The SimGrid Project

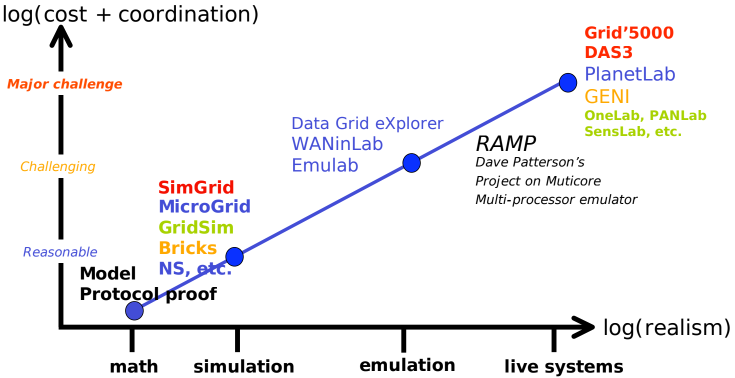
Algorille Team

Inria

October 11th, 2012

The Accuracy vs. Speed tradeoff

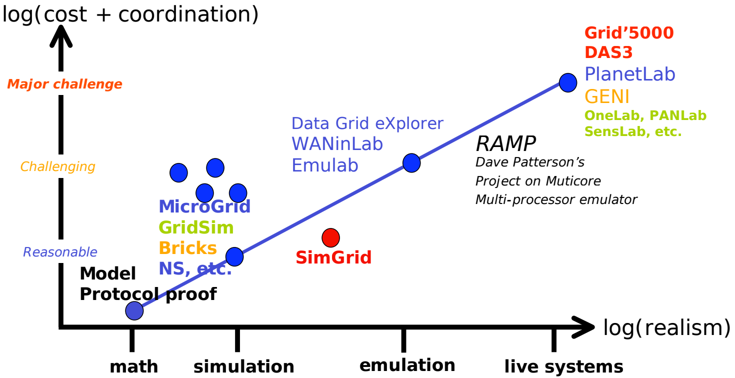
- Common Belief in 2008: Simulation as a toy methodology



Courtesy of Franck Cappello (Gri5000 keynote @ EGEE, Feb 2008)

The Accuracy vs. Speed tradeoff

- Common Belief in 2008: Simulation as a toy methodology
- Consensus in 2012: SimGrid as a scientific instrument (w/ Grid'5000)



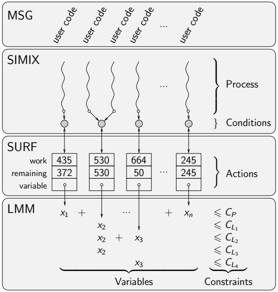
Purpose of this Talk

How did we turn **Simulation** into a
Reliable and Versatile Scientific Instrument
for Distributed Computing Research?

- A Performant et Versatile Simulation Kernel
  (high-performance simulation for computer science)
- Simulating Real MPI Applications
  (beyond prototypes)
- Toward a Coherent Workbench for Distributed Applications
  (when simulation is not enough)

Layered Infrastructure for a Versatile Tool

SimGrid: strictly layered and built bottom-up



SimGrid Functional Organization

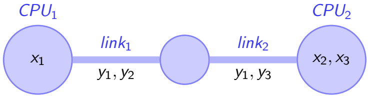
- Models: Actions get mapped onto resources
  Resource sharing and termination dates
- Activities: Processes interact and synchronize
- User interfaces: User-friendly syntaxic sugar

SimGrid user APIs

- SimDag: heuristics as DAG of (parallel) tasks
- MSG: heuristics as CSP (Java/Lua/Ruby bindings)
- SMPI: simulate MPI codes

Models: Resource Sharing between Actions

How to Model the Platform?



$$x_1 \leqslant Power\_CPU_1 \qquad (1a)$$

$$x_2 + x_3 \leqslant Power\_CPU_2 \qquad (1b)$$

$$y_1 + y_2 \leqslant Power\_link_1 \qquad (1c)$$

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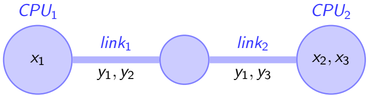

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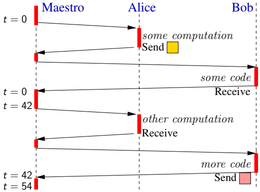
Production-grade Implementation

- Efficiency: Sparse structure; Cache oblivious; Lazy evaluation
- Realism: Several fairnesses can be expressed this way (or NS3 bindings)

Putting the Models in Use

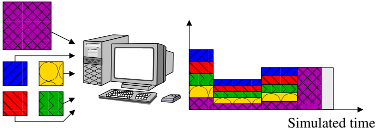
```
Alice
(some computation)
Send "toto" to Bob
(other computation)
Receive from Bob
```

```
Bob
(some code)
Receive from Alice
(other code)
Send "blah" to Alice
```



SimGrid Internal Main Loop

1. Run every ready user process in row
    - Each wants to consume resources
    - Assign actions on resources
2. Compute share for actions
3. Get earliest finishing action; update clock



Production-grade Implementation

- Scalability: Contextes instead of threads; Hierarchical networks
- Speed: Context switches in assembly; Futexes; Original parallelisation schema
- Other: Resource availability changes and failures; Dynamic Formal Verification

How big and how fast? (1/3 – Grid)

Size of platform description files

Community	Scenario	Size
P2P	2,500 peers with Vivaldi coordinates	294KB
VC	5120 volunteers	435KB + 90MB
Grid	Grid5000: 10 sites, 40 clusters, 1500 nodes	22KB
HPC	1 cluster of 262144 nodes	5KB
HPC	Hierarchy of 4096 clusters of 64 nodes	27KB
Cloud	3 small data centers + Vivaldi	10KB

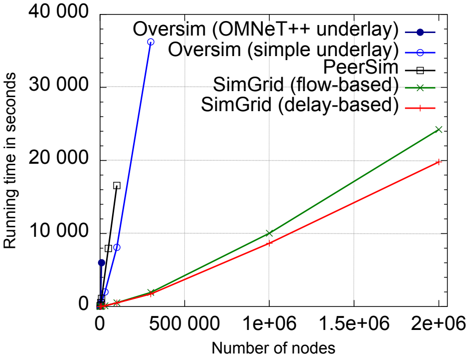
Speed of Grid Scenario

A master distributes 500, 000 fixed size jobs to 2, 000 workers (round robin)

	GridSim	SimGrid
Network model	delay-based model	flow model
Topology	none	Grid5000
Time	1h	14s
Memory	4.4GB	165MB

How big and how fast? (2/3 – P2P)

- Scenario: Initialize Chord, and simulate 1000 seconds of protocol
- Arbitrary Time Limit: 12 hours (kill simulation afterward)



Largest simulated scenario

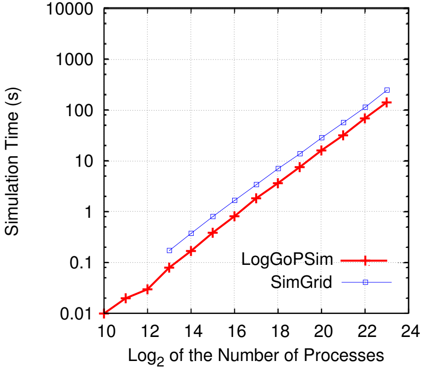
Simulator	size	time
OverSim (OMNeT++)	10k	1h40
OverSim (simple)	300k	10h
PeerSim	100k	4h36
SG (flow-based)	10k 300k 2M*	130s 32mn 6h23
SG (delay-based)	2M	5h30

∗ 36GB = 18kB/ process (16kB for the stack)

- SimGrid orders of magnitude more scalable than state-of-the-art P2P simulators
- Precise model incurs a ≈ 20% slowdown, but accuracy is not comparable

How big and how fast? (3/3 – HPC)

Simulating a binomial broadcast



Model:

- SimGrid: contention + cabinets hierarchy
- LogGOPSim: simple delay-based model

Results:

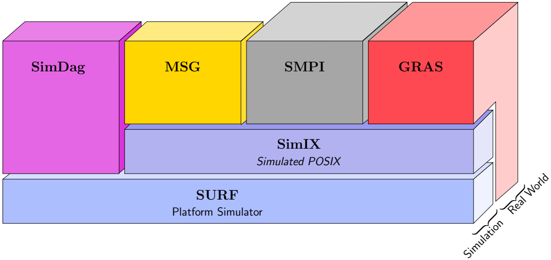
- SimGrid is roughly 75% slower
- SimGrid is about 20% more fat
  (15GB required for 2^{23} processors)

The genericity of SimGrid data structures comes at the cost of a slight overhead
BUT scalability does not necessarily comes at the price of realism

Conclusion

SimGrid is ready to ground your Research

- Versatile: Grid, P2P, HPC, Volunteer Computing, Clouds, ...
- Valid: Accuracy limits studied and pushed further for years
- Scalable: 3M chord nodes; 1000× faster than other (despite sound models)
- Usable: Tooling (generators, runner, vizu); Open-souce, Portable, ...



But a simulation kernel is not sufficient

- Users need love (Coming: Simulating MPI applications)
- Simulation is no universal solution (Coming: coherent workbench)

Single online simulation with SMPI

October 12th, 2012

On-line simulation in SMPI

- General Motivation: offer domain specific interfaces to SimGrid

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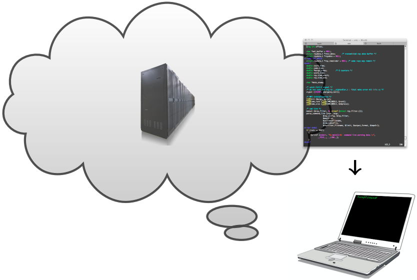

On-line simulation in SMPI

- Computations: real execution on the host computer
  - CPU bursts are benched
  - Scale linearly CPU time according to power ratios

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- Communications: simulated
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  - Validity of these models for MPI applications

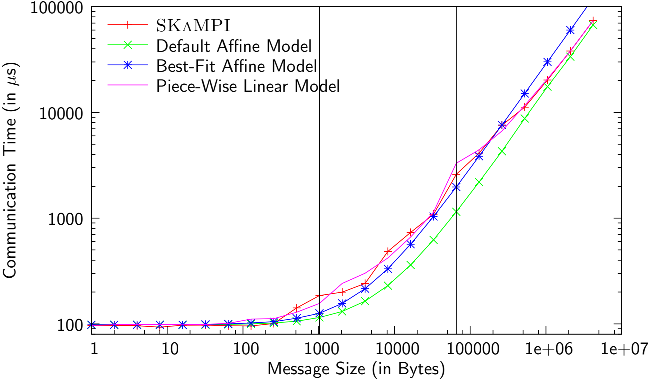
On-line simulation in SMPI

- Computations: real execution on the host computer
  - CPU bursts are benched
  - Scale linearly CPU time according to power ratios
- Communications: simulated
  - Network models are flow-based models (TCP)
  - Validity of these models for MPI applications
- Folding of the parallel program processes onto a single node
  - Serialization of computations
  - Single address space
  - Requires to reduce
    - Memory footprint (scalability)
    - Simulation time (speed)

Reworked Network Model

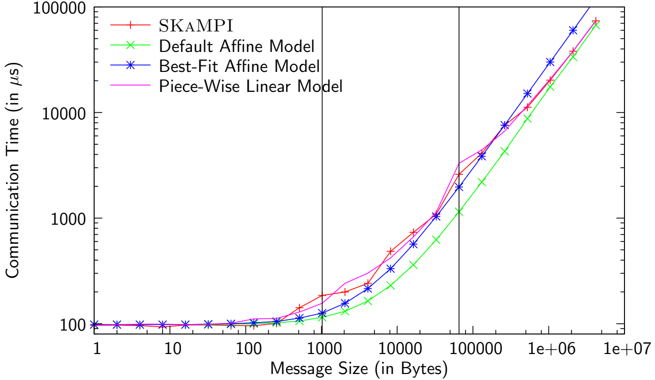
- Simple Model: $T(S) = L + \frac{S}{B}$
- Improved model: $T(S) = \alpha \cdot L + \frac{S}{min\left(\beta \cdot B, \frac{\gamma}{2 \cdot L}\right)}$
  - α accounts for TCP slow-start
  - β accounts for the overhead induced by TCP/IP headers (*e.g* 92%)
  - γ enables the modeling of the TCP window induced behavior
  - Model valid for $S \geq 100$ KiB, does not address a lot of message sizes found in MPI applications
- Need for a new, accurate network model when $S < 100$ KiB

Point-to-point Communication



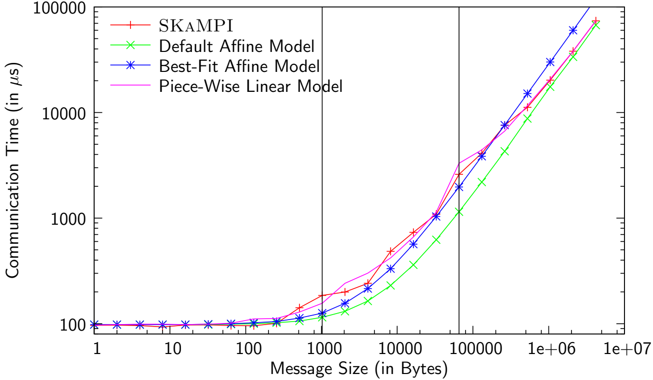
Experimental measurement using SKaMPI

Point-to-point Communication



Experimental measurement using SKaMPI
Default linear model, error: 32.1%
Ok with asymptotic message sizes,
but wrong for 1KiB-1MiB messages

Point-to-point Communication



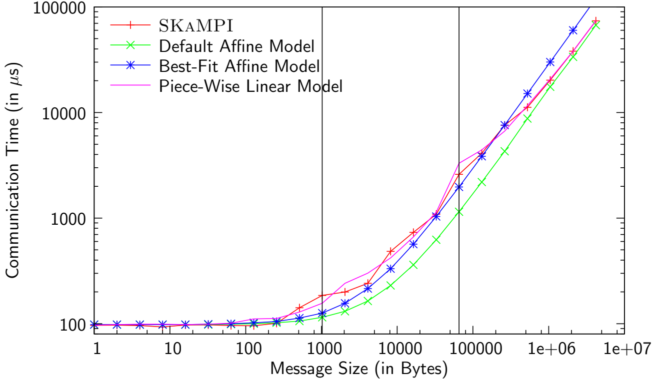
Experimental measurement using SKaMPI

Best-fitted linear model (α, β, γ), error: 18.5%

Better for a lot of sizes,

but cannot fit all real values

Point-to-point Communication



Experimental measurement using SKaMPI

Breakdown depending on message size

– packet size < MTU,

– eager/rendezvous switch limit

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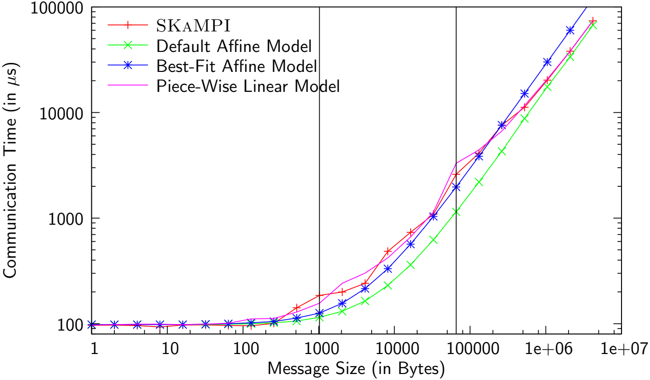
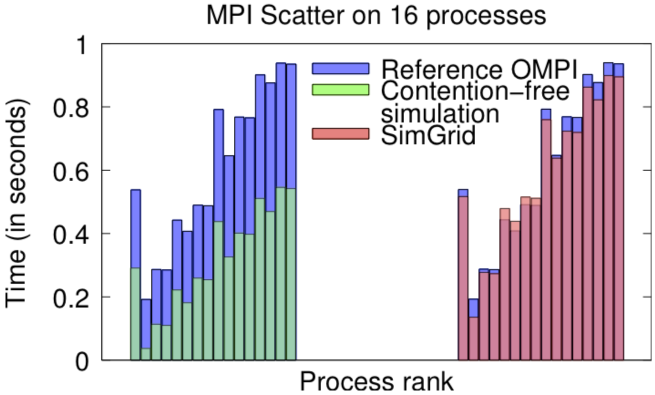


Experimental measurement using SKaMPI
New piece-wise linear model, error: 8.63%
Correctly adjust linear segments

Collectives and Contention

Scatter: 16-processes test



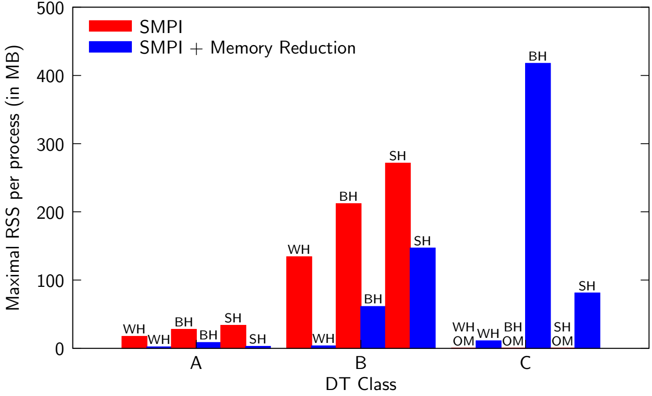
- Comparison SMPI/OpenMPI: error 5.3%
- Taking contention into account is important

Reducing the Memory Footprint

- Idea: Share arrays between processes
- Implemented as **optional** macros

```
double* data = (double*)SMPI_SHARED_MALLOC(...);
...
SMPI_SHARED_FREE
(data);
```

Reducing the Memory



- Average reduction by factor of 11.9 (maximum 40.5x)
- Class C can now be simulated

Reducing the Simulation Time

- Idea: Do not execute all the iterations
- Use sampling instead
  - LOCAL: each process executes a specified number of iterations
  - GLOBAL: a specified number of samples is produced by all processors
- Remaining iterations are replaced by average of measured values
- Implemented as **optional** macros

```
for(i = 0; i < n; i++) SMPI_SAMPLE_LOCAL( 0.75*n , 0.01 ) {   .
}
...
for(j = 0; j < k; j++) SMPI_SAMPLE_GLOBAL(0.5*k,0.01) {
   ...
}
```

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```

max part of iterations performed

threshold average variability

Wrap-up

- SMPI is a functional simulation tool
  - Open Source and freely available
  - Reproducible simulation of unmodified MPI application
  - On a single node
  - Main issues addressed:
    - scalability and speed through macros,
    - accuracy through extensions of the network model

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- However, microscopic behaviors are difficult to capture, e.g:
  - network communication jitters,
  - network catastrophes,
  - cache effects,
  - ...

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And hence, simulation must be used in conjunction with other experimental approaches: emulation or experimentation in the real environment.

Experimentation methodologies in Algorille

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Simulator

- **M. Quinson** – core team,
  PI ANR SONGS 2012-2016
- **S. Genaud**, **J. Gossa**,
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Testbed

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  Proxy steering / tech. committees
- Team Focus on emulation and orchestration of experiments
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Key role in both projects

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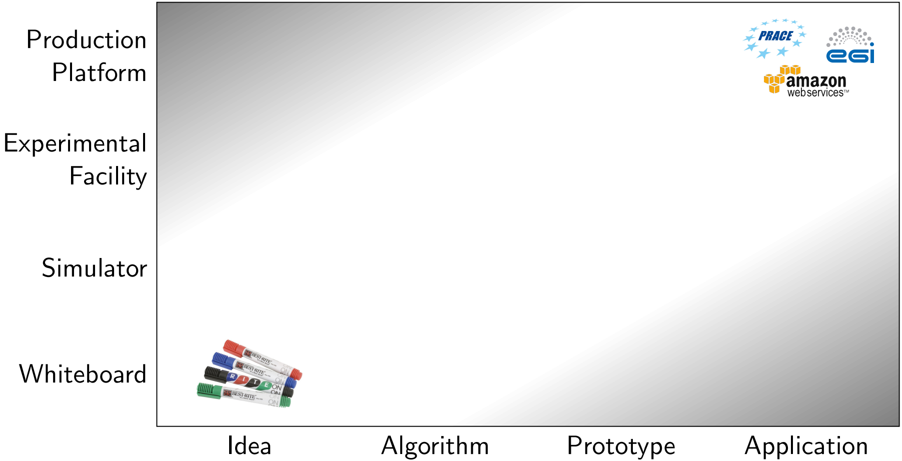
Complementary solutions:

☺ Work on algorithms
☺ More scalable, easier

☺ Work on applications
☺ Perceived as more realistic

Leading users from ideas to applications



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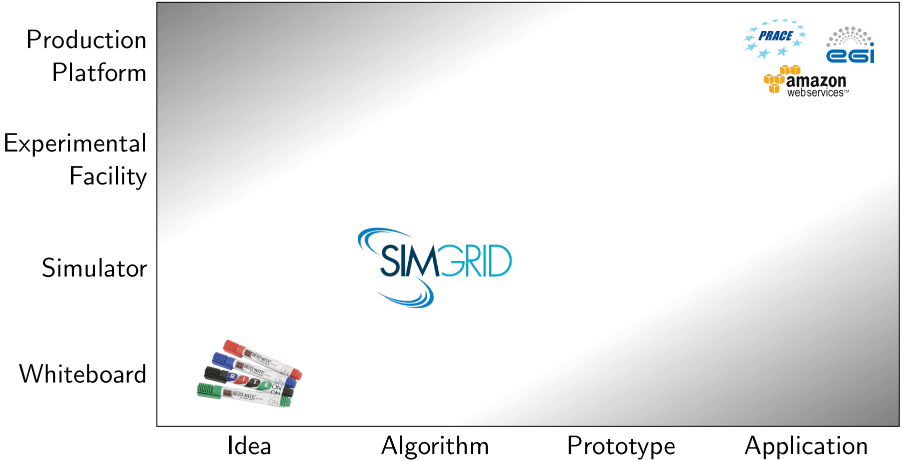

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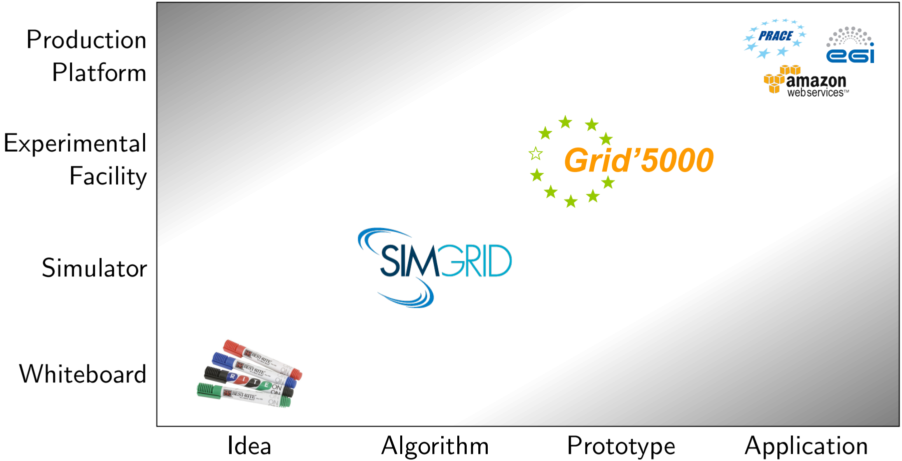

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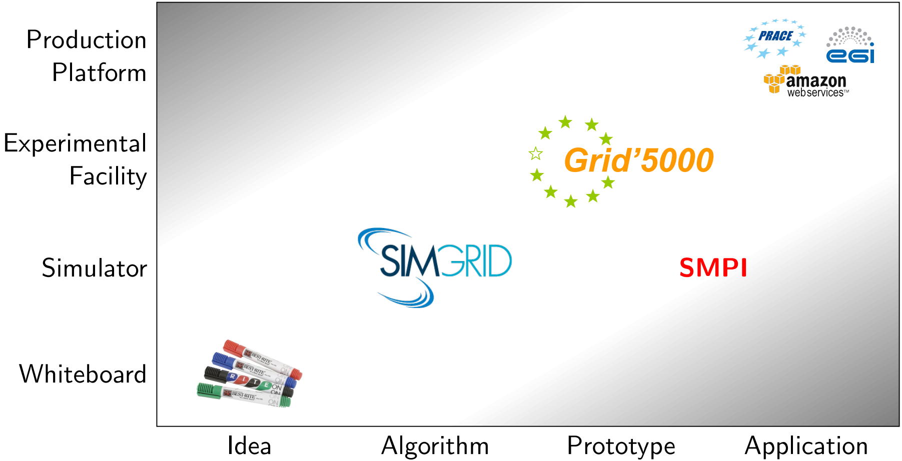

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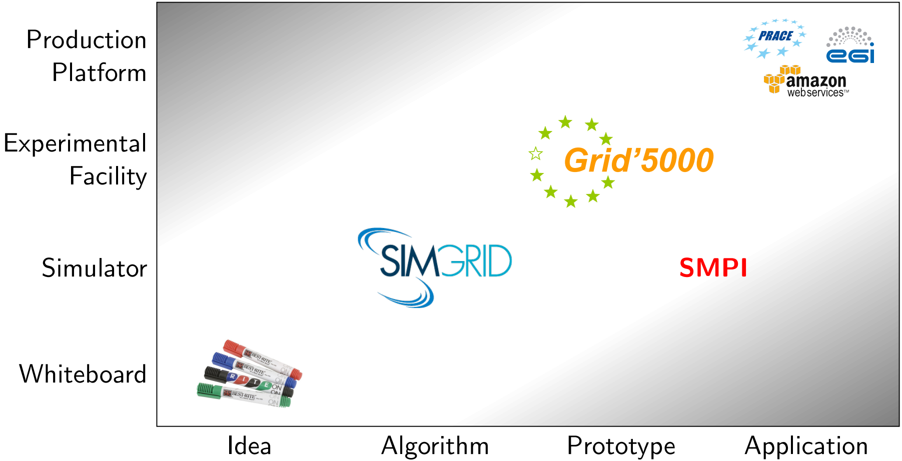

Goal: convergence of methodologies

Challenges and opportunities

- Share experimental methods and software
  - Infrastructure for Design of Experiment
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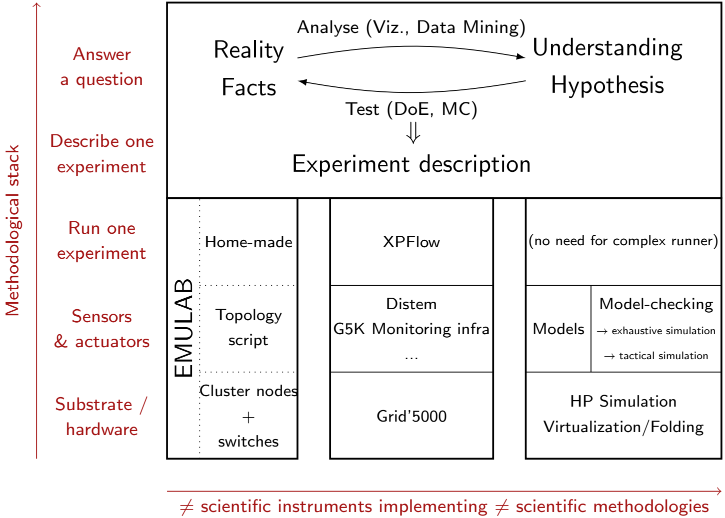

Challenges and opportunities

- Share experimental methods and software
  - Infrastructure for Design of Experiment
  - Frameworks for data analysis and vizualisation
- Design better models and better testbeds using the common expertise
  e.g. network or power consumption modelling vs instrumentation
- Attack the same goals together, from both sides
  Reproducibility, trustworthiness, Open Science

We are in a unique position
to address those challenges