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Position Paper
Relaxed Timed Coloured Petri Nets
A Motivational Case Study

Guy Edward Gallasch
Jonathan Billington

University of South Australia

Motivation

Scheduling applications:

- **We have used both Timed and Untimed CPNs for a number of task scheduling projects involving time.**
  - **Timed CPNs exhibit an *eagerness-to-execute* semantics which may exclude the discovery of optimal *schedules*.**
  - **Untimed CPNs do not exhibit this property, hence allow all possible *sequences* of events without regard to timing, including sequences that correspond to optimal schedules.**
  - **When timing is imposed on the untimed sequences, we discover the globally optimal schedules, but also *infeasible* schedules – schedules that are not realisable.**
- **Ideally, we want a time semantics that captures all feasible schedules (including optimal) and no infeasible schedules.**
  - **A time semantics relaxing the eagerness-to-execute property.**

Task Scheduling

Consider a set of tasks that are executed to reach a *goal state*

Task Characteristics:

- **A duration**
- **Require preconditions and produce effects that become preconditions of future tasks.**
- **May require resources.**

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Three Task Example

Consider three tasks:

Task	Precondition	Effect	Required Resources	Duration
T1	C1	C2	R1	5
T2	C1	C2	R2	50
T3	C2	C3	R2	10

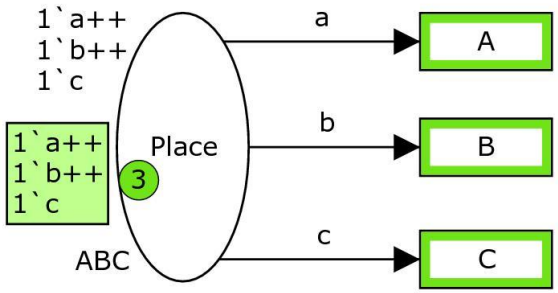
Initial state: C1 holds. Goal state: C3 holds.

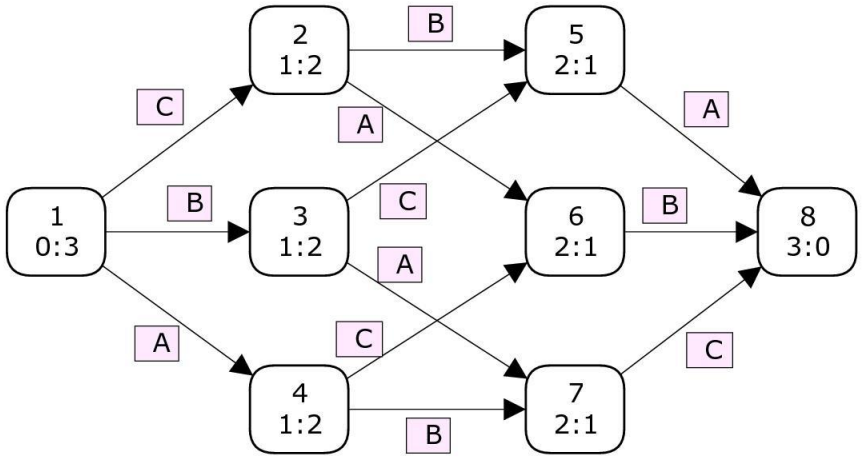
- **Both T1 and T2 can and do start at time 0**
- **T3 requires R2, hence cannot start until after T2 terminates and releases R2, at time 50**
- **Goal state reached when T3 terminates, at time 60**

But if T2 was delayed (or not executed at all), T3 could start as soon as T1 terminates. The goal would be reached at time 15

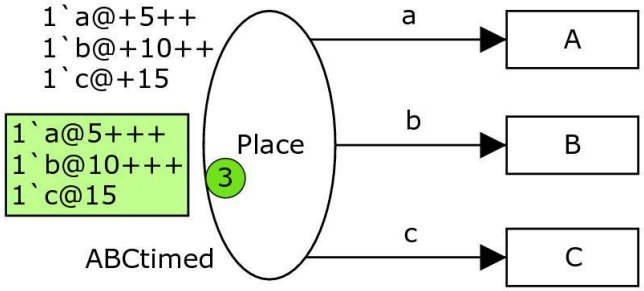
Untimed and Timed Semantics

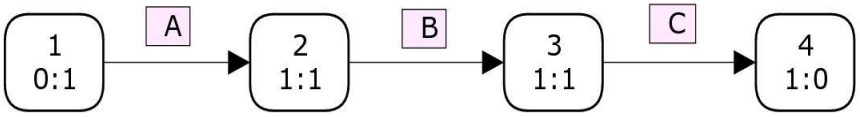
Untimed CPN and its RG:





Timed CPN and its RG:

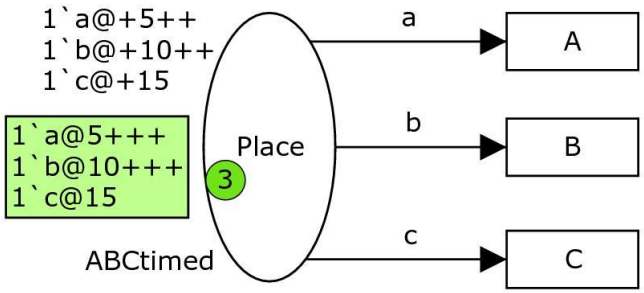


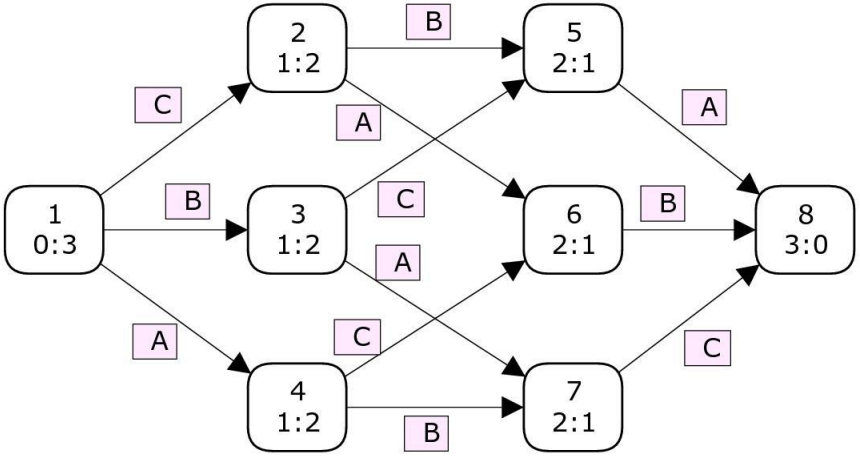


Relaxed Time Semantics

Basic idea: remove the restriction that the next binding element to occur must have the minimum time of all enabled binding elements.

Relaxed Timed CPN and its RG:





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Relaxed Time Semantics

Current Timed CPN enabling rule (see Def 11.6 in new CPN book):

A step, *Y*, is enabled at time *t'* in a timed marking, (*M,t) (where *t** is the value of the global clock in marking *M*), if and only if:**

1. The binding b of each binding element (t,b) in step *Y* satisfies the guard of t;
2. Sufficient tokens exist in all untimed input places to satisfy the multiset sum of evaluated untimed input arc expressions for all binding elements in step *Y*;
3. Sufficient and appropriately timed tokens exist in all timed input places to satisfy the multiset sum of timed input arc expressions evaluated for b at time *t'* for all binding elements in step Y;
4. The current global clock, *t**, is less than or equal to *t'*; and
5. *t'* is the smallest time value for which there exists a step satisfying conditions 1 to 4.

Modified enabling rule for Relaxed Timed CPNs:

5. *t'* is the smallest time value that satisfies conditions 1 to 4 for step *Y*.

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Relaxed Time Semantics - Refinement

Idea:

A subset of transitions may be required to occur at the earliest opportunity.

- **E.g. transitions that represent termination of tasks that have a fixed duration should not be delayed**
- **Removes infeasible schedules**

Allows the generation of a whole spectrum of RGs:

- **From the RG of the existing Timed CPNs (no transitions can be delayed)**
- **To the RG obtained when all transitions can be delayed (fully relaxed Timed CPNs)**

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Conclusions

- **Propose a relaxation of the semantics of Timed CPNs**
  - **some or all of the transitions can be excluded from the *eagerness-to-execute* property.**
- **Conjecture: the proposal preserves the same properties as the existing semantics of Timed CPNs with respect to preservation of markings and occurrence sequences of the corresponding untimed CPN.**
  - **hence the new time semantics has the potential to be applied to the analysis of any system currently modelled by Timed CPNs.**
- ***In Particular* the new semantics allows**
  - **all schedules to be captured by the RG, and hence the determination of optimal schedules.**
  - **infeasible schedules to be removed**

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Future Work

- **Establish a firm theoretical foundation**
- **Prove the preservation of markings and occurrence sequences**
- **Provide support in CPN Tools**
- **Investigate the use of this modified time semantics in a case study of significance, such as our operational planning work.**