Verification of Communicating Automata

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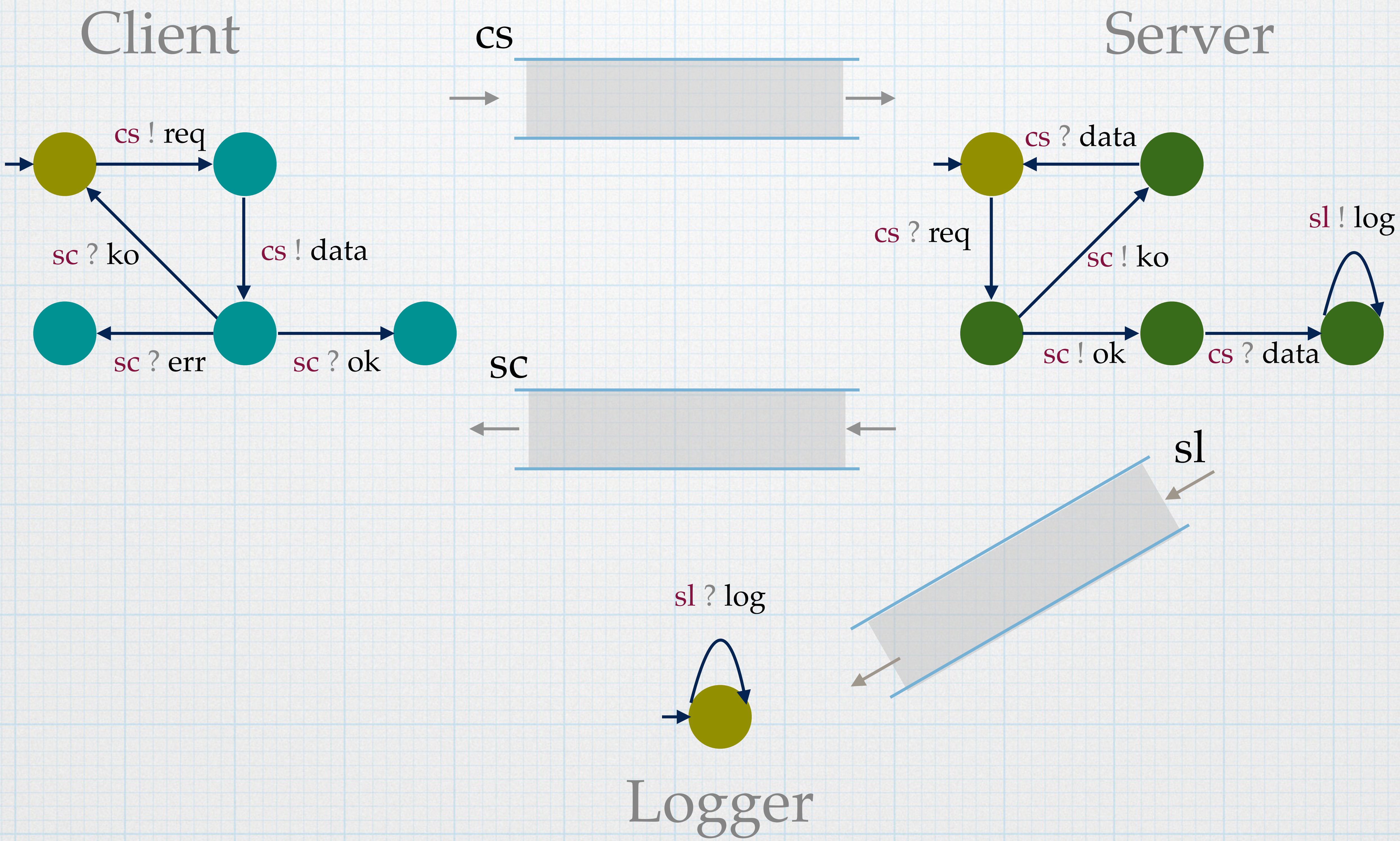
The model

- Labelled transition systems, or automata communicating via FIFO queues
- Model distributed behaviour
  - composition of web services
  - cyber-physical devices
  - program behaviours, etc.

[LY19]

The model



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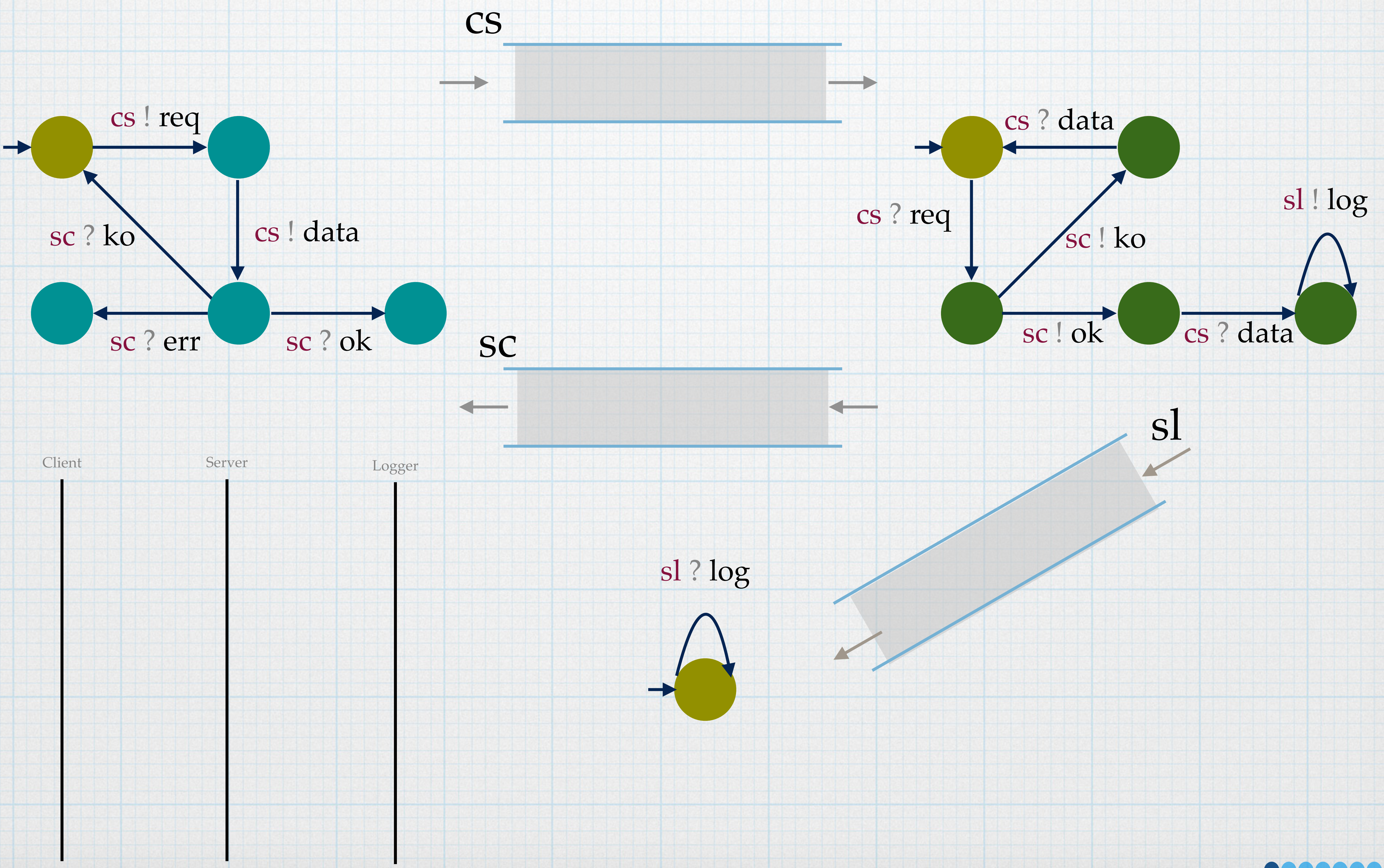
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Logger

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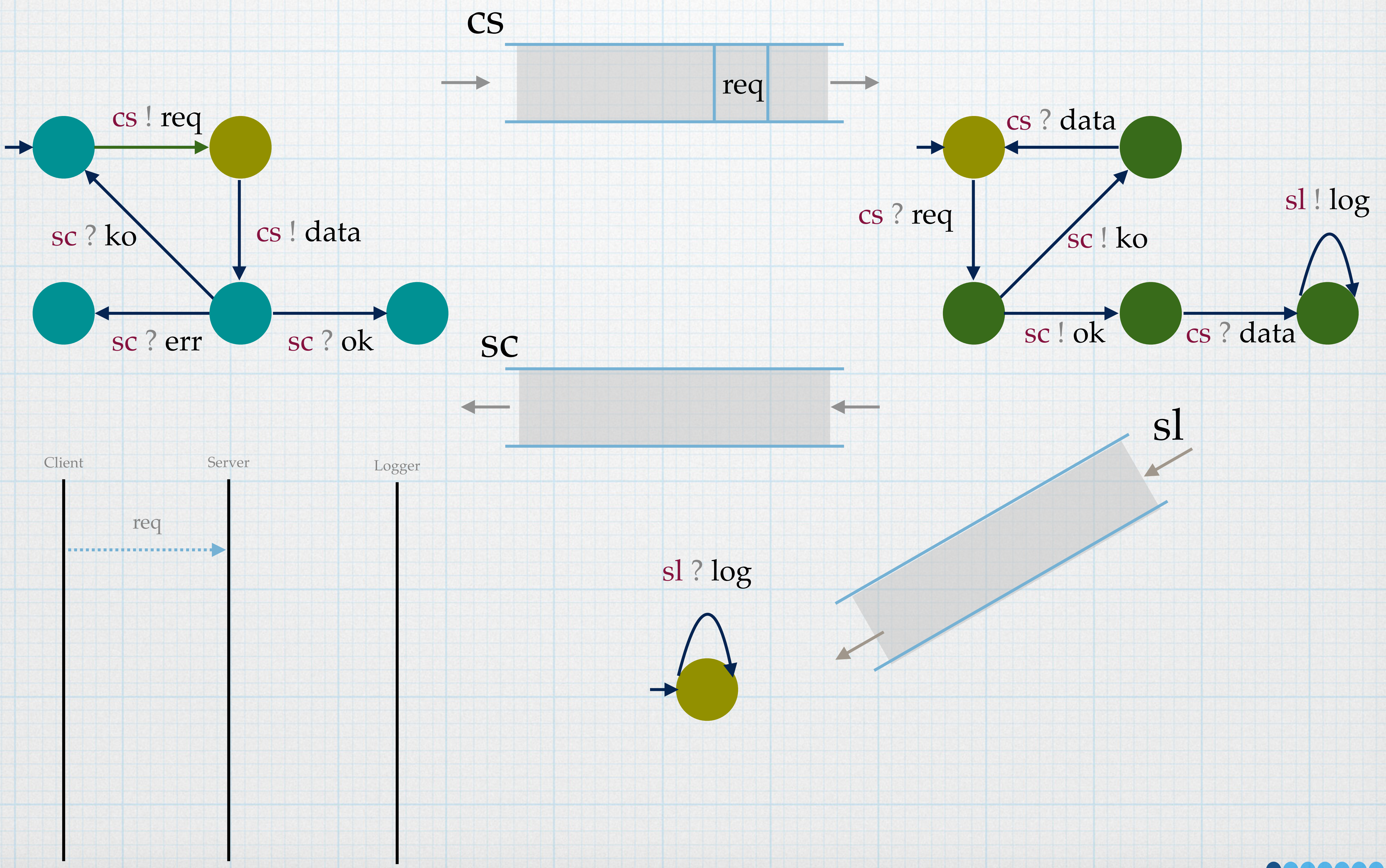
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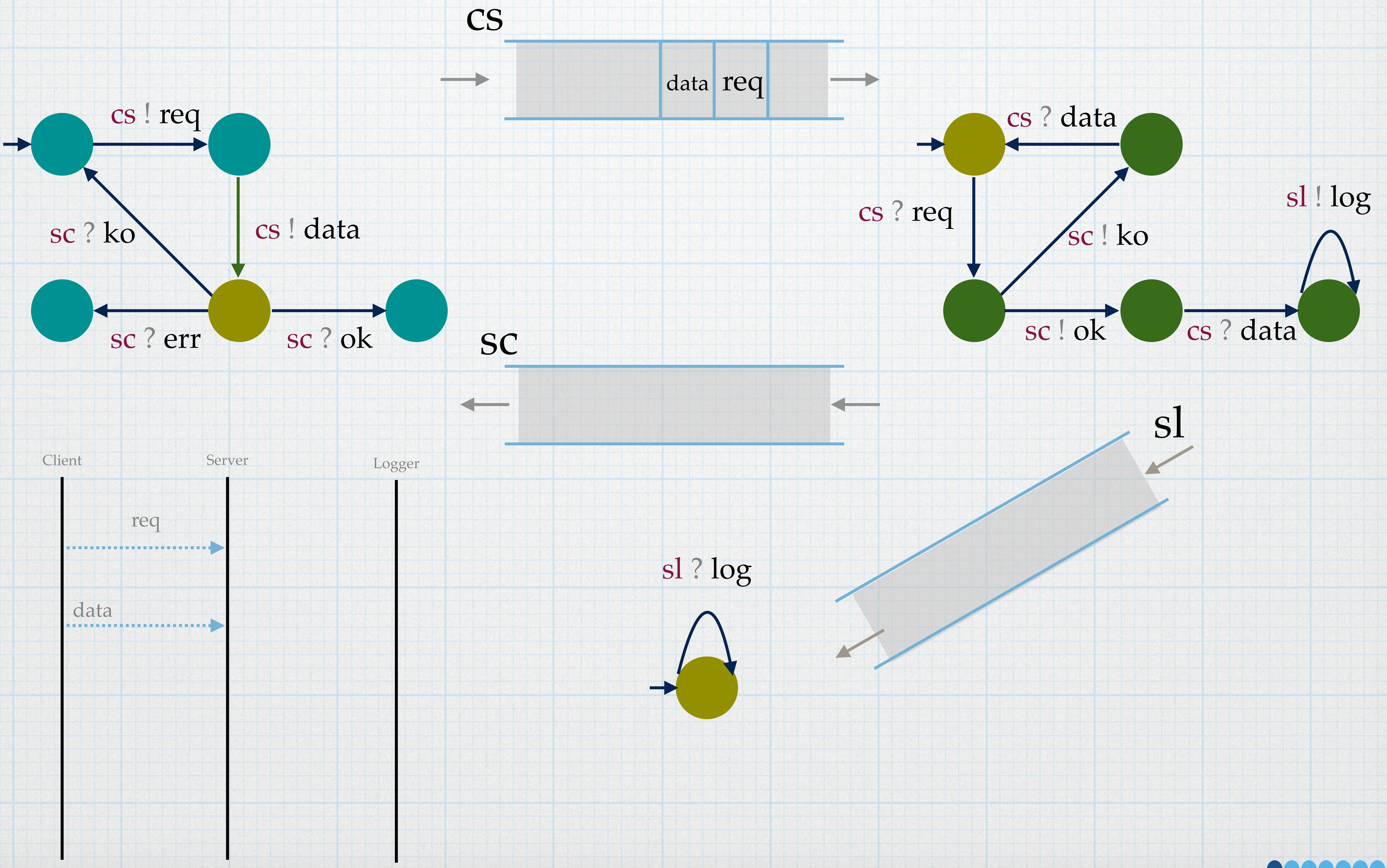
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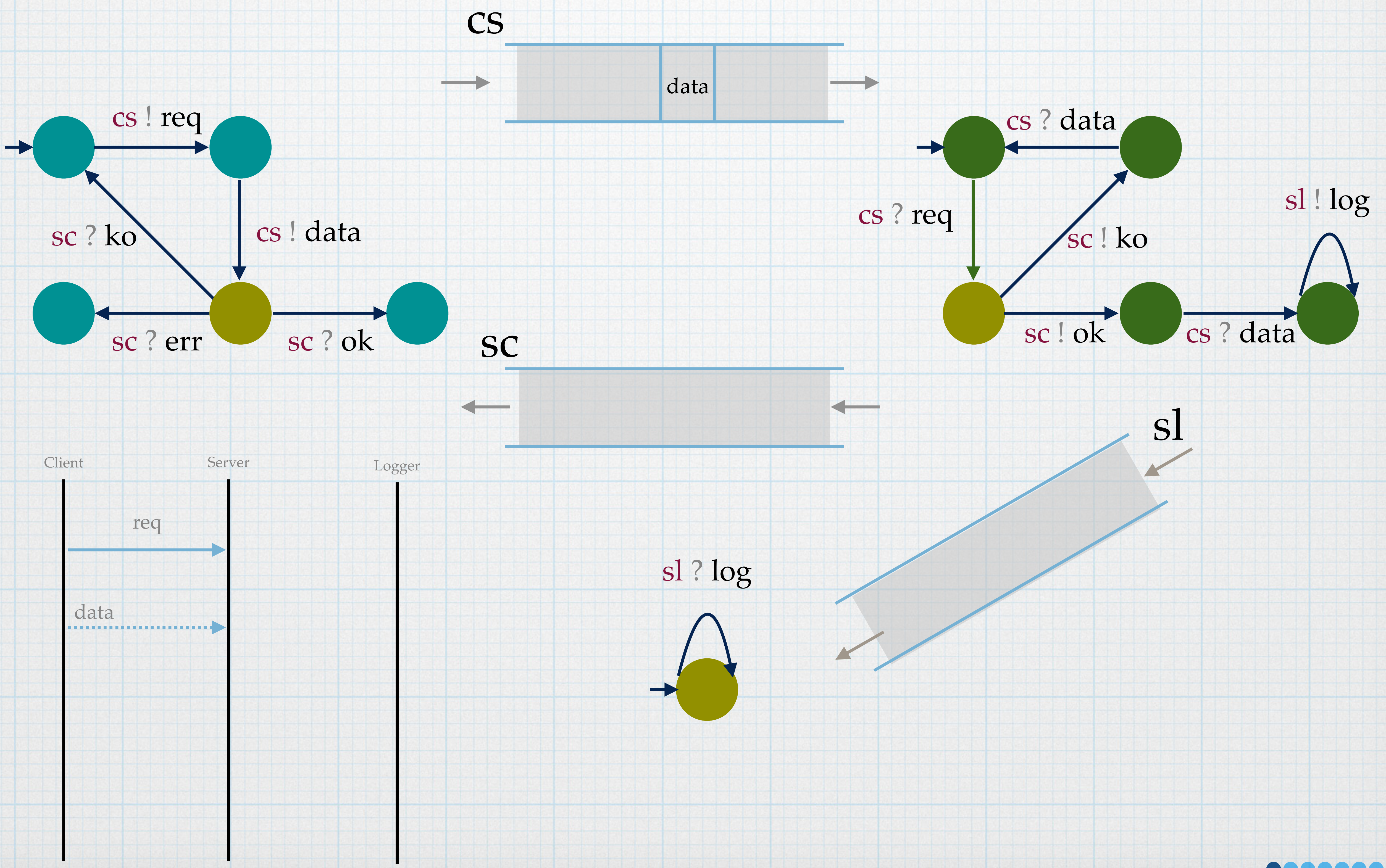
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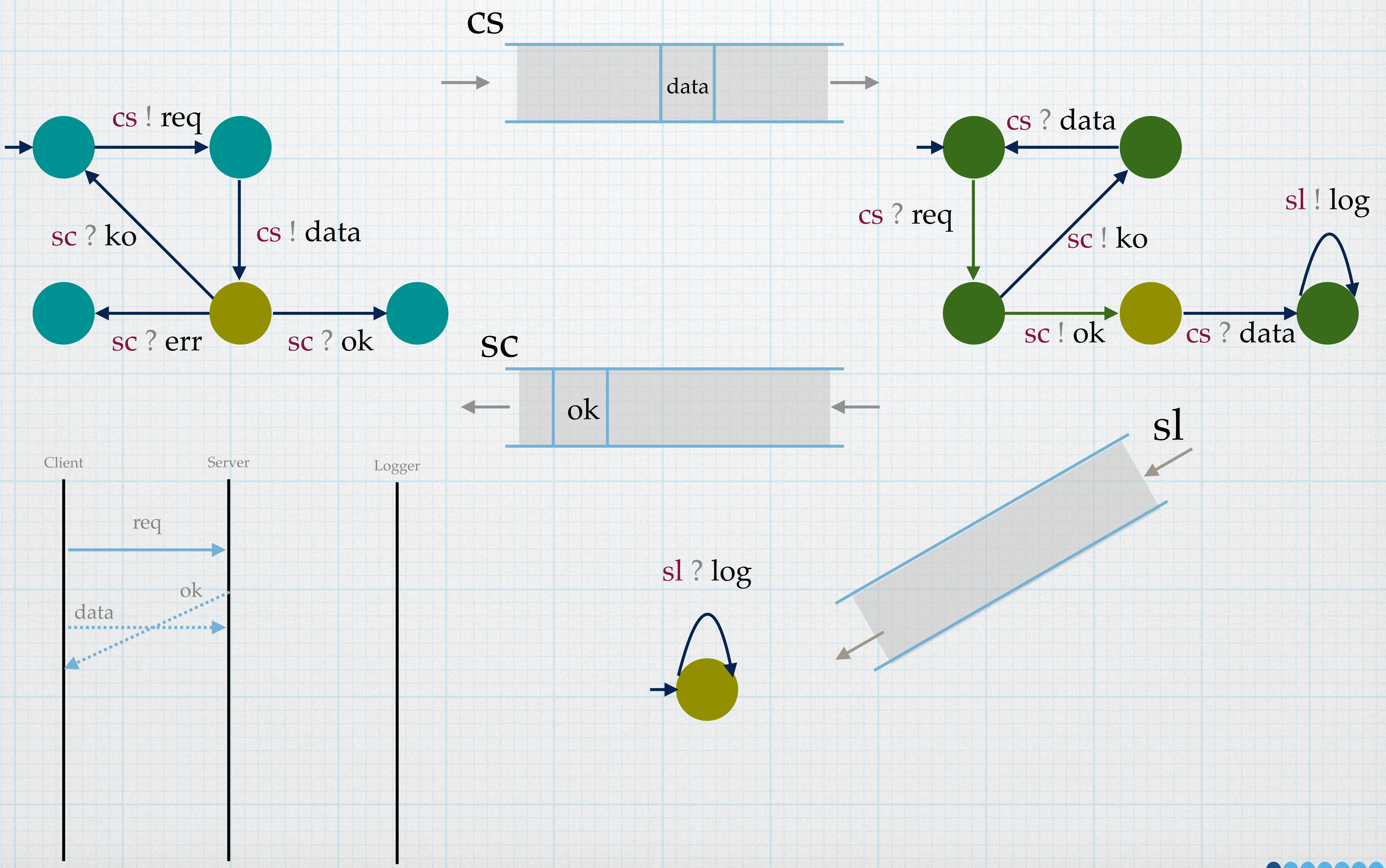
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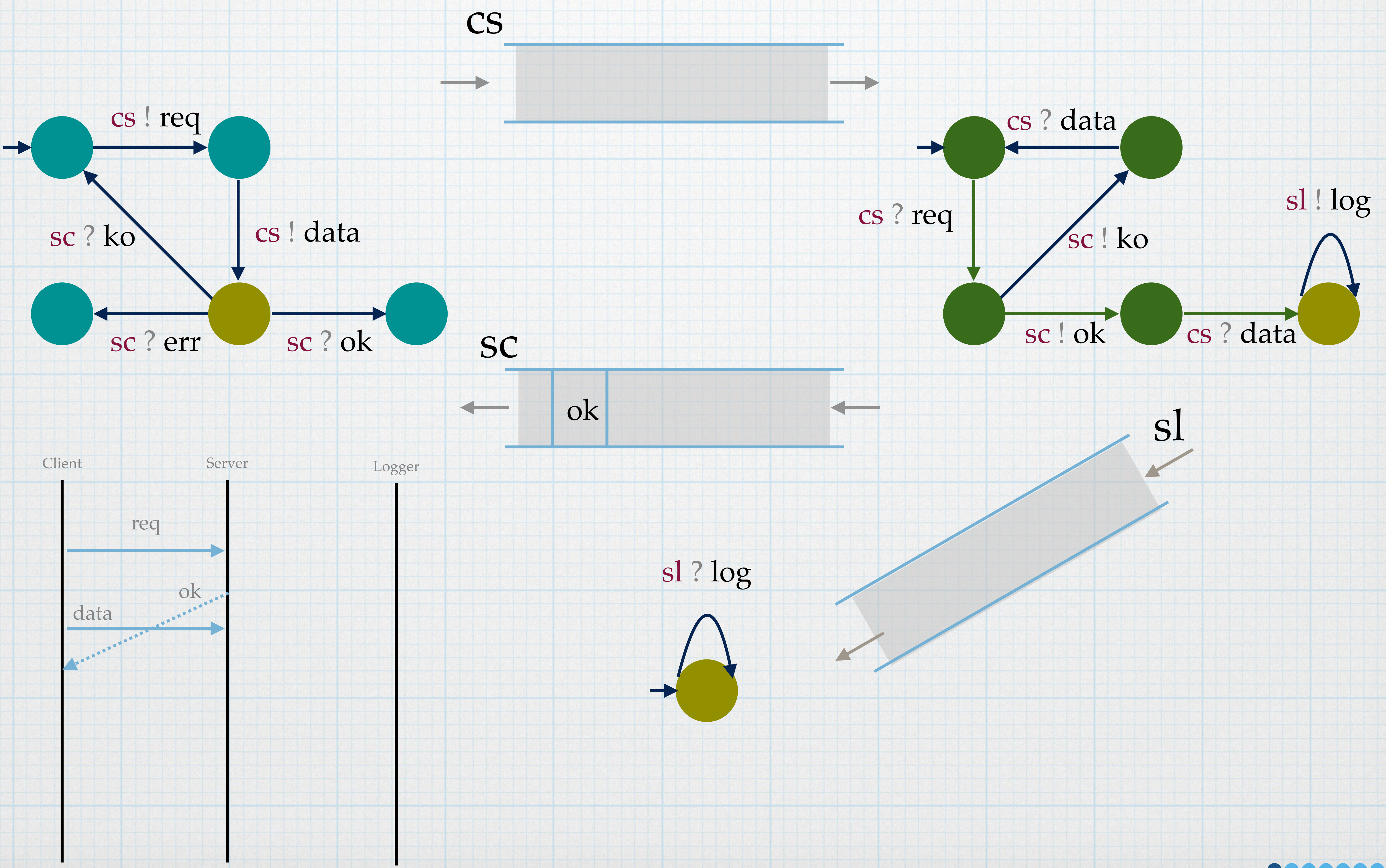
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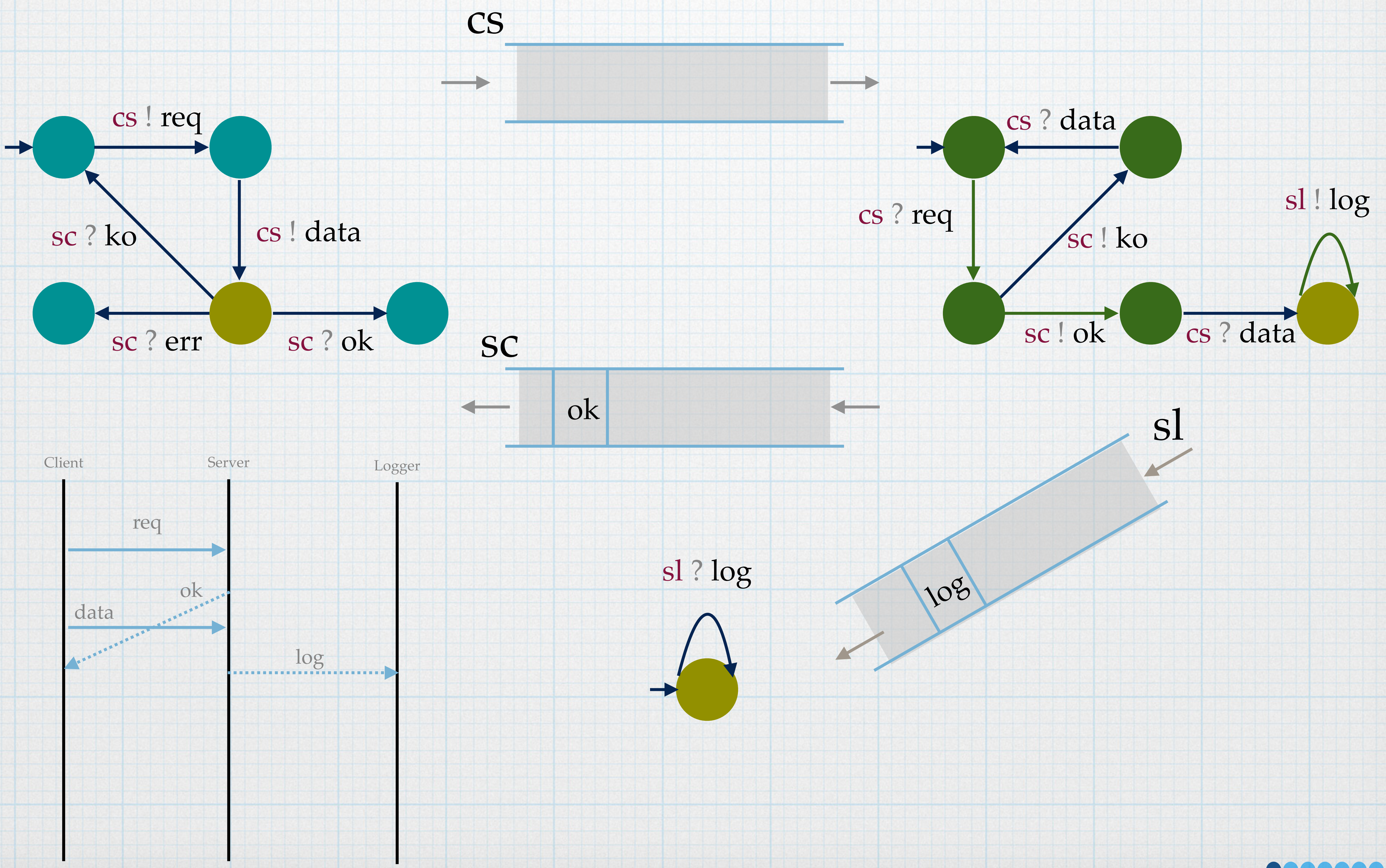
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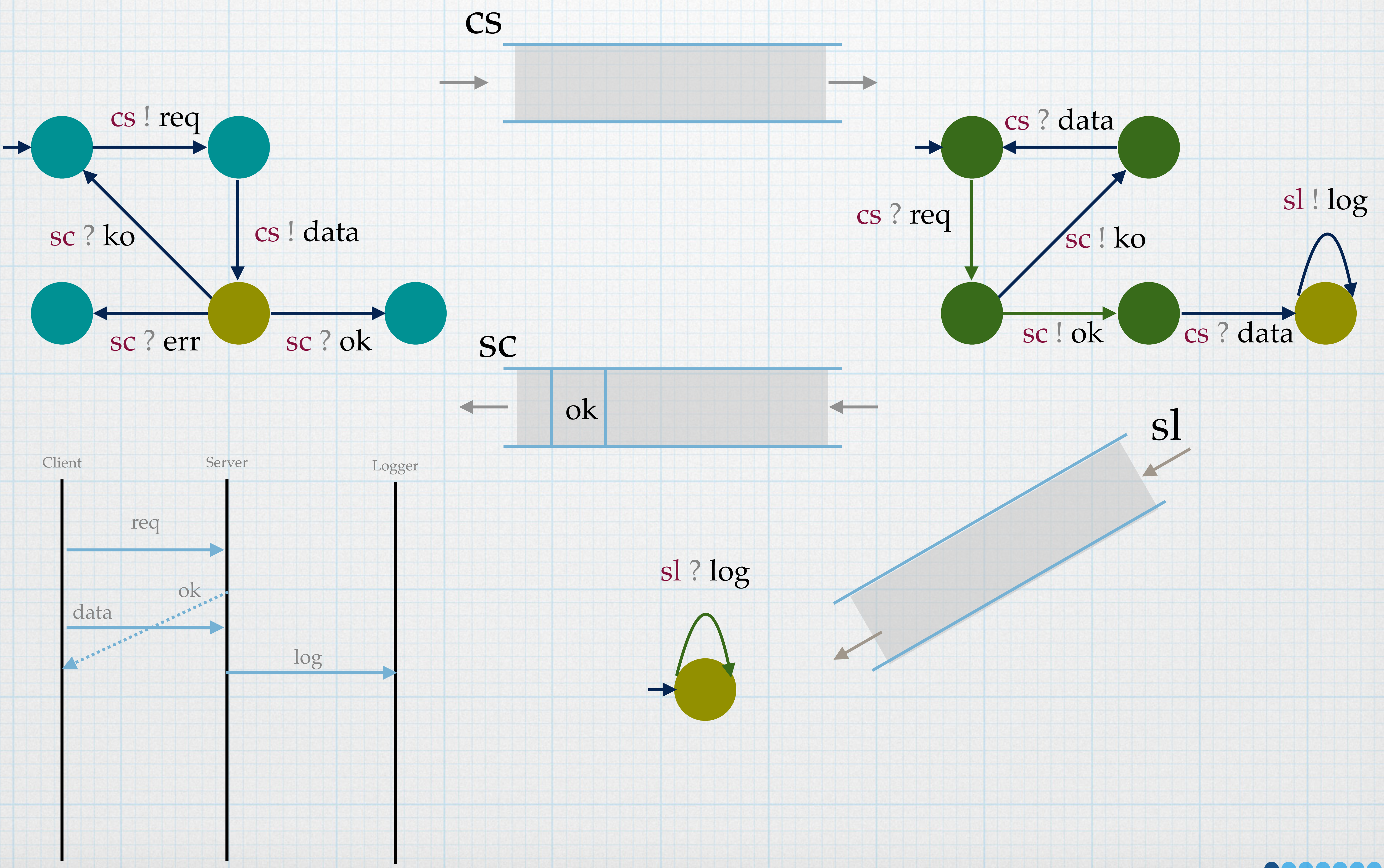

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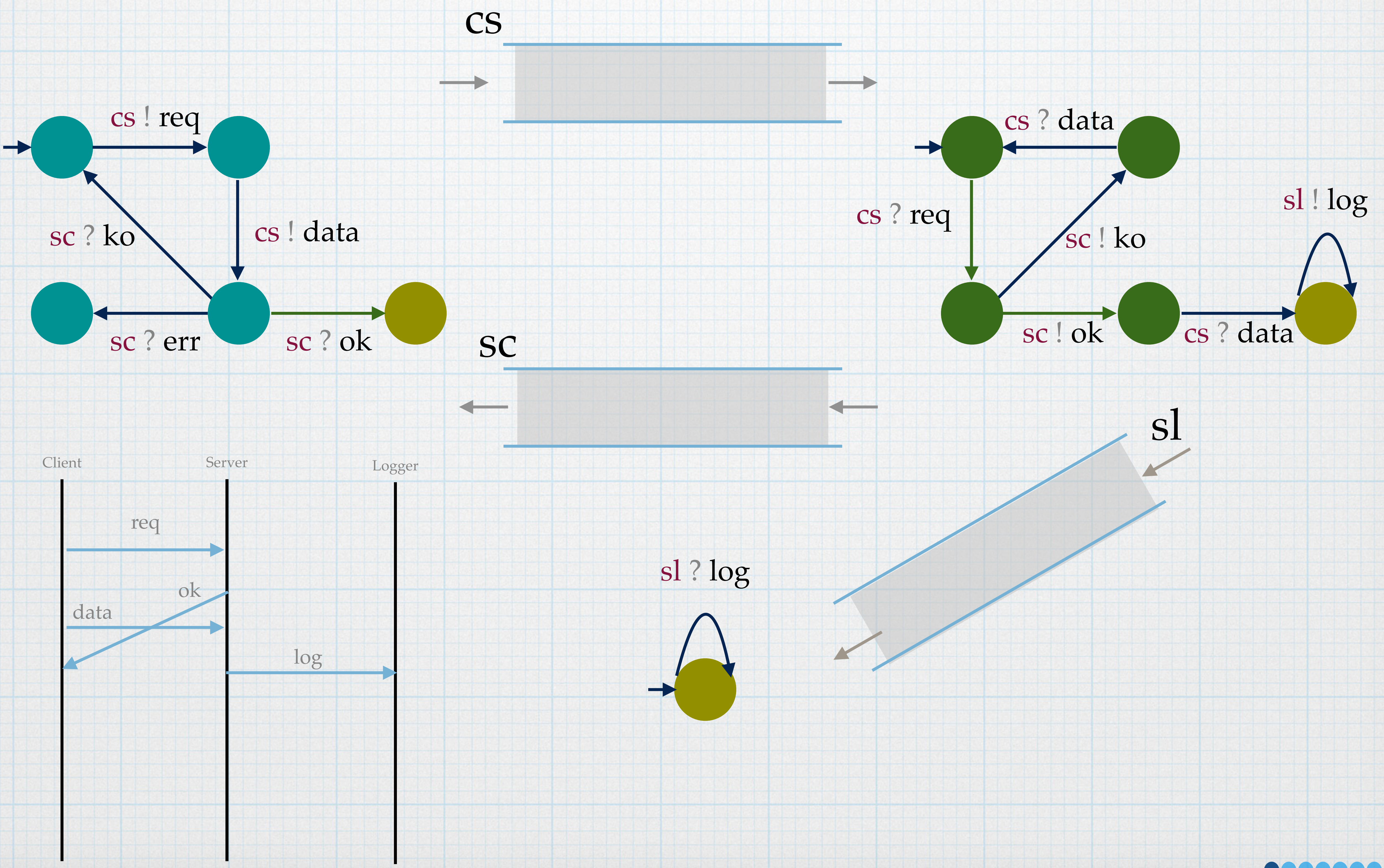
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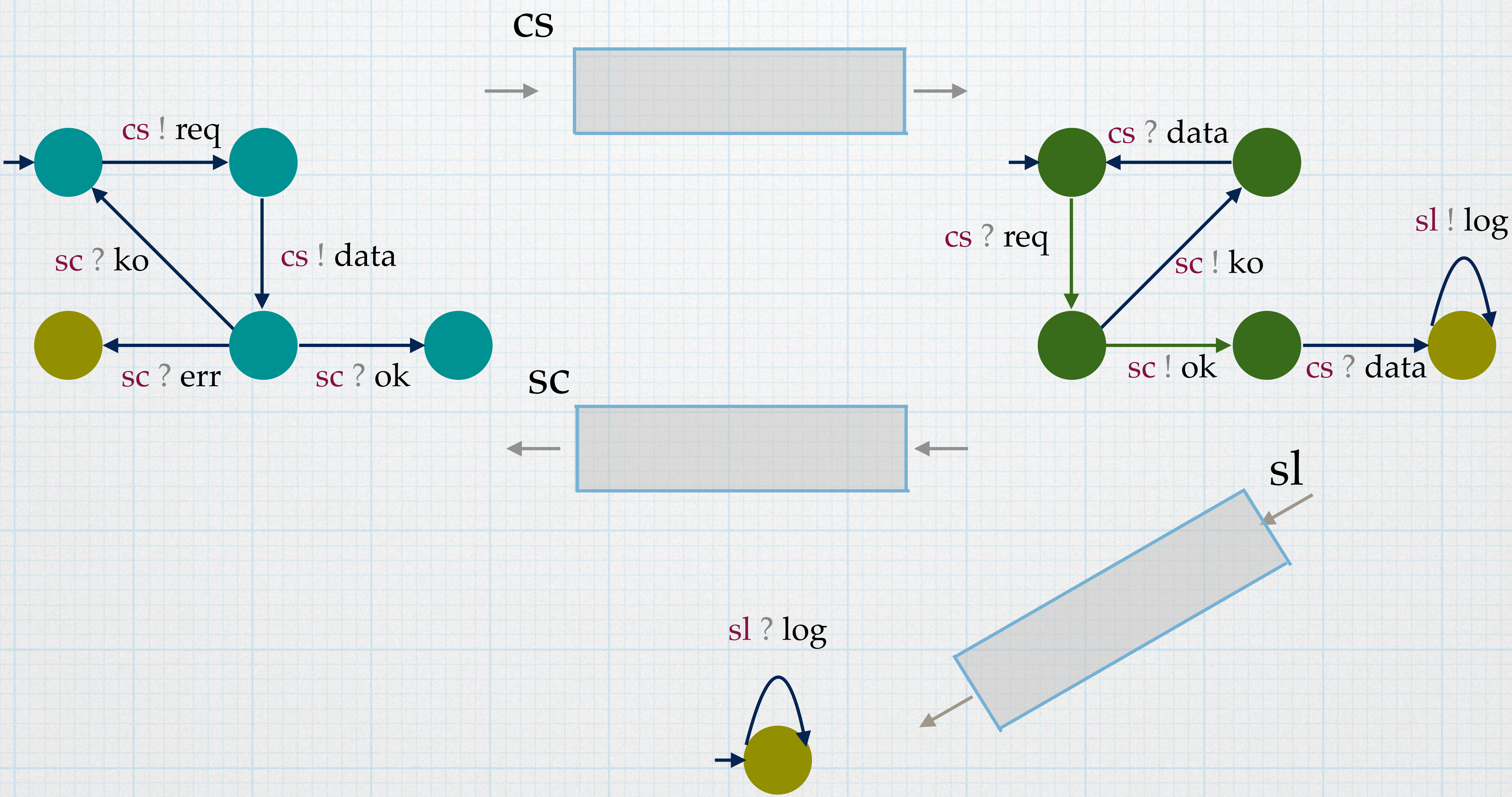
The Boundedness Problem



Does the model need an infinitely long channel?

The Boundedness Problem

- Turing-hard for communicating[BZ83] systems
- Therefore, there is a need for under-approximations

Bounded language

- A language is bounded if it is of the form:

  $u^* v^* w^*\ldots$ for words u, v, w…

- e.g. $(ab)^* (cd)^* a^*$ is bounded but

  $(a (ab)^* c)^*$ is not

Input-bounded channel

- If the language that enters the channel is bounded

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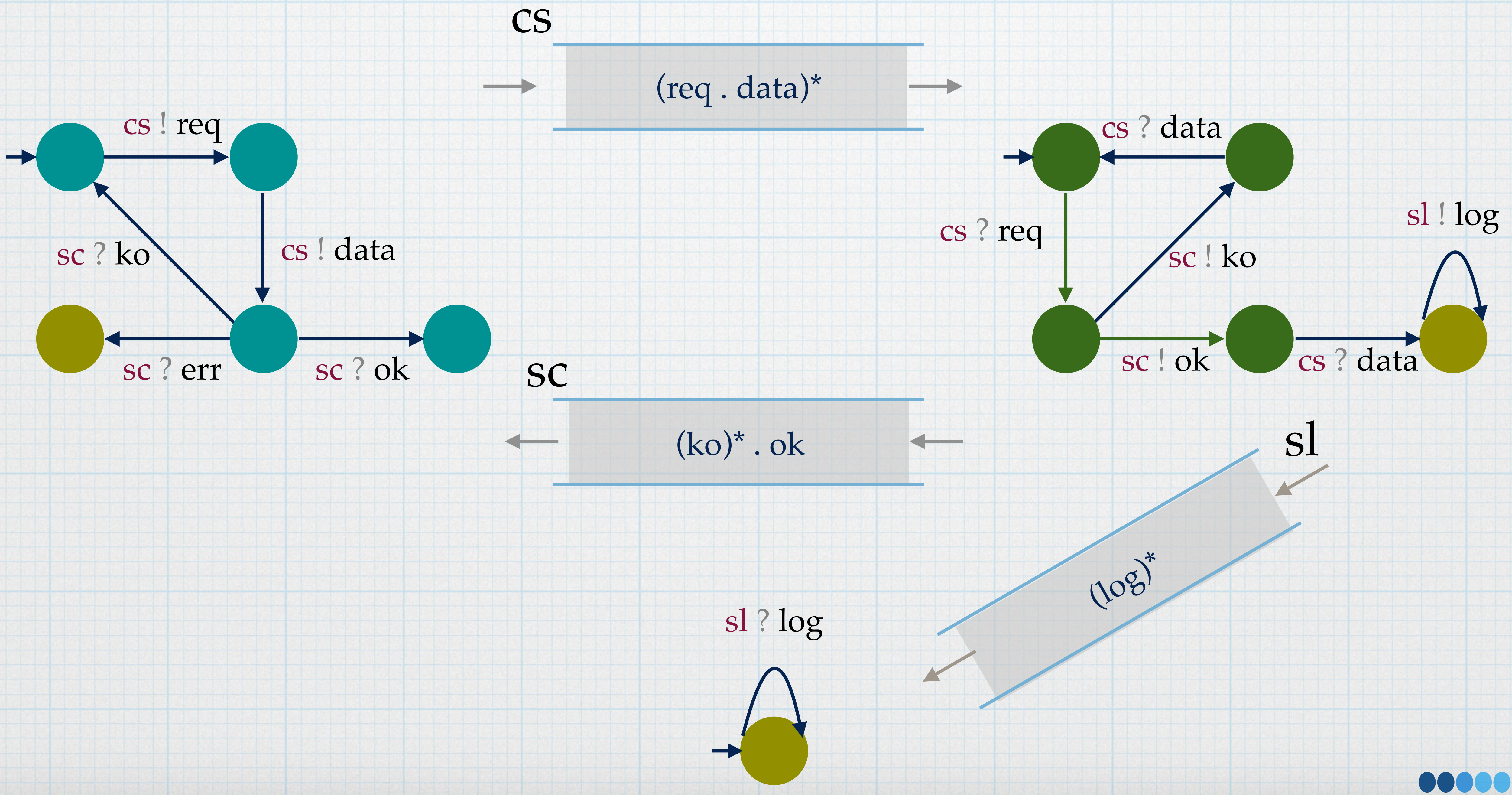


Result I

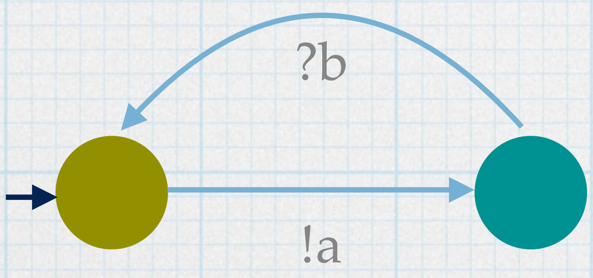
[BFS20, BFS22a]

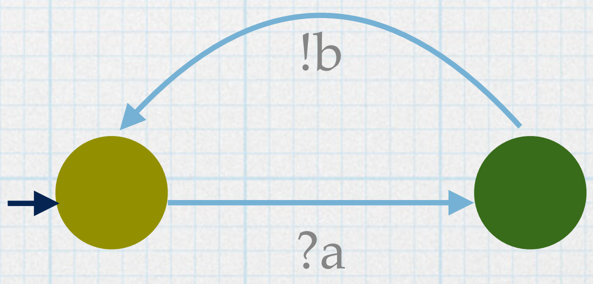
- Reachability (and many other verification problems) are decidable for input-bounded systems (where are channels are input-bounded)

Synchronizability

- A synchronous run:

  one where the channel size can be zero





Synchronizability

- A synchronizable run:

every run is *equivalent* to a synchronous run

Result II

- Framework for deciding synchronizability for a variety of definitions [BGF+21]

Other under-approximations

- Branch-WSTS [BFS22b]

  - a large class of systems for which we can decide boundedness and termination

Other under-approximations

- Send-synchronizable systems

  - the receptions can be reordered to become synchronous

Other under-approximations

- Reversal-bounded systems

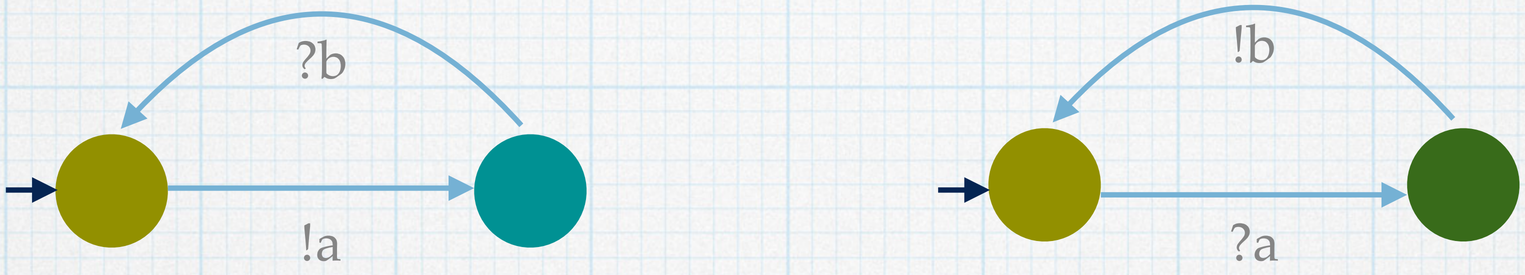
  - limit the number of alternations of sending and reception

FUTURE WORK

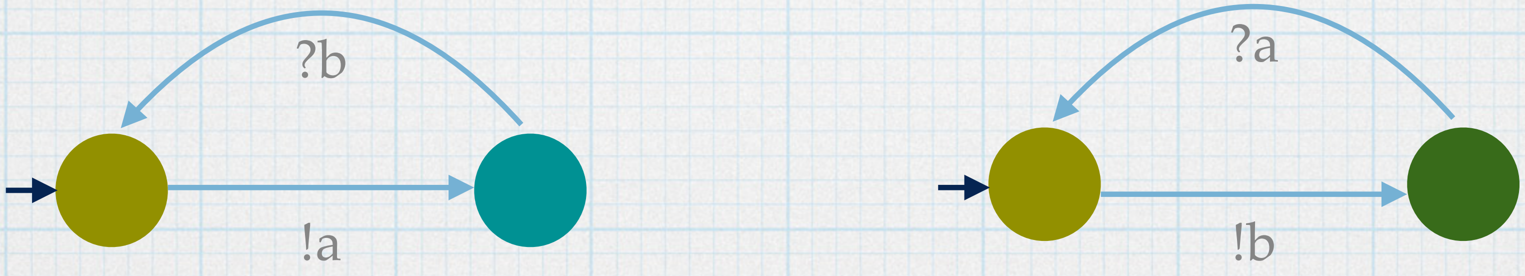
Half-Duplex systems [CF05]

- For every pair of processes, at most one of the channels between them is non-empty

Half-Duplex systems



Half-duplex



Not half-duplex

Half-Duplex systems

- For two processes, membership (and some other verification problems are decidable.
- For three processes, it is Turing-hard.

Application in the realm of channel contracts

- Half-duplex contracts can be seen as a way of defining reliable contracts [LV11]
- We obtain determinism and uniform choice
- Robust in the presence of error-prone communication

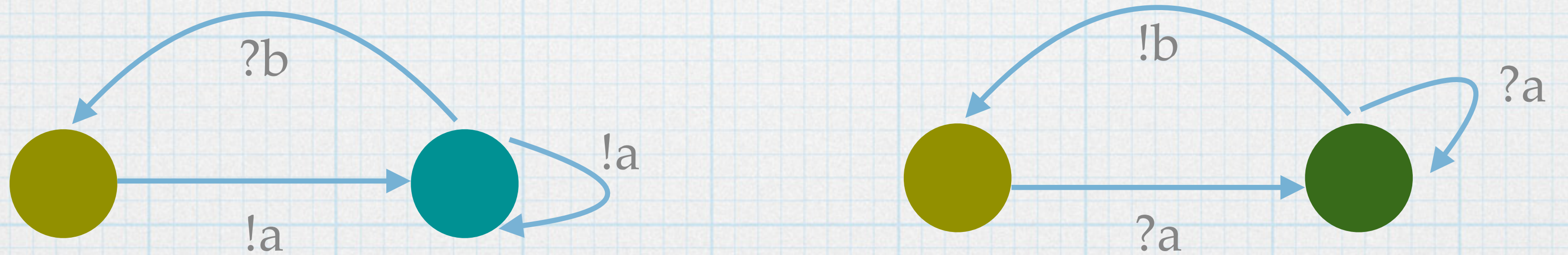
Open question I

- Can we modify the definition for more than 2 processes? [DGGL21]
- What is class of “reliable” channel contracts for multiparty FIFO systems?

[LY19]

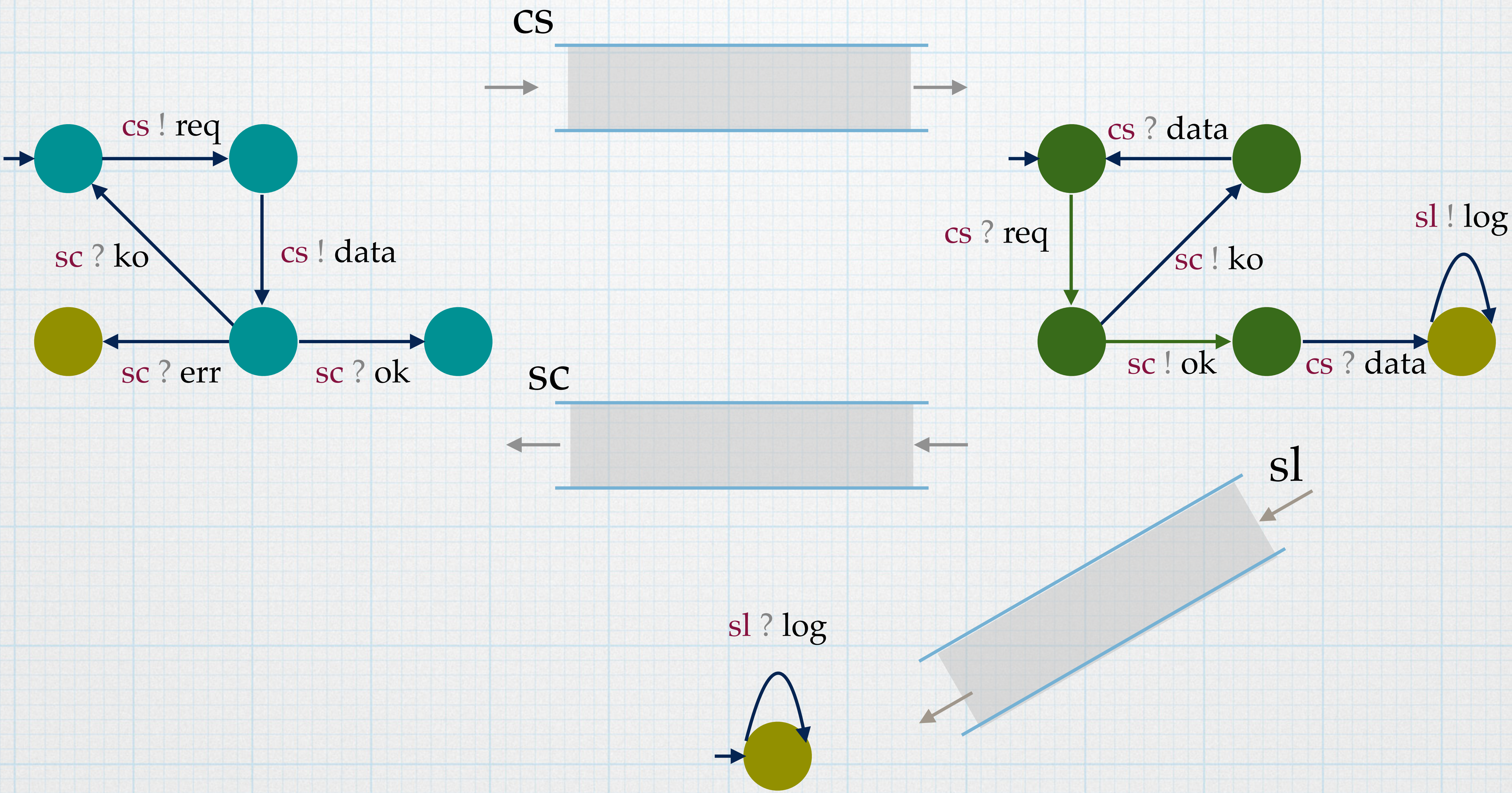
Communicating Session Automata

- Deterministic automata and each control state is uniquely sending or receiving



Not a communicating session automata

Communicating Session Automata



Multiparty compatibility

- Absence of deadlocks, orphan messages, unspecified receptions
- Whenever a message can be sent, it should eventually be sent

Multiparty compatibility

- Captures asynchrony
- Sufficient condition of existential boundedness
- Each automaton behaves similarly when you take any larger bound

Open question II

- Does the unifying framework capture this property?
- Can we try to extend this class to include mixed states?

Mid-term objectives

- A practical tool for verifying synchronizability (and other under-approximations of communicating automata) in the spirit of earlier works [LY19, BEJQ18]

Mid-term objectives

- Studying the relationship between k-synchronizability and high-level message sequence charts (HMSCs)

- Is an HMSC computable from a k-synchronous system?

- Can we characterize them?

Long-term objectives

- Adapting existing results to build a bounded model-checking strategy for general CFSMs (and the same for input-bounded)
- Using session types to formally model choreography languages and characterize realizability
- Extending the notions of synchronizability and choreography realizability for other communication models (bags, causally ordered channels, etc.)

References

- [BEJQ18] Ahmed Bouajjani, Constantin Enea, Kailiang Ji, and Shaz Qadeer. *On the completeness of verifying message passing programs under bounded asynchrony*, CAV 2018.

- [BFG+21] Benedikt Bollig, Cinzia Di Giusto, Alain Finkel, Laetitia Laversa, Etienne Lozes, and Amrita Suresh. *A Unifying Framework for Deciding Synchronizability*, CONCUR 2021.

- [BFS20] Benedikt Bollig, Alain Finkel, and Amrita Suresh. *Bounded Reachability Problems Are Decidable in FIFO Machines*, CONCUR 2020.

- [BFS22a] Benedikt Bollig, Alain Finkel, and Amrita Suresh. *Bounded Problems Are Decidable in FIFO Machines*, LMCS 2022.

- [BFS22b] Benedikt Bollig, Alain Finkel, and Amrita Suresh. *Branch-Well-Structured Transition Systems and Extensions*, FORTE 2022.

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- [BZ83] Daniel Brand and Pitro Zafiropulo. *On communicating finite-state machines*, J. ACM 1983.
- [CF05] Gerald Cécé and Alain Finkel. *Verification of Programs with Half-Duplex Communication*, Inf Comp 2005.
- [DGGL21] Cinzia Di Giusto, Loïc Germerie Guizouarn, and Etienne Lozes. *Multiparty Half-Duplex Systems and Synchronous Communications*, ICE 2021.
- [LV11] Étienne Lozes and Jules Villard. *Reliable Contracts for Unreliable Half-Duplex Communications*, WS-FM 2011.
- [LY19] Julien Lange and Nobuko Yoshida. *Verifying Asynchronous Interactions via Communicating Session Automata*, CAV 2019.