

C++20 Coroutines, with Boost ASIO in production: Frightening but awesome

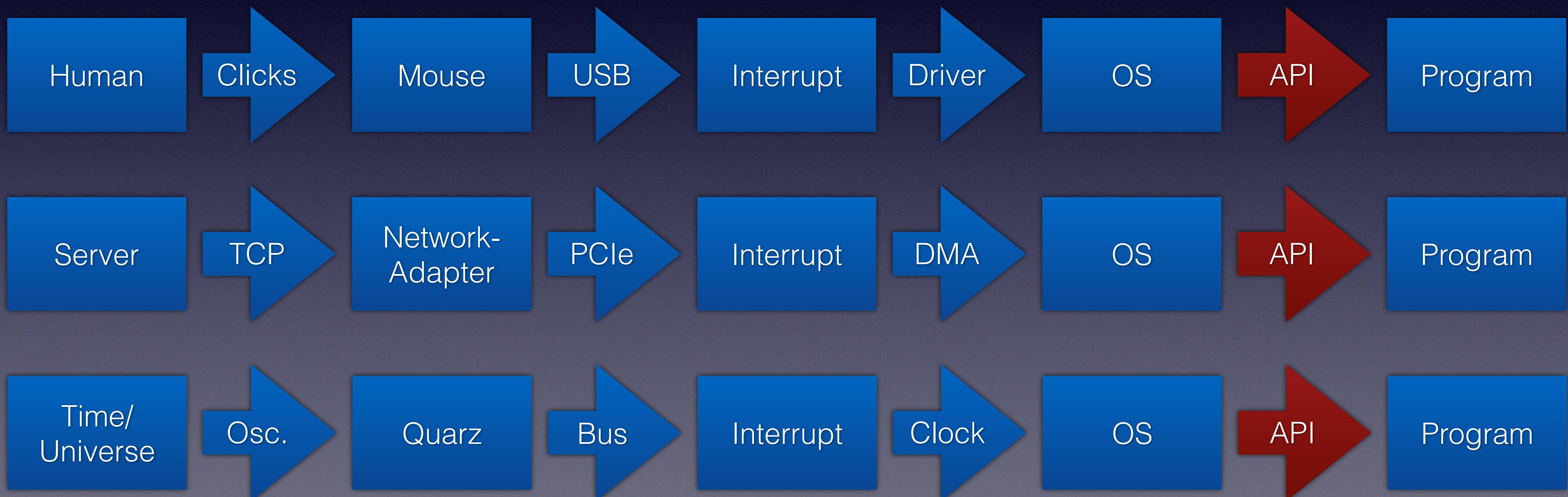
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TOC

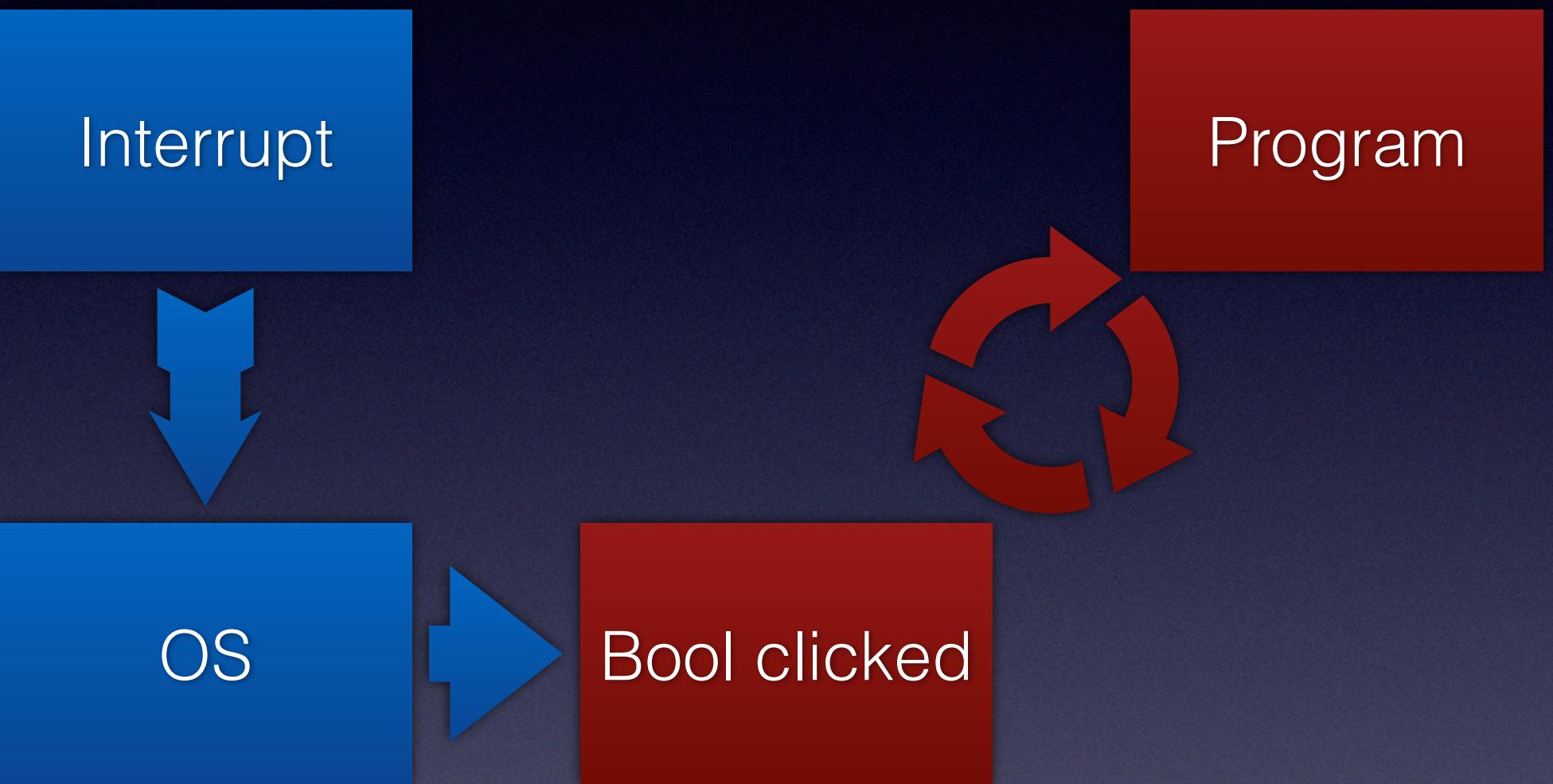
- Little Recap: What is async? Why is async? How is async?
 - We live in a interrupt, trigger based world
 - Concurrency/Multithreading, we are not the same
 - Reactor Pattern

Life is a series of moments



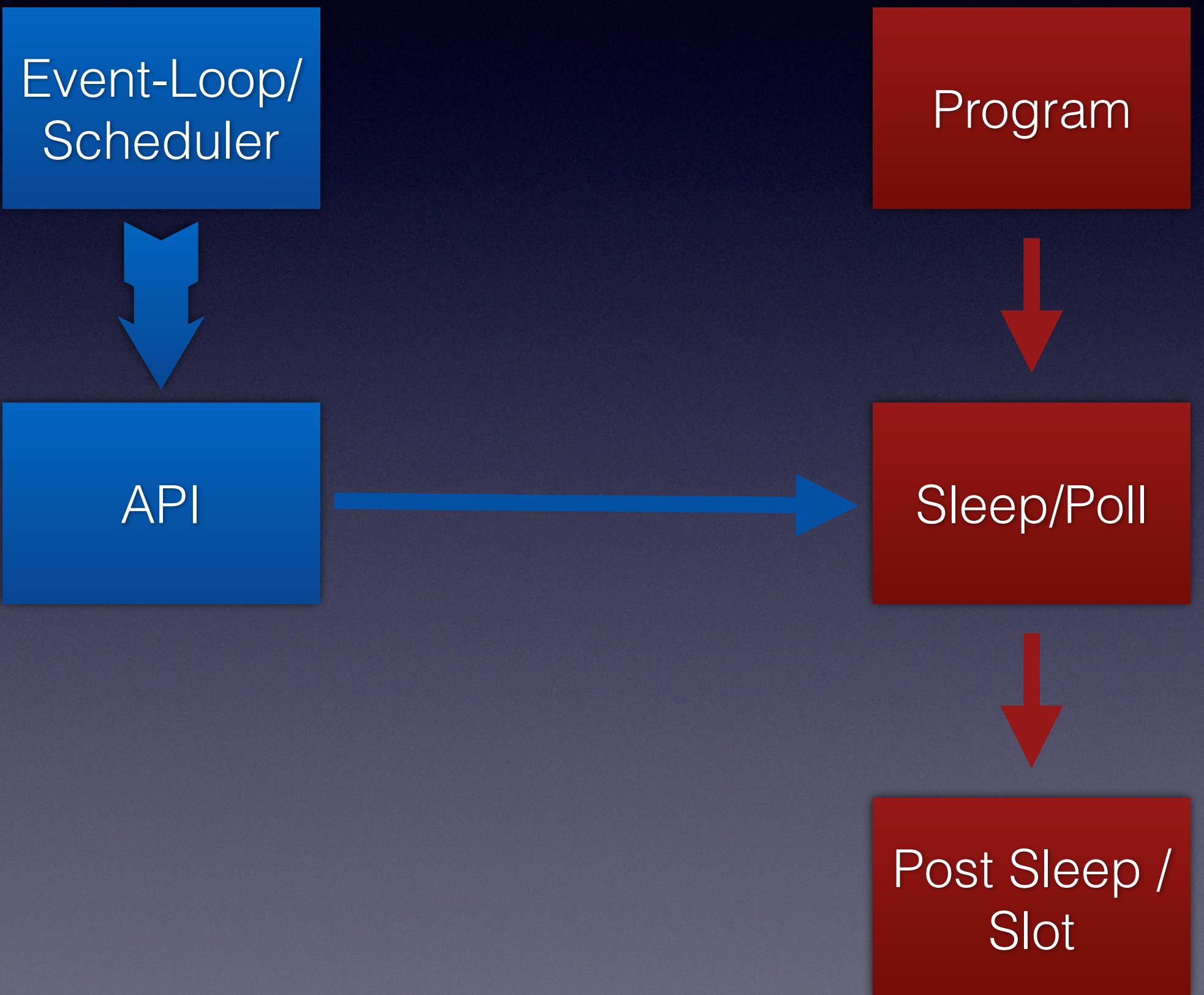
Polling: Busy wait

- `while(!button.clicked());`
- `while(cpu_cycle_counter < 1337000);`
- „Are we there yet?“-„No“„Are we there yet?“-„No“„Are we there yet?“-„No“„Are we there yet?“-„No“„Are we there yet?“-„No“
- Ressource waste
- Not working without preemptive multitasking (no embedded, freestanding, bare metal)



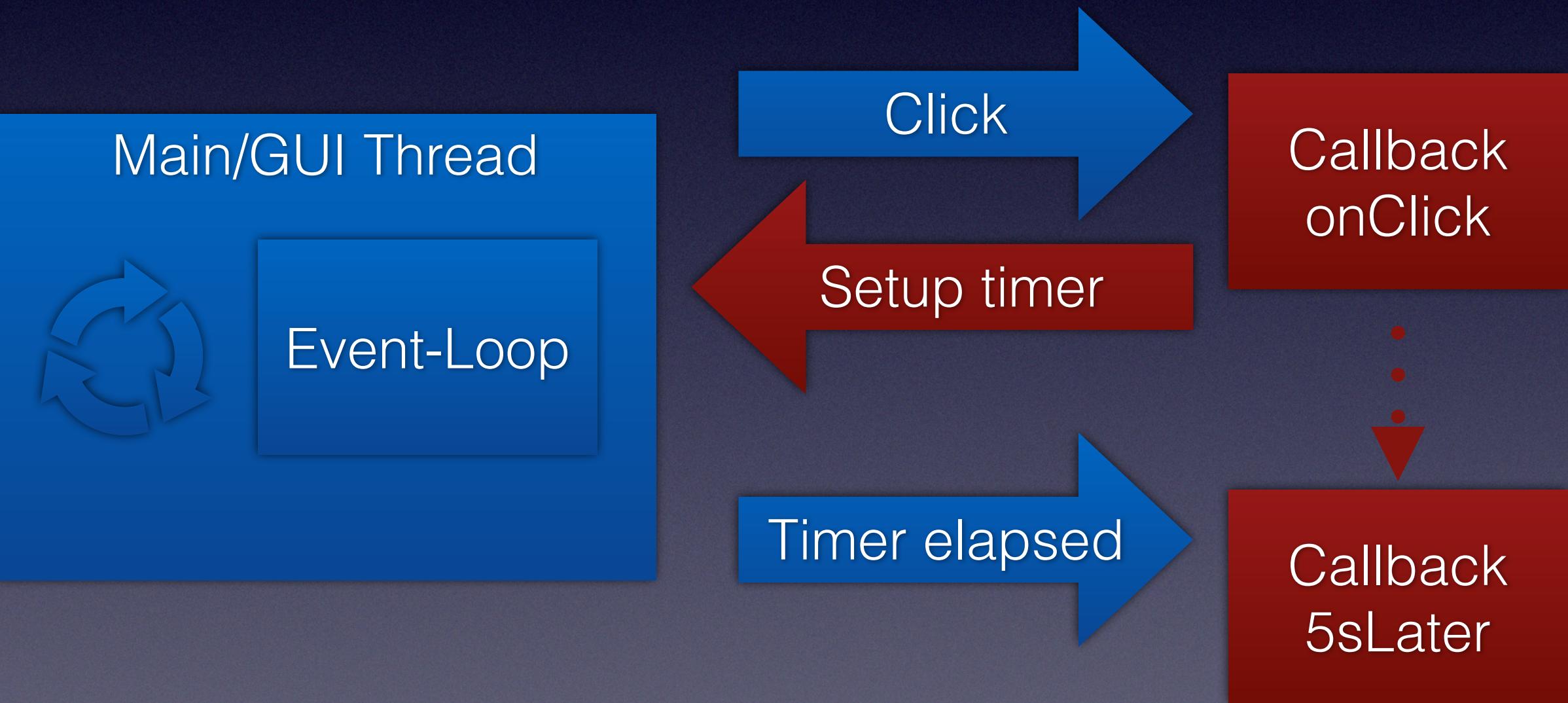
Polling: Blocking API

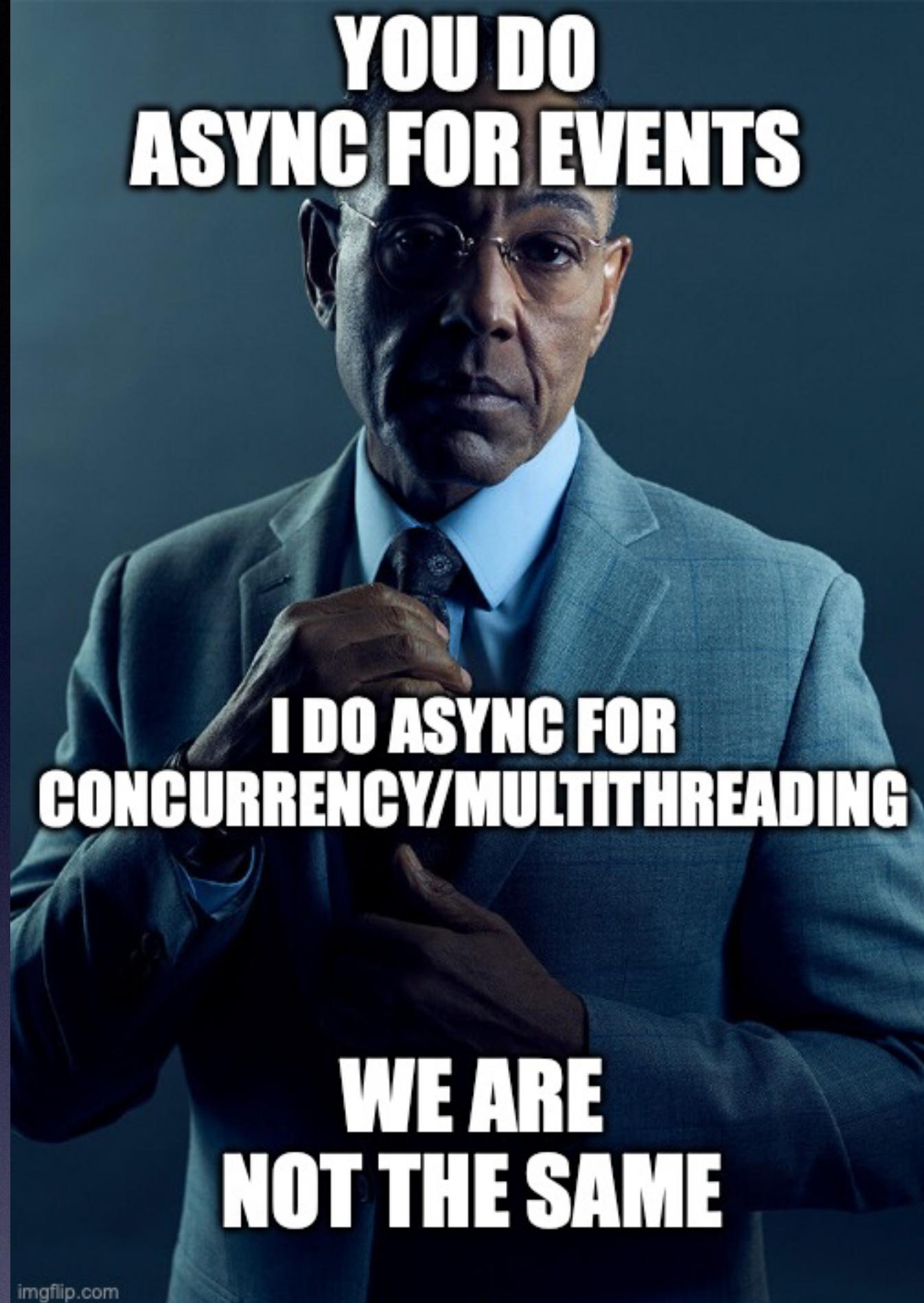
- `SDL_PollEvent()`
- `boost::asio::steady_timer::wait();`
- `std::this_thread::sleep_for(std::chrono::seconds{2});`
- „I go sleep, wake me up when something happens“



Async: Java, Qt, Javascript

- Qt::QCoreApplication::exec()
- Browser JS main thread
- One Thread to rule them all
- No fear of data races, no mutex, no strand needed
- Callback can block main thread



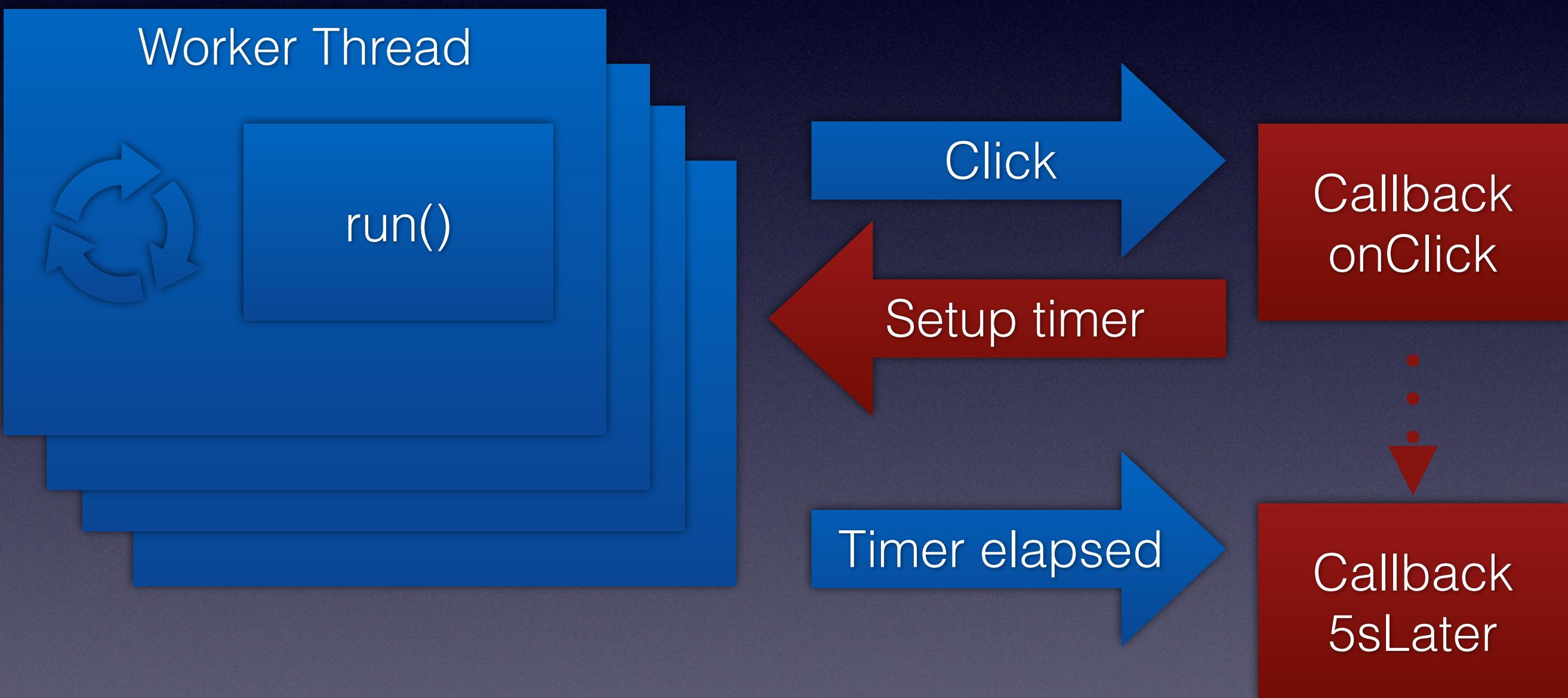


What does this have to do with concurrency?

Proactor pattern

One simple but major change

- Thread[n]: Boost::asio::io_context::run()
- One of the Worker threads will call the callbacks
- Callback only blocks one worker thread
- Is optional: You can just call run() in one thread, might be just the main() thread
- To put simply: userland cooperative multitasking
- Boost can use OS native async facilities, up to transitive from the original interrupt



OK, but was has this to do with coroutines?



Callback-Hell

- „Wake me in 1 second. If this happens: do this, do that, and wake me again, if this happens: do that....“
- Pyramid of doom
- Loops no longer visible
- Lifetime/Scope-Issues

```
void op_a() {
    std::cout << "op_a " << ++session_data_ << "\n";
    timer_.expires_after(std::chrono::seconds{1});
    timer_.async_wait([self = shared_from_this()] (const auto& boost_error){
        if (boost_error) {
            throw std::runtime_error(boost_error.message());
        }
        self->op_b();
        self->timer_.expires_after(std::chrono::seconds{1});
        self->timer_.async_wait([self = self->shared_from_this()] (const auto& boost_error){
            if (boost_error) {
                throw std::runtime_error(boost_error.message());
            }
            self->op_a();
        });
    });
}
```

Javascript Evolution

- From Callback-Hell to

```
setTimeout( handler: (arg) => {
    console.log(`arg1 was => ${arg}`);
    setTimeout( handler: (arg) => {
        console.log(`arg2 was => ${arg}`);
        setTimeout( handler: (arg) => {
            console.log(`arg3 was => ${arg}`), timeout: 1500, arguments: 'funky3');
        }, timeout: 1500, arguments: 'funky2');
    }, timeout: 1500, arguments: 'funky1');
```

- Promises aka then.then.then.catch to

```
timersPromises.setTimeout( handler: 3000, timeout: "Promise 1")
    .then((value) => {
        console.log("Then ", value); return timersPromises.setTimeout( handler: 1000, timeout: 'Promise2');
    })
    .then( onfulfilled: (value) => {
        console.log("Then ", value); return timersPromises.setTimeout( handler: 1000, timeout: 'Promise3');
    });
});
```

- Async/Await/Coroutines

```
async function co_coutine():Promise<number> {
    let res :number = await timersPromises.setTimeout( handler: 2000, timeout: 'result1');
    console.log("Co Routine 1", res);

    res = await timersPromises.setTimeout( handler: 2000, timeout: 'result2');
    console.log("Co Routine 2", res);

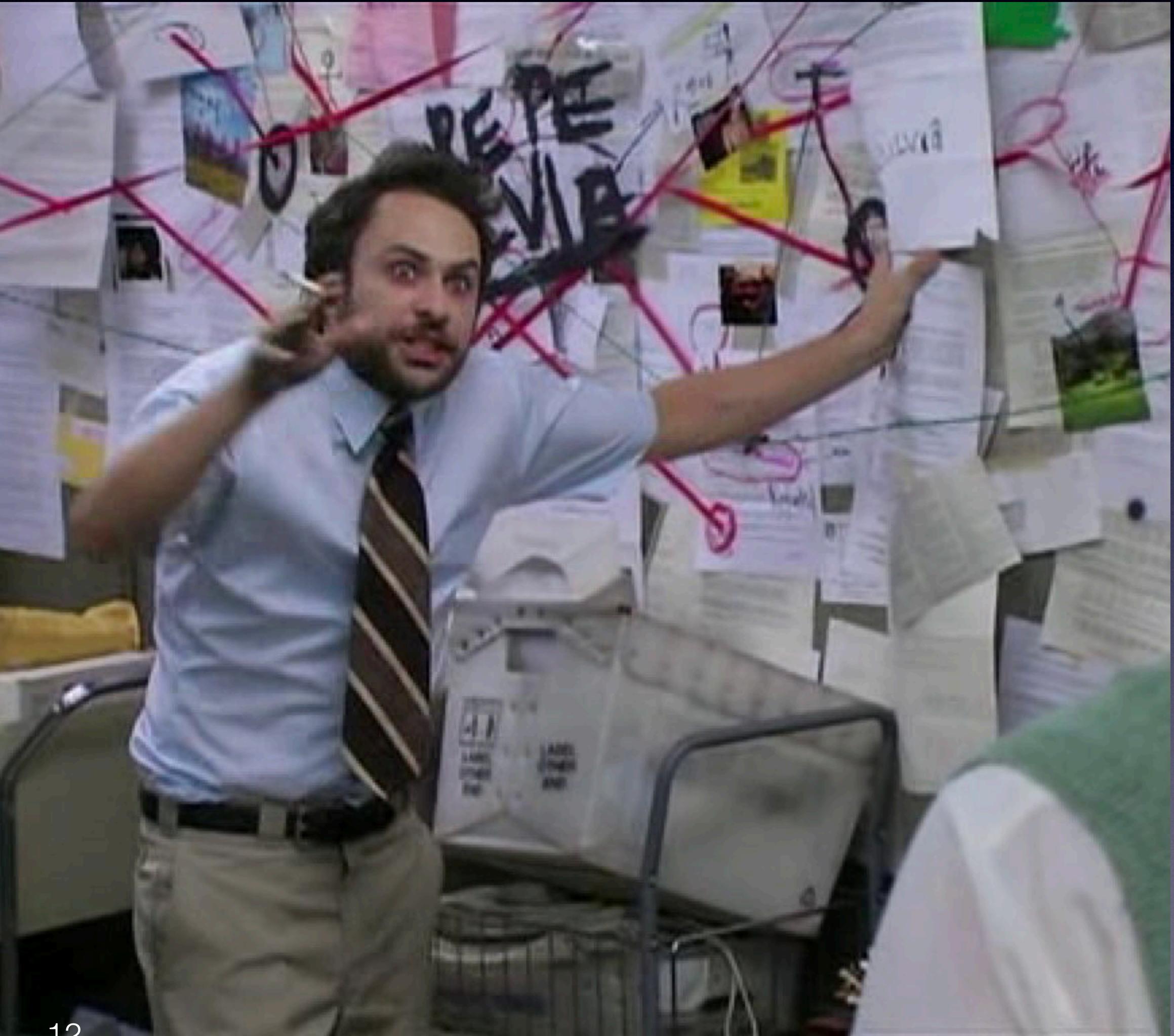
    res = await timersPromises.setTimeout( handler: 2000, timeout: 'result3');
    console.log("Co Routine 3", res);
    return res;
}
```

So lets use C++20 Coroutines

Screenshot of the en.cppreference.com website showing the C++20 Coroutines documentation. The page is titled "Promise" and discusses how the Promise type is determined by the compiler from the return type of the coroutine using `std::coroutine_traits`. It provides several bullet points about the rules for determining the Promise type based on the coroutine's definition (return type, parameter types, class type, cv-qualification). Below this, there is a table comparing different coroutine definitions and their corresponding Promise types. The table has two columns: "If the coroutine is defined as ..." and "then its Promise type is ...". Examples include `task<void> foo(int x);` resulting in `std::coroutine_traits<task<void>, int>::promise_type`, and `task<void> Bar::foo(int x) const;` resulting in `std::coroutine_traits<task<void>, const Bar&, int>::promise_type`.

If the coroutine is defined as ...	then its Promise type is ...
<code>task<void> foo(int x);</code>	<code>std::coroutine_traits<task<void>, int>::promise_type</code>
<code>task<void> Bar::foo(int x) const;</code>	<code>std::coroutine_traits<task<void>, const Bar&, int>::promise_type</code>
<code>task<void> Bar::foo(int x) &&;</code>	<code>std::coroutine_traits<task<void>, Bar&&, int>::promise_type</code>

The page also includes sections on `co_await` and `co_await expr`, detailing the unary operator `co_await` and the expression `co_await expr`.



Co-Routines TL;DR

- C++20 Standard [dcl.fct.def.coroutine]: „A function is a coroutine if its function-body encloses a coroutine-return-statement (8.7.4), an await-expression (7.6.2.3), or a yield-expression (7.6.17).“ (Draft N4861 for ISO/IEC 14882:2020)
- You want to use
 - `boost::asio::co_spawn` to call a coroutine, usually with `boost::asio::detached` and a `boost::asio::strand<boost::asio::io_context::executor_type>` as executor
 - A return value that fulfills the C++20 Coroutine Concept like `boost::asio::awaitable`

From the old

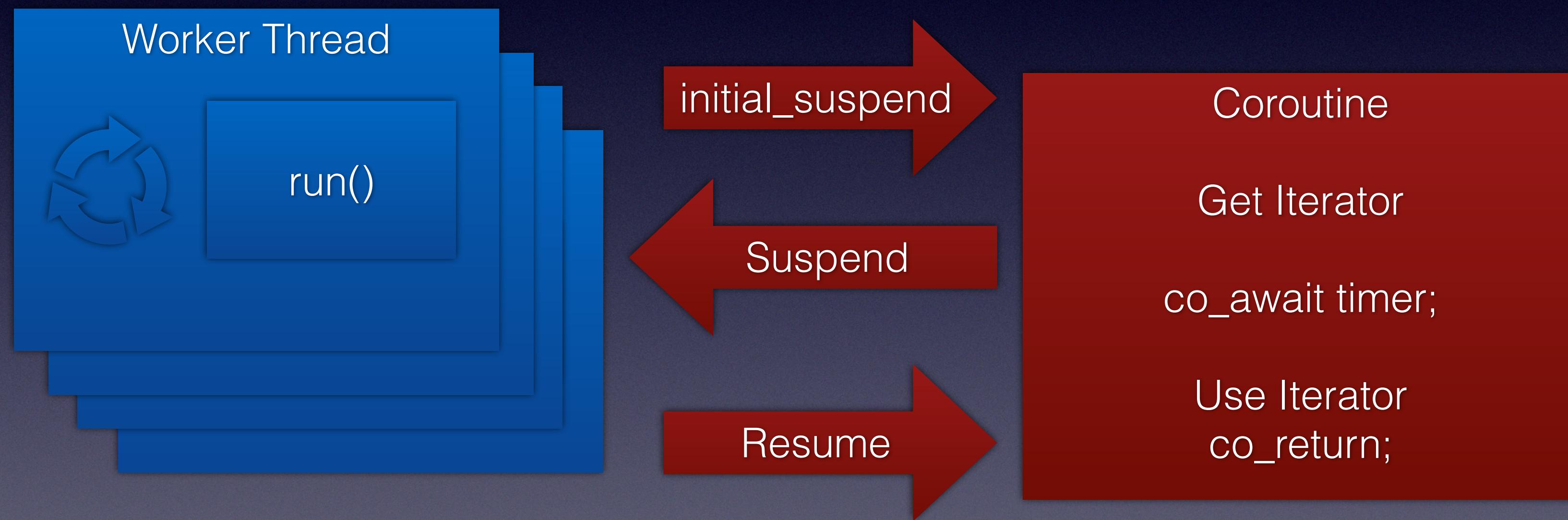
```
std::future<int> scope_stuff::old_async() {
    sync_ops example_instance; auto value = 7;
    this->timer_.expires_after( expiry_time: boost::asio::chrono::milliseconds( rep: 5));
    this->timer_.async_wait( token: [self : shared_ptr<scope_stuff>] = shared_from_this(), example_instance, value]
        (const auto &boost_error : const error_code &) mutable -> void {
        auto value2 : int = example_instance.op2( input: value);
        self->timer_.expires_after( expiry_time: boost::asio::chrono::milliseconds( rep: 5));
        self->timer_.async_wait( token: [self, example_instance, value2]
            (const auto &boost_error) mutable{
            auto value3 : int = example_instance.op3( input: value2);
            self->promise.set_value( r: value3);
        });
    });
    return this->promise.get_future();
}
```

To the new

```
boost::asio::awaitable<int> scope_stuff::getValue() {
    sync_ops example_instance; auto value = 7;
    this->timer_.expires_after( expiry_time: boost::asio::chrono::milliseconds( rep: 5));
    co_await this->timer_.async_wait( token: boost::asio::use_awaitable);
    value = example_instance.op2( input: value);
    this->timer_.expires_after( expiry_time: boost::asio::chrono::milliseconds( rep: 5));
    co_await this->timer_.async_wait( token: boost::asio::use_awaitable);
    value = example_instance.op3( input: value);

    co_return value;
}
```

Important



Demo: Dragons beware

- <https://github.com/Superlokkus/coroutine>



What we learned

- Its best to always include a `co_return`
- The `calll` operator does not behave as you expect in all cases anymore
- Execution is suspended during a `await`, a strand is released meanwhile!
- Magic happens in the return value

Async keyword

- C++ misses the `async` keyword for function declarations, it's signaled by the keyword in the body

Hello World!

```
import asyncio

async def main():
    print('Hello ...')
    await asyncio.sleep(1)
    print('... World!')

asyncio.run(main())
```

```
async function asyncCall() {
  console.log('calling');
  const result = await resolveAfter2Seconds();
  console.log(result);
  // Expected output: "resolved"
}

asyncCall();
```

What helped me

- <https://www.scs.stanford.edu/~dm/blog/c++-coroutines.html>
- <https://think-async.com/Asio/asio-1.22.1/doc/asio/overview/composition/coro.html>
- https://www.boost.org/doc/libs/1_82_0/doc/html/boost_asio/overview/composition/cpp20_coroutines.html

Thank you

- <https://stackoverflow.com/q/76950493/3537677>
- <https://stackoverflow.com/q/77060868/3537677>
- <https://stackoverflow.com/q/76922347/3537677>