Two-Round Concurrent 2PC from Sub-Exponential LWE

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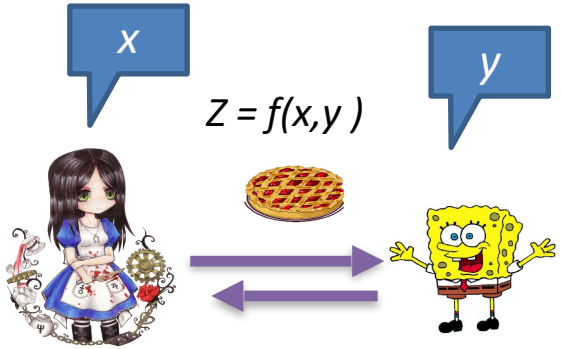
5. Max Planck Institute for Security and Privacy, Germany
6. UCLA, USA

08.12.2023

Problem Statement of Concurrent 2PC

-Def.:Two-party computation (2PC) protocols where both parties receive output z = f(x,y)



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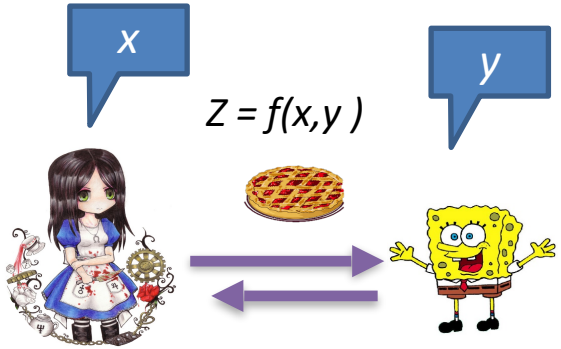

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- Adversary should learn nothing besides the output z.
- Formally: simulation-based security.

Concurrent Security:

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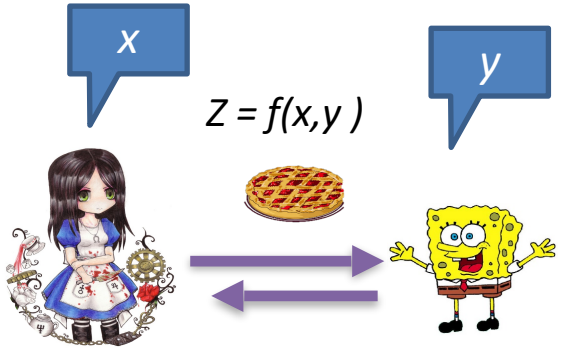


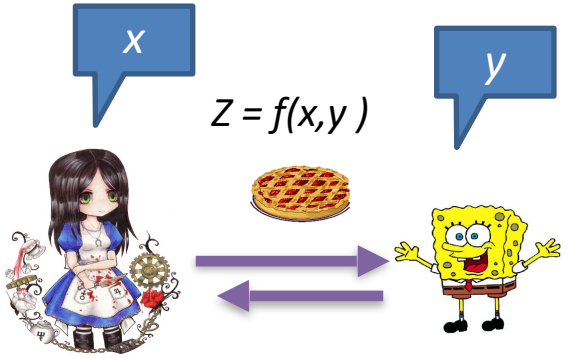
Concurrent Security:

- Where adversary sees many instances of the protocol are executed in parallel.

Can we achieve two-round concurrently secure two-party computation under simple, post-quantum assumptions, in the plain model?

The Concurrent Setting

- A more realistic setting allows parties to participate concurrently in arbitrarily many instances.



Impossibility Result:

[BPS06]: Achieving the standard definition of concurrent security is impossible in any rounds in the plain model, without a trusted setup

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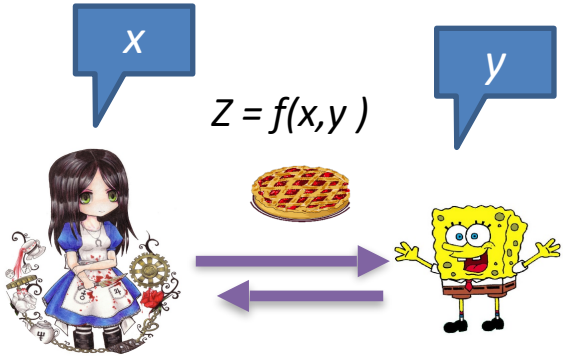

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Overcome the above mentioned impossibility results:

- The bounded concurrent model [Pass04],
- In the multiple ideal-query model [GoyJai13],
- input-indistinguishable computation [MicPas06].

-And an standard relaxation of simulation security: the notion of super-polynomial simulation, or SPS [Pass03]. (which is widely used to circumvent many lower-bound results)

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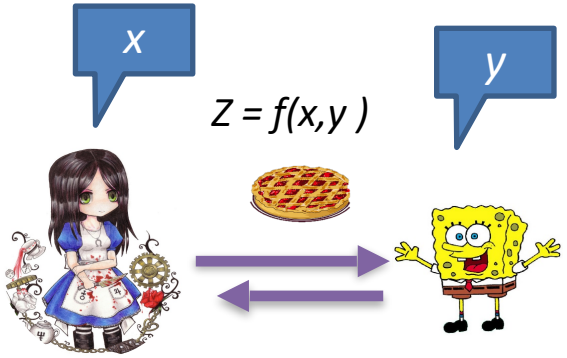

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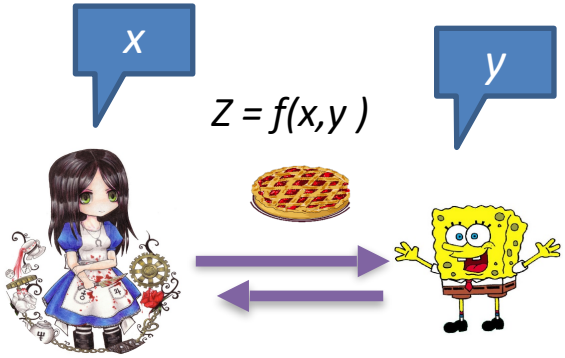
The Round Complexity

- In 2PC (with two-side output) setting, a round is defined in the simultaneous exchange message model



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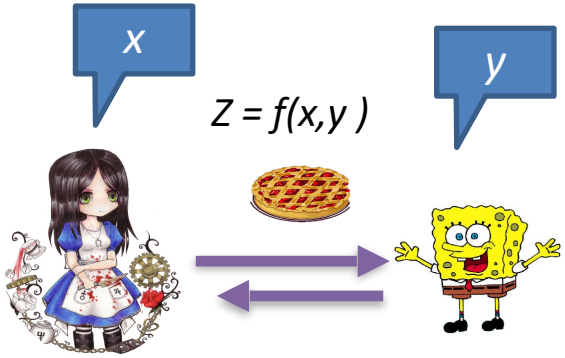

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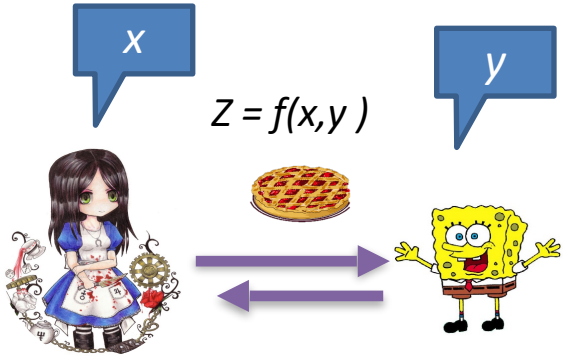

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Time line and Results:

[GGJS12, KMO14]: Constant-round protocols (approximately 20 rounds).

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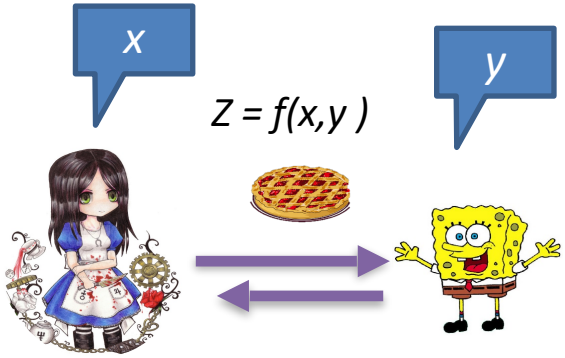

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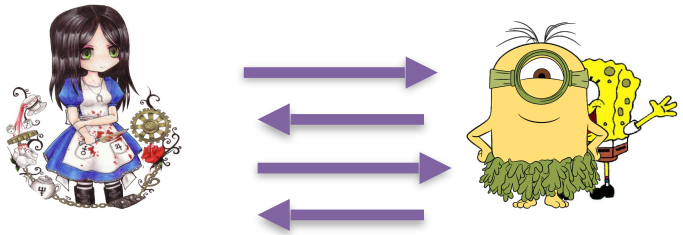
[ABGKM21] : Two-round MPC with standalone security in the plain model assuming subexponential NIWI arguments, the subexponential SXDH assumption, and the existence of non-interactive NMC

[FJK22]: Concurrent two-round MPC protocol, assuming subexponential quantum hardness of LWE, subexponential classical hardness of SXDH, the existence of a subexponentially-secure (classically-hard) iO, and time-lock puzzles

Standard Simulation-Real Ideal Paradigm

Real

Ideal



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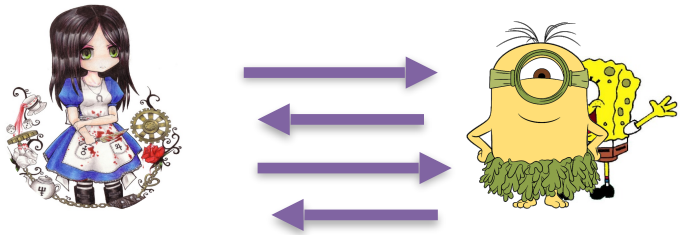

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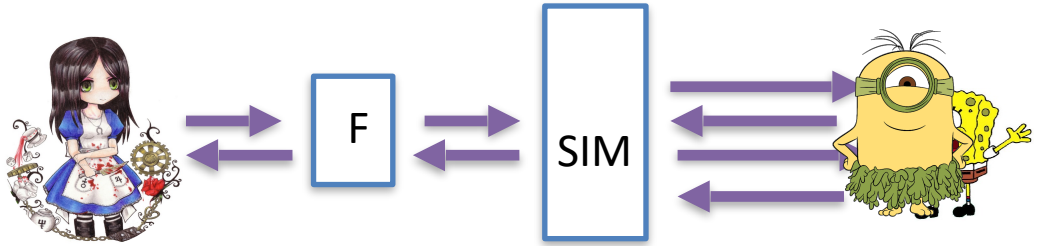

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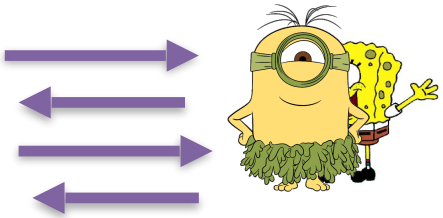
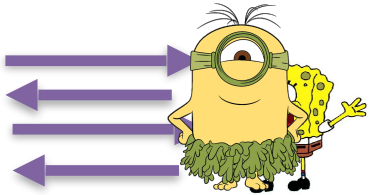
SIM runs in Poly time



F

SIM

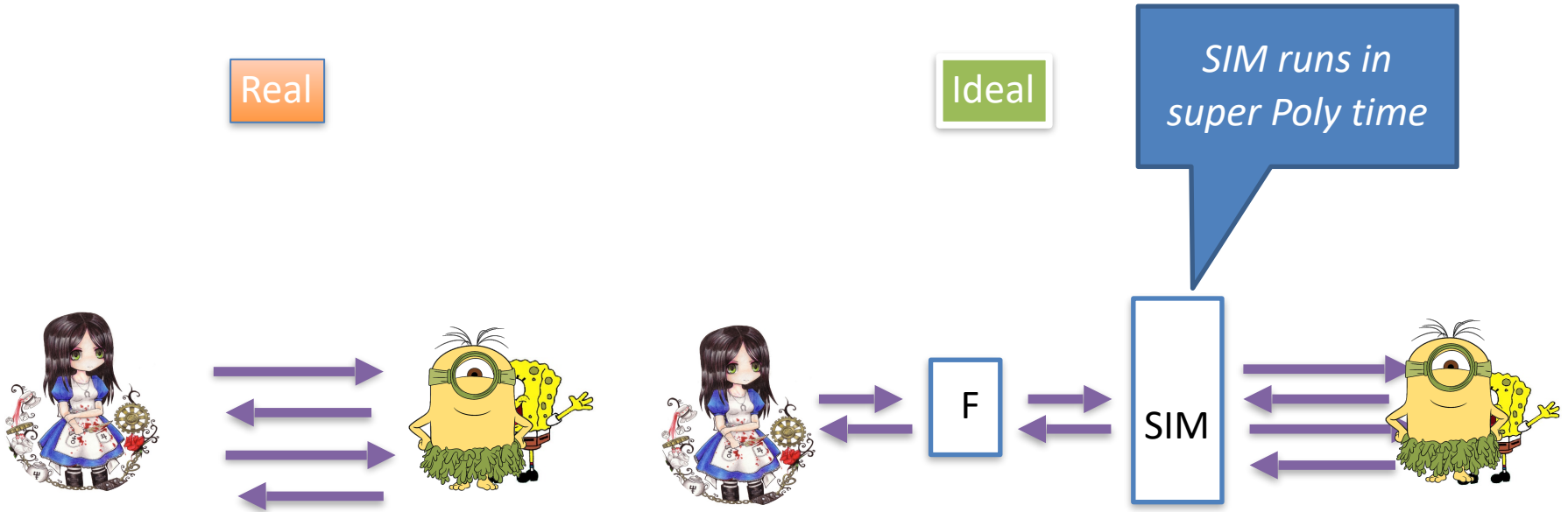


Real

Computationally Indistinguishable

Ideal

SPS Simulation Paradigm [Pass03, PS04, BS05, BGJKS17]



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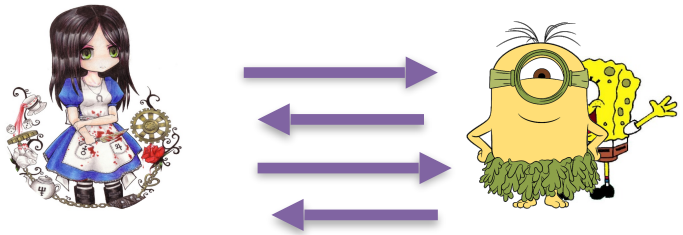

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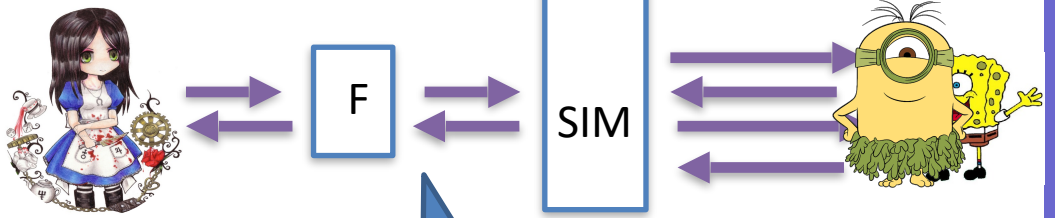

SIM runs in super Poly time

But F is secure even against super poly adversary

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Computationally Indistinguishable

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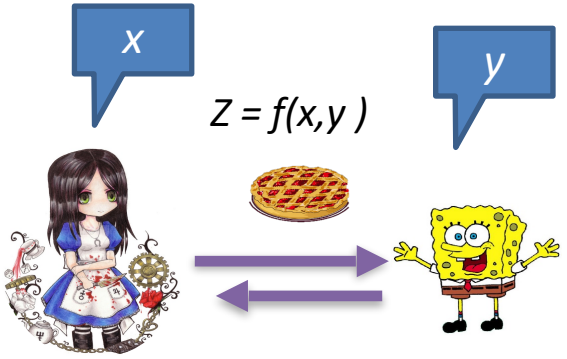
Our Results

Main Result:



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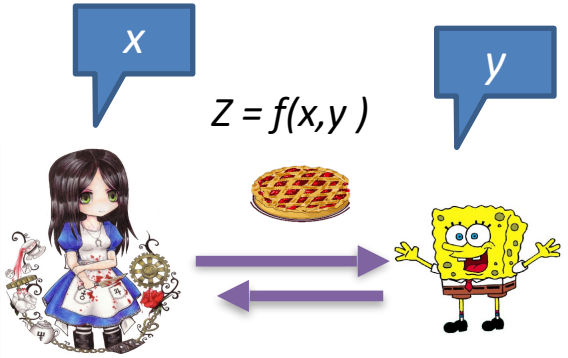

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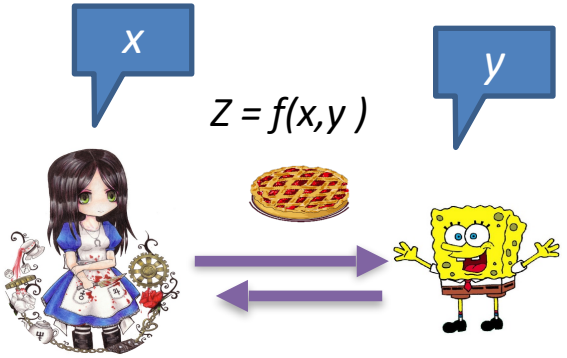

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First two-round concurrent-secure 2PC thaty does not require:

- The existence of a one-round NMC. Instead, we are able to use the two-round NMCs of [KhuSah17], which is instantiable from sub-exponential LWE.
- The existence of non-interactive witness indistinguishable arguments or time-lock puzzles.

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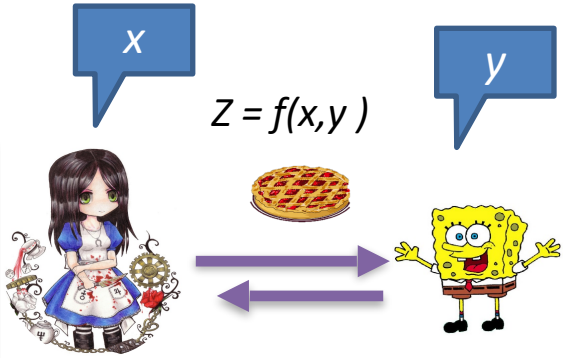

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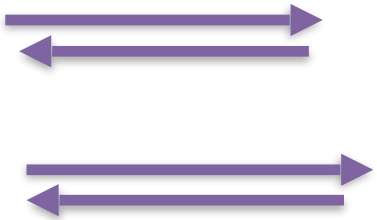
The Applications:

1) The first two-round PAKE scheme in the plain model, resolving a long-standing open problem in the area

2) The first concurrent 2PC for quantum functionalities (in the plain model) with classical inputs and outputs

Observarion: The 2PC Construction

Observarion from [ABGKM21] -The need for Verifiability



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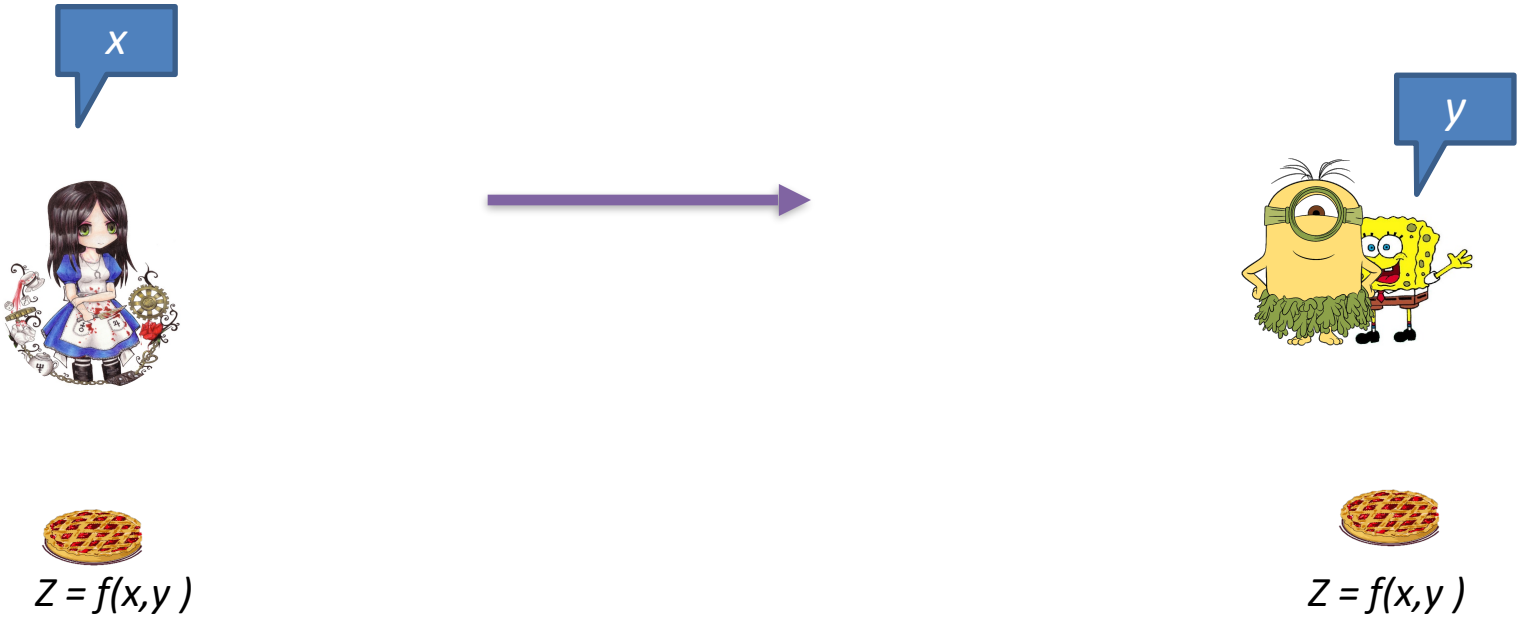

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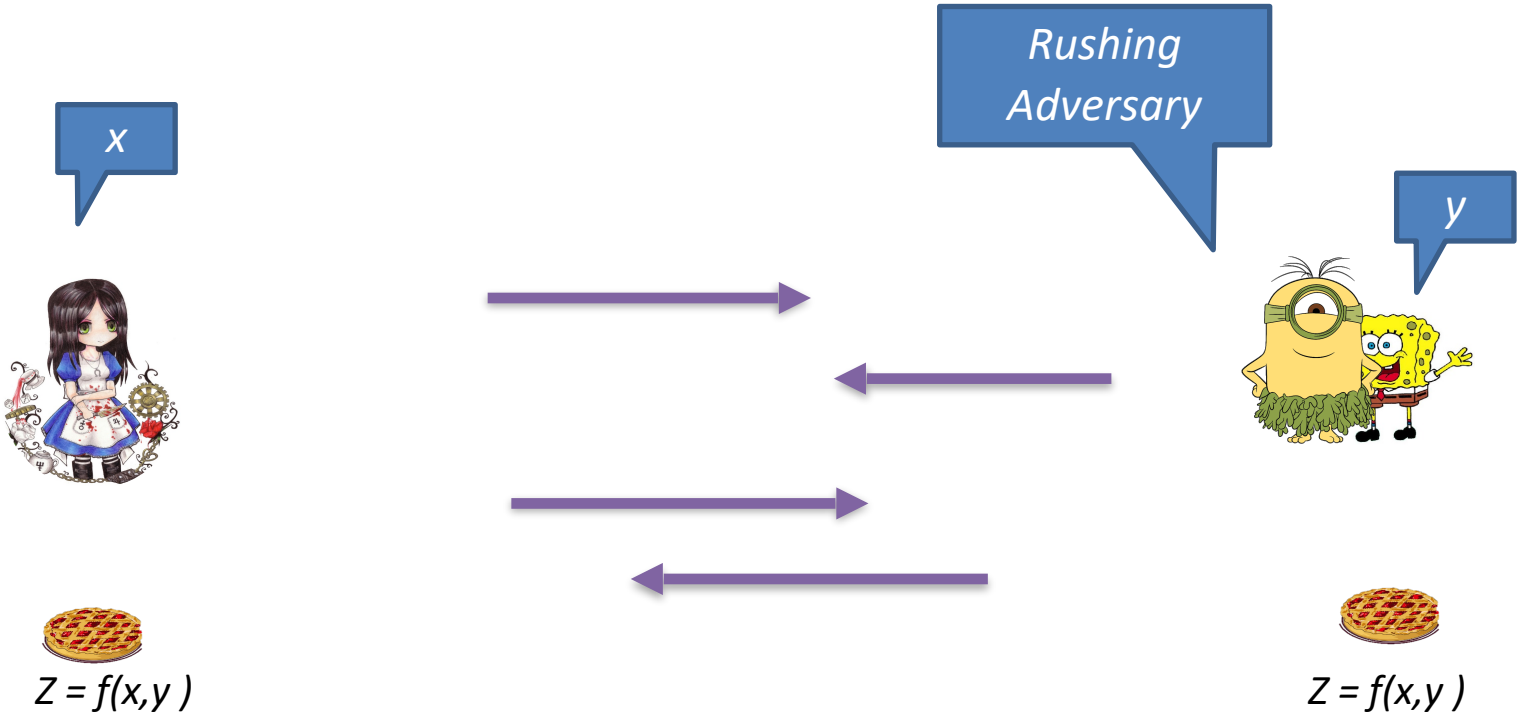

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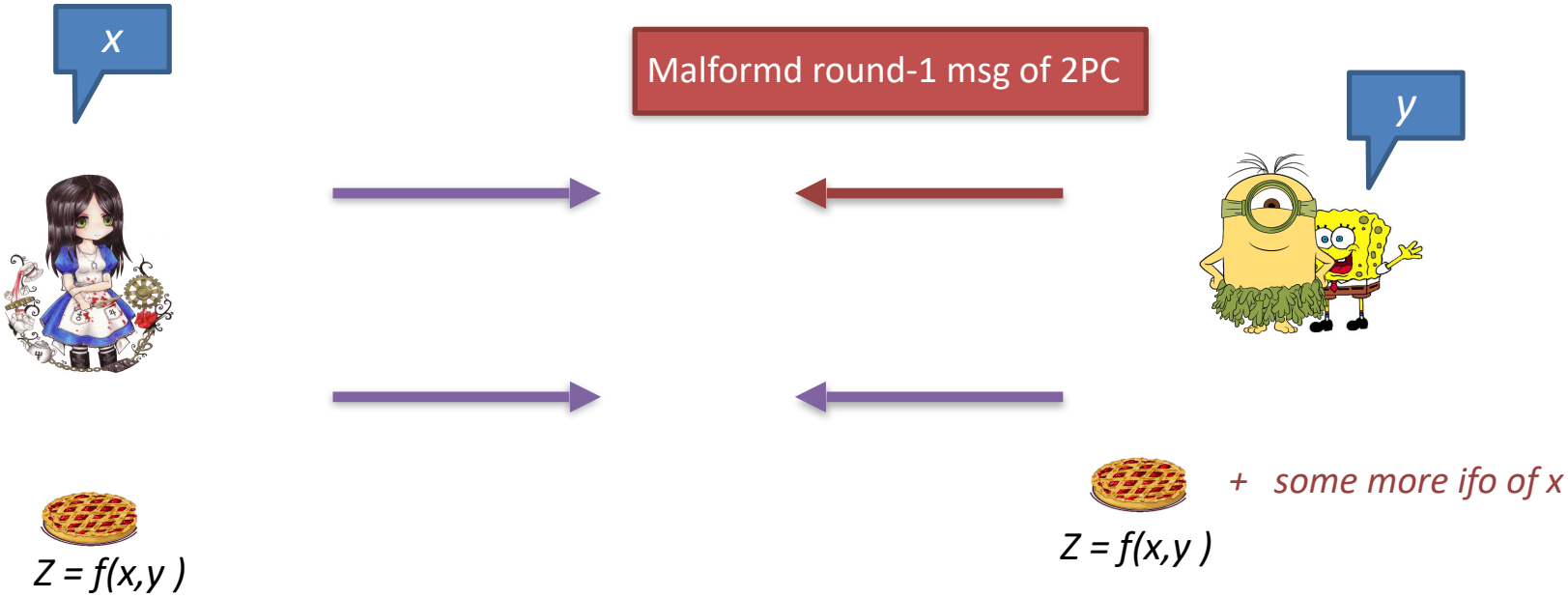

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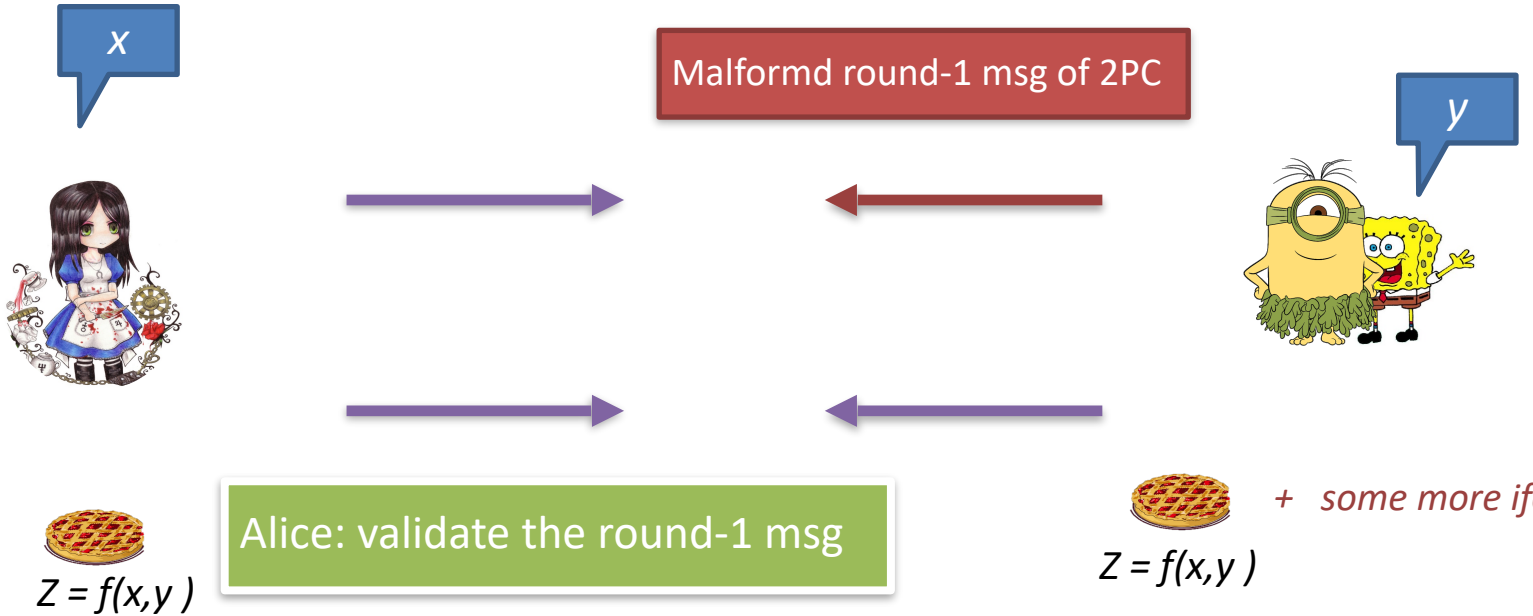

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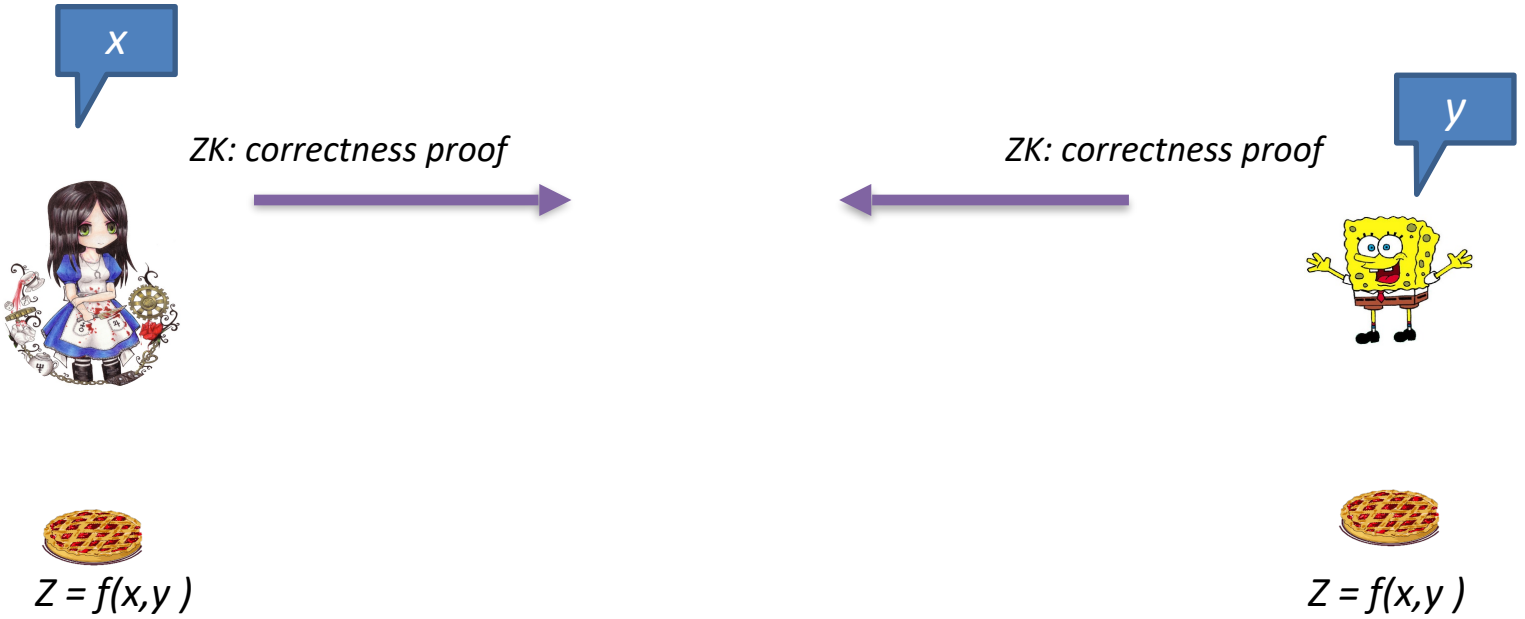

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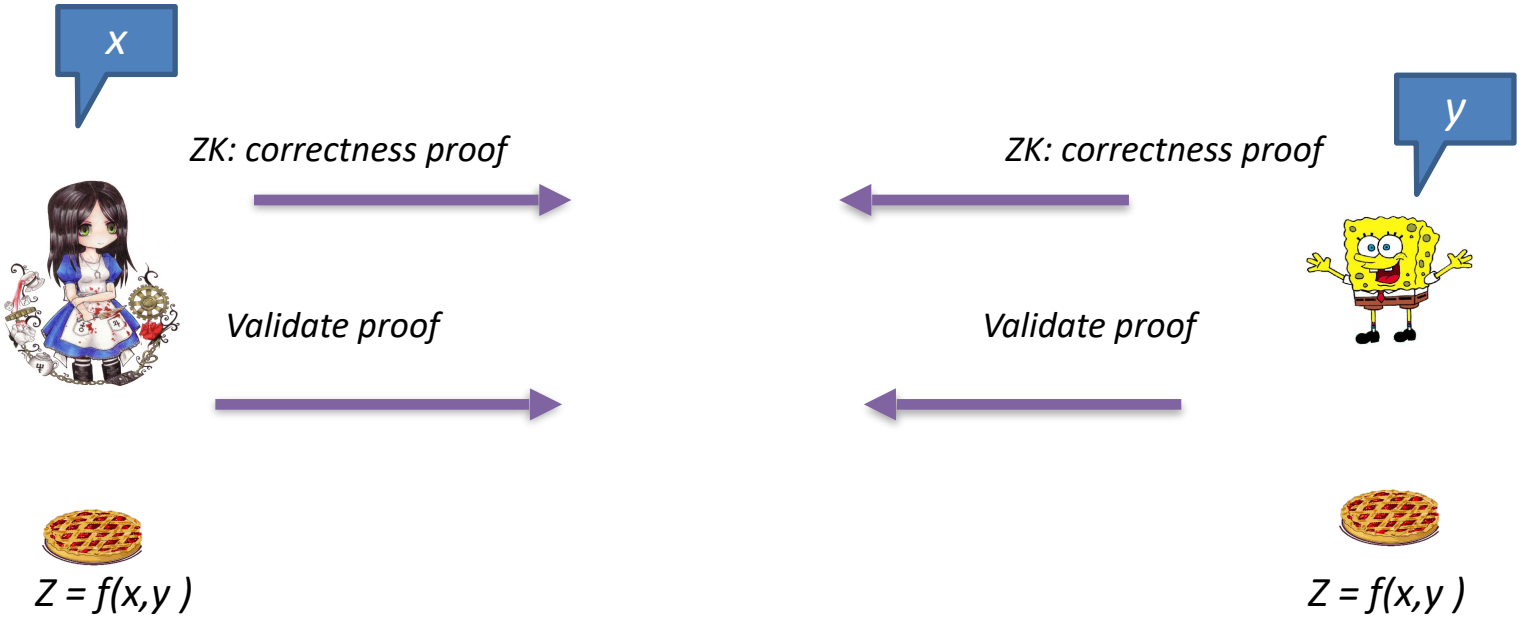

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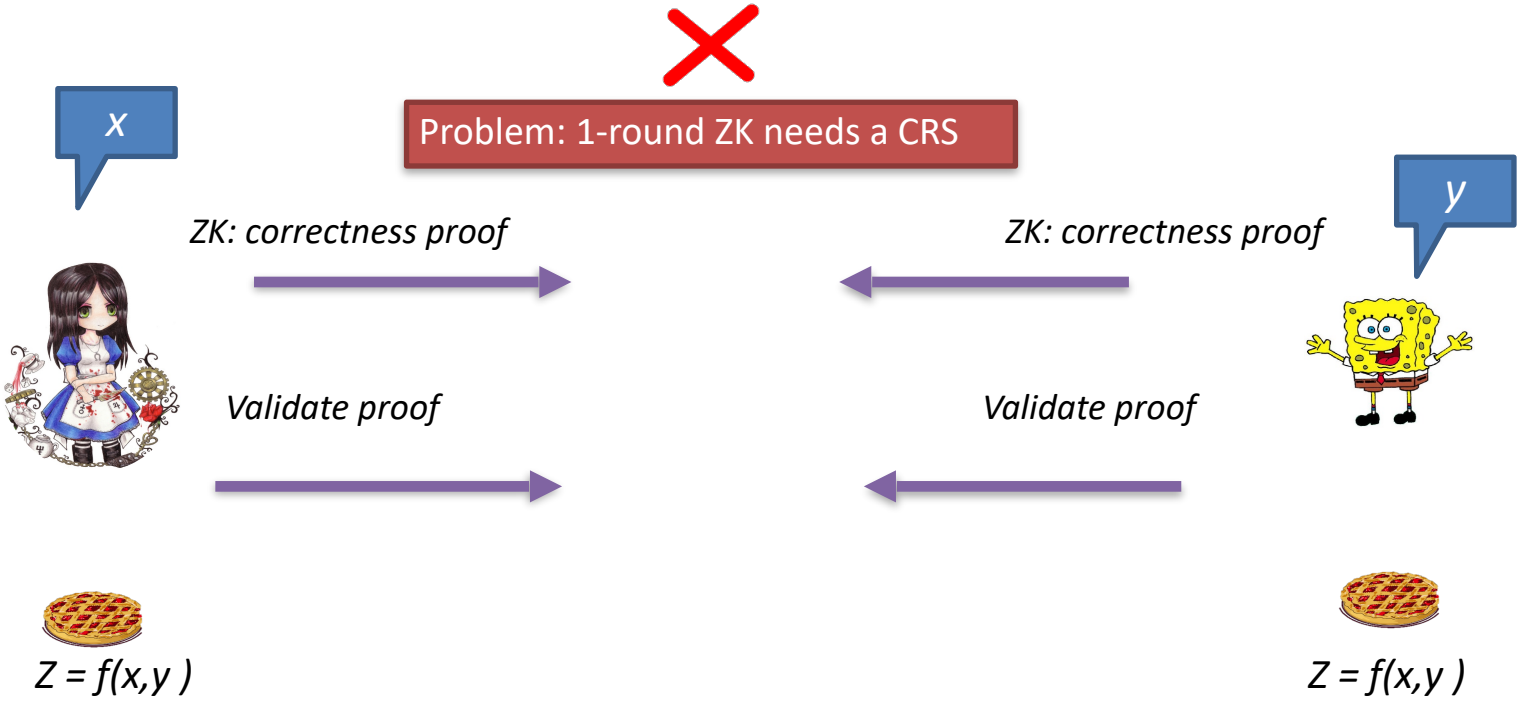

Intuition: Alternative Approach

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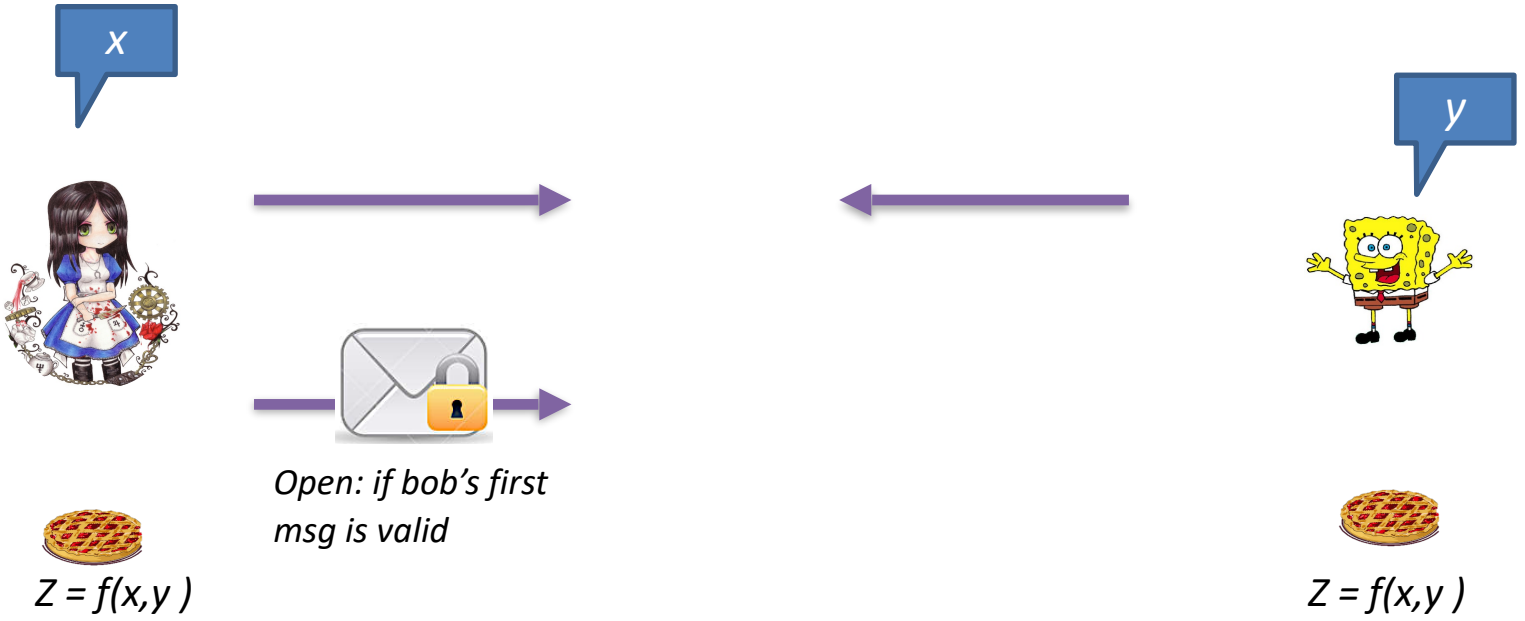

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Open: if bob's first msg is valid

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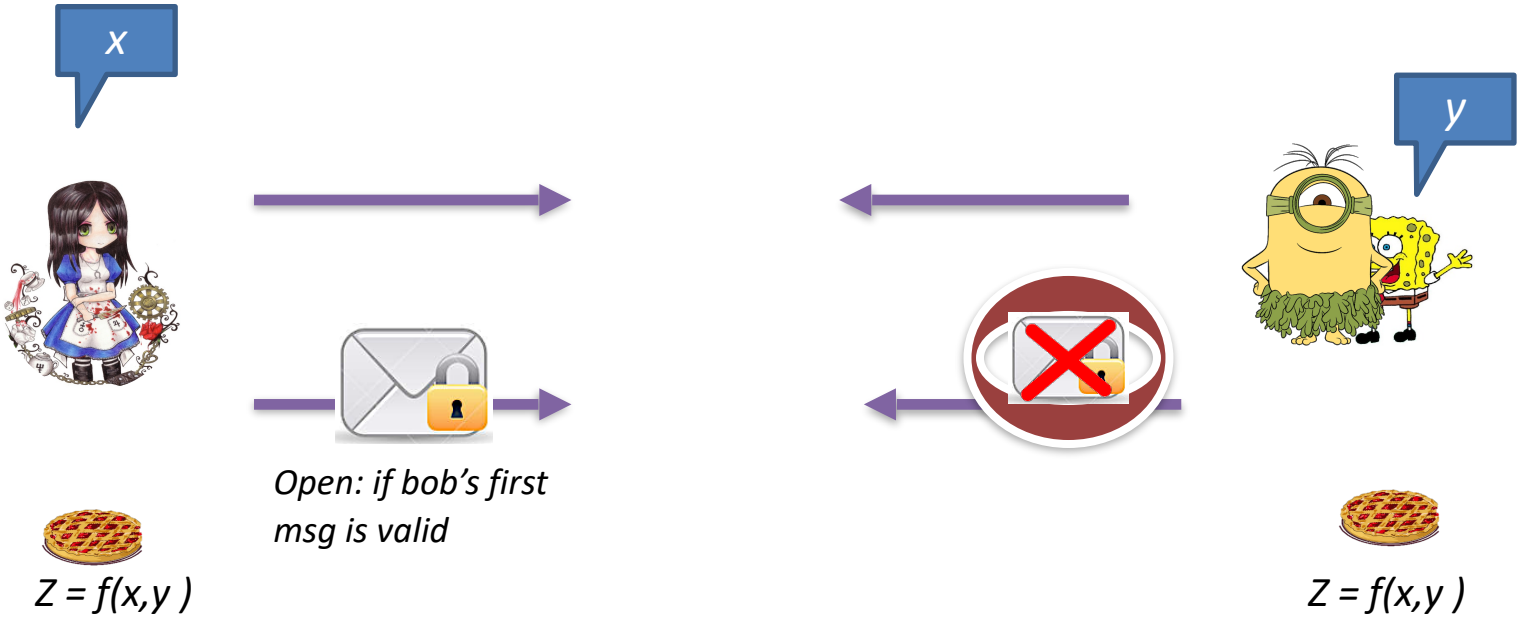
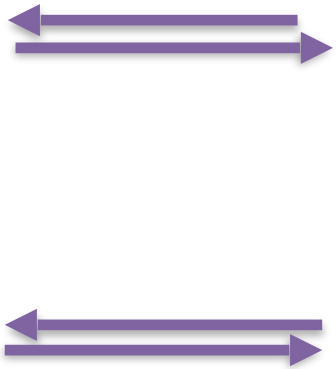
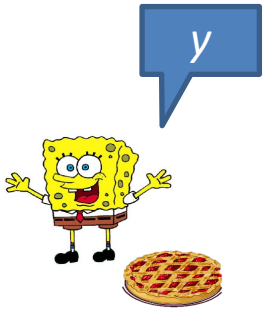


Our Technique/Construction

Four main tools in our construction:





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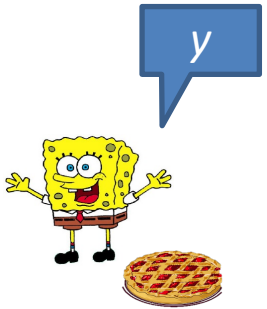
Four main tools in our construction:

a two-round NMC | a two-round SSP OT, | a two-round strong SPS zero-knowledge | garbled circuits

P_i: Two different types of commitments to its input, (NMC1 and OT1 message).



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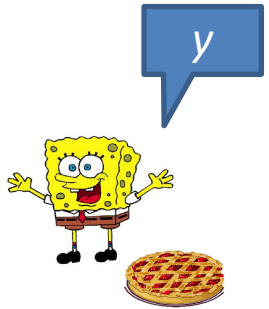

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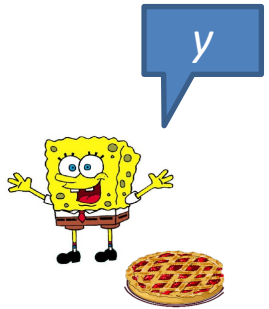

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x

Z = f(x,y)

How do we prevent the adversary from learning f(x, y), then?

y

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The SSP OT: an adversary can only unlock the protocol output if it knows the input of its OT1 message.

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Are we done?

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Z = f(x',y)

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we must somehow connect the NMC1 with the OT1

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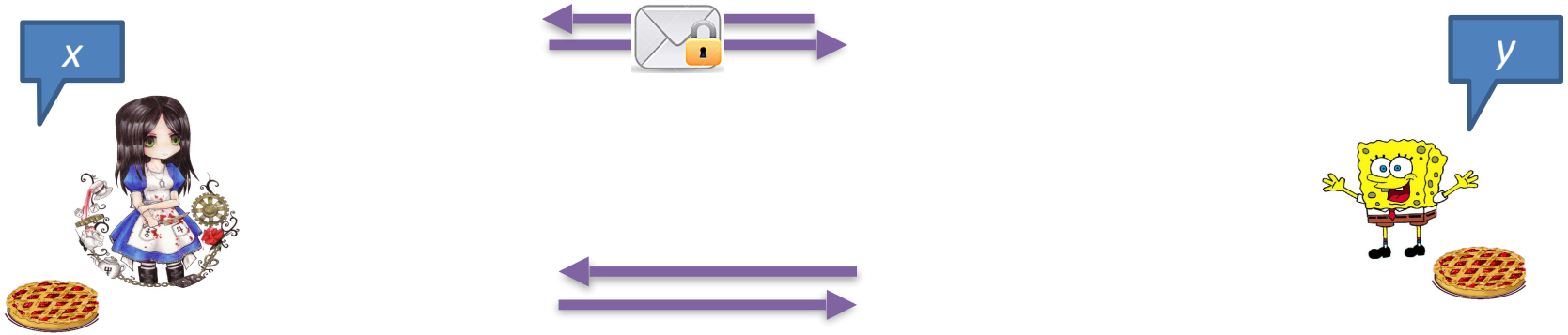
A two-round NMC | Atwo-round SSP OT, | A two-round strong SPS zero-knowledge | Garbled Circuits

P_i: Two different types of commitments to its input: NMC1 and OT1 message).

+

P_i: Commit to the randomness used for its NMC1



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+

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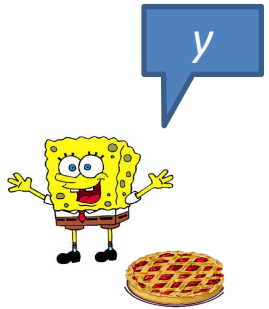
P_i: NMC2 , OT2



$Z = f(x,y)$

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Our Technique/Construction

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P1−i: can construct its garbled circuit to only reveal the output if this randomness is correct.

P_i: Two different types of commitments to its input: NMC1 and OT1 message). + **P_i: Commit to the randomness used for its NMC1**

x

P_i: NMC2 , OT2, Garbled Circuit C, and SPS.ZK.

y

$Z = f(x,y)$

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x

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Done!

y

$Z = f(x,y)$

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Thanks