A transport layer

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Communication service

Assume we have a communication channel that allow us to send *frames* between two connected nodes. The channel is not reliable so messages can be lost or delivered out of order. .....

We want to build a communication service that is ..... better.

Our task is to build a communication service that provides:

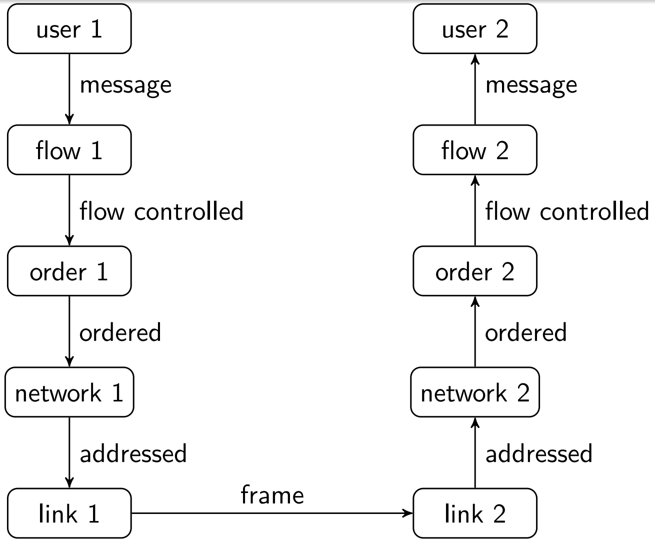
- reliable delivery: despite frames being lost
- ordered delivery: FIFO - first-in-first-out
- identity: an addressing scheme
- flow control: prevented from overflowing a receiver

layered architecture

Build a solution using a layered architecture.

Each layers provides an *abstraction* that the layer above can make use of.

layers



user 1

message

flow 1

flow controlled

order 1

ordered

network 1

addressed

link 1

frame

user 2

message

flow 2

flow controlled

order 2

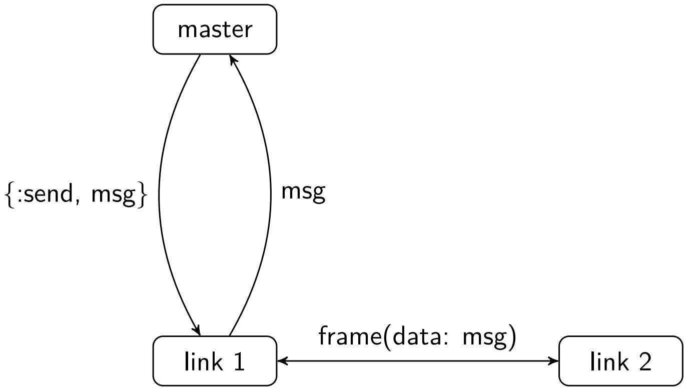
ordered

network 2

addressed

link 2

the link layer



master

{:send, msg}

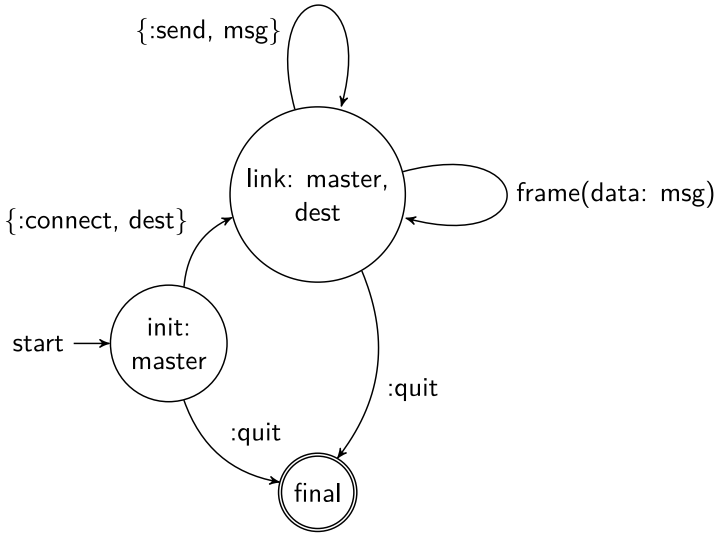
msg

link 1

frame(data: msg)

link 2

the link process - a state diagram



{:send, msg}

link: master, dest

frame(data: msg)

{:connect, dest}

start

init: master

:quit

:quit

final

the link process

```
require Record

Record.defrecord(:frame, data: nil)

def start(master) do
  {:ok, spawn(fn() -> init(master) end)}
end

defp init(master) do
  receive do
    {:connect, dest} ->
      link(master, dest)
    :quit ->
      :ok
  end
end
```

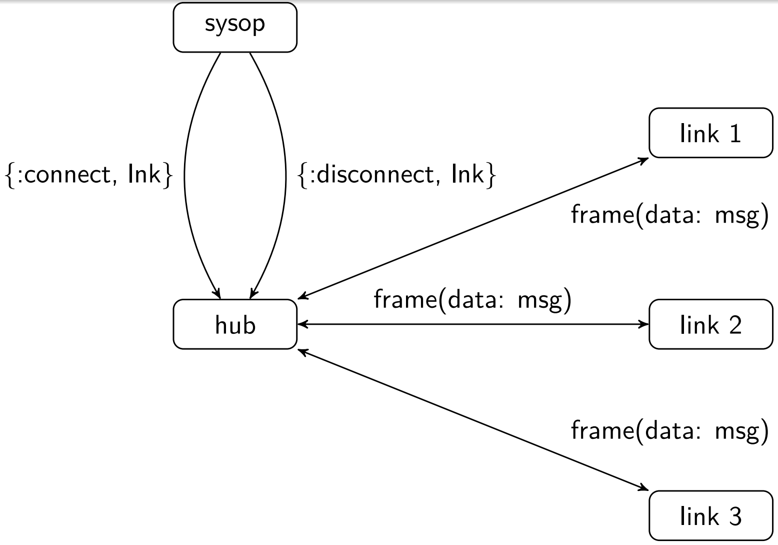
the link process

```
def link(master, dest) do
  receive  do
    {:send, msg} ->
      send(dest, frame(data: msg))
      link(master, dest)

    frame(data: msg) ->
      send(master, msg)
      link(master, dest)

    :quit ->
      :ok
  end
end
```

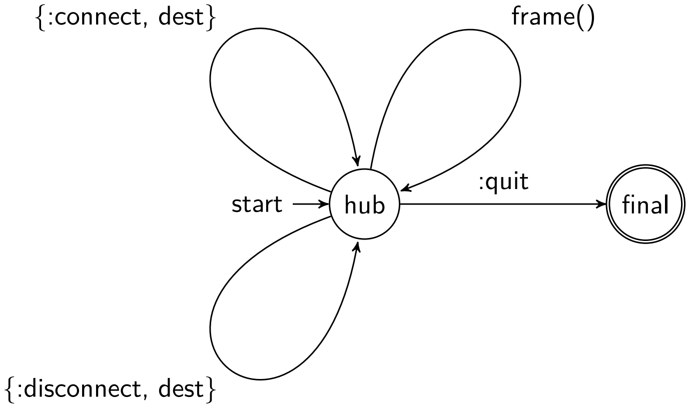
a first try

```
def test() do
  sender = spawn(fn() -> sender() end)
  receiver = spawn(fn() -> receiver() end)
  link1 =   Link.start(sender)
  link2 =   Link.start(receiver)
  send(link1, {:connect, link2})
  send(link2, {:connect, link1})
  send(sender, {:connect, link1})
  send(reciever, {:connect, link2})
  :ok
end
```

a hub



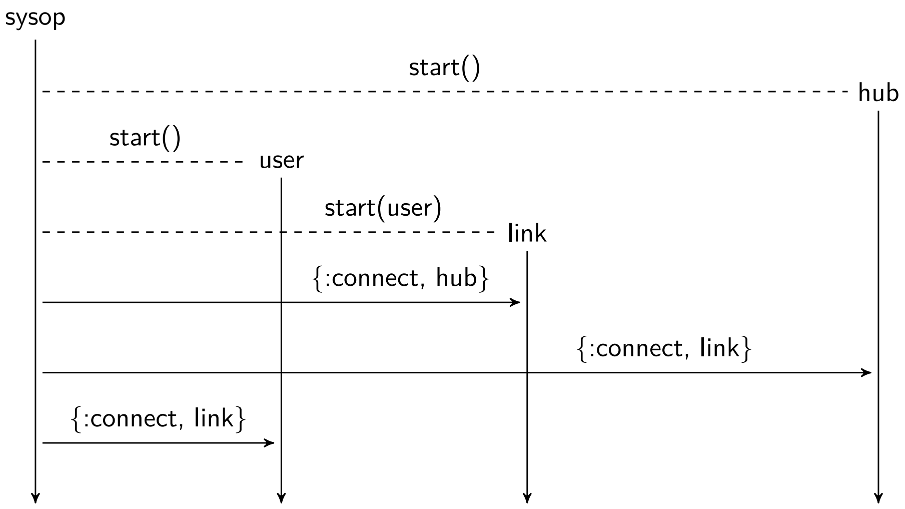
the hub - a state diagram



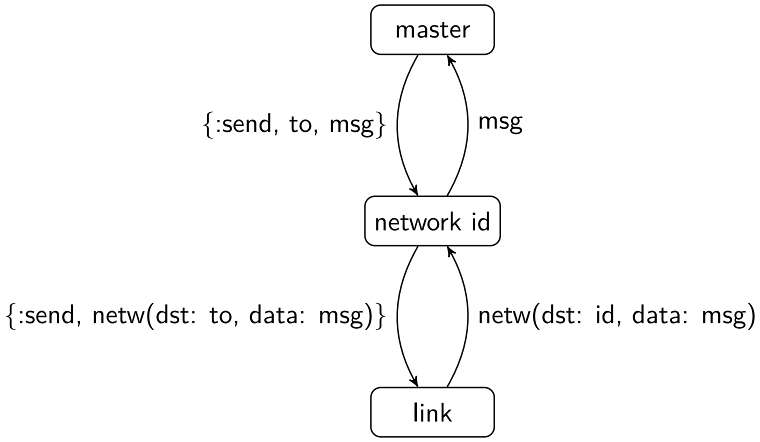
the hub process

```
def hub(connected) do
  receive do
    {:connect, pid} ->
      hub([pid|connected])

    {:disconnect, pid} ->
      hub(List.delete(connected, pid))

    frame() = frm ->
      Enum.each(connected, fn(pid) -> send(pid, frm) end)
      hub(connected)

    :quit ->
      :ok
  end
```

the setup - a sequence diagram

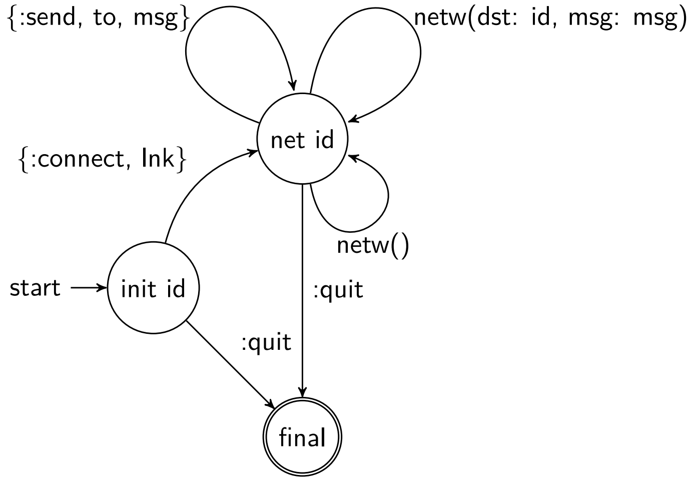


the network layer



The network layer will only forward messages with the right destination.

network process - a state diagram



the network process

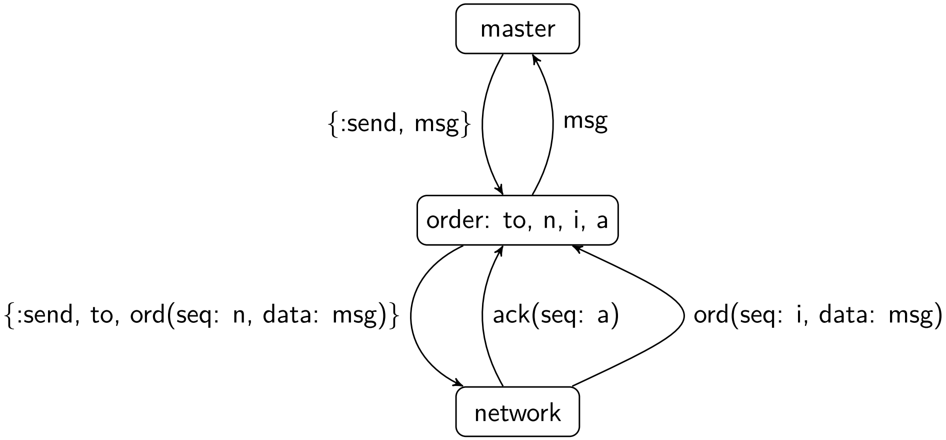
```
def network(master, id, link) do
   receive do
     {:send, to, msg} ->
       send(link, {:send, netw(src: id, dst: to,  data: msg)})
       network(master, id, link)

     netw(dst: ^id, data: msg) ->
       send(master, msg)
       network(master, id, link)

     netw() ->
       network(master, id, link)

     :quit ->
       :ok
   end
 end
```

order and reliability

A *communication channel* is a duplex flow of an ordered sequence of messages.

- add a sequence number to each message
- order messages as they arrive and
- resend lost messages

the order layer



master

{:send, msg}

msg

order: to, n, i, a

{:send, to, ord(seq: n, data: msg)}

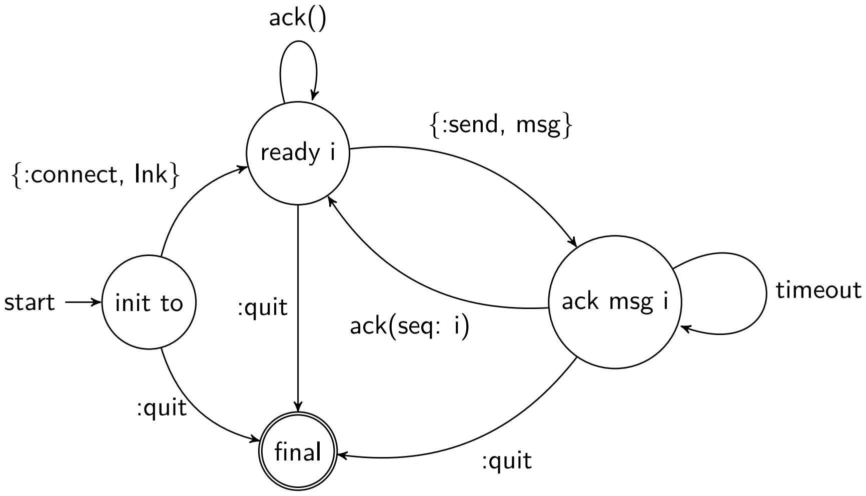
ack(seq: a)

ord(seq: i, data: msg)

network

The layer will need to buffer messages and use a timeout to detect missing datagrams.

the sending process - state diagram



ack()

{:send, msg}

ready i

{:connect, lnk}

start

init to

:quit

ack(seq: i)

ack msg i

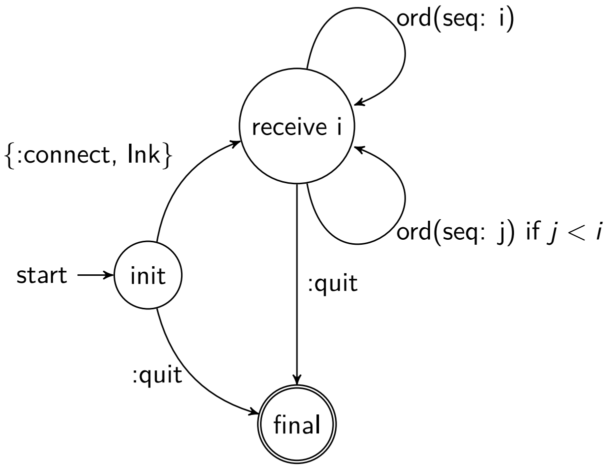
timeout

:quit

final

:quit

the receiving process - state diagram



ord(seq: i)

receive i

{:connect, lnk}

ord(seq: j) if $j < i$

start

init

:quit

:quit

final

the order process

```
def order(master, to, n, i, [], netw) do
  receive do
    ord(seq: ^i, data: msg) ->
      send(netw, {:send, to, ack(seq: i)})
      send(master, msg)
      order(master, to, n, i+1, [], netw)

    :

    {:send, msg} ->
      send(netw, {:send, to, ord(seq: n, data: msg)})
      order(master, to, n+1, i, [{n, msg}], netw);
  end
end
```

the order process

```
def order(master, to, n, i, [{a,res}|rest]=buffer, netw) do
  receive do
     :
    ack(seq: ^a) ->
      order(master, to, n, i, rest, netw)

     :

     :

  after 10 ->
      dgr = ord(seq: a, data: res)
      send(netw, {:send, to, dgr})
      order(master, to, n, i, buffer, netw)
  end
```

flow control

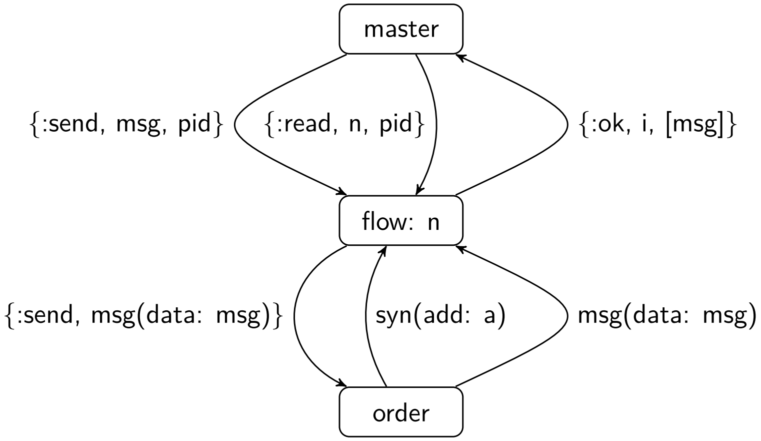
- do not overflow the receiver
- keep track of the reciever buffer size
- wait for the user to activly read messges

We are introducing a synchronous interface - only send if receiver prepared.

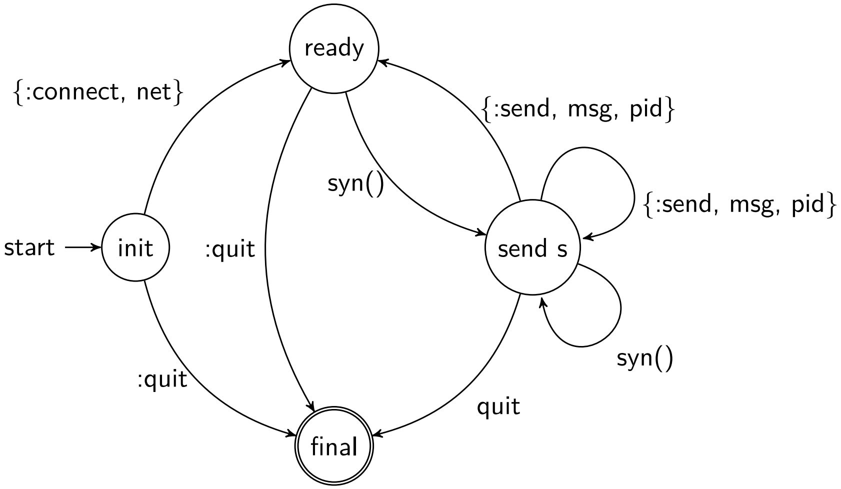
the flow control

- `{:send, msg, pid}`
- `{:read, n, pid}`
- `msg(data:  msg)`
- `syn(add:  a)`

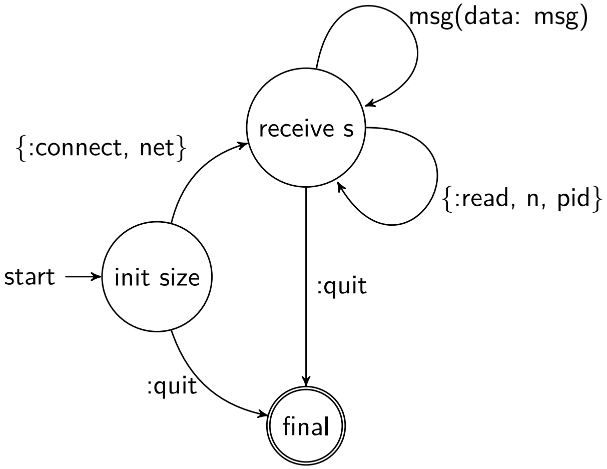
the flow control



the flow sending process



the flow receiving process



extensions

- What if the link layer could only send sequences of bytes?
- Can we add error detection in the link layer?
- Could we build a switch or router?

a switch

summary

- divide a service into processes
- layers of abstraction
- finite State Machine (FSM) description of a process
- sequence diagrams to show protocol
- asynchronous and synchronous interfaces

.. and hopefully, you have learned about communication stacks