Using Erlang for Distributed Simulation for the Derivation of Fault Tolerance Measures

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Outline

- Motivation
- Theory
- Erlang
- Simulation
- Conclusion

Motivation

- Why Fault Tolerance?

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- Why Simulation?

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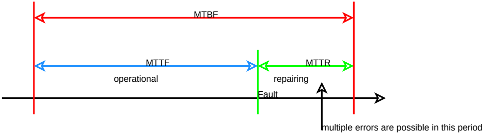
- Why Simulation?
- Why Erlang?

Fault Tolerance Measures

- Reliability, Availability, Safety, Trustworthiness



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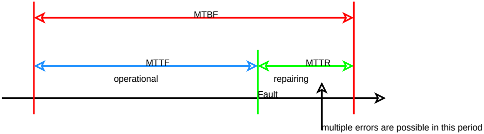

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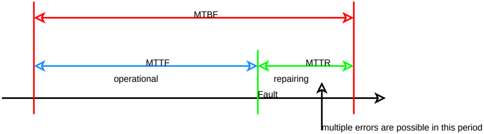

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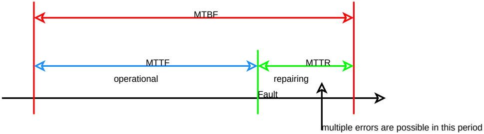

- Essential for Critical Systems
- Masking, Nonmasking and Failsafe
  - Masking: Safety and Liveness
  - Nonmasking: Liveness
  - Failsafe: Safety

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- BUT: Requires (many) resources

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- *pure* (no side-effects, lazy evaluation) and *eager*

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- Easy to verify

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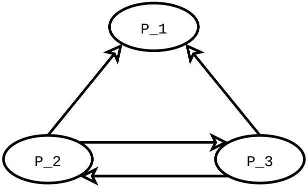
- derive *Fault Tolerance Measures*

Getting Results with Analytic Methods: Theory

- Model Distributed System as Markov Chain



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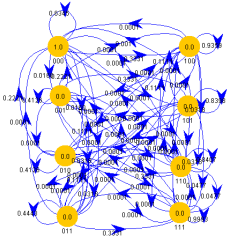

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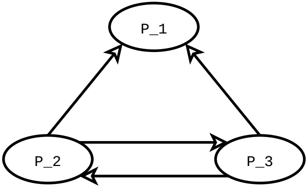

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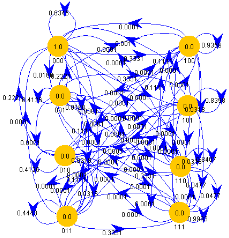

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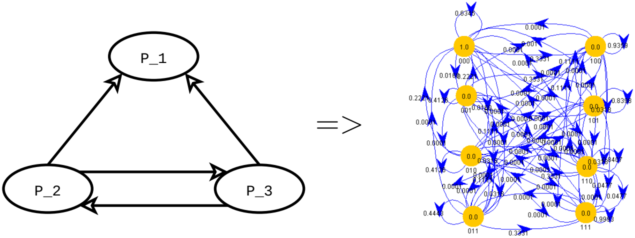

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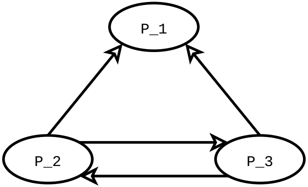

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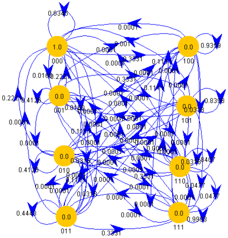

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- Problem: Abstraction hinders accuracy of results derived tremendously

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- Advantage: results are proven...

Erlang 1/5


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- Hot Code Plugging

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- No variable declarations => duck types
- Prolog Style Syntax, but not a logic language!

```
-module(math).
-export([fac/1]).

fac(N) when N > 0 -> N * fac(N-1);
fac(0) -> 1.
```

,,

```
-module(pingpong).
-export([start/0, ping/2, pong/0]).

ping(0, Pong_PID) ->
        Pong_PID ! finished,
        io:format("ping finished ~n", []);

ping(N, Pong_PID) ->
        Pong_PID ! {ping, self()},
        receive
                pong ->
                        io:format("Ping received pong~n", [])
        end,
        ping(N - 1, Pong_PID).

,,
```

```
pong() ->
        receive
                finished ->
                        io:format("Pong finished~n", []);
                {ping, Ping_PID} ->
                        io:format("Pong received ping~n", []),
                        Ping_PID ! pong,
                        pong()
        end.

start() ->
        Pong_PID = spawn(pingpong, pong, []),
        spawn(pingpong, ping, [3, Pong_PID]).
```

"

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- runs until desired accuracy is reached (maximal acceptable deviation within last n turns)
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  - Depth First Search
  - Leader Election
  - Mutual Exclusion
- easy to extend

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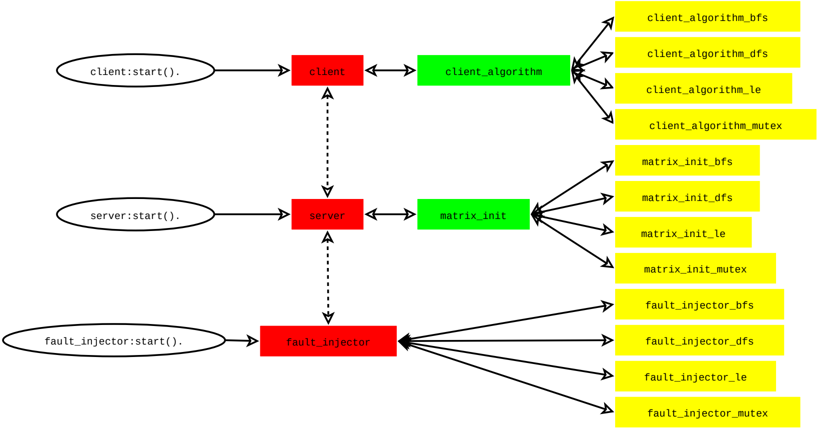
- external fault injection and monitoring facilities
- event logging (if needed)
- choice of schedulers (three provided)
- Load balancing (each client a lightweight process, can be mapped to any processor/computer)

Simulation Framework 3/5

```
7> server:start().
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%                                                                     %%%%%
%%%%%                              SiSSDA                                 %%%%%
%%%%%                                                                     %%%%%
%%%%%                               v "1.0"                               %%%%%
%%%%%                                                                     %%%%%
%%%%%                                                                     %%%%%
%%%%%                  Welcome to the Simulator for                       %%%%%
%%%%%             Self-Stabilizing Distributed Algorithms                 %%%%%
%%%%%                                                                     %%%%%
%%%%%                              SERVER                                 %%%%%
%%%%%                                                                     %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%% INITIALIZATION-PHASE 1: CHOOSE ALGORITHM                            %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
true
%%%%% The following algorithms are available:                            %%%%%
%%%%%    [1]bfs
%%%%%    [2]dfs
%%%%%    [3]le
%%%%%    [4]mutex
%%%%% Please enter the appropriate number [n.]>
```

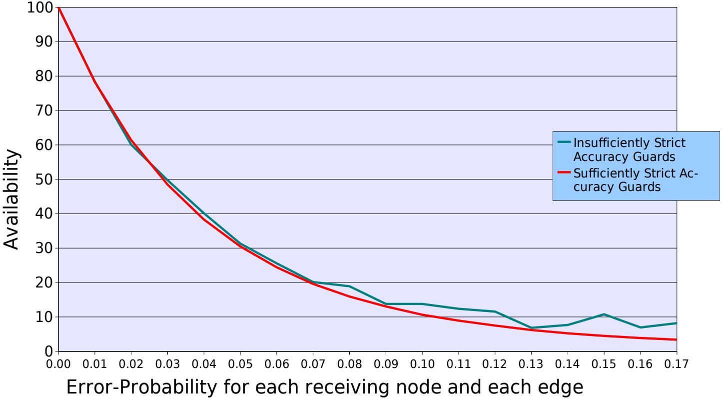
Simulation Framework 4/5



Accuracy 1/2

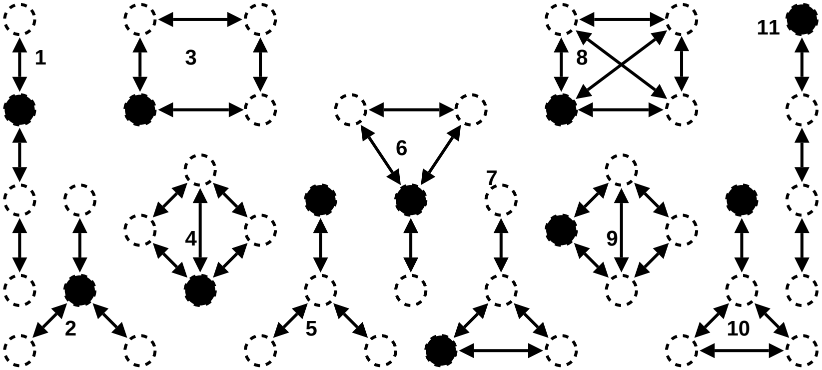
This figure exemplifies availability for first $20,000$ steps of an eight-processor system. The desired accuracy is reached if maximum the deviation within last n steps is lower than a certain threshold. The Results presented in the following feature about $1,000,000$ steps per system node.

Accuracy 2/2

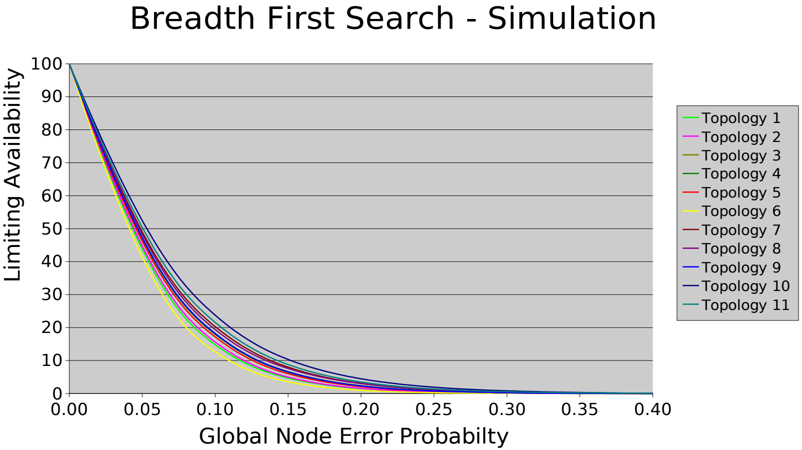


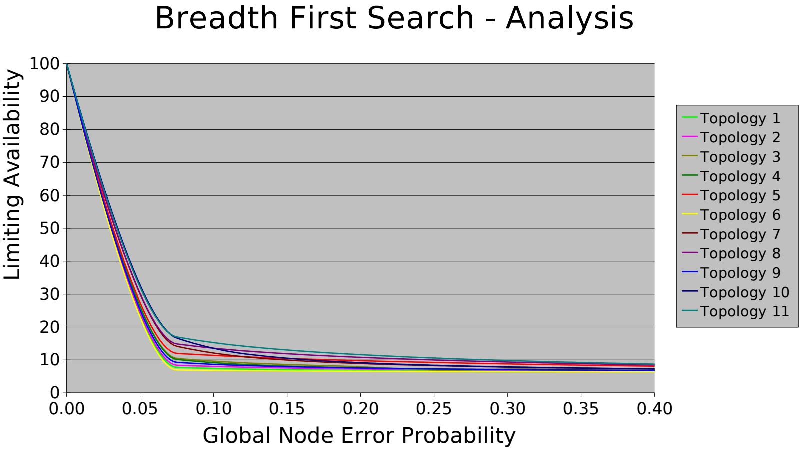
Strictness of accuracy guards is crucial for reliability of results!

Test Case: All Possible 4-node Graphs



We chose *depth first search* (DFS) and *breadth first search* (BFS) algorithms for comparison with the analytic approach, executed on all possible 4-node graphs.


Breadth First Search - Simulation
Limiting Availability
100
90
80
70
60
50
40
30
20
10
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Global Node Error Probabilty
Topology 1
Topology 2
Topology 3
Topology 4
Topology 5
Topology 6
Topology 7
Topology 8
Topology 9
Topology 10
Topology 11


Breadth First Search - Analysis
Limiting Availability
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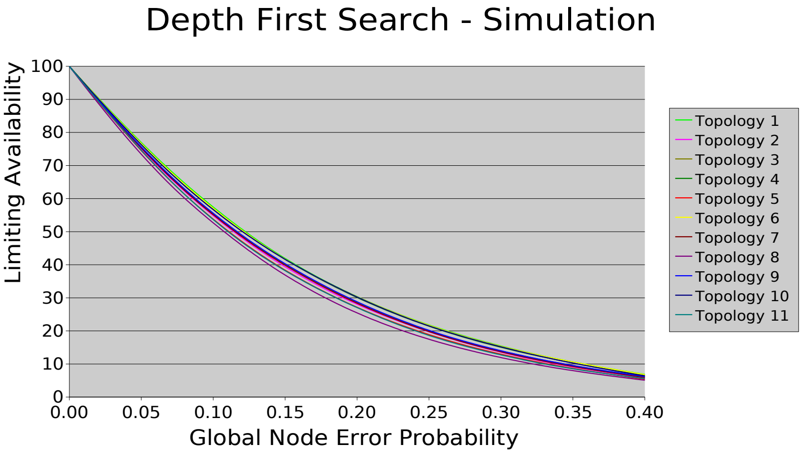
Depth First Search - Simulation
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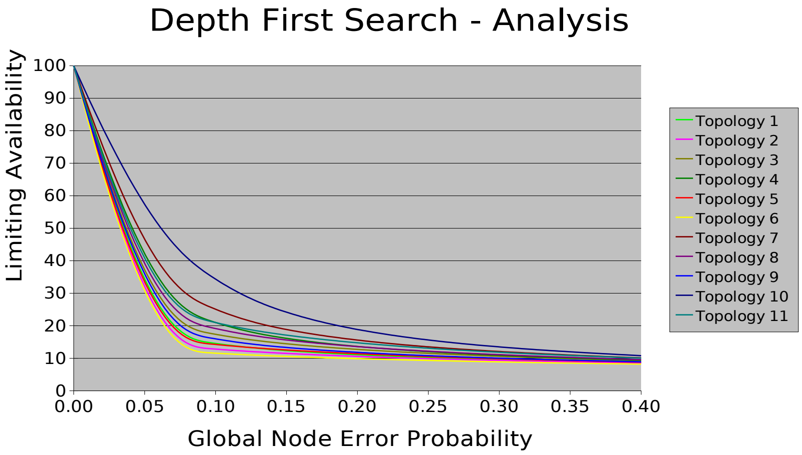
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Derivation of fault tolerance measures by simulation

- reason: analytic method is insufficient
- method: simulation of self-stabilizing distributed algorithms
- features: modular design, scalability, performance, reliability of results

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