CS 672
Alternative Modeling Approaches

Dr. Daniel A. Menascé

http://www.cs.gmu.edu/faculty/menasce.html

Department of Computer Science

George Mason University

Modeling Techniques

- Analytic
  - Queuing Networks
  - Stochastic Petri Nets
  - Generalized Stochastic Petri Nets
  - Markov Chains
  - Process Algebras
- Simulation
- Hybrid Models: combination of analytic and simulation models.

Petri Nets (PNs)

- Queuing Networks (QNs) are not good at expressing nor modeling concurrent events (e.g., fork and join situations, blocking, etc)
- Petri Nets (PNs) are good at representing concurrency but do not lend itself to performance analysis.
- Adding time to PNs can enable them to be used in modeling.

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Review of Basic Petri Nets

- Directed bi-partite graph with two types of nodes:
  - Places: used to hold tokens.
  - Transitions
- Firing Rule: a transition t is enabled if all input arcs have at least one token. When a transition fires, a token is removed from each input place and one token is placed in each output place.

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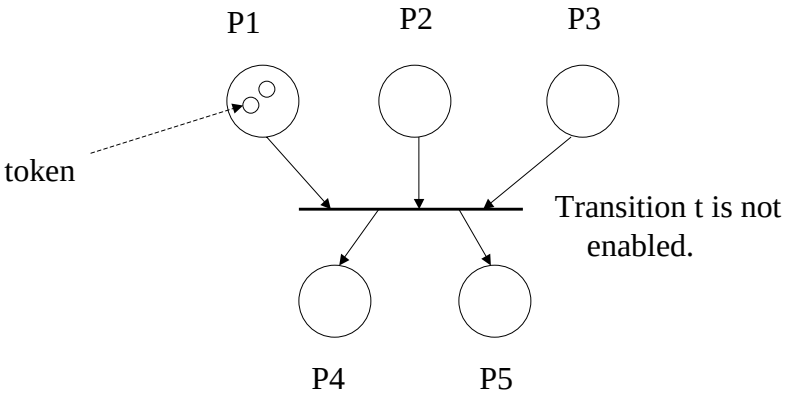
Review of PNs



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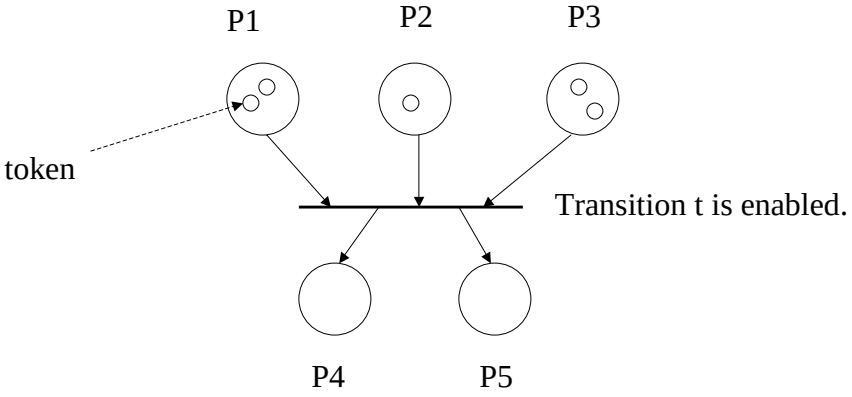
Review of PNs



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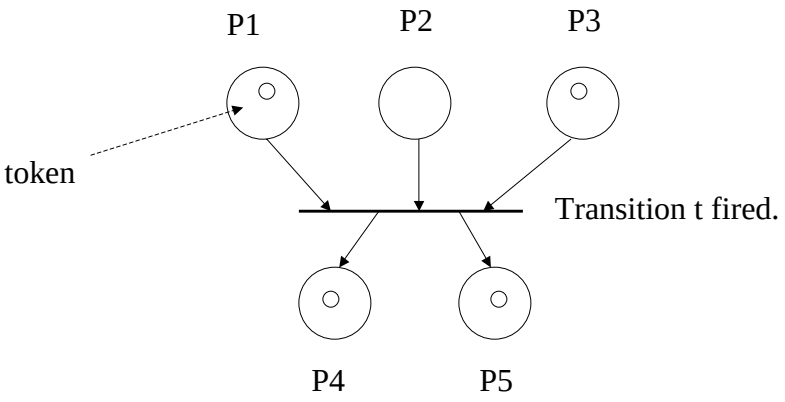
Review of PNs



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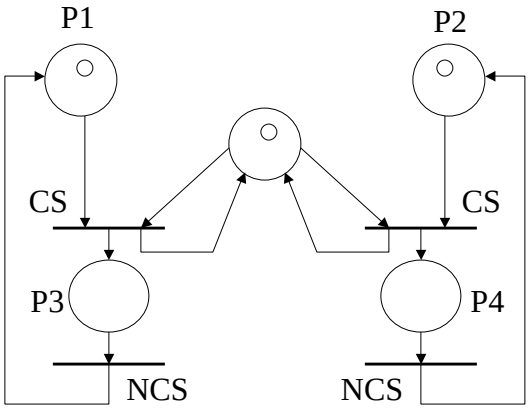
PN for Mutual Exclusion



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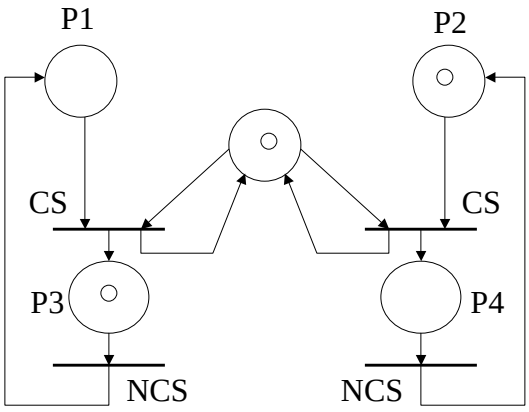
PN for Mutual Exclusion



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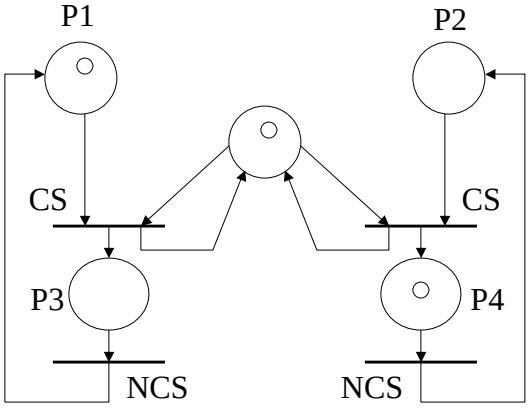
PN for Mutual Exclusion



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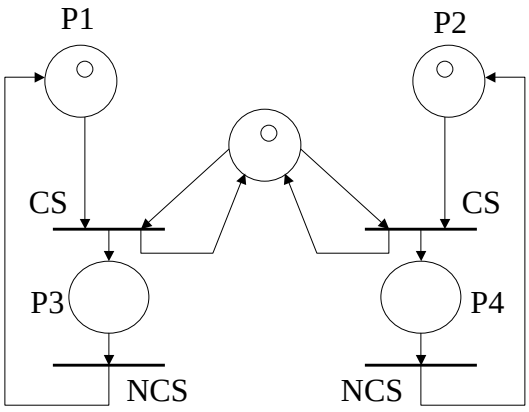
PN for Mutual Exclusion



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Reachability Set

- A marking of a PN is a tuple of the form

$$M = (m_1, ..., m_P)$$

  where m_i is the number of tokens in place *i*.
- *R* = set of all possible markings
- M_0: initial marking.

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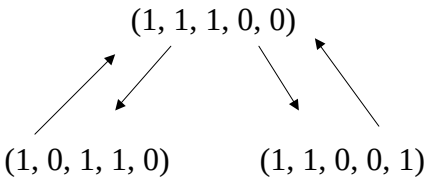
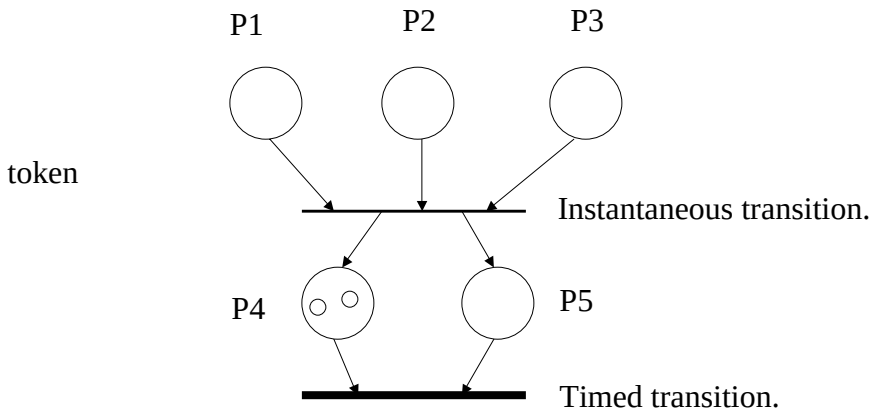
Reachability Set for Mutual Exclusion Example



Adding Time to PNs

- Transitions correspond to actions and places to conditions.
- Actions do not occur in zero time in real life.
- Make transitions take a time to fire. If firing time is exponentially distributed, then PN becomes a Stochastic Petri Net (SPN).
- If the SPN also allows instantaneous transitions as well as exponential transitions, then it is a Generalized Stochastic Petri Net (GSPN).
- Instantaneous transitions are used to specify control.

GSPN Graphical Notation



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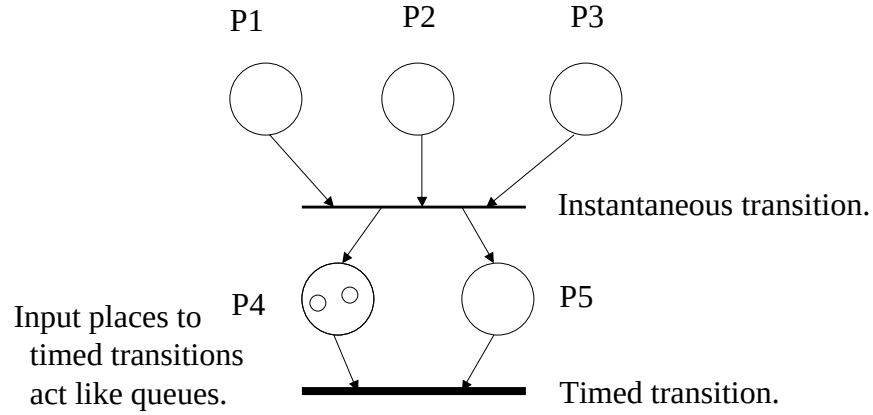
GSPN Graphical Notation



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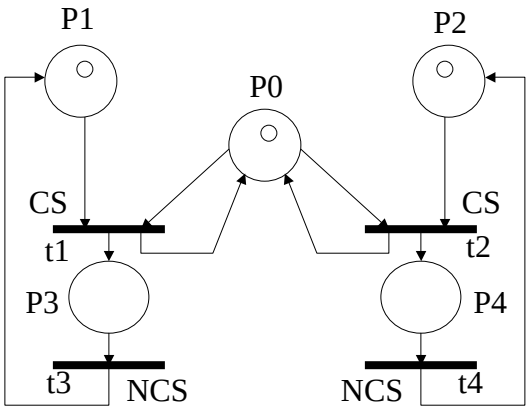
GSPN for Mutual Exclusion



M= (1,1,1,0,0)

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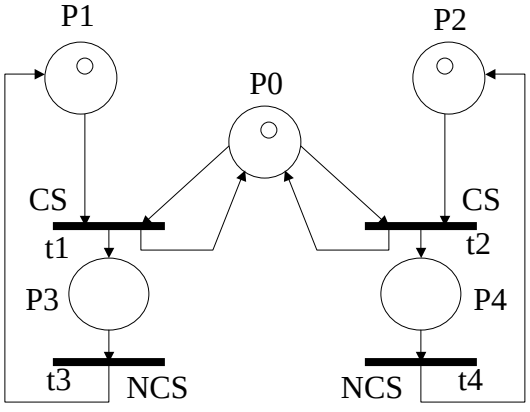
GSPN for Mutual Exclusion



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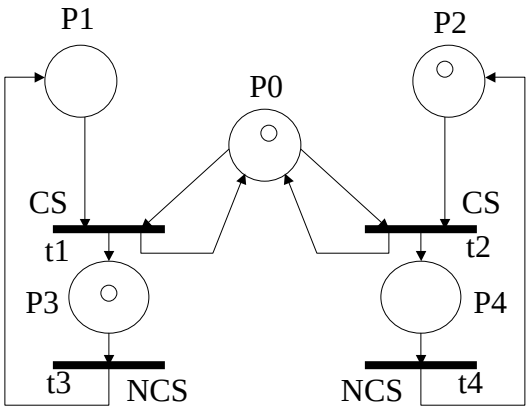
GSPN for Mutual Exclusion



M= (1,0,1,1,0)

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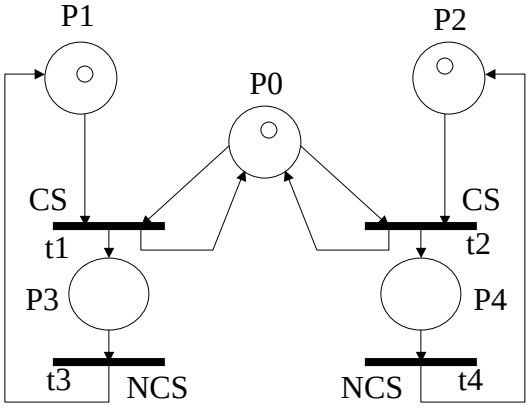
GSPN for Mutual Exclusion



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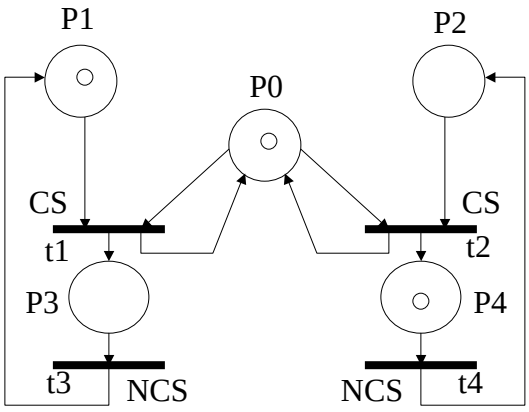
GSPN for Mutual Exclusion



M= (1,1,0,0,1)

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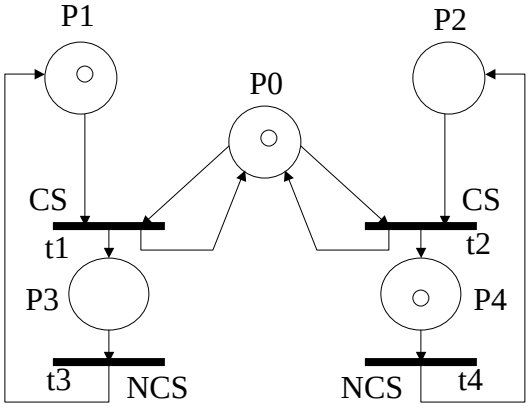
GSPN for Mutual Exclusion



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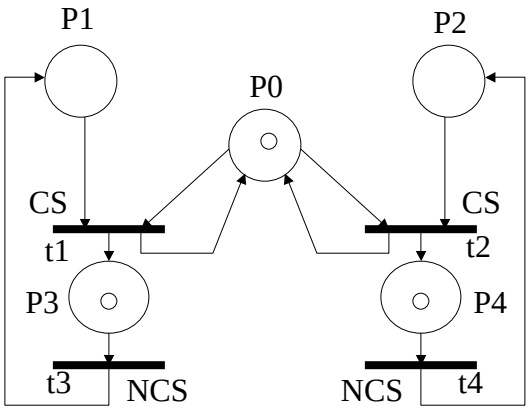
GSPN for Mutual Exclusion



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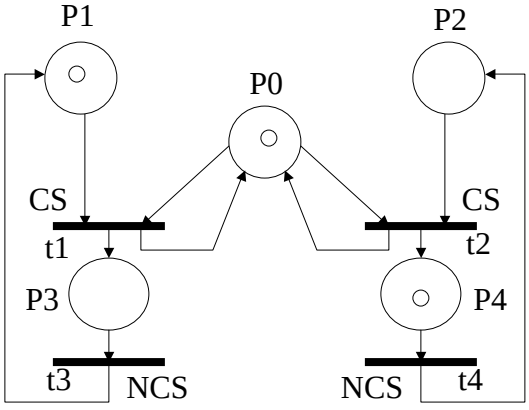
GSPN for Mutual Exclusion



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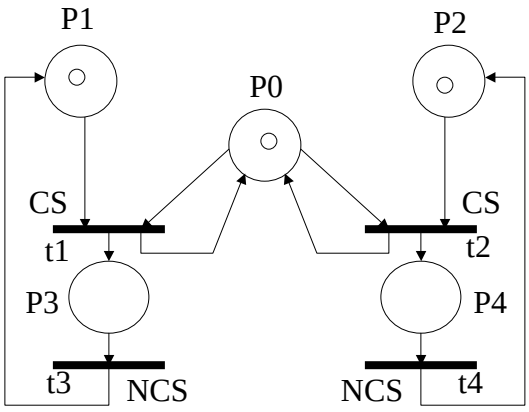
GSPN for Mutual Exclusion



M= (1,1,1,0,0)

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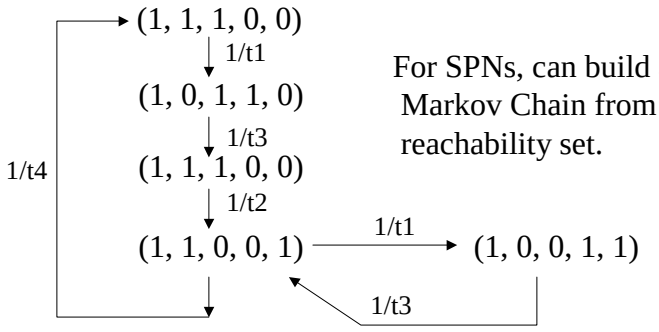
Reachability Set for Mutual Exclusion Example



For SPNs, can build a Markov Chain from the reachability set.

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Computing Performance Metrics from GSPNs

- Packages (e.g., GSPN) allow one to:
  - Specify a GSPN using a graphic editor, language or combination.
  - Solve GSPN to obtain probabilities of each marking.
  - Metrics of interest are associated with functions of marking probabilities.

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Simulation

- Discrete event simulation:
  - Event generation
  - Calendar of events
  - Event processing procedures
  - Clock (simulated clock)
- Trace-drive simulation: part of the input data comes from traces of execution (e.g., memory references, HTTP logs, etc).

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Simulation Programs

- Written in general purpose programming languages (e.g., C, C++).
- Written in high-level programming languages with the help of simulation libraries (e.g., SMPL, Simpack, CSim).
- Using special purpose simulation languages (e.g., GPSS/H).
- Using simulation packages (e.g., SES Workbench, OPNET).

Simulation Basics