

IFIP WG 10.4

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Research Report

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Topics

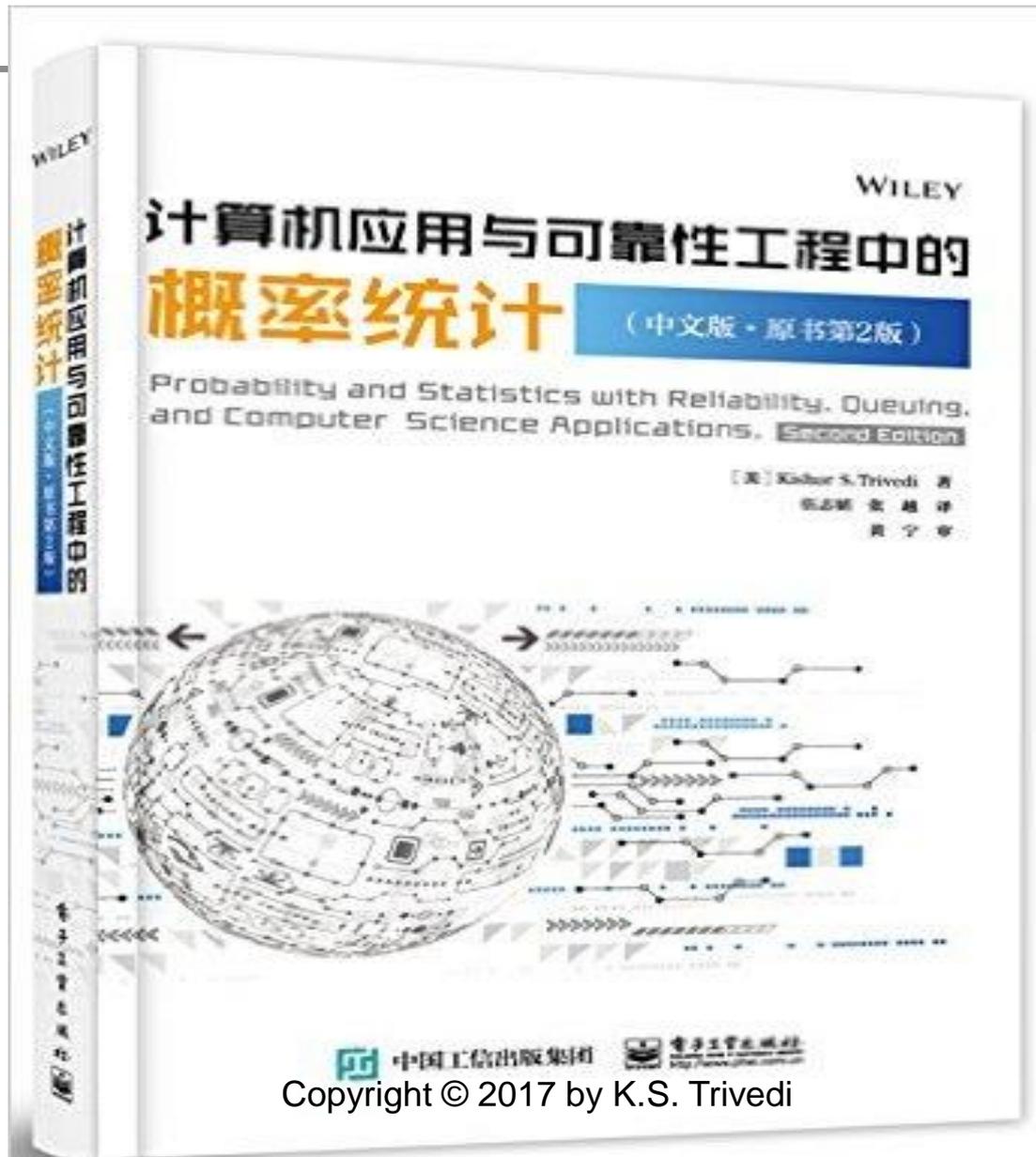
- Usable artifacts (Engineering)
 - Books
 - Software packages
- Dependability Economics
 - Cloud Capacity planning
 - Smartgrid optimization
- User-perceived dependability (higher level dependability?)
 - Completion time of programs in presence of failure/recovery
 - Completion time and reliability of a sequence of tasks
- Hierarchy in Dependability Evaluation

Books Update

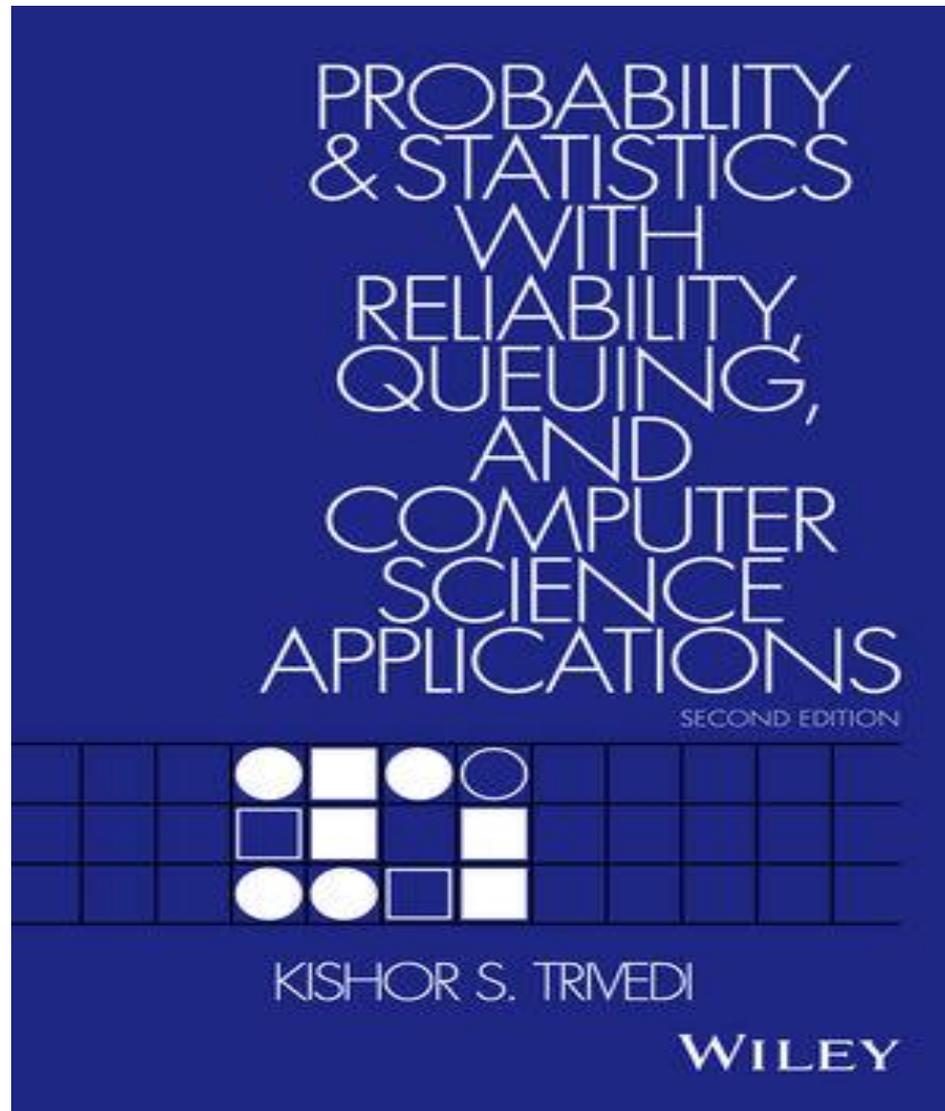
- **Probability and Statistics with Reliability, Queuing, and Computer Science Applications, 1982; Second edition, John Wiley, 2001 (Blue book) - Chinese translation, 2015; fully revised paperback, 2016**
- **Performance and Reliability Analysis of Computer Systems: An Example-Based Approach Using the SHARPE Software Package, Kluwer, 1996 (Red book)**
- **Queuing Networks and Markov Chains, 1998
John Wiley, second edition, 2006 (White book)**

**Reliability and Availability Engineering,
Cambridge University Press, 2017 (green book)**

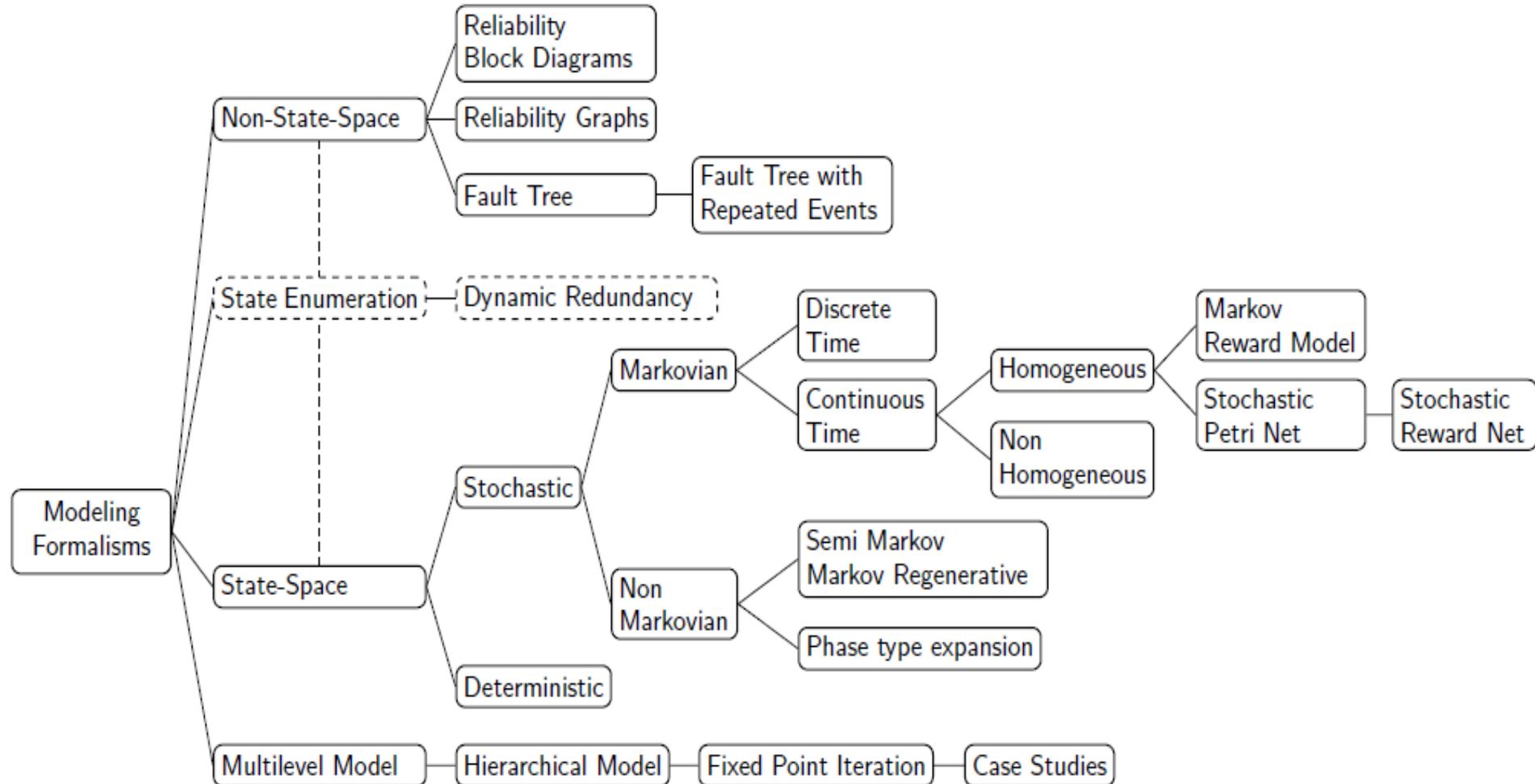
Chinese Version by Prof. Ning Huang's group



Paper back



Outline of the latest book (Green Book)



Springer Series in Reliability Engineering

Lance Fiondella
Antonio Puliafito *Editors*

Principles of Performance and Reliability Modeling and Evaluation

Essays in Honor of Kishor Trivedi on his
70th Birthday

 Springer

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Software Packages from WG 10.4

- UCLA: CARE, ARIES
 - Umich, Arizona, UofI: Metasan, Ultrasan, Mobius
 - Duke: HARP, SAVE, SHARPE, SPNP, SREPT
 - LAAS: SURF
-
- Many tools for fault/error injection

Dependability Economics

Stochastic Model Driven Capacity Planning for an IaaS Cloud,

R. Ghosh, F. Longo, R. Xia, V. Naik, and K. Trivedi,
IEEE Trans. On Services Computing, 2014

Capacity Planning Problem

Determine the number of Physical
Machines
That
Minimize the overall cost

Duke/IBM project on cloud computing

Joint work with
Rahul Ghosh, Ruofan Xia and Dong Seong Kim (Duke),
Francesco Longo (Univ. of Messina)
Vijay Naik, Murthy Devarakonda and Daniel Dias
(IBM T. J. Watson Research Center)

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Cost components

■ Capital Expenditure (CapEx)

- Infrastructure cost

■ Operational Expenditure (OpEx)

- Penalty due to violation of different SLA metrics
 - Cost of job rejection due to insufficient resources
 - Cost of downtime
- Cost of carrying out repairs
- Power usage cost

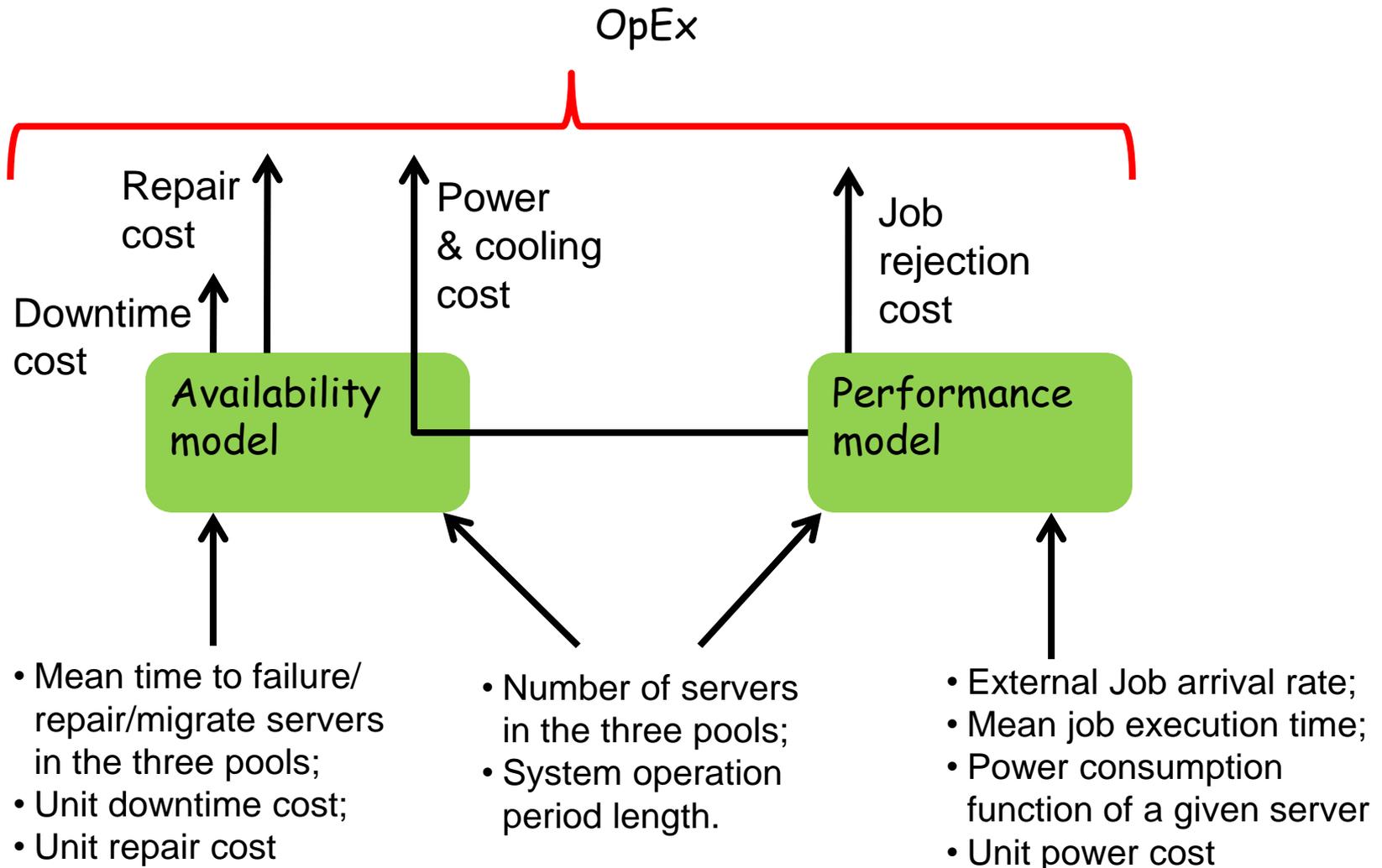
Three Pools of Servers (PMs)

- To reduce power usage costs, physical machines are divided into three pools [IBM Research Cloud]
 - Hot pool (high performance & high power usage)
 - Warm pool (medium performance & power usage)
 - Cold pool (lowest performance & power usage)

Optimization Problem

- Determine the number of PMs in each pool: n_h, n_w, n_c so as to minimize $CapEx(n_h, n_w, n_c) + OpEx(n_h, n_w, n_c)$
 - n_h, n_w, n_c : number of servers in the hot, warm, cold pool
- CapEx function can be “easily” determined
- OpEx for each vector of PMs in each pool needs to be computed
- For a search-based optimization algorithm, this OpEx computation needs to be done many times
 - We need an efficient algorithm for doing this
- Scalable models are developed for such a computation

High level view of developed models for OpEx



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Optimization Problems and Solution Approach

- The problem is a non-linear integer programming problem
- We use Simulated Annealing but other search algorithms can be used as well. I welcome you to experiment with other optimization techniques such as :
- For each vector of values of the number of servers in each pool, we need an efficient method of computing the job rejection probability, downtime and the power usage cost
→ scalable **availability, performance and power** models are needed

Cloud computing

➤ Performance analysis:

- ✓ Developed scalable interacting stochastic sub-models for large Clouds
- ✓ Analysis of provisioning delay and impact of different factors, e.g., arrival rate, system capacity, resource holding time etc.
 - R. Ghosh, F. Longo, V. K. Naik, and K. S. Trivedi, "Modeling and Performance Analysis of Large Scale IaaS Clouds", Elsevier Future Generation Computing Systems, July 2013.

➤ Quantification of power-performance trade-offs:

- ✓ Developed a three pool architecture to show the trade-offs between response time and power consumption
 - R. Ghosh, V. K. Naik, and K. S. Trivedi, "Power-Performance Trade-offs in IaaS Cloud: A Scalable Analytic Approach", DSN Workshop on DCDV, June 2011.

Cloud Computing (contd.)

➤ Scalable Availability analysis:

✓ Interacting stochastic sub-models for failure-repair analysis

- R. Ghosh, F. Longo, F. Frattini, S. Russo and K. S. Trivedi, "Scalable Analytics for IaaS Cloud Analytics", IEEE Trans. On Cloud Computing, 2014.

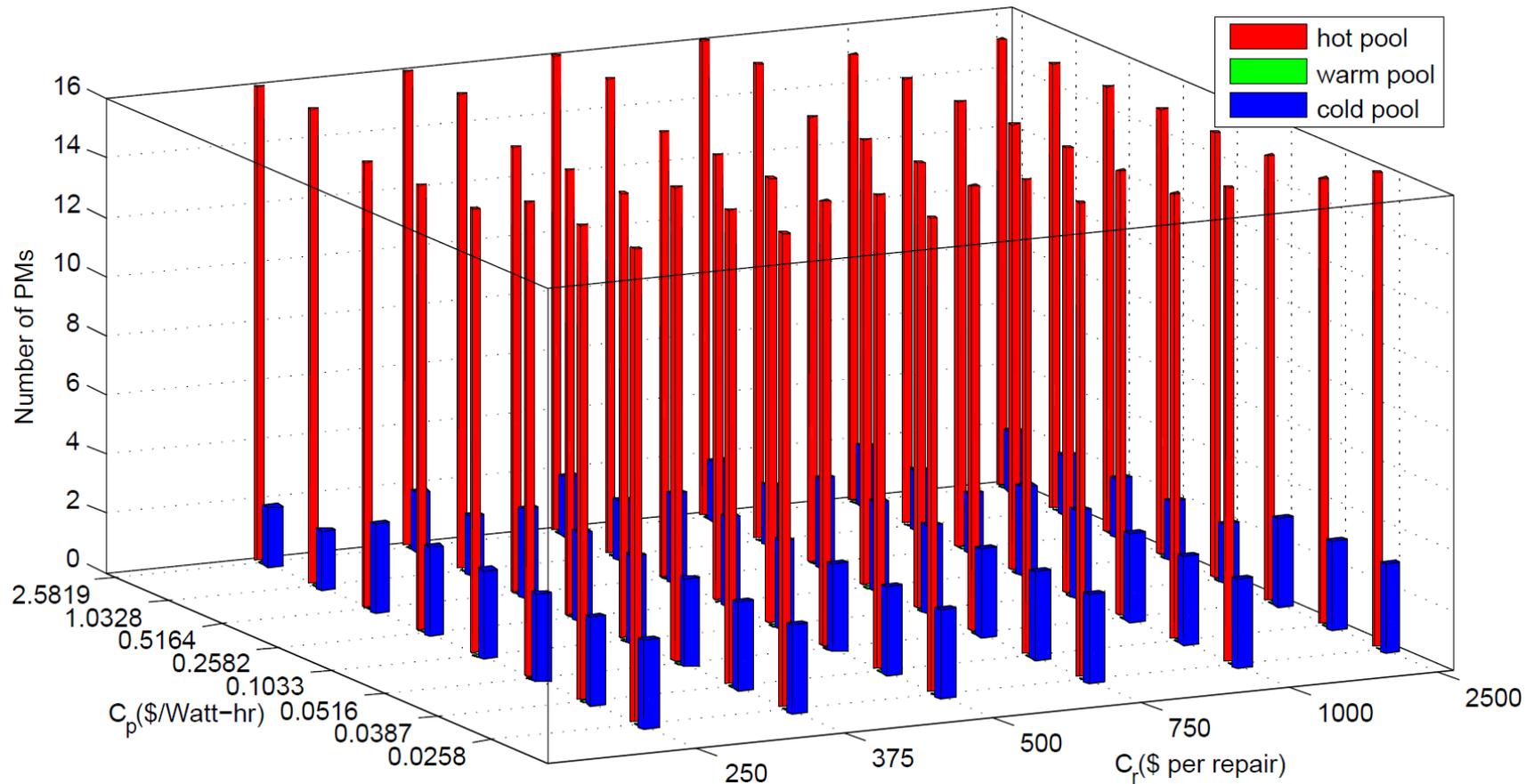
➤ Cost analysis, optimization and Cloud capacity planning:

✓ Developed and solved optimization problems to minimize the total cost without violating the SLAs

- R. Ghosh, F. Longo, R. Xia, V. K. Naik, and K. S. Trivedi, "Stochastic Model Driven Capacity Planning for an Infrastructure-as-a-Service Cloud", IEEE Trans. On Services Computing, 2014.

Sample Results

- Optimal configurations in different problem instances



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Dependability Economics: Smartgrid

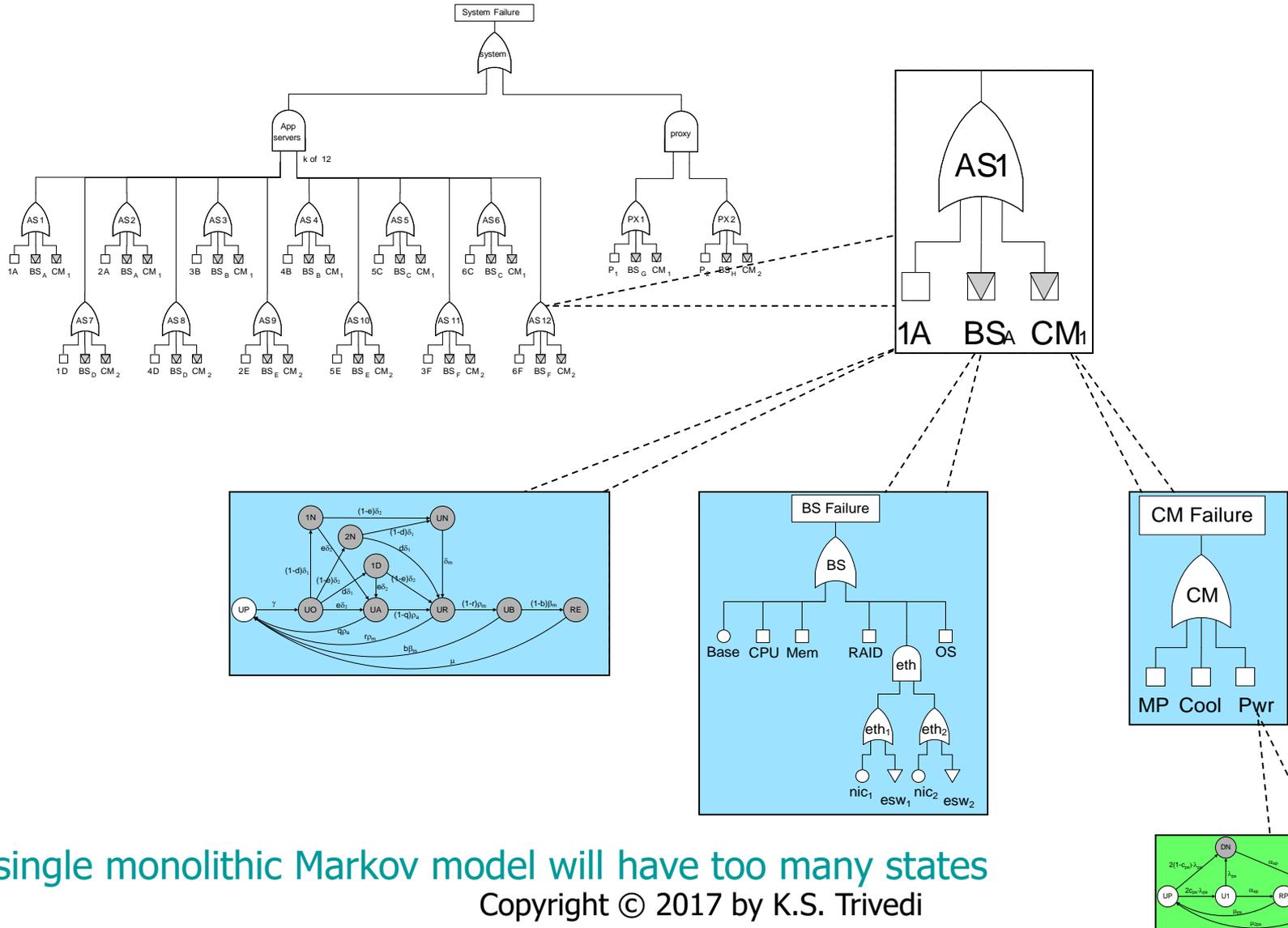
Daniel Sadoc Menasché, Alberto Avritzer, Sindhu Suresh, Rosa Maria Meri Leão, Edmundo de Souza e Silva, Morganna C. Diniz, Kishor S. Trivedi, Lucia Happe, Anne Koziolk: Assessing survivability of smart grid distribution network designs accounting for multiple failures. *Concurrency and Computation: Practice and Experience* (2014)

Anne Koziolk, Alberto Avritzer, Sindhu Suresh, Daniel S. Menasché, Morganna Carmem Diniz, Edmundo de Souza e Silva, Rosa Maria Meri Leão, Kishor S. Trivedi, Lucia Happe: Assessing survivability to support power grid investment decisions. Rel. Eng. & Sys. Safety (2016).

Higher Levels of dependability

- Task Completion Time in the presence of failure/recovery
 - V. G. Kulkarni, V. F. Nicola, and K. S. Trivedi, The completion time of a job on multi-node systems, *Advances in Applied Probability*, 1987.
 - P. Chimento and K. S. Trivedi, The completion time of programs on processors subject to failure and repair, *IEEE Transactions on Computers*, 1993.
 - D. Wang & K. Trivedi, Modeling user-perceived reliability based on user behavior graphs. *Int. Journal of Reliability, Quality and Safety Engineering (IJRQSE)*, 2009.
 - F. Machida, V. Nicola & K. Trivedi, Job Completion Time on a Virtualized Server with Software Rejuvenation, *ACM JETC*, 2014.

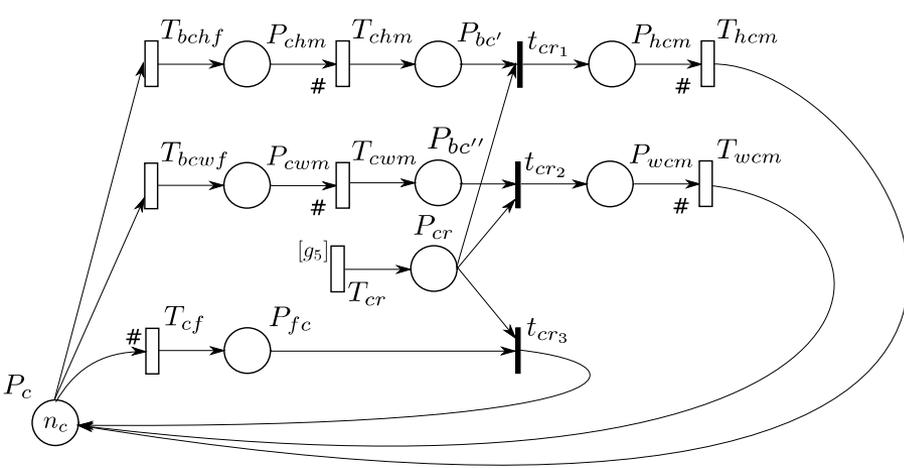
Hierarchical Composition in Evaluation



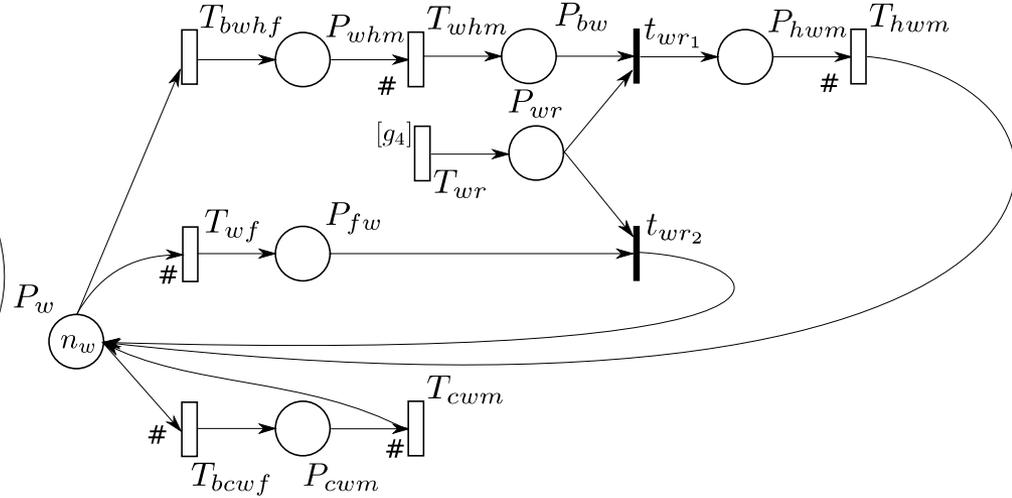
A single monolithic Markov model will have too many states

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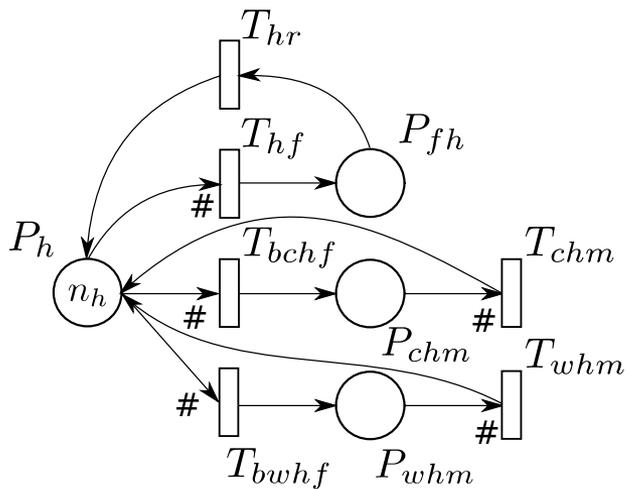
Decompose into Interacting Sub-models



SRN sub-model for cold pool

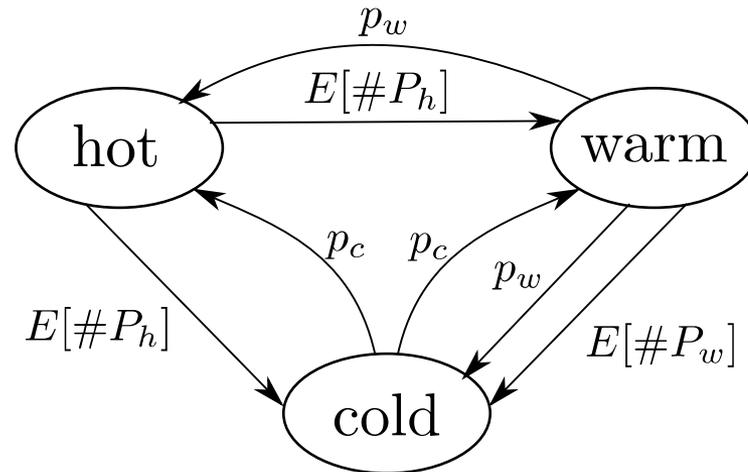


SRN sub-model for warm pool



SRN sub-model for hot pool

Import graph and model outputs



■ Model outputs:

- mean number of PMs in each pool ($E[\#P_h]$, $E[\#P_w]$, and $E[\#P_c]$)
- Downtime in minutes per year

Thanks!