Marlon - A Domain-Specific Language for Multi-Agent Reinforcement Learning on Networks

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Context: distributed systems

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Smart grids

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Intelligent traffic systems

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Smart grids

Intelligent traffic systems

Cloud services

Problem statement

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- Optimizing throughput, reliability, latency, resource usage, ...
- Automate with multi-agent RL (MARL)
- Problems inherent to distributed systems:
  - Networks are dynamic
  - Nodes, connections can fail or be unreliable
  - Communication cost

Marlon

Marlon

Multi-**A**gent **R**einforcement **L**earning **O**n **N**etworks

Marlon

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Multi-**A**gent **R**einforcement **L**earning **O**n **N**etworks

- Domain-specific programming language to:
  - implement network environment
  - plug in existing MARL algorithms into this environment
- Enable domain experts to use MARL with little background knowledge
- MARL researchers can focus on MARL, rather than the intricacies of distributed systems

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  - Designed for scalable, fault-tolerant applications

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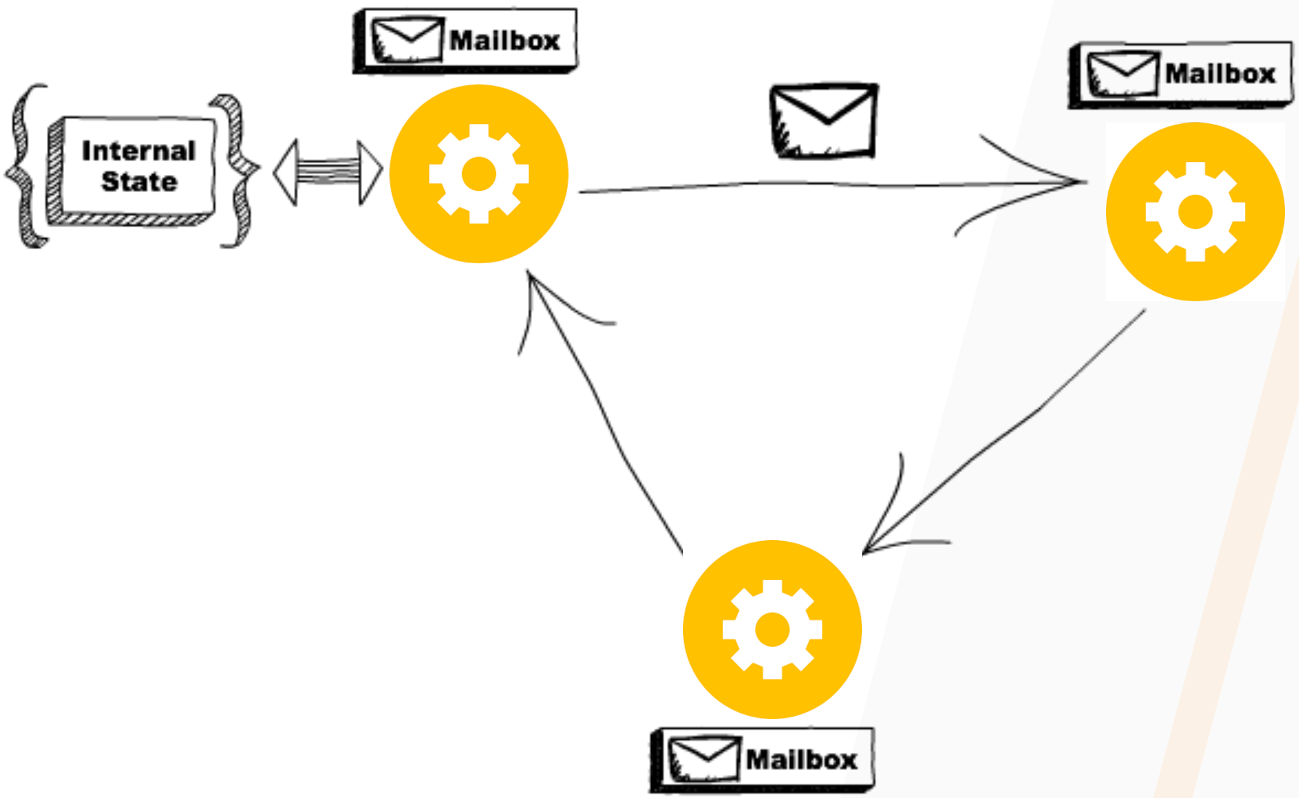
    - Designed for scalable, fault-tolerant applications
- python™ integration to use existing MARL algos.
- Two main concepts: actors and agents
    - Environment represented as an actor-based system
    - Agents observe, interact and learn from the environment

Actor-based concurrency



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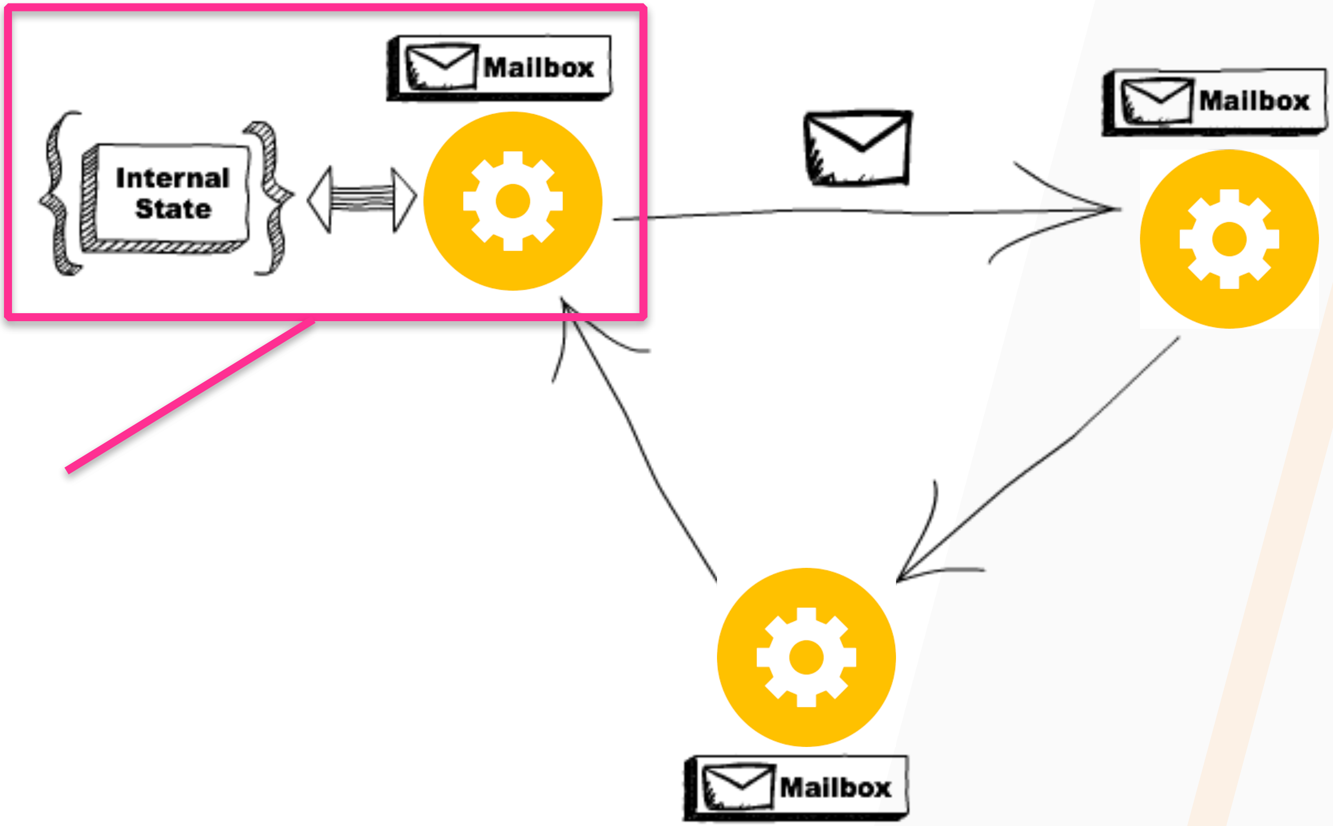
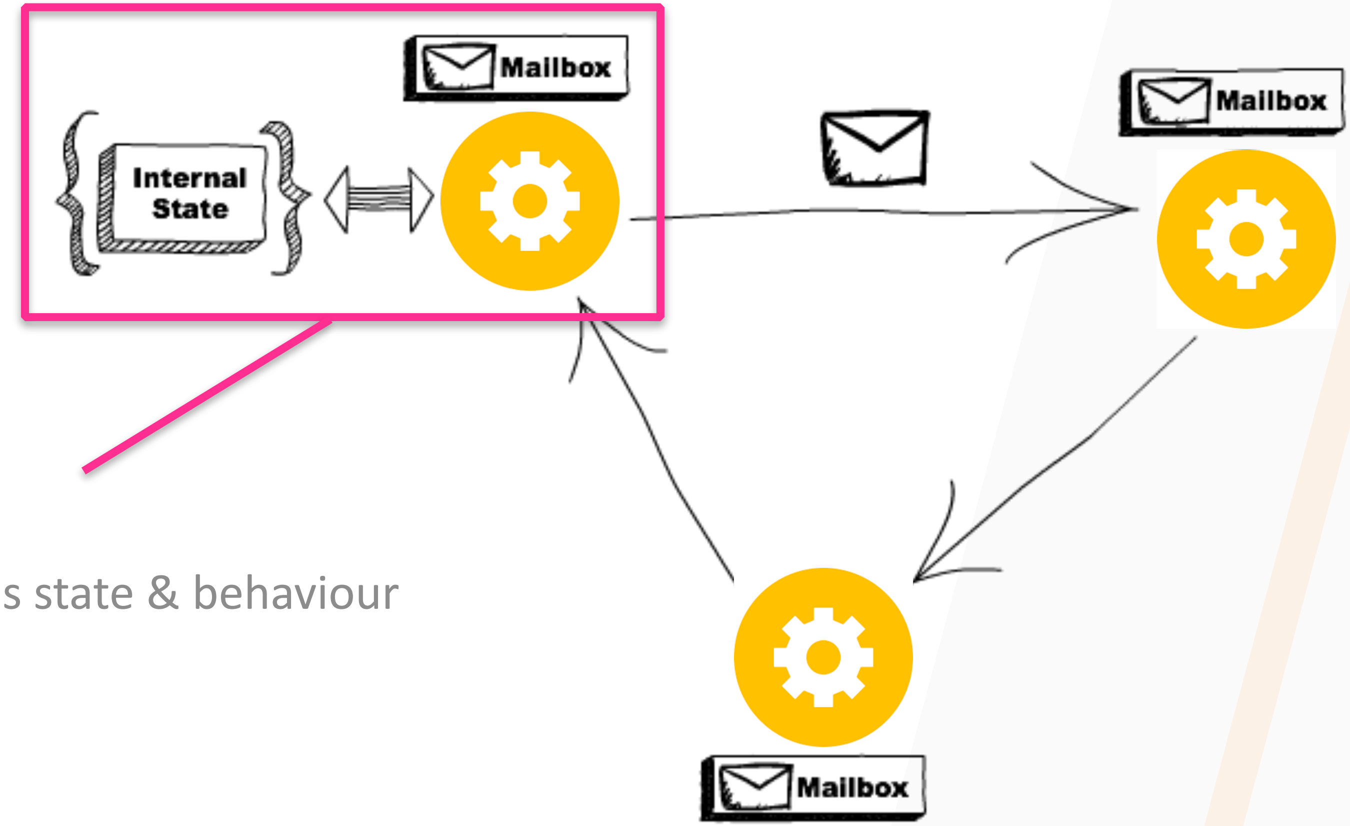


An actor

Actor-based concurrency



An actor

- Contains state & behaviour

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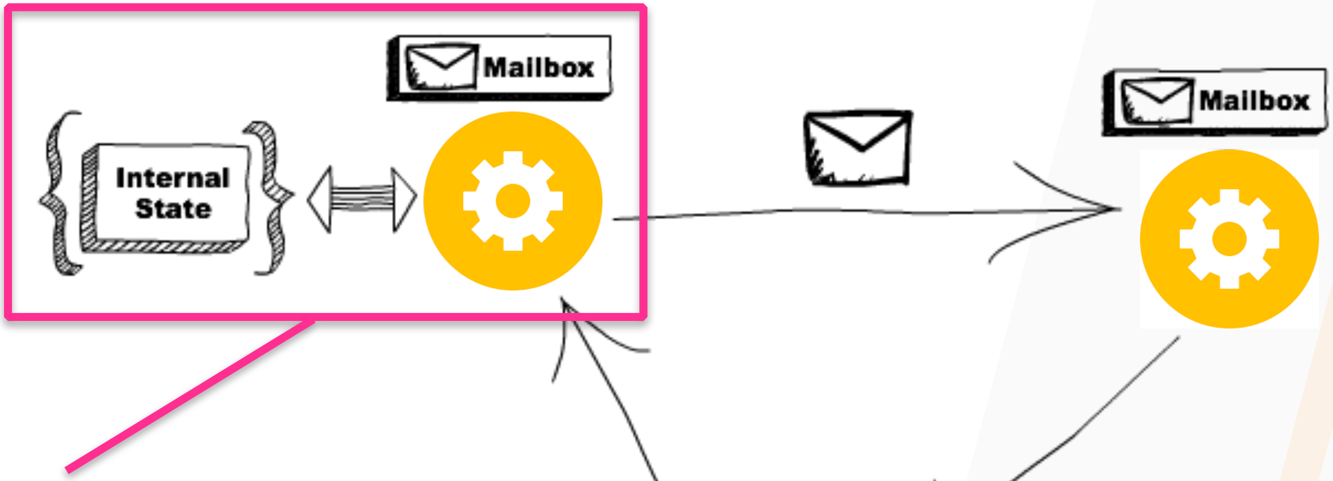
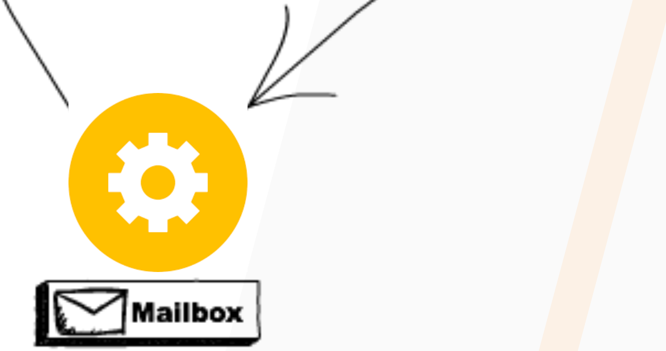
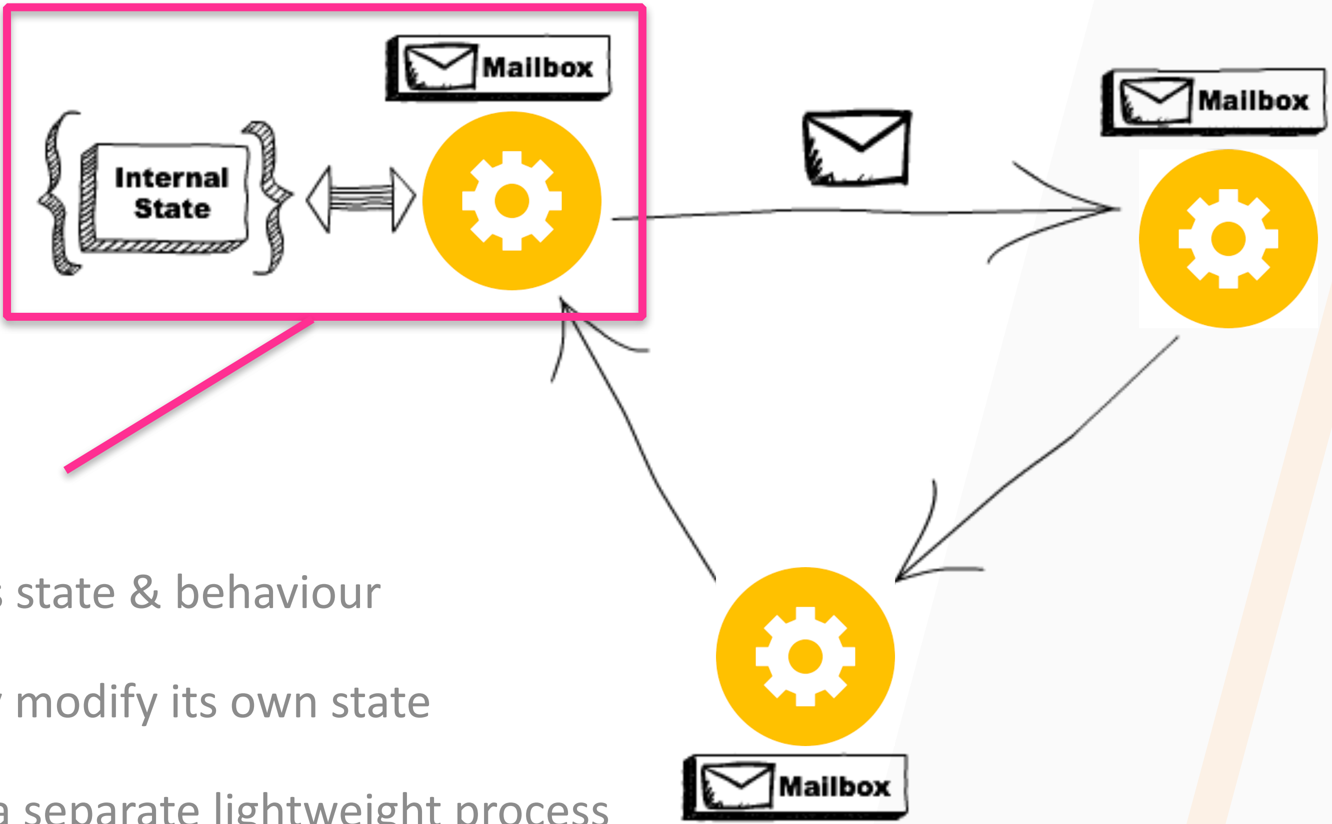




An actor

- Contains state & behaviour
- Can only modify its own state

Actor-based concurrency



An actor

- Contains state & behaviour
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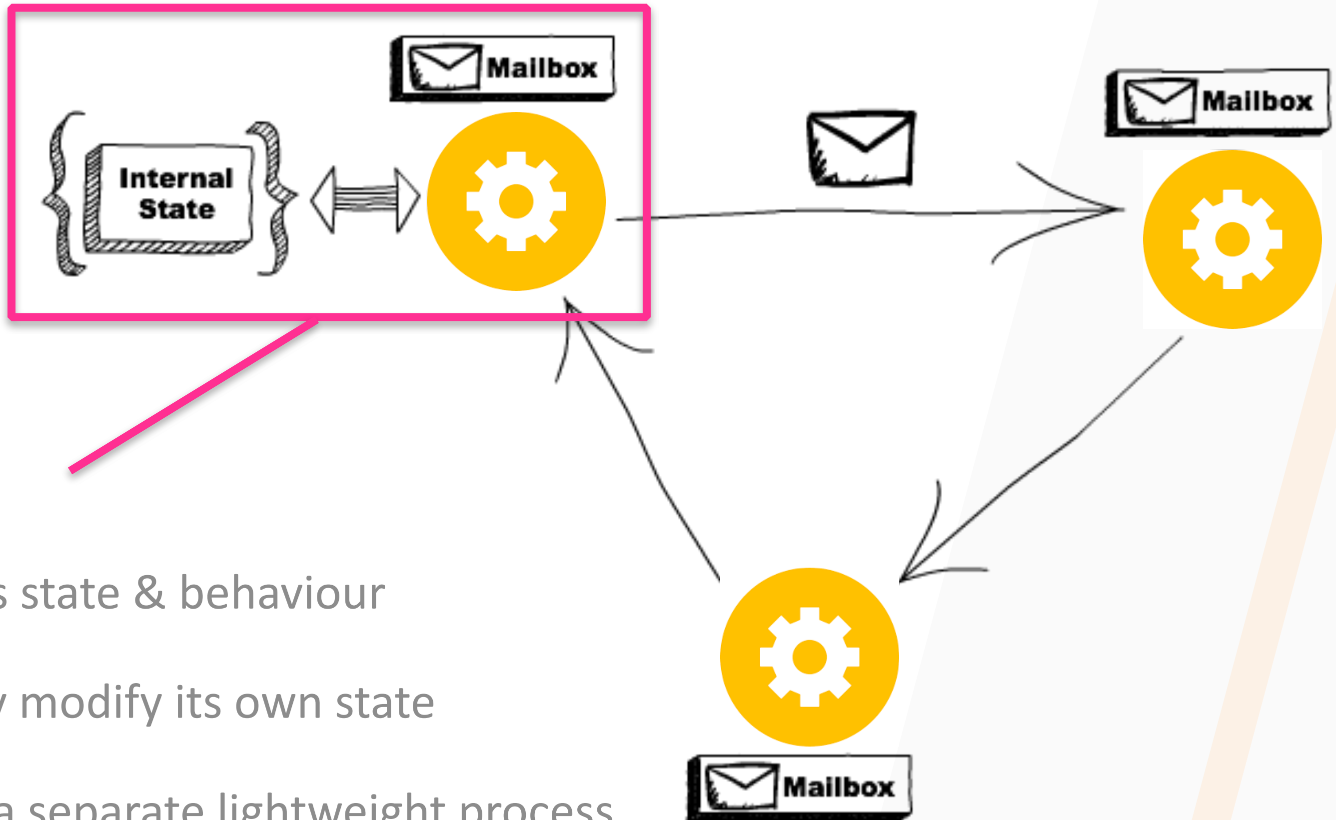
- Runs in a separate lightweight process

Actor-based concurrency



An actor

- Contains state & behaviour
- Can only modify its own state
- Runs in a separate lightweight process
- Communicates by sending messages

Marlon application overview

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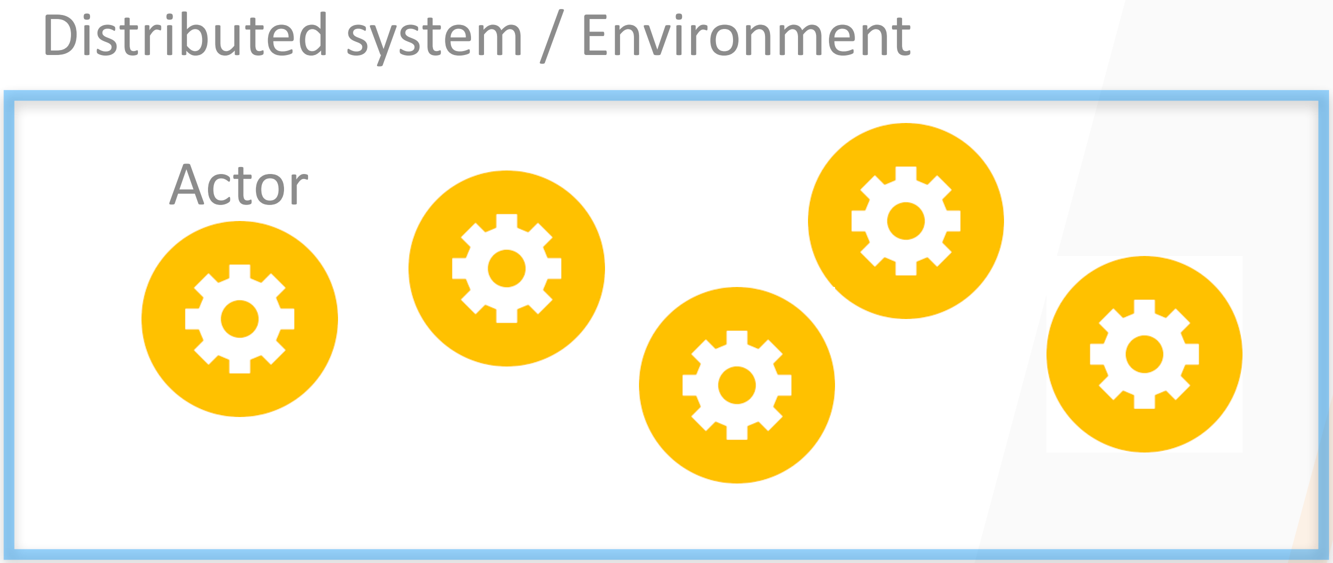
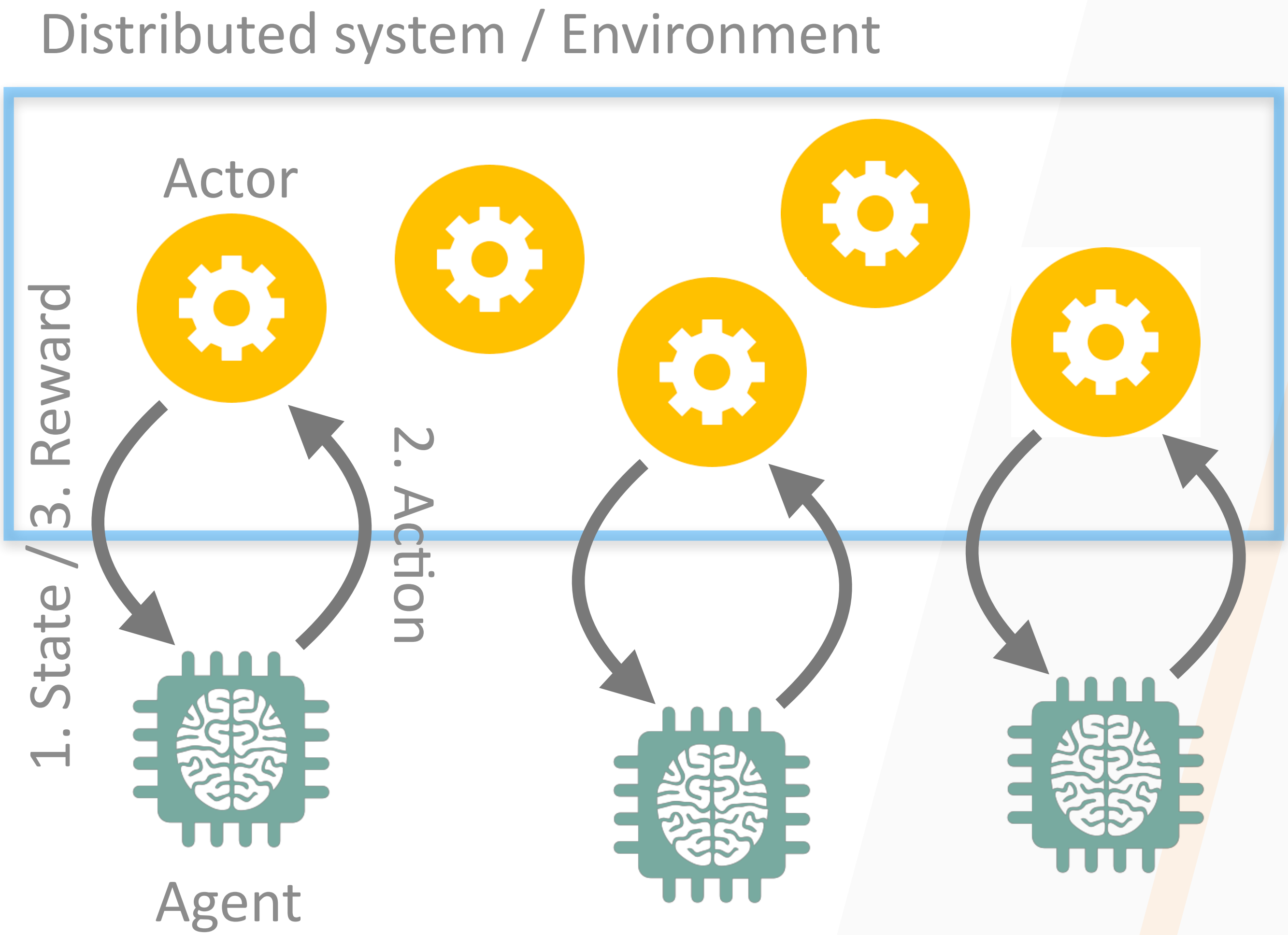
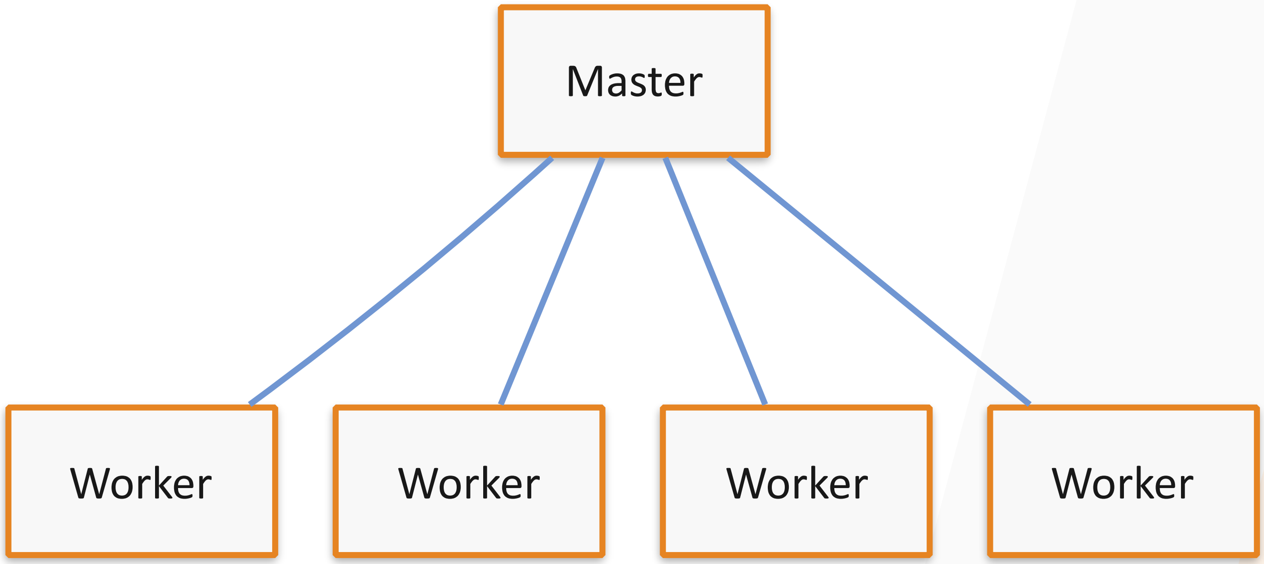


Marlon application overview



Load balancing example



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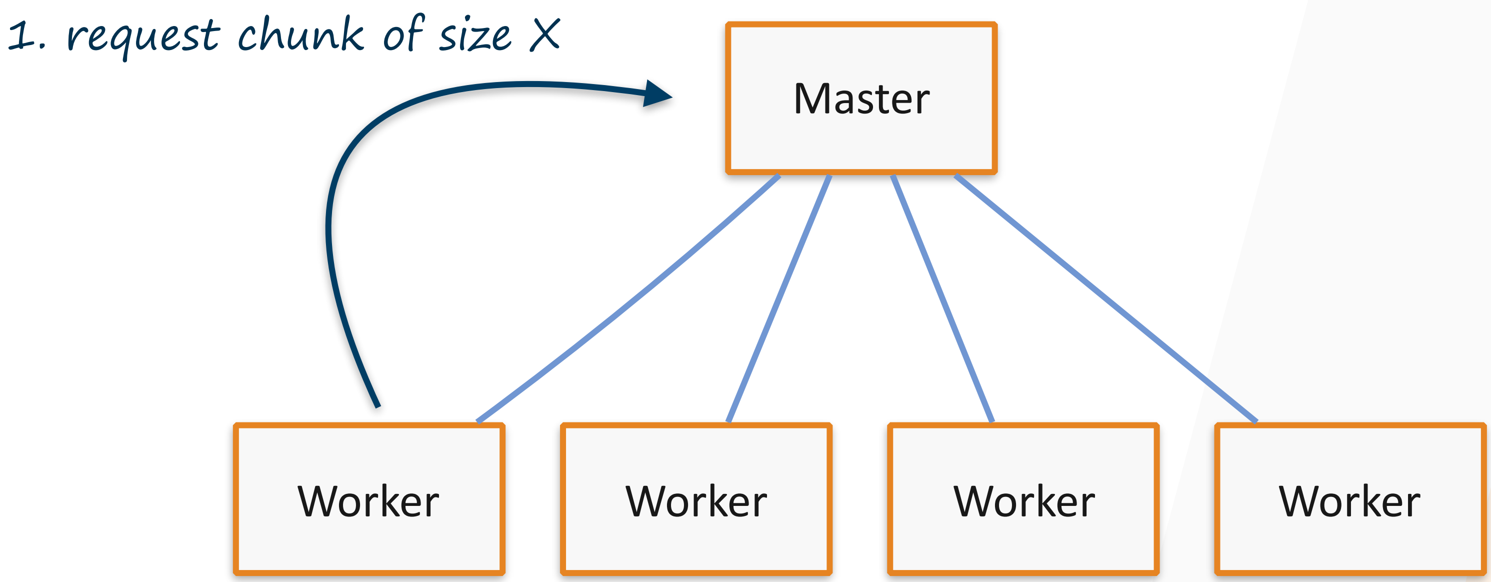

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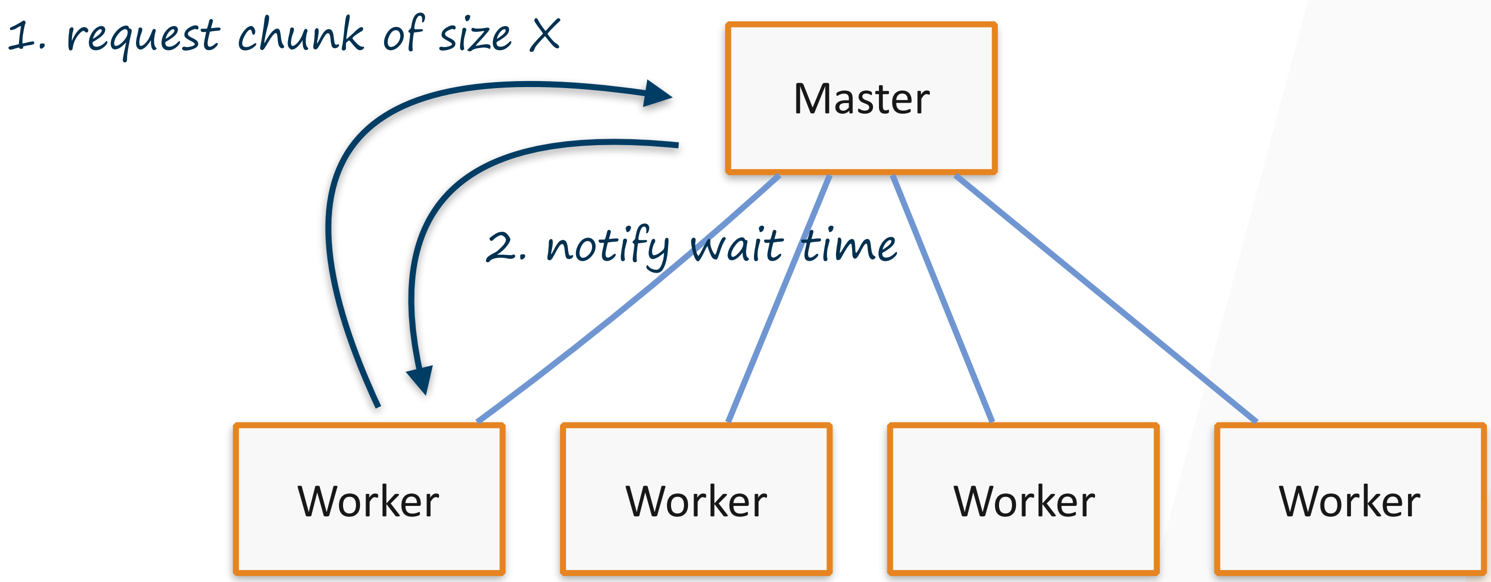

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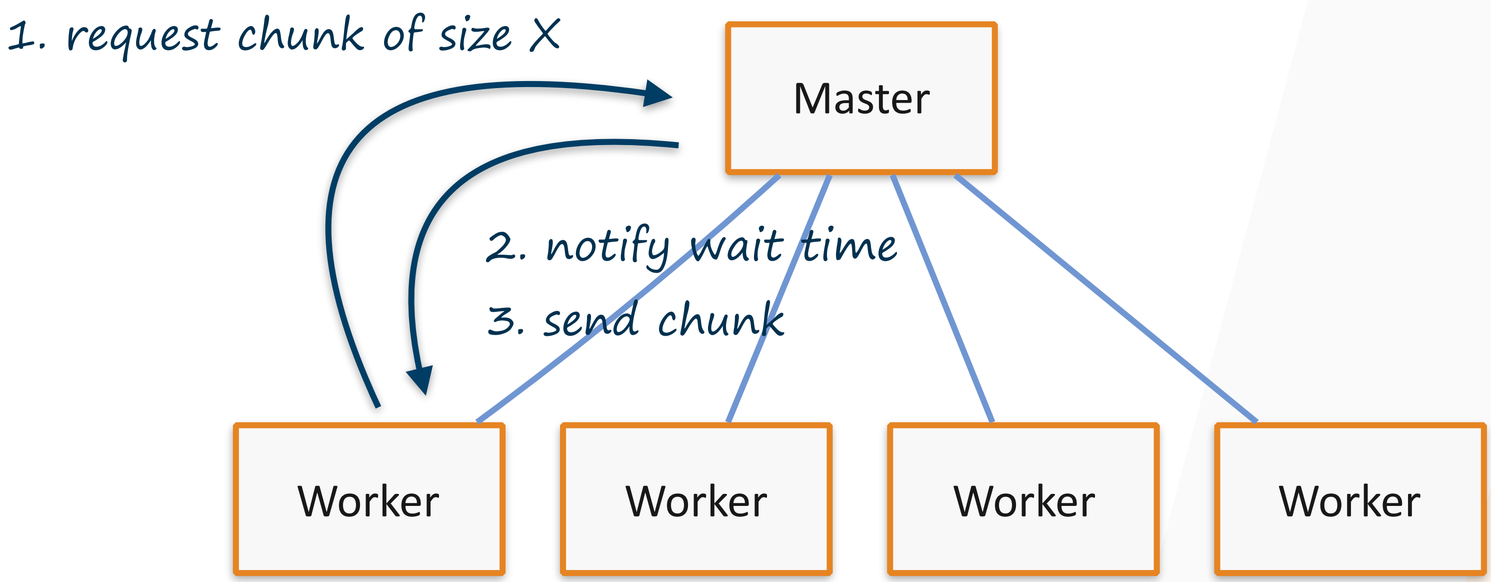

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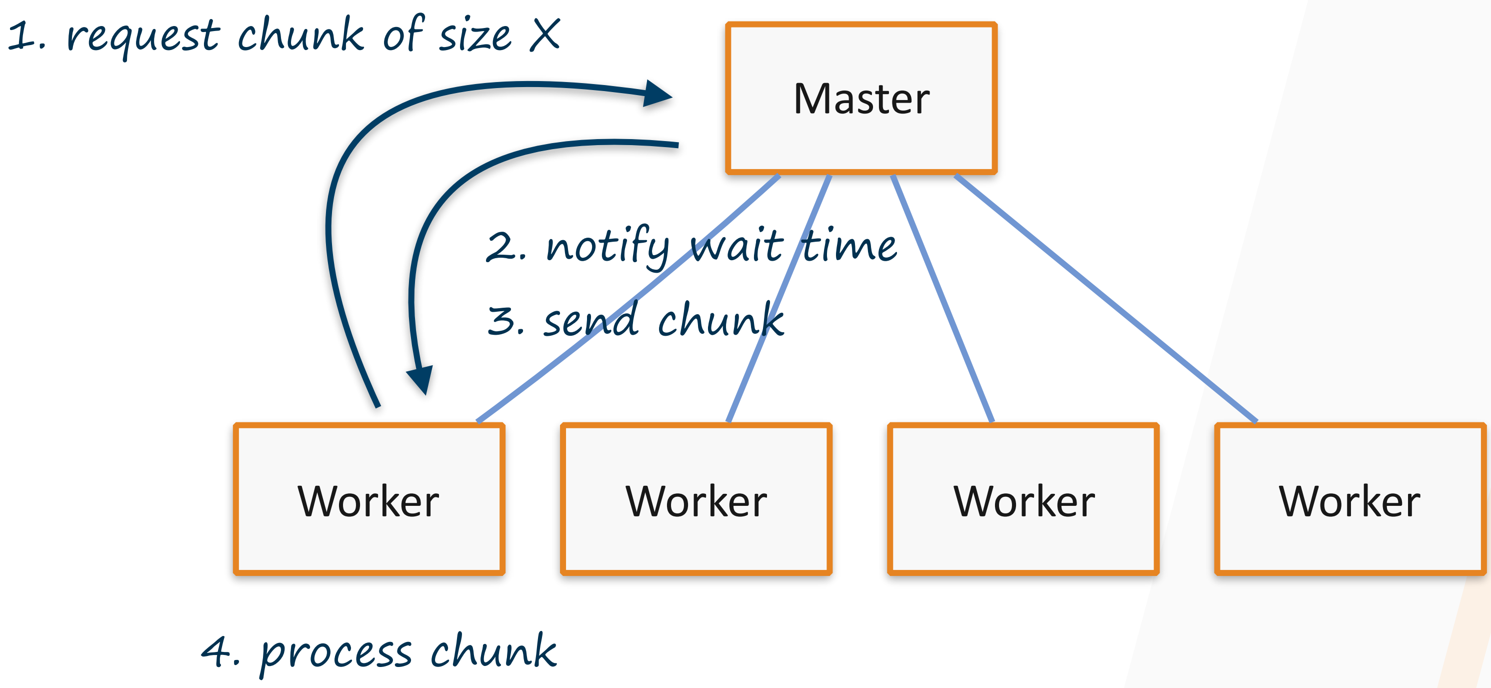

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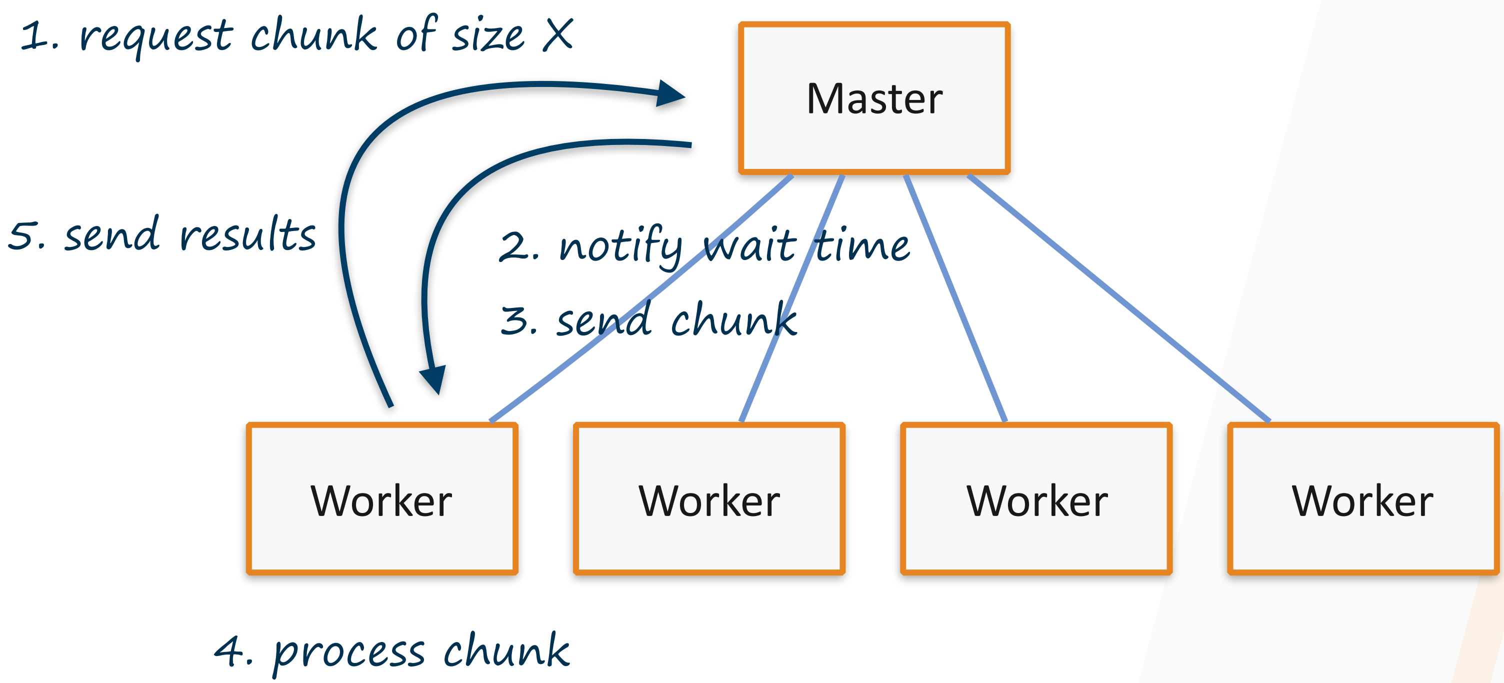

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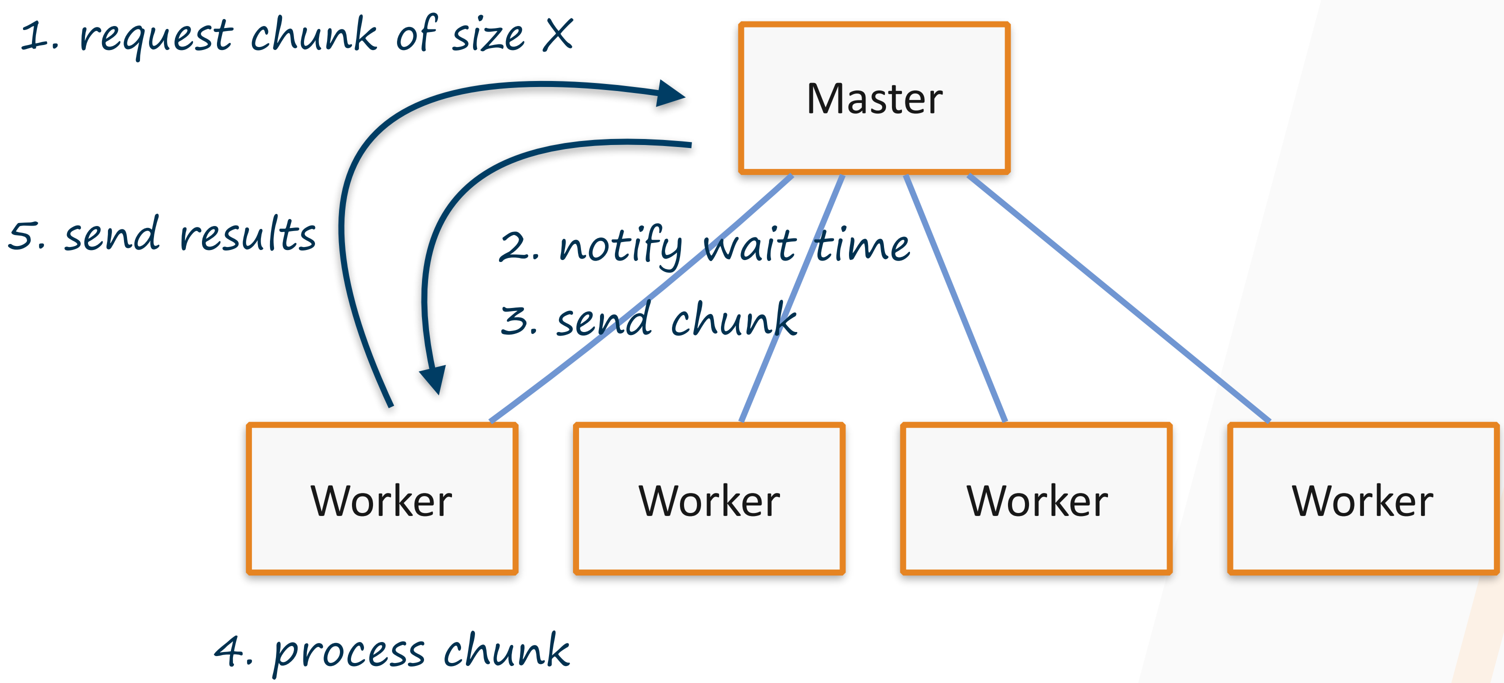

- Master can only handle one request at a time

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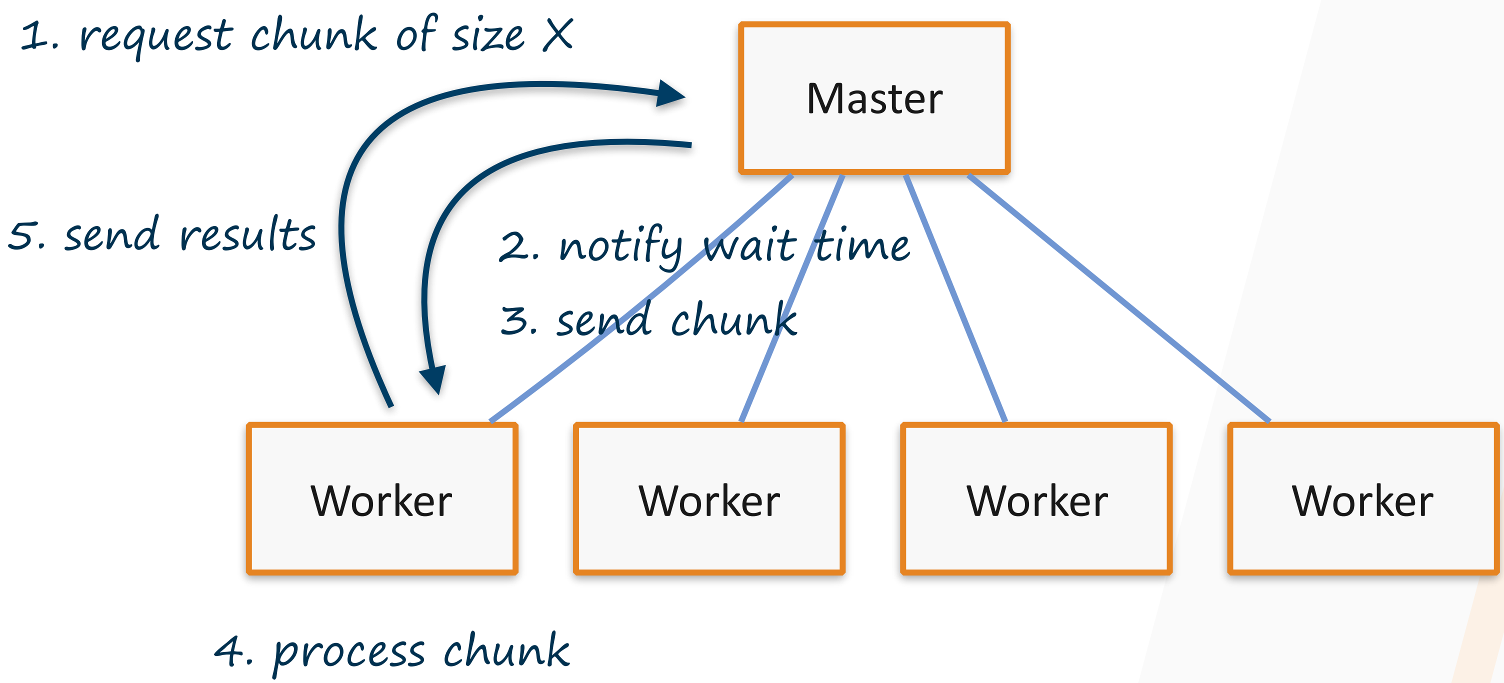

- Master can only handle one request at a time
- Workers can join/leave; they can have different processing speeds

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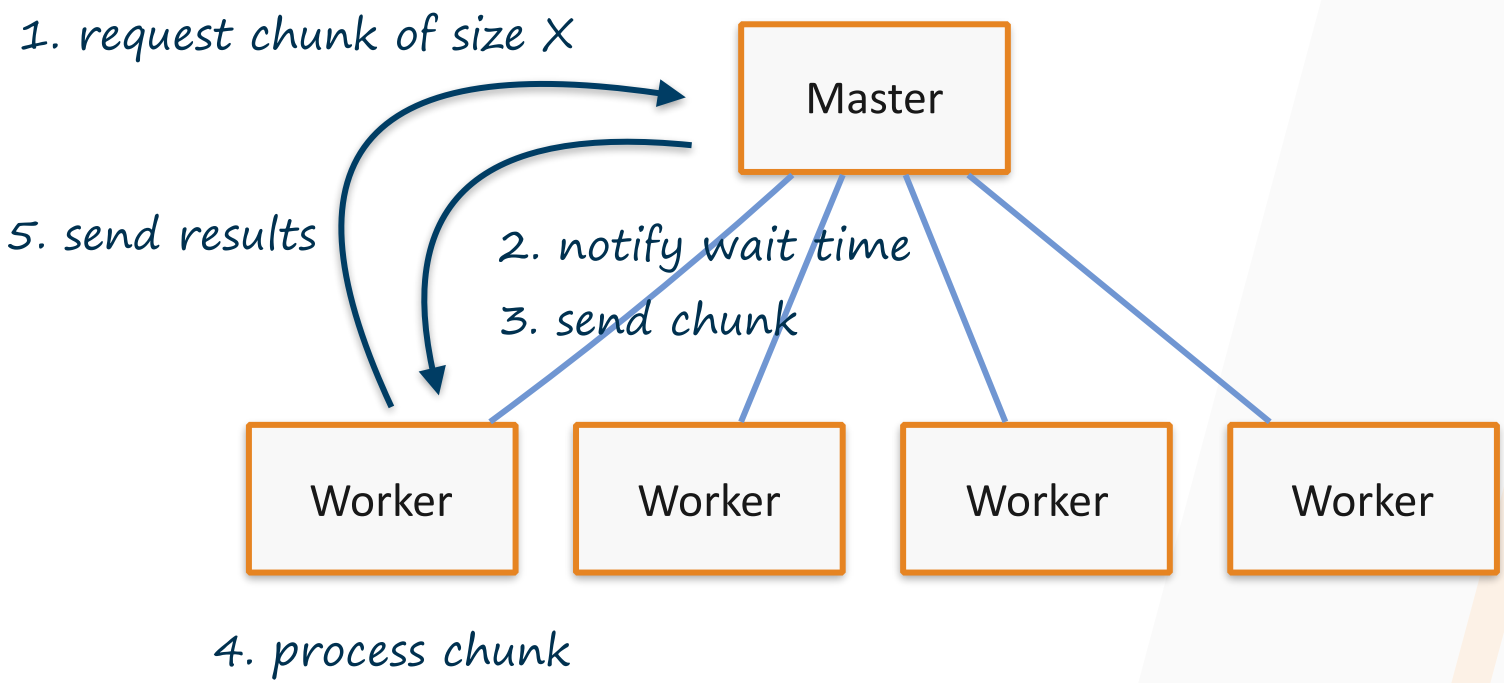
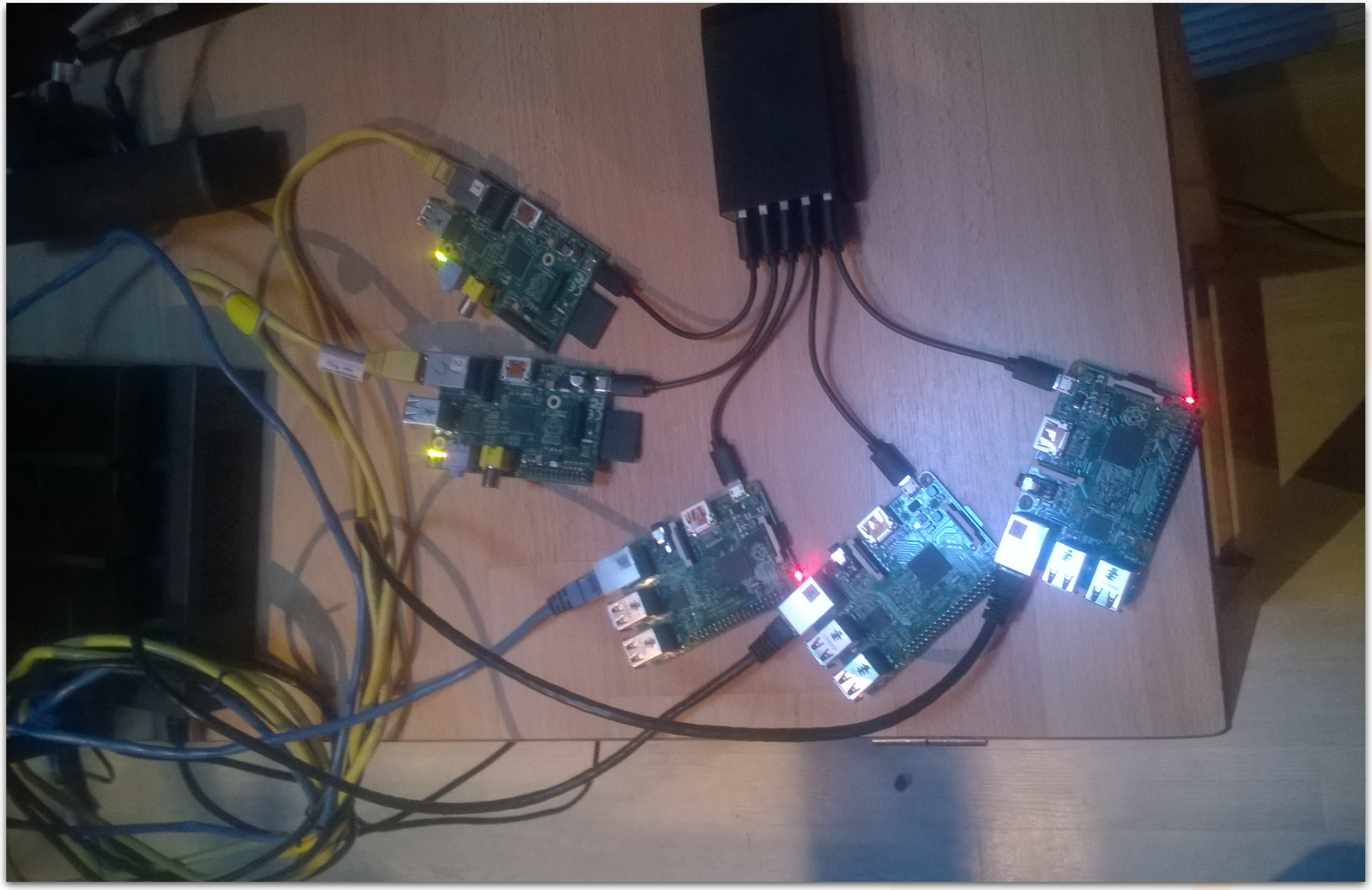


- Master can only handle one request at a time
- Workers can join/leave; they can have different processing speeds
- Goal: Minimize idle time by optimizing X for each worker

Load balancing example

Load balancing example



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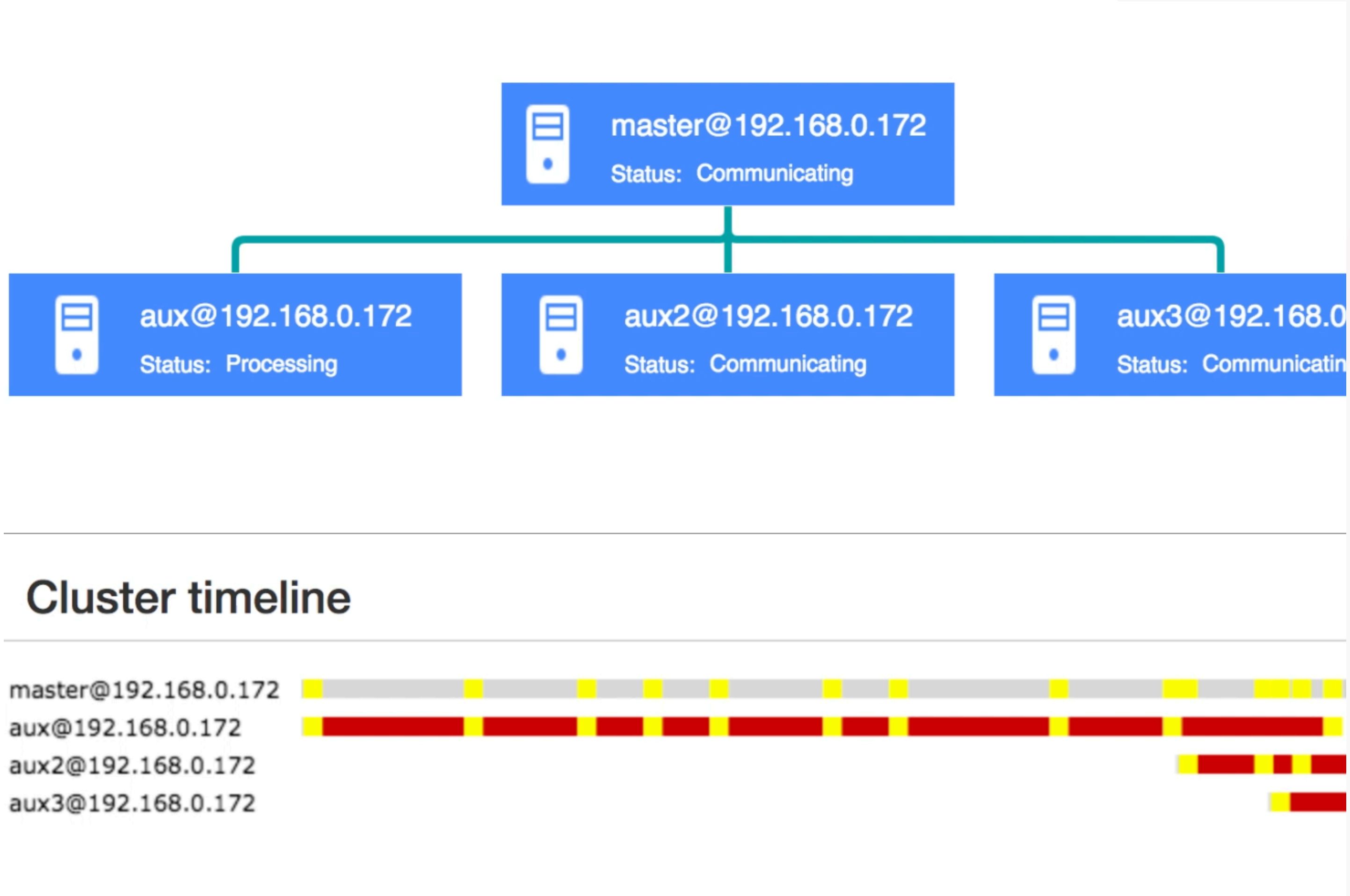

Environment

```
{:ok, m} = Master.start_link([Application.fetch
    Master.create_job(m, 10000)
    Enum.map(Node.list(),
      fn(node) -> LoadBalancingExample.init_wo
    {:noreply, %{this | master: m}}
  end

def init_worker(this,master,node) do
  speed = Marlon.Utils.random_int(1,5)
  {:ok, w} = Worker.start_link_remote(node, [ma

  Worker.start(w)
  {:noreply, this}
end


defactor Worker do
  def init ([m, speed, chunk_time]) do
    {:ok, %{
      master: m,
      speed_factor: speed,
      wait_time: 0,
      chunk_time: chunk_time}}
  end

  async def start(this) do
    Worker.process_chunk(self(), 1)
    {:noreply, this}
  end

  async def process_chunk(this, chunk_size) do
    result = Master.request_work(this[:master],
    if result != :no_more_work do
      Process.send_after self(), {:processed_ch
        round(this[:chunk_time] * chunk_size /
    end
    {:noreply, this}
  end
```

```
reply def processed_chunk(this) do
  Master.work_finished(this[:master], self()
  Worker.process_chunk(self(), 1)
  {:noreply, this}
end

async def notify_wait_time(this, wait_time)
  new_state = %{this | wait_time: wait_time}

  {:noreply, new_state}
end
end

defactor Master do
  def init([comm_time]) do
    {:ok, %{
      comm_time: comm_time,
      chunks_remaining: 0,
      pending_request_size: 0,
      chunks_in_progress: %{}
    }}
  end

  sync def create_job(this, _from, job_size) do
    Logger.info "Job created (size: " <> to_string(job_size) <> ")"
    {:reply, :ok, %{this | chunks_remaining: job_size}}
  end

  sync def request_work(this, from, chunk_size) do
    new_pending = this[:pending_request_size] + chunk_size
    Worker.notify_wait_time(elem(from,0), new_pending * this[:comm_time])
    Process.send_after(self(), {:request_work_reply, chunk_size, from}, this[:comm_time])
    {:noreply, %{this | pending_request_size: new_pending}}
  end

  async def work_finished(this, worker) do
    {:noreply, %{this | chunks_in_progress: Map.delete(this[:chunks_in_progress], worker)}}
  end
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```
  async def work_cancelled(this, worker) do
    revert_remaining = this[:chunks_remaining] - Map.
    {:noreply, %{this | chunks_in_progress: Map.delet
      chunks_remaining: revert_remaining}}
  end

  reply def request_work_reply(this, chunk_size, from
    {worker_pid, _} = from
    new_remaining = this[:chunks_remaining] - chunk_s
    new_pending = this[:pending_request_size] - chunk
    if (new_remaining >= 0) do
      GenServer.reply(from, :ok)
      {:noreply, %{this |
        chunks_remaining: new_remaining,
        pending_request_size: new_pending,
        chunks_in_progress: Map.put(this[:chunks_in_p
    else
      Logger.info "Master - No more work!"
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  end
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Environment + MARL integration

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  async def start(this) do
    Worker.do_action(self())
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  end

  async def process_chunk(this, chunk_size) do
    result = Master.request_work(this[:master],
    if result != :no_more_work do
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defgoal OptimizeChunkSize do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
  actions [process_chunk: [[1,2,3]]],
  reward fn(_agent, worker_state) ->  1 / worker_stat
end
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MARL integration

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Learning algorithm (Exploring Selfish RL)

MARL integration

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```

Algorithm parameters

MARL integration

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Worker.update_reward(self(), new_state)
```

~~Worker.process_chunk(self(), 1)~~

```
Worker.do_action()
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```

Action space

MARL integration

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Worker.attach_agent(w, ChunkSizeGoal)

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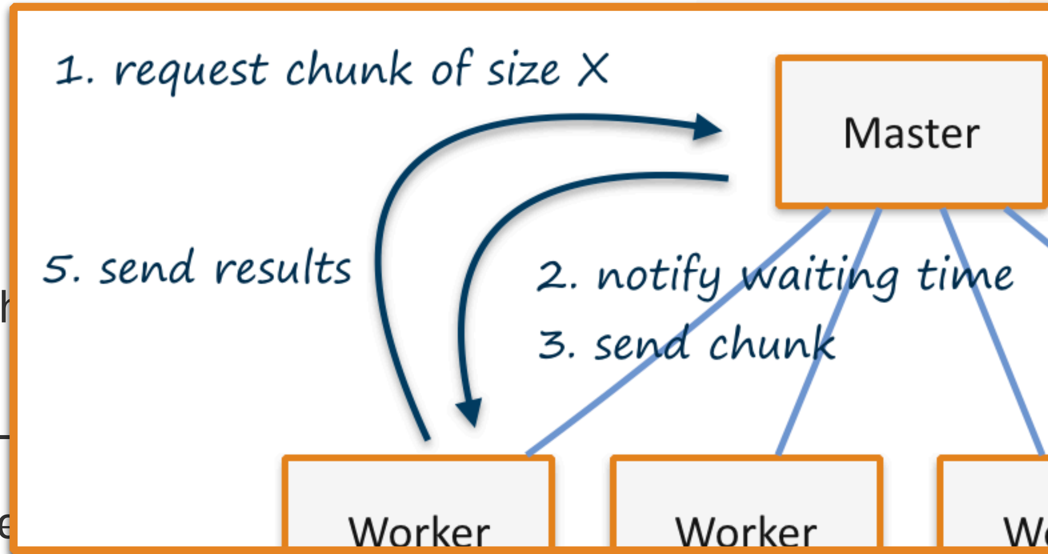
```

Reward function

MARL integ



Worker.attach

Worker.update_

~~Worker.pre~~

Worker.do_action()

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Reward function

Additional options

```
defgoal ChunkSizeGoal do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
  actions [process_chunk: [[1,2,3]]]
  reward fn(_agent, worker_state) ->
    1 / worker_state[:wait_time] end]
  shared [:wait_time]
  share_deviation [wait_time: 5]
  state_abstraction fn(worker_state) ->
    cond do
      worker_state[:wait_time] > 100 -> 2
      worker_state[:wait_time] > 10 -> 1
      true -> 0
    end
  end
end
```

Additional options

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      true -> 0
    end
  end
end
```

Which state to share with other agents

Additional options

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defgoal ChunkSizeGoal do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
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    1 / worker_state[:wait_time] end]
  shared [:wait_time]
  share_deviation [wait_time: 5]
  state_abstraction fn(worker_state) ->
    cond do
      worker_state[:wait_time] > 100 -> 2
      worker_state[:wait_time] > 10 -> 1
      true -> 0
    end
  end
end
```

Additional options

```
defgoal ChunkSizeGoal do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
  actions [process_chunk: [[1,2,3]]]
  reward fn(_agent, worker_state) ->
    1 / worker_state[:wait_time] end]
  shared [:wait_time]
  share_deviation [wait_time: 5]
  state_abstraction fn(worker_state) ->
    cond do
      worker_state[:wait_time] > 100 -> 2
      worker_state[:wait_time] > 10 -> 1
      true -> 0
    end
  end
end
```

Reduce the amount of communication

Additional options

```
defgoal ChunkSizeGoal do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
  actions [process_chunk: [[1,2,3]]]
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    cond do
      worker_state[:wait_time] > 100 -> 2
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      true -> 0
    end
  end
end
```

Additional options

```
defgoal ChunkSizeGoal do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
  actions [process_chunk: [[1,2,3]]]
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    1 / worker_state[:wait_time] end]
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    cond do
      worker_state[:wait_time] > 100 -> 2
      worker_state[:wait_time] > 10 -> 1
      true -> 0
    end
  end
end
```

Reduce the state space

Additional options

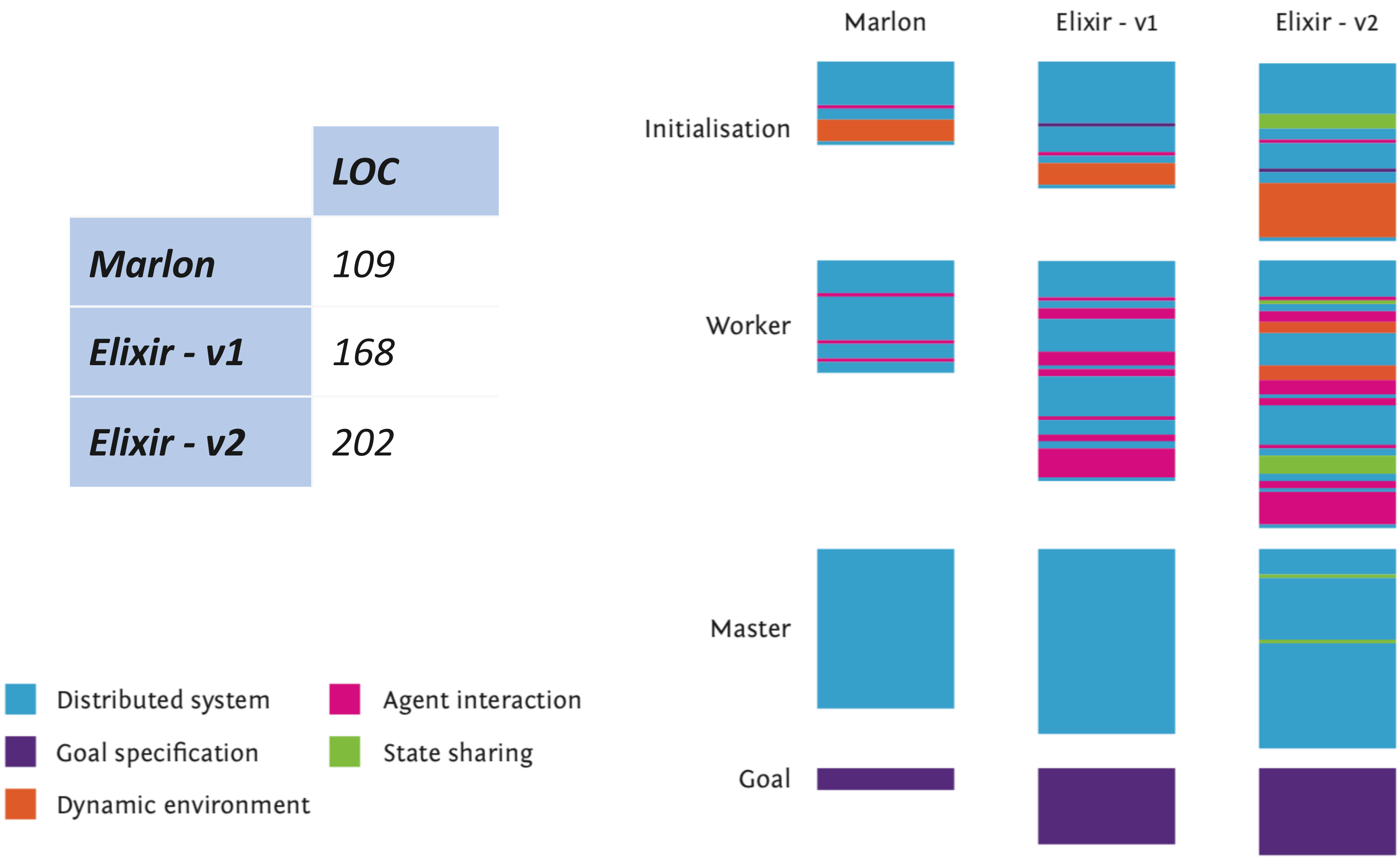
```
defgoal ChunkSizeGoal do
  type Marlon.ESRL
  params [explorations: 7, steps: 20]
  actions [process_chunk: [[1,2,3]]]
  reward fn(_agent, worker_state) ->
    1 / worker_state[:wait_time] end]
  shared [:wait_time]
  share_deviation [wait_time: 5]
  state_abstraction fn(worker_state) ->
    cond do
      worker_state[:wait_time] > 100 -> 2
      worker_state[:wait_time] > 10 -> 1
      true -> 0
    end
  end
end
```

MARL algorithm API

```
defclass Marlon.LearningAlgorithm do
  def init_agent(this, actor_state)
  def is_learning(this)
  def sample_action(this)
  def update(this, actor_state, reward)
  def action_probabilities(this)
  def agent_joined(this, agent_pid)
  def agent_left(this, agent_pid)
  ...
end
```

Marlon evaluation

	LOC
Marlon	*109*
Elixir - v1	*168*
Elixir - v2	*202*



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- Marlon, a language to facilitate integrating MARL into distributed systems

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- Future work: additional MARL algorithms, evaluate scalability

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- Marlon, a language to facilitate integrating MARL into distributed systems
- Future work: additional MARL algorithms, evaluate scalability
- For more information, visit bit.ly/marlon-lang

Get in touch!

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