A New Discrete Algorithm for the Computing a Reachability Graph of a weakly defined Time Petri Net

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Extended abstract

The Petri nets, meanwhile well known, are very usefull and rather convenient for modelling and checking concurrent systems. This is because of their graphical description possibilities on the one hand, and the formal definition on the other hand and therefore a wide software support possibilities.

Several time extensions of Petri nets already can be found (comp. Starke [12]). Two main directions in using the time are recognized: considering the time as a duration (first intriduced by Ramchandani[10]) and considering time intervals (comp. Merlin[5], Popova[6], Berthomieu/Diaz[2], Boucheneb/Berthelot[4]). Combinations of high-level nets and time constrains are desirable, e.g. for modelling industrial control systems, but difficult to analyze. For the verification of such systems simulation can be used. (comp. Schöf/Sonnenschein/Wieting[13]).

Time Petri nets, in sense of Merlin, are classical Petri Nets where to each transition t a time interval $[a_t, b_t]$ is associated. The times a_t and b_t are relative to the moment at which t was last enabled. Assuming that t was last enabled at time c_t, then t may fire only during the interval $[c_t + a_t, c_t + b_t]$ and must fire at the time $c_t + b_t$ at the latest, unless it is disabled before by the firing of another transition. Firing a transition takes no time. Thus, the philosophy of this kind of time dependent Petri net is : when a transition becomes enabled it may not fire at once (in general) but during a certain time interval and at the end of the interval there is a force for firing - weak version. If the end of the interval is infinite then the second characteristic of this kind of net, the force for firing is lost - strong version of the Time Petri nets.

For analysing Time Petri Nets there are defined two different methods: one is defined by Berthomieu/Diaz/Menasche (as well for the strong version as for the weak one) and the other is defined by Popova (for the strong version). The both consist on the computation of a reachability graph of the Time Petri Net but they have different backgrounds.

By Berthomieu/Diaz/Menasche the notion "state" is used for describing (infinitely) many situations of the Time Petri Nets and it is defined by a marking and time intervals for the enabled transitions (comp. Berthomieu/ Menasche[3], Berthomieu/Diaz[2]) while in Popova[6] a state is a description for a snapshot of the net. A state here is given by marking and the momentary local time for the enabled transitions and the "special" sign for the disabled transitions. Therefore we develop completely different method for building a reachability graph for a Time Petri Net: a node of the Berthomieu/Diaz/Menasche's reachability graph (a state class (comp. Berthomieu/ Menasche[3], Berthomieu/Diaz[2])) include an infinite number of possible situations of the Time Petri Net and is given as a solution of a system of inequalities.The nodes of our reachability graph (comp. Popova[6]) are only the "essential" states, these are the integer-states, where the momentary local time for all enabled transitions are integers. For example $z = (m = (1,0,3), \begin{pmatrix} 3 \\ \sharp \\ 0 \\ \sharp \end{pmatrix})$ can be a state in a Time Petri Net with 3 places and 4 transitions. The first and the third transitions are enabled. The first transition is enabled at least since 3 time units, and the third transition is just enabled at least (since 0 time units). The second and the fourth transitions are disabled. An interpretation of the notion "state" is as follows: in the net each transition t has a watch. The watch does not work (signed by $\#$) at the marking m, if t is disabled at m. If t is enabled at m, the watch of t shows the time , elapsed since t was enabled last. Obviously, this reachability graph includs only a discrete part of all the situations, which are possible for a given Time Petri Net. But the knowledge of the net behaviour in the integer-states is sufficient to know the whole behaviour of the net (comp. Popova [6]). The computing of the integer-states is easy.

Here, we will extend the discrete algorithm for computing a reachability graph for a weakly defined Time Petri nets.

For transitions with "open end" intervals, we consider the time until it reaches its eft's. The reachability graph contains all "essential" states, again. These are now all reachable states, where the watch of each transition shows to an integer time: for transitions with finite intervals - all reachable times, and for transitions with infinite intervals - all reachable times till the corr. eft's.

First, we will prove the equivalence between the languages of the Time Petri net (comp. Popova[7]) and of the new defined reachability graph. Further, we show that the Time Petri net is unbouded, if and only if, the reachability graph is infinite. Thus, we obey the justification for the newly introduced reachability graph for bondedness, dead locks and liveness considerations, computing the shortest path (with reference to the time) in the net between two arbitrary reachable states or markings, etc.

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