Building and verifying a quasi-certification entity over Distributed Hash Tables

Join work with X. Bonnaire, R. Cortes & O. Marin
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Certification, why?

Motivations

- Digital filling for tax purpose
  - **Certify that somebody did it before a given deadline**
- Certified emails
  - **Use emails for legal purposes**
- Online game refereeing
- e-voting, etc.

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Existing Solutions

- Centralized
  - **Public Key Infrastructures (traditional PKI)**
  - **Scaling problem/prone to faults/implementation (atomic multicast)**
- Decentralized
  - **Certification on top of Distributed Hash Tables (DHT)**
  - **Rapidly brings Byzantine consensus (for a 100.0% guarantee)**

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Objective

(quasi)-certify that a given action has been performed at a certain time

Distributed context (DHT)

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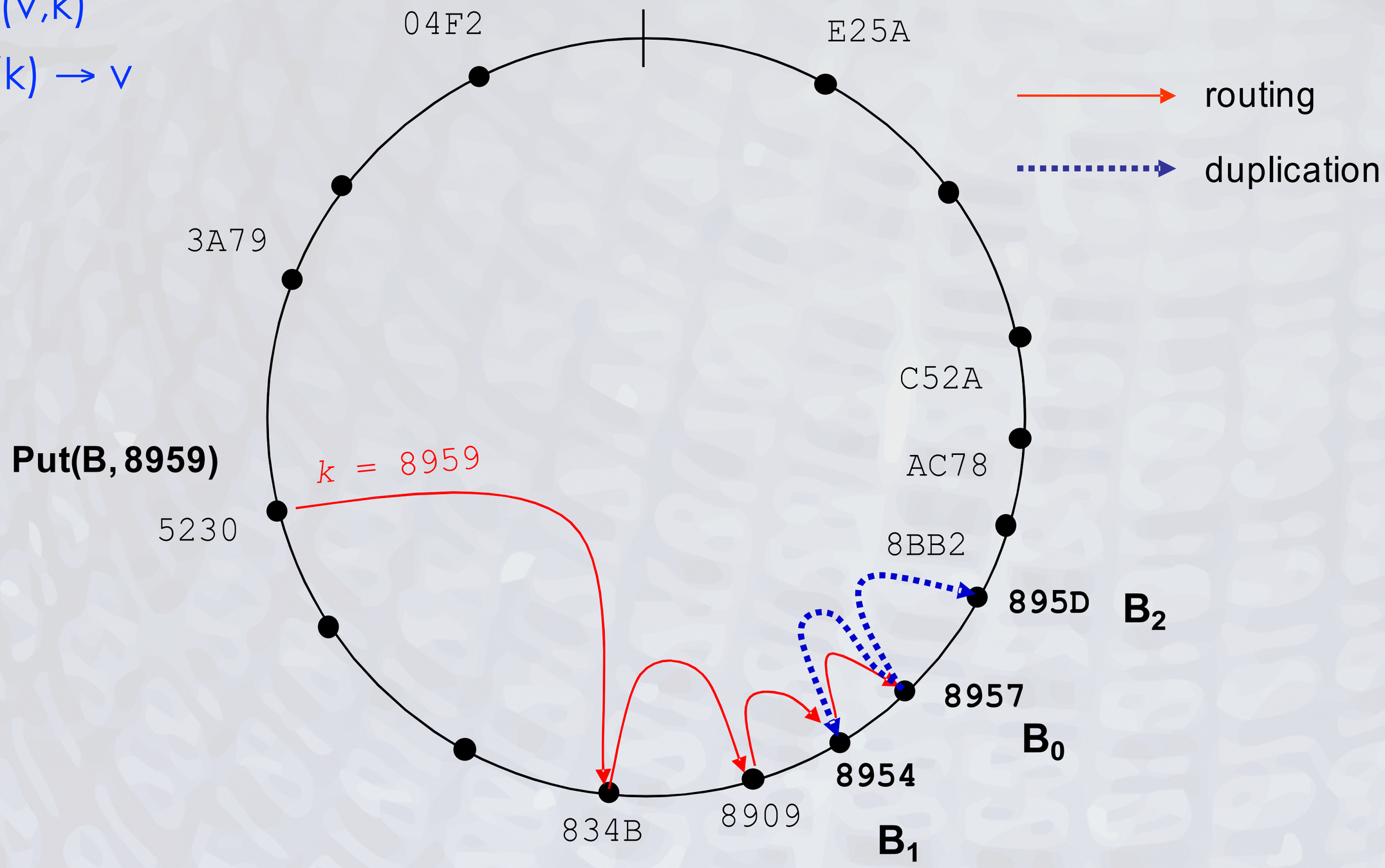
DHT in a nutshell

Retrieve data (key + value)

- put (v,k)
- get(k) → v



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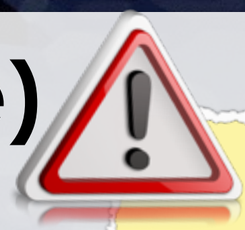
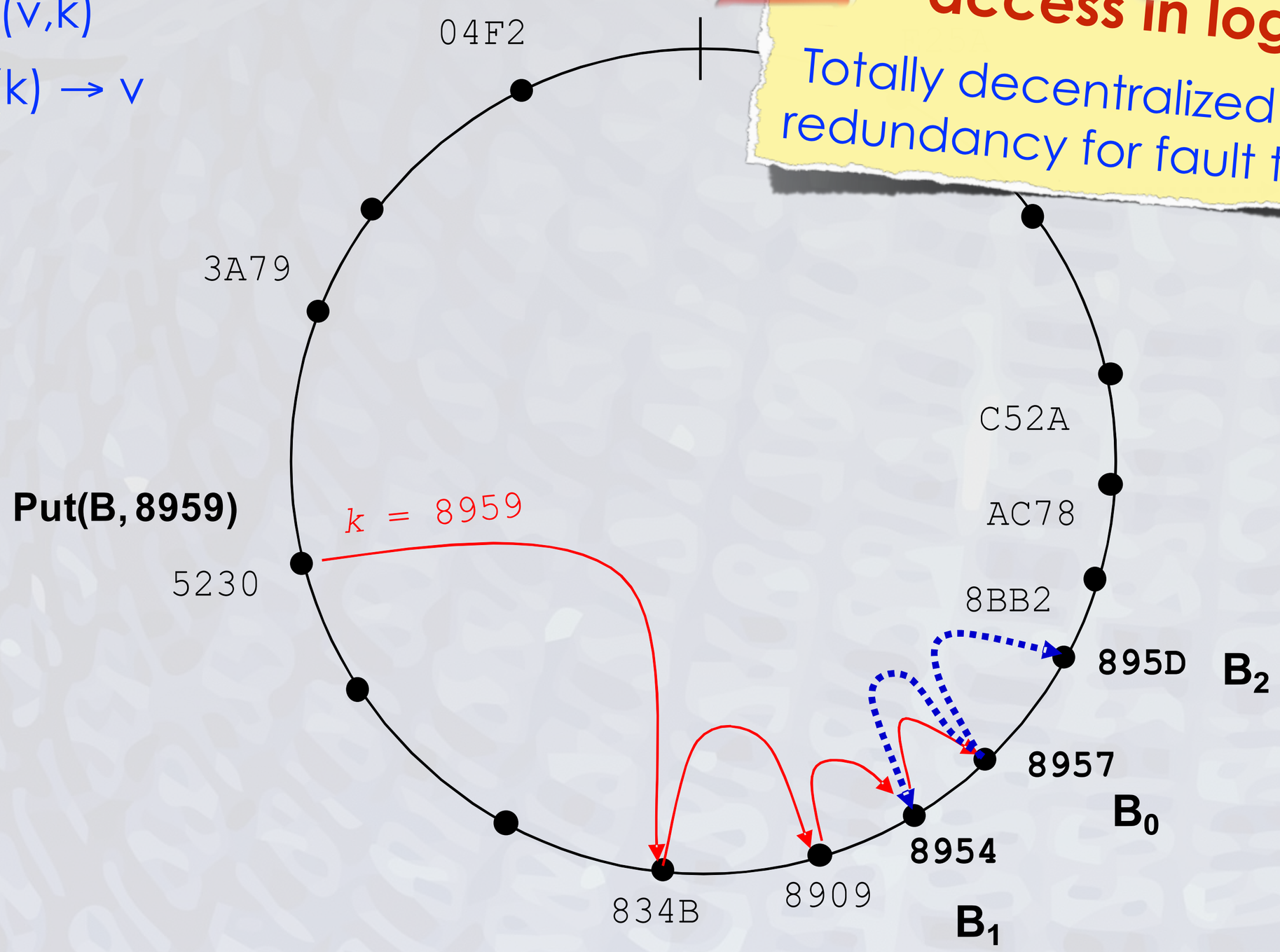


access in log(n)

Totally decentralized + built)in redundancy for fault tolerance



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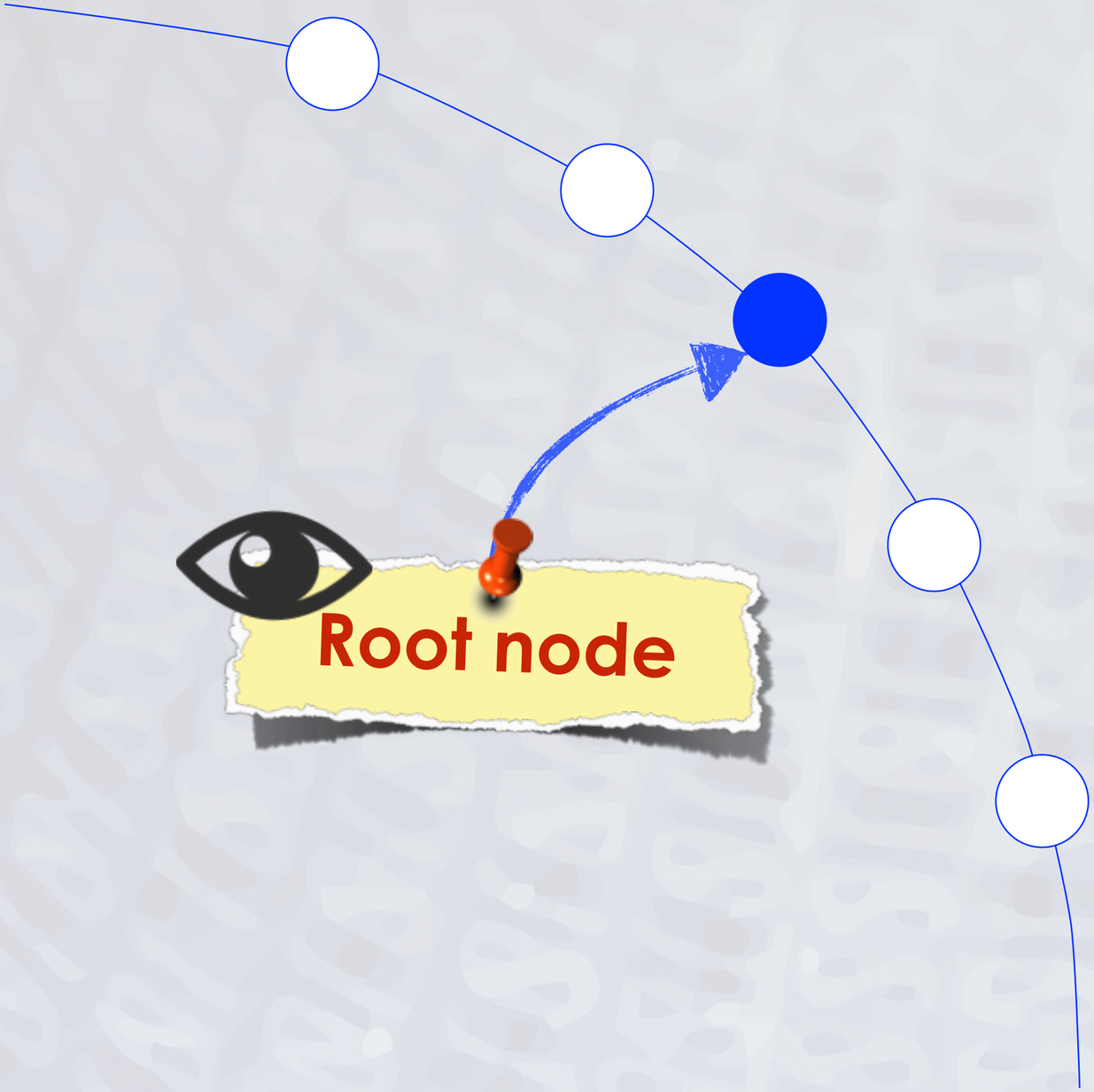

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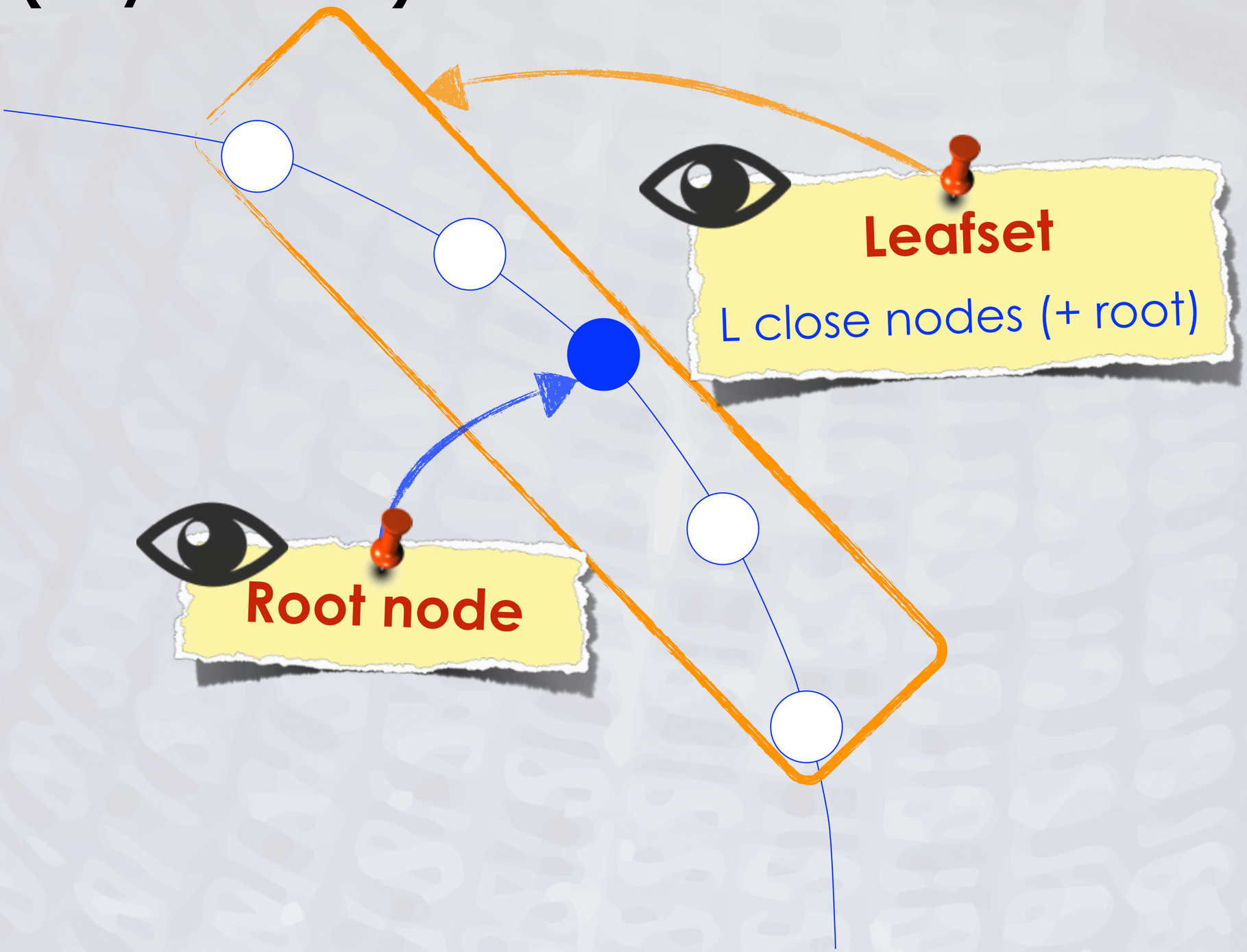

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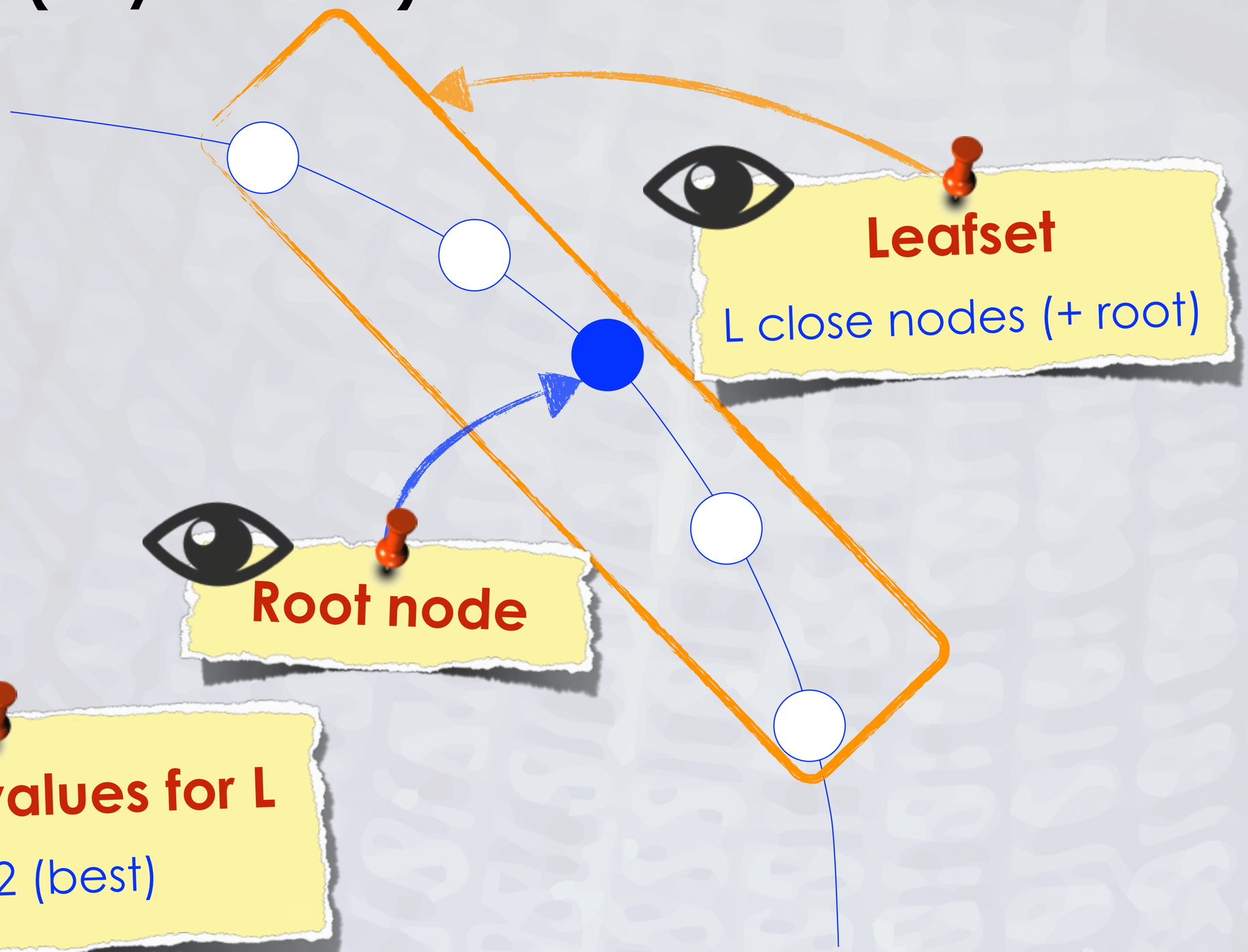
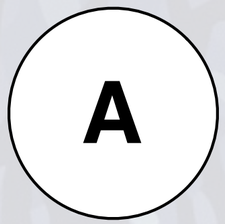


Quasi-certification — entities

- A → an actor performing a service



Quasi-certification — entities

- A → an actor performing a service
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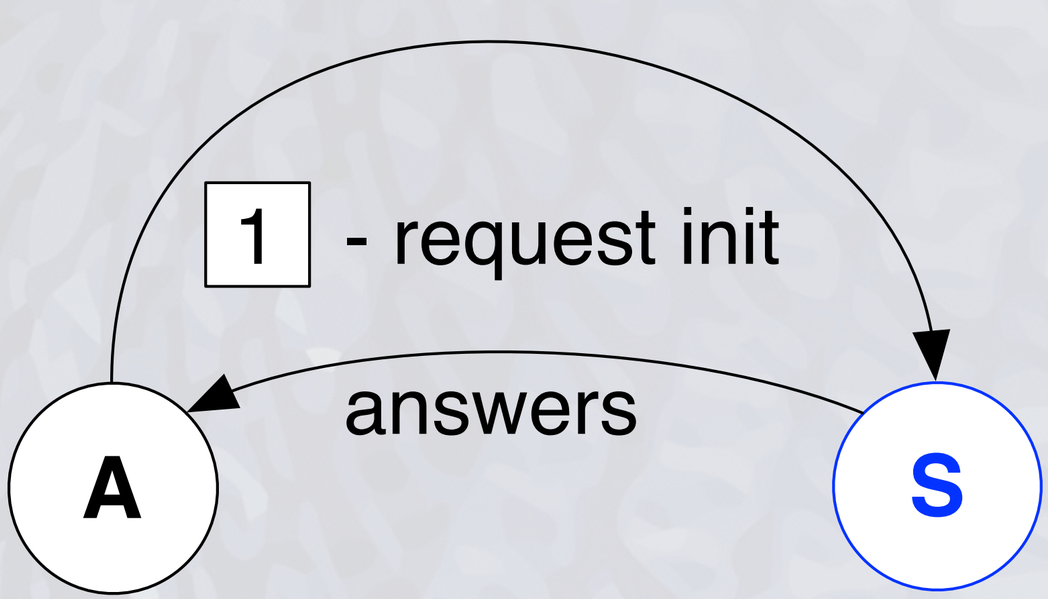

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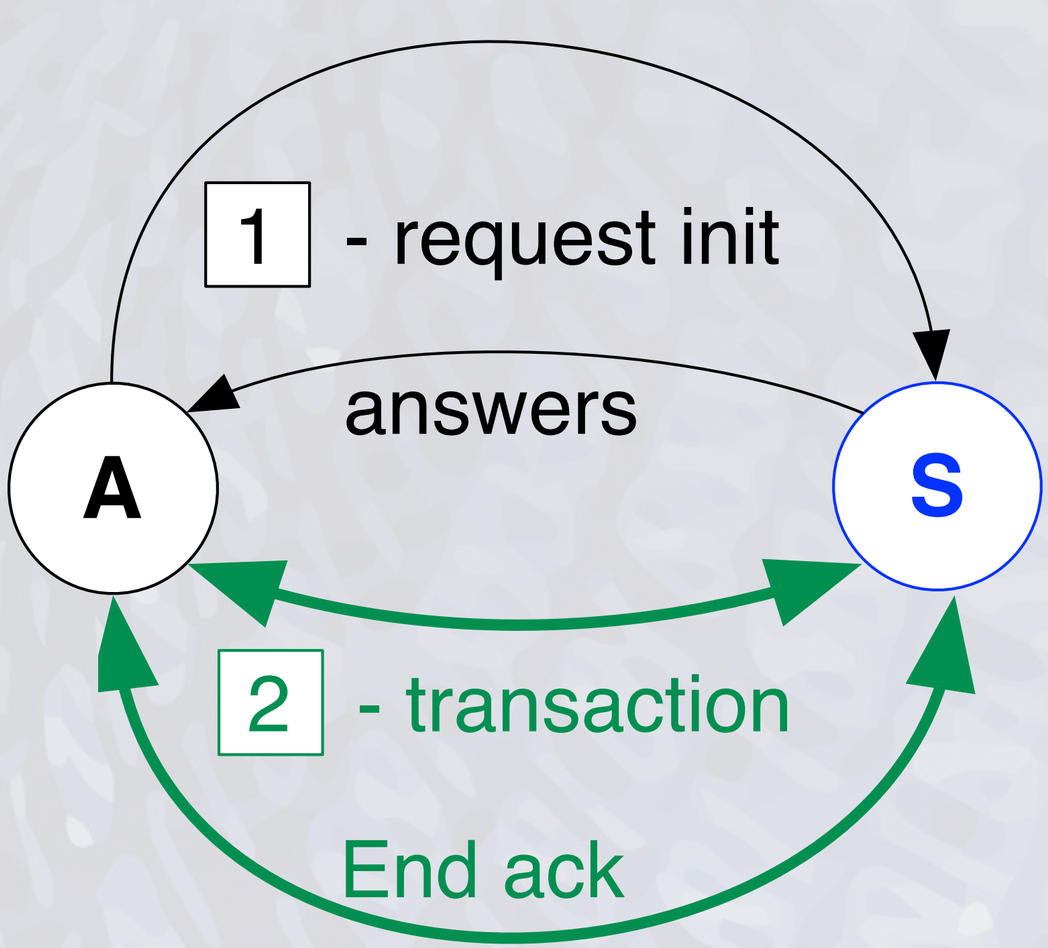

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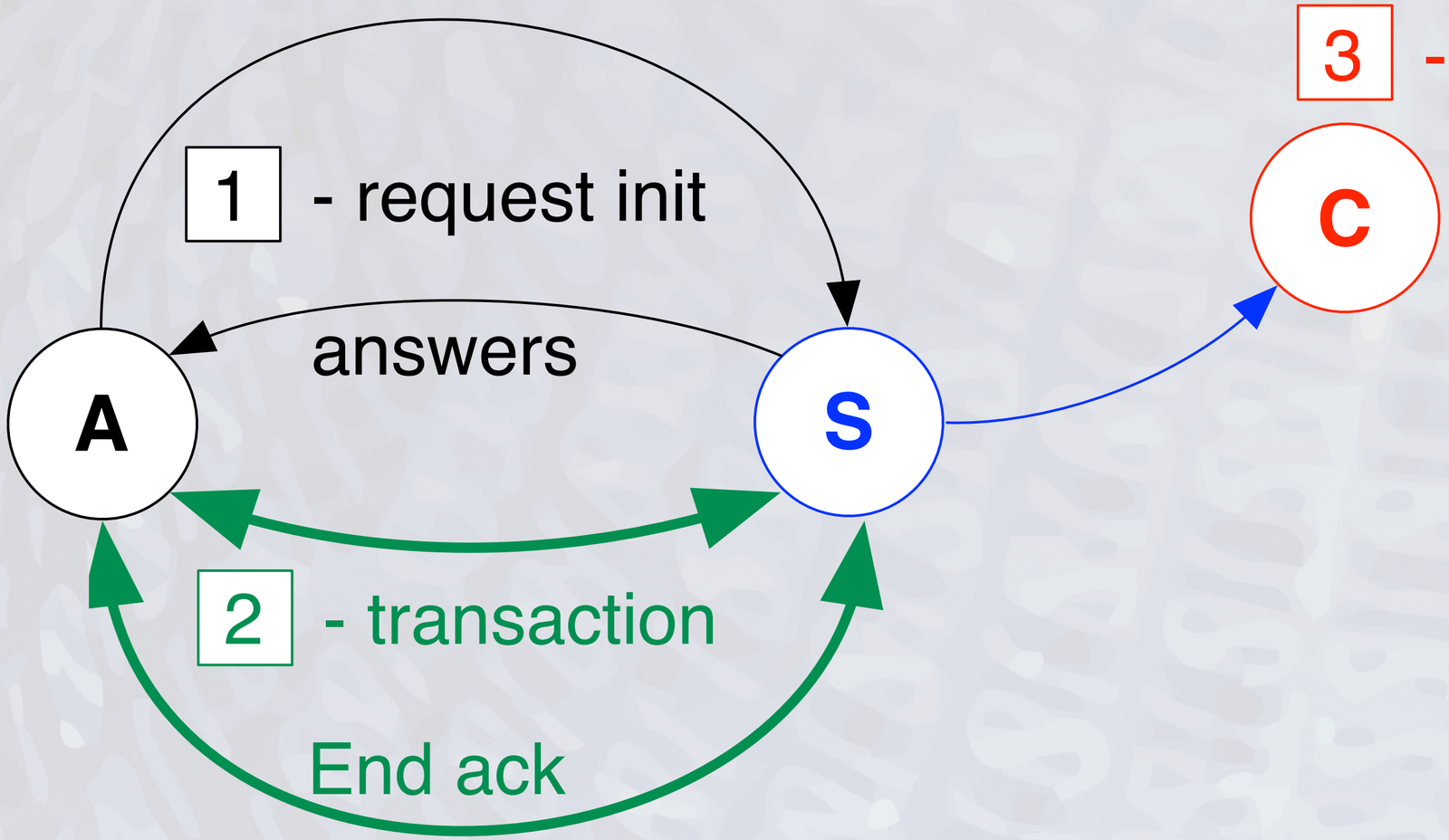

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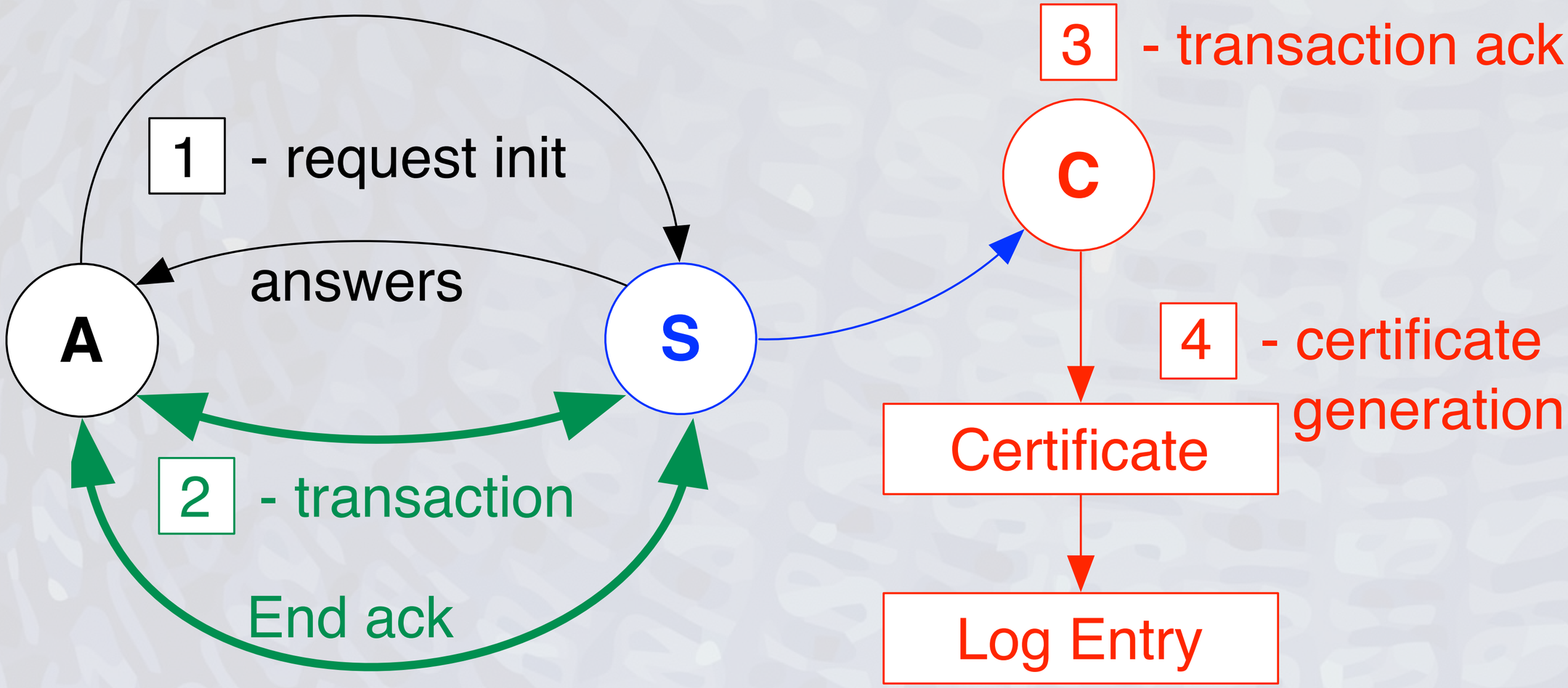

Quasi-certification — protocol structure

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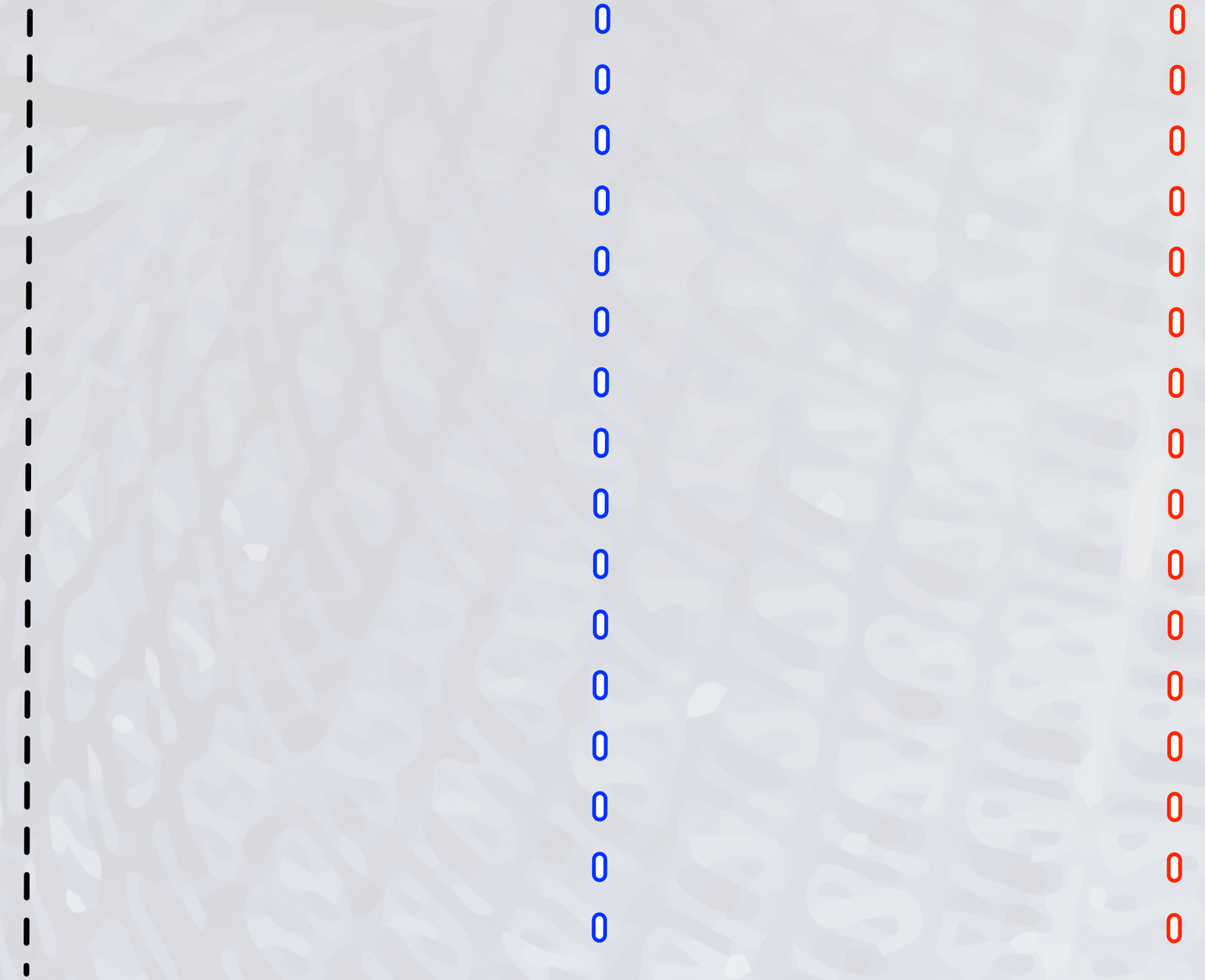

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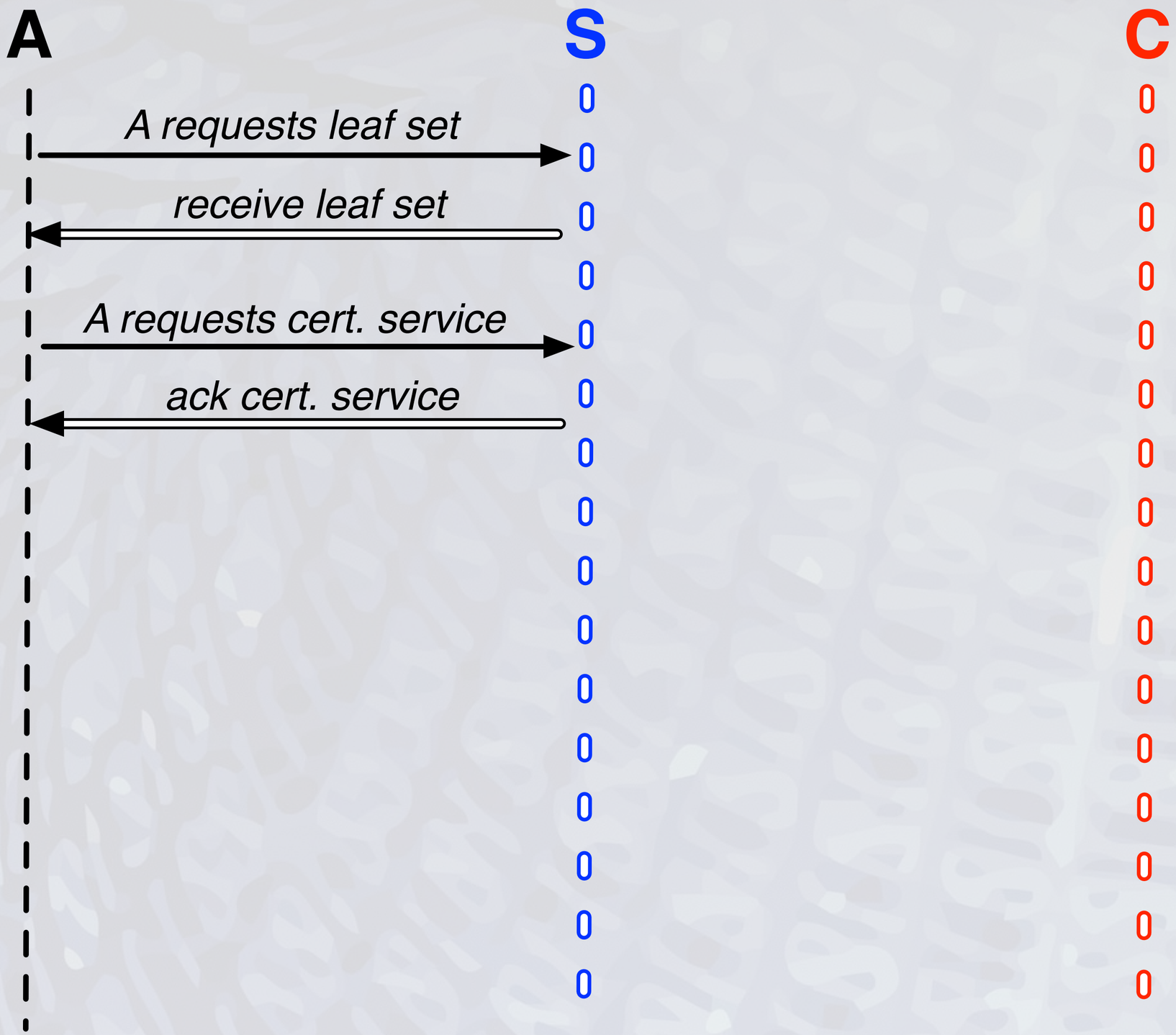

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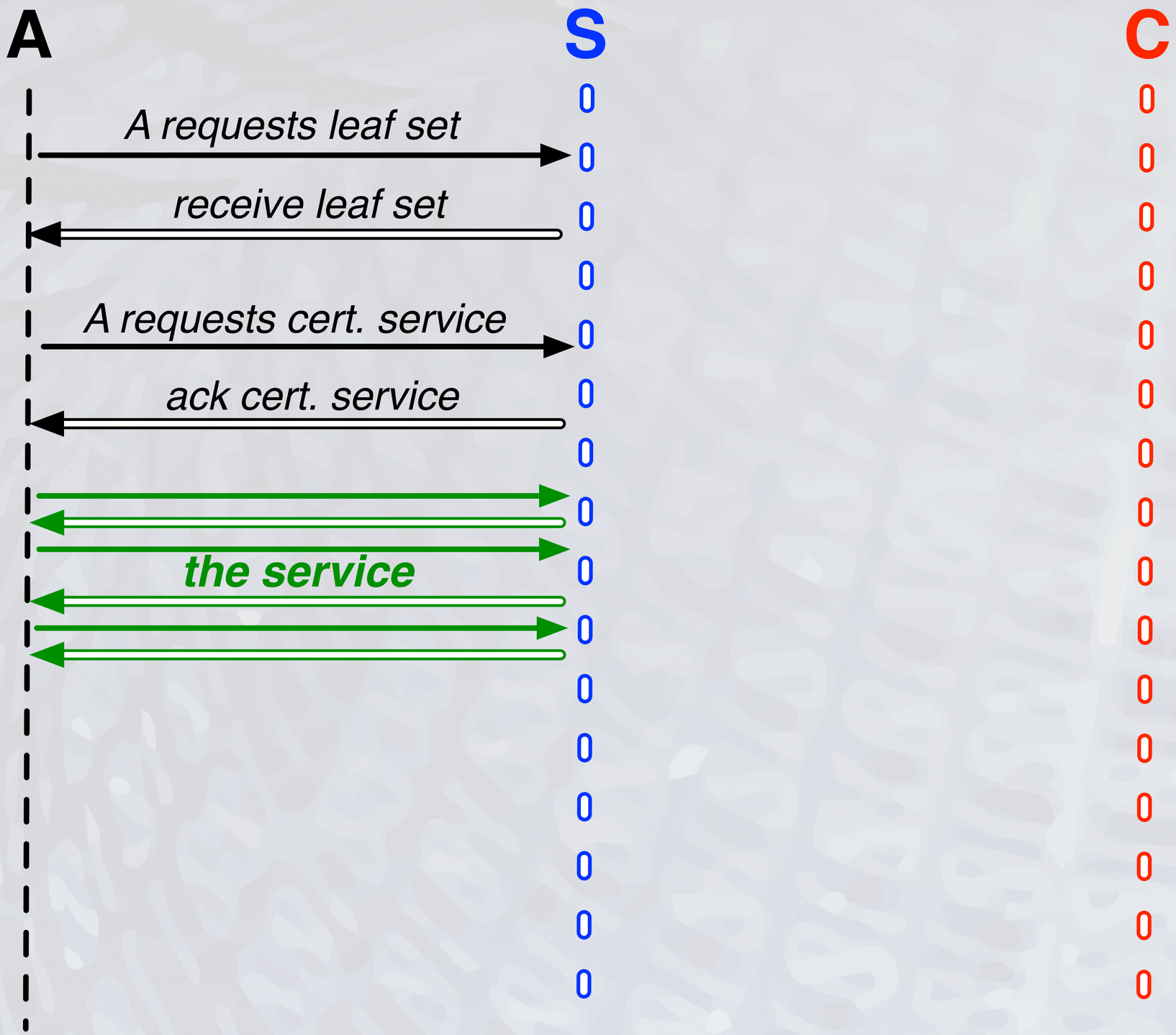

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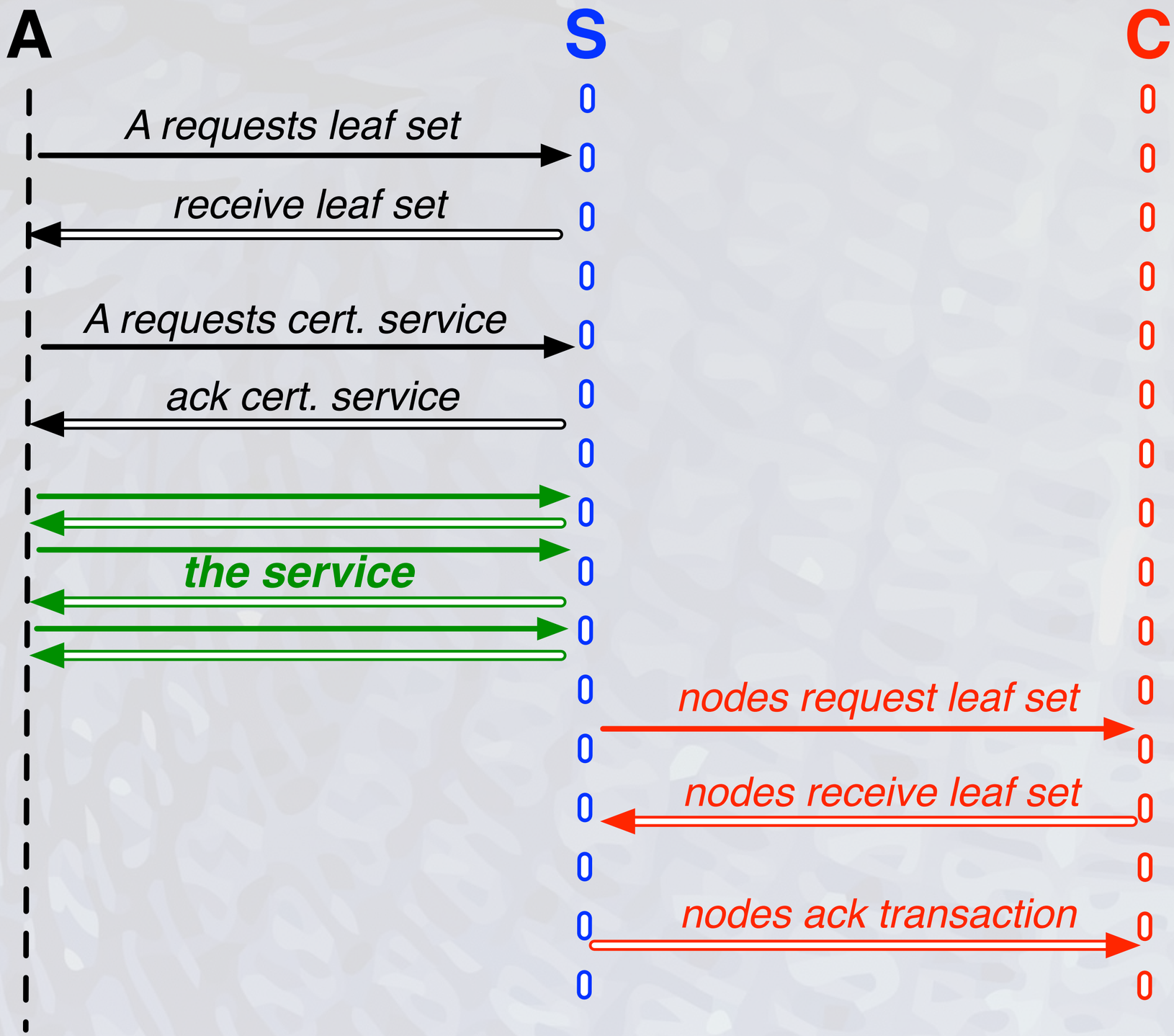

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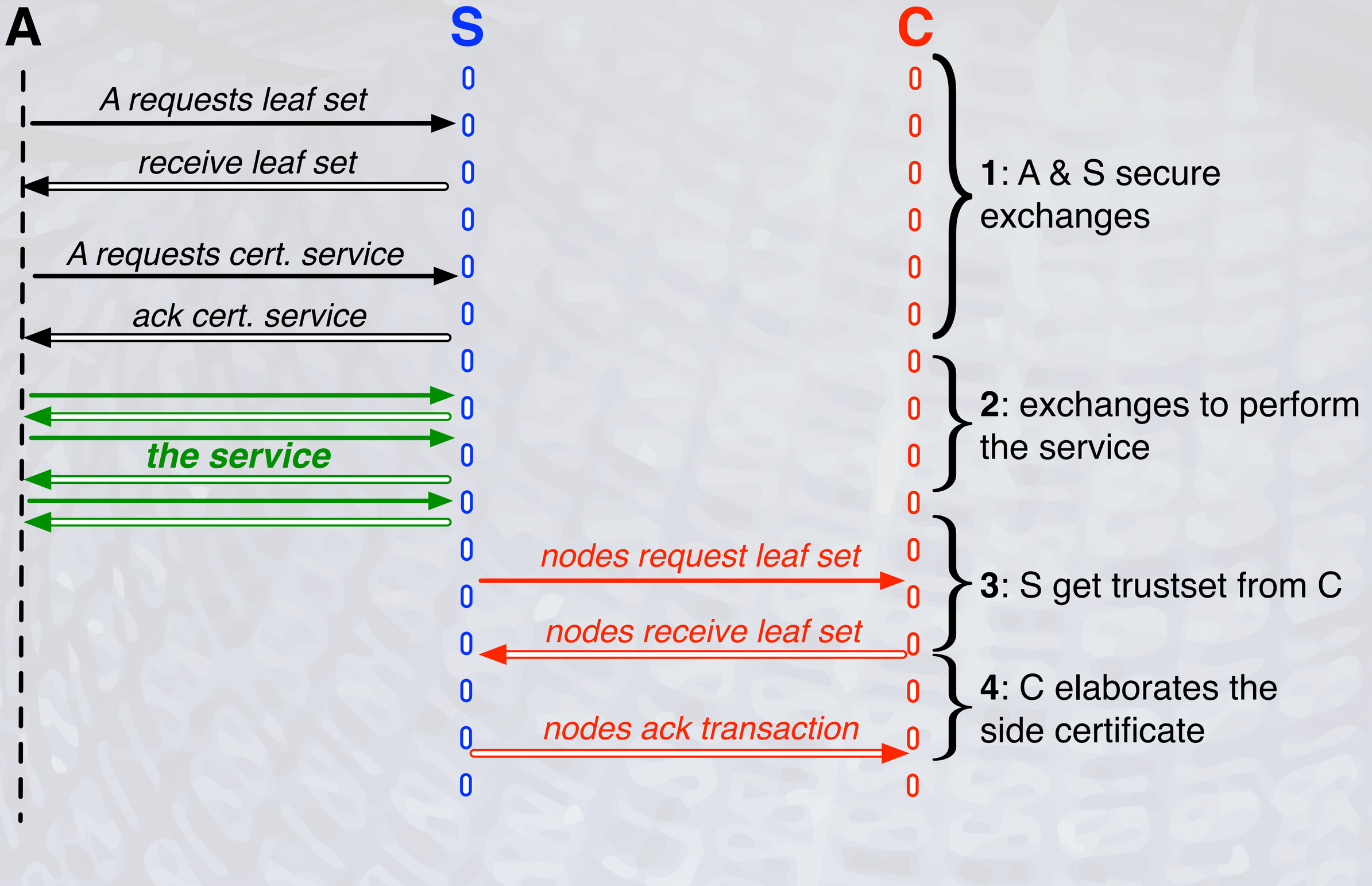

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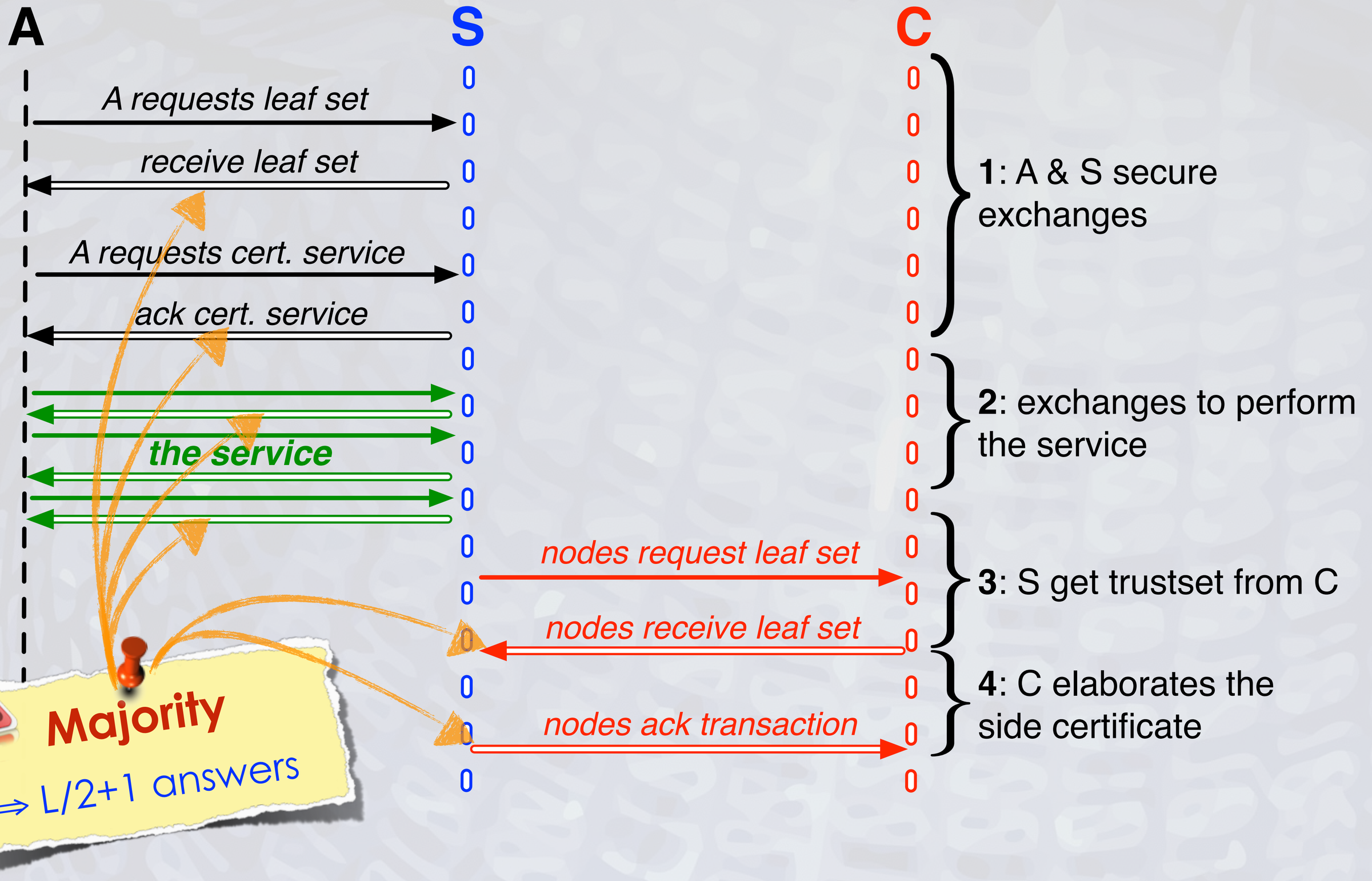

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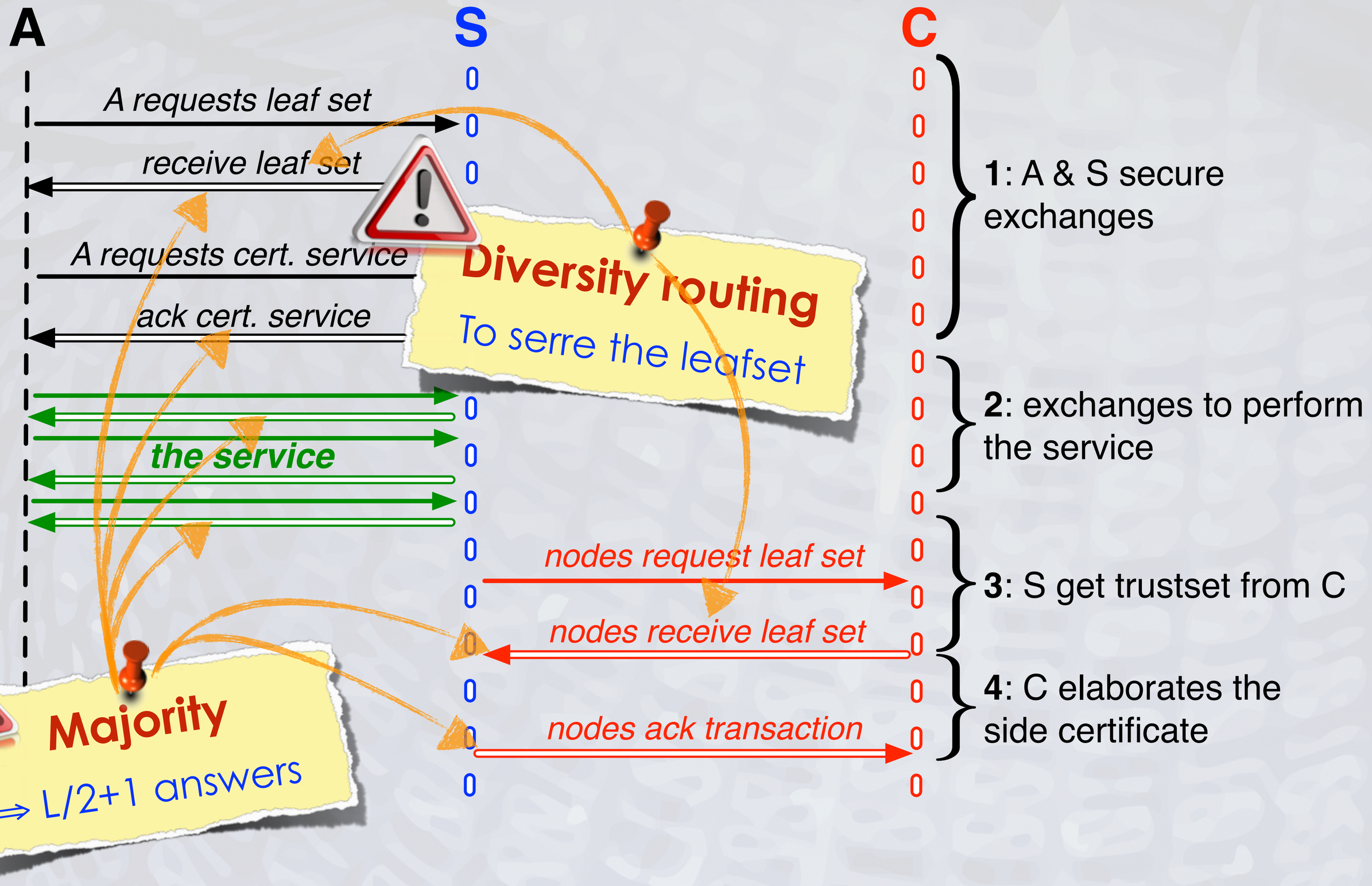
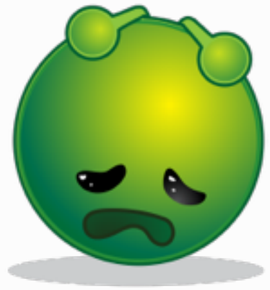


The verification process

- **Proof (by any method?)**
  - Proven to be undecidable [FLP 85]



Impossibility of Distributed Consensus with One Faulty Process

MICHAEL J. FISCHER

Yale University, New Haven, Connecticut

NANCY A. LYNCH

Massachusetts Institute of Technology, Cambridge, Massachusetts

AND

MICHAEL S. PATERSON

University of Warwick, Coventry, England

Abstract. The consensus problem involves an asynchronous system of processes, some of which may be unreliable. The problem is for the reliable processes to agree on a binary value. In this paper, it is shown that every protocol for this problem has the possibility of nontermination, even with only one faulty process. By way of contrast, solutions are known for the synchronous case, the "Byzantine Generals" problem.

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General Terms: Algorithms, Reliability, Theory

Additional Key Words and Phrases: Agreement problem, asynchronous system, Byzantine Generals problem, commit problem, consensus problem, distributed computing, fault tolerance, impossibility proof, reliability

1. *Introduction*

The problem of reaching agreement among remote processes is one of the most fundamental problems in distributed computing and is at the core of many

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- **So what?**
  - Being pragmatic
  - Going for «quasi»

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The verification process

Proof (by any method?)

- Proven to be undecidable [FLP 85]

So what?

- Being pragmatic
- Going for «quasi»

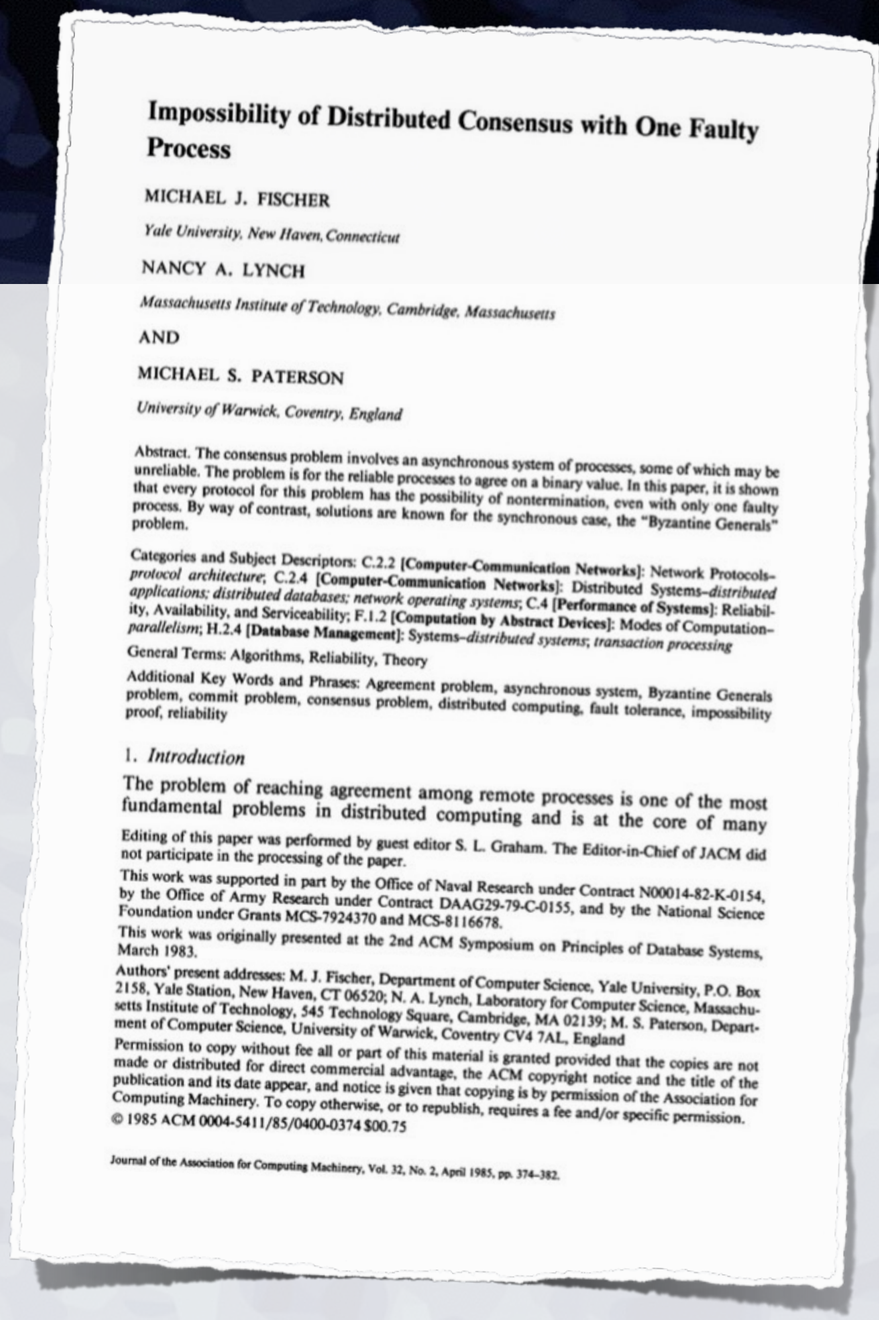
Two steps

1. modeling the protocol in a perfect world (no error)

   Use of Petri nets

2. Probabilistic analysis to evaluate the failure rate

   Use of a classical fault model,
   building a formula + numeric evaluation



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Modeling the protocol (step 1)

Hypotheses

H_1: perfect world

H_2: service reduced to 1 interaction

H_3: L+1 answer requested instead of L/2+1

- **Symmetric net with Bags?**

Modeling the protocol (step 1)

Types and variables

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type tsid is 0..L;
type tsidxtsid is <tsid, tsid>;

var i in tsid;
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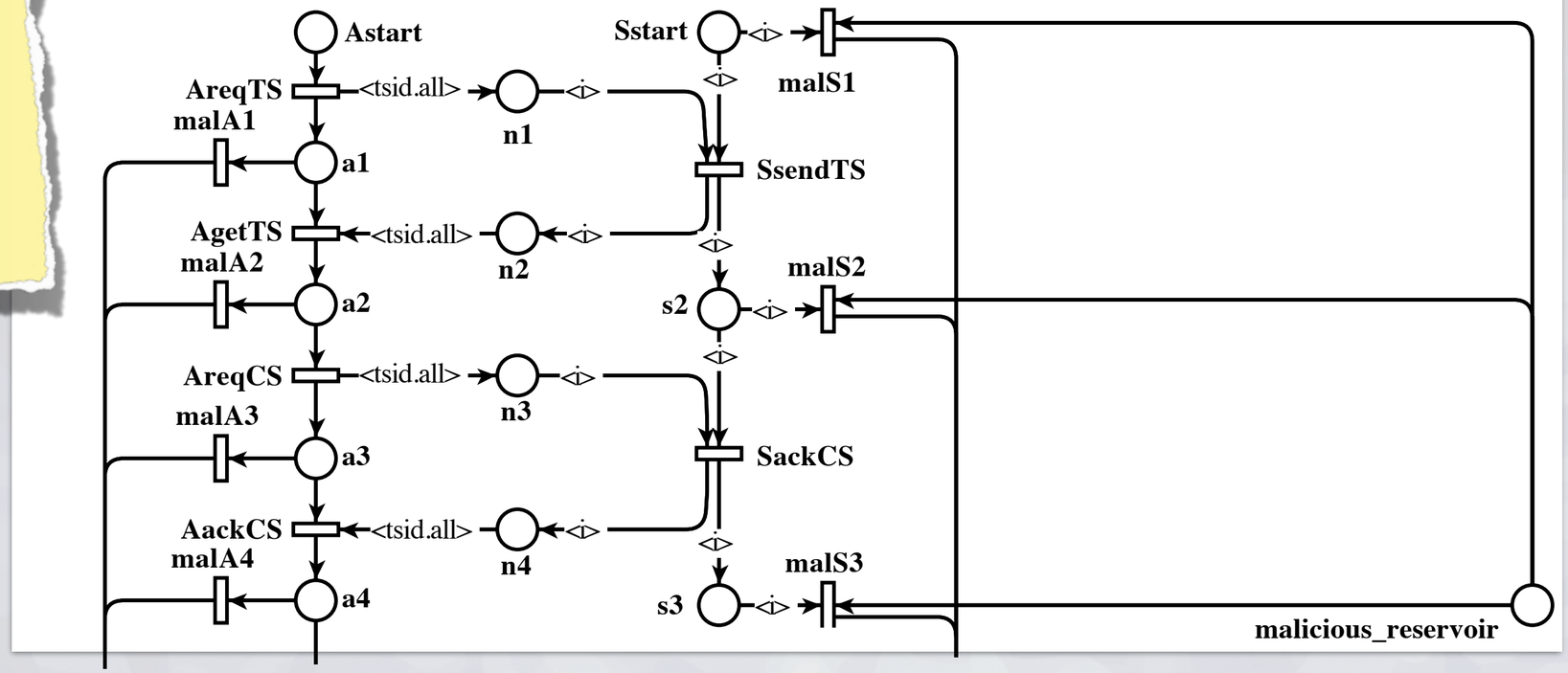

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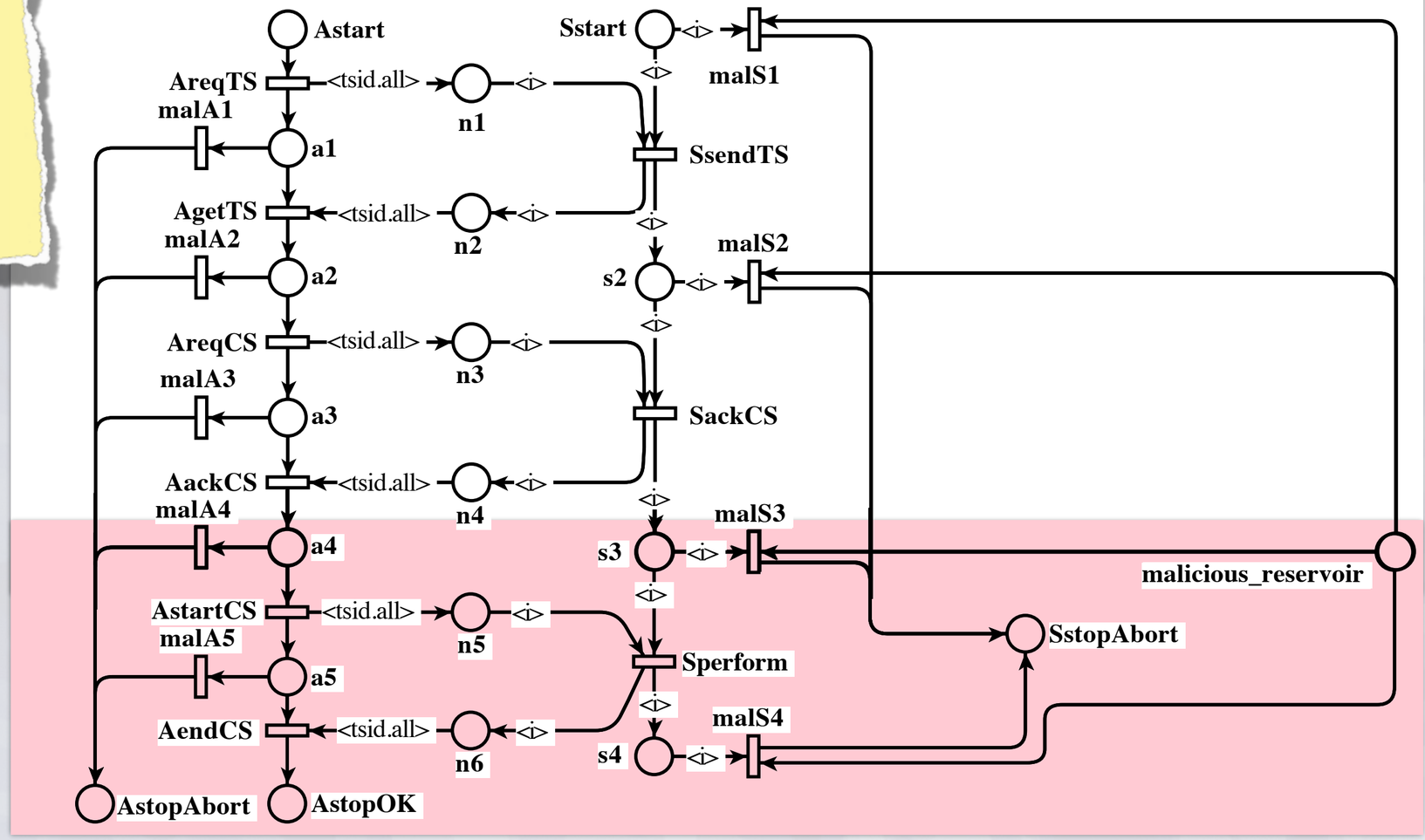

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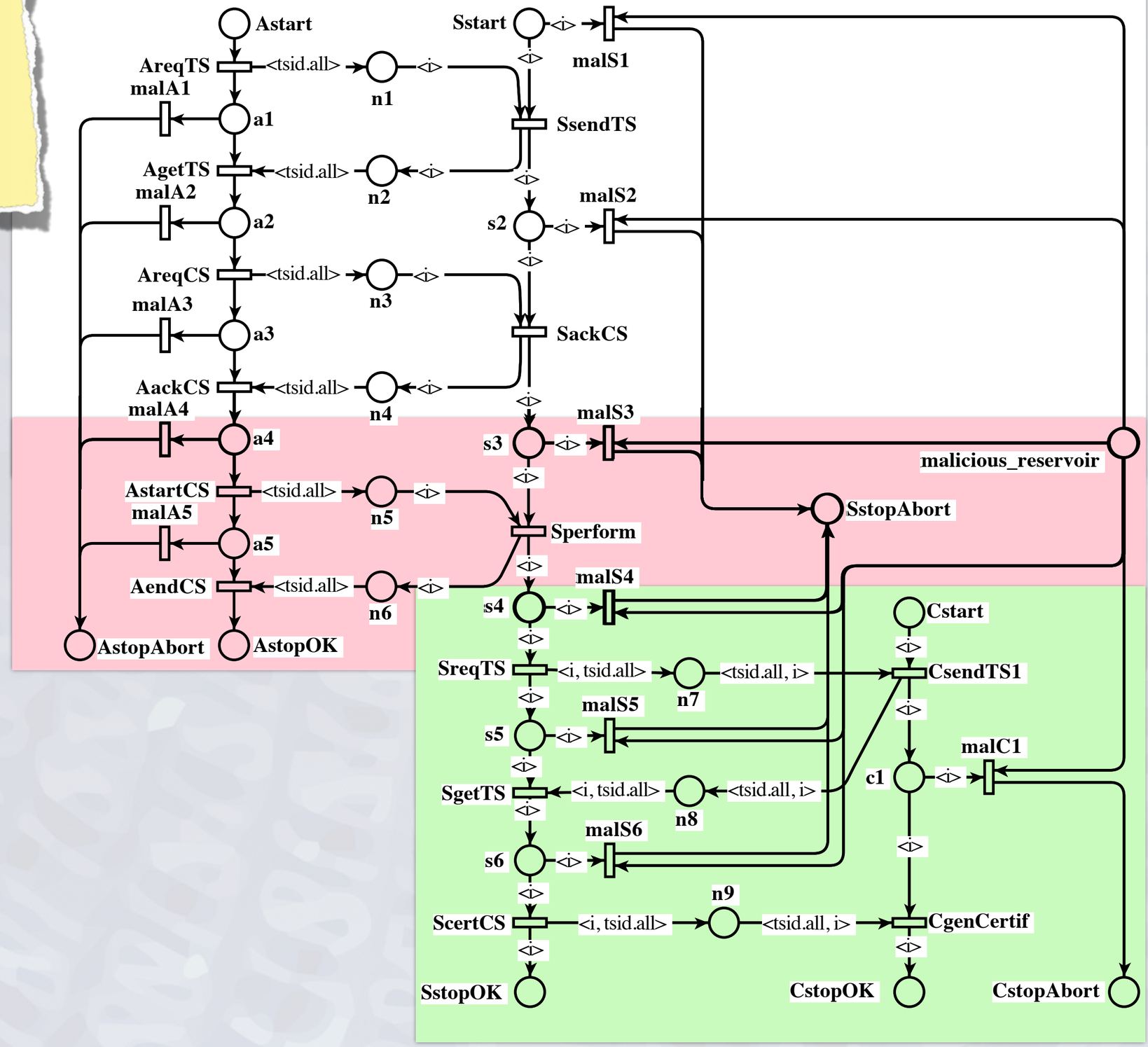

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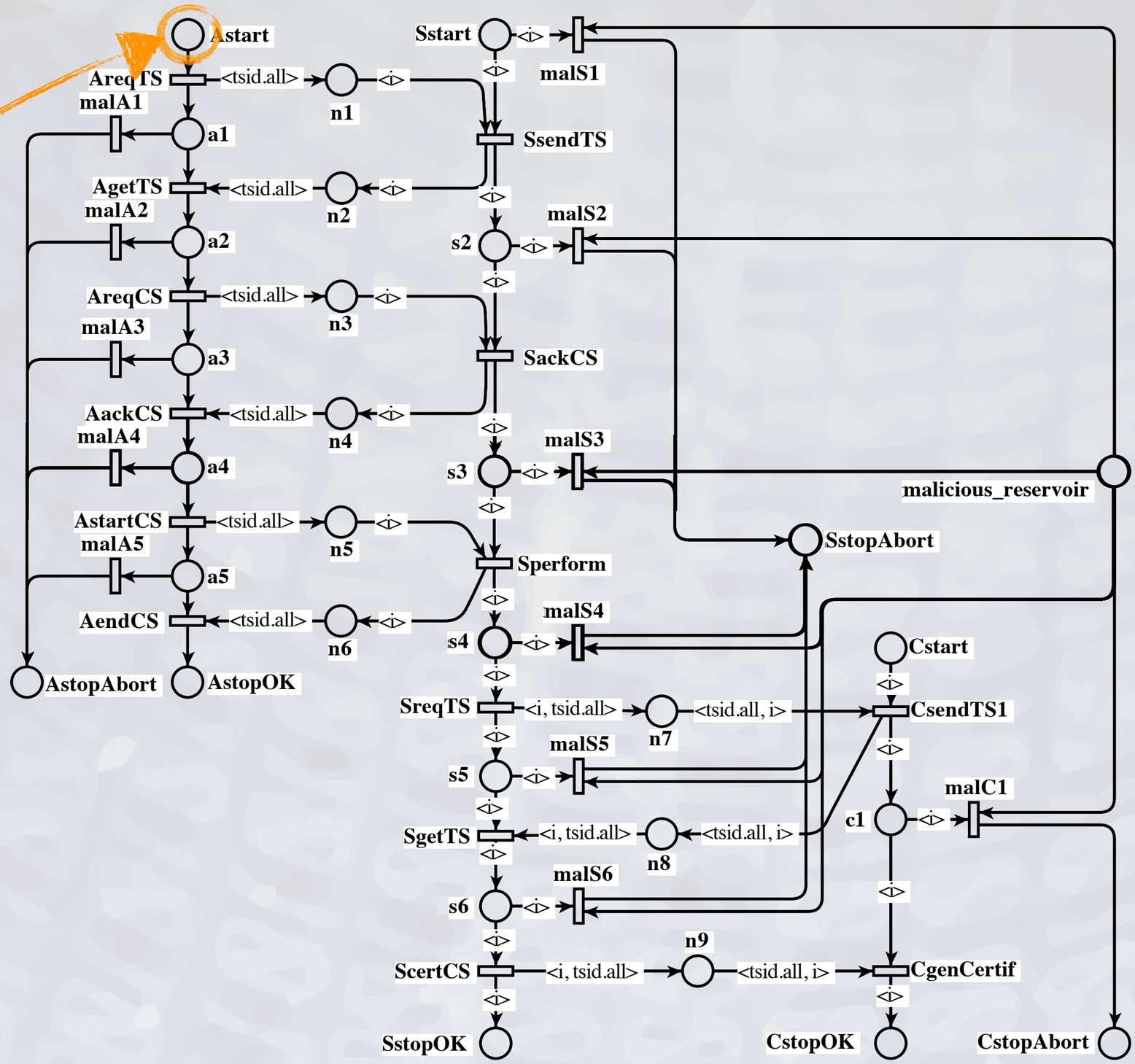

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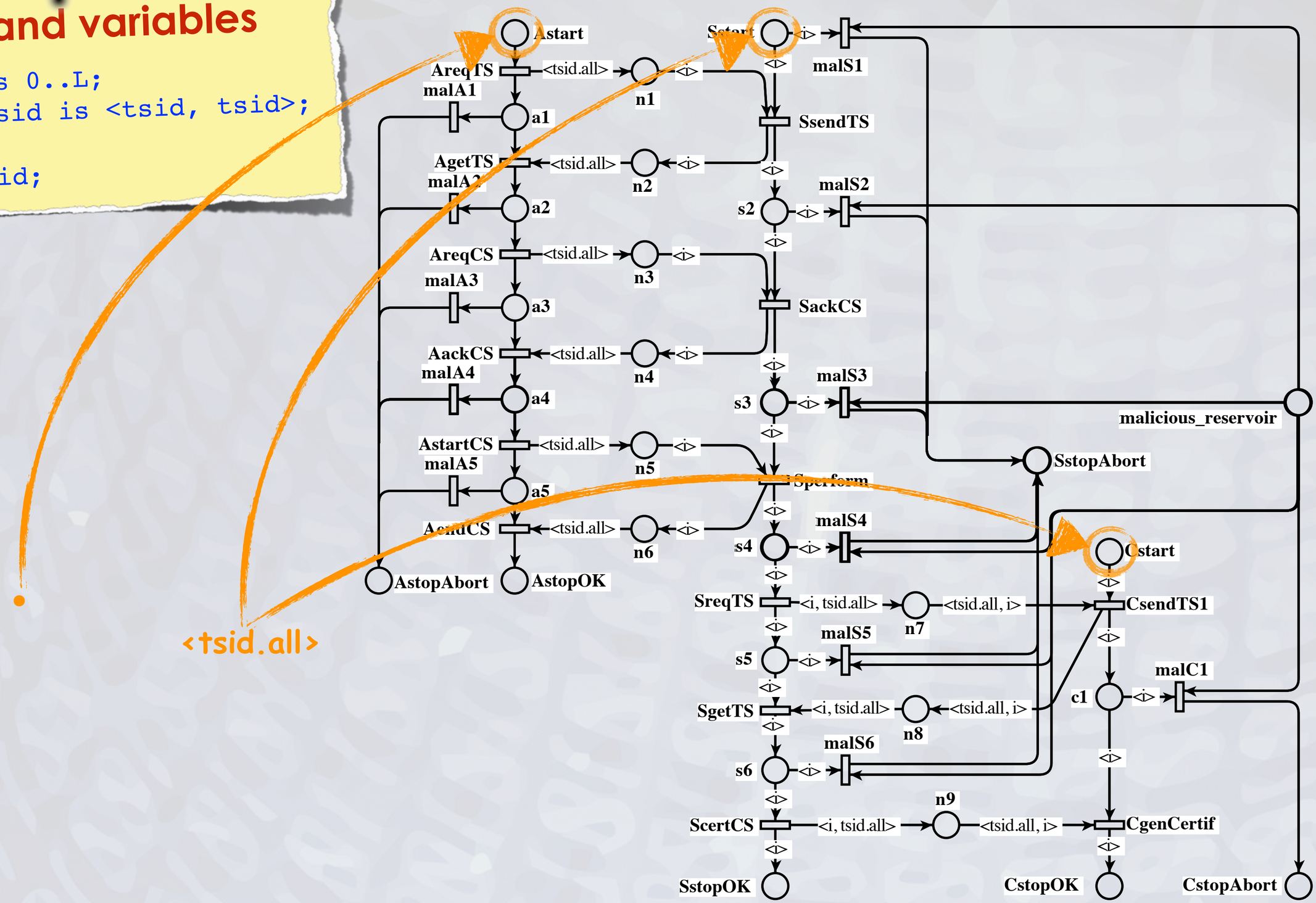

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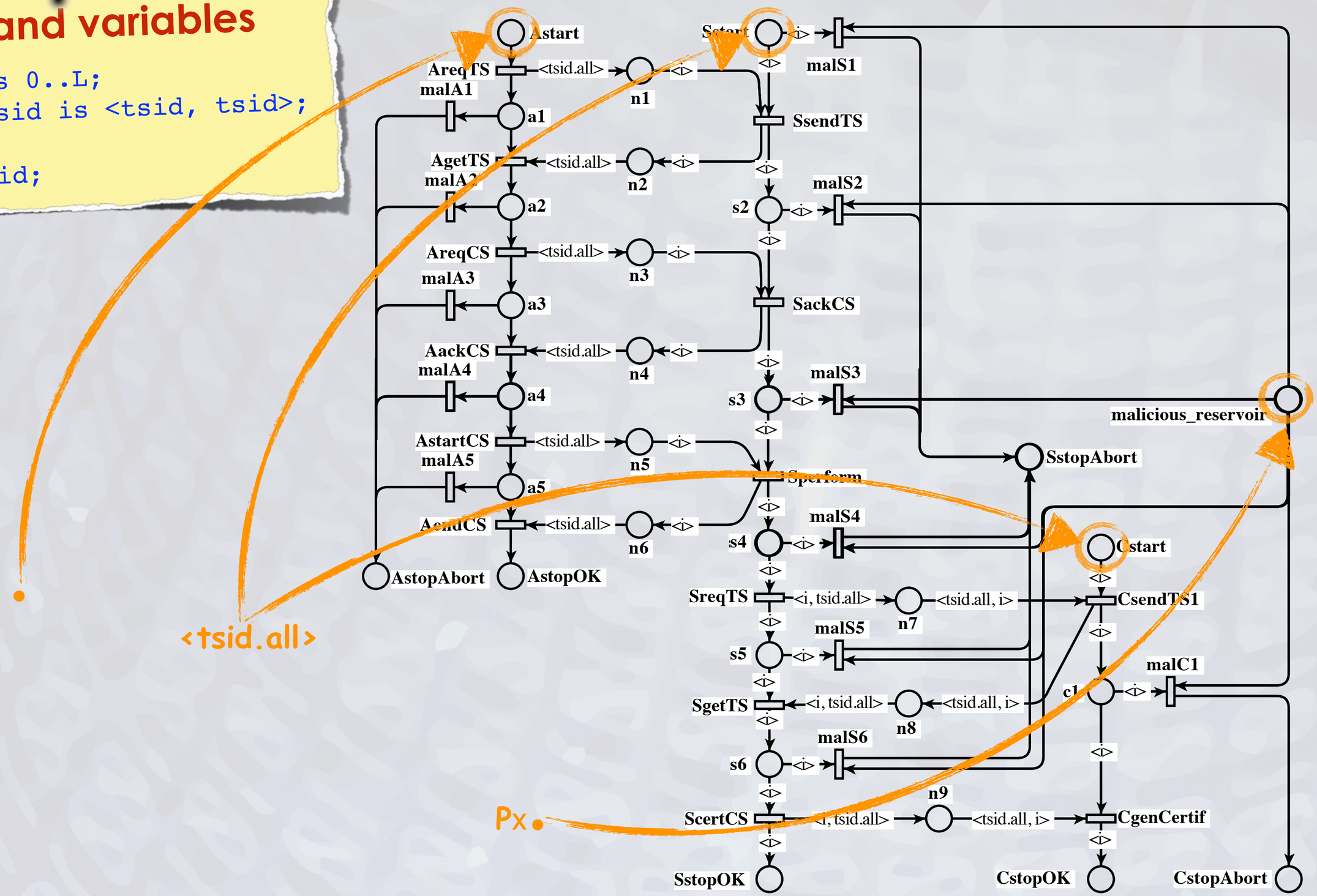

Modeling the protocol (step 1)

$$F_{ok} = |SstopOK| > \frac{L}{2} \wedge |CstopOK| > \frac{L}{2}$$

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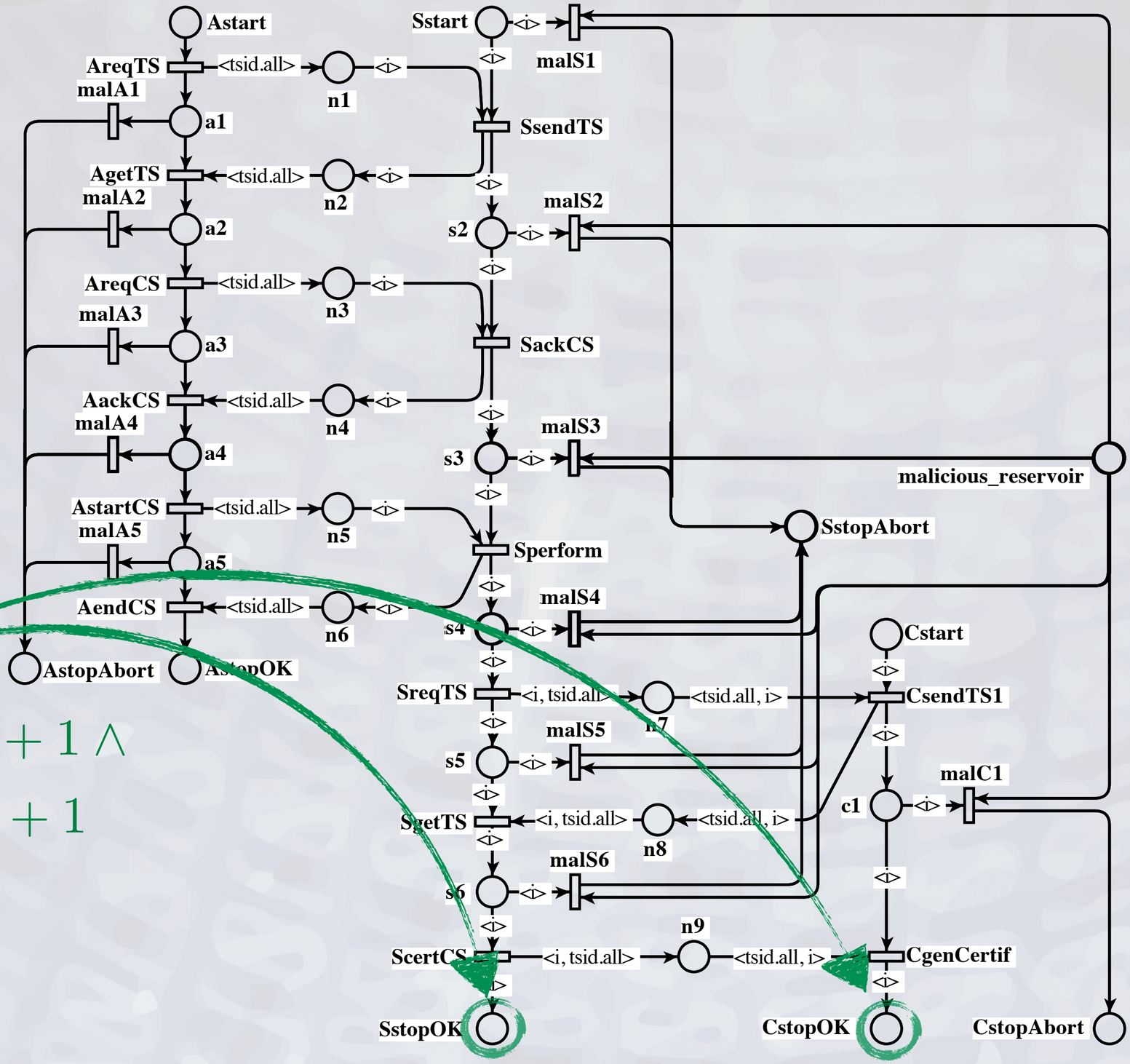

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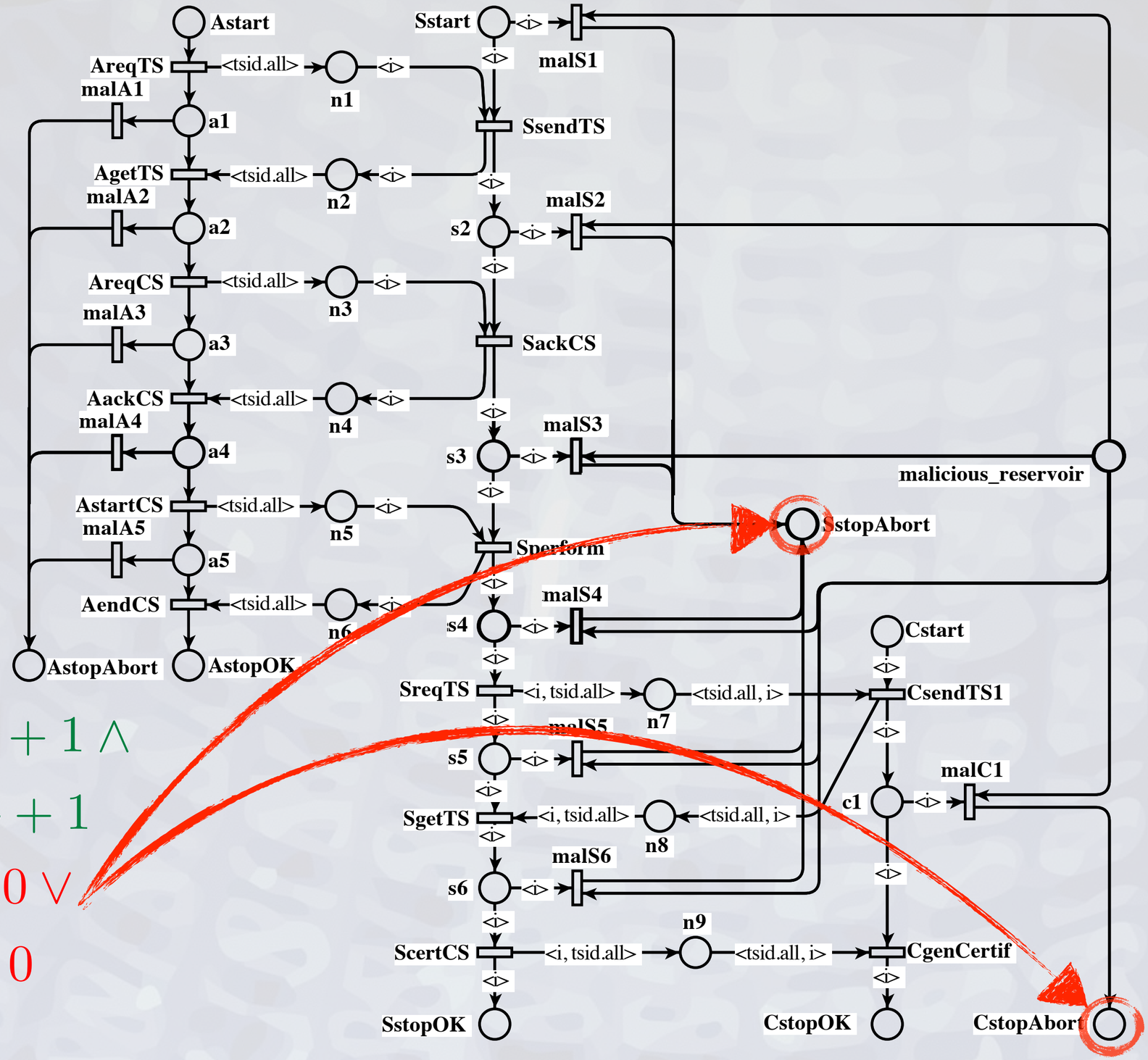
$$F_{abort} = |SstopAbort| > \frac{L}{2} \vee |CstopAbort| > \frac{L}{2}$$

$$F_{ok} = |SstopOK| = L+1 \wedge |CstopOK| = L+1$$

$$F_{abort} = |SstopAbort| > 0 \vee |CstopAbort| > 0$$



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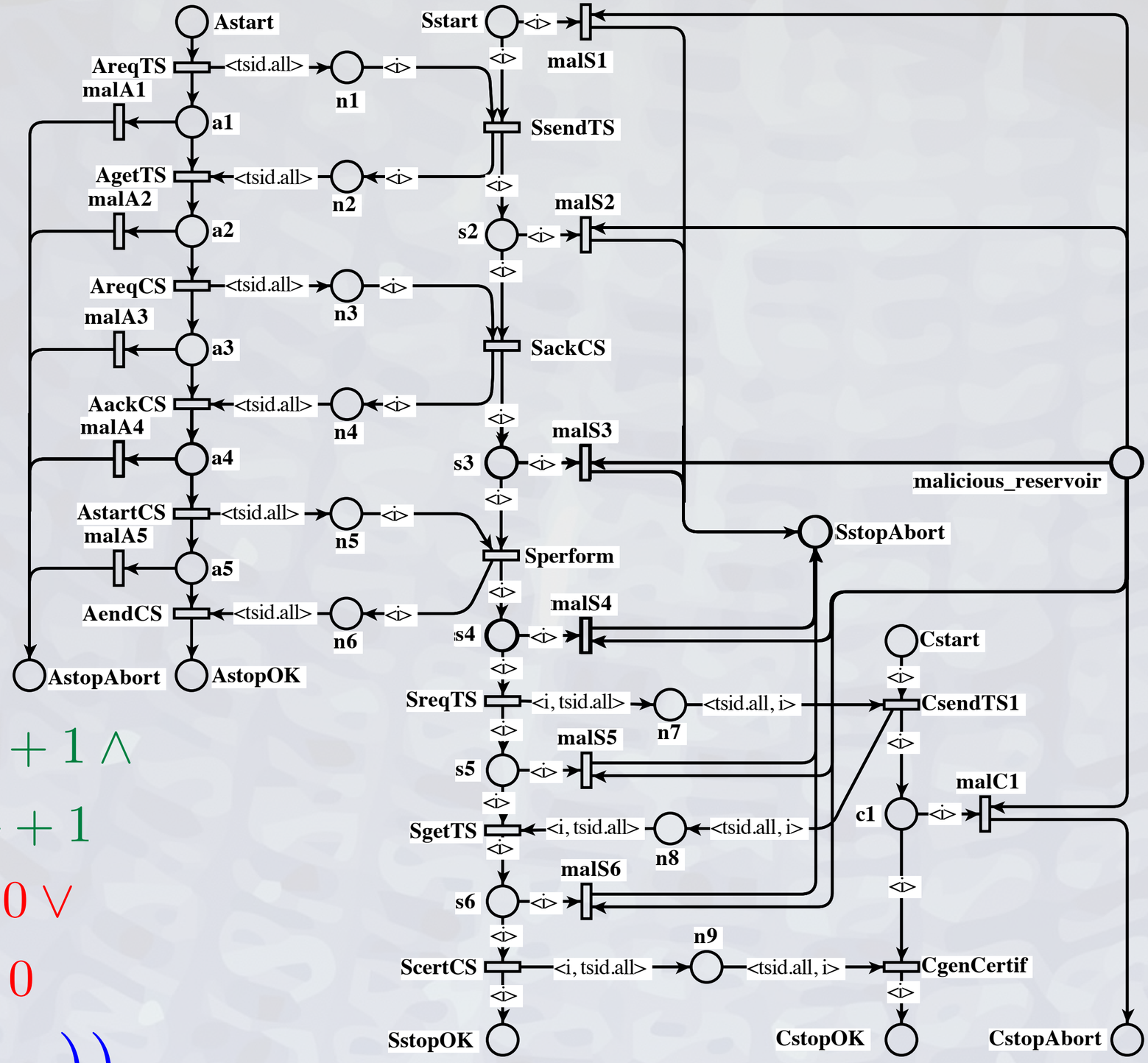

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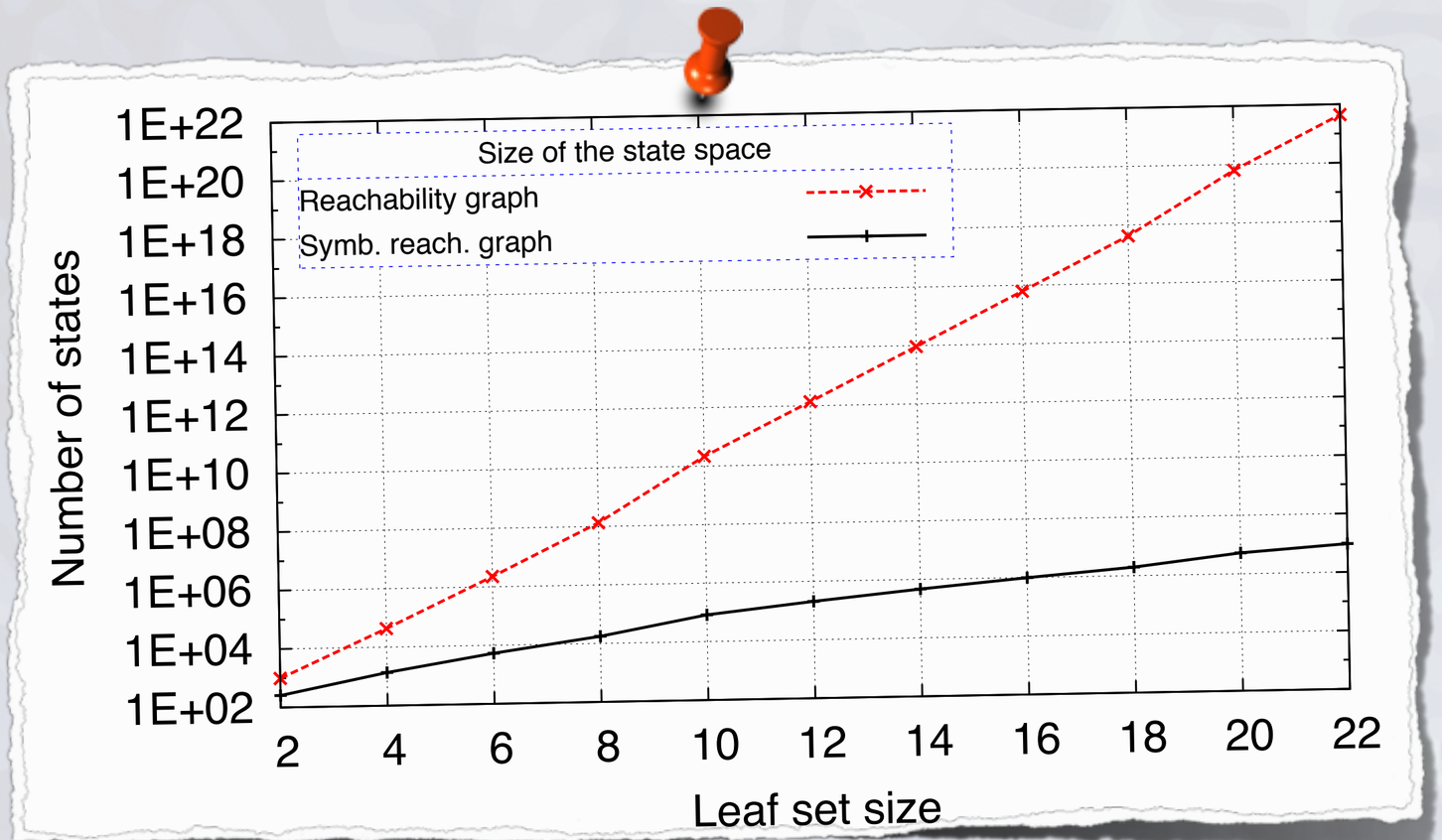
$$AF(F_{ok} \vee F_{abort})$$

Verifying the perfect world

About the complexity of the state space

- Roughly 10^L states
- 1 state= 13 int + 17 multistep ⇒ memory problem to check for L=32



Verifying the perfect world

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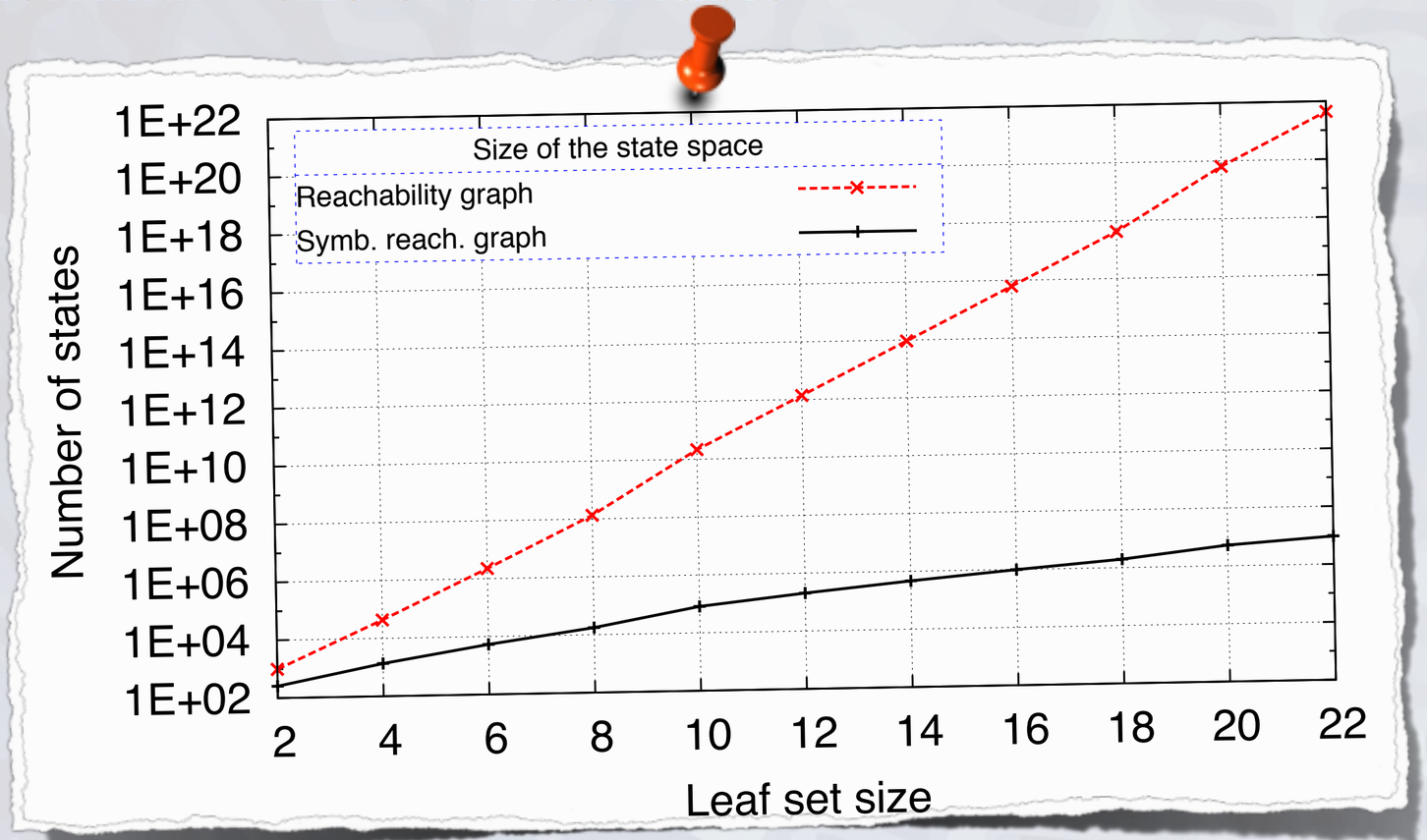

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- **ITS-Tools (hierarchical decision diagrams)**
  - Completed for L=32 in less than one minute
    - **Handling of symmetries in the system by means of a dedicated encoding**

Verifying the perfect world

http://cosyverif.org

Probabilistic analysis (step 2)

Classical approach of the domain

- Based on **p**, probability of node failure

Hypotheses required

Diversity routing to avoid coalitions

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Numerical applications

p = 0.3 («untrusted»)

P = 0.05 («trusted»)

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Formulas and experimental values

Protocol failure

- More that L/2 nodes are malicious
- The formula:

$$\underbrace{\sum_{i=1}^{L+1} \binom{L+1}{i} p^i (1-p)^{L+1-i}}_{\text{at most L+1 malicious nodes}} - \underbrace{\sum_{i=1}^{\frac{L}{2}} \binom{L+1}{i} p^i (1-p)^{L+1-i}}_{\text{at most L/2 malicious nodes}}$$

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- Two parts
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8	0.216	4.97×10^{-4}
16	0.075	3.50×10^{-8}
32	0.014	4.24×10^{-13}

Conclusion

- **Quasi-certification entity (elaboration + verification)**
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- **3 years of work (details recently fixed)**
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  - **Without formal proof (there was yet glitches details with hypotheses)**
- **Realistic problem with applicability to e-government**
  - Probably numerous applications in the future
  - The model is now a metric for the Model Checking Contest
  - Potential applicability for Symmetric Nets with Bags
    - **Excellent playground for this type of problems**