The validation problem on on distributed heterogeneous computing platforms: simulation, modeling, observation . . . ?

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Outline

Scheduling on an heterogeneous environment: validation

Simulation: a brief state of the art

SimGrid, a modular trace-based simulator

Obtaining a realistic platform model

Conclusion

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Even when an optimal solution to a scheduling problem can be found in polynomial time, small modifications of the underlying assumptions (e.g. addition of non-zero network latencies) often render the problem NP-hard:

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Simulation has been used extensively as a way to evaluate and compare scheduling strategies as simulation experiments are repeatable, configurable, and generally fast. But. . .

- No standard : "throw-away" simulators make it difficult to reproduce results. This lack of standard simulation procedure and software was somewhat justifiable when the simulation models in use were simplistic but traditional models and assumptions

  forms.
- Need for realistic and more complex models than the one used for designing algorithms. The assumption that the behavior of the computing platform is perfectly predictable also needs to be revisited as modern platforms exhibit dynamic resource availabilities.

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Network Simulators

Goal :

- understanding networks behavior, routing protocols, QoS, ...
- identifying limitations of network protocols and developing improvements.

⇝ requires a precise simulation of the movement of packets along the network links: NS, DaSSF, OMNeT++.

Inadequate

We are interested by the network behavior as it is experienced by an application.

- Due to their highly detailed simulation models, most network simulators induce long simulation times (e.g. they implement the TCP stack).
- Adding CPU resources to model applications using the network is labor-intensive.
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Platform Emulation

A few examples:

MicroGrid (UCSD)

- The computing platform is mapped onto a fast cluster: a fraction of CPU is allocated to each process according to the speed and the load of the simulated host.
- Network simulation is handled through DaSSF
- No external load for the network.

PANDA (Amsterdam)

- Two-level grid (High speed LAN or slow WAN) and no processor heterogeneity: one-to-one mapping of the computing platform on a cluster; virtual inter-cluster links are artificially slowed down.
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The code is *run for real* $\leadsto$ too slow, too "precise", too difficult for simple tests or the design phase.

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History:

- Application Level Scheduling (AppLeS) : to a given application corresponds a given scheduler. $\rightsquigarrow$ Many students have been working on scheduling on the grid with specific needs.
- From these experiences, Henri Casanova (UCSD) designed a minimal set of low-level basic functions essential for building a simulator that uses traces: SG (SimGrid v.1)
- MSG is a simulator built on top of SG and adapted to the study of non-centralized scheduling (SimGrid v.2). Simulation is described in terms of communicating processes.

Strong points:

- Ability to use complex and realistic platforms.
- Fast simulations : ratio $\frac{\text{simulation time}}{\text{simulated time}} \approx 10^{-6}$.

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A trace is a time-stamped series of values.

Two different types: resources and tasks.

`SG_Resource` Name, availability trace (CPU, bandwidth), time access trace (latency), sharing policy (sequential, shared, TCP).

`SG_Task` Name, amount of work

SG allows to create those objects and to schedule a task on a resource.

- Starting a transfer of S bytes on a resource at time t_0 requires T units of time with T s.a.:

$$\int_{t=t_0+L(t_0)}^{t_0+T} B(t)dt = S$$

- On shared resources, all tasks get an amount of power proportional to their priority.

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`SG_Resource` Name, availability trace (CPU, bandwidth), time access trace (latency), sharing policy (sequential, shared, TCP).

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SG allows to create those objects and to schedule a task on a resource.

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$$\int_{t=t_0+L(t_0)}^{t_0+T} B(t)dt = S$$

- On shared resources, all tasks get an amount of power proportional to their priority.

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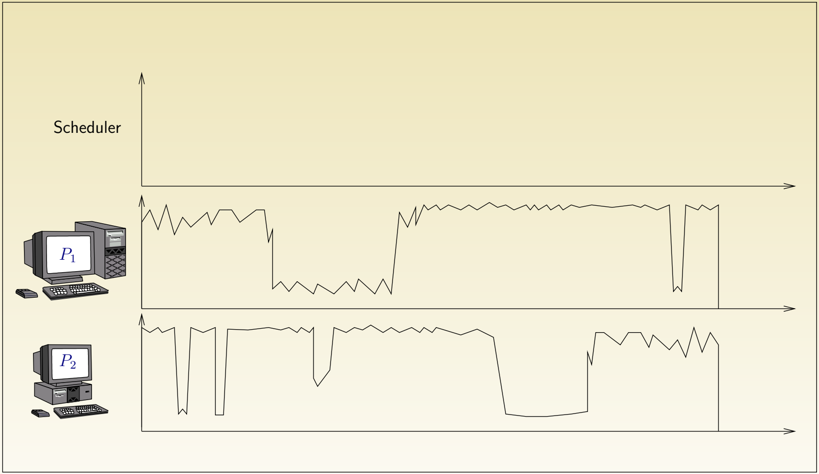

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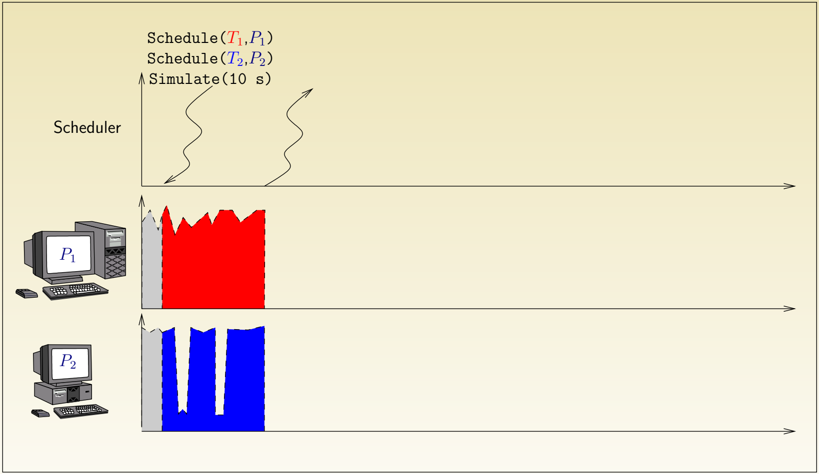

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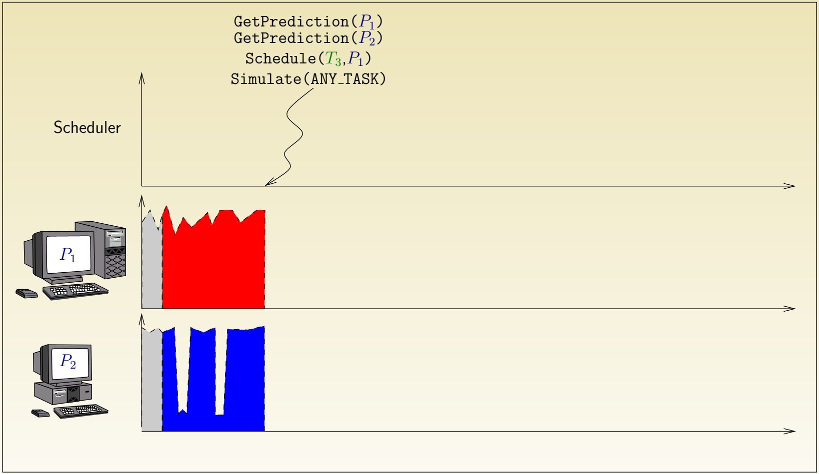

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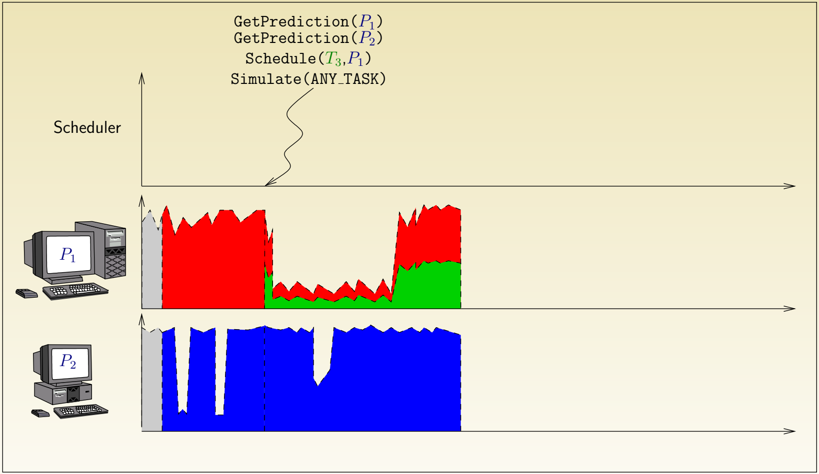

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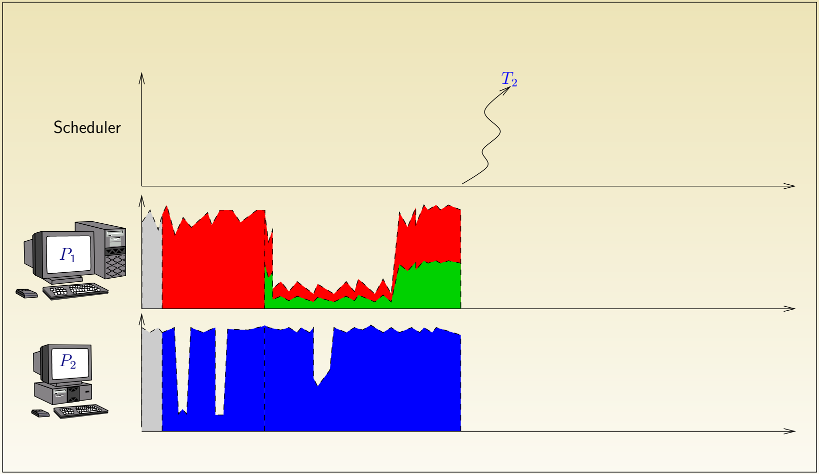

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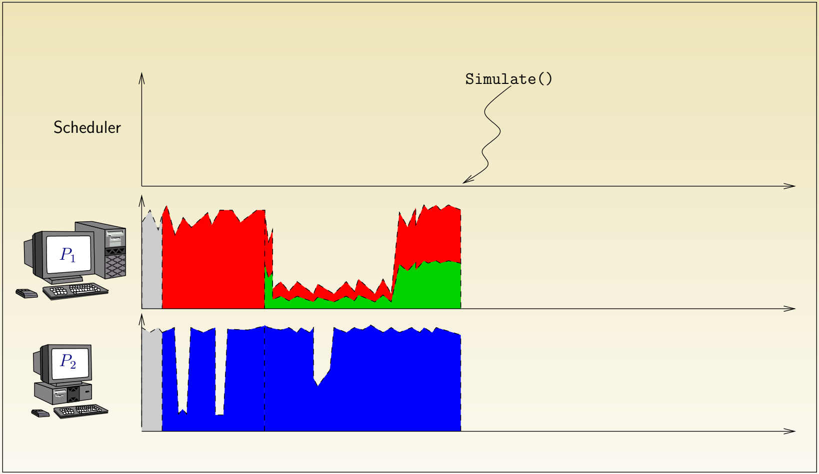

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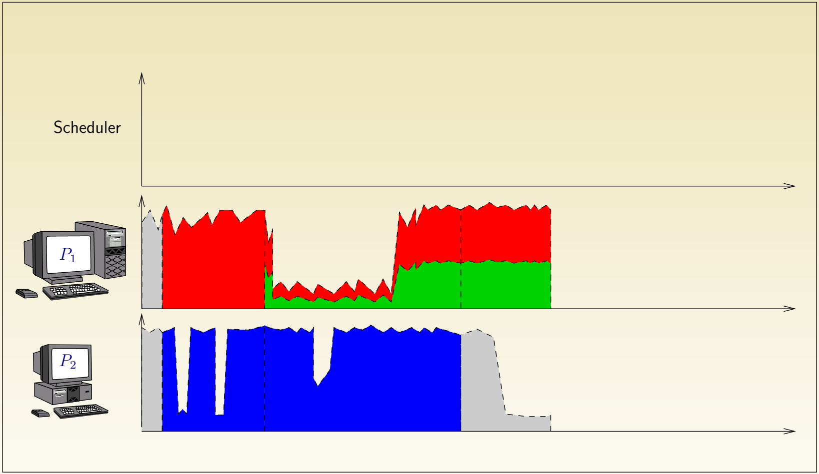

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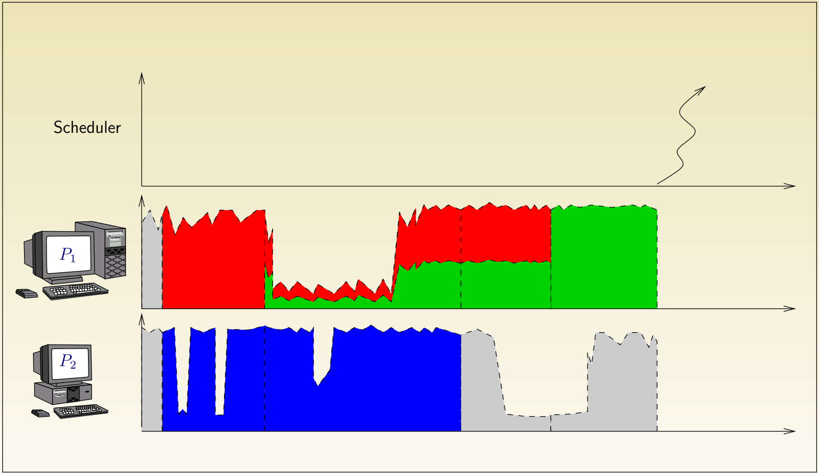

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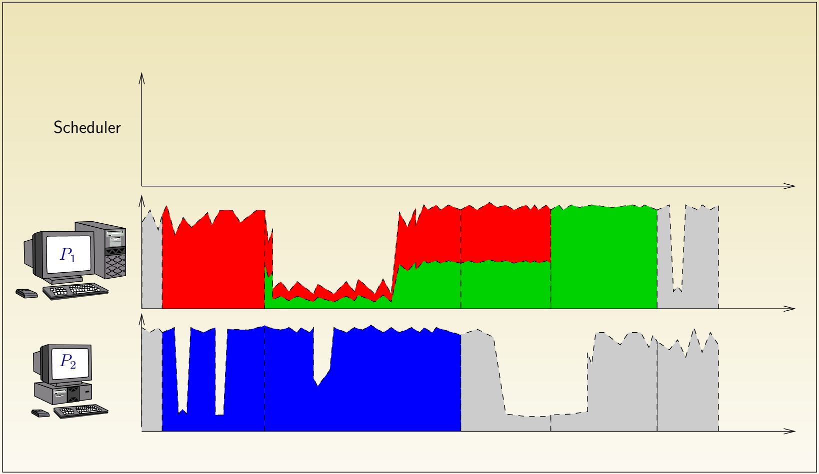

Store & Forward, WormHole, TCP

How to model a file transfer along a path?

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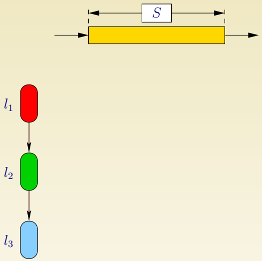

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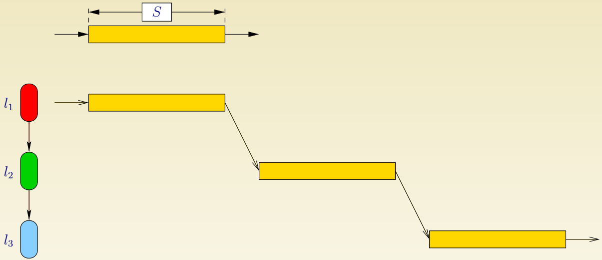

Store & Forward : bad model for contention

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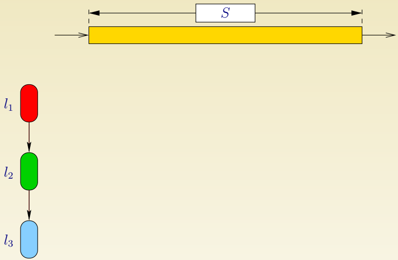

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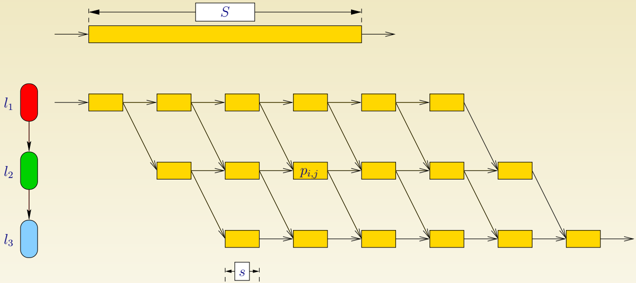

WormHole : computation intensive (packets), not that realistic

Store & Forward, WormHole, TCP

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$$\forall l \in \mathcal{L}, \quad \sum_{r \in \mathcal{R} \text{ s.a. } l \in r} \rho_r \leqslant c_l,$$

Analytical model

Store & Forward, WormHole, TCP

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TCP behavior Close to max-min. In MSG : max-min + bound by $1/RTT$

Non-centralized scheduling ?

Centralized scheduling do not scale and SG is not well suited to study such scheduling policies.

MSG abstractions:

Agents some code, private data, and the location at which it executes;

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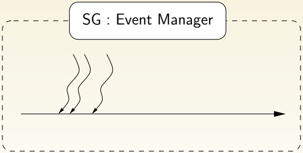

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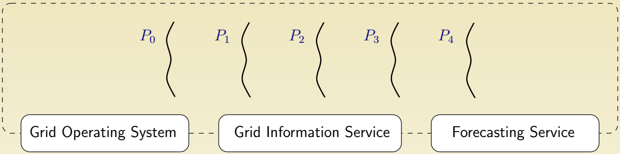

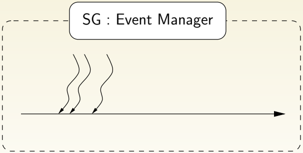

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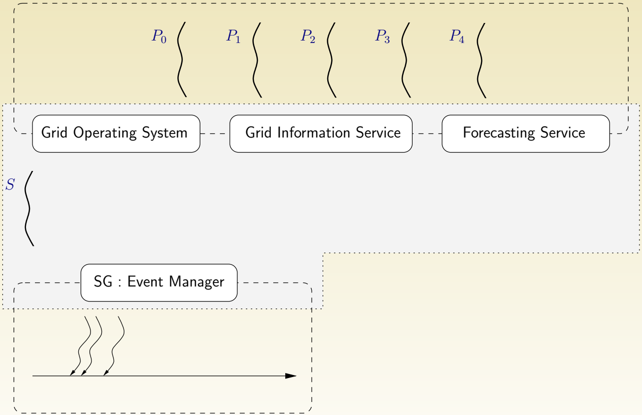

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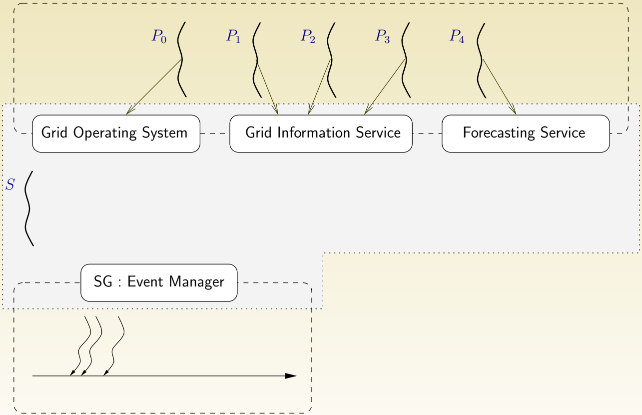

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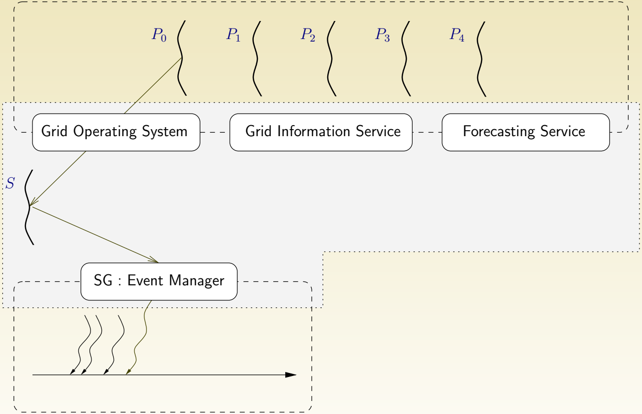

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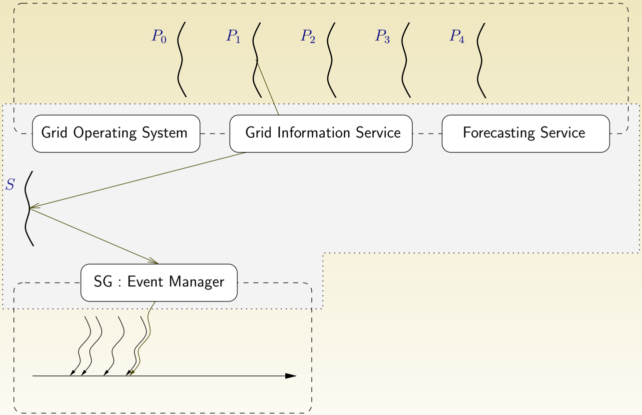

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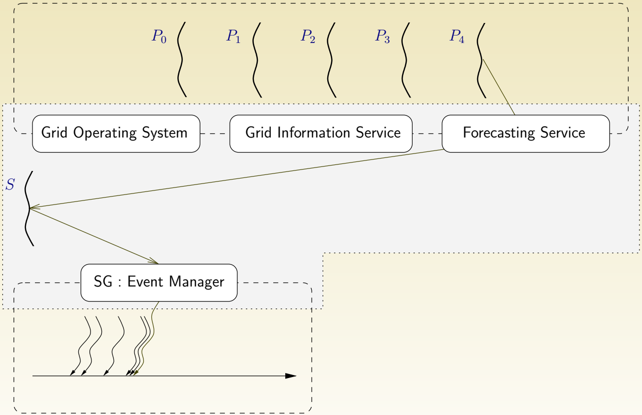

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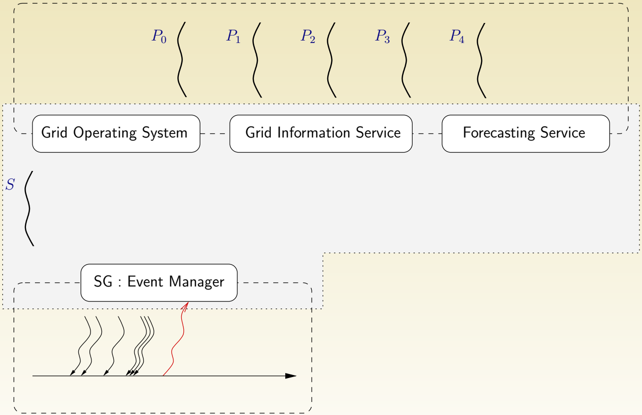

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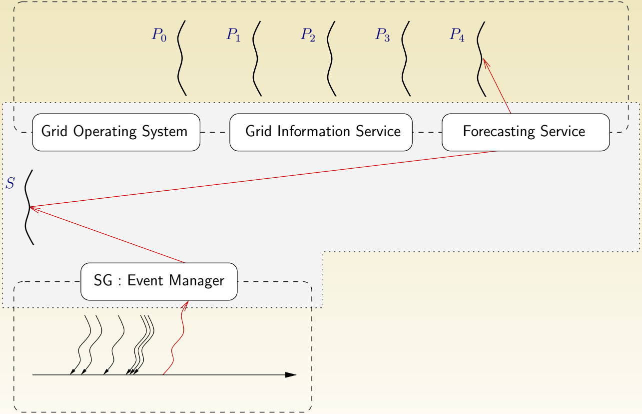

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Scheduling on an heterogeneous environment: validation

Simulation: a brief state of the art

SimGrid, a modular trace-based simulator

Obtaining a realistic platform model

Conclusion

Building a platform is a pain

Realistic platforms are complex and building such platforms is generally fastidious since it requires to create a large number of elements:

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- Links
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- Traces

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- Real topology
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Waxman Dots are randomly placed on a square of side c and are randomly connected with a probability $P(u,v) = \alpha e^{-d/(\beta L)}$, $0 < \alpha, \beta \leqslant 1$ where d is the Euclidean distance between u and v and $L = c\sqrt{2}$. The edge number increases with α and the edge length heterogeneity increases with β.

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Locality This model is due to Zegura. Dots are randomly placed and are connected with a probability

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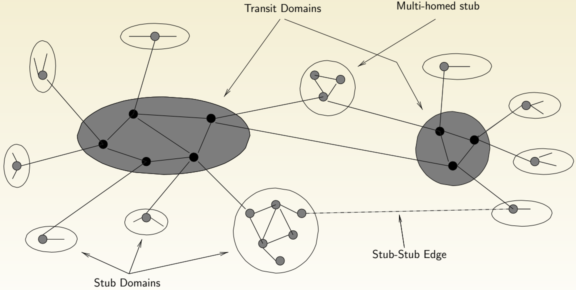
N-level Starting from a connected graph, at each step, a node is replaced by another connected graph (Tiers, GT-ITM).

Transit-stub 2-levels of hierarchy and some additional edges (GT-ITM, BRITE).



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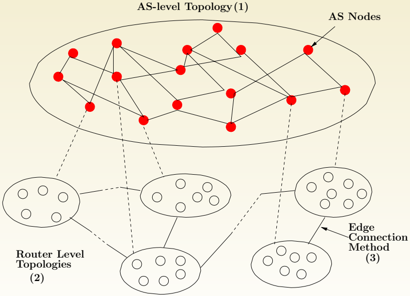

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- Designed to improve master/slave scheduling. $\leadsto$ master point of view (tree)
- Only relies on user level tools (pyhton, ssh, traceroute, . . .)

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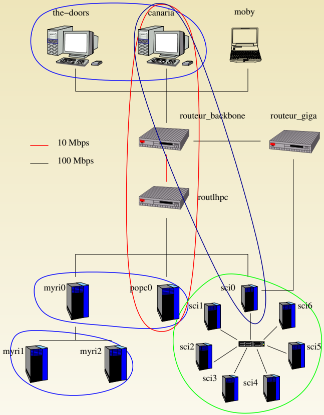

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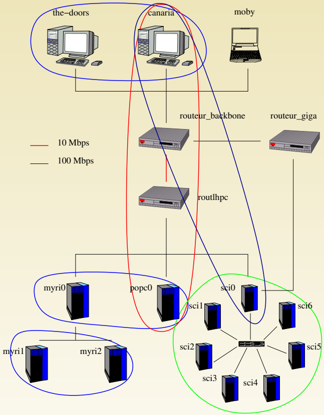

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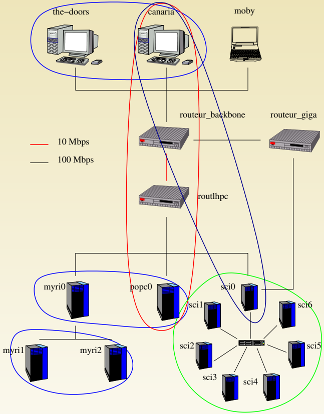

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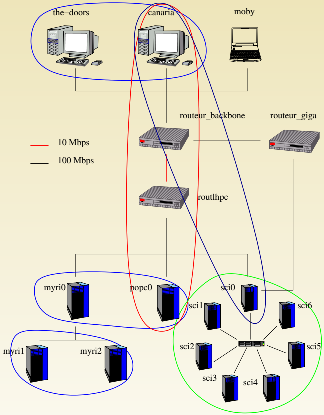

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A few remarks

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help you to figure out what is going to be the duration of a real application	help you to compare two algorithms
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model accurately the behavior of a computing platform	help you to study the robustness of your algorithm in a noisy environment
help you to fix some experimental thresholds	be used to design adaptive thresholds strategies and test them against a wide variety of environments
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- If you are working with DAGs and perfectly centralized scheduling (i.e. with Gantt Charts) then you should use SG.
- If many scheduling actions may occur independently, then use MSG. If you fail to express something with MSG, just wonder what you would do if you had to implement it for real.
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