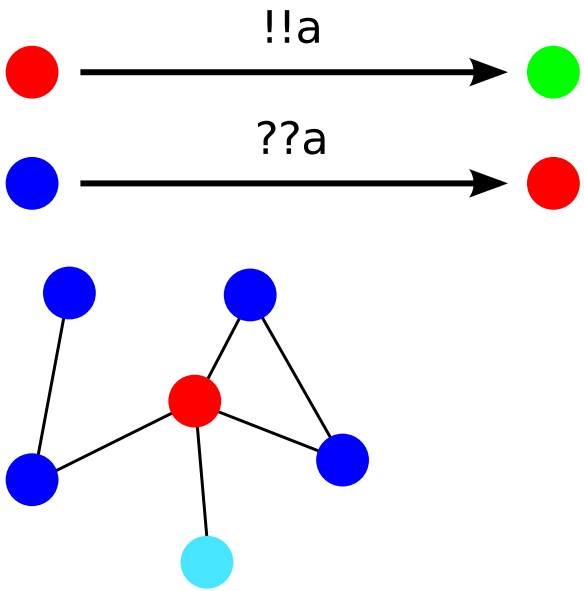
Specification and Verification of Concurrent and Distributed Systems

C.I.N.A. meeting

Riccardo Traverso Giorgio Delzanno

Pisa, February 5th, 2013

The starting point: Ad Hoc Networks (AHN)



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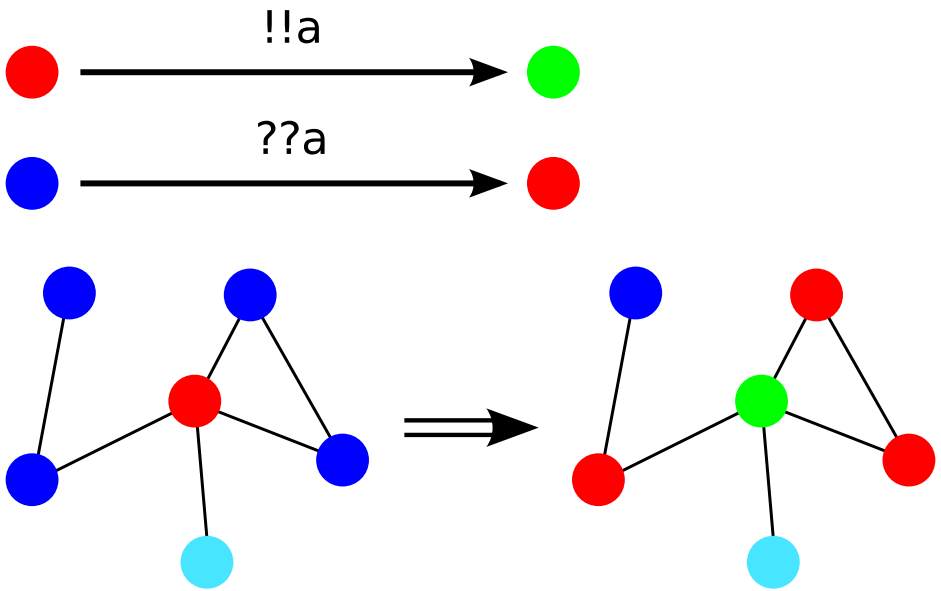

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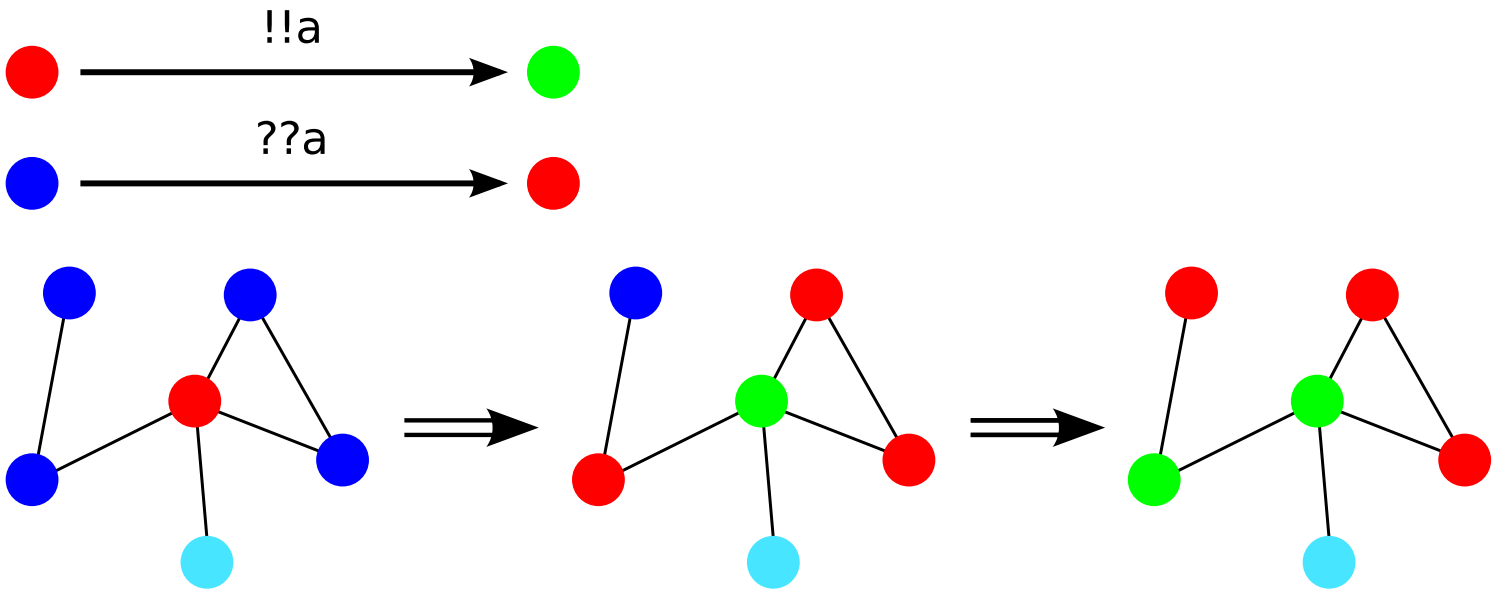

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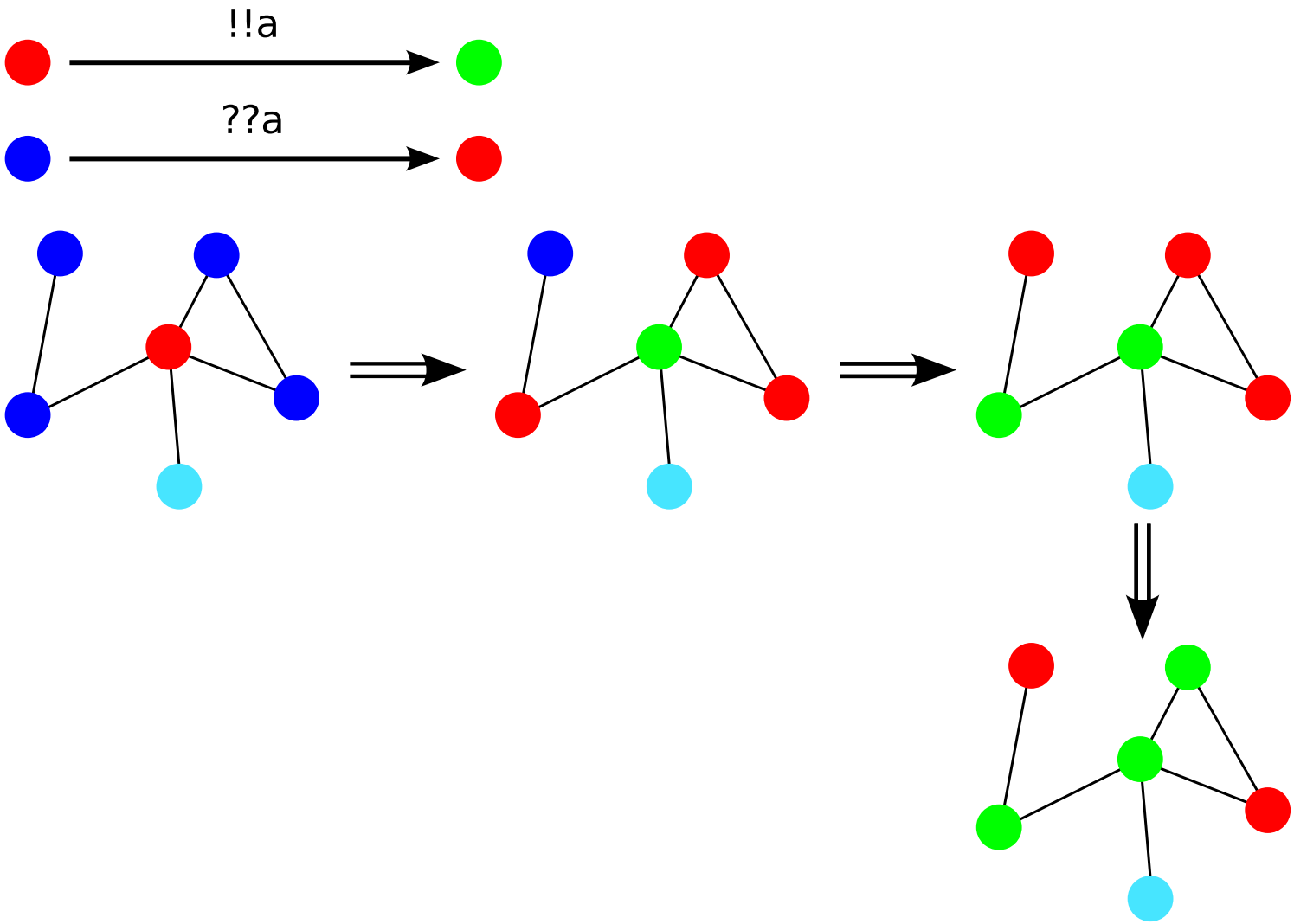

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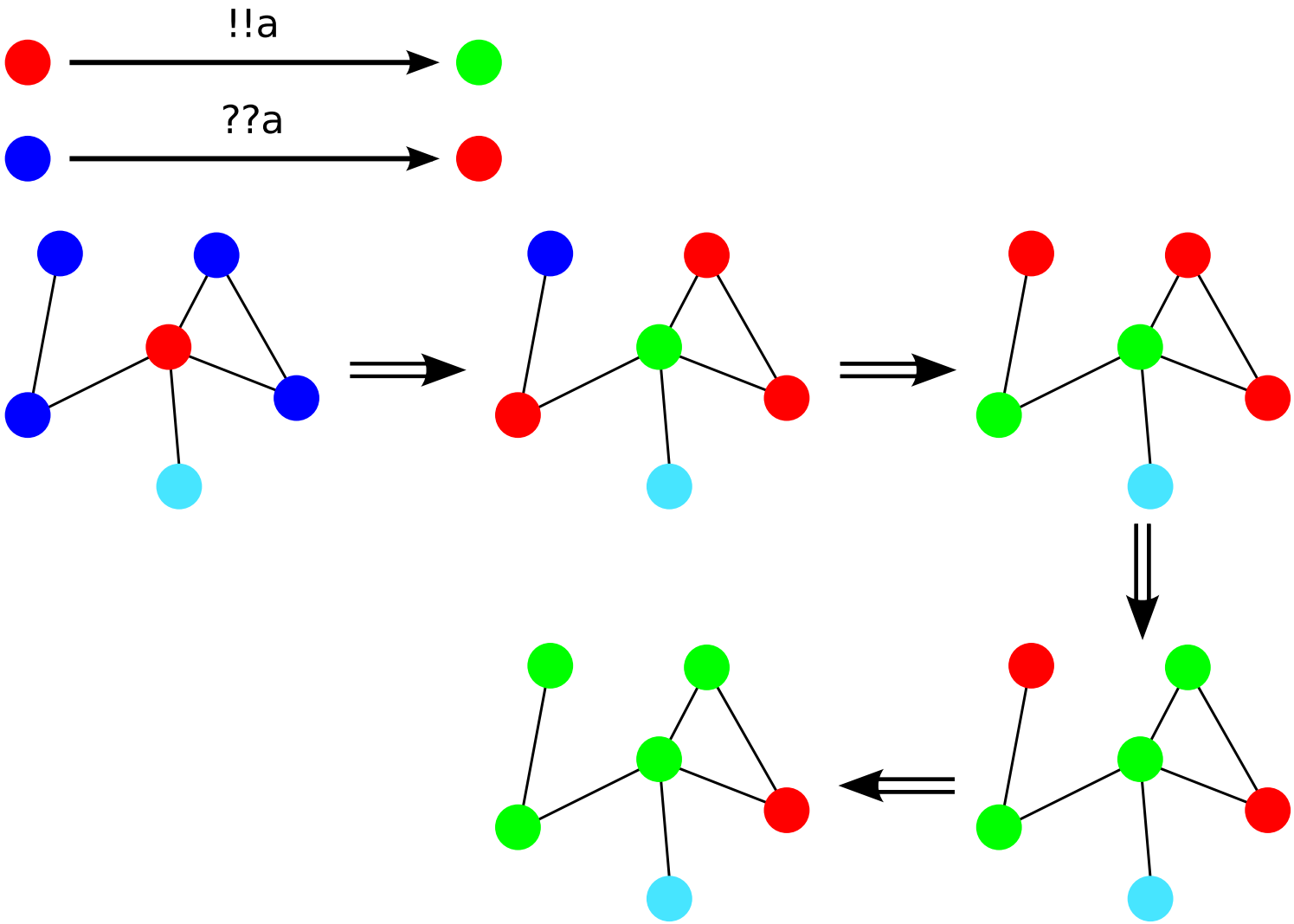

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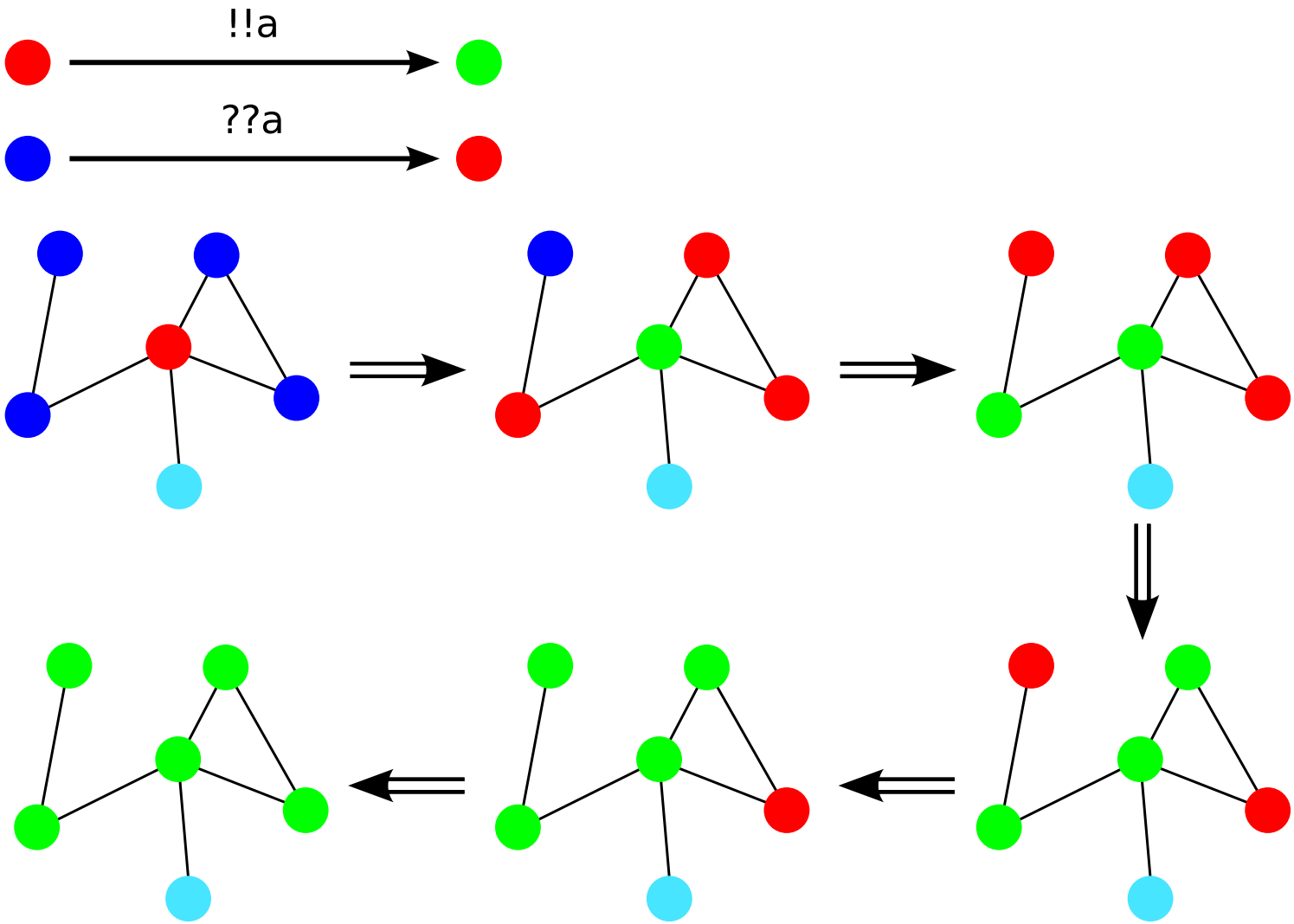


Parameterized verification on AHN

Given a protocol (automaton) and its associated transition system (AHN), compute:

- reachability of a configuration with at least one process in a given state (COVER);
- reachability of a configuration with all processes in a given state (TARGET);
- existence of a computation traversing infinitely often configurations with at least one process in a given state (REPEAT-COVER).

Results on AHN problems

- Those problems are all undecidable for arbitrary graphs.
- There are some decidability results by restricting COVER to configurations in specific classes of graphs.
- By introducing mobility in the model, COVER, TARGET and REPEAT-COVER become decidable.

Aim

To investigate the interplay between richer models of distributed systems and the underlying communication topology.

- Features inspired from routing protocols for Ad Hoc Networks:
  - dynamic networks;
  - more realistic communication (synch. vs asynch, broadcast vs unicast);
  - node identifiers.
- Theoretical research: existing approaches are mostly about modelling rather than analysis.

With whom do we work?

Collaborations

Uppsala University, Program Verification Group:

- Parosh Aziz Abdulla (prof.), Faouzi Atig (PhD), Othmane Rezine (PhD student)

University Paris Diderot - Paris 7 - LIAFA:

- Arnaud Sangnier (prof.)

Università di Bologna INRIA - FOCUS Research Team:

- Gianluigi Zavattaro (prof.)

Which are the models considered?

Reconfigurable Broadcast Networks (RBN)

- Synchronous broadcast and reception of messages (like AHN).
- Random rearrangements of the network connections.

RBN: Parameterized Reachability Problem

We consider cardinality constraints (CC) on the number of processes in a given control state:

$$\varphi ::= a \leq \#q < b \mid \varphi \wedge \varphi \mid \varphi \vee \varphi \mid \neg\varphi$$

($a \in \mathbb{N}$, q is a local control state, and $b \in (\mathbb{N} \setminus \{0\}) \cup \{+\infty\}$)

- PRP: can we reach a configuration satisfying some CC φ from an initial configuration?
- No restrictions on the initial number of processes.

RBN: Results (FSTTCS12)

- PRP is PTime-complete for CC without negation and with only $\#q \geq 1$ atoms.
- For CC with $\#q \geq 1$ atoms and negation PRP is NP-complete.
- PRP is PSpace-complete for unrestricted CC.

RBN: Extension with node identifiers

- Each node in a configuration has its own identifier (unbounded data domain).
- It is a basic requirement in order to build routing tables.
- Identifiers may be:
  - exchanged with broadcast messages;
  - saved in local variables;
  - tested for equality.

RBN: Extension with node identifiers (in progress)

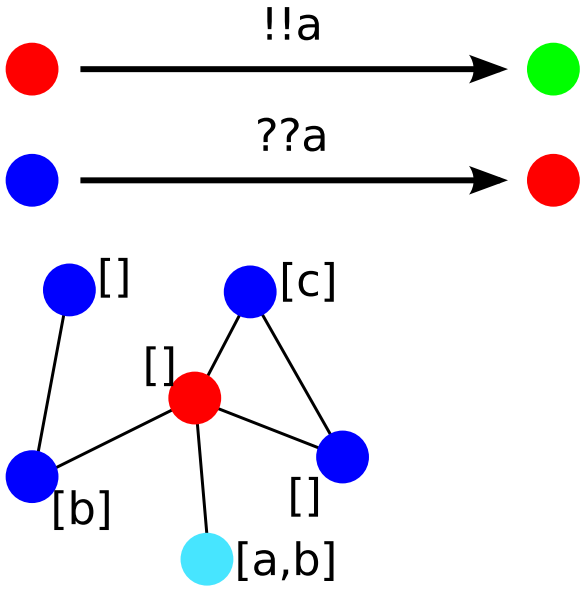
We consider COVER, without network reconfigurations (fully connected case):

- 1 RO + 1 RW locals, 1 ID per message $\Longrightarrow$ undecidability
- 1 RW local, 1 ID per message $\Longrightarrow$ decidability

And with reconfigurations:

- 1 RO + 1 RW locals, 2 ID per message $\Longrightarrow$ undecidability
- 1 RO + 1 RW locals, 1 ID per message $\Longrightarrow$ decidability?

Asynchronous Broadcast Networks (ABN)



(with multisets as mailboxes)

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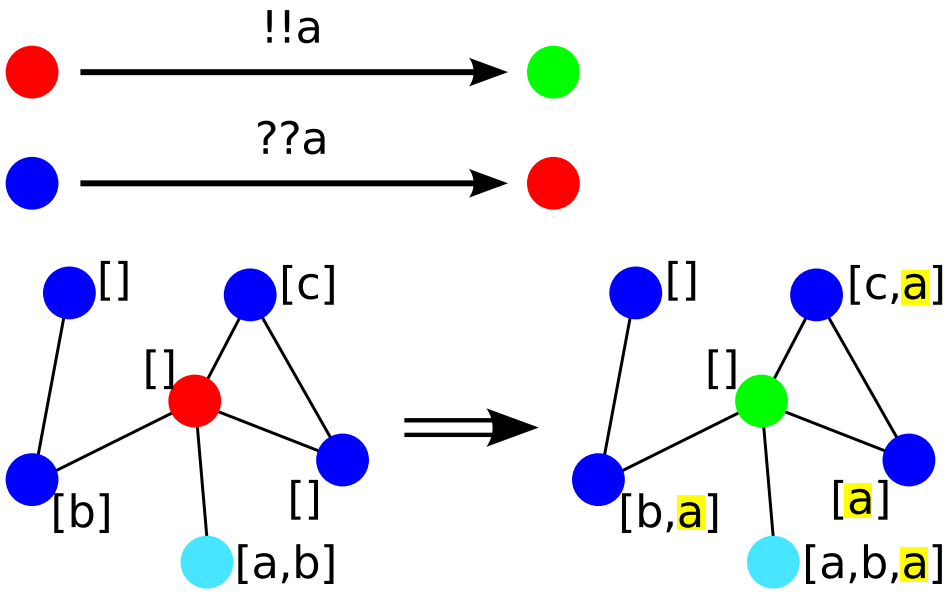

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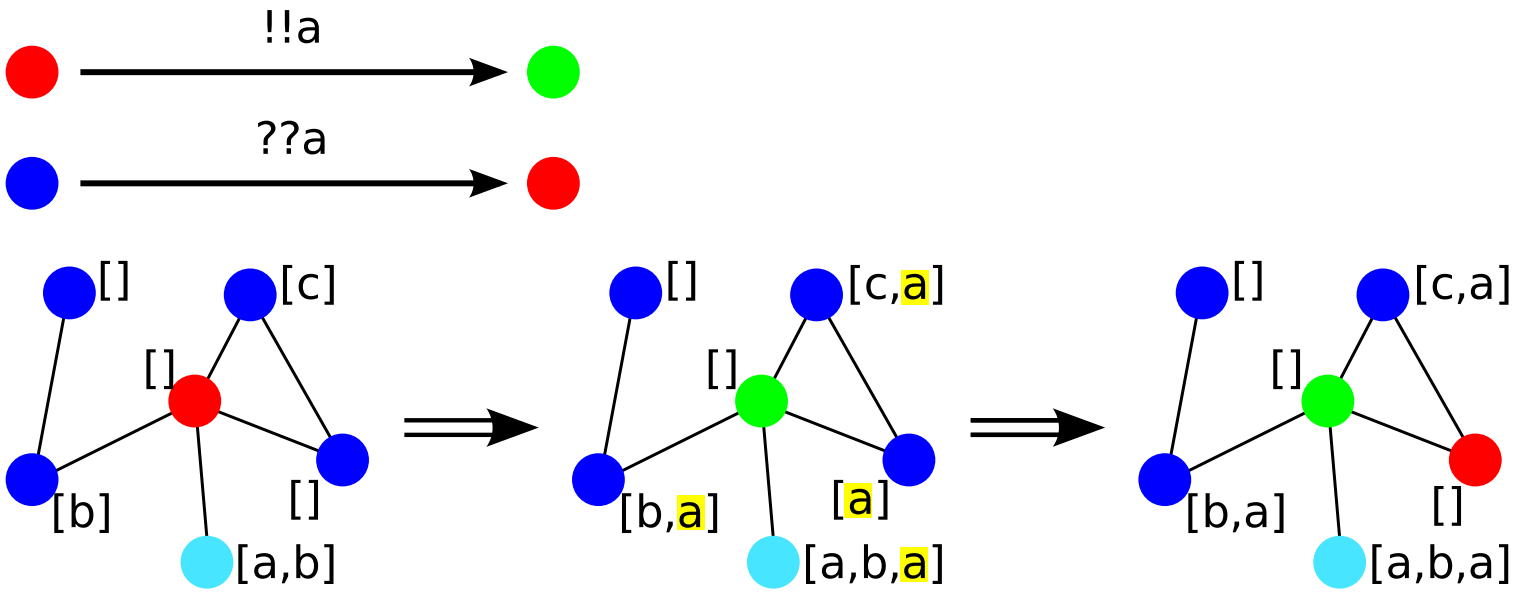

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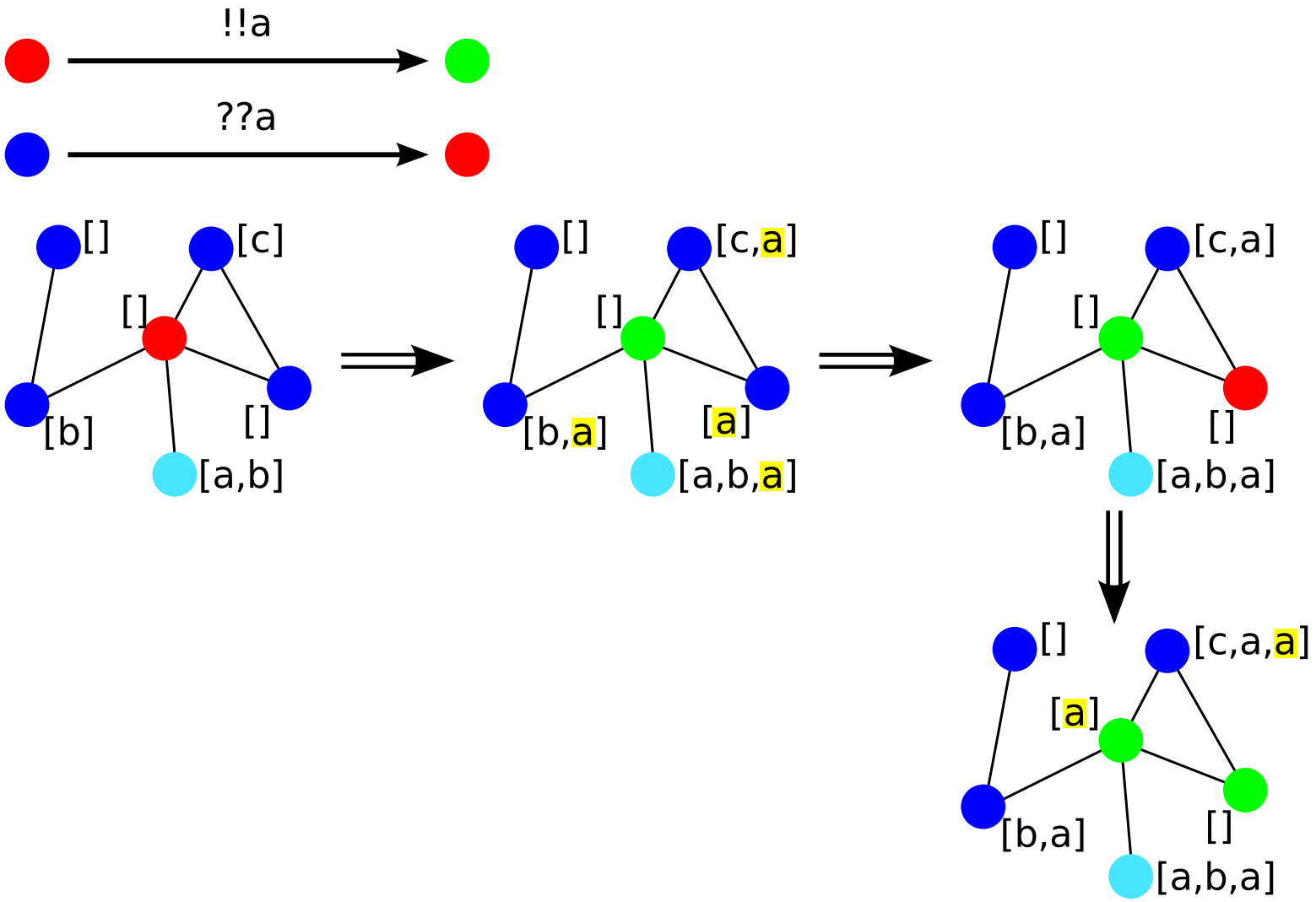

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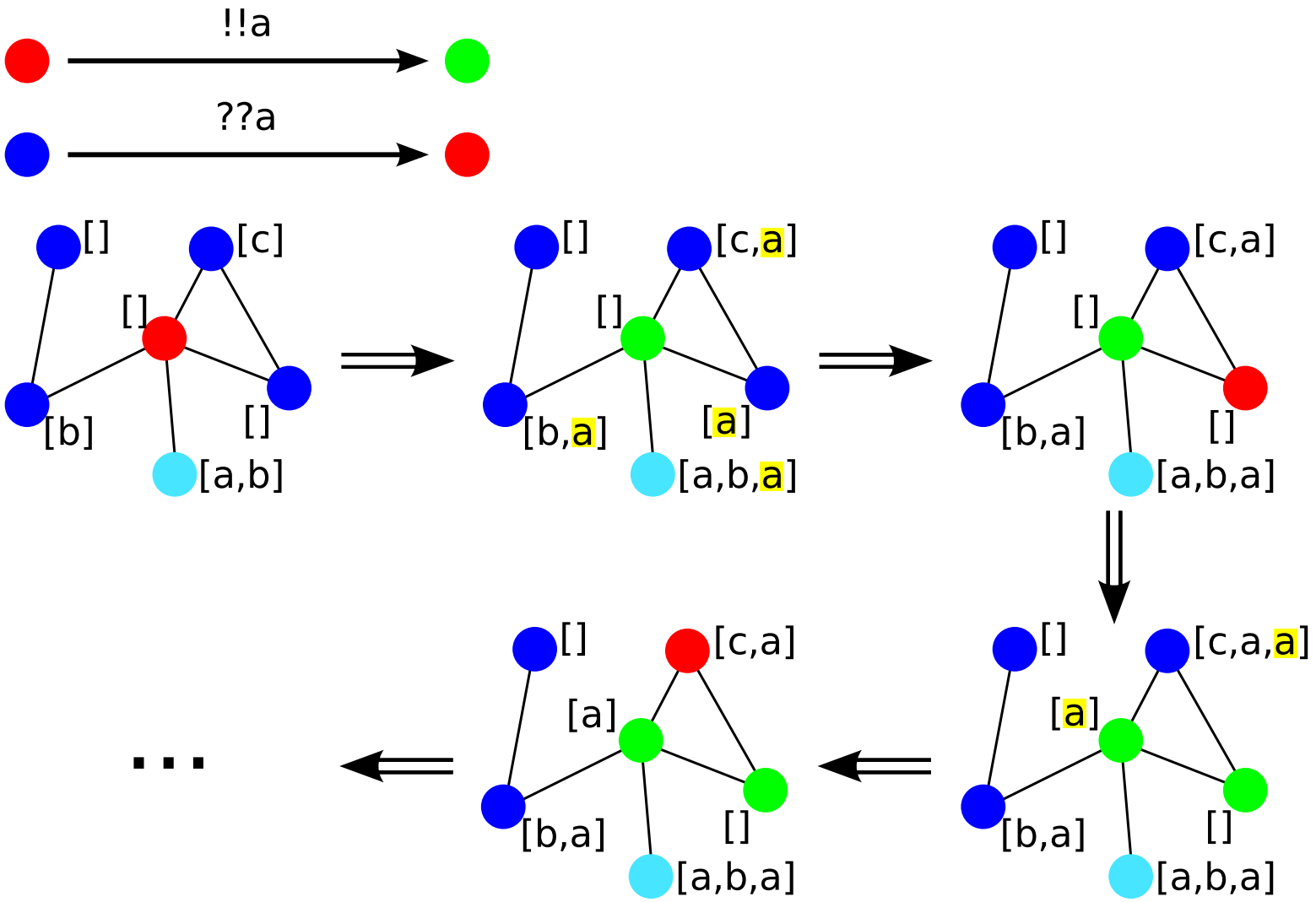

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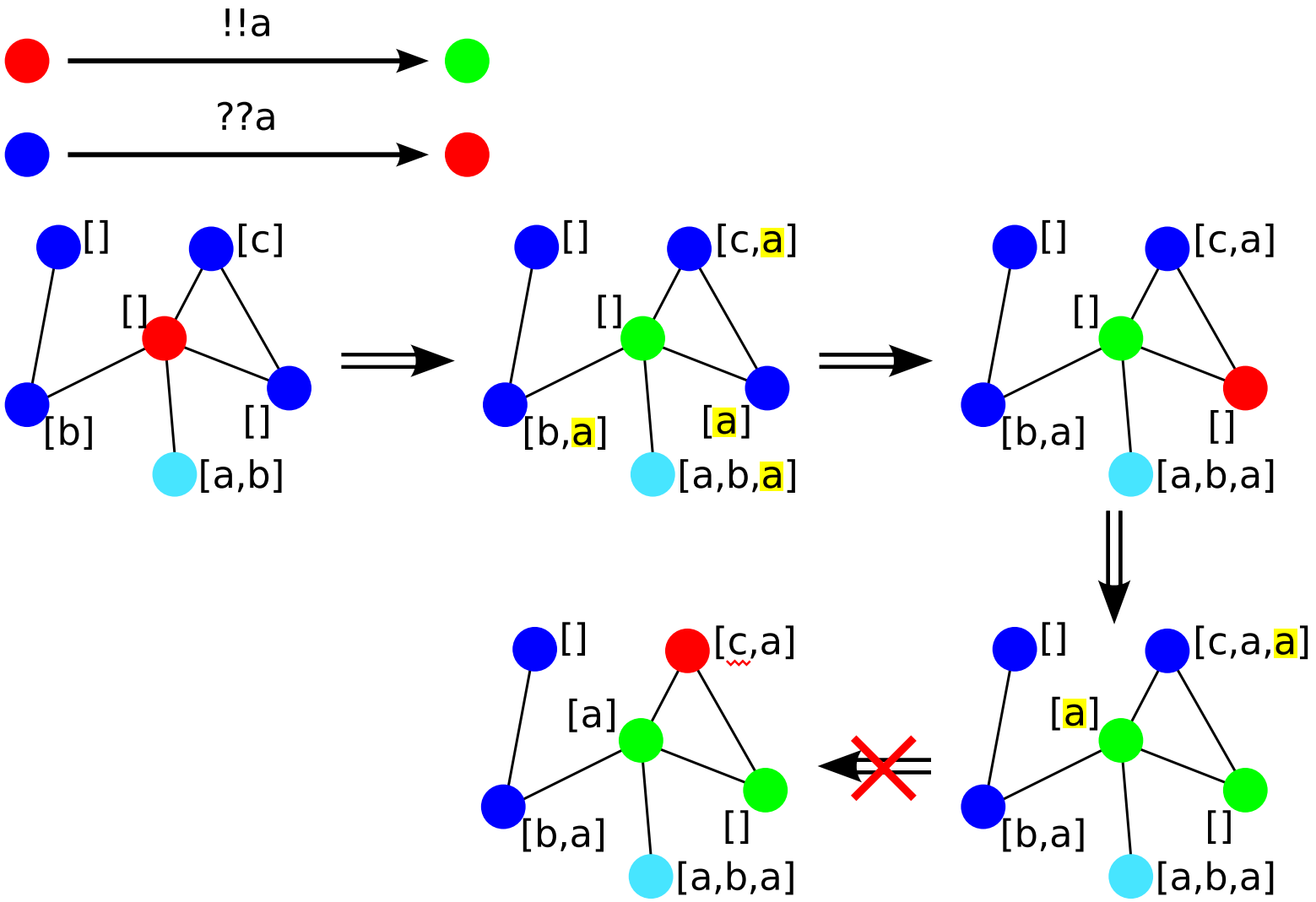

(with FIFO queues as mailboxes)

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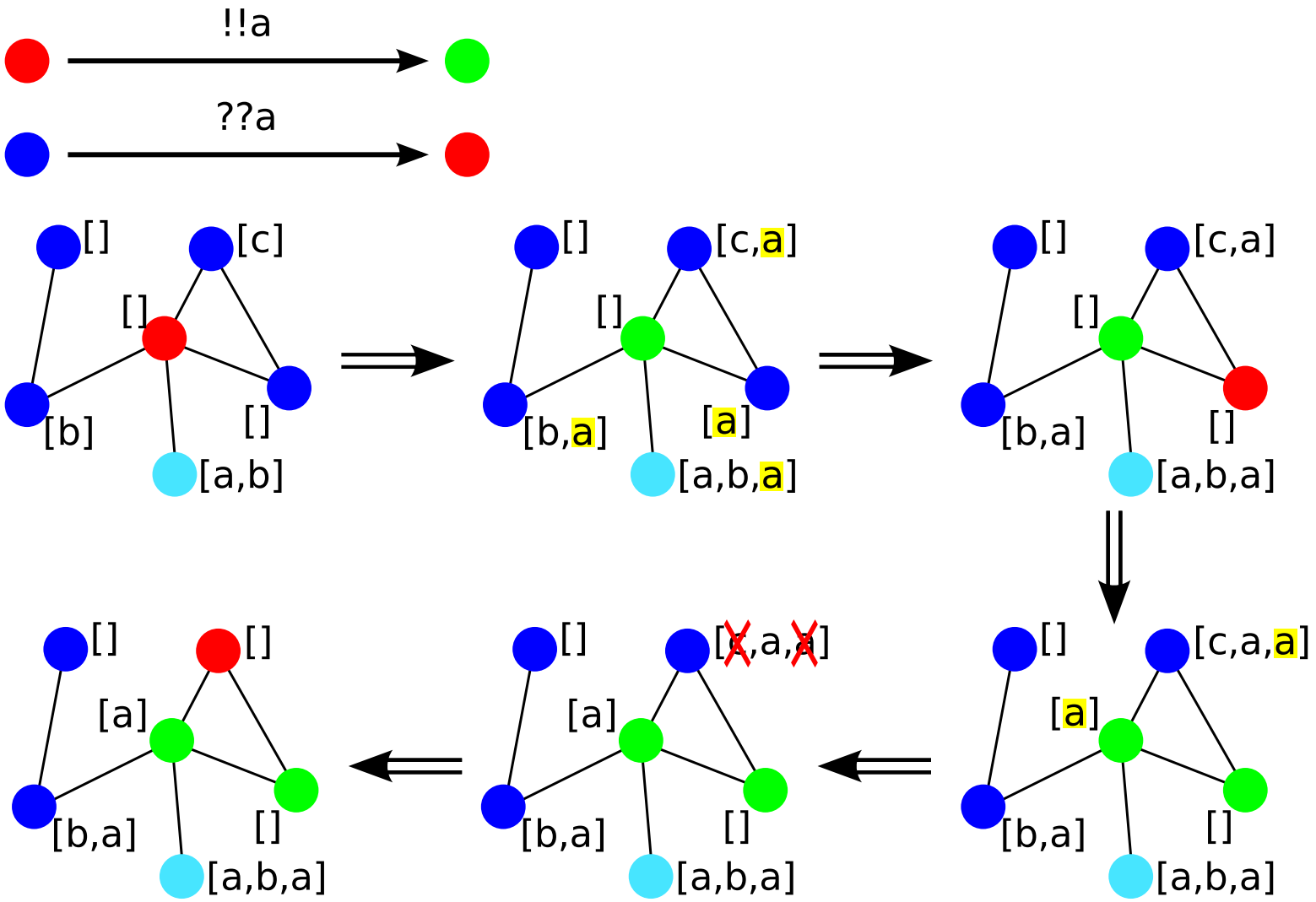

(with lossy FIFO queues as mailboxes)

ABN: Results (ICTCS12, LATA13)

	$COVER^{\mathcal{K}}(\mathbb{M})$		$COVER(\mathbb{M})$	
	ABN	ABN_ϵ	ABN	ABN_ϵ
LFIFO	PTime	PTime	PTime	PTime
Bag	PTime	undec.	PTime	undec.
FIFO	undec.	undec.	undec.	undec.

		ABN / ABN_ϵ		
	AHN	LFIFO	Bag	FIFO
Fully connected graphs	✓	PTime	PTime/undec.	undec.
Arbitrary graphs	undec.	PTime	PTime/undec.	undec.

ABN: Extension with time (in progress)

Extensions to the model:

- Each automaton is equipped with $k \in \mathbb{N}$ local clocks.
- Each received message is associated to its current age.
- Transition guards.
- With $k = 0$, COVER should be decidable.

ABN: Extension with quantified send and receive (future)

Two new communication primitives:

- existential send ($!!_{\exists}a$);
- universal receive ($??_{\forall}a$).

COVER, by adding only $??_{\forall}a$ actions:

- in fully-connected graphs, it should be undecidable;
- uncommonly, it seems to be more difficult to be able to solve it in fully-connected graphs rather than in arbitrary graphs.

With both $!!_{\exists}a$ and $??_{\forall}a$ actions:

- for arbitrary graphs, it should be undecidable;

Thank you for your attention!