Projection of Message Sequence Chart (MSC)

To ABSTRACTION and BEYOND!

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MSCs: graphical specifications of communication protocols
(norm of Int. Telecomm. Union)

Ex: RMTP2 (send data on a tree)

1 PARENT sends new DATA to CHILDREN.

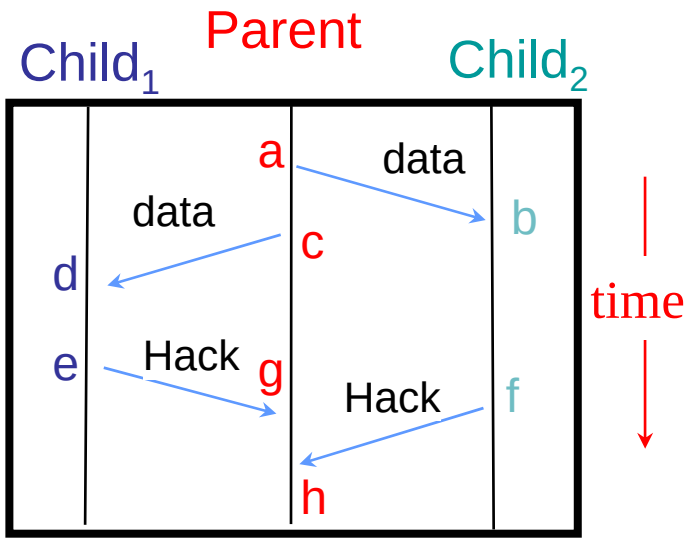
2 Each CHILD sends HACK (acknowledgement).

3 If PARENT does not receive quickly all HACK
Then PARENT RESENDS DATA and Goto 2

→ early verification

I Definition MSC & Projections
II Representation of MSC-graph projection
III Algorithms for MSC-graph projection

Definition of MSC [ITU Z120]



MSC

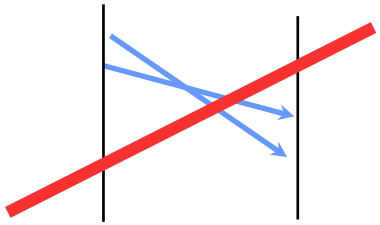
Partial order on events a,b,c…

f incomparable with d

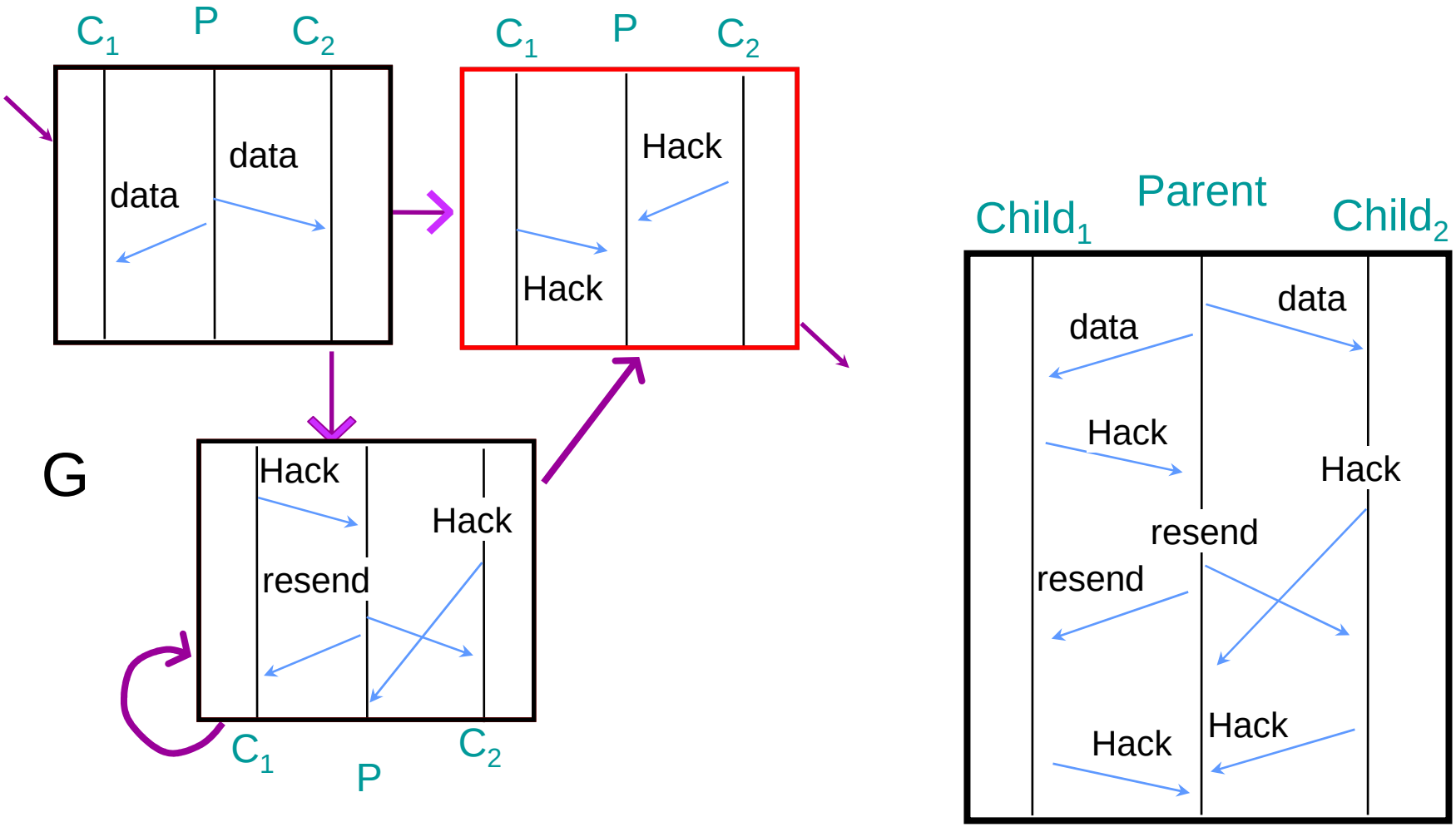
Each process: total order

a<c<g<h

FIFO channels (no overtaking)



Definition of MSC-graph [Z120]



L(G) = set of MSC labeling accepting paths of G

Projection of MSC-graphs

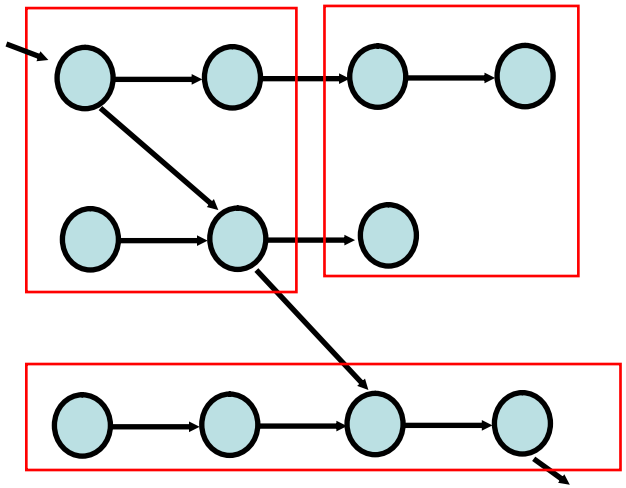
MSC-graph specification:

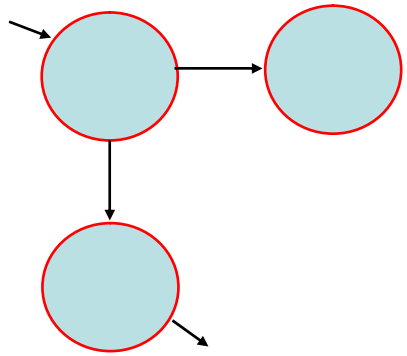
- Collection of scenarios (wanted / unwanted)

Projection = Hide some parts (usually whole processes)

- To run algorithms faster
- For a good understanding of interactions
  (abstraction of unnecessary parts)

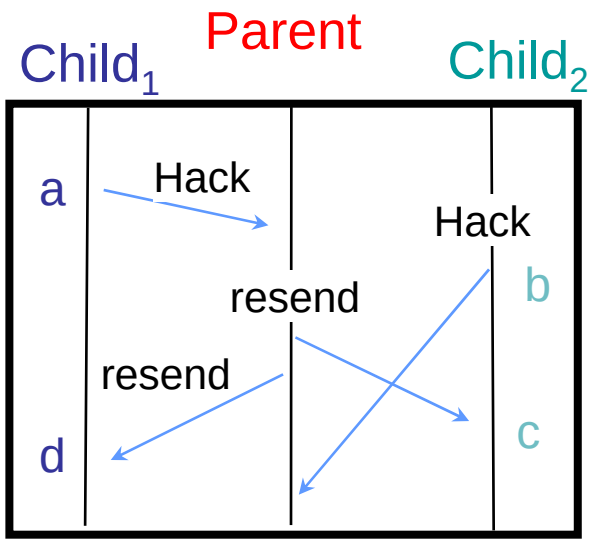
Abstraction for Automata



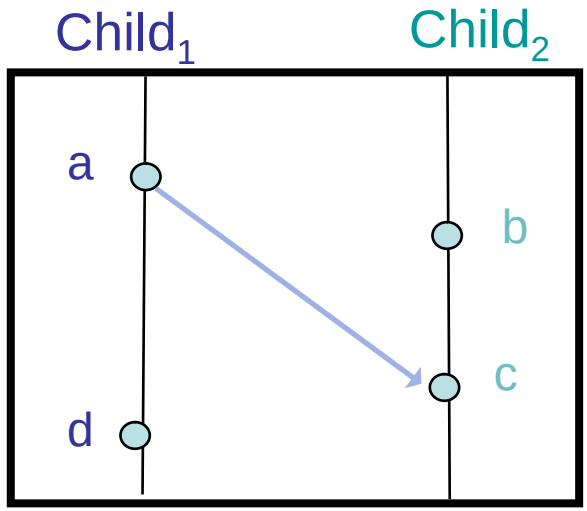


Transitions are crucial

Abstraction of MSC with MSC Projection



Project PARENT away

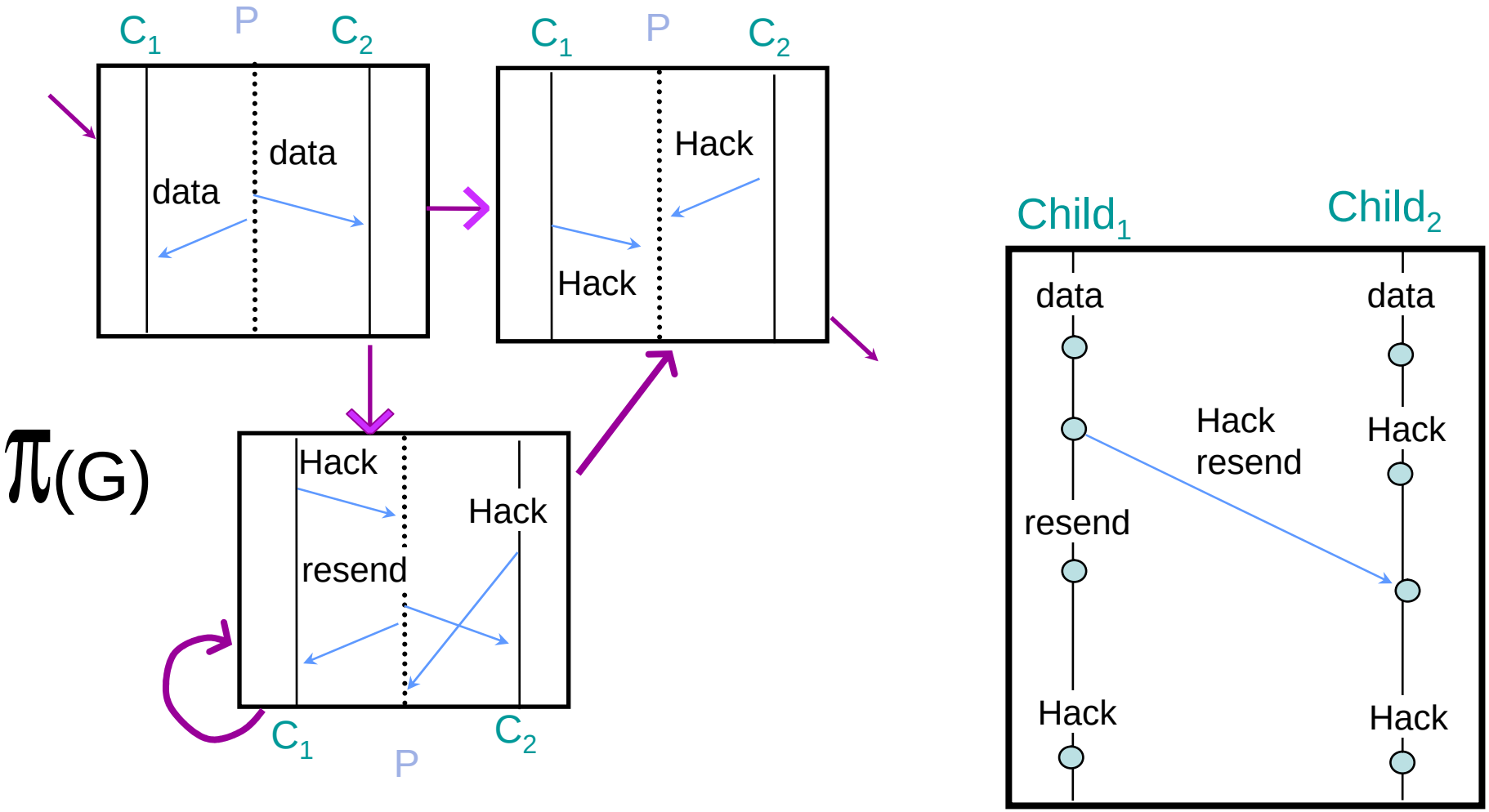


Messages/Ordering is crucial

a // b d // b

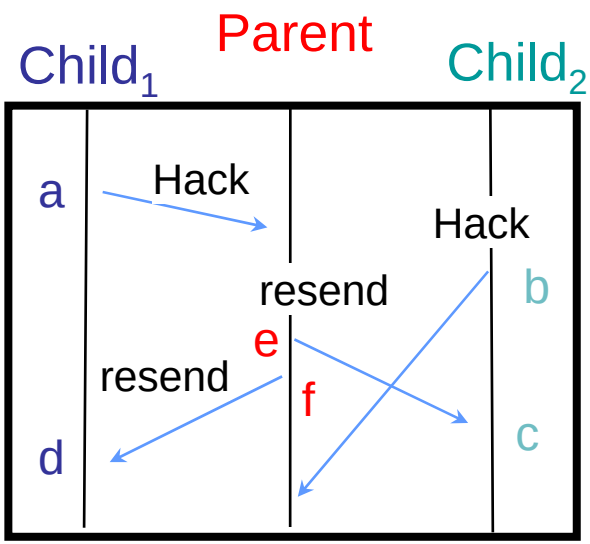
a < c & (a < y < c)

Abstraction of MSC-graph

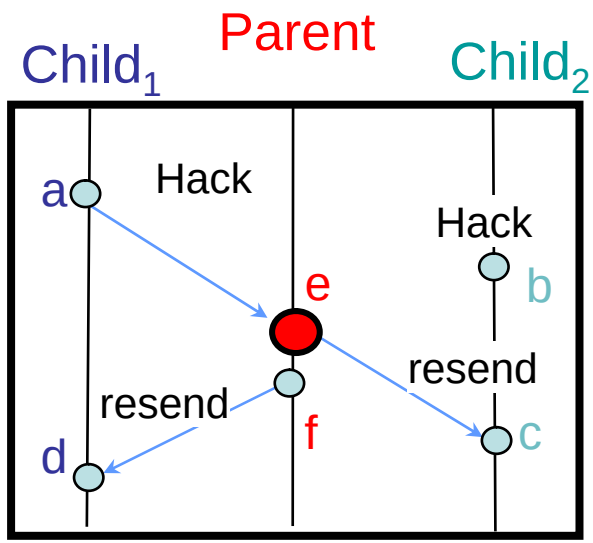


L(π (G)) = set of projected MSC labeling accepting paths of G

Problem of projecting MSC



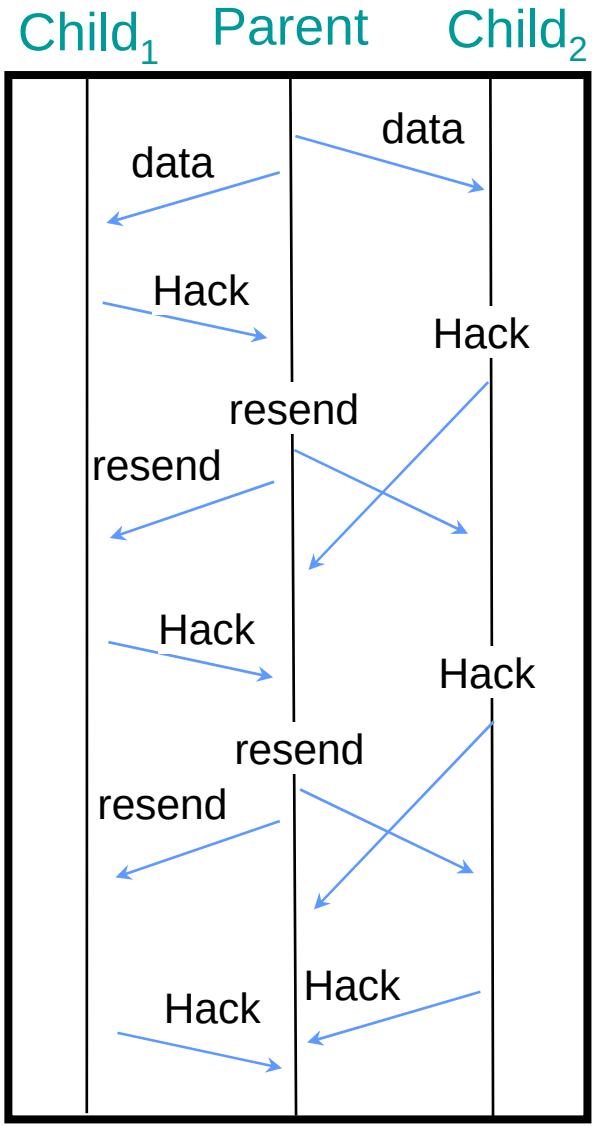
Forget HACK on PARENT

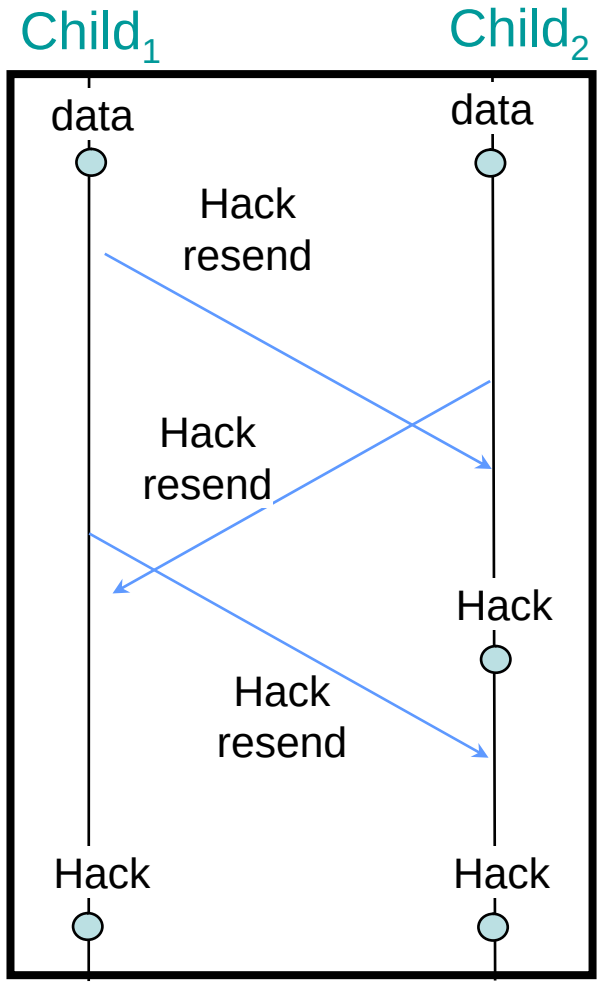


Multitype event

MSC projections are not MSC

Problem of projecting MSC-graph

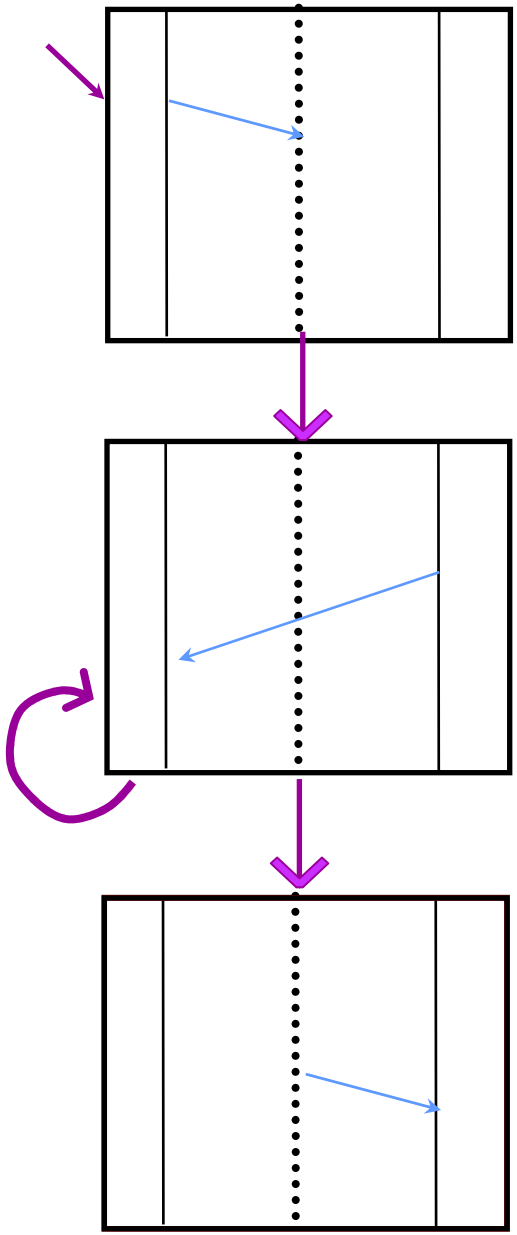


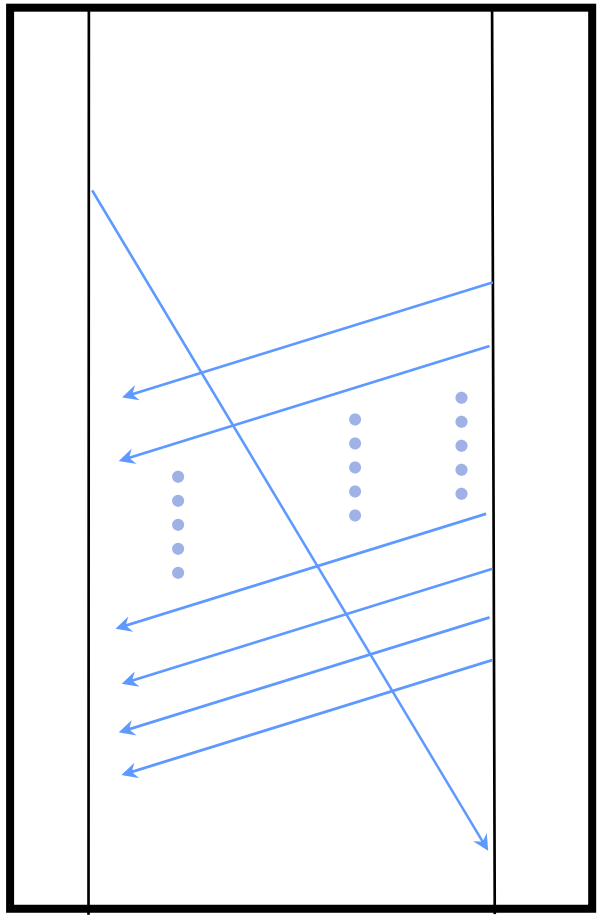


Infinite non-decomposable MSC in L(G)

projection of MSC-graph ≠ MSC-graph

Problem of projecting MSC-graph





Not possibe with MSC-graph

Representing MSC-graph projection

Goals :

- To understand what happens
- To try to compact representation

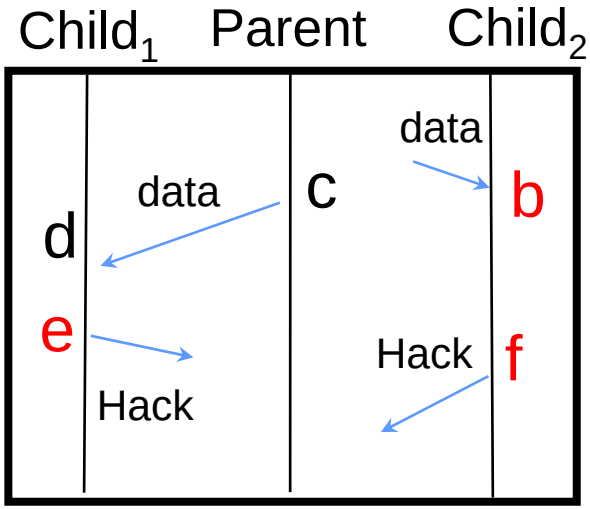
Actual representation:

- Implicit
- The whole HMSC & the projected events

Solution: Representation with MSC-based specification

→ compositional MSC-graph

Definition of compositional MSC [GMP01]

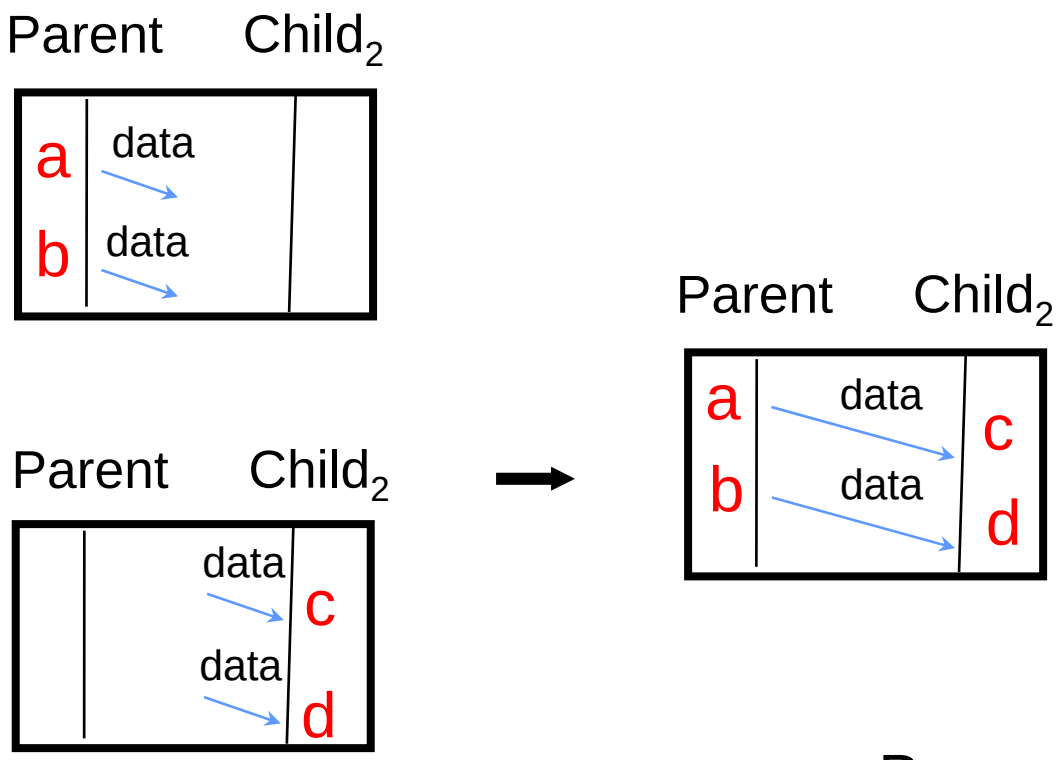


MSC + unmatched sends/receives

e,f b

MSC $\subsetneq$ compositional MSC

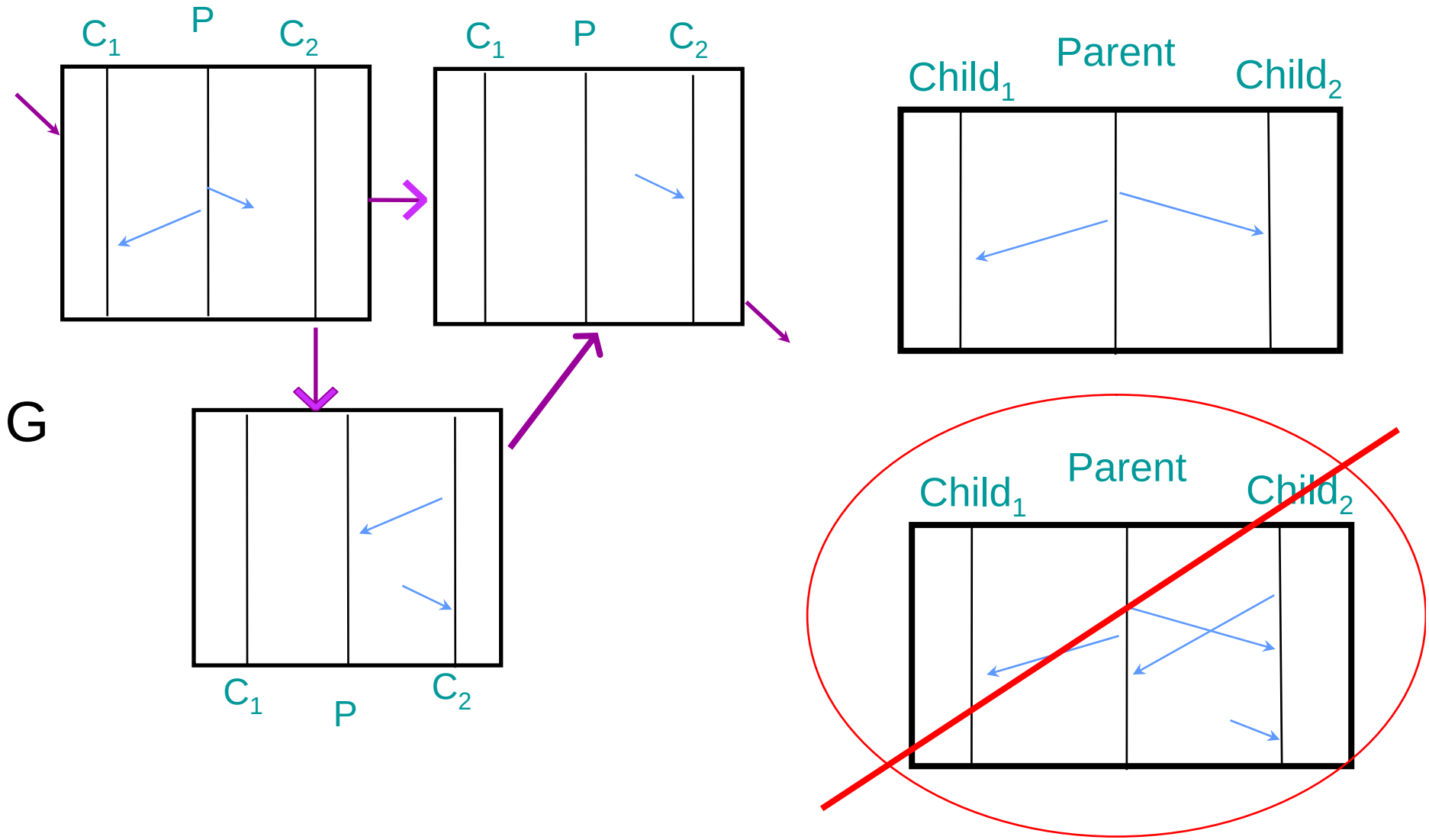
Composition of compositional MSC [GMP01]



Because of FIFO

Compositinal MSC-graph more powerful than HMSCs
(undecidability results)

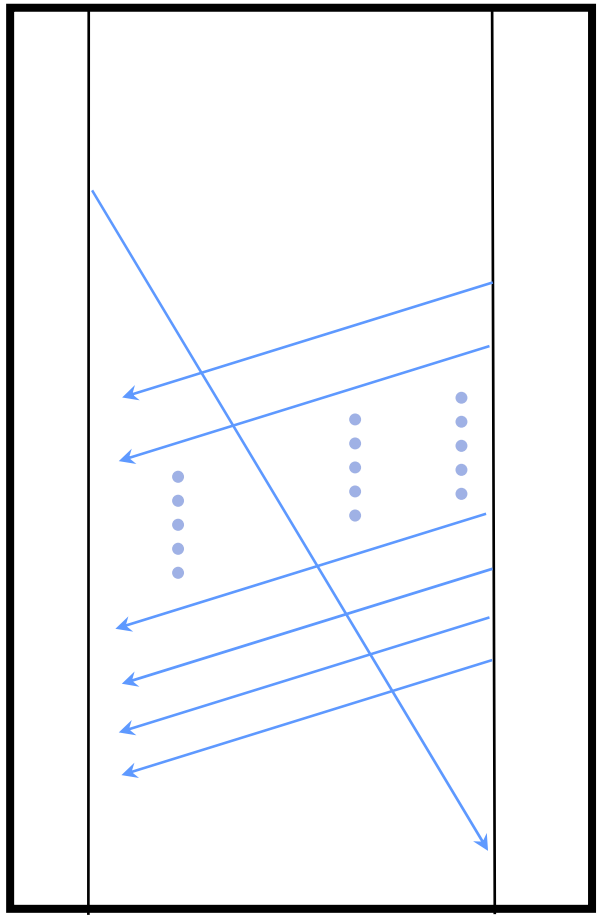
Definition of comp.MSC-graph [GMP01]



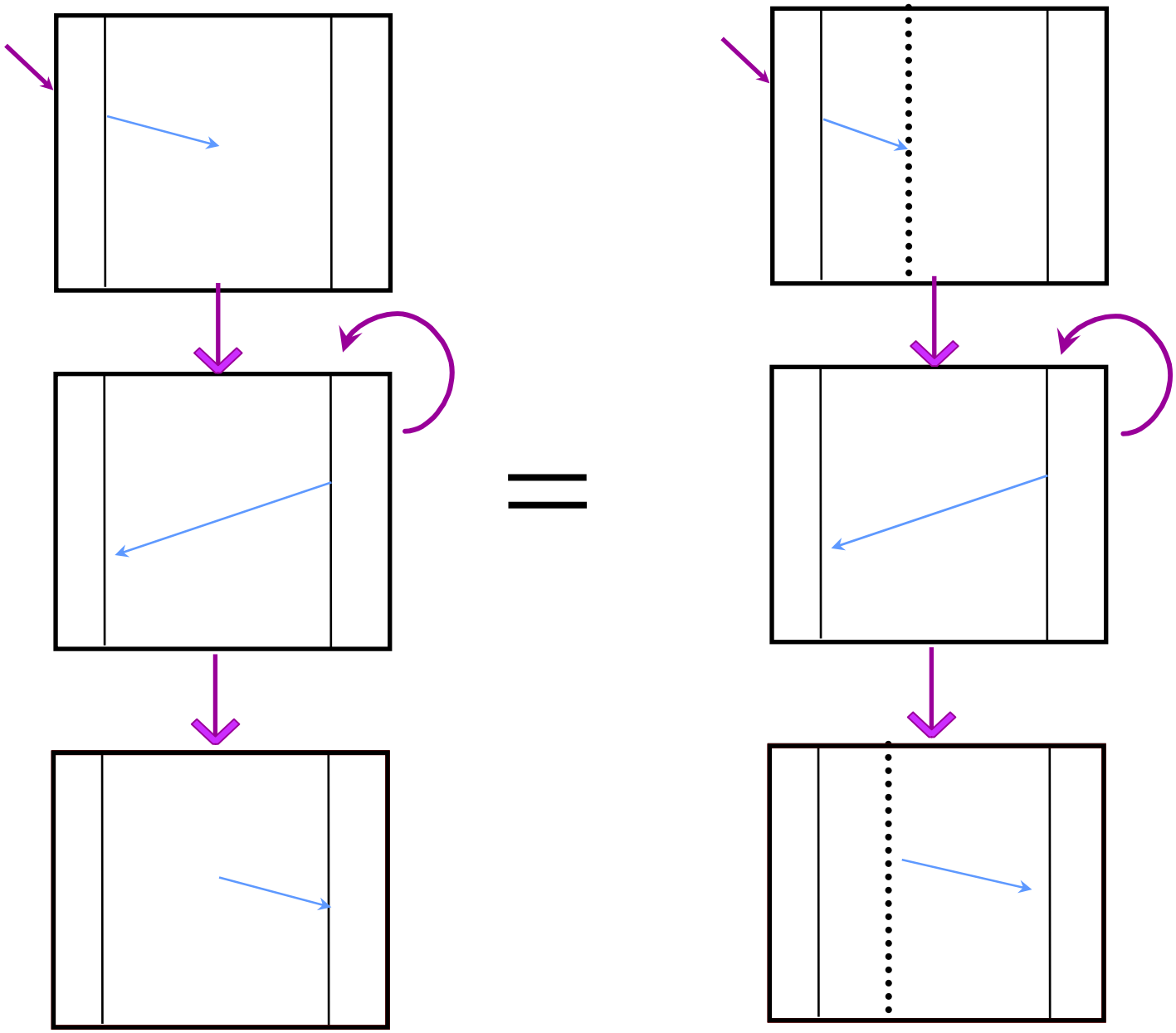
L(G) = set of (complete) MSCs labeling accepting paths of G

Why compositional MSC-graph?

We can do this with compositional MSC-graph

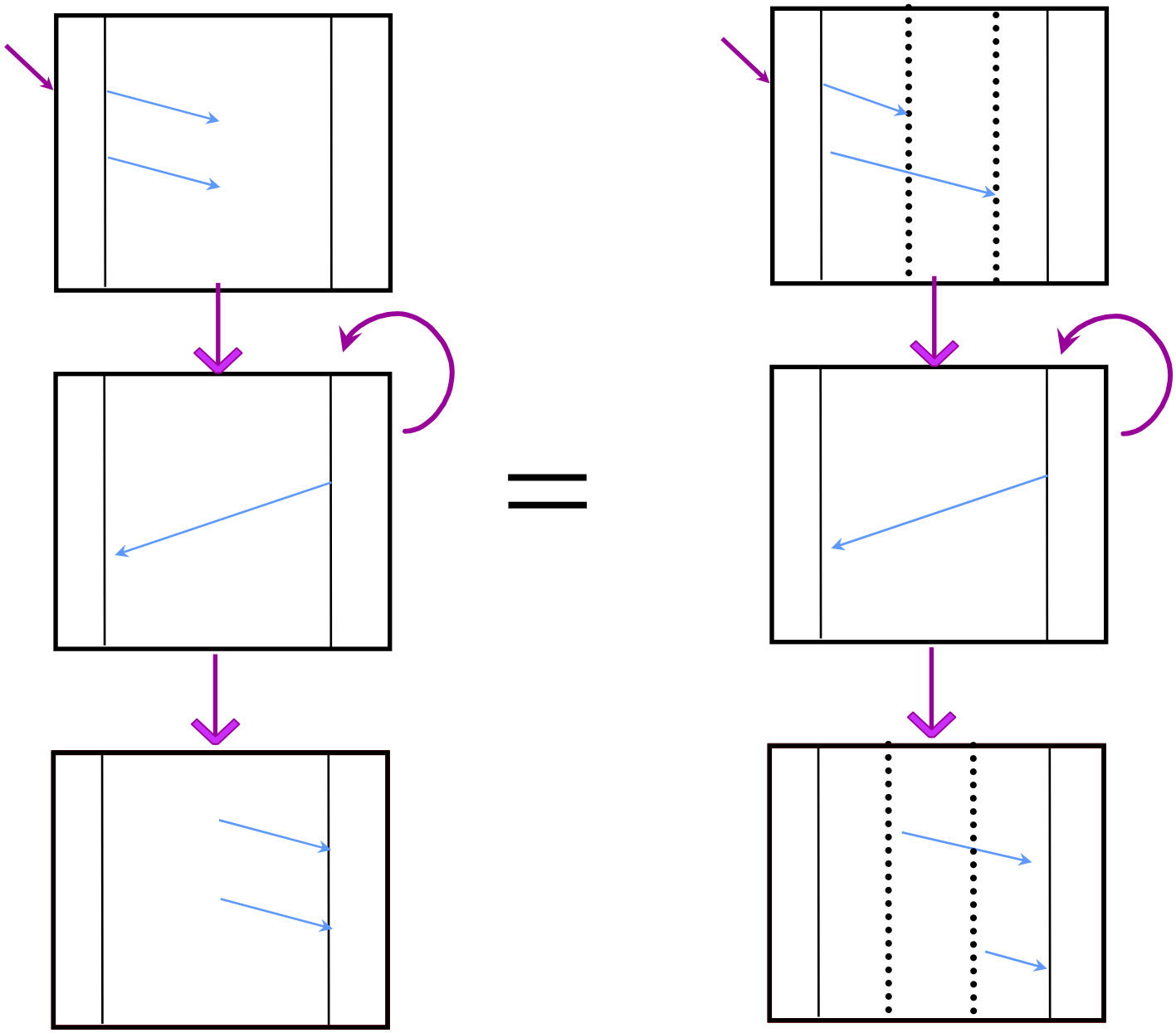


Comp. MSC-graph $\not\subseteq$ MSC-graph projection



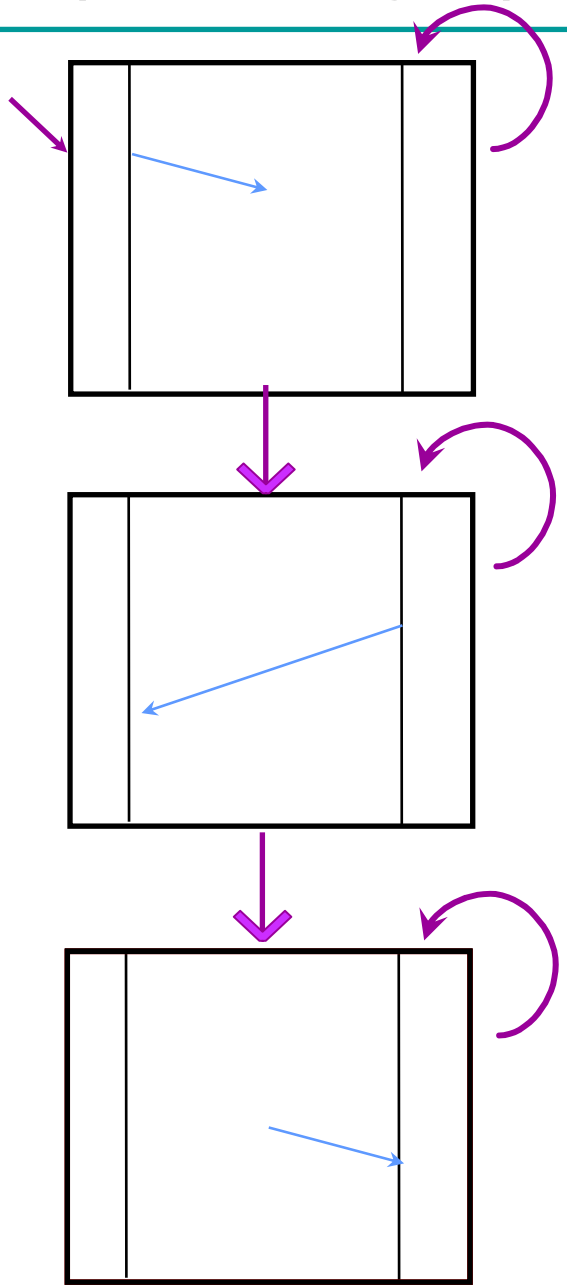
More processes needed

Comp. MSC-graph $\not\subseteq$ MSC-graph projection



More processes needed

Comp. MSC-graph $\not\subseteq$ MSC-graph projection



$=$?

Claim: few delayed messages in MSC-graph projection

MSC-graph projection $\subsetneq$ compo. MSC-grapg

Theorem[GHM03]: We can effecively transform

MSC-graph projection G $\rightarrow$ compo MSC-graph H.

Properties:

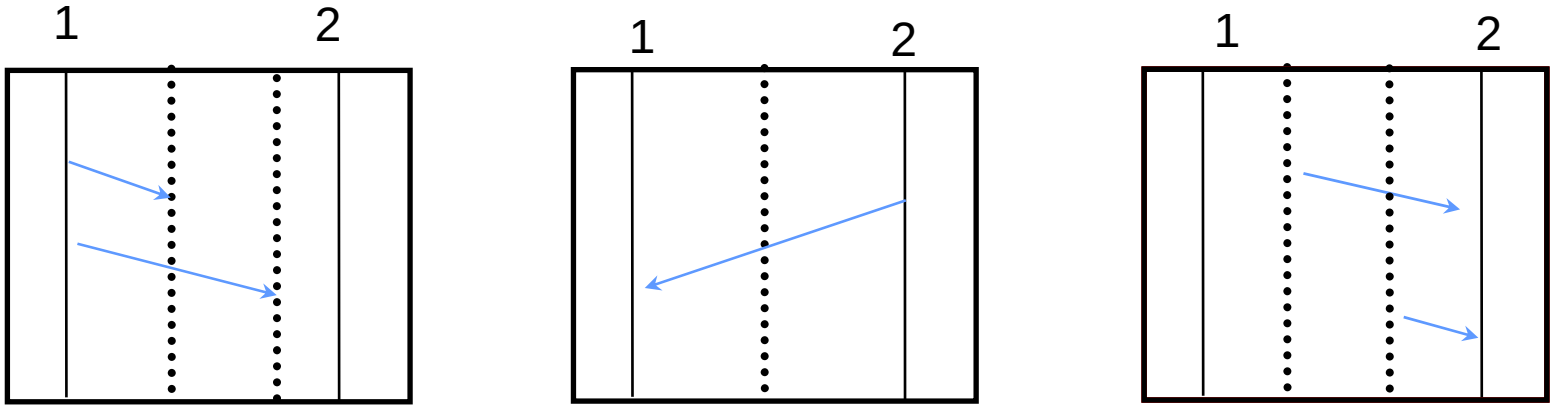
- |H| exponential in nb_unmatched_send
- In any factor of H, nb_unmatched_send < nb_processes^2

MSC-graph projection $\subsetneq$ compo. MSC-grapg

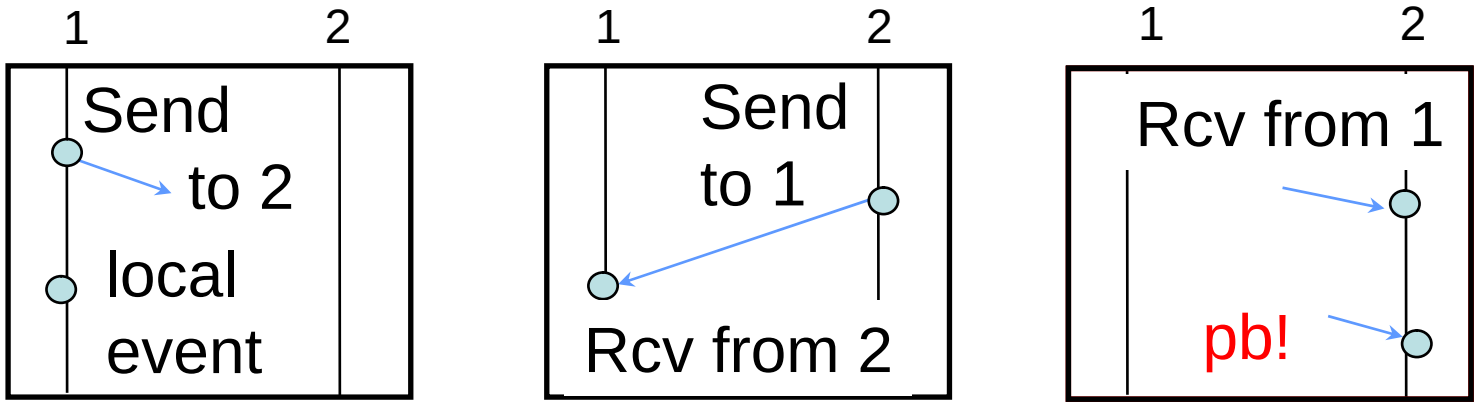
Proof:

- We know exactly events, not type

$\longrightarrow$ Guess the type on the fly
Check whether guess is correct

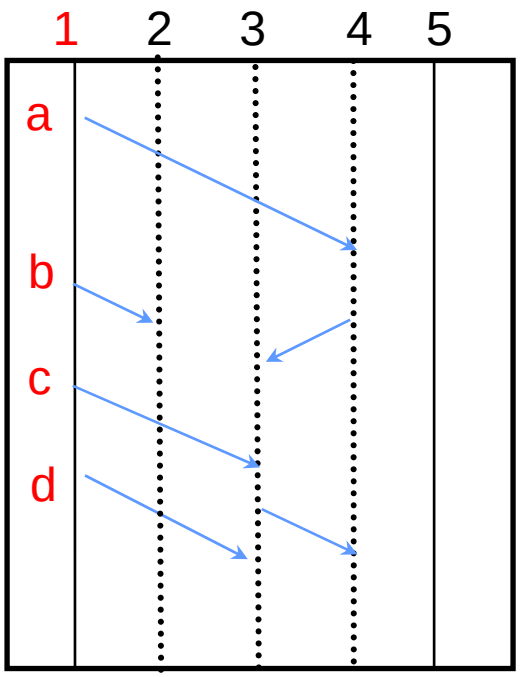


Guess:



nb_unmatched_sends < nb_processes^2

Proof:



Proc_in_Future(a) = {1,2,3,4}

$\cup|$

Proc_in_Future(b) = {1,2,3,4}

$\cup|$

Proc_in_Future(c) = {1,3,4}

$\cup|$

Proc_in_Future(d) = {1,3}

at most 3 different sets

a<b<c<d

Matched by b

Matched by d

Matched by c

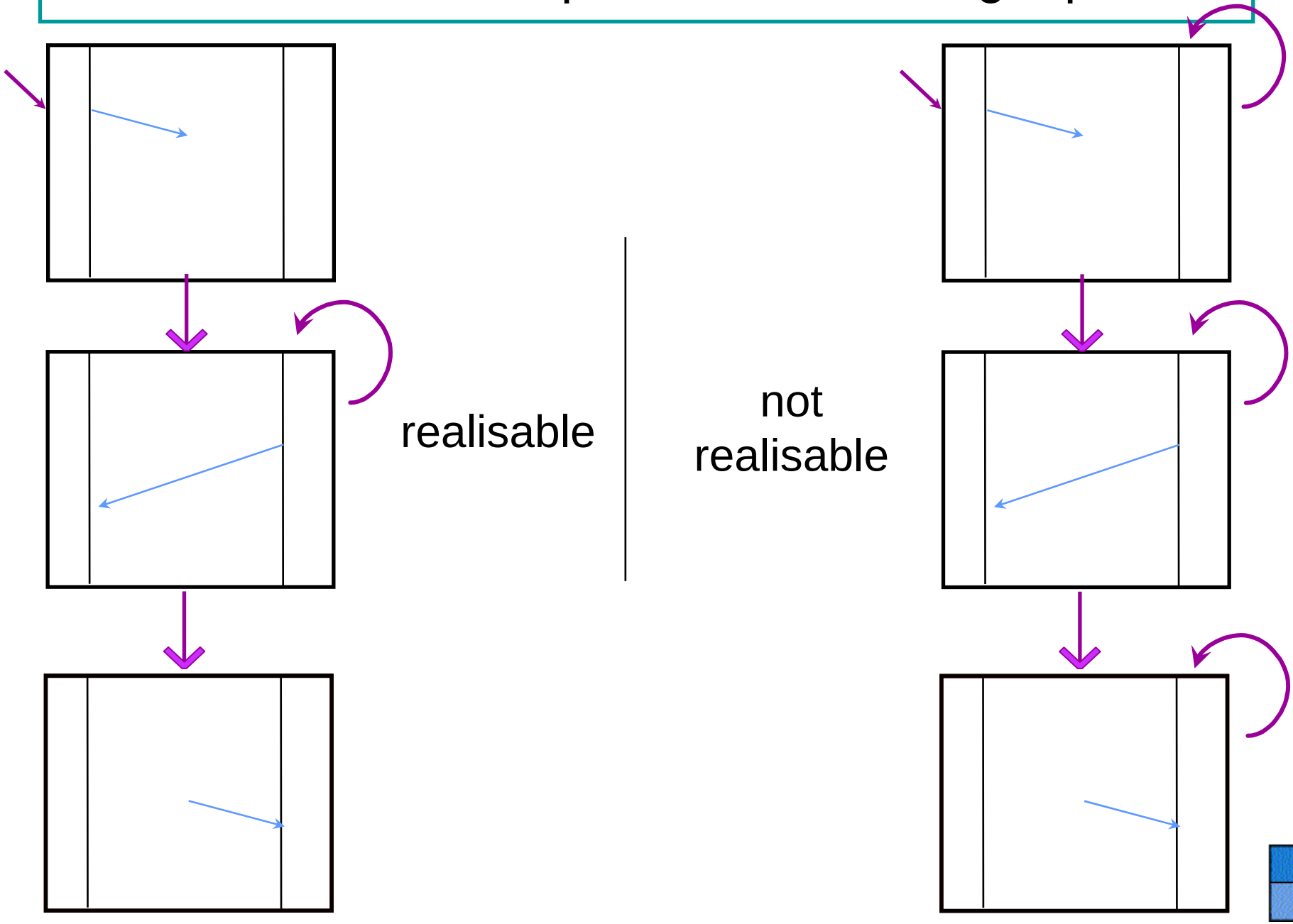
a can match no more event

Realizable compositional MSC-graph

Theorem[GHM03]: MSC-graph projection coincide with compositional MSC-graph where nb_unmatched_send are bounded

(Realizable in [GMP01])

Realizable compositional MSC-graph



III Algorithms for projection of MSC-graph

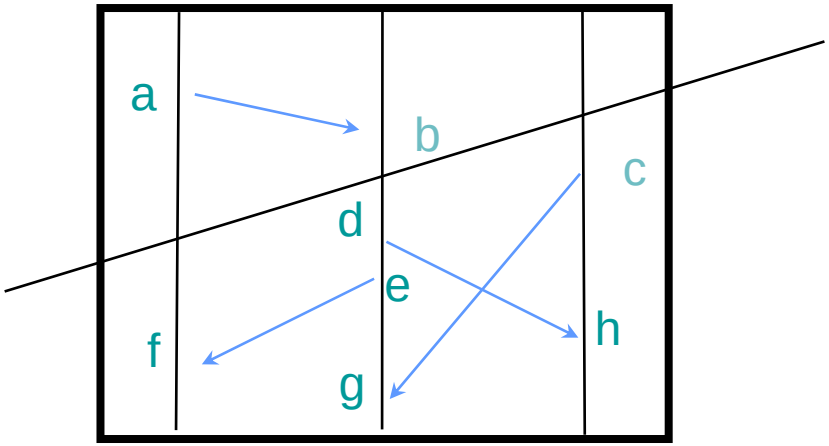
No known algorithms for realizable compositional MSC-graph

Ideas:

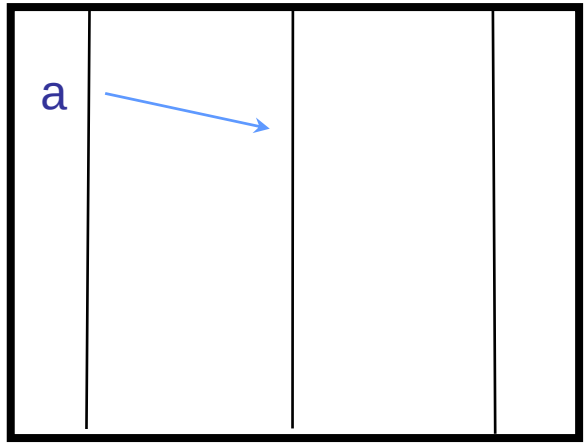
- If possible, transform Realizable compo $\longrightarrow$ MSC-graph
  Then apply algorithms for MSC-graph

- Devellop new algortihms for Realizable compo.
  when transformation not possible
  or MSC-graph too big

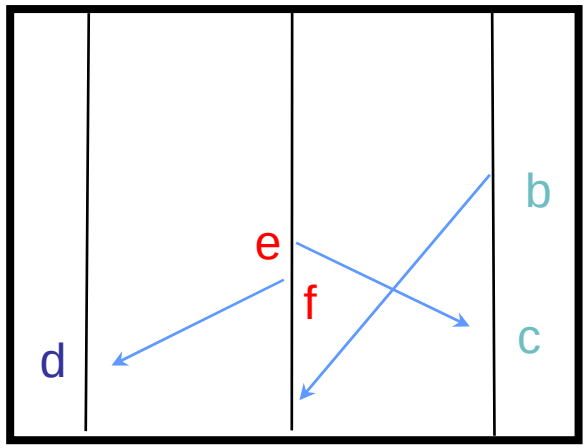
Definition of Atoms [HL00]



Non atomic =
decomposable MSC

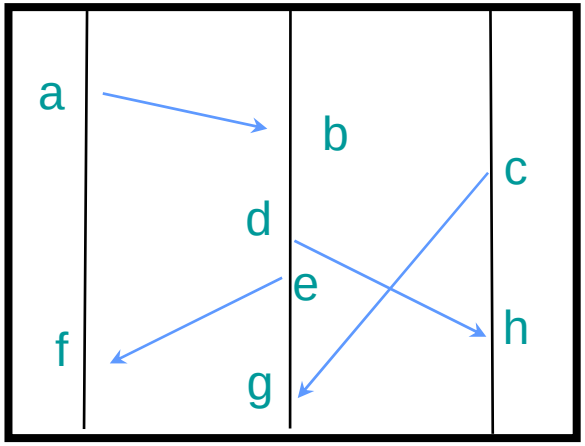


Atomic MSCs

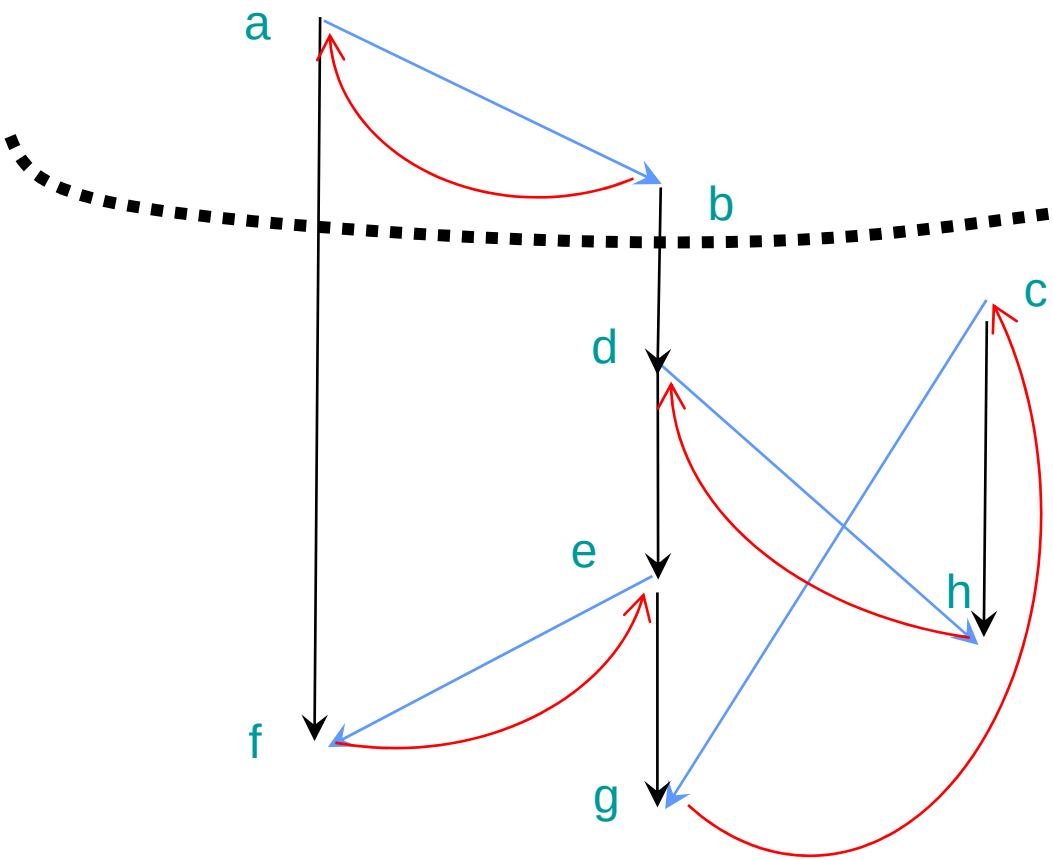


Atoms = prime MSC

Computing Atoms [HL00]



MSC G



Connection Graph CG

Atoms = strongly connected component of CG

A is atomic if any last event reaches all first in CG

Properties of Atoms: Powerful

	events	nodes	Atoms	Prime numbers
comutation	semi & partial	partial (Traces)	partial (Traces)	total
Decomp of an MSC	unique	not unique	unique	unique
Member	P	P	P	P
decompose	P	P	P	Sub exponent

From projection of MSC-graph to MSC-graph

Th[GHM03] A Realizable compo MSC-graph equivalent to HMSC iff atoms are finite

Th[GHM03] Atoms of a projection MSC-graph form a regular langage

Size: exponential in size of pHMSC or rcHMSC
Test: PSPACE & co-NP-hard

Atoms is a regular Language

Proof

- Guess where the suppose atom starts and end.
- On the fly, Check whether Any last event reaches all first events in CG

We just need current final events
unmatched sends
what they see

From projection of MSC-graph to MSC-graph

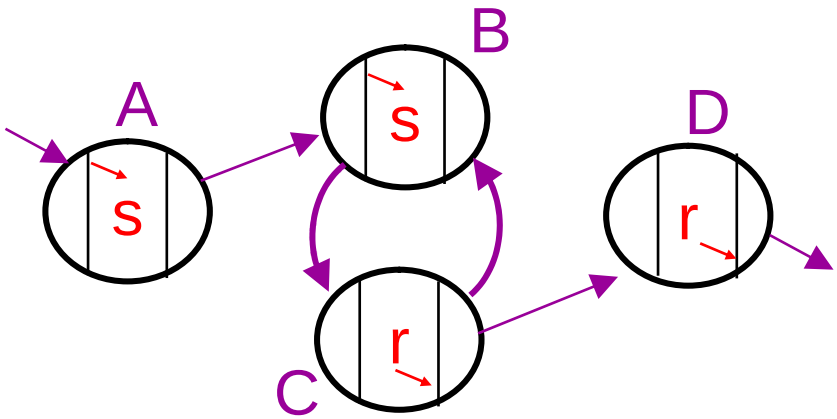
Th[GHM03] If atoms of are in finite number,
we can transform projection MSC-graph $\longrightarrow$ MSC-graph

$$\text{nb_atoms} \leq 2^{\text{size_biggest_atom}}$$

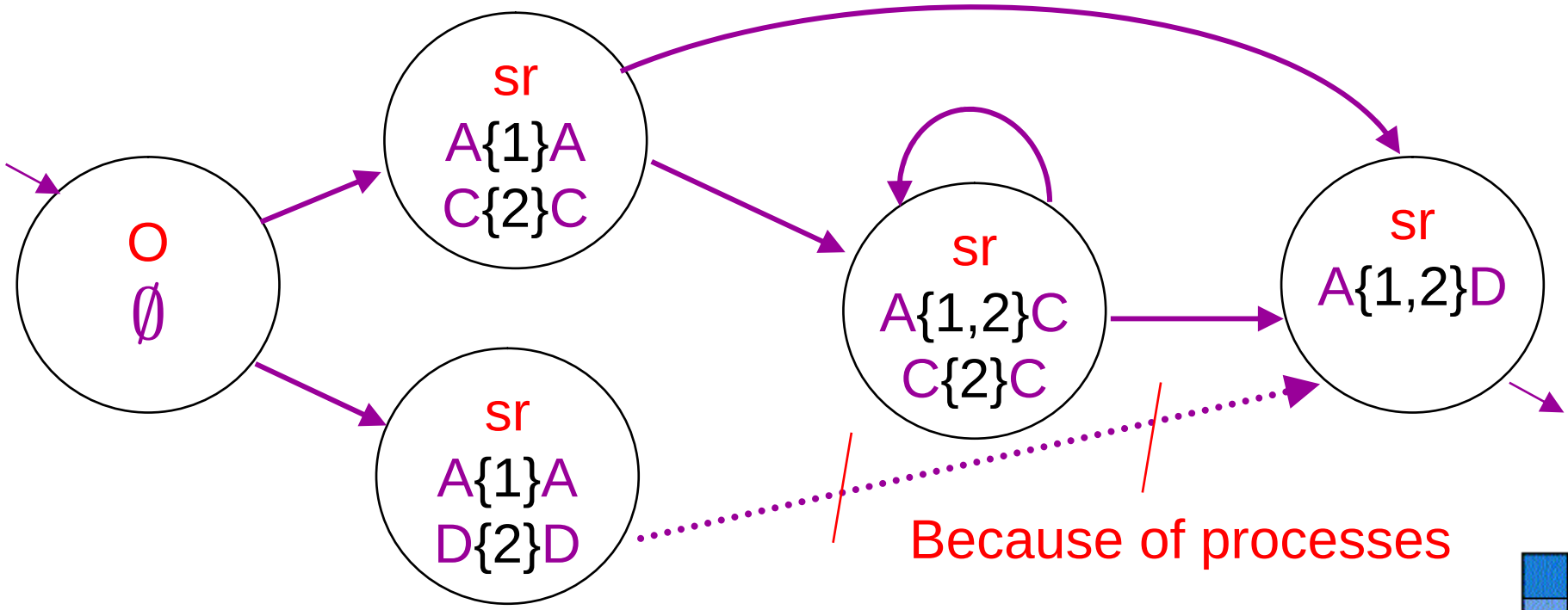
Size: Exponential in size_biggest_atom.

From projection of MSC-graph to MSC-graph

Proof:



Atoms : sr

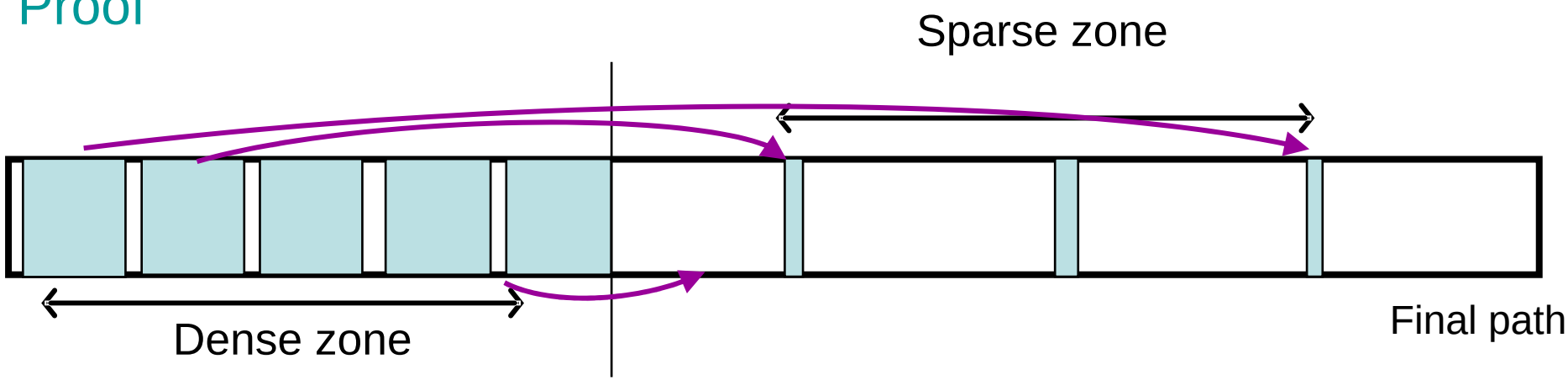


From projection of MSC-graph to MSC-graph

Technical Lemma[GHM03]:

Nb_subpathes $\leq$ size_biggest_atom $\times$ nb_unmatched_send

Proof



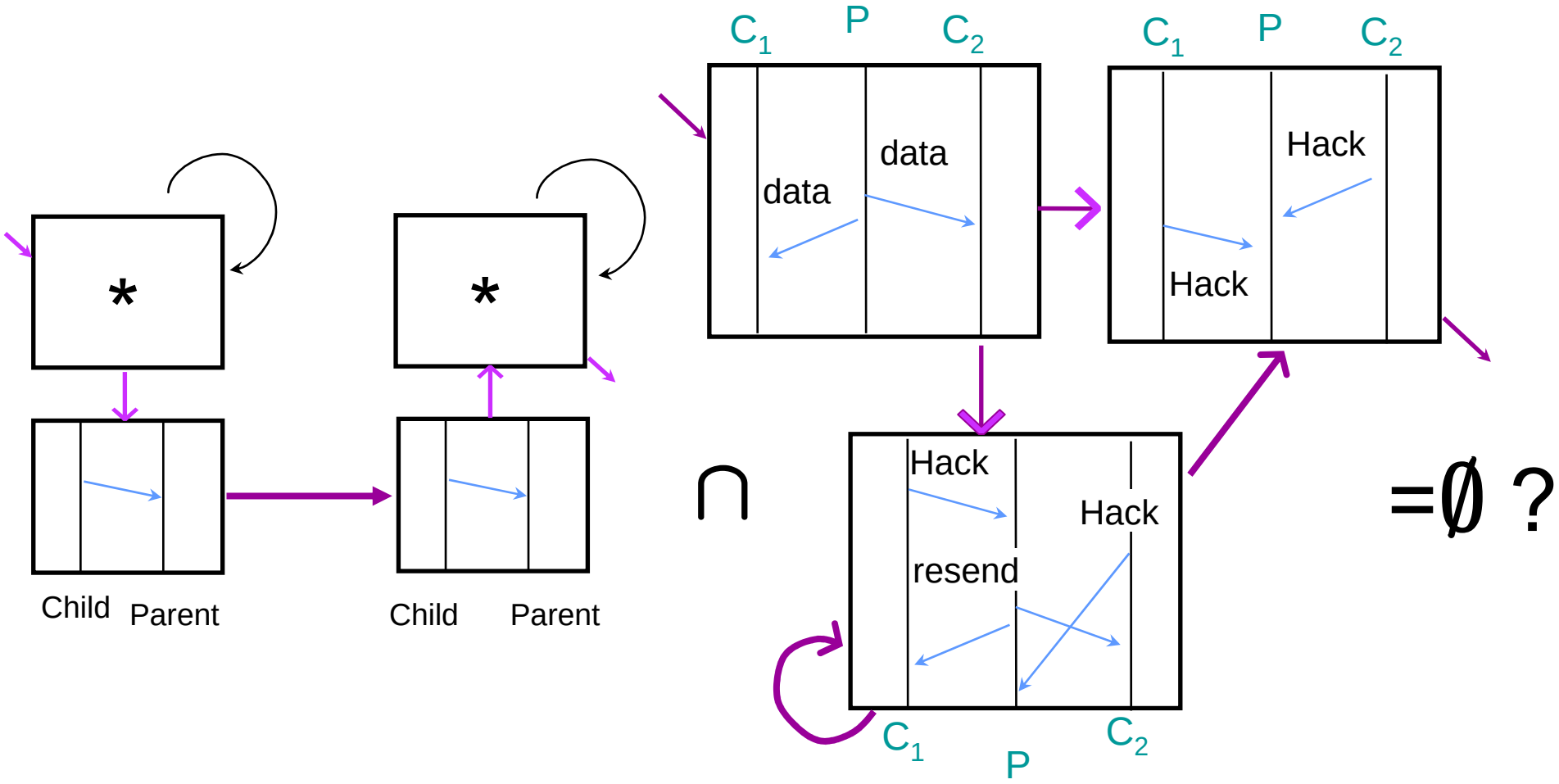
Algorithms for projection of MSC-graph

- If possible, transform Realizable compo $\longrightarrow$ MSC-graph
  Then apply algorithms for MSC-graph

  Checked

- Devellop new algortihms for Realizable compo.
  when transformation not possible
  or MSC-graph too big

Model Checking versus MSC-graph



Negative property

Model

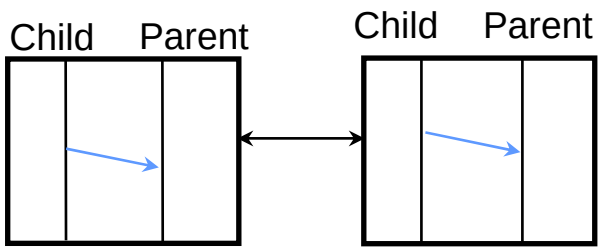
Model Checking MSC-graphs

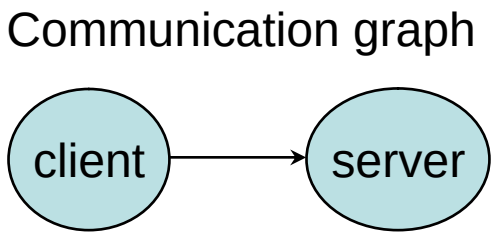
[AY99] // [MP99]:
Undecidable for MSC-graphs

Model Checking MSC-graphs : Decidability

Bounded MSC-graphs :

Communication graph of each loop is strongly connected





Non bounded

Th[AY/MP'99]: PSPACE-complete for bounded MSC-graph

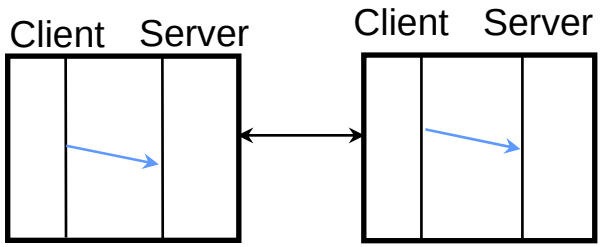
Proof: Trace theory applied on sequence of events

Automaton representing L(G) of exponential size

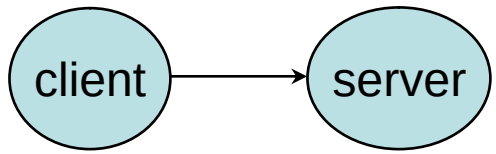
Model Checking MSC-graphs : Decidability

Globally-Connected MSC-graphs :

Communication graph of each loop is weakly connected



Communication graph



Globally Cooperative

Th[GMSZ02]: PSPACE-complete for Globally-Cooperative HMSCs

Proof: Trace theory applied on atoms. Automaton representing representative for L(G) of exponential size

Algorithms for projection of MSC-graph

Th[GHM03]: H globally cooperative MSC-graph
G projected MSC-graph

Then $H \cap G = \emptyset$ is PSPACE-complete

Proof: Build G' recognizing sequences of atoms of H
that label paths of G
Apply known results on globally-cooperative.

Algorithms for projection of MSC-graph

Th[GHM03]: H bounded MSC-graph, H' a projection of H
G projected MSC-graph

Then H' $\cap$ G = $\emptyset$ is PSPACE-complete

Proof: The projection of automaton representing L(H)
= automaton representing H'.
Linearise G into an automaton.
Apply known results on automaton.

Conclusion

We have shown

- projection = realizable compositional MSC-graph

- How to build compositional from projection of MSC-graph.

- Representation for atoms of any projectiob MSC-graph

- How to build MSC-graph from pHMSC when possible

- How to Model-check projections of MSC-graph (abstraction) in many cases