches:
  - Collect and append data across multiple "`data`" events. Write the output when an "end" event is emitted
  - Use a **third-party package** to abstract the difficulties involved in collecting an entire stream of data, e.g., **`bl`** and **`concat-stream`**

Exercise 8: HTTP collect

- Let's try the second approach to explore an important component in Node.js: **npm** – the **package manager** for node
  - FYI, the package manager for Python is **`pip`**
- To install the Node package `bl`, type in the terminal:

```
$ npm install bl
```

  - npm will download and install the latest version of the package into a subdirectory named **`node_modules`**
- When you write "**`var bl = require('bl');`**" in your program, Node will first look in the **core modules**, and then in the **`node_modules`** directory where the package is located.
- Read https://www.npmjs.com/package/bl for its usage

Exercise 9: Juggling async

- **Problem:** Same as Exercise 8, but this time you will be provided with **3 URLs** as the first 3 command-line arguments
  - Print the complete content provided by each of the URLs to the console (`stdout`), one line per URL
  - No need to print out the length
  - The content must be printed out in the **same order** as the URLs are provided to you as command-line arguments
- **This exercise is tricky!**
  - **`http.get()`** is an asynchronous call
  - The callback function is executed when any of the servers response
  - The responses will probably be **out of order**!
    - You need to **queue the results** and print the data when all data is ready

Exercise 10: Time server

- **Problem:** Write a TCP time server!
  - Your server should listen to **TCP connections** on the port provided by the first argument to your program
  - For each connection you must write the **current date & 24 hour time** in the format: "**`YYYY-MM-DD hh:mm`**", followed by a newline character
  - Month, day, hour and minute must be zero-filled to 2 integers
    - For example: "`2013-07-06 17:42`"
- This exercise demonstrates the power of Node.js!
  - Challenge to CSCI 4430 students: Solve this problem in **C/C++ socket programming**!

Exercise 10: Time server

- To create a **raw TCP server**, use the **net** module
  - Use the method named **net.createServer()**
    - It returns an instance of your server
    - To start listening on a particular port, use **server.listen(*<port>*)**
    - It takes a callback function with the following signature:

```
function callback ( socket ) { /* ... */ }
```

  - The **socket** object passed into the callback function contains a lot of metadata regarding the connection
  - To write data to the **socket**: `socket.write( data );`
  - To close the **socket**: `socket.end();`
  - **Ref.:** http://nodejs.org/api/net.html

Can be combined

```
socket.end( data );
```

Exercise 10: Time server

- To create the date, you will need to create a custom format from a `new Date()` object
- The following methods will be useful:
  - `date.getFullYear()`
  - `date.getMonth()  // starts at 0`
  - `date.getDate()  // returns the day of month`
  - `date.getHours()`
  - `date.getMinutes()`

Exercise 11: HTTP file server

- ***Now we are ready to learn how to use Node.js to implement server-side program!***
- **Problem:** Write an **HTTP server** that **serves the same text file** for each request it receives
  - ***1st argument*: Port number** that the server listens on
  - ***2nd argument*:** The **location** of the file to serve
- You must use the `fs.createReadStream()` method to stream the file contents to the response
  - It creates a **stream** representing the file
  - Use `src.pipe( dst )` to pipe data from the `src` stream to the `dst` stream

Exercise 11: HTTP file server

- Use the **`http`** module to create an HTTP server
  - **`http.createServer()`** take a callback that is called once for each connection received by your server

```
function callback ( request, response ) { /* ... */ }
```

  - The two arguments are **Node `stream`** objects representing the HTTP request and the corresponding response
    - Request is used for **fetch properties**, e.g., the header and query string
    - Response is for **sending data to the client**, both headers and body
  - ***Ref.:*** http://nodejs.org/api/http.html

Exercise 12: HTTP uppercaserer

- **Problem:** Write an HTTP server that **receives only POST requests** and converts incoming **POST body characters** to **upper-case** and returns it to the client
  - ***1st argument*: Port number** that the server listens on
- You can use the "**`through2-map`**" module to create a **transform stream** using only a single function that takes a **chunk of data** and returns a chunk of data
  - Install **`through2-map`** using **npm**
  - Read https://www.npmjs.com/package/through2-map for its usage

Exercise 13: HTTP JSON API server

- **Problem:** Write an HTTP server that serves **JSON data** when it
  - Receives a GET request to the path "`/api/parsetime`"
    - The JSON response should contain only '`hour`', '`minute`' and '`second`' properties
  - Receives a GET request to the path "`/api/unixtime`"
    - The JSON response should contain the **UNIX epoch time in milliseconds** (the number of milliseconds since 1 Jan 1970 00:00:00 UTC) under the property '`unixtime`'
  - Both requests accept a query string with a key '`iso`' and an ISO-format time as the value
  - ***1st argument of the program*: Port number** that the server listens on

Exercise 13: HTTP JSON API server

- Use the `url.parse()` method in the `url` module to parse the URL and query string
  - ***Ref.:*** http://nodejs.org/api/url.html
- Use `JSON.stringify()` to convert an object into JSON string format
- To parse a date in **ISO format**, use `new Date( <ISO date string> )`
- Use `date.getTime()` to get the **UNIX epoch time in milliseconds**

Congratulations!

- You have learnt the fundamental concepts involved in Node.js development!
- To develop web applications even faster, we will use a **web framework** called **Express**
  - Please refer to the corresponding tutorial slides

– End –