Hybrid Modelling using Generalised Hybrid Petri Nets

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Motivations

- Some biological models require to be represented in hybrid way (Cells/Molecular interactions in one model).
- Continuous deterministic simulation does not consider the fluctuation of molecules, specially when there is a low number of them.
- Stochastic Simulation is computational expensive (fast reactions, large number of molecules).

CPN and GSPN

- Continuous Petri Nets:
  - Continuous places
  - Continuous transitions
- Generalized Stochastic Petri Nets
  - Discrete places
  - Stochastic transitions
  - Immediate transitions
  - Deterministic transitions
  - Scheduled transitions

Features of GHPN

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Elements

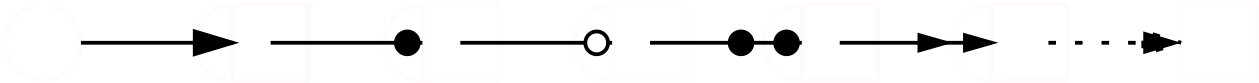
Places

Discrete Continuous

Transitions

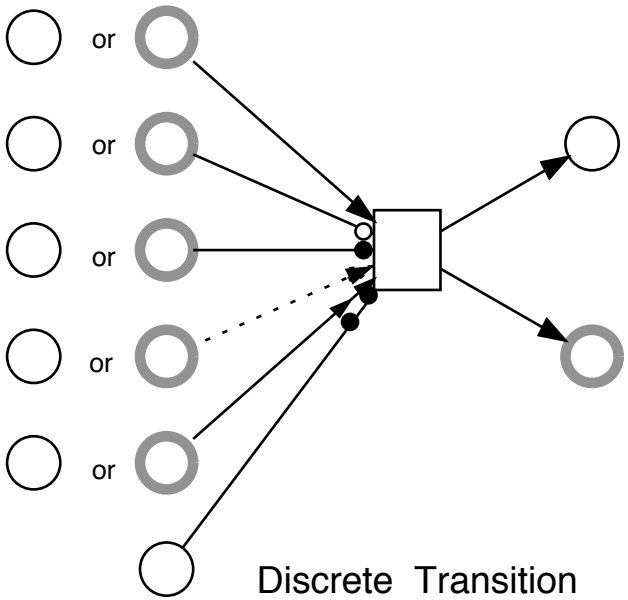
Stochastic Continuous Immediate Deterministic Scheduled

Edges

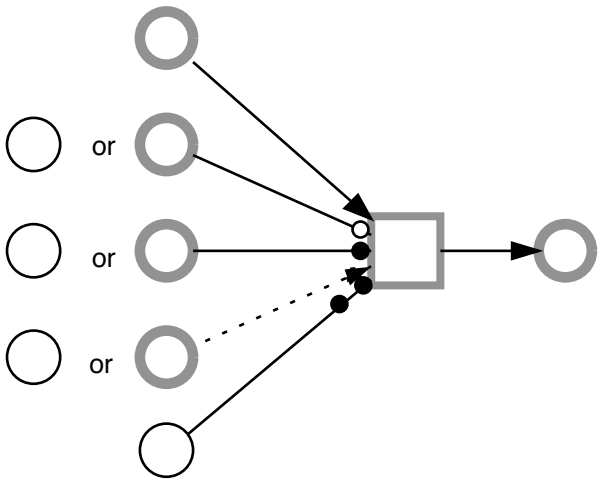


Standard Read Inhibitor Equal Reset Modifier

Connectivity

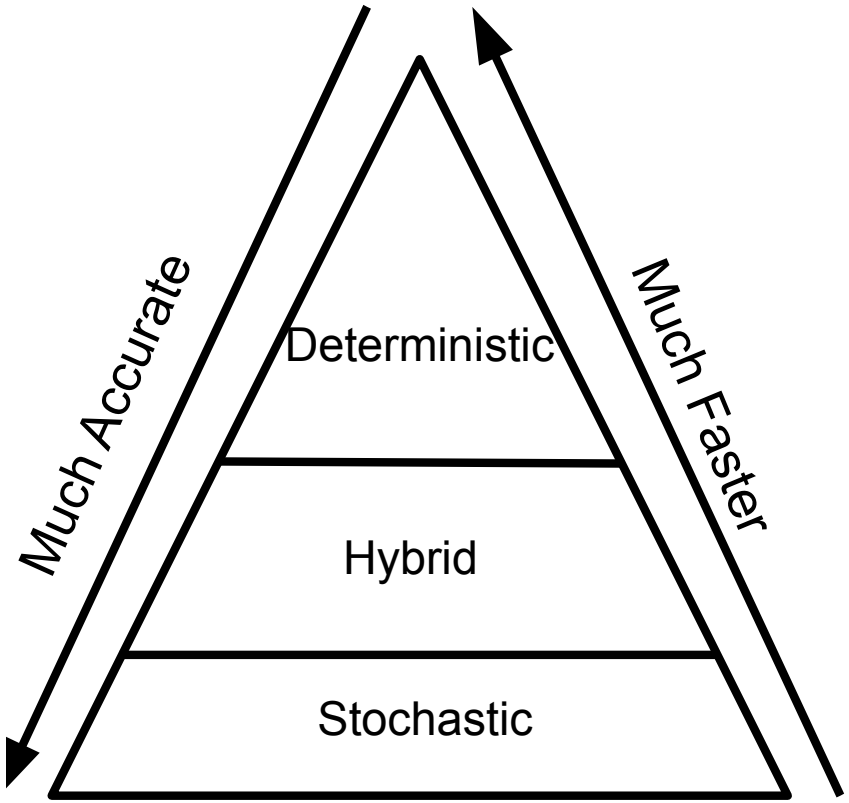


Discrete Transition



Continuous Transition

Simulation Methods



Simulation of GHPN

- Static partitioning: partitioning is done off-line before the simulation starts.
- Dynamic partitioning: partitioning is done on-line during the simulation.

Static Partitioning:

- The user has to provide the partitioning.
- There is no additional computational overhead due to partitioning.
- It is not user friendly.
- It is not suitable for all applications.

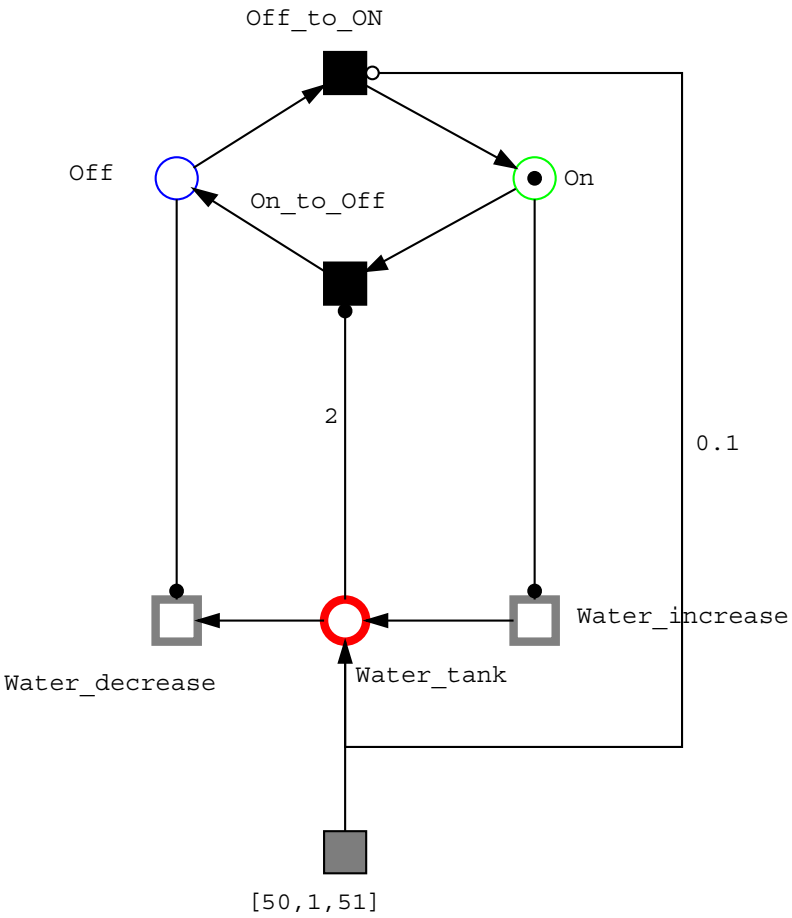
Dynamic Partitioning:

- The partitioning is done automatically without user intervention.
- There is additional computational overhead due to partitioning.
- The simulation is independent from the Petri net representation.
- It is suited for models where the time saving due to on-line partitioning is greater than the partitioning time overhead.

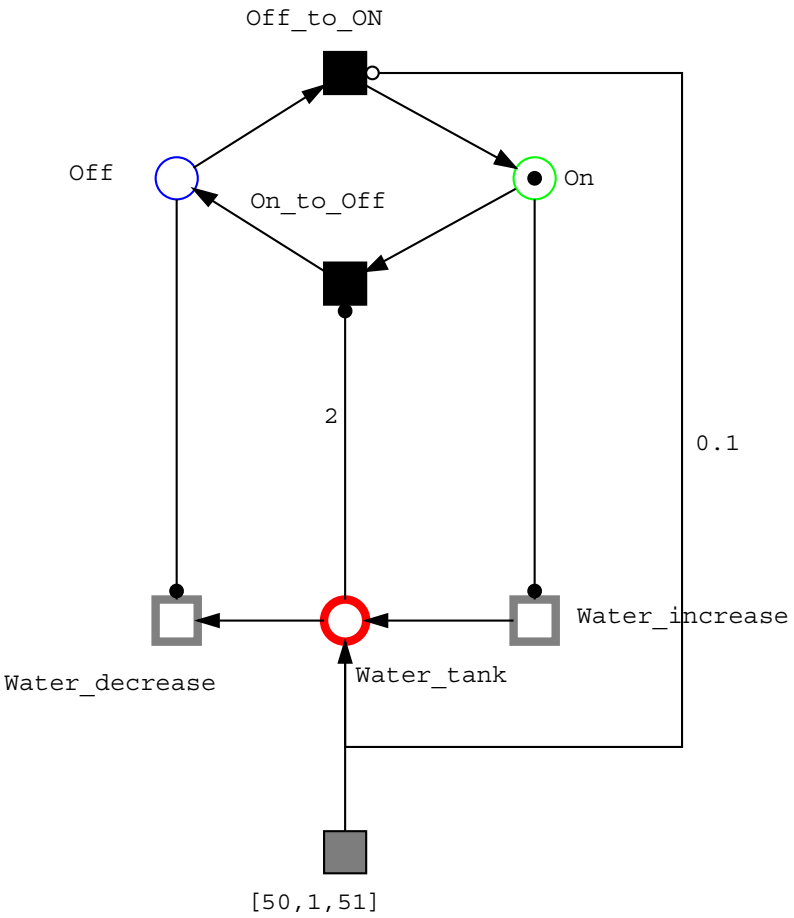
Examples

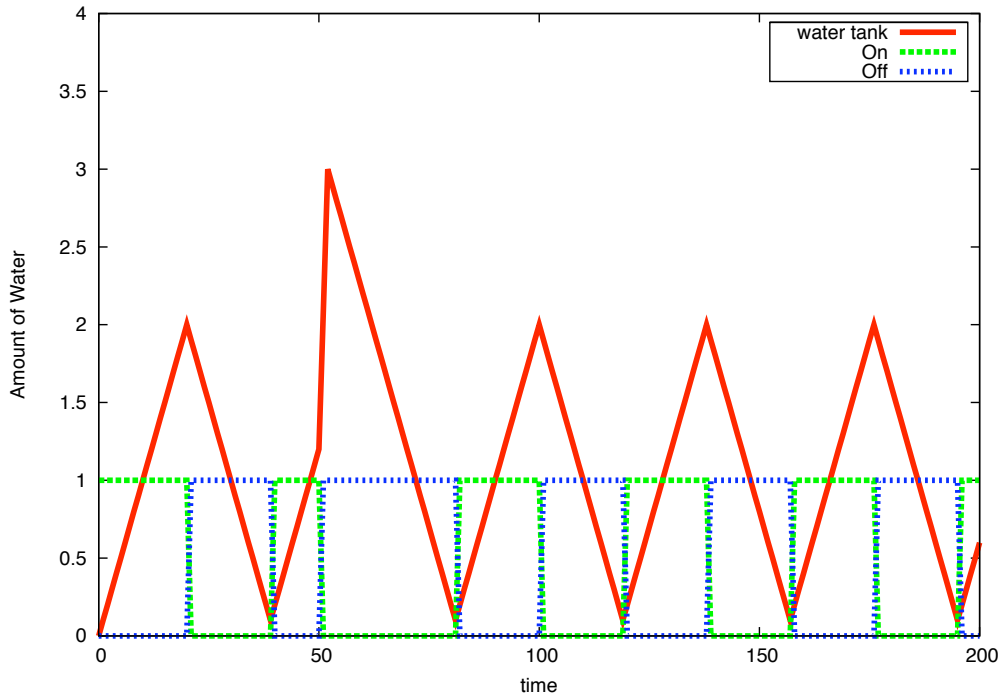
- Water Tank
- T7 Phage
- Goutsias Model
- Circadian Oscillator

The Water Tank Model



The Water Tank Model





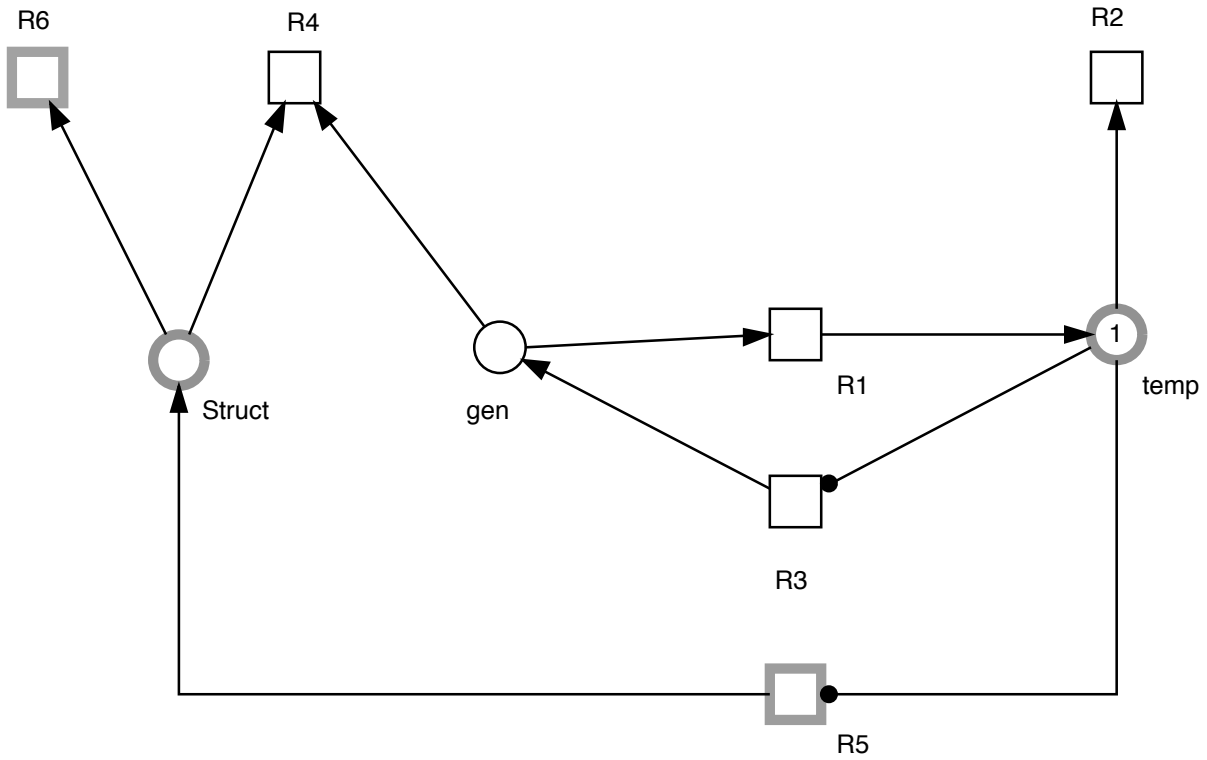
T7 Phage

No.	Reaction	Propensity	Rate
R1	$gen \rightarrow temp$	$c_1 \cdot gen$	$c_1 = 0.0025$
R2	$temp \rightarrow \phi$	$c_2 \cdot temp$	$c_2 = 0.25$
R3	$temp \rightarrow temp + gen$	$c_3 \cdot temp$	$c_3 = 1.0$
R4	$gen + struct \rightarrow$ "$virus$"	$c_4 \cdot gen \cdot struct$	$c_4 = 7.5 \times 10E - 6$
R5	$temp \rightarrow temp + struct$	$c_5 \cdot temp$	$c_5 = 1000$
R6	$struct \rightarrow \phi$	$c_6 \cdot struct$	$c_6 = 1.99$

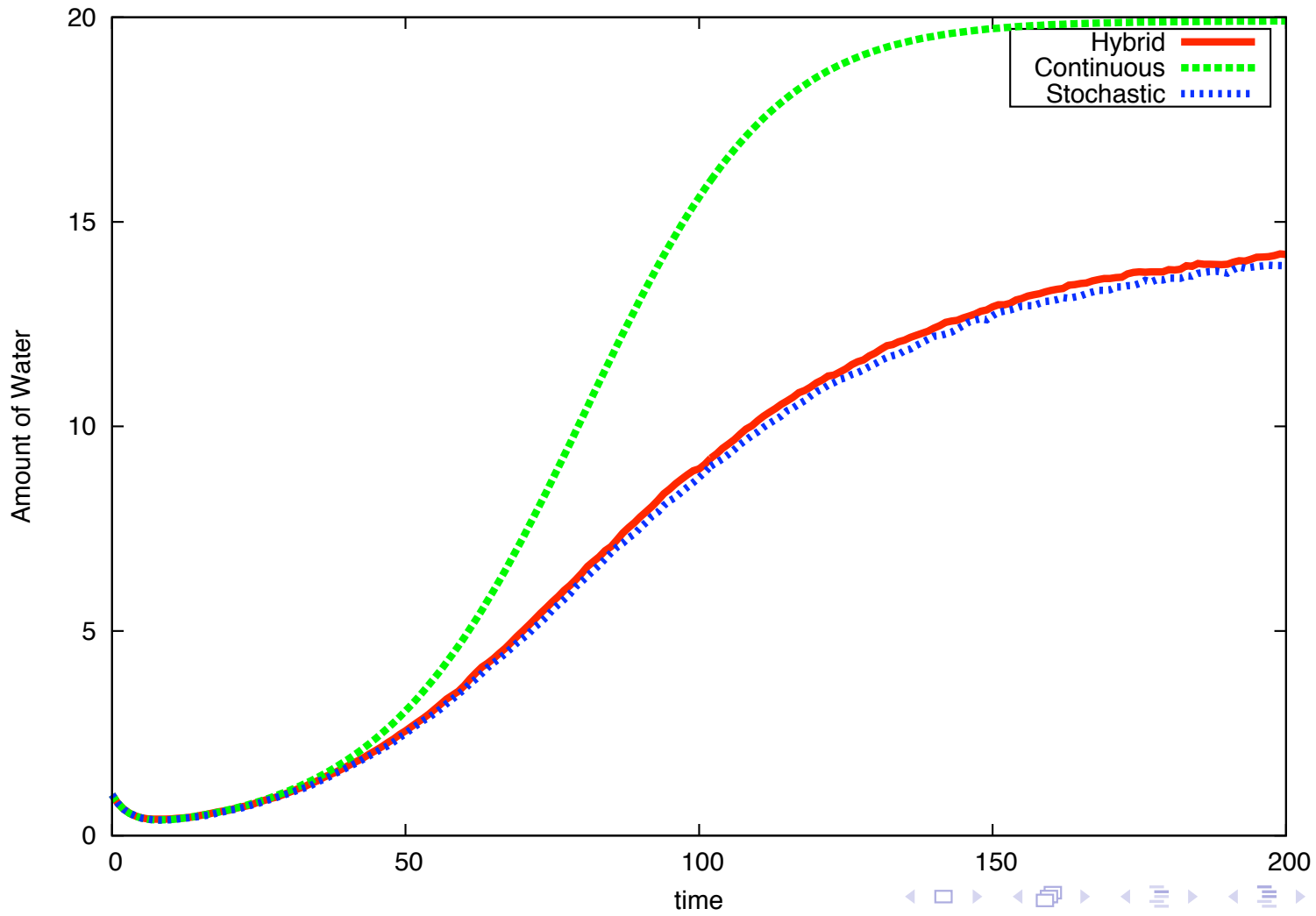
Srivastava et al 2002

T7 Phage (GHPN)

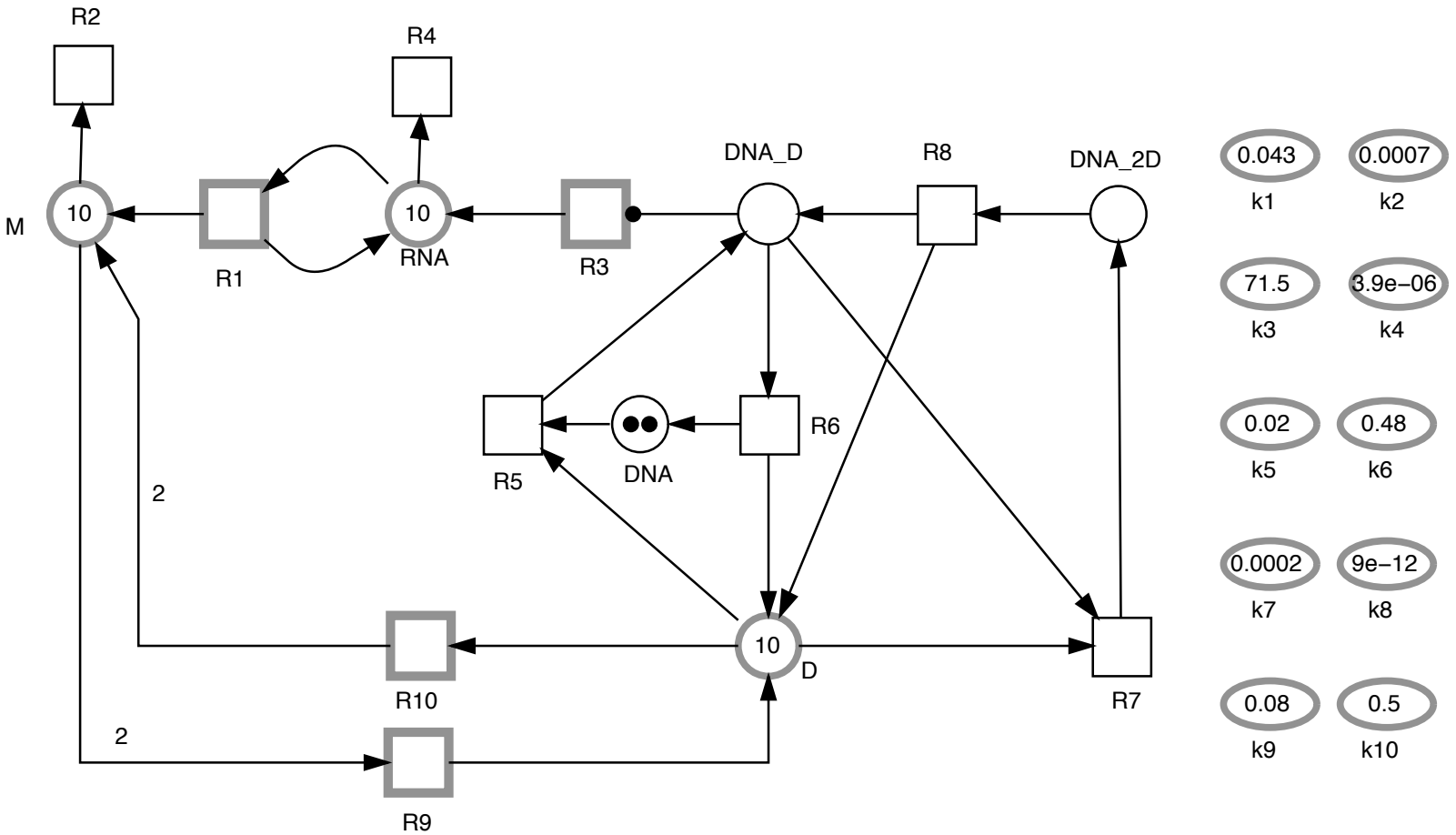
- R_5 and R_6 are represented as continuous reactions
- R_1, R_2,R_3, and R_4 are represented as continuous reactions



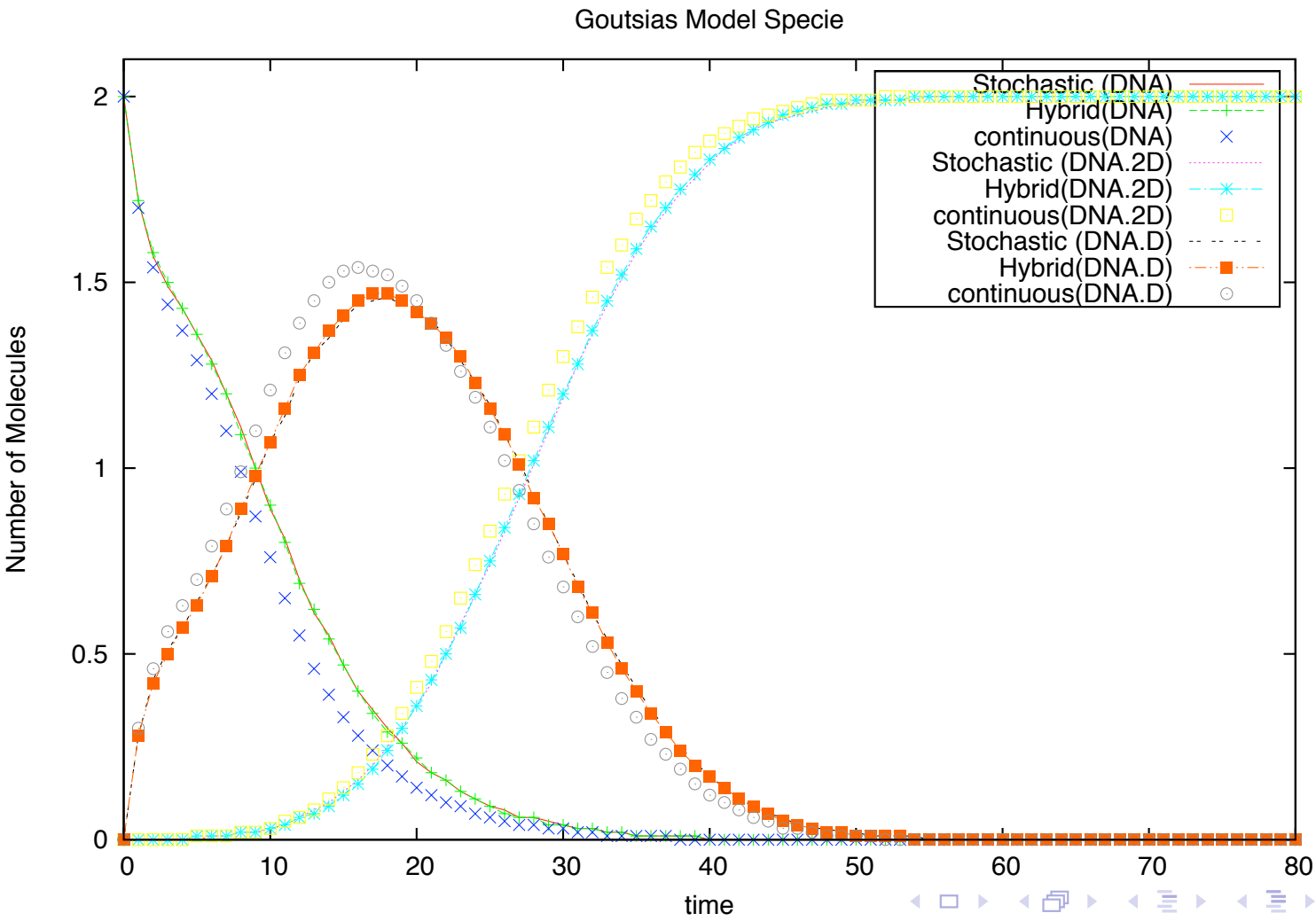
T7 Phage Simulation Results



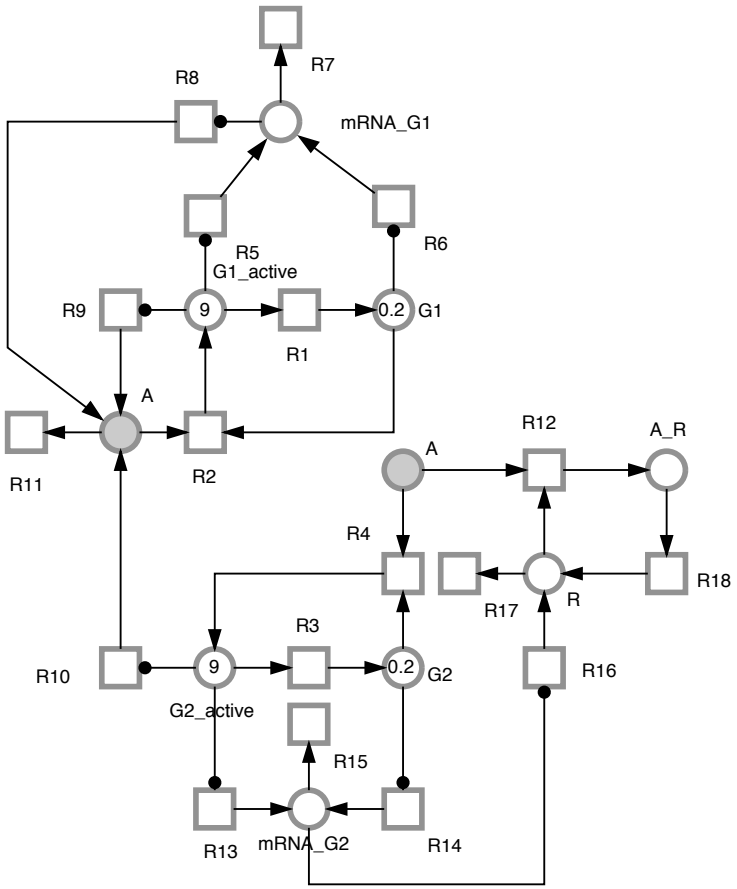
Goutsias Model (GHPN)

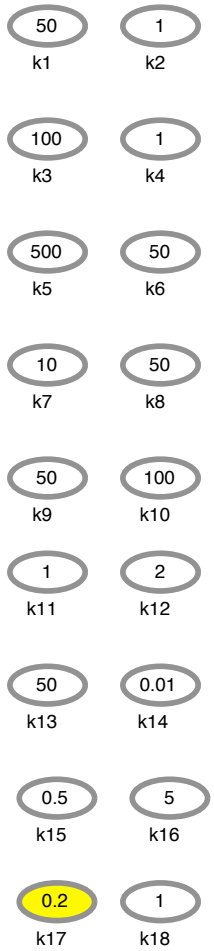


Goutsias Model (Simulation Results)



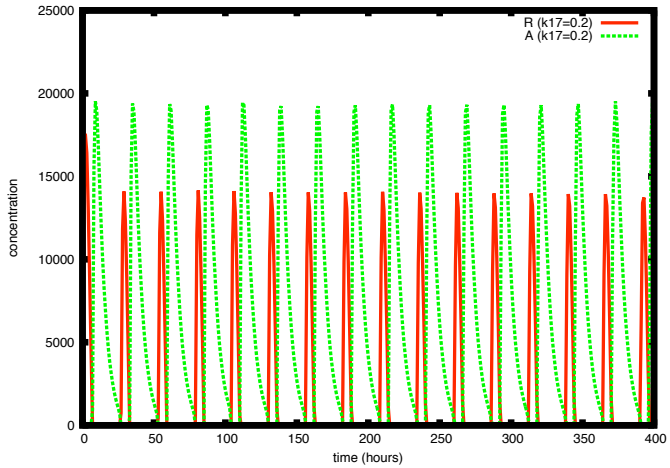
Circadian Oscillator



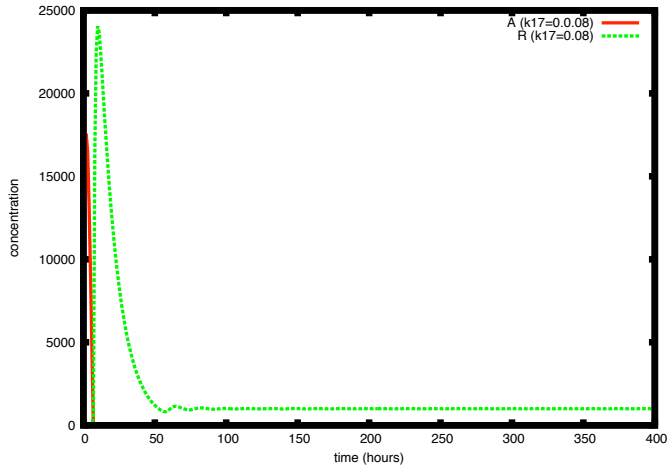


Circadian Oscillator(Cont.)

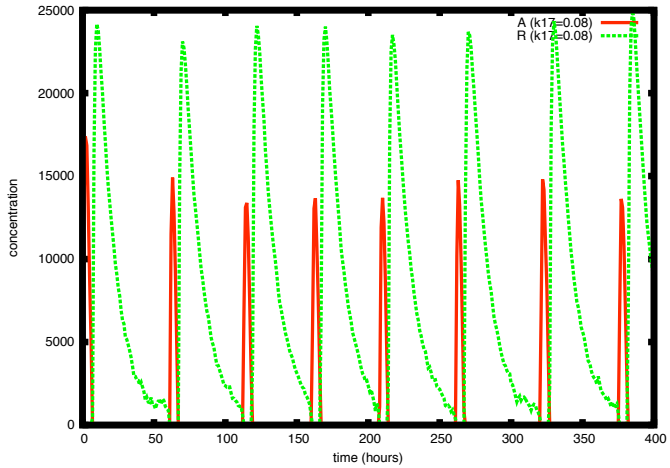
Continuous(k17=0.2)



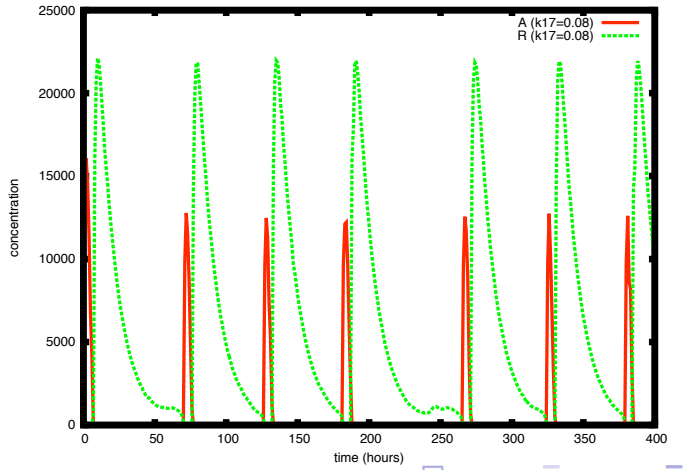
Continuous(k17=0.08)



Stochastic(k17=0.08)



Hybrid(k17=0.08)



Simulation Time

	Continuous	Stochastic	hybrid (static)	hybrid (dynamic)
Goutsias	0.01	0.972	0.014	0.138
Oscillator	0.258	5.995	4.21	1.991
T7 Phage	0.007	12.36	0.210	0.107

Live Demo using Snoopy

Thank You