UKPEW 2005 Invited Talk

The Future is Collaborative Performance Engineering!

Jeremy Bradley

Email: jb@doc.ic.ac.uk

Department of Computing, Imperial College London

Produced with prosper and LaTeX

Drowning!

- We are drowning in modelling techniques and formalisms:
  - SPA (Stochastic Process Algebras)
  - SAN (Stochastic Automata Networks)
  - SPN (Stochastic Petri Nets)
  - LQN (Layered Queueing Networks)
  - ...

Drowning!

- We have underlying models:
  - CTMC (Continuous Time Markov Chains)
  - DTMC (Discrete Time Markov Chains)
  - MDP (Markov Decision Processes)
  - MRP (Markov Reward Processes)
  - SMP (Semi Markov Processes)
  - GSMP (Generalised Semi Markov Processes)
  - ...

Drowning!

- Not to mention analysis techniques:
  - steady-state analysis
  - transient analysis
  - passage time analysis
  - entropy maximisation
  - simulation
  - continuous approximation
  - ...

Drowning!

- ...performance query formalisms
  - CSL/eCSL/aCSL
  - pCTL
  - stochastic probes
  - NICE automata
  - ...

Drowning!

- ...and tools:
  - ETMCC
  - PRISM
  - ipc/DNAmaca
  - PEPA workbench
  - DSPNexpress
  - SMARTA
  - Two Towers
  - GreatSPN
  - Möbius
  - ... and many others...

Some questions

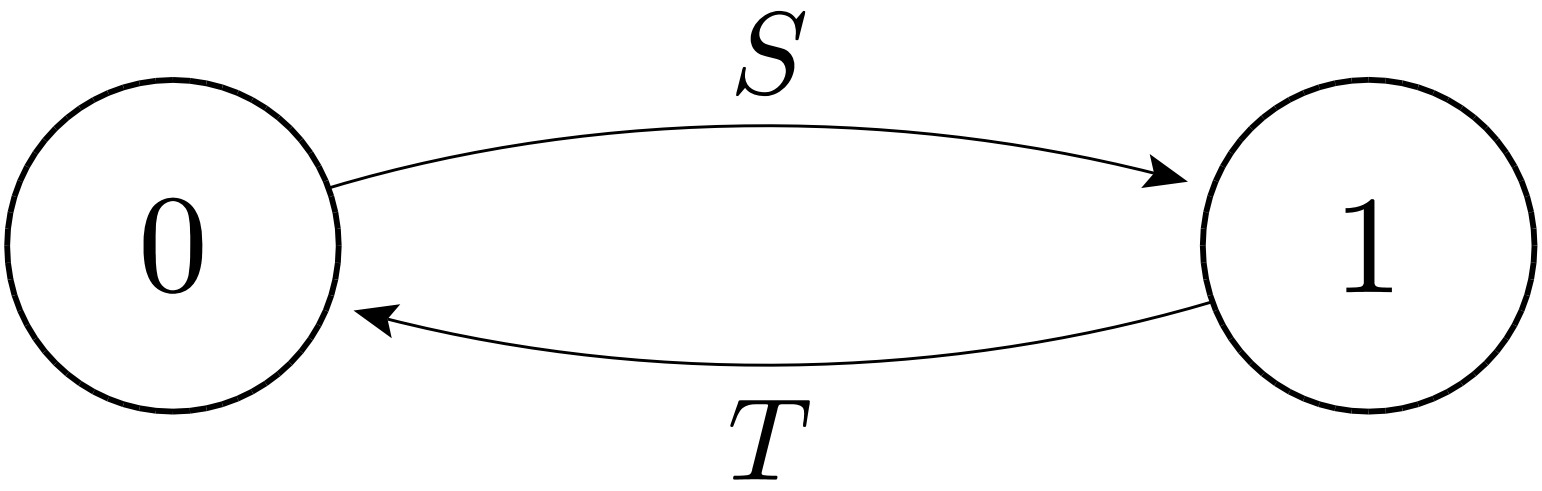
- Do all the tools produce the same results for the same questions and models?
- Are some tools/formalisms/performance models better at capturing/modelling certain systems better than others?
- Which tools run faster on which type of model? Is this because they use BDDs/out-of-core solvers/MDDs/hypergraph partitioning?
- Are we reinventing the wheel?... in terms of tools and models?

An answer...?

- The answer is another tool: Perform-DB!
- Not quite! More an *integrated collaborative performance engineering environment*
- Encourage a *performance engineering lifecycle*

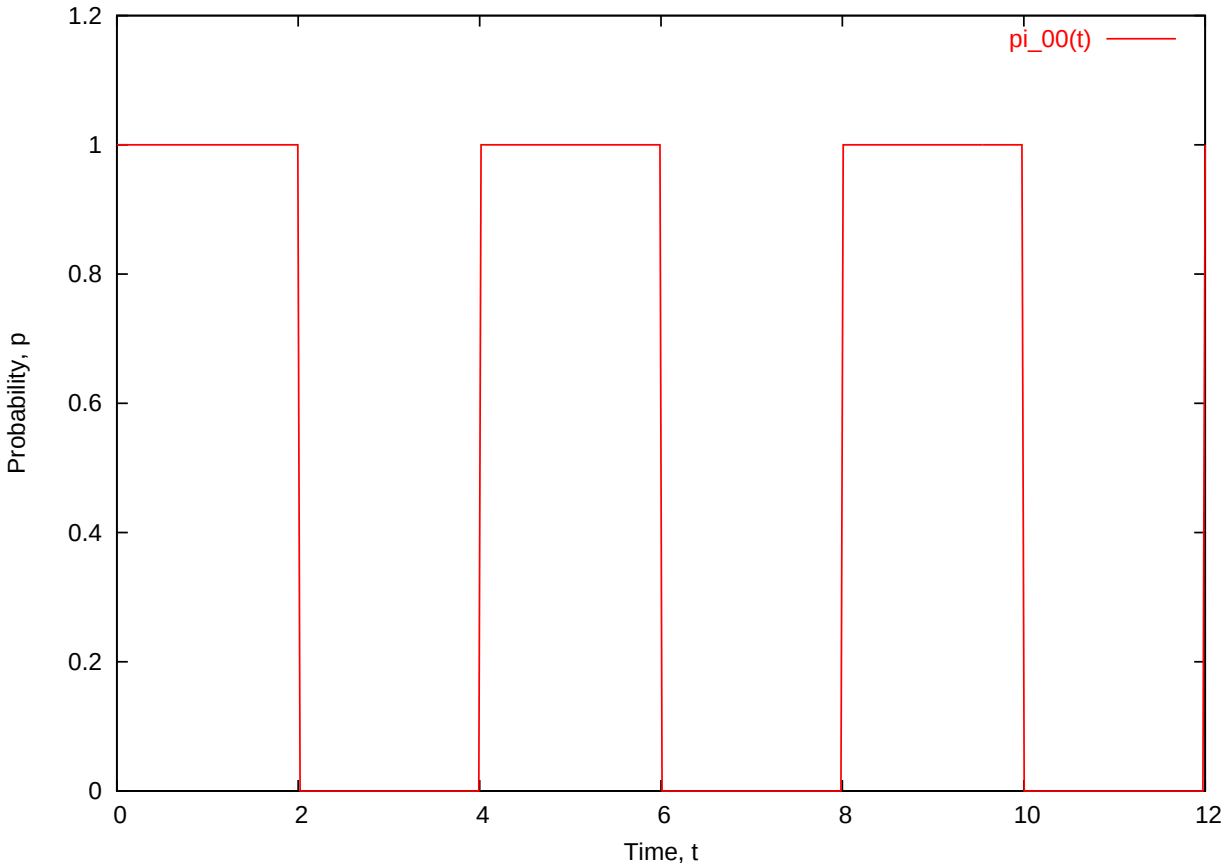
A small but significant example...

- Fully deterministic system:
  - $S \sim det(1)$
  - $T \sim det(1)$



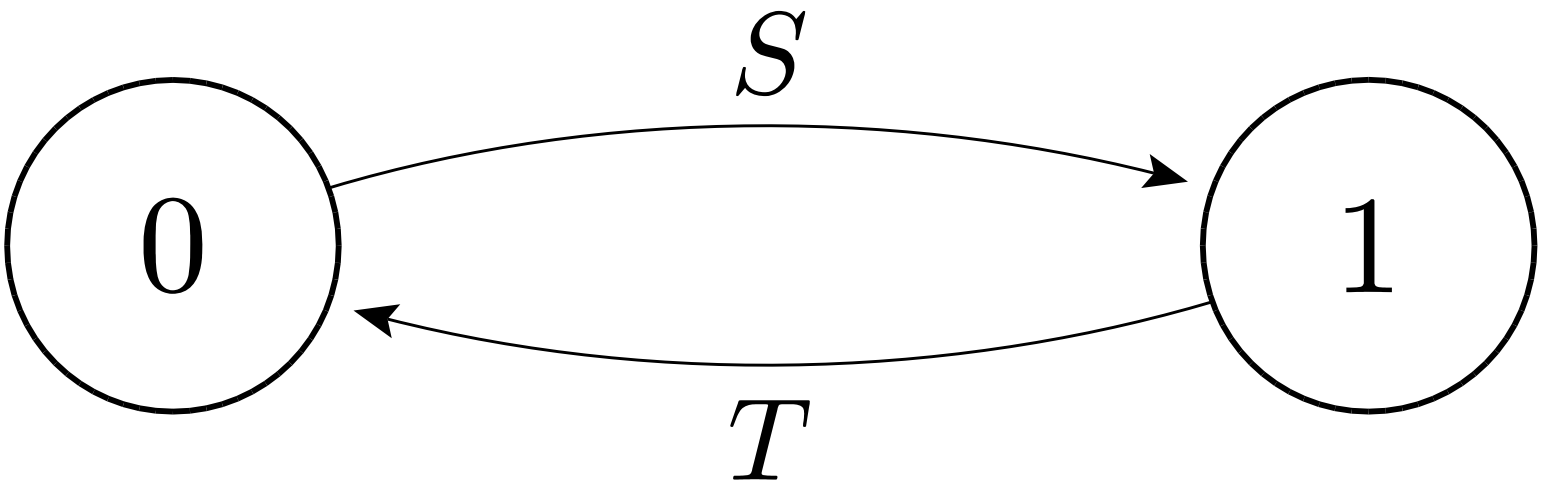
Transient analysis...

- $\pi_{00}(t)$:probability of being in state 0 having started in state 0



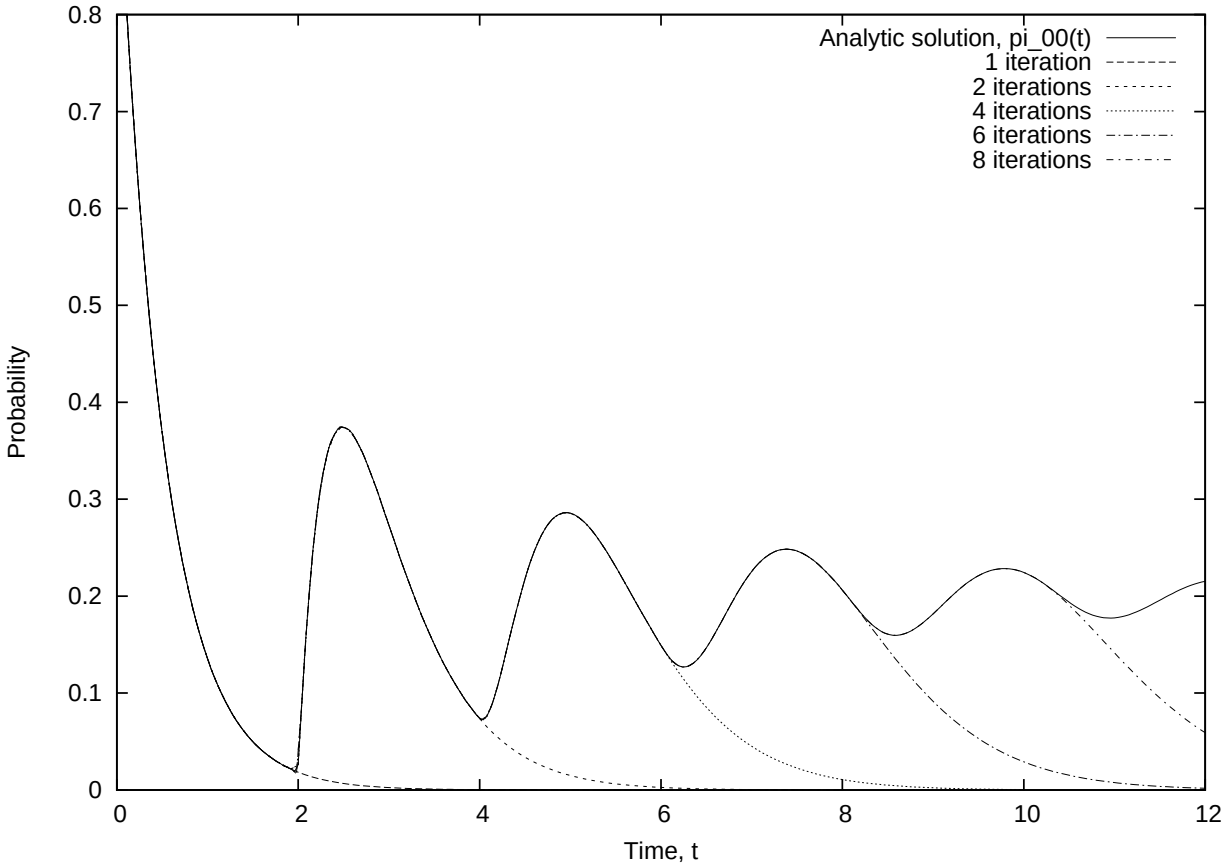
With a small bit of randomness

- Semi deterministic system:
  - $S \sim exp(1)$
  - $T \sim det(1)$



Transient analysis...

- $\pi_{00}(t)$:probability of being in state 0 having started in state 0



Stochastic Process Algebra

PEPA syntax:

$$\mathrm{P} \quad ::= \quad (\mathrm{a}, \lambda).\mathrm{P} \;\Big|\; \mathrm{P} + \mathrm{P} \;\Big|\; \mathrm{P} \underset{L}{\bowtie} \mathrm{P} \;\Big|\; \mathrm{P}/\mathrm{L} \;\Big|\; \mathrm{A}$$

Stochastic Process Algebra

PEPA syntax:

$$\mathrm{P} \quad ::= \quad (\mathrm{a}, \lambda).\mathrm{P} \;\Big|\; \mathrm{P} + \mathrm{P} \;\Big|\; \mathrm{P} \underset{L}{\bowtie} \mathrm{P} \;\Big|\; \mathrm{P}/\mathrm{L} \;\Big|\; \mathrm{A}$$

- Action prefix: $(\mathrm{a}, \lambda).\mathrm{P}$

Stochastic Process Algebra

PEPA syntax:

$$\mathrm{P} \quad ::= \quad (\mathrm{a}, \lambda).\mathrm{P} \;\Big|\; \mathrm{P} + \mathrm{P} \;\Big|\; \mathrm{P} \underset{L}{\bowtie} \mathrm{P} \;\Big|\; \mathrm{P}/\mathrm{L} \;\Big|\; \mathrm{A}$$

- Action prefix: $(\mathrm{a}, \lambda).\mathrm{P}$
- Competitive choice: $\mathrm{P}_1 + \mathrm{P}_2$

Stochastic Process Algebra

PEPA syntax:

$$\mathrm{P} \quad ::= \quad (\mathrm{a}, \lambda).\mathrm{P} \;\Big|\; \mathrm{P} + \mathrm{P} \;\Big|\; \mathrm{P} \underset{L}{\bowtie} \mathrm{P} \;\Big|\; \mathrm{P}/\mathrm{L} \;\Big|\; \mathrm{A}$$

- Action prefix: $(\mathrm{a}, \lambda).\mathrm{P}$
- Competitive choice: $\mathrm{P}_1 + \mathrm{P}_2$
- Cooperation: $\mathrm{P}_1 \underset{L}{\bowtie} \mathrm{P}_2$

Stochastic Process Algebra

PEPA syntax:

$$\mathrm{P} \quad ::= \quad (\mathrm{a}, \lambda).\mathrm{P} \;\Big|\; \mathrm{P} + \mathrm{P} \;\Big|\; \mathrm{P} \underset{L}{\bowtie} \mathrm{P} \;\Big|\; \mathrm{P}/\mathrm{L} \;\Big|\; \mathrm{A}$$

- Action prefix: $(\mathrm{a}, \lambda).\mathrm{P}$
- Competitive choice: $\mathrm{P}_1 + \mathrm{P}_2$
- Cooperation: $\mathrm{P}_1 \underset{L}{\bowtie} \mathrm{P}_2$
- Action hiding: P/L

Stochastic Process Algebra

PEPA syntax:

$$\mathrm{P} \quad ::= \quad (\mathrm{a}, \lambda).\mathrm{P} \;\Big|\; \mathrm{P} + \mathrm{P} \;\Big|\; \mathrm{P} \underset{L}{\bowtie} \mathrm{P} \;\Big|\; \mathrm{P}/\mathrm{L} \;\Big|\; \mathrm{A}$$

- Action prefix: $(\mathrm{a}, \lambda).\mathrm{P}$
- Competitive choice: $\mathrm{P}_1 + \mathrm{P}_2$
- Cooperation: $\mathrm{P}_1 \underset{L}{\bowtie} \mathrm{P}_2$
- Action hiding: P/L
- Constant label: A

PEPA: Example

$$\mathrm{Sys} \stackrel{\mathrm{def}}{=} (\mathrm{AA} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{A1}) \underset{\{\mathrm{alert}\}}{\bowtie} (\mathrm{BB} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{B1})$$

PEPA: Example

$$\mathrm{Sys} \stackrel{\mathrm{def}}{=} (\mathrm{AA} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{A1}) \underset{\{\mathrm{alert}\}}{\bowtie} (\mathrm{BB} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{B1})$$

$$\mathrm{AA} \stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA}$$

PEPA: Example

$$\mathrm{Sys} \stackrel{\mathrm{def}}{=} (\mathrm{AA} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{A1}) \underset{\{\mathrm{alert}\}}{\bowtie} (\mathrm{BB} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{B1})$$

$$\mathrm{AA} \stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA}$$

$$\mathrm{A1} \stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3}$$

$$\mathrm{A2} \stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3}$$

$$\mathrm{A3} \stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1}$$

PEPA: Example

$$\mathrm{Sys} \stackrel{\mathrm{def}}{=} (\mathrm{AA} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{A1}) \underset{\{\mathrm{alert}\}}{\bowtie} (\mathrm{BB} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{B1})$$

$$\mathrm{AA} \stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA}$$

$$\mathrm{A1} \stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3}$$

$$\mathrm{A2} \stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3}$$

$$\mathrm{A3} \stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1}$$

$$\mathrm{BB} \stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{BB}$$

PEPA: Example

$$\mathrm{Sys} \stackrel{\mathrm{def}}{=} (\mathrm{AA} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{A1}) \underset{\{\mathrm{alert}\}}{\bowtie} (\mathrm{BB} \underset{\{\mathrm{run}\}}{\bowtie} \mathrm{B1})$$

$$\begin{aligned}
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1}
\end{aligned}$$

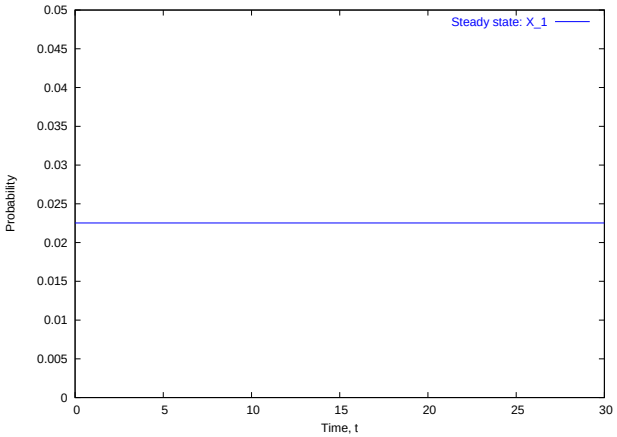
$$\begin{aligned}
\mathrm{BB} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{BB} \\
\mathrm{B1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{B2} + (\mathrm{pause}, r_2).\mathrm{B1} \\
\mathrm{B2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{B1}
\end{aligned}$$

Types of Analysis

Steady-state and transient analysis in PEPA:

$$
\begin{aligned}
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1} \\
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{Sys} &\stackrel{\mathrm{def}}{=} \mathrm{AA} \underset{\{run\}}{\bowtie} \mathrm{A1}
\end{aligned}
$$

$\Longrightarrow$

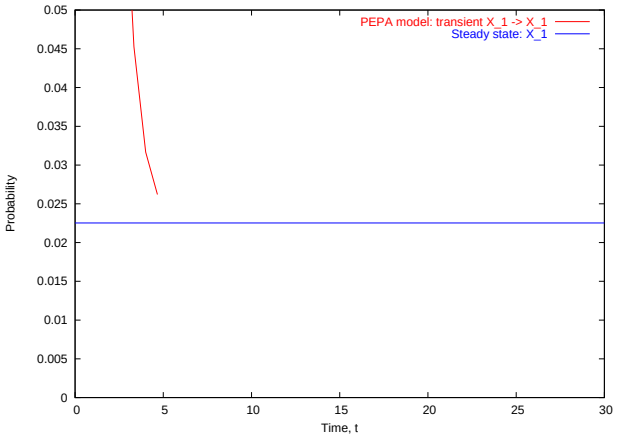


Types of Analysis

Steady-state and transient analysis in PEPA:

$$
\begin{aligned}
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1} \\
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{Sys} &\stackrel{\mathrm{def}}{=} \mathrm{AA} \underset{\{run\}}{\bowtie} \mathrm{A1}
\end{aligned}
$$

$\Longrightarrow$

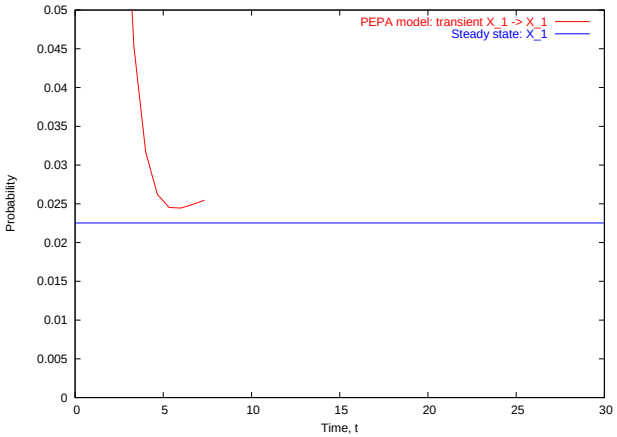


Types of Analysis

Steady-state and transient analysis in PEPA:

$$
\begin{aligned}
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1} \\
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{Sys} &\stackrel{\mathrm{def}}{=} \mathrm{AA} \underset{\{run\}}{\bowtie} \mathrm{A1}
\end{aligned}
$$

$\Longrightarrow$

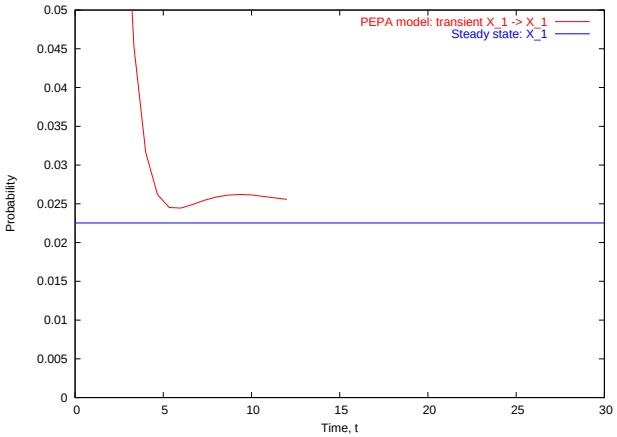


Types of Analysis

Steady-state and transient analysis in PEPA:

$$
\begin{aligned}
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1} \\
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{Sys} &\stackrel{\mathrm{def}}{=} \mathrm{AA} \underset{\{run\}}{\bowtie} \mathrm{A1}
\end{aligned}
$$

$\Longrightarrow$

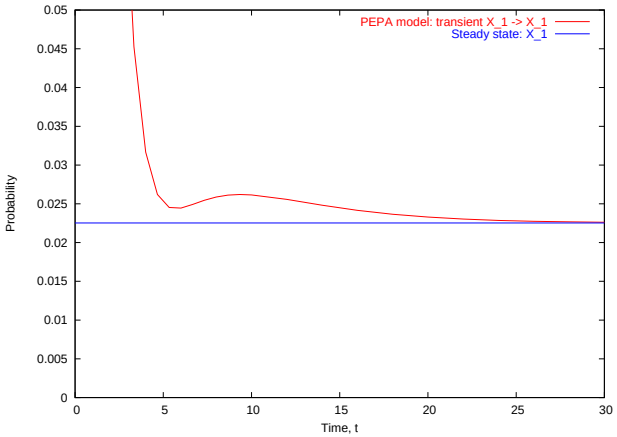


Types of Analysis

Steady-state and transient analysis in PEPA:

$$
\begin{aligned}
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1} \\
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{Sys} &\stackrel{\mathrm{def}}{=} \mathrm{AA} \underset{\{run\}}{\bowtie} \mathrm{A1}
\end{aligned}
$$

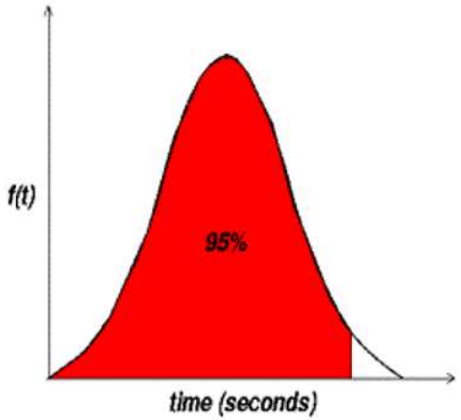
$\Longrightarrow$



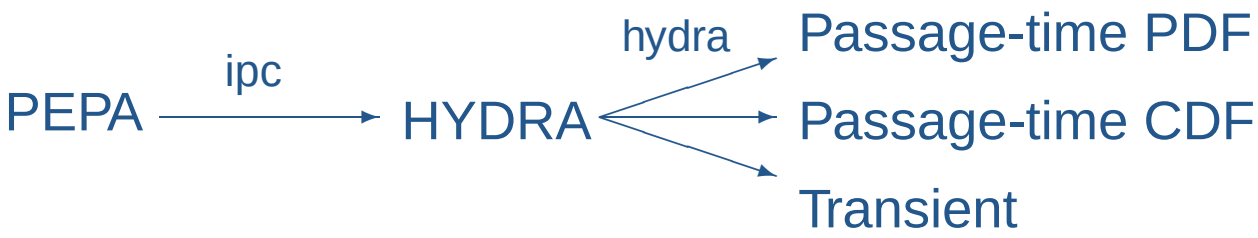
Passage-time Quantiles

Extract a passage-time density from a PEPA model:

$$
\begin{aligned}
\mathrm{A1} &\stackrel{\mathrm{def}}{=} (\mathrm{start}, r_1).\mathrm{A2} + (\mathrm{pause}, r_2).\mathrm{A3} \\
\mathrm{A2} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, r_3).\mathrm{A1} + (\mathrm{fail}, r_4).\mathrm{A3} \\
\mathrm{A3} &\stackrel{\mathrm{def}}{=} (\mathrm{recover}, r_1).\mathrm{A1} \\
\mathrm{AA} &\stackrel{\mathrm{def}}{=} (\mathrm{run}, \top).(\mathrm{alert}, r_5).\mathrm{AA} \\
\mathrm{Sys} &\stackrel{\mathrm{def}}{=} \mathrm{AA} \underset{\{run\}}{\bowtie} \mathrm{A1}
\end{aligned}
\quad \Longrightarrow
$$

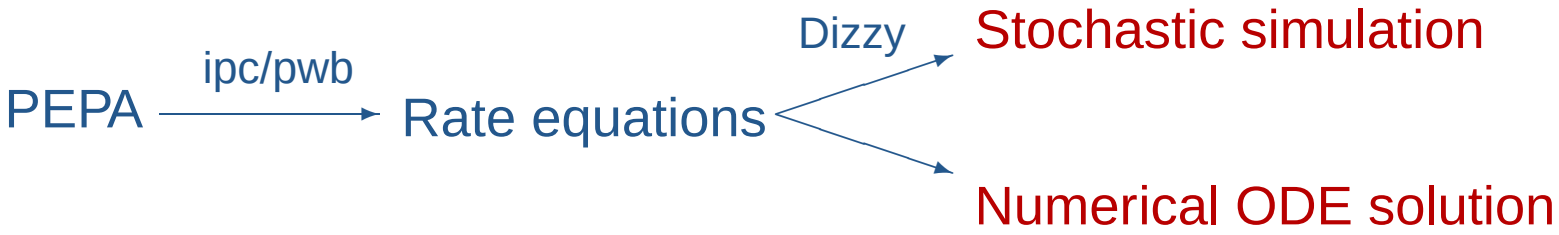


The story used to be...



- For state spaces of $O(10^9)$
- Very precise probabilistic results

Now the story is...



- For very large state spaces, e.g. $10^{1000}+$ states
- Aggregate deterministic results

Keeping track...

- Keeping track of:
  - model version
  - documentation of model version
  - type/version of query
  - parameter sets in model
  - tool version numbers
- ...is non-trivial

Perform-DB

- Allow modellers to link to/import/alter! other peoples' models
- Keep track of model-result trail
  - model $\longrightarrow$ query $\longrightarrow$ result
- Allow modellers to compare results from:
  - different queries
  - different parameters
  - different models!

Parameter Sweeping

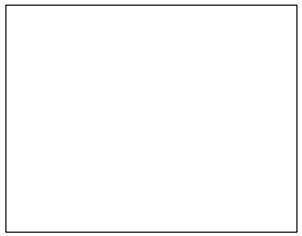
Model

PEPA net

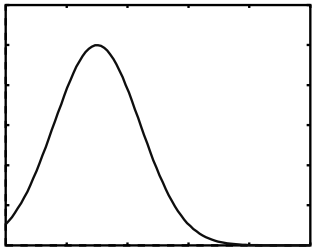
$$A \underset{L}{\bowtie} B[B]$$

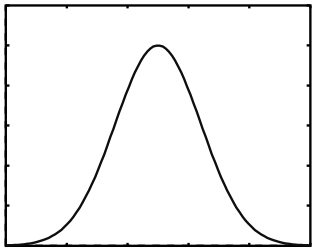
$$A \stackrel{\text{def}}{=} (up, \rho).A' + \cdots$$

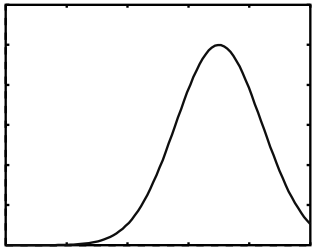
Rate parameter sweep



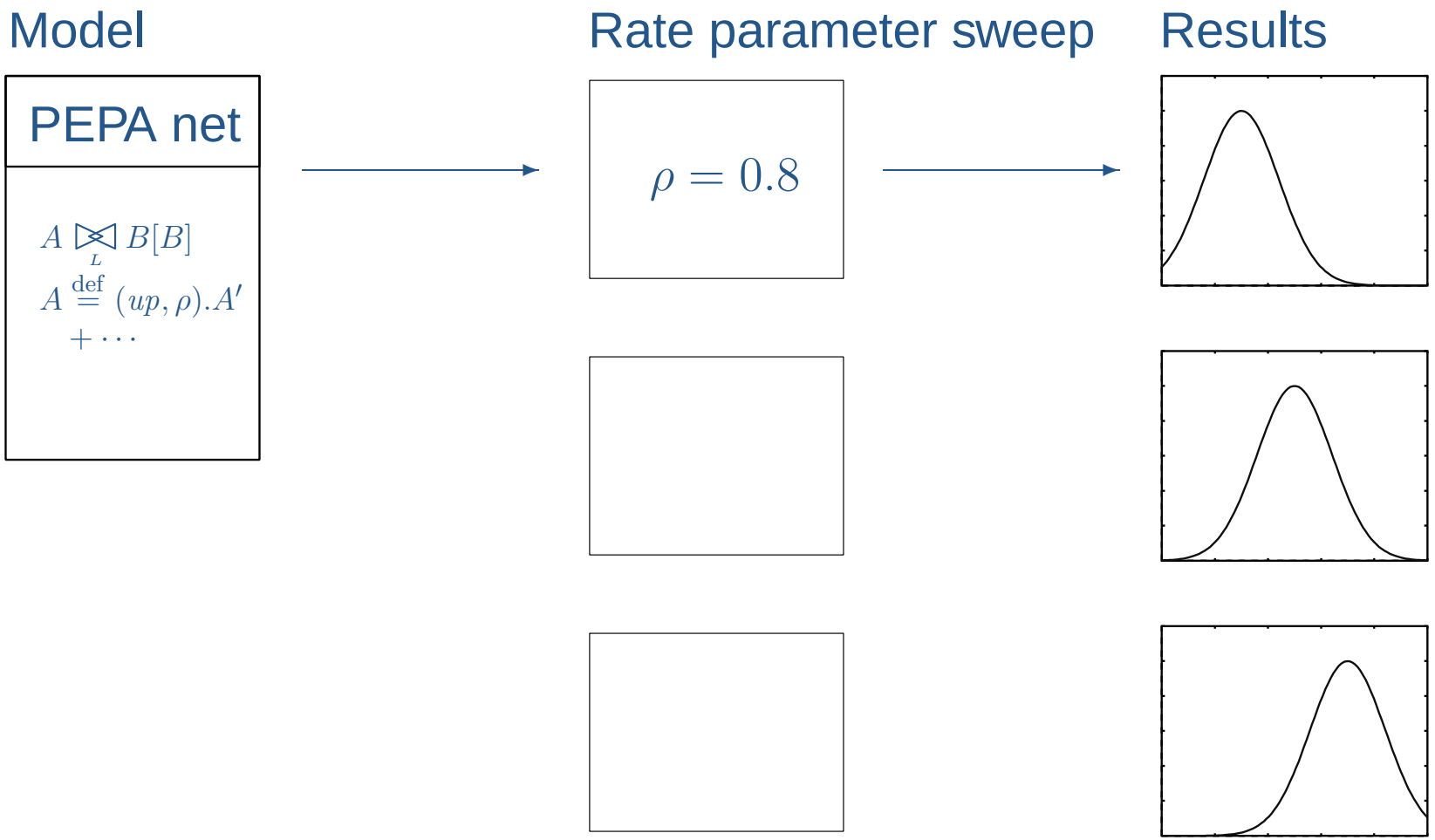
Results



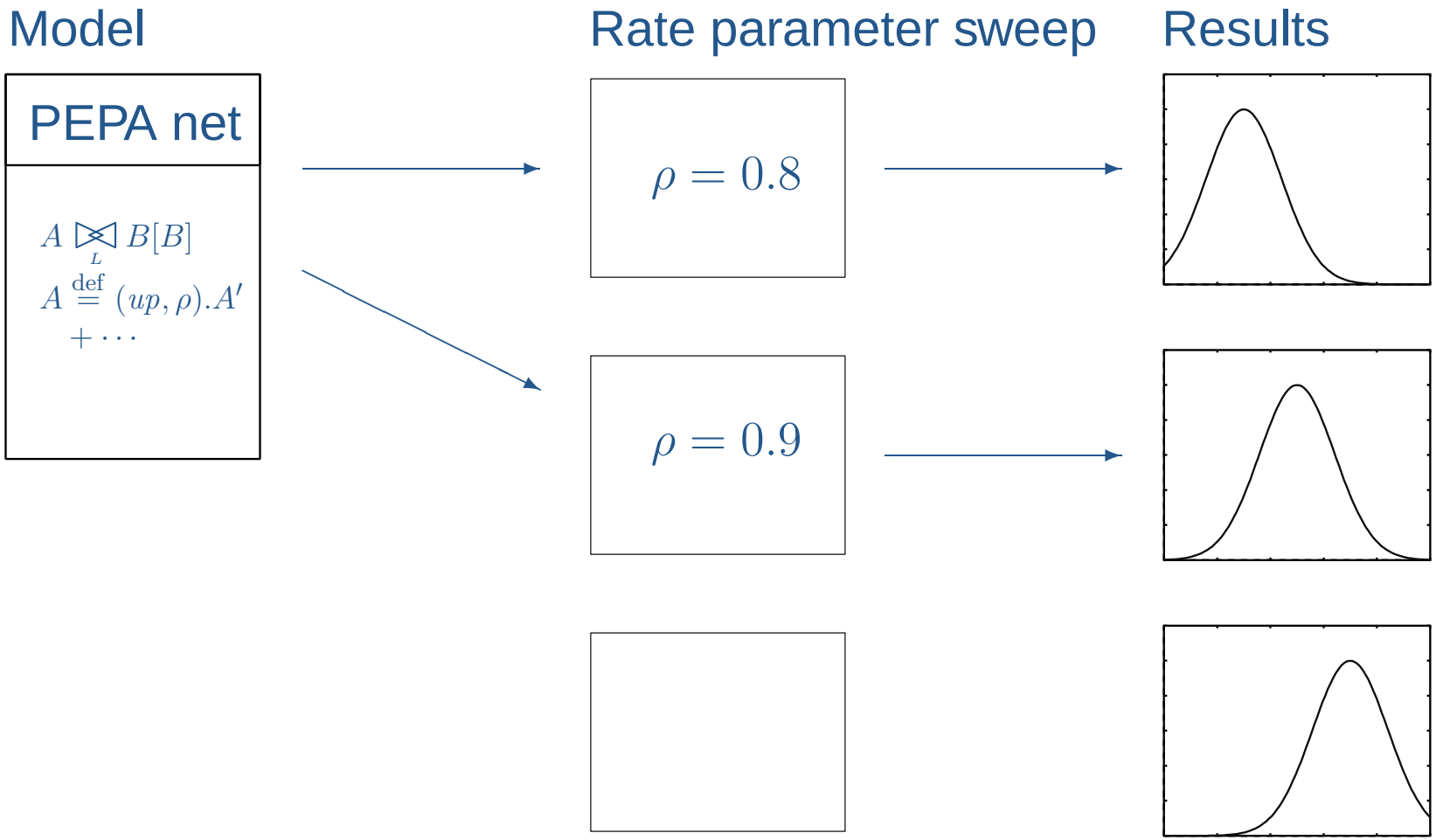




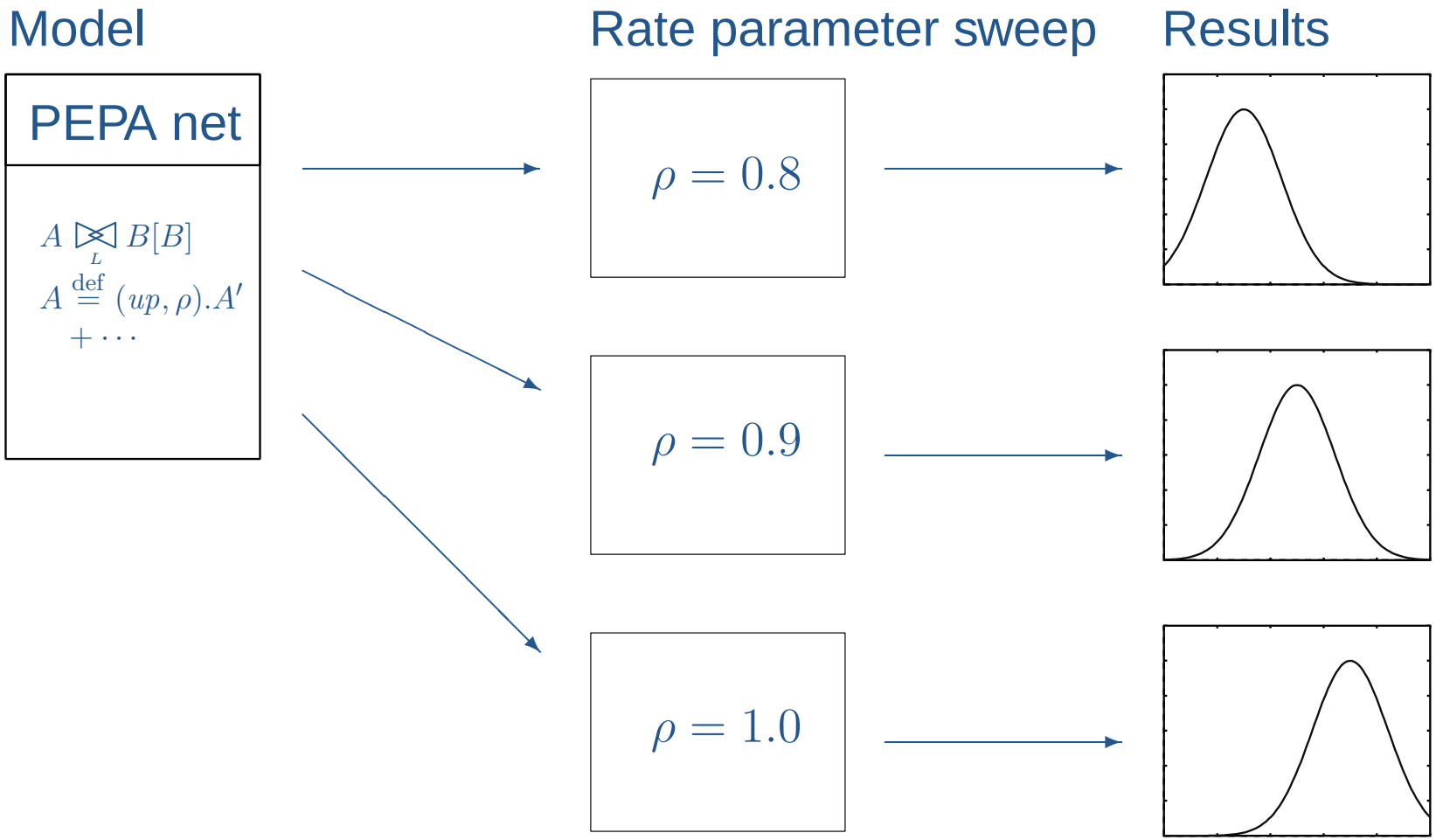
Parameter Sweeping



Parameter Sweeping



Parameter Sweeping



Distinct formalism support

Model description

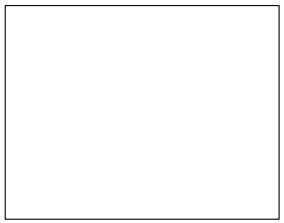
GSPN

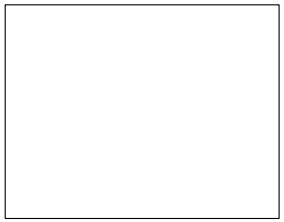
```
...
\transition{t1}{
  \condition{cpu>0}
  \action{
    cpu = cpu - 1;
    id = id + 1;
  }
  \rate{mu}
}
...
```

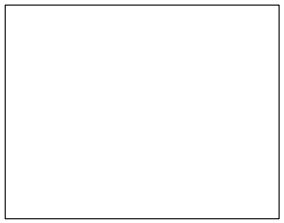
PRISM m

```
...
module queue
q : [0..N];
 [] q < N ->
  mu:(q'=q+1);
 [] q = N ->
  mu:(q'=q);
 [serve] q > 0 ->
  lambda:(q'=q-1);
endmodule
...
```

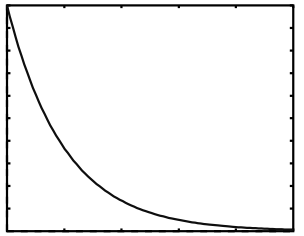
Performance query

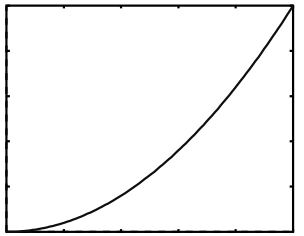


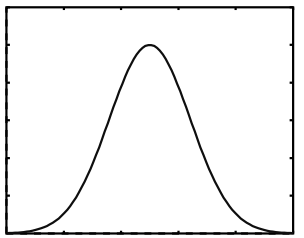




Performance results







Distinct formalism support

Model description

GSPN

```
...
\transition{t1}{
  \condition{cpu>0}
  \action{
    cpu = cpu - 1;
    id = id + 1;
  }
  \rate{mu}
}
...
```

PRISM m

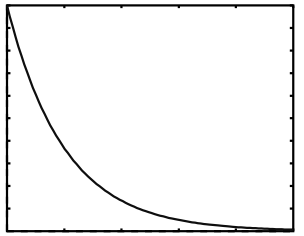
```
...
module queue
q : [0..N];
 [] q < N ->
  mu:(q'=q+1);
 [] q = N ->
  mu:(q'=q);
 [serve] q > 0 ->
  lambda:(q'=q-1);
endmodule
...
```

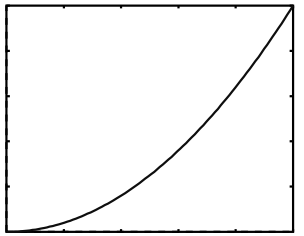
Performance query

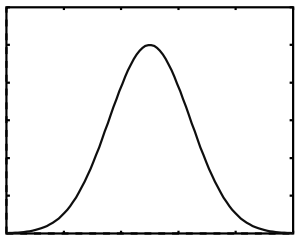
Response time

```
\passage{
   \source{cpu==1}
   \target{id==1}
   \t_start{0.1}
   \t_stop{10.0} }
```

Performance results







Distinct formalism support

Model description

GSPN

```
...
\transition{t1}{
  \condition{cpu>0}
  \action{
    cpu = cpu - 1;
    id = id + 1;
  }
  \rate{mu}
}
...
```

PRISM m

```
...
module queue
q : [0..N];
 [] q < N ->
  mu:(q'=q+1);
 [] q = N ->
  mu:(q'=q);
 [serve] q > 0 ->
  lambda:(q'=q-1);
endmodule
...
```

Performance query

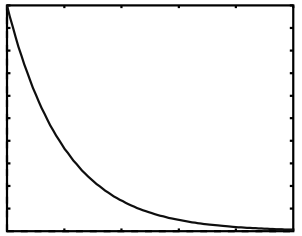
Response time

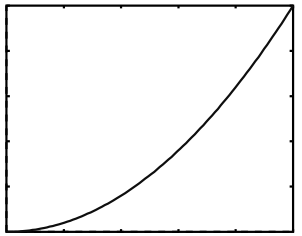
```
\passage{
   \source{cpu==1}
   \target{id==1}
   \t_start{0.1}
   \t_stop{10.0} }
```

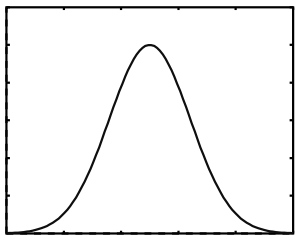
Transient dist.

```
\transient{
   \source{id==1}
   \target{ex==1}
   \t_start{0.1}
   \t_stop{5.0} }
```

Performance results







Distinct formalism support

Model description

GSPN

```
...
\transition{t1}{
  \condition{cpu>0}
  \action{
    cpu = cpu - 1;
    id = id + 1;
  }
  \rate{mu}
}
...
```

PRISM m

```
...
module queue
q : [0..N];
 [] q < N ->
  mu:(q'=q+1);
 [] q = N ->
  mu:(q'=q);
 [serve] q > 0 ->
  lambda:(q'=q-1);
endmodule
...
```

Performance query

Response time

```
\passage{
   \source{cpu==1}
   \target{id==1}
   \t_start{0.1}
   \t_stop{10.0} }
```

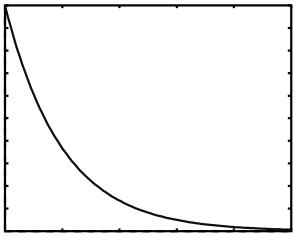
Transient dist.

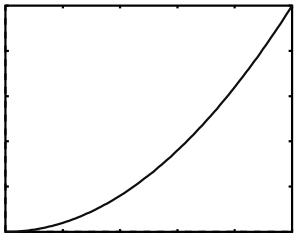
```
\transient{
   \source{id==1}
   \target{ex==1}
   \t_start{0.1}
   \t_stop{5.0} }
```

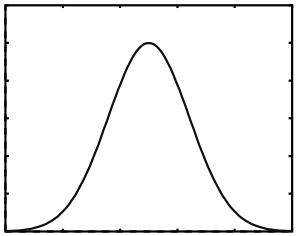
CSL query

$$serve \Rightarrow \mathcal{P}(ar\,\mathcal{U}^{\leq t}\,fi)$$

Performance results







More than a database...

- When can I reuse the results of someone else's model as well as the model itself
- separable solution
  - steady-state $\longrightarrow$ RCAT, product-forms
  - passage-time/transient $\longrightarrow$?

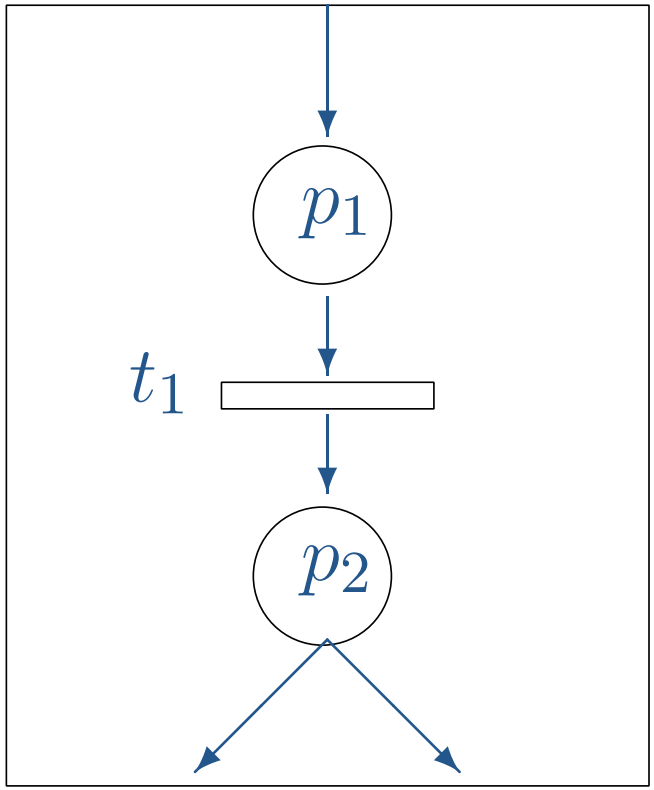
Engineering collaboration

- use your tool/formalism of choice
- allow modellers to write system components in the formalism that best suits the component

Interformalism synchronisation

- How can a stochastic Petri net model synchronise with stochastic process algebra component?
- ...or a PEPA component with a PRISM module?
- ...or an IMC component with a Stochastic automata network?

Interformalism synchronisation



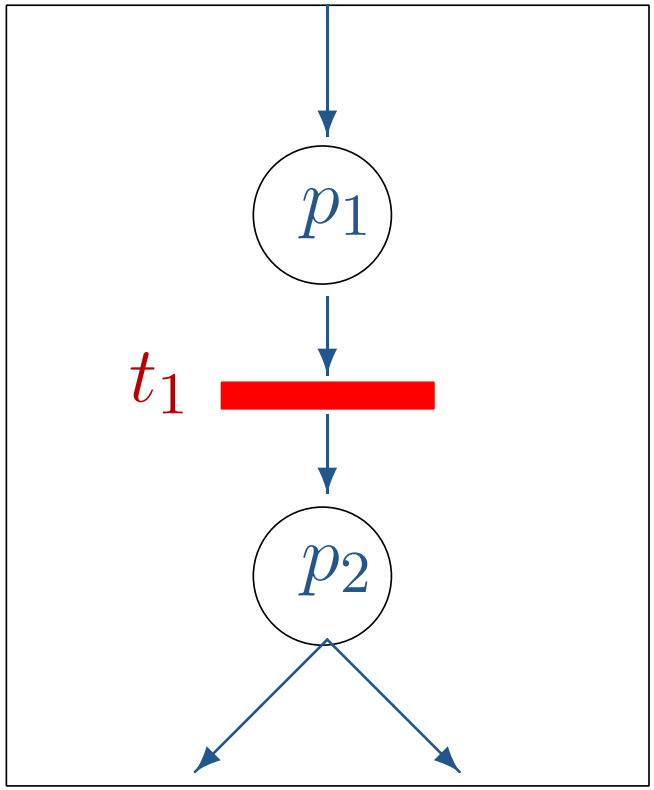
$\bowtie$
?

$$A \stackrel{\text{def}}{=} (a, \nu).A'$$
$$A' \stackrel{\text{def}}{=} (b, \top).A$$

$$B \stackrel{\text{def}}{=} (c, \lambda).B'$$
$$B' \stackrel{\text{def}}{=} (b, \mu).B$$

$$Sys \stackrel{\text{def}}{=} A \underset{\{b\}}{\bowtie} B$$

Interformalism synchronisation



$\bowtie_{\{t_1/a\}}$

$$A \stackrel{\text{def}}{=} (a, \nu).A'$$
$$A' \stackrel{\text{def}}{=} (b, \top).A$$

$$B \stackrel{\text{def}}{=} (c, \lambda).B'$$
$$B' \stackrel{\text{def}}{=} (b, \mu).B$$

$$Sys \stackrel{\text{def}}{=} A \underset{\{b\}}{\bowtie} B$$

User-definable semantics

- My idea of how a DSPN should communicate with a SAN will differ from another modeller
- user-definable cooperation semantics
- user-definable translation semantics

Conclusion

- Integrate with some parallelised toolsets: e.g. ETMCC, PRISM, DNAmaca, PWB
- Attach to a large cluster computer
- Allow jobs to be received/sent to other Perform-DB enabled clusters
- Hopefully has potential!