

Real-Time Programming

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Timed Petri Nets

- Extend the Petri net model with time to model timing attributes of a system. Either of the followings:
- **P-Timed**: Associate a constant number with every place. The number indicates the time interval that the place takes, i.e., the time a token has to stay in the place before it can be available
- **T-Timed**: Associate a constant number with every transition. The number indicates time interval that the transition takes
- Any of P-Timed or T-Timed Petri net models can be transformed to the other one. Thus we only consider one of them (P-Timed)

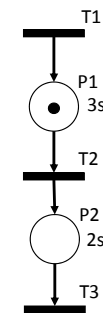
P-Timed Petri Nets

- Assume a place is associated with time interval d . When a token is added to the place it has to stay for d time units in the place until it can be available

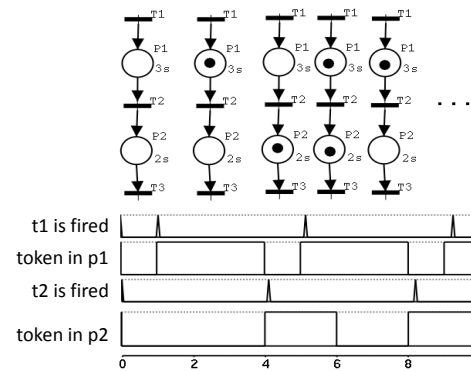


P-Timed Petri Nets

- Example



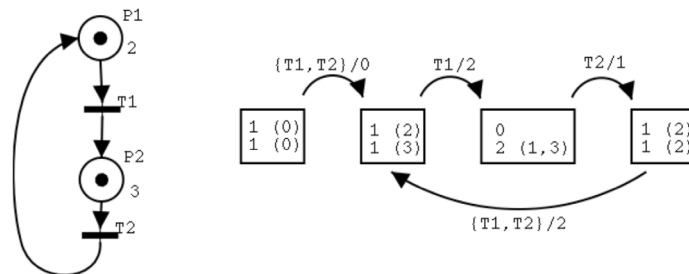
P-Timed Petri Nets Example



Reachability Graph for P-Timed Petri Nets

- For each individual token in a place the time it needs to spend in the place has to be recorded
- On each arrow we write the followings:
 - The transitions that are fired
 - The minimum time that takes to transfer from one marking to another one
- A marking is shown by a rectangle in which the followings are written:
 - The number of tokens in each place
 - The remaining time for each token to be ready

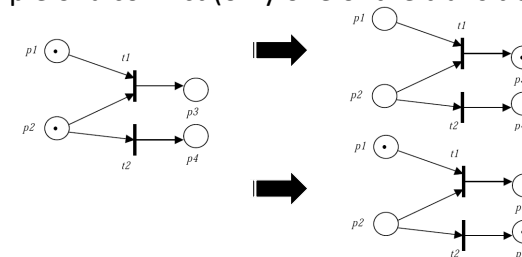
Reachability Graph for P-Timed Petri Nets; Example



- $\{T1, T2\}/0$ means that both T1 and T2 are fired at the beginning

P-Timed Petri Nets

- Every limited P-Timed Petri net without effective conflicts has a periodic behavior meaning that after a constant period it is repeated. Such a Petri net is said to have a **stationary behavior**
- Example of a conflict (only one of the transitions can be fired):

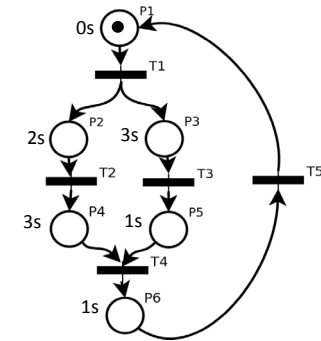


P-Timed Petri Nets

- **Maximum Speed:** If any transition is fired as soon as tokens in its input-places are available, the Petri net is executed in maximum speed
- **Firing Frequency:** The firing frequency of a transition is the number of firings it performs in one time unit

P-Timed Petri Nets; Exercise

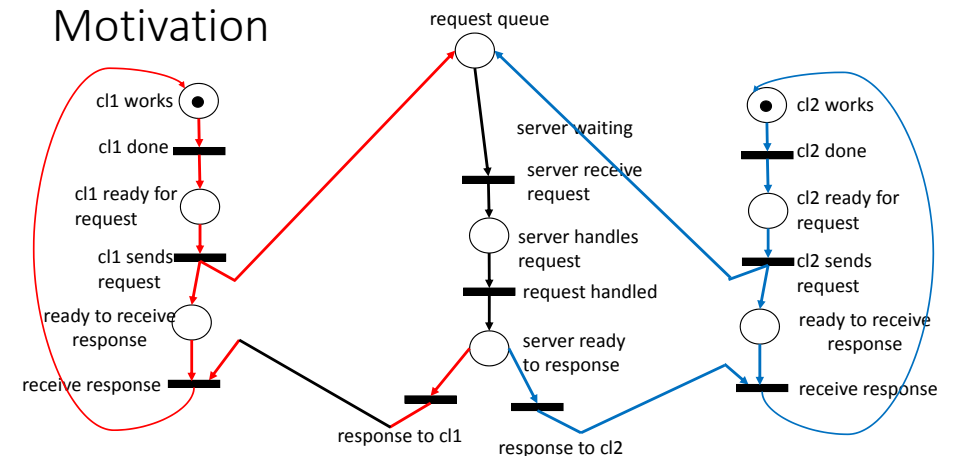
- Assuming the following Petri net executes with maximum speed, draw its reachability graph
- What is the period of the net?
- What is the firing frequency of T1?



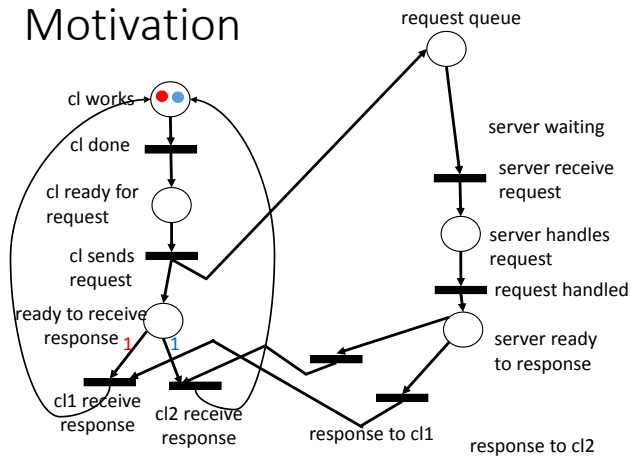
Colored Petri Nets

- So far all tokens have been identical
- Let look at an example

Colored Petri Nets; Motivation



Colored Petri Nets; Motivation



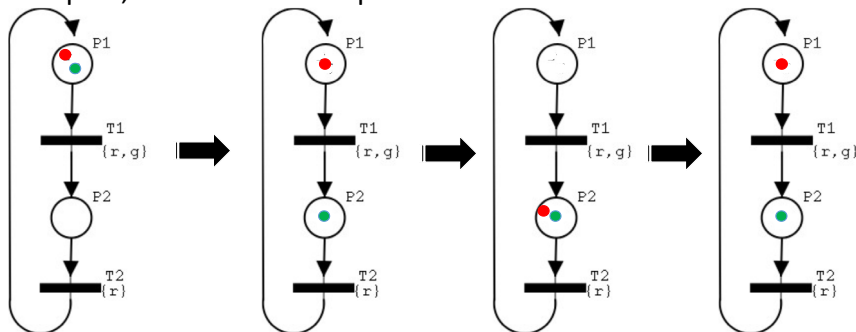
Colored Petri Nets

• In a colored Petri net:

- Each token may have a color.
- The color is a metaphor to differentiate values of tokens, i.e., a color represents the value of a token
- Transitions are sensitive to colors, i.e., they distinguish between different colors. A transition might be enabled by **some** of the colored tokens
- An arc is associated with a function with colored tokens as its parameters, e.g., $f(\text{red}) = \text{green}$ or $f(\text{green}) = 2\text{reads}$. If no function is specified, each token remains at it is, e.g., $f(\text{red}) = \text{red}$, $f(\text{green}) = \text{green}$, etc.

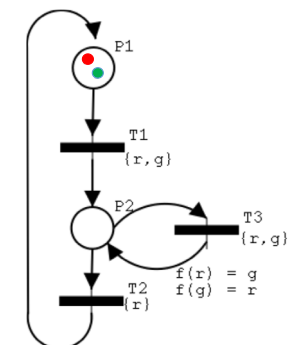
Colored Petri Nets

• Example1, the arcs are not specified with function



Colored Petri Nets

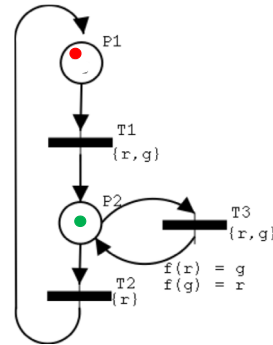
• Example2, an arc is specified with a function that transforms the colors



Colored Petri Nets

- Example2, an arc is specified with a function that transforms the colors

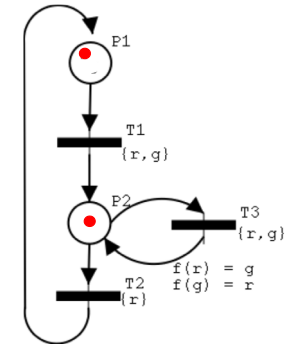
- T1(g) is fired
 - Remove $f(g)=g$ from P1
 - Add $f(g)=g$ to P2



Colored Petri Nets

- Example2, an arc is specified with a function that transforms the colors

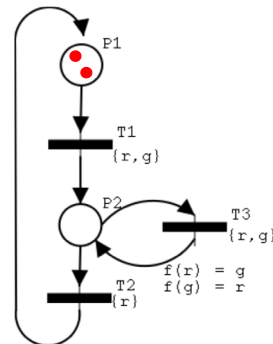
- T1(g) is fired
 - Remove $f(g)=g$ from P1
 - Add $f(g)=g$ to P2
- T3(g) is fired
 - Remove $f(g)=g$ from P2
 - Add $f(g)=r$ to P2



Colored Petri Nets

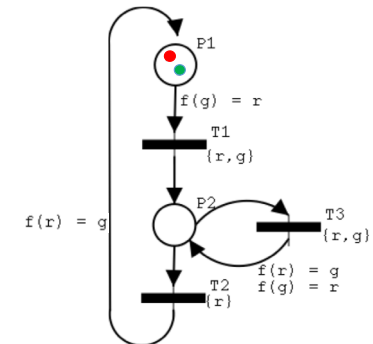
- Example2, an arc is specified with a function that transforms the colors

- T1(g) is fired
 - Remove $f(g)=g$ from P1
 - Add $f(g)=g$ to P2
- T3(g) is fired
 - Remove $f(g)=g$ from P2
 - Add $f(g)=r$ to P2
- T2(r) is fired
 - Remove $f(r)=r$ from P2
 - Add $f(r)=r$ to P1



Colored Petri Nets

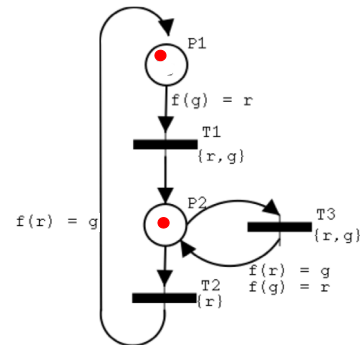
- Example3, three arcs are specified with functions that transform the colors



Coloured Petri Nets

- Example3, two arcs are specified with functions that transforms the colours

- T1(g) is fired
 - Remove $f(g)=r$ from P1
 - Add $f(r)=r$ to P2



Coloured Petri Nets

- Example3, two arcs are specified with functions that transforms the colours

- T1(g) is fired
 - Remove $f(g)=r$ from P1
 - Add $f(r)=r$ to P2
- T2(r) is fired
 - Remove $f(r)=r$ from P2
 - Add $f(r)=g$ to P1

