ERICSSON

CONCURRENT PROGRAMMING XXL

Industrial Use of Erlang – Introduction

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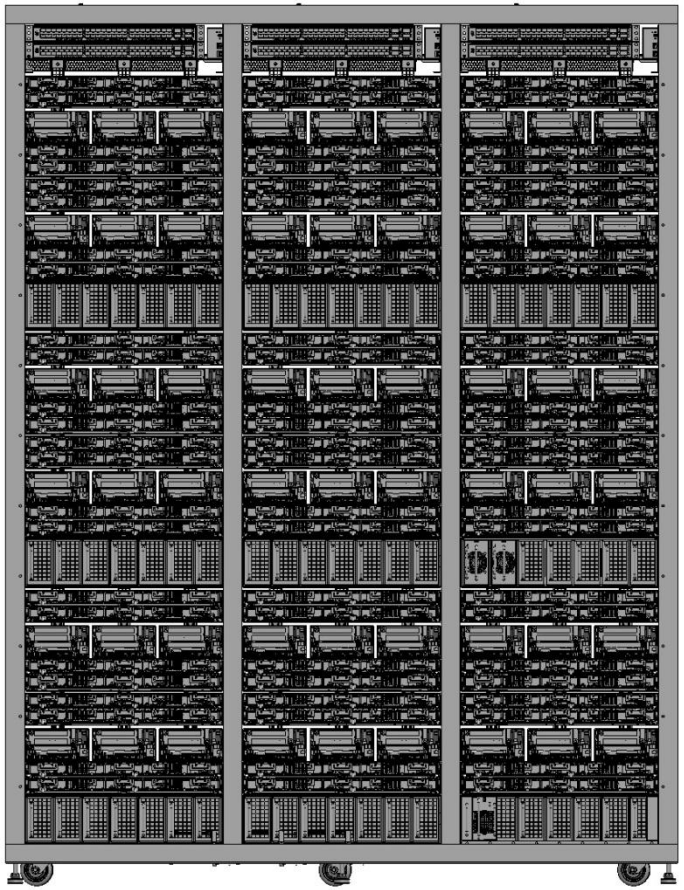
MOTIVATION – MACHINE

- Ericsson Blade System
  - 3 sub-racks
  - 14 blades
    - 2 routers
    - 12 compute nodes
  - 6 core Intel x86
    - 12 SMT threads total
  - 432 simultaneously running processes
  - Backplane: 1 or 10Gbps

MOTIVATION – MACHINE

- Open Compute System
  - New OpenRack design
  - Triplet rack
  - 3 sub-racks
  - 18 dual-CPU blades
  - 8 core Intel x86
    - 16 SMT threads total
  - 2592 simultaneously running processes



MOTIVATION – THE TASK

› *Design on of the following systems:*

› Payment transaction handling
› Instant messaging back-end
› Multi-player game back-end
› Cloud infrastructure message-passing middleware
› Cloud routing/switching
› Telephone exchange

MOTIVATION – CONSIDER

- What are the main challenges?
- What distinguishes those systems from others (see the picture on the right)?
- What tools might be appropriate?

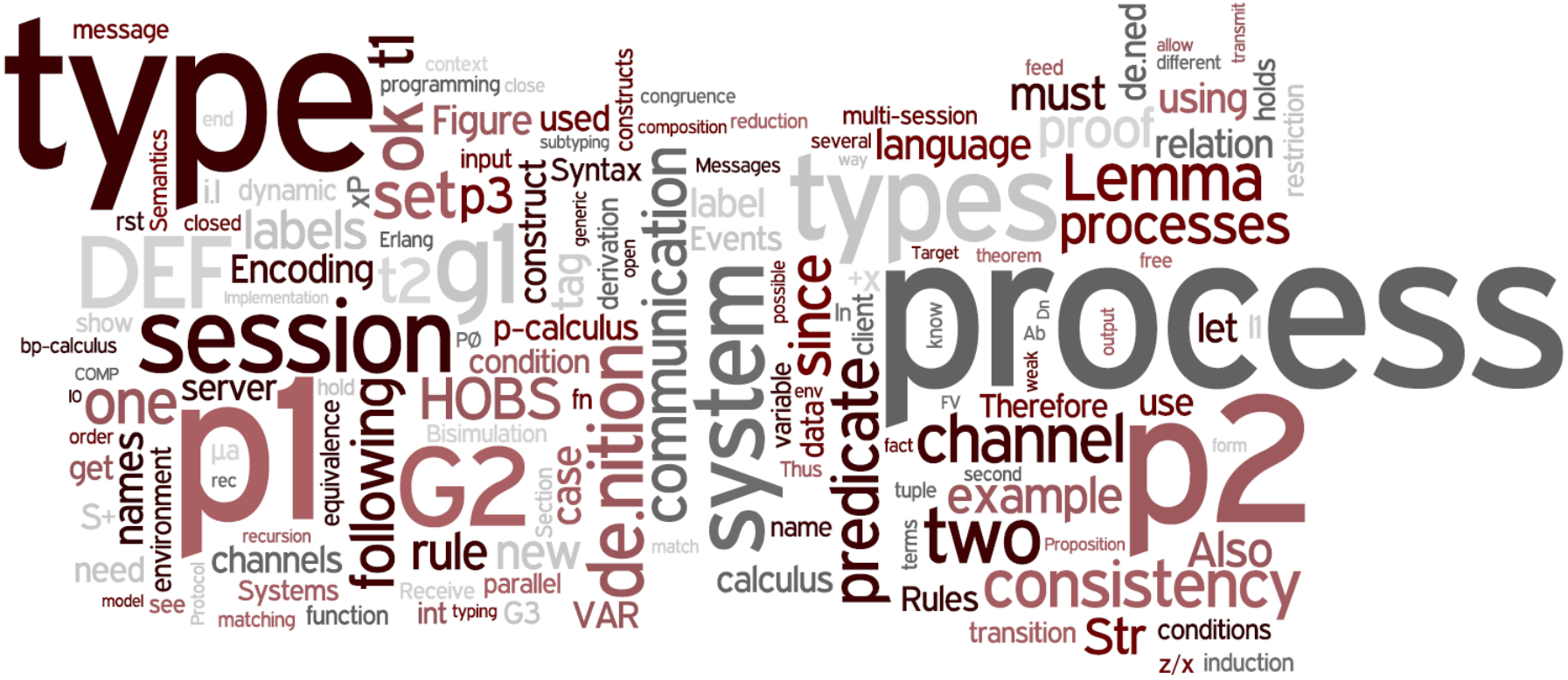
KAROL OSTROVSKÝ

- M.Sc. – Comenius University, Bratislava
- Ph.D. – Chalmers
- Post-doc – Chalmers
- System Designer – Dfind, on assignment at Ericsson
  - Operations & Maintenance Subsystem

MY CHALMERS YEARS

- Research in static analysis of concurrent programming languages
  - Type systems
  - Protocol analysis
- Main course responsible PPxT
  - Developed the course between 2005 and 2010

PHD THESIS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Rules
consistency
transition
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conditions
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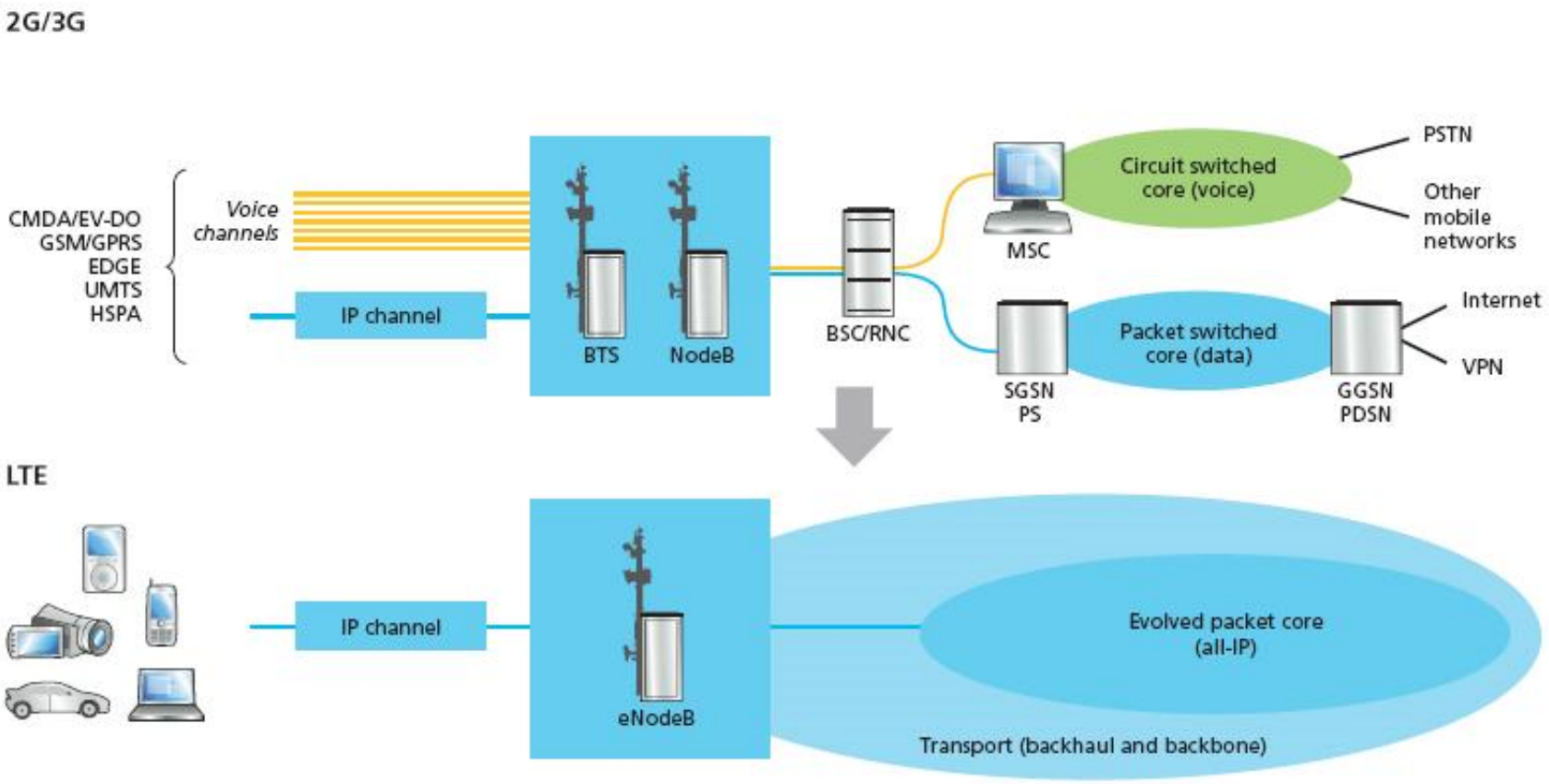
KO@ERICSSON

- Business Unit Networks
  - Development Unit IP and Broadband
    - Product Development Unit Packet Core
      - SGSN-MME
        - *O&M sub-system*
        - 2G sub-system
        - 3G sub-system
        - ...
      - EPG
      - CPG
      - ...

MOBILE TELECOM NETWORK



PACKET CORE NETWORK

- 3GPP
  - Defines standards (mostly protocols)
  - Interoperability is essential
- SGSN-MME
  - Servicing GPRS Support Node (2G/3G)
  - Mobility Management Entity (4G)
  - Control signalling
    - Admission control, Authentication
    - Mobility, roaming
  - Payload transport (not in 4G)

CHALLENGES

- Open *soft* real-time system
- Resilience
  - HW failures
  - SW failures
    - External
    - Internal
- Appropriate tools?

ENTER ERLANG

- Functional
- Concurrent
- Distributed
- “Soft” real-time
- OTP (fault-tolerance, hot code update…)
- Open
  - Check the source code of generic behaviours

RECURSION

```
-module(list_stuff).
-export([append/2, reverse/1]).

append([X|Xs], Ys) ->
   [X | append(Xs, Ys)];
append([],     Ys) ->
   Ys.

reverse([H|T]) ->
   append(reverse(T), [H]);
reverse([])    ->
   [].
```

TAIL RECURSION

```
-module(list_stuff).
-export([reverse/1, append/2]).

reverse(Xs) -> reverse_a(Xs, []).

reverse_a([X|Xs], Acc) ->
    reverse_a(Xs, [X|Acc]);
reverse_a([],     Acc) ->
    Acc.

%%continues
```

TAIL RECURSION

```
%%continuation

append(Xs, Ys) ->
    reverse_a(reverse(Xs),Ys).
```

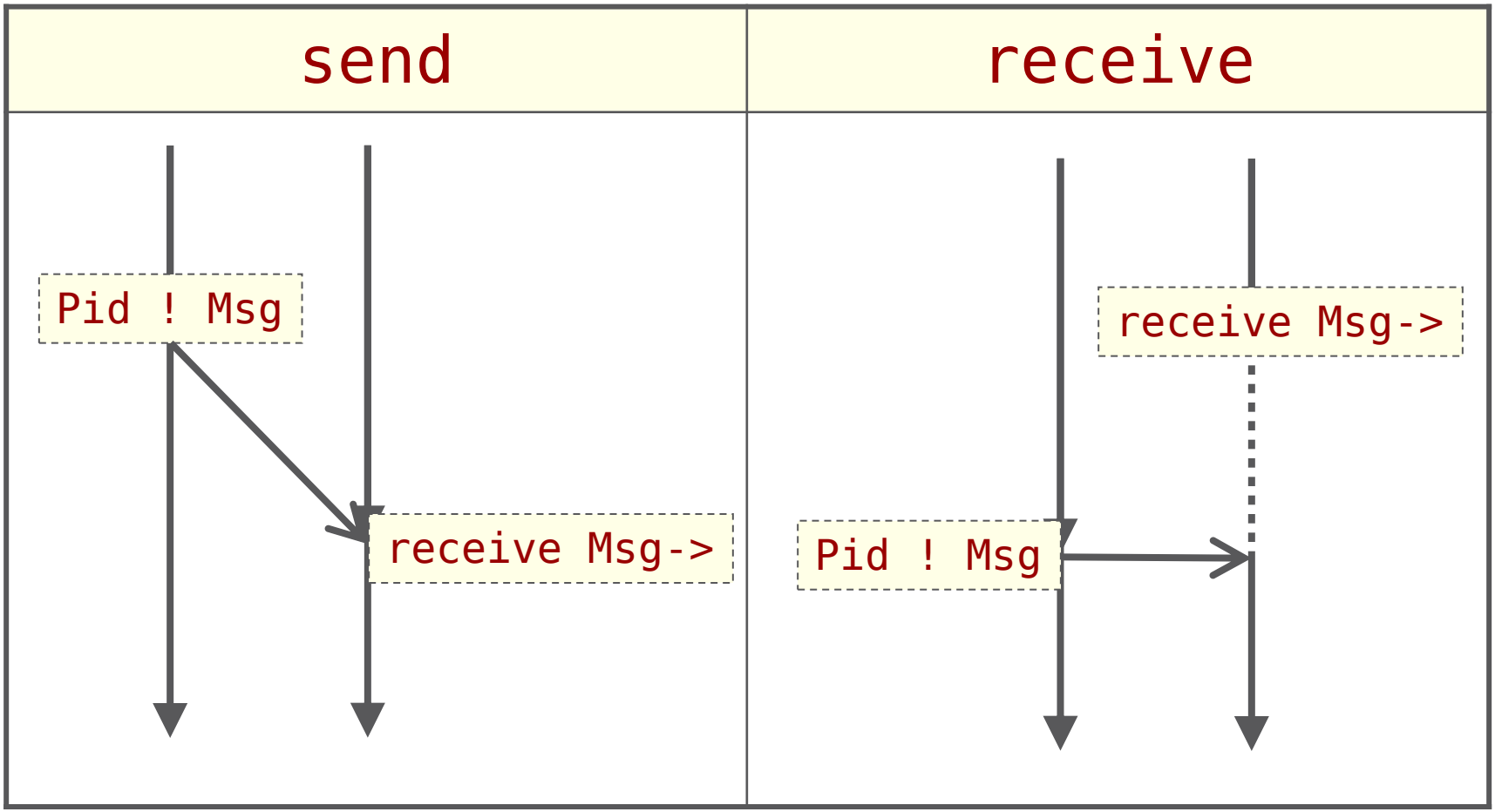
CONCURRENCY

- Based on Message Passing:
  - Q: What form of synchronisation?
  - A: Asynchronous

  - Q: What form of process naming?
  - A: Direct, asymmetric

ASYNCHRONOUS MP

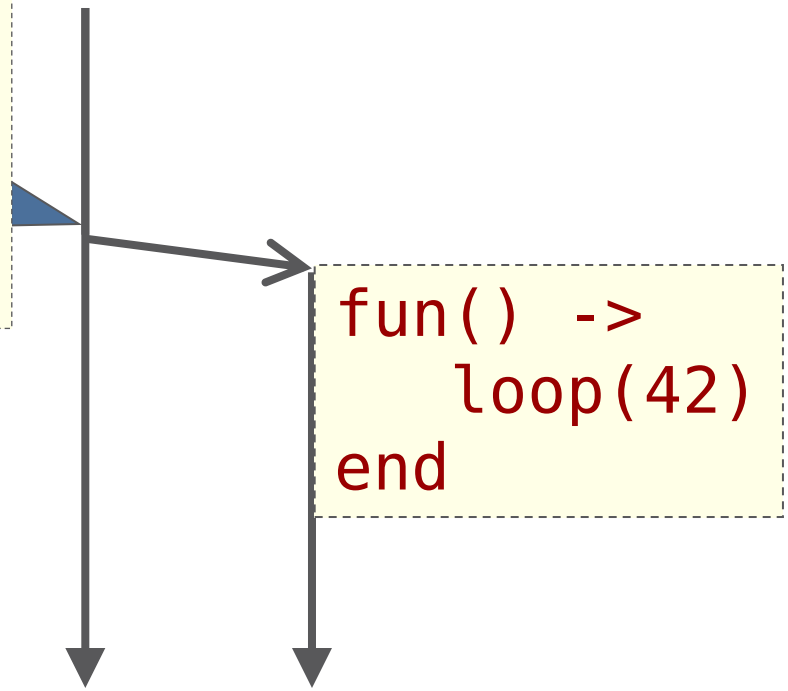
› Asynchronous send, receive from mailbox



CONCURRENT EXECUTION

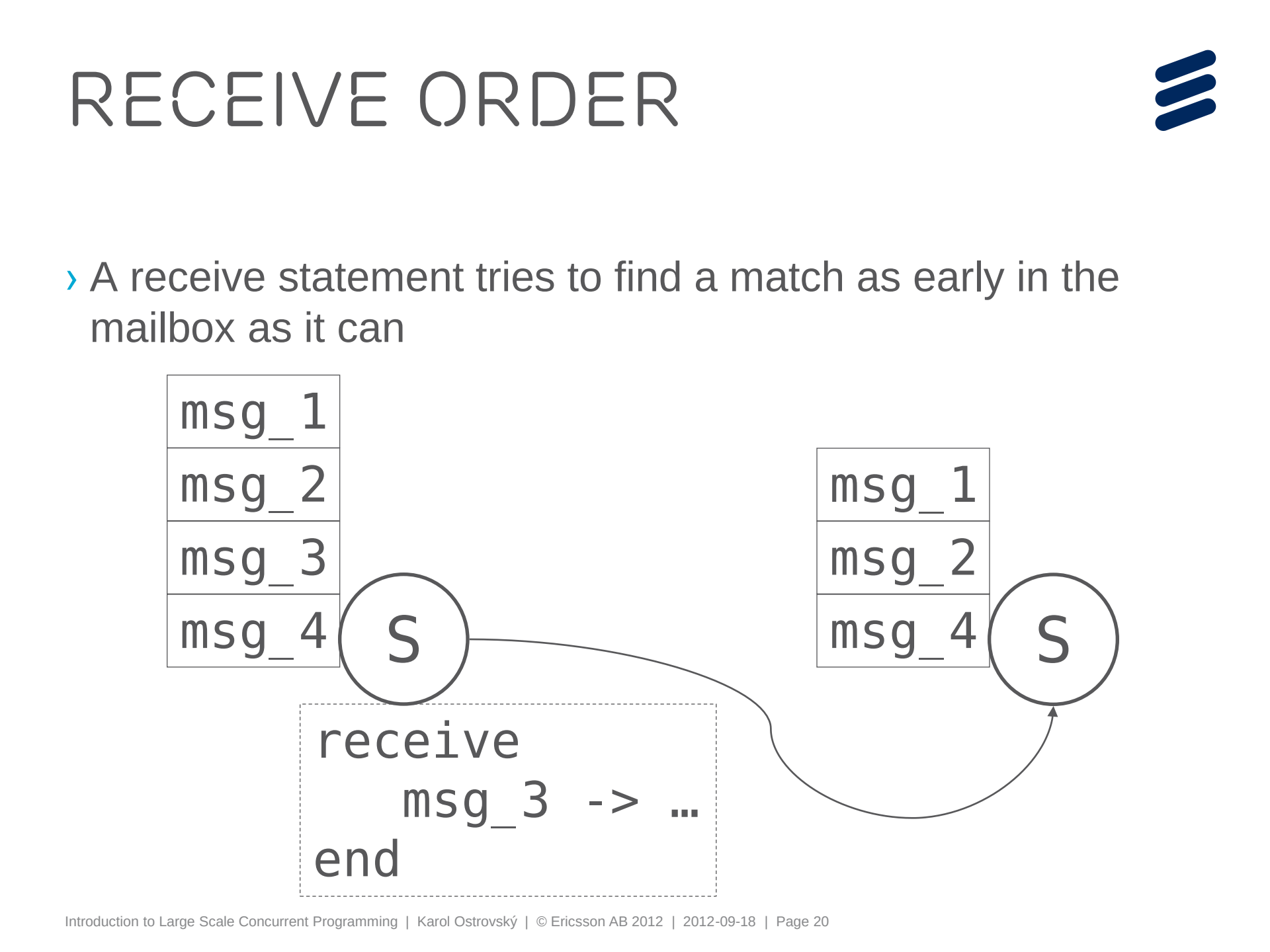
› Spawn a function evaluation in a separate thread

```
Pid = spawn(
          fun() ->
             loop(42)
          end)
```



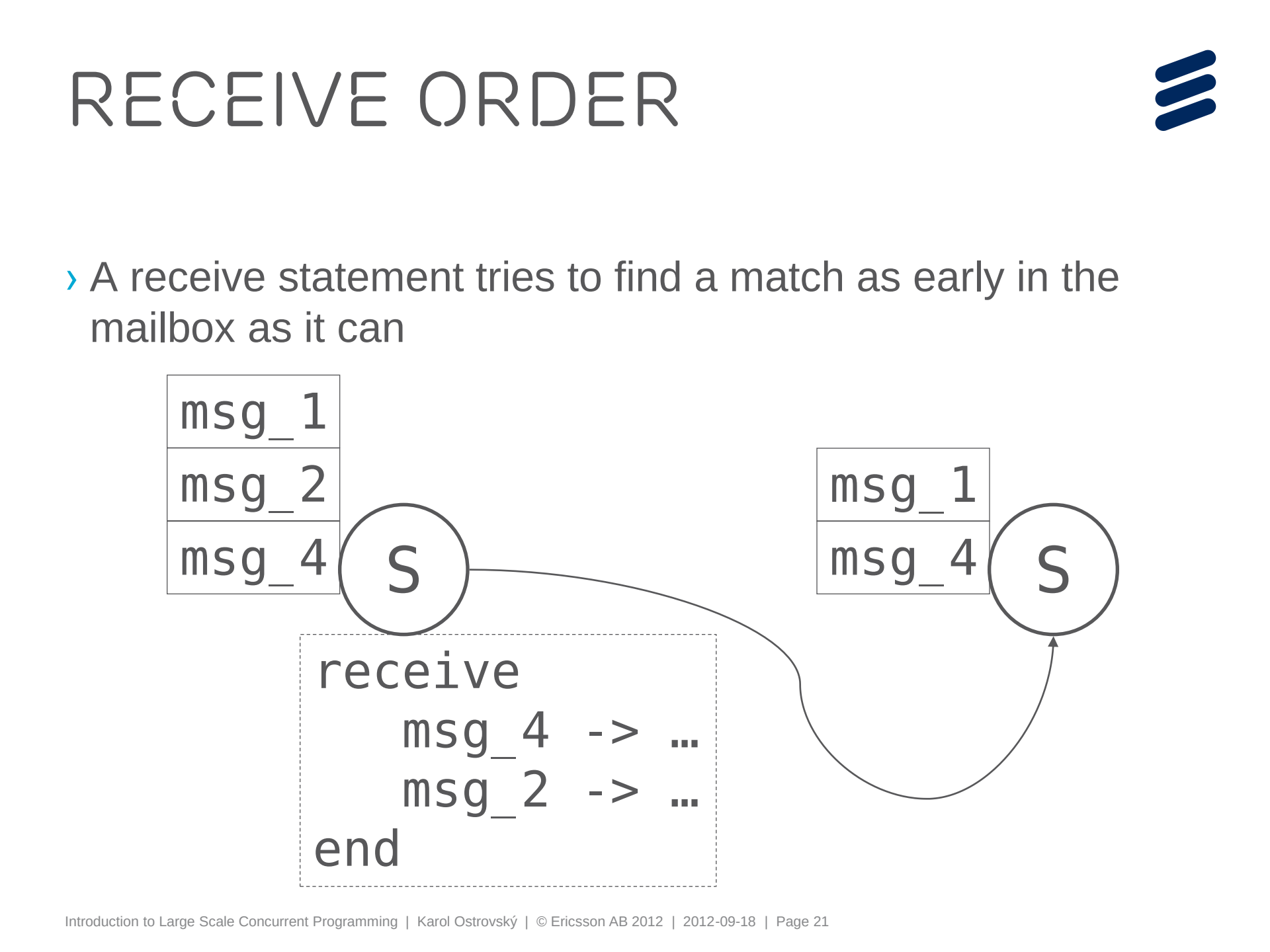
› Function must use constant space
  – Tail recursive

RECEIVE ORDER



› A receive statement tries to find a match as early in the mailbox as it can

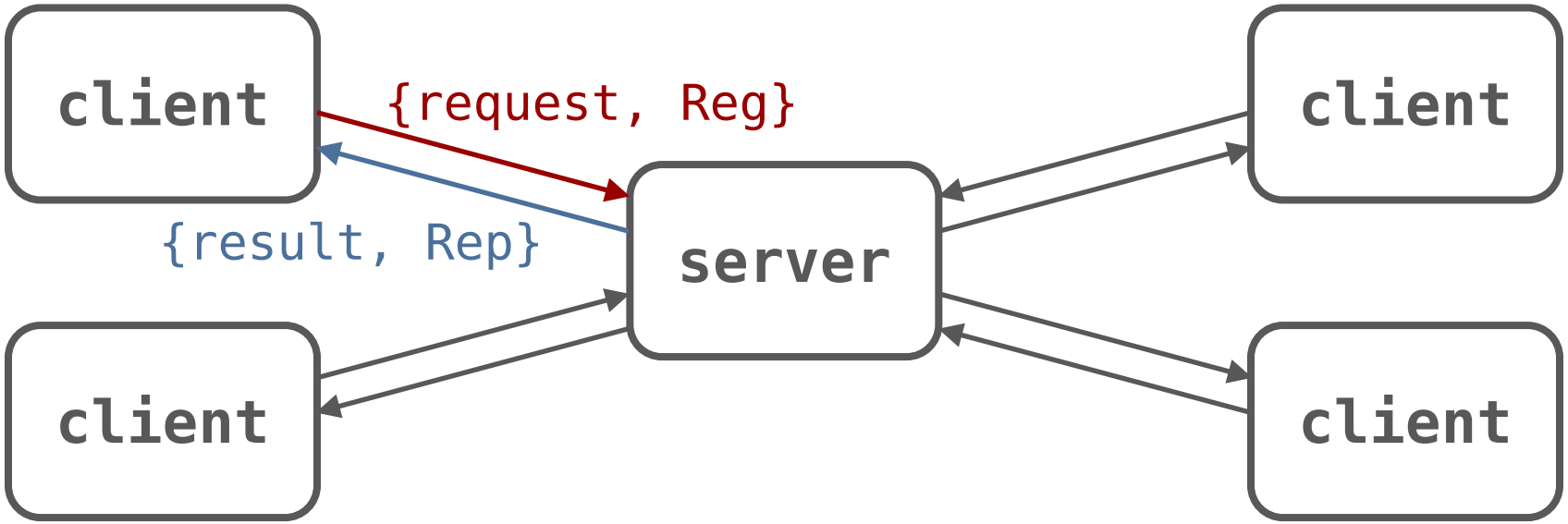
RECEIVE ORDER



› A receive statement tries to find a match as early in the mailbox as it can

CLIENT-SERVER

- Common asynchronous communication pattern
  - For example: a web server handles requests for web pages from clients (web browsers)



MODELLING C-S

- Computational server
  - Off-loading heavy mathematical operations
  - For example: factorial

```
-module(math_server).
-export([start/0]).
-export([compute_factorial/2,
         get_count/2]).
-export([loop/1]).

start() -> spawn(fun() -> loop(0) end).

%%continues
```

MAIN SERVER LOOP

```
%%continuation
loop(Count) ->
    receive
        {factorial, From, N} ->
            Result = factorial(N),
            From ! {result, Result},
            ?MODULE:loop(Count+1);
        {get_count, From} ->
            From ! {result, Count},
            ?MODULE:loop(Count);
        stop ->
            true
    end.
```

CLIENT INTERFACE

- Encapsulating client access in a function
- Private channel for receiving replies?

```
%%possible continuation
compute_factorial(Pid, N) ->
   Pid!{factorial, self(), N},
   receive
      {result, Result} ->
         Result
   end.
```

REFERENCES

- Private channel for receiving replies?
  - Find the corresponding reply in the mailbox

```
receive
    {result, Result} -> Result
end
```

- BIF `make_ref()`
  - Provides globally unique object different from every other object in the Erlang system including remote nodes

RPC – CLIENT INTERFACE

- References to uniquely identify messages
  - References allow only matching

```
%%usual continuation
compute_factorial(Pid, N) ->
    Ref = make_ref(),
    Pid!{factorial, self(), Ref, N},
    receive
        {result, Ref, Result} ->
            Result
    end.
```

RPC – MAIN SERVER LOOP

```
%%continuation
loop(Count) ->
    receive
        {factorial, From, Ref, N} ->
            Result = factorial(N),
            From ! {result, Ref, Result},
            ?MODULE:loop(Count+1);
        {get_count, From, Ref} ->
            From ! {result, Ref, Count},
            loop(Count);
        stop ->
            true
    end.
```

A GENERIC SERVER

- Desired features
- Proper reply behaviour — RPC
- Parameterised by the “engine” function F
- Allows the engine to be “upgraded” dynamically
- Robust: does not crash if the engine “goes wrong”

GENERIC CLIENT-SERVER

- Higher-order functions can be used to capture the design pattern of a client-server in a single module
  - The main engine of a server has “type”:

```
F(State, Data) -> {Result, NewState}
```

The state of the server before computing the query

The new state of the server after the query

GENERIC SERVER LOOP

```
loop(State, F) ->
   receive
      {request, From, Ref, Data} ->
         {R, NS} = F(State, Data),
         From ! {result, Ref, R},
         loop(NS, F);
      {update, From, Ref, NewF} ->
         From ! {ok, Ref},
         loop(State, NewF);
      stop ->
         true
   end.
```

CLIENT INTERFACE

› Generic client can make a generic request

```
request(Pid, Data) ->
    Ref = make_ref(),
    Pid!{request, self(), Ref, Data},
    receive
        {result, Ref, Result} ->
            Result
    end.
```

REGISTERED PROCESSES

- Centrally register a process under a name
  - BIF: `register(atom(), pid()) -> true`

```
start(Name, State, F) ->
    Pid = spawn(fun() ->
                    loop(State, F)
                end),
    register(Name, Pid),
    Pid.
```

REGISTERED PROCESSES

› Sending to a registered process

```
math_server ! stop.
```

› For registered processes the name is the same as its pid
  – Almost (subtle differences in error handling)

SERVER INSTANCE

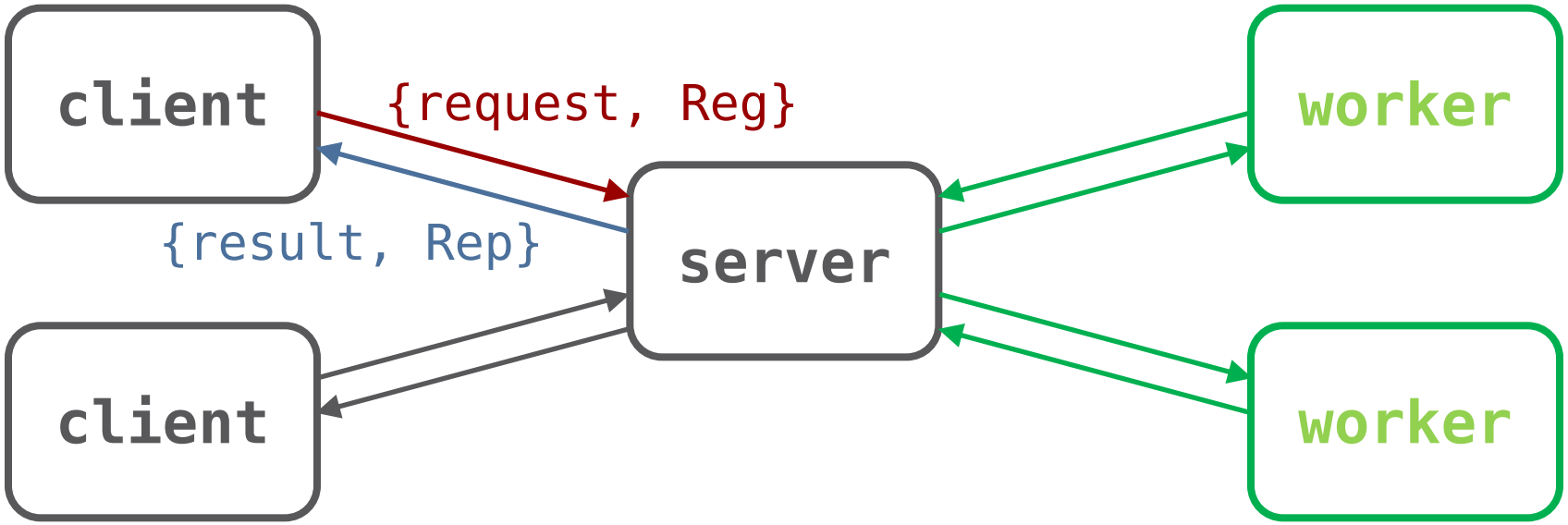
```
-module(g_math_server).
-export([start/0]).
-export([compute_factorial/1, get_count/0]).

start() ->
    g_server:start(
        math_server, 0, fun fx/2).

fx(Count, {factorial, N}) ->
    Result = factorial(N),
    {Result, Count+1};
fx(Count, get_count) ->
    {Count, Count}.
%%continues
```

SERVER INSTANCE

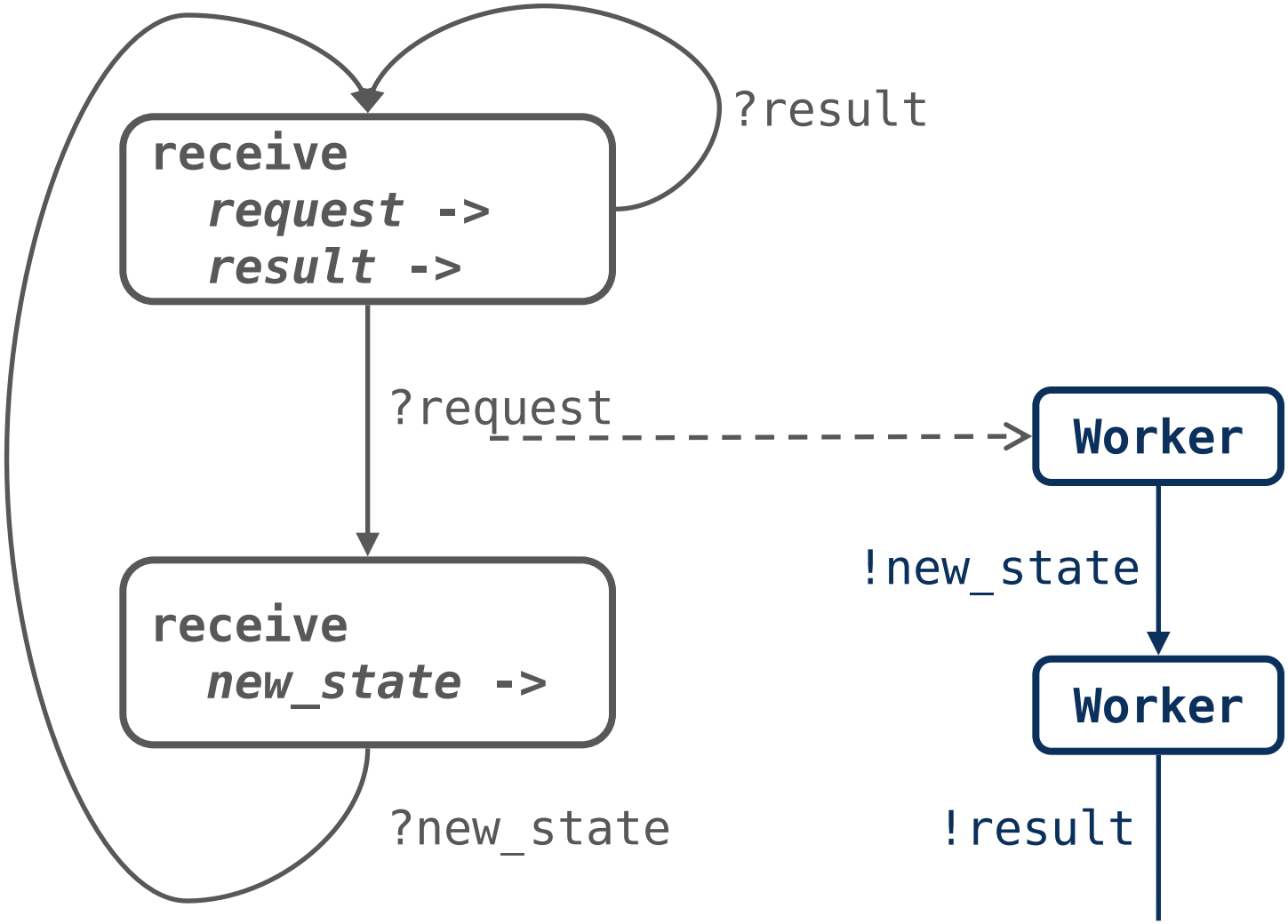
```
%%continuation

compute_factorial(N) ->
    g_server:request(math_server,
                     {factorial, N}).


get_count() ->
    g_server:request(math_server,
                     get_count).
```

PARALLELISED SERVER

- Compute the heavy computations in separate worker processes
  - New engine function
  - New error handling issues



STATE DIAGRAM



NEW ENGINE FUNCTION

- Higher-order functions can be used to capture the design pattern of a client-server in a single module
  - The engine function will run a as process
  - The main engine of a server has “type”:

```
F(State, Data, SPid, Ref) ->
 Proc()⟨
   SPid!{new_state,Ref,NewState},
   SPid!{result,Ref,Result}⟩
```

PARALLEL SERVER LOOP

```
loop(Count, F, Pending) ->
  receive
    {request, From, Ref, Data} ->
      Self = self(),
      Pid = spawn(
          fun() ->
            F(State, Data, Self, Ref)
          end),
      receive
        {new_state, Ref, NewState} ->
          ?MODULE:loop(NewState, F,
           [{From,Ref,Pid}|Pending]);
      end;
```

PARALLEL SERVER LOOP

```
  {result, Ref, Result} ->
     case keysearch(Ref, 2, Pending) of
       {value, {From, Ref, _}} ->
          From!{result, Ref, Result},
          ?MODULE:loop(State, F,
                       keydelete(Ref,2,Pending));
       false ->
          ?MODULE:loop(State,F,Pending)
     end;
  %% update and stop as before
end.
```

Module lists

DYNAMIC CODE UPDATE

- We want to update the running math server from V1 to the parallelised V2
  - Compile and load new version,
  - Send any message,
  - And the new loop code will be called
  - Problems?
    - New engine function type
    - New internal state (pending list)
    - loop/2 versus loop/3

DYNAMIC CODE UPDATE

› Updating the loop between versions

```
loop(OldState, OldF) ->
  io:format("This is V2 starting...~n",[]),
  loop(OldState,
       fun(State, Data, SPid, Ref) ->
         {Result,NewState} = OldF(State,Data),
         SPid!{new_state, Ref, NewState},
         SPid!{result, Ref, Result}
       end,
       []).
```

NEW MATH ENGINE

```
fx(Count, {factorial, N}, SPid, Ref) ->
    SPid!{new_state, Ref, Count+1},
    SPid!{result, Ref, factorial(N)};
fx(Count, get_count, SPid, Ref) ->
    SPid!{new_state, Ref, Count},
    SPid!{result, Ref, Count}.

update_fx() ->
    g_server:update(math_server,
                    fun fx/4).
```

ERLANG/OTP

- Framework for defining applications
- Defines several general behaviours, examples:
  - Servers
  - Finite state machines
  - Event handlers
  - Supervisors
  - Applications
- Behaviour captured once and for all
  - Remains to define application-specific functions,
  - Which are often without concurrency problems

ERLANG/OTP

- The main source
  - http://www.erlang.org/
- Excellent learning resource
  - http://learnyousomeerlang.com/
- Plenty of useful blogs and mailing lists

ERLANG – STRENGTHS

- Well suited for
  - Control handling of telecom traffic
  - Application layer (OSI model) applications
    - Web servers, etc.
  - Domain Specific Language – framework
    - Test scripting
- Reasonably high-level (as compared to for example C)
  - Good for software maintenance
- OTP – includes useful building blocks
  - Supervisor
  - Generic server
  - Finite state machine

ERLANG – WEAKNESSES

- A bit too low-level language
  - Given current HW limitations one must sometimes optimise to the point where the code is not portable (with the same performance)
  - Raise the abstraction and provide a customisable compiler, VM
- Where is the type system?
  - A static type system of Haskell-nature would be a hindrance
  - But good static analysis tools are desperately needed

THE MISSING SUBJECT

- Software maintenance
  - Software lives long
    - Especially telecom systems (decades)
    - Banking systems live even longer (think COBOL)
  - People change
  - Organisations change
  - Hardware changes
  - Requirements change
  - Documentation often *does not* change

MAINTENANCE

- The developer's challenge
  - Write simple (readable) and efficient code:
    1. Write a straightforward and working solution first
    2. Optimise later (or even better skip this step)
- Think smart but do not over-optimise
  - Optimisations complicate maintenance
- The code is often the only reliable document
  - Types can be very good documentation

SYNTHESIS VS. ANALYSIS

- Emphasis on synthesis so far
  - Software development
- Around 30% of manpower is spent on testing
  - Analytical work
  - Do you like to break a system?
- But testing can also be “synthetical”
  - Testing frameworks
    - Quickcheck
    - SGSN-MME has its own
  - Would you like to formally prove the system correct?

MORE THAN TRUE

Sayings

- The greatest performance improvement of all is when a system goes from not-working to working
- The only thing worse than a problem that happens all the time is a problem that doesn't happen all the time

MY FAVOURITE

The Message from this Course

- Should you forget everything from this course, please, remember at least this saying:

> Use the right tool for the job.

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