Eio 1.0 – Effects-based IO for OCaml 5

Thomas Leonard Patrick Ferris Christiano Haesbaert
Lucas Pluvinage Vesa Karvonen Sudha Parimala KC
Sivaramakrishnan Vincent Balat Anil Madhavapeddy

Tarides

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Overview

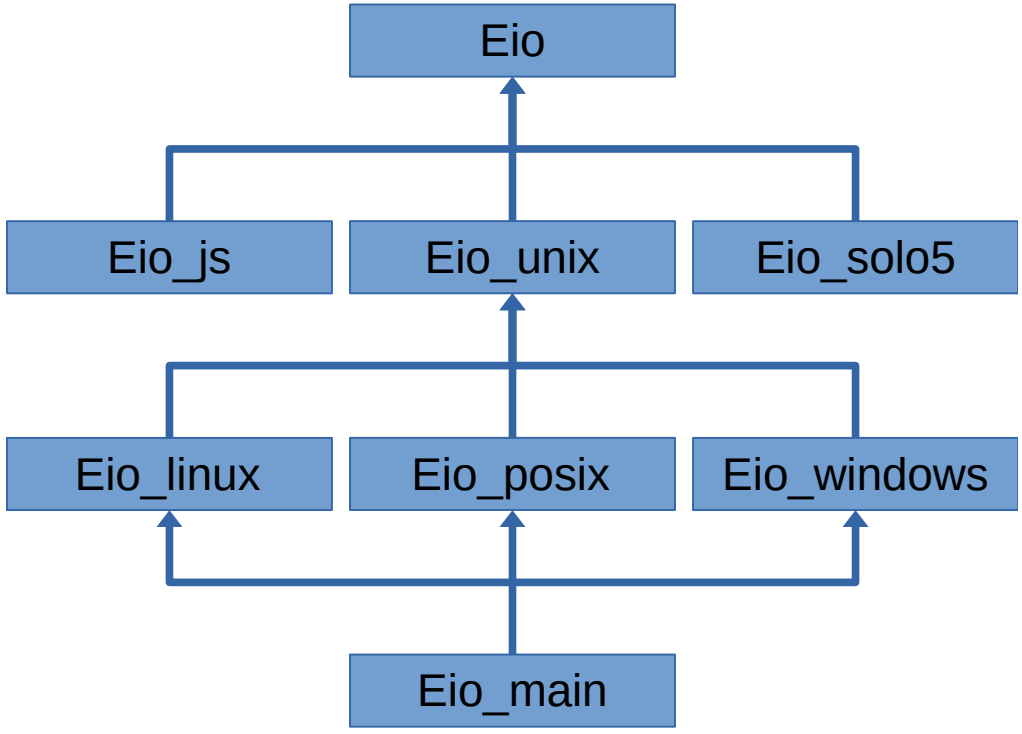
- Motivation and design
- Interoperability (Lwt, Async, Kcas, Domainslib)
- Comparison with Lwt
- Experiences porting software

Motivation

- Support effects
  - No special monad syntax
  - Can use `try`, `match`, `while`, etc
  - No separate Lwt or Async versions of code
  - No heap allocations needed to simulate a stack
  - A real stack means backtraces and profiling tools work
- Support multiple cores
- Fix some annoyances with Lwt

Eio packages

- Eio defines:
  - 3 effects (`Suspend`, `Fork`, `Get_context`)
  - Generic cross-platform APIs
- Backends for various platforms
- `eio_main` chooses the best backend



Performance : single core

Eio (0.38 s):

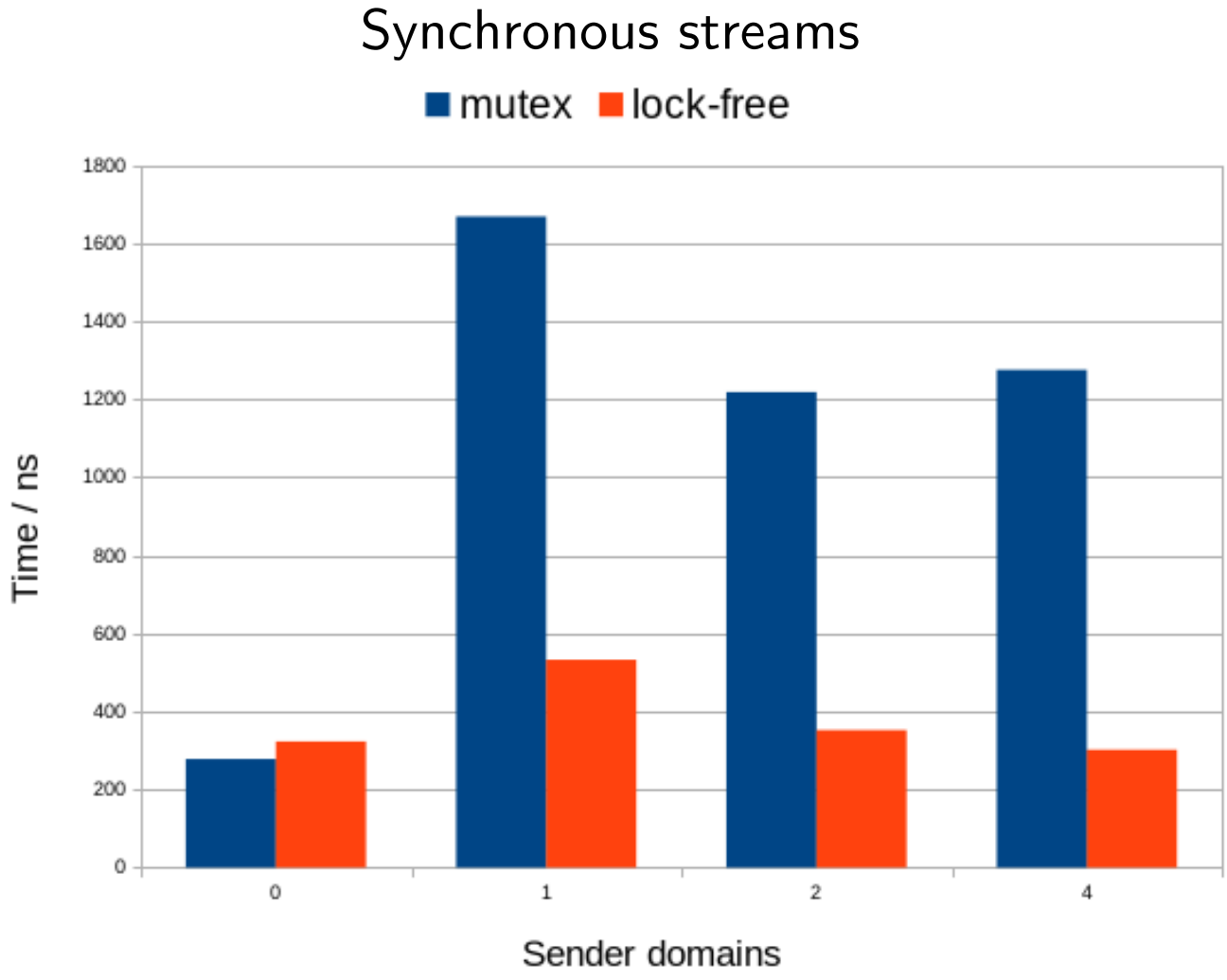
```
let parse r =
  for _ = 1 to n_bytes do
    let r = Eio.Buf_read.any_char r in
    ignore (r : char)
  done
```

Lwt (1.49 s):

```
let parse r =
  let rec aux = function
    | 0 → Lwt.return_unit
    | i →
      let* r = Lwt_io.read_char r in
      ignore (r : char);
      aux (i - 1)
  in
  aux n_bytes
```

Performance : multi-core

- Many data-structures are now lock-free
- Better performance with multiple domains



Interoperability : Lwt

To run Lwt programs under Eio, replace `Lwt_main.run` with:

```
Eio_main.run @@ fun env →
Lwt_eio.with_event_loop ~clock:env#clock @@ fun _ →
Lwt_eio.run_lwt @@ fun () →
...
```

`run_lwt` and `run_eio` switch between Lwt and Eio code:

```
val run_lwt : (unit → 'a Lwt.t) → 'a
val run_eio : (unit → 'a) → 'a Lwt.t
```

https://github.com/ocaml-multicore/lwt_eio

Interoperability : Async

`Async_eio` does the same for async:

```
val run_eio :
  (unit → 'a) → 'a Async_kernel.Deferred.t

val run_async :
  (unit → 'a Async_kernel.Deferred.t) → 'a
```

https://github.com/talex5/async_eio

Interoperability : Async, Eio and Lwt

You can even use all three libraries together in a single domain!

```
Eio_main.run @@ fun env →
Lwt_eio.with_event_loop ~clock:env#clock @@ fun _ →
Async_eio.with_event_loop @@ fun _ →
...
```

https://github.com/talex5/async-eio-lwt-chimera

Interoperability : Domainslib and Kcas

Eio, Domainslib and Kcas all use `domain-local-await`, allowing e.g. Domainslib to add items to a Kcas queue, which is being read from an Eio doman.

Resource leaks

- Resources are attached to switches
- When the switch finishes, the resource is freed

Eio:

```
let accept socket =
  Switch.run @@ fun sw →
  let conn, _addr = Eio.Net.accept ~sw socket in
  ...
  Eio.Net.close conn      (* Optional *)
```

Lwt (leaks conn if cancelled):

```
let accept socket =
  let* conn, _addr = Lwt_unix.accept socket in
  ...
  Lwt_unix.close conn
```

Bounds on behaviour : Lwt

```
let () =
  Lwt_main.run (main ())
```

- What does this program do?
- What firewall rules should we set?
- Global state is hard to reason about

Bounds on behaviour : Eio

```
let () =
  Eio_main.run @@ fun env →
  Switch.run @@ fun sw →
  let addr = `Tcp (Eio.Net.Ipaddr.V4.any, 8080) in
  let socket =
    Eio.Net.listen ~sw env#net addr
      ~backlog:5
      ~reuse_addr:true
  in
  let dir = Eio.Path.open_dir ~sw (env#fs / "/srv/htdocs") in
  main ~socket dir
```

- Listens on port 8080 (no other network use)
- Uses `/srv/htdocs` (no other file-system use)

https://roscidus.com/blog/blog/2023/04/26/lambda-capabilities/

Experiences porting software

- Solver service (cache-dir bug)
- Wayland proxy
- Libraries: ocaml-tls, cohttp, dream, capnp-rpc, ...

https://github.com/ocaml-multicore/awesome-multicore-ocaml

Future

Eio 1.0:

- Finish file-system APIs
- OCaml 5.1 events

Get involved:

- Chat on `#eio` (https://matrix.to/#/#eio:roscidus.com)
- Developer video call every two weeks

https://github.com/ocaml-multicore/eio

Questions

perf : test code

Eio

```
let run_task1 () =
  for _ = 1 to 2000 do
    do_work ()
  done

let run_task2 () =
  for _ = 1 to 2000 do
    do_work ()
  done

let run () =
  Fiber.both run_task1 run_task2
```

Lwt

```
let run_task1 () =
  let rec outer = function
    | 0 → Lwt.return_unit
    | i →
      let* () = do_work () in
      outer (i - 1)
  in
  outer 2000

let run_task2 () = ...

let run () =
  Lwt.join [
    run_task1 ();
    run_task2 ();
  ]
```

perf : results

perf shows task1 vs task2 for Eio part:

```
- 49.94% Lwt_main.run_495
   - Lwt_main.run_loop_435
      - 49.83% Lwt_sequence.loop_346
         - Lwt.callback_1373
            - 49.77% Dune.exe.Perf.fun_967
               + 49.77% Dune.exe.Perf.use_cpu_273
- 49.90% Eio_linux.Sched.with_sched_inner_3088
   - 49.89% Eio_linux.Sched.with_eventfd_1738
      - Stdlib.Fun.protect_320
         - 49.86% caml_runstack
            - Eio.core.Fiber.fun_1369
               - 25.07% Dune.exe.Perf.run_task2_425
                  + Dune.exe.Perf.use_cpu_273
               - 24.78% Dune.exe.Perf.run_task1_421
                  + 24.77% Dune.exe.Perf.use_cpu_273
```

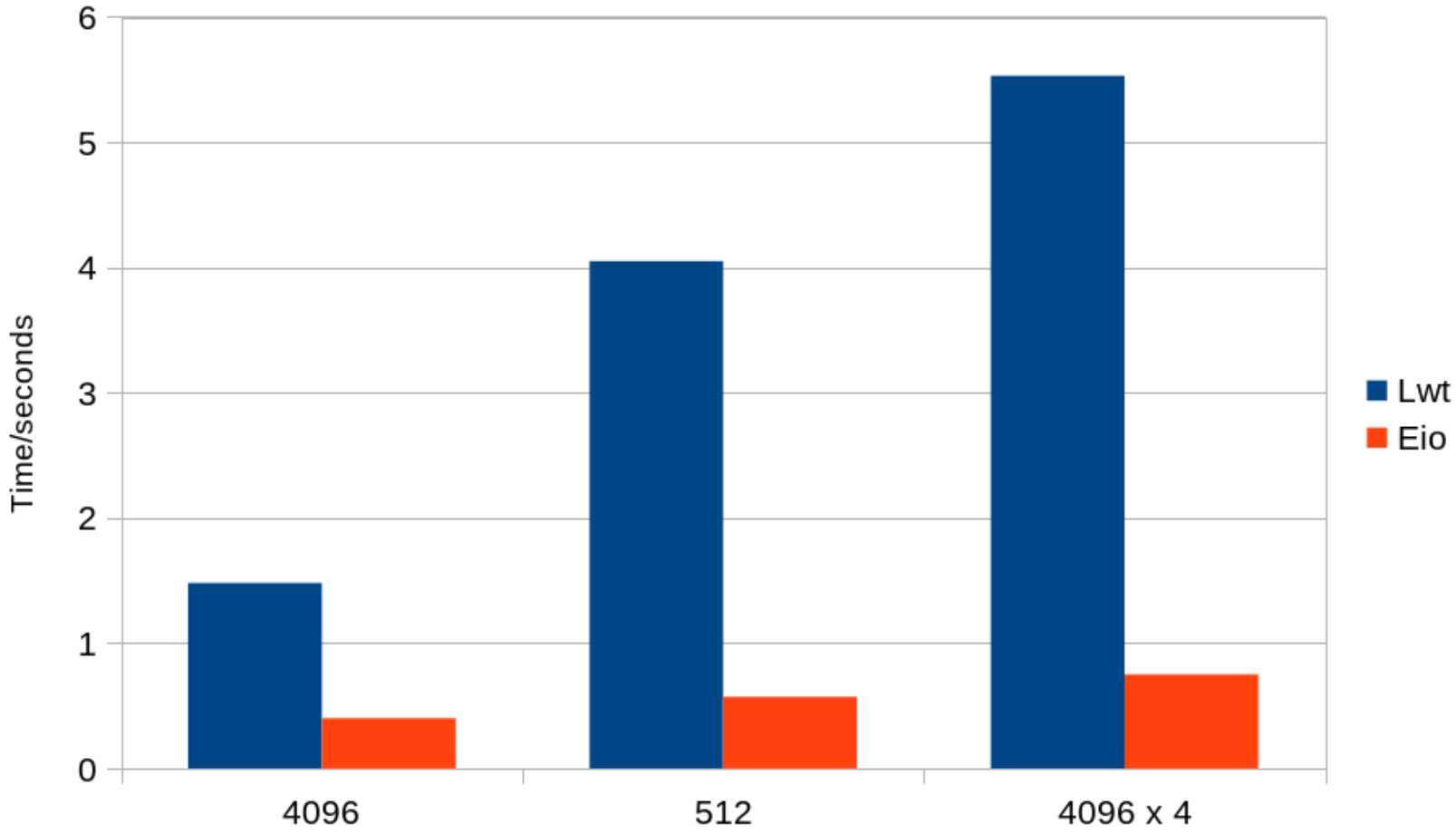
Error reporting

- Eio takes care to preserve stack-traces
- `Lwt.join` waits for all threads before reporting errors; errors may never be seen
- `Eio.Fiber.both` cancels the other fiber

```
Fiber.both
  (fun () →
     for x = 1 to 1000 do
       traceln "x = %d" x;
       Fiber.yield ()
     done
  )
  (fun () → failwith "Simulated error")

+x = 1
Exception: Failure "Simulated error"
```

Parsing benchmark



Parsing 100,000,000 bytes, one at a time:

- With a 4096-byte buffer (3.7x faster)
- With a 512-byte buffer (7.1x faster)
- With four runs in parallel (7.4x faster)