UNIVERSITY OF TWENTE.

CTIT CENTRE FOR TELEMATICS AND INFORMATION TECHNOLOGY

McSTORES: Model Checking Stochastic Systems using Rare Event Simulation

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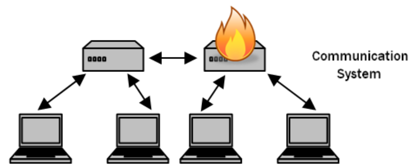
Highly Reliable Systems

Setting: Computer or communication system with a *very low probability of system failure*.

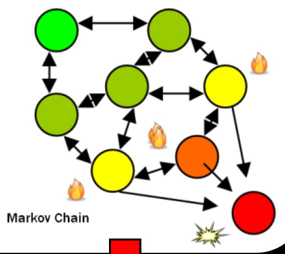
Goal: Testing whether given *Quality of Service thresholds* are met. *Example:* probability of system failure before time *t* is less than *p*.



Markov Chain Representation

Setting: *Markov Reward Model* that consists of states that represent the condition of the components in the system.

Approach: Numerical solution – however, this might suffer from *state space explosion*, and for certain types of time and reward bounds, efficient numerical methods are *not available*.



Monte Carlo Simulation

Setting: Computer program that *stochastically simulates* the Markov model.

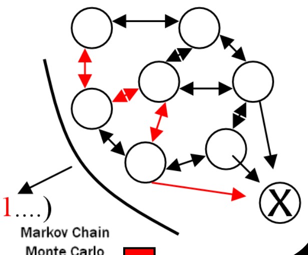
Approach: Run the program to generate N *observations* that consist of a 1 – a *hit* – if the system reaches a critical state before time *t*, 0 otherwise.

Problem: If the probability is *very small*, as we assumed, then the program will need to run an *unpractical amount of times* before seeing a 1.

$$\hat{p} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

$$\uparrow$$

$$\vec{x} = (000\ldots0000000\mathbf{1}\ldots.)$$



Rare Event Simulation

Setting: Computer program that *simulates* the Markov model with *different transition rates* so that the probability of a hit is *increased*.

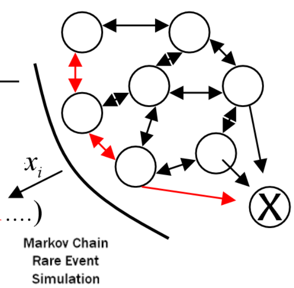
Approach: Run the new program as in the previous approach. Then, *weigh* the hits with the *likelihood* that the path ϕ is seen under the original measure compared to the new one.

Problem: Finding a *good change of probability measure* that leads to better results in this context.

$$\hat{p} = \frac{1}{N}\sum_{i=1}^{N} \frac{dP(\phi_i)}{dP^*(\phi_i)} x_i \longleftarrow \phi_i$$

$$\uparrow$$

$$\vec{x} = (110111110110\mathbf{1}\ldots.)$$



Goal of our research: Finding a solution to the latter problem.

Most current applications that use Rare Event Simulation rely on the *most likely path* into the set of critical states. The approach is then to twist the transition rates in the system so that the altered system is expected to follow this path.

Preliminary investigations indicate that the *most likely path* is only *slightly more likely* than the most similar others. So paths that are relatively likely in the original setting become rare in the new approach. This leads to inaccurate results (large estimator variance). This means that we are in a *regime of asymptotic behaviour* that is not often mentioned in the literature, and we expect to solve this problem (and others) in the remaining 3.5 years of the PhD research track.

NWO Nederlandse Organisatie voor Wetenschappelijk Onderzoek

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