INTRODUCING NODE.JS

Agenda

- Install Node.js
- Understand the power of Node.js
- Discuss Node.js architecture
- Use nvm & npm
- Understand module system
- Control flow strategies
- General topics

What

- Node.js is a server side JavaScript platform
- Built on Chrome's V8 engine
- Is open source
- Single threaded
- Event-driven, non blocking I/O
- Developed in 2009 by Ryan Dahl
- Supported by Joyent

Node.js as a Web server

- According to w3techs.com Node.js has only 0.4% market share
- Still, it gains more and more popularity
  - ~1million web sites world wide
  - PHP is ~40 million
- Top web sites
  - Aliexpress.com
  - bbc.com
  - outbrain.com
  - flickr.com

Node.js as BFF

- Node.js cannot easily replace existing server side infra written in Java/.NET
- Common scenario is to put Node.js at the front of Java/.NET → Backend for Frontend
- Usually is controlled by Front End engineers
  - Thus allowing the developer to push JavaScript code to the server
  - Improve client side performance

Node.js as Development Tools

- This is where Node.js really shines
- Extreme echo system of development tools
  - Build tools – Webpack, Gulp, Grunt
  - Compilers – Typescript, Babel
  - Testability – Selenium, Jasmine, Mocha
  - Desktop applications – VSCode, GithubDesktop

When should we use?

- Node.js is great when most work is I/O
- Think of a web server. The “hard” work relates to
  - HTTP → Networking I/O
  - Database → Networking I/O
  - File system
- The server is more of a controller/facade

When NOT to use

- Heavy server-side computation
  - Can offload the “hard” work to background processes
  - Can use threads (not common)
- Direct access to OS API is required
  - Can integrate C/C++ code

Installation

- Depends on the OS
- Starts with https://nodejs.org
- Amazingly you can just download Node.js as a tar/zip file and start using it
  - https://nodejs.org/dist/latest-v8.x/
- On Windows you may execute nodevars.bat which fixes the PATH with
  - node
  - npm

NVM

- Each Node.js project may be dependent on different Node.js version
- Can resolve that by installing Node.js per project
  - Less common
- NVM allows managing multiple versions of Node.js at the machine level while having only ONE active version at a time

NVM

- Ensure you don’t have any previous installation of Node.js
- nvm list – Get a list of all installed versions
- nvm install latest – Installs latest Node.js version
- nvm use 9.8.0 – Configure machine to use the specified version

Hello World Sample

- □ Create new main.js file
- □ Paste the following

```
console.log("Hello Node.js");
```

- □ From the command line execute

```
node main.js
```

- □ Can it be simpler ?

Http Server Sample

```
const http = require('http');

const requestHandler = (req, res) => {
    res.end('Hello Node.js Server!');
}

const server = http.createServer(requestHandler);

server.listen(3000, (err) => {
    if (err) {
        return console.log('something bad happened', err);
    }

    console.log(`server is running`);
});
```

Better abstraction with Express

- npm install express

```
const express = require("express");

const app = express();

app.get("/api/contact", function (req, res) {
    res.json([
        {id: 1, name: "Ori"},
        {id: 2, name: "Roni"}
    ]);
});

app.listen(3000, function() {
    console.log("Server is running");
});
```

Toolings

- But what if we just need a simple web server that returns static content from current directory
- No need to re-implement that
- npm install http-server
- node_modules/.bin/http-server
- A web server is up and running on port 8080 …

Typscript

- Adds type safety to Node.js
- npm install typescript
- npx tsc -init
- npm install @types/node
- npx tsc

Typescript generates compilation error ☺

```
import * as fs from "fs";

fs.readFile("main.ts", function(err, data: string) {
    console.log(data);
});
```

Quick Exercise

- Install nvm
- Install Node.js using nvm
- Create a simple HTTP echo server using Express
- /api/echo/hello → Returns “hello”

NODE.JS ARCHITECTURE

Agenda

- □ Discuss Node.js architecture
- □ Understand main characteristics
- □ Write some code

Characteristics

- Built on Chrome’s V8 engine
- Uses libuv
- Single threaded
- Event-driven
- Non blocking I/O

V8

- JavaScript engine
- Compiles JS to native machine code
- Written in C++
- Used in Chrome & Node.js
- Supports Windows, macOS, Linux
- Can be embedded into C++
- Hello world sample

V8 vs. The World

- Same role as Java's JVM or .NET's CLR
- However, JavaScript is dynamic language
- Therefore less optimization opportunities
- V8 profiles code at runtime and optimizes it
  - Same as Java HotSpot technique
  - Has two compilers Full-Codegen & Crankshaft
  - Therefore can be faster than GCC
  - Shouldn't be faster than Java/.NET
  - See some benchmarks

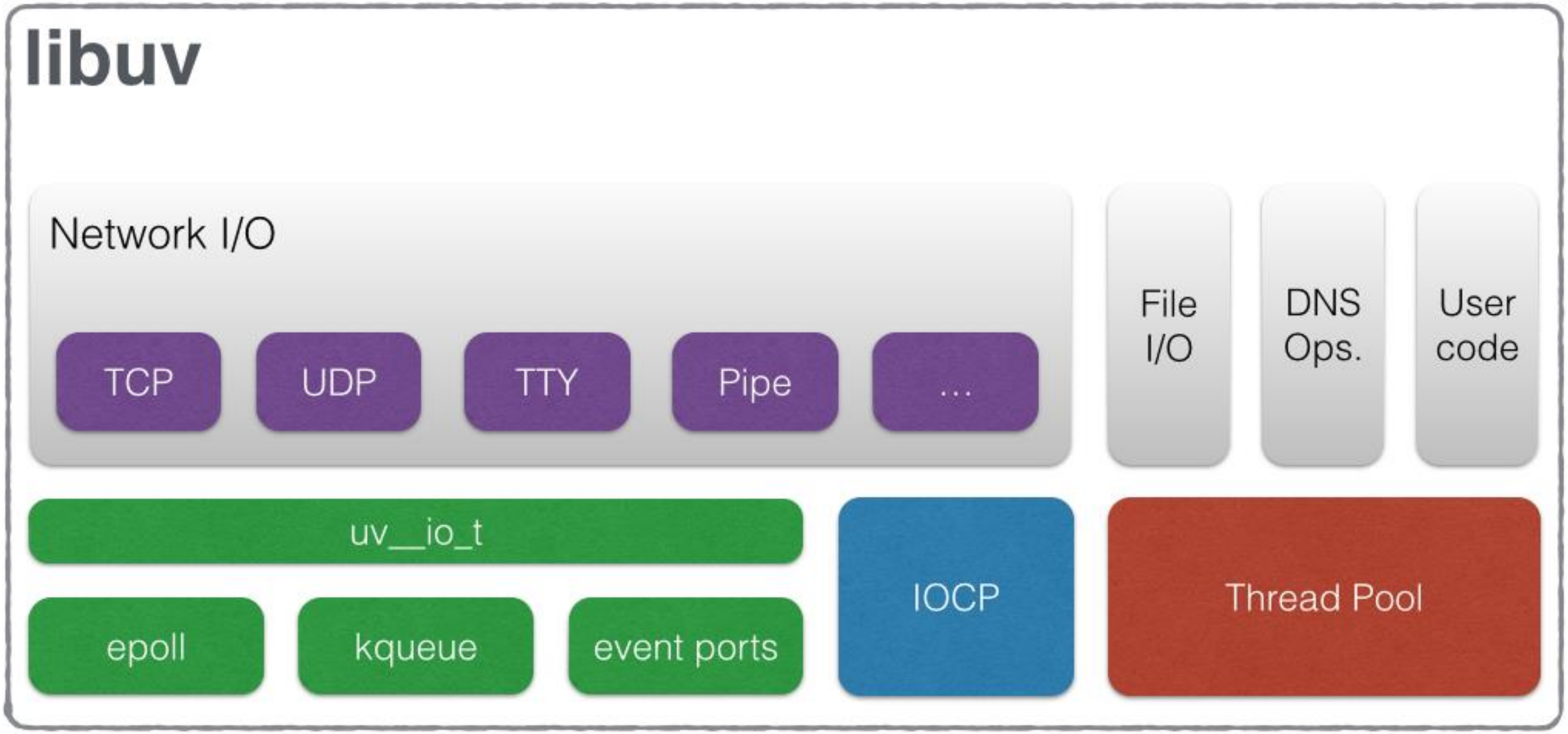
libuv

- Multi platform library with focus on asynchronous I/O
- Was developed for use by Node.js
  - But is now used by others
- Supports all the goodies of Node.js
  - Event loop
  - Async TCP & UDP sockets
  - Async file system operations
  - IPC
  - More …
- Create thread sample

libuv

- When possible uses OS asynchronous API
- Surprisingly does not use asynchronous file I/O
  - Code complexity
  - Poor APIs
  - Poor implementation
- Uses thread pool instead

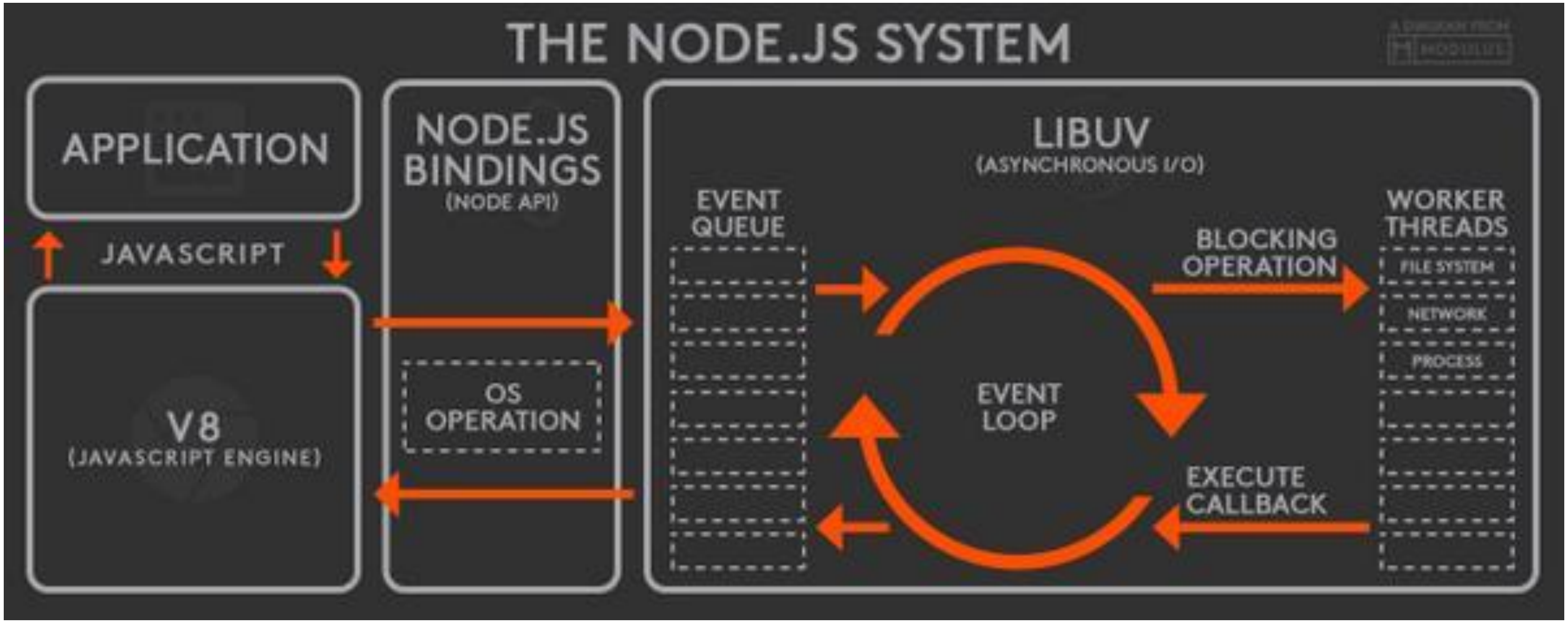
libuv


libuv
Network I/O
TCP
UDP
TTY
Pipe
...
File I/O
DNS Ops.
User code
uv__io_t
epoll
kqueue
event ports
IOCP
Thread Pool

Integrating

- Take V8
- Combine it with libuv
- Implement some JavaScript API to be consumed by the application
- And voila … Node.js

Node.js Architecture



Traditional Web Server

- Spawns new thread for each request
  - May use some kind of thread pool
- Each thread consumes memory and increases context switching
- Thread blocks when accessing file system/networking
- Programmer must synchronize access to shared/static data
  - Thus increasing even more blocking time

Single Threaded

- Only JavaScript code is Single Threaded
  - NodeJS has multiple worker threads

```
setTimeout(function() {
    console.log("timeout");
}, 1000);

console.log("Before");
sleep(2000);
console.log("After");

function sleep(ms) {
    const before = new Date();

    while(new Date() - before < ms);
}
```

```
Before
After
timeout
```

Event Queue

- □ Continuing with our previous sample
- □ What happens after 1000 milliseconds ?
- □ A worker thread handles the timer event by putting an appropriate event inside the queue
- □ Only when our JavaScript code completes it returns to the event loop and fetches the next waiting event

Asynchronous I/O

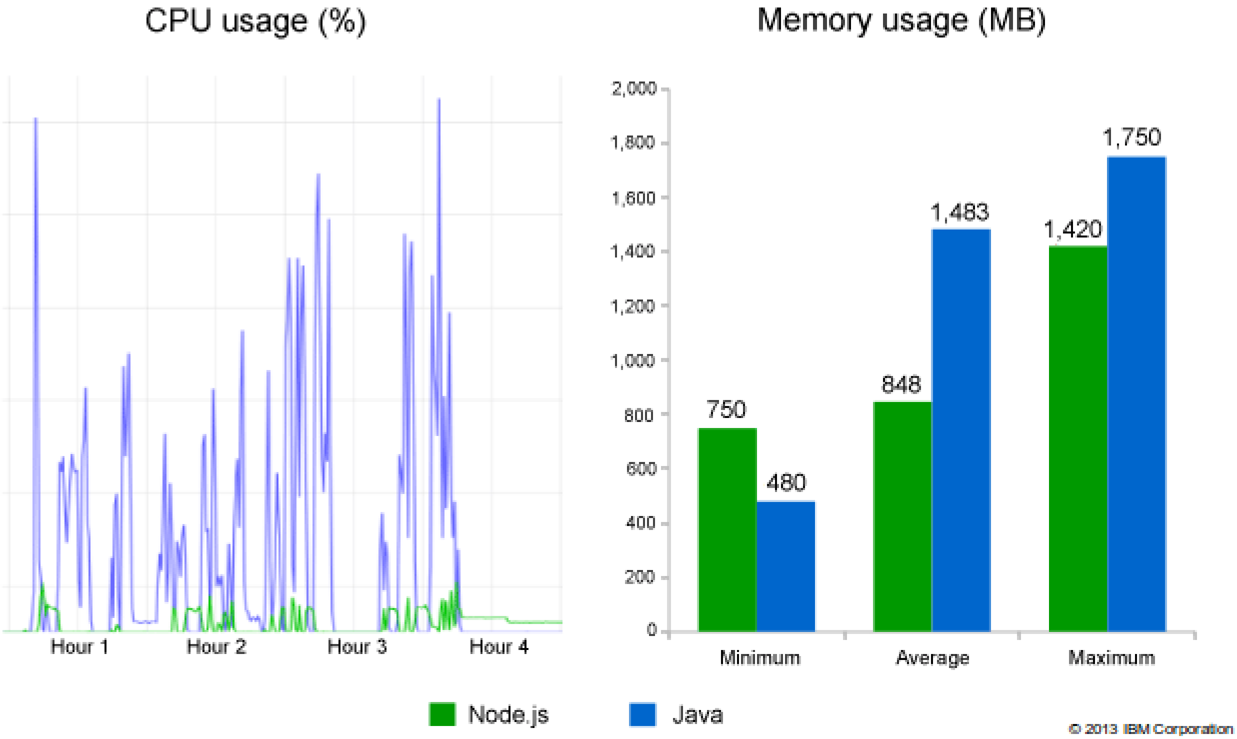
- Node.js uses callbacks to handle async operations
- The function returns immediately and the “real work” executes at the background
- Once completes, an event is pushed to the event queue waiting to be processed by the main thread

```
const fs = require("fs");

fs.readFile("main.js", function(err, buffer) {
    if(err) {
        return;
    }

    console.log(buffer.toString());
});
```

Performance



CPU usage (%)

Memory usage (MB)

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REPL

- □ Execute “node” and then enter
- □ Interactive mode
- □ Write and evaluate JavaScript code

```
> node
> 8 + 5
13
>
```

Debugging

- □ node --inspect --inspect-brk main.js
- □ Open Chrome at chrome::/inspect
- □ Wait for remote target list to refresh
- □ Click inspect
- □ Use Console/Sources/Memory tabs

Attach Debugger

- Find the PID of the running process
- Send SIGUSR1 signal

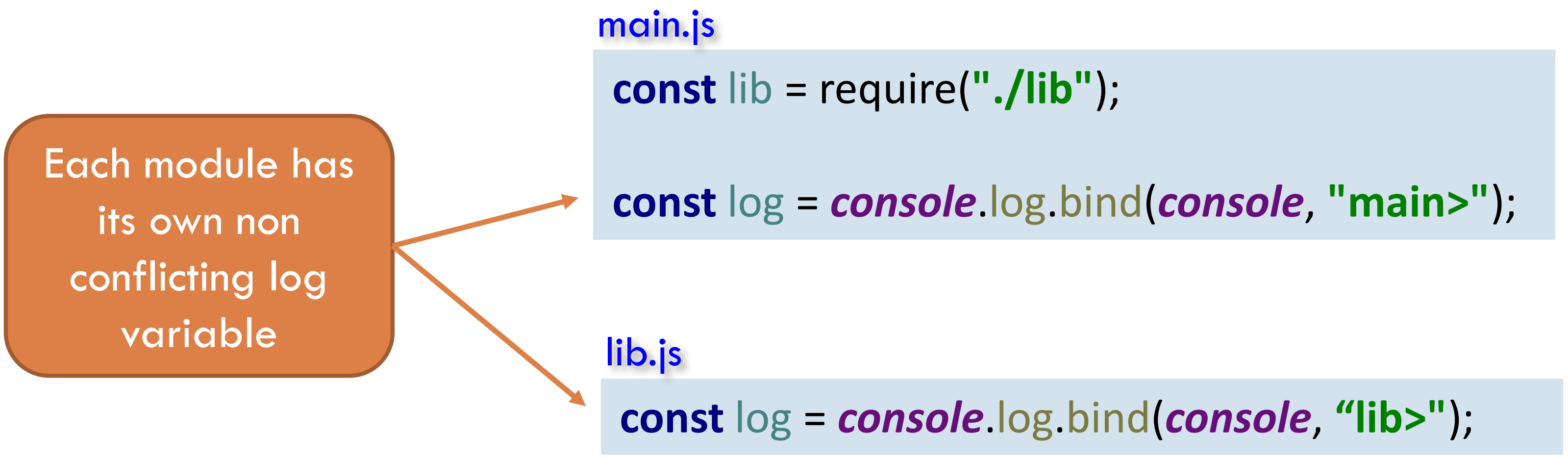
```
kill -s SIGUSR1 nodejs-pid
```

- Windows does not support the SIGUSR1 signal
  - Can use process._debugProcess(pid) instead
- Once the relevant process is signaled can use Chrome as usual

MODULES

Module System

- Each file is treated as a separate module
- Variables local to the module are private and cannot be accessed by other modules



Each module has its own non conflicting log variable

main.js

```
const lib = require("./lib");

const log = console.log.bind(console, "main>");
```

lib.js

```
const log = console.log.bind(console, “lib>");
```

Exporting

- Exporting a variable/function is done through the exports object

```
const log = console.log.bind(console, "lib>");

function doSomething() {
    log("doSomething");
}

exports.doSometing = doSomething;
```

require returns the exports object

```
const {doSometing} = require("./lib");
```

Module Wrapper

- □ Each file has its own exports, module and other variables
- □ Node.js achieves that by wrapping your code inside a function

```
(function(exports, require, module, __filename, __dirname) {
    // Module code actually lives in here
});
```

Module Scope

- □ __dirname – Full path of the directory containing the current module
- □ __filename – Full path of the current module
- □ exports – We saw that already
- □ module – Reference to the module object
- □ require – We saw that already

module.exports

- The exports object is created by the module system
- Sometimes you want to control the exports instance
  - For example, exporting a class

```
class Logger {
    constructor(prefix) {
        this.log = console.log.bind(console, prefix + ">");
        this.warn = console.warn.bind(console, prefix + ">");
        this.error = console.error.bind(console, prefix + ">");
    }
}

module.exports = Logger;
```

```
const {Logger} = require("./logger");

const logger = new Logger("main");

logger.log("In the beginning");
```

Cyclic Dependencies

- In case of cyclic dependency Node.js returns the original module.exports object
  - Thus, think twice before overwriting it

lib1.js

```
const lib2 = require("./lib2");

function run() {
    console.log("lib2", lib2);
}

module.exports = {
    run
};
```

lib2.js

```
const lib1 = require("./lib1");

function run() {
    console.log("lib1", lib1);
}

module.exports = {
    run
};
```

Might be empty object

Resolving require

- □ When using a relative path Node.js follows exactly that path

```
require("./lib");
```

- □ Same for absolute path

```
require("/lib");
```

- □ Supported extensions are: .js, .json, .node

Resolving require

- When specifying non relative/none absolute path Node.js looks for the following locations
  - Core module: http, fs, path
  - ./node_modules/lib1.js
  - ../node_modules/lib1.js
  - ../../node_modules/lib1.js
- Up until the root folder

```
require("lib1");
```

Require a folder

- □ It is valid to require a folder. In that case Node.js looks for index.js file
- □ You can change the default name by using a package.json file

```
{
  "main": "main.js"
}
```

Node.js looks for main.js instead of index.js

module.paths

- □ Allows for dynamic modification of the locations Node.js uses when resolving a dependency

```
module.paths.push("c:\\1");

require("lib");
```

require.cache

- □ Holds a map of all loaded modules
- □ Can manipulate it and force module reload

```
const path = require("path");

require("./lib");

delete require.cache[path.resolve(__dirname, "./lib.js")];

require("./lib");
```

Delete reference to module object from require.cache

Native Modules

- When Node.js public API is not enough you may implement native modules which access OS directly
- Not straight forward ☹
- Need to write cross platform C++ code
  - May use libuv to achieve that
- Must use V8 APIs to interact with JavaScript code
  - V8 changes a lot over time
  - Thus, native module tend to break cross Node.js versions

C++ Addon

```
#include <node.h>

namespace demo {

using v8::FunctionCallbackInfo;
using v8::Isolate;
using v8::Local;
using v8::Object;
using v8::String;
using v8::Value;

void Method(const FunctionCallbackInfo<Value>& args) {
  Isolate* isolate = args.GetIsolate();
  args.GetReturnValue().Set(String::NewFromUtf8(isolate, "world"));
}

void init(Local<Object> exports) {
  NODE_SET_METHOD(exports, "hello", Method);
}

NODE_MODULE(NODE_GYP_MODULE_NAME, init)

}  // namespace demo
```

Compile the Addon

- □ Create binding.gyp file

```
{
  "targets": [
    {
      "target_name": "addon",
      "sources": [ "hello.cc" ]
    }
  ]
}
```

- □ npm install –g node-gyp
- □ node-gyp configure → Makefile/vcxproj file is created
- □ node-gyp build → addon.node is created

```
const addon = require('./build/Release/addon');
console.log(addon.hello());
```

CONTROL FLOW

The Challenge

- □ Node.js asynchronous nature impose non intuitive programming model

Callback hell

```
function readFileIfExists(filePath, callback) {
    fs.stat(filePath, function (err, stat) {
        if (err) {
            callback(err);
            return;
        }

        if (stat.isFile()) {
            fs.readFile(filePath, function (err, data) {
                if (err) {
                    callback(err);
                    return;
                }

                callback(null, data.toString());
            });
        }
    });
}
```

async package

- □ Async utilities for node and the browser
- □ npm install async

```
function readFileIfExists(filePath, cb) {
    async.seq(
        fs.stat,
        (stat, cb) => stat.isFile() ? fs.readFile(filePath, cb) : cb(new Error("Not a file")),
        )(filePath, cb);
}
```

Promise Flow

- □ Convert each function to promise based

```
function readFile(filePath) {
    return new Promise((resolve, reject)=> {
        fs.readFile(filePath, function(err, data) {
            if(err) {
                reject(err);
                return;
            }

            resolve(data);
        });
    });
}
```

- □ Can wrap that logic inside a promisify helper

promisify

```
function promisify(func) {
    return function (...args) {
        return new Promise((resolve, reject) => {
            args.push(callback);
            func.apply(this, args);

            function callback(err, res) {
                if(err) {
                    reject(err);
                    return;
                }

                resolve(res);
            }
        });
    }
}
```

es6-promisify package offers an almost identical function

Use the new functions

```
function readFileIfExists(filePath) {
    return stat("1.txt").then(stat => {
        if (stat.isFile()) {
            return readFile(filePath);
        }

        throw new Error("Not a file");
    });
}
```

Return a promise to allow “continuation”

Must throw exception to signal an error

Callback hell ?

- The promise flow simplifies code since middle layers does not have to deal with errors
- However, the code still suffers from the callback hell

```
function readFileIfExists(filePath) {
    return stat("1.txt").then(stat => {
        if (stat.isFile()) {
            return readFile(filePath);
        }

        throw new Error("Not a file");
    });
}
```

async/await

- Code feels almost synchronous

```
async function readFileIfExists(filePath) {
    const info = await stat(filePath);
    if(!info.isFile()) {
        throw new Error("Not a file");
    }

    return await readFile(filePath);
}
```

```
async function main() {
    try {
        const data = await readFileIfExists("1.txt");
        console.log(data.toString());
    }
    catch(err) {
        console.error(err);
    }
}
```

Promise Flow

- Unfortunately most Node.js APIs are callback based
- Need to manually wrap the code
- Be careful when wrapping instance methods
  - Must keep the correct this

```
const obj = {
    id: 123,
    oldStyle: function(callback) {
        callback(null, this.id);
    }
};

const newStyle = promisify(obj.oldStyle.bind(obj));
```

Promise Limitation

- Promise can be resolved only once
- Therefore, it cannot represent a reoccurring event
  - Stream
  - Button clicks
- Runs immediately

Rxjs

- ReactiveX library for JavaScript
- A big concept
- Some love it, some hate it
- Out of scope for us
- However, lets take a simple look

Rxjs

- Observable generates a stream of values

```
const filePath = "1.txt";
const source = stat(filePath).switchMap(stat => {
    if (!stat.isFile()) {
        throw new Error("Not a file");
    }

    return readFile(filePath);
});

source.subscribe(res => {
    console.log(res.toString());
}, err => {
    console.error(err);
});
```

GENERAL TOPICS

Auto Restart

- When developing a web server it is convenient that the server is automatically restarted with each code modification
- npm install nodemon
- node_modules/.bin/nodemon main.js
- Other alternatives
  - forever
  - pm2

Yarn

- https://yarnpkg.com/en/
- Yarn follows the same NPM rules but is considered faster
- Has better caching strategic
- Automatically creates package.json
- Supports workspace

Summary

- Node.js is a lean platform
  - Less Than 20MB of installation
- Easily installed and getting started
- Lot's of open source packages
  - Some time its hard to choose the right one