A²L: Anonymous Atomic Locks for Scalability in Payment Channel Hubs

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IEEE Symposium on Security and Privacy 2021

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  - Atomicity:
    - No honest party loses coins
  - Unlinkability:
    - Gateway does not learn who is paying to whom
  - Interoperability:
    - Exchange coins between different currencies (e.g., ethers for bitcoin)

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- One cannot open payment channel with everyone, hence, in practice parties use gateways (payment channel hubs (PCHs))

Atomicity in PCHs

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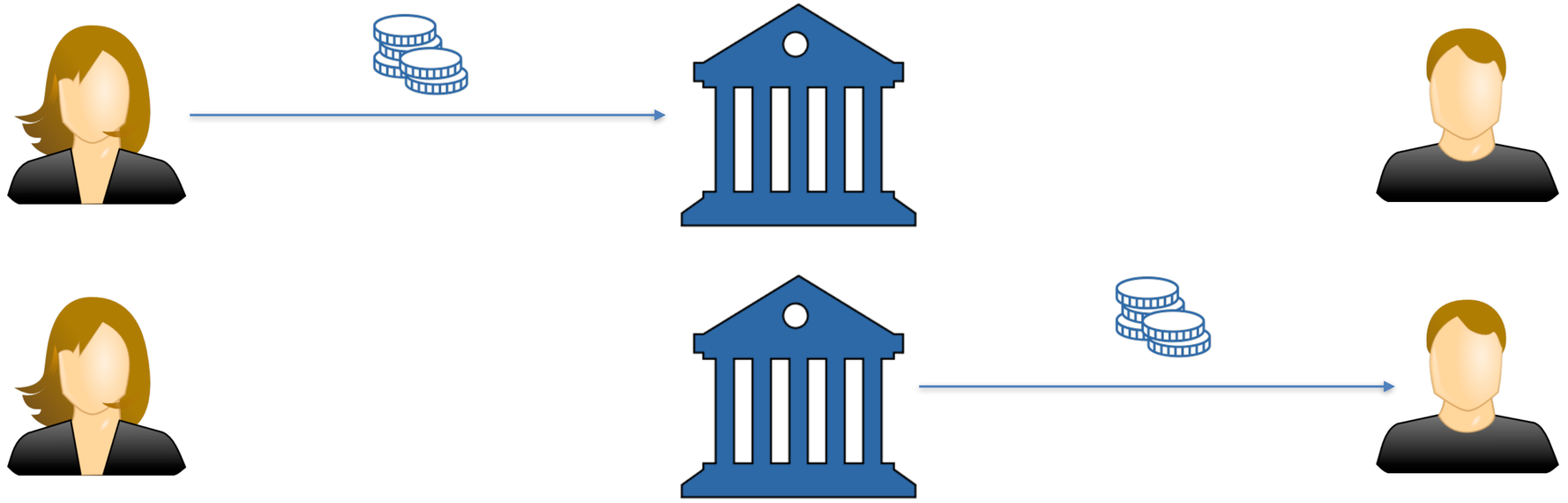
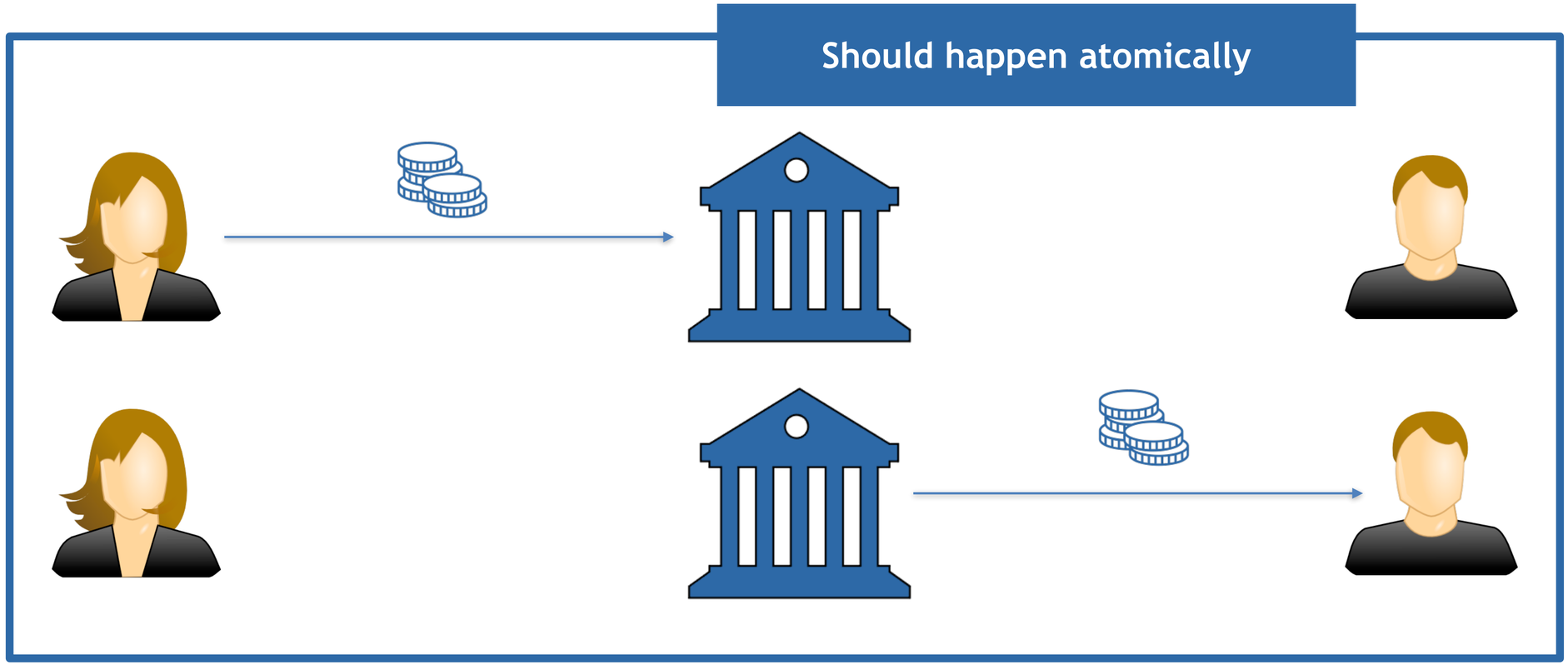


Atomicity in PCHs

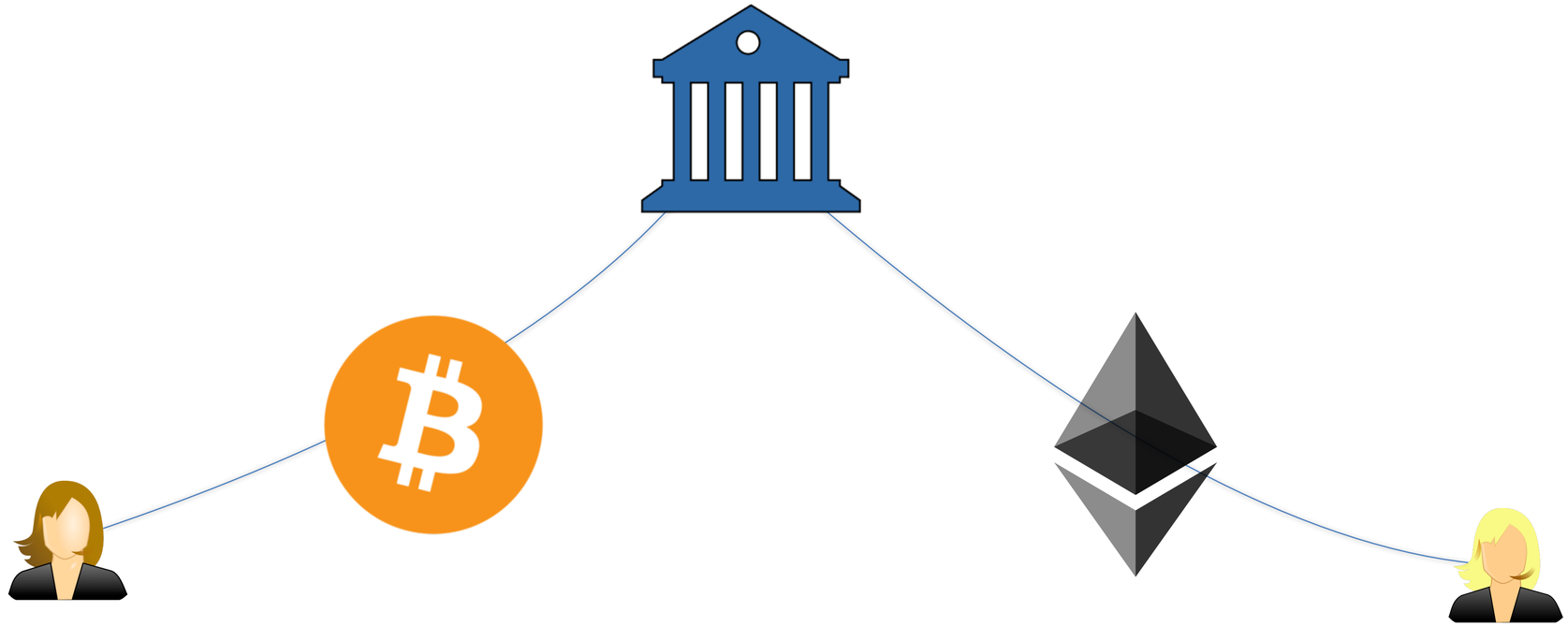


Unlinkability in PCHs

- The gateway should not learn who is paying to whom (i.e., link sender/receiver pairs)

Interoperability in PCHs

- Create a PCH payment protocol backwards compatible with Bitcoin (and as many currencies as possible)



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- TumbleBit is the state-of-the-art PCH introduced by Heilman et al. (NDSS'17), composed of *puzzle promise* and *puzzle solver* protocols

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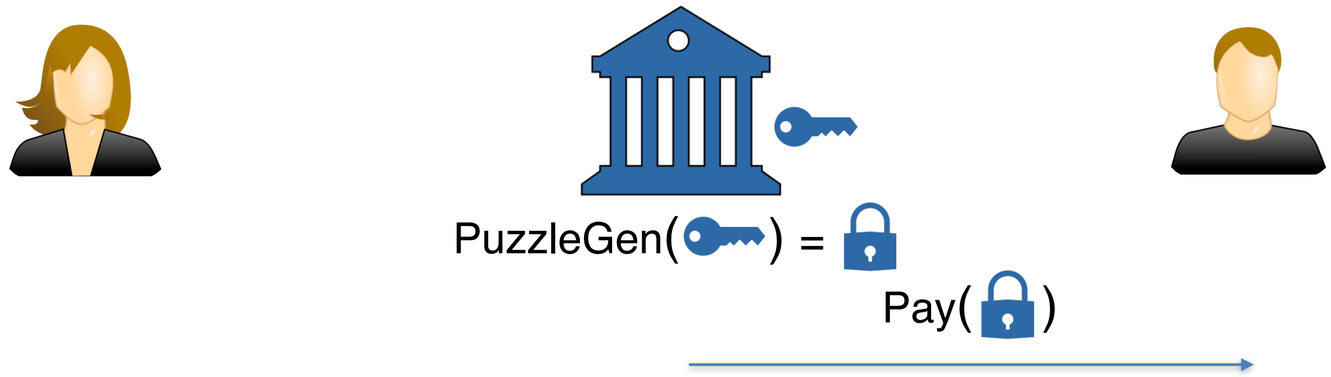

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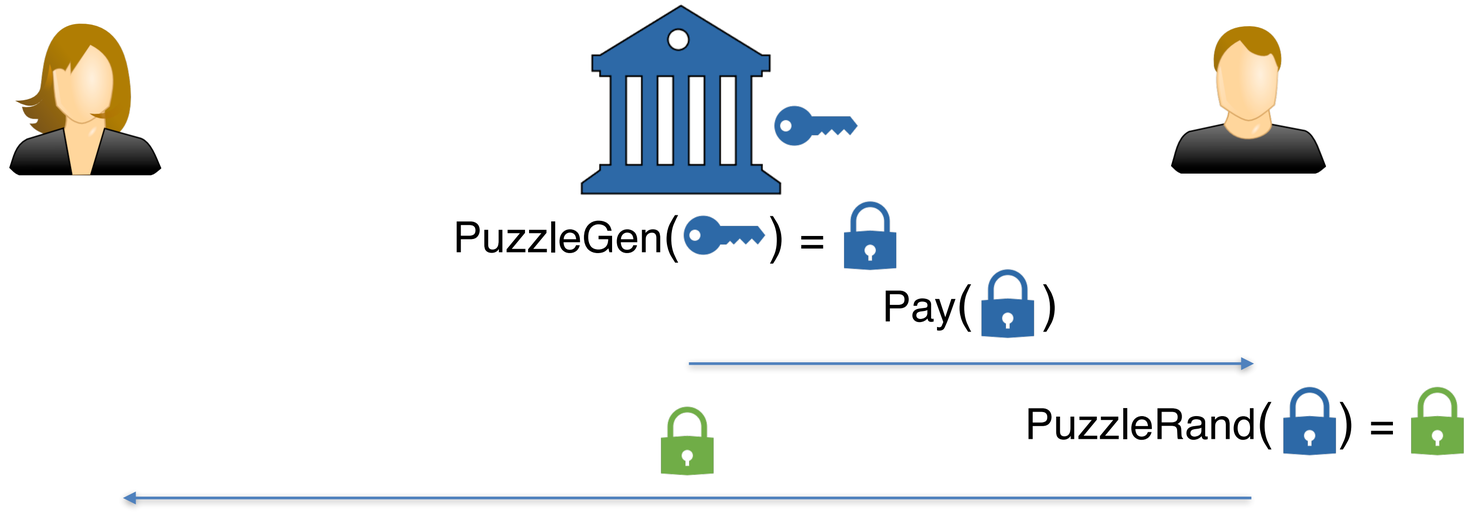

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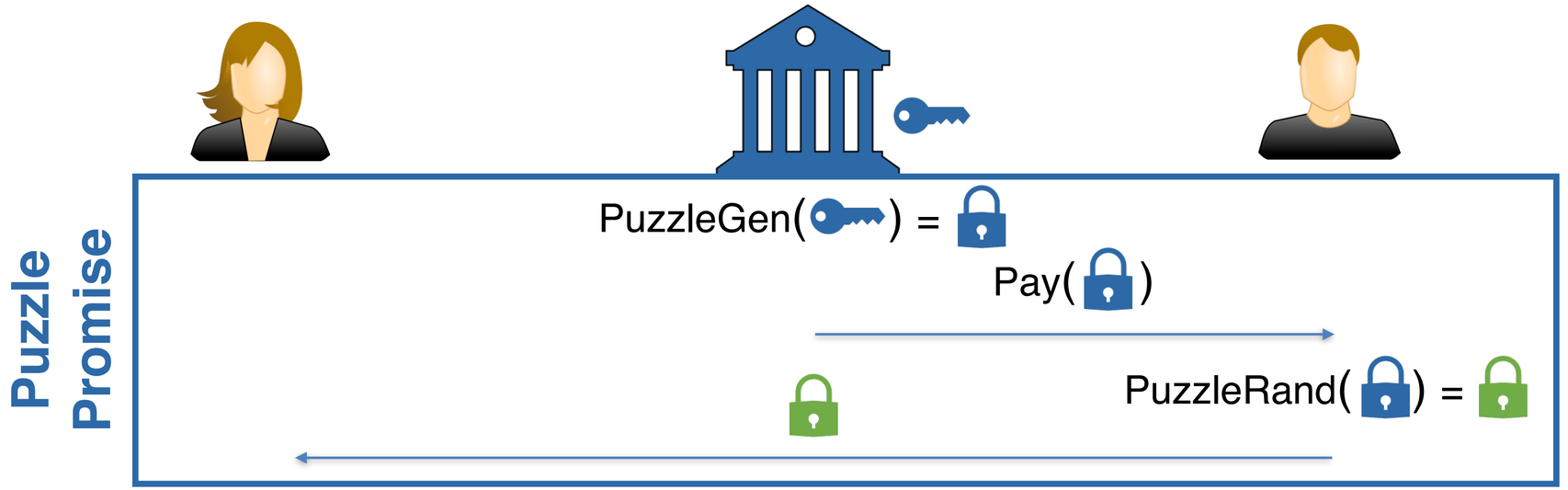

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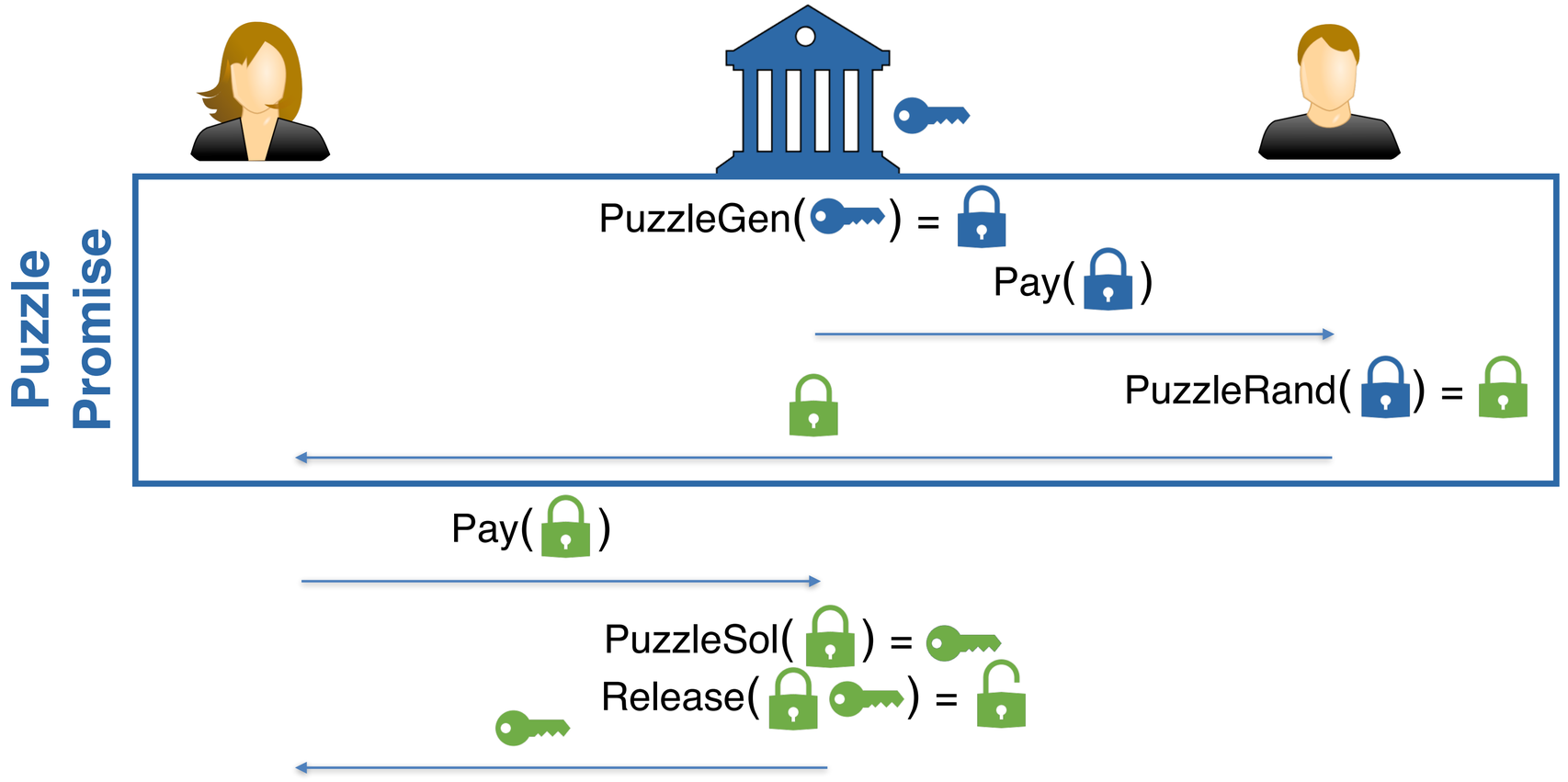

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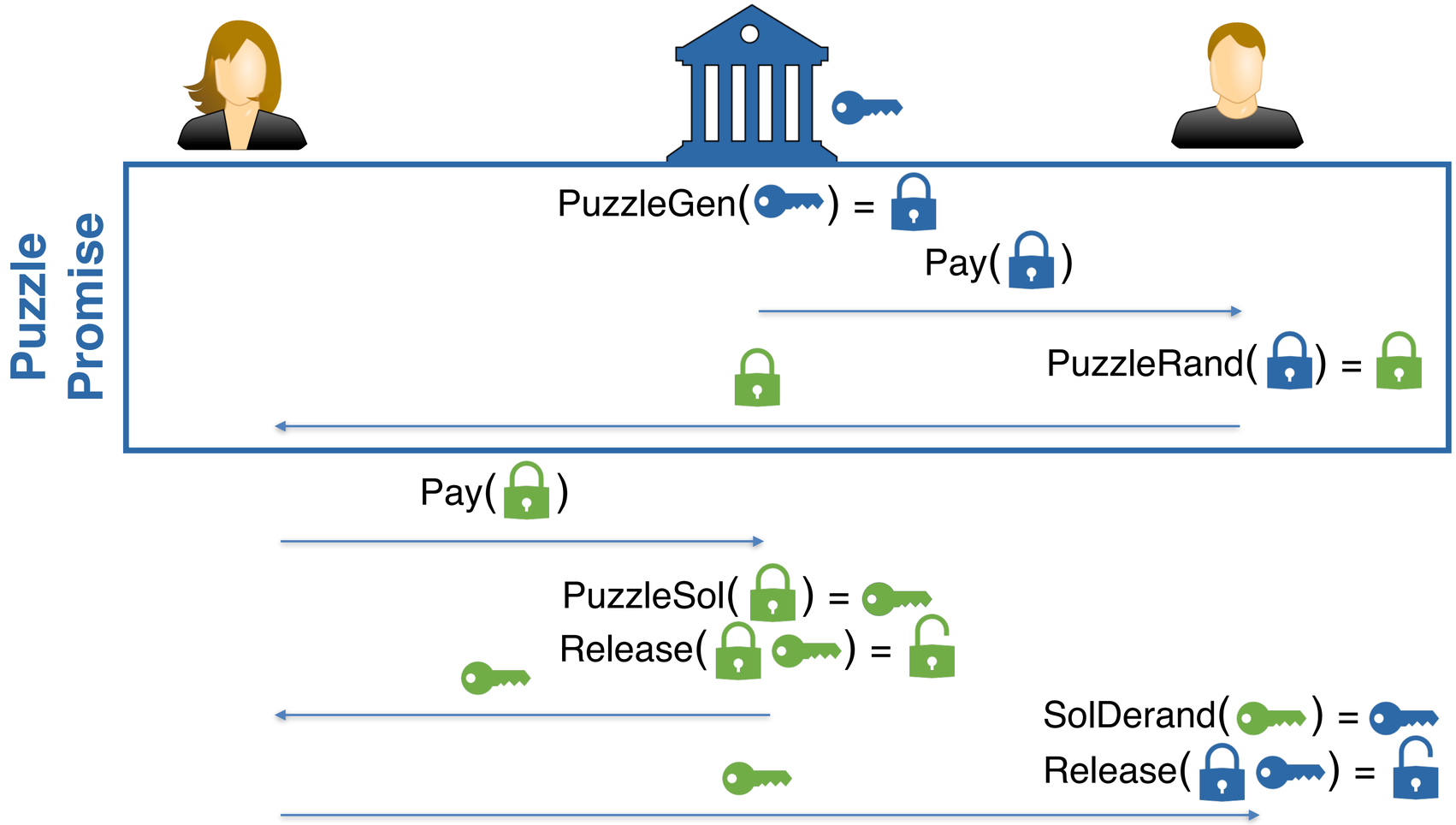

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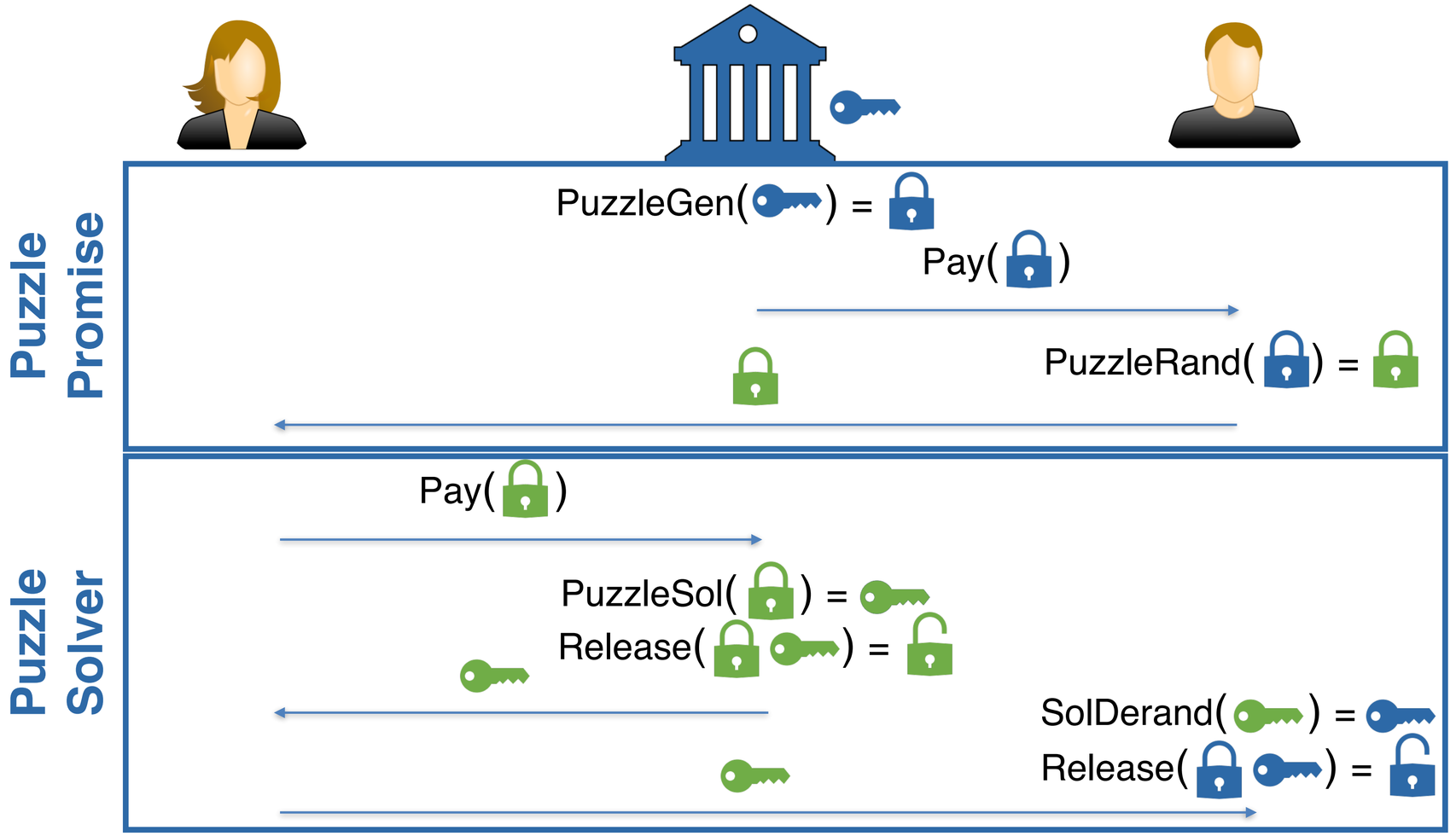

State-of-the-art

- Drawbacks of TumbleBit:
  - Lacks interoperability (only supports HTLC-based currencies,  is a hash)
  - Large communication overhead (due to the cut-and-choose proof technique needs to send large number of )
  - Susceptible to griefing attacks (i.e., asking the gateway for a large number of promises which never get released later)

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Is it possible to design a PCH that is efficient and that provides atomicity, unlinkability, and interoperability (with virtually all cryptocurrencies)?

Yes!

Building Block: Adaptor Signatures (AS)

- Formally defined by Aumayr et al. (https://eprint.iacr.org/2020/476)
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  - Gateway can create an “incomplete-signature” that Bob can only finish using a secret value k. The condition of the signature corresponds to  , and the secret k to 
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🔒 Condition: $C = k * G$

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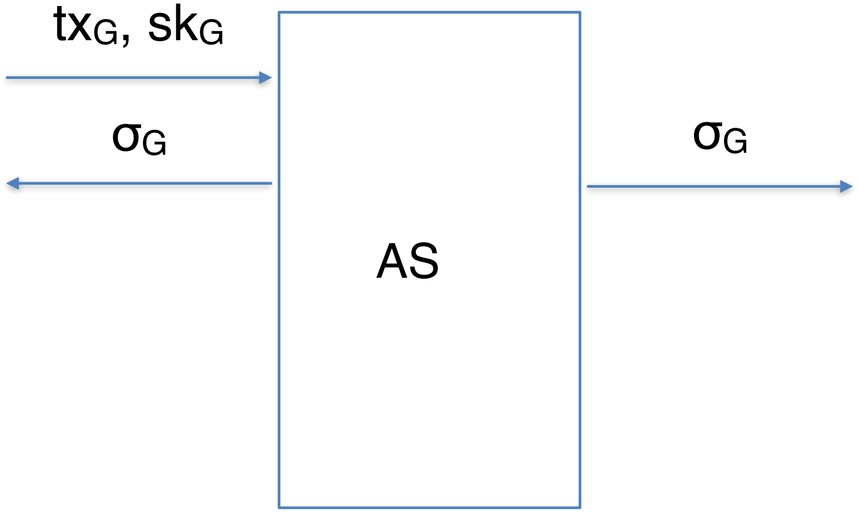

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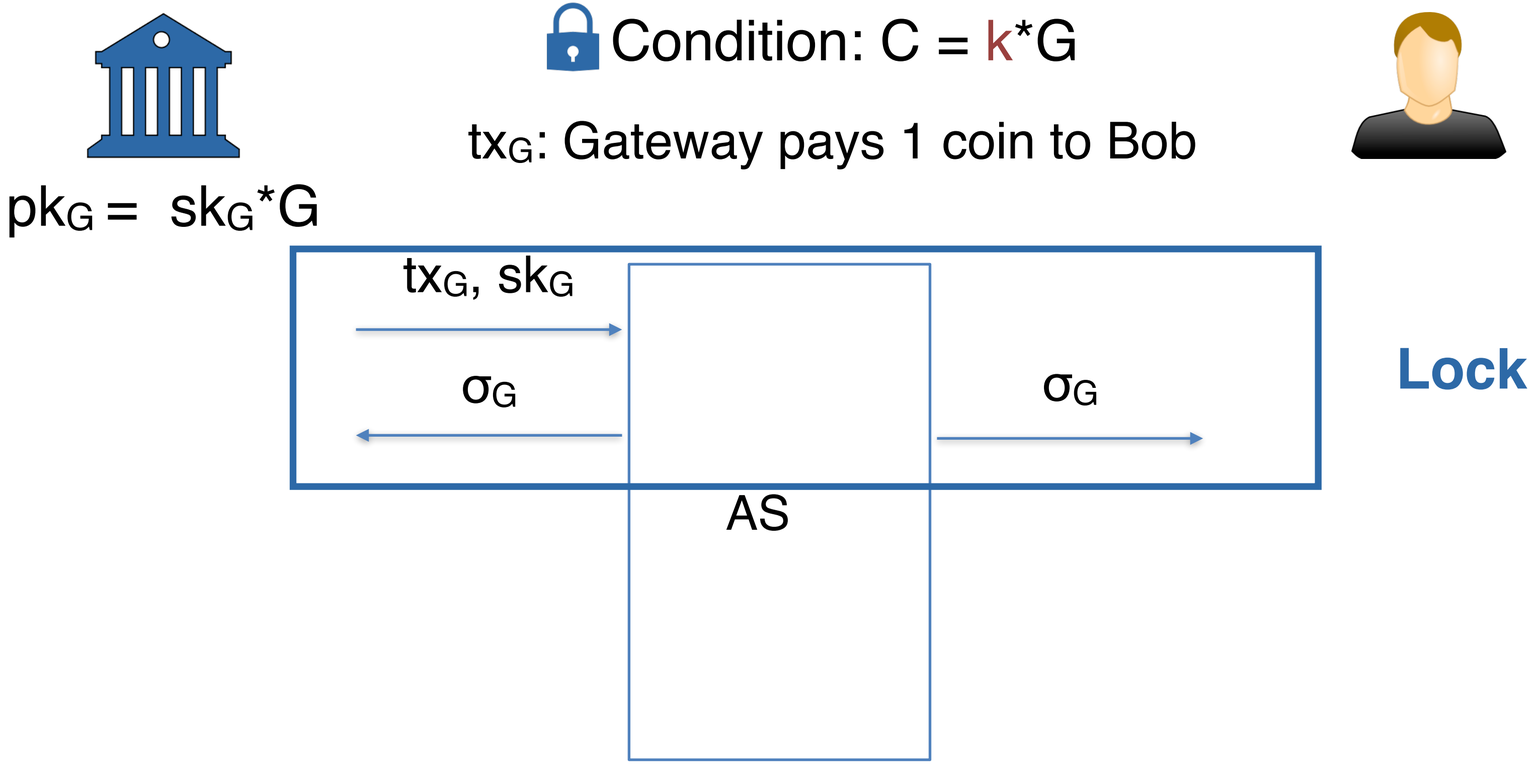

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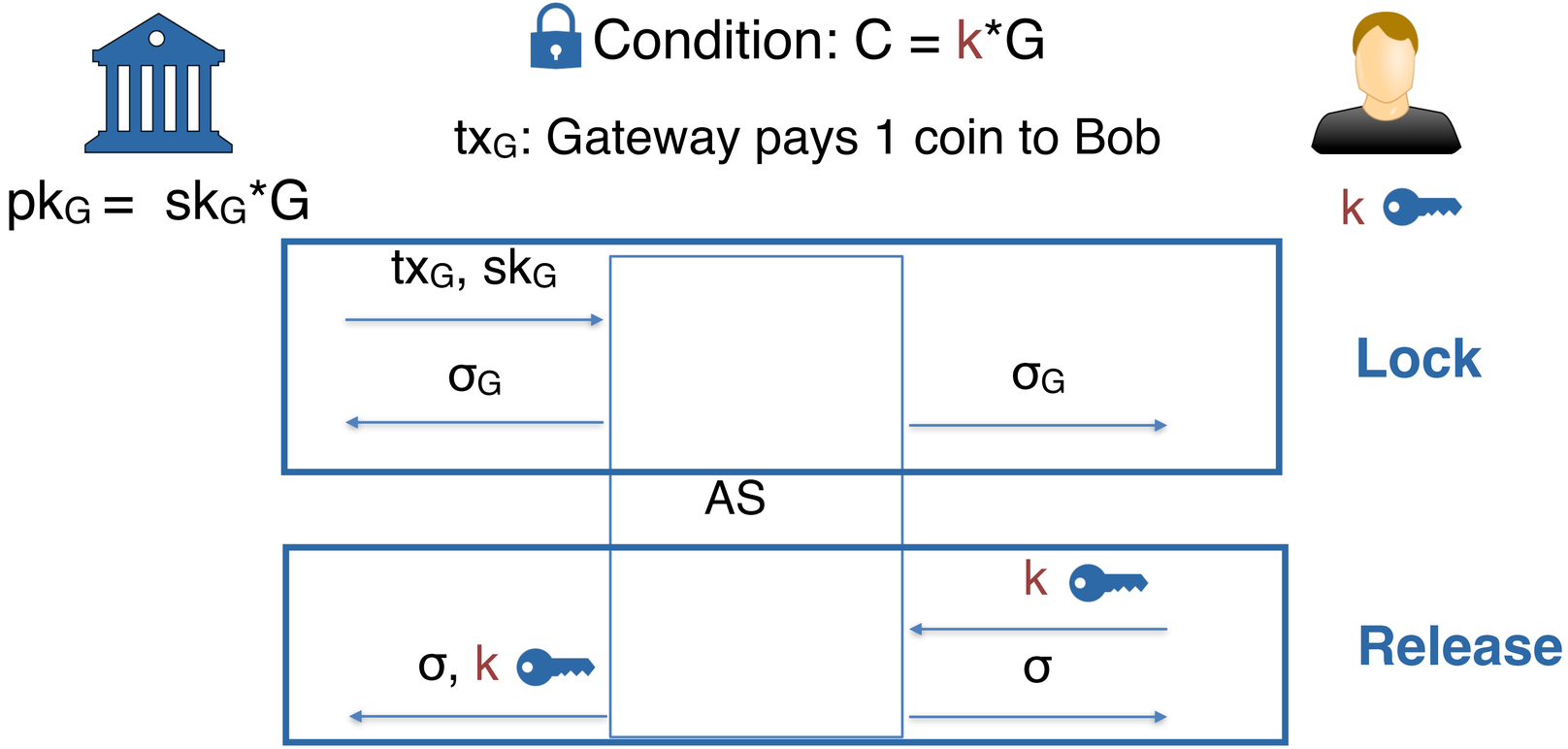

Payment in PCH: First Attempt

(pk_A, sk_A)

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(pk_G, sk_G, k)

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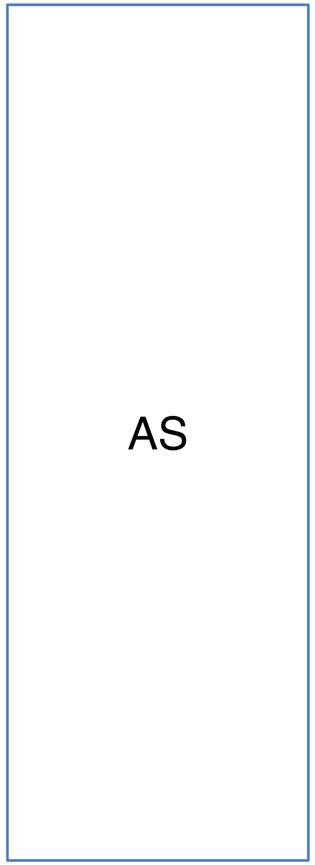

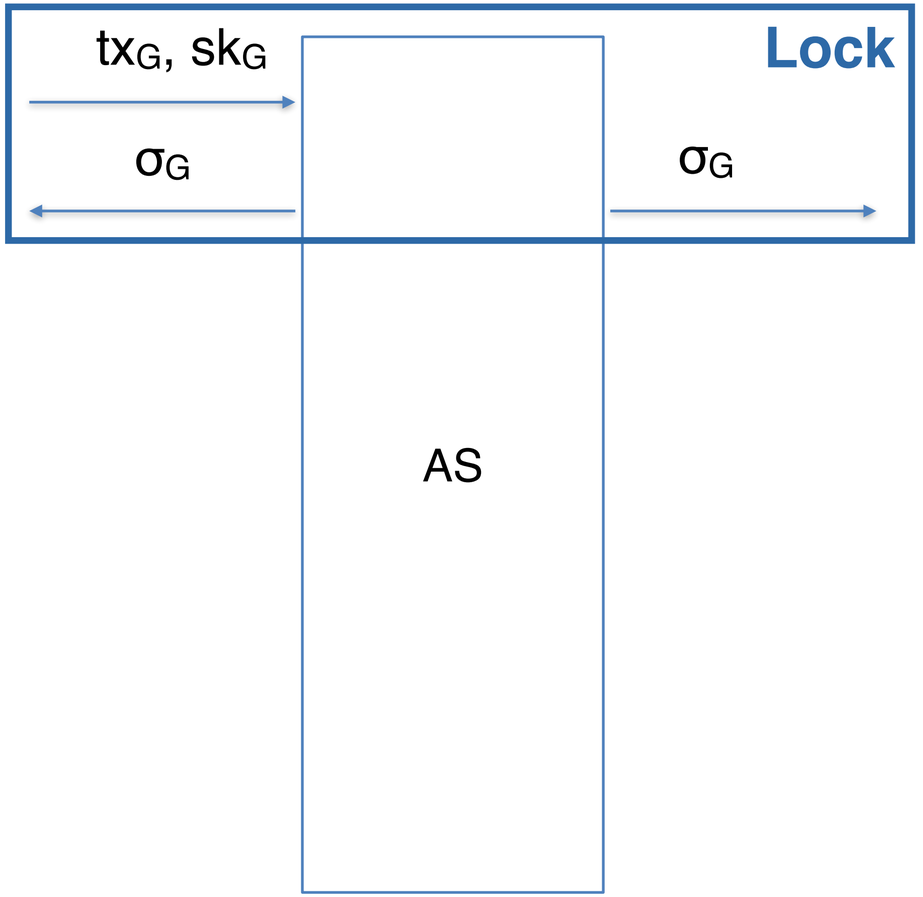

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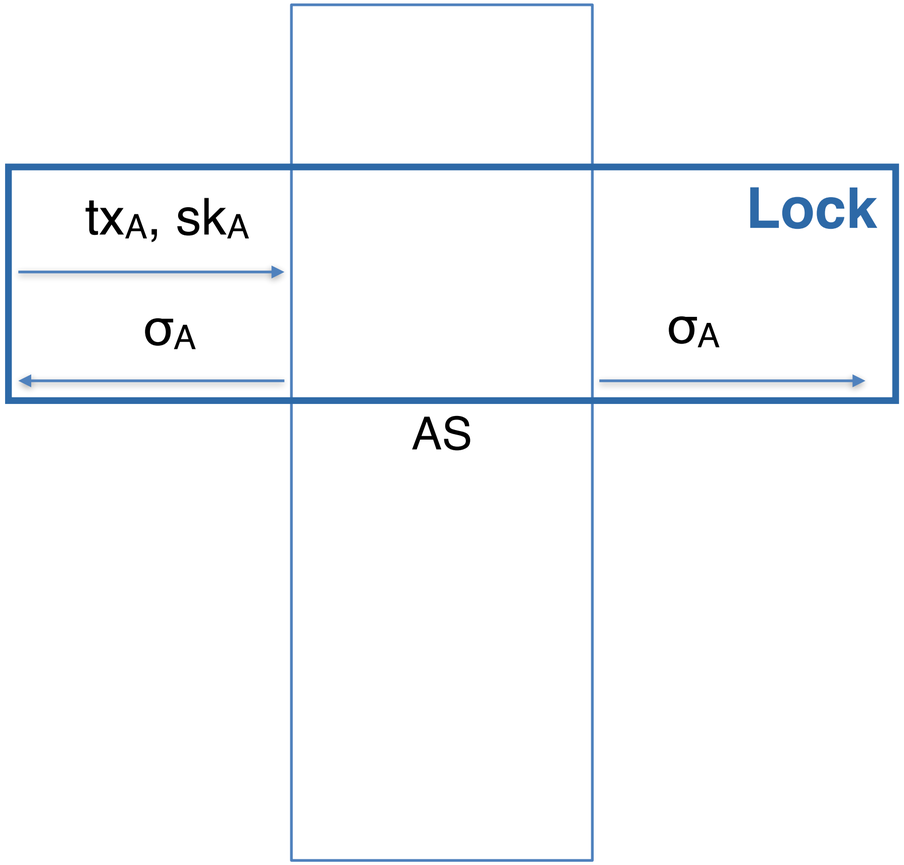

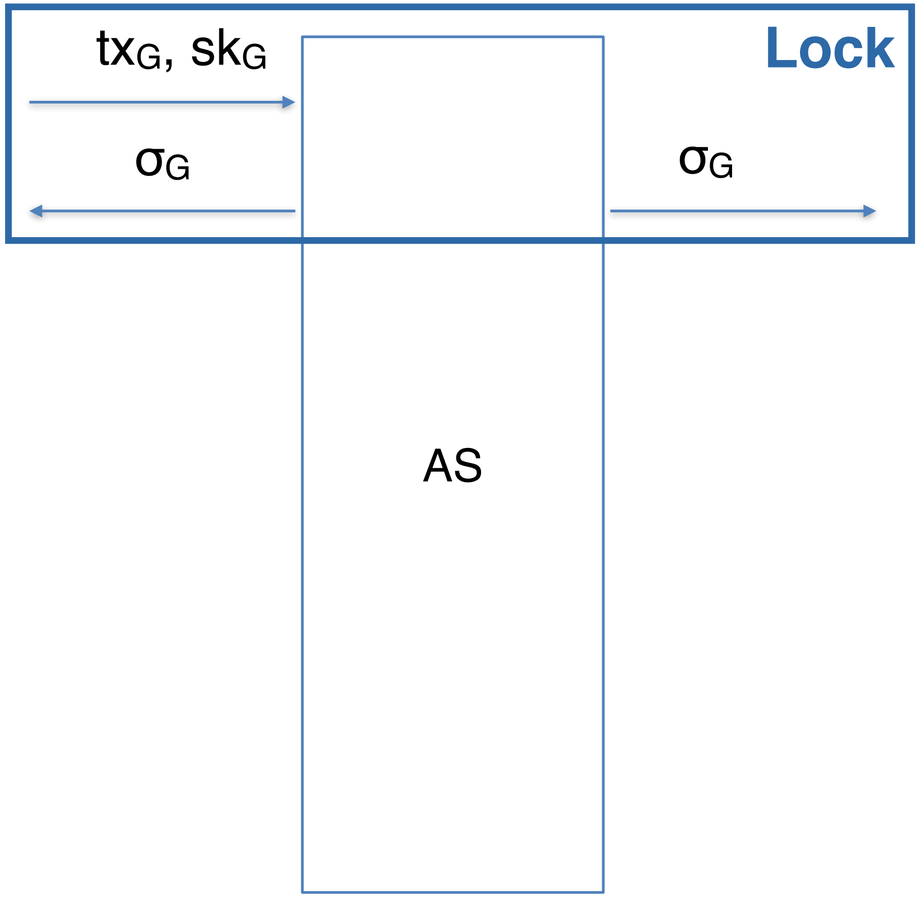

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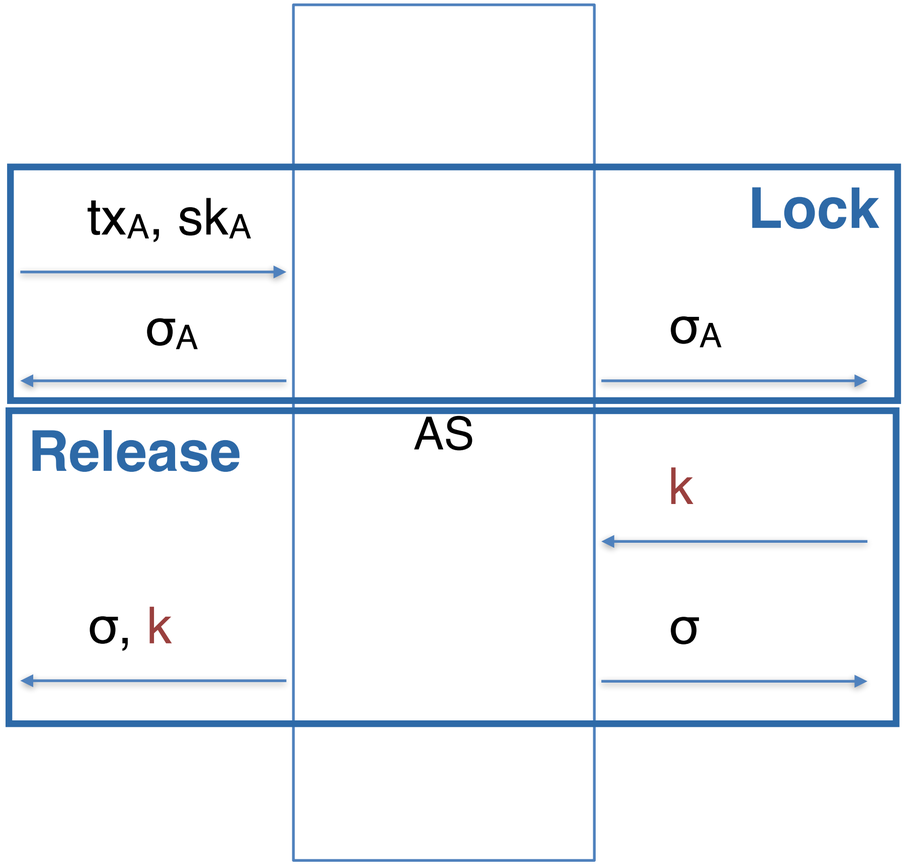

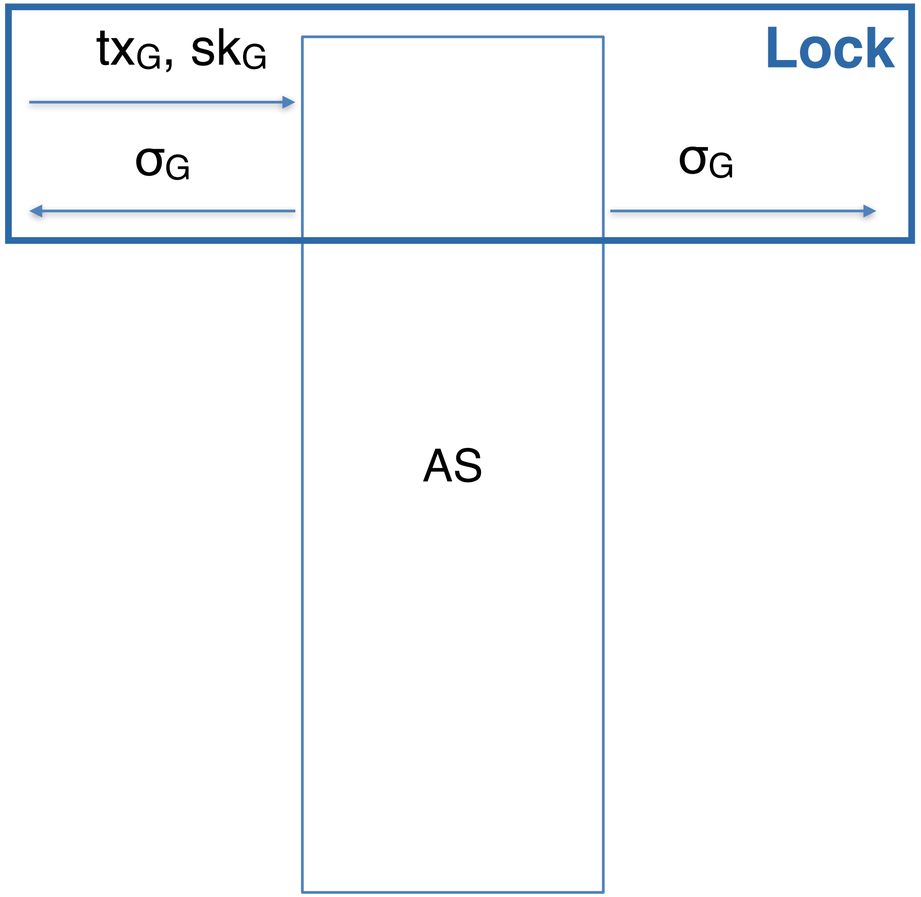

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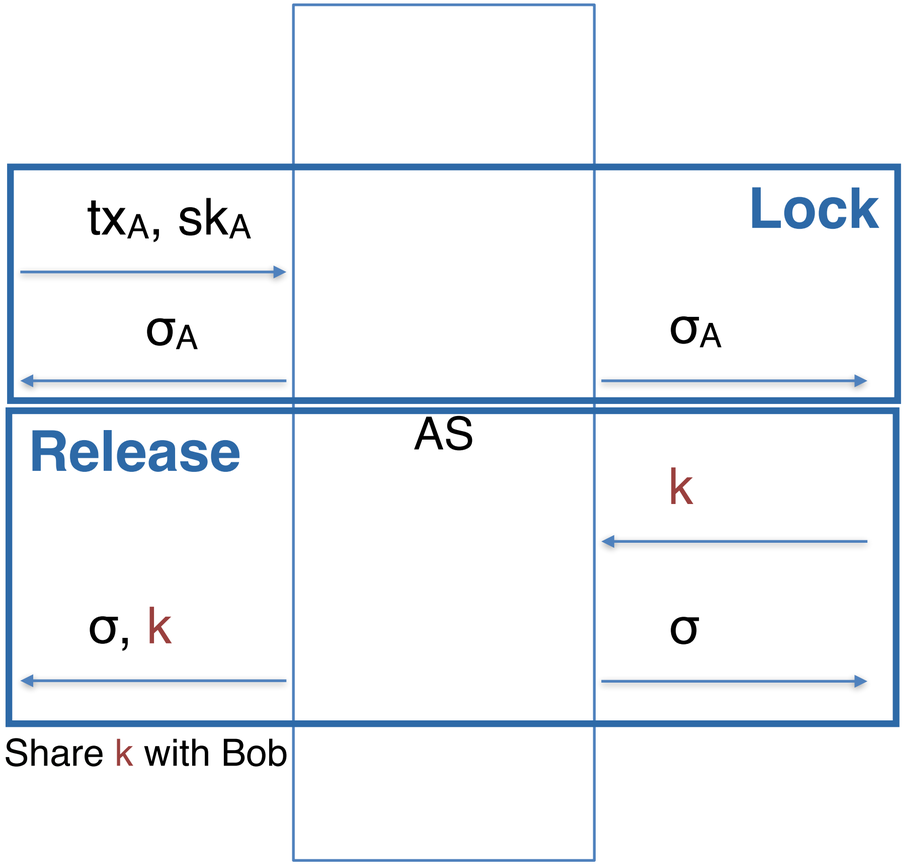

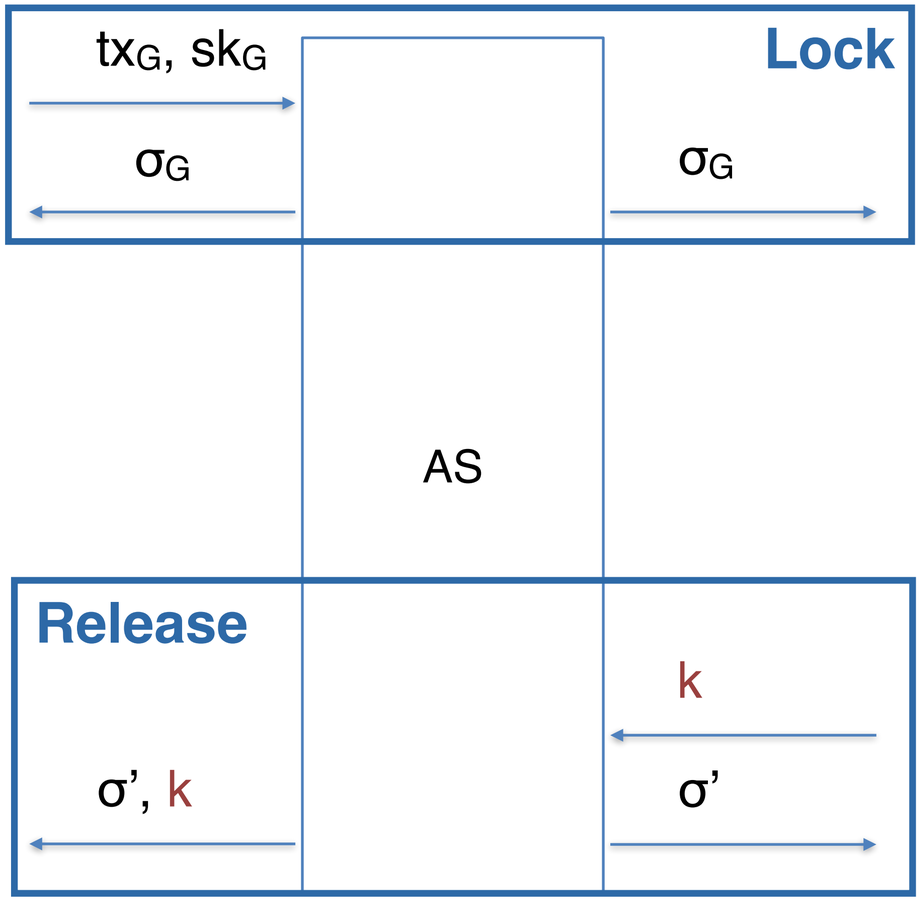

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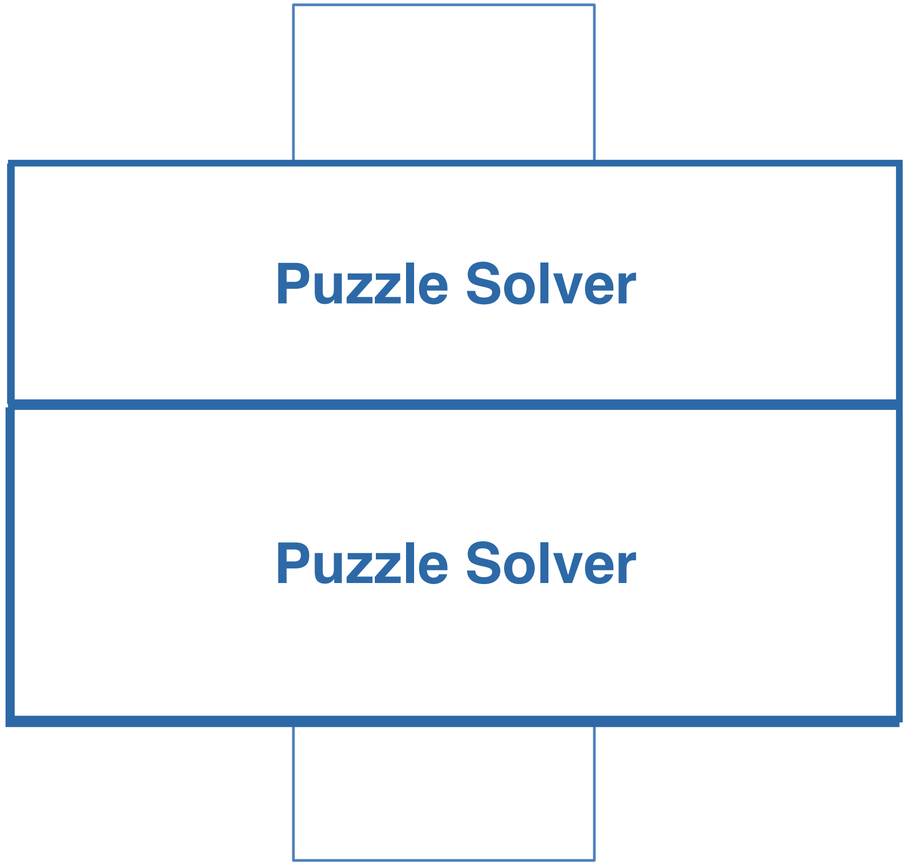

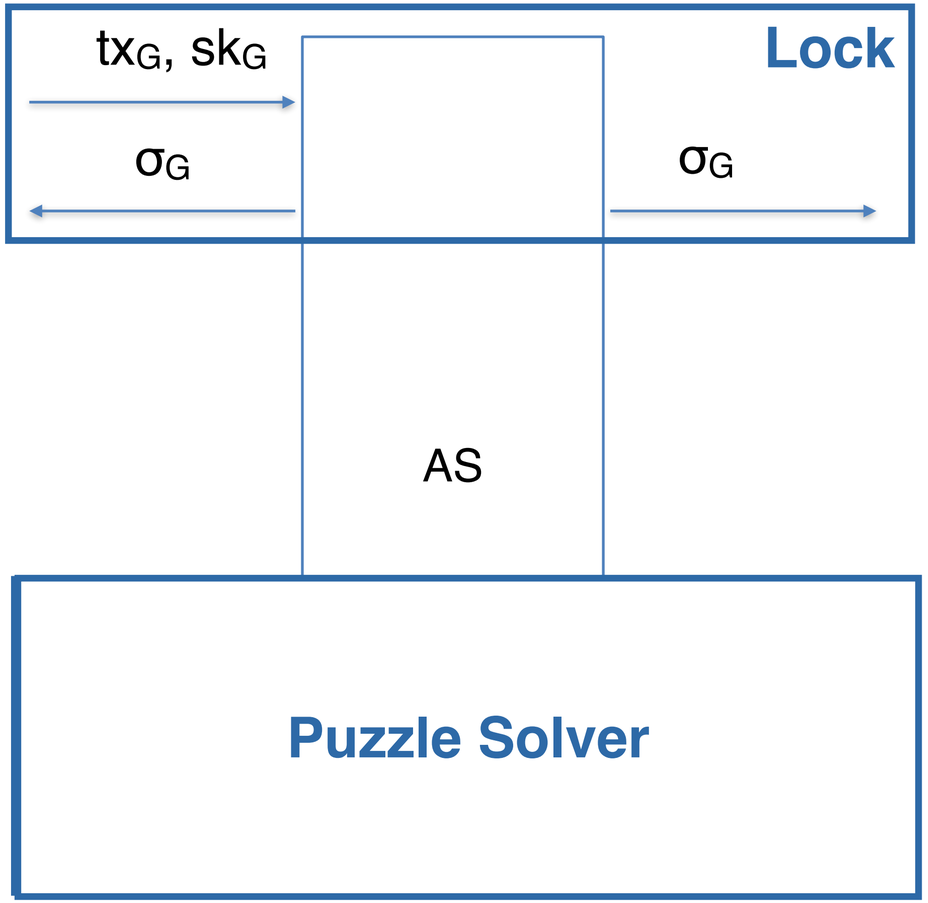

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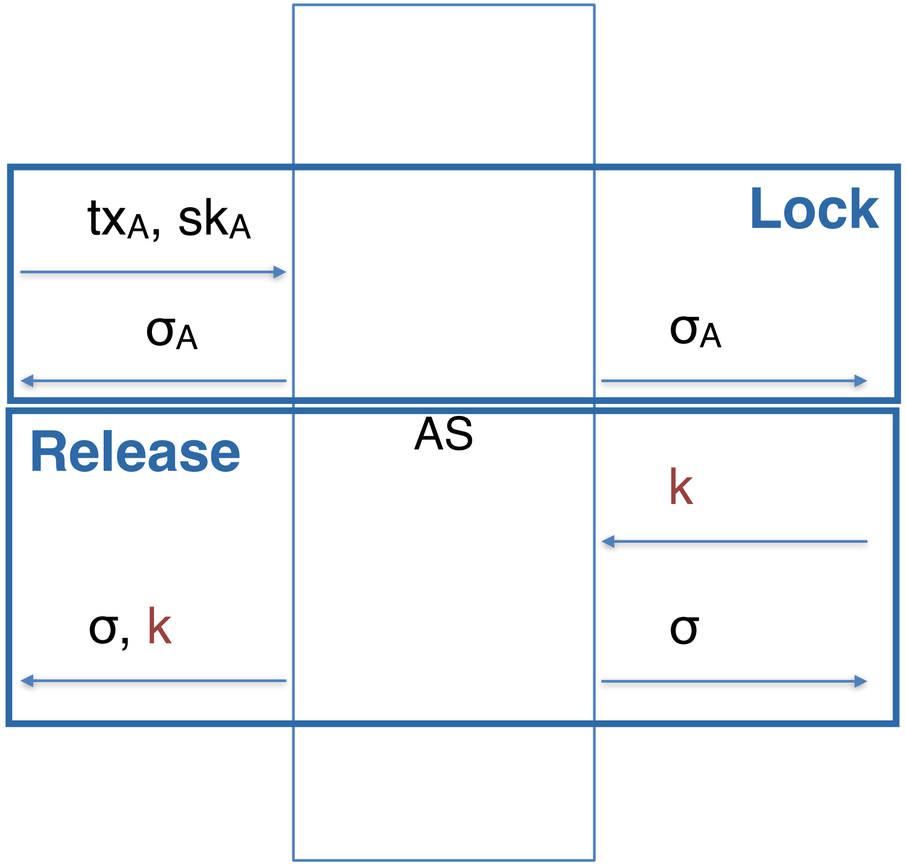

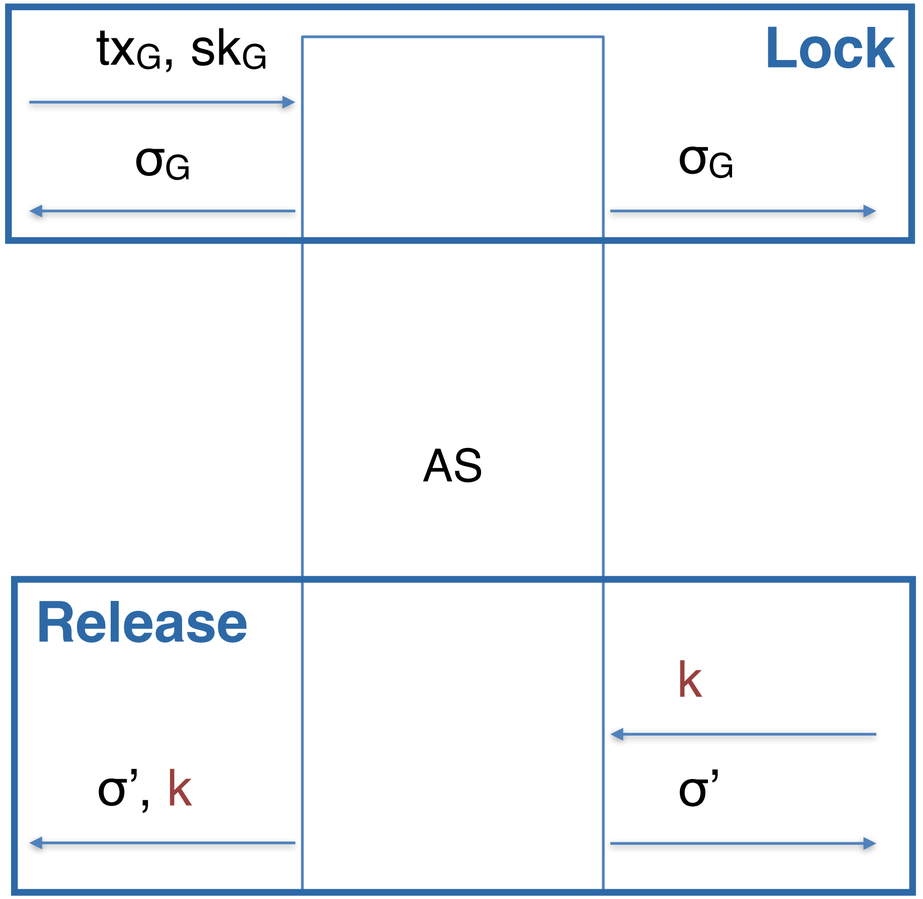

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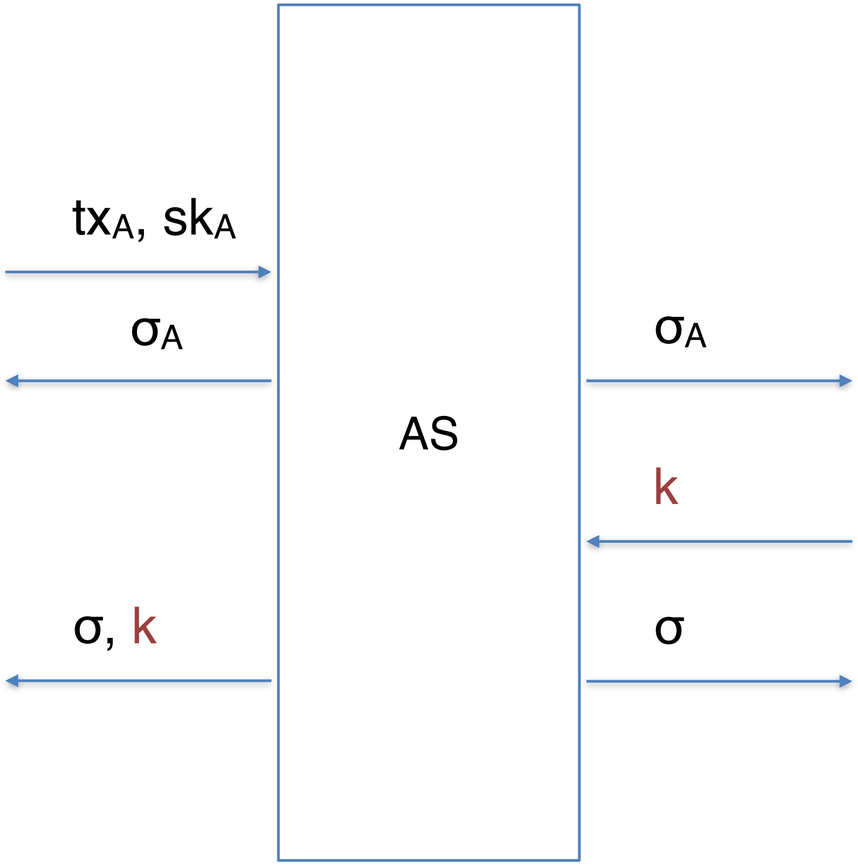

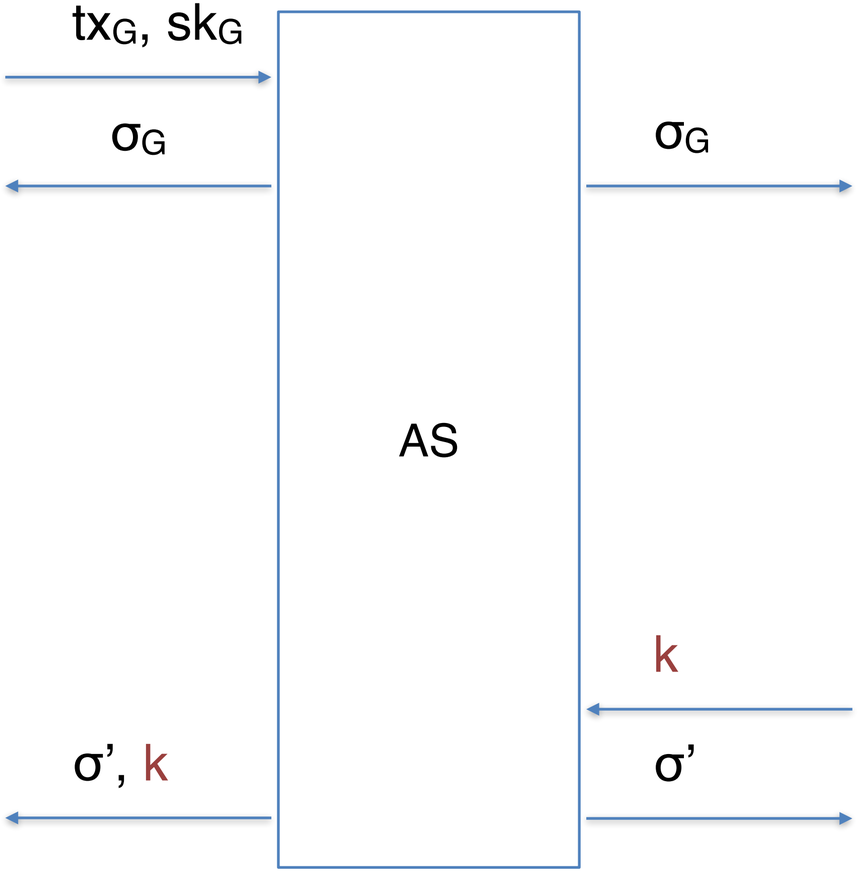

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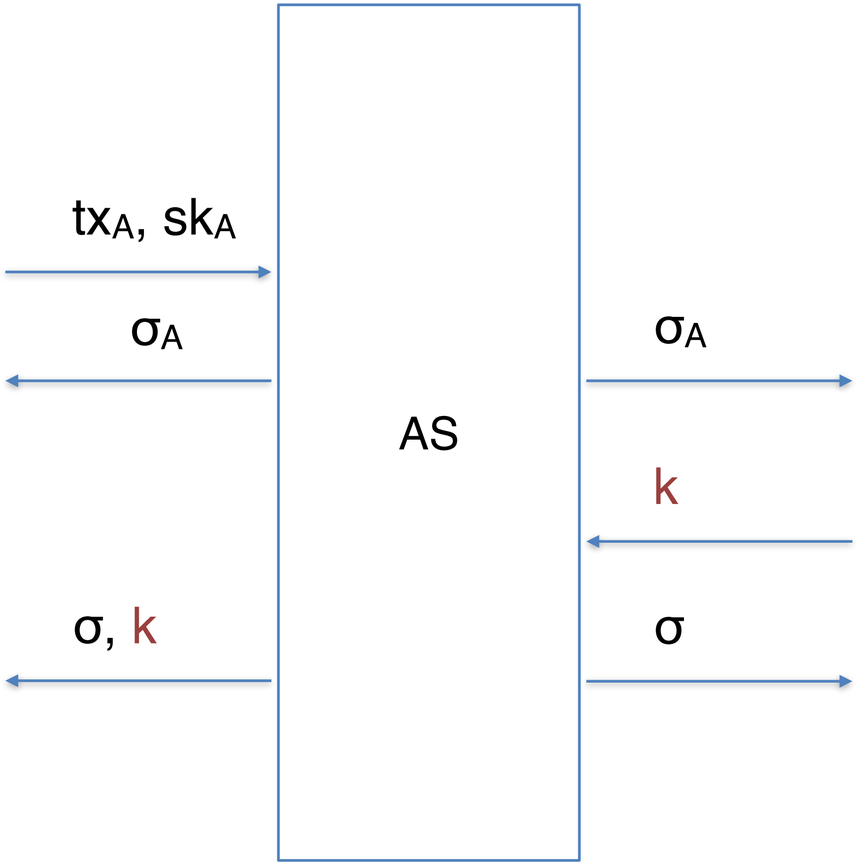

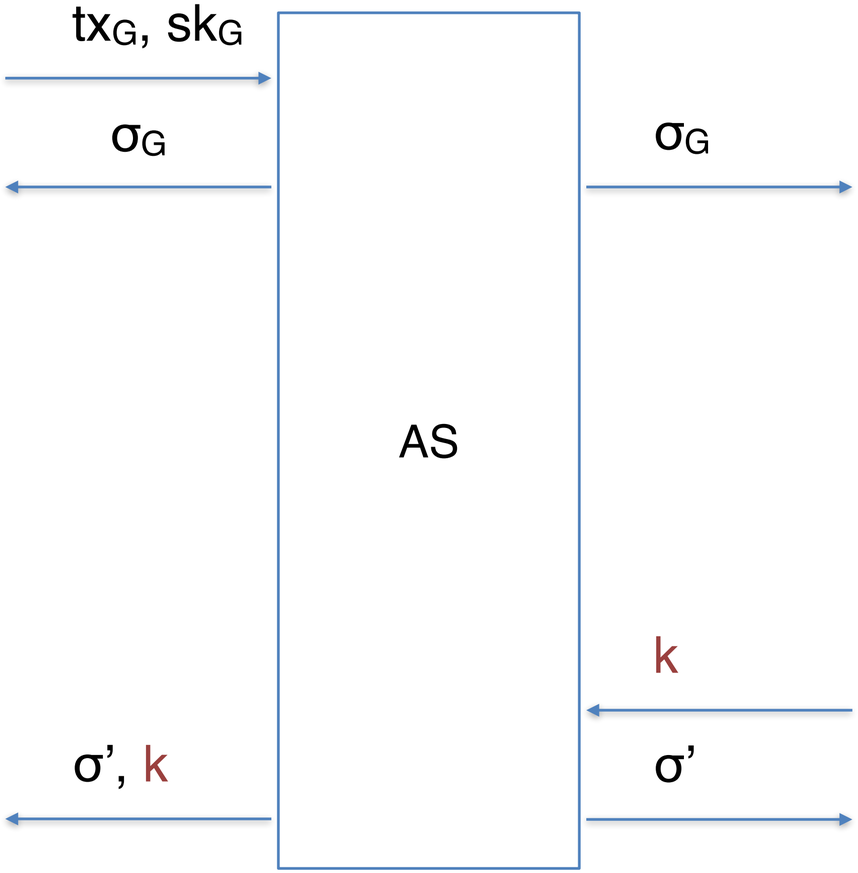

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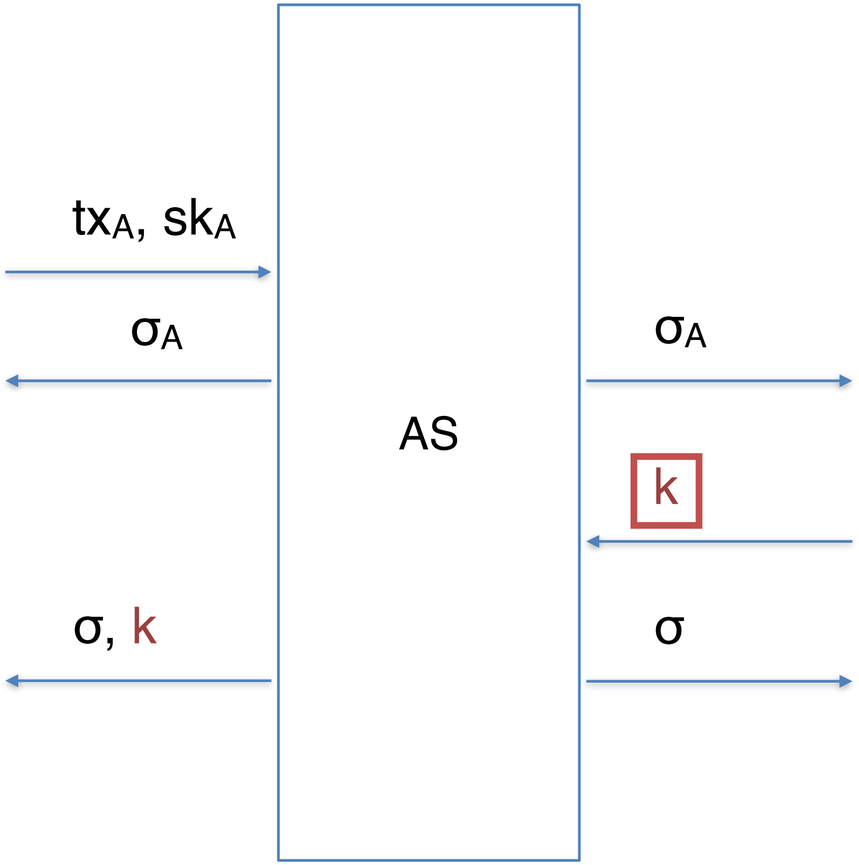

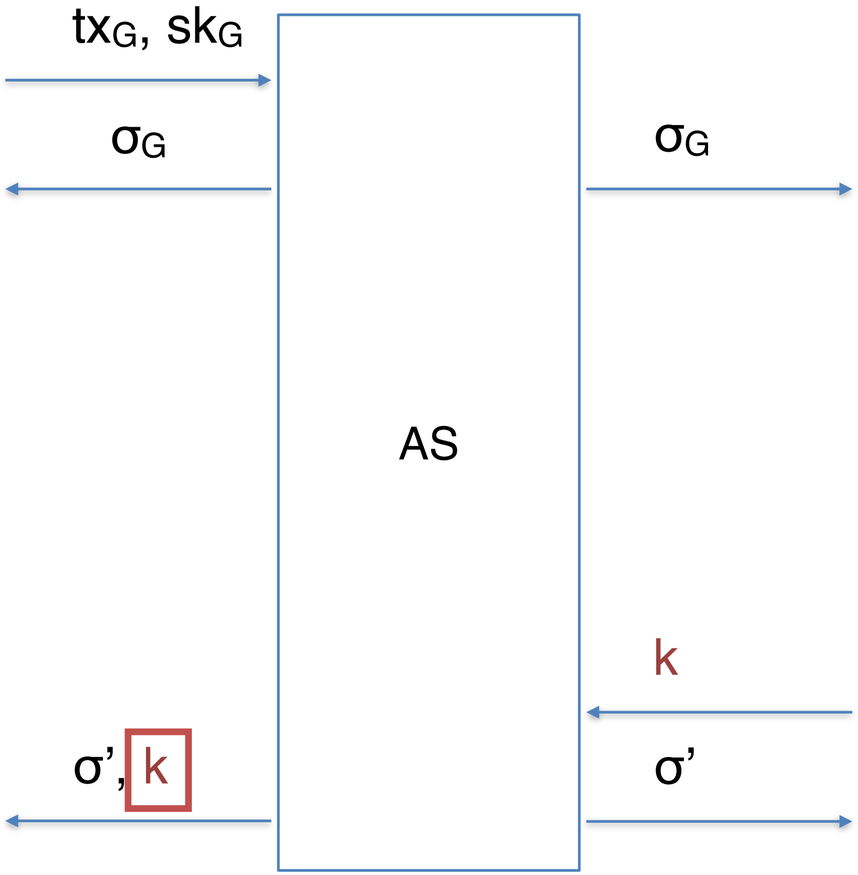

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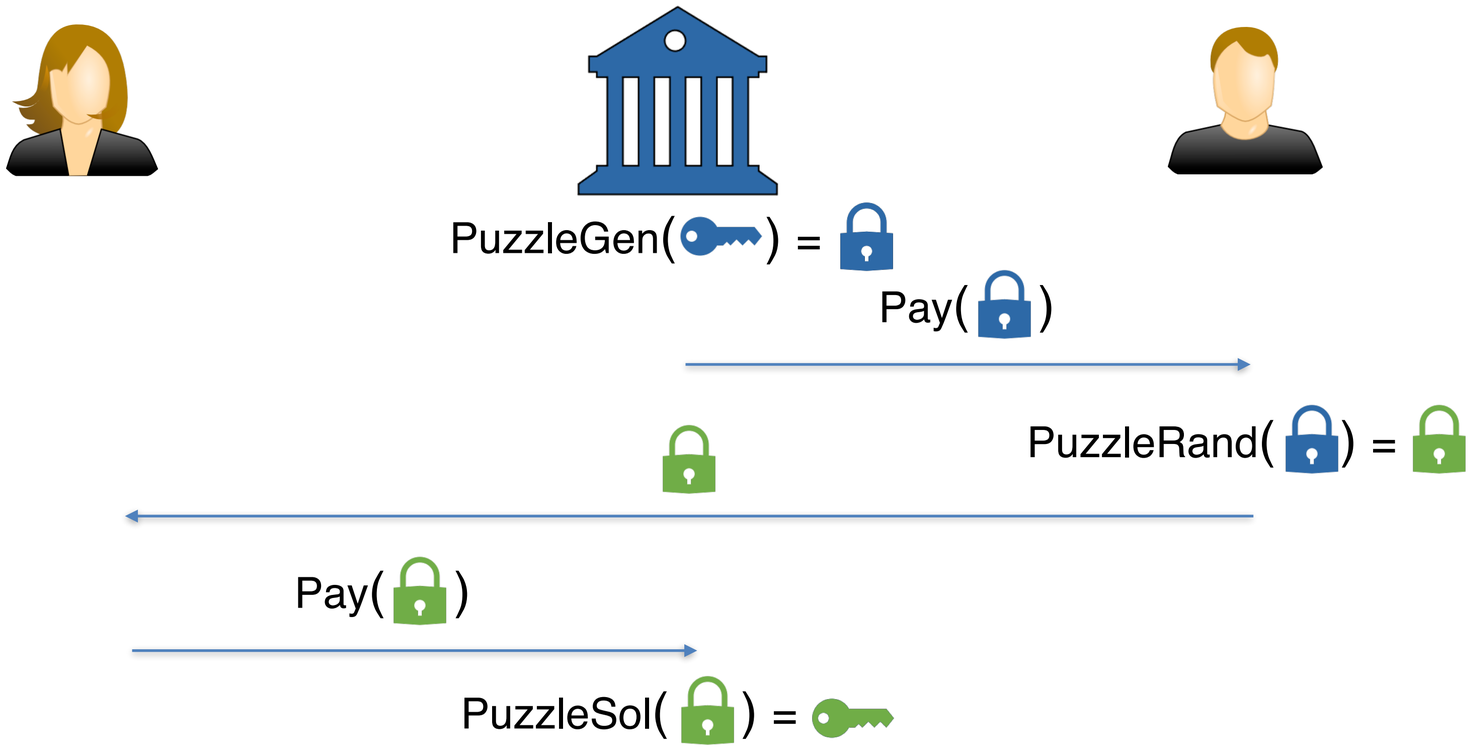

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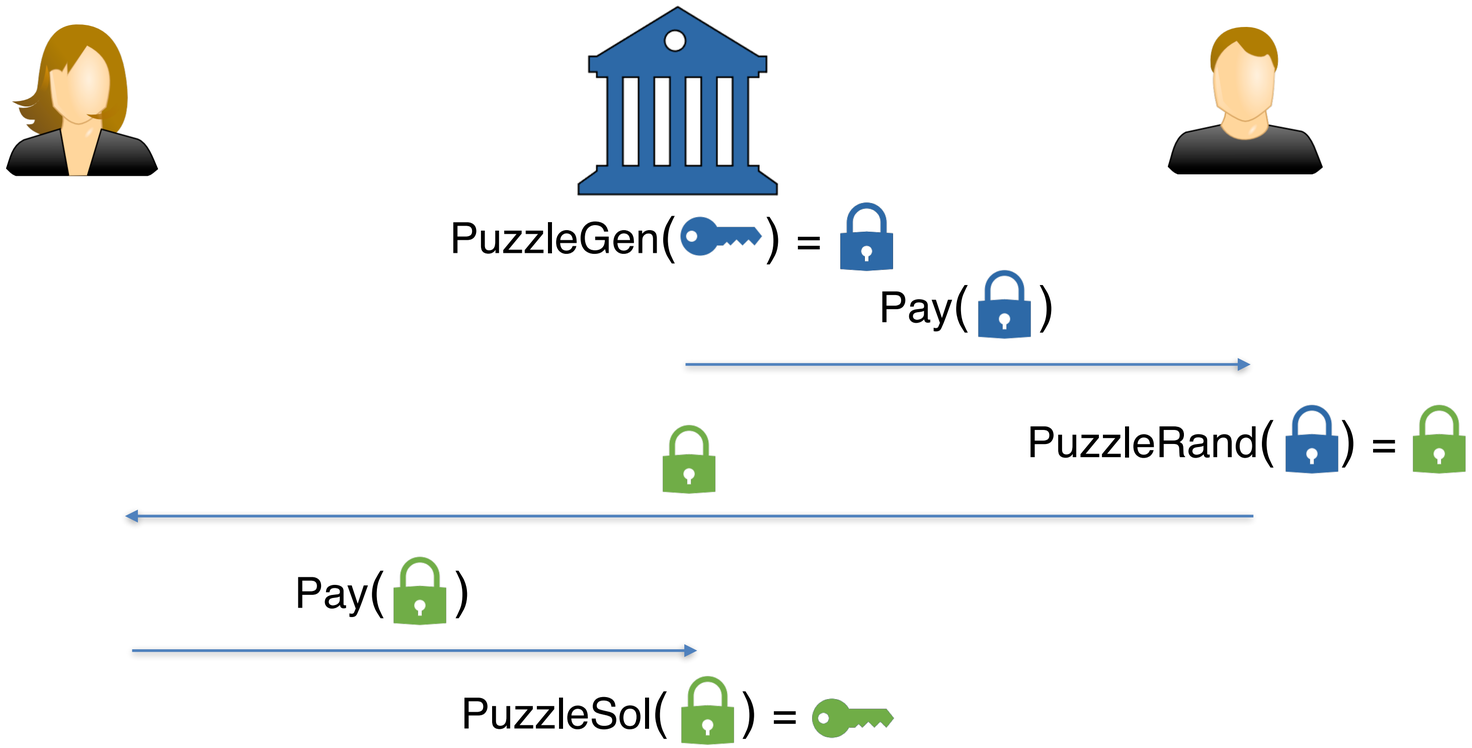

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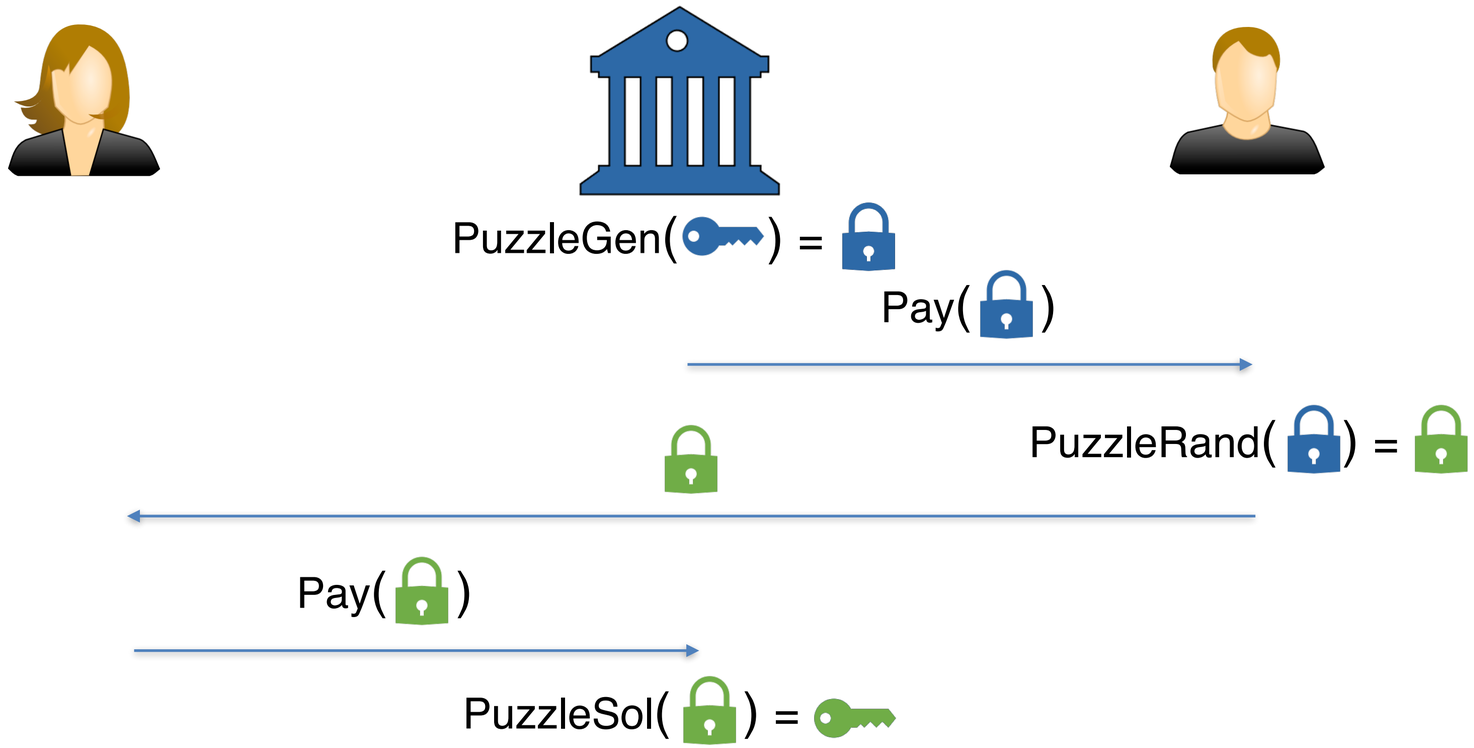

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- Gateway cannot solve the puzzle now as it does not know r. The solution is to extend the puzzle with the encryption of the secret k under the gateway's key

Building Block: Randomizable Puzzle

- Randomizable puzzle combines the condition of adaptor signature with an encryption under additively homomorphic encryption scheme
- Goals:
  - Gateway can create a puzzle  that can be solved using a trapdoor (e.g., secret key)
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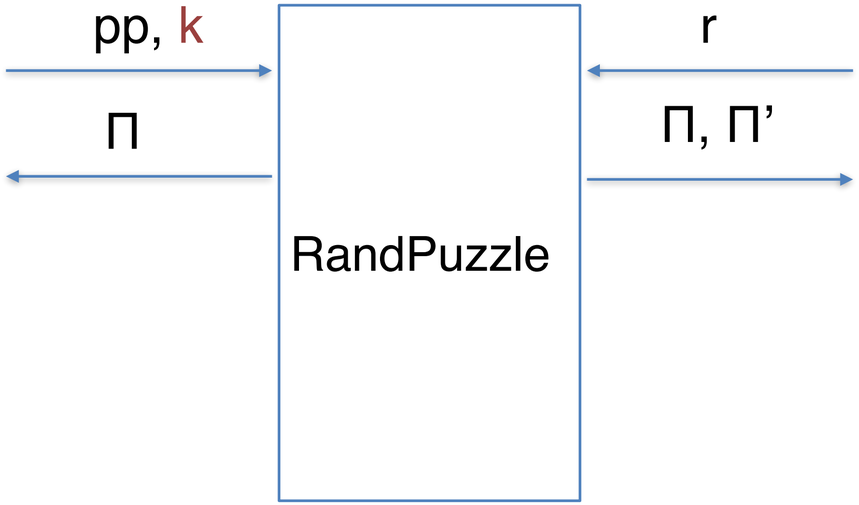
$\Pi' = (C' = k*r*G,\ c' = Enc(pk_G,\ k*r))$

r



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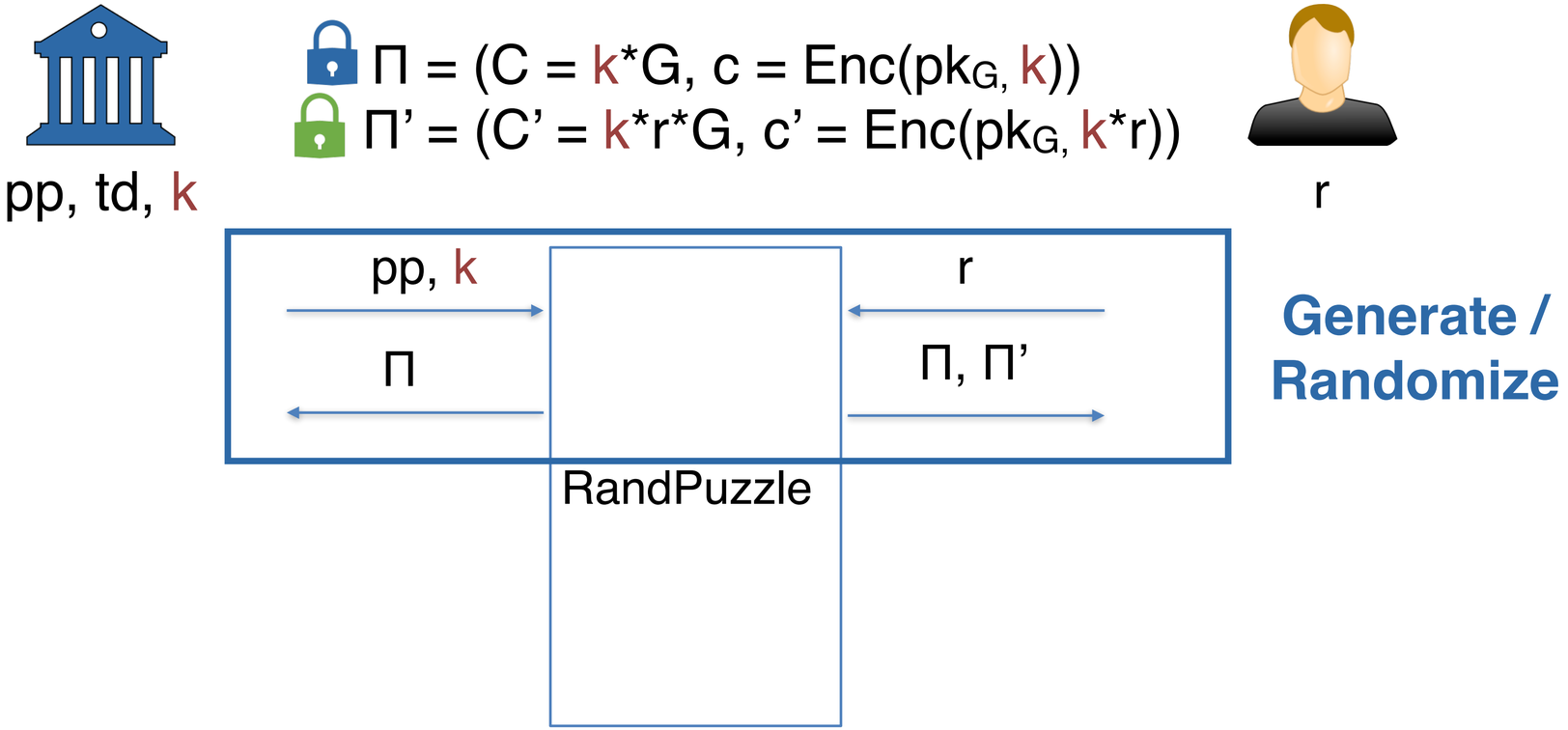

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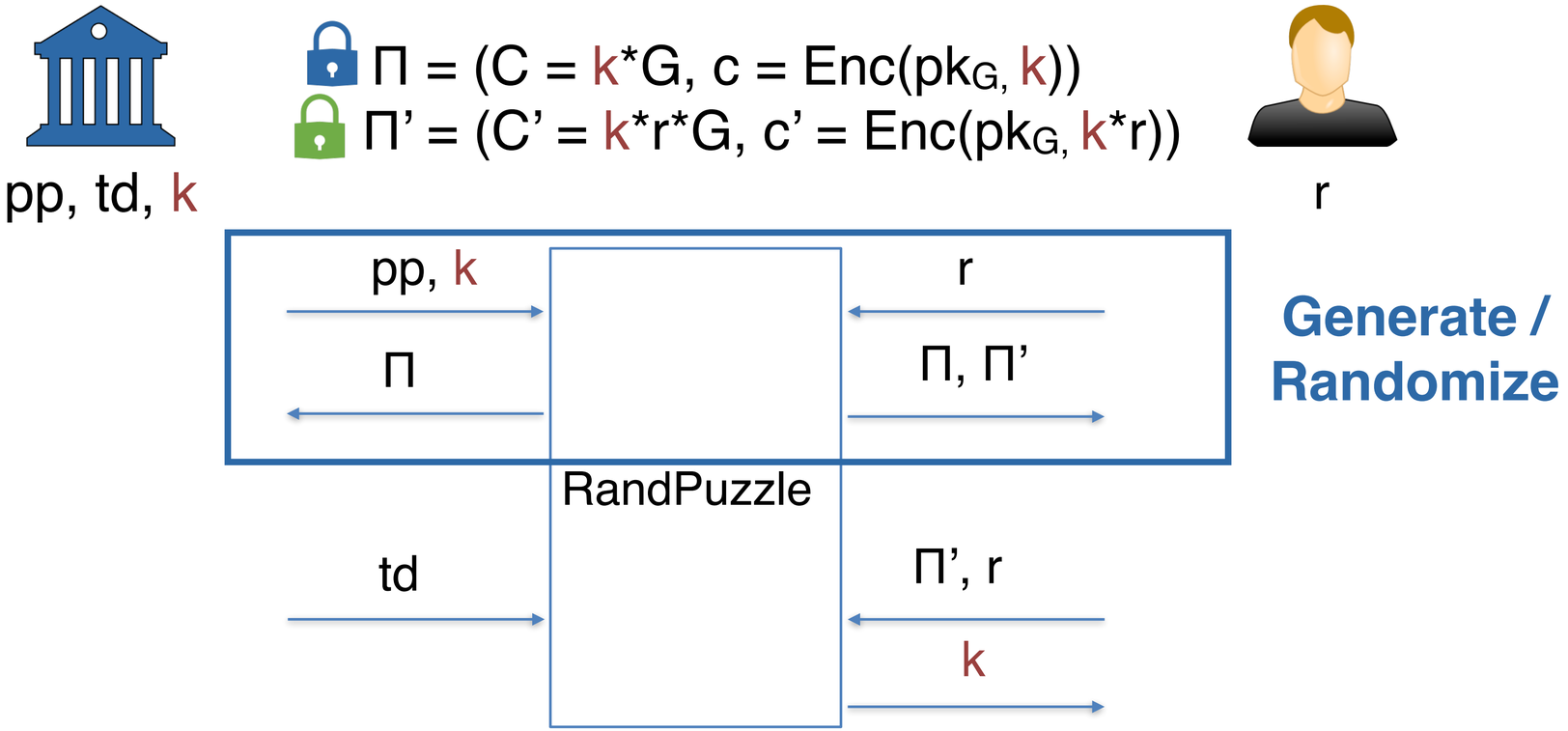

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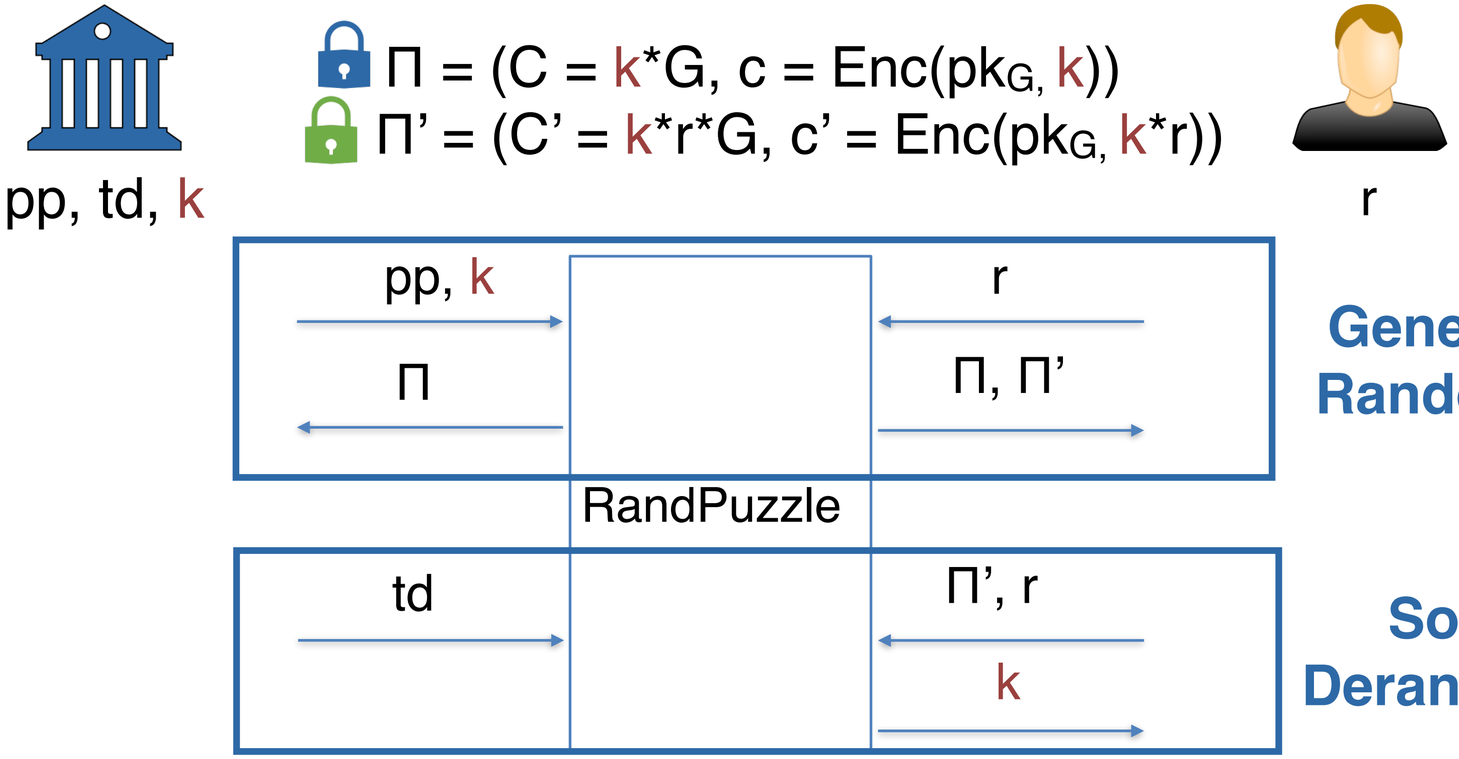

A²L: Protocol Overview

C = k*G

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$(pk_G, sk_G, pp_G, td_G, k)$

r_B

AS + RandPuzzle

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σ_G, Π, Π'

Share Π' with Alice

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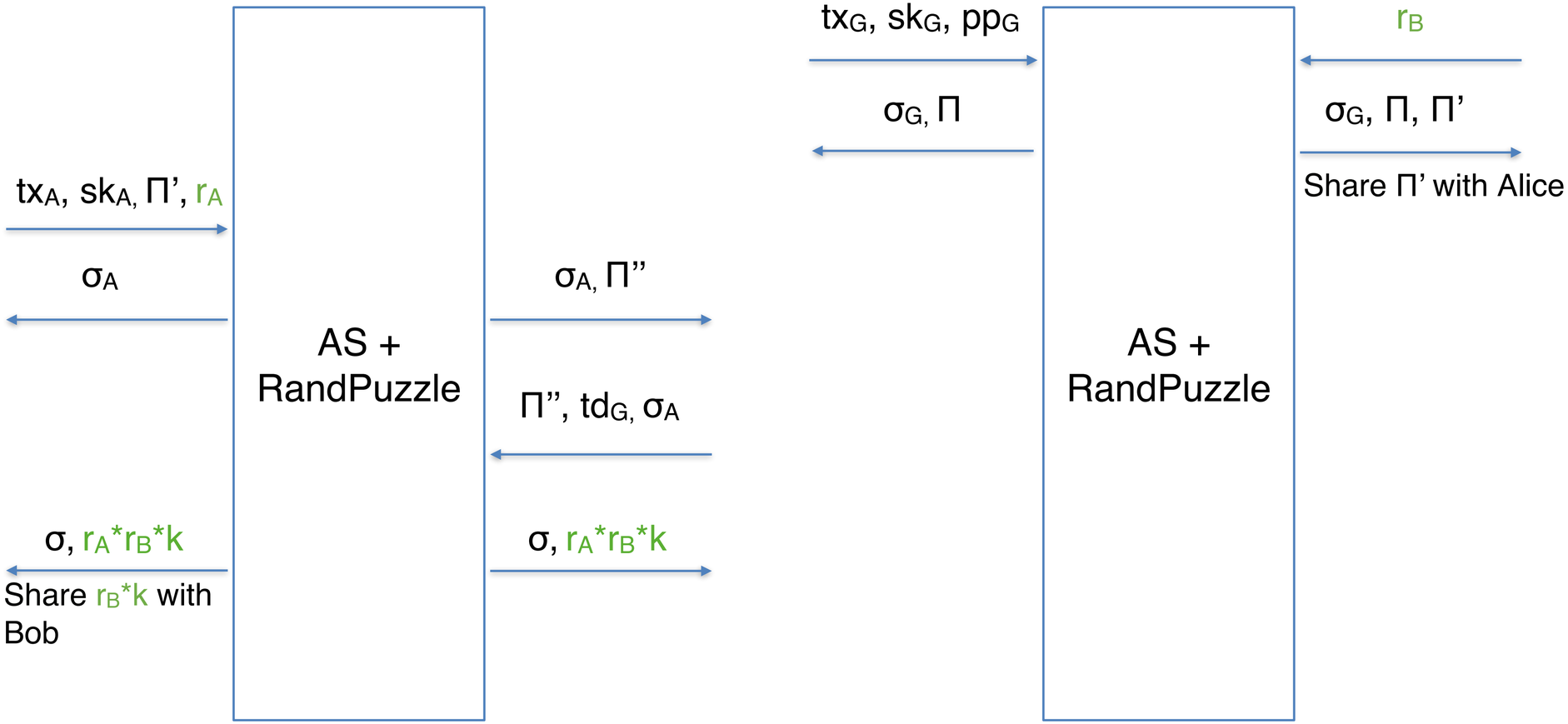

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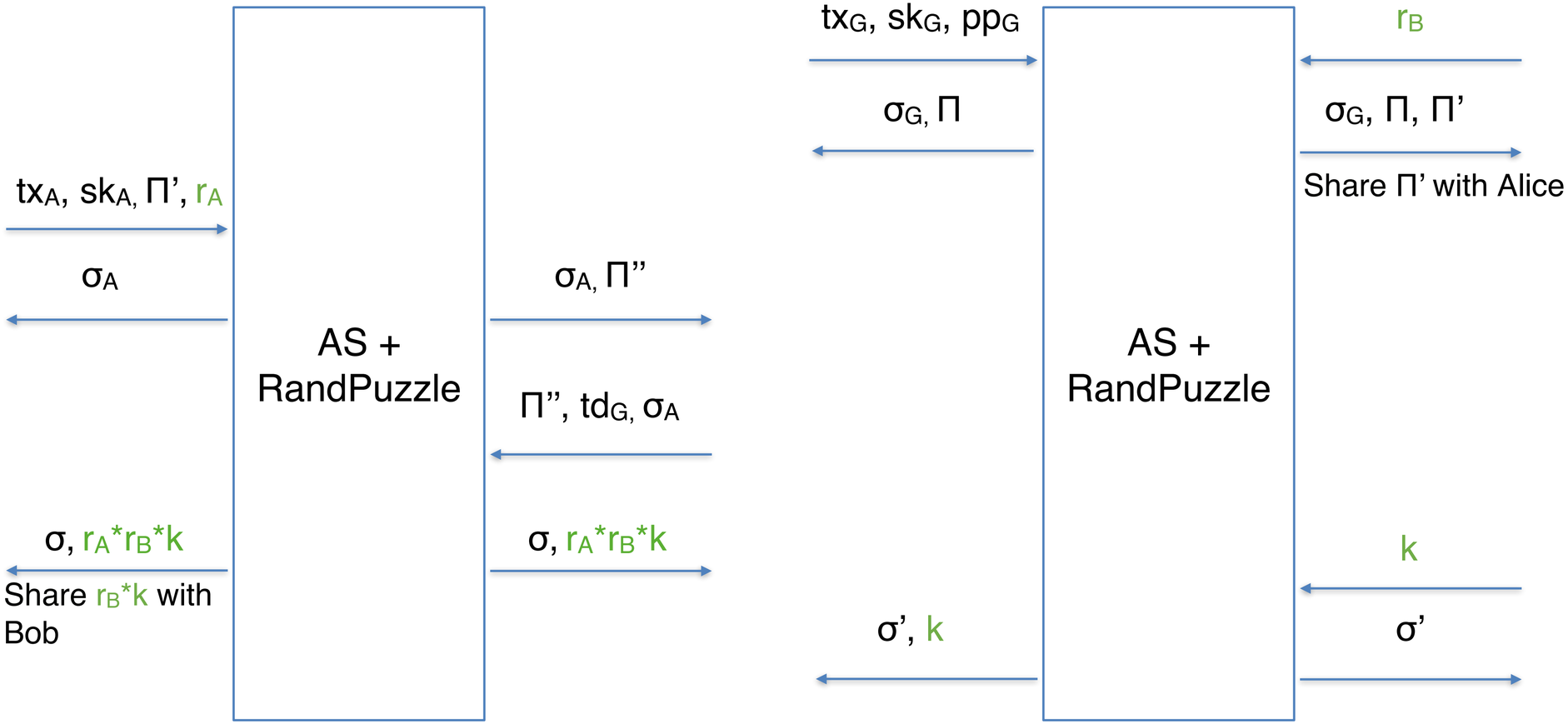

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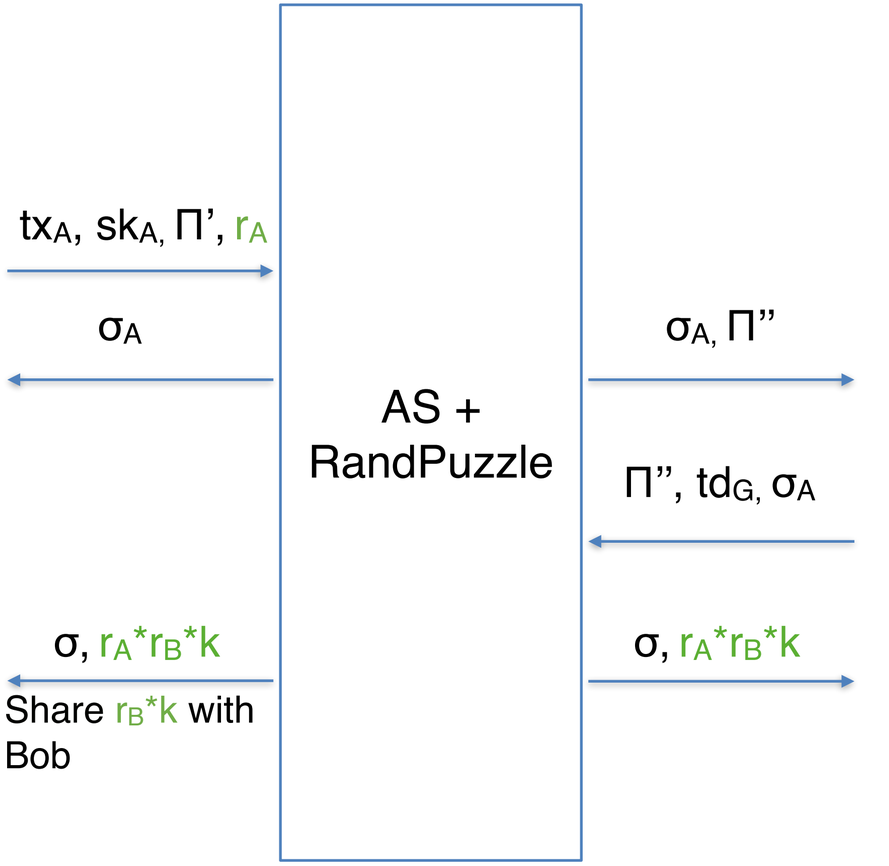

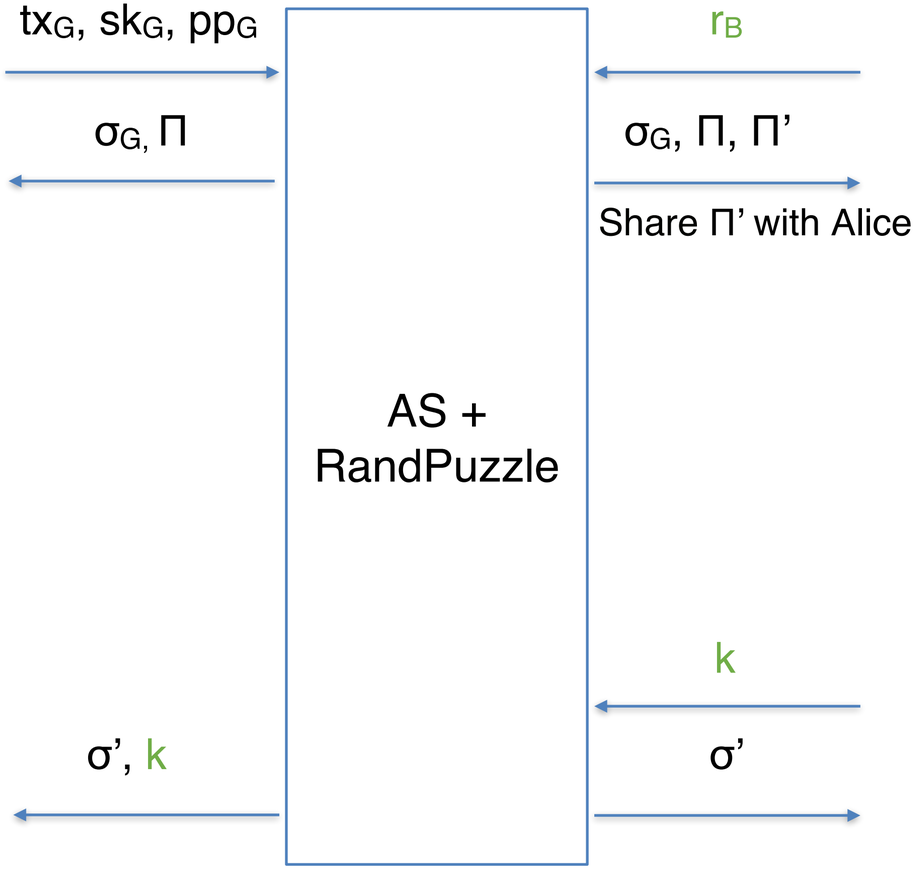

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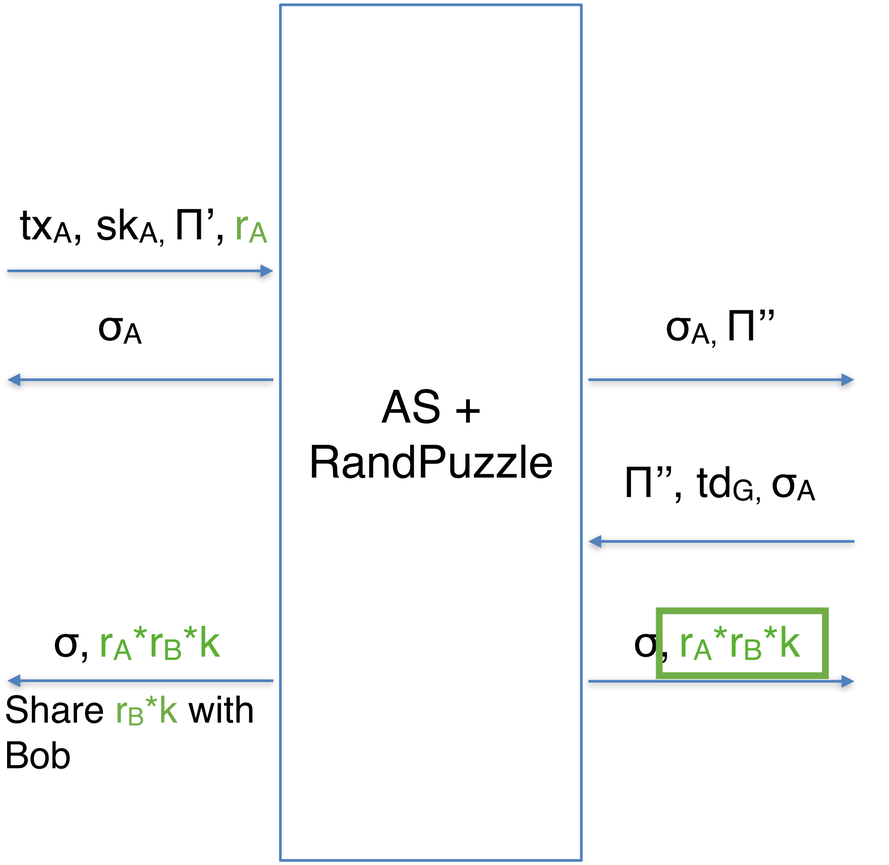

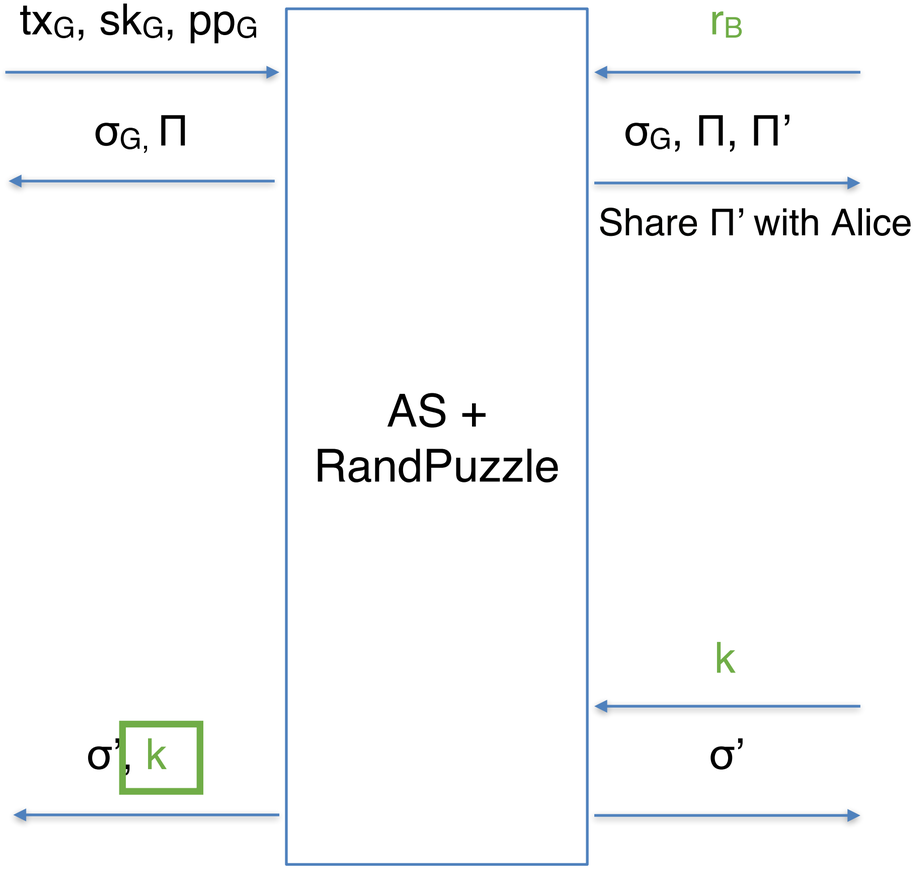

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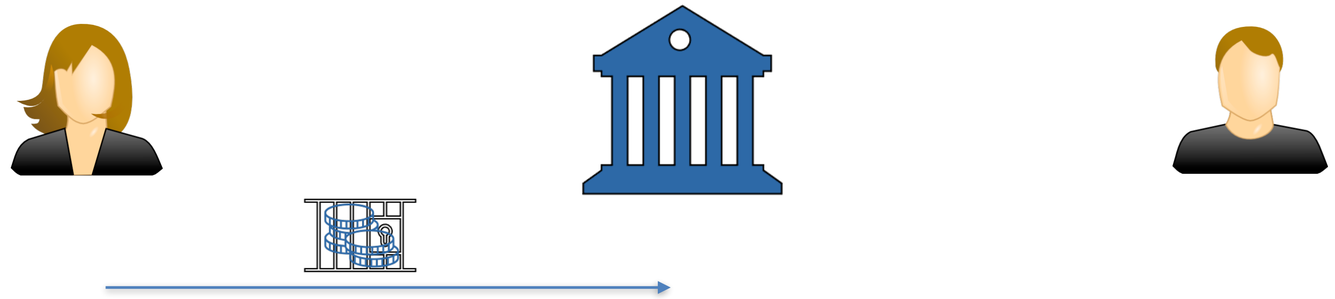

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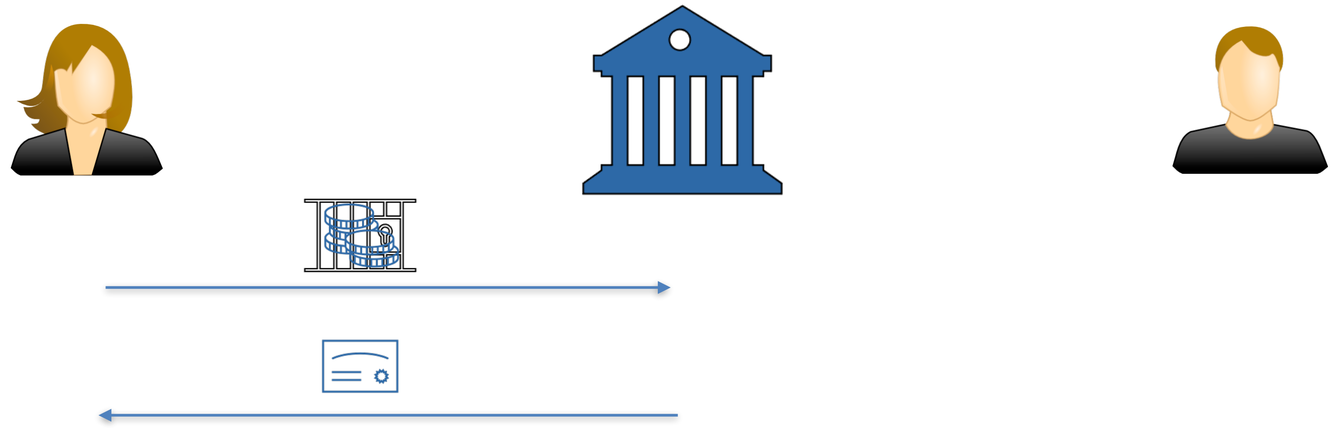

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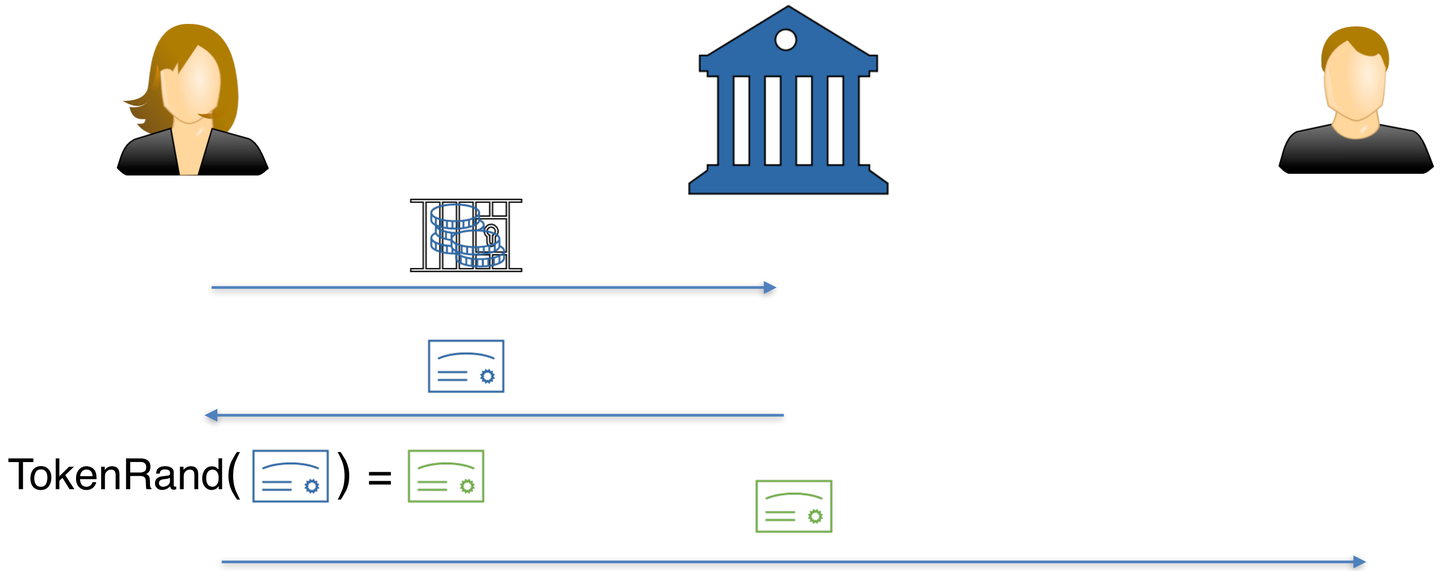

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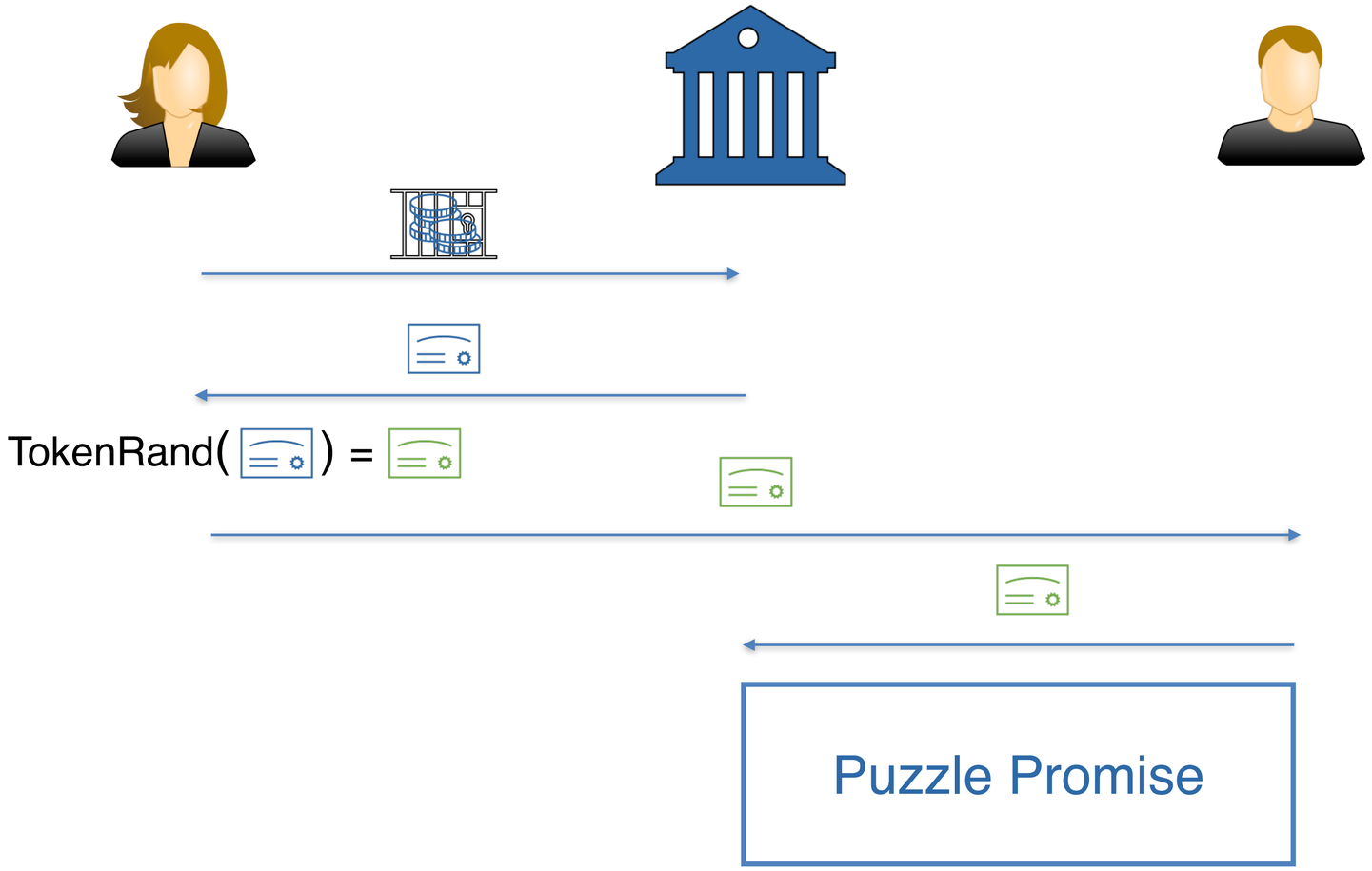

Discussion

- A²L incurs 33x less bandwidth overhead and provides 2x speedup in computation compared to TumbleBit

	Registration	Puzzle Promise	Puzzle Solver	Total
WAN[1]	0.726	1.251	1.076	3.053
LAN	0.008	0.475	0.118	0.601
LAN (pre-processing)	0.008	0.194	0.118	0.320
Bandwidth (KB)	0.30	7.31	2.31	9.92

Performance of A²L instantiated with ECDSA signature. Time shown in seconds.
[1]Payment hub over Amazon AWS machines in Oregon-Frankfurt-Singapore.

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Thank You!

@erkantairi