ERLANG

Functional Programming in industry

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Courtesy of Urban Boquist and Christer Nilsson (Ericsson Gothenburg)

Outline

- Mobile Telecommunications Networks
- Packet Core Network – GPRS, UMTS & SGSN
- Use of Erlang in SGSN
- SGSN Design Principles for Erlang:
  - concurrency
  - distribution
  - fault tolerance
  - overload protection
  - runtime code replacement
- Erlang basics and examples

Mobile Telecommunications Networks - GSM

Services in telecommunications networks:

CS – circuit switched

- voice
- SMS

PS – packet switched

- everything that is “IP”
- wap / www
- email
- MMS

GPRS - General Packet Radio Service

Packet Core Network

Radio Network | Packet Core Network

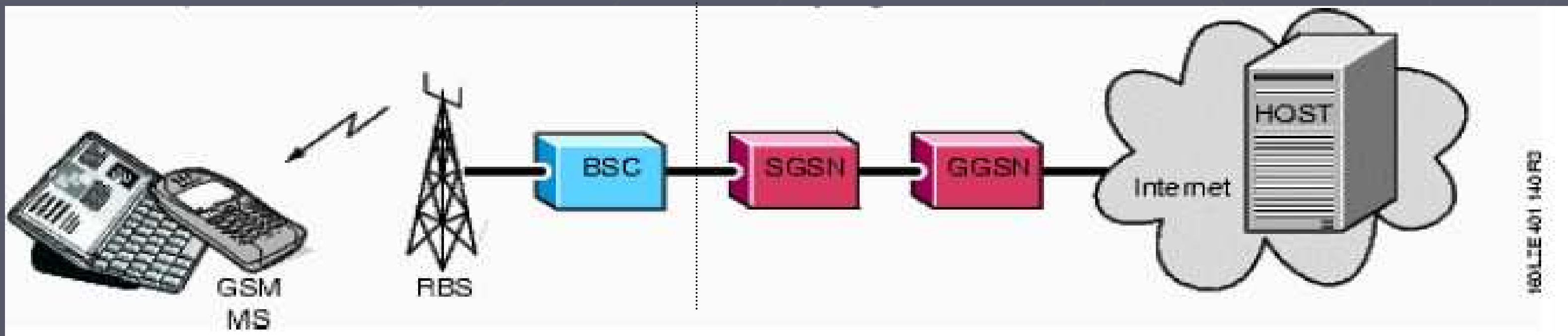


Figure: User Plane through the GSM network

- GSN (GPRS Support Network) nodes:
  - SGSN – Serving GSN
  - GGSN – Gateway GSN
- Basic throughput:
  - Up to 115 kbps with GPRS
  - Up to 240 kbps with EDGE – Enhanced Data Rates for GSM Evolution

PCN in "3G" and "Turbo-3G" – WCDMA and HSDPA

- Different Radio Network
- Packet Core Network (almost) the same as the one in GPRS
- Ericsson SGSN is "dual access" – GPRS and WCDMA in one
- Much higher (end user) speeds:
  Up to 384 kbps for 3G (WCDMA)
  Up to 14.4 Mbps for HSDPA (later up to 42 Mbit – Evolved HSPA)
- Voice / video calls are still CS!
- Streaming video is PS
  (TV == MBMS – Multimedia Broadcast Multicast Service)
- Future: voice / video in PS
- "Voice-over-IP"

Ericsson SGSN Node

Capacity

- ~ 50 k subscribers, 2000
- ~ 100 k subscribers, 2002
- ~ 500 k subscribers, 2004
- ~ 1 M subscribers, 2005
- ~ 2 M subscribers, 2008

SGSN – Basic Services

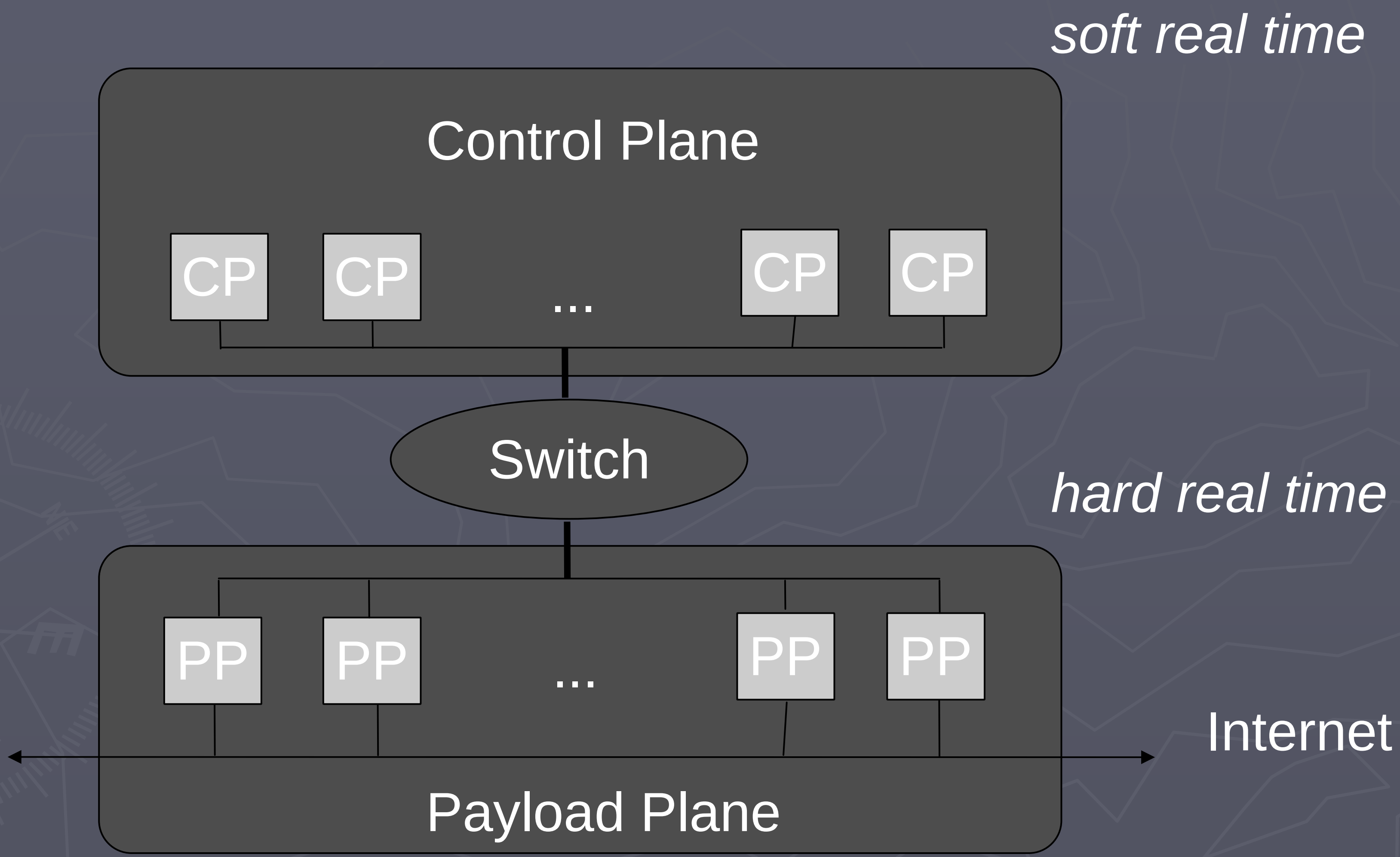
Control Signalling

- authentication
- admission control
- quality of service
- mobility
- roaming
- ...

Payload transport

- user traffic
- charging

SGSN Architecture



SGSN Hardware

- ≈ 20-30 Control Processors (boards):
  - UltraSPARC or PowerPC CPUs
  - 2 GB memory
  - Solaris/Linux + Erlang / C / C++
- ≈ 20-30 Payload Processors (boards):
  - PowerPC CPUs
  - Special hardware (FPGAs) for encryption
  - Physical devices: frame relay, atm, ...
  - VxWorks + C / C++
- Backplane: 1 Gbit Ethernet

SGSN Control Signalling

- attach (phone is turned on)
- israu (routing area update, mobility in radio network)
- activation (initiate payload traffic)
- etc. [hundreds of signals]

<u>Telecom standards are HUGE (see www.3gpp.org)!</u>

We need a high level language – concentrate on GPRS, not on programming details!

Erlang/OTP

- Invented at Ericsson Computer Science Lab in the 1980s.
- Intended for large scale reliable telecom systems.
- Erlang is:
  - functional language
  - with built-in support for concurrency
- OTP (Open Telecom Platform)
  == Erlang + lots of libraries.

Why Erlang?

- Good things in Erlang:
  - built-in concurrency (processes and message passing)
  - built-in distribution
  - built-in fault-tolerance
  - support for runtime code replacement
  - a dynamic language
  - a dynamically typed language
- This is exactly what is needed to build a robust Control Plane in a telecom system!

In SGSN:

- Control Plane Software is not time critical (Erlang)
- User Plane (payload) is time critical (C)

Erlang – Concurrency

- "Normal" synchronization primitives - semaphores or monitors
  - does not look the same in Erlang
  - instead everything is done with processes and message passing.
- Mutual exclusion:
  - use a single process to handle resource
  - clients call process to get access.
- Critical sections:
  - allow only one process to execute section

Erlang - Distribution

- General rule in SGSN:
  - avoid remote communication or synchronization if possible
- Design algorithms that work independently on each node:
  - fault tolerance
  - load balancing
- Avoid relying on global resources
- Data handling:
  - keep as much locally as possible (typically traffic data associated with mobile phones)
  - some data must be distributed / shared (e.g. using mnesia)
  - many different variants of persistency, redundancy, replication

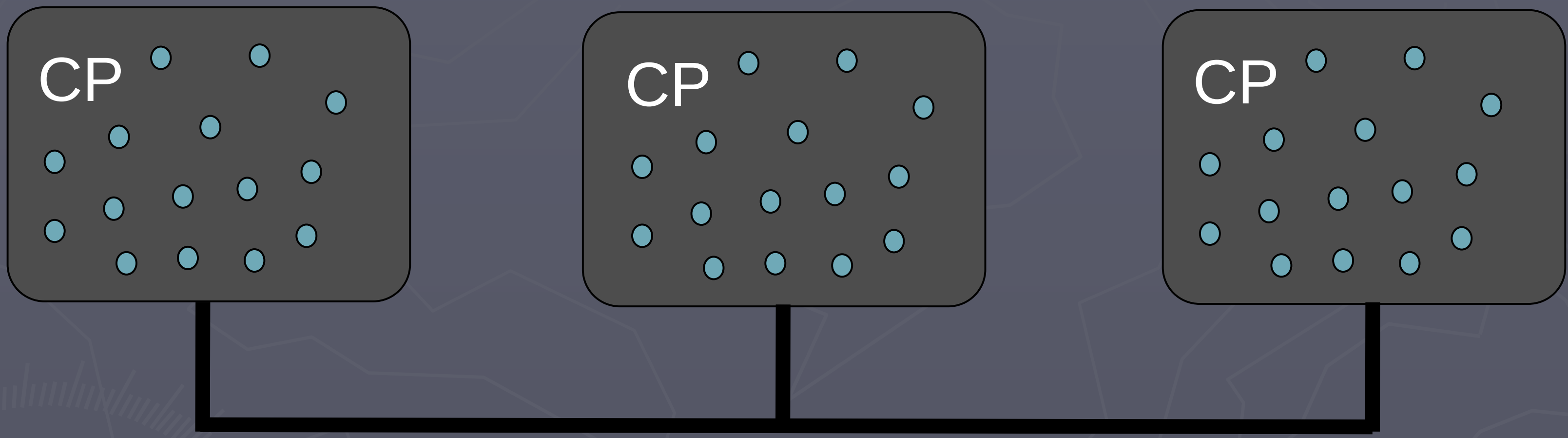
Fault Tolerance

- SGSN must never be out-of-service! (99.999%)
- Hardware fault tolerance
  - Faulty boards are automatically taken out of service
  - Mobile phones automatically redistributed
- Software fault tolerance
  - SW error triggered by one phone should not affect others!
  - Serious error in “system SW” should affect at most the phones handled by that board (not the whole node)

How can such requirements be realized?

Example: the SW handling one phone goes crazy and overwrites all the memory with garbage.

SGSN Architecture – Control Plane



- On each CP ≈ 100 processes providing “system services”
  - “static workers”
- On each CP ≈ 50.000 processes each handling one phone
  - “dynamic workers”

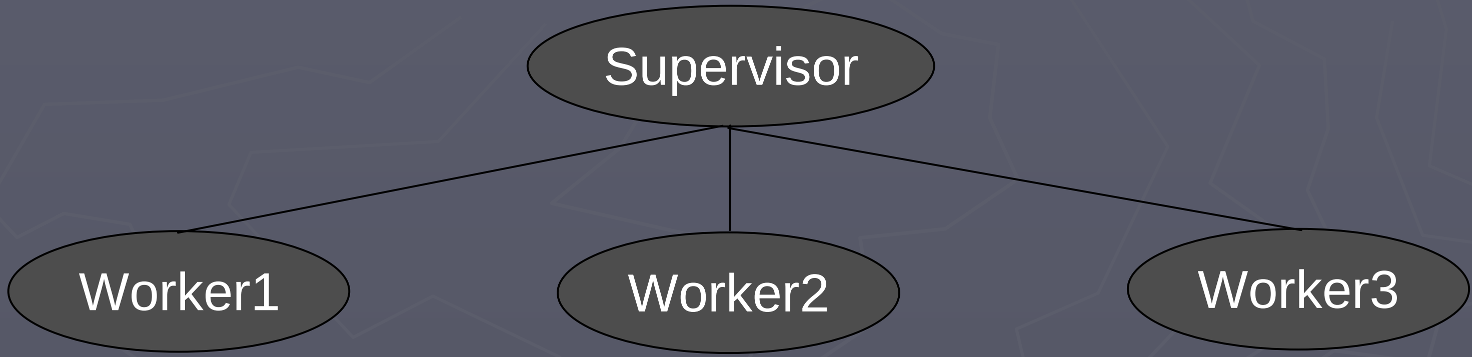
Dynamic workers

- System principle:
  - one Erlang process handles all signalling with a single mobile phone
- When a signal received in payload plane:
  - payload plane translates a “signal” from the mobile phone into an Erlang message
  - then sends it to the correct dynamic worker, and vice versa
- A worker has a state machine:
  - receive a signal – do some computation – send a reply signal
  - a little bit like an Entity Bean in J2EE

Dynamic workers cont.

- A process crash should never affect other mobiles:
  - Erlang guarantees memory protection
- SW errors in SGSN:
  - lead to a short service outage for the phone
  - dynamic worker will be restarted after the crash
- Same for SW errors in MS:
  - e.g. failure to follow standards will crash dynamic worker (offensive programming)

Supervision and Escalation



- Crash of worker is noticed by supervisor
- Supervisor triggers “recovery action”
- Either the crashed worker is restarted

  or
- All workers are killed and restarted

Runtime code replacement

- Fact: SW is never bug free!
- Must be able to install error corrections into already delivered systems without disturbing operation
- Erlang can load a new version of a module in a running system
- Be careful!
  Code loading requires co-operation from the running SW and great care from the SW designer

Overload Protection

- If CPU load or memory usage goes to high SGSN will not accept new connections from mobile phones
- The SGSN must never stop to “respond” because of overload, better to skip service for some phones
- Realized in message passing - if OLP hits messages are discarded:
  - silently dropped
  - or a denial reply generated

Erlang basic syntax

- Erlang shell :

```
erl
```

- Modules and Functions:

```
-module(my_mod).
-export(double/1).

double(X) -> 2 * X.
```

- Calling double/1:

```
my_mod:double(4).
```

- Atoms:

```
cat, dog, home, a2 ..
```

- Tuples :

```
{1,2,cat,home}
```

- Lists :

```
[{1,2,cat,home},1,2,3]
```

- Variables :

```
A = {2,3,horse,stable}.
B = [{1,2,cat,home},1,2,3].
Var = [A|B].
```

- Writing to output:

```
io:format(“Hello world”).
```

Erlang syntax - case and functional clause

- Case clause - case and pattern matching:

```
…
Loc =
  case Var of
    {_,_,cat,X} -> io:format(“Hello Cat”),X;
    {_,_,horse,X} -> io:format(“Hello Horse”),X;
    _ -> io:format(“No entrance”),none
  end.
…
```

- Function clause:

```
…
hello({_,_,cat,X}) -> io:format(“Hello Cat”),X;
hello({_,_,horse,X}) -> io:format(“Hello Horse”),X.
hello(_) -> io:format(“No entrance”),none.
…
```

Erlang syntax - Recursion

- Simple:

```
-module(fact).
-export([fact1/1]).

fact1(0) ->
  1;
fact1(N) ->
  N*fact1(N-1).
```

- Optimal - tail recursive:

```
-module(fact).
-export([fact2/1]).

fact2(N) ->
  fact2(N,1).
fact2(0,A) ->
  A;
fact2(N,A) ->
  fact2(N-1,N*A).
```

Erlang advanced syntax

- Dynamic code:

```
…
Fun = fun(Var)
  case Var of
    {_,_,cat,X} -> io:format(“Hello Cat”),X;
    {_,_,horse,X} -> io:format(“Hello Horse”),X;
     _ -> io:format(“Not welcome here”),none
  end.
…
```

Calling Fun:

```
Fun({1,2,cat,home}).
```

Passing Fun to another function:

```
call_fun(Fun,[]) -> ok;
call_fun(Fun,[X|T]) -> Fun(X), call_fun(Fun,T).
…
List = [{1,2,cat,home},{2,3,horse,stable}].
call_fun(Fun,List).
```

Erlang message passing

sender:

```
…
Pid ! Msg,
…
```

receiver:

```
…
receive
    Msg ->
        <action>
end,
…
```

Example cont. - gen_server

sender:

```
…
Ret = gen_server:call(Pid, Msg),
…
```

receiver:

```
handle_call(Msg) ->
    case Msg of
        {add, N} ->
            {reply, N + 1};
        ...
    end.
```

What about ”functional programming”?

- Designers implementing the GPRS standards should not need to bother with programming details.
- Framework code offers lots of ”abstractions” to help out.
- Almost like a DSL (domain specific language).
- To realize this, functional programming is very good!

- But to summarize: FP is a great help – but not vital. Or?

Conclusions

Pros:

- Erlang works well for GPRS traffic control handling
- High level language – concentrate on important parts
- Has the right capabilities:
  - fault tolerance
  - distribution
  - ...

Cons:

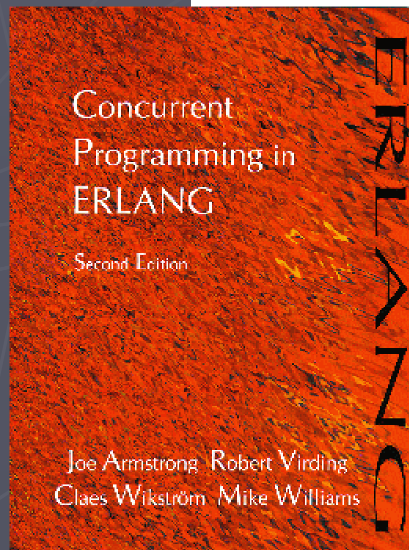
- Hard to find good Erlang programmers
- Erlang/OTP not yet a main stream language
  - Insufficient programming environments (debugging, modelling, etc)
  - Single implementation maintained by too few people - bugs
- High level language – easy to create a real mess in just a few lines of code...

Links and References

- Erlang site:
  http://www.erlang.org
- Erlang User Conference (Nov 2008)
- Erlang Community:
  http://trapexit.org
- Erlang group on LinkedIn

Books

- J. Armstrong
  "Programming Erlang"
- J. Armstrong, R. Virding, C. Wikström, M. Williams
  "Concurrent Programming in Erlang"



Questions?