TECHNISCHE UNIVERSITÄT WIEN
Vienna | Austria

FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

SECURITY & PRIVACY GROUP

A2L: Anonymous Atomic Locks for Scalability and Interoperability in Payment-Channel Hubs

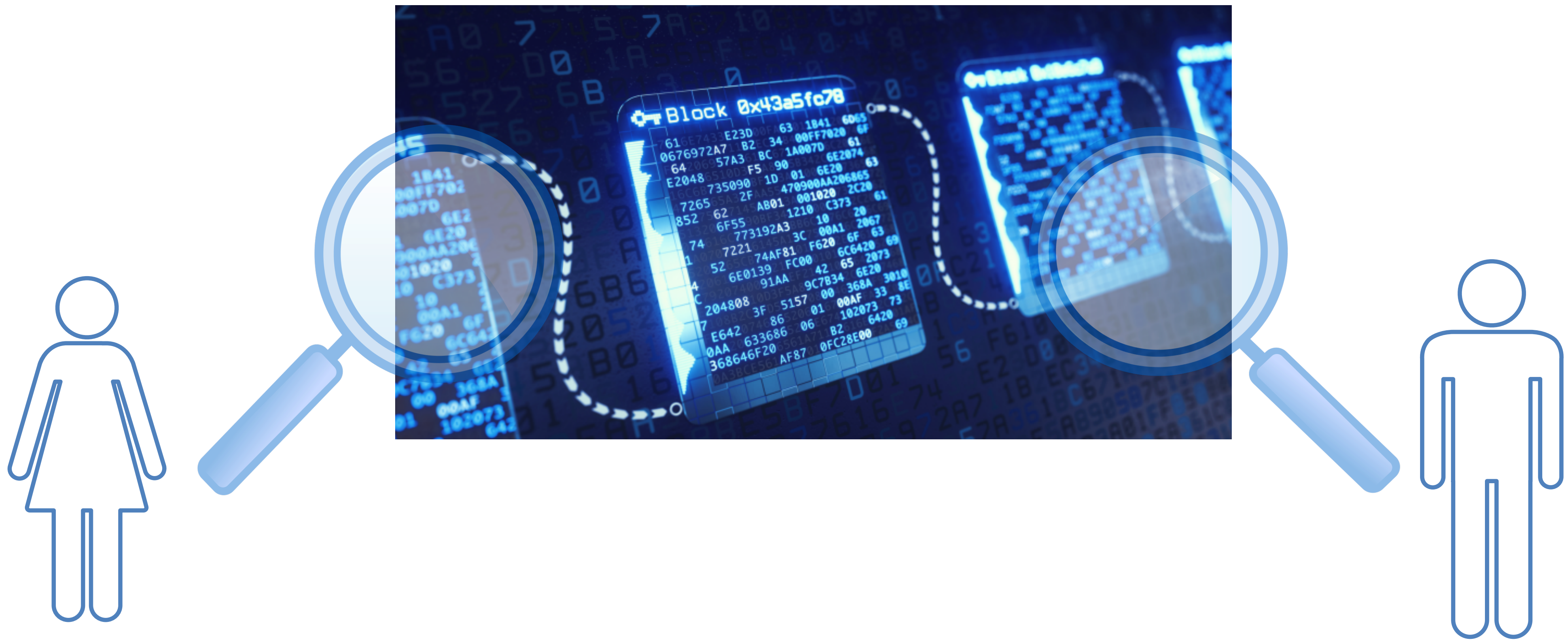
Erkan Tairi[1], **Pedro Moreno-Sanchez**[1], Matteo Maffei[1]

@erkantairi @pedrorechez @matteo_maffei

[1]TU Vienna

Scaling Bitcoin
Tel Aviv, Sep12th 2019

Scalability Issues



- Decentralized data structure recording each transaction in order to provide public verifiability
- Global consensus: everyone checks the whole blockchain

Bitcoin's transaction rate: ~10 tx/sec

Visa's transaction rate: ~10K tx/sec

Scalability Solutions?

- On-chain (tweak consensus)
  e.g., DAG Blockchain, sharding, ...
- Off-chain (use blockchain only for disputes)
  e.g., Payment Channel Networks

Lightning Network (Bitcoin)

RAIDEN

Raiden Network (Ethereum)

Many other projects (Bolt, Perun, Liquidity Network...)

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Background on Payment Channels

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    - Analogy: pay with the gift card

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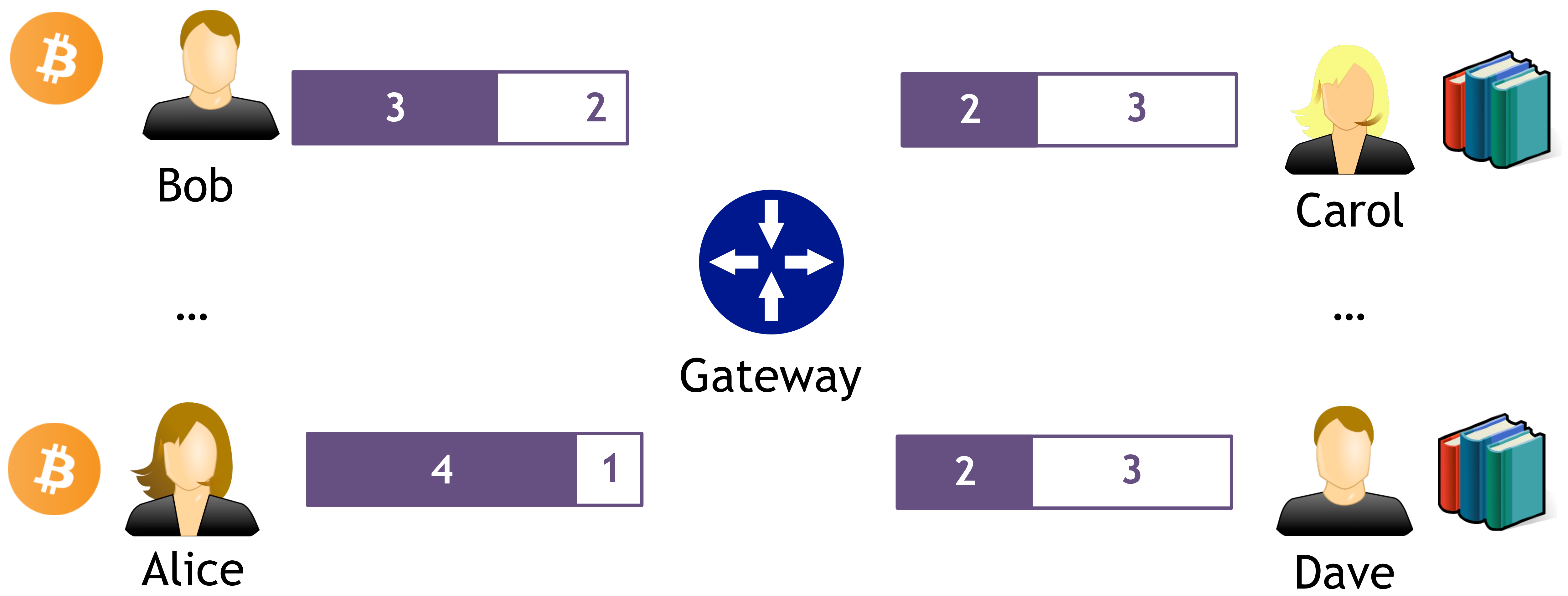
  - Open channel: Deposit coins in the channel
    - Analogy: get a gift card
  - Pay: Send coins off-chain by exchanging authenticated messages in a peer-to-peer fashion
    - Analogy: pay with the gift card
  - Close channel: Redeem coins according to the last agreed state (or dispute resolution)
    - Analogy: redeem remaining coins at the gift card

101 Payment Channels

- Key point for scalability:
  - Only open and close channel are on-chain
  - Rest are off-chain operations
- For more technical description:
  - See talk: Pedro Moreno-Sanchez, "*Atomic Multi-Channel Updates with Constant Collateral in Bitcoin-Compatible Payment-Channel Networks*", ScalingBitcoin 2019

Payment Channel Hubs (PCHs)

One cannot open channels with everyone...
$\Rightarrow$ exploit gateway channels!



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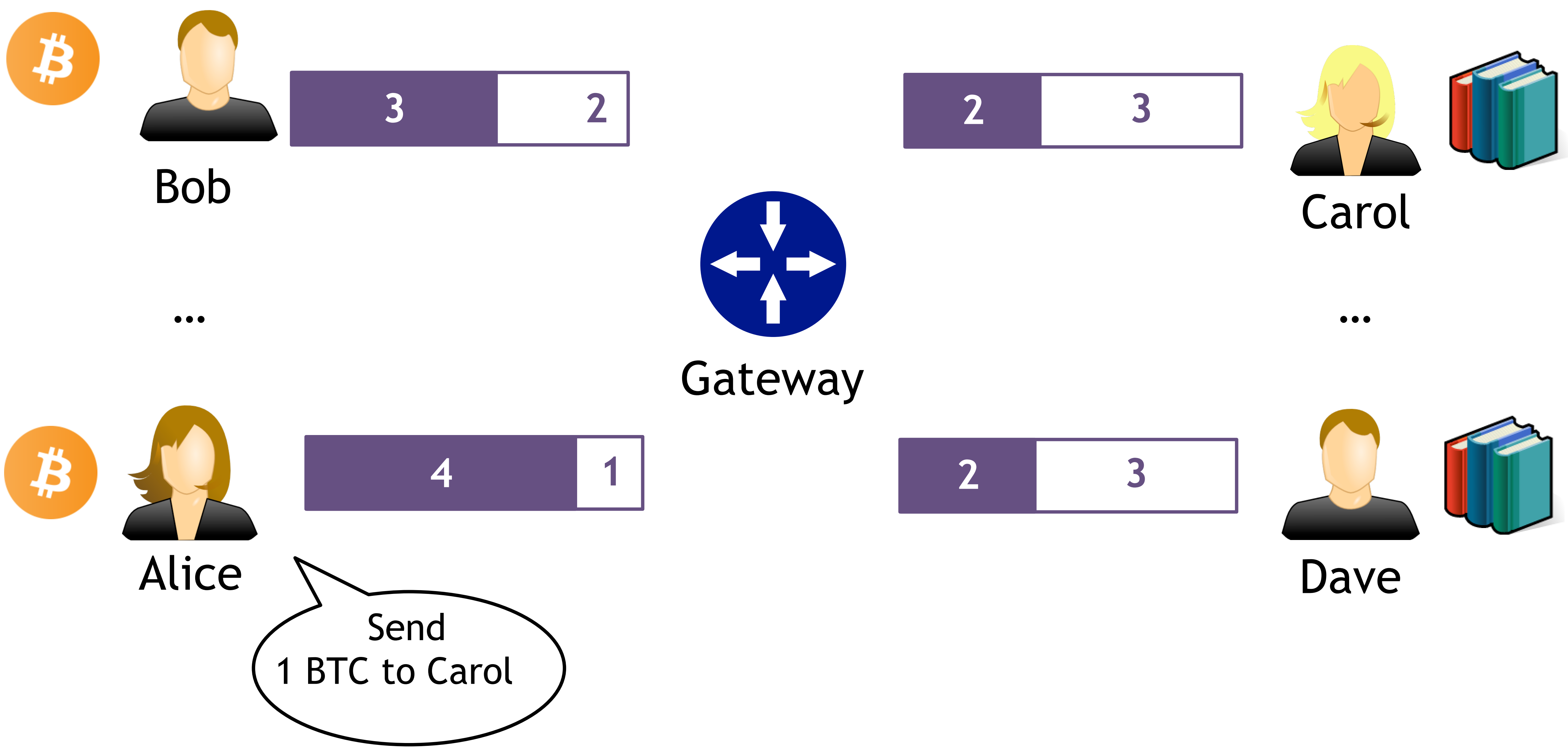

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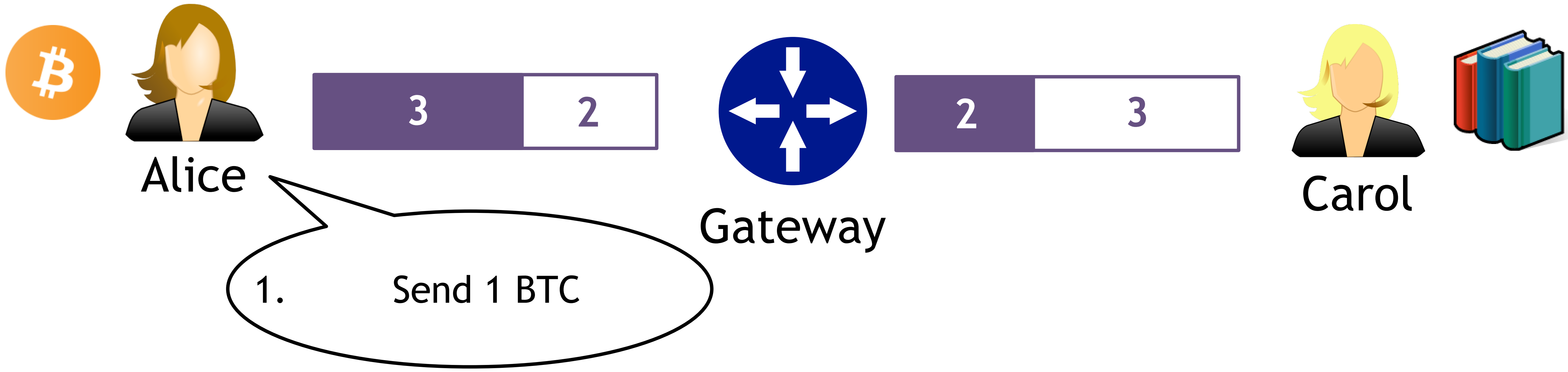

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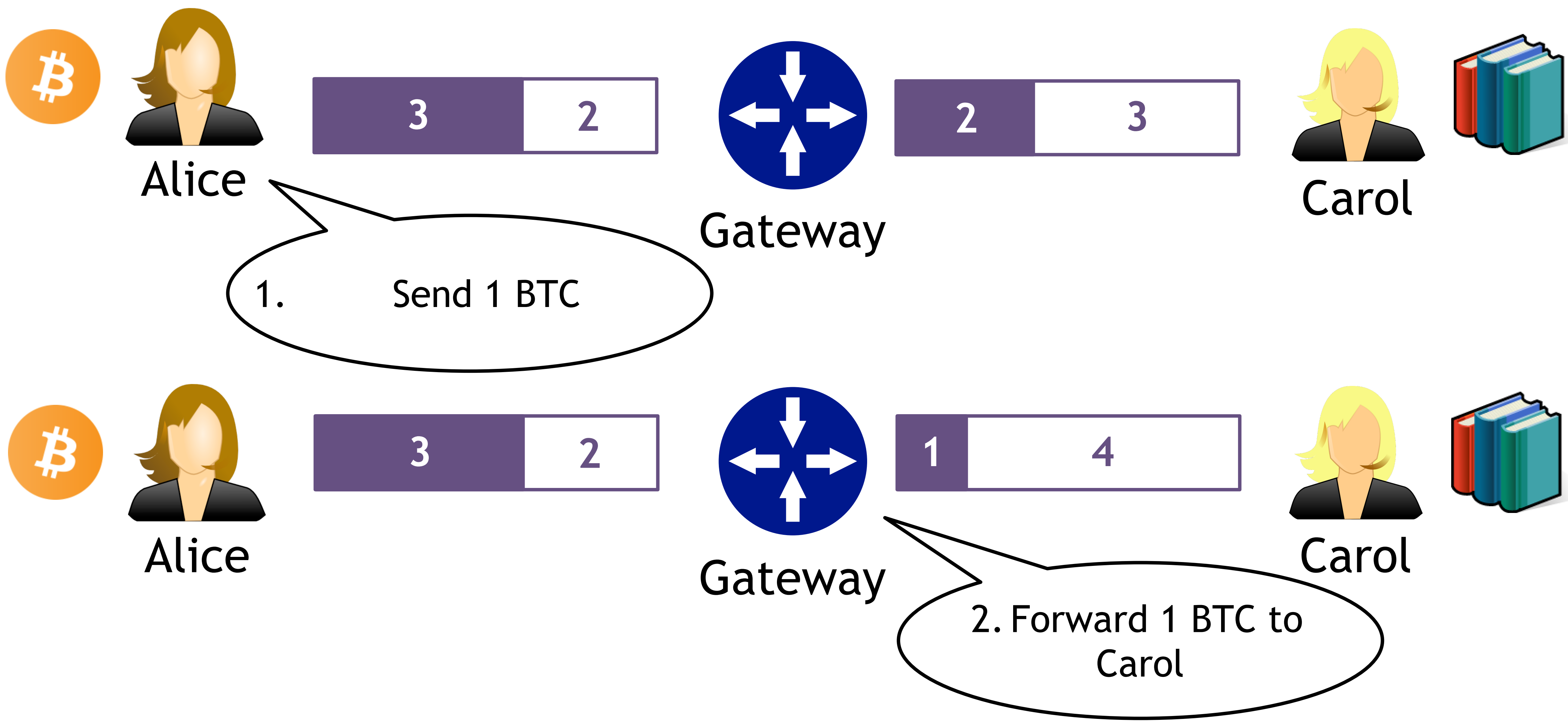

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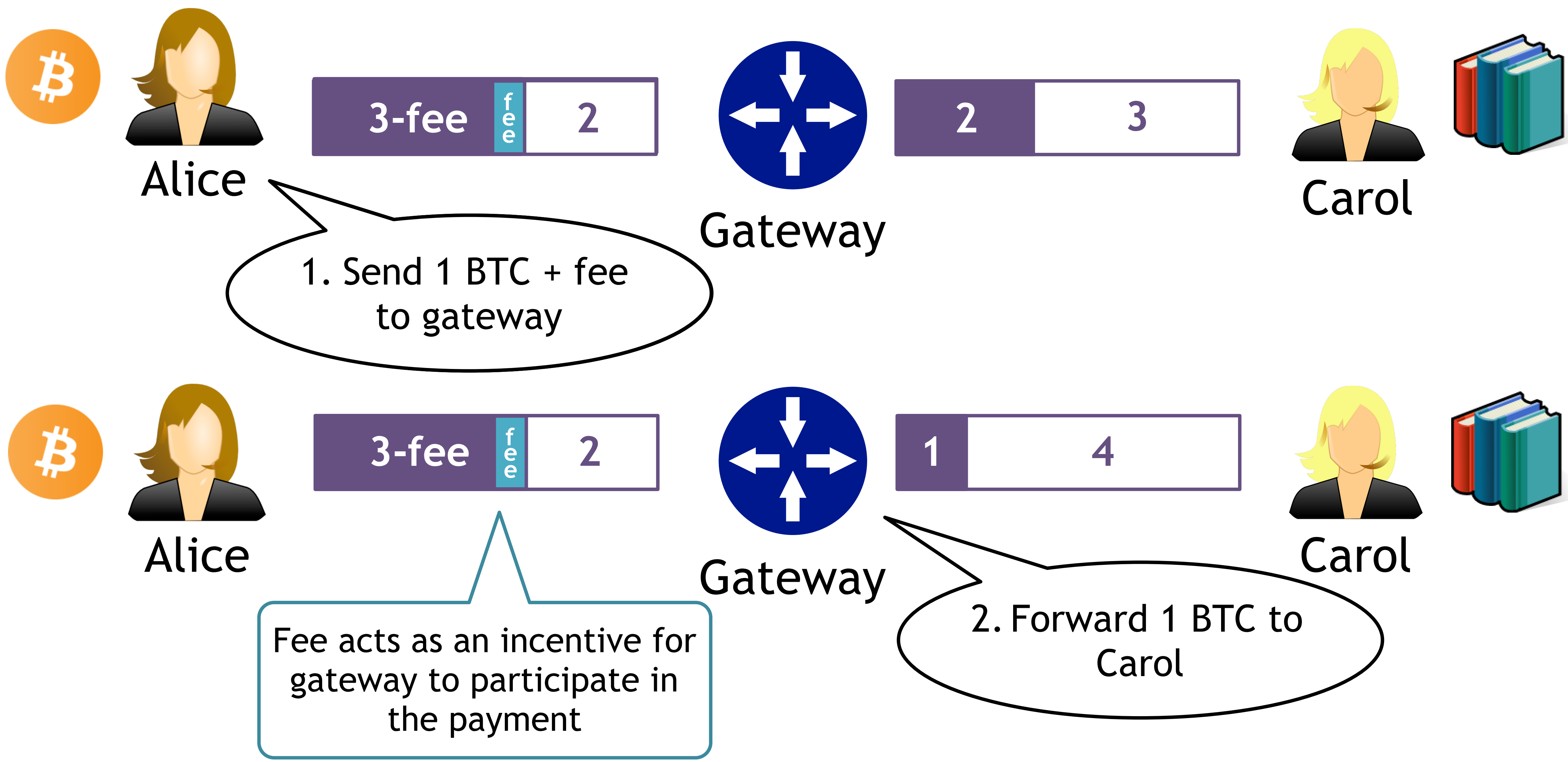


Security, Privacy and Interoperability in PCHs

Under Submission

A^2L: Anonymous Atomic Locks for Scalability and Interoperability in Payment Channel Hubs

Erkan Tairi, Pedro Moreno-Sanchez and Matteo Maffei
TU Wien
{erkan.tairi,pedro.sanchez,matteo.maffei}@tuwien.ac.at

***Abstract*—The striking growth in cryptocurrencies is revealing several scalability issues that go beyond the growing size of the blockchain. Payment channel hubs (PCHs) constitute a promising scalability solution by performing off-chain payments between sender and receiver through an intermediary, called the tumbler. While currently proposed PCHs provide security and privacy guarantees against a malicious tumbler, they fall short of other fundamental properties, such as interoperability and fungibility.**

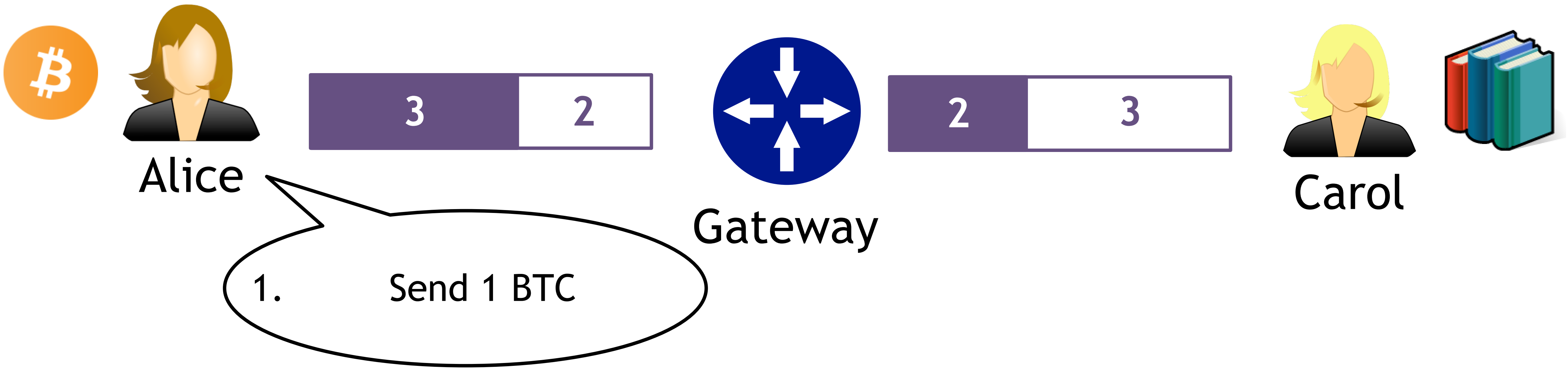
In this work, we present A^2L, the first secure, privacy-preserving, interoperable, and fungibility-preserving PCH. A^2L builds on a novel cryptographic primitive that realizes a three-party protocol for conditional transactions, where the intermediary pays the receiver only if the latter solves a cryptographic challenge with the help of the sender. We prove the security and privacy guarantees of A^2L in the Universal Composability framework and present two provably secure instantiations based on Schnorr and ECDSA signatures.

We implemented A^2L and our evaluation shows that it outperforms TumbleBit, the state-of-the-art PCH in terms of

simply agreeing on a new distribution of the coins locked in the channel: the corresponding transactions are stored locally, that is, off-chain. When the two users disagree on the current redistribution or simply terminate their economical relation, they submit an on-chain transaction that sends back the coins to their owners according to the last agreed distribution of coins, thereby closing the channel. Thus, payment channels require only two on-chain transactions (i.e., open and close channel), yet supporting arbitrarily many off-chain payments, which significantly enhances the scalability of the underlying blockchain.

The problem with this simple construction is that in order to pay different people, a user should establish a channel with each of them, which is computationally and financially prohibitive, as this party would have to lock an amount of coins proportional to the number of users she wants to transact with.

Security in PCHs: Atomicity



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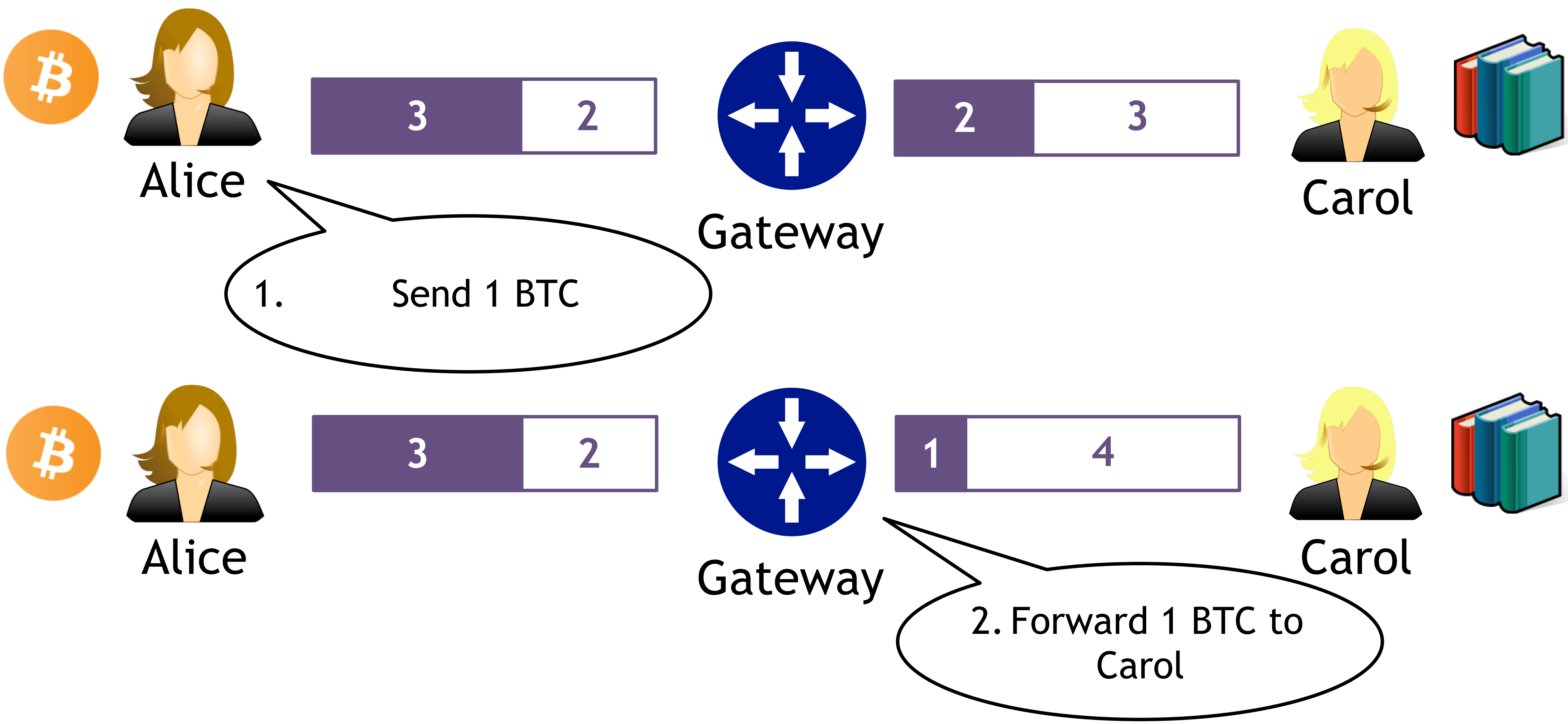

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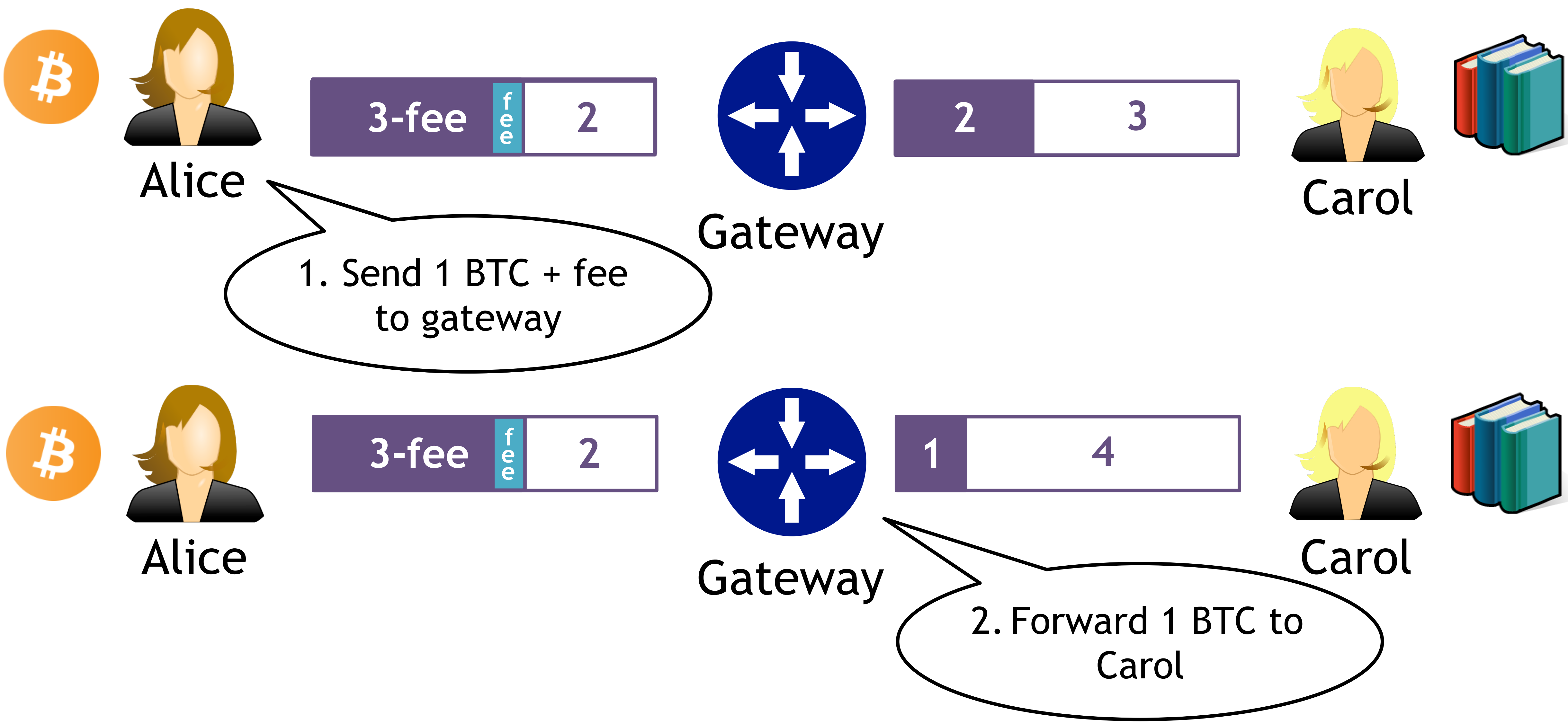

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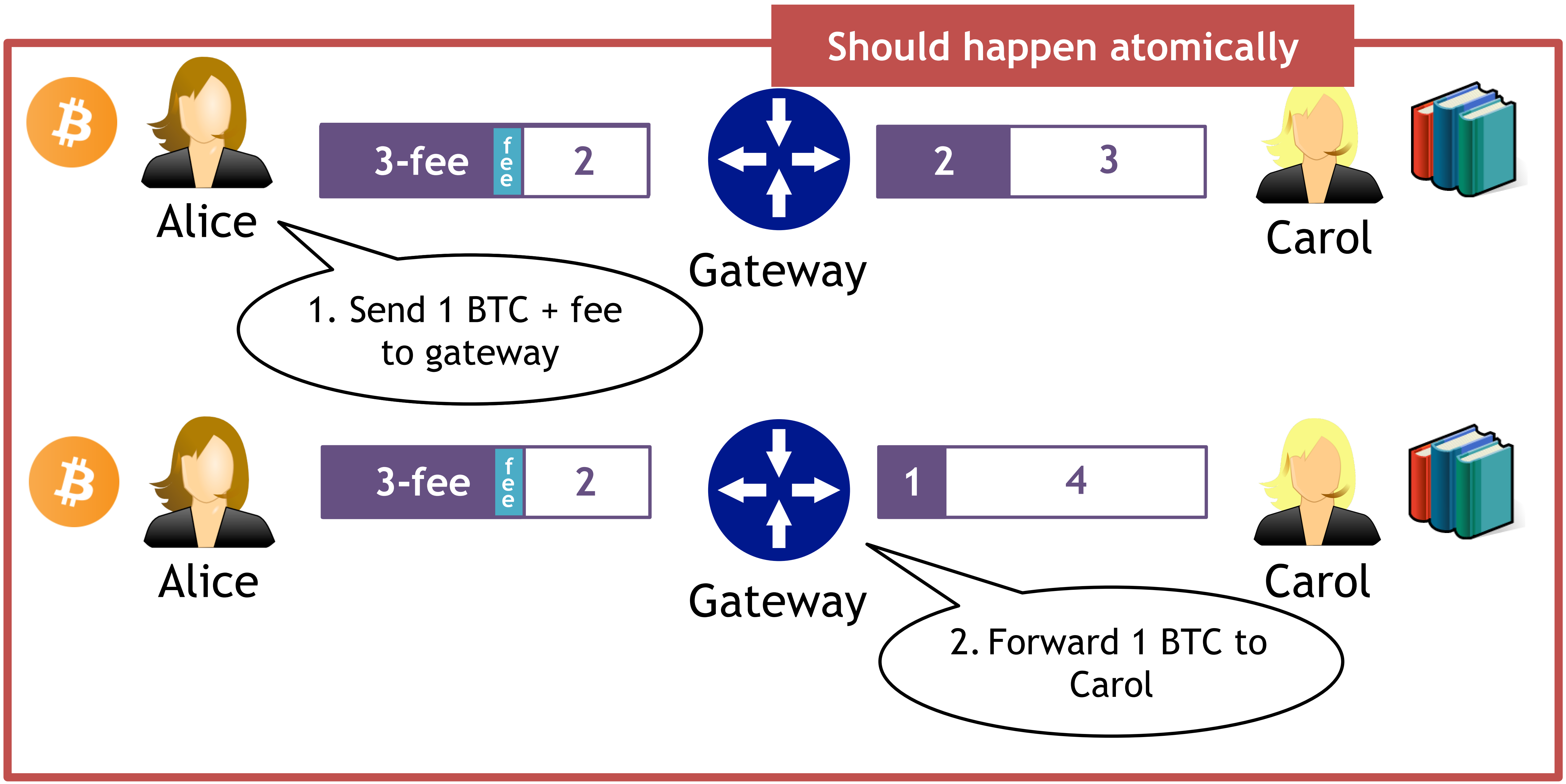

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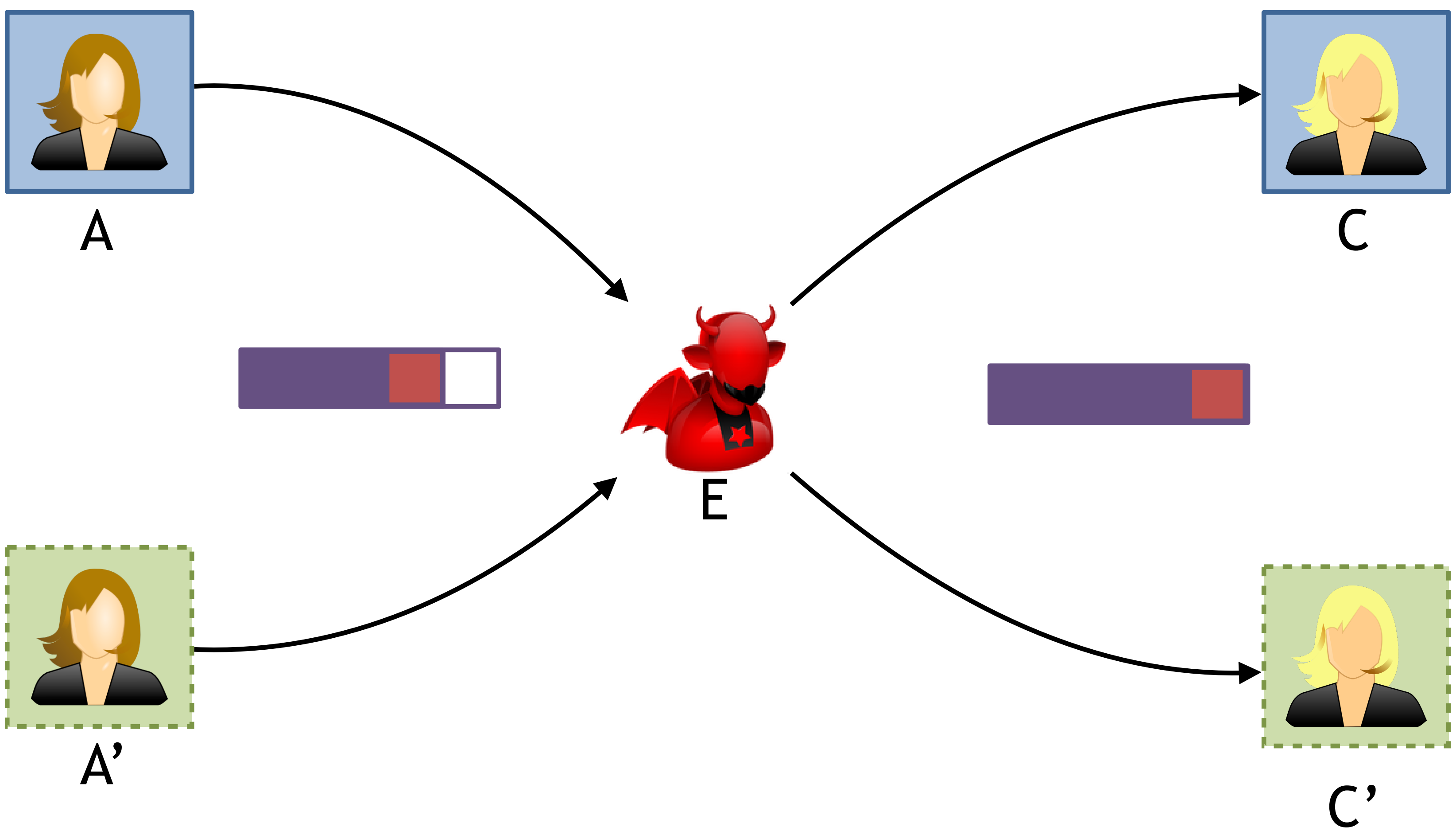

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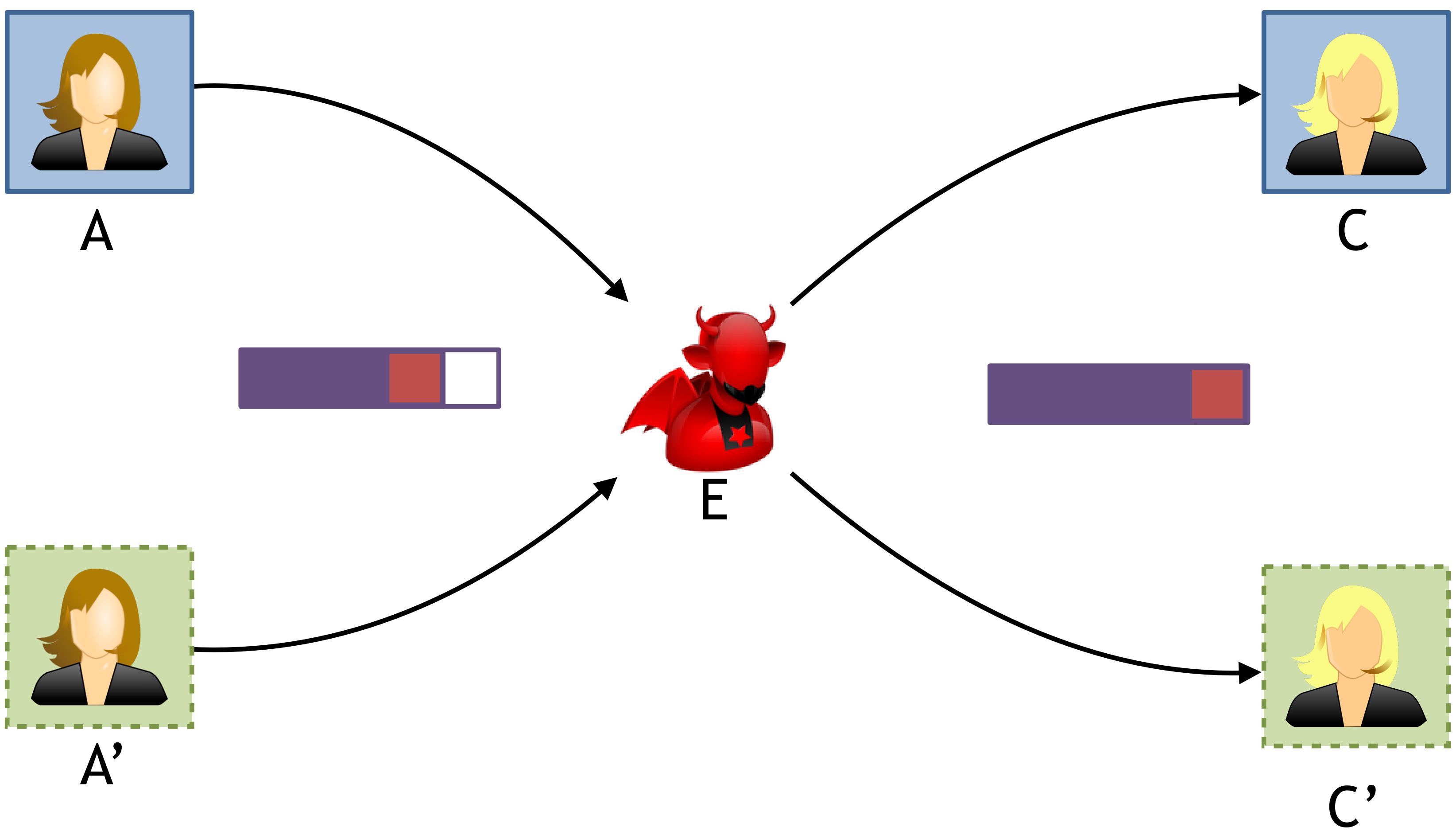
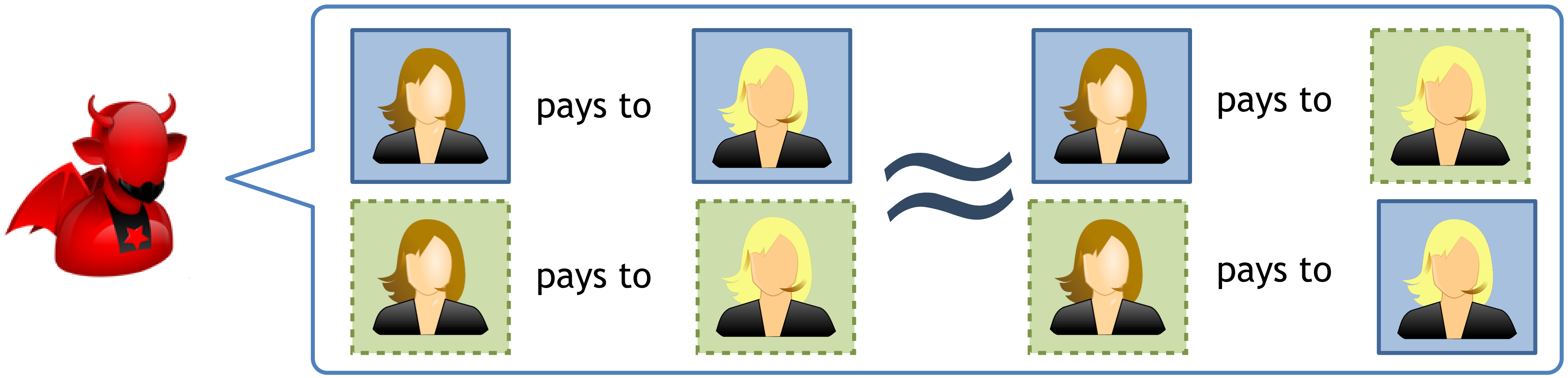




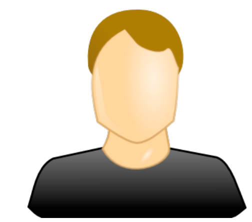
Interoperability in PCHs

- Create a PCH payment protocol backwards compatible with Bitcoin (and as many cryptocurrencies as possible)
- Not an easy task:
  - Perun, Liquidity Network: Ethereum-based solutions
  - BOLT: Requires opcodes not available in Bitcoin
  - TeeChain: Requires trusted execution environment (e.g., intel SGX)
  - Blind Swaps: Requires Schnorr signatures
  - TumbleBit: Compatible with Bitcoin
    - Requires HTLC: Not possible in cryptocurrencies without scripting language (e.g., Monero)
    - Efficiency can be improved

Our Approach: Building Block

- Based on adaptor signatures (AS)

Adaptor: (pk_C, sk_C)



(pk_A, sk_A)

(pk_B, sk_B)

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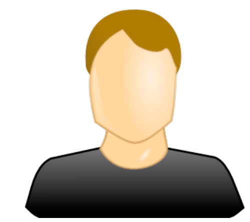

(pk_B, sk_B)

- Goals:
  - Alice can create a “half-signature” that Bob can only finish by knowing the adaptor sk_C
  - If Bob finishes the signature, Alice learns sk_C

Our Approach: Building Block

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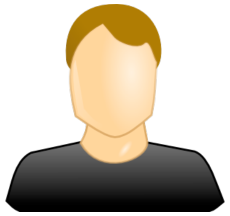
(pk_A, sk_A)

Adaptor: (pk_C, sk_C)

tx_A: Alice pays 1 coin to Bob



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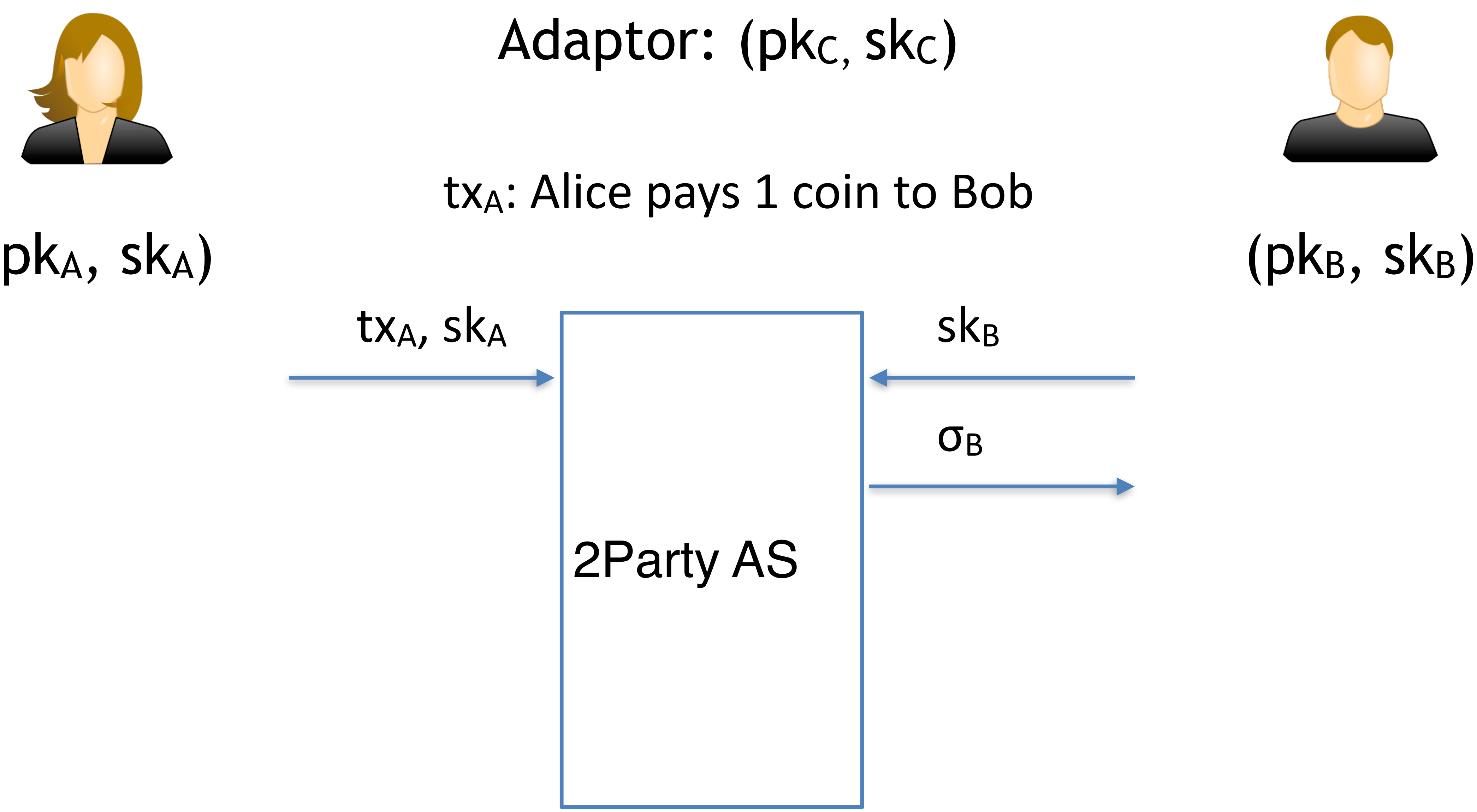

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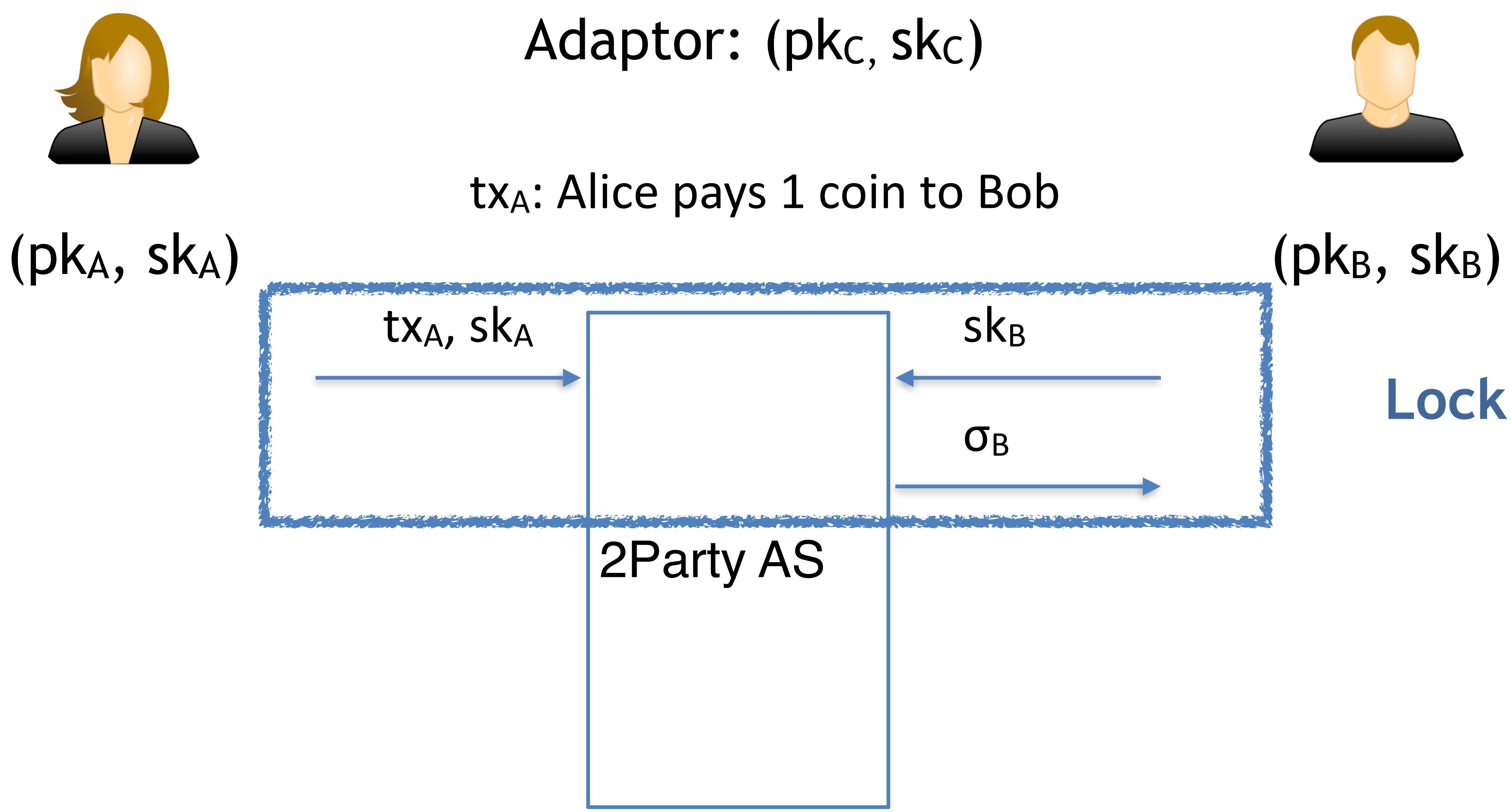

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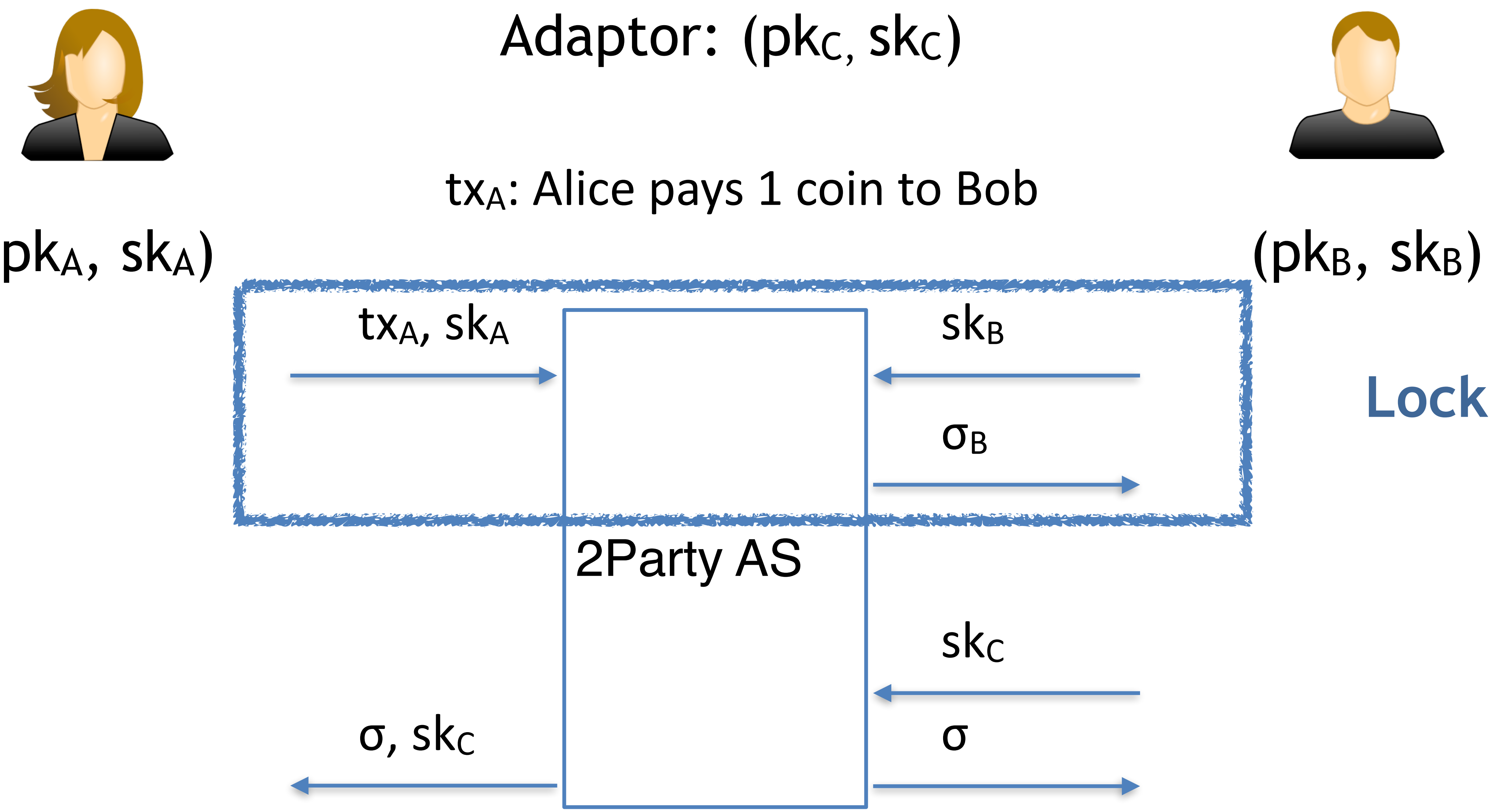

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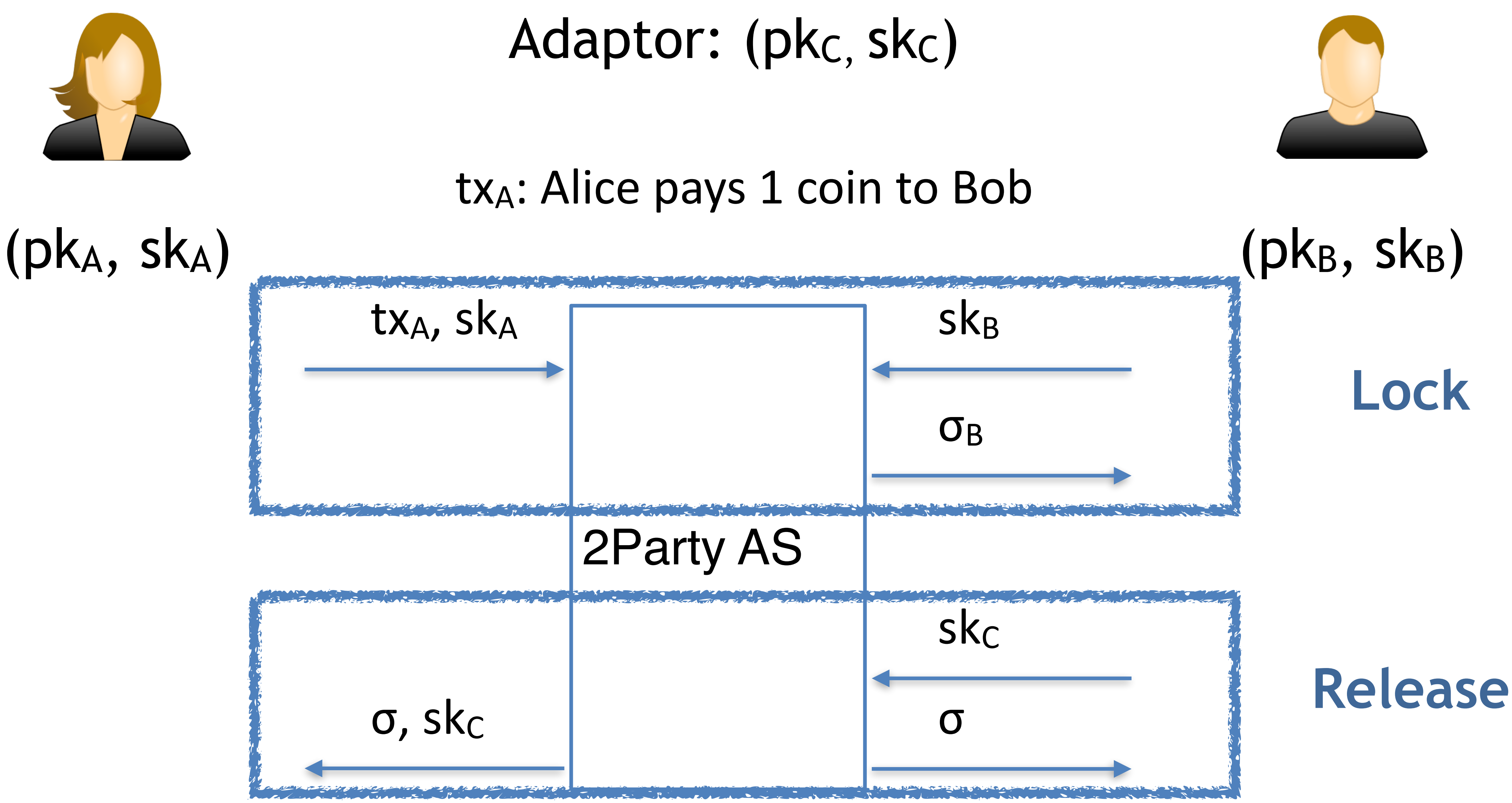

2Party AS: Instantiation

- See talk: Omer Shlomovits, “Threshold Scriptless Scripts”, ScalingBitcoin 2019
- See talk: Andrew Poelstra, “Workshop on Scriptless Scripts”, ScalingBitcoin 2018
- More details, see paper: Malavolta et al., “Anonymous Multi-Hop Locks for Blockchain Scalability and Interoperability”, NDSS 2019. Constructions with:
  - One-way homomorphic functions
  - Schnorr signatures
  - ECDSA (building on 2p-ECDSA of Lindell)

Our Approach: First Attempt

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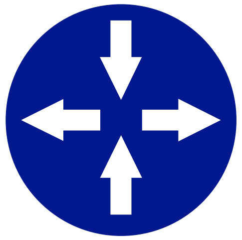

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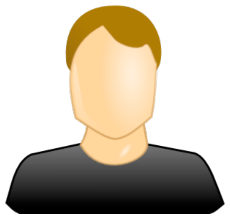

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(pk_G, sk_G, sk_C)

(pk_B, sk_B)

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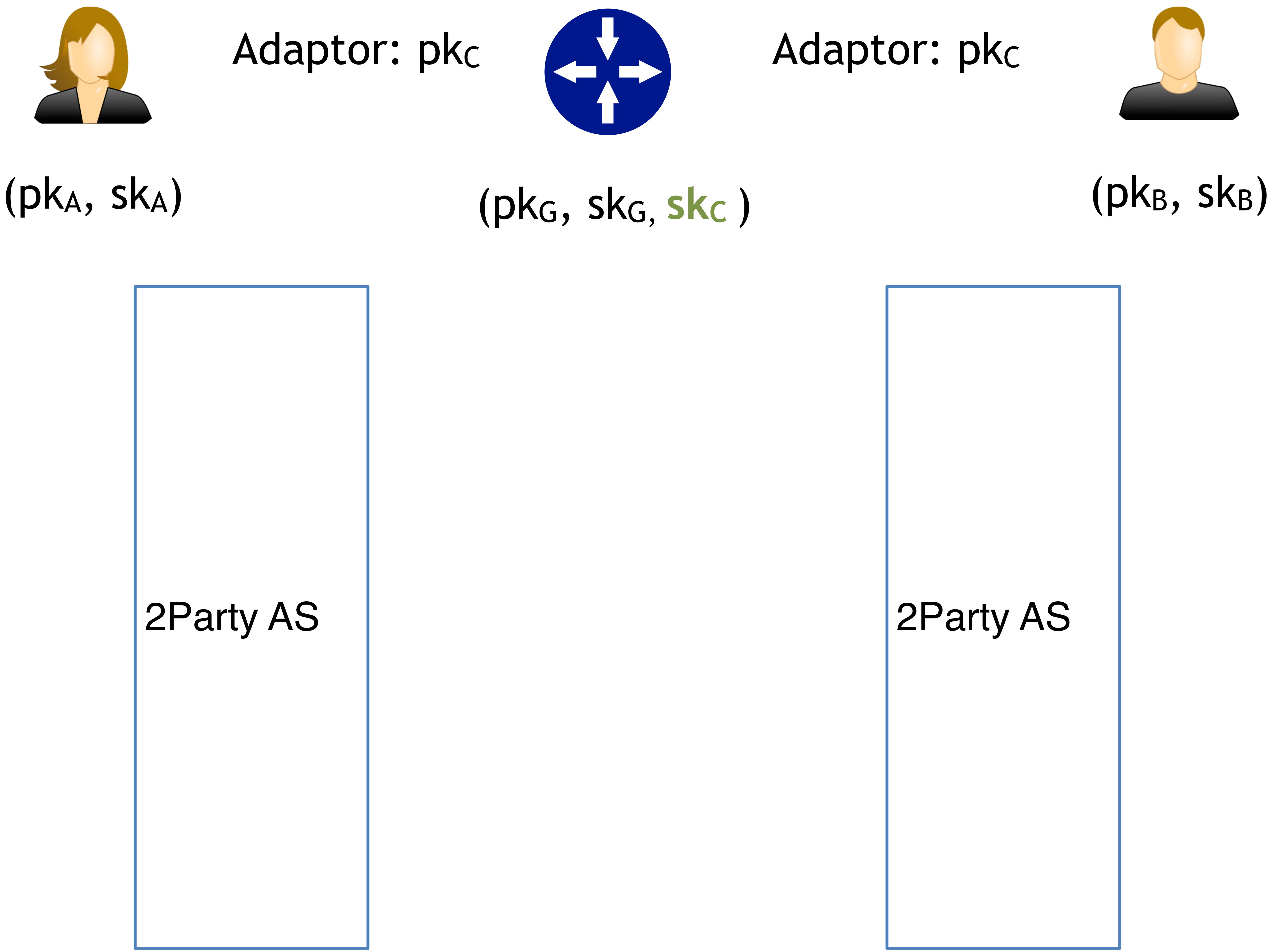

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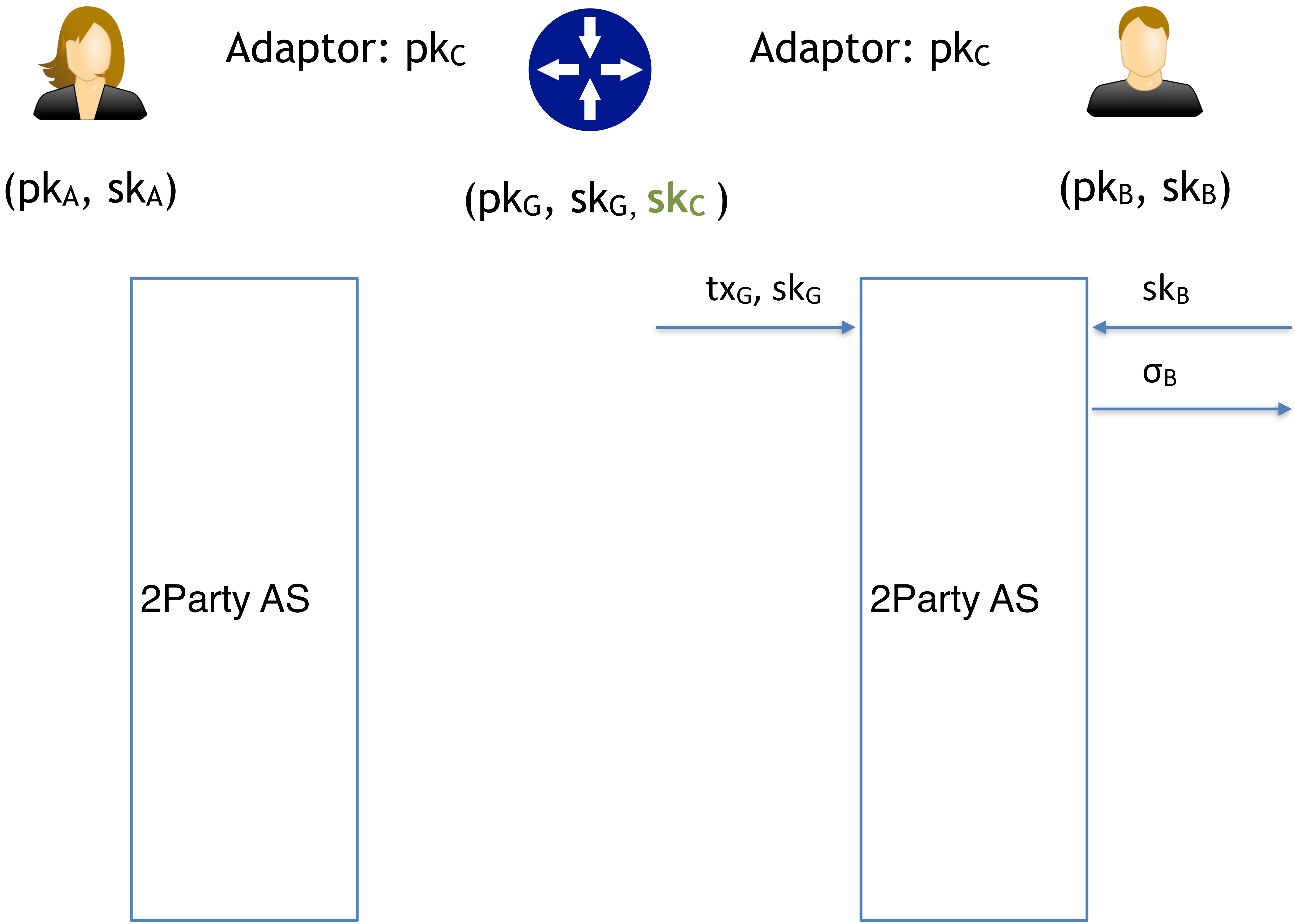

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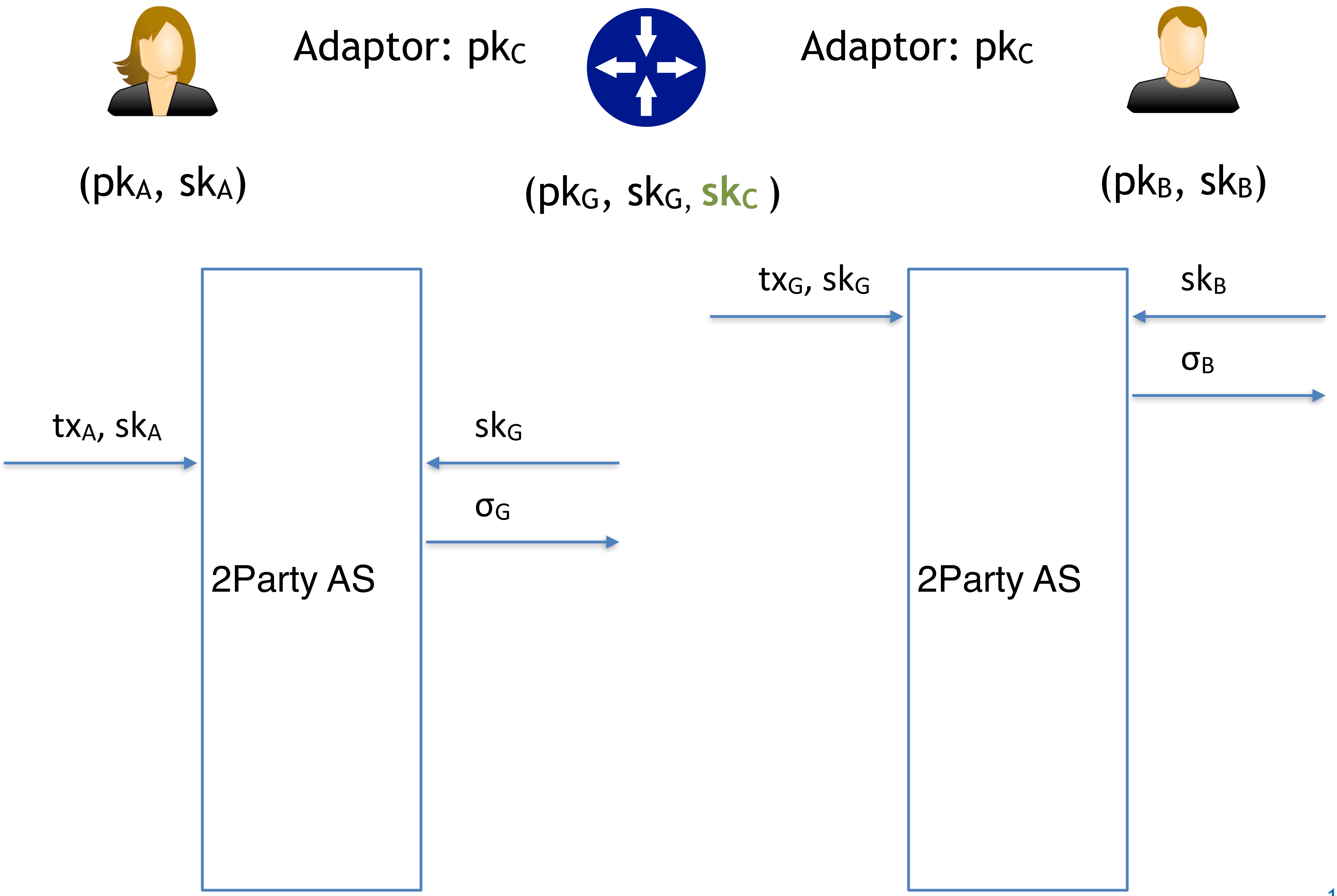

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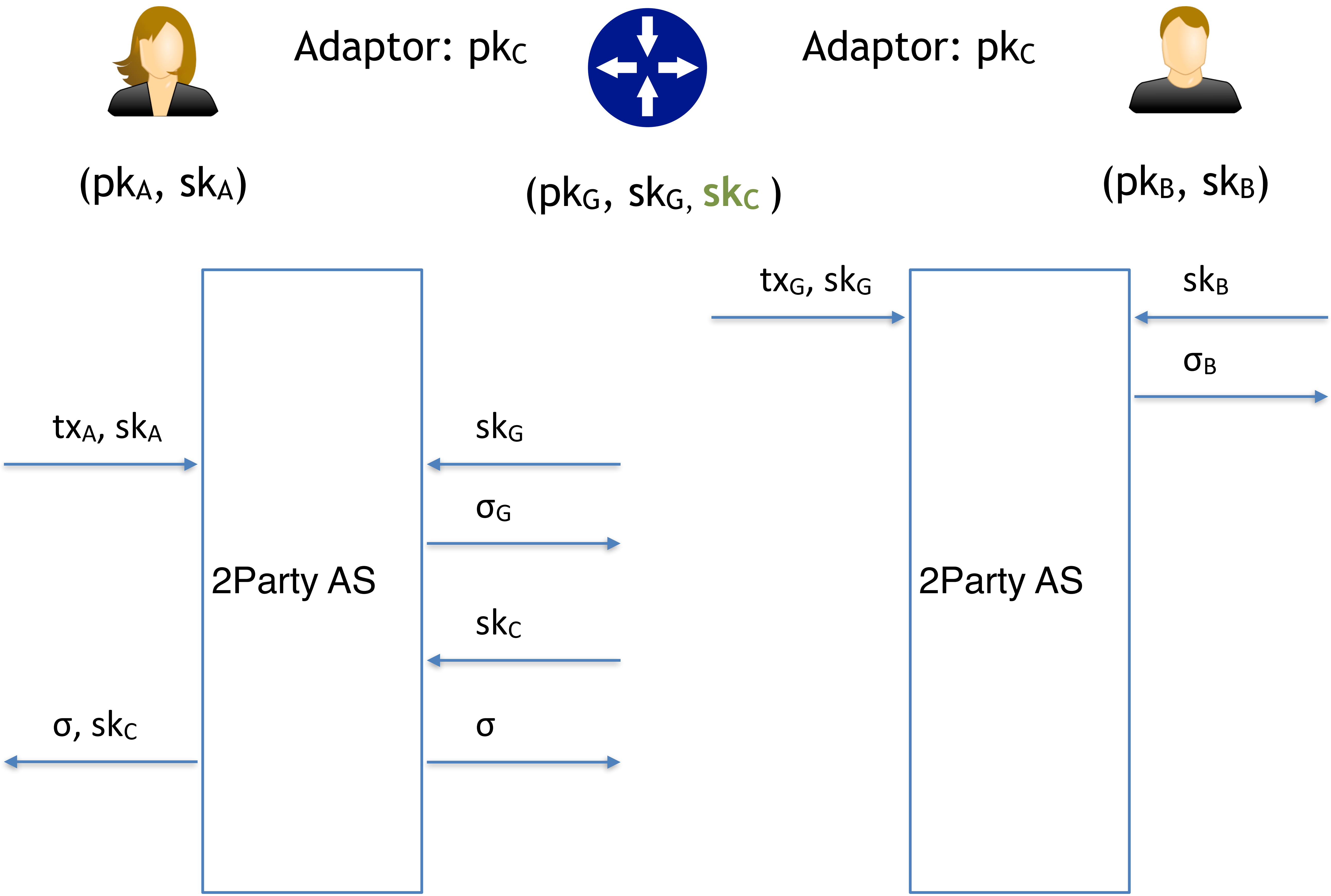

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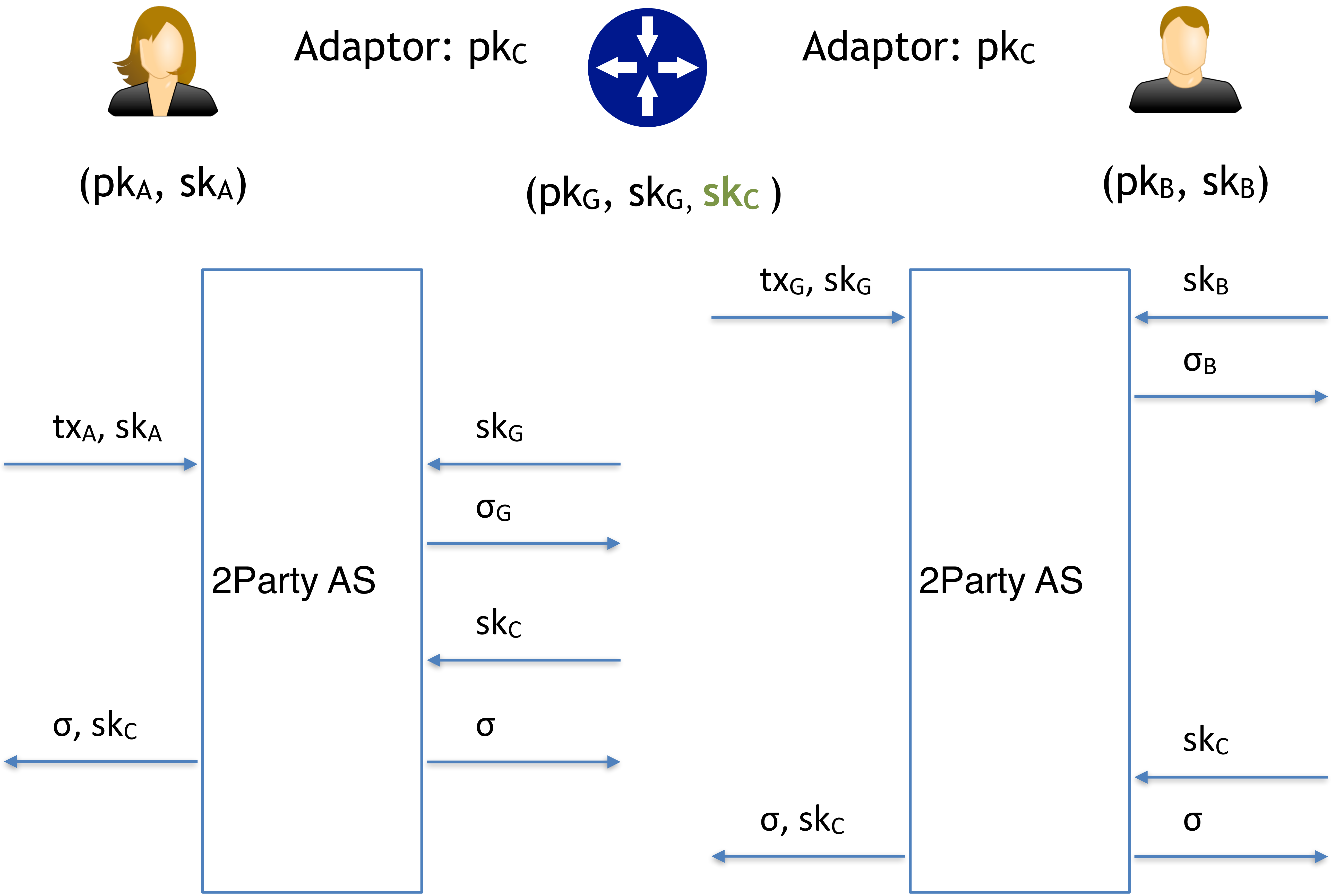

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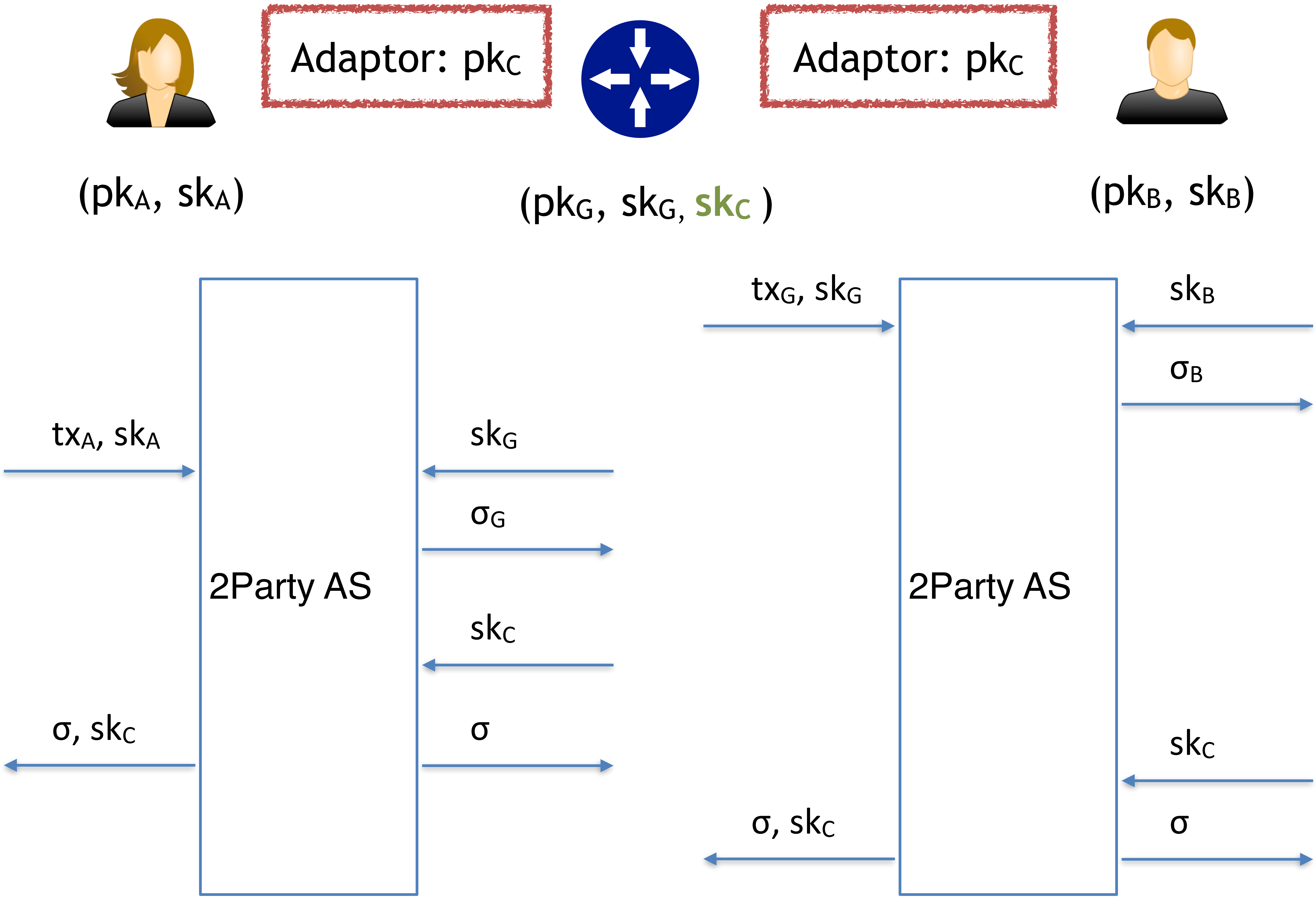

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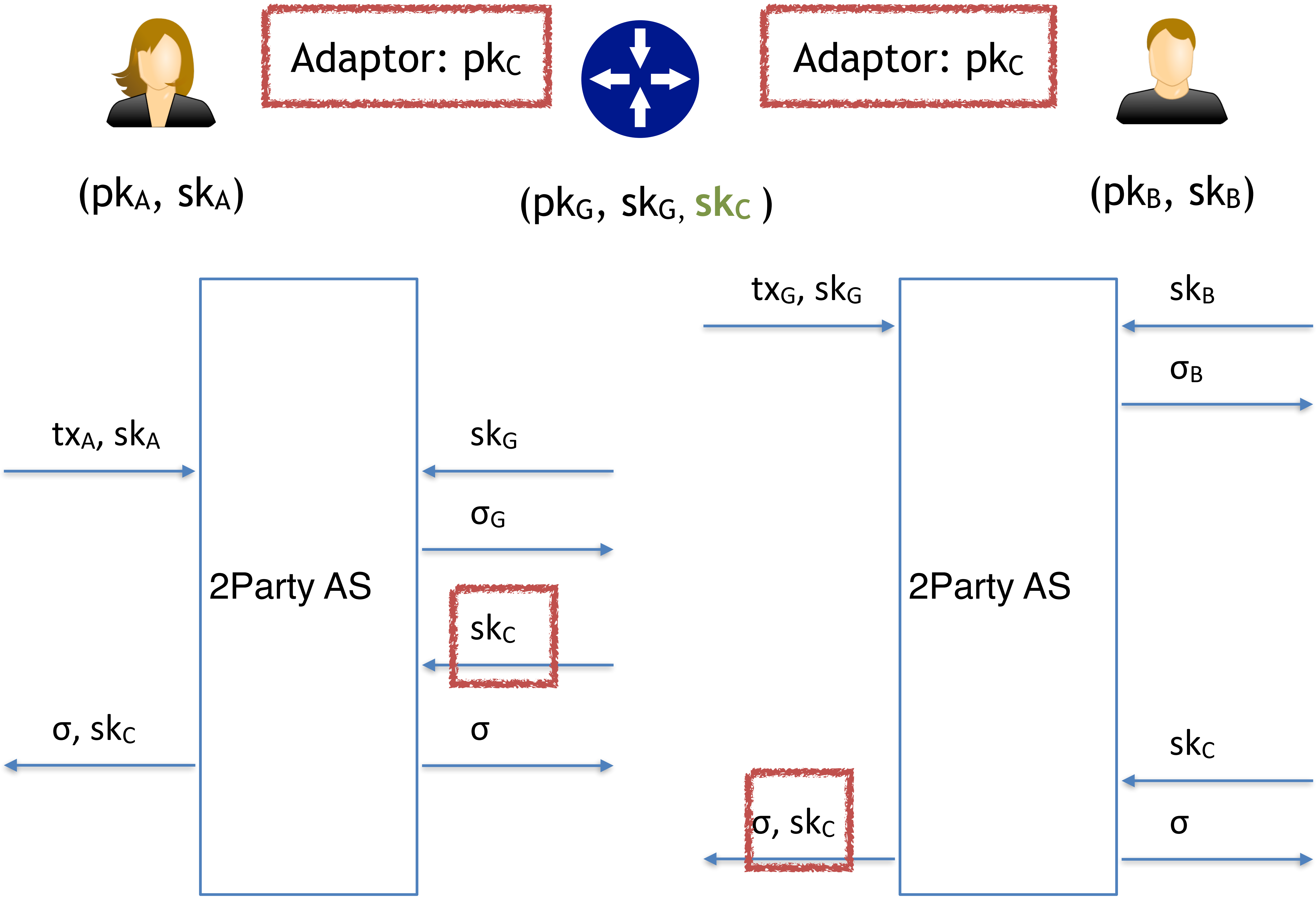

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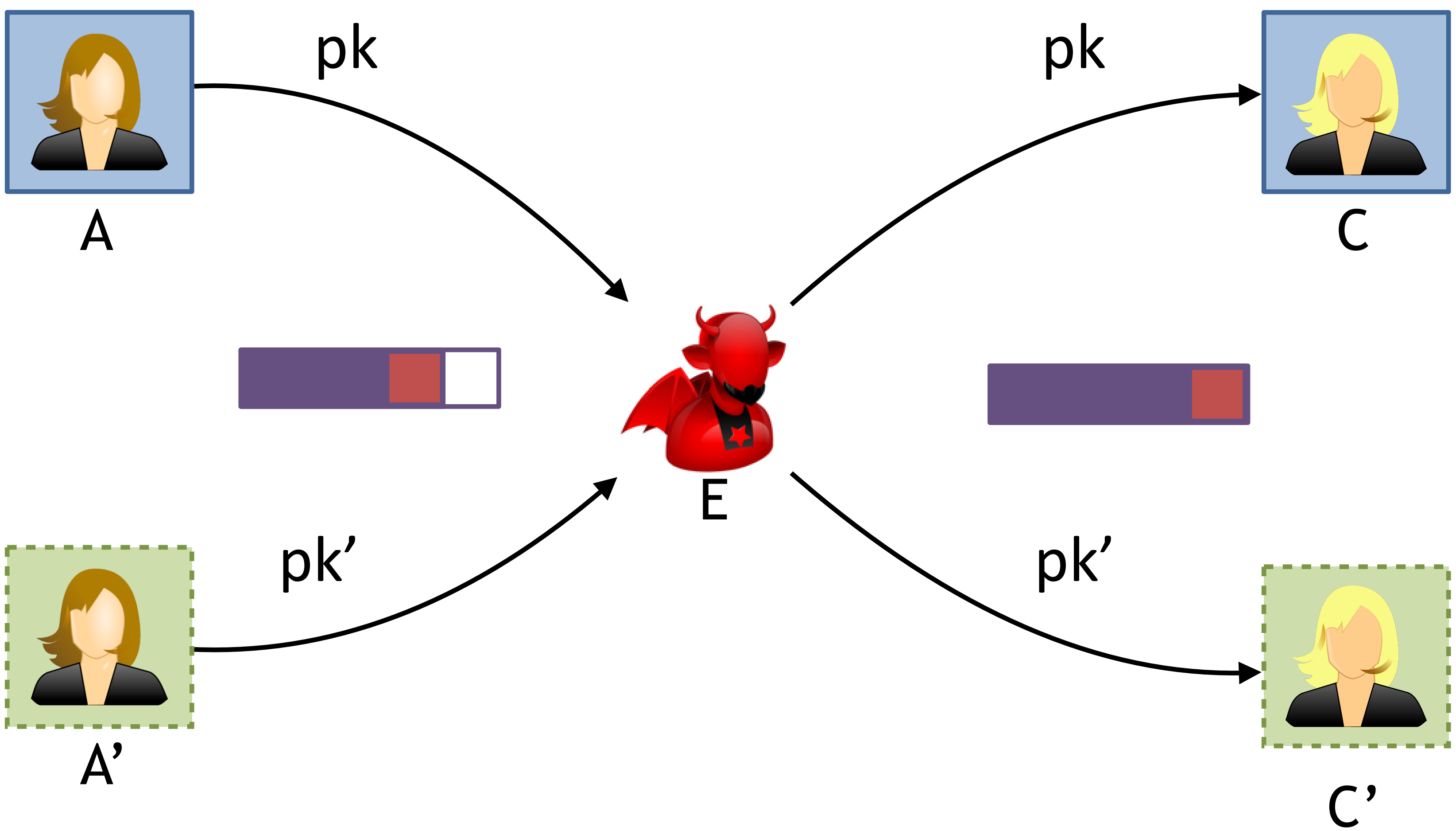

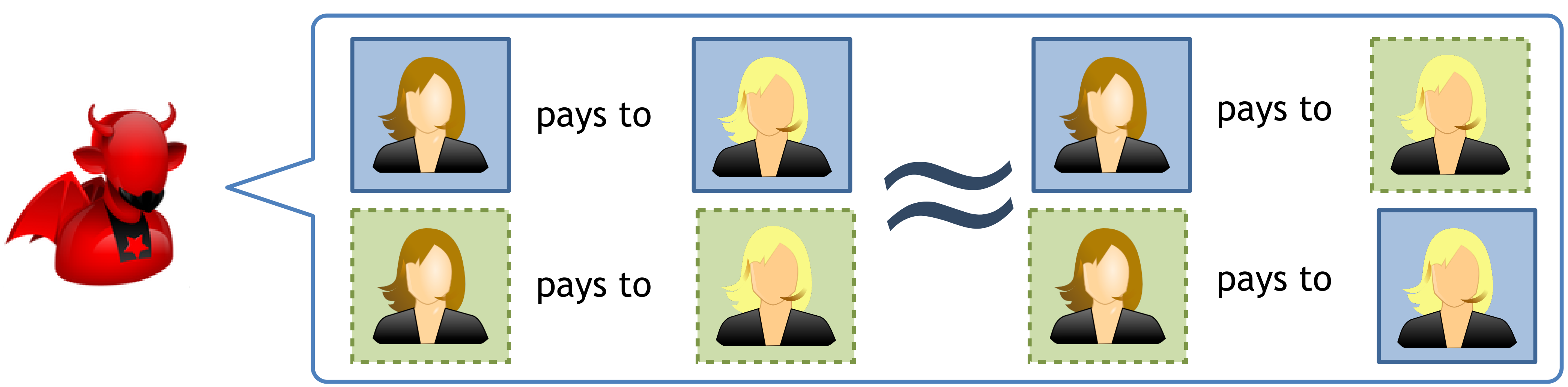

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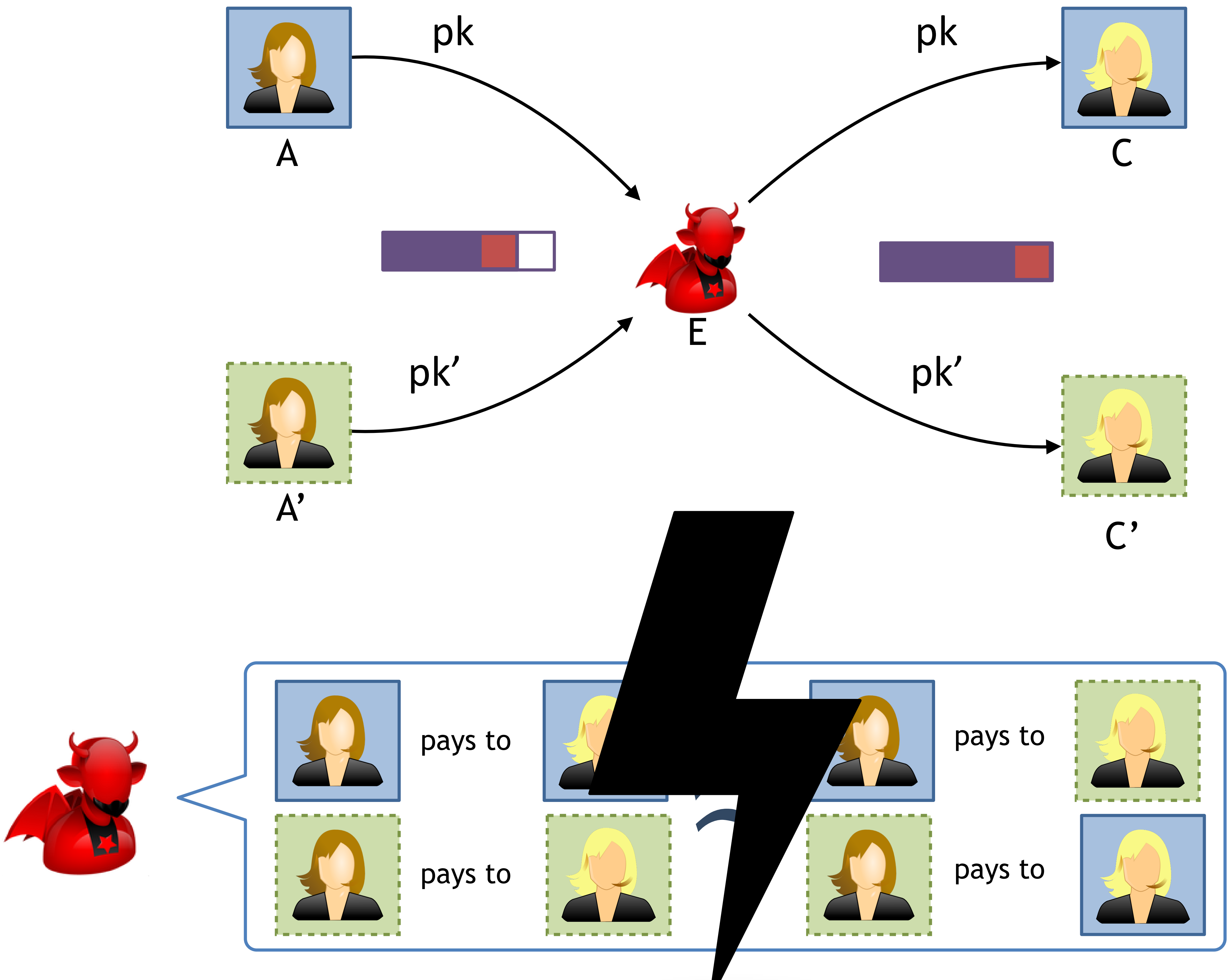
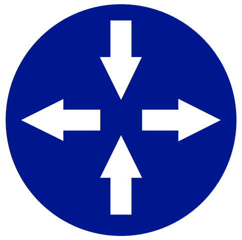


A2L: Protocol Overview



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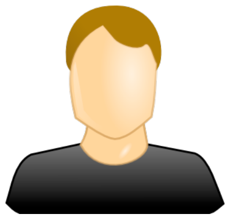

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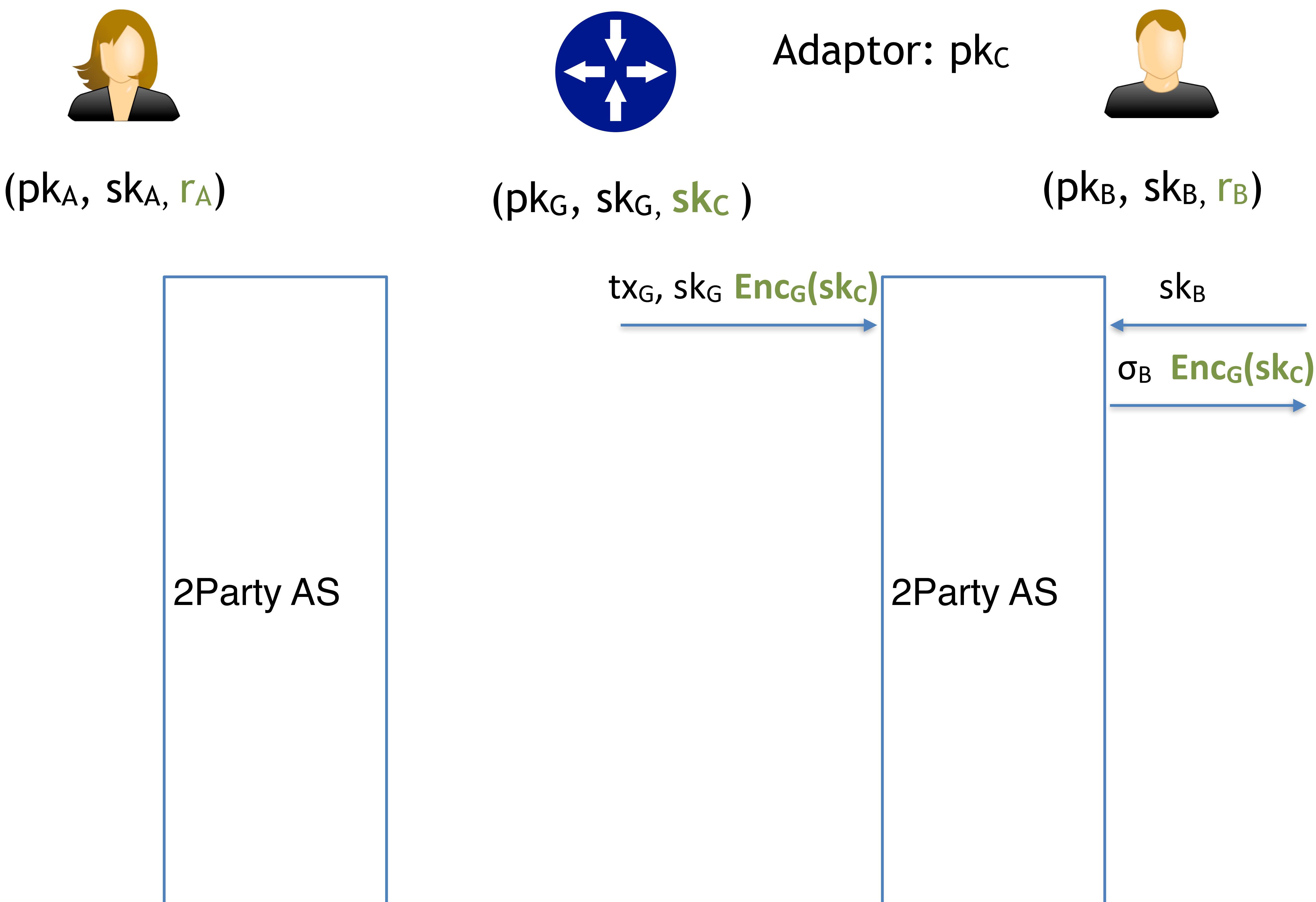

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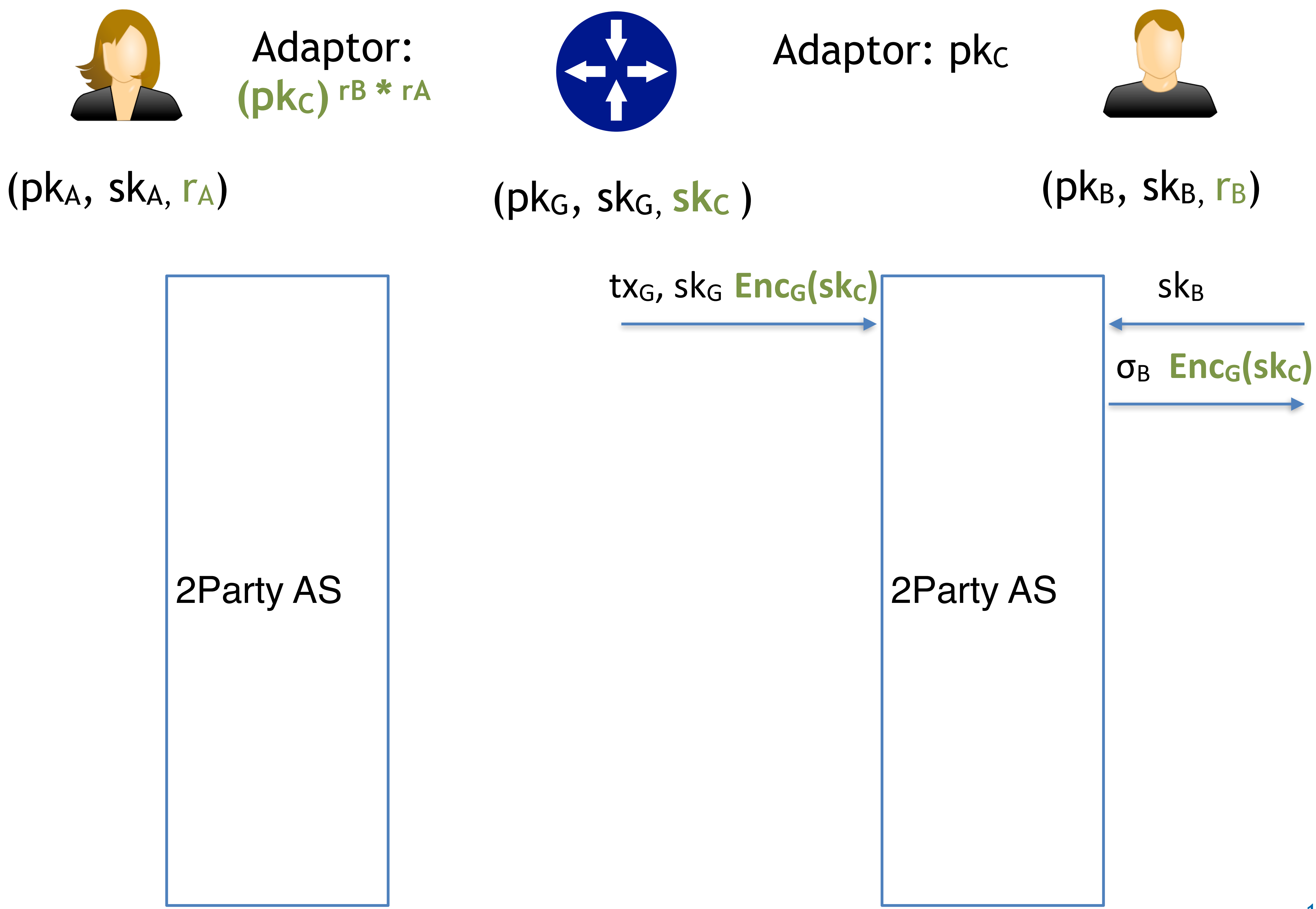

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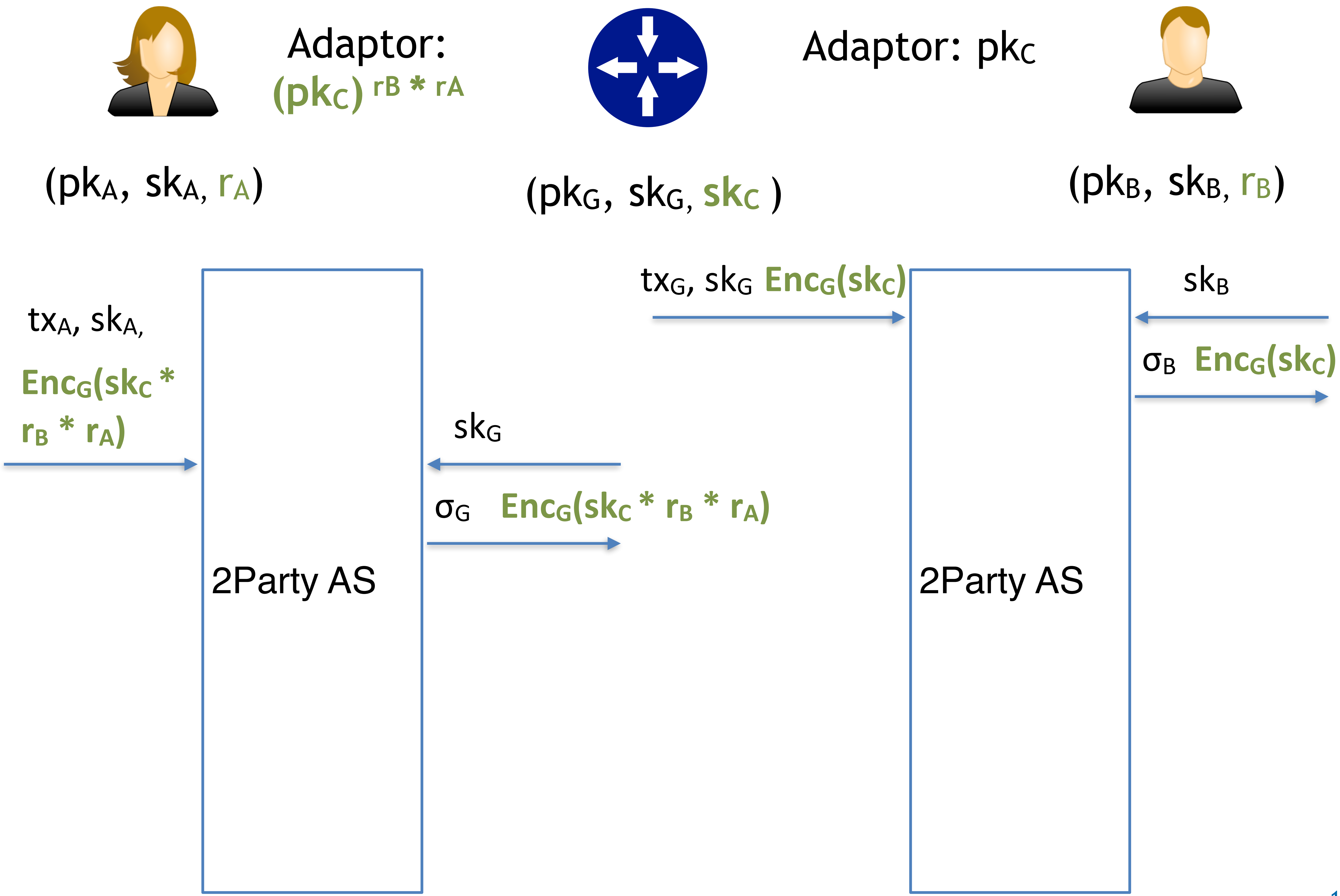

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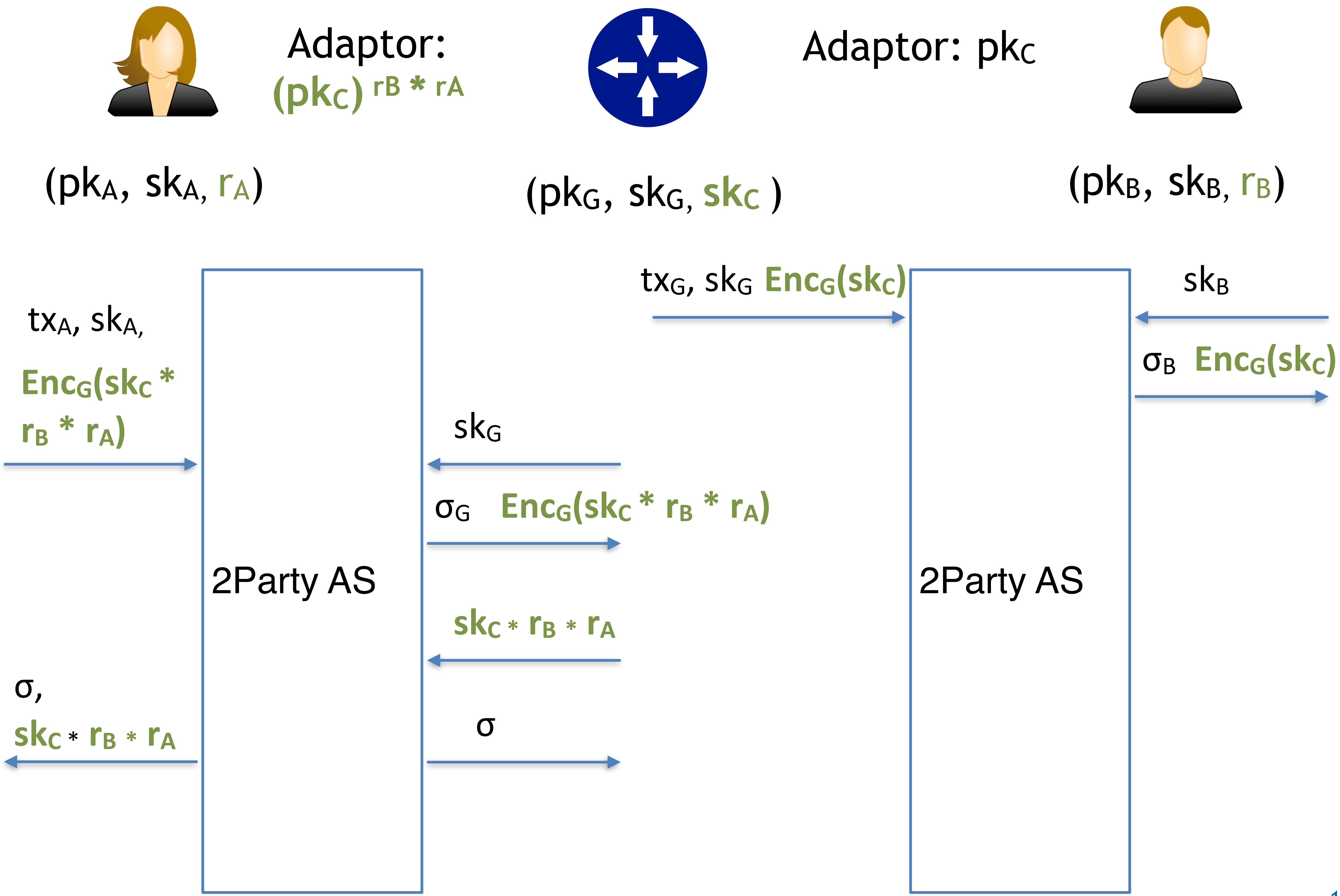

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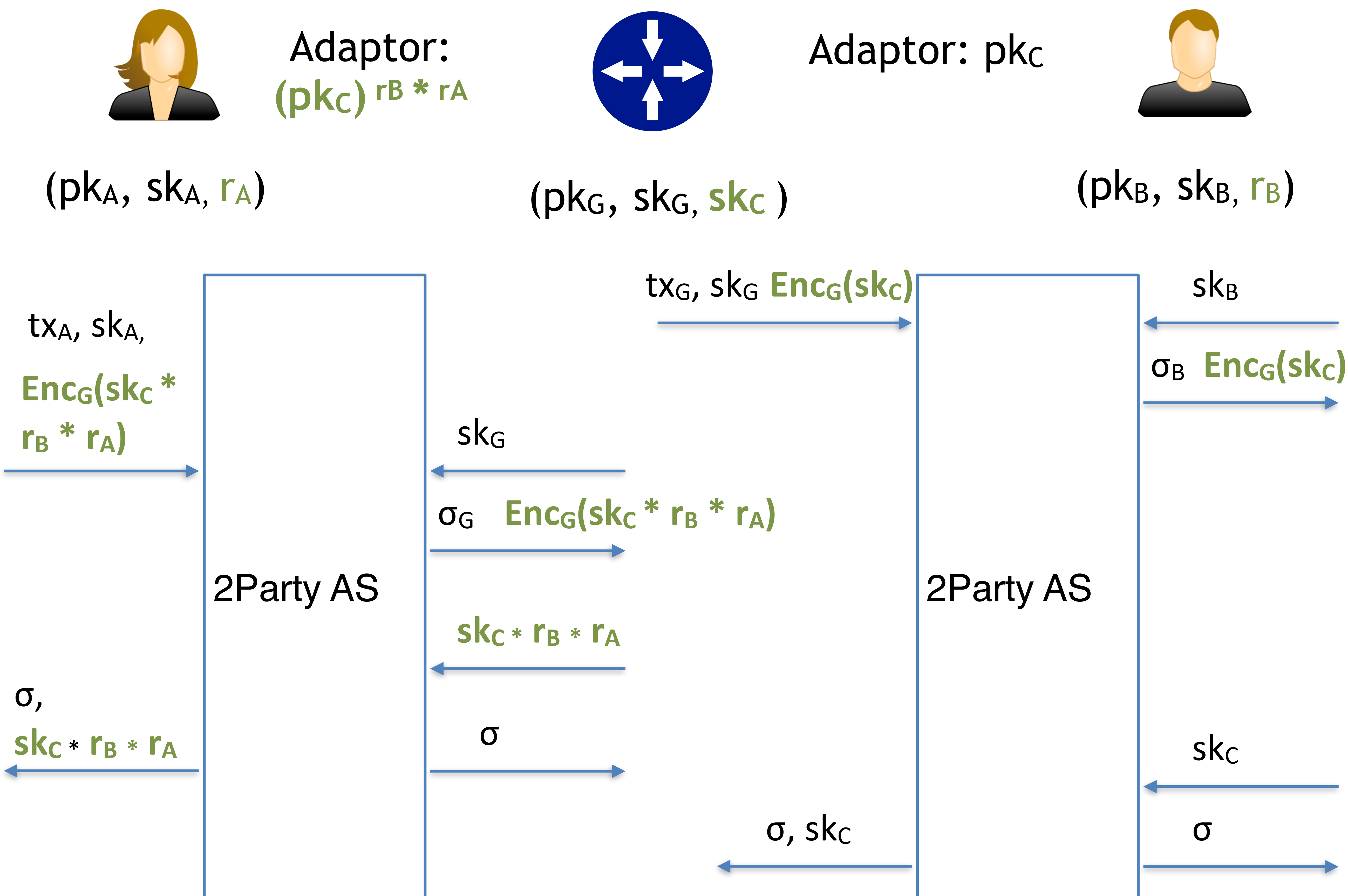

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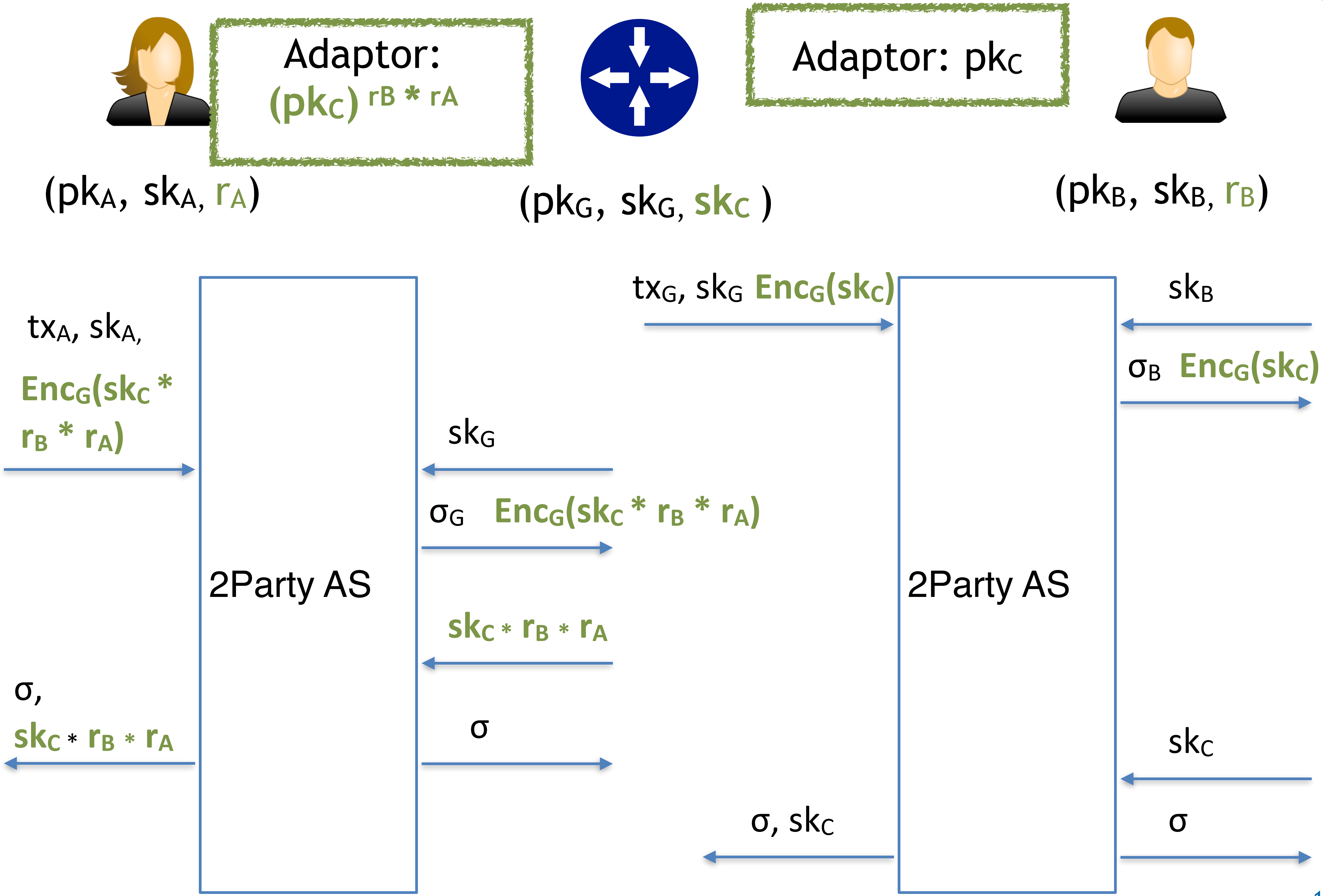

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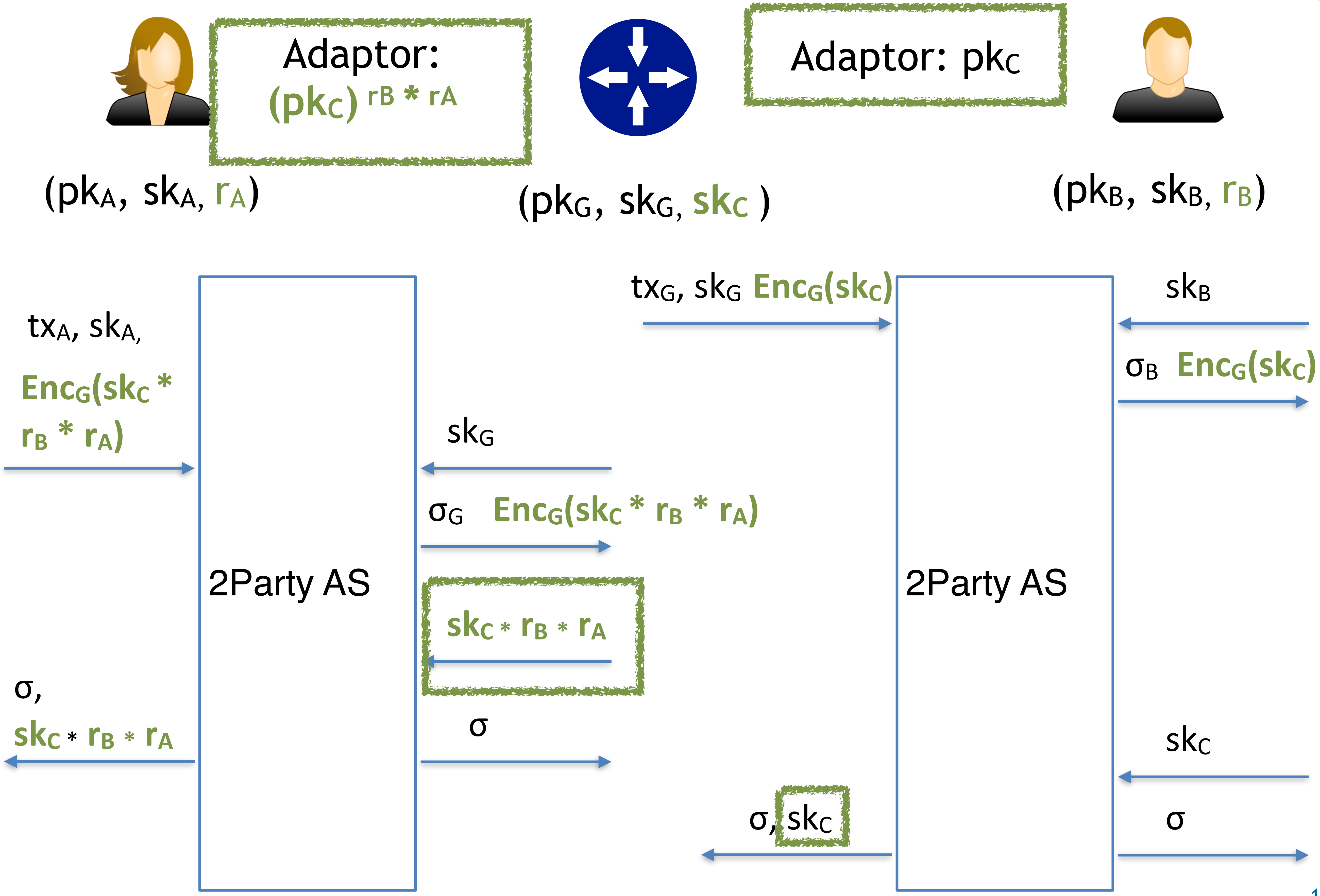

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- It requires only signature verification and timelocks (instead of HTLC):
  - Interoperability with scriptless currencies (e.g., Monero)
- Good for fungibility
  - Protocol results in a valid signature similar to any other transaction
  - Other information (e.g., encryptions) are not included

Evaluation

- Prototype implementation in C
- We evaluate the computation and communication overhead in LAN network
  - Comparison with TumbleBit

	TumbleBit	A2L (Schnorr)	A2L (ECDSA)
Computation Overhead	600 ms	70 ms; 8x faster	110 ms; 5x faster
Communication Overhead	326 KB	3.5 KB; 95x reduction	5 KB; 65x reduction

- Number of operations and communication overhead are asymptotically reduced
  - TumbleBit uses cut-and-choose
  - Size of exchanged messages grow non-linearly in the security parameter

Take Home...

- A2L is a cryptographic protocol for PCHs that achieves security, unsinkability and interoperability
- Formally specified and proven secure in the UC Framework
- Advantages:
  - Fully backwards compatible with Bitcoin (and Schnorr if adopted in Bitcoin), and scriptless cryptocurrencies (e.g., Monero)
  - The most efficient Bitcoin-compatible PCH
- Paper available at https://eprint.iacr.org/2019/589.pdf
- Implementation available at https://github.com/etairi/A2L

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@pedrorechez