# *Petri Nets*

- Part of this discussion is based on the paper
  - *Petri Nets: Properties, Analysis and Applications*
  - by Tadoa Murata, Proc. IEEE, Vol. 77, No. 4, April 1989.

- Petri Nets
  - graphical and mathematical modeling tool
  - tool for describing systems characterized as being:
    - concurrent, asynchronous, distributed, parallel, nondeterministic and/or stochastic

# *Petri Nets*

- History
  - **1962:** Carl Adam Petri's submitted his dissertation at the Uni. Darmstadt, Germany
  - **1970:** early development was published by A.W. Host and in the records of the 1970 Project MAC Conference on Concurrent Systems and Parallel Computation
  - **1970-75:** Computation Structure Group and MIT was most active
  - **1975:** conference on Petri Nets and Related Methods at MIT
  - **1979:** 135 researchers assembled in Hamburg, Germany, for 2-week advanced course on General Net Theory of Processes and Systems
  - **1980:** first European Workshop on Applications and Theory of Petri Nets, Strasbourg, France.
  - check out Murata's paper for the extensive literature discussion

# Petri Nets

- General:
  - directed, weighted, bipartite graph
  - two kinds of notes (Places P, Transitions T)
  - arcs from P to T or from T to P
  - arcs have integer weights
  - non-negative Place weights are called tokens

# *Petri Nets*

- A Petri Net is a 5-touple PN={P,T,A,W,M0}
- Place Set $P = \{p_1, p_2, \ldots, p_m\}$
  - finite set of places
  - condition = place
  - one condition or set of atomic conditions
  - symbol
- Transition Set $T = \{t_1, t_2, \ldots, t_n\}$
  - finite set of transitions
  - action = transition
  - one action or set of atomic transitions
  - symbol

# Petri Nets

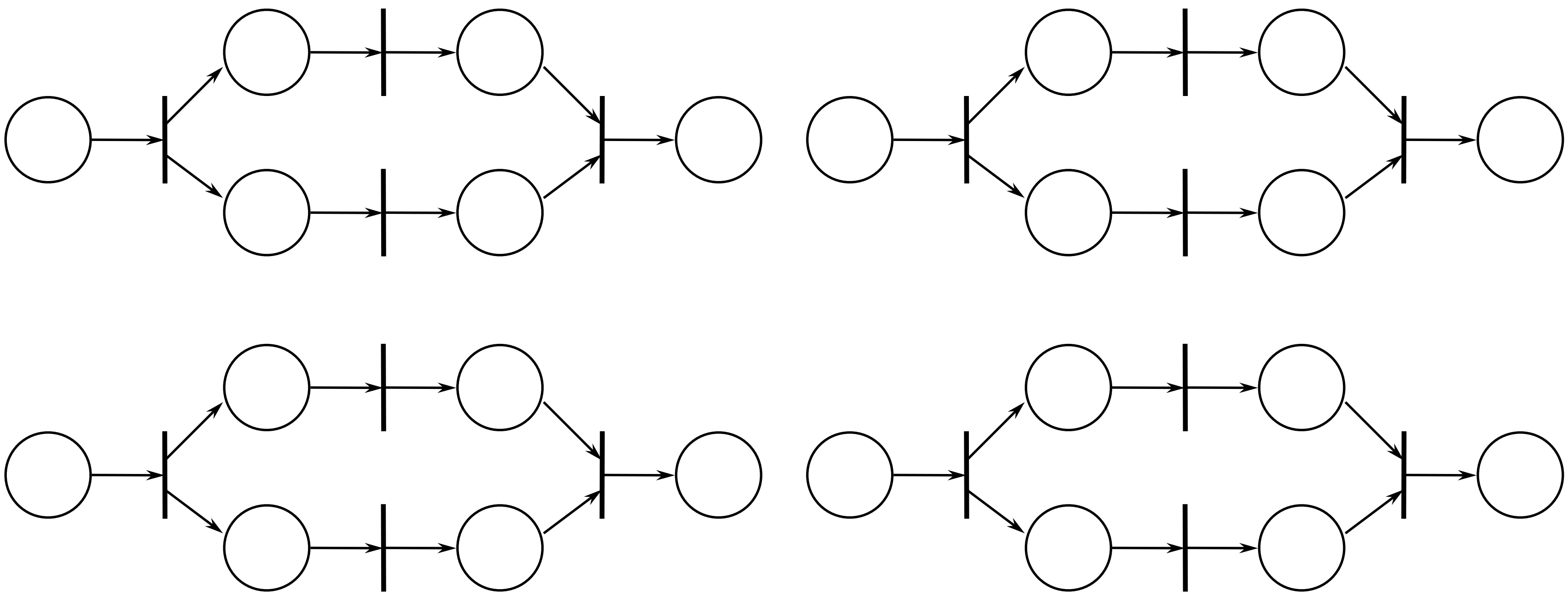
- Arc Set $A \subseteq (P \times T) \cup (T \times P)$
  - set of directed arcs
  - edge of graph = arc
  - symbol $\longrightarrow$

- Weight Function $W = A \rightarrow \{1,2,3,\ldots\}$
  - weights are associated with arcs

- Initial Marking $M_0 = P \rightarrow \{0,1,2,\ldots\}$
  - the initial assignment of tokens to places

# Petri Nets

- example



# Petri Nets

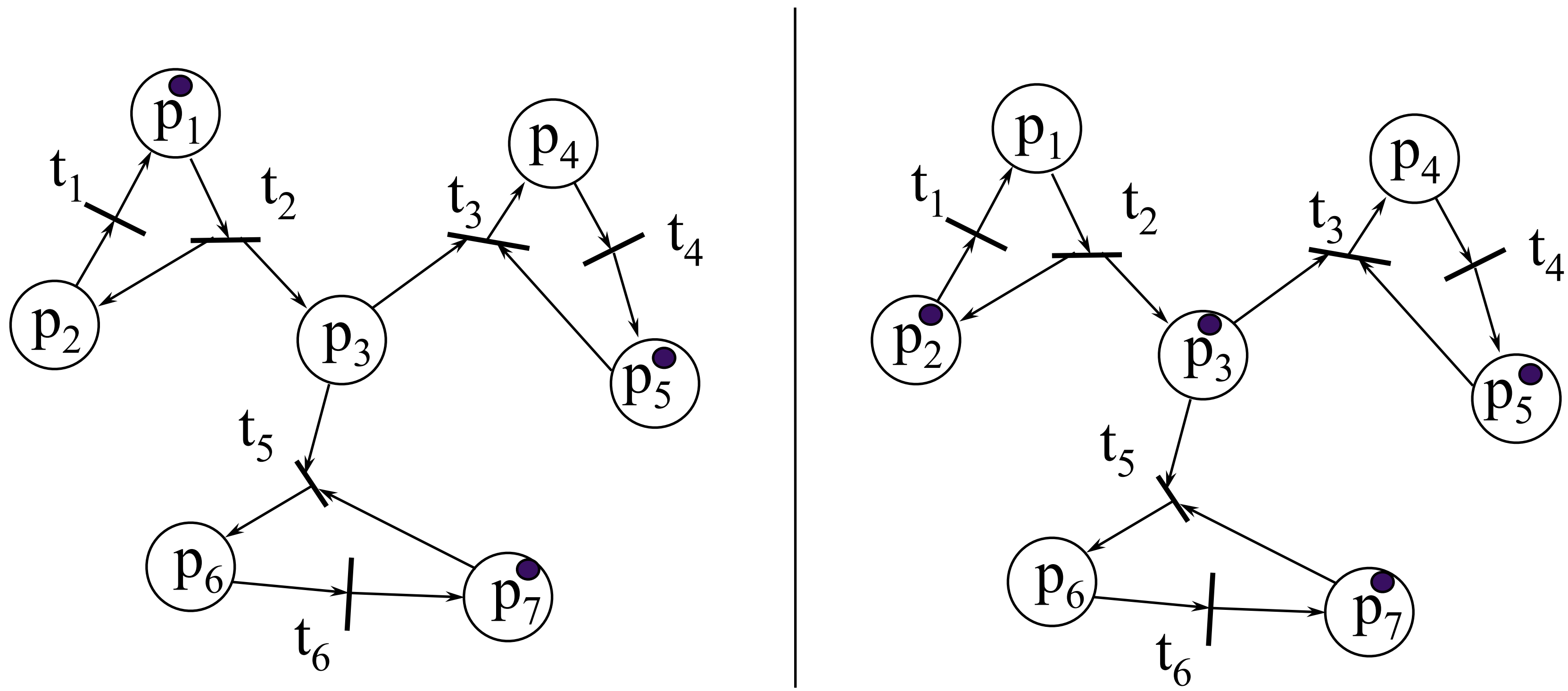
- Dynamic Behavior
  - during simulation of a petri net the state of the net may change
  - change of state:
    - transitions can be enabled
    - enabled transitions may fire
    - firing transition changes the marking of the net
    - the marking is the “snap-shot” of all the tokens

# Petri Nets

- Firing rules
  - A transition $T$ is said to be *enabled* if each input place $P$ is marked with at least $W(P,T)$ tokens
    - $W(P,T)$ is the weight of the arc from $P$ to $T$
  - An enabled transition may or may not fire (depending on whether or not the event actually takes place).
  - A *firing* of an enabled transition $T$ removes $W(P,T)$ tokens from each input place $P$ of $T$, and adds $W(T,P)$ tokens to each output place $P$ of $T$
    - $W(T,P)$ is the weight of the arc from $T$ to $P$
  - Common misconception: When a transition fires, it does **not** *move* tokens
    - i.e. the number of tokens in the system is not necessarily constant

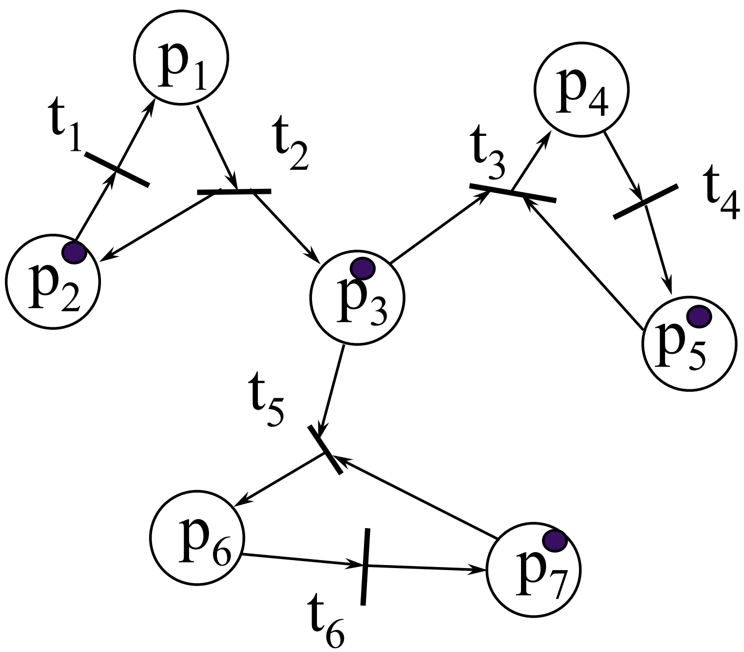
# *Petri Nets*

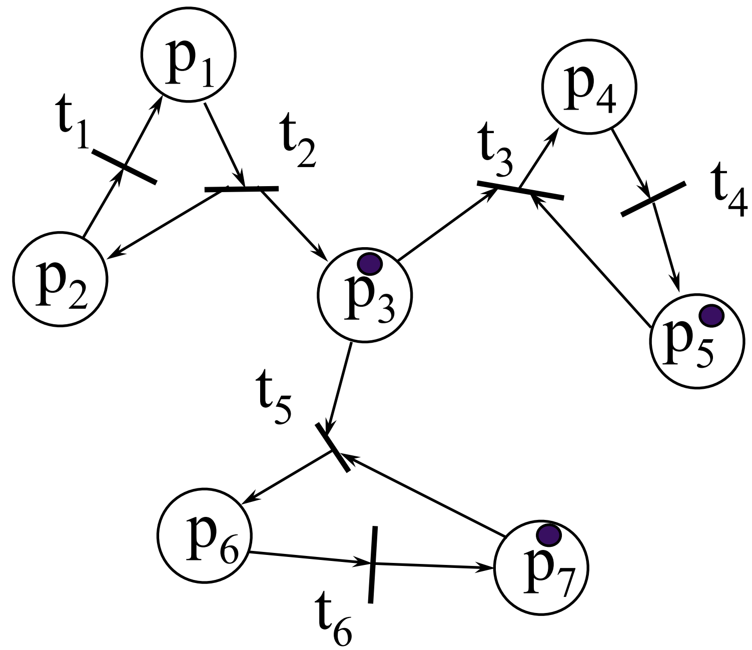
- Example: assume the following initial marking
  - Only one transition is enabled, i.e. $t_2$



# Petri Nets

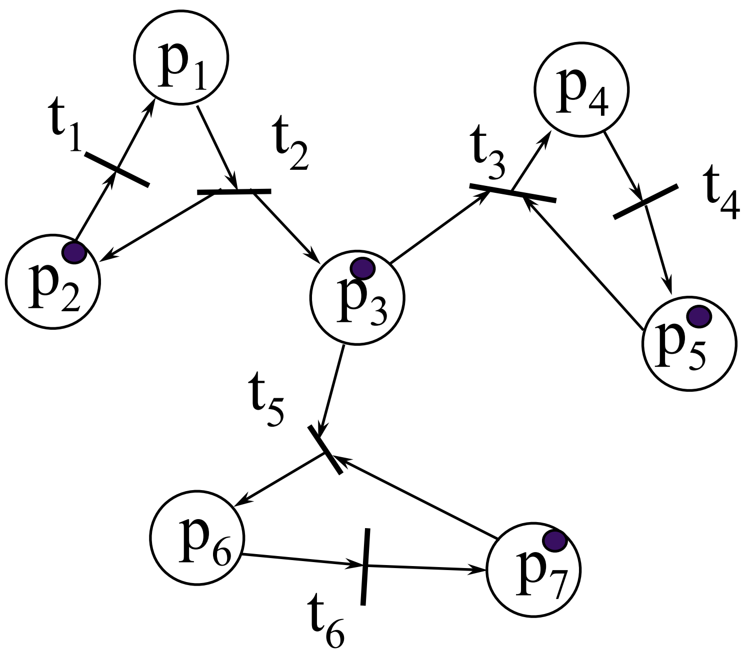
- Now several transitions are enabled, i.e. $t_1$ $t_3$ and $t_5$
- if $t_1$ fires first

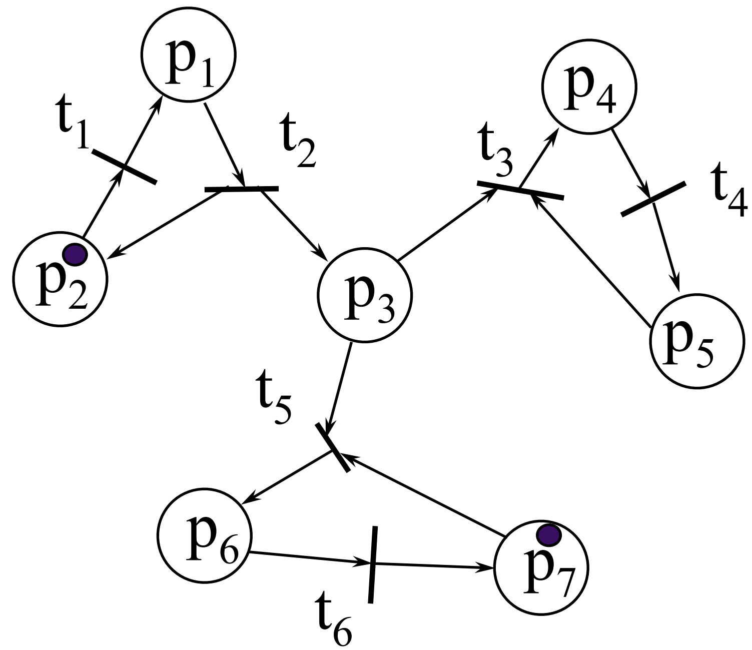


# Petri Nets

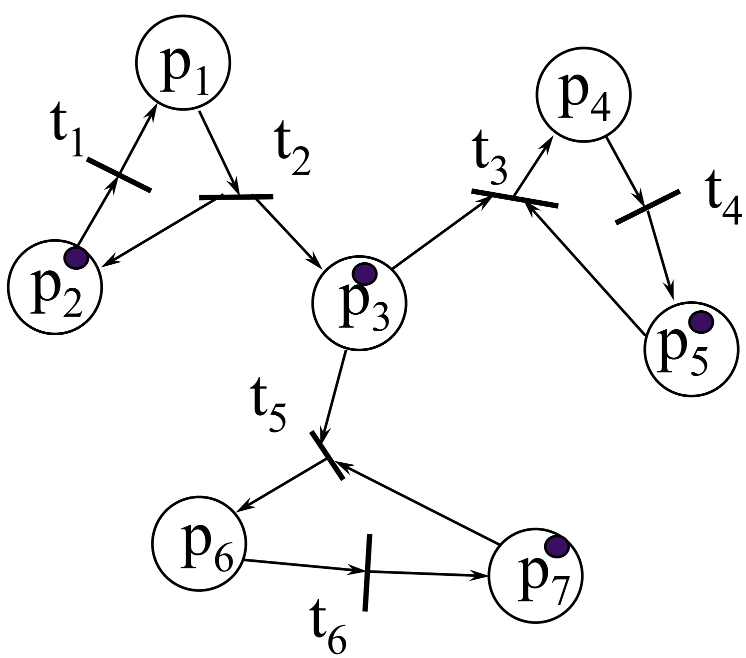
– if $t_3$ fires first

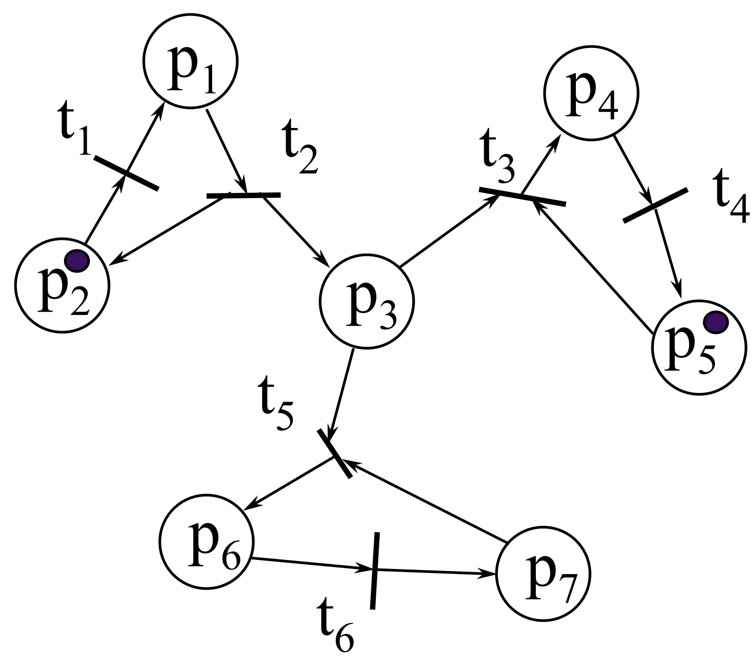


# *Petri Nets*

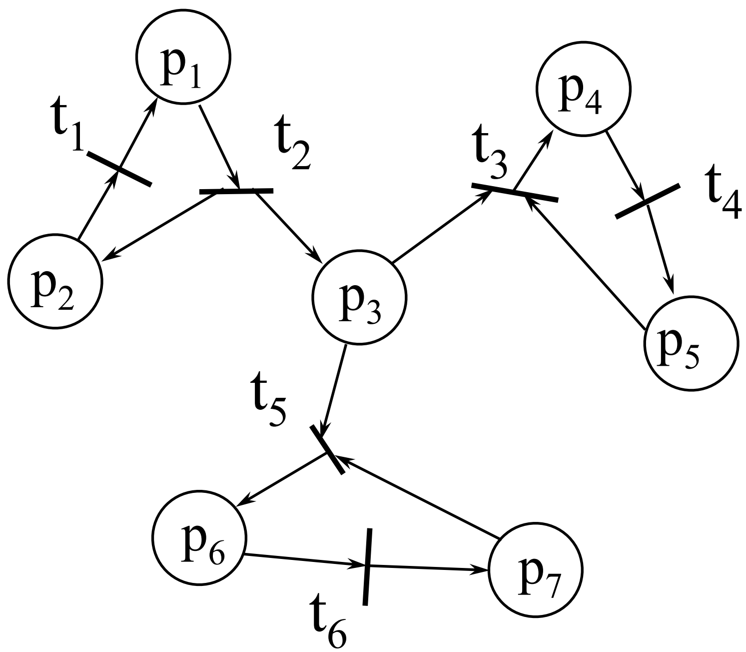
- if $t_5$ fires first
- $t_3$ and $t_5$ are said to be in conflict



# Petri Nets

– what could this Petri net represent?



# *Petri Nets*

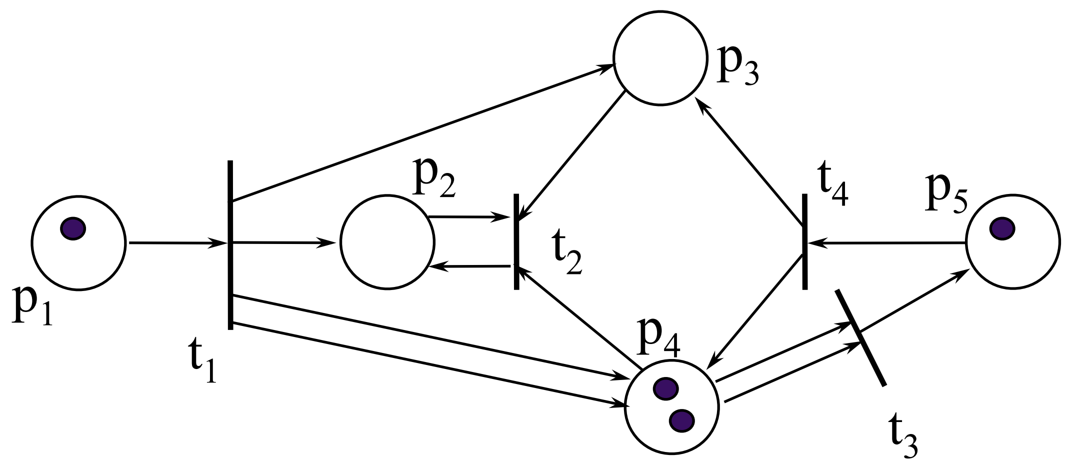
- Marking: Number and placement of tokens
  - let $m_i$ = # of tokens in place $p_i$
  - then marking

    $$M = \{m_1, m_2, ..., m_n\}$$

  - marking -- system state
  - Advantage: economy of model
    - e.g. assume net with 6 places
      - we limit each place to maximal 1 token
      - then there are $2^6$ possible markings
      - => 64 states
      - thus Petri Nets are a lot smaller than state diagrams, i.e. Markov chains

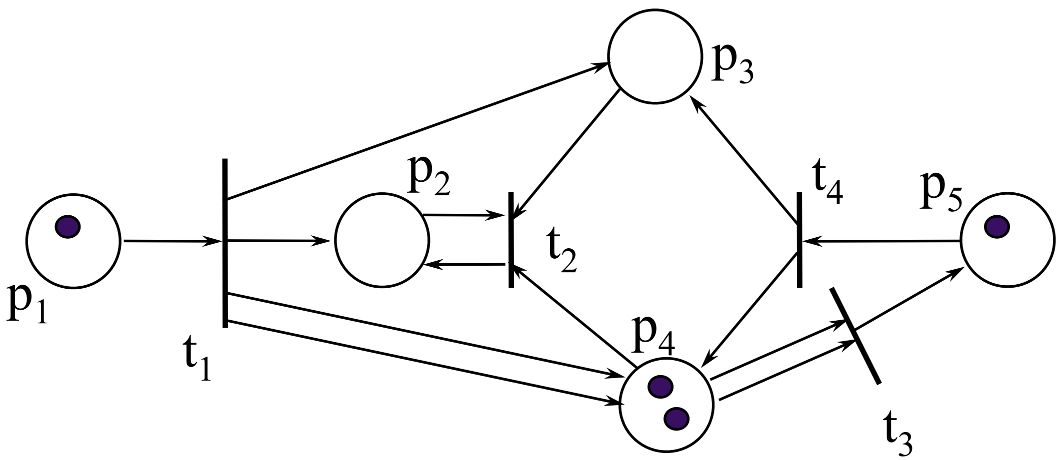
# Petri Nets

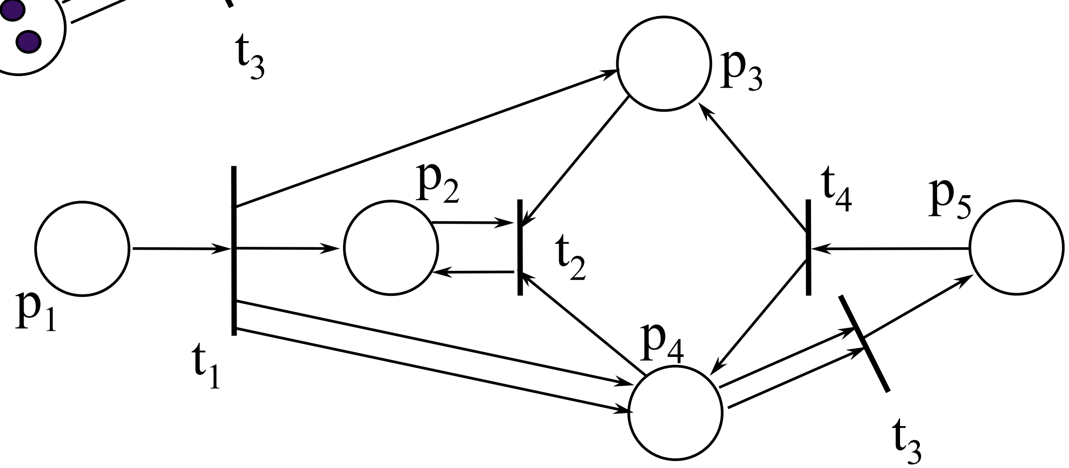
- Firing rules
  - transition 1,3 and 4 are enabled



# Petri Nets

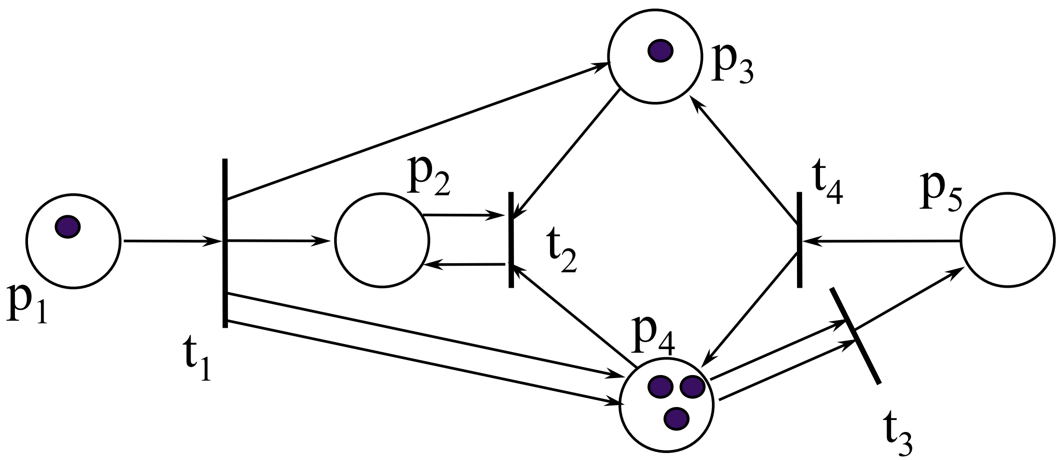
- Firing rules
  - transition 4 fires

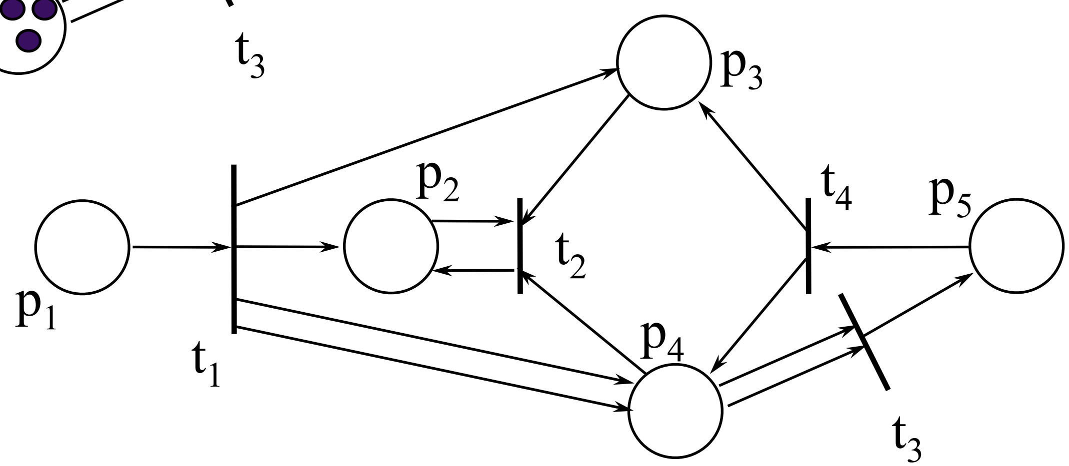


# Petri Nets

- Firing rules
  - transition 1 fires



# Petri Nets

- Firing rules
  - transition 3 fires