A Journey Into Node.js Internals

Tamar Twena-Stern

Tamar Twena-Stern

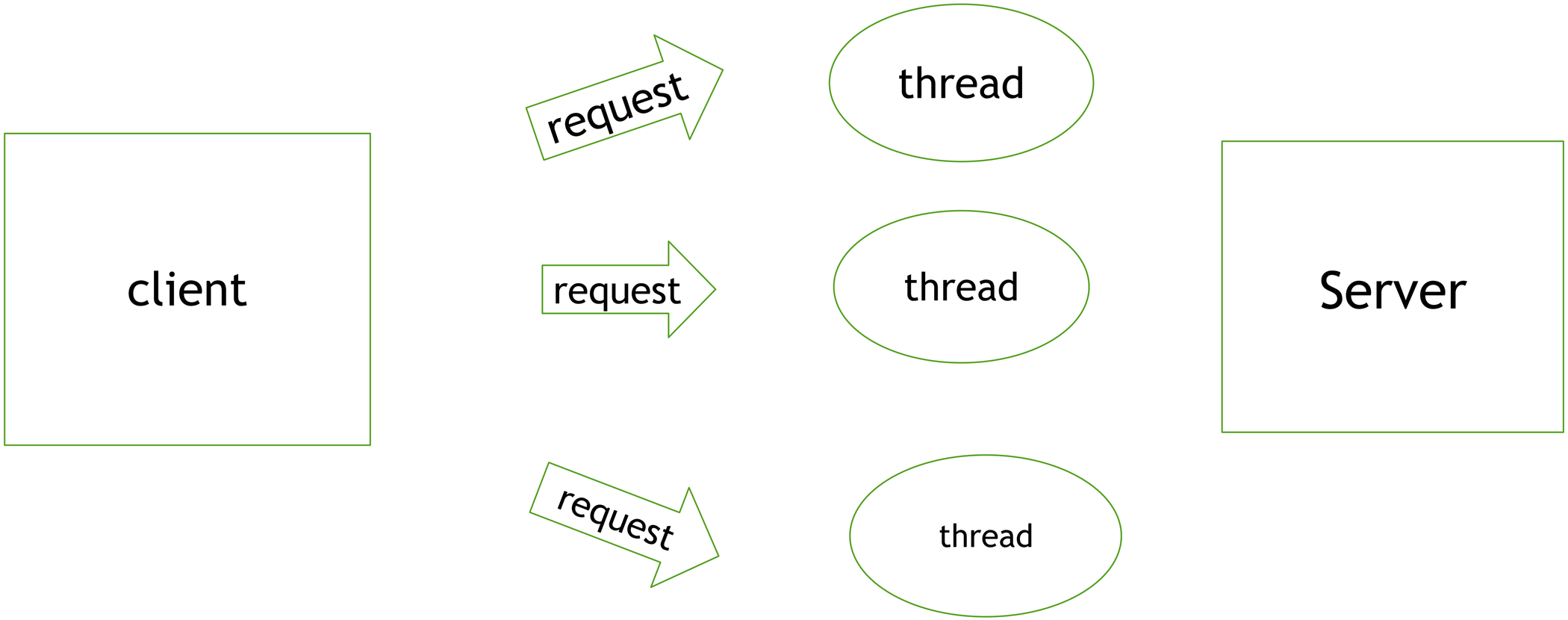
- Software Engineer - manager and architect
- Architect @PaloAltoNetworks
- Was a CTO of my own startup
- Passionate about Node.js !
- Twitter: **@SternTwena**

Tamar Tena-Stern

- On Maternity Leave
- Have 3 kids
- Loves to play my violin
- Javascript Israel community leader

Introduction

Traditional Approach

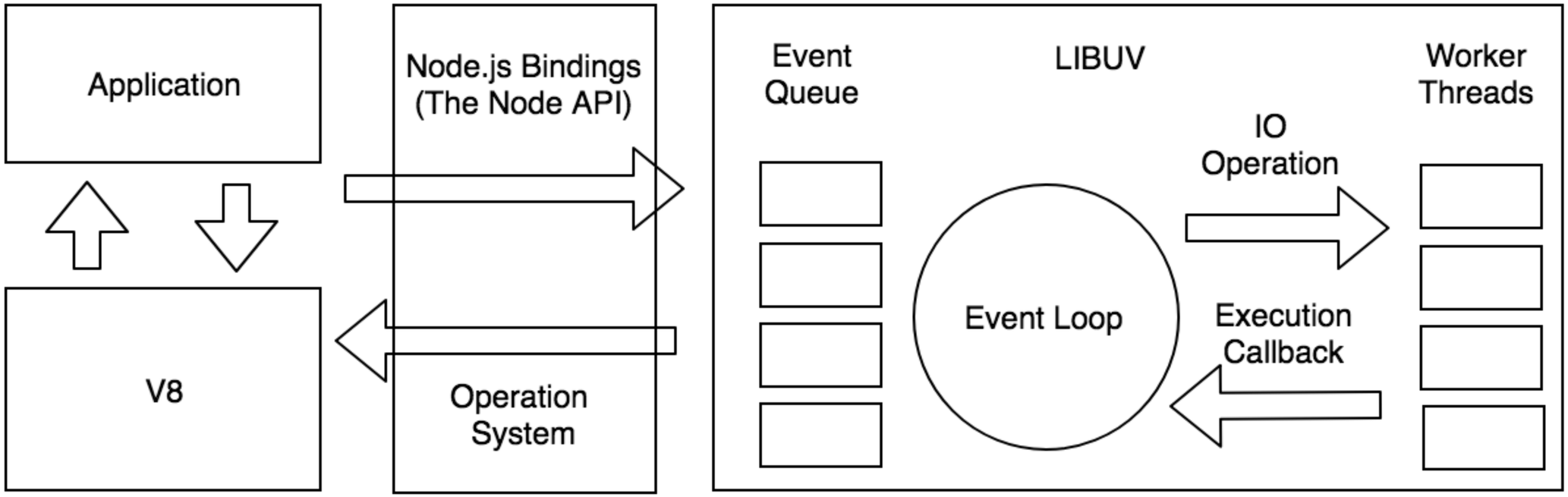


Problems

- The system allocates CPU and memory resources for every new thread
- When the system is stressed – overhead of thread scheduling and context switching
- The system waste resources for allocating threads instead of doing actual work

Node.js Architecture

Node.js Architecture - High Level

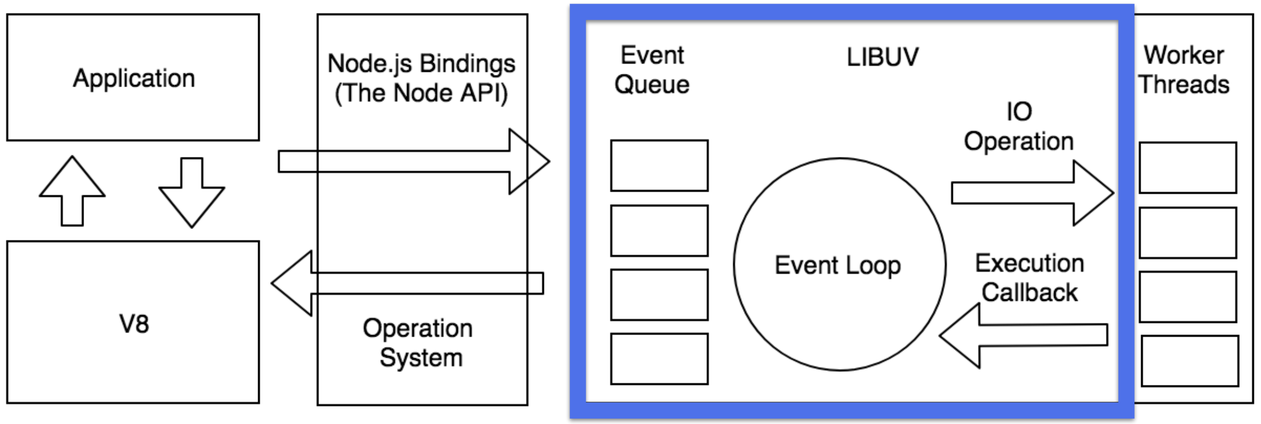


Now, Lets Get Into The Details

Single Threaded ?

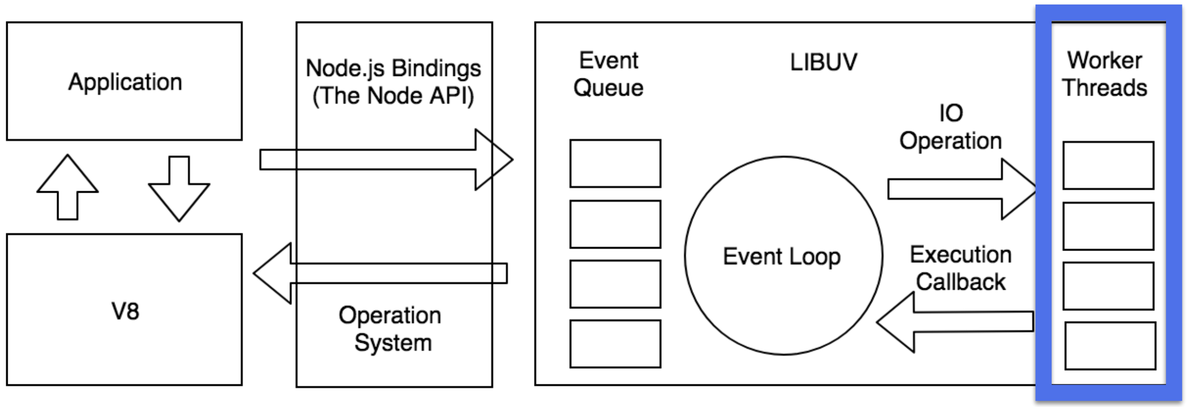
- Not really single threaded
- Several threaded :
  - Event Loop
  - The workers thread pool

Event Loop Thread



- Every request registers a callback which executes immediately
- The event loop execute JavaScript callbacks
- Offloads I/O operations to worker thread pool.
- Handle callbacks for asynchronous I/O operations from multiple requests.

Worker Thread Pool

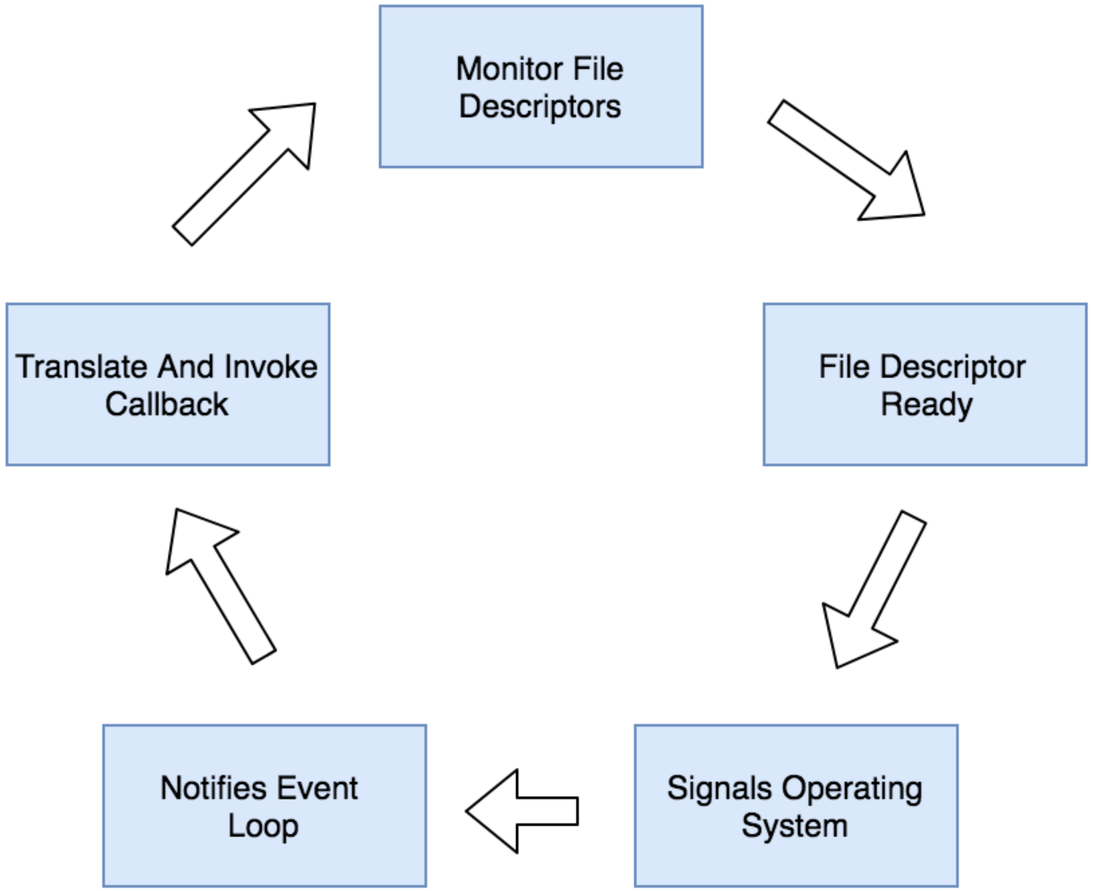


- Thread pool to perform heavy operations
  - I/O
  - CPU intensive operations
- Bounded by fixed capacity
- A node module can submit a task to libUV API

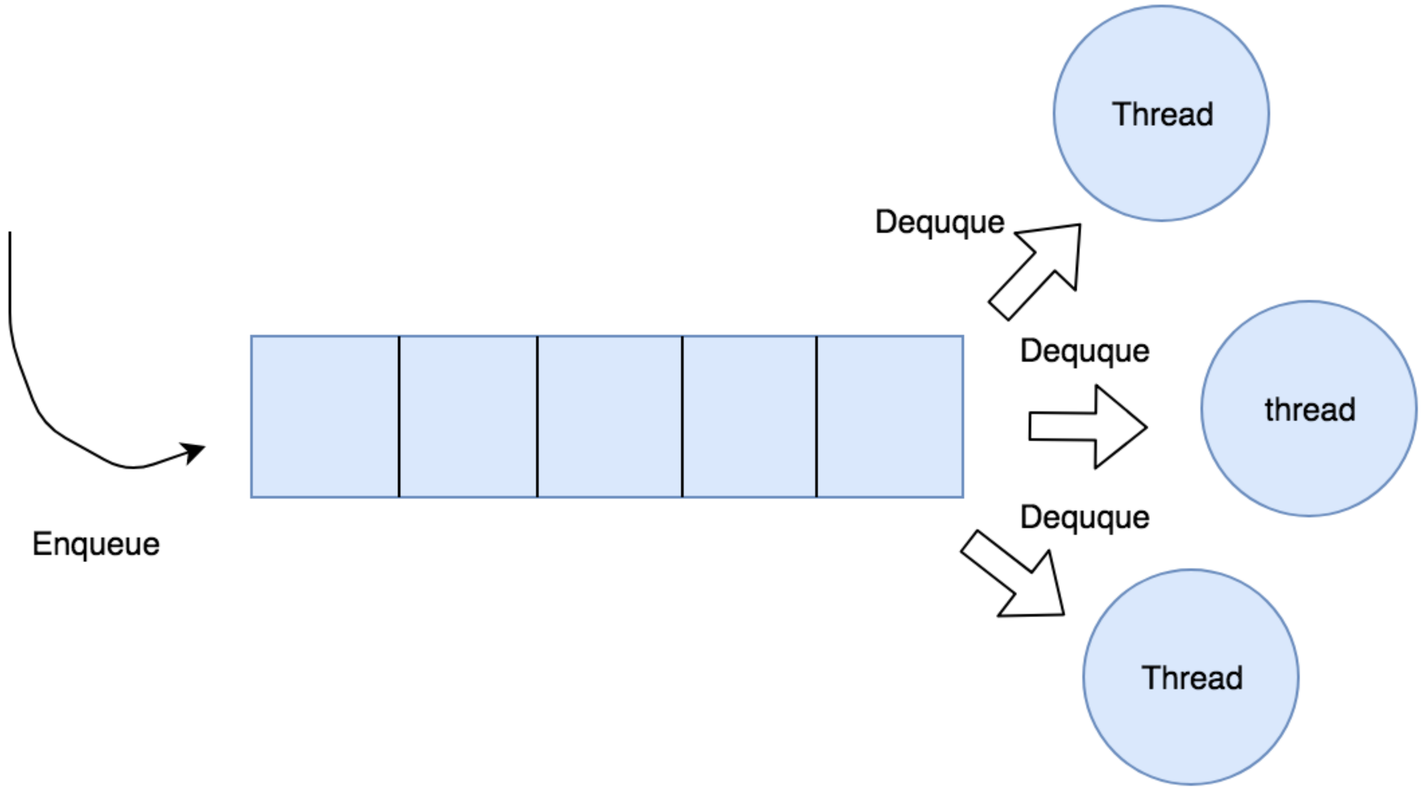
Submitting A Request To The Worker Pool

- Use a set of ‘basic’ modules that work with the event loop
  - Examples:
    - Fs
    - Dns
    - Crypto
    - And more
- Submit a task to libUV using c++ add-on

Event Loop Implemented With A Queue ?



How Worker Pool Implemented ?

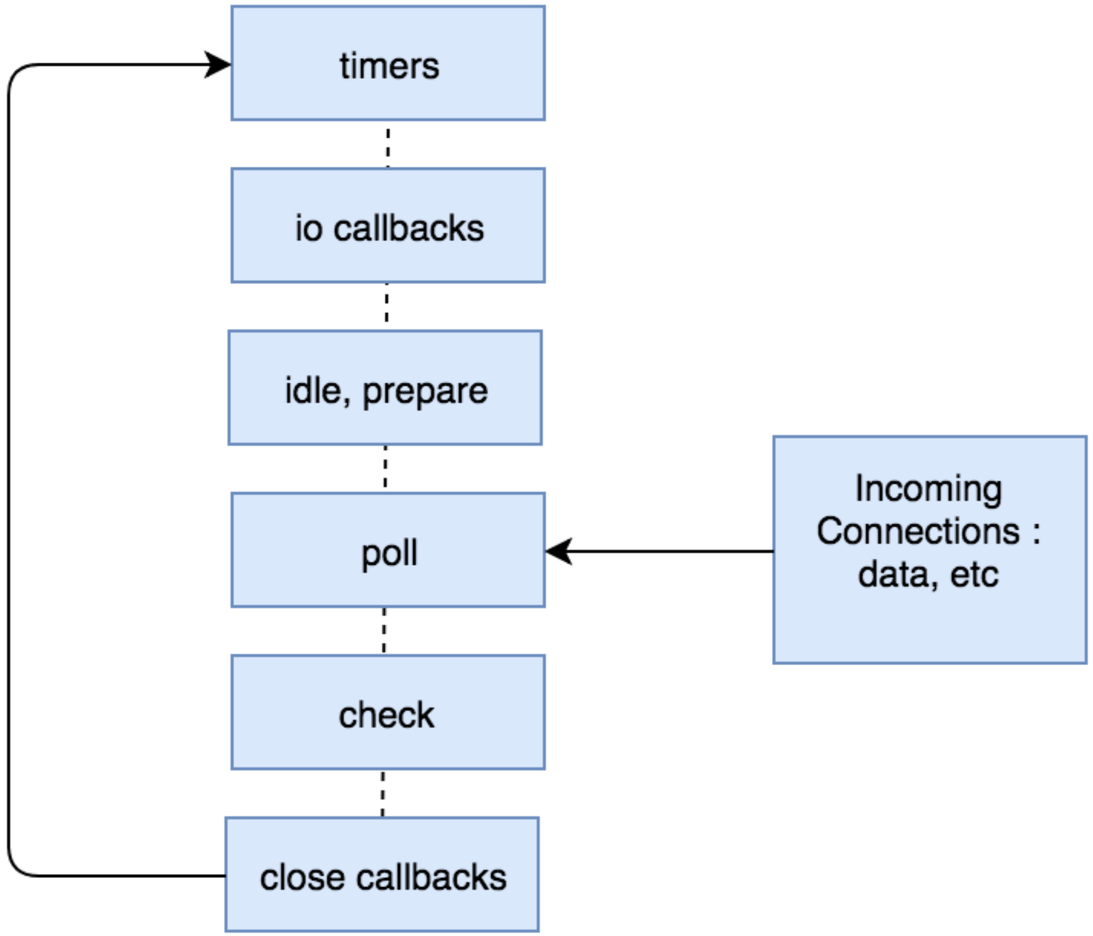


libuv

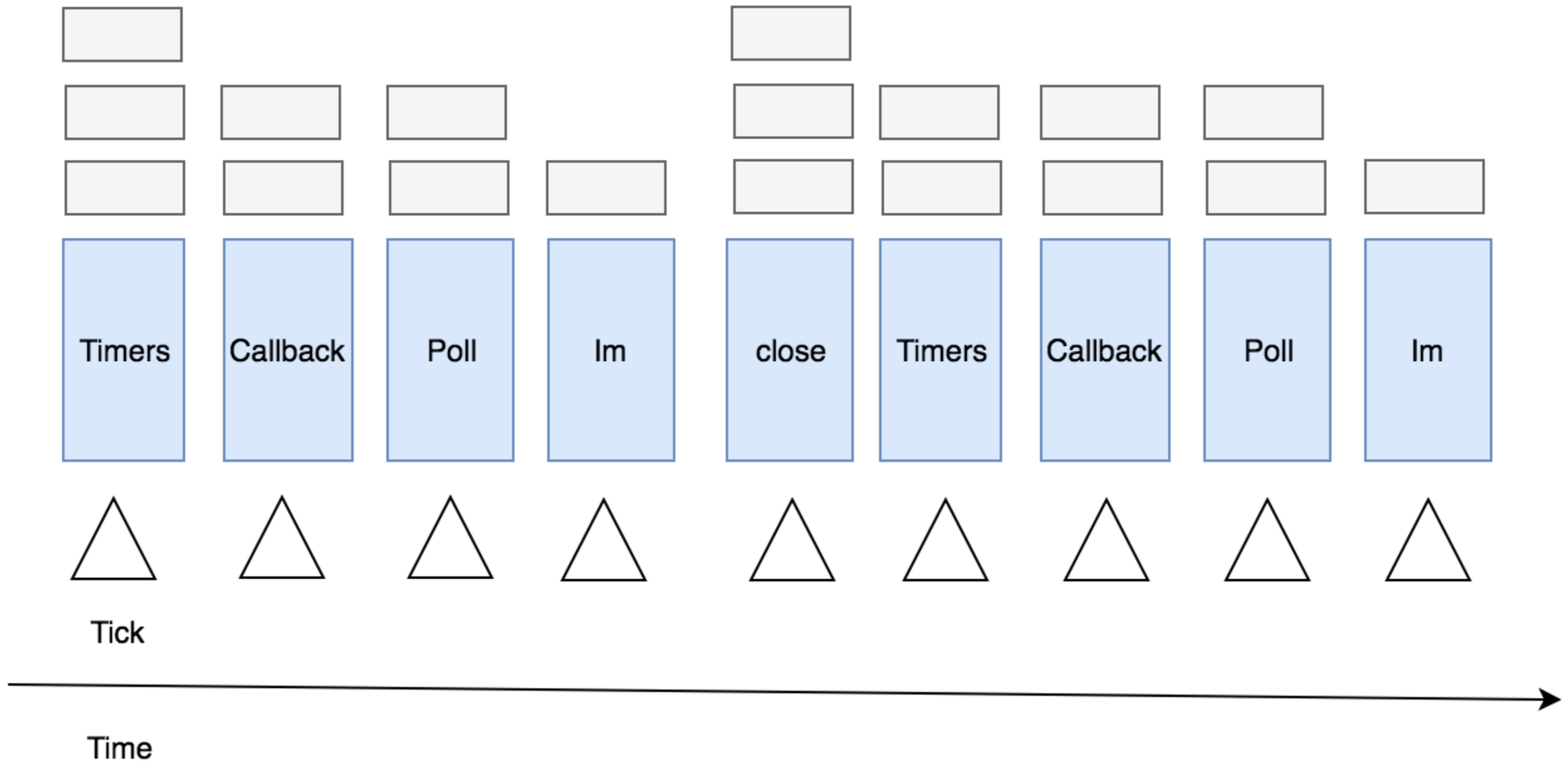
- Libuv in a nutshell :
  - Multi platform C library
  - Provides support for async I/O based on event loop
- Supports :
  - Epoll (Linux)
  - Kqueue (OSX)
  - Windows IOCP
  - Solaris event ports

The Event Loop - The Different Phases

Event Loop Phases Overview



Phase General Mechanism



Timers Phase

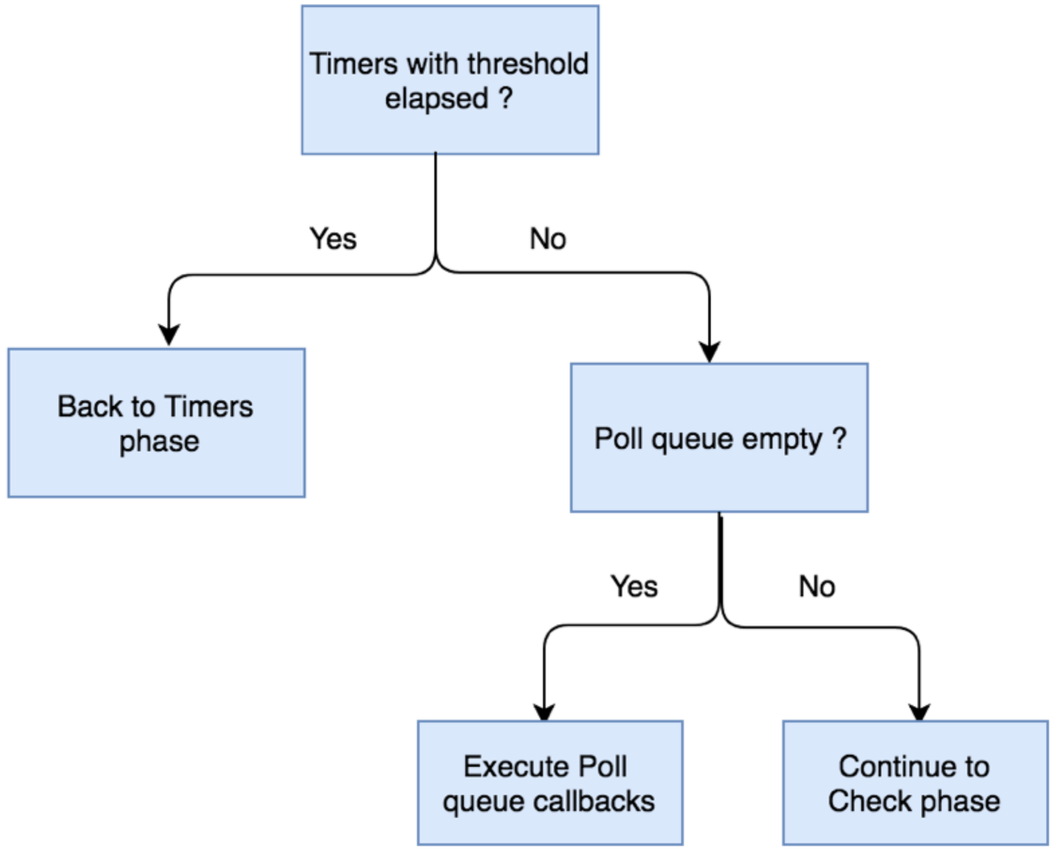
- setTimeout, setInterval
- Timer’s callback will run as soon as they can be scheduled after the threshold
- Timer’s callback scheduling controlled by the “poll” phase

I/O Callback Phase

- Executes system error callbacks
  - Example : TCP socket connection error.
- Normal I/O operation callbacks are executed in the poll phase.

```
socket.on('error', function(exception) {
  console.log('SOCKET ERROR');
  socket.destroy();
})
```

Poll phase


Timers with threshold elapsed ?
Yes
No
Back to Timers phase
Poll queue empty ?
Yes
No
Execute Poll queue callbacks
Continue to Check phase

Check Phase And Close Phase

- Check Phase - Execute callbacks for setImmediate timers
- Close Phase – Handles an abruptly close of a socket or a handle

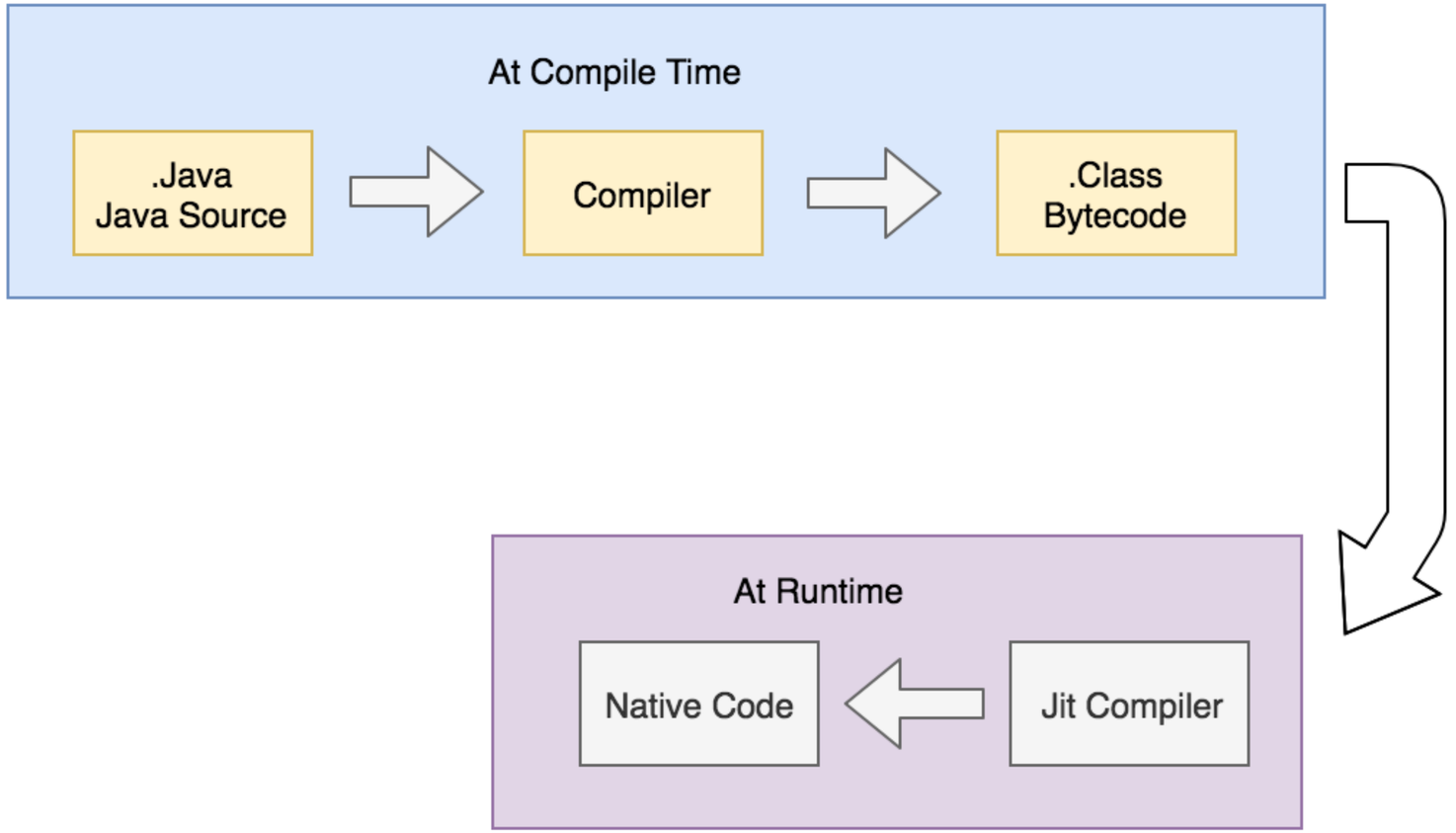
Lets profile some code

The JIT Compiler And V8 Engine

What Is Just-In-Time Compilation ?

- Compilation during run time
- Combines two approaches :
  - Ahead of compilation
  - Interpreter

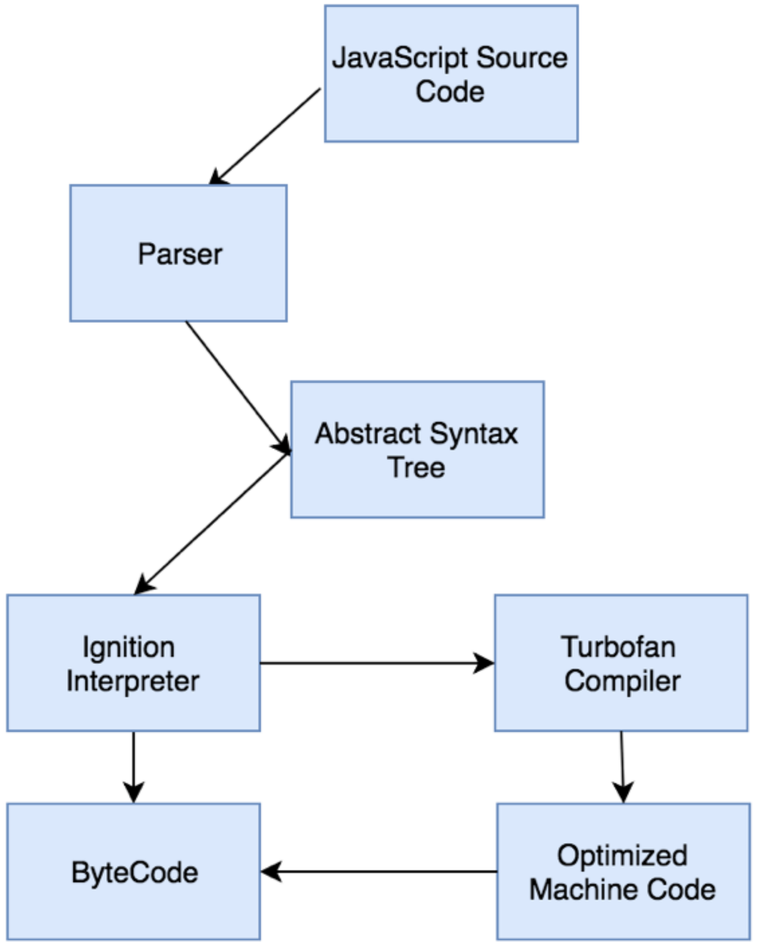
JIT Compiler In Java

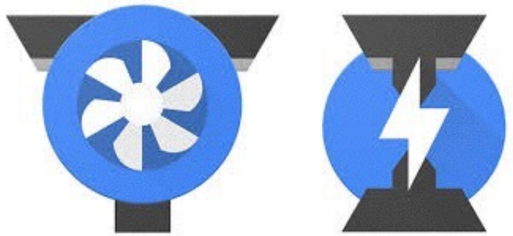


Chrome

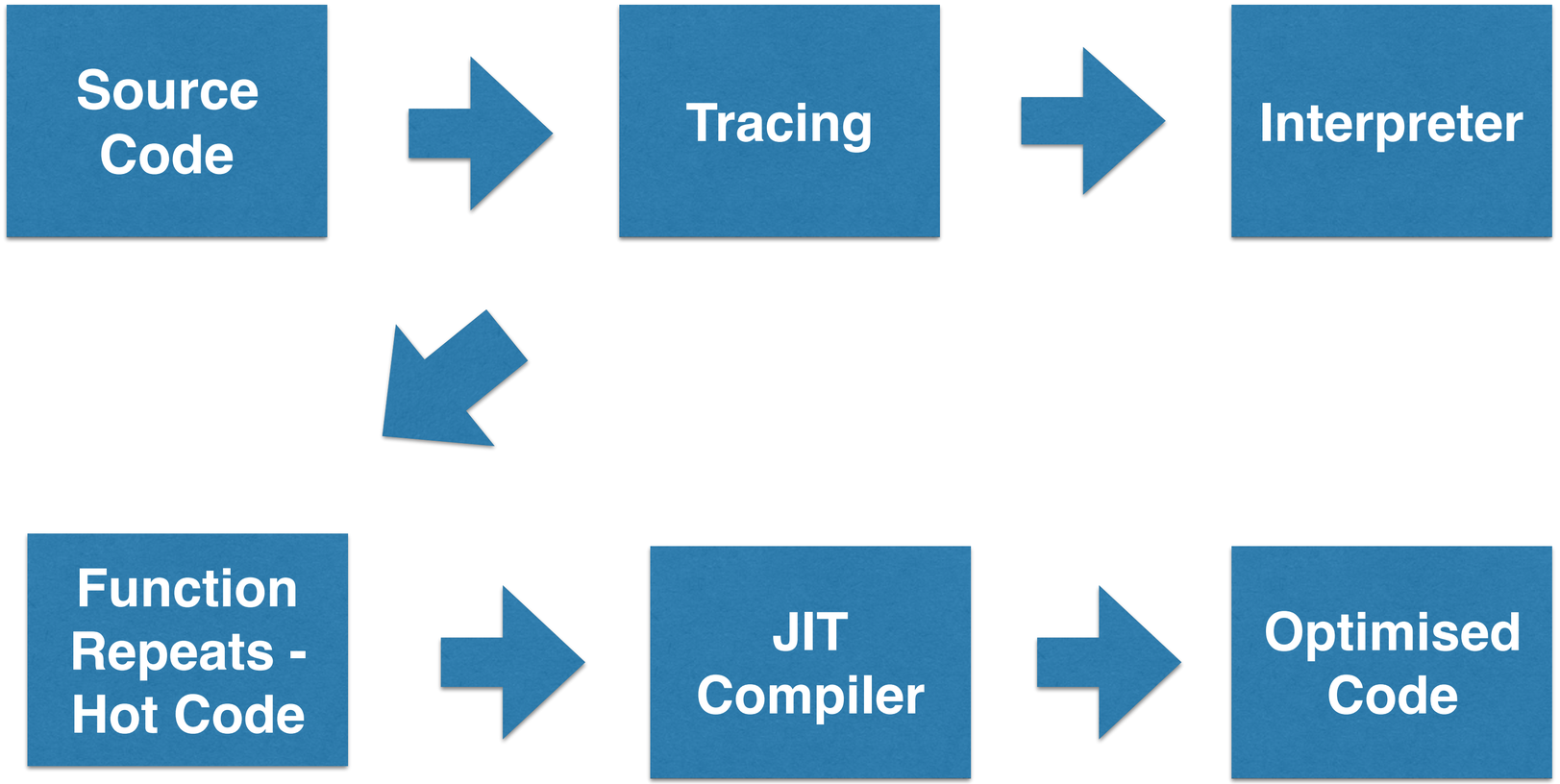
- Open source JavaScript engine
- Developed originally for Google Chrome and chromium
- Also used for
  - Couchbase
  - MongoDB
  - Node.js

V8 Architecture





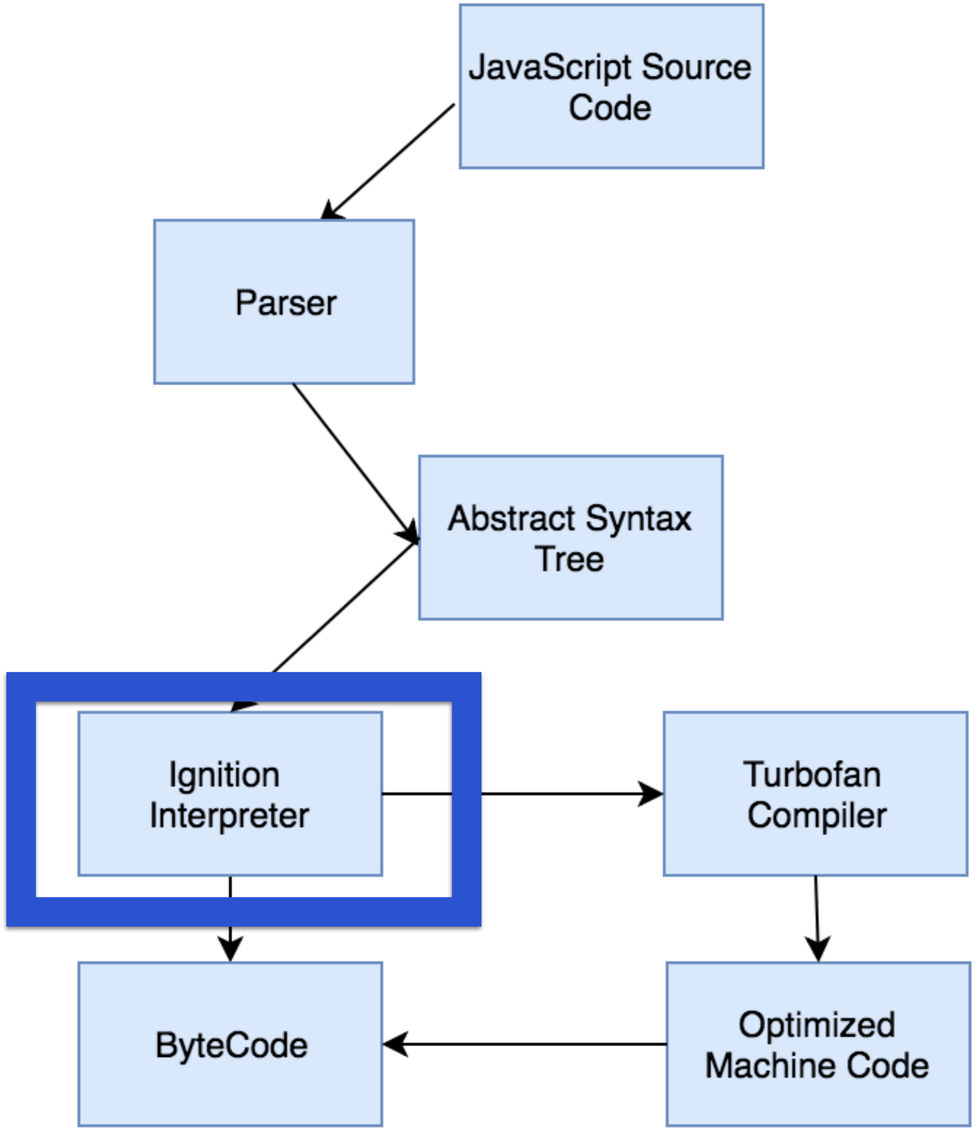
The JIT Compilation In V8

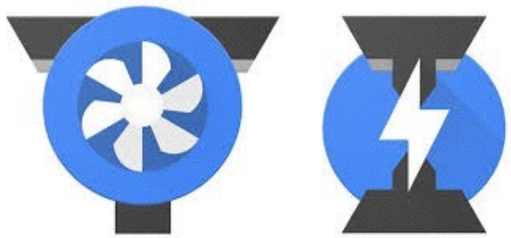


What Is An Optimised Compiler?

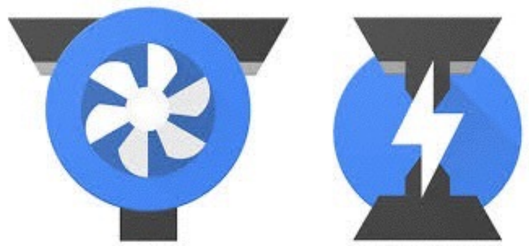
- When a code is hot – it is worth doing multiple optimisations
- Tracing will send it to optimising compiler
- Creates an even faster version of the code
- Tracing pulls it when the function code runs

Ignition Interpreter



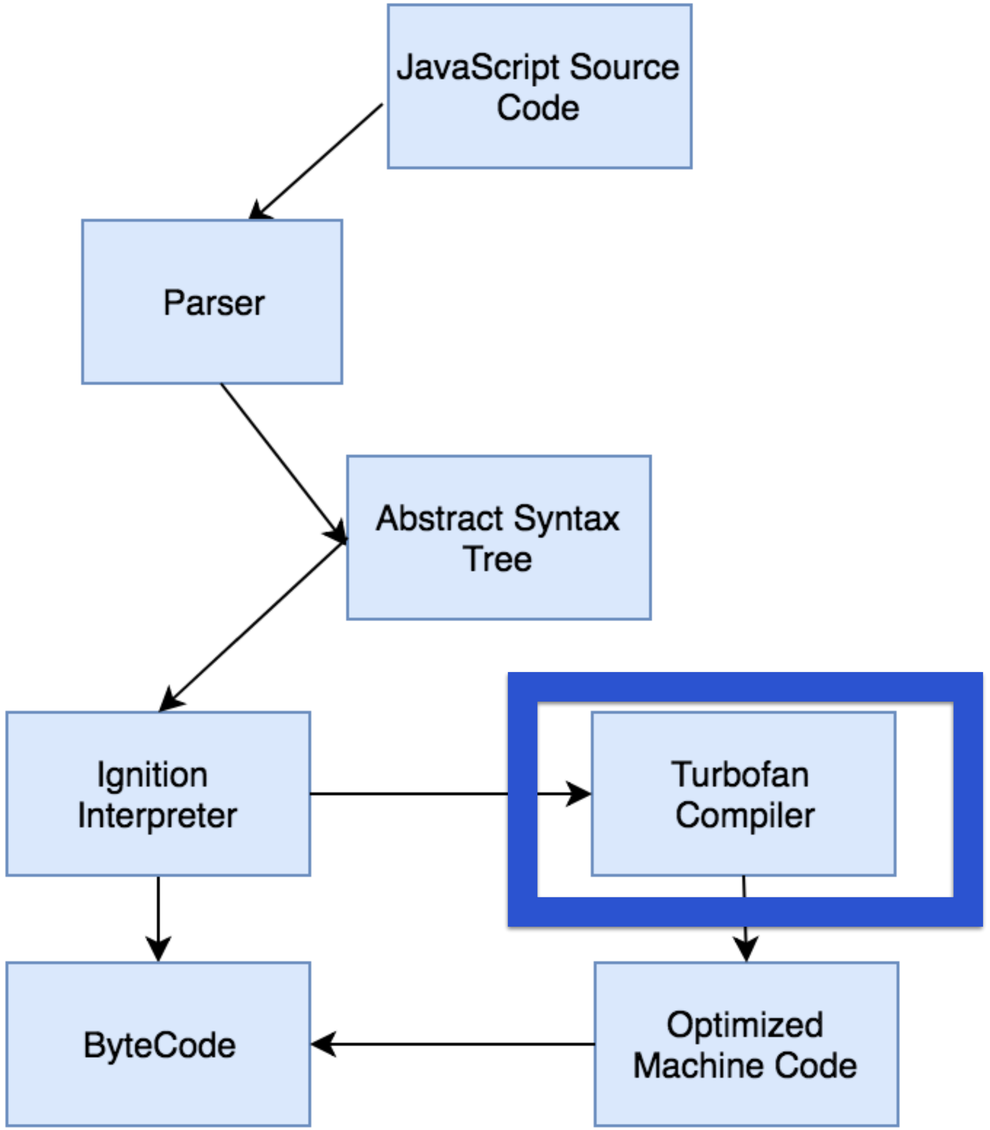


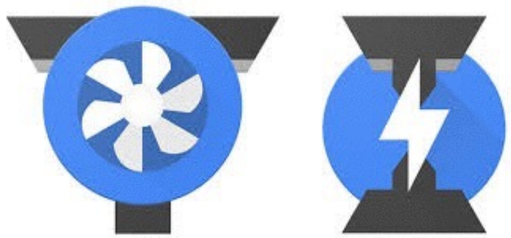
Ignition Interpreter



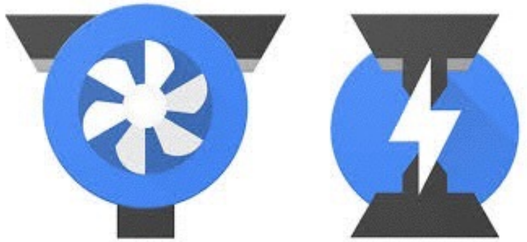
- Interpreter for V8
- Translates to low level Bytecode
- Enabling the following code to be stored more compactly in Bytecode
  - Run once code
  - Non hot code

Turbofan Compiler





Turbofan Compiler



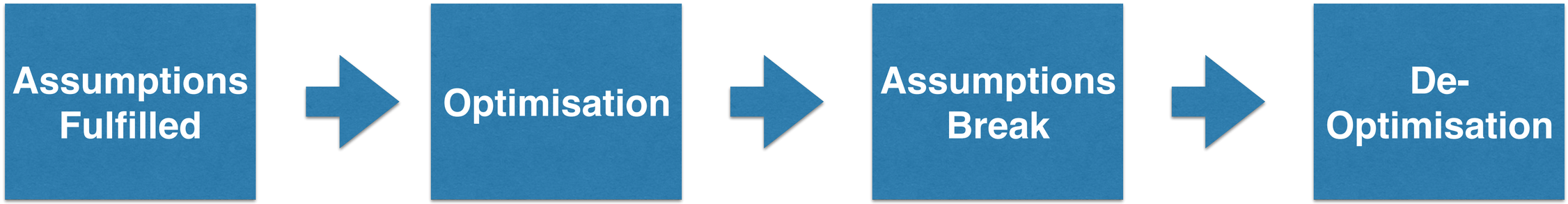
- Make hot code run as fast as possible
- Relies on input type information collected via inline caches while functions run via the Ignition interpreter.
- Generates the best possible code handling the different types it encountered
- The fewer function input type variations the compiler has to consider, the smaller and faster the resulting code will be

How To Help Turbofan Optimise Hot Code ?

- The fewer function input type variations lead to smaller and faster resulting code.
- Keeping your functions *monomorphic* or at least *polymorphic*
  - ***Monomorphic***: one input type
  - ***Polymorphic***: two to four input types
  - ***Megamorphic***: five or more input types

Optimisation And De-optimisation

- **Optimisation** - All assumptions fulfilled – Compiled code runs.
- **Deoptimisation** – Not all assumptions fulfilled – Compiled code erased



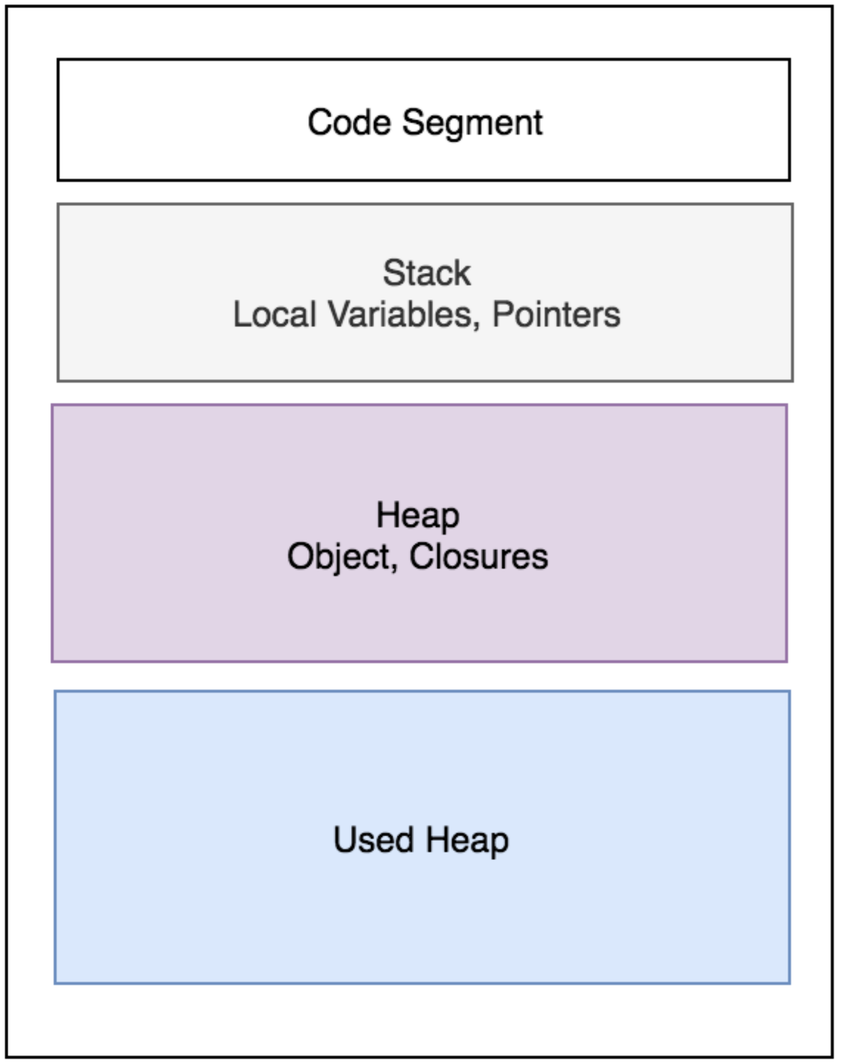
Avoid De-optimisation

- When a code is optimised and de-optimised – it ended up being slower then just use the baseline compiled version
- Most browsers and engines will stop trying after several iterations of optimising and de-optimizing

De-optimisation Demo

V8 Memory Management

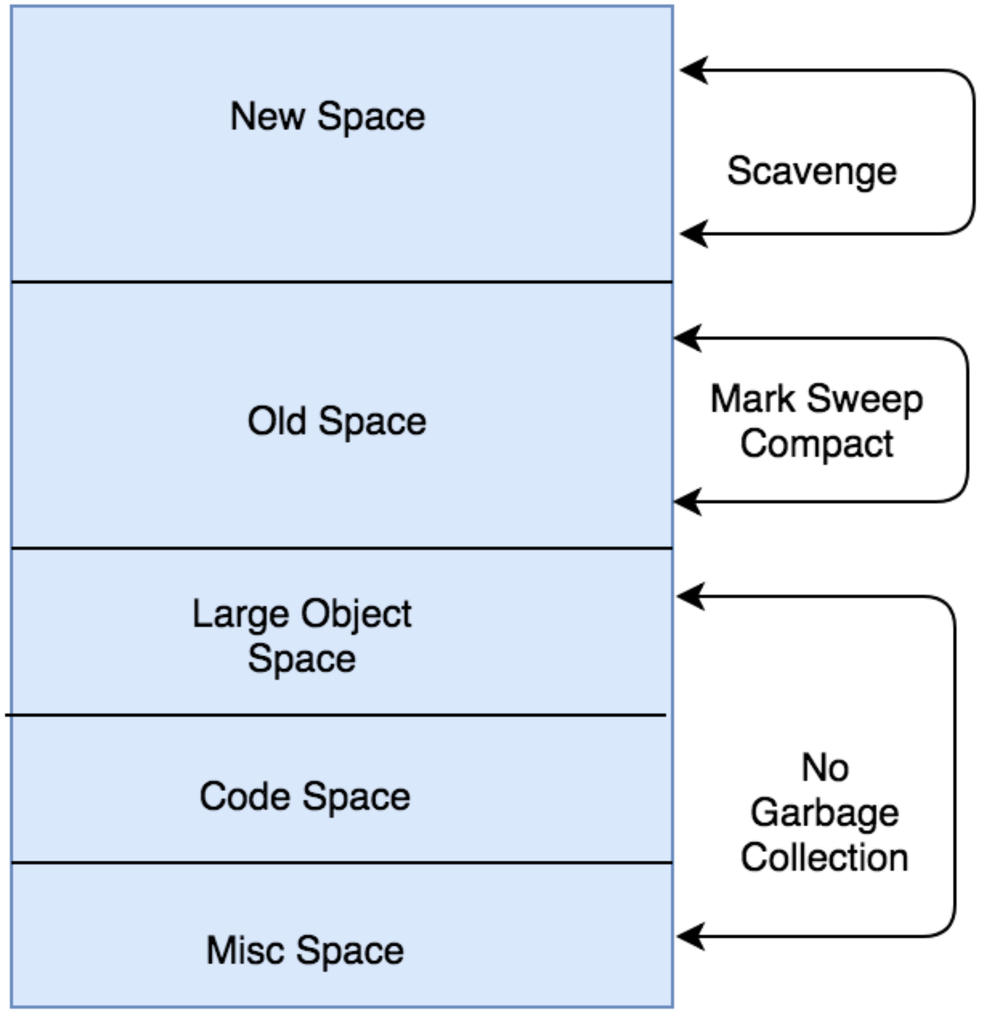
V8 Memory Structure



The Stack

- Every executing function pushes its local variables and arguments
- Maintains two pointers – Stack Pointer and Base Pointer
- Divided into stack frames
- No Garbage Collection - self cleaning
- Hold the key to the garbage collection process - Starts from active objects that has pointers to the stack.

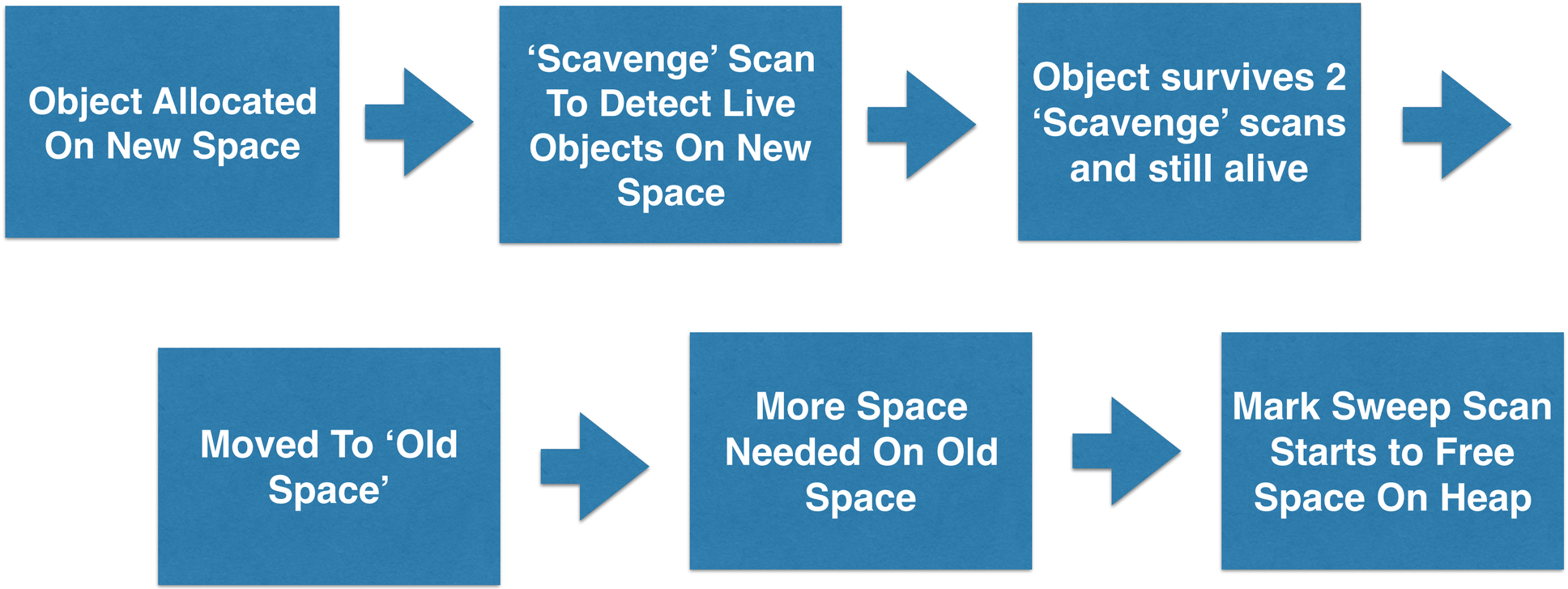
The Heap Structure



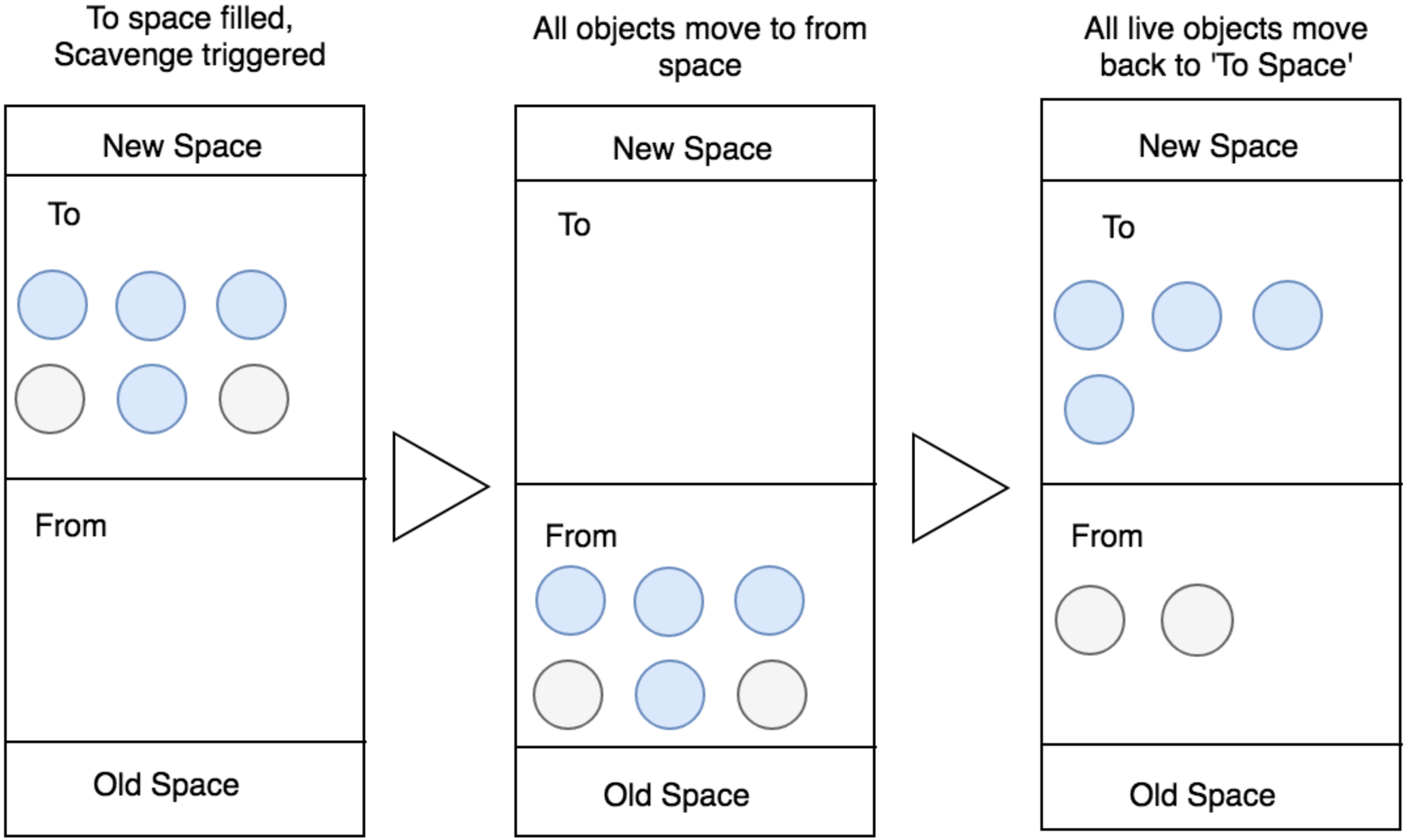
Generational GC System

- Lifetime of objects determines their place on the heap
- New Space – short lived Objects
- Old Space – long lived Objects
- Scan on ‘New Space’ called ‘Scavenge’
  - Very fast – takes less then a millisecond
- Scan on ‘Old Space’ called ‘Mark Sweep’
  - Slower scan

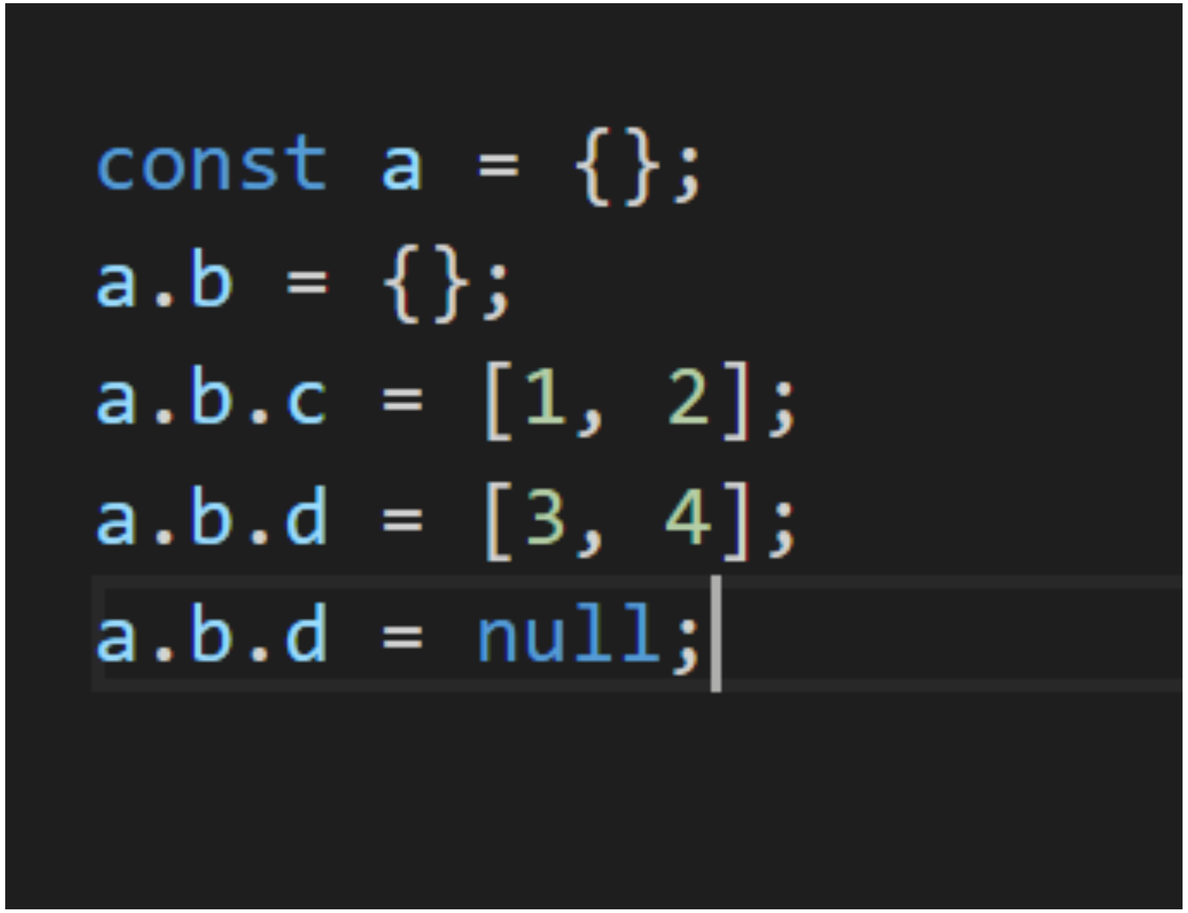
Object Life On The Heap



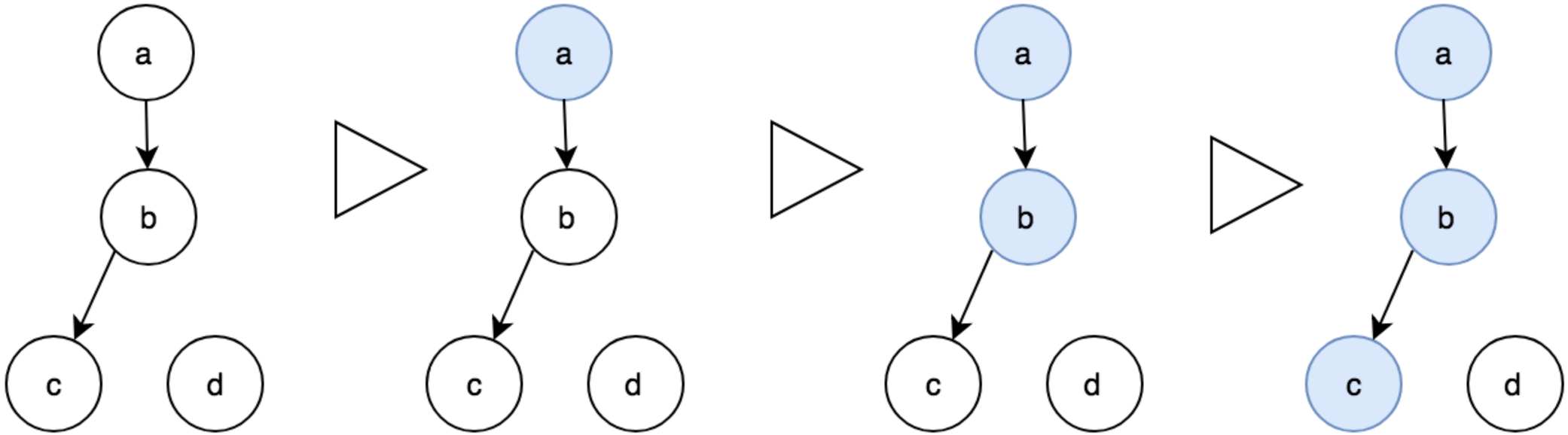
Scavenge Scan Explained



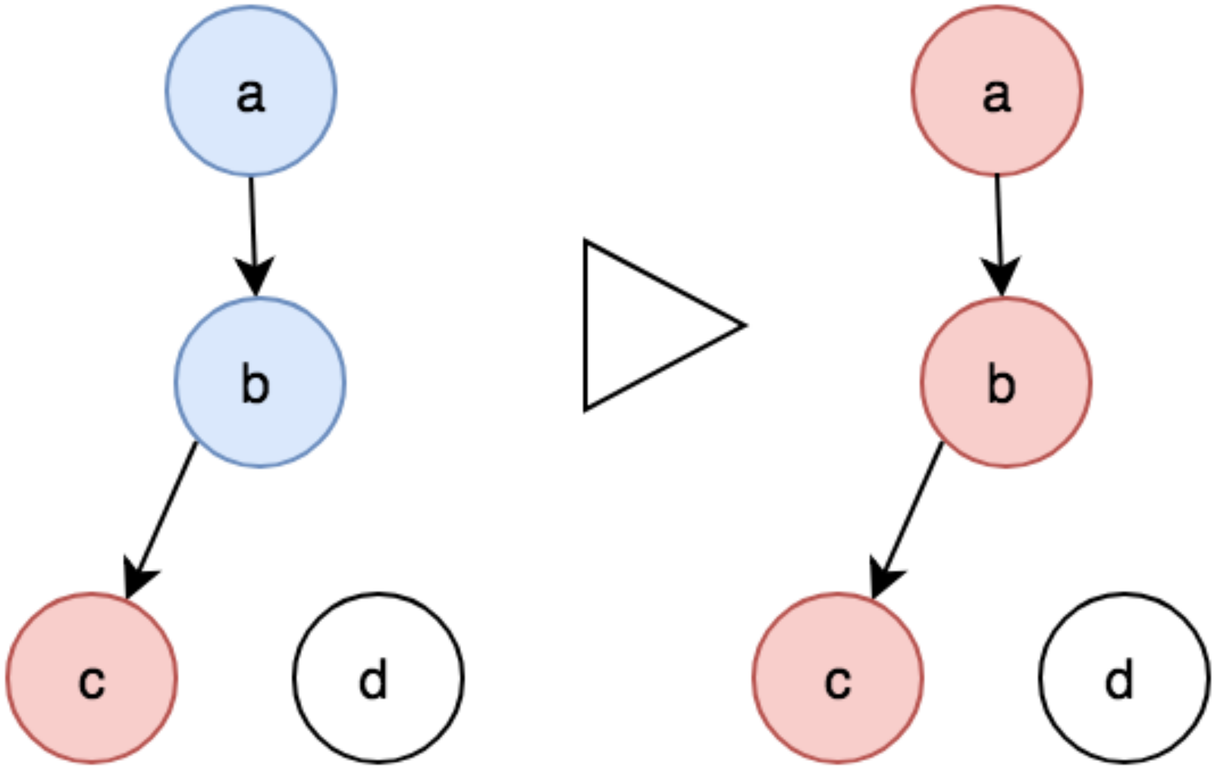
Mark Sweep For The Following Code



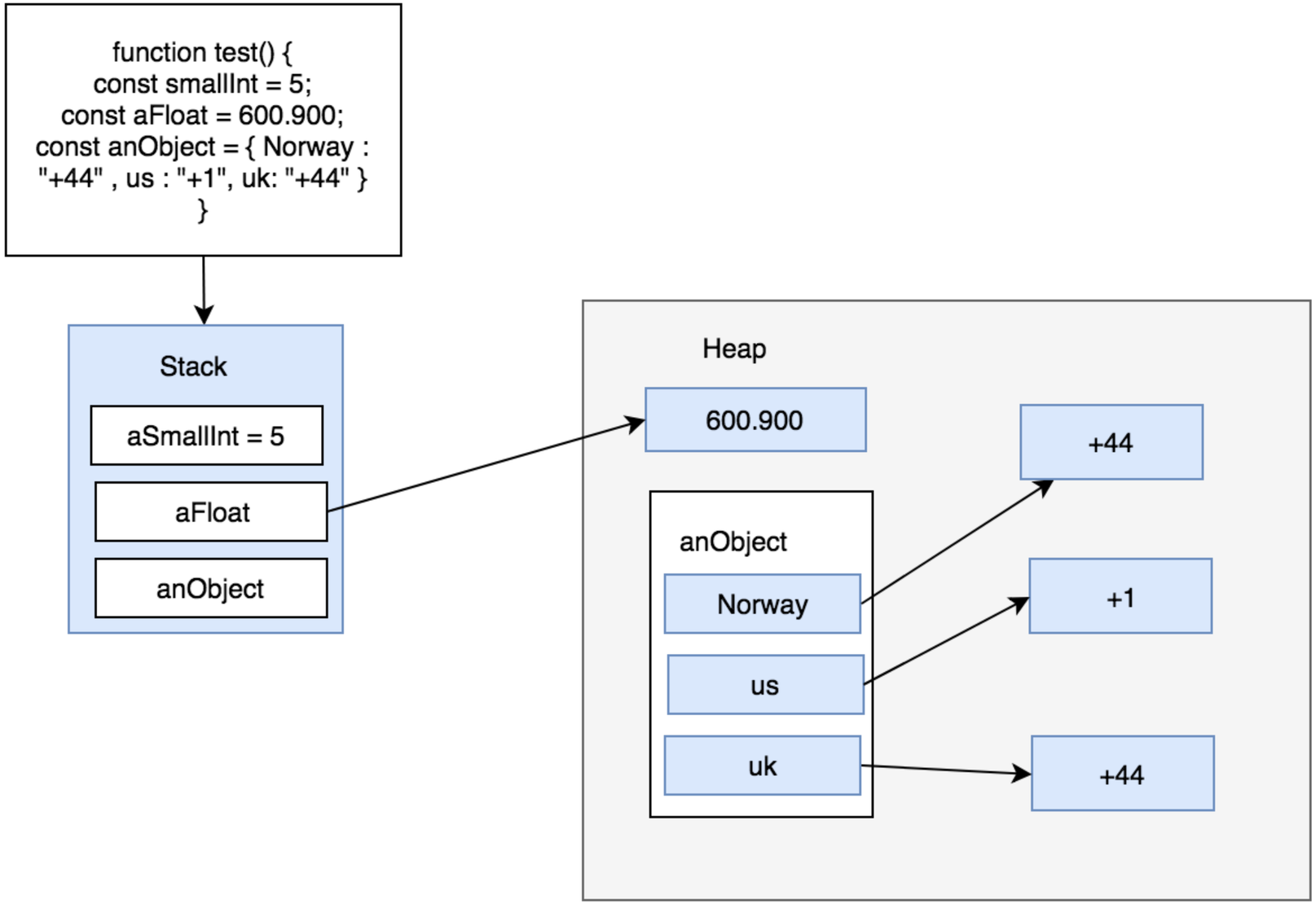
Mark Sweep - DFS



Mark Sweep - DFS



Whats Allocated Where ?



Lets Find Some Memory Leaks !

- Twitter: **@SternTwena**