Tecnologie e applicazioni web

Node.js

Filippo Bergamasco (filippo.bergamasco@unive.it)
http://www.dais.unive.it/~bergamasco/
DAIS - Università Ca'Foscari di Venezia
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Server-side JavaScript

Historically, creating the server part of a web application is more complex and tedious because it requires an in-depth knowledge of:

- Multi-threaded programming
- Scalability
- Security
- Server deployment
- .. etc ...

Server-side JavaScript

JavaScript was not meant to be used in a server-side environment:

- Basic memory management
- No built-in interface with the operating system
- Slow execution speed

Before Google V8, JavaScript was primarily used in the web browser.

Node.js

Node.js is a JavaScript **runtime** composed of the Google V8 engine and an integration layer with the operating system. It provides a full-featured JavaScript environment outside the web browser.

- Open-source
- Cross-platform
- Designed to develop server-side networking applications

Why Node.js?

- Lightweight compared to traditional environments like Java, PHP, etc.
- Easy to configure and install
- Vast selection of modules (libraries) freely available and easily installable through **npm**
- Modules to connect to relational and NoSQL databases.
- JavaScript can be the only language needed for the entire web application (both server- and client-side).

Installation

Direct installation:
http://nodejs.org

Via Docker, just pull the node image:

https://hub.docker.com/_/node

Batteries included

Node.js is distributed together with:

- A REPL (Read, Evaluate, Print, Loop) frontend
- A command line executable to run standalone JavaScript files
- A package manager called npm (Node Package Manager)
  - Manages the installation of additional modules
  - Resolves the dependencies among modules
  - Installs and manages additional command-line tools (like TypeScript, etc)

Node REPL

```
$ node --version
v12.14.1
$ node
> var a="filippo"
undefined
> console.log(a)
filippo
undefined
```

Code and Modules

You can execute a JavaScript file by running the node process:

```
$ node javascriptfile.js
```

A project is usually composed of multiple JavaScrpt files. The entry point is defined in the **package.json** file, together with some metadata about the project version, its dependencies, etc.

package.json

https://docs.npmjs.com/files/package.json

```
{
      “name”: “my-project-name”,
      “main”: “main-project-js-file”,
      “version”: “0.0.1”,
      “dependencies”: {
            “colors”: “0.5.0”
      },
      “private”: true
}
```

Modules

A Node package, defined in package.json, defines a **module** that can be executed (if the main property is present) or used by other modules as a library.

npm can manage module dependencies, simplifying the installation of required external modules

Modules

Historically, modules in Node.js follow the CommonJS convention:

- The `require()` function allows the module loading of local and global modules
- All the variables defined inside a module are local for that module (ie. not visible to other modules)
- To export a variable, it must be added in the module.exports object (or just exports since module is the global object)

Modules

Since version 13.2.0, Node also supports the ES module syntax.

- The `export` keyword is used to export functions
- The `import` keyword is used to import functions from other modules

Note: the two methods can coexist, but ES modules must have extension mjs instead of js

Note 2: ES module syntax is the one preferred in TypeScript

CommonJS vs. ES modules

- CommonJS modules are loaded synchronously (blocking) , while ES modules are loaded asynchronously (non-blocking)
- CommonJS modules can be loaded “on demand” while ES module import must be placed at the beginning of a module

Ex: `if( … ) { const m = require(…); }`

npm

To install all package dependencies (defined in package.json) we can use the command:

```
$ npm install
```

All the dependencies will be downloaded and installed in a new directory named `node_modules` (in the same path as package.json file)

npm

Our own module can be published to the npm registry (if not marked as private) with the command:

```
$ npm publish
```

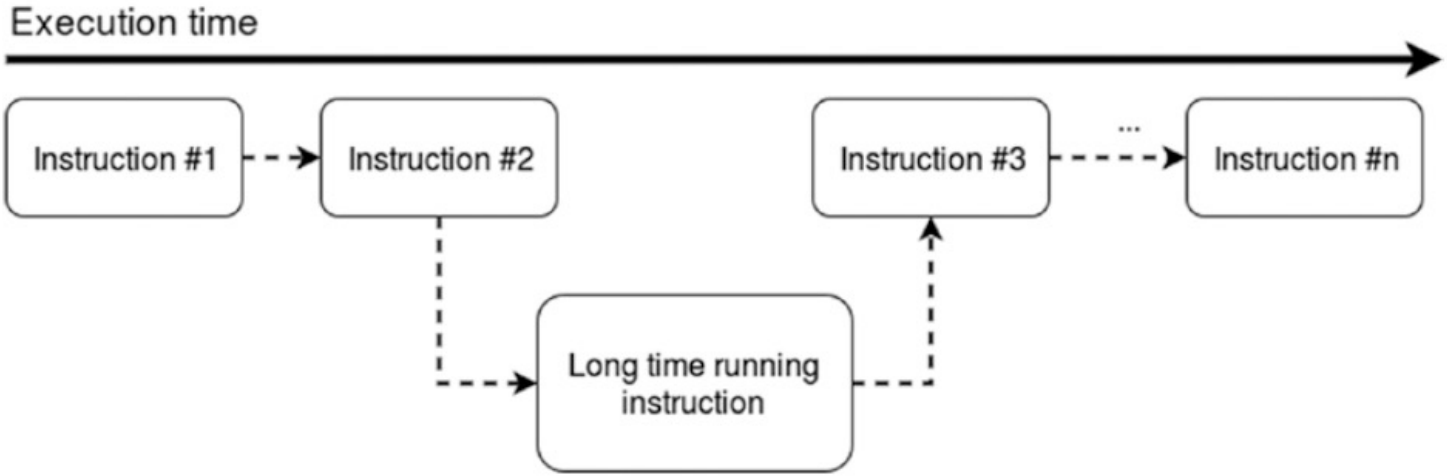
It is also possible to search for a certain module with the command

```
$ npm search <module name>
```

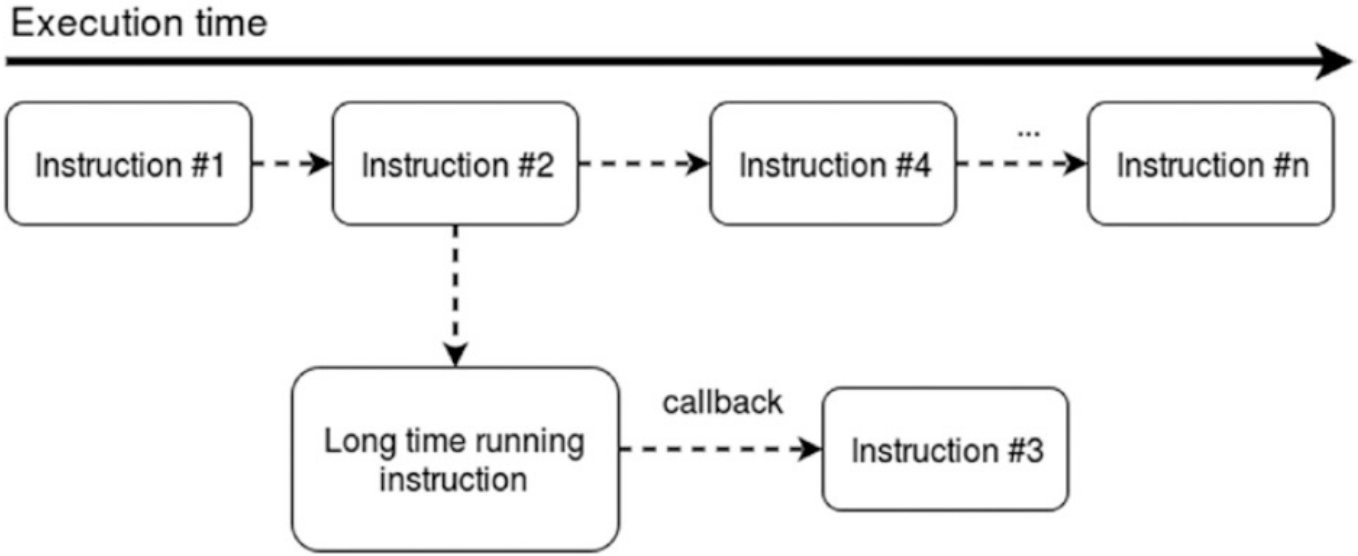
Node.js key concepts

1. Asynchronous (non-blocking) operations
2. Single threaded code
3. Shared-state concurrency

Synchronous flow



Asynchronous flow



Single threaded

Node.js executes code asynchronously but not in parallel. There is one single event loop (like in the browser) executing all the callbacks.

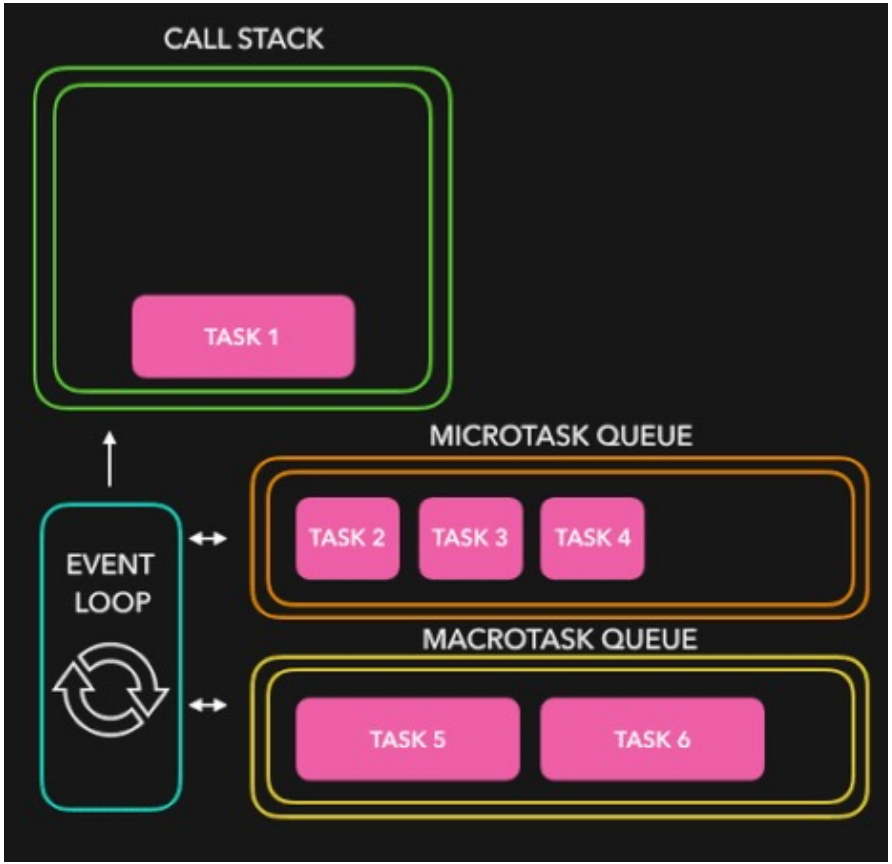
Internally, Nodejs manages a thread pool and non-blocking IO

Async IO operations

Node.js was designed with the mindset that I/O operations are the actual bottleneck of every operation

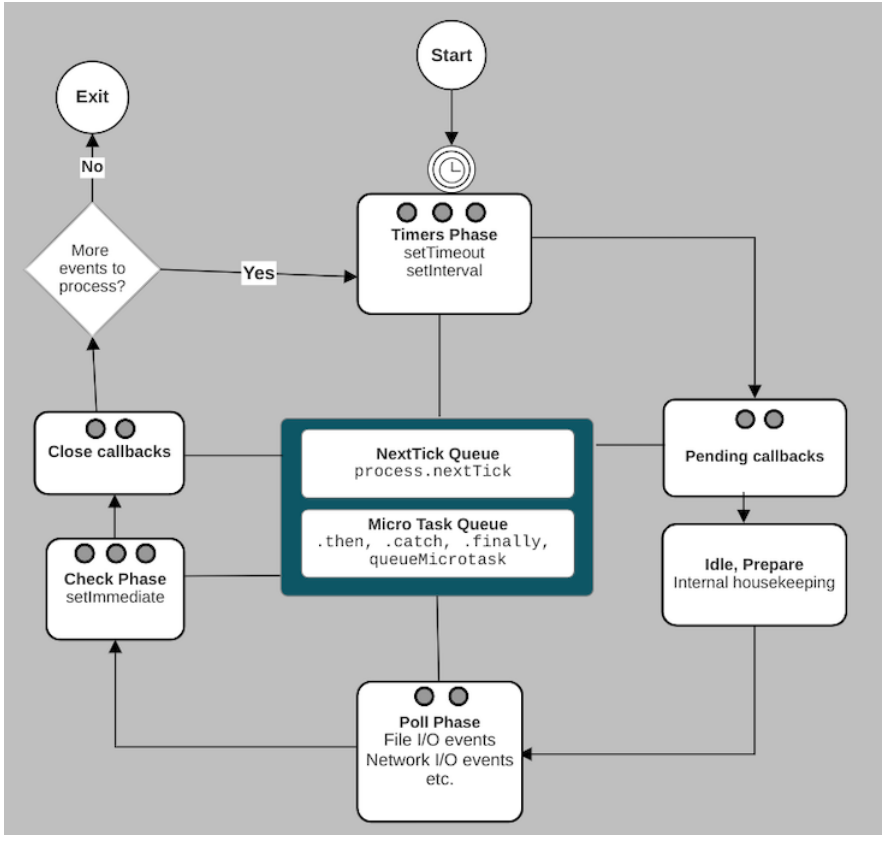
Instead of waiting for the IO operation to complete, a callback will be registered on a separate queue, and the main program's flow will continue

The event loop



The Event Loop allows Node.js to perform non-blocking I/O operations (despite the fact that JavaScript is single-threaded) by offloading operations to the system kernel whenever possible.

The event loop

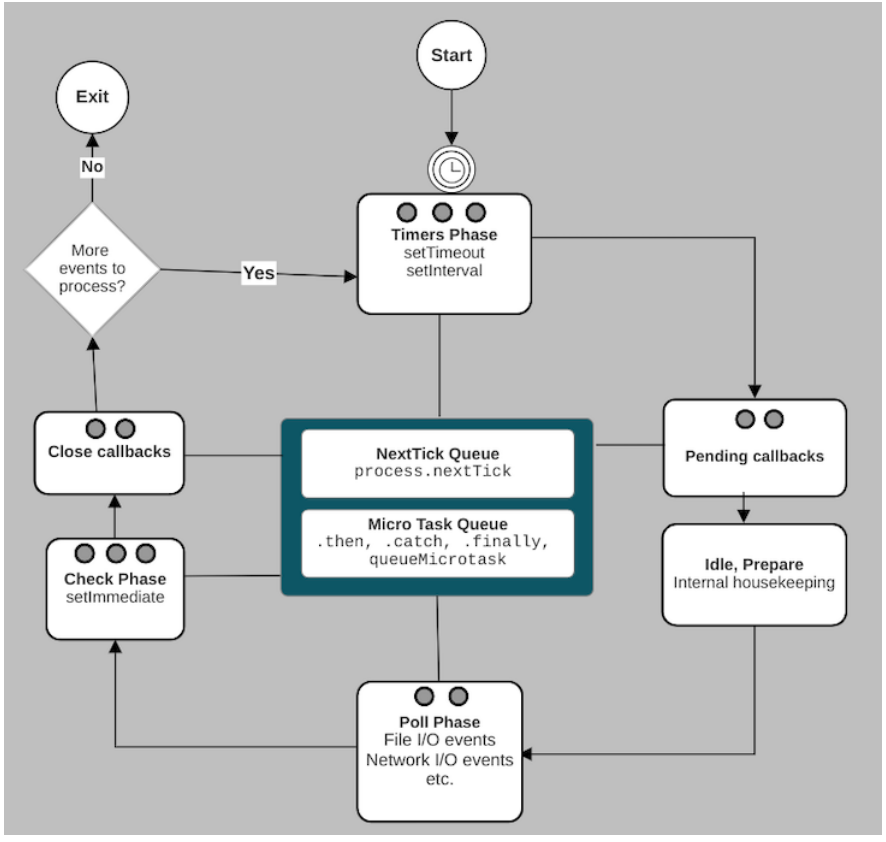


Each phase has a FIFO queue of callbacks to execute.

When the event loop enters a given phase, it will:

- perform any operations specific to that phase (check if a timer is expired, poll io events, etc.)
- execute callbacks in that phase's queue until the queue has been exhausted or the maximum number of callbacks has executed.
- Move to the next phase

The event loop

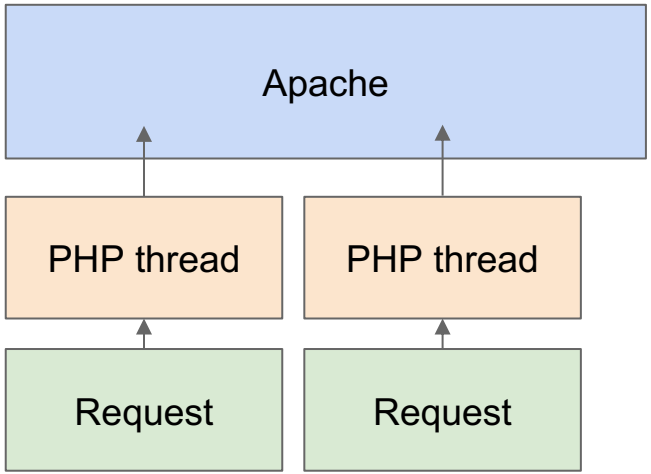


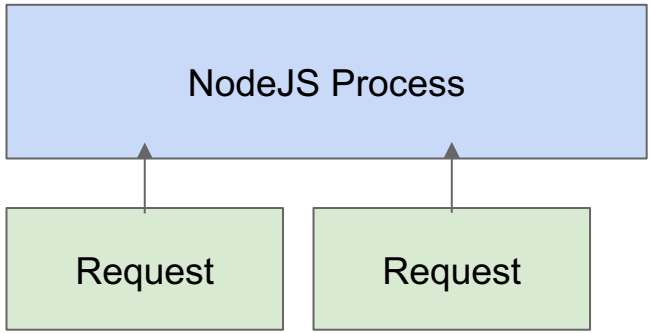
NextTick and MicroTask are higher-priority queues whose elements are executed before any callbacks in the current phase queue.

When all the queues are empty, the nodejs process exists

Shared-state concurrency

All concurrent functions observe the same consistent memory state (There is no overhead due to the creation and destruction of threads)





Use cases

When Node.js is convenient?

When the program is IO-bound. In other words, when time is mostly spent managing the IO (disk, network, database, etc.) instead of executing computationally expensive tasks

Typical of Web servers, databases, etc!

Use cases

When Node.js is NOT convenient?

For its single-threaded nature, Node.js is not efficient to execute CPU-bound programs:

- if the server is asked to manage complex CPU-intensive tasks (like video encoding)
- If the operations are naturally parallelizable in a multi-threaded environment

The global object

Useful properties of the global object:

- `__filename, __dirname`
- `setImmediate(callback[, ...args])`
- `setInterval(callback, delay[, ...args])`
- `setTimeout(callback, delay[, ...args])`
- `require()`

APIs

Node.js provides a useful set of APIs to interface with the underlying operating system:

- Filesystem access
- TCP/UDP socket creation
- Execution of other tasks or processes
- HTTP and HTTPs built-in webserver

https://nodejs.org/api/index.html