Project 22703: SYRF

**Deliverable 4/5.3.3**

# Integrating synchrony & asynchrony: timing analysis

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Abstract

We have proposed a systematic modelling approach for the timing evaluation of systems which can be modelled by partial order automata. Partial order automata are a convenient abstraction for synchronous reactive systems, as discussed elsewhere in this project. In references [1, 2] we have introduced our model, based on so-called $\text{Max}_+$ algebraic approach. This approach handles tensor products of (usual) automata and so-called maxplus automata, which are timed models revealing the worst case execution times for partial order automata. Alternatively, such models are represented by *timed diagrams,* i.e., diagrams with pairs {signal,state} as vertices, and branches labelled by action words and time delay symbols.

In this short note we sketch how this approach can be used to model High level Message Sequence Charts (HMSC) equipped with timing information. We illustrate this on the alternate bit protocol.

In the extended version of this abstract [3] (in french) we also describe how this model can be used to perform nonstandard analyses such as *maximum throughput.* Such type of analysis is not encompassed by usual formal methods for timed automata models, as these are unable to perform asymptotic analyses for the long time behaviour of the system.

As a perspective, we plan to build a tool implementing this approach, by connecting an HMSC editor to $\text{Max}_+$ tools developed at Inria Rocquencourt by S. Gaubert et al.


## References


[1] A. Benveniste, C. Jard, S. Gaubert, "Algebraic techniques for timed systems". In 9th International Conference on Concurrency Theory, Concur'98, Nice, France, sep. 1998.

[2] A. Benveniste, S. Gaubert, C. Jard, "Monotone rational series and max-plus algebraic models of real-timesystems". Wodes'98, August 1998.

[3] Pierre Le Maigat and Loic Hélouët, "$\text{Max}_+$, a new apporach for time in Message Sequence Charts", draft, 1999.

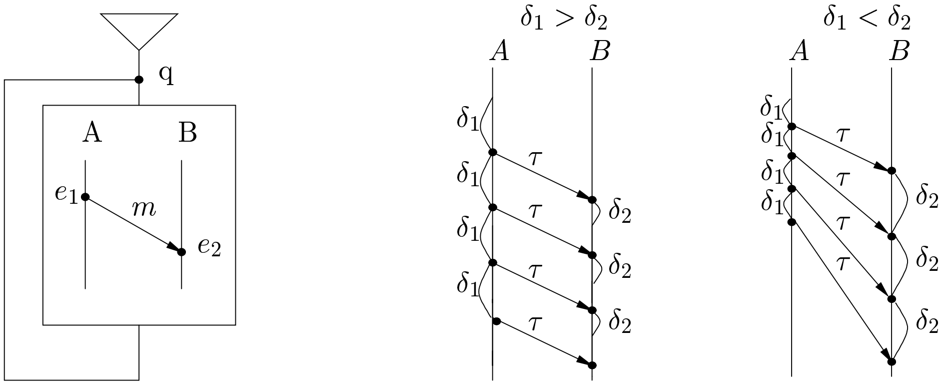


Figure 1: *A timed HMSC example.* The first diagram shows an HMSC, in which the same MSC is repeated for ever. Tming attributes are attached to the actions of sending the message $e_1$, receiving the message $e_2$, and communication $m$. Corresponding durations are $\delta_1, \delta_2, \tau$, respectively. Unfoldings of this HMSC are depicted on the second and third diagrams, for $\delta_1 > \delta_2$ and $\delta_1 < \delta_2$ respectively. This shows that one can see a divergence or a stable behaviour, depending on timing characteristics. This is one example of the type of property that we would like to capture with our study.

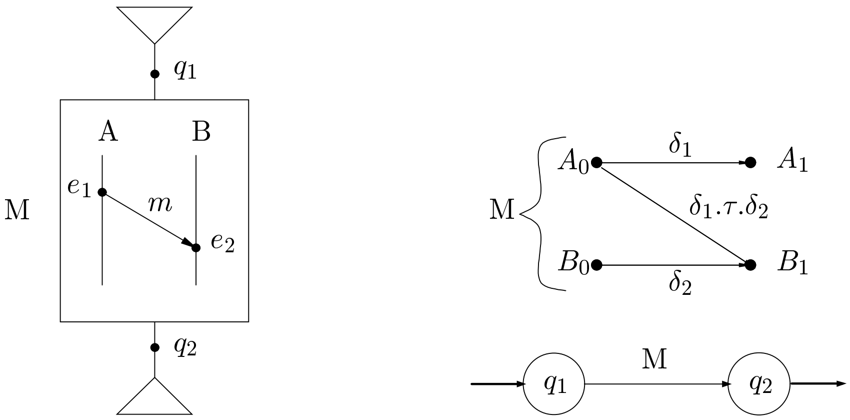


Figure 2: *Timed HMSC example, and its associated partial order automaton.* The first diagram shows the same basic MSC already considered in figure 1 — here it is activated only once. The right diagram depicts the corresponding partial order automaton. The right bottom diagram is the automaton, it has a source state and a sink state, and a unique transition which is labelled by the symbol $M$. $M$ is a partial order depicted on the right top diagram, it relates instances $A, B$ before and after executing the basic MSC. Branches of the partial order $M$ are labelled with time labels, showing the minimum time elapsed between the source and the sink of each branch.

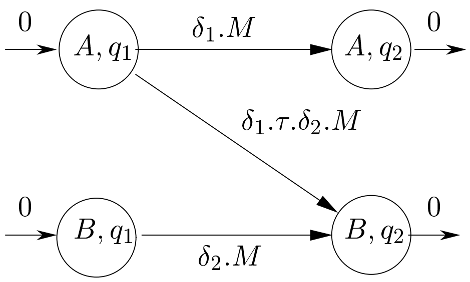


Figure 3: *Timed diagram corresponding to the partial order automaton of figure 2.*

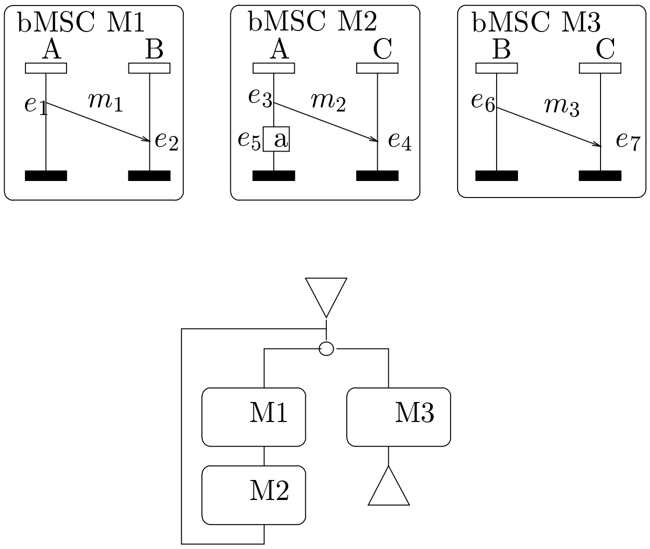


Figure 4: *a more complex example of HMSC.*

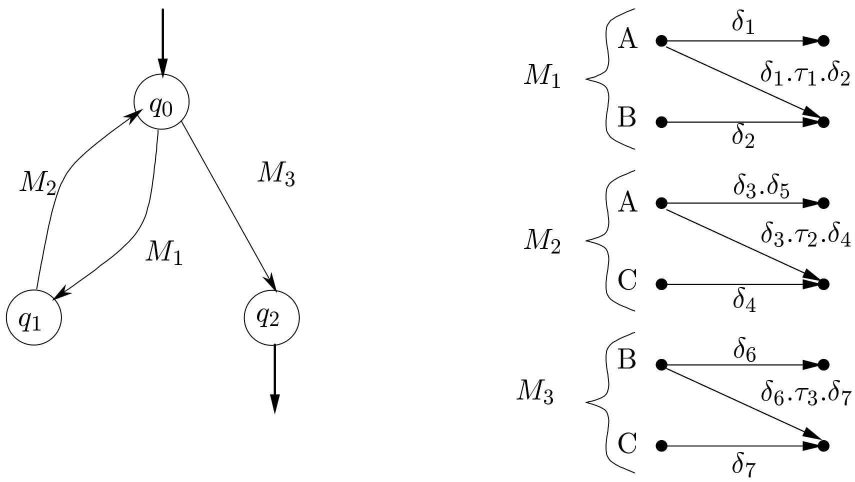


Figure 5: *The partial order automaton associated with the HMSC of figure 4.*

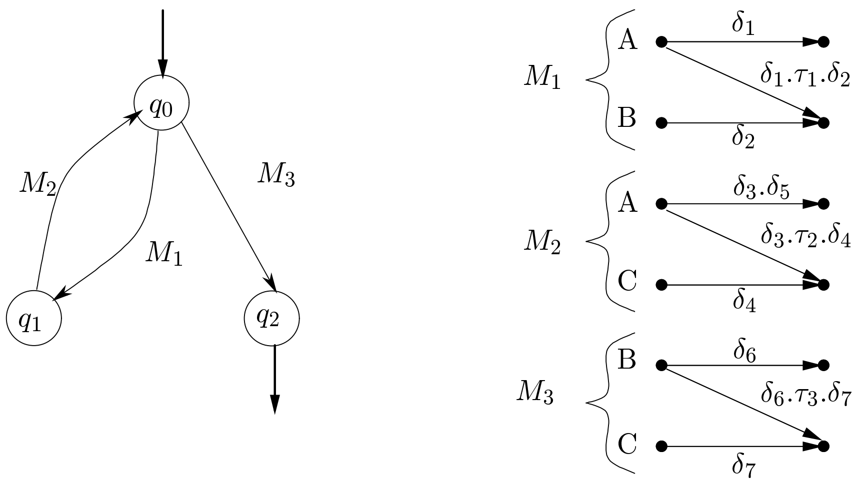


Figure 6: *The figure 5, repeated.*

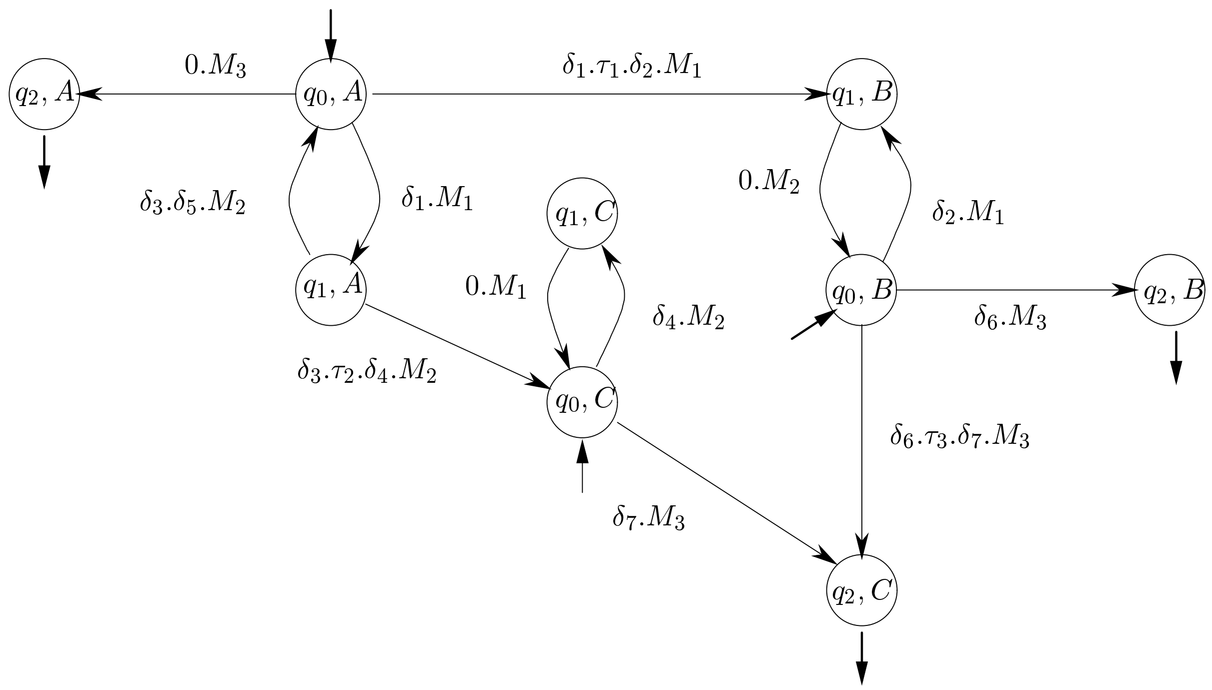


Figure 7: *Timed diagram associated with the partial order automaton of figure 6.*

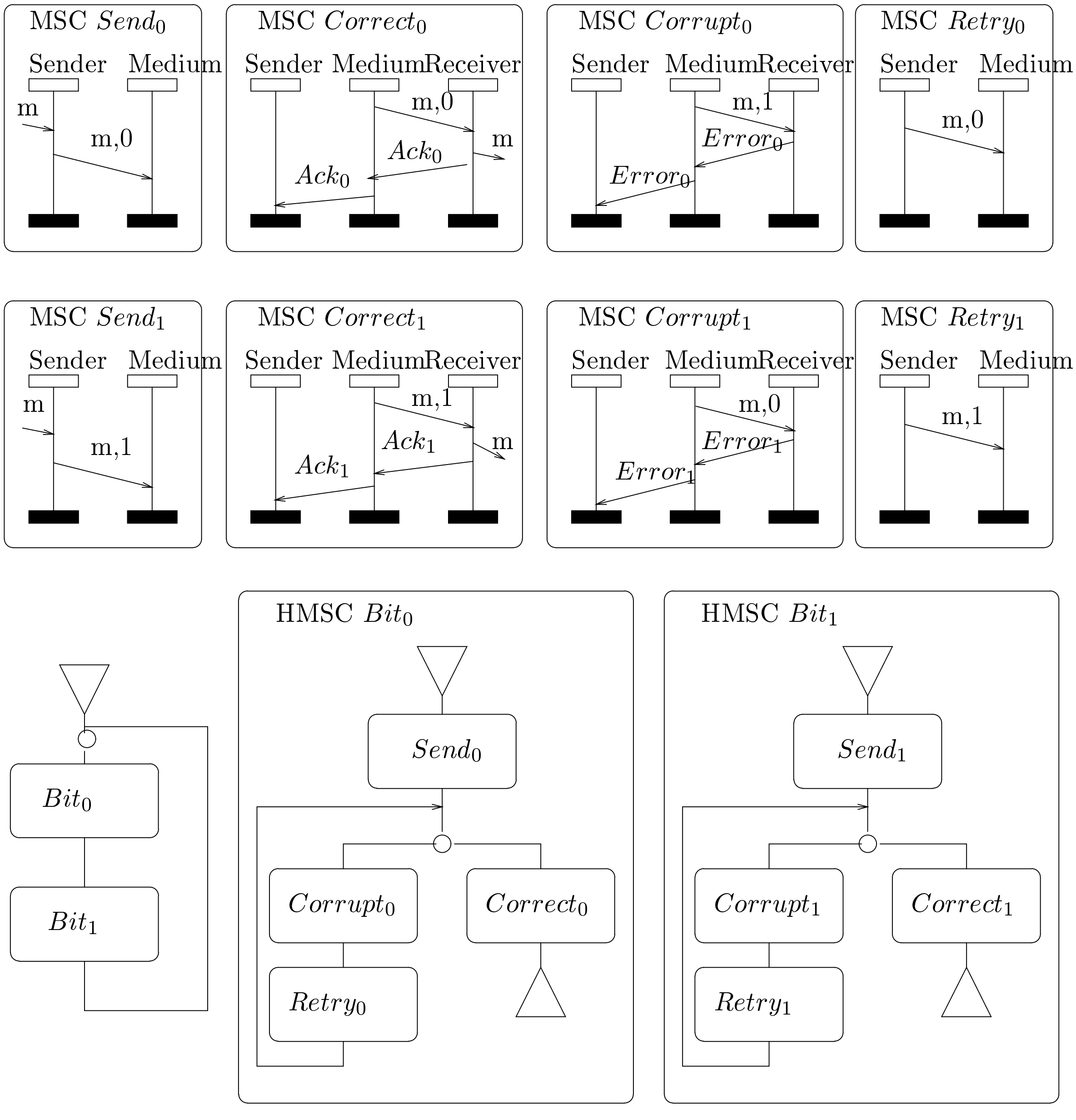


Figure 8: *HMSC for alternate bit protocol.*

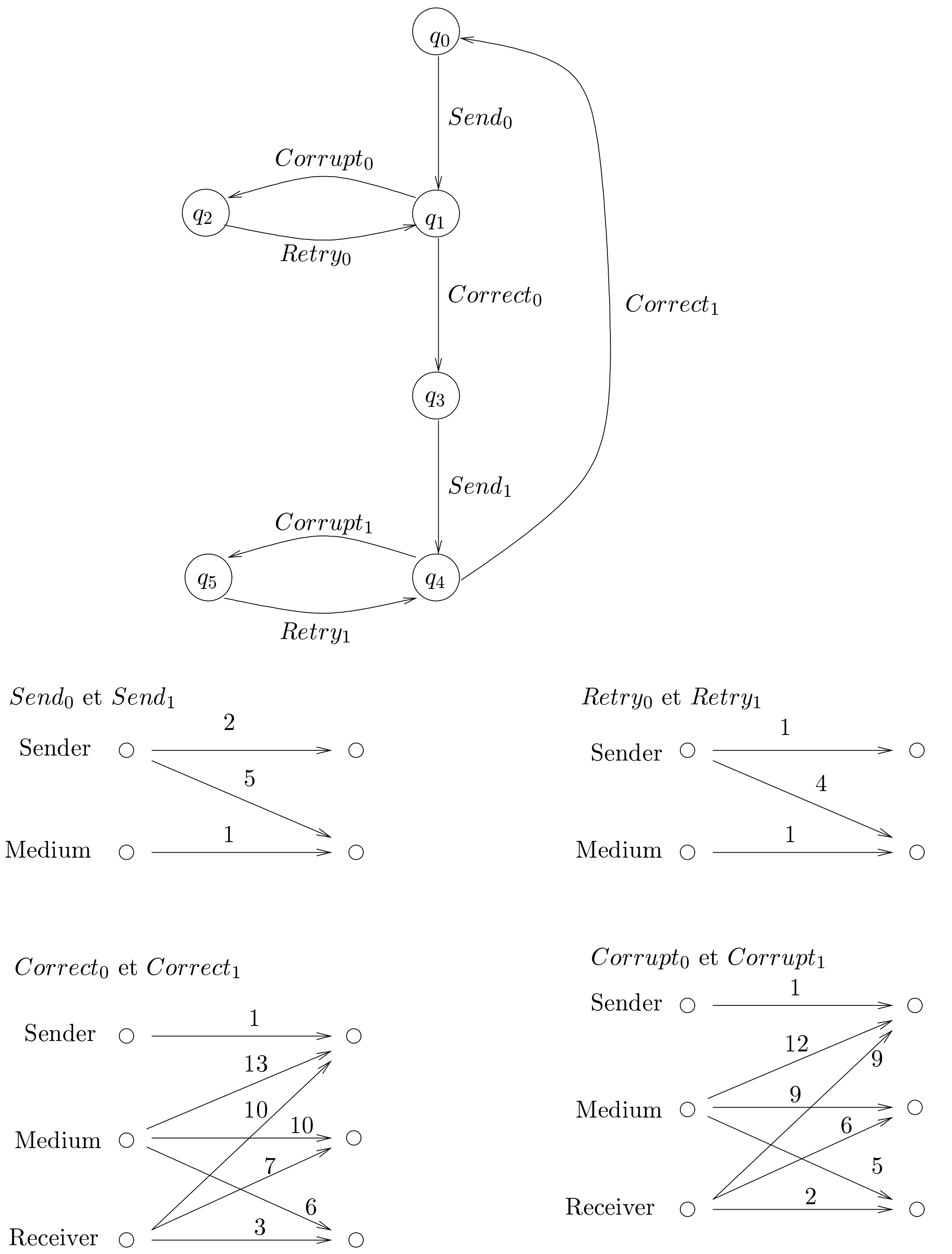


Figure 9: *Partial order automaton associated with the HMSC of Figure 8.* From this partial order automaton, a timed diagram is generated, as before. Using this model it was possible to evaluate the maximum throughput of this protocol, i.e., the maximum traffic per unit of time, for a given type of message, or any type of message.