# From loosely time-triggered systems to a taxonomy of MOCCs

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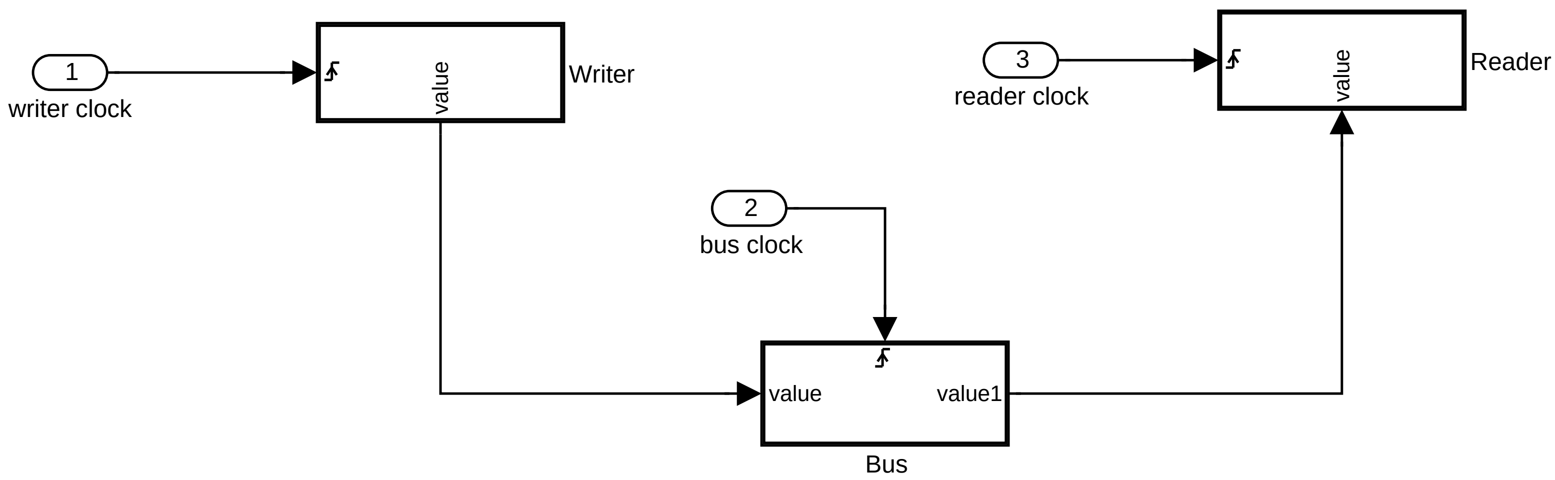
- A Tagged System Model for Loosely Time-Triggered Systems
- Merging it into Lee & Sangiovanni
- Generalisation
- Conclusion and Perspectives

# Loosely Time-Triggered Systems

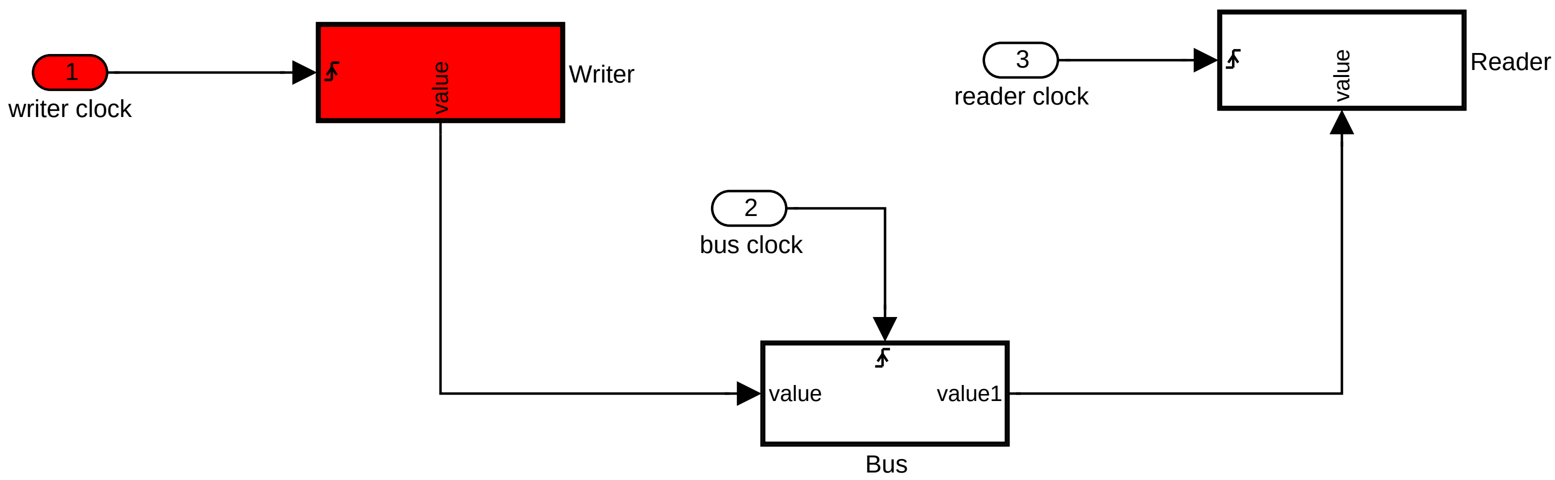



A popular communication scheme (Airbus flight control)

Clocks are as periodic as possible

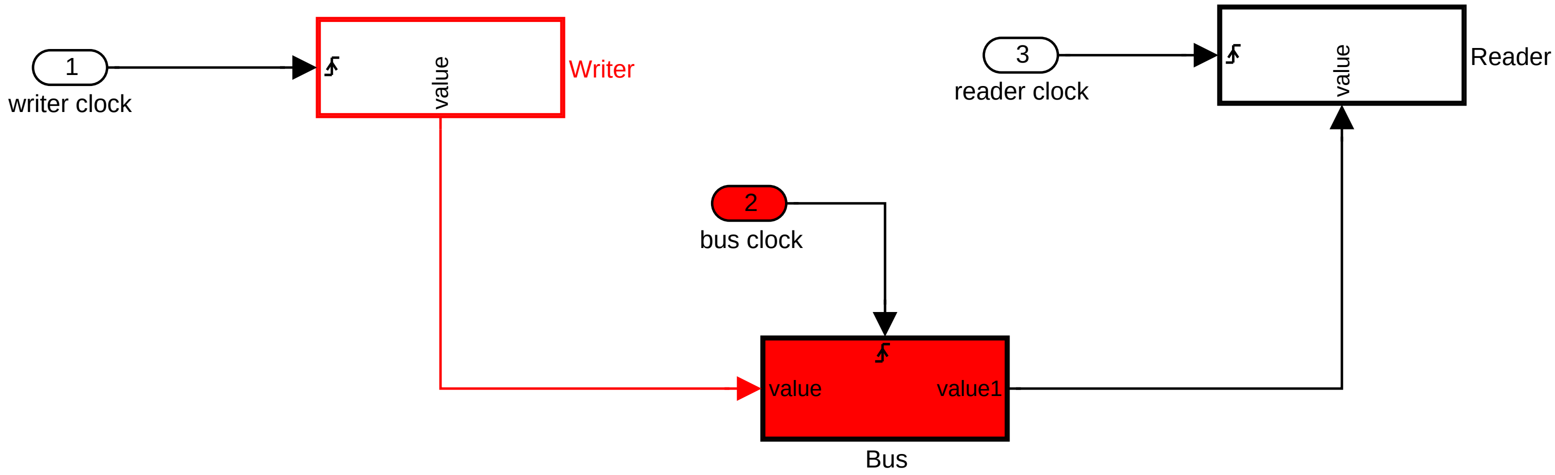
but unsynchronised

# Loosely Time-Triggered Systems



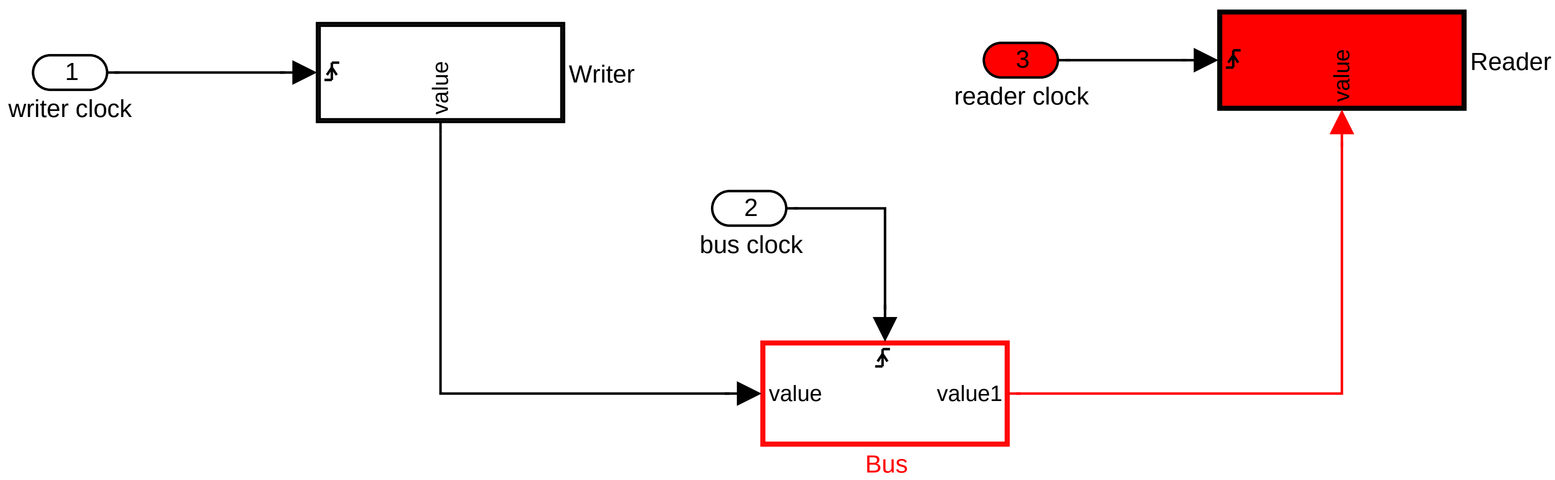

When the writer is triggered, a fresh writer value is produced

# Loosely Time-Triggered Systems



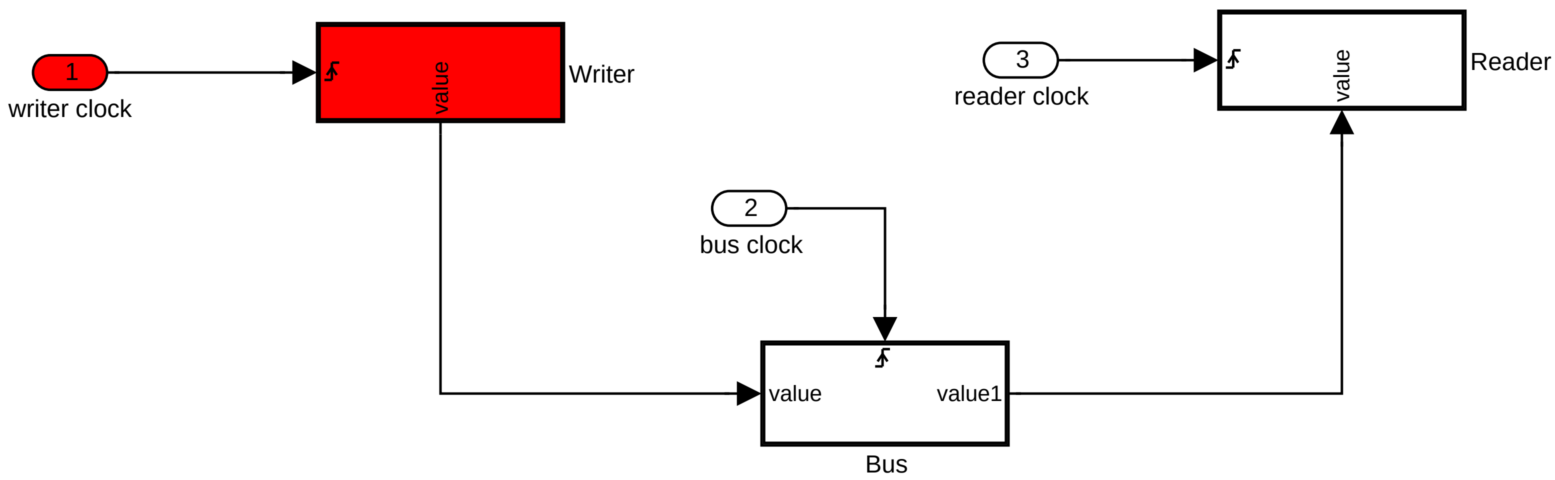

When the bus is triggered, the current writer value is stored into the bus

# Loosely Time-Triggered Systems



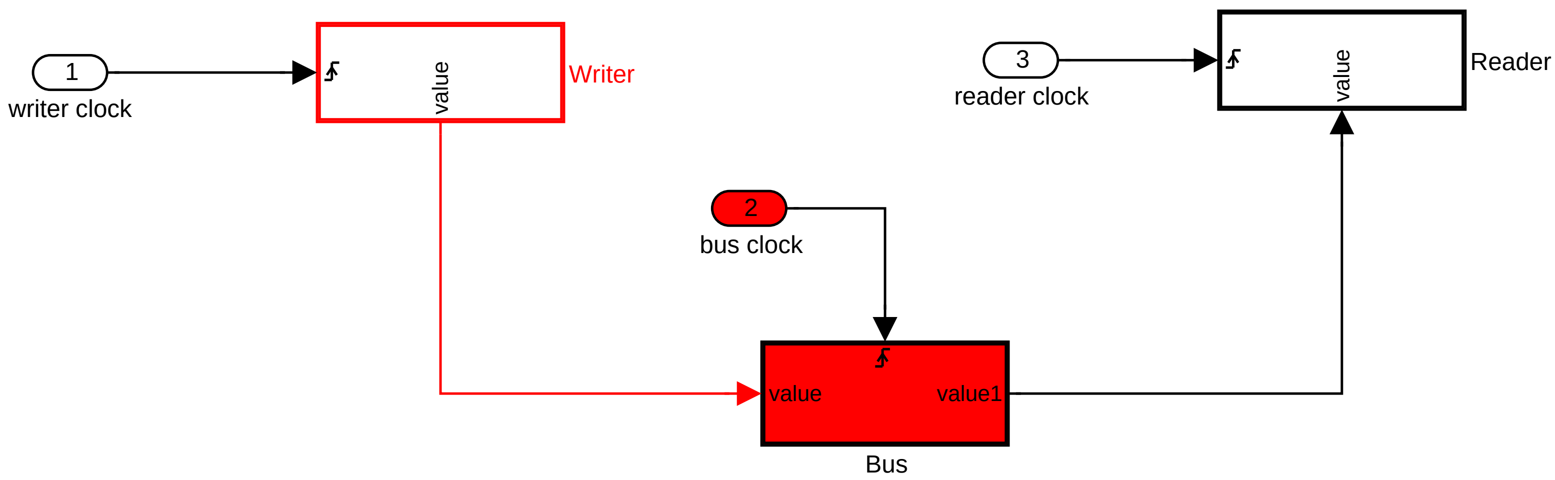

When the reader is triggered, the current bus value is used by the reader

# Denotational Modelling




At the time $t_w(n)$ of the $n^{th}$ writer clock tick, a fresh value $v_w(n)$ is produced

# Denotational Modelling

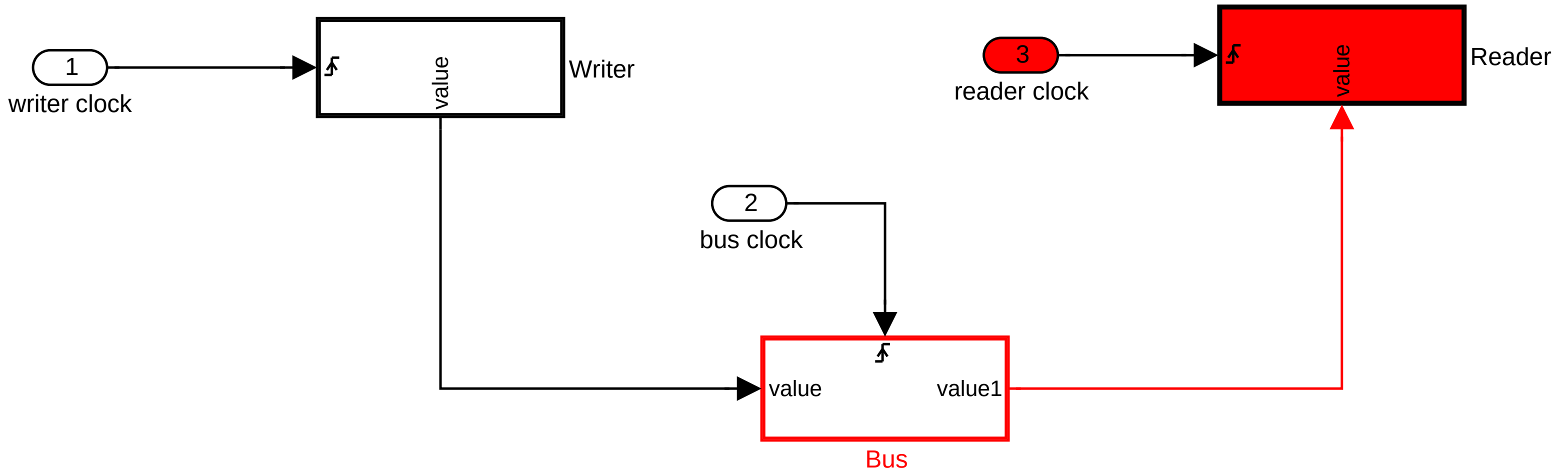



At the time $t_b(n)$ of the $n^{th}$ bus clock tick,

$$v_b(n) = v_w(m)$$

where $m = \sup\{k \mid t_w(k) < t_b(n)\}$

# Denotational Modelling




At the time $t_r(n)$ of the $n^{th}$ reader clock tick,

$$v_r(n) = v_b(m)$$

where $m = \sup\{k \mid t_b(k) < t_r(n)\}$

# Benveniste’s Tag Systems Model

A generalisation of this framework:

Signals are sequences of pairs (tags, values)

$$Signals = Naturals \rightarrow Tags \times Values$$

Behaviours are tuples of (named) signals:

$$Behaviours = Names \rightarrow Signals$$

Processes are sets of behaviours

$$Processes = Behaviours \rightarrow Booleans$$

Process composition is by unification

Heterogeneity is handled by Tag morphisms

# Beneveniste’s Tag Systems Model

Applications:

- Desynchronisation of distributed systems
- Modelling timing behaviours, dead-lines, wcet,...
- Semantic preservation in time sensitive systems
- ...

# Comparison with Lee & Sangiovanni

| Benveniste | LSV |
| --- | --- |
| $Signals = Naturals \rightarrow Tags \times Values$ | $Signals = Tags \times Values \rightarrow Booleans$ |
| $Behaviours = Names \rightarrow Signals$ | $Behaviours = Names \rightarrow Signals$ |
| $Processes = Behaviours \rightarrow Booleans$ | $Processes = Behaviours \rightarrow Booleans$ |

How can we understand it?

# Taxonomy Elements

$Tags$ is a partial order

It can be:

- A non total order $POT$
- A total order $TOT$

We can also consider countability; $Tags$ sets can be:

- Continuous, *i.e.*, not discrete $CT$
- Discrete $DT$

This gives us 4 cases.

*Yet, some of them look quite strange, for instance continuous and not total?*

Is it enough?

# Taxonomy Elements

Adding properties of the considered signal tags

- Non totally ordered signals $POS$
- Totally orderer signals $TOS$

- Continuous signals $CS$
- Discrete signals $DS$

All cases are not possible. We use the abbreviations :

$$
\begin{array}{lcllcl}
PO & = & POT + POS & C & = & CT + CS \\
TOS & = & POT + TOS & DS & = & CT + DS \\
TO & = & TOT + TOS & DT & = & DT + DS
\end{array}
$$

# Taxonomy Elements

9 cases :

| | $PO$ | $TOS$ | $TOT$ |
|---|---|---|---|
| $C$ | $surfaces?$ | $curves?$ | $continuous\ time$ |
| $DS$ | $timed\ trees$ | $timed\ data\ flow$ | $discrete\ events$ |
| $DT$ | $trees$ | $data\ flow$ | $synchronous$ |

Not included: determinism, dynamic creation

# Benveniste's Tag Systems Model

9 cases :

| | $PO$ | $TOS$ | $TOT$ |
|---|---|---|---|
| $C$ | $surfaces?$ | $curves?$ | $continuous\ time$ |
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Encompasses most useful cases? (but continuous signals)

# Transductions in Heterogeneous Systems

Some transductions are for free:

$$TO \stackrel{Id}{\rightarrow} PO$$

Some transductions need Tags morphisms:

$$PO \stackrel{\Phi}{\rightarrow} TO$$

Some transductions need Signal depend morphisms:

- Sampling:

$$C \stackrel{\Phi(S)}{\rightarrow} DT$$

- Holding:

$$DT \stackrel{\Psi(S)}{\rightarrow} C$$

# Conclusions and Perspectives

Results:

- Benveniste's model is an interesting variation of Lee & Sangiovanni's
- It can be understood within the latter framework
- A taxonomy is proposed which yields interesting questions

Future work:

- Exercise the model on other examples
- Investigate more deeply the transducer question
- ...

# Continuous and Discrete

The idea is to patch topological separability:

Continuous:

$$\forall t, t' : t < t' \Rightarrow \exists t'' : t < t'' < t'$$

Discrete: (*a bit more involved*)

$$\begin{aligned} \forall t, t' : \;\; & t < t' \\ & \Rightarrow \exists t_1, t_2 : \qquad t \leq t_1 < t_2 \leq t' \\ & \qquad\qquad\qquad \& \quad not\ \exists t'' : \; t_1 < t'' < t_2 \end{aligned}$$

But what about Cantor sets ? Should we require countability here?