How to Efficiently Evaluate RAM Programs with Malicious Security

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April 29, 2015

Background

- Secure Two-Party Computation (2PC)
  - Secure evaluation of "any" function
  - Preserve input privacy and correctness
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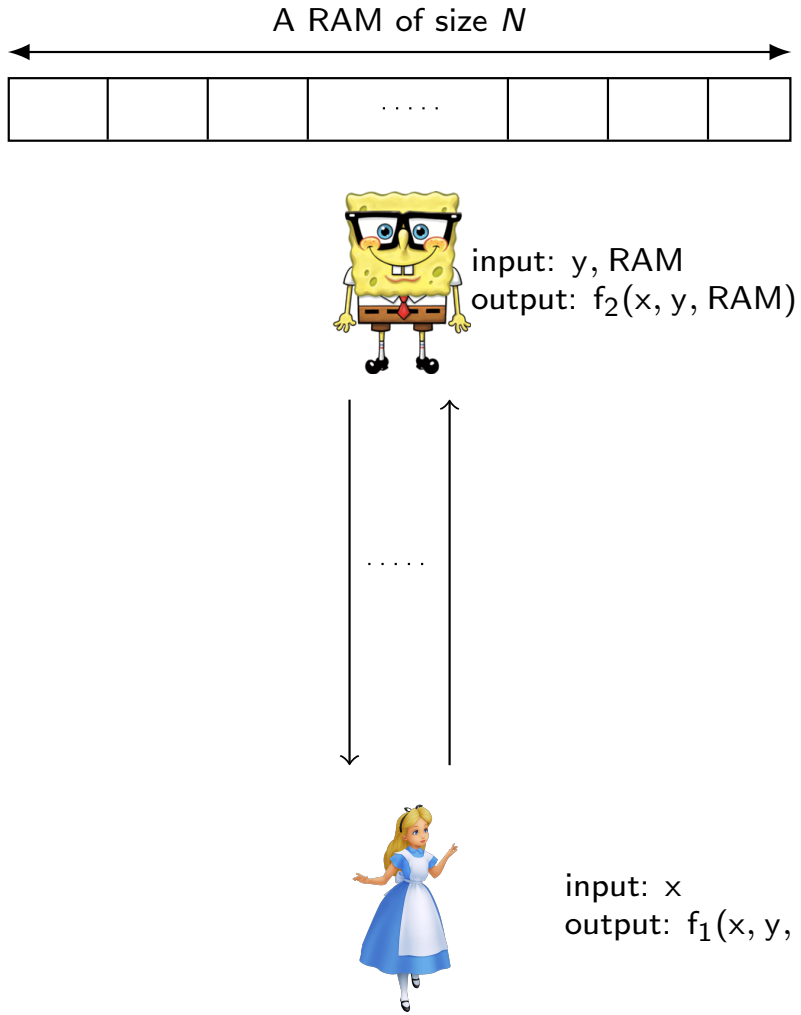
  - Accessing a portion of the RAM.
- Solution [GKK+12]
  - Combine "Oblivious RAM" (ORAM) with 2PC

Oblivious RAM (ORAM)

- Privacy of Alice input
  - *ORAM*: $O(\log N)$
- Privacy of Bob input
  - No guarantee



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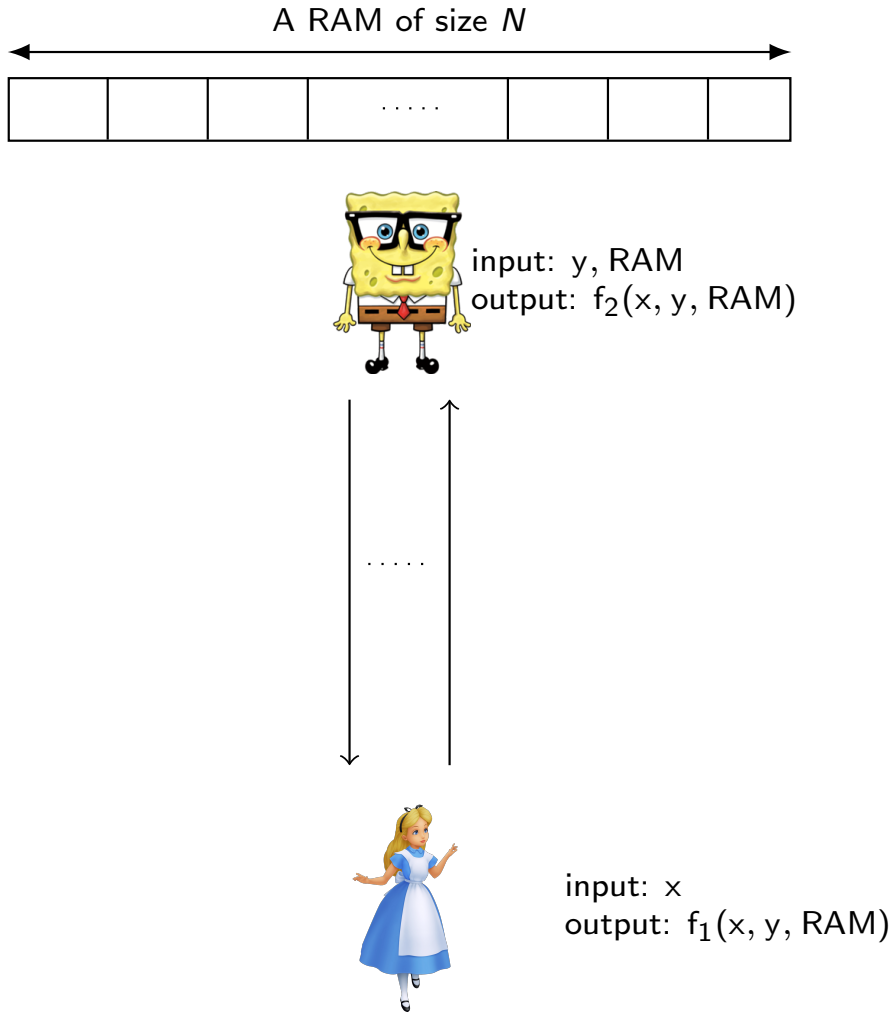

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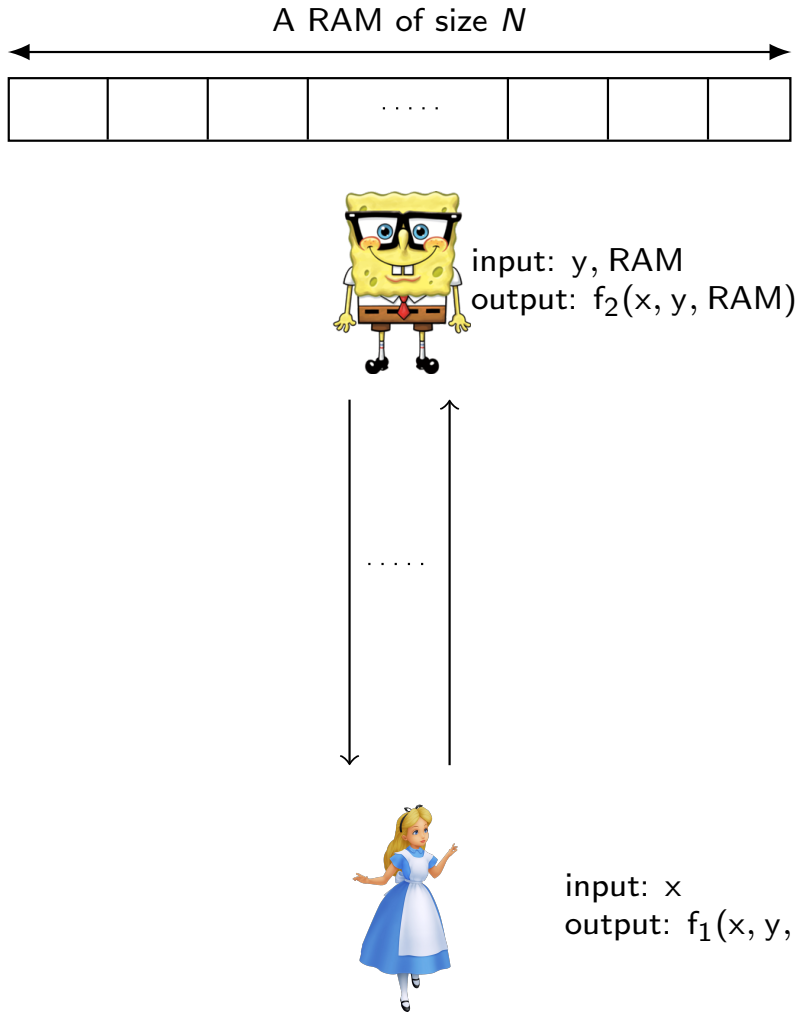
    - Store it in a data structure in RAM



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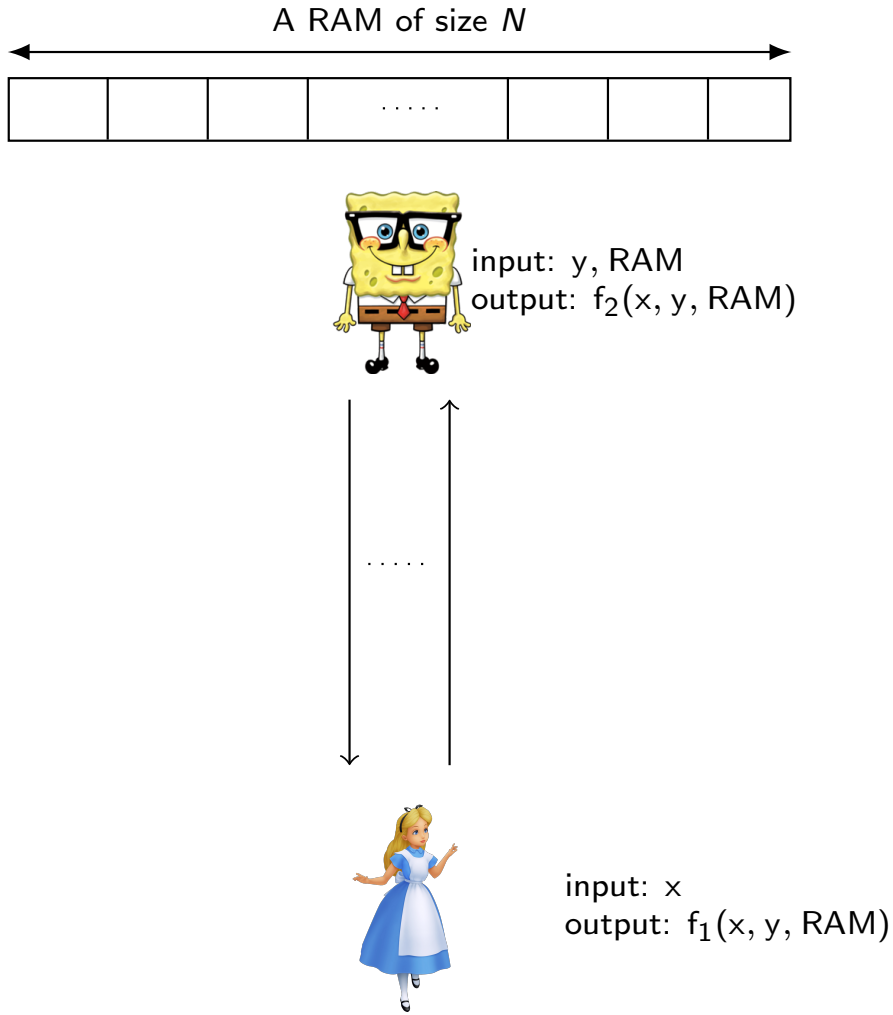

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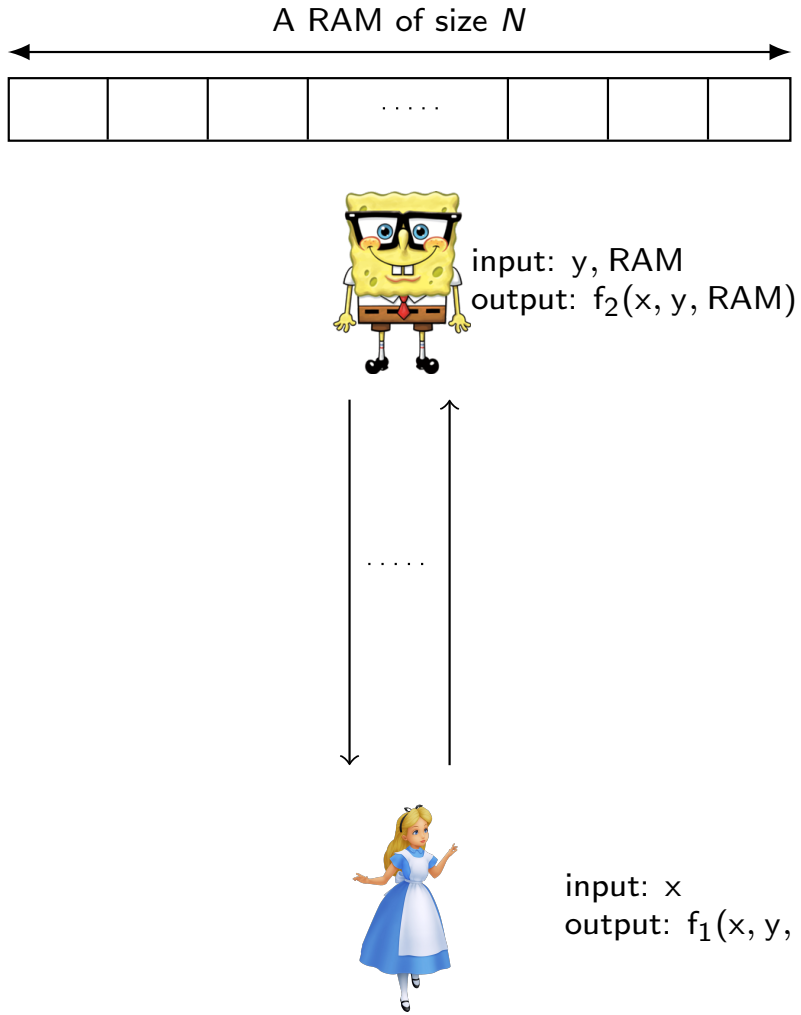
    - multiple actual memory access



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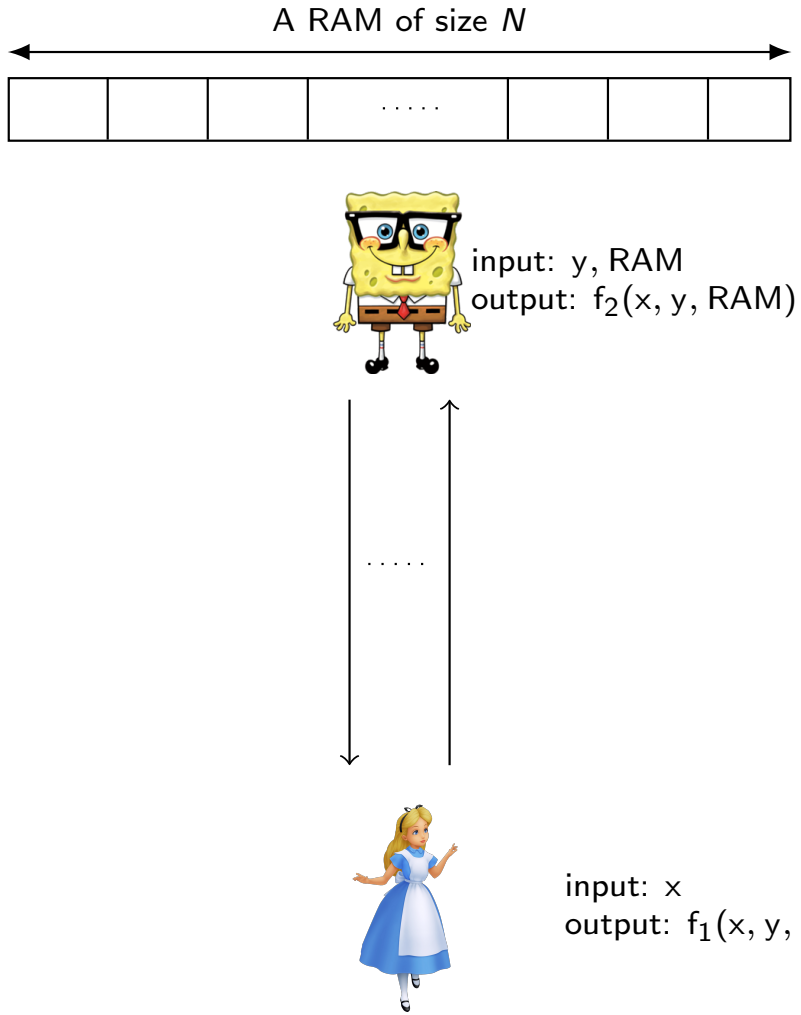

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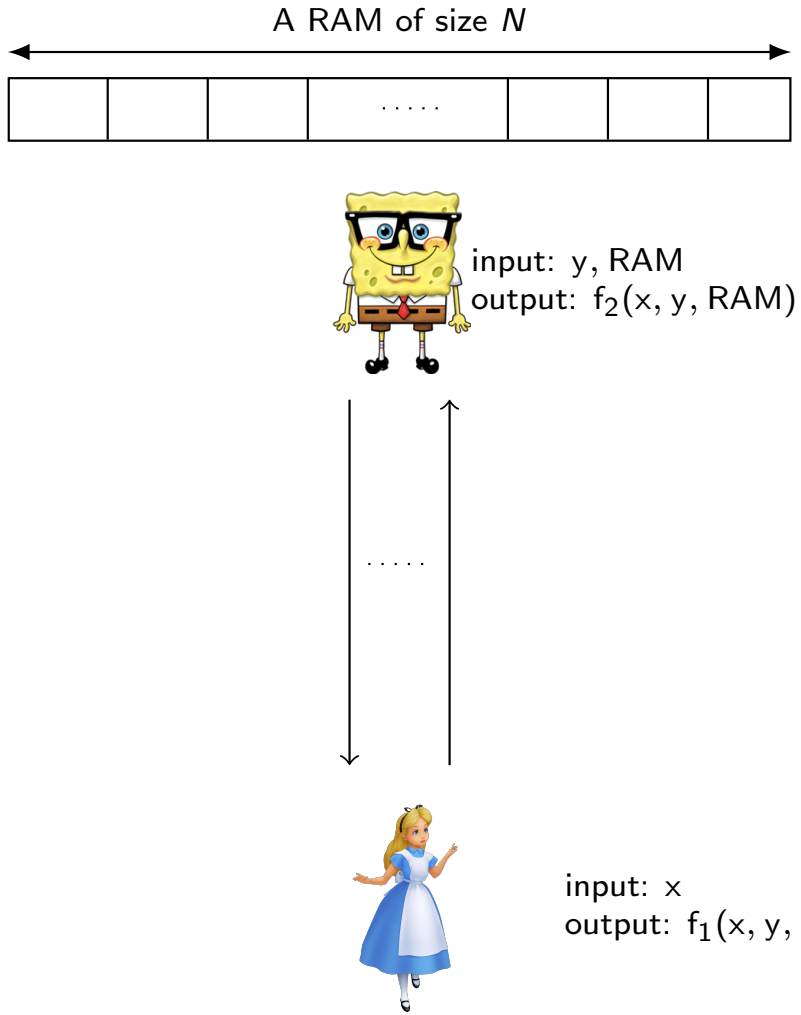
  - Update *state* for next iteration



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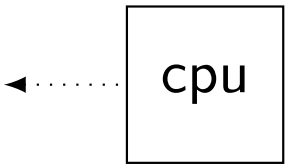
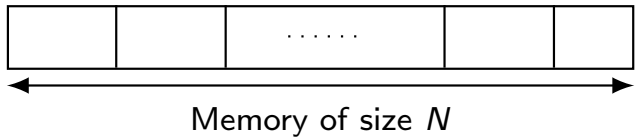
  - Secret share "state" & last read "data"
  - Compute until "state" equals "halt"

Semi-honest RAM-2PC [GKK+12]

Garbled Circuits

for a *Single* ORAM Step.





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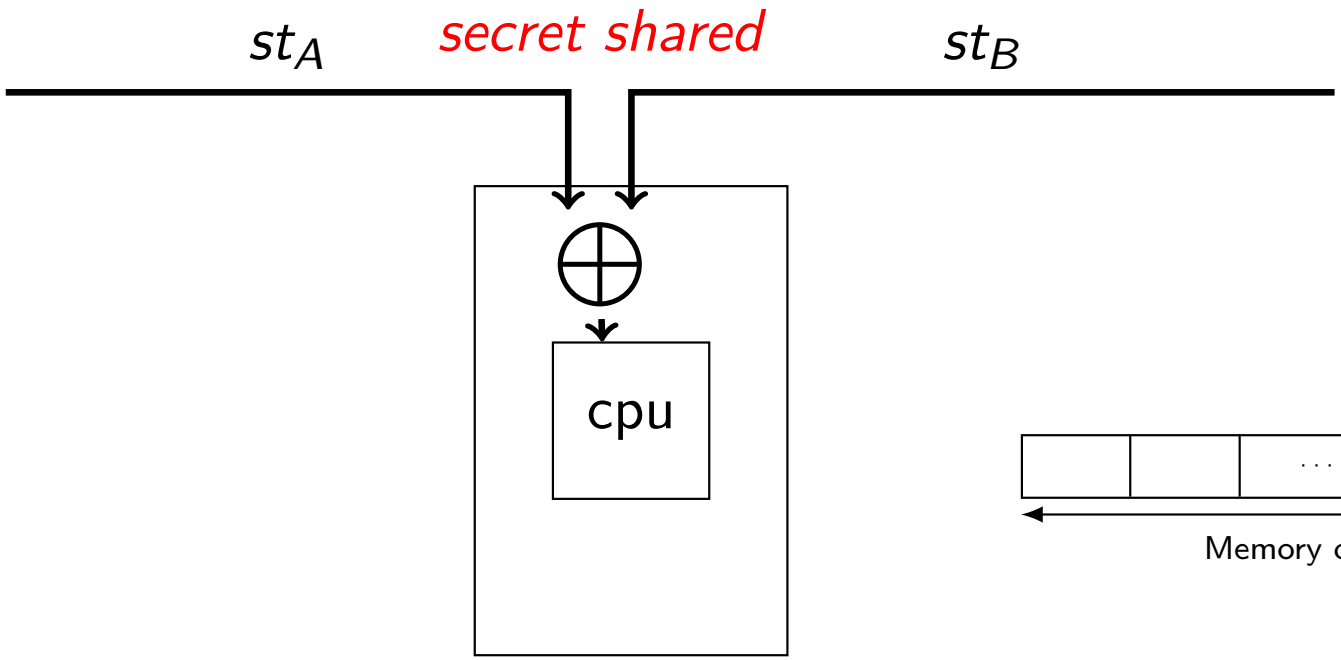

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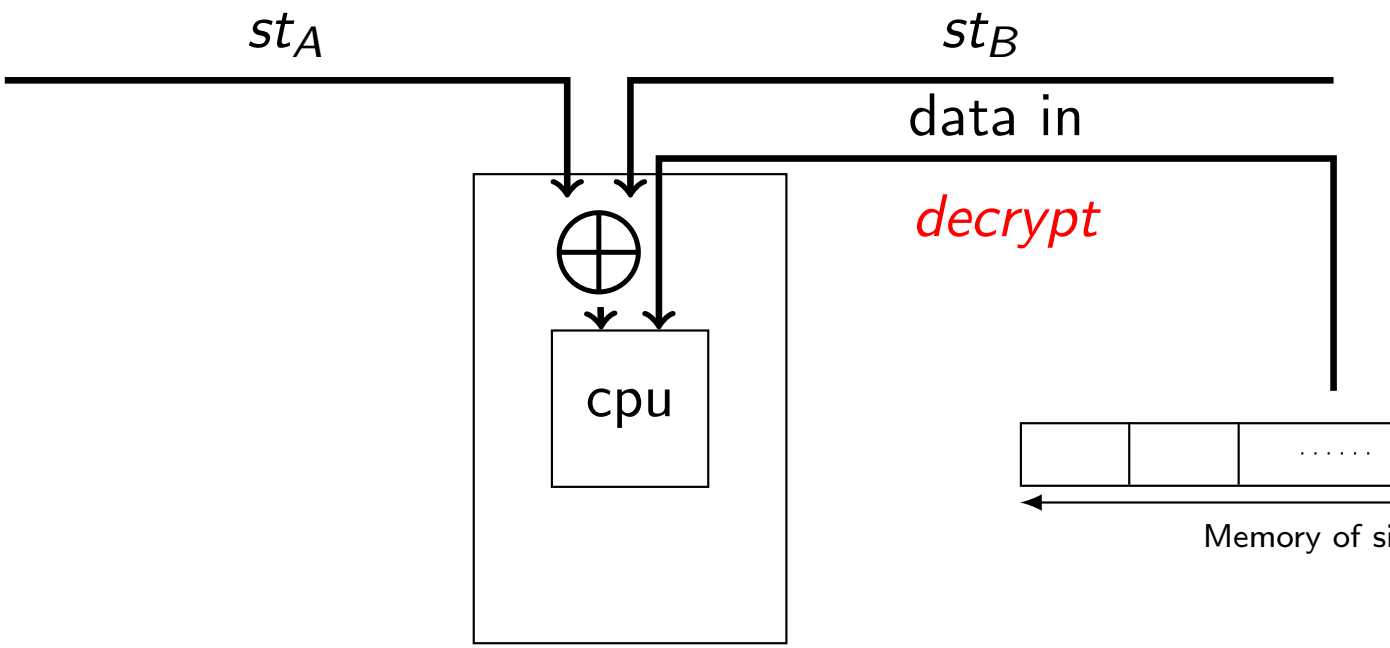

Semi-honest RAM-2PC [GKK+12]

Possible attacks

- Garbler may garble different circuits
  - Needs *cut-and-choose*

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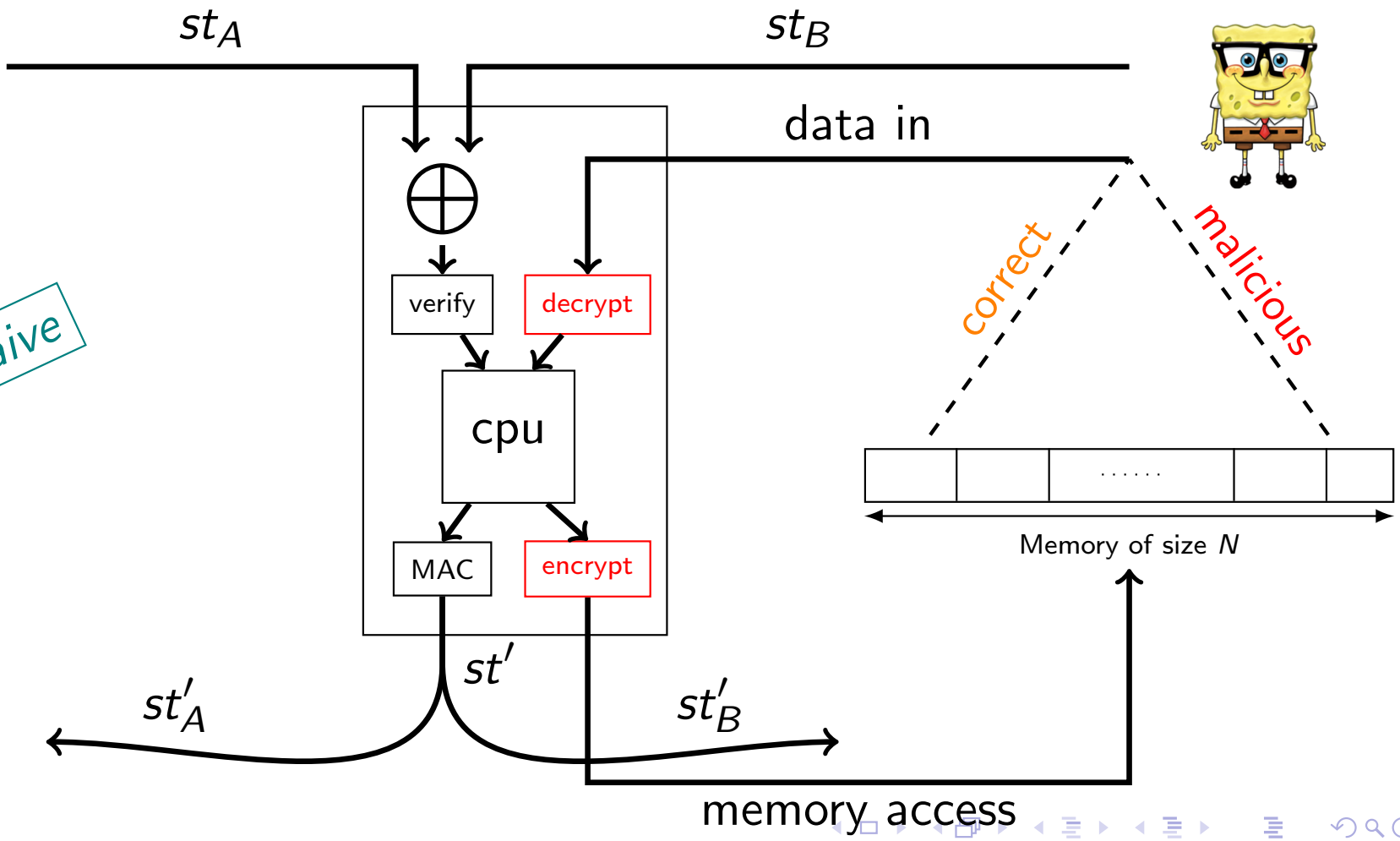
  - Needs *cut-and-choose*
- Parties use incorrect inputs to the circuit, i.e.
  - Original inputs
  - Shares of the state
  - Memory contents
  - Needs *consistency* and *authenticity* checks

Naive Solution for Malicious RAM-2PC

- *Integrity and consistency of state*

Naive Solution for Malicious RAM-2PC

- *Memory privacy/consistency*



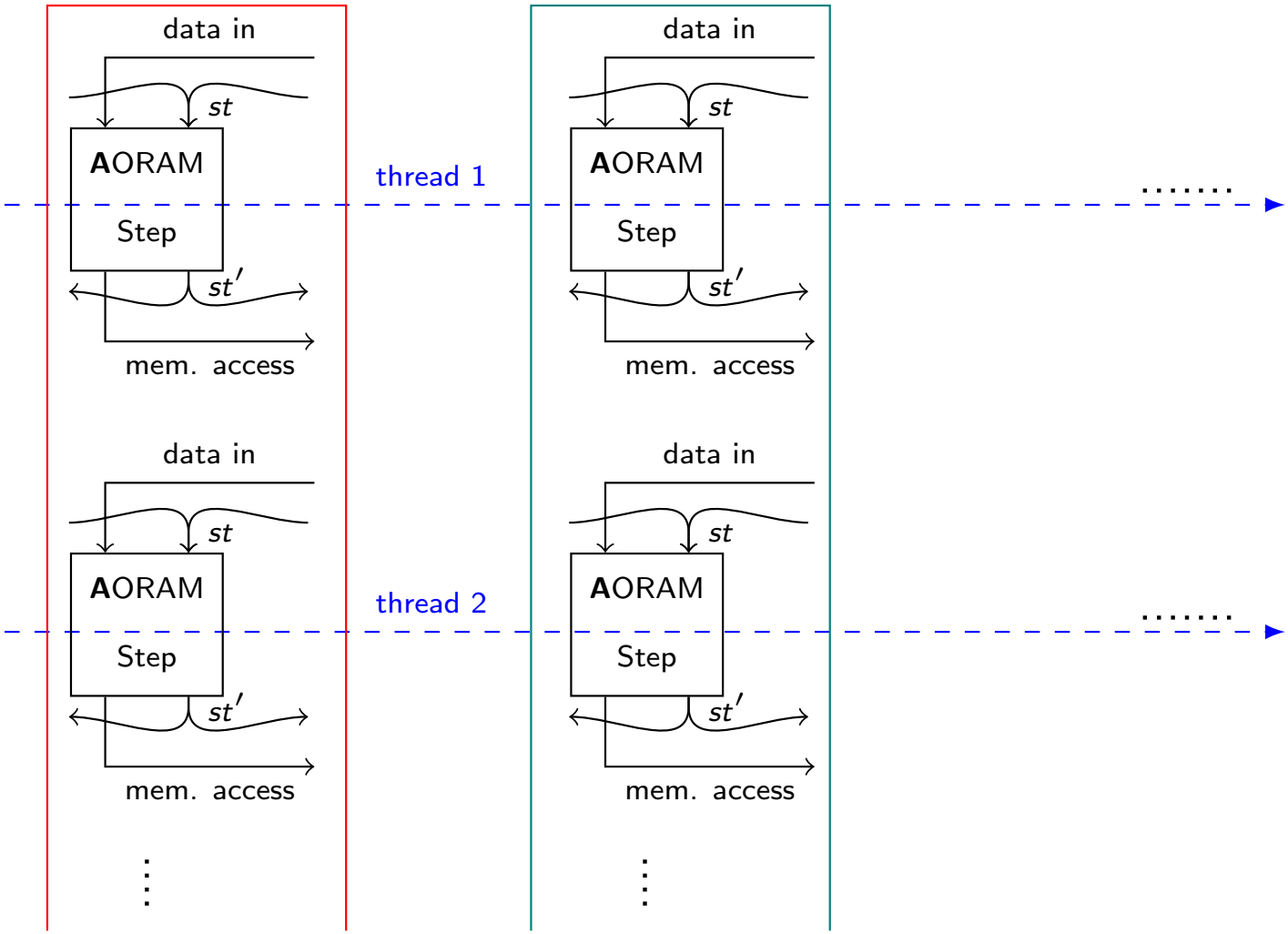
Naive Solution for Malicious RAM-2PC

Augmented ORAM Step.

(*AORAM* Step)

Naive Cut-and-Choose Approach

- Separate Malicious 2PCs



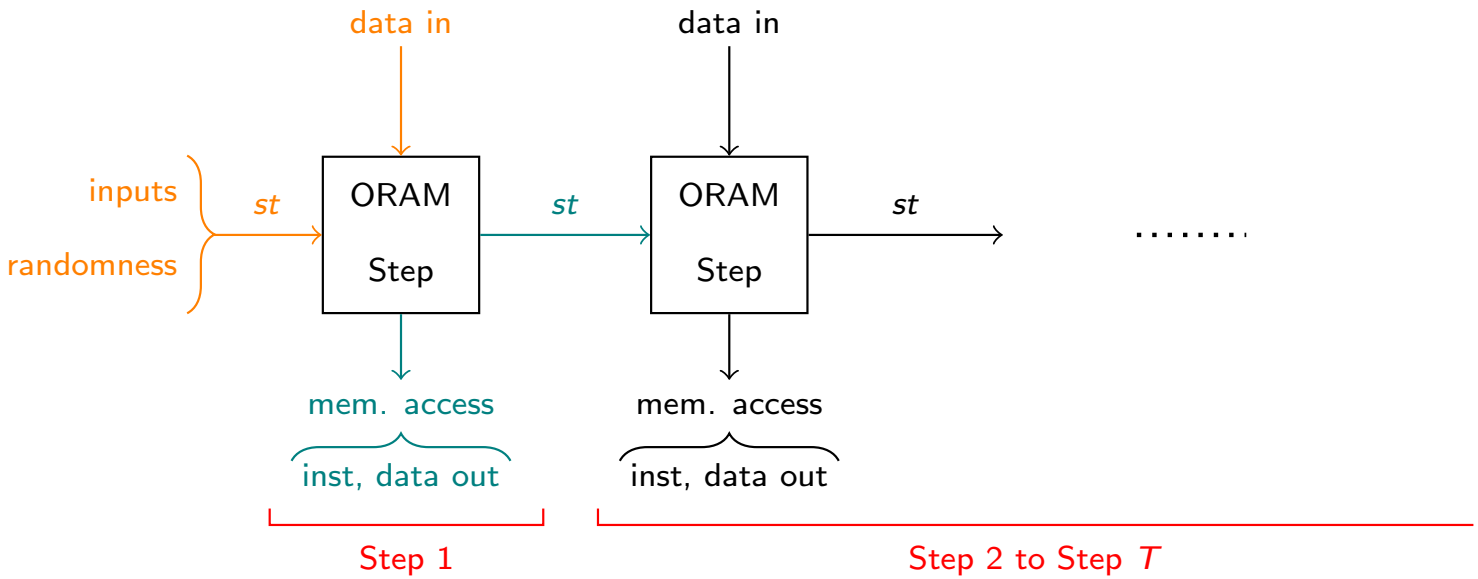
Our Approach: Two Protocols

- Batching Protocol, based on LEGO idea [FJN+13, NO09]
- Streaming Cut-and-Choose Protocol
  - This talk

Stream Cut-and-Choose Protocol

Garbled Values

- Memory and state as *garbled values*
  - No encryption
  - No MAC/Verification



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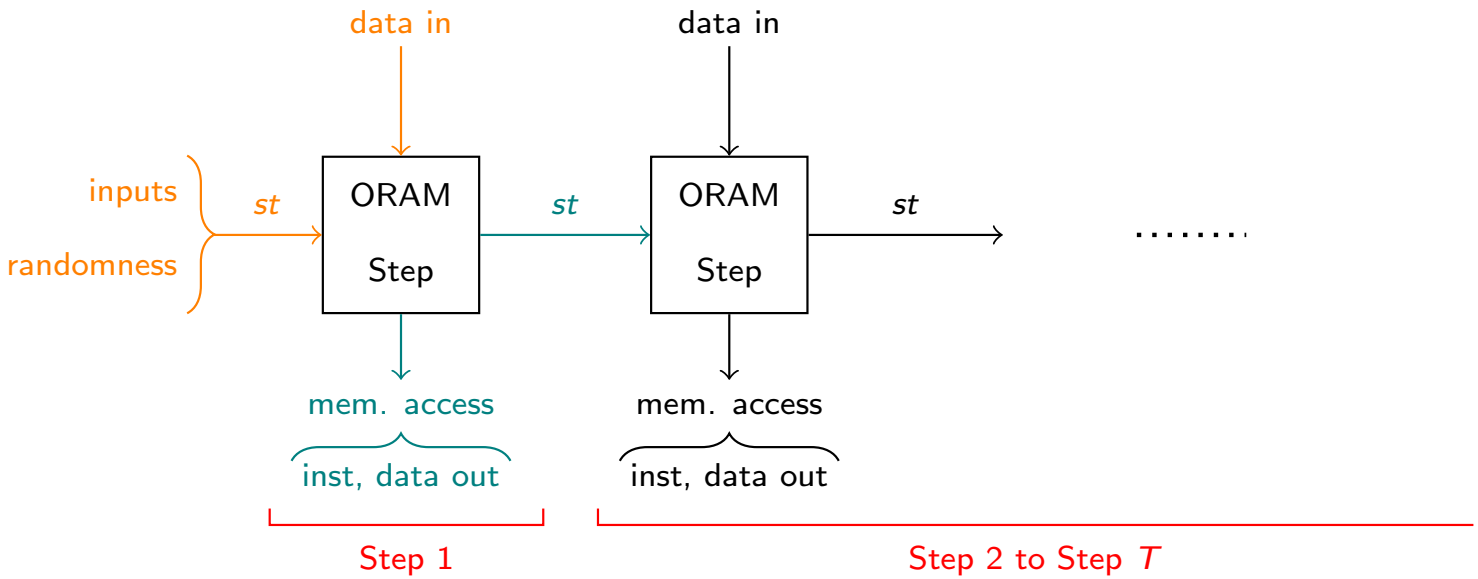

Garbled Values

- Memory and state as *garbled values*
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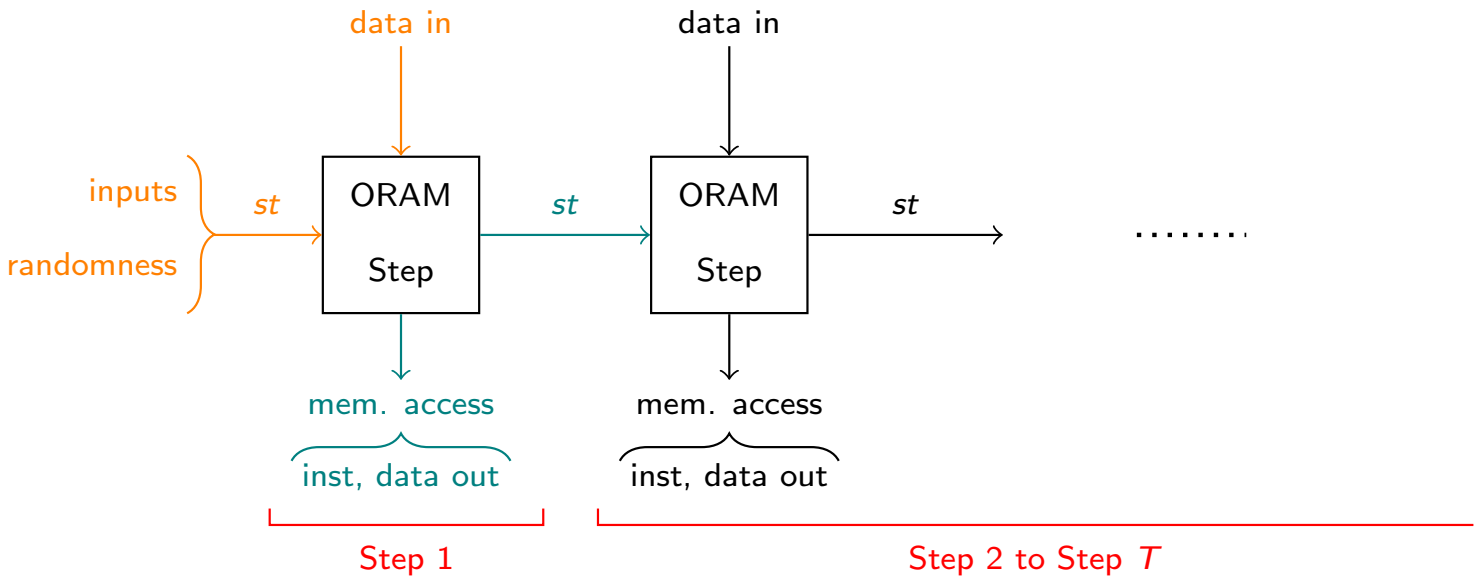
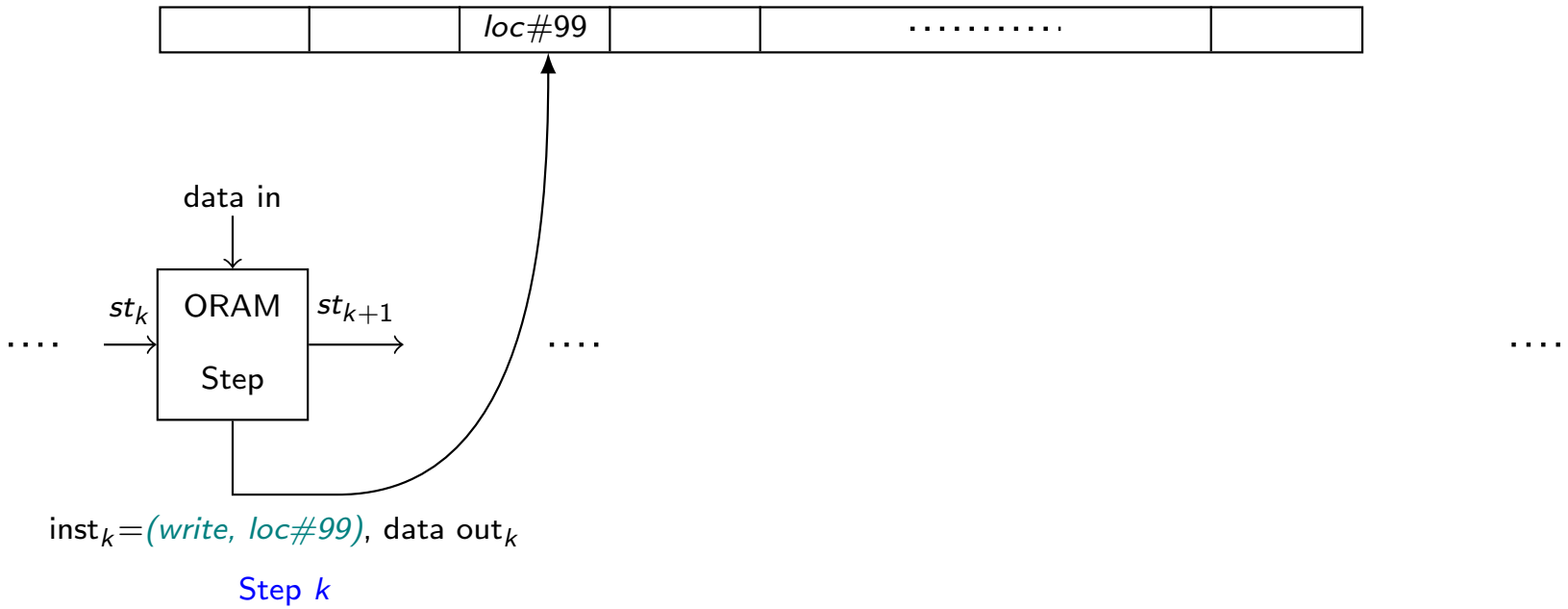
    - *Authenticity*
    - *Privacy*
- *Re-use* garbled values
  - No input consistency checks in intermediate circuits



Memory Privacy/Consistency

- Memory items are garbled values
  - Bob reports the memory location
  - Correctness: *cut-and-choose*
- Consistency of memory location [MR13]



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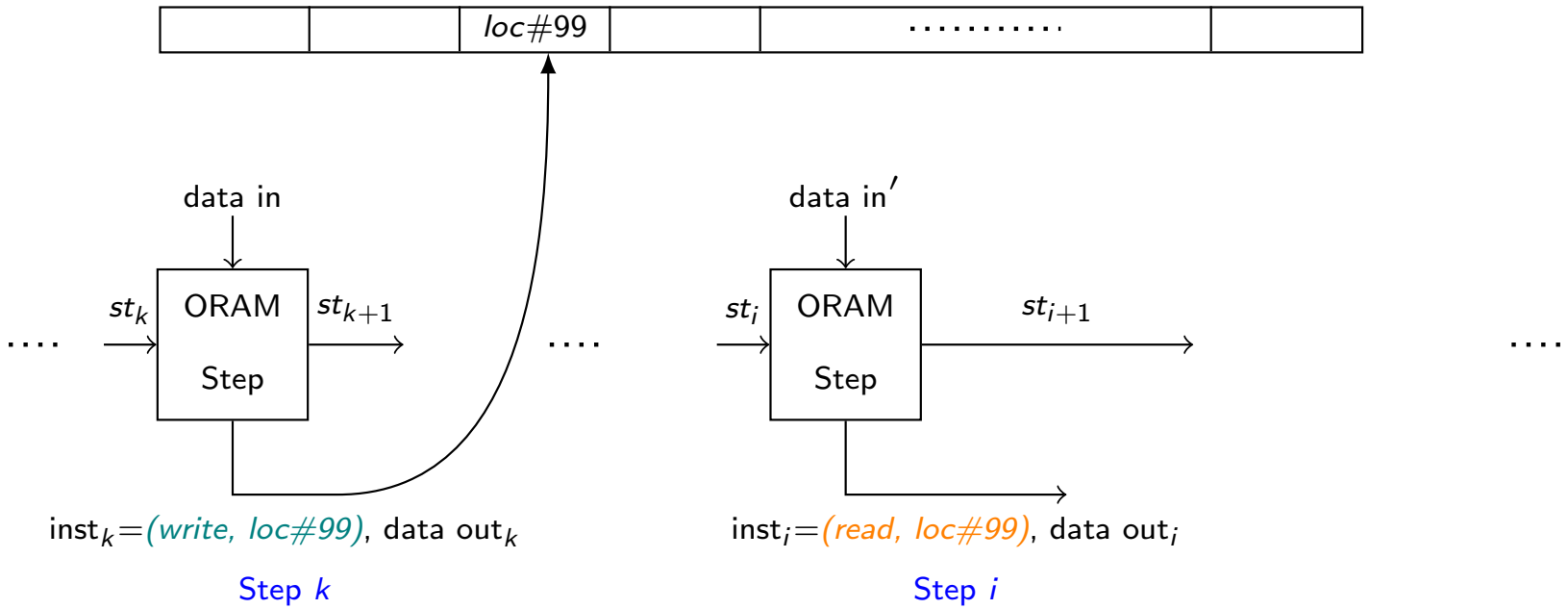

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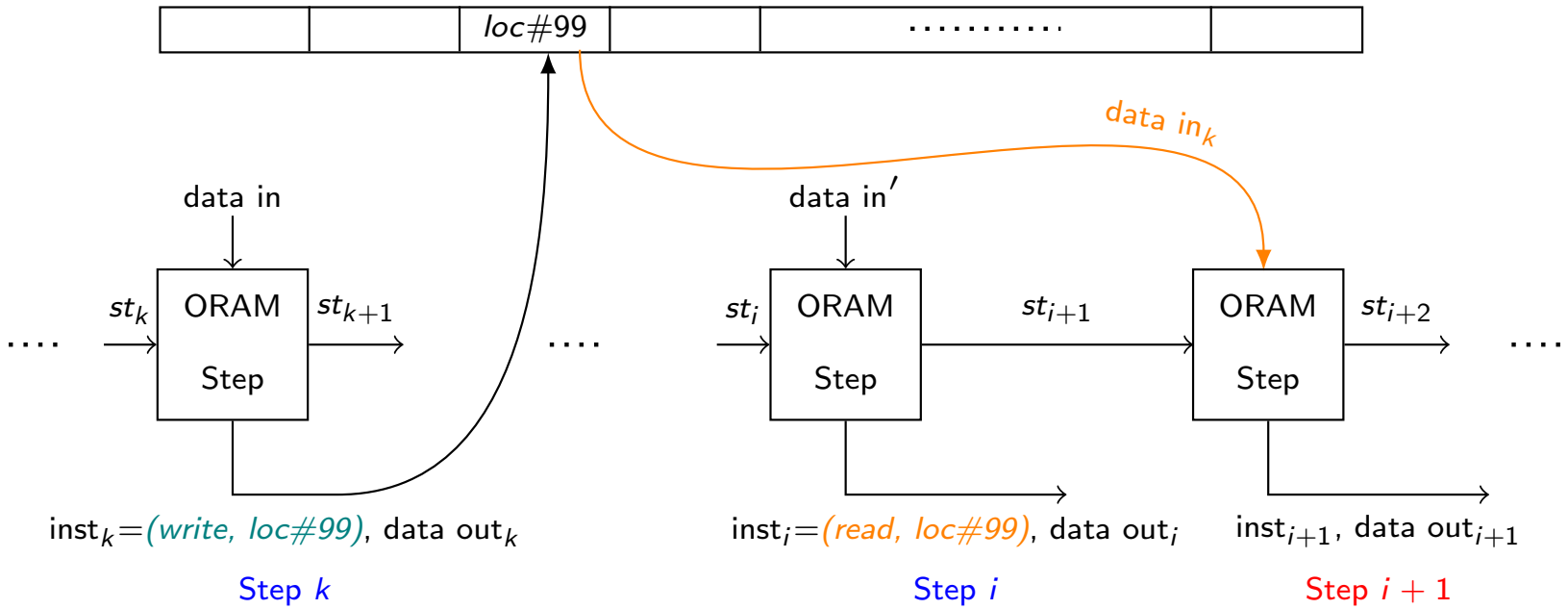
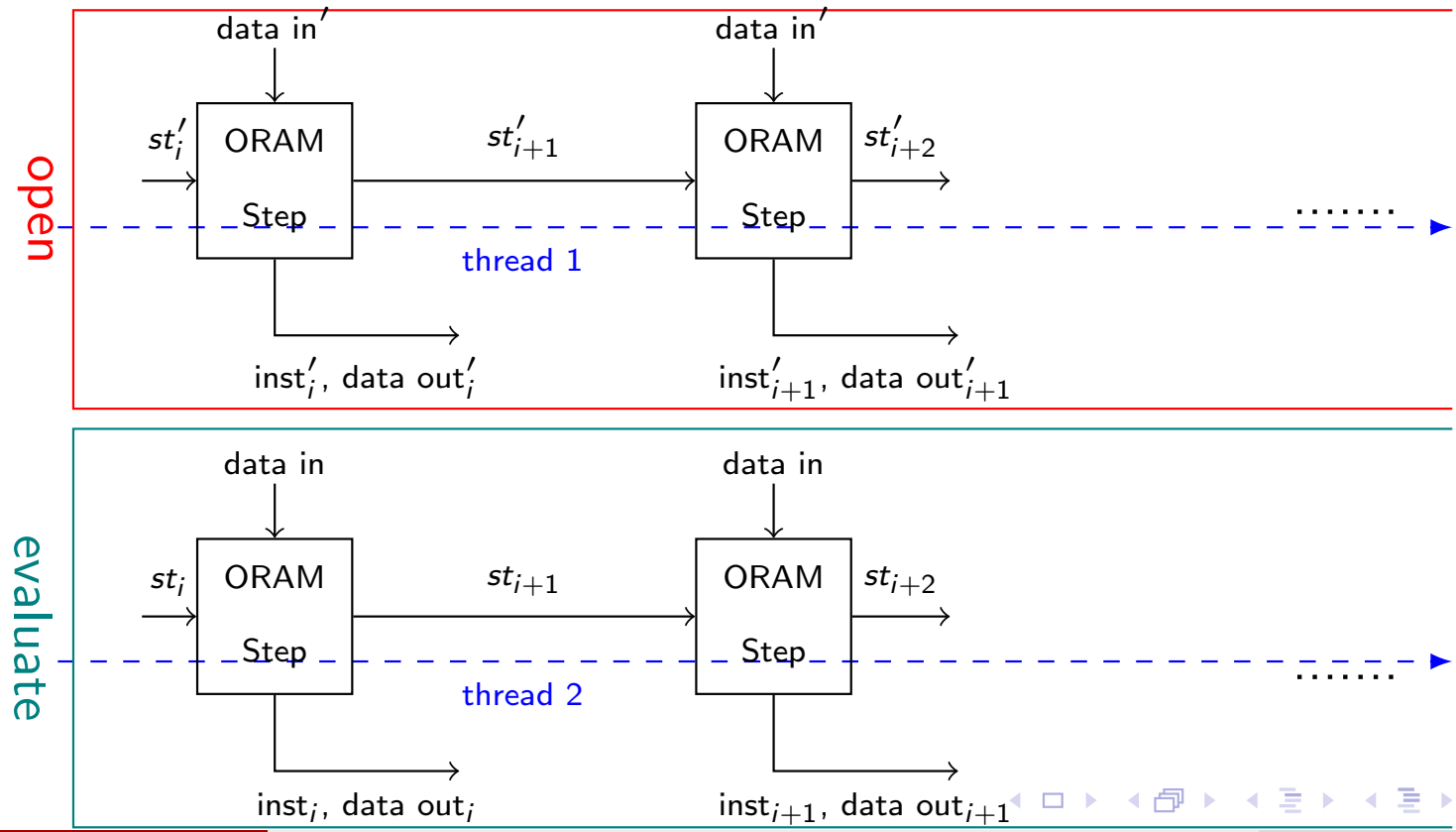


Step Generation

- ... hence:
  - Given inst_i
  - Step $i+1$ is generated *after* Step i is *evaluated*

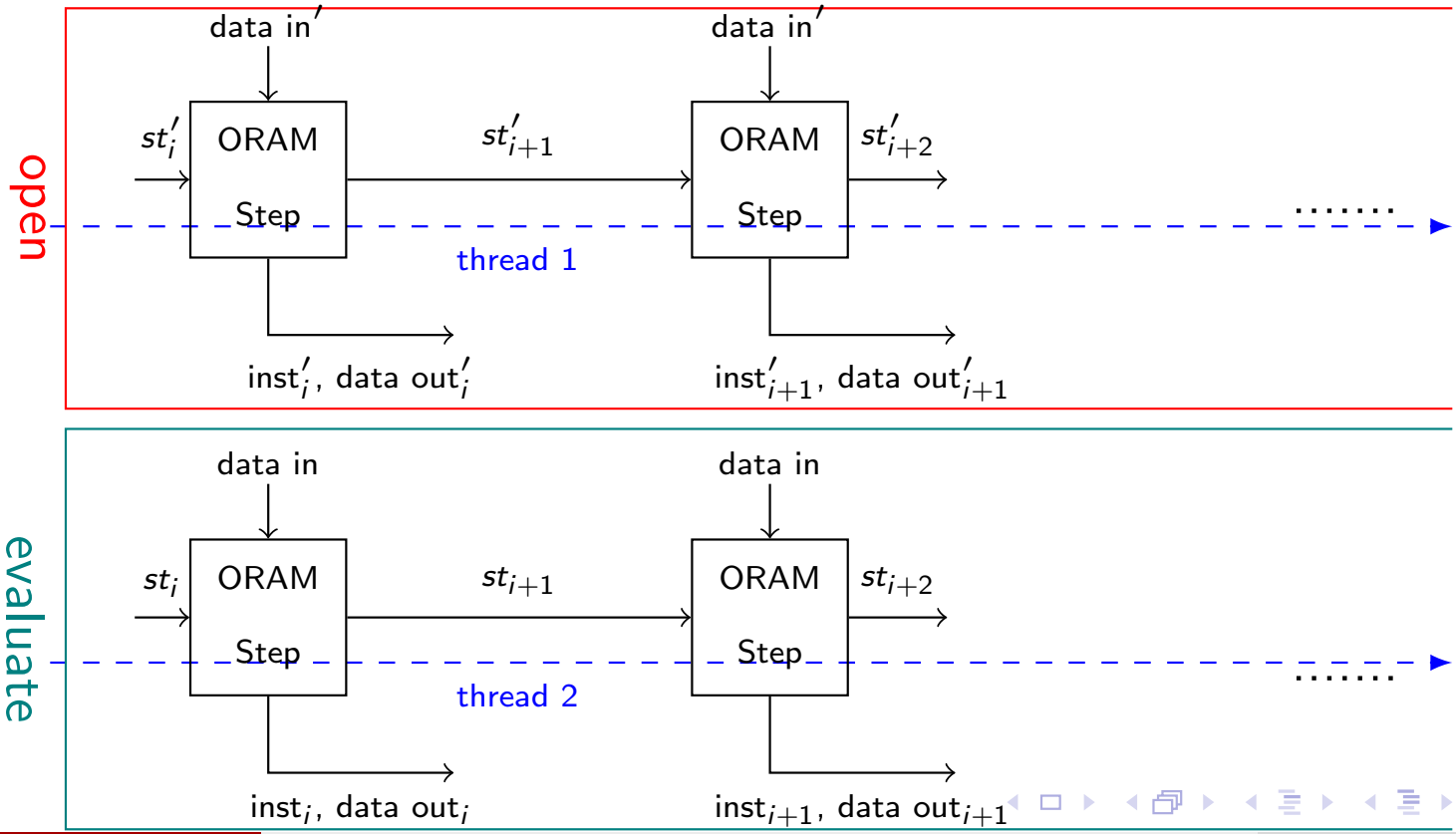
A Single Cut-and-Choose

- One 2PC vs. many 2PCs
  - Input consistency check: *Once at the beginning*



A Single Cut-and-Choose

- One 2PC vs. many 2PCs
  - Input consistency check: *Once at the beginning*
  - Cut-and-Choose rely on one correct circuit
    - Also known as *cheating recovery*
    - Once at the end vs. after each step



Comparison

Table : Overhead

	Naive implementation	Streaming cut-and-choose
Circuit Size (non-XOR gates)	$T \times 154.36 \times 2^{20}$	120
Alice Storage	0	$5MB + \log T \times 40KB$
Input Consistency Checks	$O(T \times IC \times ND)$	0

- Where
  - T is the running time of the RAM
  - IC is the overhead of input consistency check for one bit of data on "s" garbled circuits.
  - S is statistical security parameter
  - N is the length of memory
  - D is the length of ORAM metadata

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Thank You!