Node.js: a little overview

Nicola Del Gobbo

Who am I?

Developer

packly

Full stack developer highly focused on performance

N-API Team

My research field

How to implement a native addon for Node.js with programming languages different from C or C++

Agenda

Introduction to Node.js 

How to create distributed services 

Native Addons 

Who use **Node.js**?

What can I do with **Node.js**?

Everything

Great thank to Node.js **Community** and **Working Groups**

Packages	Downloads - Last Week	Downloads - Last Month
963,619	**10,822,198,617**	**48,577,378,041**

What can I do with **Node.js**?

express

MQTT.js

socket.io

fastify

CLI APPLICATION

DISRTRUBUTED SYSTEM

REAL TIME SYSTEM

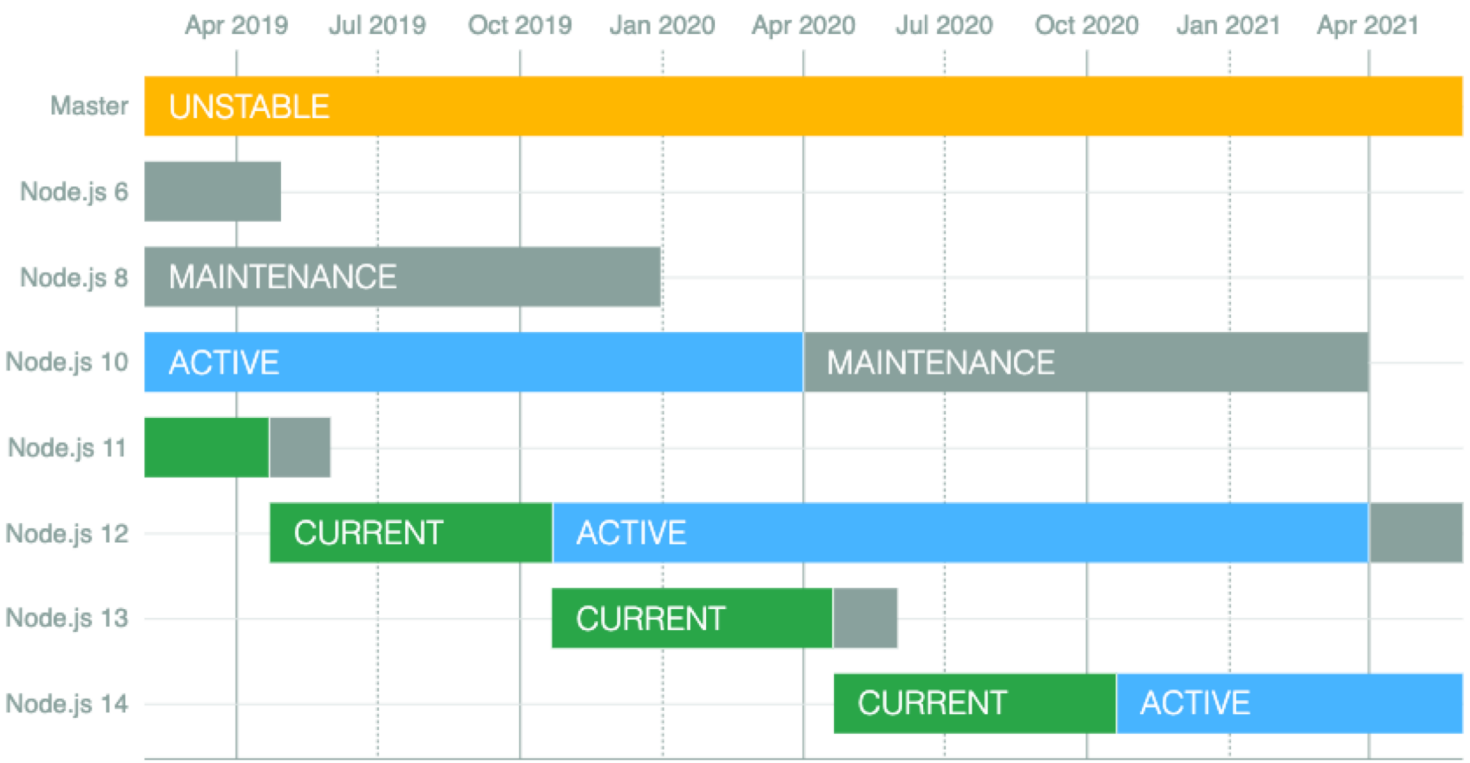
DESKTOP APPLICATION

Release

LTS Recommended For Most Users		Current Latest Features
 Windows Installer node-v10.15.3-x86.msi	 macOS Installer node-v10.15.3.pkg	 Source Code node-v10.15.3.tar.gz

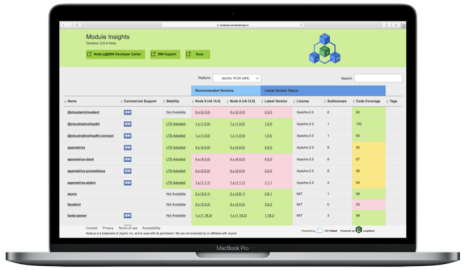
Windows Installer (.msi)	32-bit	64-bit	
Windows Binary (.zip)	32-bit	64-bit	
macOS Installer (.pkg)	64-bit		
macOS Binary (.tar.gz)	64-bit		
Linux Binaries (x64)	64-bit		
Linux Binaries (ARM)	ARMv6	ARMv7	ARMv8
Source Code	node-v10.15.3.tar.gz		

Release



https://github.com/nodejs/Release

CloudNativeJS.io



Choose your modules

Add health checking

OPENTRACING

Track your requests

Power your metrics

Build your Docker image

Deploy to Kubernetes

What is **Node.js**?

Node.js is a **JavaScript runtime** built on Chrome's **V8 JavaScript engine**

A **JavaScript engine**

Asynchronous I/O

~100k LOC of JS and C++

Node is a **glue**

Node.js architecture

Node.js API

Node.js Bindings

C / C++ Addons

c-ares

HTTP parser

Open SSL

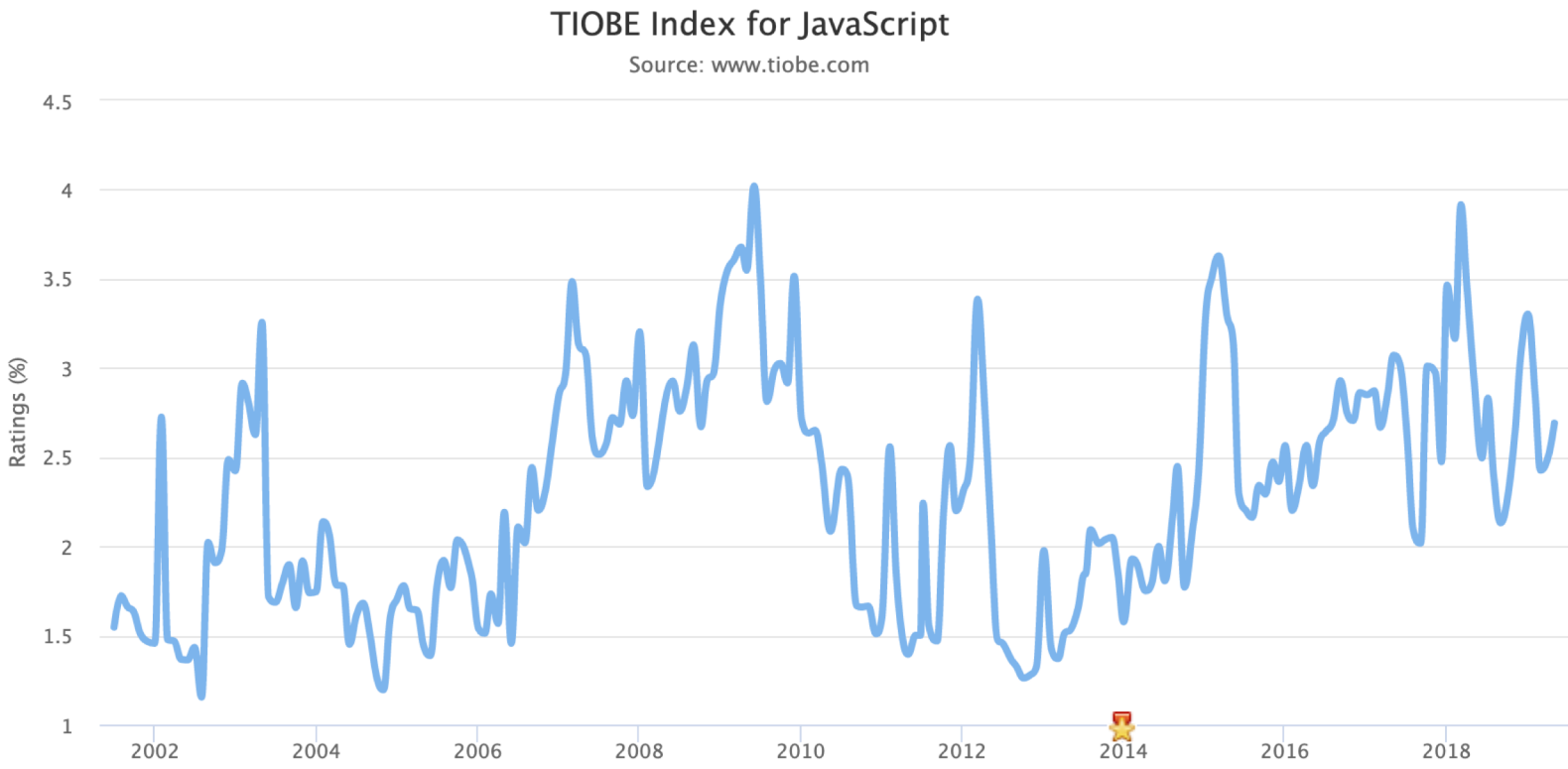
zlib

nghttp2

JavaScript

“The world's most **misunderstood** programming language“

Douglas Crockford



JavaScript

- **let** and **const**
- Better **Unicode** support
- **Template literals**
- **Arrow function**
- **Default parameters**
- Spread operator
- **Class**
- **Destructuring**
- Symbols

- **Sets** and **Maps**
- **Iterator**
- Generator
- **Promise**
- **Async** / **Await**
- **Async Iterator**
- Proxy API
- Reflection API

ES2015 **ES2016** **ES2017** **ES2018** **ES2019**

JavaScript

“JavaScript developers should **focus** on writing ***idiomatic***, ***readable*** and *maintainable* code“

Peter Marshall & Arunesh Chandra

“Use **JavaScript** like **JavaScript**“

CONCURRENCY MODEL?

Single threaded

by default

Worker Threads from Node.js v10.5.0

Asynchronous I/O

Execution never stop

Don’t block the event loop

Synchronous model?

```
var result = db.query('select ...');
// use result
```

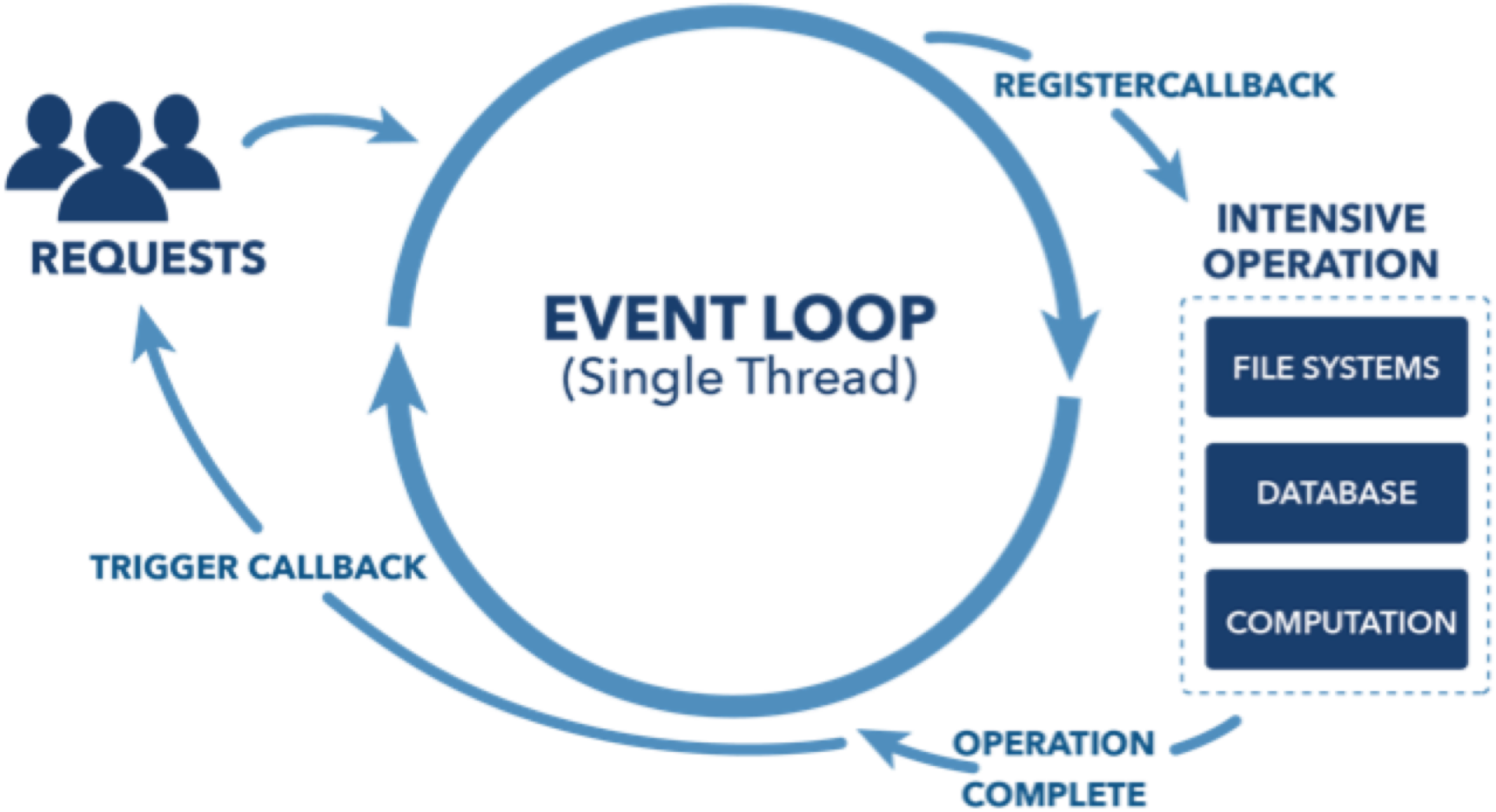
Blocking the whole process or you need to have **multiple execution stacks**

Asynchronous model?

```
db.query('select ...', function (result) {
    // use result
})

// Execution continue
console.log('Do other stuff ...')
```

The **main** process is **never blocked**. No strategy is required to handle competing requests

The **event loop**



Asynchronous in low level

```
'use strict'

const bcrypt = require('bcrypt')

const SALT_ROUNDS = 10
const STR_TO_HASH = 'Node.js: little overview'

async function run() {
    const hashed = await bcrypt.hash(STR_TO_HASH, await bcrypt.genSalt(SALT_ROUNDS))
    console.log(hashed)
}

run().catch( err => { console.error(err) })
```

Asynchronous in low level

```
Napi::Value GenerateSalt(const Napi::CallbackInfo& info) {
    if (info.Length() < 3) {
        throw Napi::TypeError::New(info.Env(), "3 arguments expected");
    }
    if (!info[1].IsBuffer() || (info[1].As<Napi::Buffer<char>>()).Length() != 16) {
        throw Napi::TypeError::New(info.Env(), "Second argument must be a 16 byte Buffer");
    }
    const int32_t rounds = info[0].As<Napi::Number>();
    Napi::Function callback = info[2].As<Napi::Function>();
    Napi::Buffer<char> seed = info[1].As<Napi::Buffer<char>>();
    SaltAsyncWorker* saltWorker = new SaltAsyncWorker(callback, std::string(seed.Data(), 16), rounds);
    saltWorker->Queue();
    return info.Env().Undefined();
}
```

Modularity

CommonJS Module

ES6 Module from v8.5.0

“Se non hai provato Node.js non sai cos’è la **modularità** e il **riuso**”

Matteo Collina

Modularity

```
'use strict'

function Person (opts) {
    this._firstName = opts.firstName || ''
    this._lastName = opts.lastName || ''
}

Person.prototype.toString = function toString() {
    return `First name: ${this._firstName}
    Last name: ${this._lastName}`
}

module.exports = Person
```

```
'use strict'

function isPrime (p) {
    const upper = Math.sqrt(p)
    for (let i = 2; i <= upper; i++) {
        if (p % i === 0) {
            return false
        }
    }
    return true
}

exports.isPrime = isPrime
```

Modularity

```
'use strict'

const Persone = require('./Person')

const p = new Persone({
    firstName: 'Nicola',
    lastName: 'Del Gobbo'
})

console.log(p.toString())
```

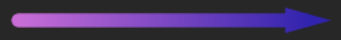
```
'use strict'

const isPrime = require('./is-prime')

console.log(isPrime(3))
```

Events

EventEmitter is a very important class in Node.js. It provides a **channel for events to be dispatched** and **listeners notified**. Many objects you will encounter in Node.js inherit from EventEmitter

Emitter

Emitter object emits event with optional data associated it



Event with data

Listener

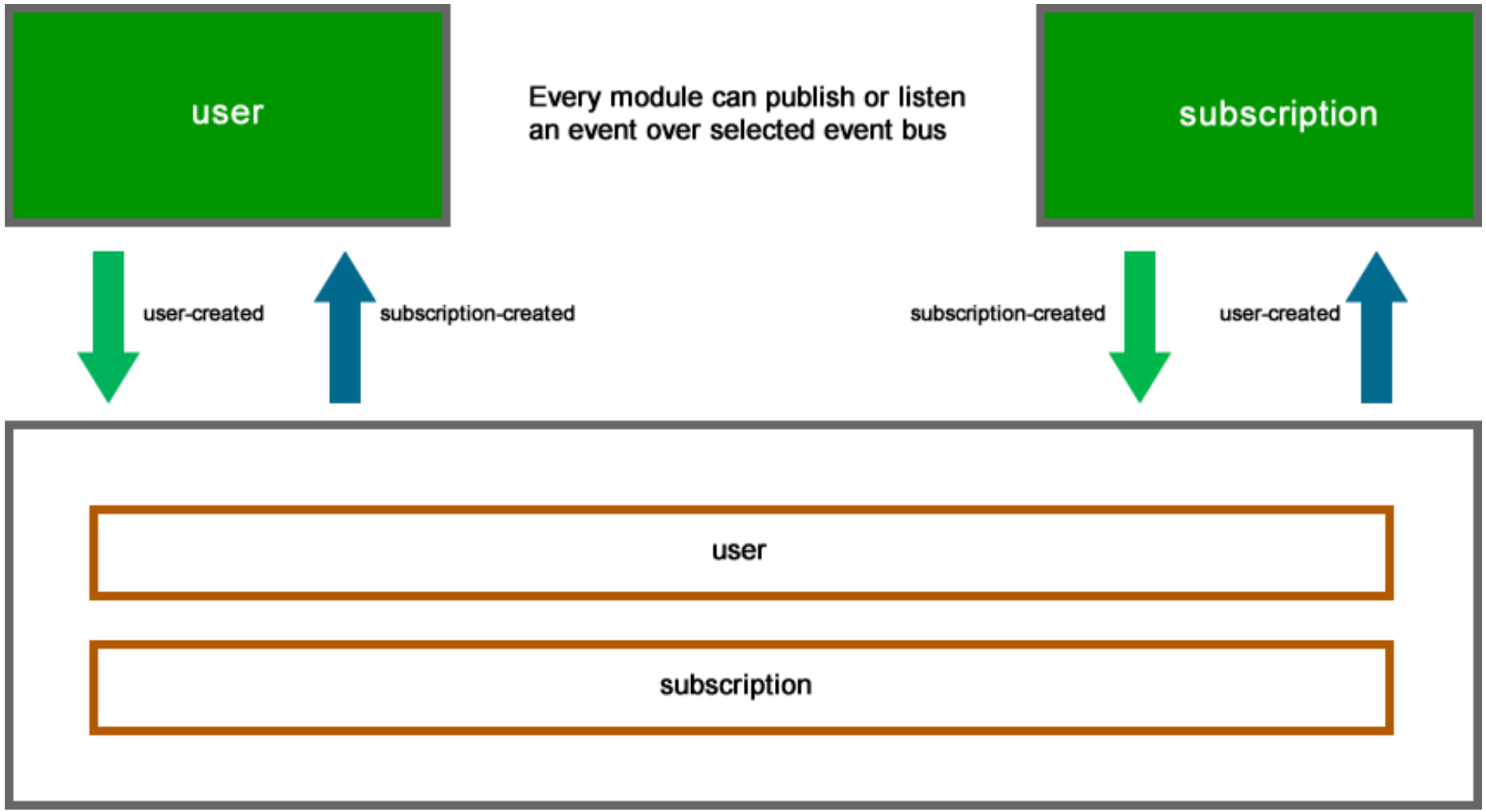
Listeners execute some actions when one event is emitted

Events

```
'use strict'

const { EventEmitter } = require('events')

class UserCtrl extends EventEmitter {

    constructor () {
        // do some initialization tasks
    }

    addUser (user) {
        // register user on db
        // emit event
        this.emit('user:added', { userName: 'NickNaso' })
    }

}
```

```
'use strict'

const UserCtrl = require('./UserCtrl')

const ctrl = new UserCtrl()

ctrl.on('user:added', data => {
    // do something with data
})

ctrl.addUser({
    userName: 'NickNaso',
    password: 'nodejs'
})
```

Event bus


user
Every module can publish or listen
an event over selected event bus
subscription
user-created
subscription-created
subscription-created
user-created
user
subscription

Event bus

```
'use strict'

const Hertzy = require('hertzy')

// Obtain or create a new frequency, a channel where you can emit or listen for
// an event issued by other modules
const usr = Hertzy.tune('user')

// Listen for event 'user:add'
usr.on('user:add', function (data) {
    console.log('NEW USER ADDED WITH FOLLOWING DATA:')
    console.log(data)
})

// Emit event 'user:add'
usr.emit('user:add', {
    username: 'NickNaso',
    password: '********',
    email: 'nicoladelgobbo@gmail.com'
})
```

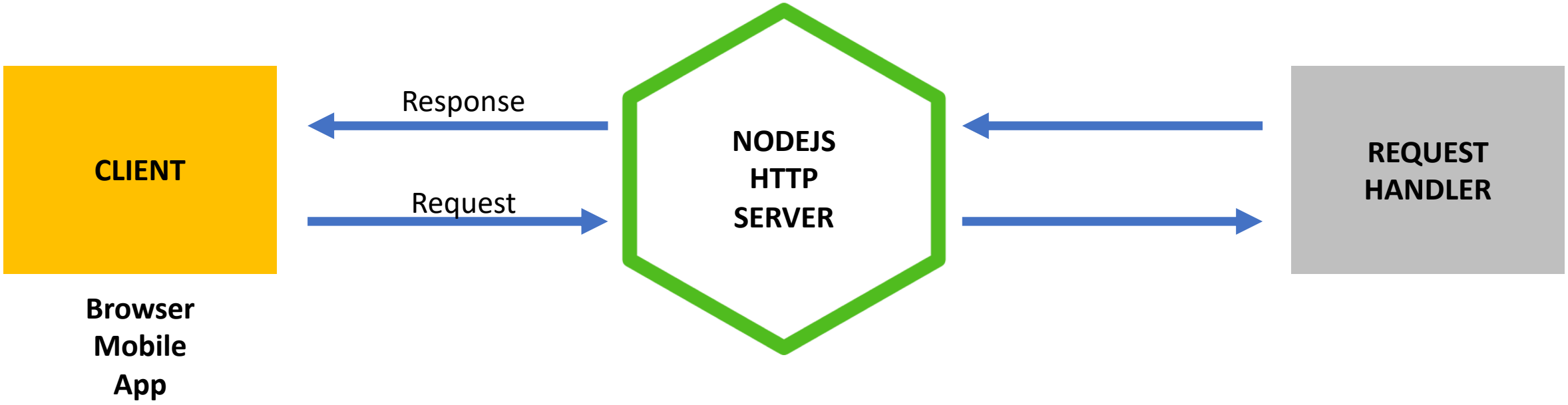
Stream

- **Buffer**: data structure to store and transfer arbitrary binary data
- **Stream**: abstract interface for working with streaming data

Stream vs Buffer

- **Streams** keep a low memory footprint even with large amounts of data
- **Streams** allow you to process data as soon as it arrives

Web application



http://your-web-application

Use **http** core

```
'use strict'

const http = require("http")
const url = require("url")

function onRequest(request, response) {
    let pathname = url.parse(request.url).pathname
    console.log("Request for " + pathname + " received.")
    if (pathname === "/start") {
        response.writeHead(200, { "Content-Type": "text/plain" })
        response.write("Hello")
        response.end()
    } else if (pathname === "/finish") {
        response.writeHead(200, { "Content-Type": "text/plain" })
        response.write("Goodbye")
        response.end()
    } else {
        response.writeHead(404, { "Content-Type": "text/plain" })
        response.end("404 Not Found")
    }
}

http.createServer(onRequest).listen(5000)
console.log("Server has started.")
```

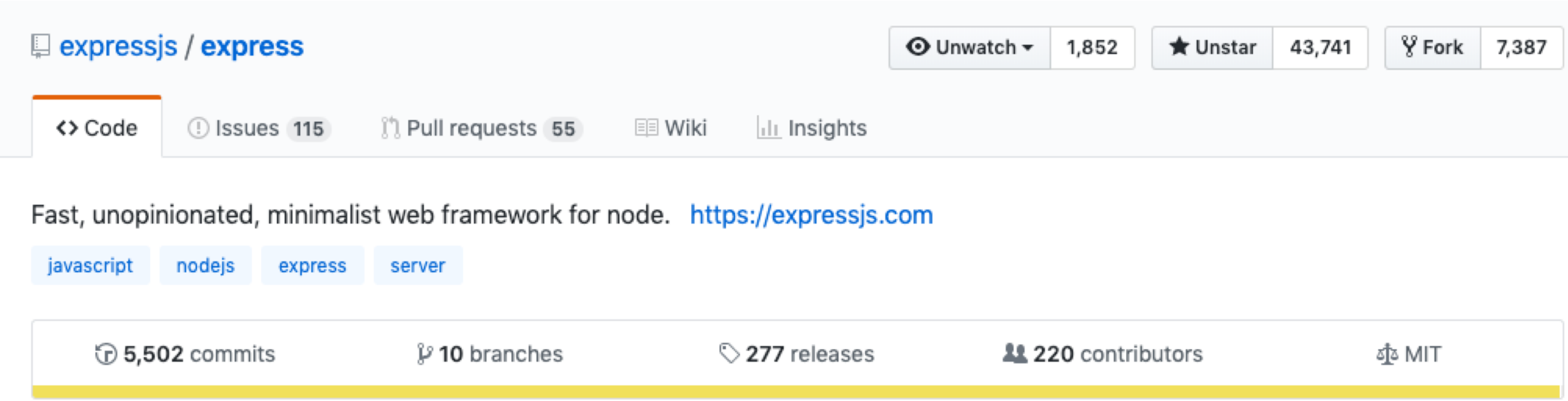
Route handler

Request handler

Frameworks

express

Express



Downloads - Last Week

7,495,349

Downloads - Last Month

33,248,650

Express

- Minimalist
- Unopinionated
- Fast (about **38k** req/sec)
- Simple (**do one thing well** philosophy from Unix world)
- Wrapper of **http** core module

```
'use strict'

const http = require("http")
const express = require('express')
const app = express()

app.get('/start', (req, res) => {
    res.status(200).send('Hello')
})

app.get('/finish', (re, res) => {
    res.status(200).send('Goodbye')
})

http.createServer(app).listen(5000)
console.log("Server has started.")
```

Import and create

Route handler

For web sockets bind express to http module

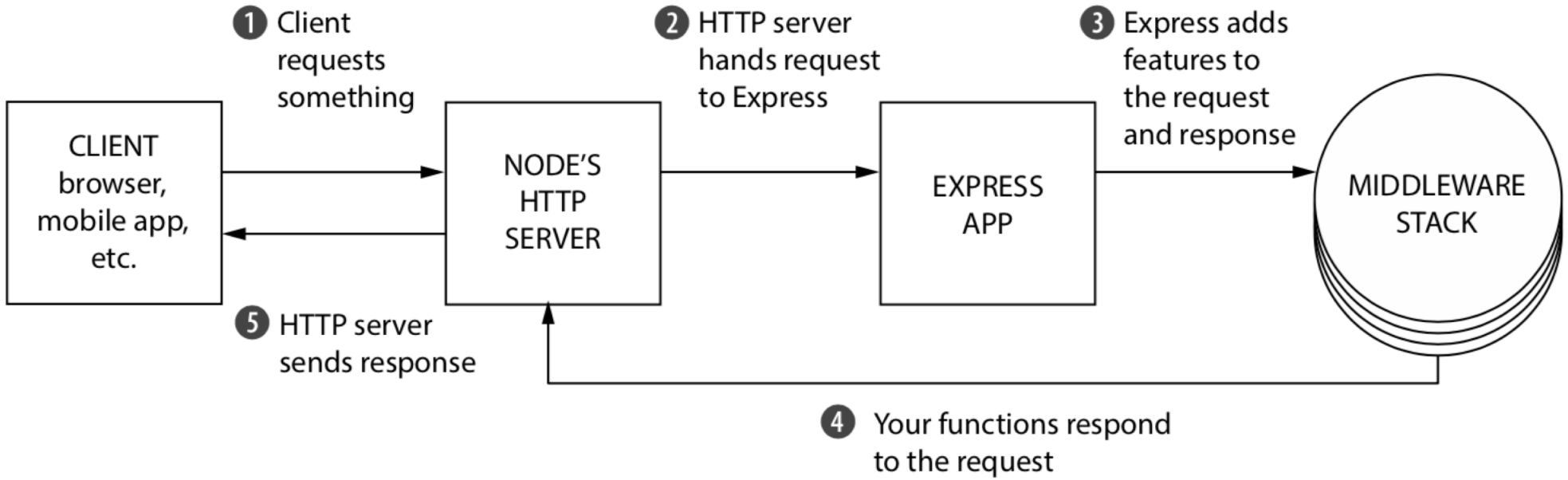
Express **milestones**

- Middleware
- Error handler
- Router
- Views / template engine

Middlewares

It’s always a question to manipulate the **Request** and **Response** object

Middlewares



Use **middlewares**

```
'use strict'

const path = require('path')
const http = require("http")
const express = require('express')
const morgan = require('morgan')
const serve = require('express').static

const app = express()
```

Attach middleware to Express

```
app.use(morgan('combined'))
app.use(serve(path.join(__dirname, 'public')))
```

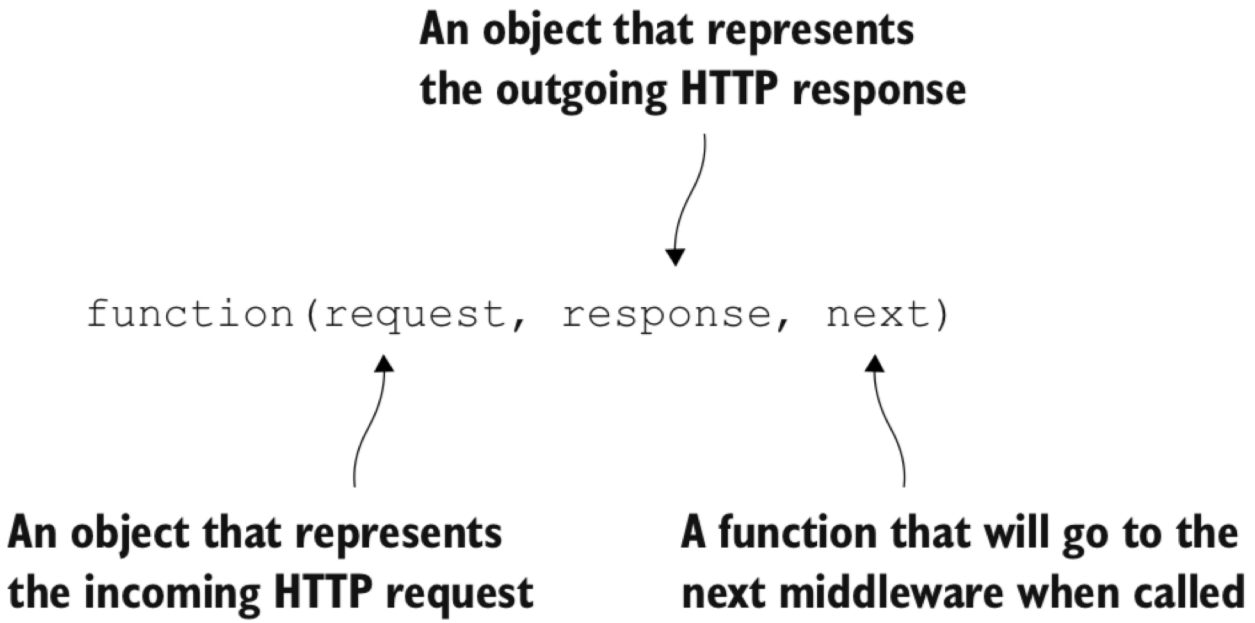
```
app.get('/', (req, res) => {
    res.status(200).sendFile('/index.html')
})

http.createServer(app).listen(5000)
console.log("Server has started.")
```

Custom **middlewares**

```
'use strict'

const bannedIps = ['192.168.0.1', '192.168.0.2', '192.168.0.3']

function myMiddleware (req, res, next) {

    // ... DO SOMETHING WITH REQUEST AND RESPONSE
    if (bannedIps.includes(req.ip)) {
        const err = new Error('Your IP is banned go away')
        next(err)
    } else {
        next()
    }

}
```

```
'use strict'

function myMiddleware (bannedIps) {
    // ... DO SOMETHING WITH BANNED IPs
    return function (req, res, next) {
        // ... DO SOMETHING WITH REQUEST AND RESPONSE
        if (bannedIps.includes(req.ip)) {
            const err = new Error('Your IP is banned go away')
            next(err)
        } else {
            next()
        }
    }
}
```

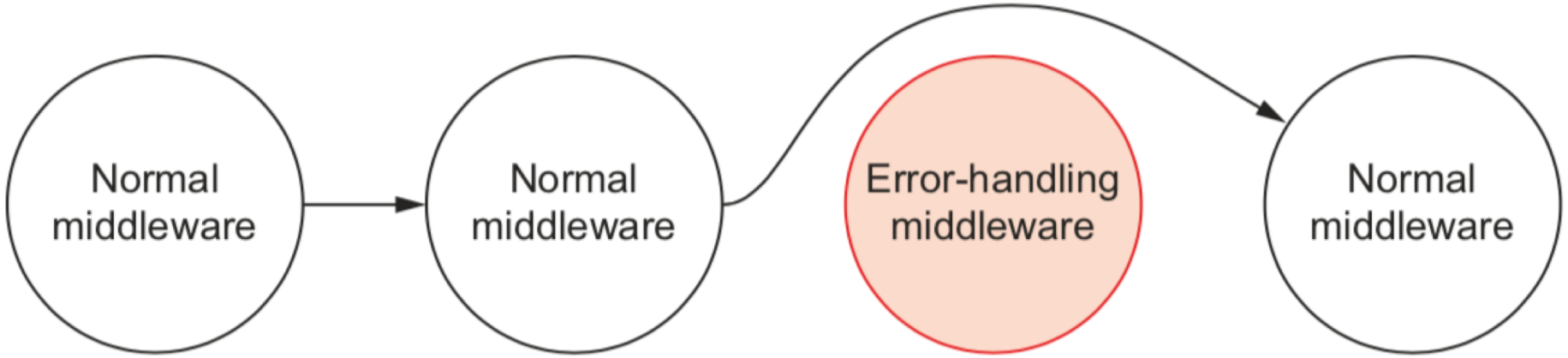
Middlewares



http://expressjs.com/en/resources/middleware.html

Error handler

```
'use strict'

function errorHandler () {
    return function (err, req, res, next) {
        // ... PARSE YOUR ERROR
        // ... DO SOMETHING WITH REQUEST AND RESPONSE
        // ... IDENTIFY STATUS CODE AND MESSAGE FOR YOUR RESPONSE
    }
}
```



Routing

```
app.get('/songs', (req, res, next) => {
    // ... DO SOMETHING ON YOUR ROUTE
})

app.get('/songs/:title', (req, res, next) => {
    // ... DO SOMETHING ON YOUR ROUTE
})

app.post('/songs', (req, res, next) => {
    // ... DO SOMETHING ON YOUR ROUTE
})

app.put('/songs/:title', (req, res, next) => {
    // ... DO SOMETHING ON YOUR ROUTE
})

app.delete('/songs/:title', (req, res, next) => {
    // ... DO SOMETHING ON YOUR ROUTE
})
```

Routing refers to determining how an application responds to a client request to a particular endpoint, which is a URI (or path) and a specific HTTP request method

Validate your input

The fastest JSON Schema validator for Node.js and browser

Views / template engine

Pug - Mustache - Dust - Nunjuks - EJS

```
app.set('view engine', 'ejs')
```
Set the engine

```
app.engine('ejs', require('ejs').__express)
```
Register the engine

```
app.set('views', path.join(__dirname, 'views'))
```
Set views folder

Security

Helmet helps you secure your Express apps by setting various HTTP headers

Logger

Log everything that happens in your application

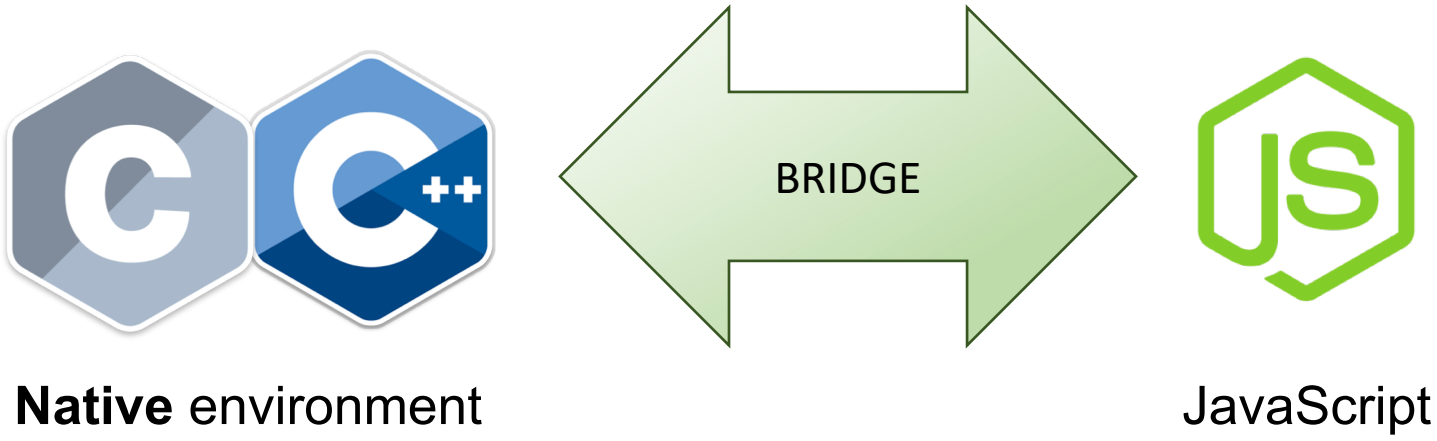
Pay attention there is a **cost** for logging

Winston

pino 

What is Node.js Native Add-on?

C / C++ code called from JavaScript



Native environment

JavaScript

From Node.js documentation

*Node.js Addons are **dynamically-linked shared objects**, written in **C++**, that can be loaded into Node.js using the **require()** function, and used just as if they were an ordinary Node.js module.*

*They are used primarily to provide an **interface** between **JavaScript** running in Node.js and **C/C++** libraries.*

Why?

Performance

In general **C / C++** code performs better than JavaScript code, but it’s not always true.

Image processing (in average 6 times faster)

Video processing

CRC cyclic redundancy check (in average 125 times faster)

Compression

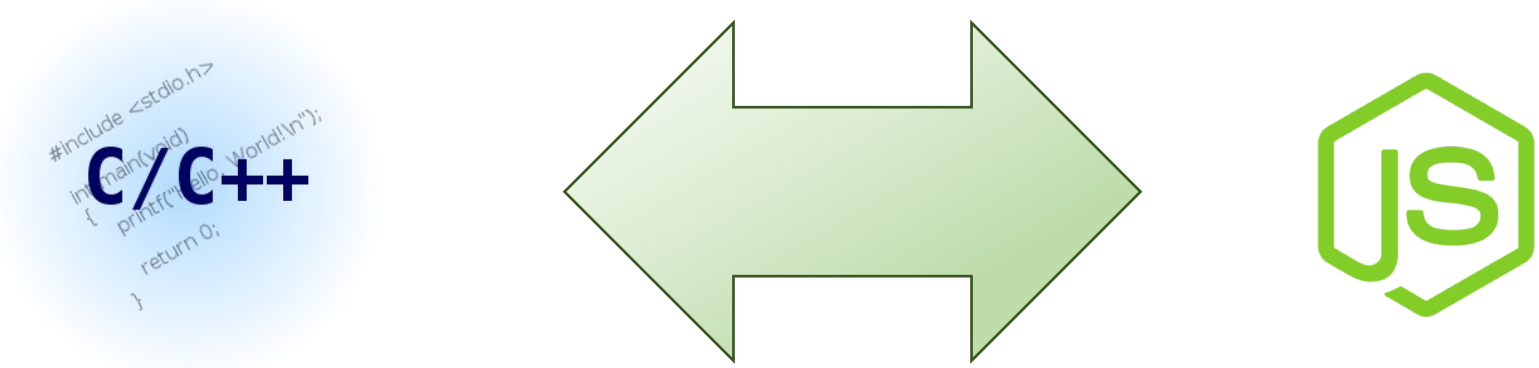
Scientific calculus

Algorithms that execute CPU heavy tasks

Why?

Integrate legacy application

You have the source code of an **old C / C++** application and want to expose something of its functionalities



Why?

You don’t find what fits your specific needs on **npm**

Sometimes completely implementing the module in **JavaScript** is not the right solution

Think at libraries like:

ImageMagick

Ghostscript

FFmpeg

TensorFlow

…

Why?

Better error handling

Even if you will use **an old C / C++** library you will get an error code that explains the error that just happened

In **new C / C++** library you have the **exception**

You don’t have to parse some string to identify if there was an error and what kind of it

With great power comes great responsibility

Ben Parker

Problems

Fragmentation API

The API to implement native add-ons has been changed across different version of Node.js

Most of the changes were on **V8 API** and **ObjectWrap API**

0.8 - 0.10.x - 0.12.x - 1.x - 2.x - 3.x - 4.x - 5.x - 6.x - 7.x - 8.x - 9.x - 10.x - 11.x - 12.x

For more info **http://v8docs.nodesource.com/**

Problems

Need an adapter to stay compatible across different version of Node.js

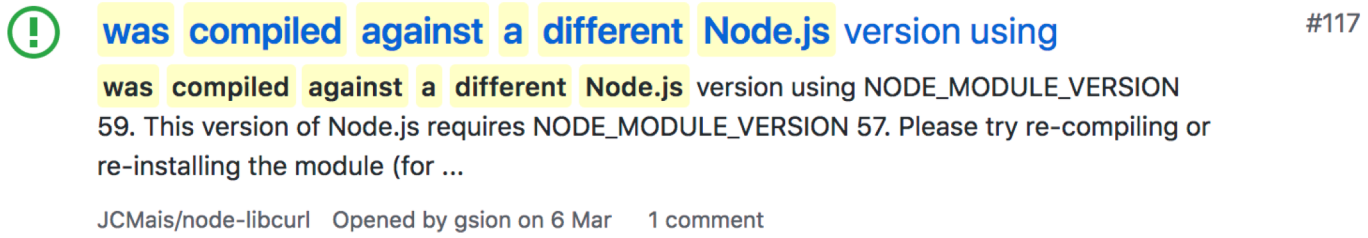
- **NAN** - Native Abstraction for Node.js
  - **API compatibility**
  - Strong bonded with **V8 API**
  - You have to recompile your native add-ons switching to different version of Node.js

Problems

End user

```
| was compiled against a different Node.js version using
| NODE_MODULE_VERSION 51. This version of Node.js requires
| NODE_MODULE_VERSION 57. Please try re-compiling or re-installing
| the module (for instance, using `npm rebuild` or `npm install`).
```

Mantainers




Addon
Node.js: 6.12.2
V8: 5.1.281
NODE_MODULE_VERSION: 48

ABI break

- At worst, mysterious segfaults
- At best, addon fails to load
- NODE_MODULE_VERSION mismatch

```
Node.js: 8.9.3
     V8: 6.1.534
NODE_MODULE_VERSION: 57
```

Problems

Write portable C / C++ code

Your native code **must compile and run** on different:

ARCHITECTURE

PLATFORM

COMPILER

Problems

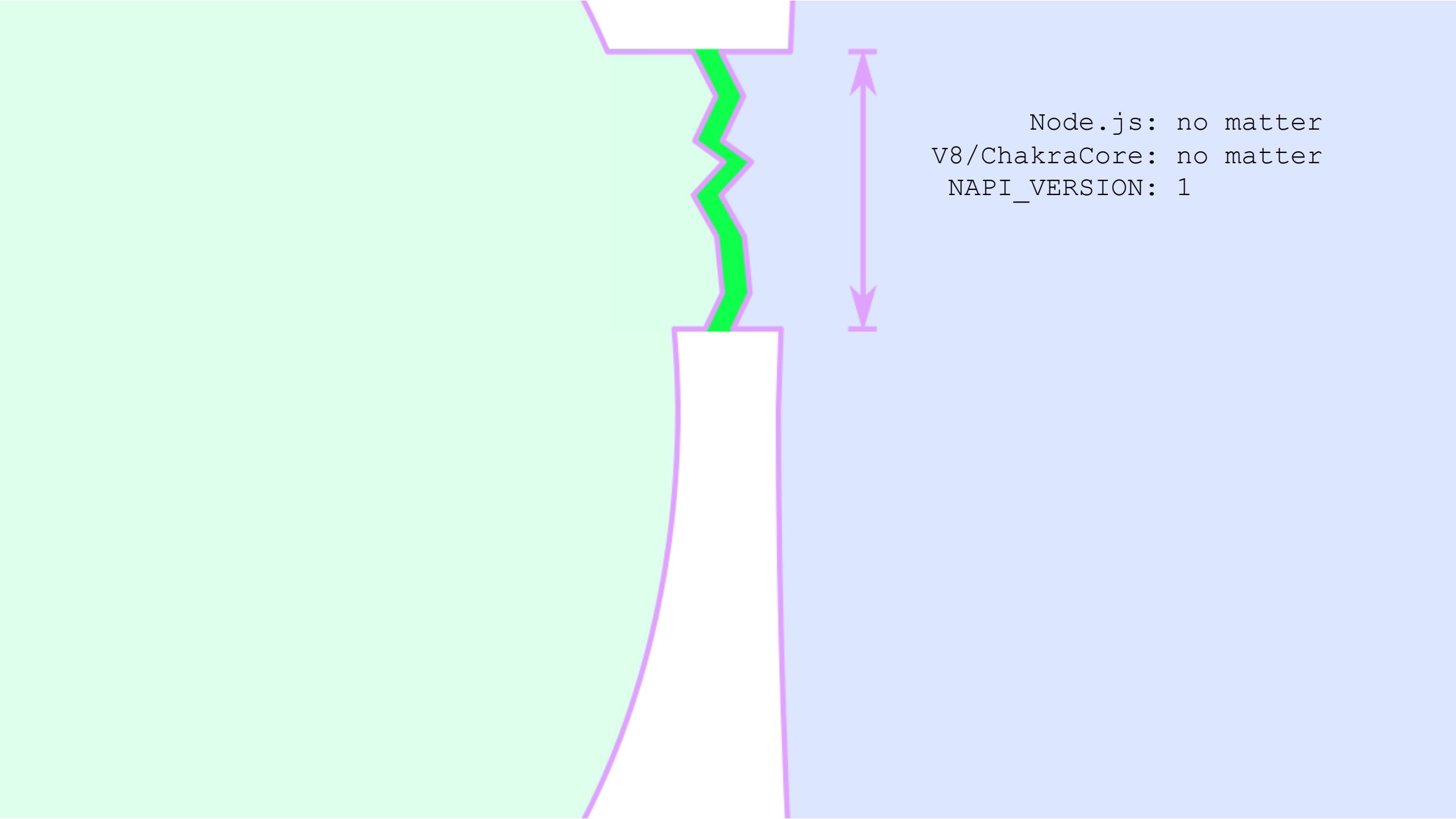
Documentation

- **C / C++** libraries that you are integrating are not well documented
- There are good **references** but not so much practical guide focusing on complex concepts about native add-ons

N-API

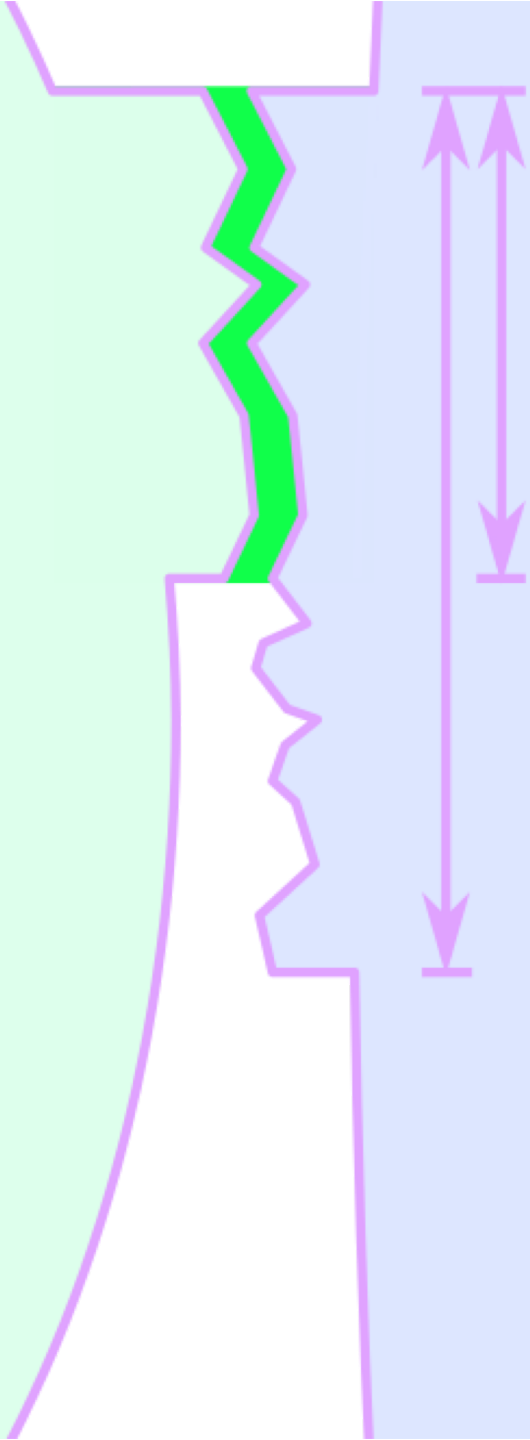
N-API will be a game changer on the native add-on development

- **API** and **ABI** compatibility
- **Isolated** from **V8** (VM agnostic)
- New **ES6** types
- C / C++ (only header wrapper)
- **Conversion** tool that helps to migrate from **NAN**
- **Generator** (helps with initial scaffolding)
- Pre-builds (**node-pre-gyp** - **prebuild** - **prebuildify**)


Node.js: no matter
V8/ChakraCore: no matter
NAPI_VERSION: 1

No ABI break

- NAPI_VERSION is cumulative
- Addon is forwards compatible



```
      Node.js: later
V8/ChakraCore: no matter
 NAPI_VERSION: 2
```

N-API

- Kicked off in VM Summit April 2016
  - Dual implementation from the start (V8 / ChakraCore)
- **EPS** Dec 2016 https://github.com/nodejs/node-eps/blob/master/005-ABI-Stable-Module-API.md
- First half of 2017 - refinement and backporting module
- May 2017 experimental release in Node.js 8
- **VM** Summit July 2017 – Exit criteria agreed
- N-API leaves experimental status March 14 2018
- Backported to all **LTS** release
- Improve core and C++ Wrapper (node-addon-api)
- Create ecosystem

N-API

- N-API is C whereas node-addon-api is C++
- node-addon-api not thechnically part of ABI stable API
  - Helper to simplify code using C++
  - All inline
  - Only depends on export N-API C functions

N-API and node-addon-api

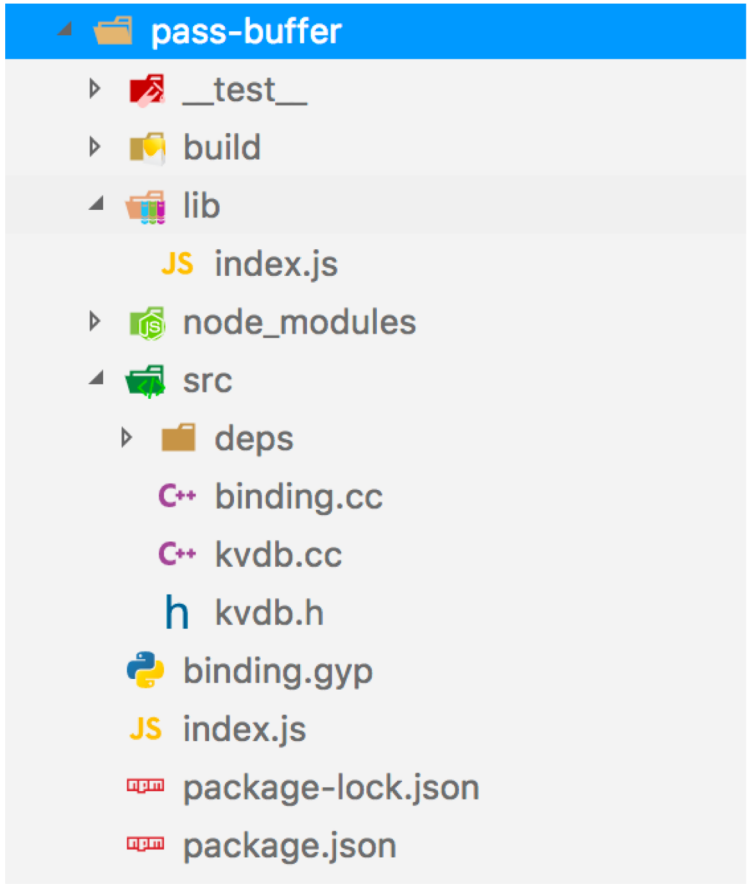
```
1  Object obj = Object::New(env);
2
3  obj["foo"] = String::New(env, "bar");
```

```
napi_status status;
napi_value object, string;
status = napi_create_object(env, &object);
if (status != napi_ok) {
  napi_throw_error(env, ...);
  return;
}
status = napi_create_string_utf8(env, "bar", NAPI_AUTO_LENGTH, &string);
if (status != napi_ok) {
  napi_throw_error(env, ...);
  return;
}
status = napi_set_named_property(env, object, "foo", string);
if (status != napi_ok) {
  napi_throw_error(env, ...);
  return;
}
```

node-addon-api vs NAN

- Same
  - Includes C++ wrapper
  - Provides common helper functionality
  - Reduces likelihood of needing to change code for new Node.js versions
- Different
  - Does not use V8 Types
  - Not tied to a specific JavaScript engine
  - Preserves compile once/ run multiple versions from N-API
  - Reduces even further likelihood of having to change code

How to organize your project



Example: the JavaScript part

```
{
  "name": "echo-example",
  "version": "0.0.0",
  "description": "Node.js Addons - echo example",
  "main": "index.js",
  "private": true,

  npm will build the add-on automatically

  "gypfile": true,

  "scripts": {
    "start": "node index.js"
  },
  "dependencies": {
    "node-addon-api": "*",
    "bindings": "*"
  }
}
```

Example: the JavaScript part

1

Import the add-on

```
const addon = require('bindings')('echo')
```

2

Call the add-on's function

```
let myEcho = addon.echo('Hey coders!')
console.log(myEcho)
```

Example: the **binding.gyp**

Name used to register the addon

```
{
  "targets": [
    {
      "target_name": "echo",
      "sources": [
        "src/addon.cc"
      ],
      'cflags!': [ '-fno-exceptions' ],
      'cflags_cc!': [ '-fno-exceptions' ],
      'include_dirs': ["<!@(node -p \"require('node-addon-api').include\")"],
      'dependencies': ["<!(node -p \"require('node-addon-api').gyp\")"],
      'conditions': [
        ['OS=="win"', {
          "msvs_settings": {
            "VCCLCompilerTool": {
              "ExceptionHandling": 1
            }
          }
        }],
        ['OS=="mac"', {
          "xcode_settings": {
            "CLANG_CXX_LIBRARY": "libc++",
            'GCC_ENABLE_CPP_EXCEPTIONS': 'YES',
            'MACOSX_DEPLOYMENT_TARGET': '10.7'
          }
        }]
      ]
    }
  ]
}
```

Example: the C / C++ part

```
Napi::Value Echo(const Napi::CallbackInfo& info) {
    Napi::Env env = info.Env();
```

3

Validate your input - Execute operations on them - Return results

```
    if (info[0].IsString()) {
        std::string in = info[0].As<Napi::String>();
        return Napi::String::New(env, in);
    } else {
        throw Napi::Error::New(env, "The argument must be a string");
    }
}
```

2

Export objects and functions

```
// Init
Napi::Object Init(Napi::Env env, Napi::Object exports) {
    exports.Set(Napi::String::New(env, "echo"), Napi::Function::New(env, Echo));
    return exports;
}
```

1

Registration and Initialization

```
NODE_API_MODULE(NODE_GYP_MODULE_NAME, Init);
```

Example

Asynchronous code

```
const addon = require('bindings')('echo')

function callback(err, data) {
    if (err) {
        console.error(err)
    } else {
        console.log(data)
    }
}

addon.echo('Hey coders!', callback) 2

console.log('My next code ...') 1
```

Asynchronous code

```
void Echo(const Napi::CallbackInfo& info) {
    Napi::Env env = info.Env();
    // You need to check the input data here
    Napi::Function cb = info[1].As<Napi::Function>();
    std::string in = info[0].As<Napi::String>();
    // std::this_thread::sleep_for(std::chrono::seconds(1));
    // In case of error
    // Napi::Error::New(env, "Error ...").Value()
```

Call a callback and return the result back

```
    cb.Call({env.Null(), Napi::String::New(env, in)});
}
```

Example

Asynchronous code

Preserve reference to function we want call

Create worker threads using libuv

Handle the results

AsyncWorker

```
class EchoWorker : public Napi::AsyncWorker {
    public:
        EchoWorker(Napi::Function& callback, std::string& echo)
        : Napi::AsyncWorker(callback), echo(echo) {}

        ~EchoWorker() {}

    // This code will be executed on the worker thread
    void Execute() {
        // Need to simulate cpu heavy task
        std::this_thread::sleep_for(std::chrono::seconds(1));
        // std::cout << echo << std::endl;
    }

    void OnOK() {
        Napi::HandleScope scope(Env());
        Callback().Call({Env().Null(), Napi::String::New(Env(), echo)});
    }


    private:
        std::string echo;
};
```

1 **This code will be executed on the Worker Thread**

2 **When the Execute method ends its computation the results will be reassembled and passed to JS context**

AsyncWorker

```
Napi::Value Echo(const Napi::CallbackInfo& info) {
    // You need to check the input data here
    Napi::Function cb = info[1].As<Napi::Function>();
    std::string in = info[0].As<Napi::String>();

    EchoWorker* wk = new EchoWorker(cb, in);
    wk->Queue();

    return info.Env().Undefined();
}
```

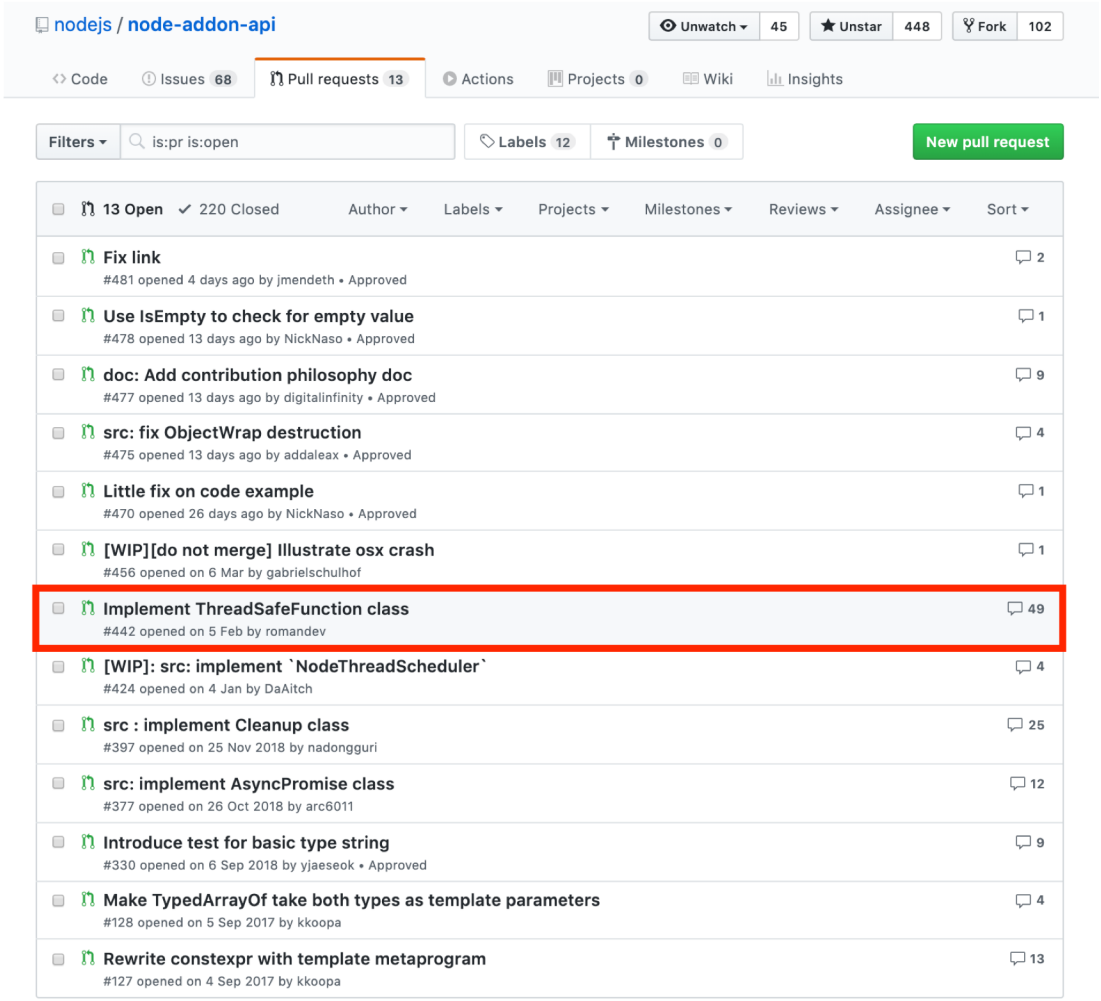
1 **Create AsyncWorker**

2 **Return immediately**

Example

AsyncWorker

You cannot call JavaScript function from the Worker Thread until this PR will be landed



ObjectWrap API

- **ObjectWrap** is a way to expose your C++ code to JavaScript
- You have to extend **ObjectWrap** class that includes the plumbing to connect JavaScript code to a C++ object
- Classes extending **ObjectWrap** can be instantiated from JavaScript using the **new** operator, and their methods can be **directly invoked from JavaScript**
- Unfortunately, the ***wrap*** part really refers to a way to group methods and state
- It's **your responsibility write custom code to bridge** each of your C++ class methods.

Example

Thanks

Don’t be afraid sometimes it’s a good thing dirty your hands with a little of C++

All examples and materials are here

https://github.com/NickNaso/node-overview