DEALING WITH VARIABLE OPERATING CONDITIONS IN SYSTEM MODELING

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Outline

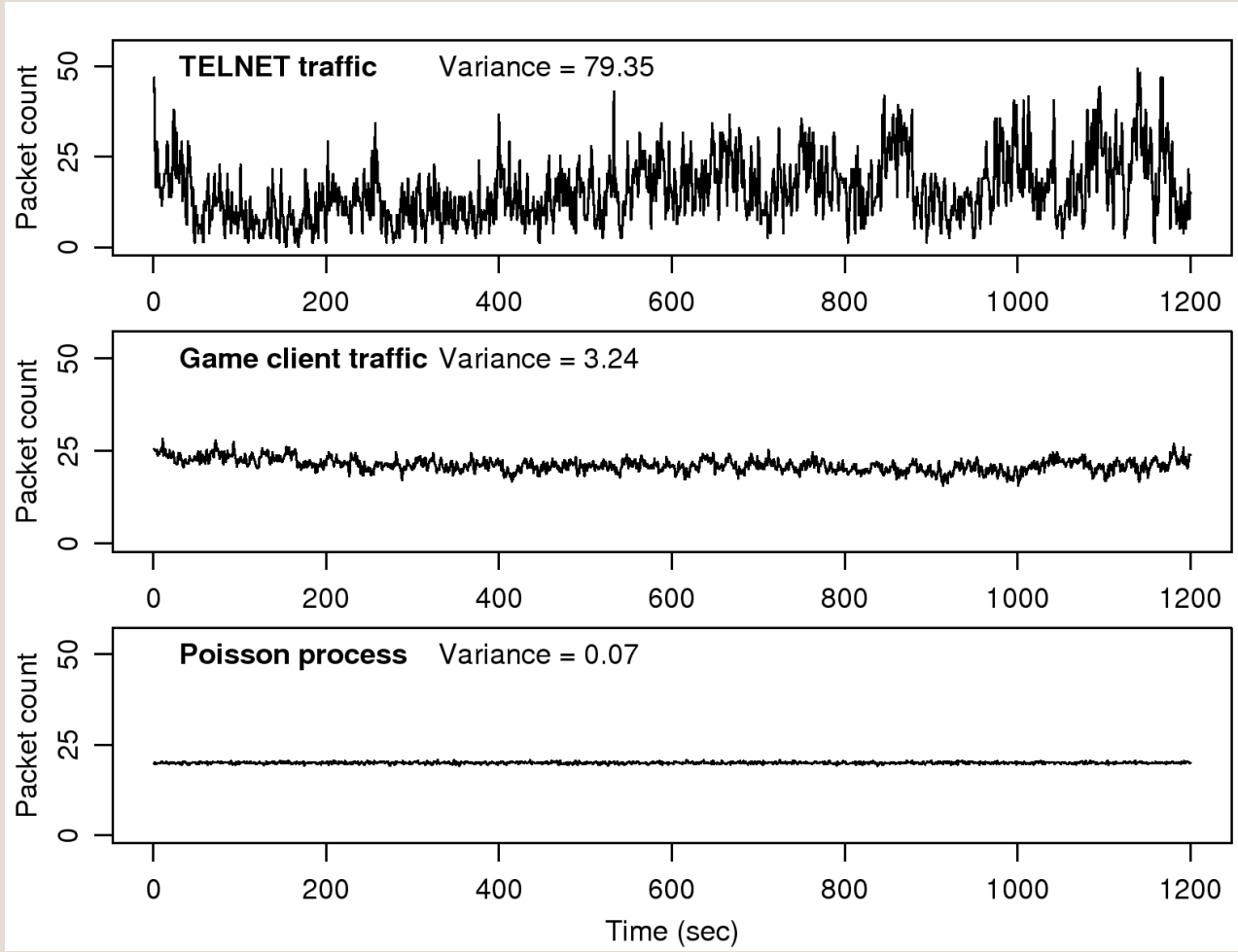
- Introduction and Issues
- Problem Rationale
- Proposed Solution
- Case Studies
- Ongoing and Future Work

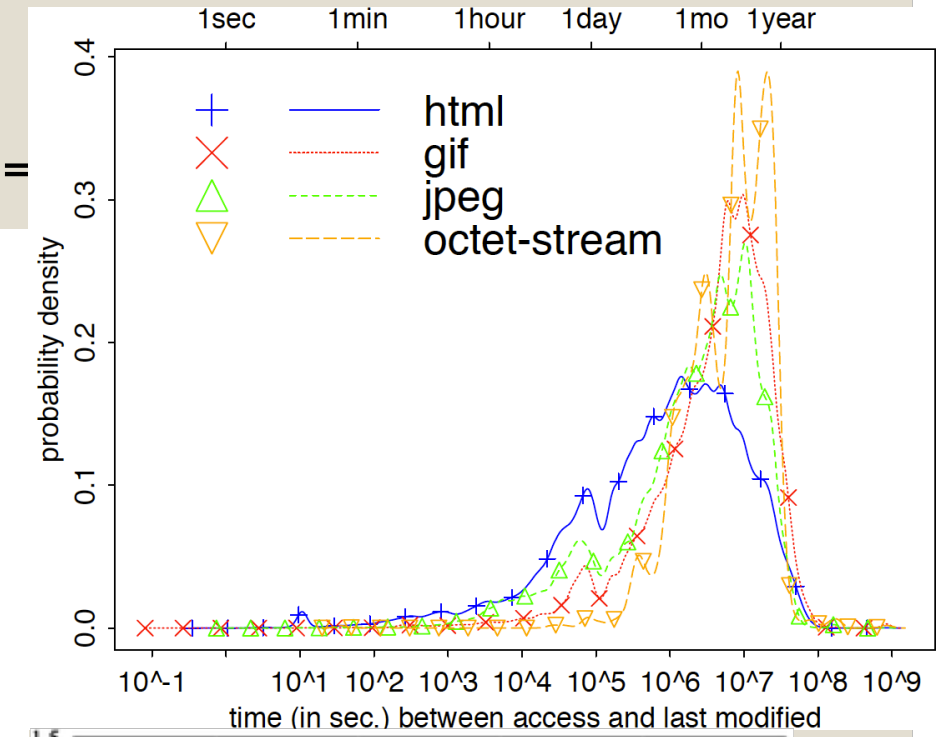
Issues in system modeling

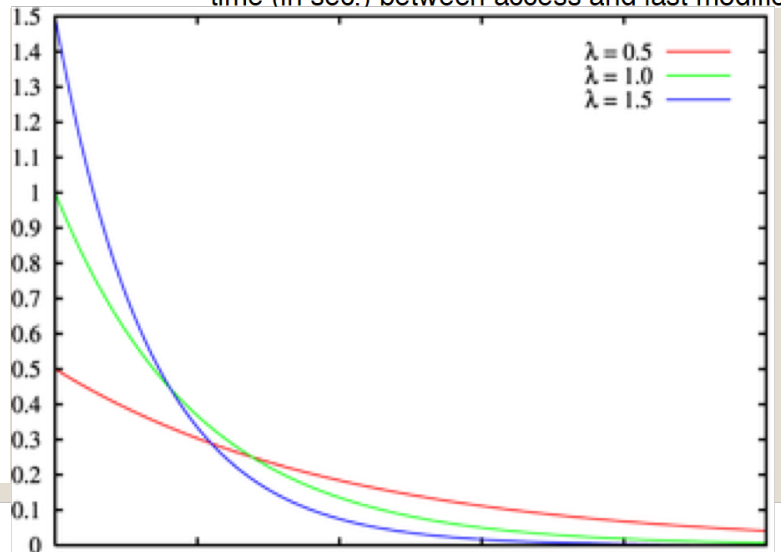
- Higher quality standards, tighter constraints
- Safety critical systems
  - Dependability, performance, sustainability, …
- Issues on models and causes of systems' disasters are:
  - neglecting the principles of redundancy and dependence
  - considering over-simplistic/approximated models

Markovian VS Non-Markovian

Memory-less property $\Pr\{X_n = x_n \mid X_{n-1} = x_{n-1}, \ldots, X_0 =$







Multiple-Variable Operating Conditions

- Operating conditions may affect the system/observed quantity behaviour
- The system operating conditions may vary due to:
  - *External* events: weather, temperature, pressure, electromagnetics, workloads fluctuations, …
  - *Internal* events: standby policies, interferences or interdependencies among components, load sharing, …

What if neglected?

Jan. 28th 1986 - Challenger Space Shuttles disaster:

"… due to rubber O-Rings breaks, … a design flaw on neglecting the rubber behaviour at low temperature …"

Feb. 1st 2003 - Columbia Space Shuttle disaster:

"… a breach in the leading edge of the left wing, … the conflict between a design specification stating that the thermal protection system was not designed …"

Problem Rationale [RESS09]

- Identify and enumerate the *mutually exclusive* operating conditions c_i in **C**=$\{c_i\}$
- *c(t)*:**R**->**C** characterises the condition at *t*
- For each c_i identify **F**=$\{F_i(t)\}$ the set of $F_i(t)$ in *isolation*

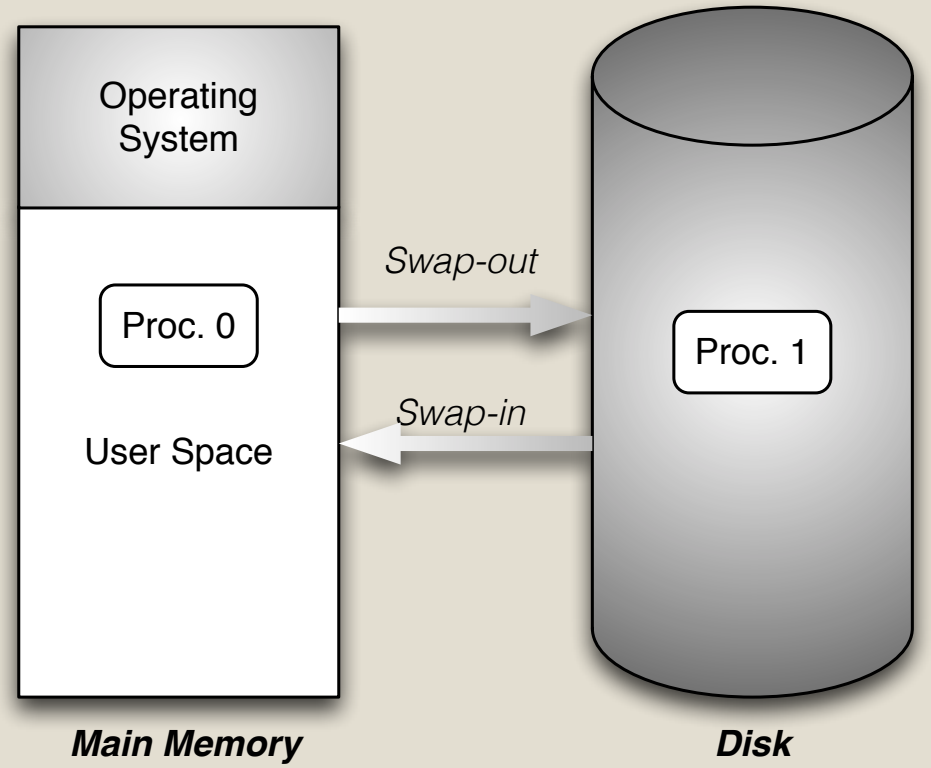
$$\forall t \in R,\ c(t) = c_i$$

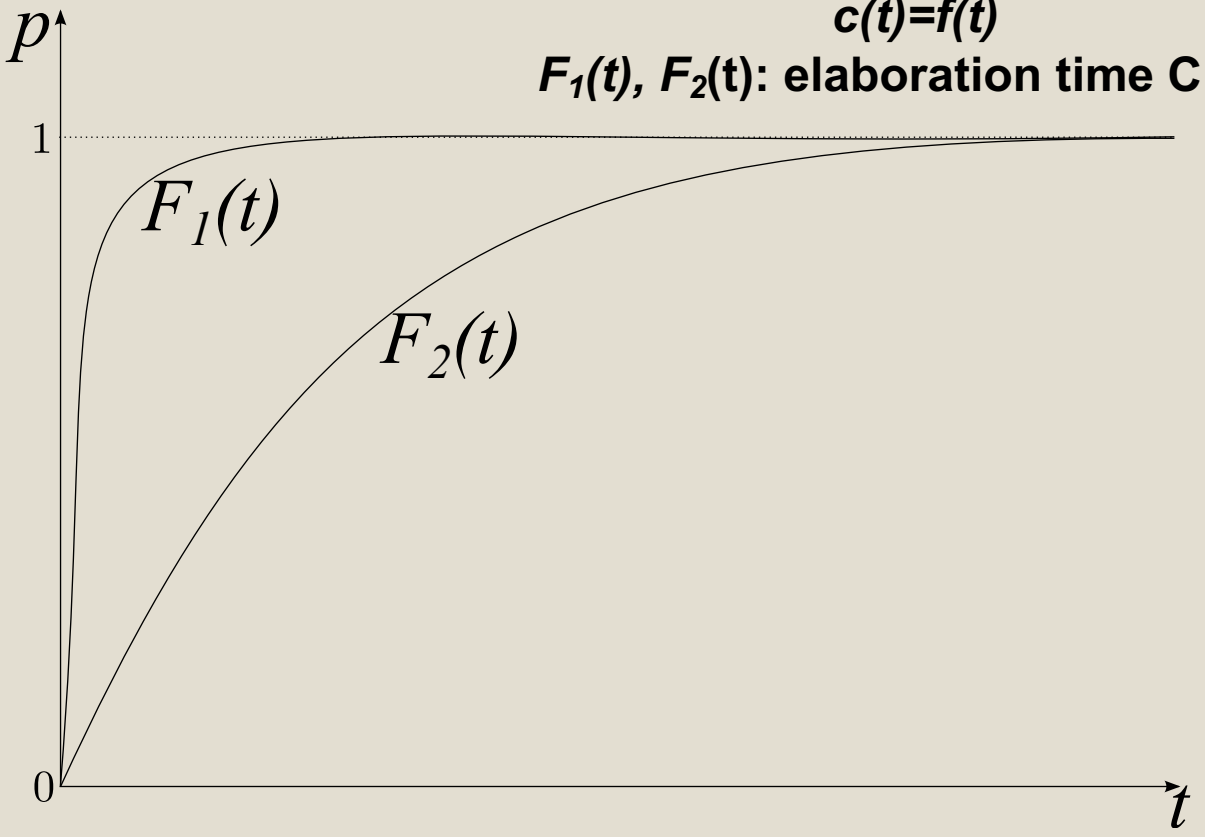
F(t)= F(F_1(t), F_2(t), …, F_i(t), …, c(t))

c_1= Mem, c_2= Disk

c(t)=f(t)

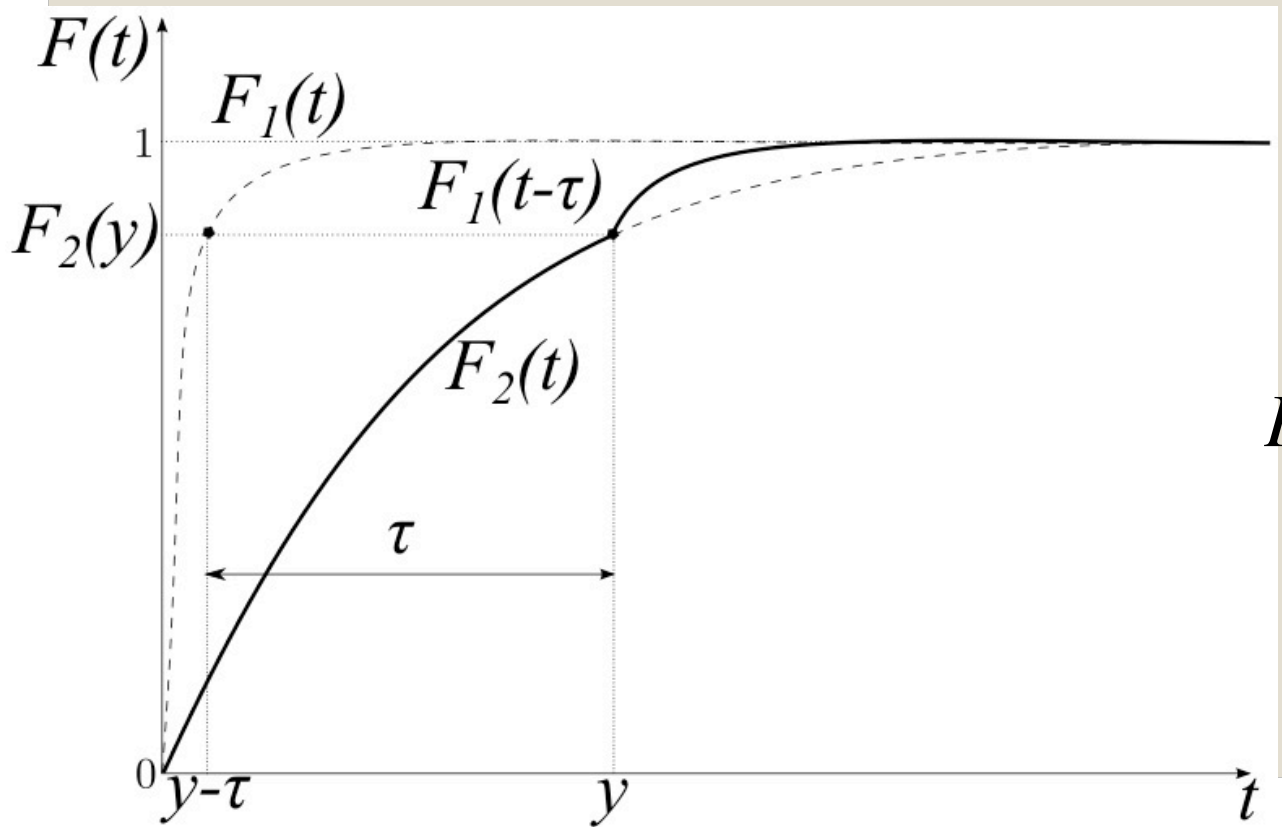
F_1(t), F_2(t): elaboration time CDFs





Memory

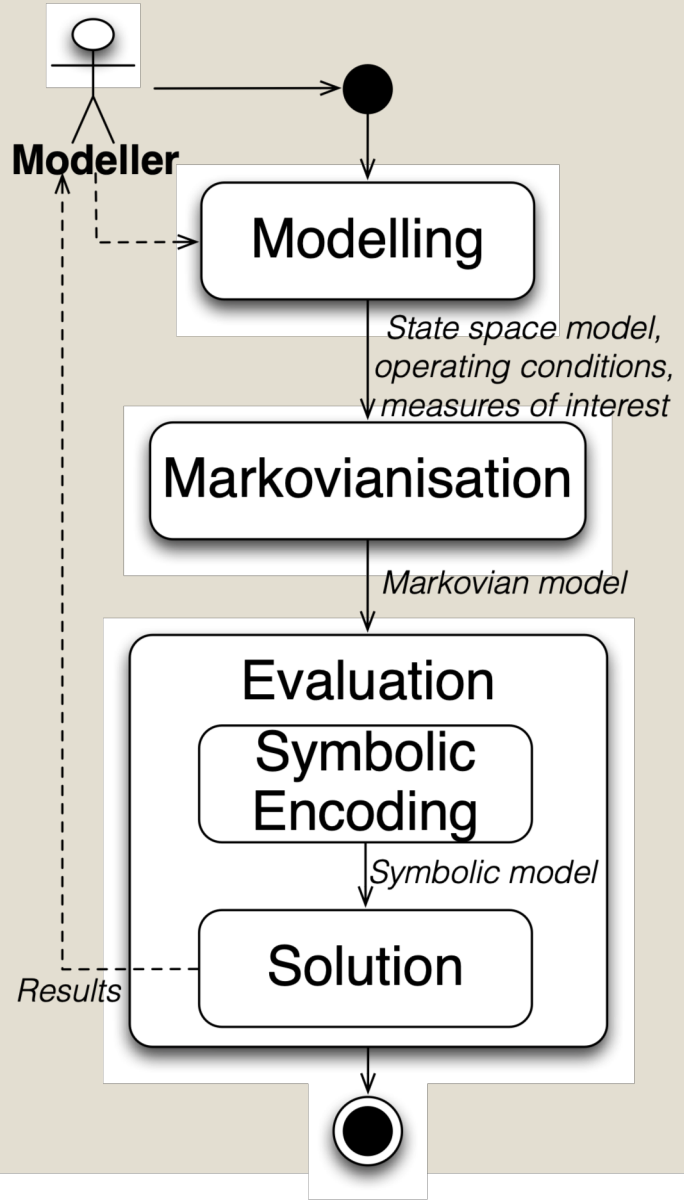
- Assumptions:
  - *i.* *F(t)* continuous
  - *ii.* $F_i(t)$ continuous and strictly monotonic -> invertible



$$F(t) = \begin{cases} F_2(t) & t \le y \\ F_1(t-\tau) & t > y \end{cases}$$

$$F_1(y-\tau) = F_2(y) \Rightarrow \tau = y - F_1^{(-1)}(F_2(y))$$

Solution Algorithm [CCPE14]

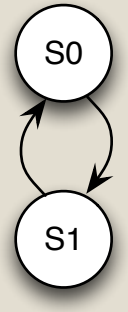


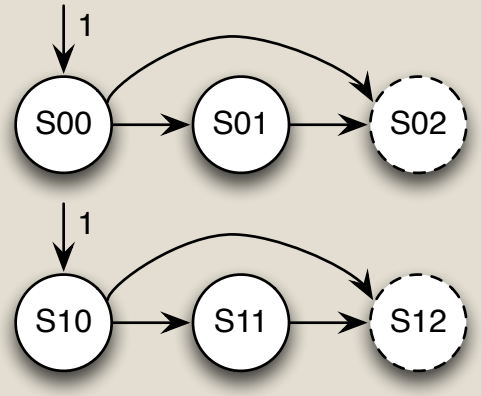
1. State space modelling
   - By the modeller
   - Through high level formalism (PN)
2. Markovianisation
   - CPH [TSE11]
3. Evaluation
   - Kronecker algebra
   - CTMC solver

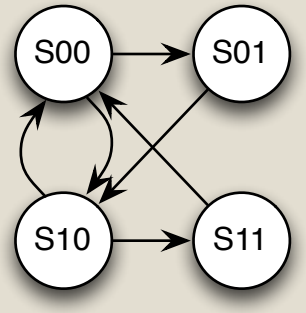
Non-Markovian Model Analysis

- Memory management
- Solution approaches
  - Supplementary Variables
  - Renewal theory
  - Phase type expansion – Markovianisation

} **One memory per state**
(Time) Domain memory

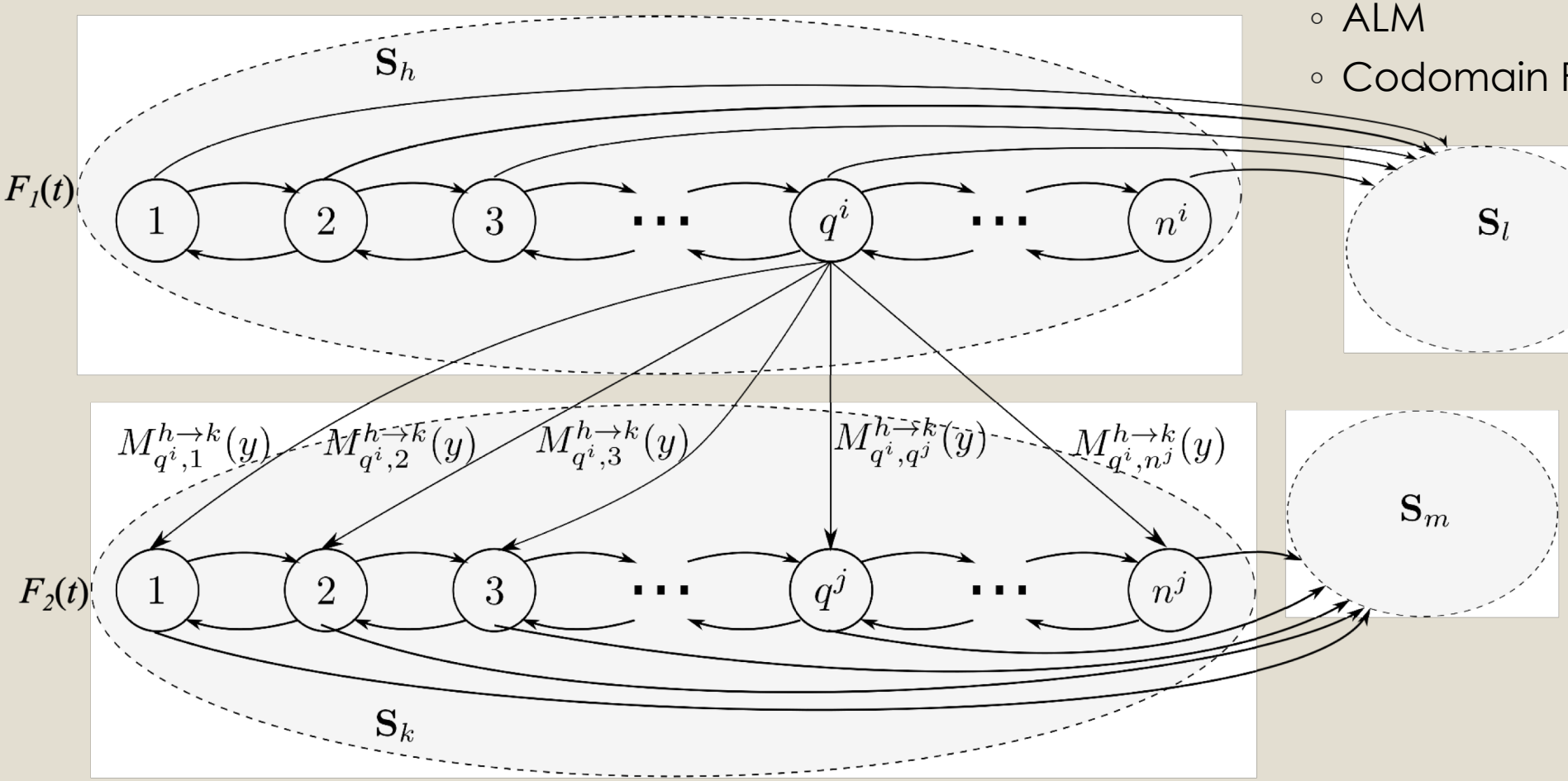






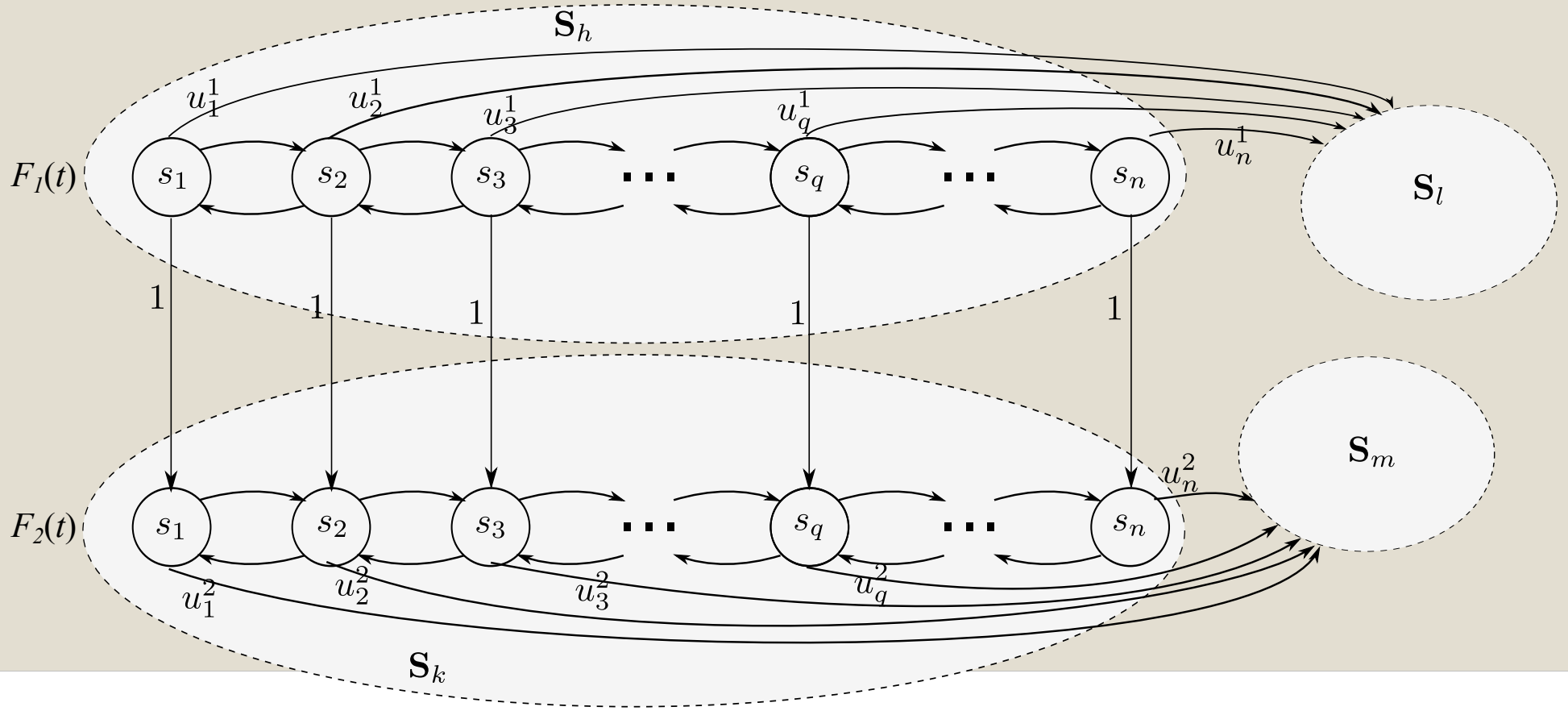
Markovianisation

- Memory Matrix
  - $\boldsymbol{M}_{i,j}(y)$: Pr. at y to switch from i of CPH F_1 to j of CPH F_2
  - In some particular cases $\boldsymbol{M}=\boldsymbol{I}$
    - ALM
    - Codomain Fitting

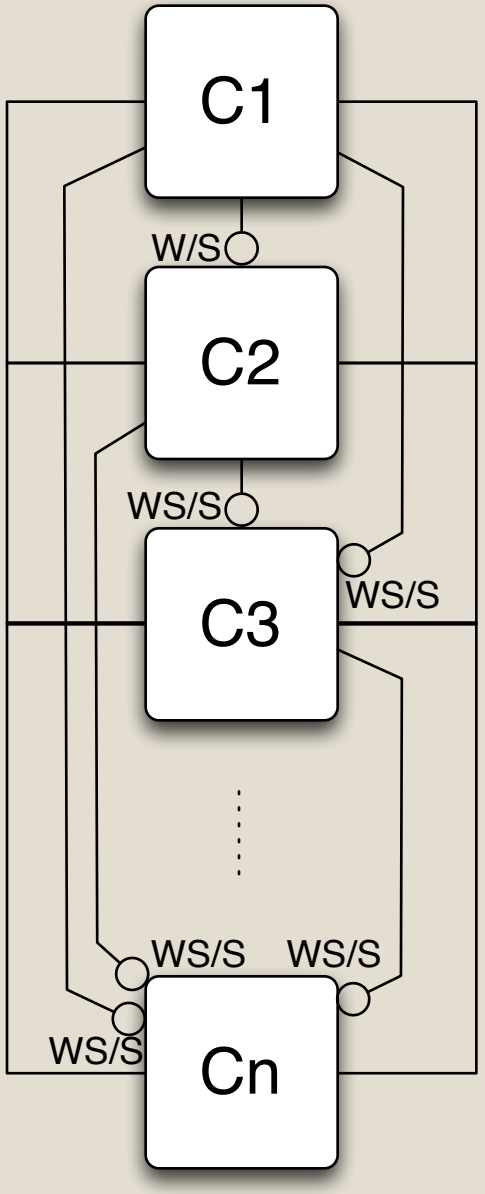


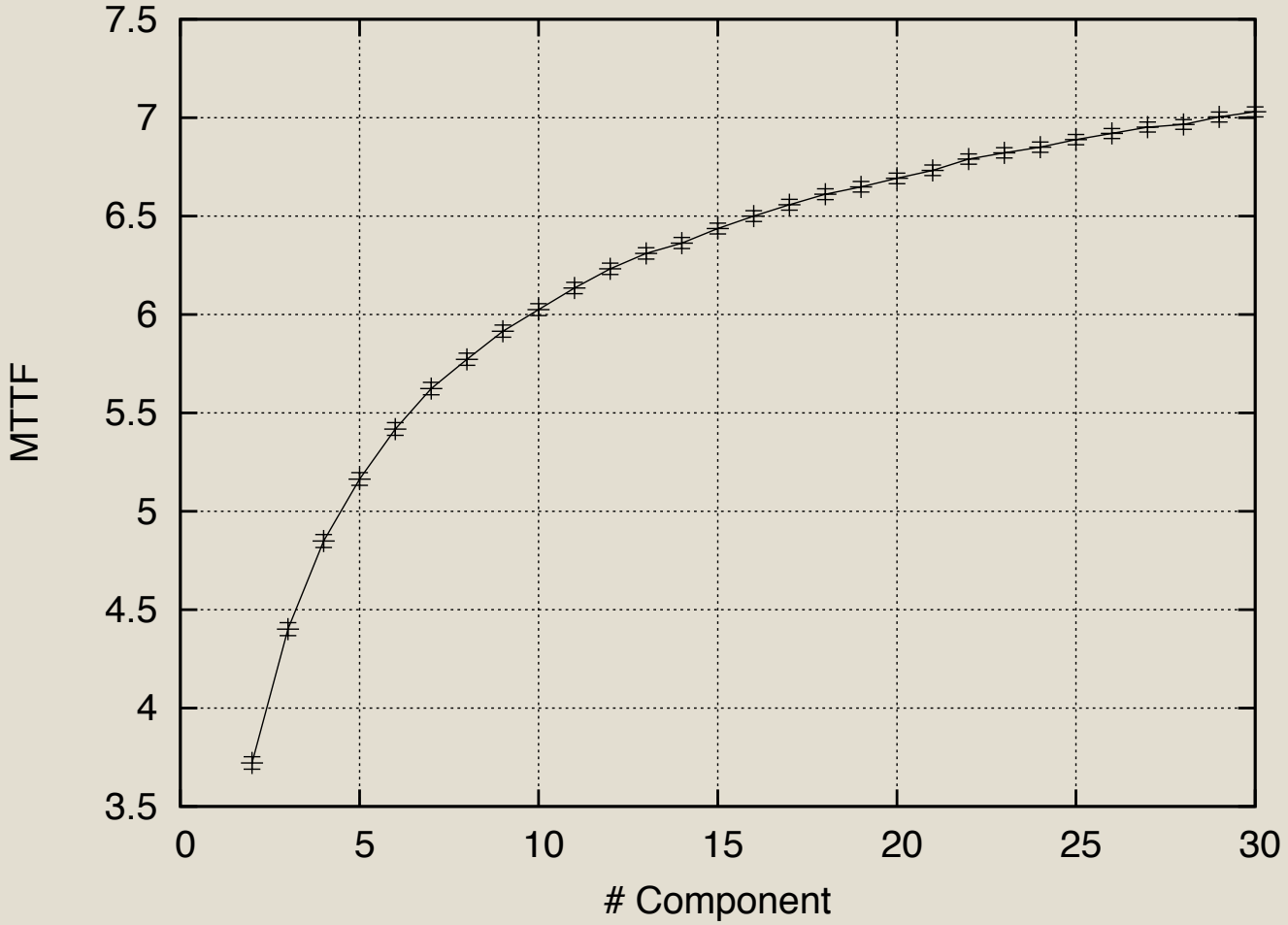
Codomain Fitting [IDCS13]

- Associate with each stage a specific codomain value range

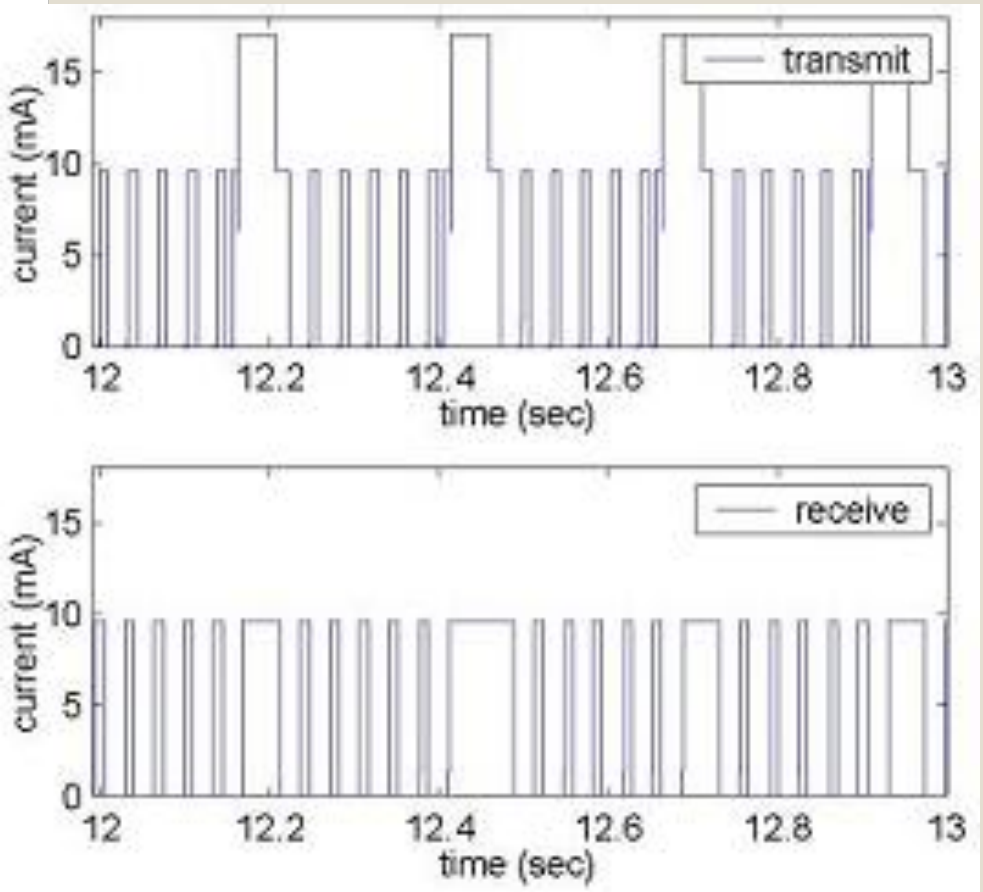


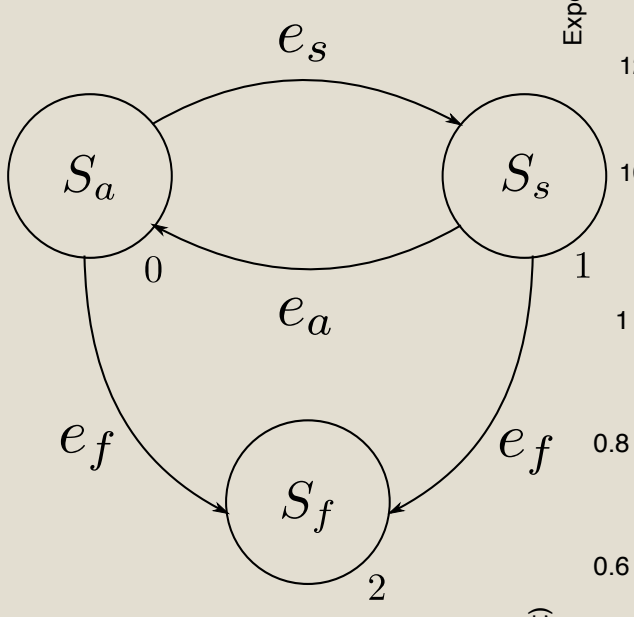
Critical System Surveillance

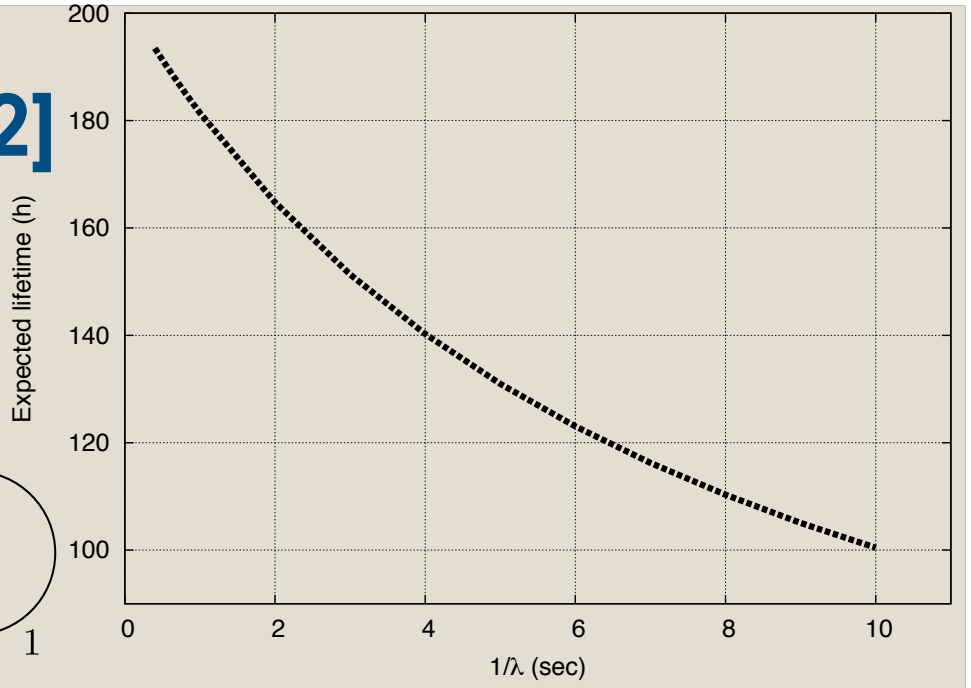


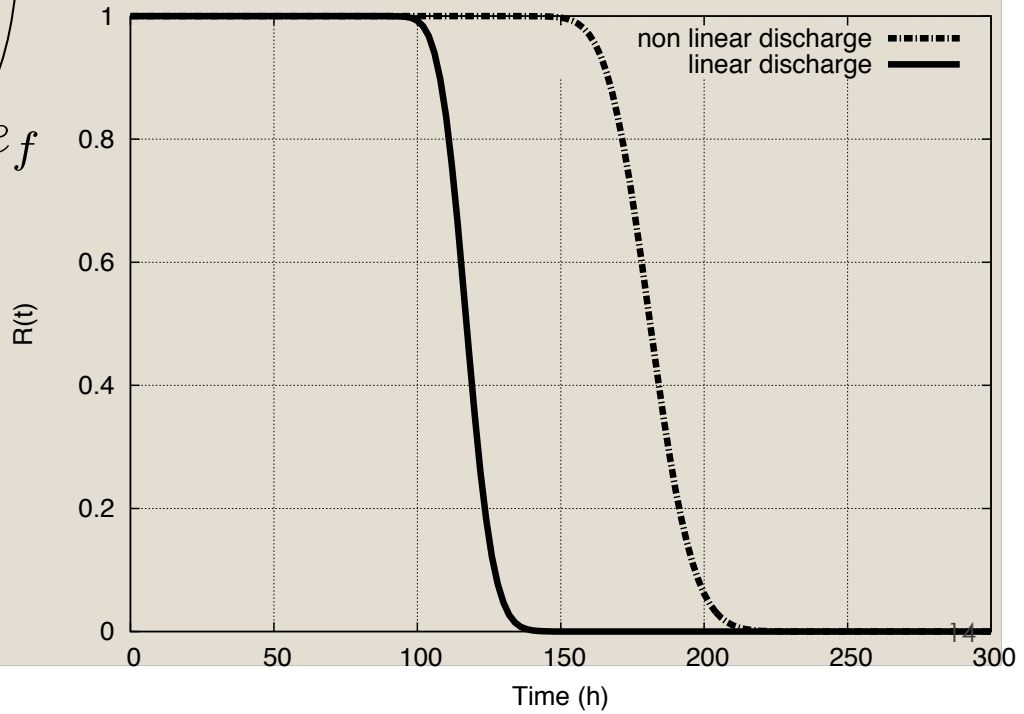


WSN Node Longevity [COMNET12]

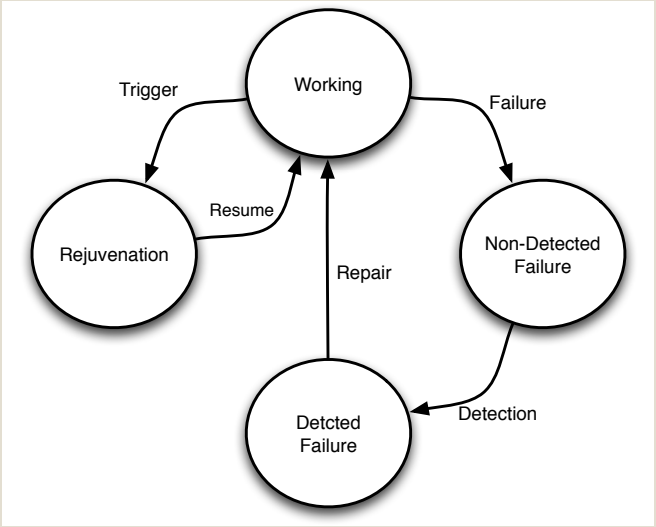


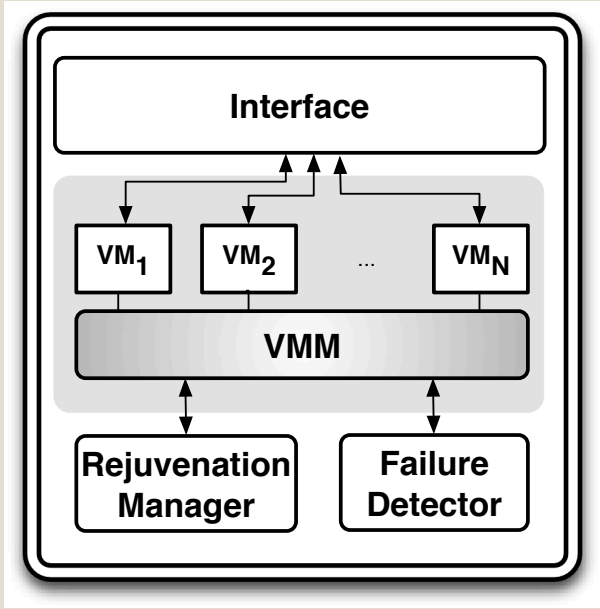


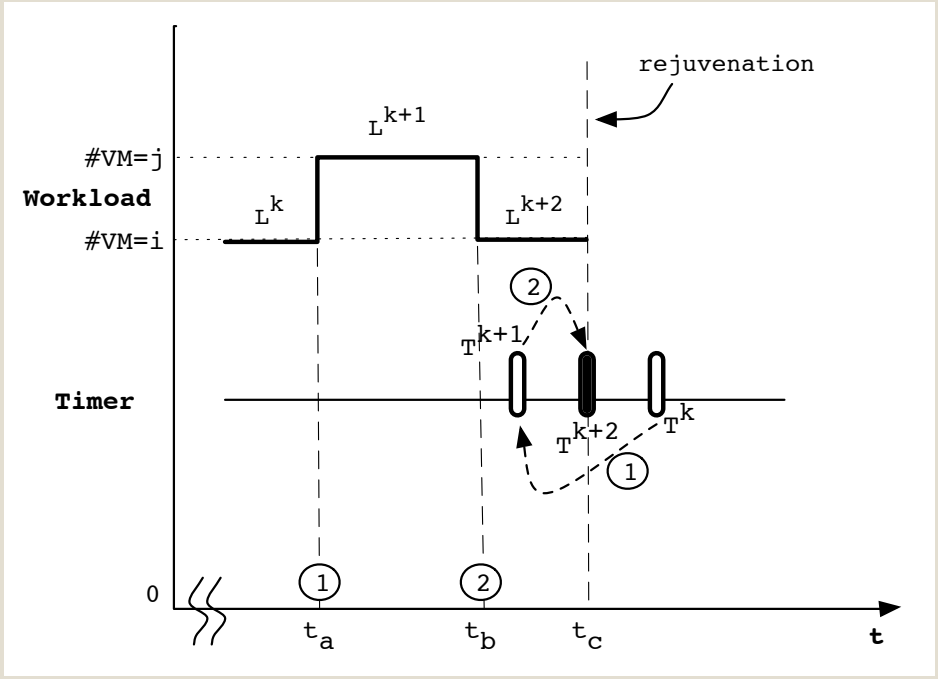


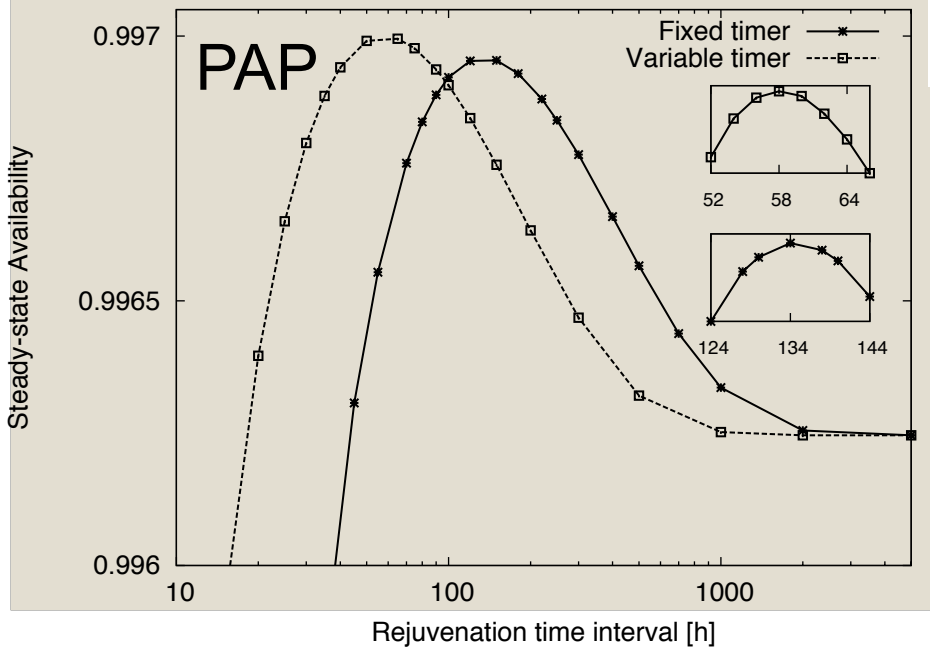


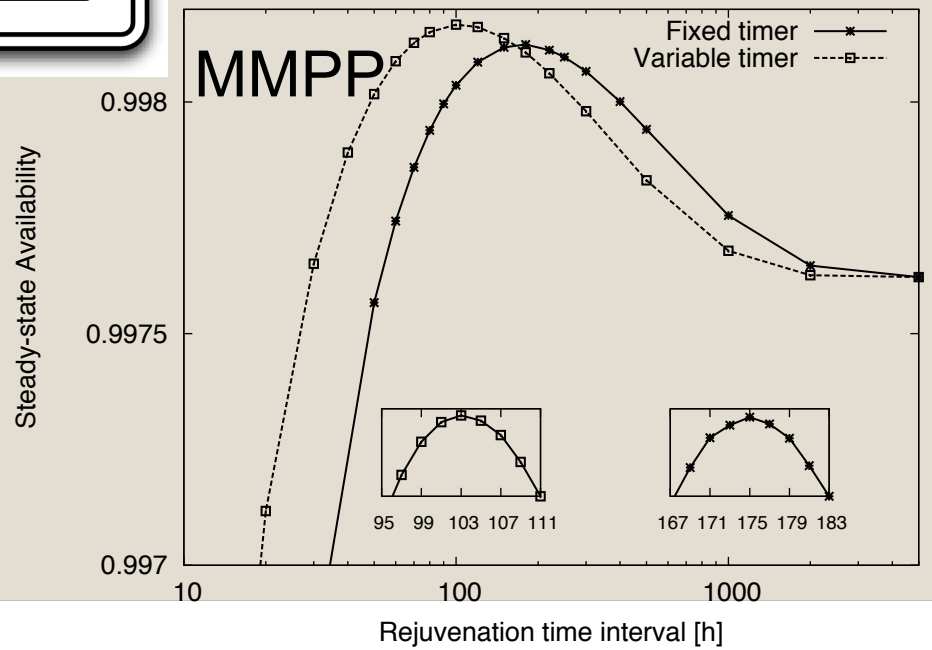
Cloud VMM SW Rejuvenation [TC13]





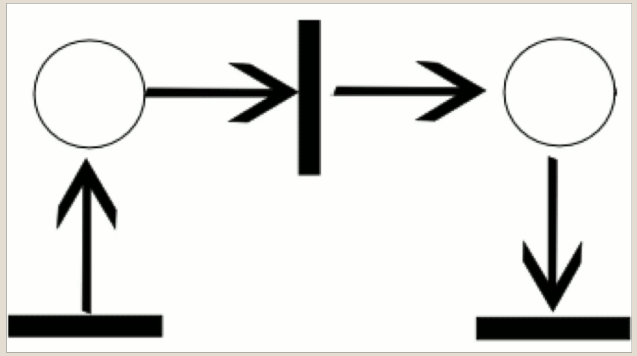






Ongoing and Future Work

◦Extension of the NMSPN formalism: MDNMSPN



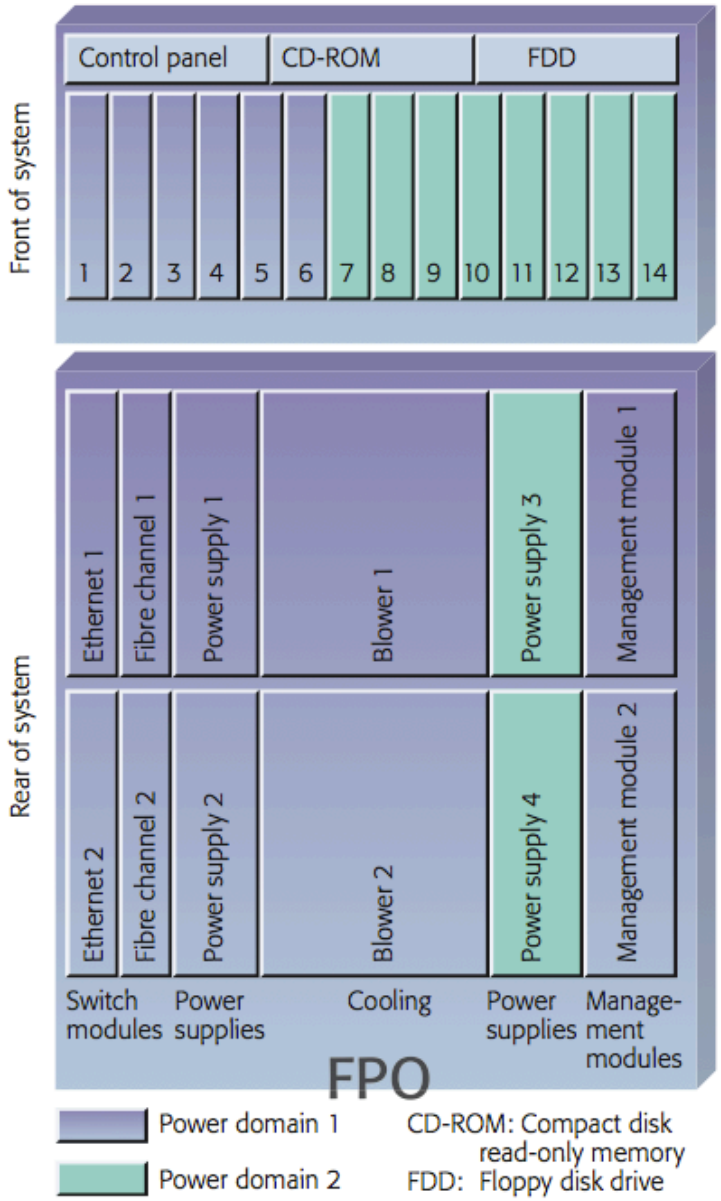
◦ Queueing Network

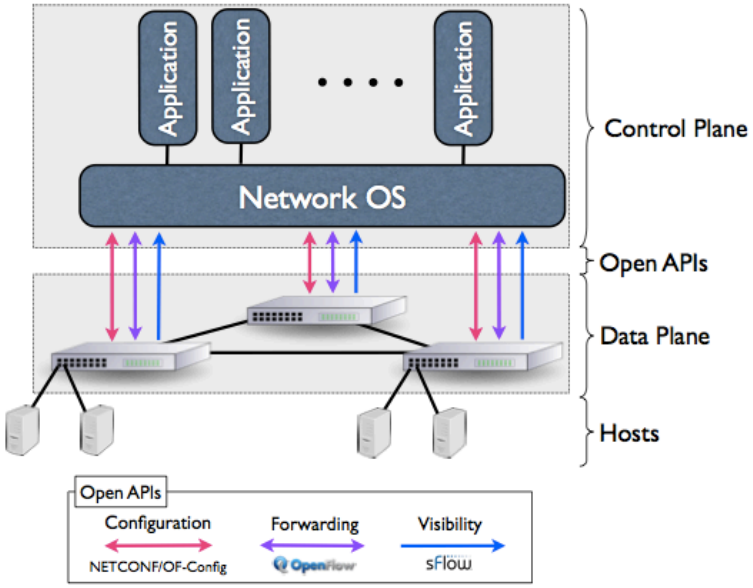
◦New G/G/x policy with variable x

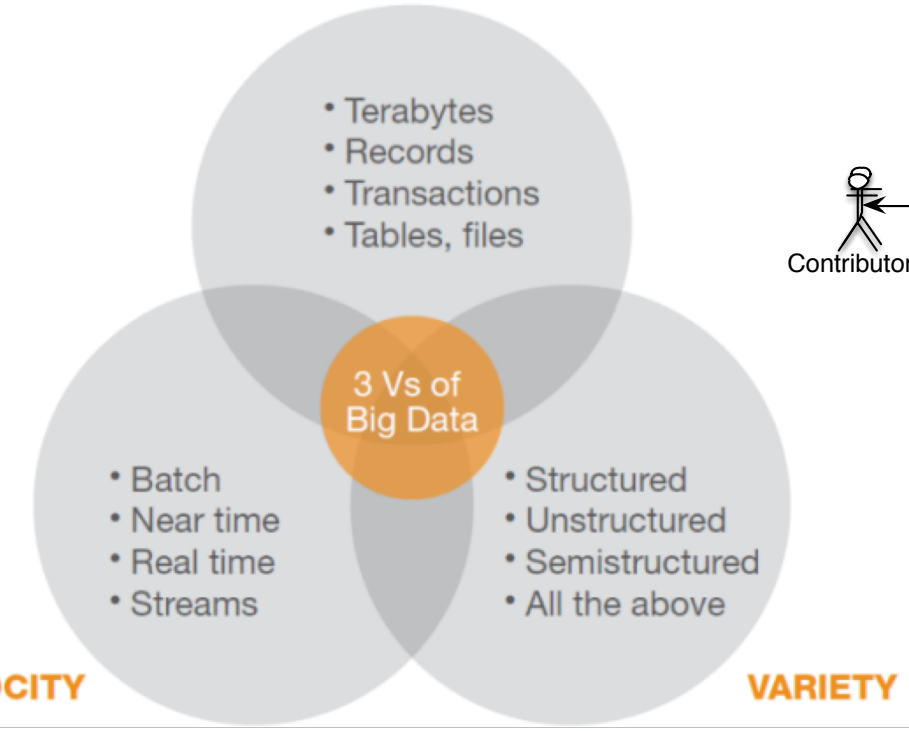
- Solution techniques
  - Lumping, symmetry
  - Fitting algorithms
  - Time domain analysis
  - Random variable algebra

- 2 or more variables analysis
  - Continuous
  - 3 or more
    - Time, workloads, temperature

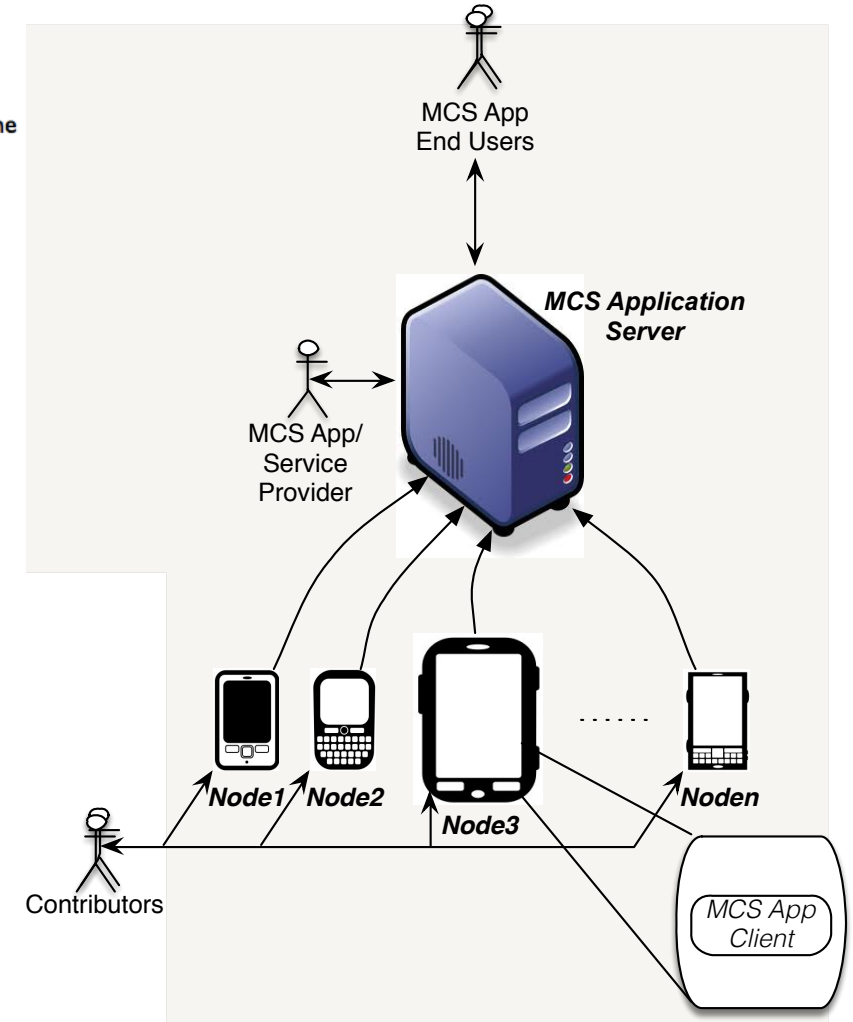
Case Studies







VOLUME



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