On Dependability Assessment of Fault Tolerant Systems by Means of Statistical Model Checking

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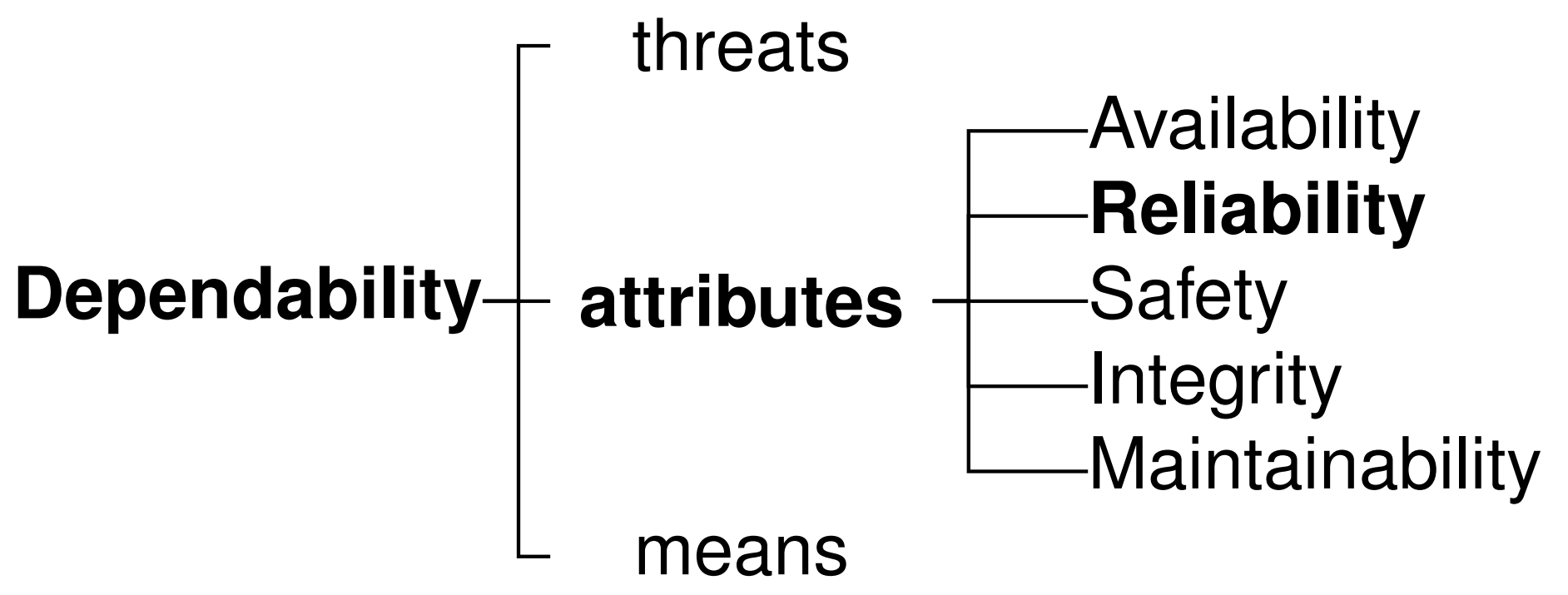
Introduction to Dependability

- The ability of a system to provide a required service and to perform it for a specified period of time within specified conditions is denoted as **dependability**.
- It can be meant in a **qualitative** or a **quantitative** manner [1]. **Qualitatively**, it can be seen as "the ability to deliver a service that can be justifiably trusted" [1] or, as a property such that "reliance can be justifiably placed on the services delivered by the system" [2].
- Since dependability is a complex feature composed of many attributes, the (overall) dependability cannot be simply quantified by a single value. Instead, the **attributes are quantified to form a complex image about dependability**. As the time of occurrence of a fault, error or failure cannot be specified certainly, the attributes are typically described by means of the probability theory based on which attributes such as reliability, maintainability or availability can be quantified.



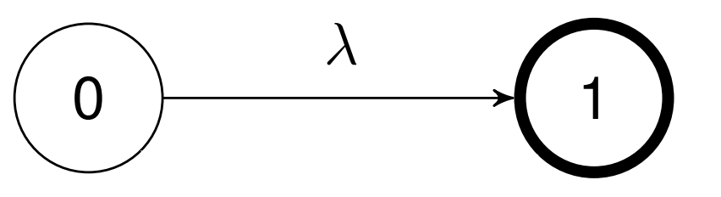
Dependability Assessment

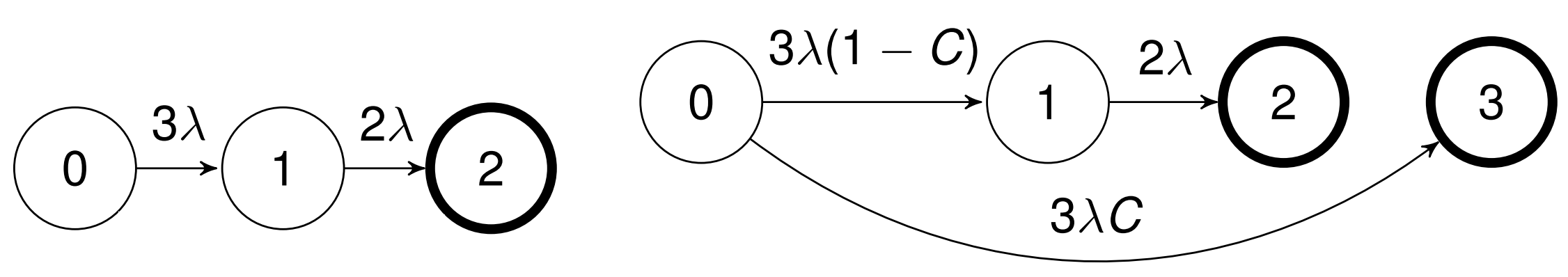
- X_{TTF} …continuous random variable representing the **time to failure** (**TTF**)
- $f(t)$ …**probability density function** (**PDF**) of X_{TTF} representing the probability that a system fails in t
- $F(t)$ …prob. that a failure occurs before or at t; i.e., **cumulative distribution function** (**CDF**) of X_{TTF}; $F(t) \overset{def}{=} \int_{-\infty}^{t} f(x)\, dx$
- $R(t)$ …**reliability function** (**reliability**): prob. that a failure occurs after t; $R(t) \overset{def}{=} 1 - F(t) = \int_{t}^{\infty} f(x)\, dx$
- MTTF (**Mean Time To Failure**)
- $h(t)$ …**hazard** (**rate**) **function**: prob. that a failure occurs in $[t, t + dt]$ given that no has occurred prior to t; $h(t) \overset{def}{=} \frac{dF(t)}{dt} \times \frac{1}{R(t)} = \frac{f(t)}{R(t)}$

But, the assessment is complicated by real facts such as fault dependencies, dynamic behavior of faults, state-dependent behavior, faults being introduced into the reconfiguration/recovery process, shared load/repair facilities, multiplicity of faults and failure modes etc.

Common Reliability Models

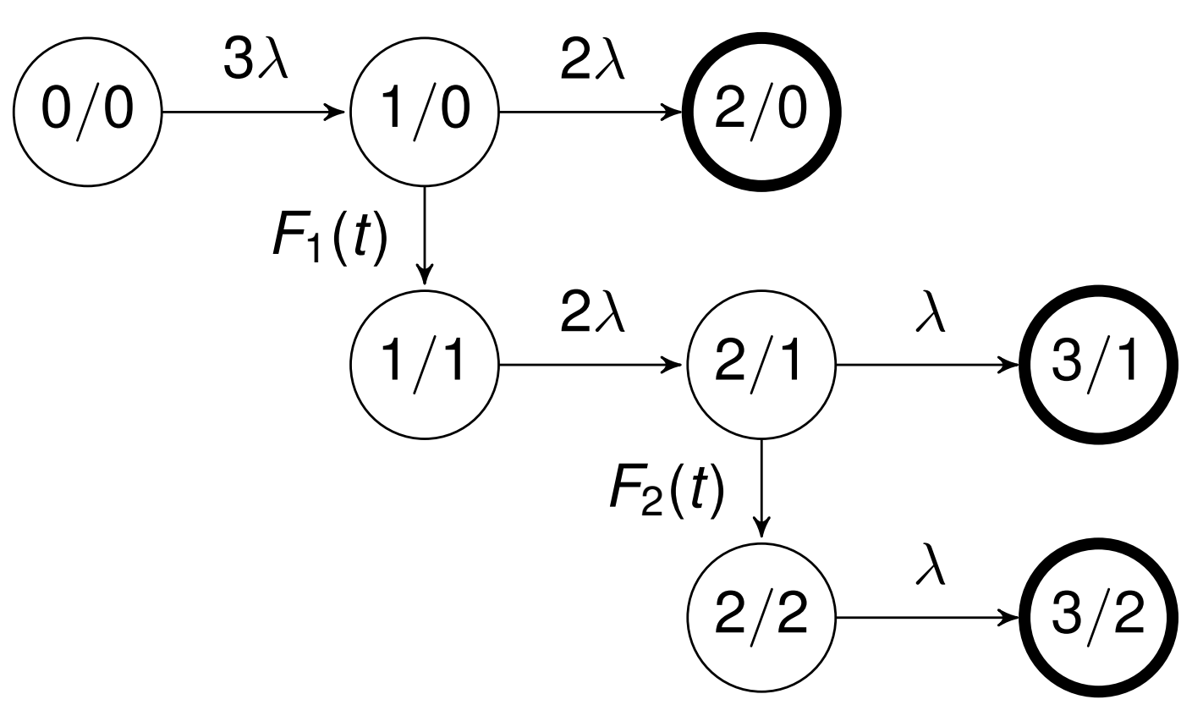
a) **Simplex** (SPX)

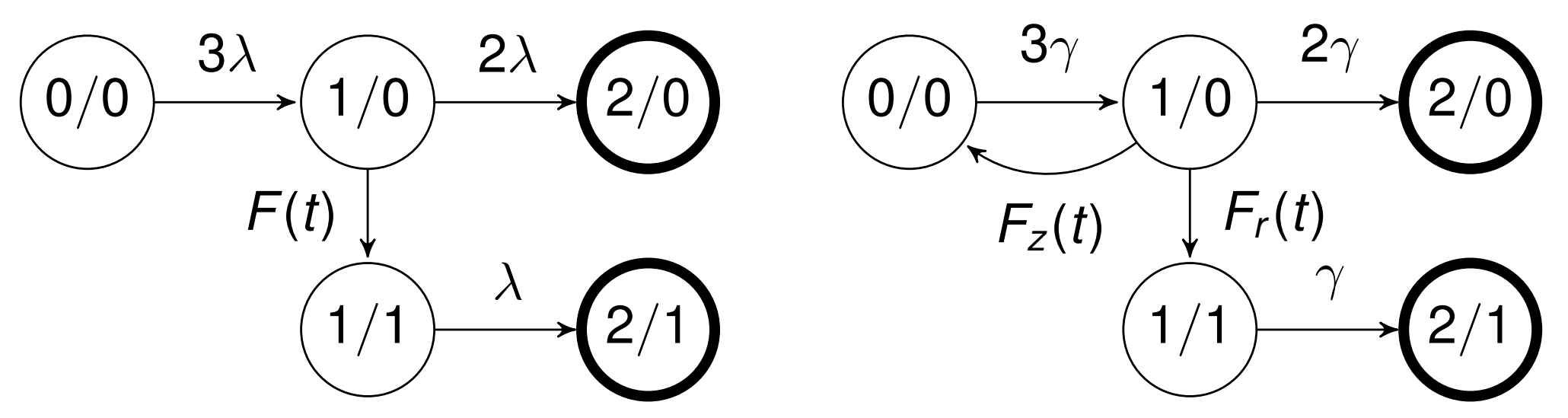




b) **Triple Modular Redundancy** (TMR) w.o. resp. with **Single Point of Failure** (SPF) on the left (TMR_{NSF}) resp. right (TMR_{1SF})

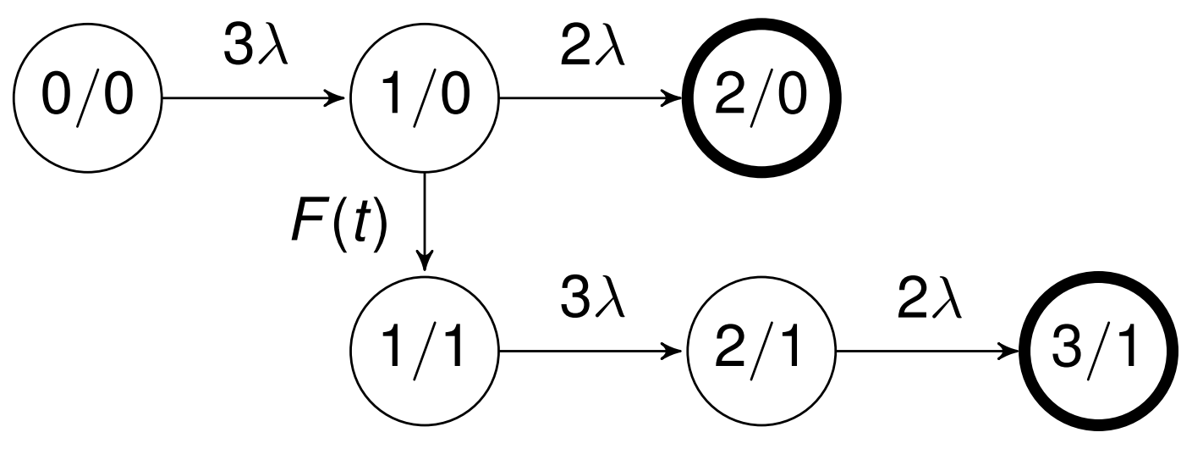
c) **Triplex with successive degradation** (TSD)



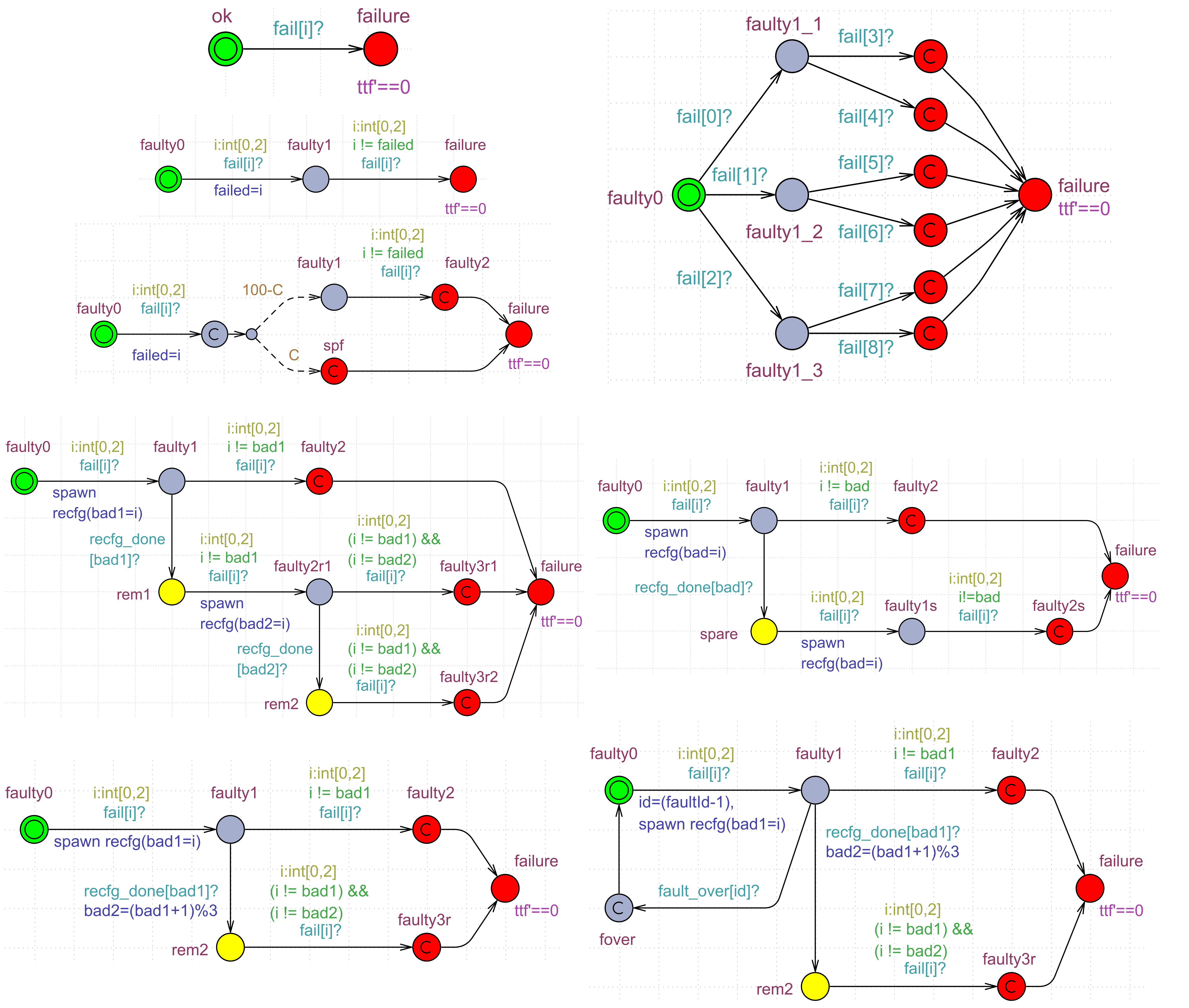


d) **Triplex to simplex degradation** (TTS) subject to permanent resp. transient faults on the left (TTS_P) resp. right (TTS_T) of the figure

e) **Triplex with one spare** (T1S)



STA Reliability Models



Utilized STA Fault Models

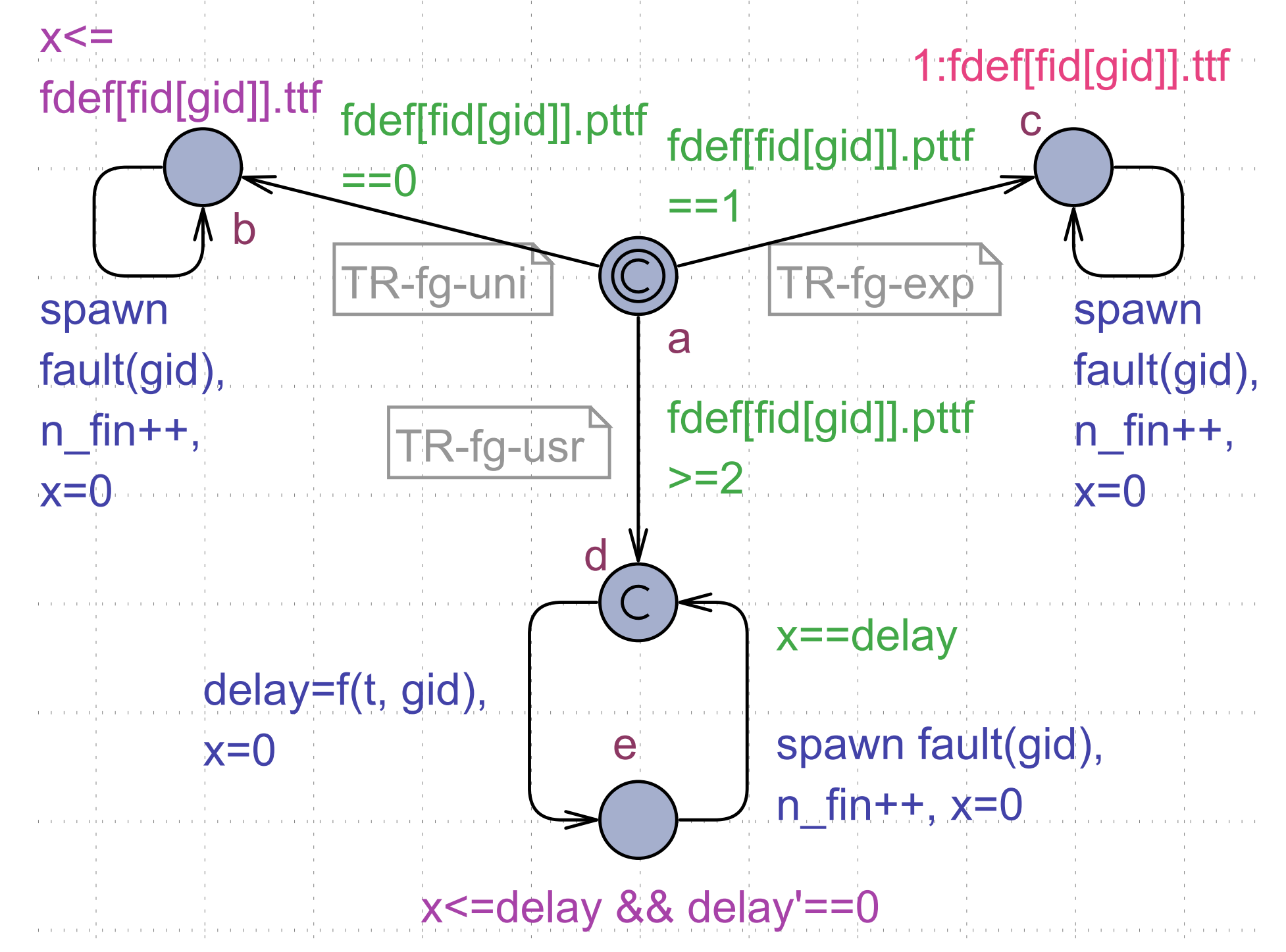


Fig. 1: Fault generator model [4]

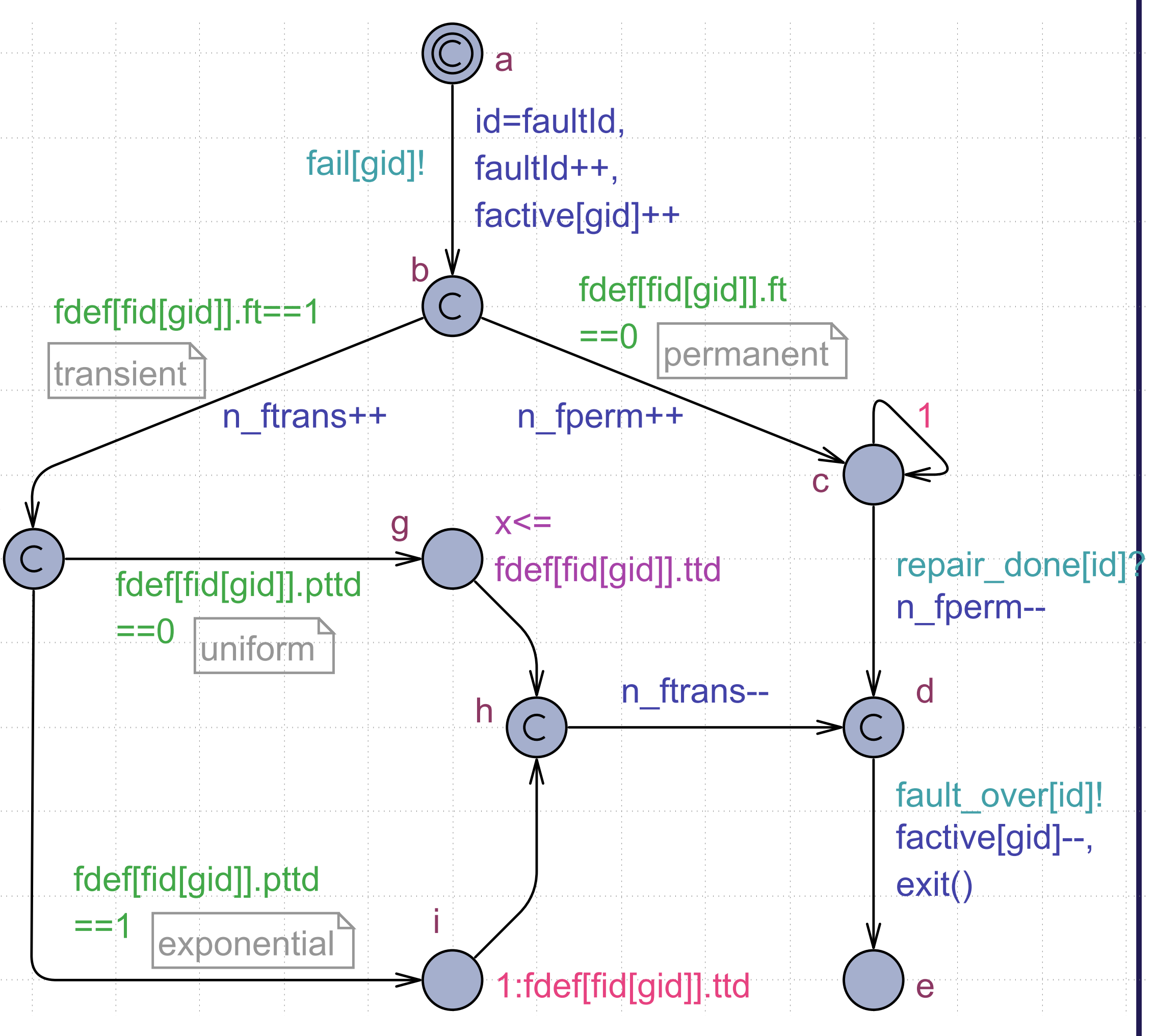


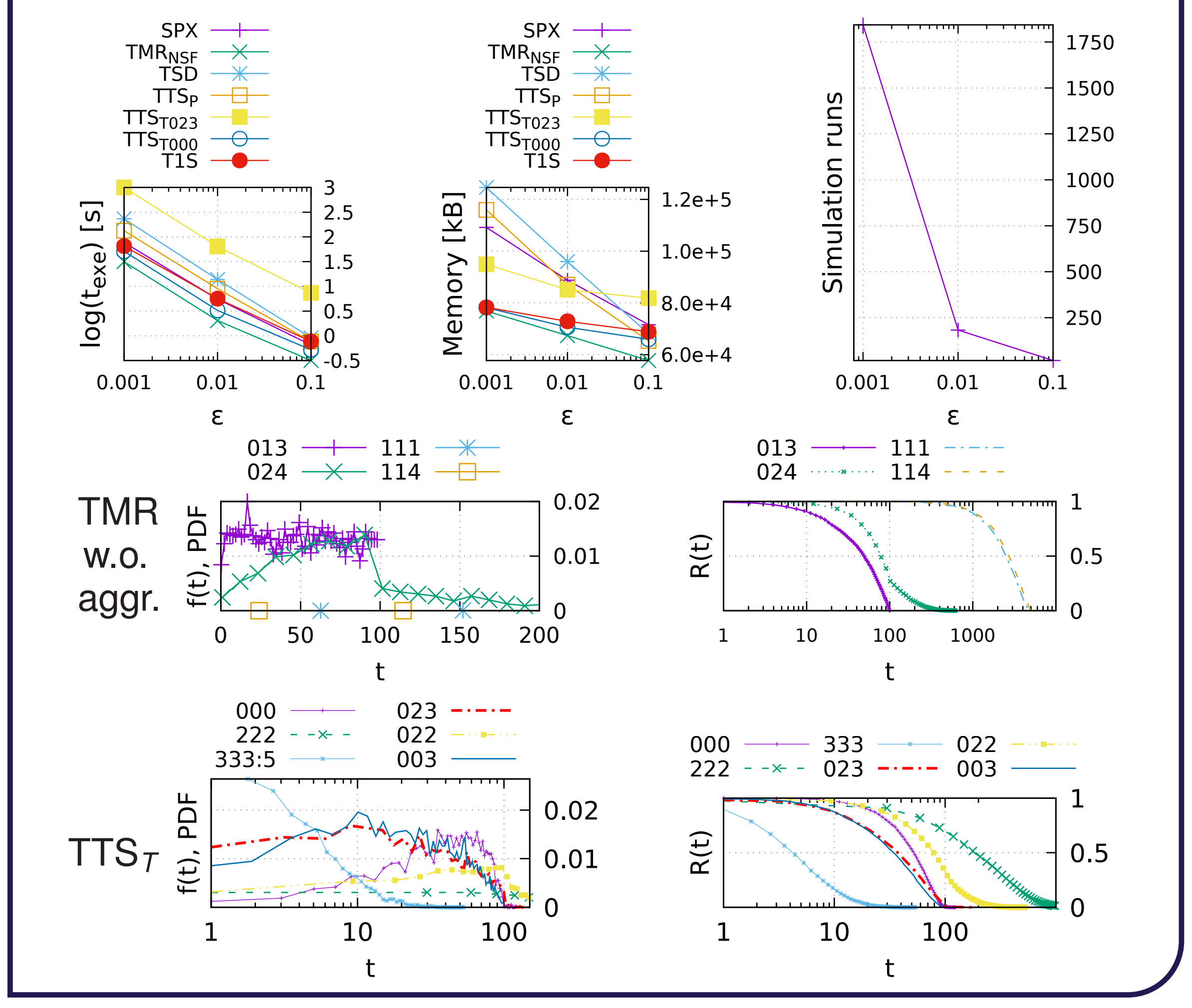
Fig. 2: Fault behavior model [4]

SMC Query Example

Probability estimation using "`Pr[bound](`ϕ`)`"

`Pr[<= 100000](<> STA.failure)`

Representative Results



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