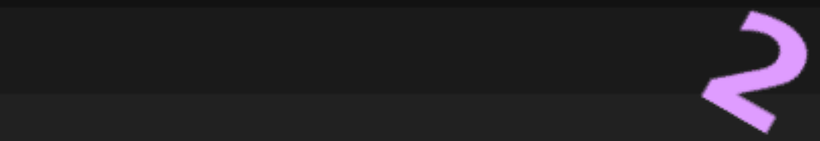
Reactor Pattern
&
Event-Driven Programming

A scalable concurrent approach,
using EventMachine with Thin as an example

Lin Jen-Shin, http://godfat.org/

Reactor Pattern
&
Event-Driven Programming



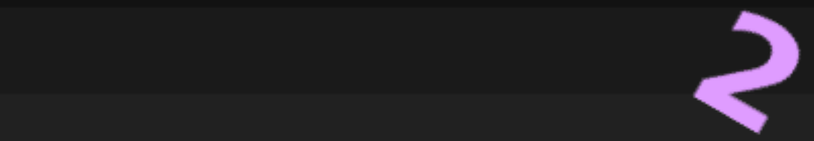
A scalable concurrent approach,
using EventMachine with Thin as an example

Lin Jen-Shin, http://godfat.org/

Reactor Pattern

&

Event-Driven Programming



http://godfat.org/slide/2010-04-13-reactor-pattern-and-2.pdf

Lin Jen-Shin, http://godfat.org/

Table of Contents

- concurrency, why and how in network
- Event-Driven Programming explained in Flash with Ruby syntax
- Reactor Pattern in EventMachine with Thin
- how Thin works
- how EventMachine works

Event-Driven Programming

```
loop{
  # you control the flow
  do_something
}
```

```
register method(:do_something)
loop{
  # event loop control the flow,
  # later it calls your callback
  event = pop_event_queue
  dispatch event if event
}
```

Reactor Pattern

```
loop{
  data = read
  handle data
}
```

```
register method(:handle)
loop{
  data = partial_read
  event = process data
  dispatch event if event
}
```

Table of Contents

- how Thin works
- how EventMachine works

Table of Contents

- how Thin works
- how EventMachine works

Table of Contents

- how Thin works
- how EventMachine works
- how AMQP works

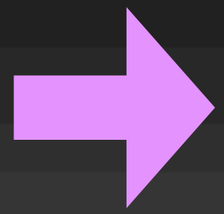
Table of Contents

- how Thin works
- how EventMachine works
- how AMQP works
- how Unicorn and Rainbows! works

Reactor Pattern

Reactor Pattern

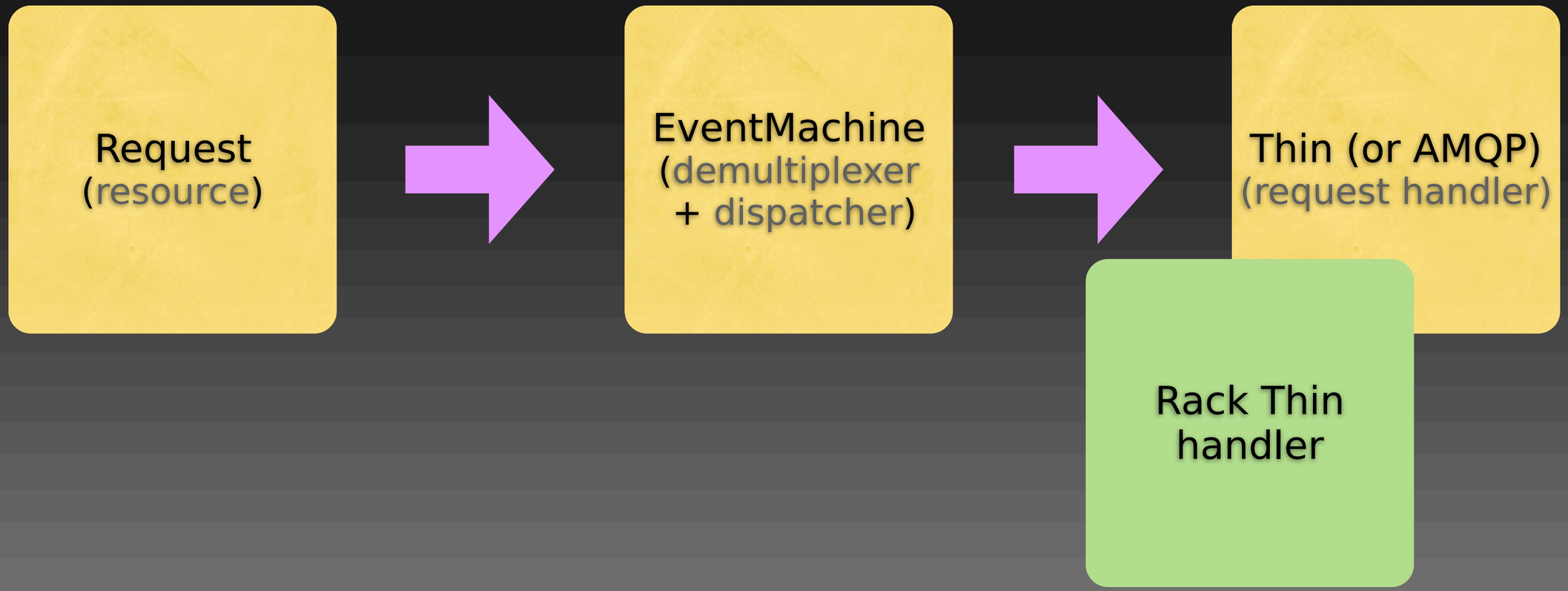
Request
(resource)



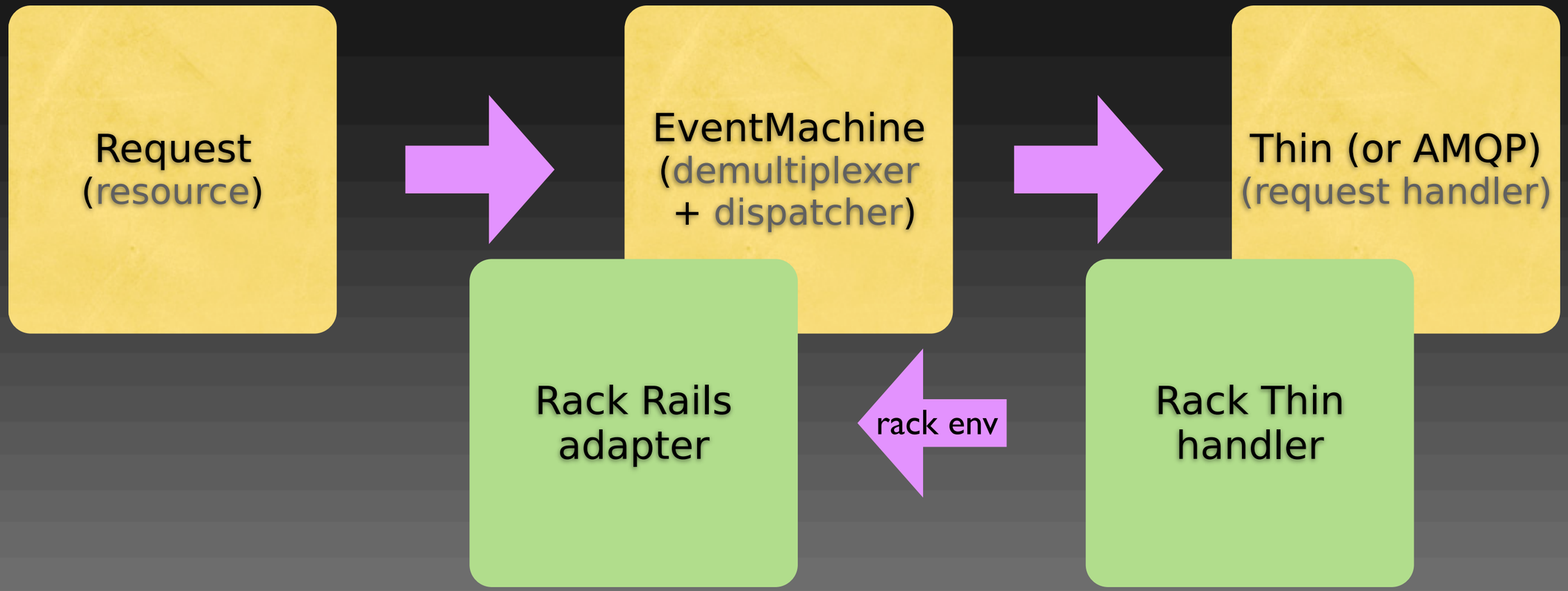
EventMachine
(demultiplexer
+ dispatcher)

Reactor Pattern

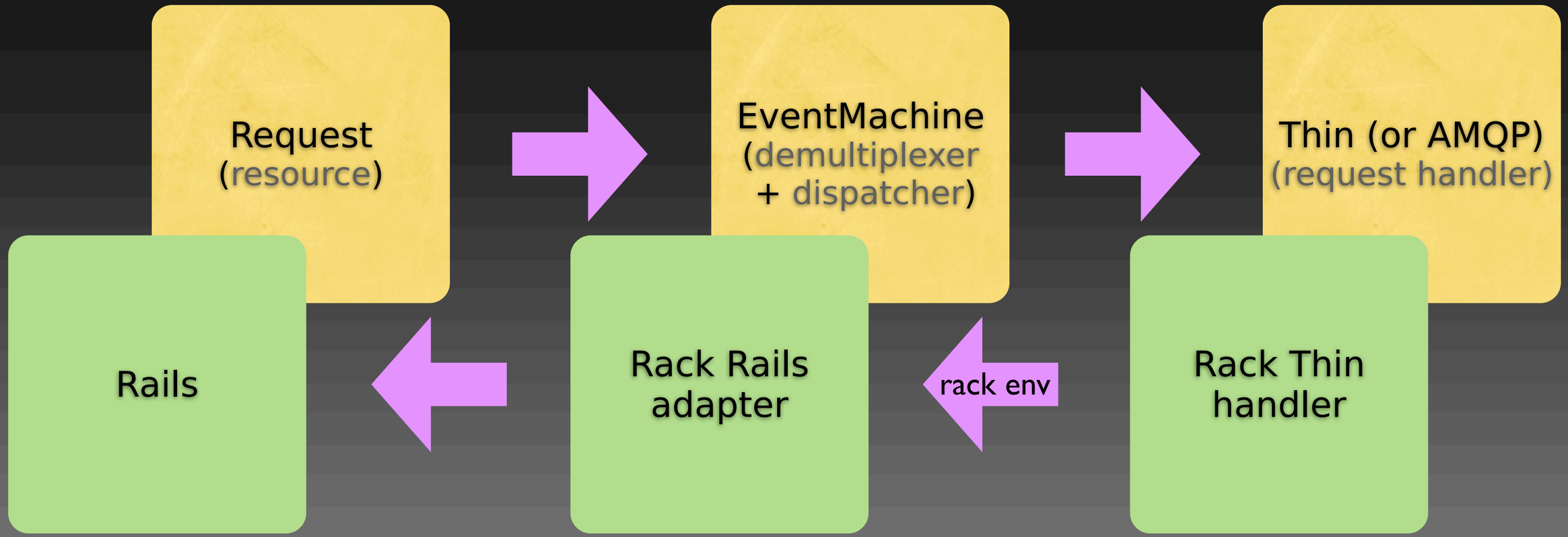
Reactor Pattern



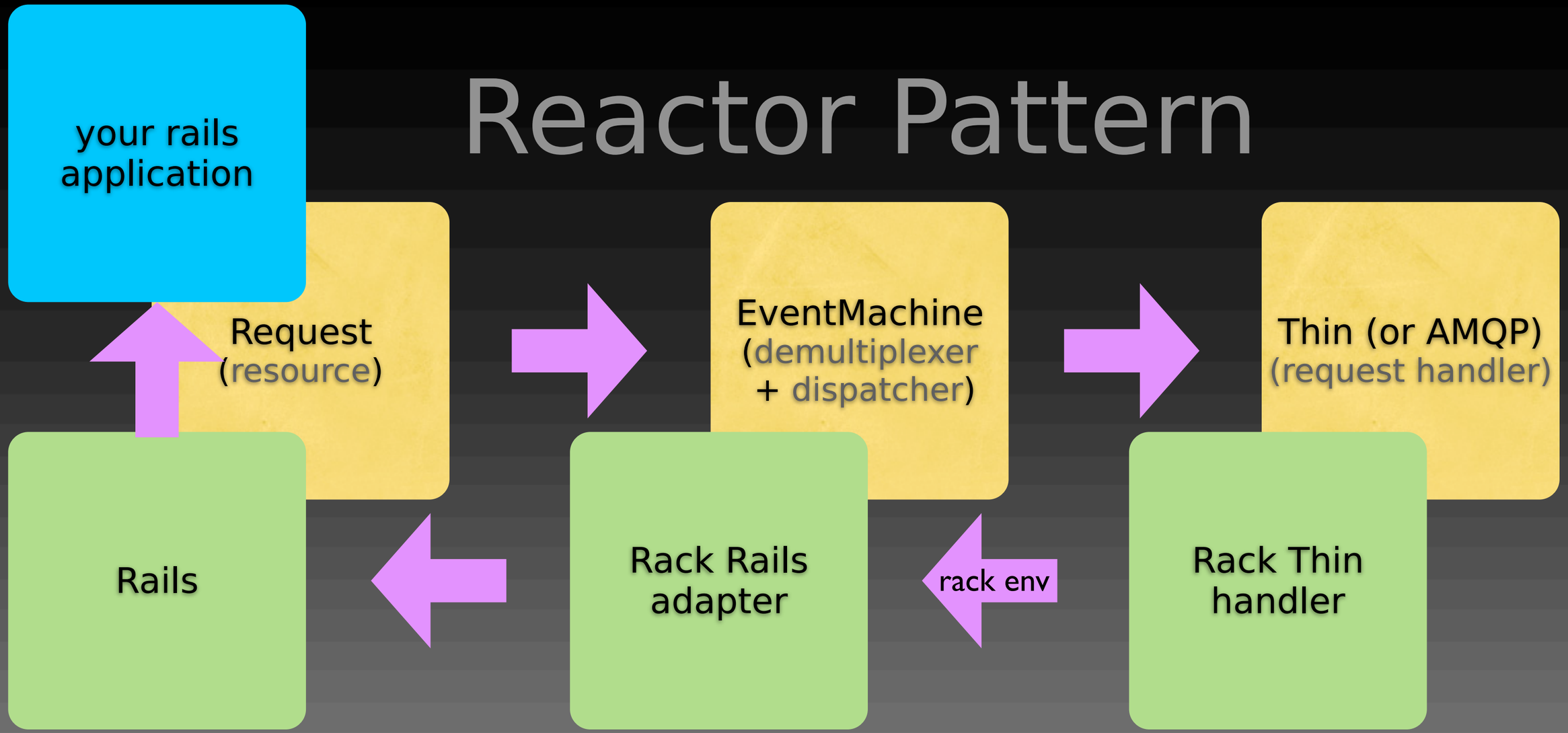
Reactor Pattern



Reactor Pattern



Reactor Pattern



how Thin works

how Thin works

- `Thin::Server`

how Thin works

- `Thin::Server`
- `Thin::Backends::TcpServer`
  `# communicate with EventMachine`

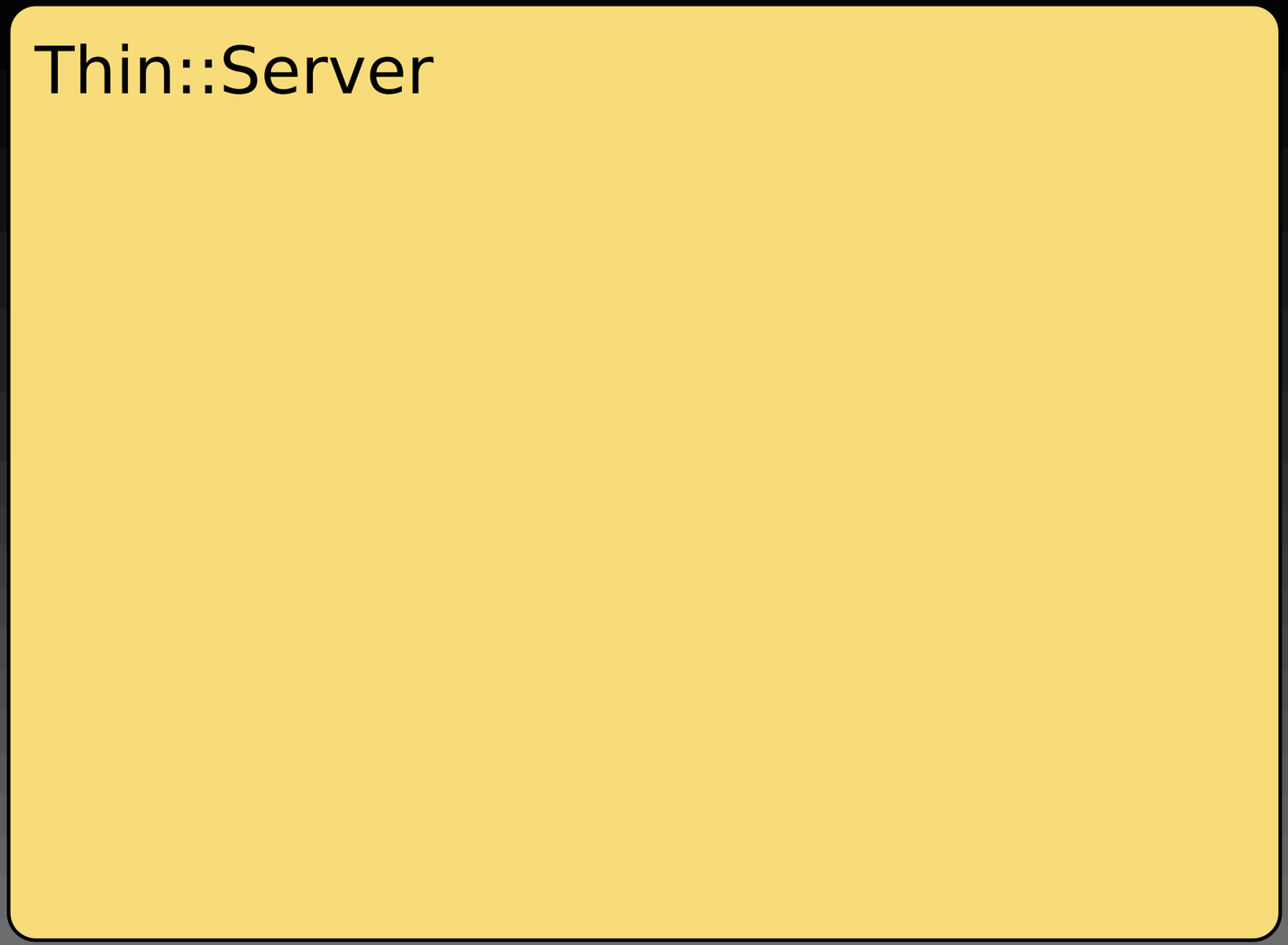
how Thin works

- `Thin::Server`
- `Thin::Backends::TcpServer`
  `# communicate with EventMachine`
- `Thin::Connection`
  `# EventMachine event handler`

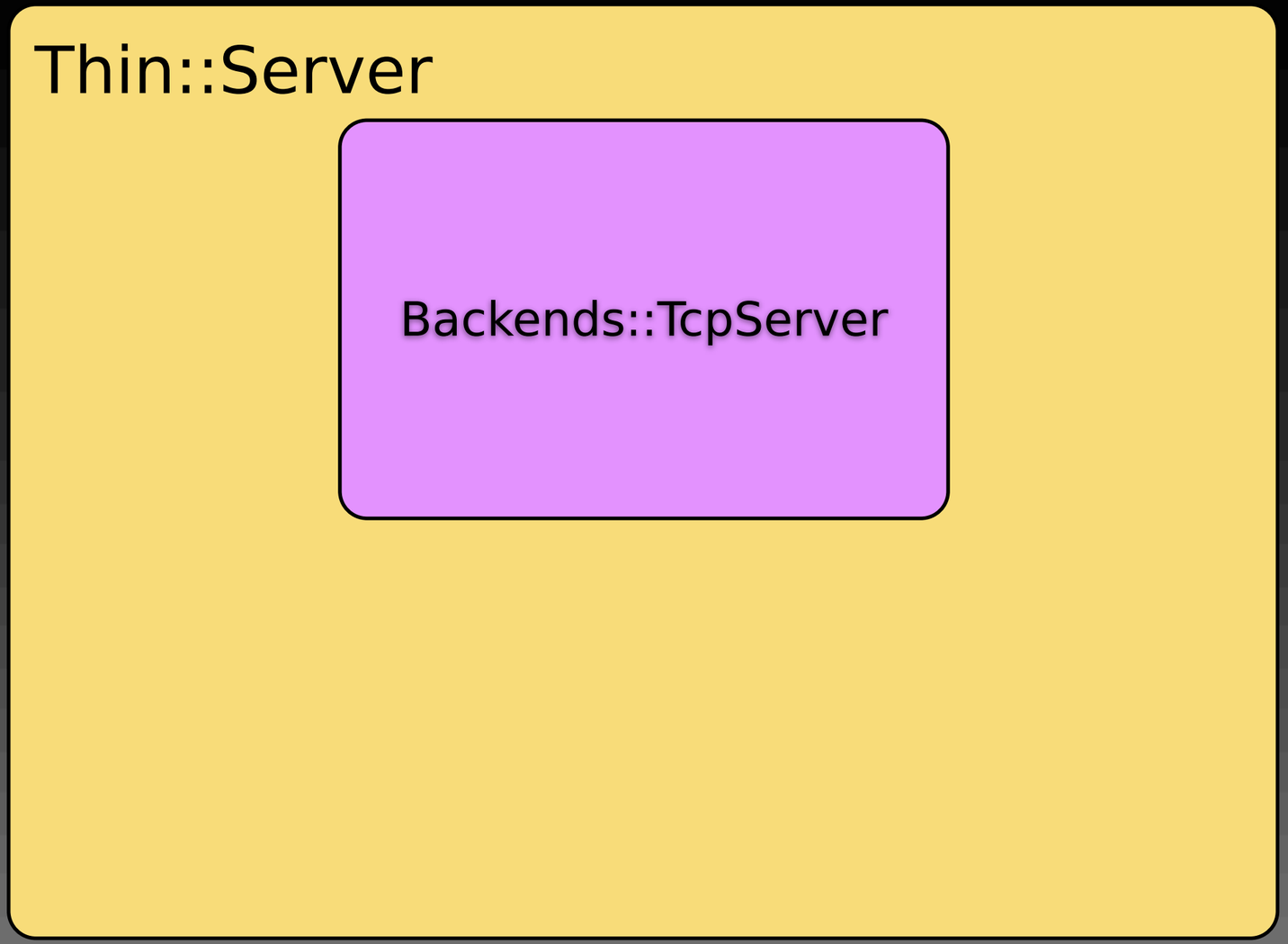
how Thin works

- `Thin::Server`
- `Thin::Backends::TcpServer`
  `# communicate with EventMachine`
- `Thin::Connection`
  `# EventMachine event handler`
- `Thin::Request`
  `# partial HTTP request parsing`
  `# Rack env builder`

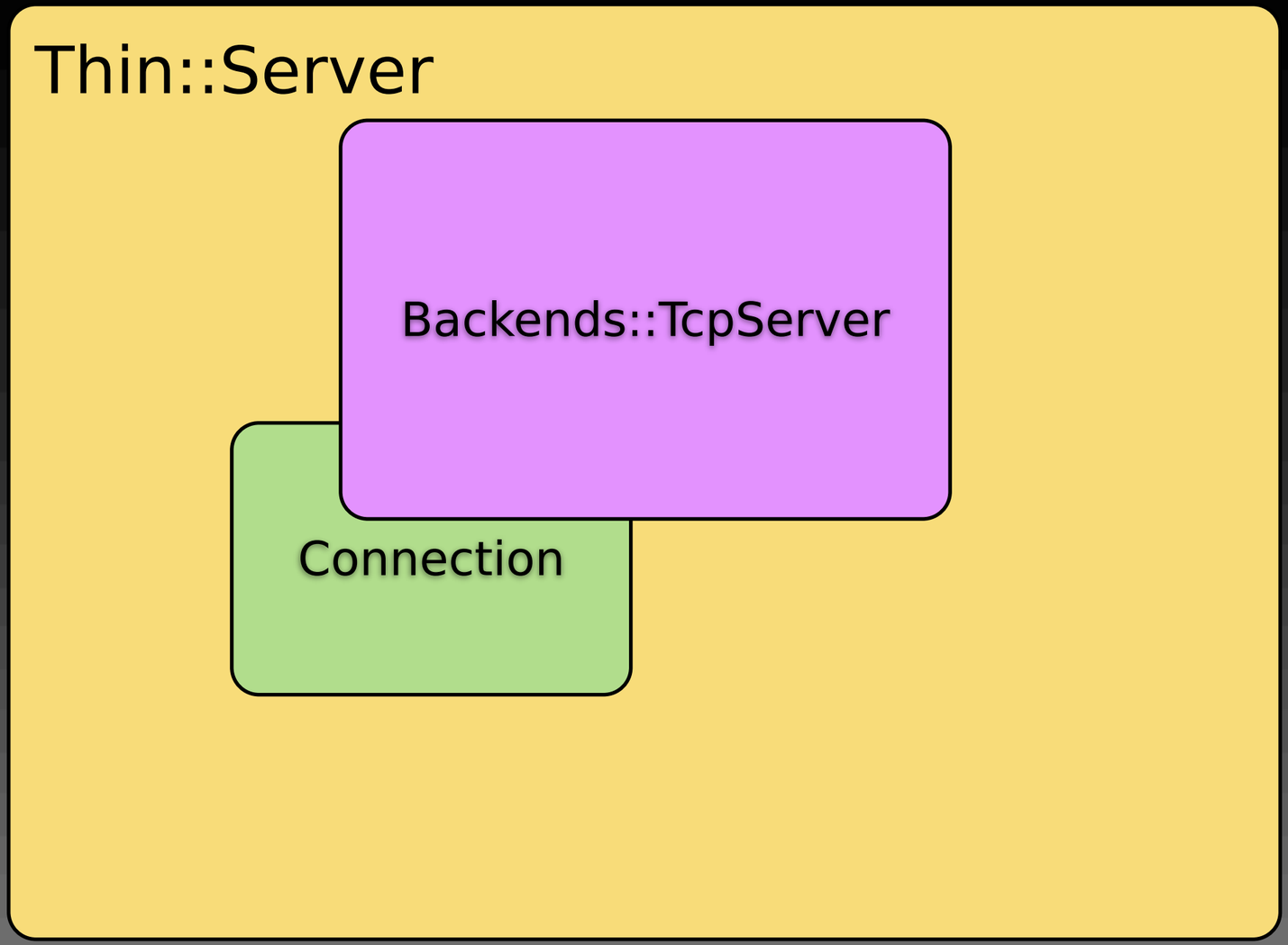
how Thin works



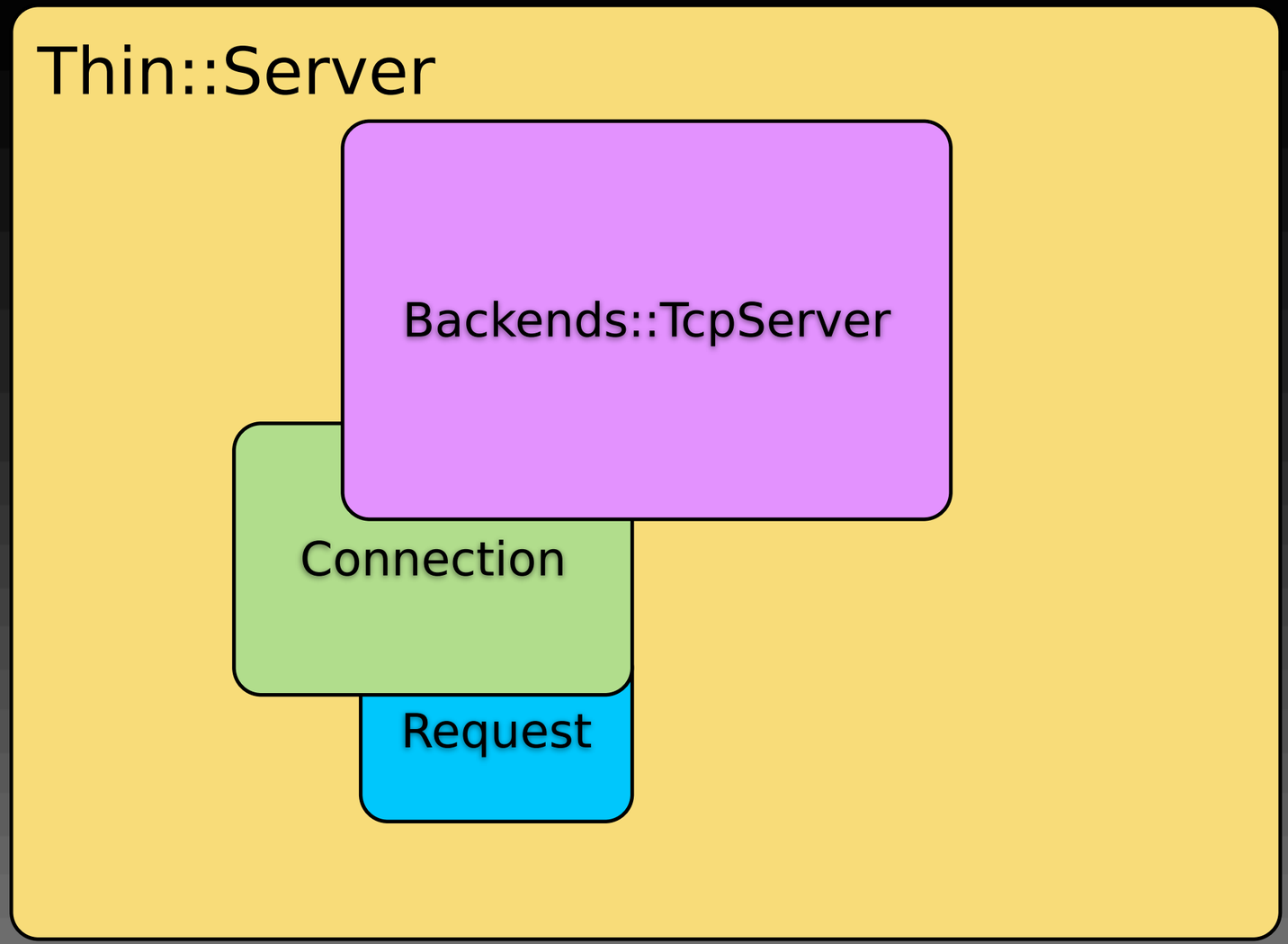
how Thin works



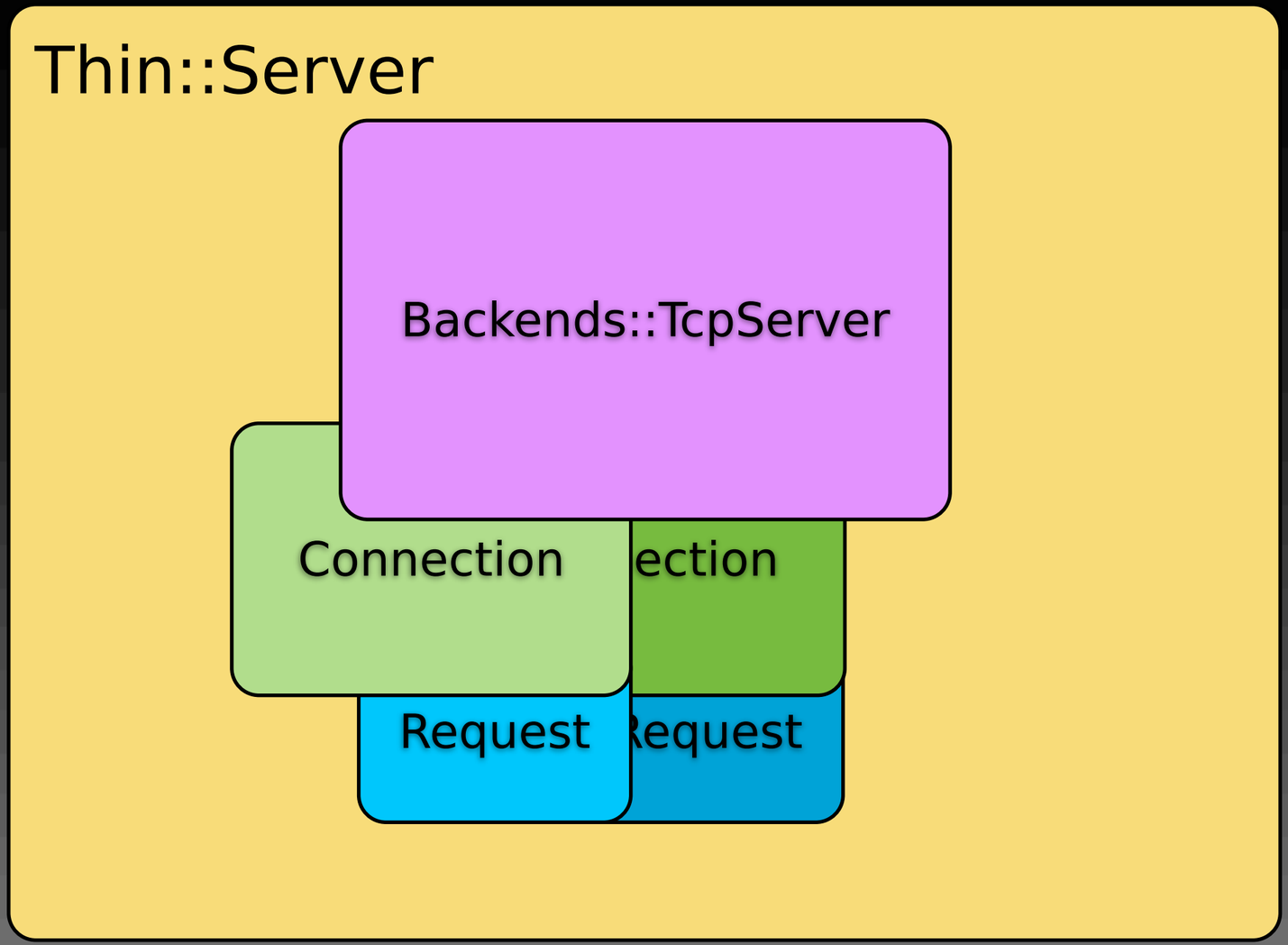
how Thin works



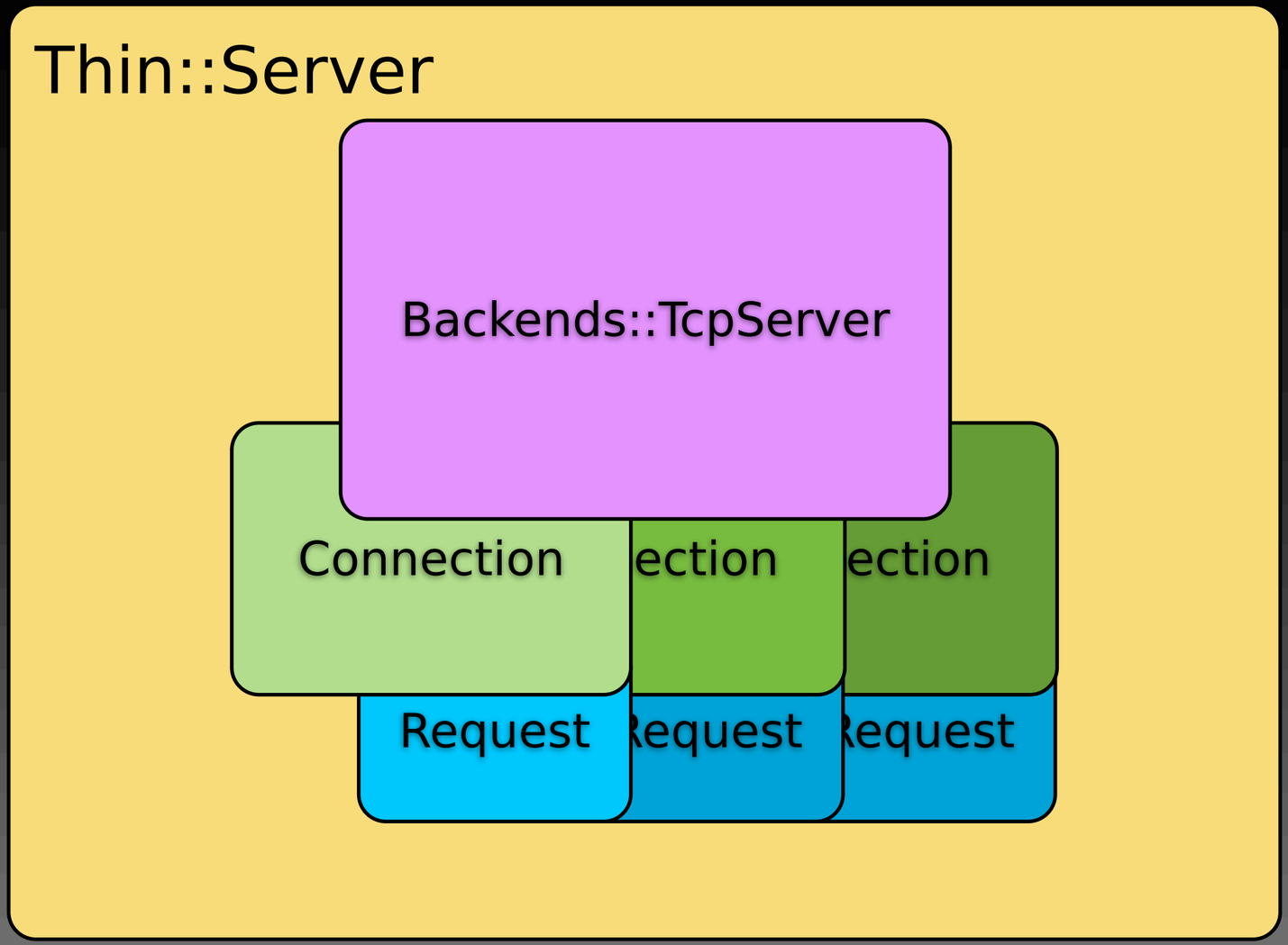
how Thin works



how Thin works



how Thin works



how Thin works

thin 1.2.7 codename No Hup

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/backends/tcp_server.rb:16
# in Thin::TcpServer#connect

   EventMachine.start_server(
     @host, @port,
     Thin::Connection,
     &method(:initialize_connection))

                # rack app, backend ref, timeout, etc
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/connection.rb:42
# in Thin::Connection#receive_data


    process if @request.parse(data)


                #  true: parsed, so process!
                # false:  we need more data!
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/request.rb:82
# in Thin::Request#parse


@request = @parser.execute(@env, @data, @nparsed)


#     @env: Rack env
#    @data: HTTP header buffer
# @nparsed: index of parsed data
```

how Thin works

thin 1.2.7 codename No Hup

```
// in ext/thin_parser/thin.c:335
// in thin.c#Thin_HttpParser_execute


thin_http_parser_execute(http, dptr, dlen, from);


                  // http: HTTP parser pointer
                  // dptr: HTTP header data pointer
                  // dlen: HTTP header data length
                  // form: previous @nparsed
```

how Thin works

thin 1.2.7 codename No Hup

```
// in ext/thin_parser/parser.rl:102
// in parser.rl#thin_http_parser_execute
// (it's mongrel's http parser)

size_t thin_http_parser_execute(
  http_parser *parser, const char *buffer,
  size_t len, size_t off)
```

how Thin works

thin 1.2.7 codename No Hup

Ragel is a finite state machine compiler with output support for C, C++, Objective-C, D, Java and Ruby source code.

how Thin works

thin 1.2.7 codename No Hup

Ragel is a finite state machine compiler with output support for C, C++, Objective-C, D, Java and Ruby source code.

- Mongrel HTTP parser
- Hpricot HTML/XML parser
- JSON parser

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/connection.rb:42
# in Thin::Connection#receive_data


    process if @request.parse(data)


                #  true: parsed, so process!
                # false:  we need more data!
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/connection.rb:52
# in Thin::Connection#process

if threaded?
  @request.threaded = true
  EventMachine.defer(method( :pre_process),
                     method(:post_process))
else
  @request.threaded = false
  post_process(pre_process)
end
```

how EventMachine works

eventmachine 0.12.10

```
# in lib/eventmachine.rb:1045
# in EventMachine.defer

    unless @threadpool
      require 'thread'
      @threadpool  = []
      @threadqueue = ::Queue.new
      @resultqueue = ::Queue.new
      spawn_threadpool
    end
    @threadqueue << [op||blk,callback]
```

how Thin works

thin 1.2.7 codename No Hup

```
      # in lib/thin/connection.rb:68
      # in Thin::Connection#pre_process
@request.async_callback = method(:post_process)
# ...
response = AsyncResponse
catch(:async) do
  # Process the request calling the Rack adapter
  response = @app.call(@request.env)
end
response
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/connection.rb:95
# in Thin::Connection#post_process
        @response.status,
        @response.headers,
        @response.body = *result
        # ...
        @response.each do |chunk|
          trace { chunk }
          send_data chunk
        end
```

Reactor Pattern

- resources
- synchronous event demultiplexer
- dispatcher
- request handler (Thin::Connection)

by wikipedia

Table of Contents

- how Thin works
- how EventMachine works
- how AMQP works
- how Unicorn and Rainbows! works

how EventMachine works

eventmachine 0.12.10

how EventMachine works

eventmachine 0.12.10

```
# in lib/eventmachine.rb:571
# in EventMachine.start_server
  s = if port
        start_tcp_server server, port
      else
        start_unix_server server
      end
  @acceptors[s] = [klass,args,block]
```

```
#      s: server (in Reactor) uuid
# klass: Thin::Connection
#  args: []
# block: method(:initialize_connection)
```

how EventMachine works

eventmachine 0.12.10

```
# in lib/eventmachine.rb:50

  case $eventmachine_library
    when :pure_ruby
      require 'pr_eventmachine'
    when :extension
      require 'rubyeventmachine'
    when :java
      require 'jeventmachine'
```

how EventMachine works

eventmachine 0.12.10

```
# in lib/pr_eventmachine.rb:318
# in EventMachine.run
  loop {
    @current_loop_time = Time.now
    break if @stop_scheduled
    run_timers # timer event
    break if @stop_scheduled
    # epoll, kqueue, etc
    crank_selectables
    break if @stop_scheduled
    # close scheduling if client timeout
    run_heartbeats
```

how EventMachine works

eventmachine 0.12.10

```
        # in lib/eventmachine.rb:1445
        # in EventMachine.event_callback

elsif opcode == ConnectionData
  c = @conns[conn_binding] or raise ConnectionNotBound,
    “received data #{data} for unknown signature:” \
    “#{conn_binding}”
  c.receive_data data
elsif opcode == LoopbreakSignalled

                    #       opcode: event enum (int)
                    # conn_binding: connection uuid
                    #         data: received data
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/connection.rb:42
# in Thin::Connection#receive_data


    process if @request.parse(data)


                #  true: parsed, so process!
                # false:  we need more data!
```

how EventMachine works

eventmachine 0.12.10

```
        # in lib/eventmachine.rb:1427
        # in EventMachine.event_callback
elsif opcode == ConnectionAccepted
  accep,args,blk = @acceptors[conn_binding]
  raise NoHandlerForAcceptedConnection unless accep
  c = accep.new data, *args
  @conns[data] = c
  blk and blk.call(c)
  c # (needed?)
elsif opcode == ConnectionCompleted
                    # conn_binding: server uuid
                    #         data: connection uuid
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/backends/tcp_server.rb:16
# in Thin::TcpServer#connect

   EventMachine.start_server(
     @host, @port,
     Thin::Connection,
     &method(:initialize_connection))

                # rack app, backend ref, timeout, etc
```

how EventMachine works

eventmachine 0.12.10

```
# in lib/pr_eventmachine.rb:256

module EventMachine
  TimerFired           = 100
  ConnectionData       = 101
  ConnectionUnbound    = 102
  ConnectionAccepted   = 103
  ConnectionCompleted  = 104
  LoopbreakSignalled   = 105
end
```

Table of Contents

- how Thin works
- how EventMachine works
- how AMQP works
- how Unicorn and Rainbows! works

how AMQP works

- `AMQP::BasicClient`
  `# extend to AMQP::Client`

how AMQP works

- `AMQP::BasicClient`
  `# extend to AMQP::Client`
- `AMQP::Client`
  `# included into EventMachine::Connection`

how AMQP works

amqp 0.6.7

how AMQP works

amqp 0.6.7

```
# in lib/amqp.rb:79
# in AMQP.start
    EM.run{
      @conn ||= connect *args
      @conn.callback(&blk) if blk
      @conn
    }
```

how AMQP works

amqp 0.6.7

```
# in lib/amqp.rb:18
# in AMQP.connect

        Client.connect *args
```

how AMQP works

amqp 0.6.7

```
      # in lib/amqp/client.rb:188
      # in AMQP::Client.connect

opts = AMQP.setting.merge(opts)
EM.connect opts[:host], opts[:port], self, opts
```

how Thin works

thin 1.2.7 codename No Hup

```
# in lib/thin/backends/tcp_server.rb:16
# in Thin::TcpServer#connect

   EventMachine.start_server(
     @host, @port,
     Thin::Connection,
     &method(:initialize_connection))

                # rack app, backend ref, timeout, etc
```

how EventMachine works

eventmachine 0.12.10

```
      # in lib/eventmachine.rb:1571
      # in EventMachine.klass_from_handler
klass = if handler and handler.is_a?(Class)
  raise ArgumentError,
    "must provide module or #{klass.name}" unless
    klass >= handler
  handler
elsif handler
  Class.new(klass){ include handle }
else
  klass
end
```

```
#   klass: EventMachine::Connection
# handler: Thin::Connection or AMQP::Client
```

how AMQP works

amqp 0.6.7

```
# in lib/amqp/client.rb:115
# in AMQP::Client#receive_data

    while frame = Frame.parse(@buf)
      log 'receive', frame
      process_frame frame
    end
```

how AMQP works

- `AMQP::Frame`
  `# basic building block of AMQP data stream`

how AMQP works

- AMQP::Frame
  # basic building block of AMQP data stream
- AMQP::Buffer
  # frame buffer and parser

how AMQP works

- AMQP::Frame
  # basic building block of AMQP data stream
- AMQP::Buffer
  # frame buffer and parser
- AMQP::Protocol::Connection
  # used in BasicClient#process_frame

how AMQP works

- MQ
  # easy to use, high level wrapper

how AMQP works

- MQ
  # easy to use, high level wrapper
- MQ::Queue
  # the entities which receive messages

how AMQP works

- MQ
  # easy to use, high level wrapper
- MQ::Queue
  # the entities which receive messages
- MQ::Exchange
  # the entities to which messages are sent

how AMQP works

- MQ
  # easy to use, high level wrapper
- MQ::Queue
  # the entities which receive messages
- MQ::Exchange
  # the entities to which messages are sent

by wikipedia

how AMQP works

```
# default connection
MQ.new.queue('name')

# default exchange (direct)
MQ.new.publish('name')

#-- convenience wrapper (read: HACK)
#   for thread-local MQ object
MQ.queue('name')
MQ.publish('name')
```

how AMQP works

```
MQ.queues     # all created queues
MQ.exchanges # all created exchanges
MQ.direct     #  direct exchange
MQ.fanout     #  fanout exchange
MQ.topic      #   topic exchange
MQ.headers    # headers exchange
```

Table of Contents

- how Thin works
- how EventMachine works
- how AMQP works
- how Unicorn and Rainbows! works

Unicorn?

Unicorn?

- is not event-driven!

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Unicorn?

Rainbows!?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- could be event-driven

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- could be event-driven
- also pure Ruby, except...

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- could be event-driven
- also pure Ruby, except...
- *any* concurrency model

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- could be event-driven
- also pure Ruby, except...
- *any* concurrency model
- provide network concurrency

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- Revactor

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- Revactor
- ThreadPool

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- Revactor
- ThreadPool
- Rev

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- Revactor
- ThreadPool
- Rev
- ThreadSpawn

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- Revactor
- ThreadPool
- Rev
- ThreadSpawn
- EventMachine

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- RevThreadSpawn
- Revactor
- ThreadPool
- Rev
- ThreadSpawn
- EventMachine

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- RevThreadSpawn
- Revactor
- FiberSpawn
- ThreadPool
- Rev
- ThreadSpawn
- EventMachine

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- RevThreadSpawn
- Revactor
- FiberSpawn
- ThreadPool
- FiberPool
- Rev
- ThreadSpawn
- EventMachine

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- RevThreadSpawn
- Revactor
- FiberSpawn
- ThreadPool
- FiberPool
- Rev
- NeverBlock
- ThreadSpawn
- EventMachine

Unicorn?

- is not event-driven!
- except Mongrel HTTP parser, all written in Ruby
- yet *super fast* for fast client
- preforking worker with blocking I/O

Rainbows!?

- RevFiberSpawn
- Revactor
- ThreadPool
- Rev
- ThreadSpawn
- EventMachine
- RevThreadSpawn
- FiberSpawn
- FiberPool
- NeverBlock
- RevThreadPool

Unicorn

Rainbows!

```
unicorn master
\_ unicorn worker[0]
|   \_ client[0]
\_ unicorn worker[1]
|   \_ client[1]
\_ unicorn worker[2]
|   \_ client[2]
...
\_ unicorn worker[M]
    \_ client[M]
```

Unicorn

```
unicorn master
\_ unicorn worker[0]
|   \_ client[0]
\_ unicorn worker[1]
|   \_ client[1]
\_ unicorn worker[2]
|   \_ client[2]
...
\_ unicorn worker[M]
    \_ client[M]
```

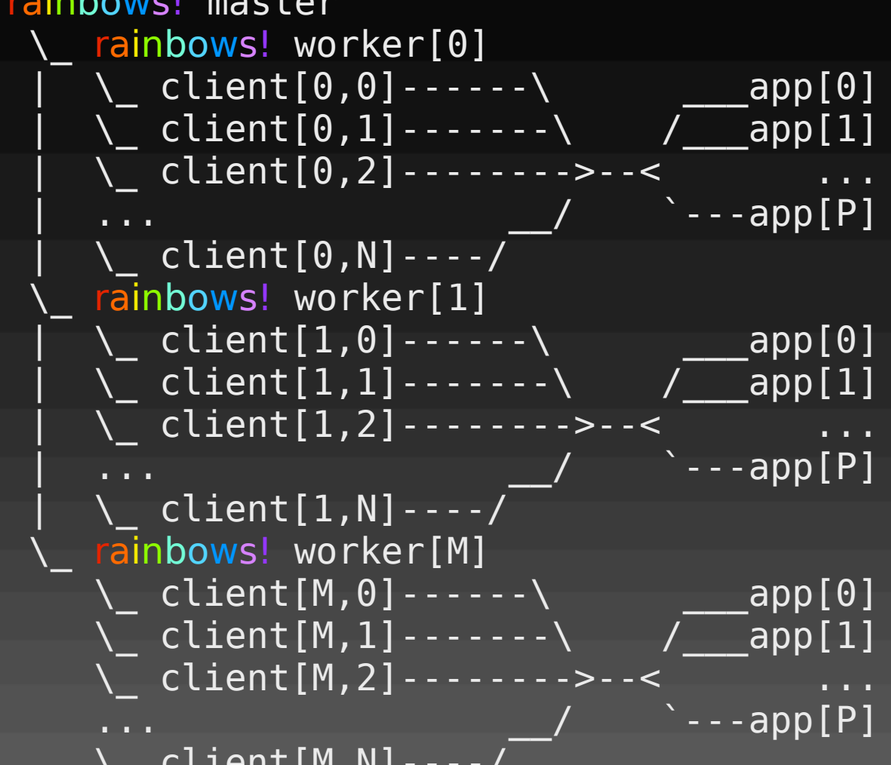
Rainbows!

```
rainbows! master
 \_ rainbows! worker[0]
 |   \_ client[0,0]
 |   \_ client[0,1]
 |   ...
 |   \_ client[0,N]
 \_ rainbows! worker[1]
 |   \_ client[1,0]
 |   ...
 |   \_ client[1,N]
 ...
 \_ rainbows! worker[M]
     \_ client[M,0]
     ...
     \_ client[M,N]
```

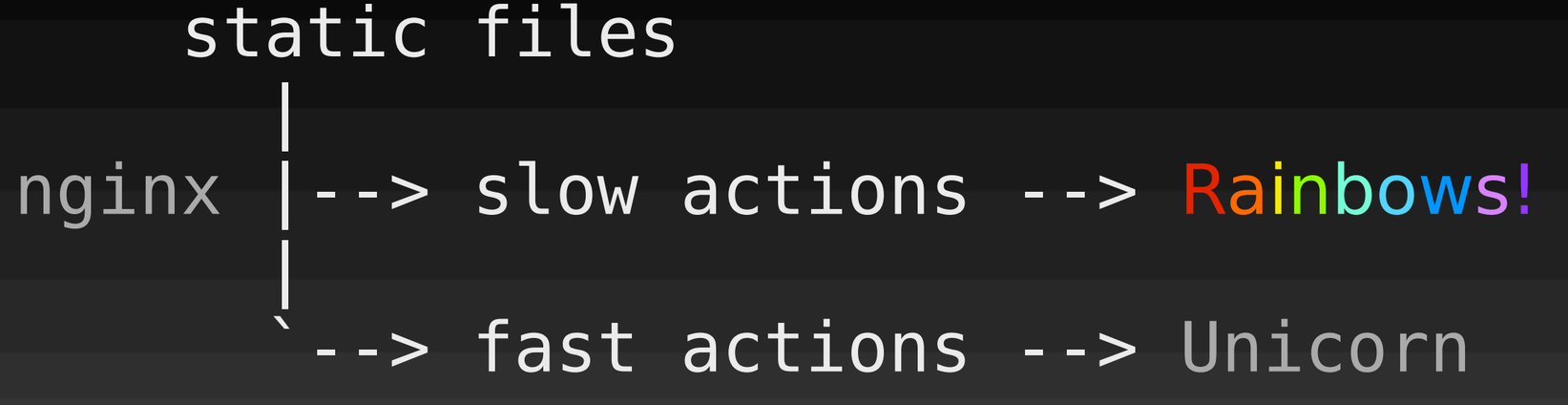
Unicorn

```
unicorn master
\_ unicorn worker[0]
|   \_ client[0]
\_ unicorn worker[1]
|   \_ client[1]
\_ unicorn worker[2]
|   \_ client[2]
...
\_ unicorn worker[M]
    \_ client[M]
```

Rainbows!



Unicorn Rainbows!

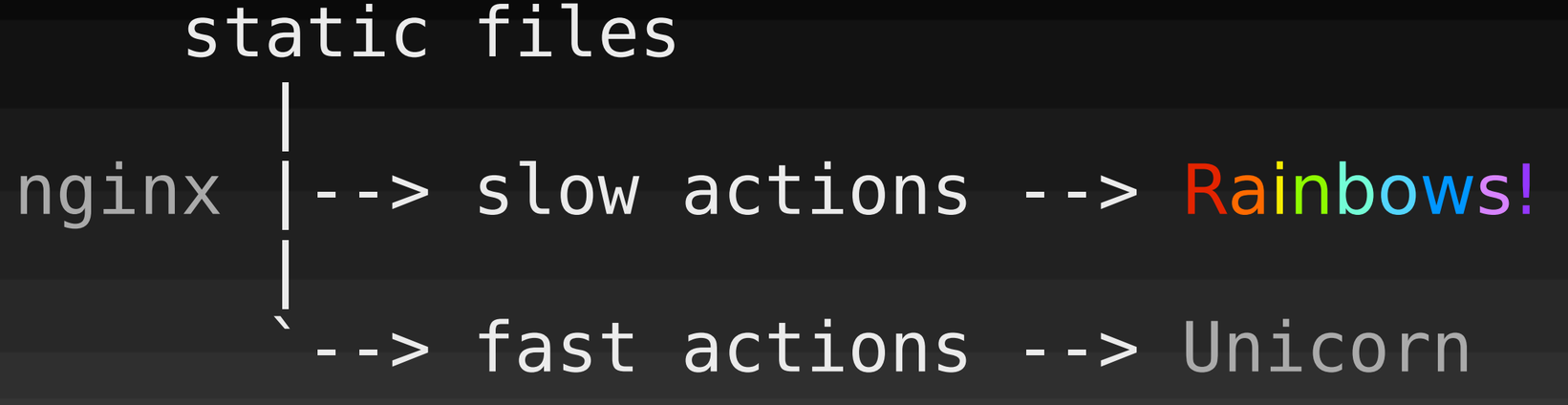


Unicorn

http://unicorn.bogomips.org/

Rainbows!

http://rainbows.rubyforge.org/



how Unicorn works

unicorn 0.97.0

how Unicorn works

unicorn 0.97.0

```
# in lib/unicorn.rb:270
# in Unicorn::HttpServer#start

        maintain_worker_count
```

how Unicorn works

unicorn 0.97.0

```
        # in lib/unicorn.rb:602
        # in Unicorn::HttpServer#maintain_worker_count

(off = WORKER.size - worker_process) == 0 and return
 off < 0 and return spawn_missing_workers
```

how Unicorn works

unicorn 0.97.0

```
        # in lib/unicorn.rb:591
        # in Unicorn::HttpServer#spawn_missing_workers
worker = Worker.new(worker_nr, Unicorn::Util.tmpio)
before_fork.call(self, worker)
WORKERS[fork {
  ready_pipe.close if ready_pipe
  self.ready_pipe = nil
  worker_loop(worker)
}] = worker
```

how Unicorn works

unicorn 0.97.0

```
# in lib/unicorn.rb:705
# in Unicorn::HttpServer#worker_loop

ready.each do |sock|
  begin
    process_client(sock.accept_nonblock)
    # workers load balancing here!! ^^
```

how Unicorn works

unicorn 0.97.0

```
        # in lib/unicorn.rb:630
        # in Unicorn::HttpServer#process_client

# read request, call app, write app response
def process_client(client)
  client.fcntl(Fcntl::F_SETFD, Fcntl::FD_CLOEXEC)
  response = app.call(env = REQUEST.read(client))
  # [...]
  HttpResponse.write(client, response,
    HttpRequest::PARSER.headers?)
```

how Unicorn works

unicorn 0.97.0

```
      # in lib/unicorn/http_request.rb:31
      # in Unicorn::HttpRequest#read

    # Does the majority of the IO processing.
    # It has been written in Ruby using about 8
    # different IO processing strategies.
    # [...]
    # Anyone who thinks they can make it faster is
    # more than welcome to take a crack at it.
```

how Rainbows! works

rainbows 0.91.0

how Rainbows! works

rainbows 0.91.0

Sorry! To be continued.....

how Rainbows! works

rainbows 0.91.0

Sorry! To be continued.....

?