Project:

Internet Worm Attacks and Stochastic Agent Models

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Produced with prosper and LaTeX

Contention...

Passage or response times are useful in an agent modelling setting

Presentation

- Internet worms at work!
- A formal agent description
- Our existing techniques
- Other solutions methods

Lifecycle of an Internet Worm

Sequence of events:

1. Malicious person infects an initial server

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5. Repeat from (2) for each new infection

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2. server may be disabled by the worm infection
3. server may be repaired and returned to the network unpatched
4. server may be repaired and patched
5. server may be rolled back, thus removing patch

Internet worms

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- Usually malicious autonomous program that spreads without user intervention
- **Emergent behaviour:** causes huge network bottlenecks – brings internet to standstill for many hours, or even days

Code Red II

- Example: Code Red II
  - 19th July 2001
  - 350,000 hosts infected in 14 hours
  - c.f. Sasser: 1–1.5 million hosts in 2 days
  - utilised *buffer overflow* in Microsoft IIS web server
  - infected machines would probe for other victims on port 80
  - 20th July 2001: mode changes from one of propagation to DDOS attack on the www.whitehouse.gov

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  - $\Rightarrow$ infected computers/computers susceptible to infection will mix homogeneously
  - potential to kill/disable a host, according to payload
  - Nicol et al use hybrid model of Internet worms: epidemiological/stochastic

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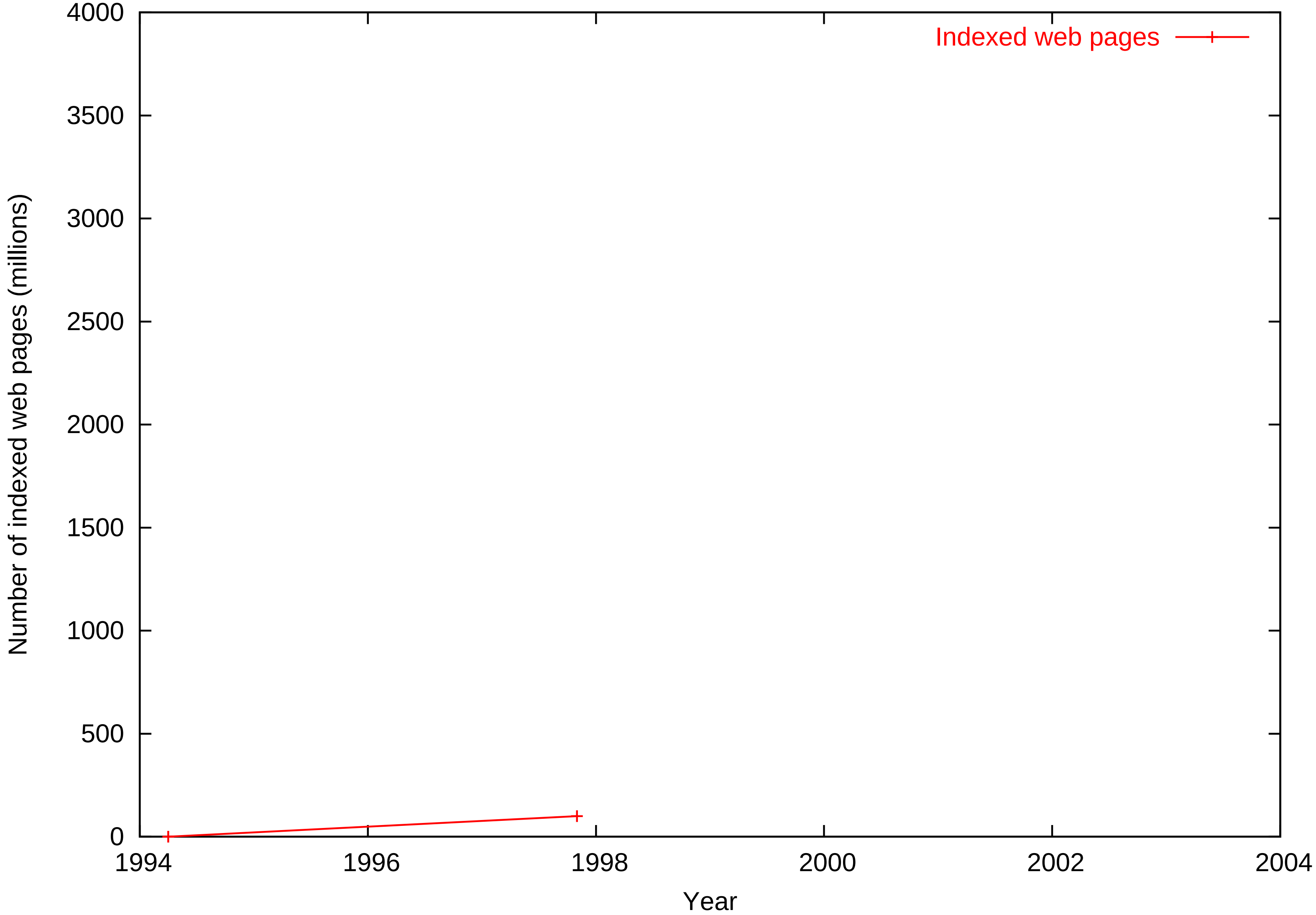
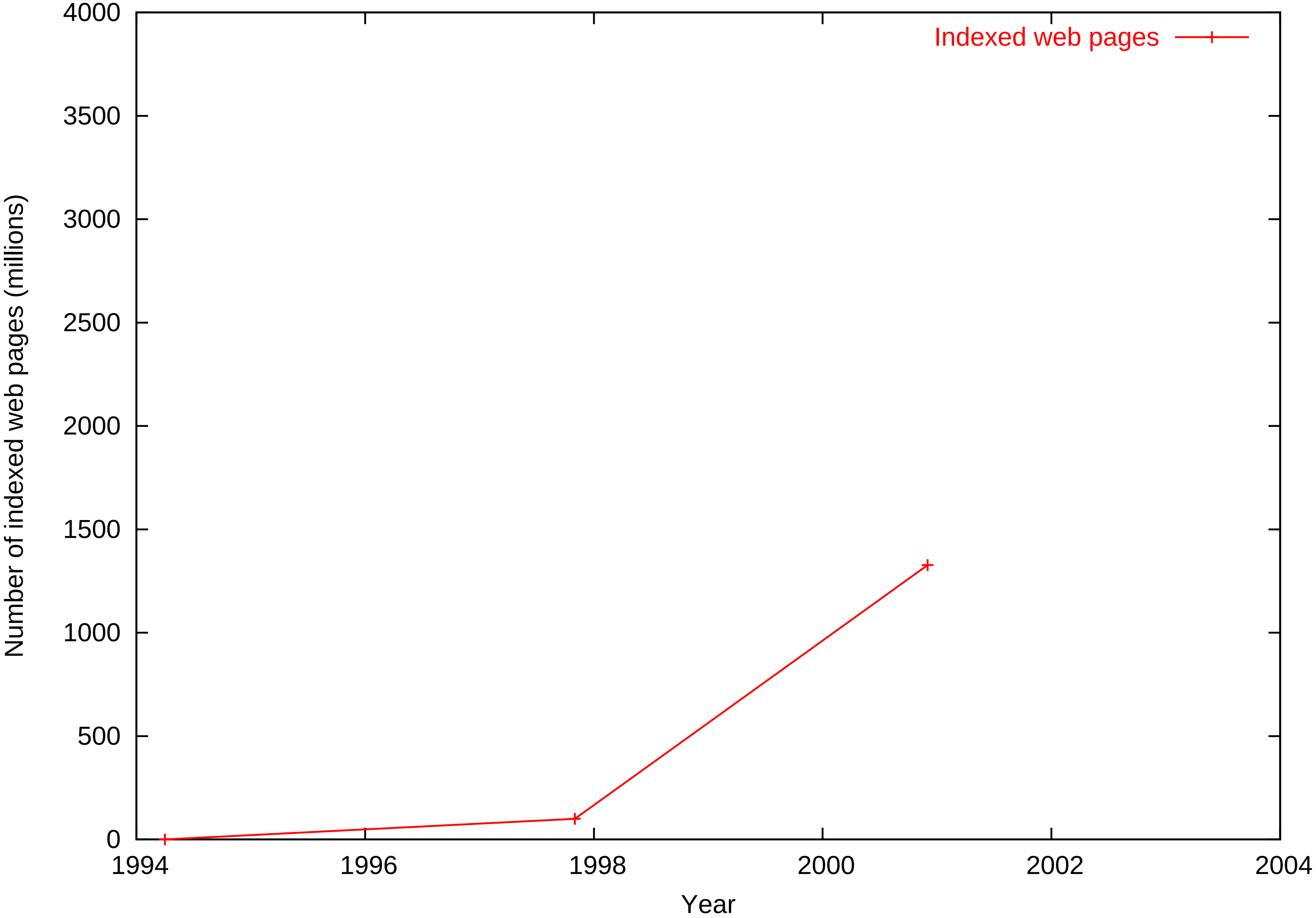
$\Rightarrow$ We have to learn to prune *unimportant* behaviour

Internet Growth



Internet Growth



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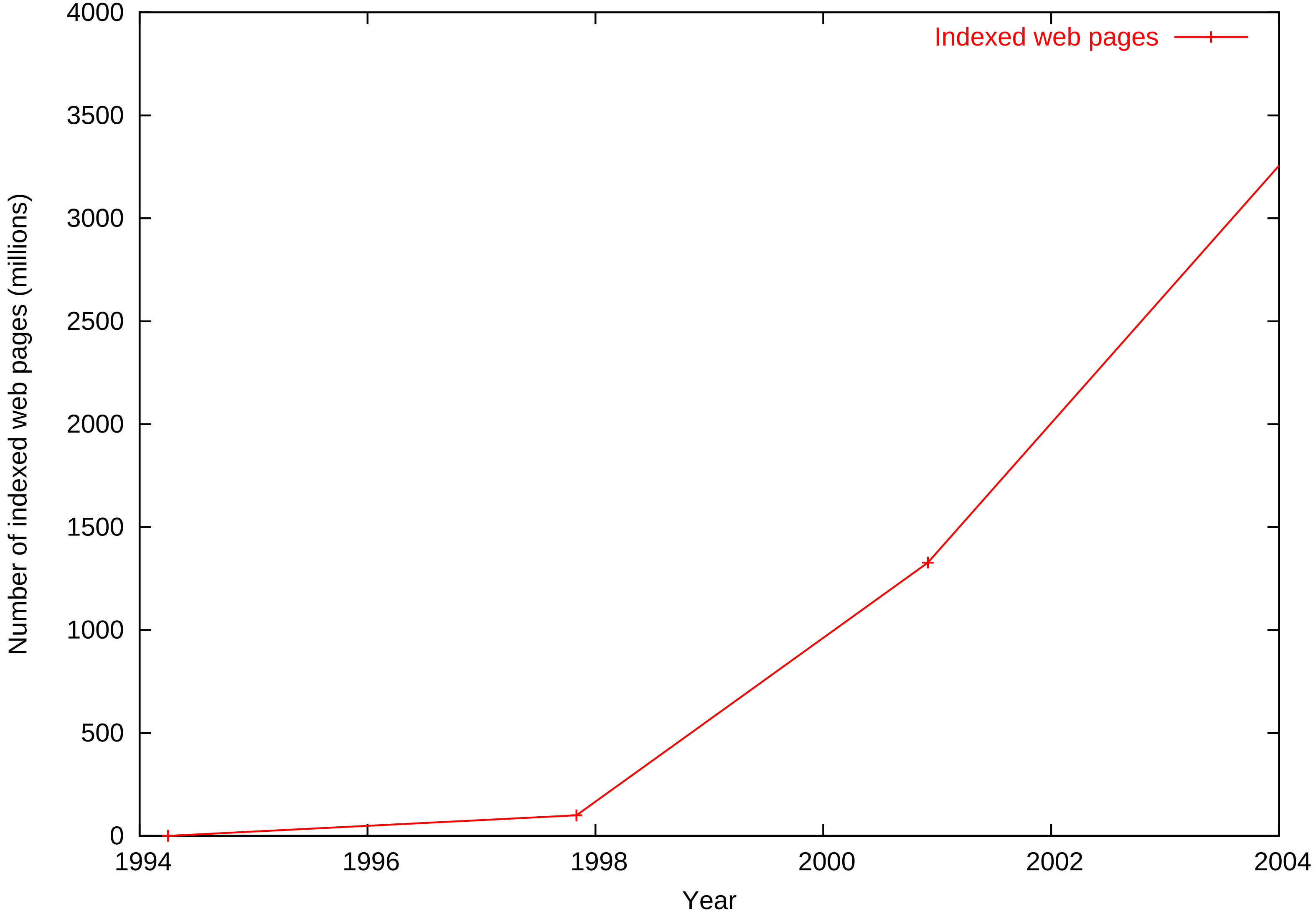

Stochastic Process Algebra

PEPA syntax:

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

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Biological PEPA Agent Modelling

Require a pairwise cooperation paradigm:

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

- Action prefix: $(\mathrm{a}, \lambda).\mathrm{P}$
- Competitive choice: $\mathrm{P}_1 + \mathrm{P}_2$
- Pairwise agent cooperation: $\mathrm{P}_1 \underset{L}{\bigoplus} \mathrm{P}_2$
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Types of Analysis

Steady-state and transient analysis in PEPA:

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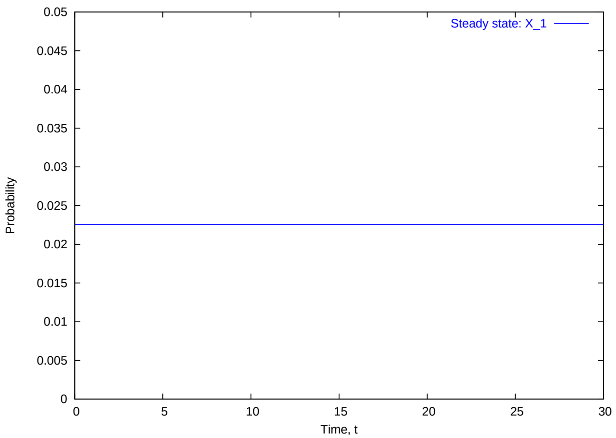

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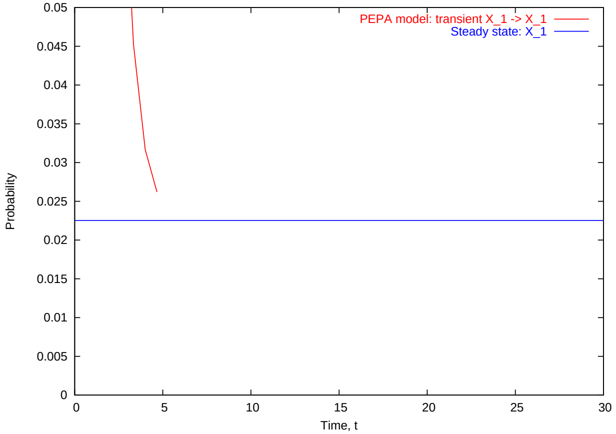

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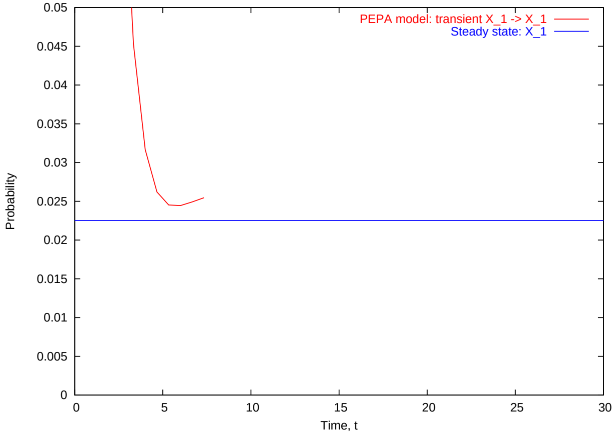

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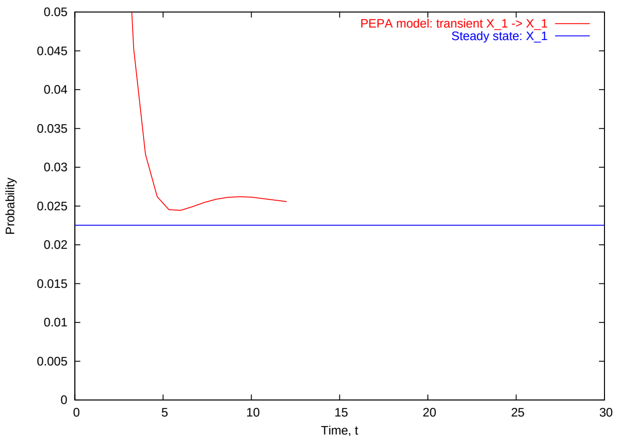

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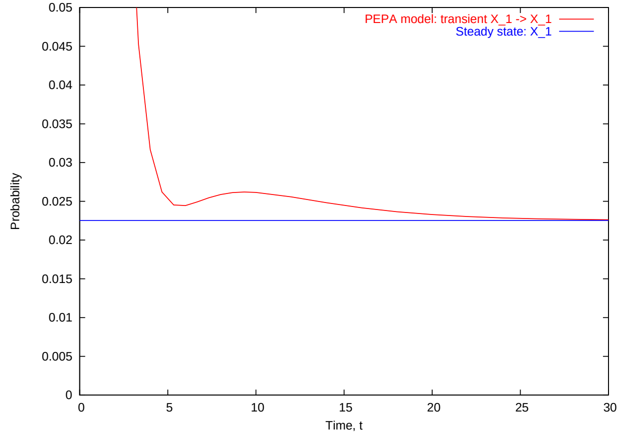

Passage-time Quantiles

Extract a passage-time density from a PEPA model:

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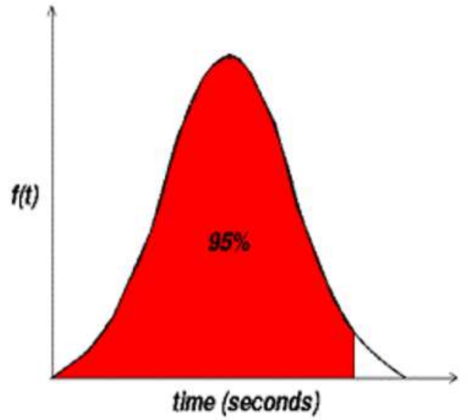

State of the Art

- Good news
  - PEPA model: passage time/transient analysis - $O(10^8)$ states
  - Semi-Markov PEPA: passage time/transient analysis - $O(10^7)$ states

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- Bad news
  - This only represents 8 agents with 10 states each!

Ways forward for PEPA Agent modelling

- Either:
  - selective model aggregation

  ⇒ allows use of passage/transient

- Or:
  - development of approximate techniques

  ⇒ automated generation of MFA/ODE equations from PEPA model [c.f. Sumpter 2000, Hillston 2004]

SIR: Epidemiological model

- Consider fixed population of N computers
- Partition population into, computers that are:
  - susceptible to infection, $s(t)$
  - infected, $i(t)$
  - removed, $r(t)$
- Deterministic system:
  - $\frac{\mathrm{d}s(t)}{\mathrm{d}t} = -\beta s(t)i(t)$
  - $\frac{\mathrm{d}i(t)}{\mathrm{d}t} = \beta s(t)i(t) - \gamma i(t)$
  - $\frac{\mathrm{d}r(t)}{\mathrm{d}t} = \gamma i(t)$

Agent worm model

$$\begin{aligned}\text{Susceptible} \;&=\; (\text{infect}, \top).\text{Infected} \\ &\quad + (\text{patch}, \lambda_p).\text{Removed}\end{aligned}$$

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\text{System} = \bigoplus_{\mathrm{i}=1}^{\mathrm{N}} \text{Susceptible}_{\mathrm{i}}
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$$\begin{aligned}
\text{System}(\mathrm{p}, \mathrm{q}) &= \bigoplus_{i=1}^{p} \text{Infected}_{\mathrm{i}} \bigoplus_{\mathrm{i}=1}^{\mathrm{q}} \text{Susceptible}_{\mathrm{i}} \\
&\quad \bigoplus_{i=1}^{N-p-q} \text{Removed}_{\mathrm{i}}
\end{aligned}$$

Analysis possibilities

Sumpter Look to count numbers of agents, $A(t)$, in a given state by solving a derived mean field equation (MFE)

$$f(t,i) = \mathbb{E}(A(t+\Delta t) \mid A(t) = i)$$

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- remodel using *bimodal assumption*

Agent Count-based Model

Bimodal characterisation of variables:

$$\begin{aligned} \mathrm{S_H} &\stackrel{\text{def}}{=} (\mathrm{infect}, \top).\mathrm{S_L} \\ &\quad + (\mathrm{patch}, r_2).\mathrm{S_L} \\ \mathrm{S_L} &\stackrel{\text{def}}{=} (\mathrm{rollback}, \lambda_s).\mathrm{S_H} \\ \vdots & \qquad \vdots \end{aligned} \quad \Rightarrow \quad \begin{aligned} \frac{\mathrm{d}s(t)}{\mathrm{d}t} &= -\beta s(t)i(t) \\ \frac{\mathrm{d}i(t)}{\mathrm{d}t} &= \beta s(t)i(t) - \gamma i(t) \\ \frac{\mathrm{d}r(t)}{\mathrm{d}t} &= \gamma i(t) \end{aligned}$$

Conclusion

- Internet worms have a reasonable biological analogy
- State spaces too large for traditional temporal modelling
- The answer: Selective aggregation/agent counting
- Passage times in an agent setting
  - a useful cost function for a model
  - probability of extinction within a given time