Enhancing the effective utilisation of Grid clusters by exploiting on-line performability analysis

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Joint work with Anne Benoit, Murray Cole and Jane Hillston

Outline

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    - allow custom recovery procedures to be specified

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  - *Hillston's Performance Evaluation Process Algebra (PEPA)*

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- We map PEPA models into ordinary differential equations (ODEs) for solution.
- The analysis is supported by an automated tool which handles the transformation from the high-level process algebra model into ODEs and numerical integration.
- The results are returned to the user as a plot of the numbers of model components as a function of time.

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$(\alpha, r).P$	Prefix
$P_1 + P_2$	Choice
$P_1 \underset{L}{\bowtie} P_2$	Co-operation
P/L	Hiding
X	Variable

Derived forms and additional syntax

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$$P[5] \equiv (P \parallel P \parallel P \parallel P \parallel P)$$

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Here the number of compute jobs is larger than the number of nodes available to execute them. Nodes specify the rate at which jobs are completed.

PEPA model of jobs and nodes

Jobs

$$
\begin{aligned}
Job &\stackrel{def}{=} (load, \top).Job1 \\
Job1 &\stackrel{def}{=} (stage1, \top).Job2 \\
Job2 &\stackrel{def}{=} (stage2, \top).Job3 \\
Job3 &\stackrel{def}{=} (stage3, \top).Clearing \\
Clearing &\stackrel{def}{=} (unload, \top).Finished \\
Finished &\stackrel{def}{=} Stop
\end{aligned}
$$

PEPA model of jobs and nodes

Nodes

$$
\begin{aligned}
\mathit{NodeIdle} &\stackrel{\mathit{def}}{=} (\mathit{load}, r_0).\mathit{Node1} \\
\mathit{Node1} &\stackrel{\mathit{def}}{=} (\mathit{stage1}, r_1).\mathit{Node2} \\
\mathit{Node2} &\stackrel{\mathit{def}}{=} (\mathit{stage2}, r_2).\mathit{Node3} \\
\mathit{Node3} &\stackrel{\mathit{def}}{=} (\mathit{stage3}, r_3).\mathit{Node4} \\
\mathit{Node4} &\stackrel{\mathit{def}}{=} (\mathit{unload}, r_0).\mathit{NodeIdle}
\end{aligned}
$$

PEPA model of jobs and nodes

System

$$\mathit{NodeIdle}[100] \underset{L}{\bowtie} \mathit{Job}[1000]$$

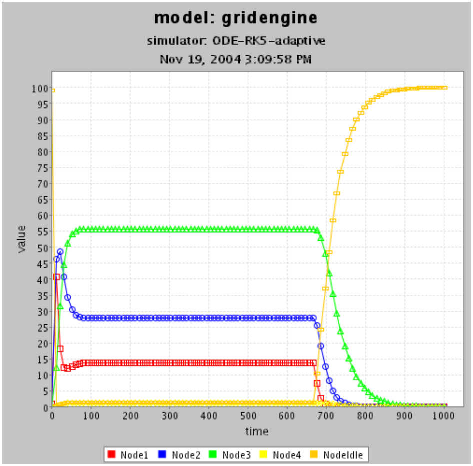
where L is $\{\, \mathit{load}, \mathit{stage1}, \mathit{stage2}, \mathit{stage3}, \mathit{unload} \,\}$.

Analysis of the model

Analysis of the model proceeds by choosing particular values for the rates. The values below are chosen to make the analysis easy to follow.

Rate	Value	Interpretation
r_0	1	(Un)loading takes one time unit
r_1	0.1	Stage 1 takes ten time units
r_2	0.05	Stage 2 takes twenty time units
r_3	0.025	Stage 3 takes forty time units

Analysis of the model: Nodes



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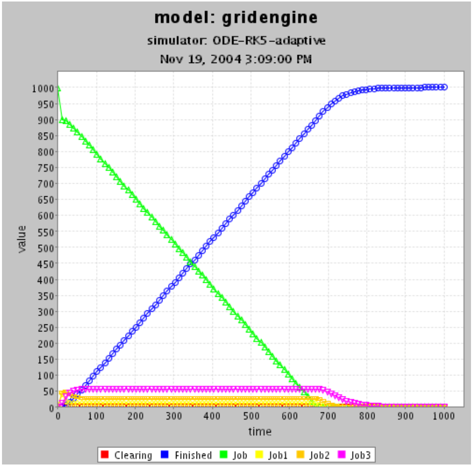

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We take the modelling decision to ignore the potential failures which could occur during the very brief stages of loading and unloading jobs.

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We model a failure and repair cycle taking a job back to re-execute the present stage (rather than restart the execution of the job from the beginning).

Nodes

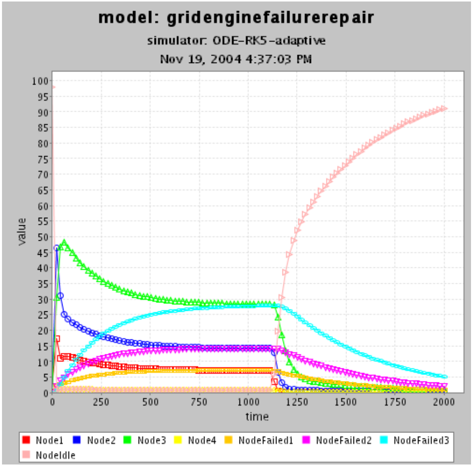
$$
\begin{aligned}
\mathit{NodeIdle} &\stackrel{\mathit{def}}{=} (\mathit{load}, r_0).\mathit{Node1} \\
\mathit{Node1} &\stackrel{\mathit{def}}{=} (\mathit{stage1}, r_1).\mathit{Node2} + (\mathit{fail1}, r_4).\mathit{NodeFailed1} \\
\mathit{Node2} &\stackrel{\mathit{def}}{=} (\mathit{stage2}, r_2).\mathit{Node3} + (\mathit{fail2}, r_4).\mathit{NodeFailed2} \\
\mathit{Node3} &\stackrel{\mathit{def}}{=} (\mathit{stage3}, r_3).\mathit{Node4} + (\mathit{fail3}, r_4).\mathit{NodeFailed3} \\
\mathit{Node4} &\stackrel{\mathit{def}}{=} (\mathit{unload}, r_0).\mathit{NodeIdle} \\
\mathit{NodeFailed1} &\stackrel{\mathit{def}}{=} (\mathit{repair1}, r_5).\mathit{Node1} \\
\mathit{NodeFailed2} &\stackrel{\mathit{def}}{=} (\mathit{repair2}, r_5).\mathit{Node2} \\
\mathit{NodeFailed3} &\stackrel{\mathit{def}}{=} (\mathit{repair3}, r_5).\mathit{Node3}
\end{aligned}
$$

Failure rates

With regard to the rates of failure of jobs, we estimate that one in ten jobs may fail during stage 3 (and so one in 20 during stage 2 and one in 40 during stage 1) and that the cost of repairs is relatively high, perhaps requiring a reboot of the failed node.

Rate	Value	Interpretation
r_4	0.0025	On average 1 in 10 stage 3 jobs will fail
r_5	0.0025	Repairing may require the reboot of a node

Analysis of the failure/repair model: Nodes



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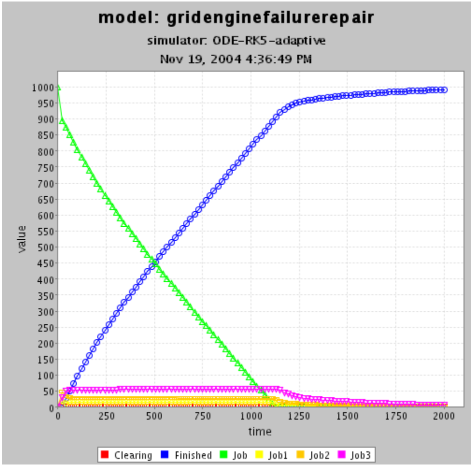

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- In practice effective only to systems of size 10^6 states, even when using clever storage representations.

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- Mapping PEPA to ODEs admits *course-of-values* analysis by solving the ODE (akin to transient analysis).
- Major benefit: avoids state-space generation entirely.
- Major benefit: ODE solving is effective in practice. (Suitable for on-line scheduling?)
- Effective for systems of size 2^{10^6} states and beyond.