University of Glasgow

RELEASE

Scalable Distributed Erlang

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December 4, 2013

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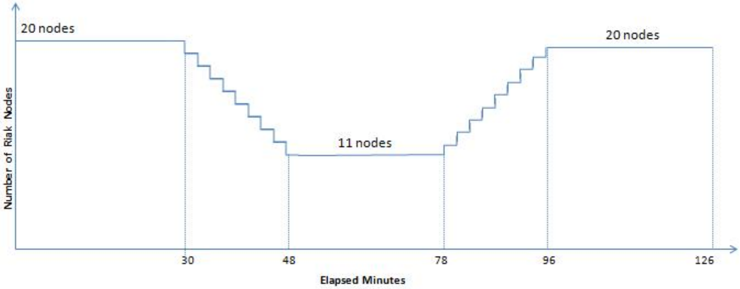
Erlang SOLUTIONS

Outline

1. Distributed Erlang
2. Scalable Distributed Erlang (SD Erlang)
3. SD Erlang Orbit
4. Semi-Explicit Placement

Why Distributed Erlang?

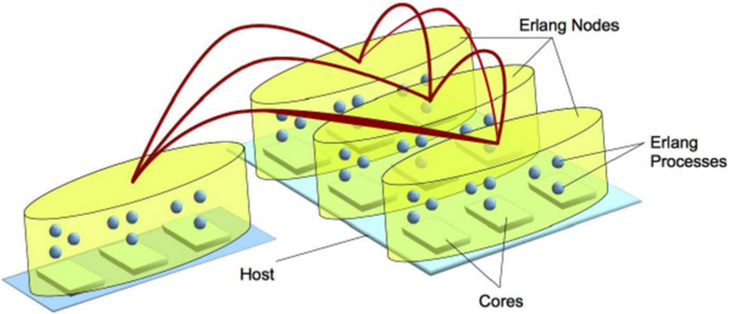
- **Reliability:** multiple hardware and software redundancy means that if one Host or Node fails, other Nodes can continue to deliver service
- **Scalability:** can only scale to around 100 cores on one Host (Node). Many systems use 1000s or 10000 cores



Distributed Erlang

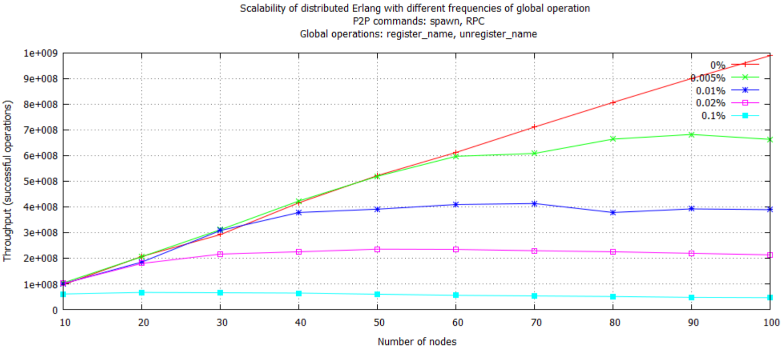
- Transitive connections
- Explicit Placement, i.e.

```
spawn(Node, Module, Function, Args) → pid()
```



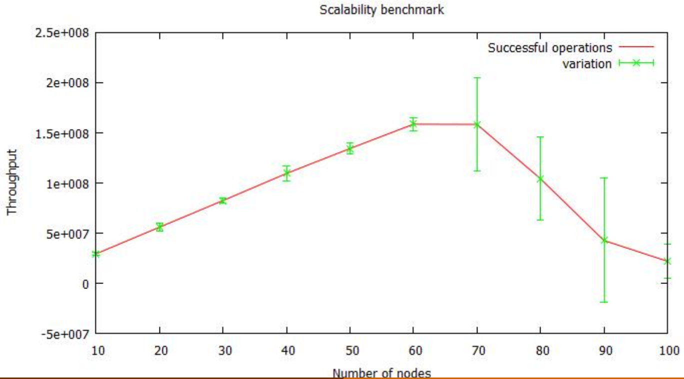
Distributed Erlang Scalability Limitations (1)

- Global operations, i.e. registering names using `global` module
- Other global operations, e.g. using `rpc:call` to call multiple nodes



Distributed Erlang Scalability Limitations (2)

- Single process bottlenecks, e.g. overloading `gen_server`'s `rec` process
- All-to-all connections (no evidence yet)



Why Orbit[LN01]?

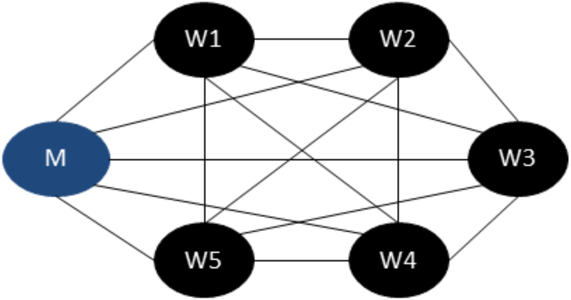
- Uses a Distributed Hash Table (DHT) similar to NoSQL DBMSs like Riak [Bas13], i.e. the hash of a value defined where the value should be stored
- Uses standard P2P techniques and credit/recovery distributed termination detection algorithm [MC98]
- Is only a few hundred lines and has a good performance and extensibility

Orbit in Distributed Erlang

Main components: `master.erl`, `worker.erl`, `table.erl`, `credit.erl`

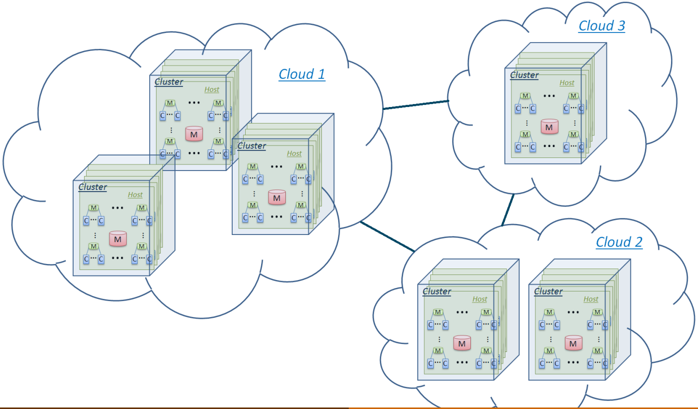
× Pid = spawn_link(worker, init, [TabSize, TmOut, SpawnImgComp])

✓ Pid = spawn_link(Node, worker, init, [TabSize, TmOut, SpawnImgComp])



Typical Target Architecture - 10^5 cores

- Commodity hardware
- Non-uniform communication
  (Level0 – same host, Level1 – same cluster, etc)

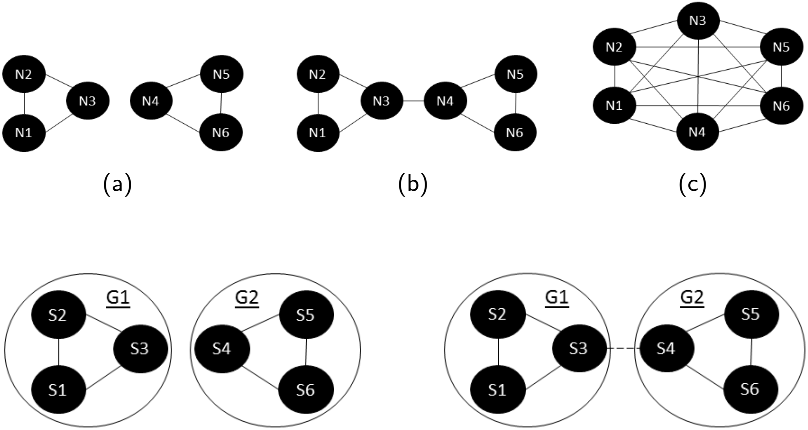


SD Erlang Overview

SD Erlang is a small conservative extension of Distributed Erlang

1. **Network Scalability**
   - Types of nodes
     - Free nodes (normal or hidden) belong to *no s_group*
     - S_group nodes belong to *at least one s_group*
   - Nodes in an s_group have transitive connections only with nodes from the same s_groups, but non-transitive connections with other nodes
2. **Semi-Explicit Placement**

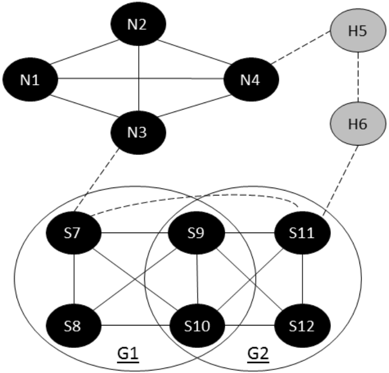
Free Node Connections vs. S_group Node Connections



(a) (b) (c)

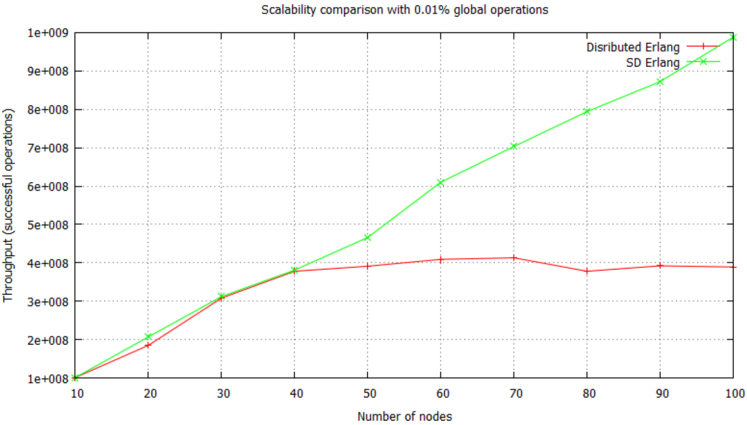
(d) (e)

Types of Connections between Different Types of Nodes



Transitive connection ———
Non-transitive connection --------

SD Erlang Improves Scalability



S_group Functions

s_group:new_s_group/1,2

```
new_s_group([Node]) → {SGName, Nodes} | {error, Reason}
new_s_group(SGName, [Node]) → {SGName, Nodes} | {error, Reason}
```

s_group:delete_s_group/1

```
delete_s_group(SGName) → 'ok' | {error, Reason}
```

s_group:add_nodes/2

```
add_nodes(SGName, Nodes) → {ok, SGName, Nodes} | {error, Reason}
```

s_group:remove_nodes/2

```
remove_nodes(SGName, Nodes) → 'ok' | {error, Reason}
```

Additional SD Erlang Functions

S_group Information

`s_groups/0, own_nodes/0, own_nodes/1, own_s_groups/0, info/0`

Name Registration

`register_name/3, unregister_name/2, re_register_name/3`

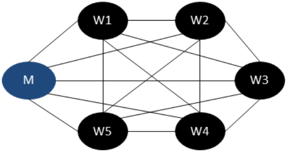
Searching and Listing Names

`registered_names/1, whereis_name/2, whereis_name/3`

Sending Message to a Process

`send/3, send/4`

Distributed Erlang Orbit vs. SD Erlang Orbit



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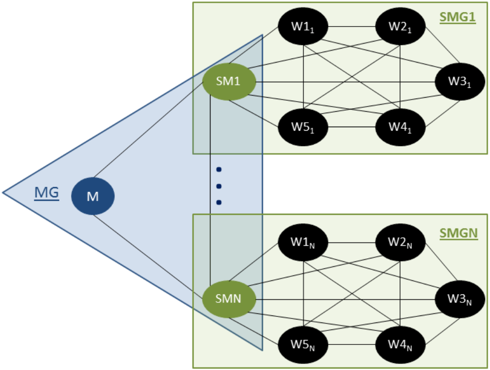


(g)

Distributed Erlang Orbit → SD Erlang Orbit

Distributed Erlang Orbit:

- `master.erl, worker.erl, table.erl, credit.erl`

SD Erlang Orbit:

- `master.erl, worker.erl, table.erl, credit.erl`
- + `submaster.erl, grouping.erl`

Details of the differences between the files can be checked by using, for example, `diff module1 module2` unix function

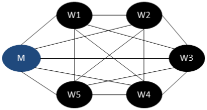
master.erl

Distributed Erlang Orbit

- Spawns worker processes

SD Erlang Orbit

- Spawns submaster and gateway processes



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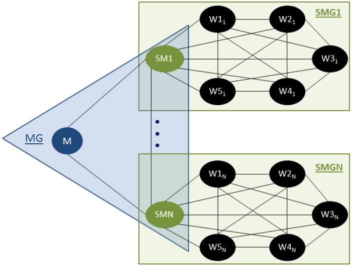


(i)

SD Erlang master.erl

Distributed Erlang

```
start_workers([{Node, M, TabSize, TmOut, SpawnImgComp} | Hosts],
              {Workers, GTabSize}) ->
...
    Pid = spawn_link(Node, worker, init, [TabSize, TmOut, SpawnImgComp]),
...
```

SD Erlang

```
start_submasters([{Node, GroupName, TabSize} | Sub_masters],
                 {Group_Hash_Tab, GlobalSize},
                 {Gs, Xs, P, Timeout, Spawn, Credit}) ->
...
    Pid = spawn_link(Node, sub_master, init,
                     [Gs, Xs, P, Timeout, Spawn, Credit, self(), GroupName]),
    Gateway = spawn_link(Node, sub_master, gateway, []),
...
```

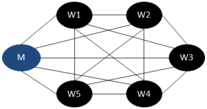
worker.erl

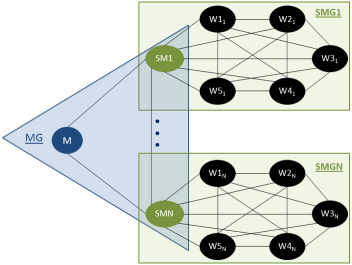
Distributed Erlang Orbit

- Sends a message with vertex X directly to the target process

SD Erlang Orbit

- Sends a message with vertex X directly to the target process only if the process is in the own s_group, otherwise sends it to a gateway process





SD Erlang worker.erl

Distributed Erlang

```
hash_vertex(StaticMachConf, X) ->
...
    %% Translate global slot into worker pid and local slot
    global_to_local_slot(Workers, GlobalSlot).
```

SD Erlang

```
hash_vertex(StaticMachConf, X, K) ->
...
    case (GlobalSlot < Start) orelse (GlobalSlot >= End+TabSize) of
        true ->   %% X should be sent to another s\_group
            Gateway = master:get_gateway(StaticMachConf),
            Gateway ! {X, K},
            ok;
        _Else ->   %% translate global slot into worker pid and local slot
            global_to_local_slot(Workers, GlobalSlot)
    end.
```

SD Erlang submaster.erl (1)

- Initiates submaster and gateway processes
- Submaster processes start worker processes

```
start_workers([{Node, TabSize}|Hosts], {Workers, GTabSize}) ->
    Pid = spawn_link(Node, worker, init, [TabSize]),
...
```

- Submaster processes transfer credit from Worker processes to the Master Process

```
collect_credit(MasterID) ->
    receive
        {done, Credit} ->
            MasterID ! {done, Credit},
            collect_credit(MasterID);
    ...
    end.
```

SD Erlang submaster.erl (2)

- Gateway processes receive {Vertex, Credit} pair and identify its corresponding s_group

```
do_gateway(Group_Hash_Table, StaticMachConf) ->
    receive
        {X, K} ->
            ...
            Gateways = find_gateway(Group_Hash_Table, GlobSlot),
            case Gateways of
                not_found_appropriate_gateway ->
                    throw("not_found_appropriate_gateway");
                _Else ->
                    case lists:member(self(), Gateways) of
                        true  ->
                            %% X belongs to the current s_group
                            %% Forward to the own Worker process
                        _Else ->
                            %% X belongs to another s_group
                            %% Forward to another s_group Gateway
                    end
            end,
...
```

SD Erlang grouping.erl

- Creation of s_groups on Submaster nodes

```erlang
make_group([Submaster|Workers], Counter) ->
    spawn(Submaster, grouping, create_group,
          [self(), [Submaster|Workers], Counter]),
    receive GroupName -> {Submaster, GroupName} end.

create_group(Master, Nodes, Counter) ->
    FixedName = group,
    GroupName = list_to_atom(atom_to_list(FixedName)++integer_to_list(Counter)),
    try
        {ok, GroupName, _Nodes} = s_group:new_s_group(GroupName, Nodes),
        Master ! GroupName
    catch
        _:_ -> sderlang_is_not_installed
    end.
```

- Creation of the master s_group, i.e.

```erlang
    s_group:new_s_group(master_group, [MasterNode|SubmasterNodes]),
```

Semi-Explicit Placement Functions

choose_nodes/1

```
s_group:choose_nodes([Parameter]) -> [Node]
where
     Parameter = {s_group, SGroupName} | {attribute, AttributeName}
     SGroupName = group_name()
     AttributeName = term()
```

Attribute Functions

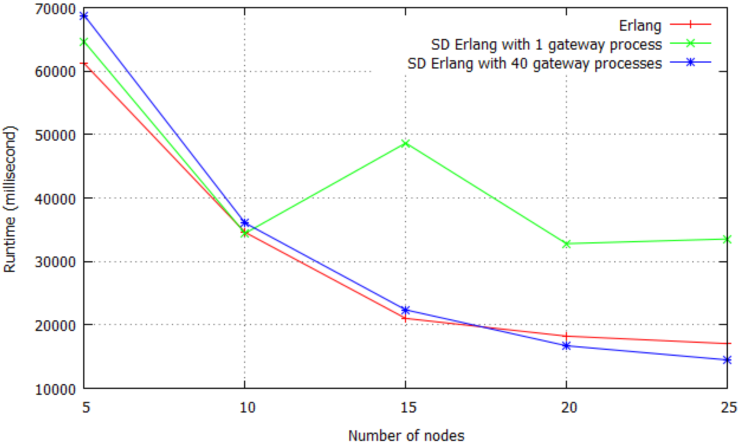
```
global:add_attribute([AttributeName]) -> 'ok' | {error, Reason}
s_group:add_attribute([Node], [AttributeName]) -> 'ok' | {error, Reason}

global:remove_attribute([AttributeName]) -> 'ok'
s_group:remove_attribute([Node], [AttributeName]) -> 'ok'

global:registered_attributes() -> [AttributeName]
```

Thank you!

Benchmarking SD Erlang Orbit on Heriot-Watt University Beowulf Cluster



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