Next Gen Networking Infrastructure With Rust

Hi, I’m @carllerche

Let’s write a database!

Most newer databases are written in a language that includes a runtime.

C / C++

Memory management

we’ll do it live…

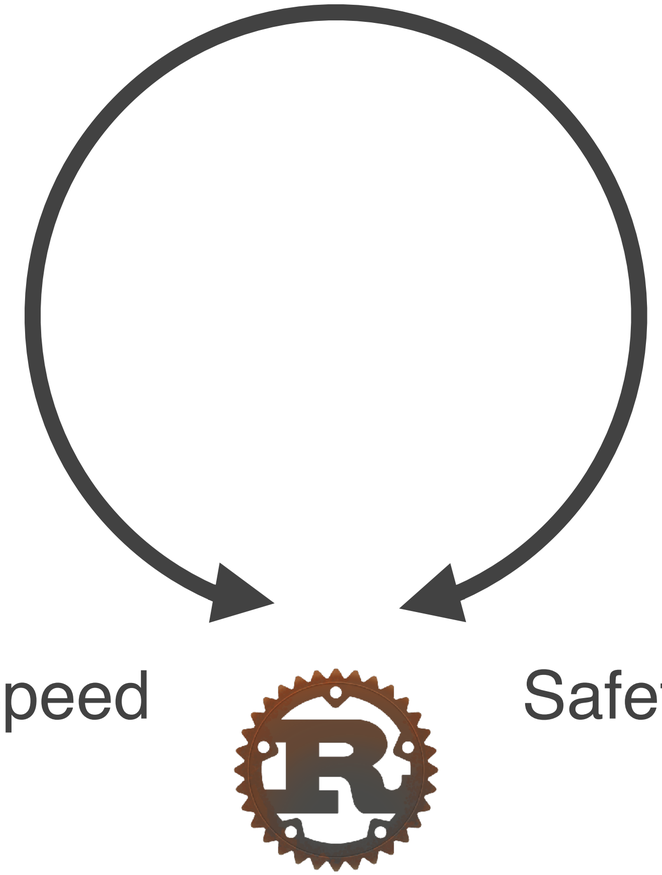
SEGV

Heartbleed, cloudbleed, WannaCry

“Just use linting tools”

– Software developer who accidentally shipped remote code execution vulnerabilities to millions of computers


Speed
Safety


Speed
Safety

Checks at compile time

Ownership

Data has one owner

Compiles

```
fn print(s: String) {
    println!("{}", s);
}

let foo = String::new();
let bar = foo;

print(bar);
```

Compiles

```
fn print(s: String) {
    println!("{}", s);
}

let foo = String::new();
let bar = foo;

print(bar);
```

```
   |
8  |     let bar = foo;
   |         --- value moved here
9  |
10 |     print(foo);
   |           ^^^ value used here after move
   |
   = note: move occurs because `foo` has
     type `std::string::String`, which does
     not implement the `Copy` trait
```

```
fn print(s: String) {
    println!("{}", s);
}

let foo = String::new();
let bar = foo;

print(foo);
```

Data is borrowed

Compiles

```
fn print(s: &String) {
    println!("{}", s);
}

let foo = String::new();
let bar = &foo;

print(&foo);
print(bar);
```

```
   |
10 | let bar = &foo;
   |             --- borrow of `foo` occurs here
...
14 | drop(foo);
   |      ^^^ move out of `foo` occurs here
```

```
fn print(s: &String) {
    println!("{}", s);
}

fn drop(s: String) {}

let foo = String::new();
let bar = &foo;

print(&foo);
drop(foo);
print(bar);
```

Mutable borrows

```
   |
8  | let bar = &mut foo;
   |                --- first mutable borrow
   |                    occurs here
9  |
10 | print(&mut foo);
   |             ^^^ second mutable borrow
   |                 occurs here
11 | }
   | - first borrow ends here
```

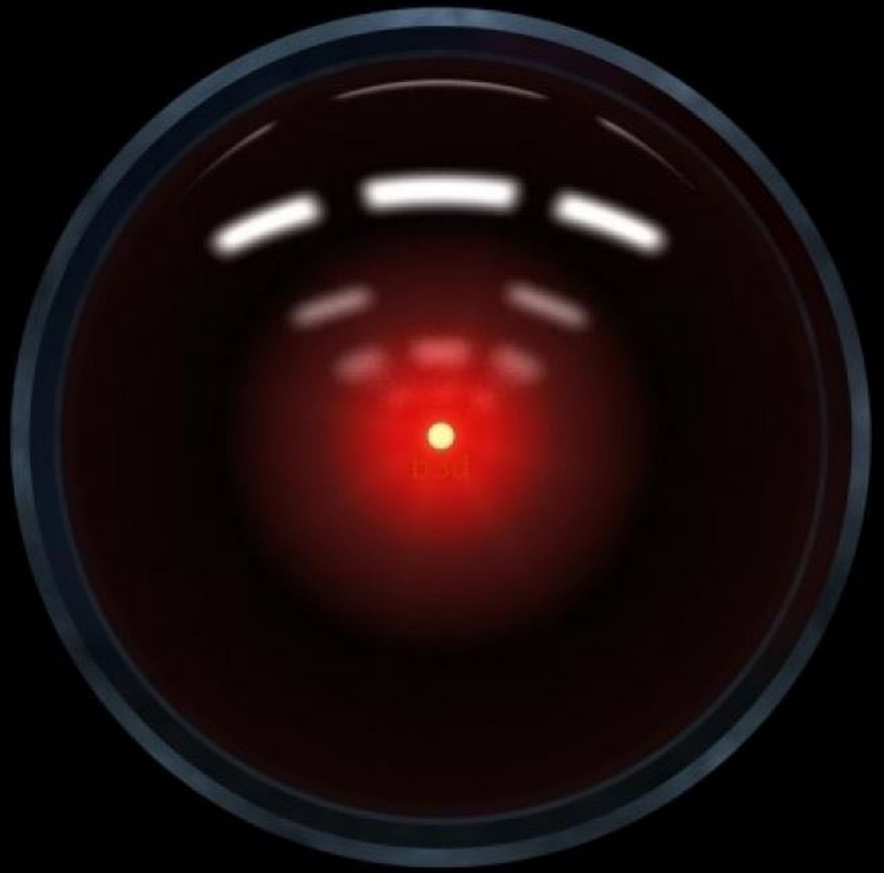
```
fn print(s: &mut String) {
    println!("{}", s);
}

let mut foo = String::new();
let bar = &mut foo;

print(&mut foo);
```

```
   |
9  | let val = &vec[0];
   |             --- immutable borrow occurs
   |                 here
...
13 | vec.push(String::new());
   | ^^^ mutable borrow occurs here
...
19 | }
   | - immutable borrow ends here
```

```
let mut vec = vec![];

vec.push(String::new());

// lots of code here

let val = &vec[0];

// lots of code here

vec.push(String::new());

// lots of code here

println!("{}", val);
```

```
let handle1 = Rc::new(my_data);
let handle2 = handle1.clone();

drop(handle1);

println!("data = {}", handle2);
```

```
struct Rc<T> {
    inner: *mut Inner<T>,
}
struct Inner<T> {
    value: T,
    ref_count: usize,
}

impl<T> Rc<T> {
    fn clone(&self) -> Rc<T> {
        unsafe {
            (*self.inner).ref_count += 1;
        }
        Rc { inner: self.inner }
    }
}

impl<T> Drop<T> {
    fn drop(&mut self) {
        unsafe {
            (*self.inner.ref_count) -= 1;
            if *self.inner.ref_count == 0 {
                // Free memory
            }
        }
    }
}
```



I’m sorry, Dave. I’m afraid I can’t do that.

Fearless concurrency

Compiles

```
let (tx, rx) = channel();

thread::spawn(|| {
    for msg in rx { … }
});

tx.send(my_msg);
```

```
error[E0382]: use of moved value: `my_msg`
   |
12 |     tx.send(my_msg);
   |             ------ value moved here
13 |     println!("msg = {}", my_msg);
   |                          ^^^^^^ value used
   |                            here after move
   |
   = note: move occurs because `my_msg` has
     type `std::string::String`, which does not
     implement the `Copy` trait
```

```
let (tx, rx) = channel();

thread::spawn(|| {
    for msg in rx { … }
});

tx.send(my_msg);
println!("{}", my_msg);
```

Compiles

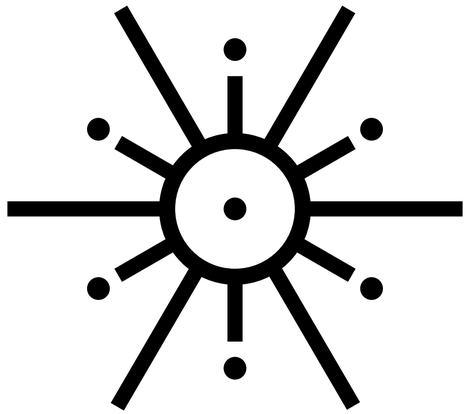
```
let mutex =
Arc::new(Mutex::new(data));

thread::spawn(|| {
    // use mutex
});

// lock() -> Guard<‘a, T>
let d = mutex.lock()?;
println!("{}", d);
```

Modern Language Features

- Closures
- Type inference
- Traits
- Package manager
- Pattern matching
- Macros

Fast, Reliable, Productive: Pick Three

Can the principles of Rust be applied to a networking library?



Tokio

Fastest, Safest

- Epoll, kqueue, IOCP backed I/O
- Timers
- Task scheduling (N:M, current thread,…)
- Filesystem access
- Child processes

- Cancellation
- Backpressure

@kanyewest
Kanye West

I hate when I'm on a flight and I wake up with a water bottle next to me like oh great now I gotta be responsible for this water bottle

16 Oct via web ☆ Favorite ↻ Retweet ↩ Reply

Secret: Do no work

```
let server = TcpListener::bind(&local_addr)?;

let server = sever.incoming().for_each(move |src| {
    let connection = TcpStream::connect(&remote_addr)
        .and_then(|move |dst| copy(src, dst));

    // Run asynchronously in the background
    tokio::spawn(connection)
});

tokio::spawn(server);
```

Futures

```
TcpStream::connect(&remote_addr)
    .and_then(move |dst| { … })
    .and_then(|foo| { … })
```

```
let fut_1 = copy(src_rd, dst_wr);

let fut_2 = copy(dst_rd, src_wr);

let fut_3 = fut_1.join(fut_2);
```

Zero cost

Epoll

- Non-blocking sockets
- Event queue

```
let socket = bind(remote_addr);
epoll.register(socket, token: 0);
let clients = State::new();

for event in epoll.poll():
  match event.token:
    0 =>
      while socket.is_ready():
        let client = socket.accept();
        let token = clients.store(client);
        epoll.register(client, token: token);

    token =>
      let client = clients[token];
      process(client);
```

1. Connect a socket
2. Send handshake message
3. Receive handshake message
4. Send request
5. Receive request

```
enum SocketState {
    Connecting,
    SendingHandshake,
    ReceivingHandshake,
    SendingRequest,
    ReceivingResponse,
}
```

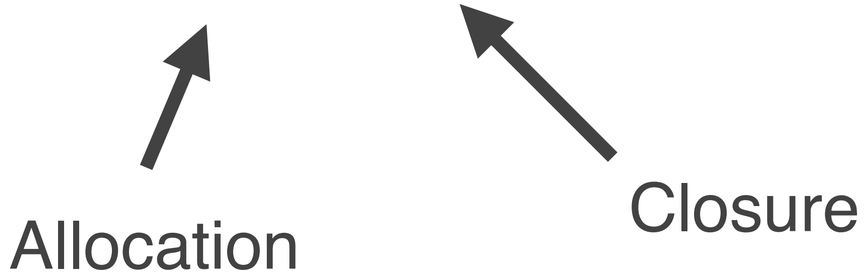
Fast

- No runtime allocations
- No dynamic dispatch
- No copying / growing the stack
- No garbage collection

After compilation, Tokio is equivalent.

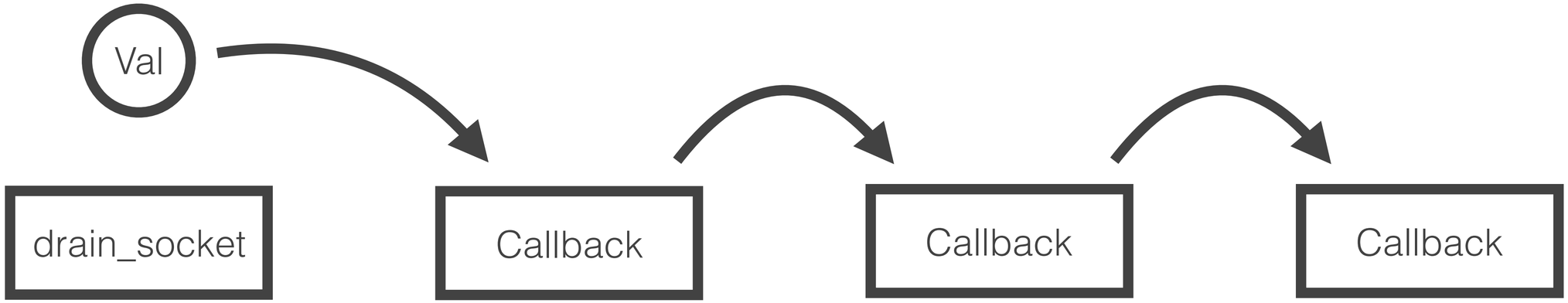
Pull, not push

```
struct DrainTcpStream {
  nread: u64,
  callback: Option<Box<Fn(u64)>>,
}
```

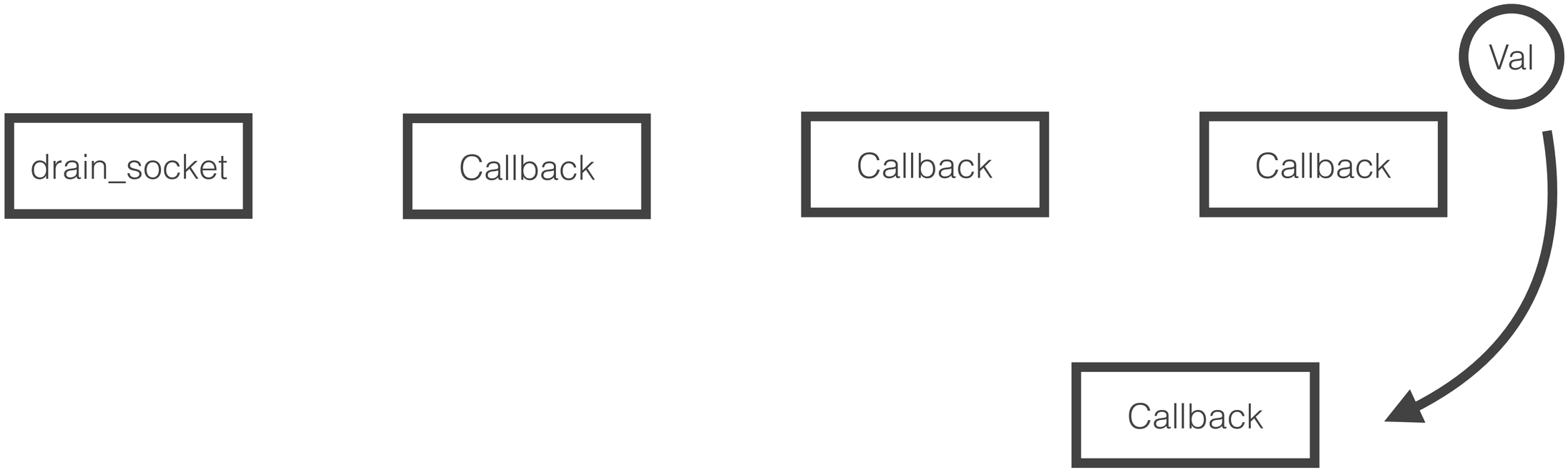


```
drain_socket
  .then(...)
  .then(...)
  .then(...)
```

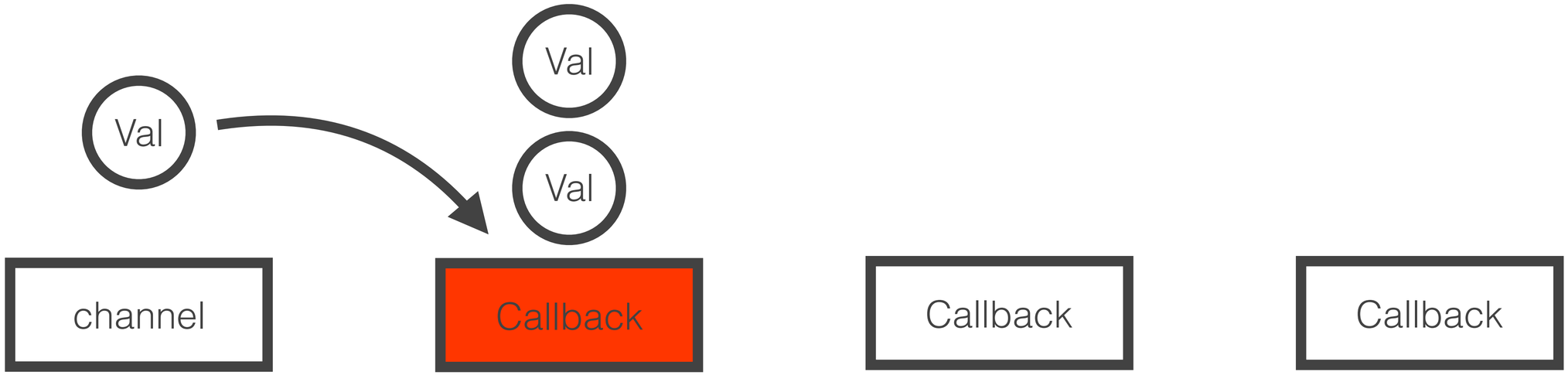

drain_socket
Callback
Callback
Callback


Val
drain_socket
Callback
Callback
Callback


drain_socket
Callback
Callback
Callback
Val


drain_socket
Callback
Callback
Callback
Val
Callback

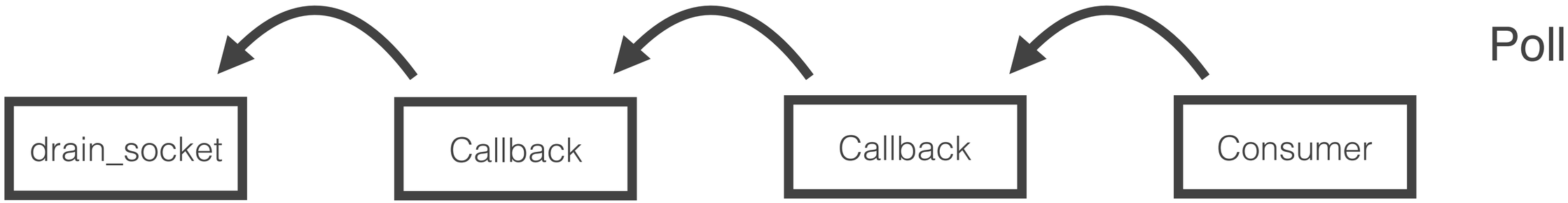

Val
channel
Callback
Callback
Callback

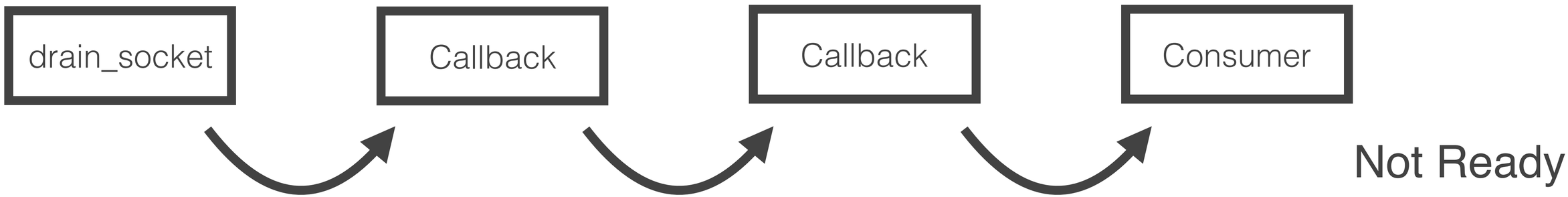

Val
Val
Val
channel
Callback
Callback
Callback

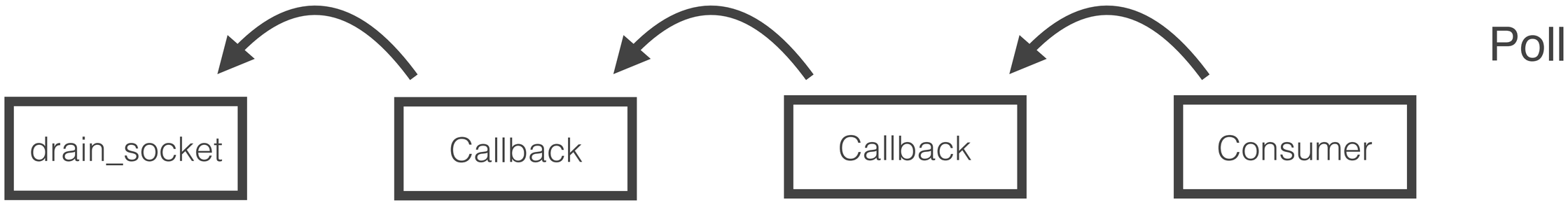
```
struct DrainTcpStream {
  socket: TcpStream,
  nread: u64,
}

fn poll(&mut self) -> Async<u64> {
  let mut buf = [0; 1024];
  loop {
    match self.socket.read(&mut buf) {
      Async::Ready(0) => return Async::Ready(self.nread),
      Async::Ready(n) => self.nread += n,
      Async::NotReady => return Async::NotReady,
    }
  }
}
```

```
drain_socket
  .then(...)
  .then(...)
  .then(...)
```

```
enum Then<A, B, F> {
    First(A, F),
    Second(B),
}

fn poll(&mut self) -> Async<B::Item> {
    loop {
        let fut_b = match *self {
            Then::First(ref mut fut_a, ref f) => {
                match fut_a.poll() {
                    Async::Ready(v) => f(v),
                    Async::NotReady => Async::NotReady,
                }
            }
            Then::Second(ref mut fut_b) => return fut_b.poll(),
        }

        *self = Then::Second(fut_b);
    }
}
```


drain_socket
Callback
Callback
Consumer
Poll


drain_socket
Callback
Callback
Consumer
Not Ready


drain_socket
Callback
Callback
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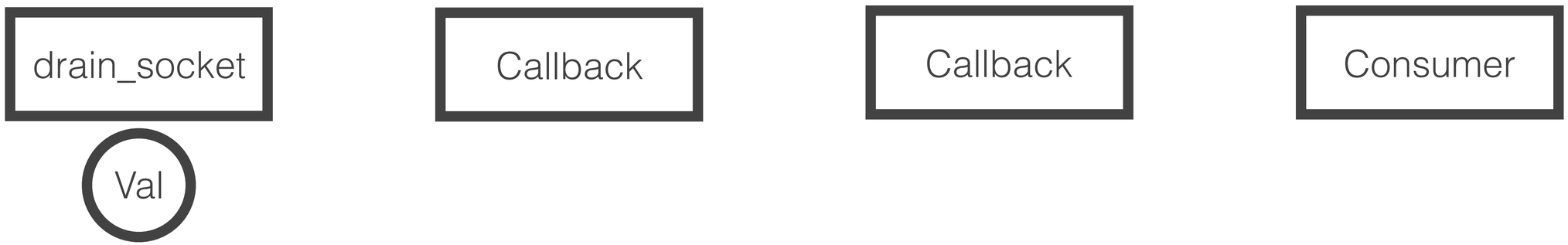
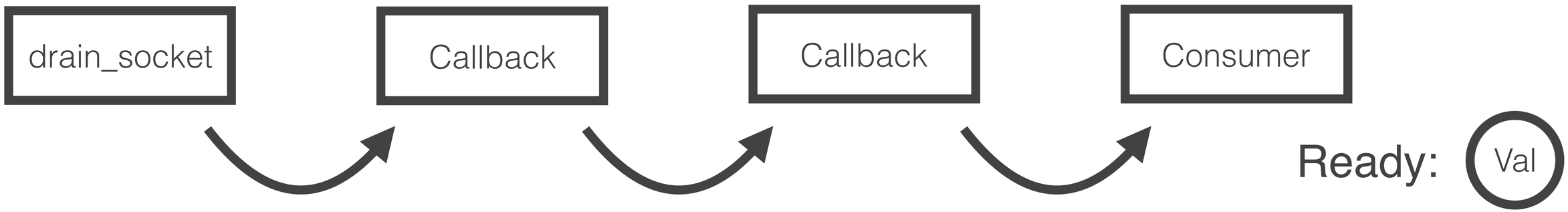
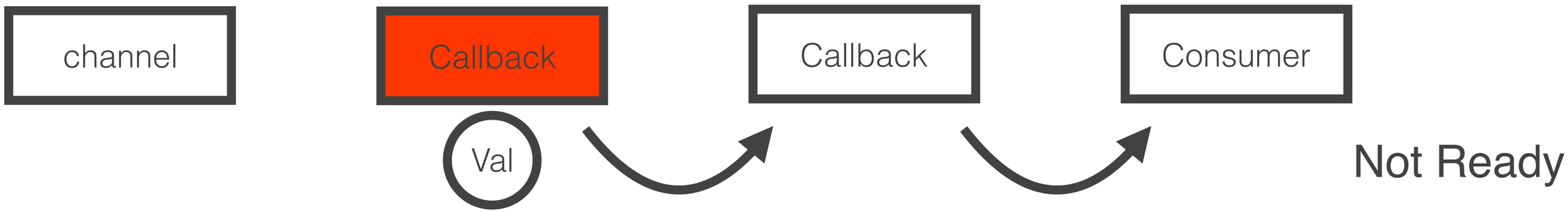
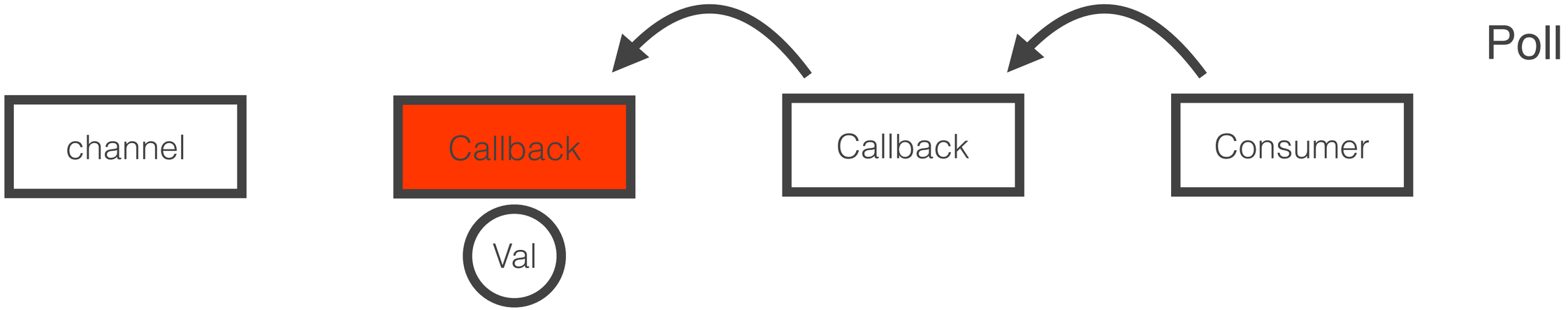
Poll

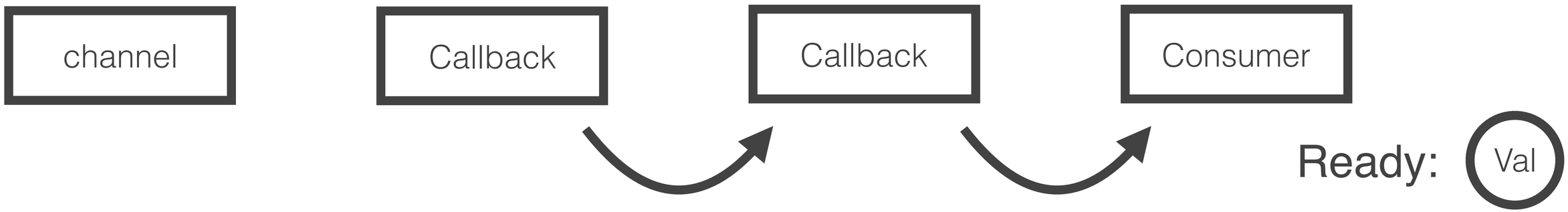

drain_socket
Val
Callback
Callback
Consumer


drain_socket
Callback
Callback
Consumer
Ready:
Val


channel
Callback
Val
Callback
Consumer


channel
Callback
Callback
Consumer
Val
Not Ready


Poll
channel
Callback
Callback
Consumer
Val


channel
Callback
Callback
Consumer
Ready:
Val

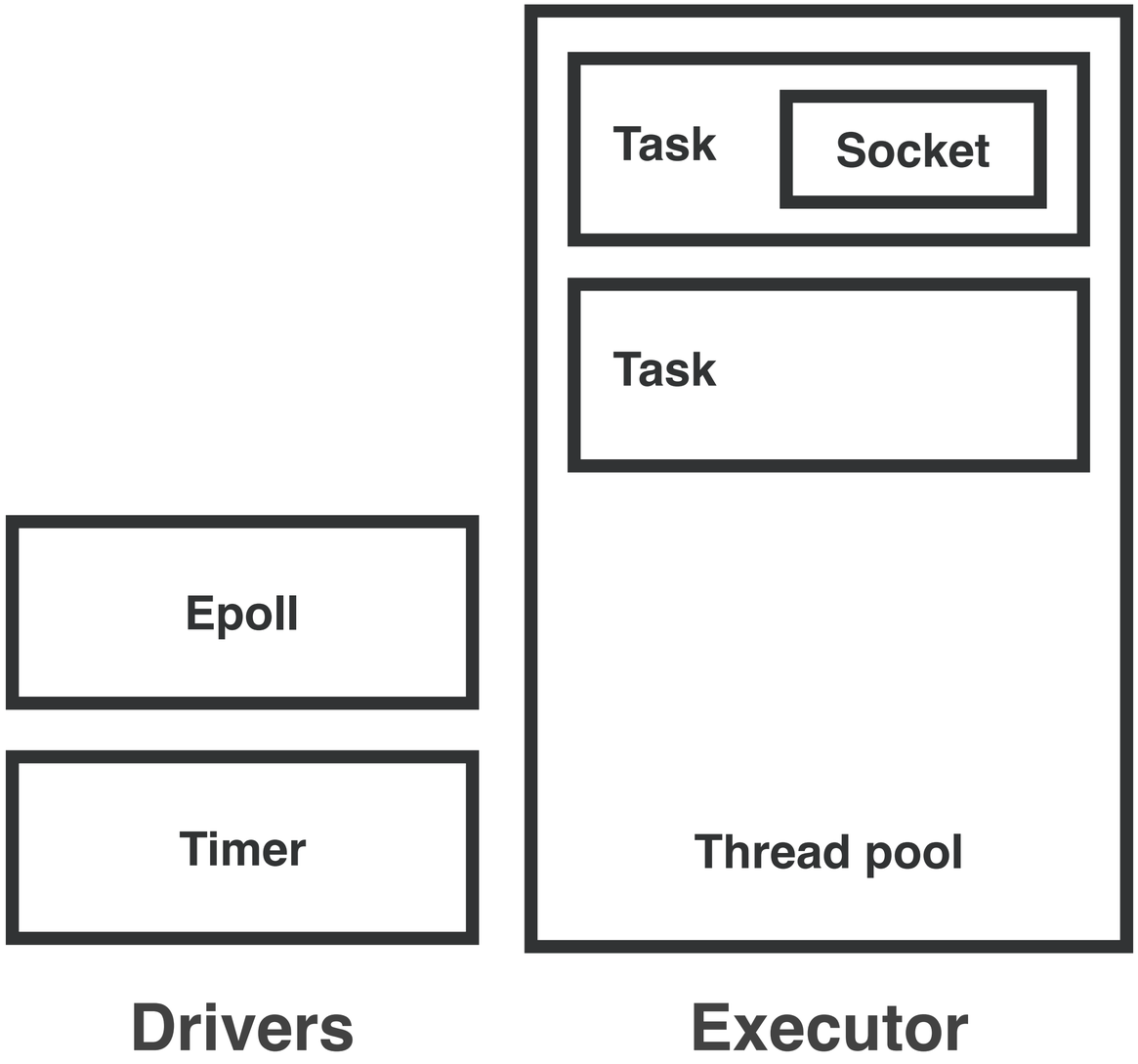
1. Connect a socket
2. Send handshake message
3. Receive handshake message
4. Send request
5. Receive request

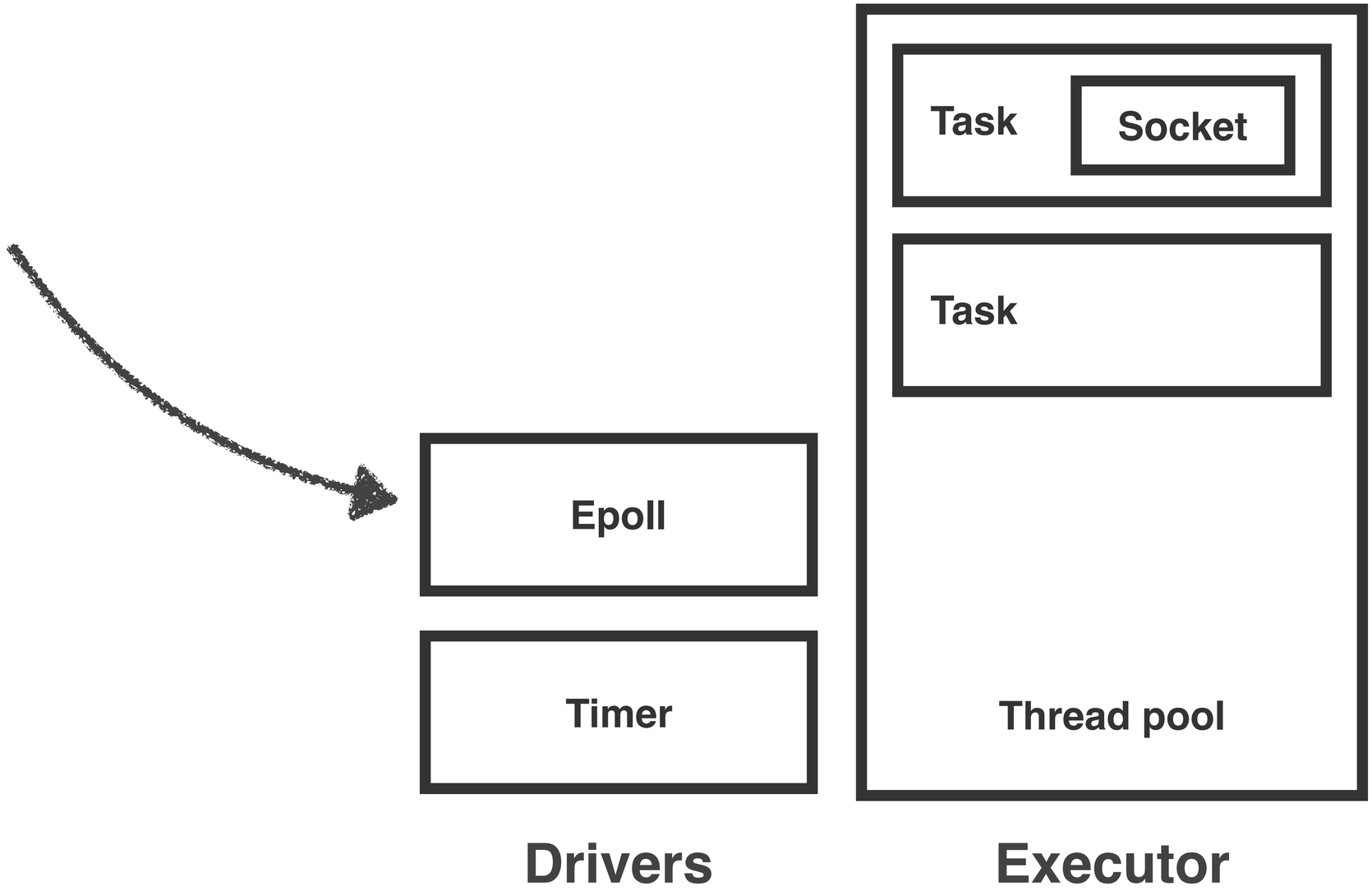
```
TcpStream::connect(&remote_addr)
  .then(|sock| io::write(sock, handshake))
  .then(|sock| io::read_exact(sock, 10))
  .then(|(sock, handshake)| {
    validate(handshake);
    io::write(sock, request)
  })
  .then(|sock| io::read_exact(sock, 10))
  .then(|(sock, response)| {
    process(response)
  })
```

1. Connect a socket
2. Send handshake message
3. Receive handshake message
4. Send request
5. Receive request

```
enum SocketState {
    Connecting,
    SendingHandshake,
    ReceivingHandshake,
    SendingRequest,
    ReceivingResponse,
}
```

```
tokio::spawn(task)
```


Task
Socket
Task
Epoll
Timer
Thread pool
Drivers
Executor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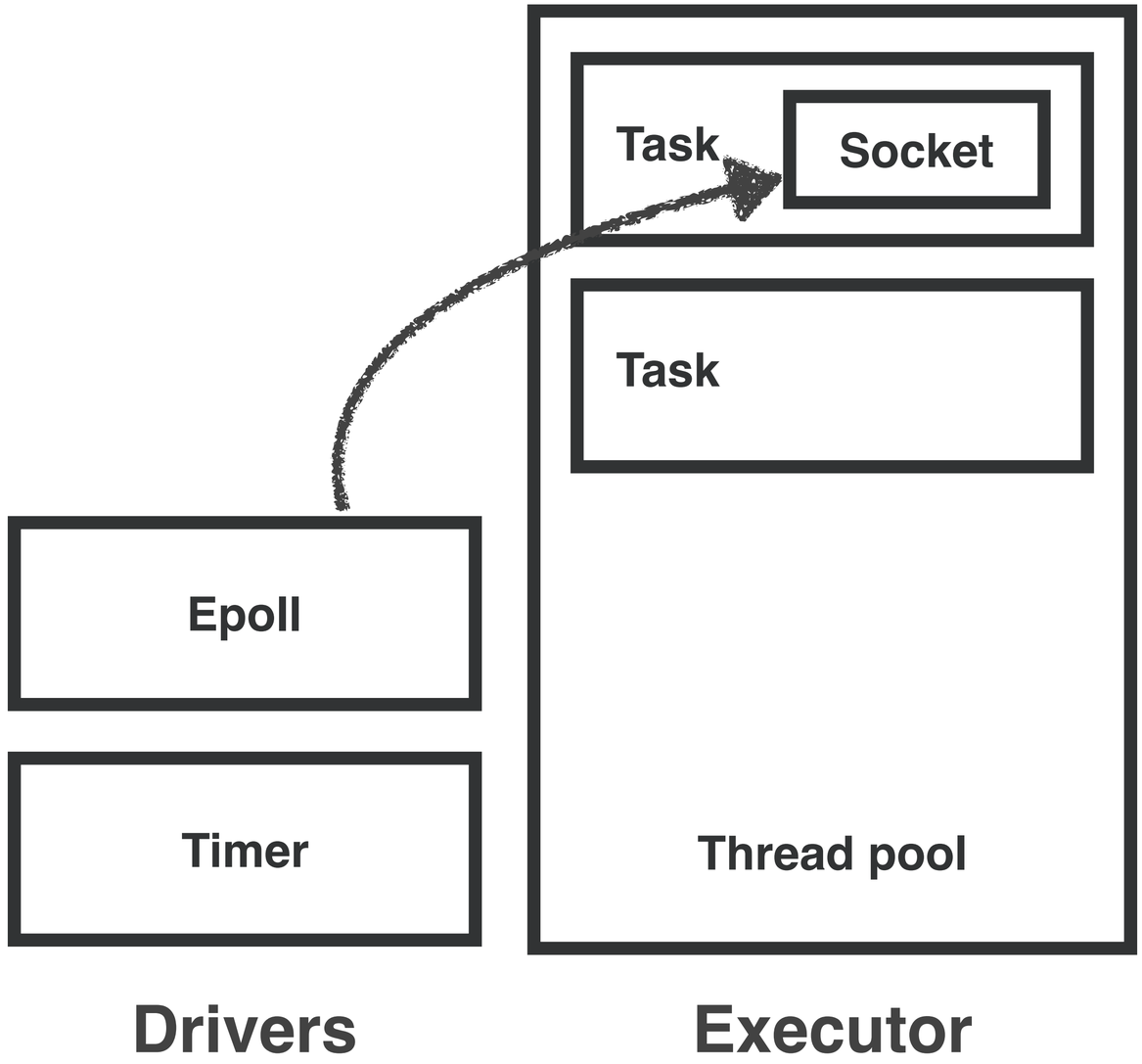
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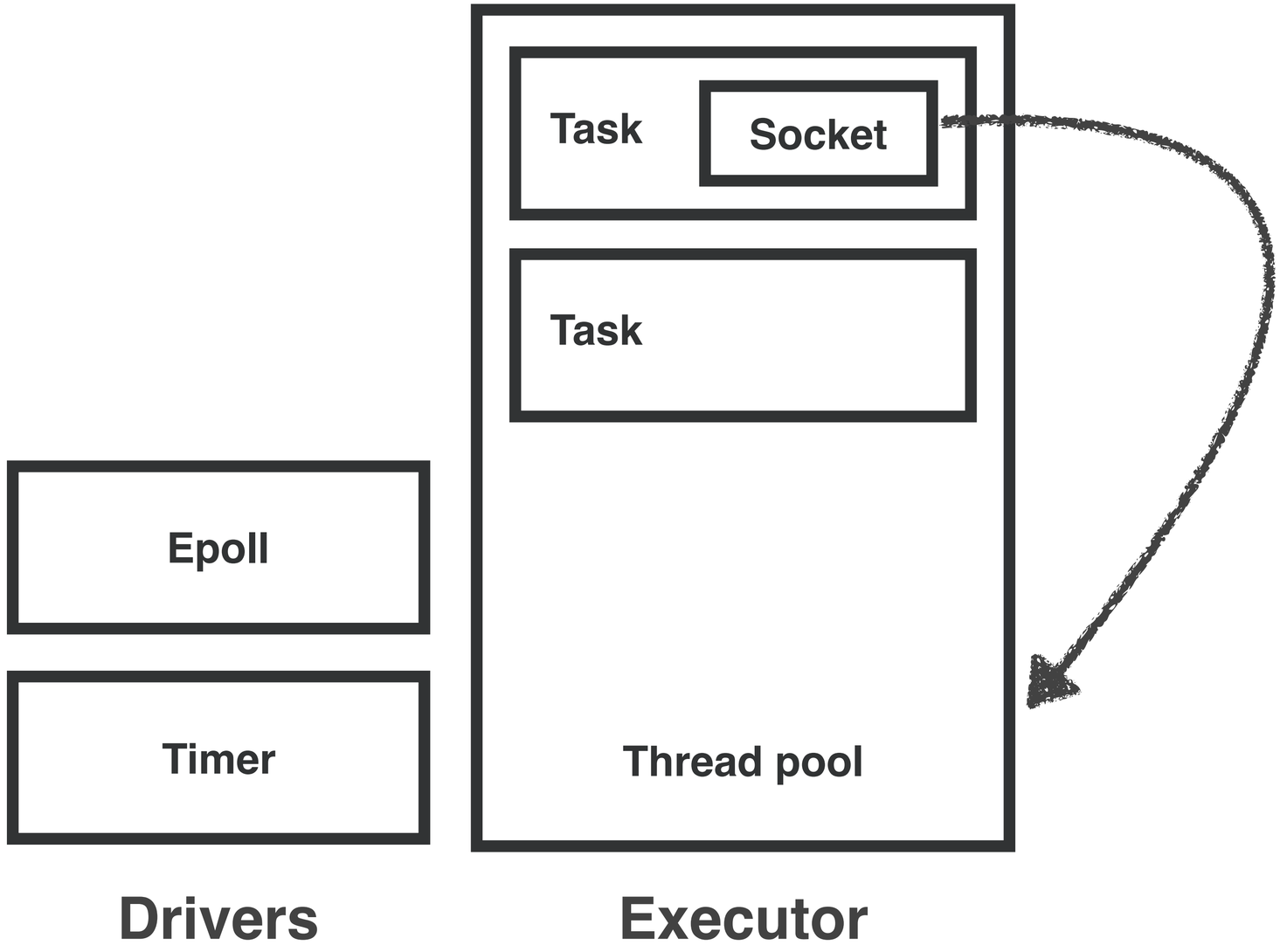
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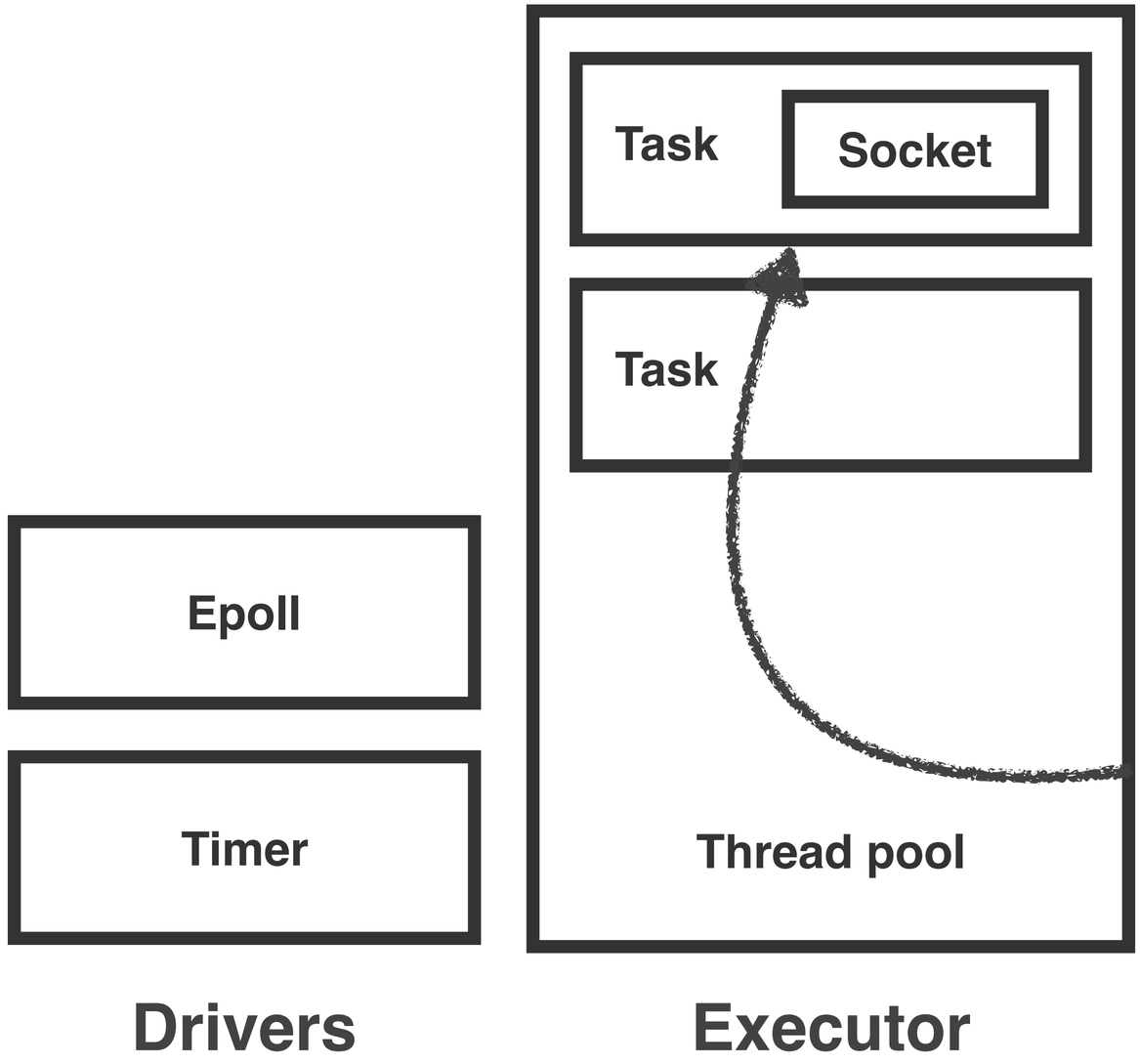
Task
Socket
Task
Epoll
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Executor

```
task::current() -> Task

Task::notify()
```

Have your 🍰 and 🍽️ it too.

Tokio + Rust gets you **speed** and **safety**.

Thanks

https://tokio.rs

https://conduit.io