ZEXE: Enabling Decentralized Private Computation

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ia.cr/2018/962   libzexe.org

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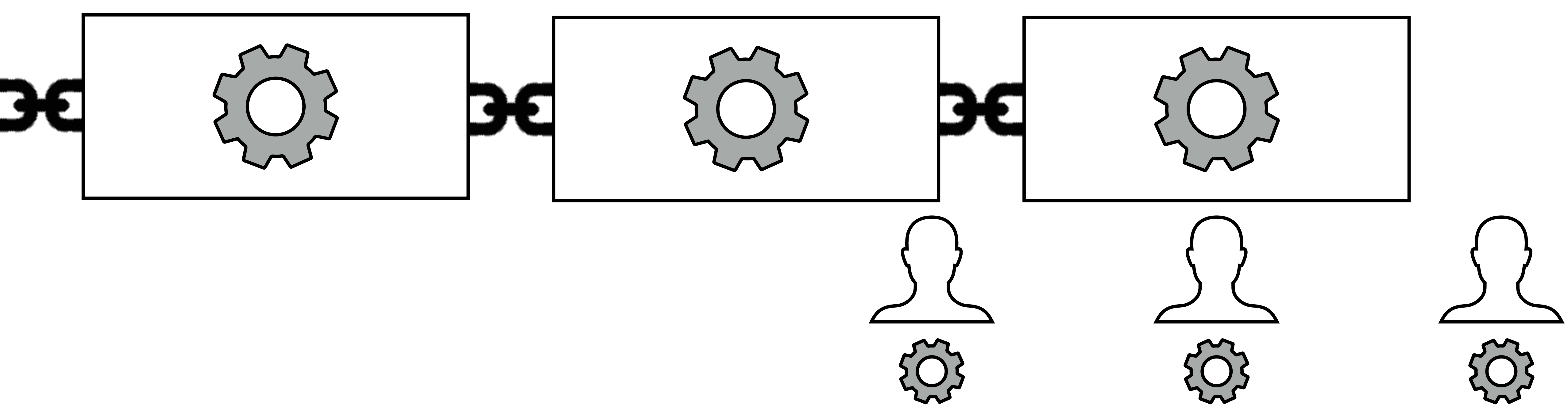

Scalability and privacy issues

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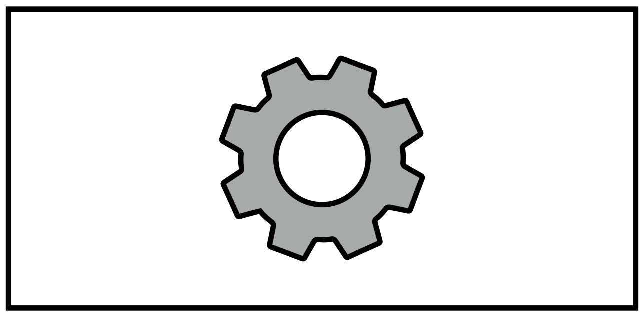

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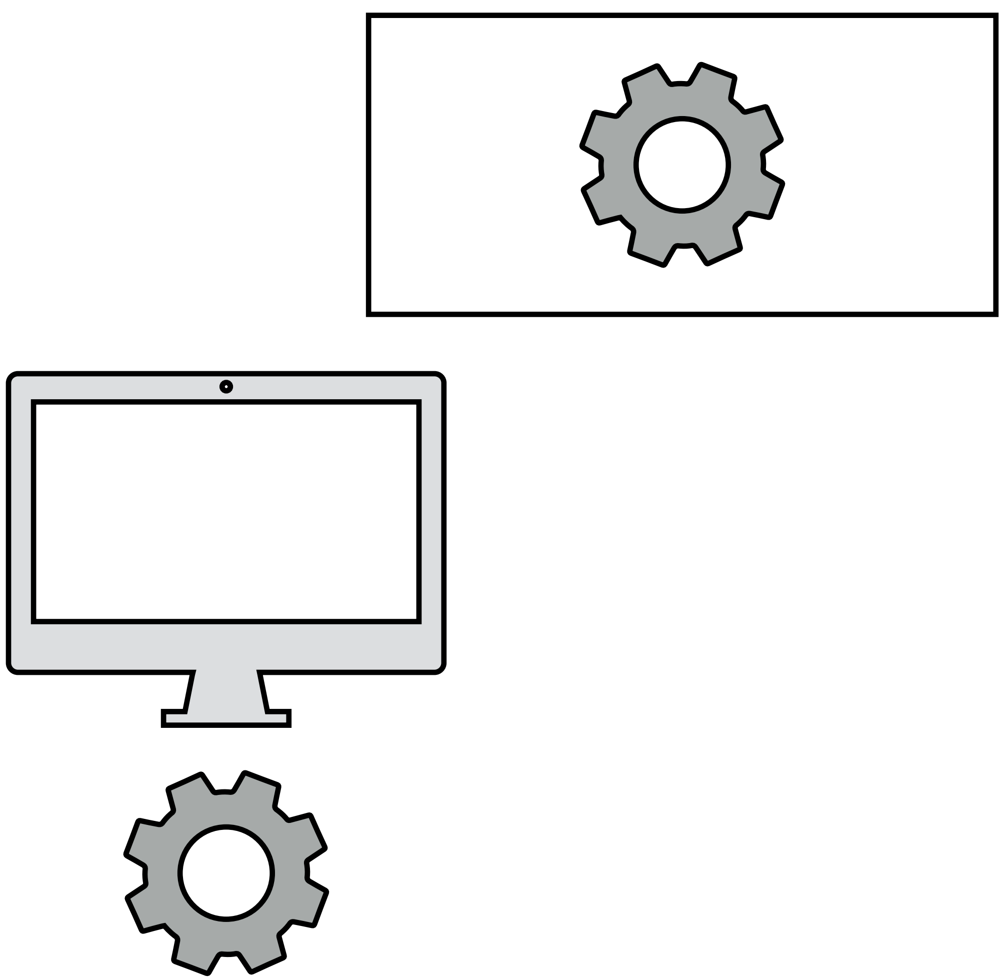

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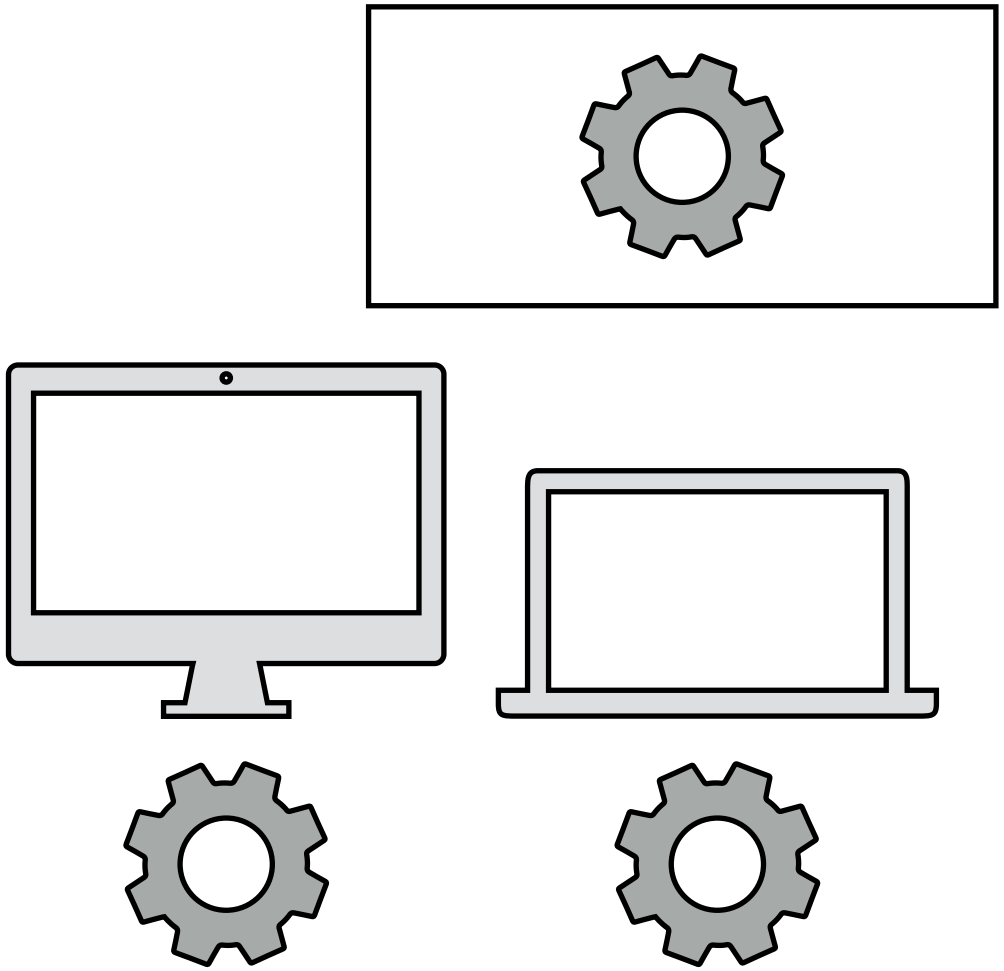

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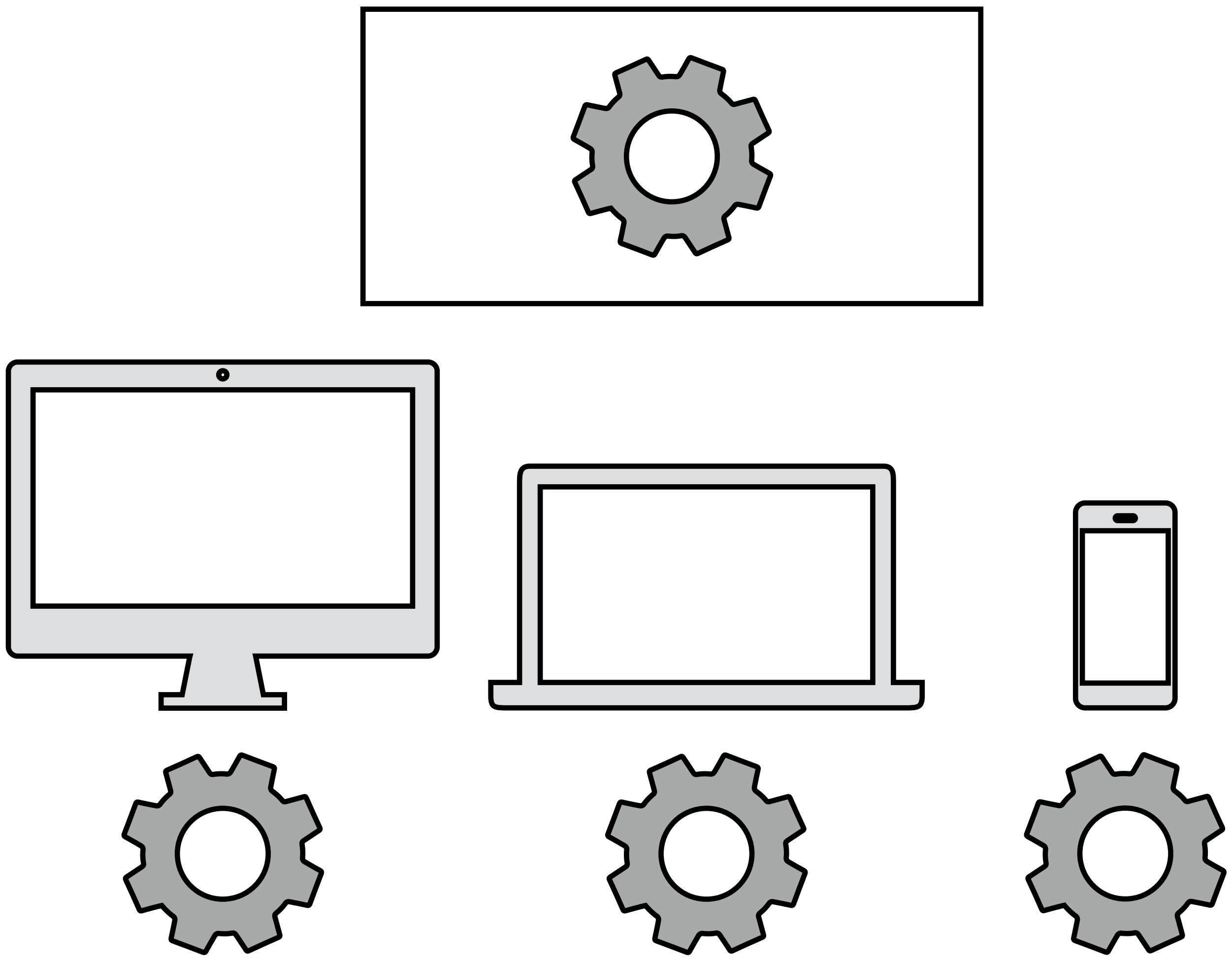

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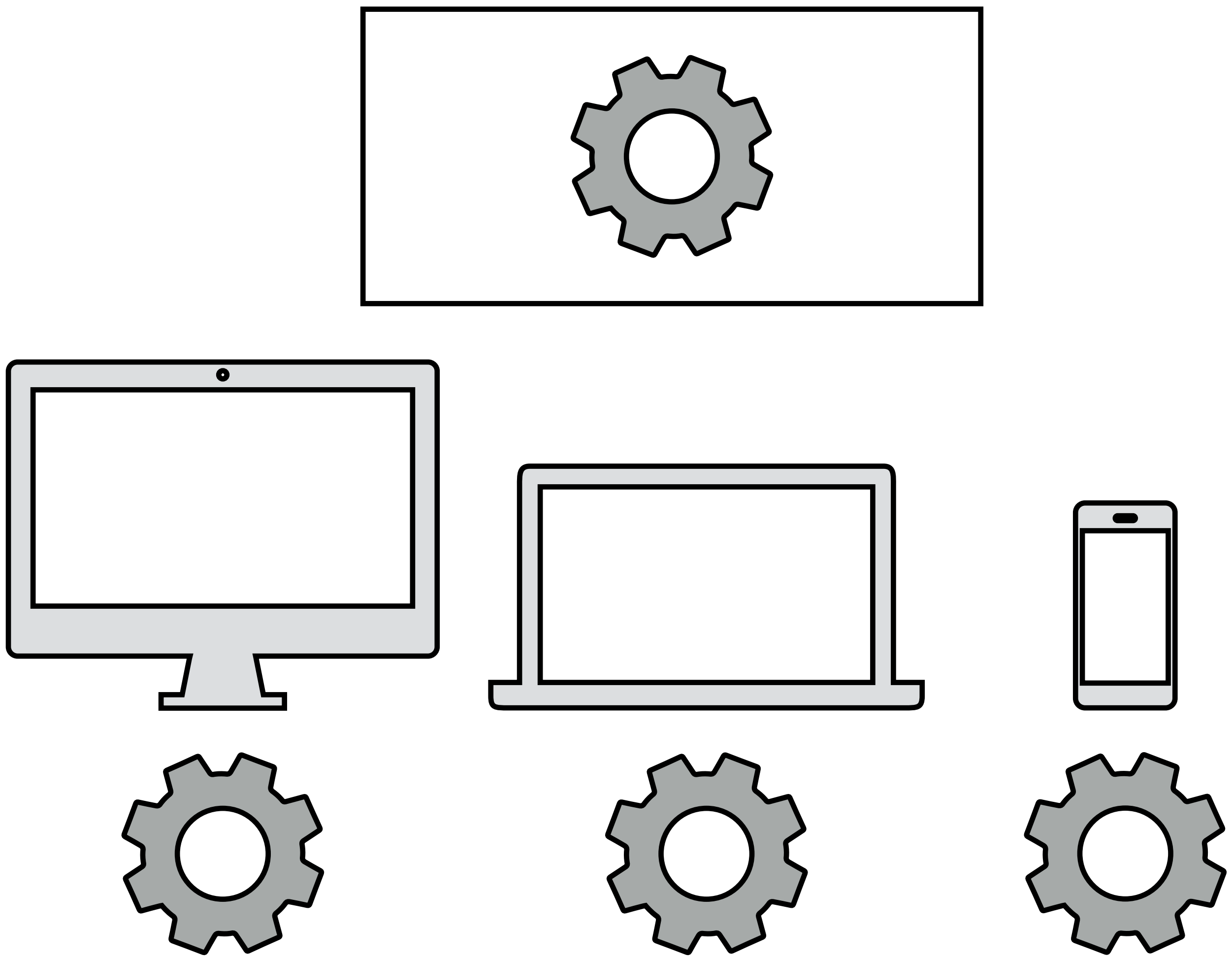

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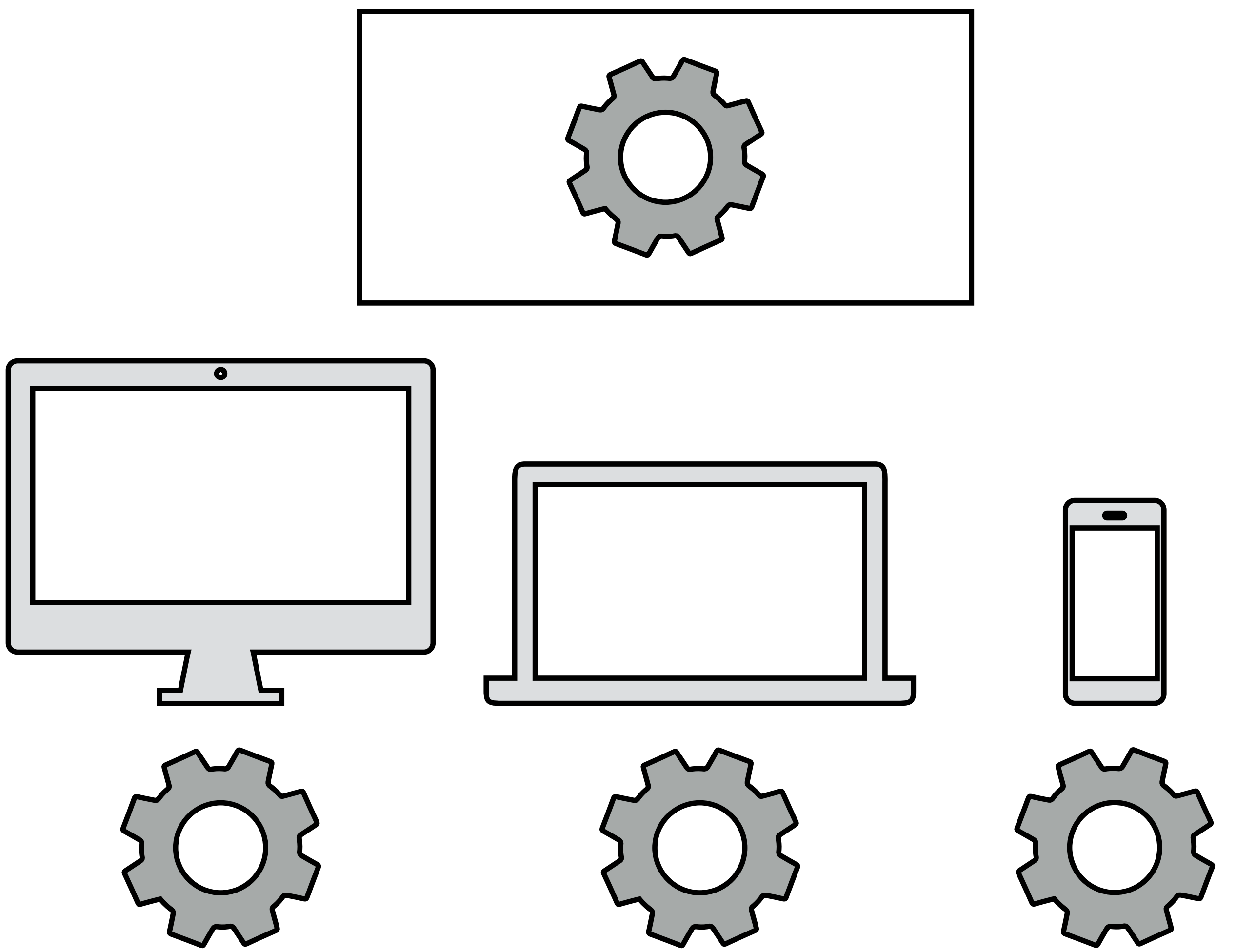

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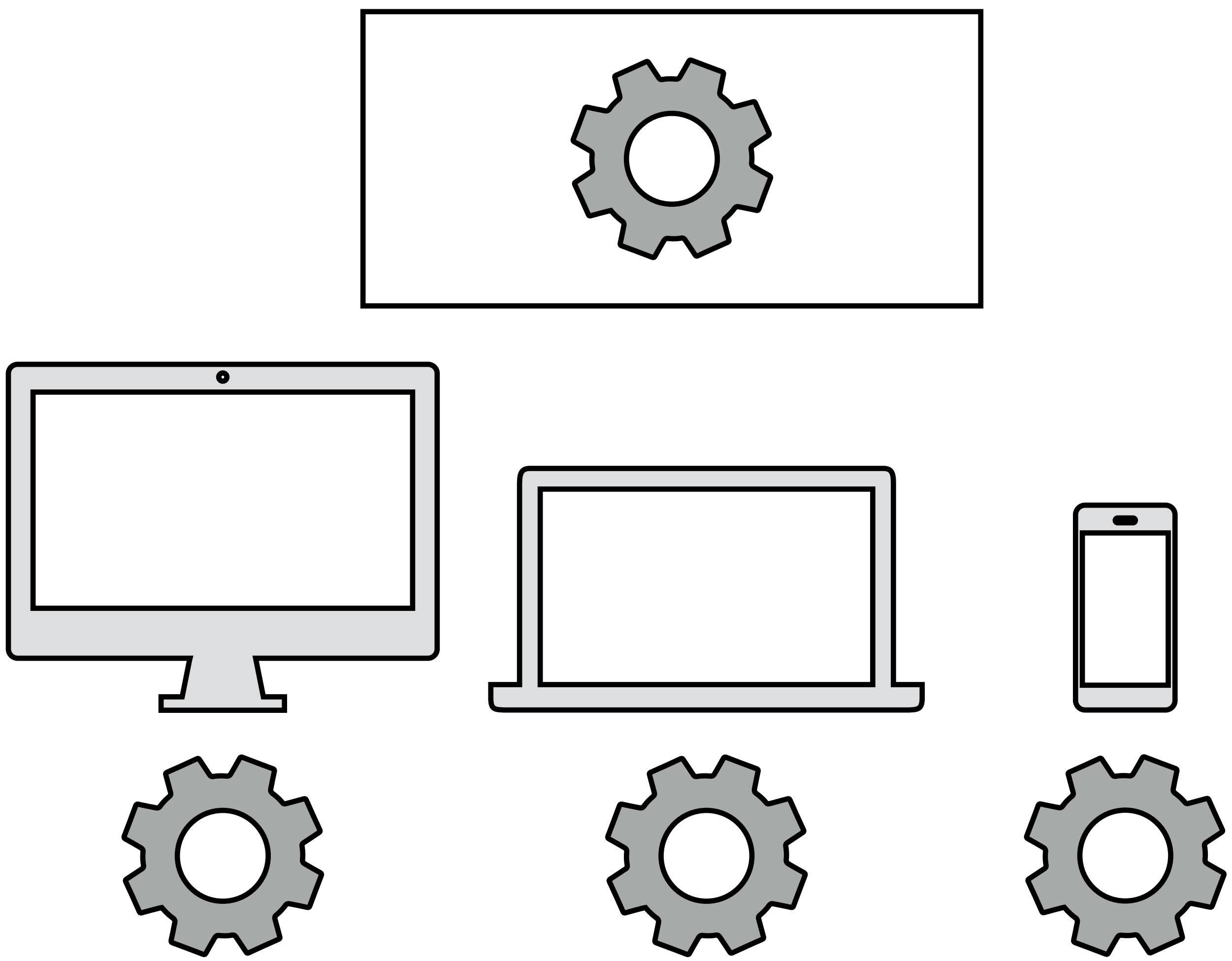

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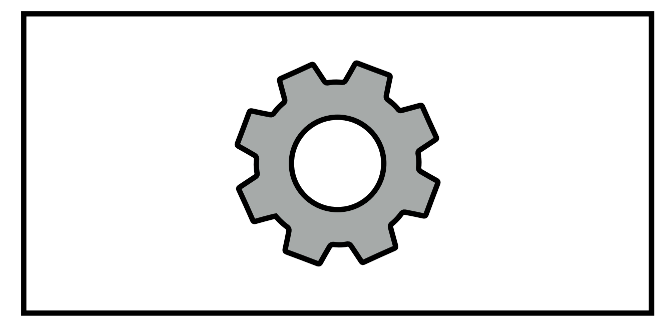

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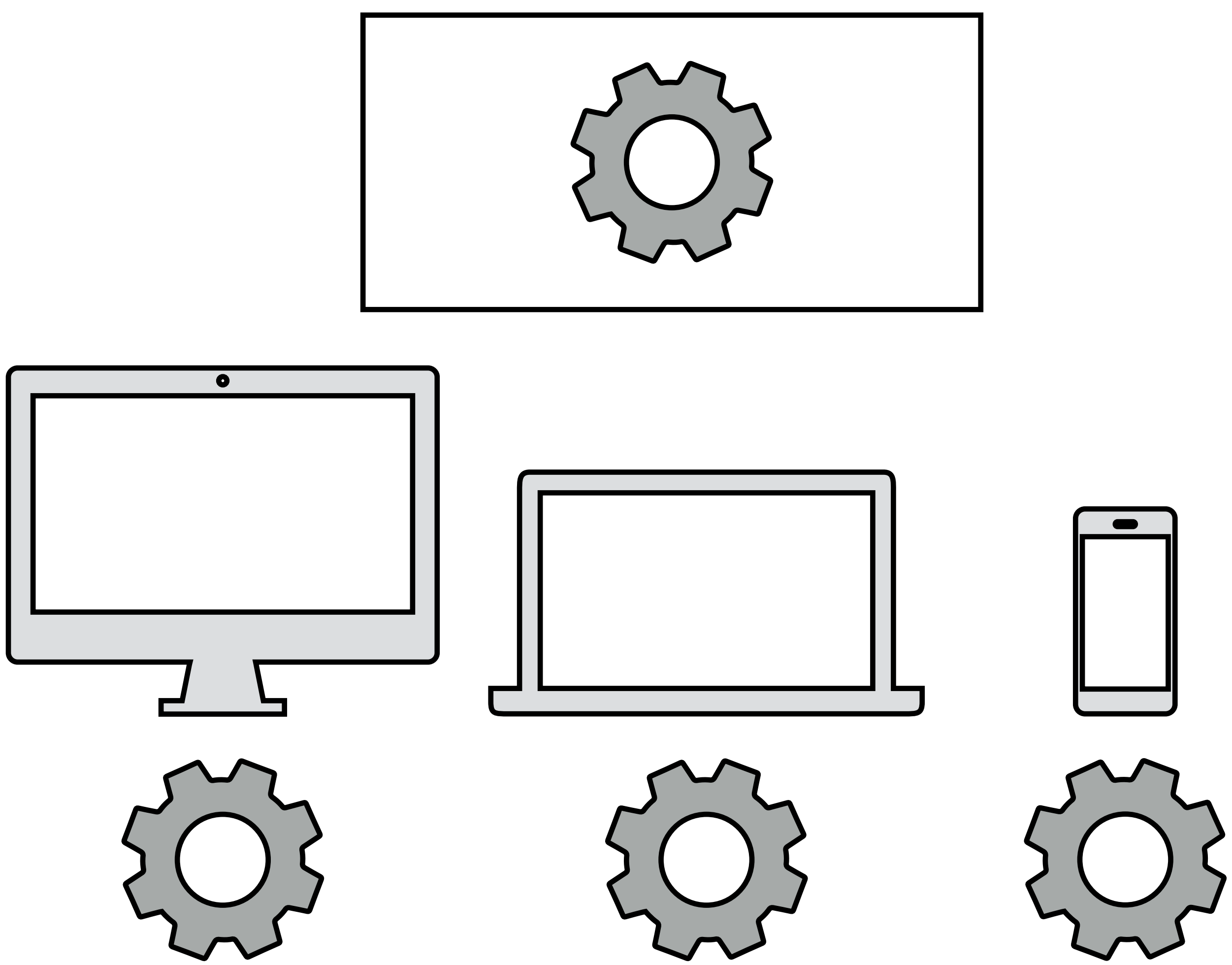

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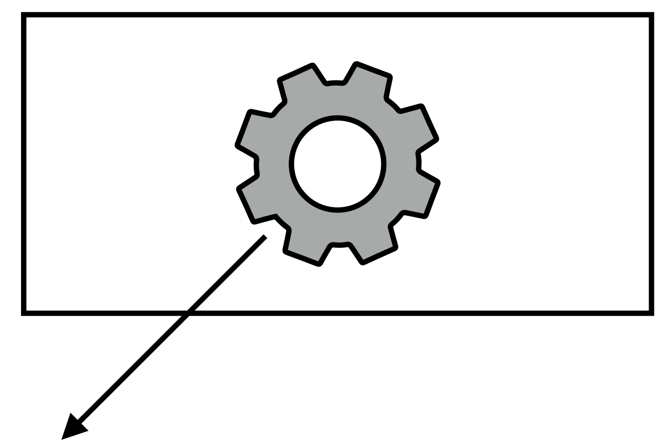

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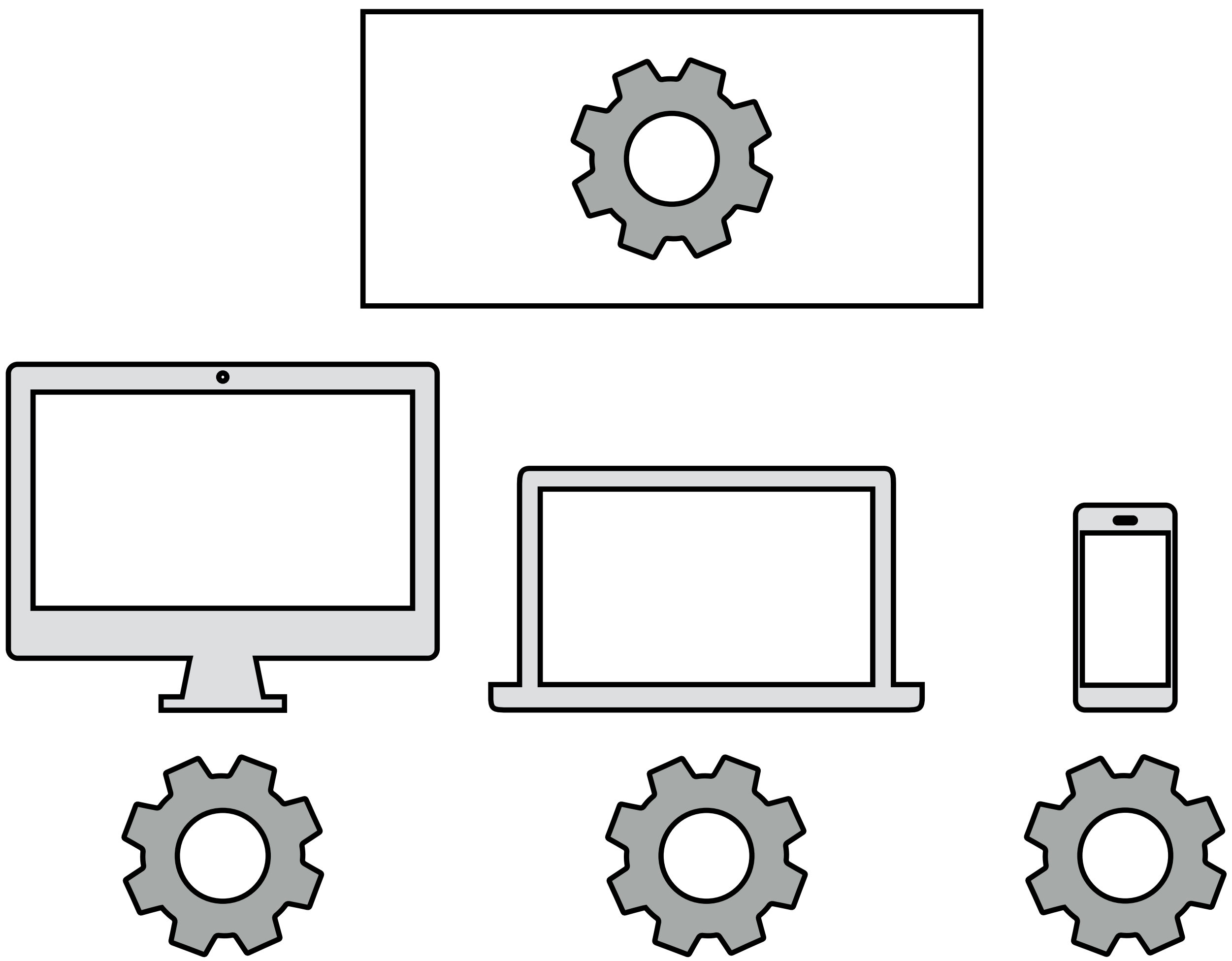

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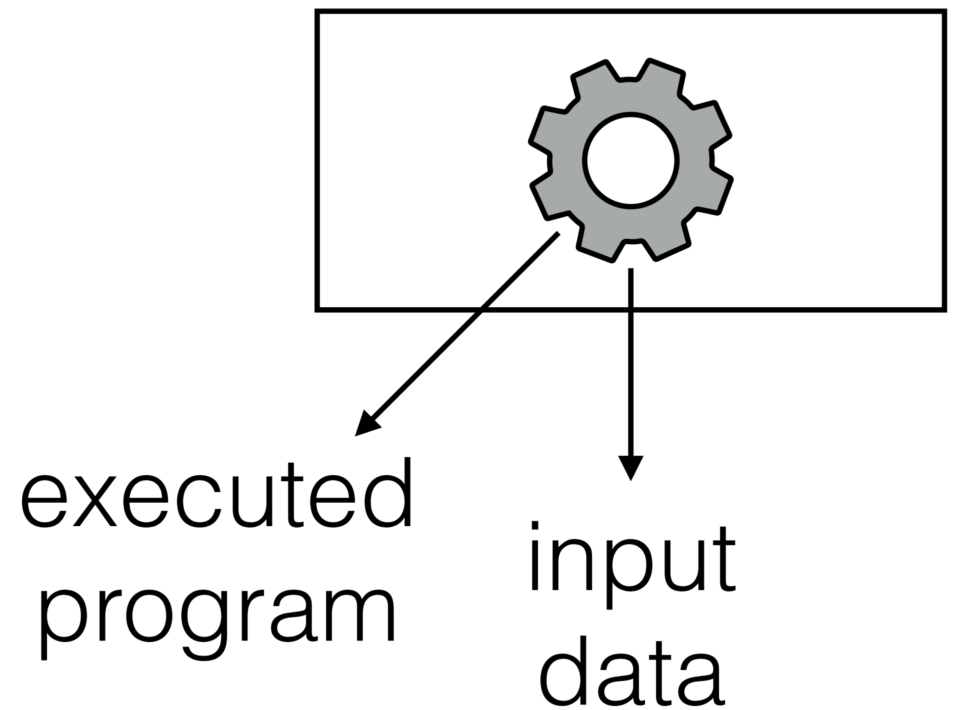

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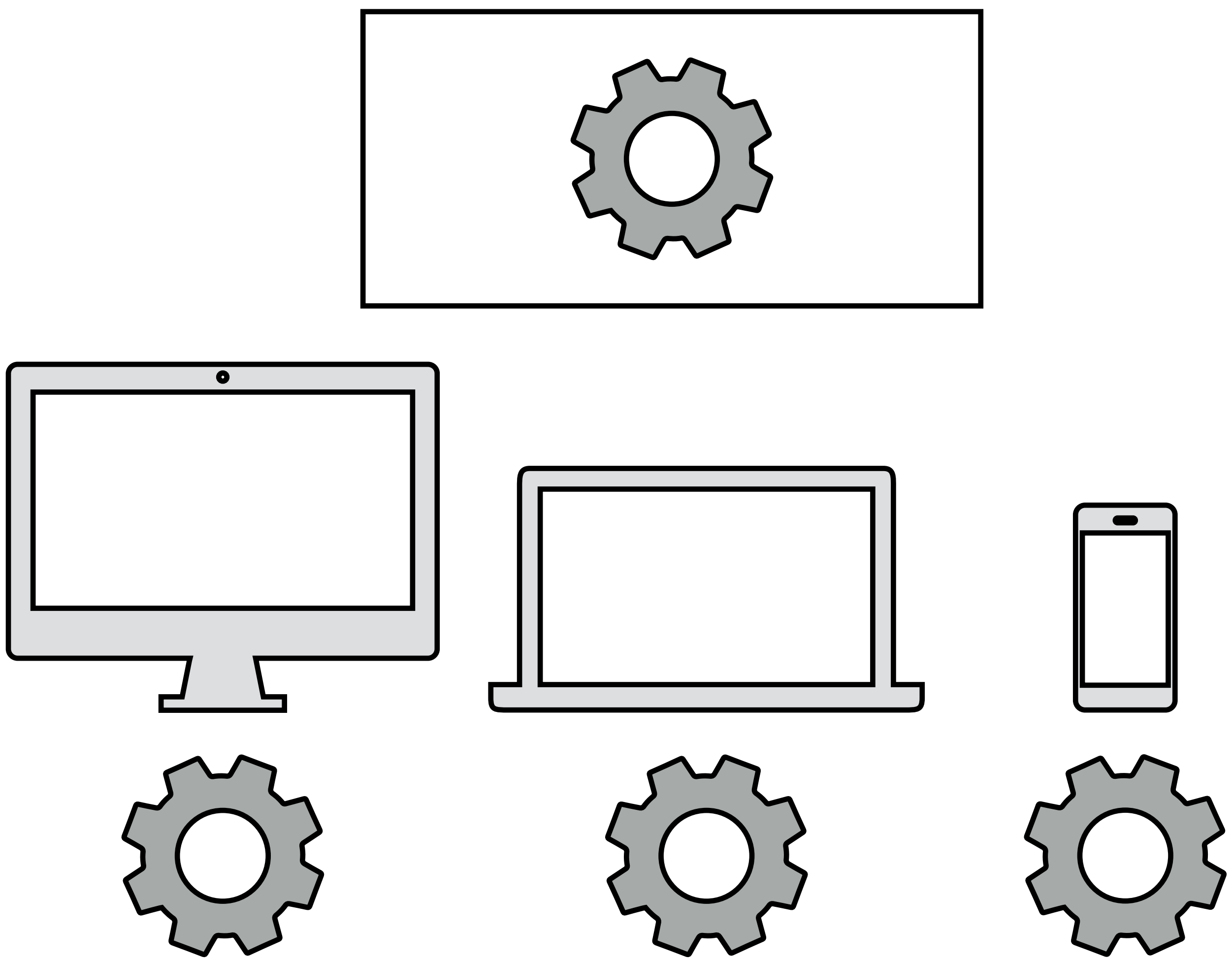

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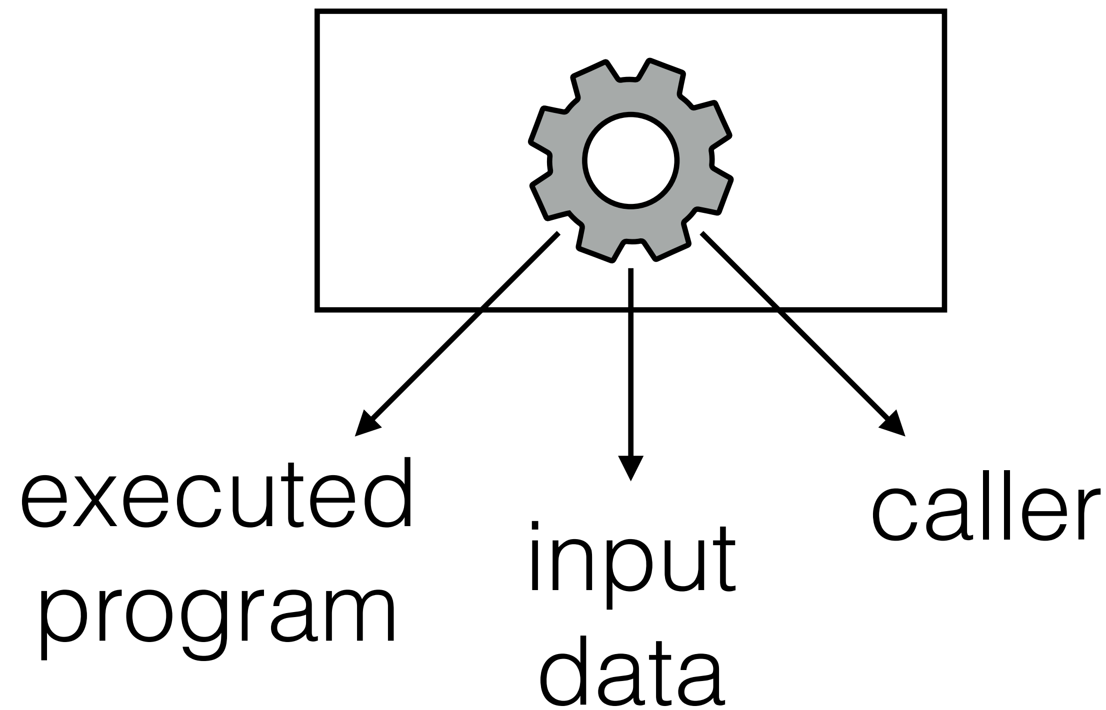

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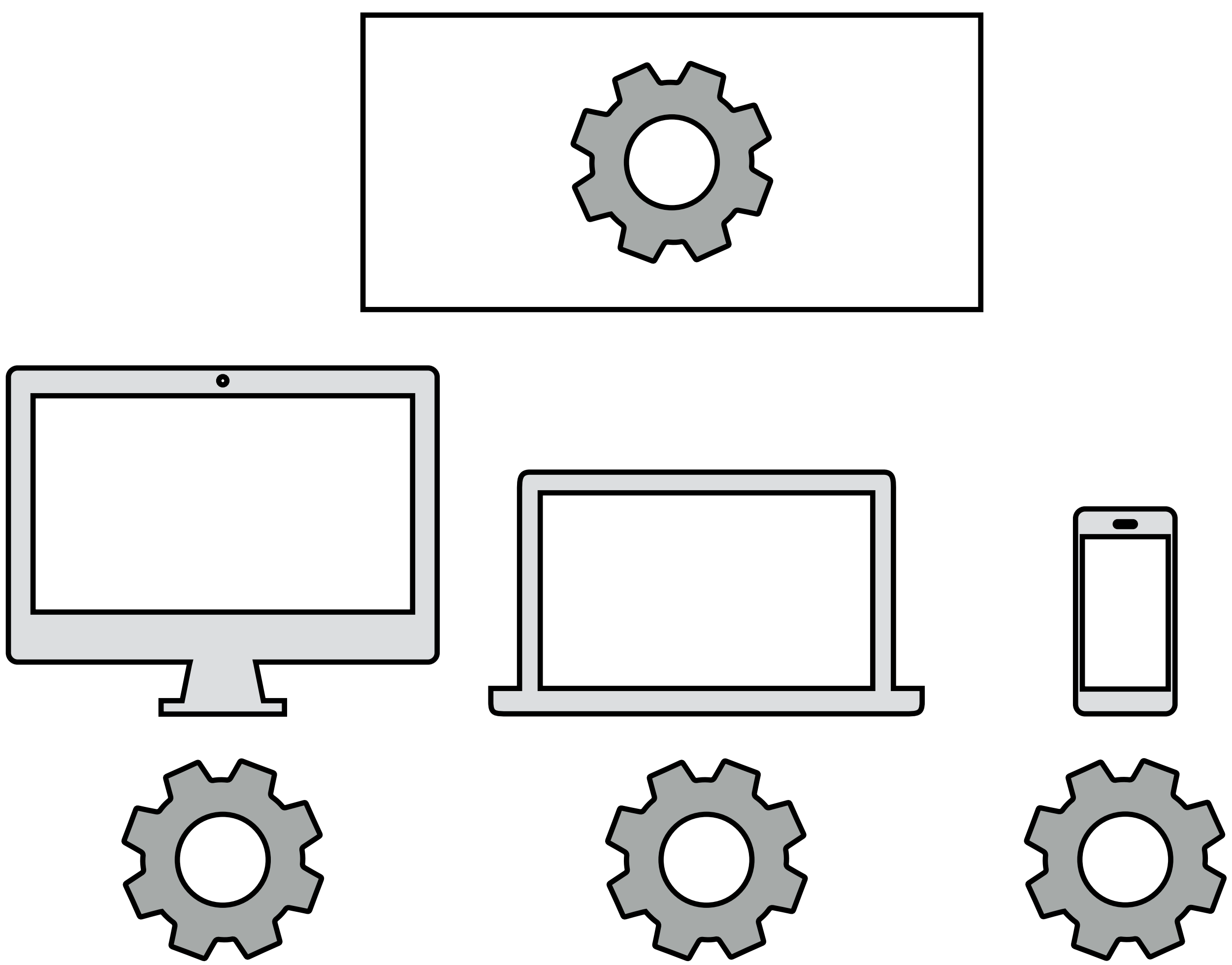

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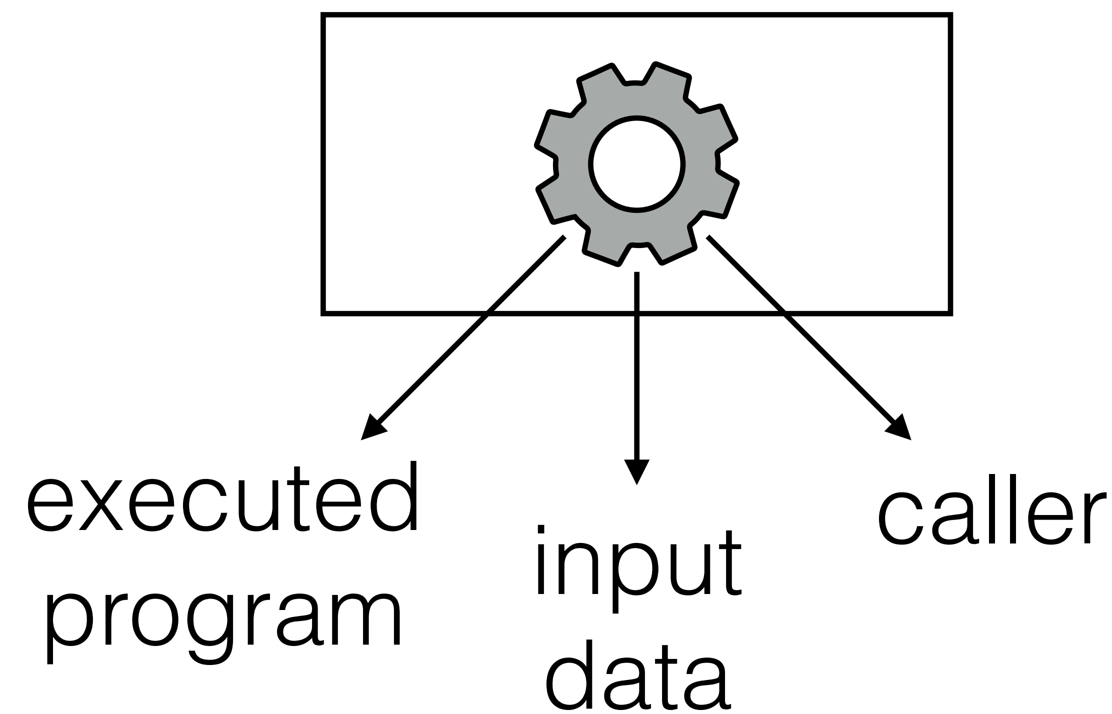

- Permanently stored on the ledger

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[BDJT17, BBDJLZ17, DGKLZBBJ19]

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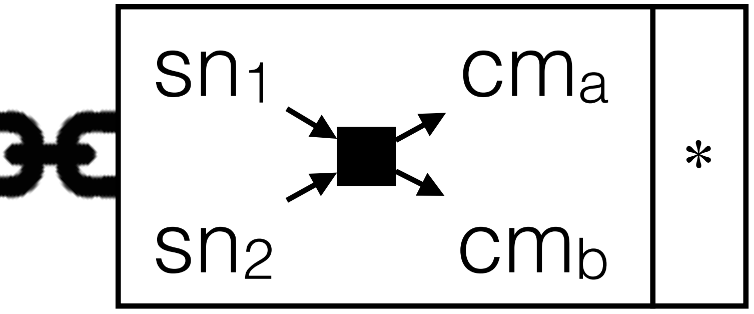

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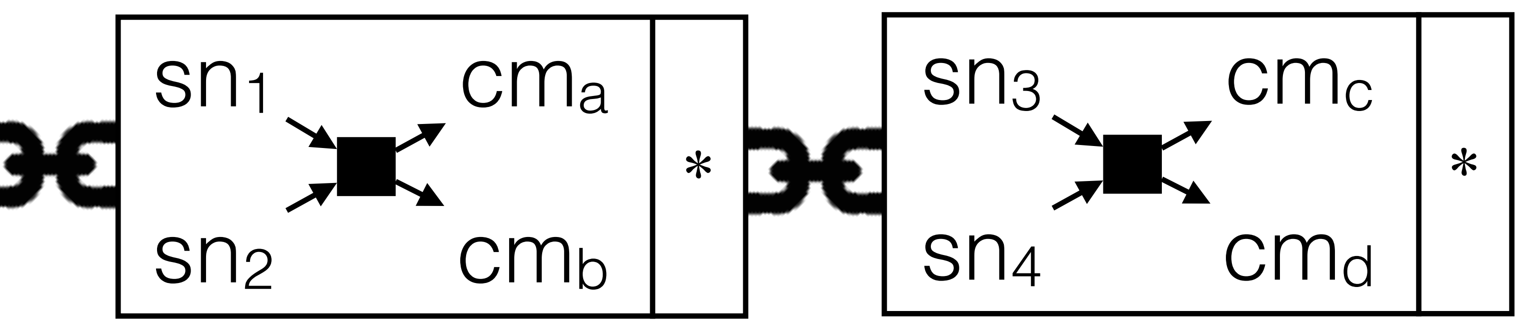

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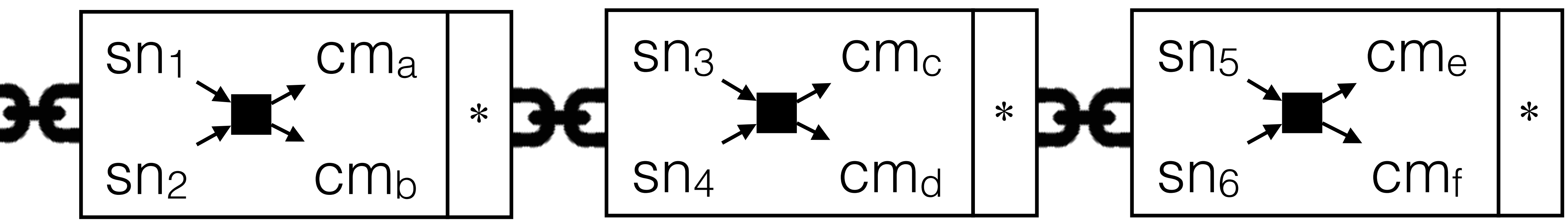

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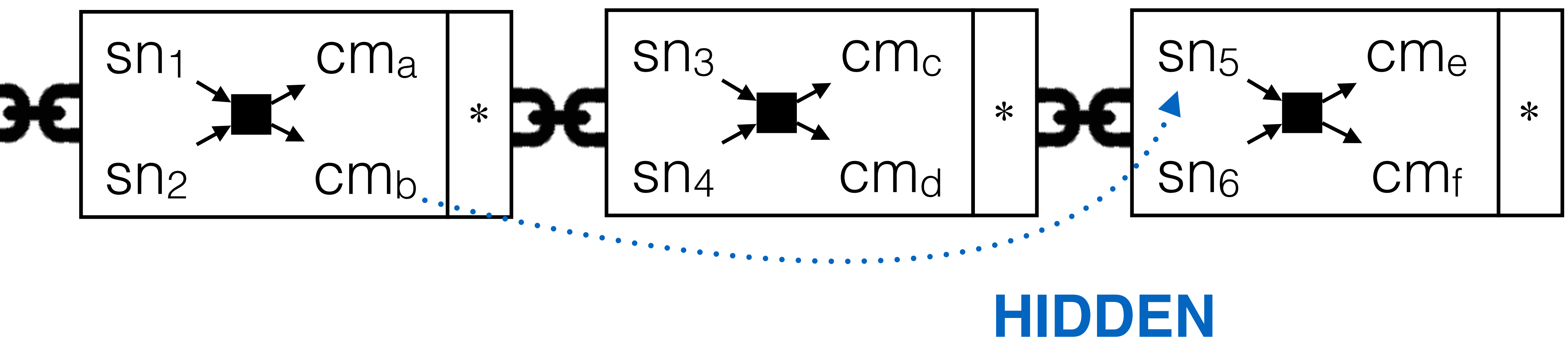

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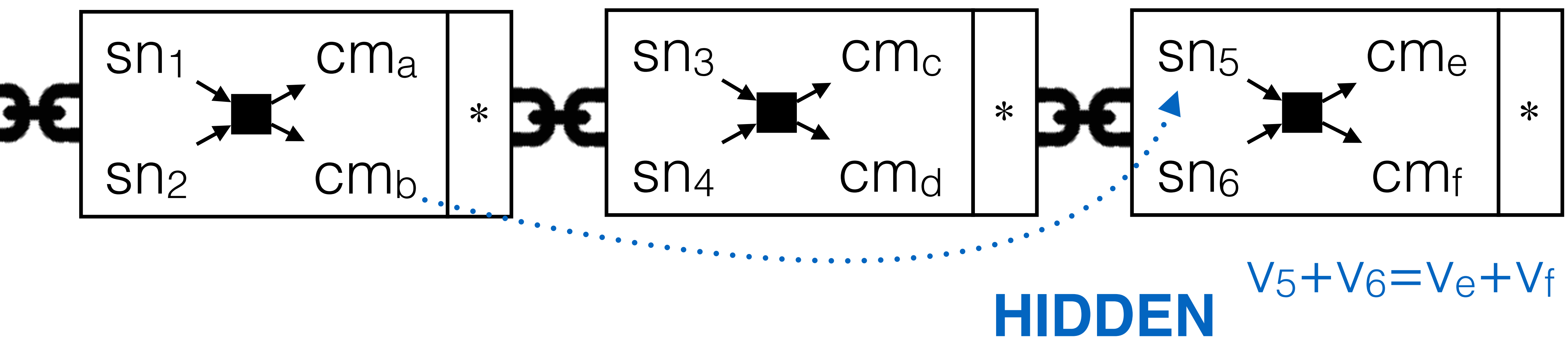

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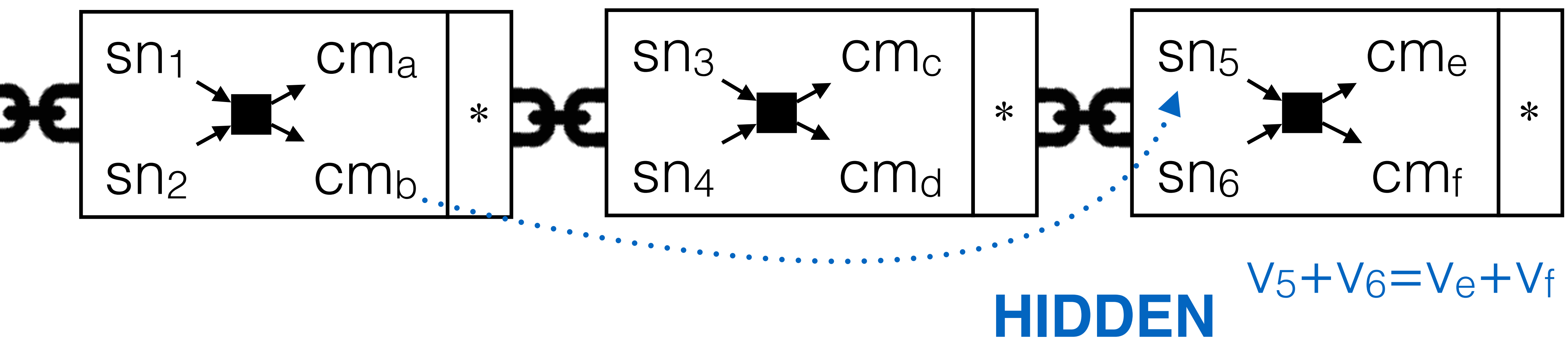

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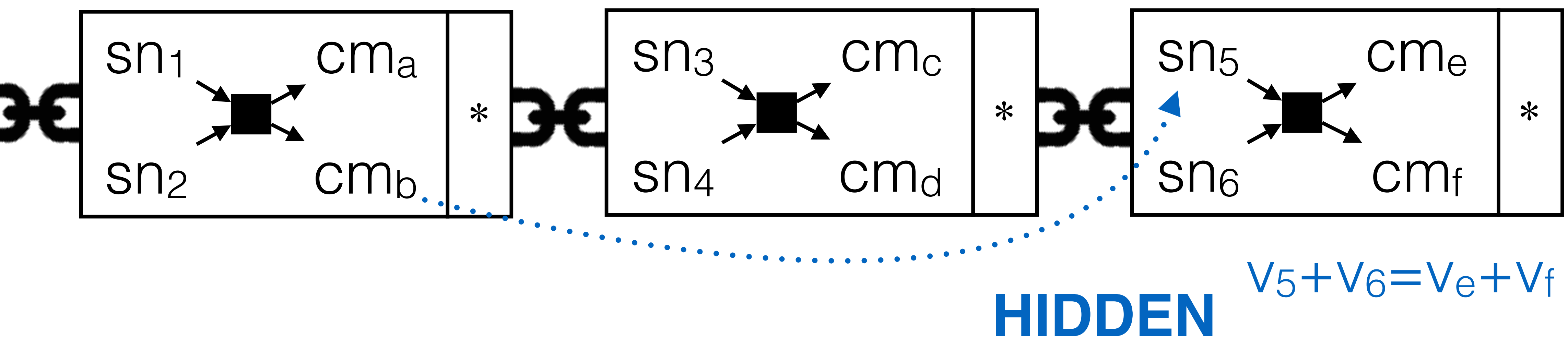

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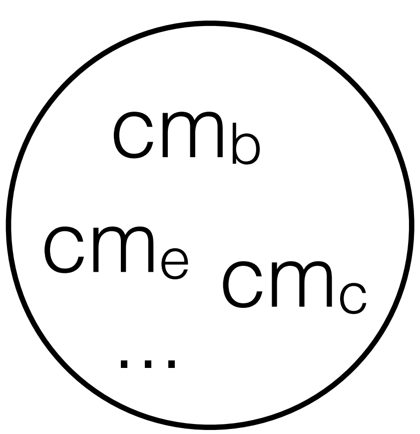

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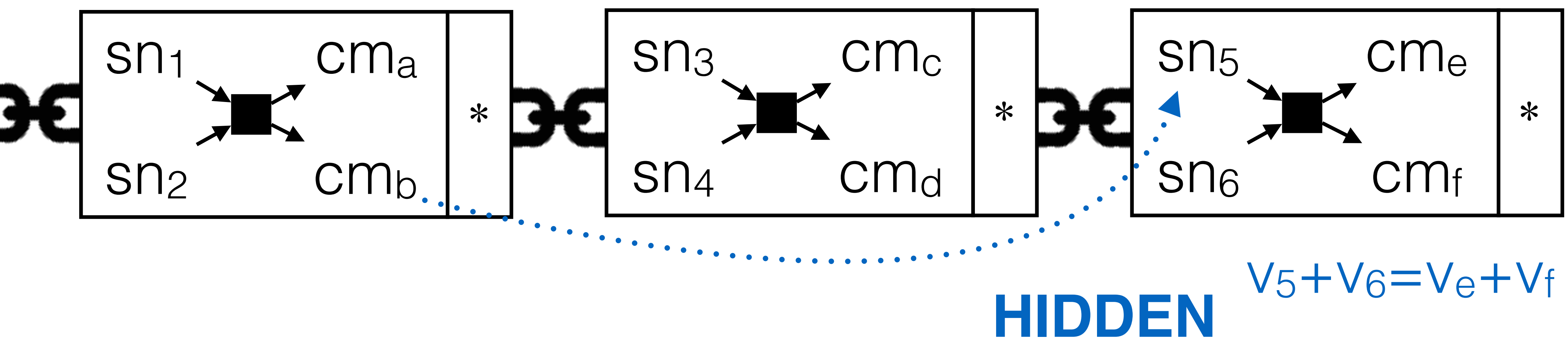

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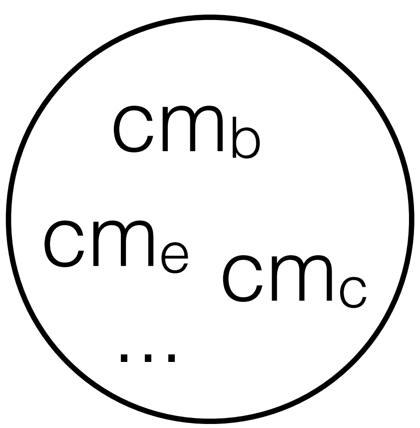

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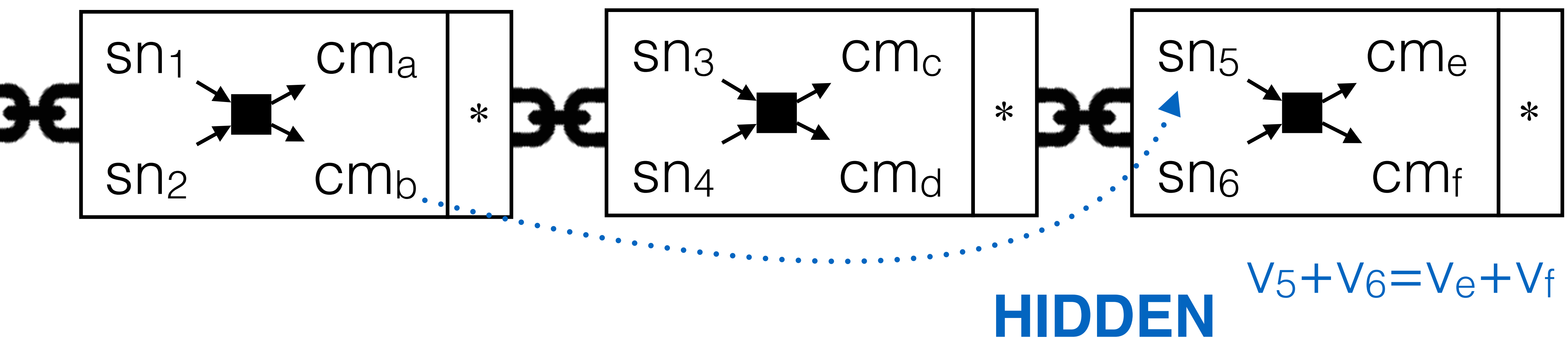

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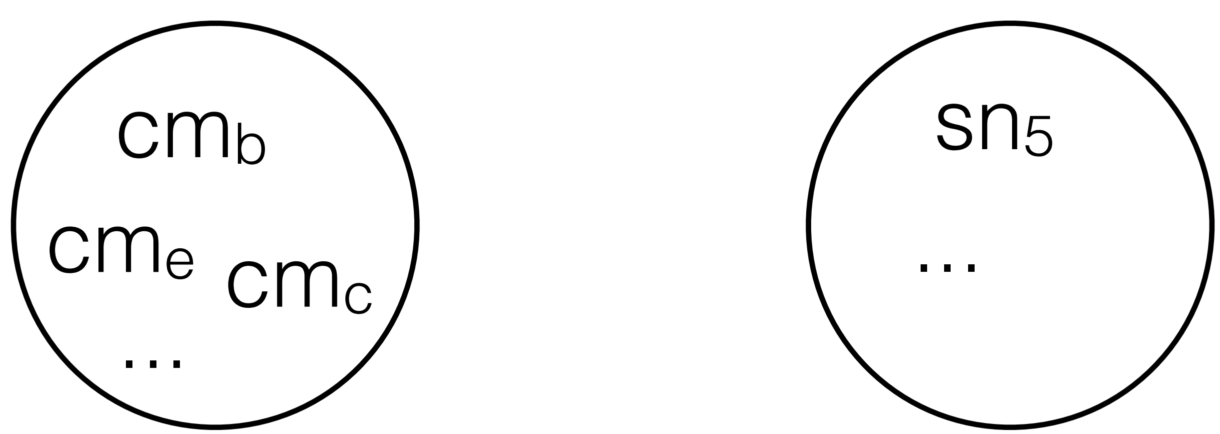

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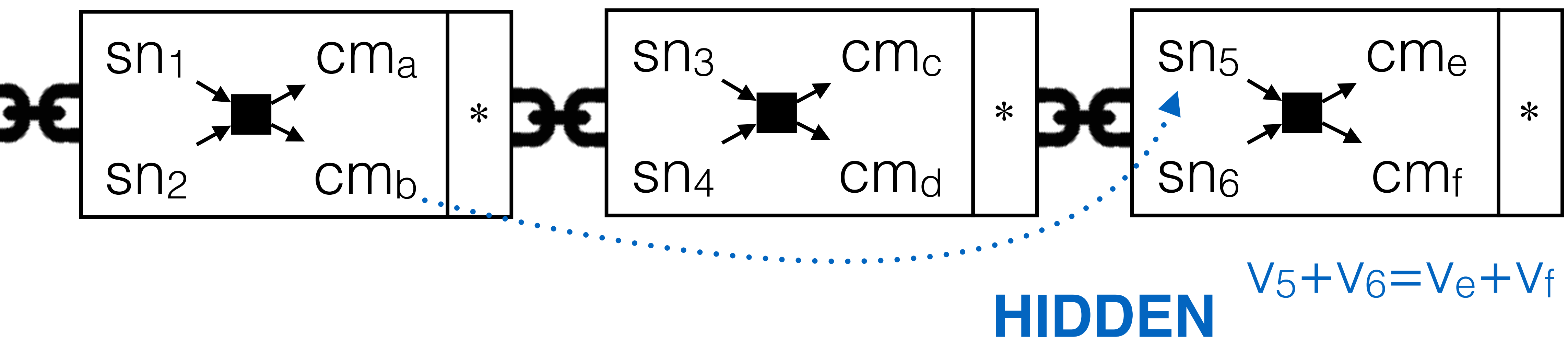

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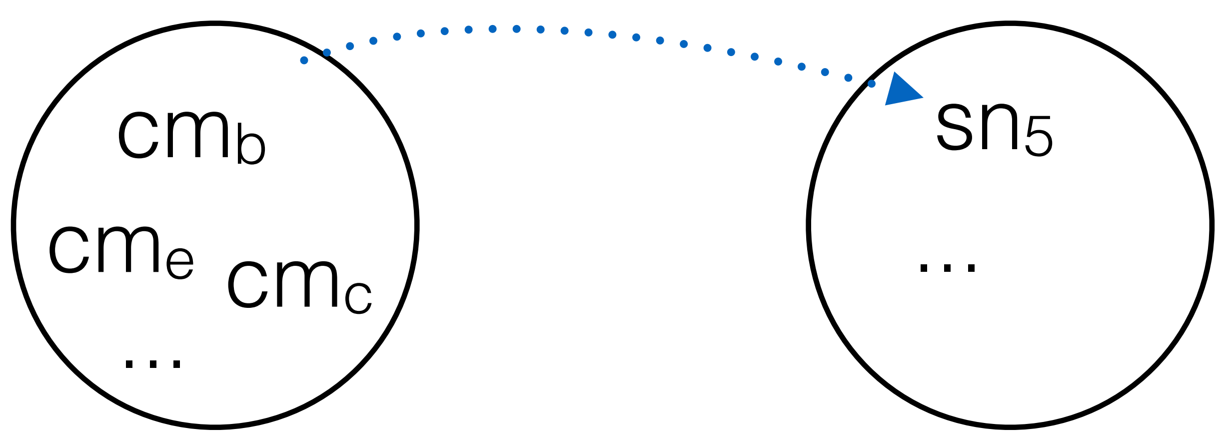

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[BCGGMTV14]

	old coin serial numbers	new coin commitments
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Simplify: just say that proof proves four things: Existence of coins, unique spends, construction of new coins, and correct values.
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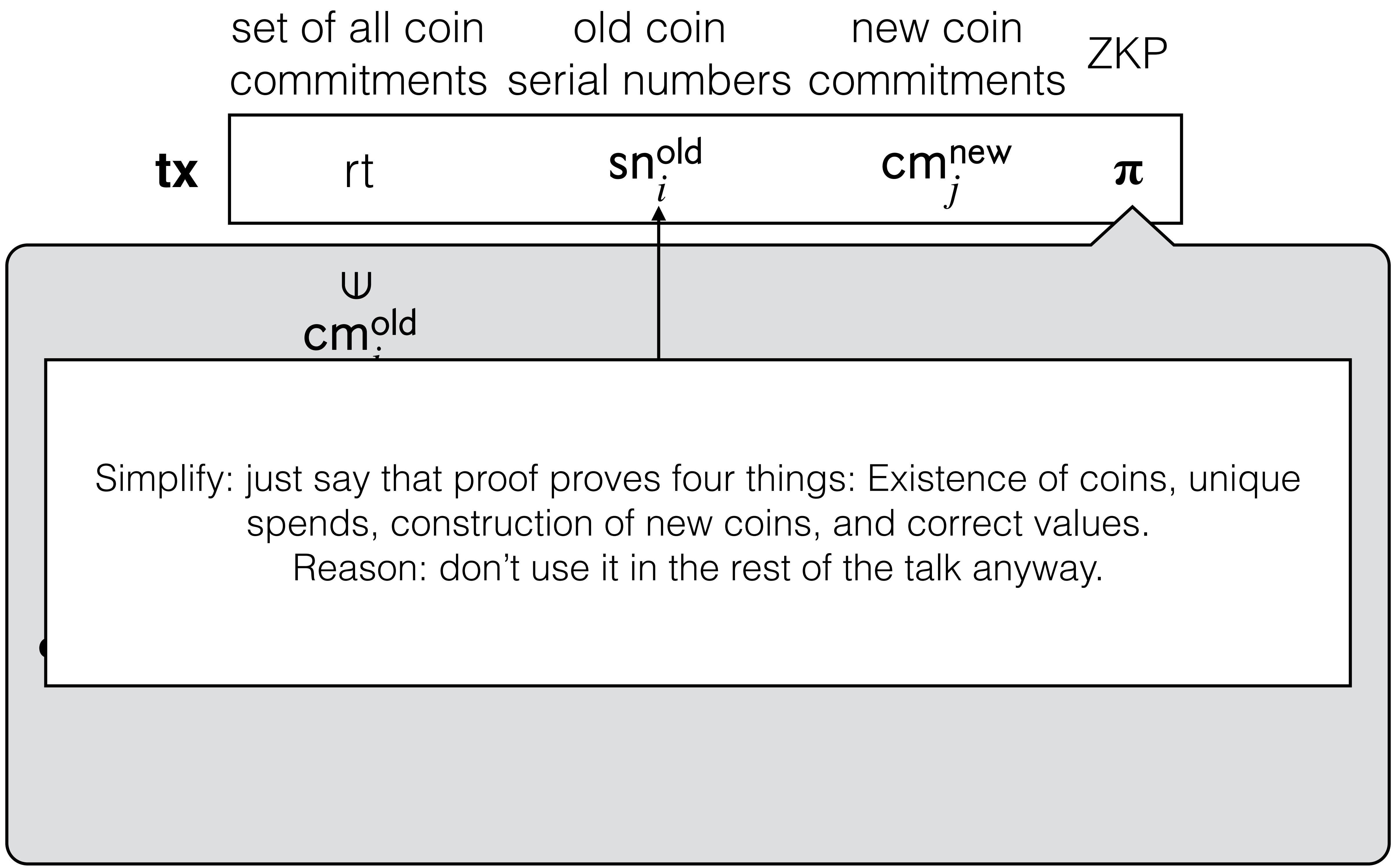

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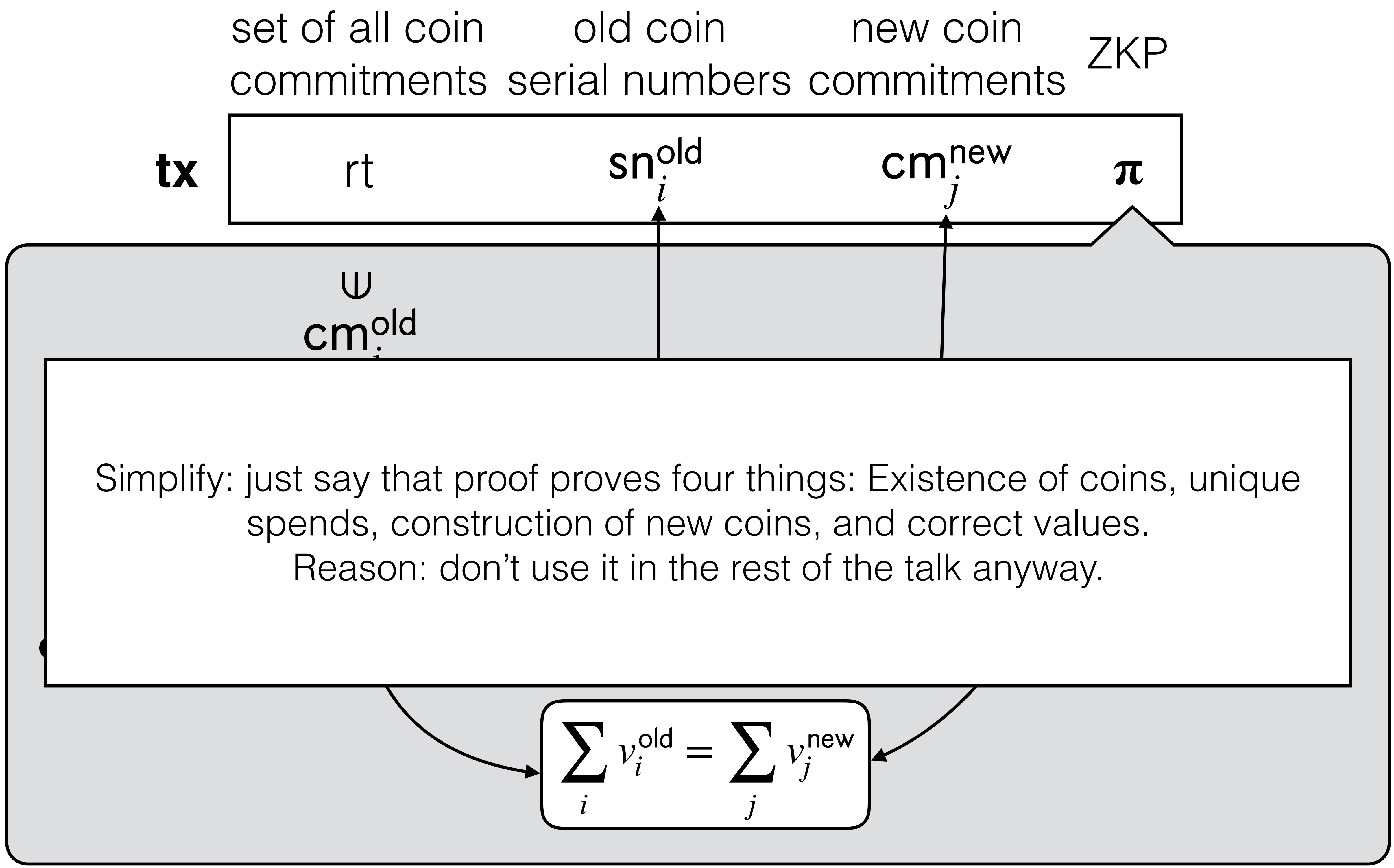
Sketch of Zerocash

[BCGGMTV14]

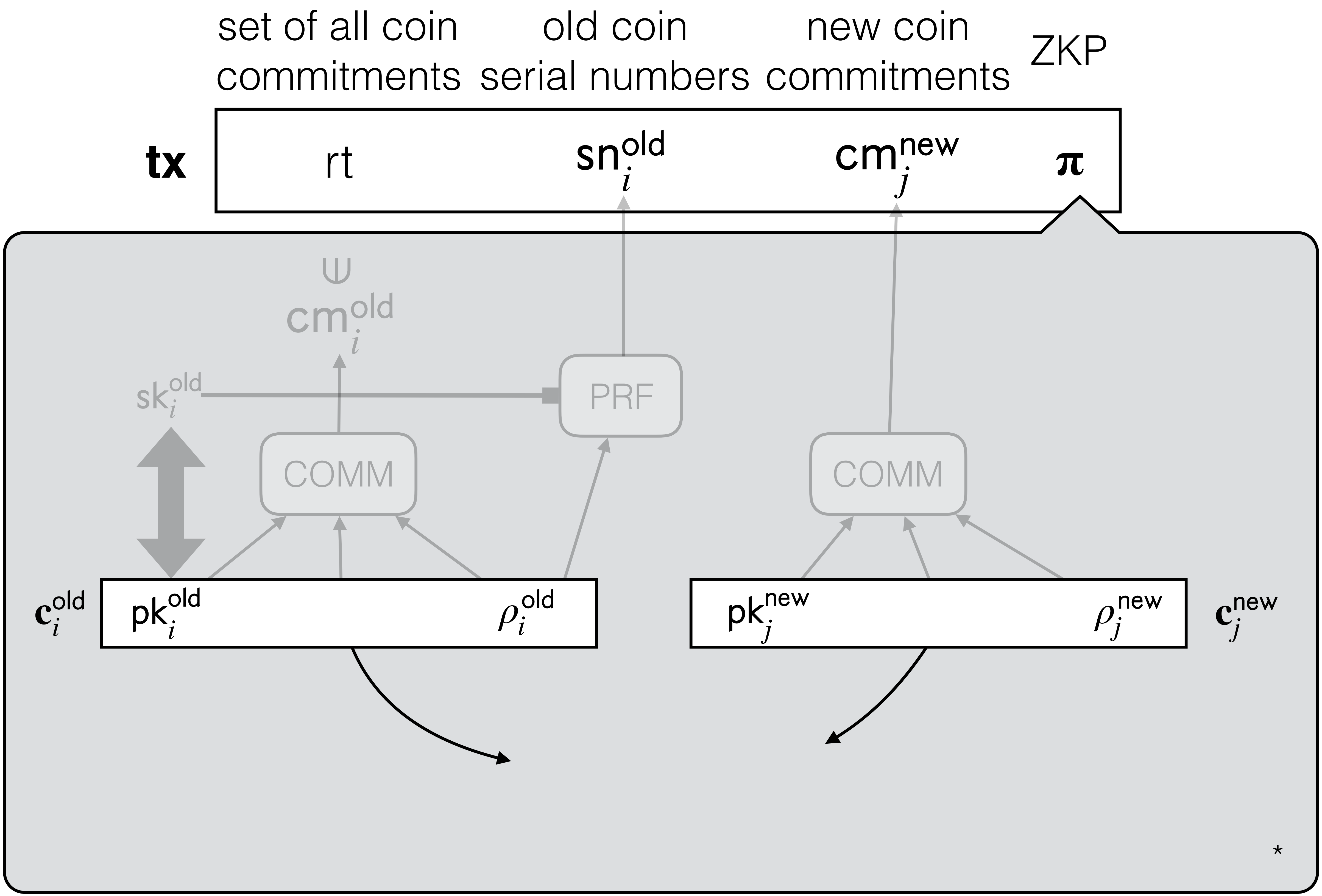


Zerocash achieves ideal anonymity for a single asset (on a single blockchain).

Zerocash achieves ideal anonymity for a single asset (on a single blockchain).

How to achieve ideal privacy for multiple user-defined assets (on the same blockchain)?

Private user-defined assets



* For now we ignore how to mint an initial supply and generate a unique id.

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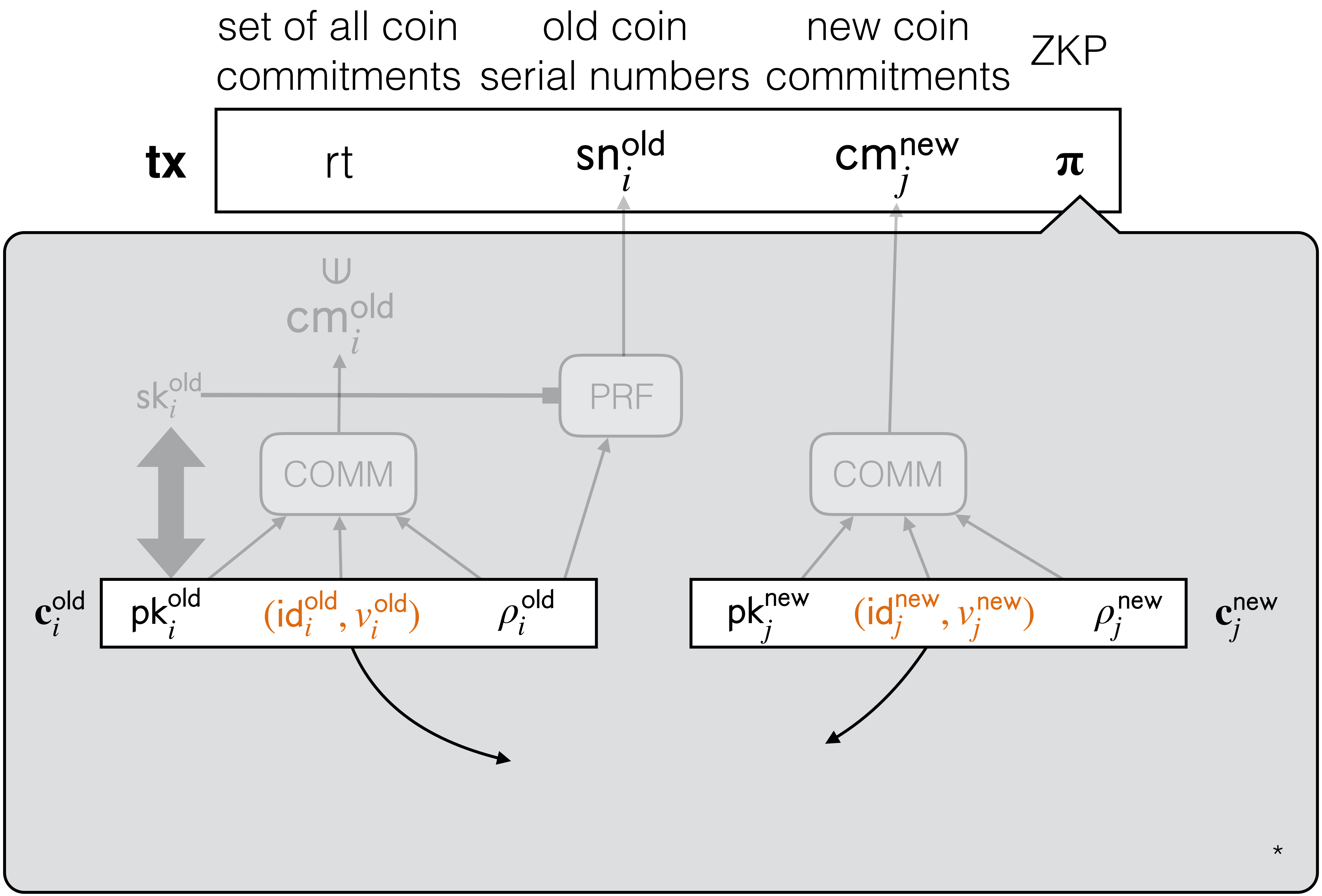

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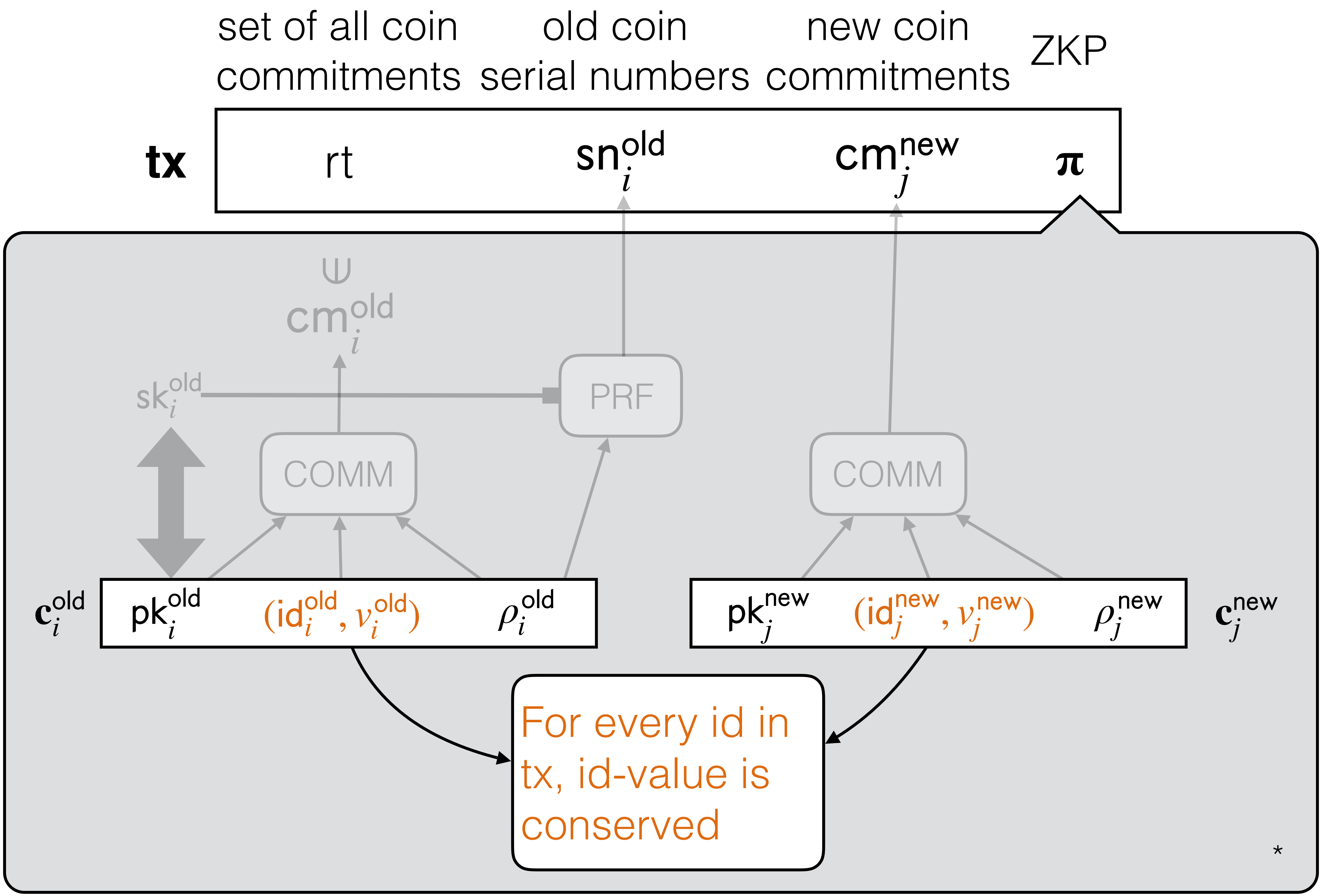

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So far: multiple, private, user-defined assets in the same transaction, with the same anonymity pool.

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But: assets are still isolated.

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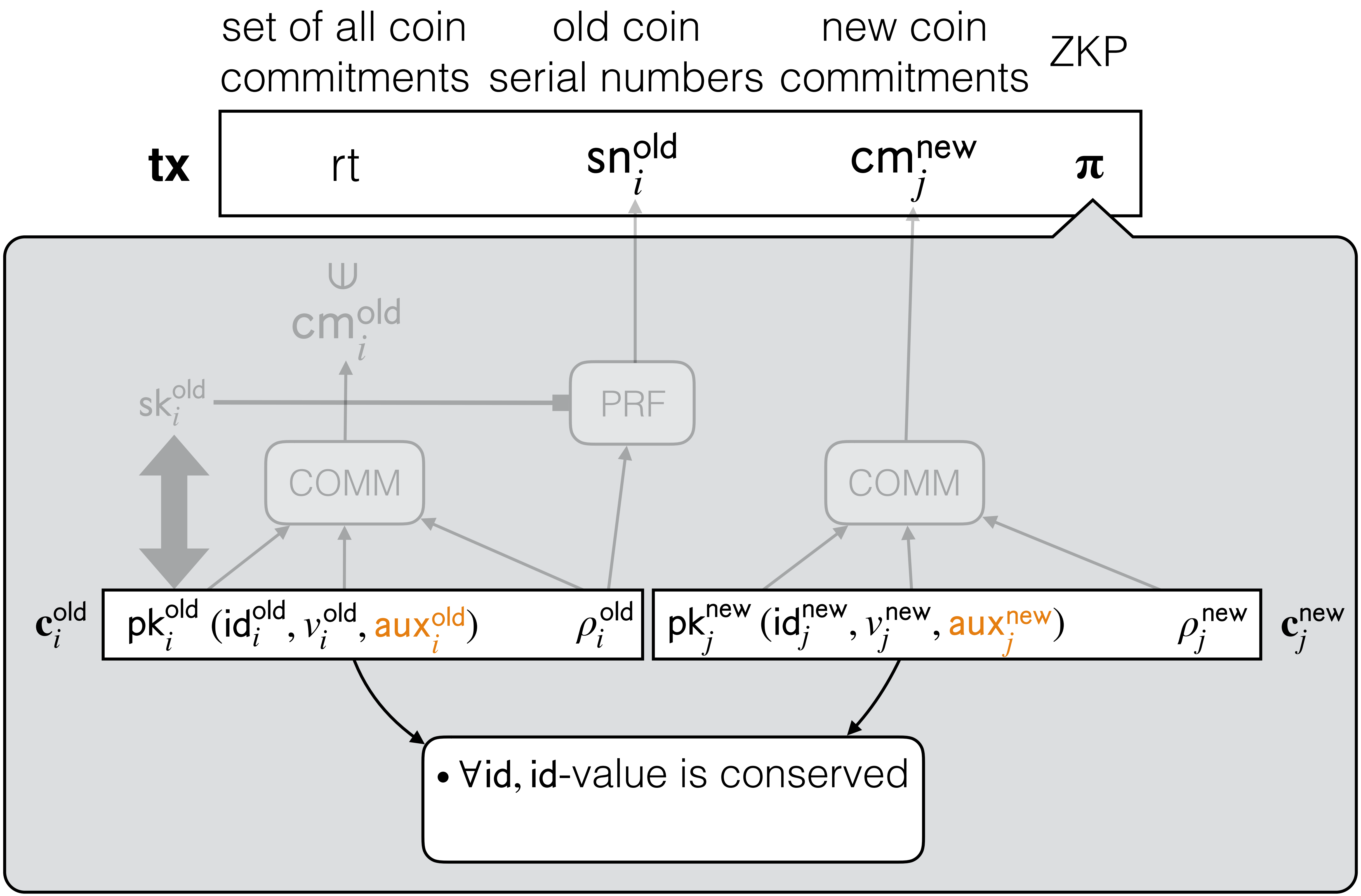
But: assets are still isolated.

How to enable applications that interact with multiple assets?

Custom access to user-defined assets



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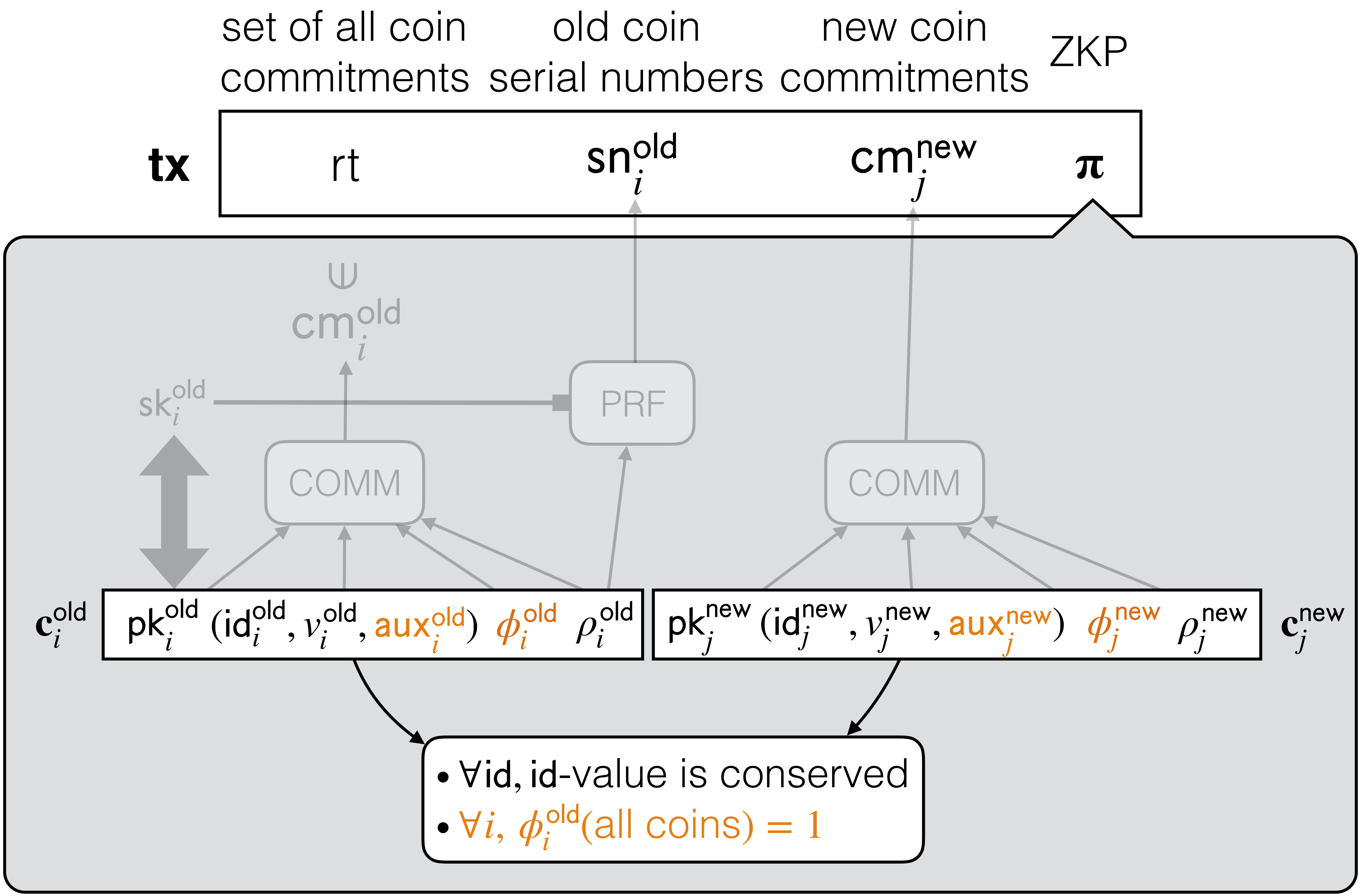

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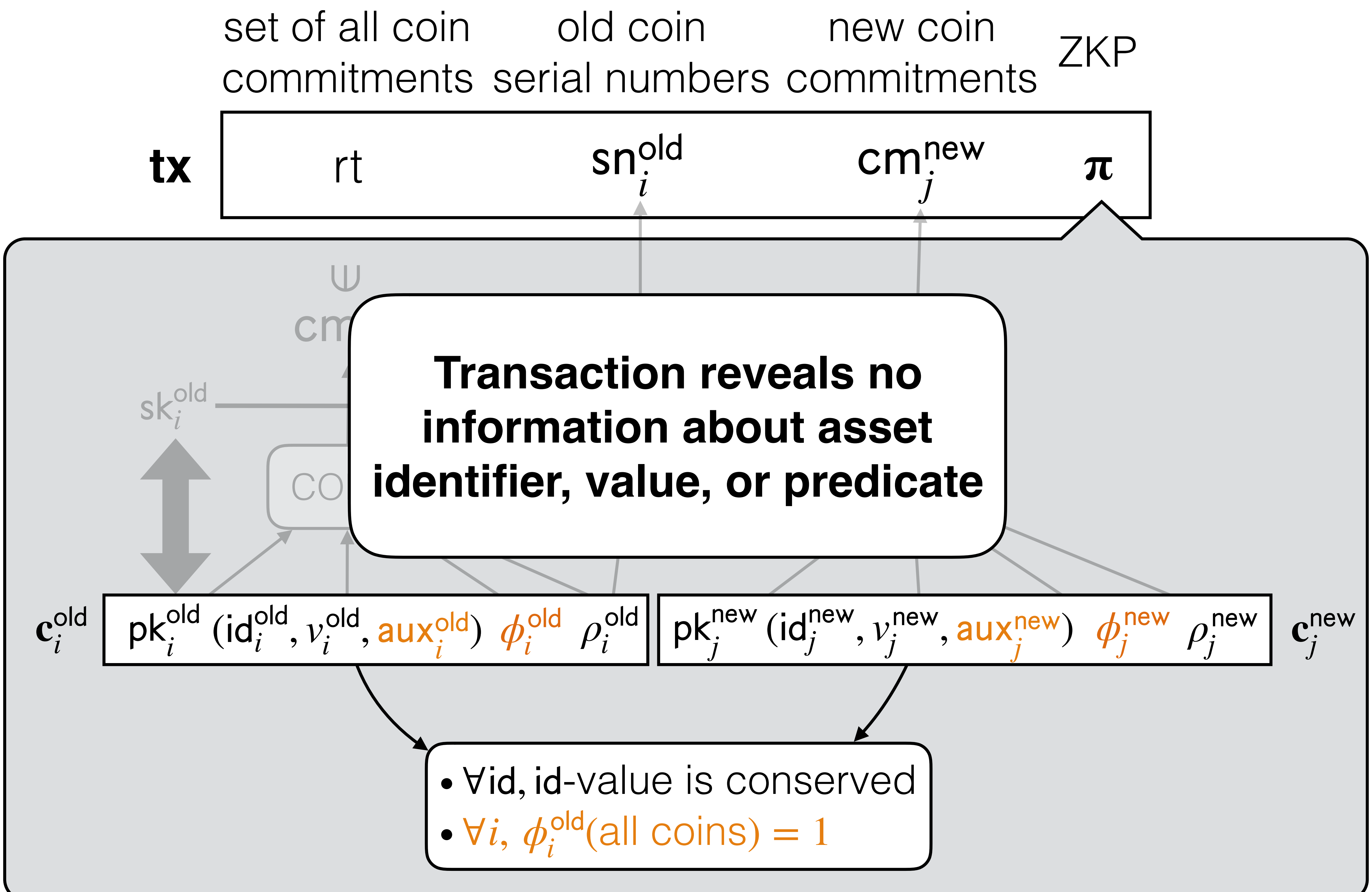

Private atomic swaps

Private atomic swaps

Key primitive for constructing DEXs

Private atomic swaps

Key primitive for constructing DEXs

$\mathbf{c}_1^{\mathsf{old}}$

$\mathsf{pk}_1^{\mathsf{old}}$

$(\mathsf{id}_1^{\mathsf{old}}, v_1^{\mathsf{old}}, \mathsf{aux}_1^{\mathsf{old}})$

$\phi_1^{\mathsf{old}} = \phi_{\mathsf{exch}}$

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ϕ_2^{old}

$\mathbf{c}_1^{\text{new}}$

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$(\mathsf{id}_1^{\text{new}}, v_1^{\text{new}}, \perp)$

ϕ_1^{new}

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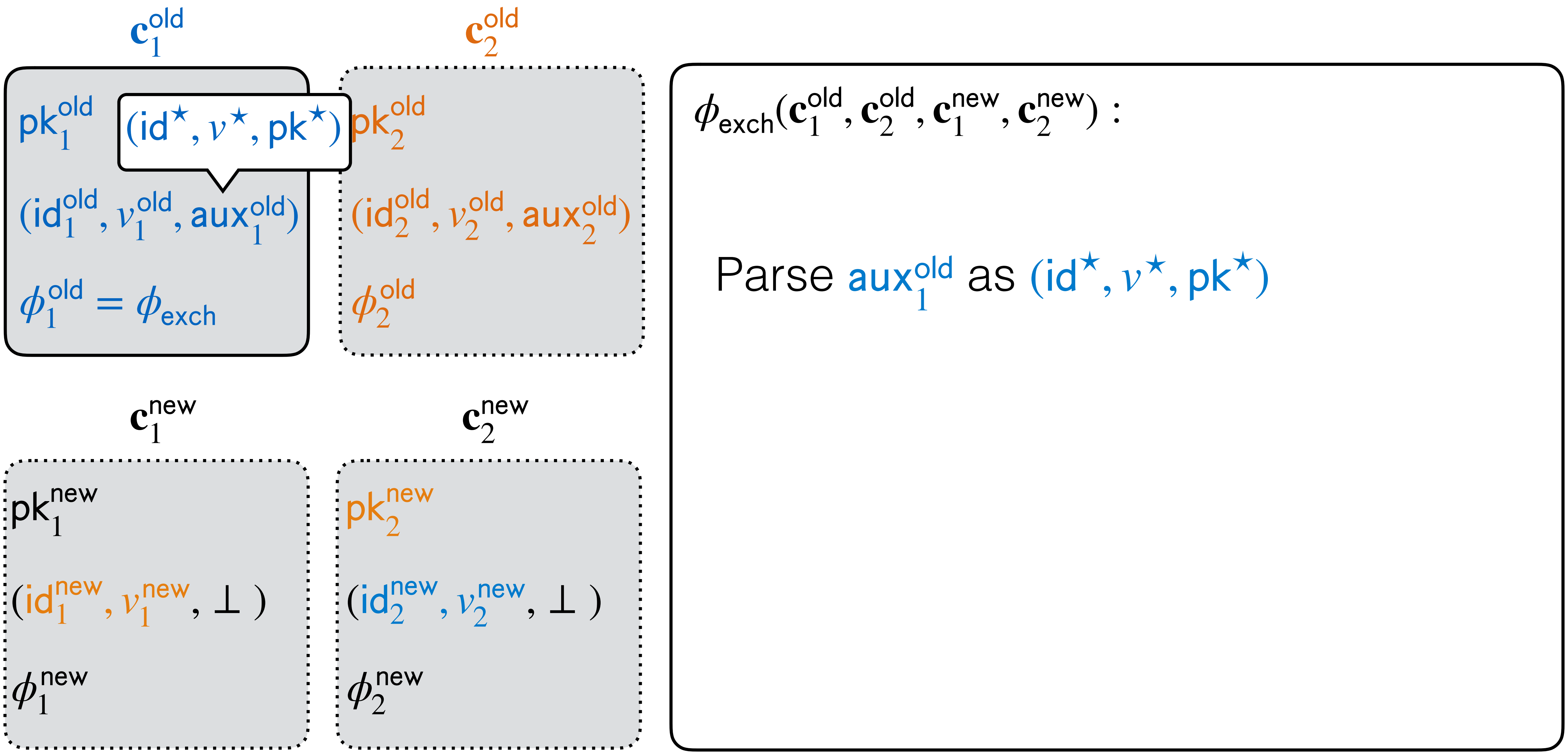

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$\phi_{\text{exch}}(\mathbf{c}_1^{\text{old}}, \mathbf{c}_2^{\text{old}}, \mathbf{c}_1^{\text{new}}, \mathbf{c}_2^{\text{new}})$:

Parse $\text{aux}_1^{\text{old}}$ as $(\text{id}^\star, v^\star, \text{pk}^\star)$

Check that $\text{id}_2^{\text{old}} = \text{id}^\star$ and $v_2^{\text{old}} = v^\star$

Private atomic swaps

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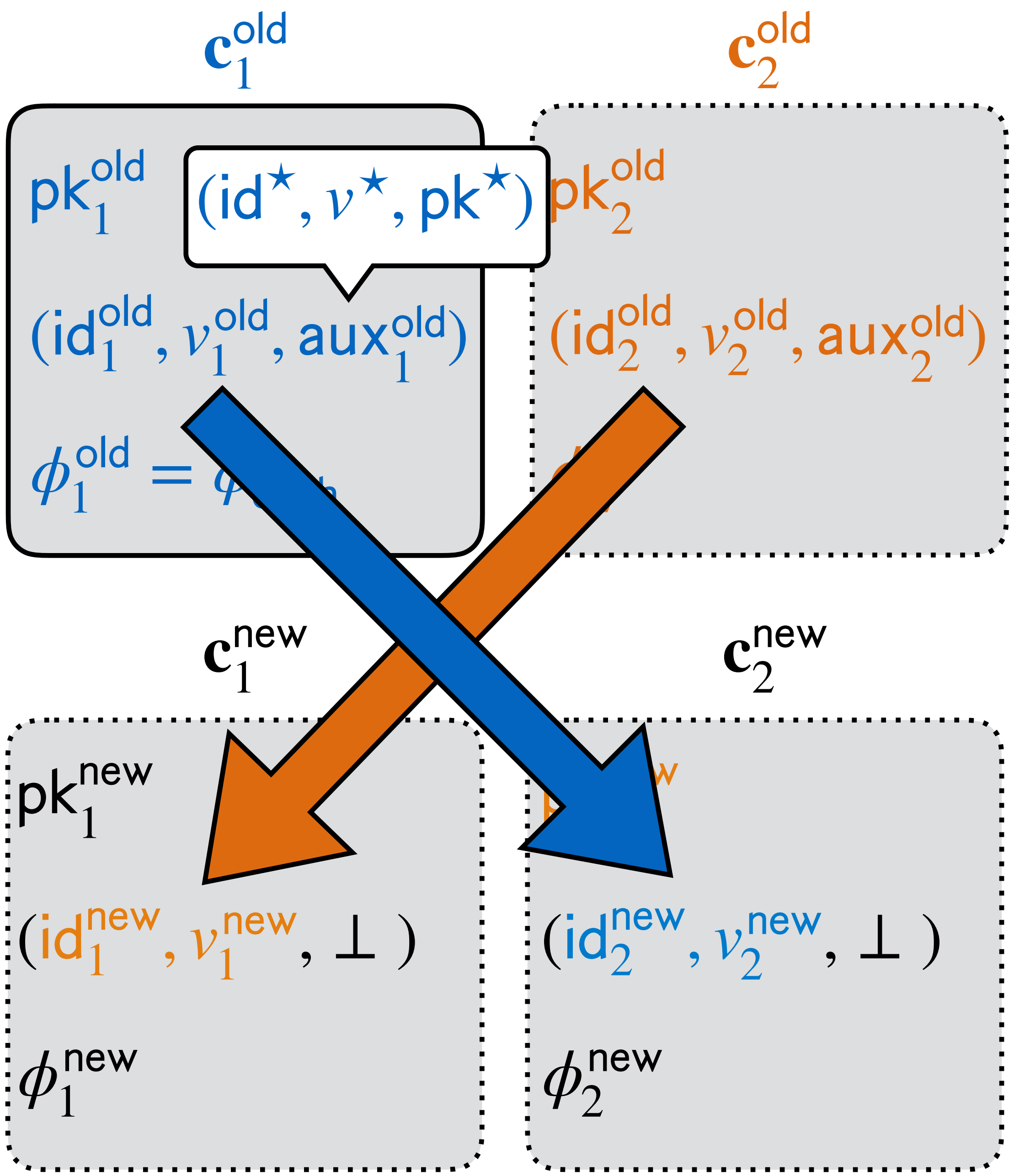

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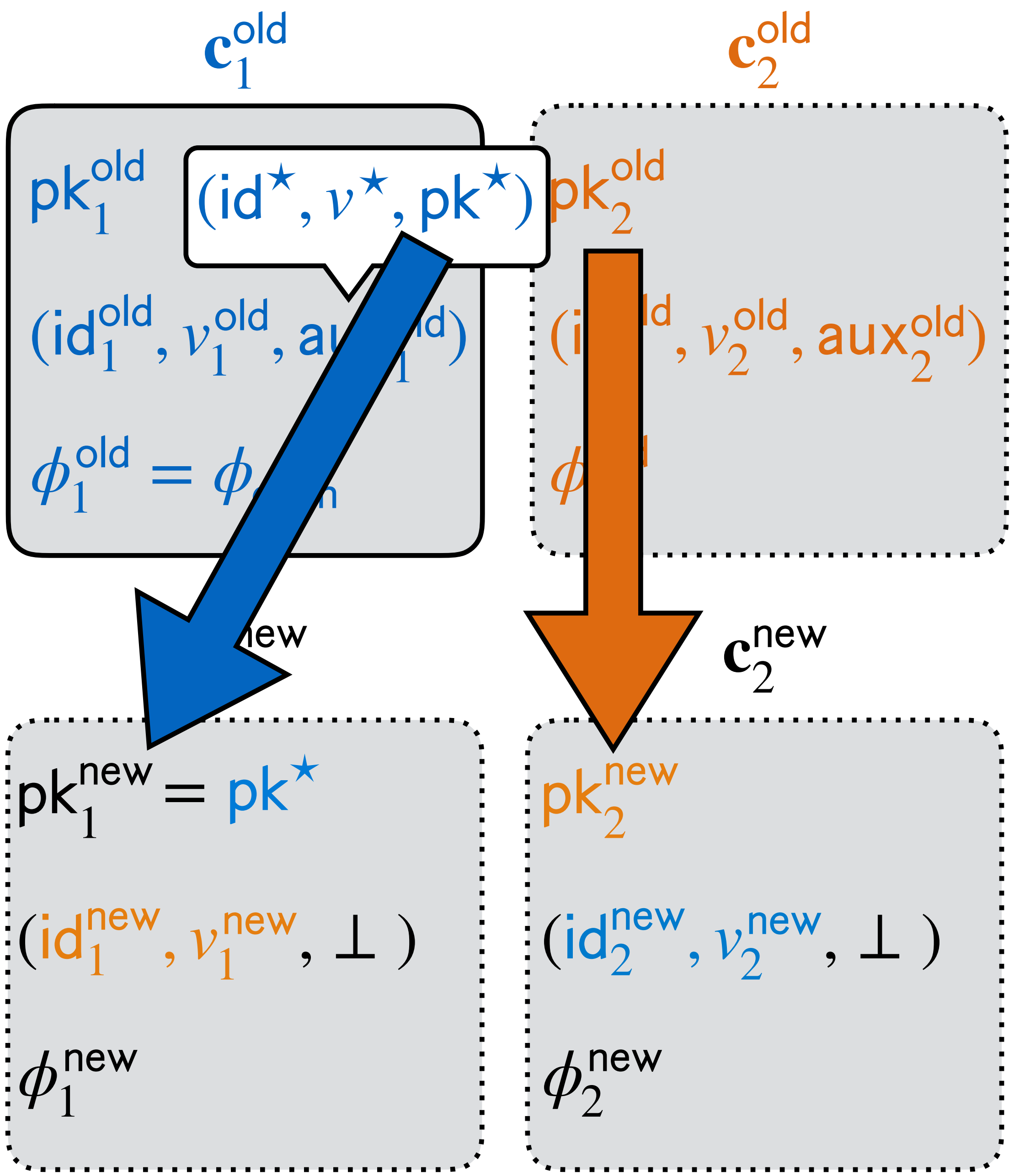

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Check addresses: $\mathsf{pk}_1^{\text{new}} = \mathsf{pk}^\star$
$\mathsf{pk}_2^{\text{new}} = \mathsf{pk}_2^{\text{old}}$

DEX

Atomic swap ✓

DEX

DEX

- Atomic swap ✓
- Order creation
- Order discovery
- Trade finalization

DEX Architectures

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Order-based:

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- *Order book* maintains list of orders published by makers

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$(A, B, v_A, v_B, \ldots)$

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Intent-based DEX

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Sell	Buy	Public key
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ZRX	OMG	pk_2

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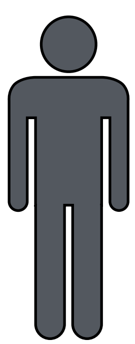

Maker

Intent-based DEX

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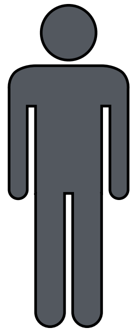

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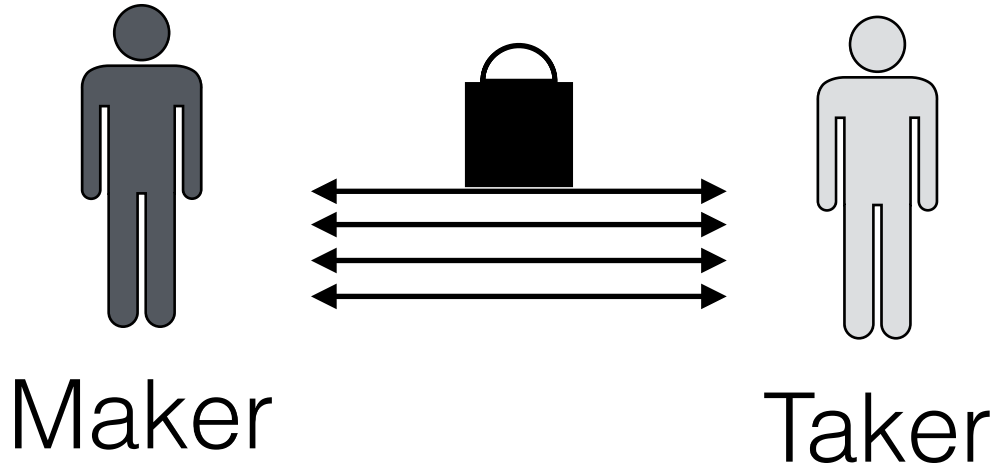

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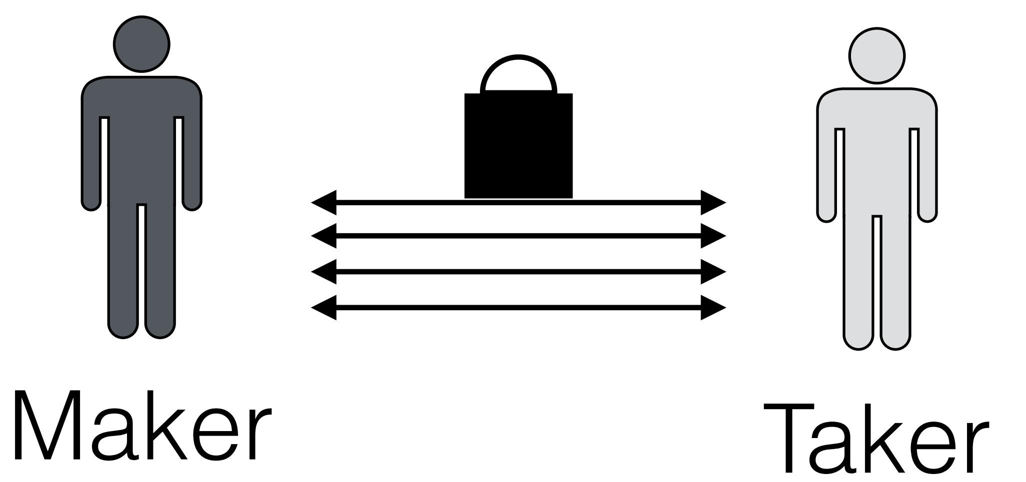
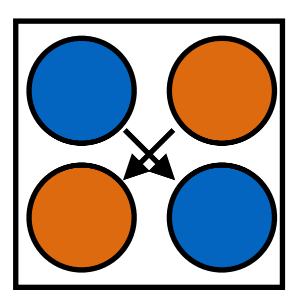


tx



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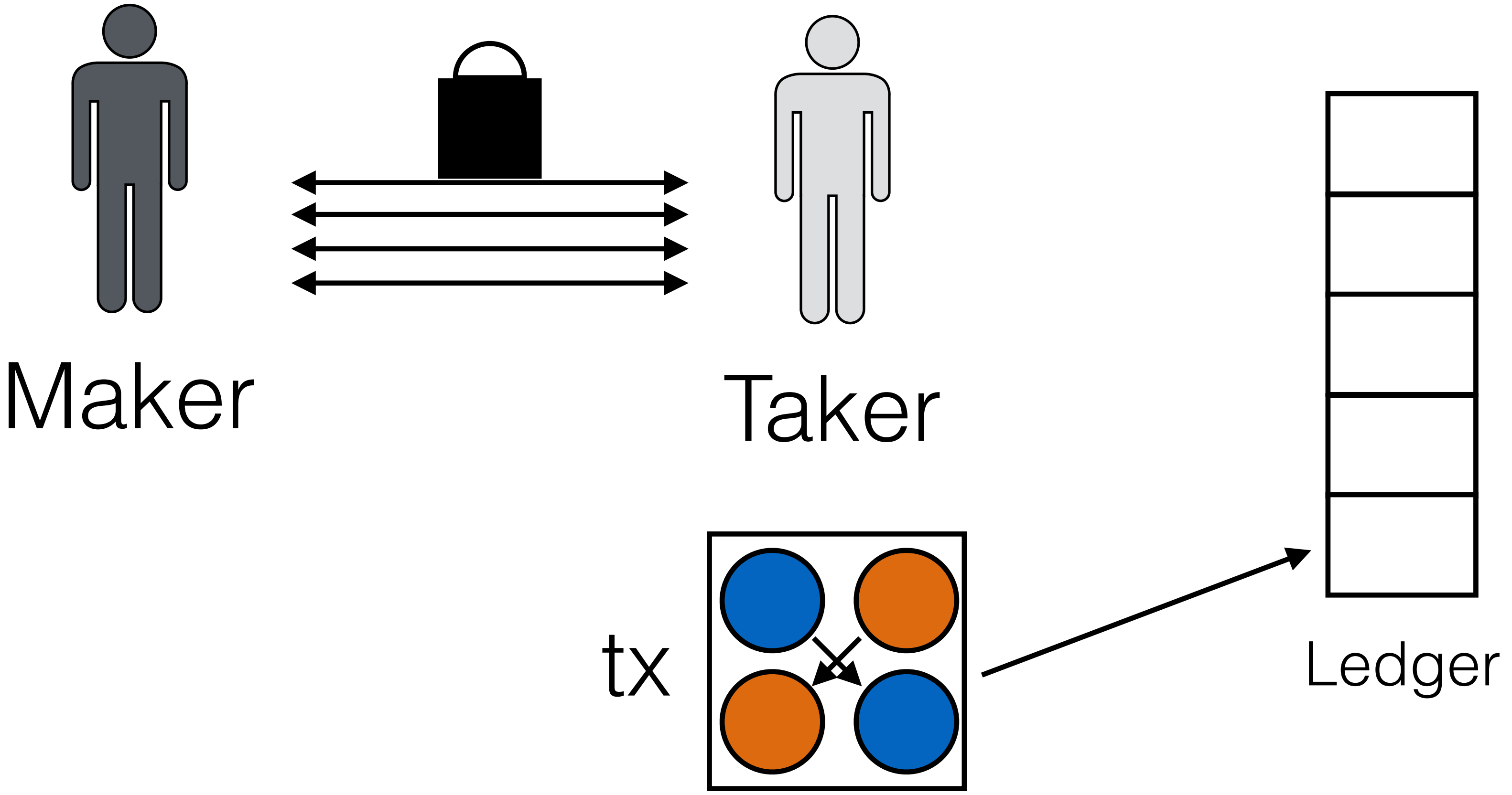
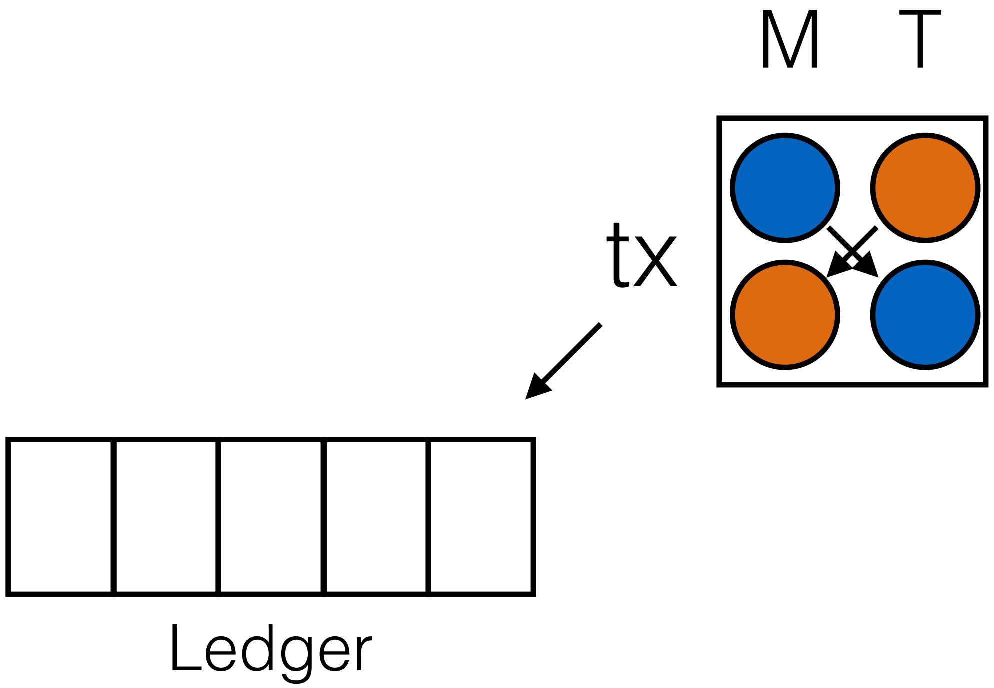


Privacy Leakage



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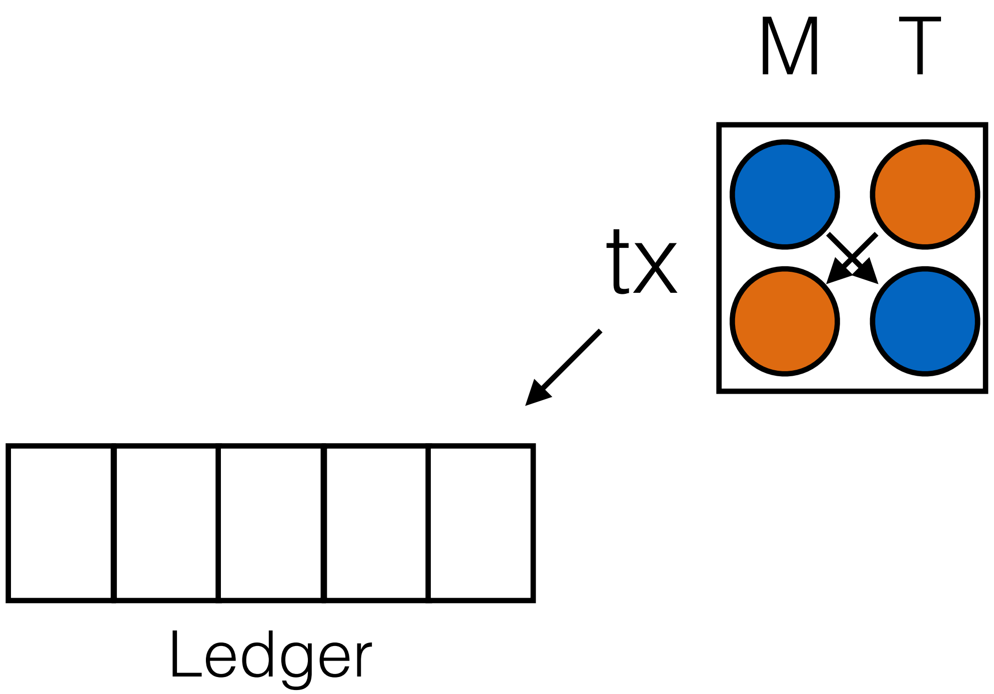


“The addresses

$addr_M$ and $addr_T$

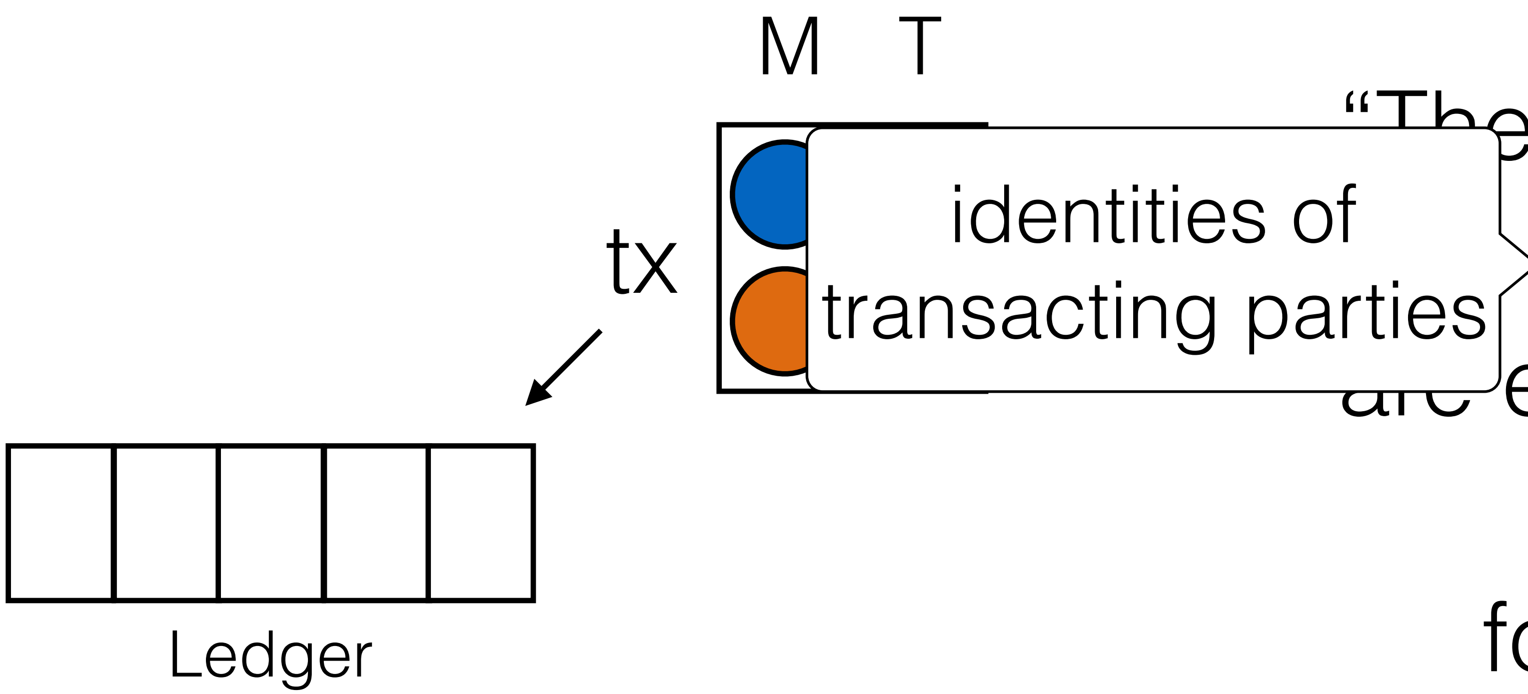
are exchanging

v_A units of A

for

v_B units of B”

Privacy Leakage



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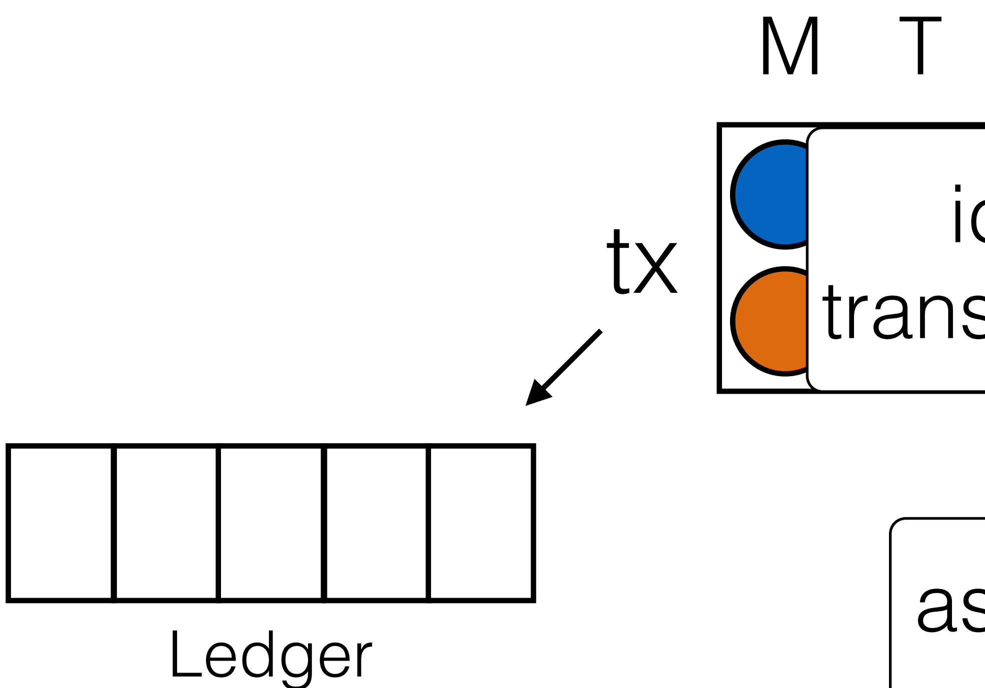

identities of transacting parties

assets and values in the trade

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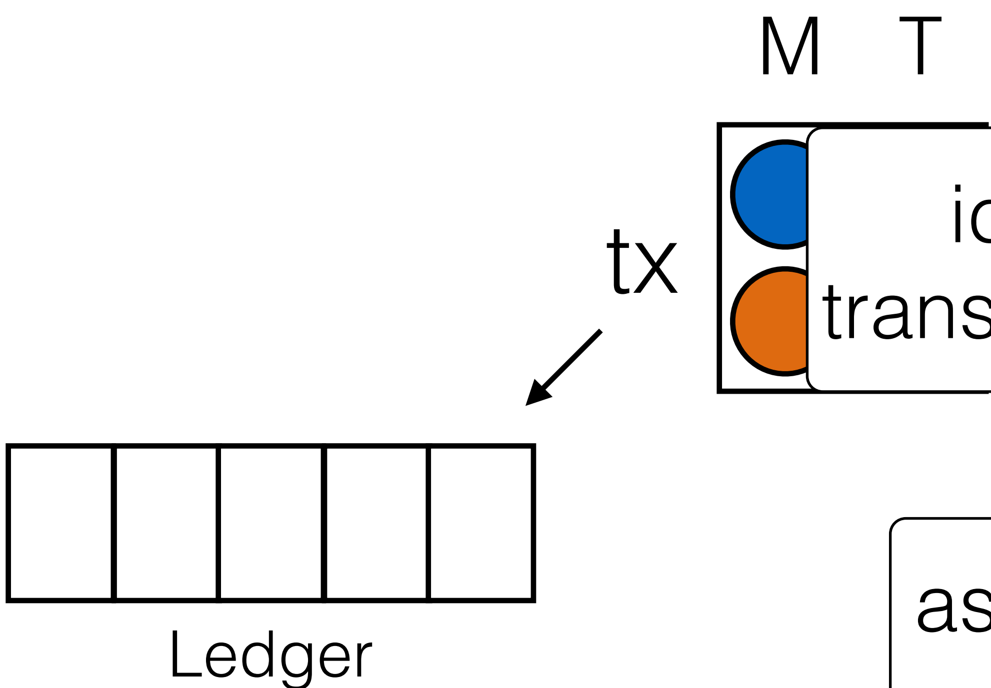

“The addresses **$addr_M$ and $addr_T$** are exchanging

identities of transacting parties

v_A units of A

assets and values in the trade

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Trade anonymity
No information about participants in the trade is revealed.

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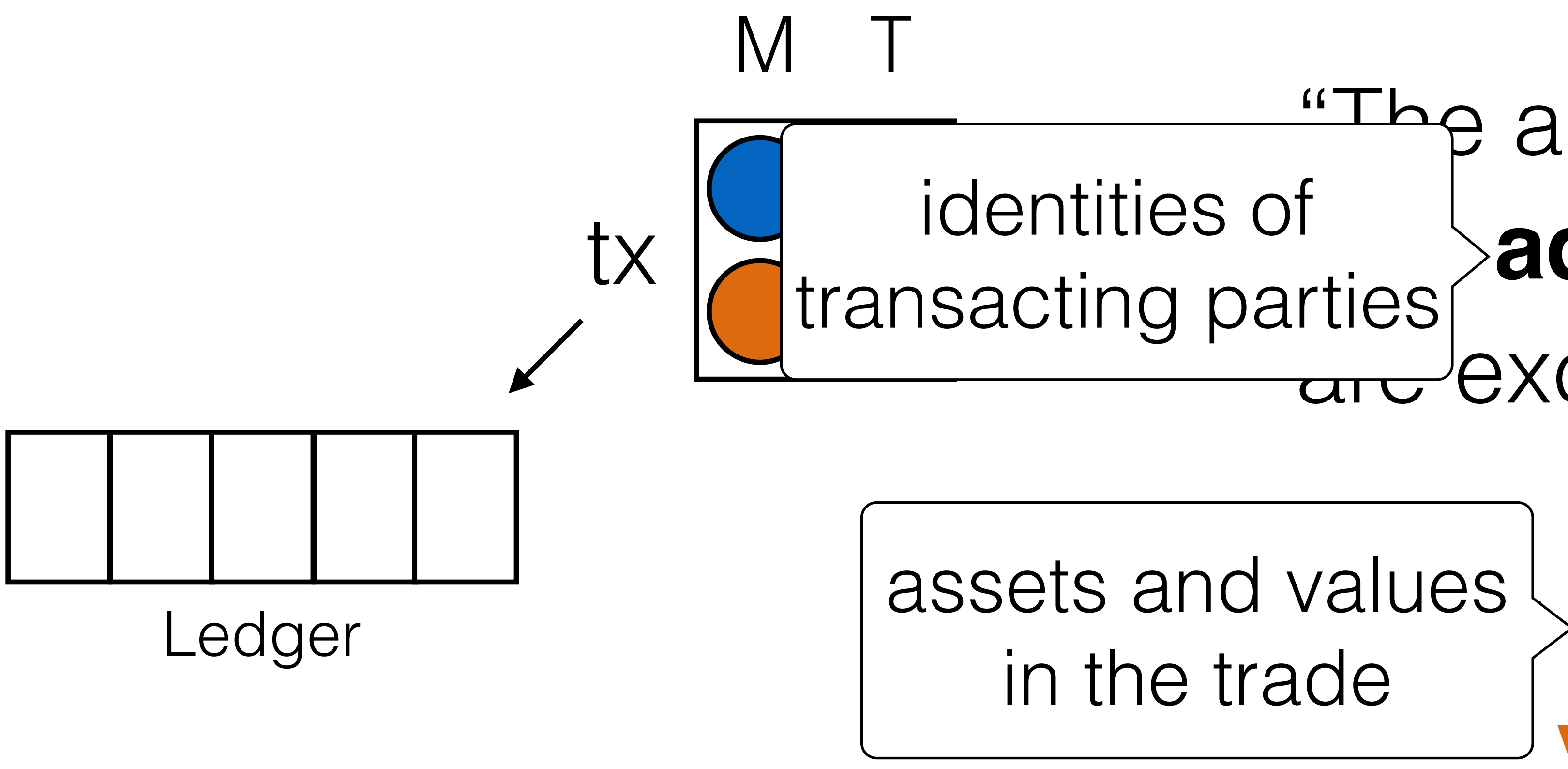

“The addresses **$addr_M$ and $addr_T$** are exchanging **v_A units of A** … **v_B units of B**”

Trade anonymity
No information about participants in the trade is revealed.

Trade confidentiality
No information about the assets and values used in the trade is revealed.

Private Intent-based DEX

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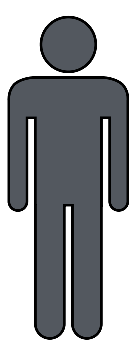

Maker

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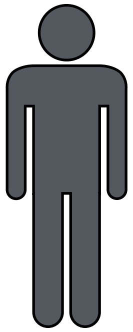

Maker

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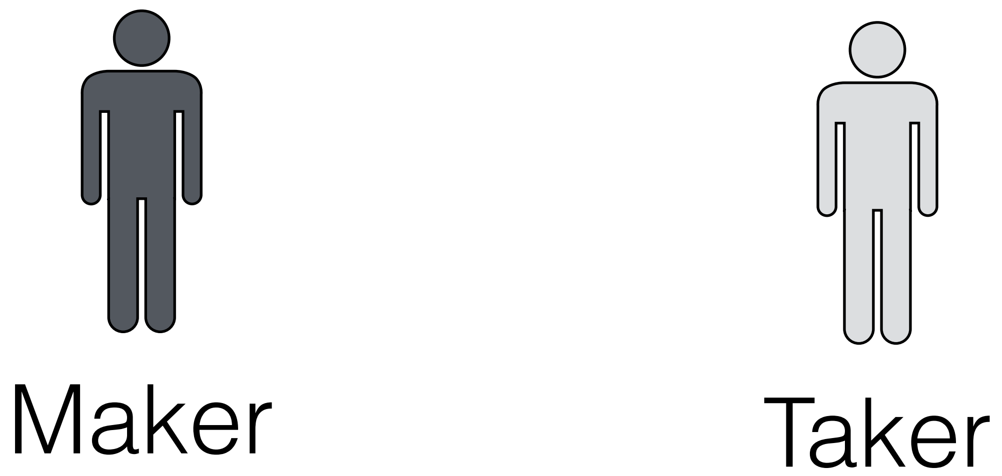

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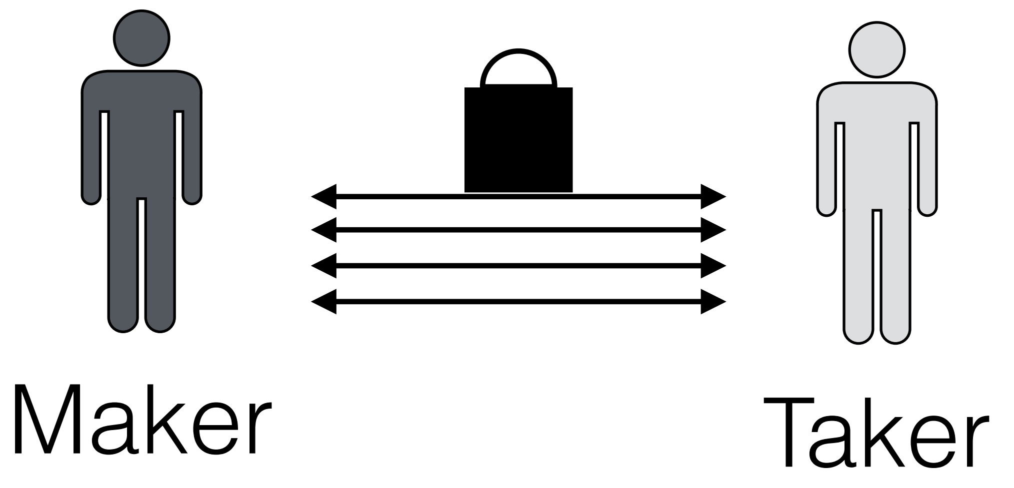

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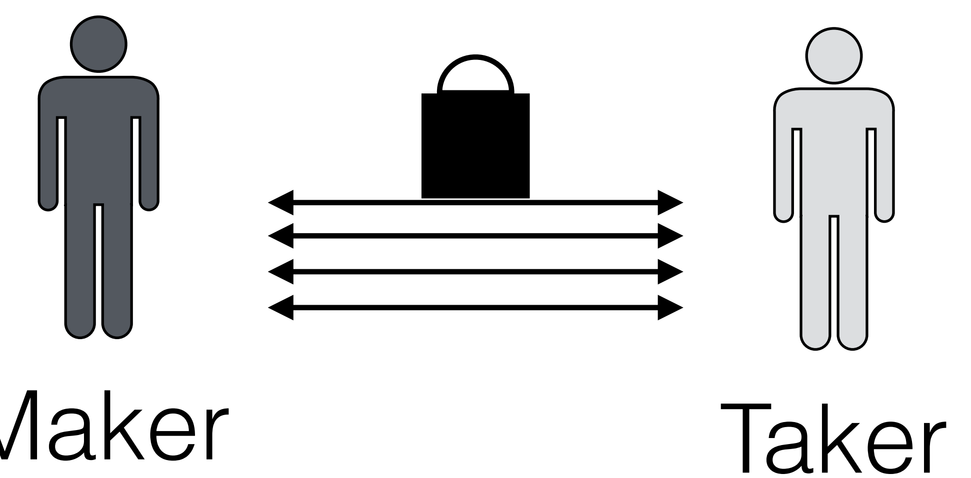
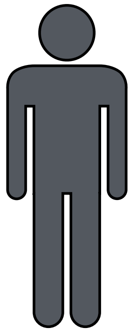


Maker: (A, v_A) (B, v_B)

Taker: (A, v_A) (B, v_B)

Private Intent-based DEX



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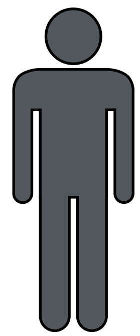


Maker

$\mathbf{c}_1^{\mathsf{old}}$

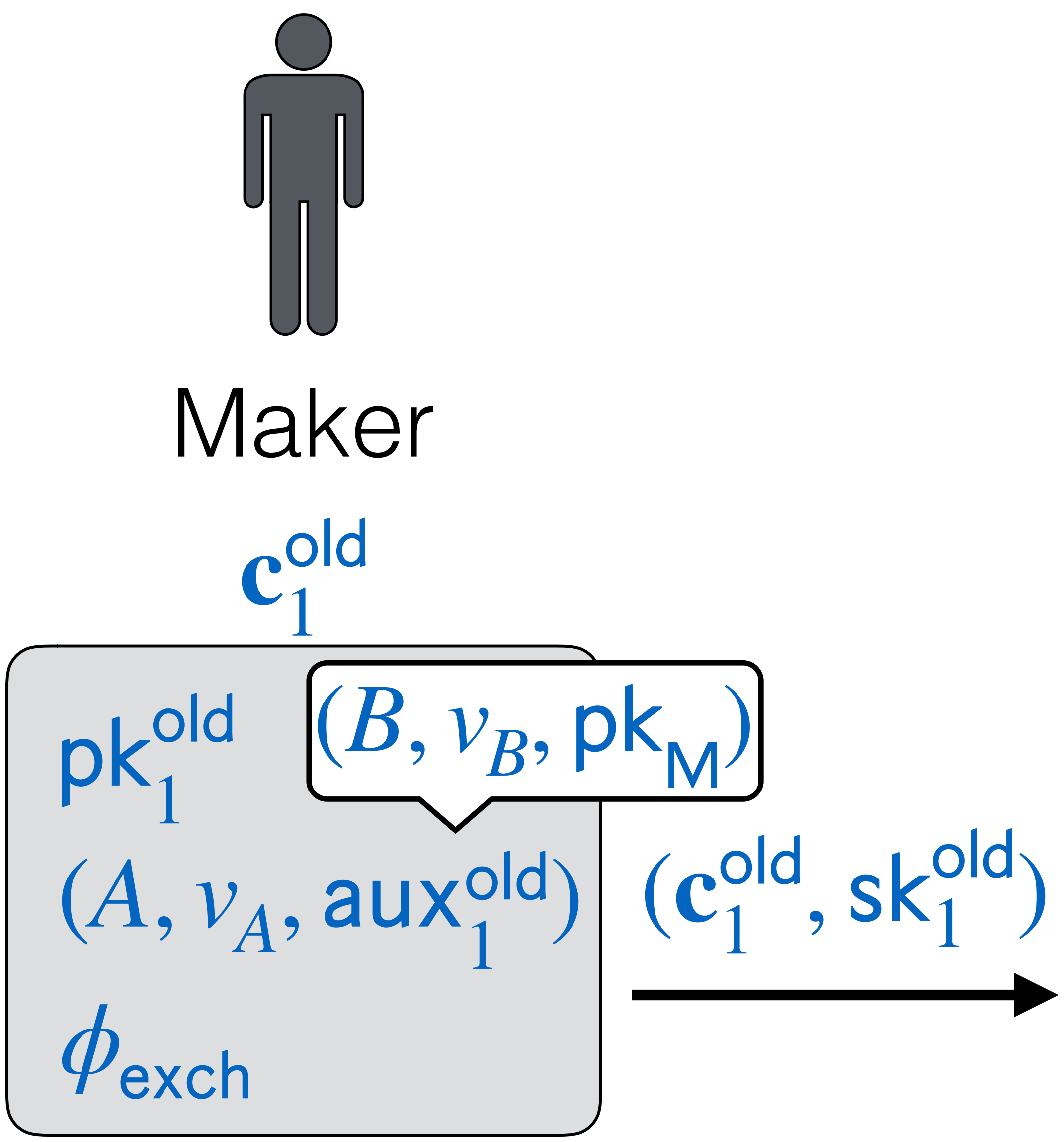
$\mathsf{pk}_1^{\mathsf{old}}$

$(B, v_B, \mathsf{pk}_{\mathsf{M}})$

$(A, v_A, \mathsf{aux}_1^{\mathsf{old}})$

ϕ_{exch}

Private Intent-based DEX



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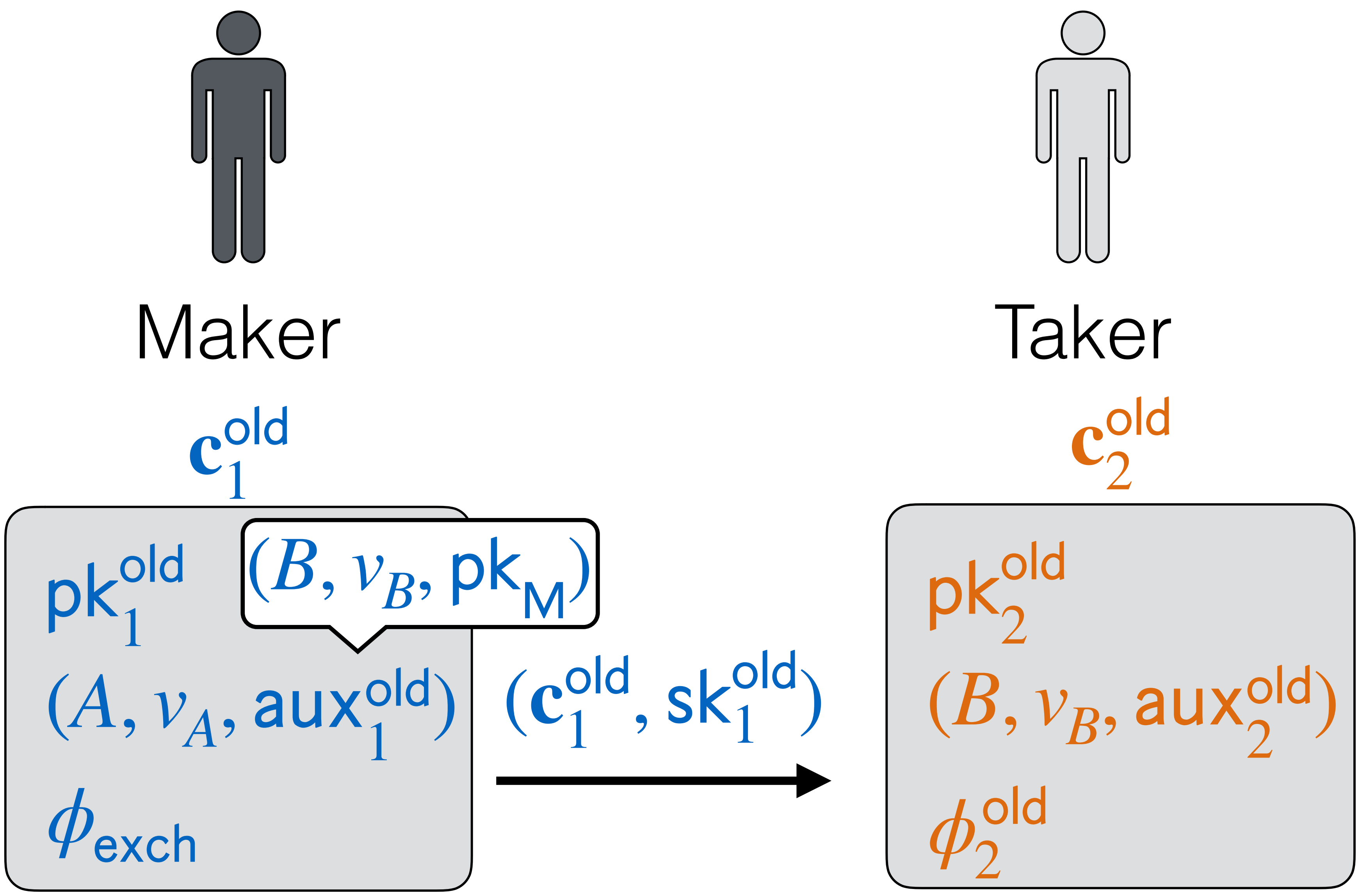

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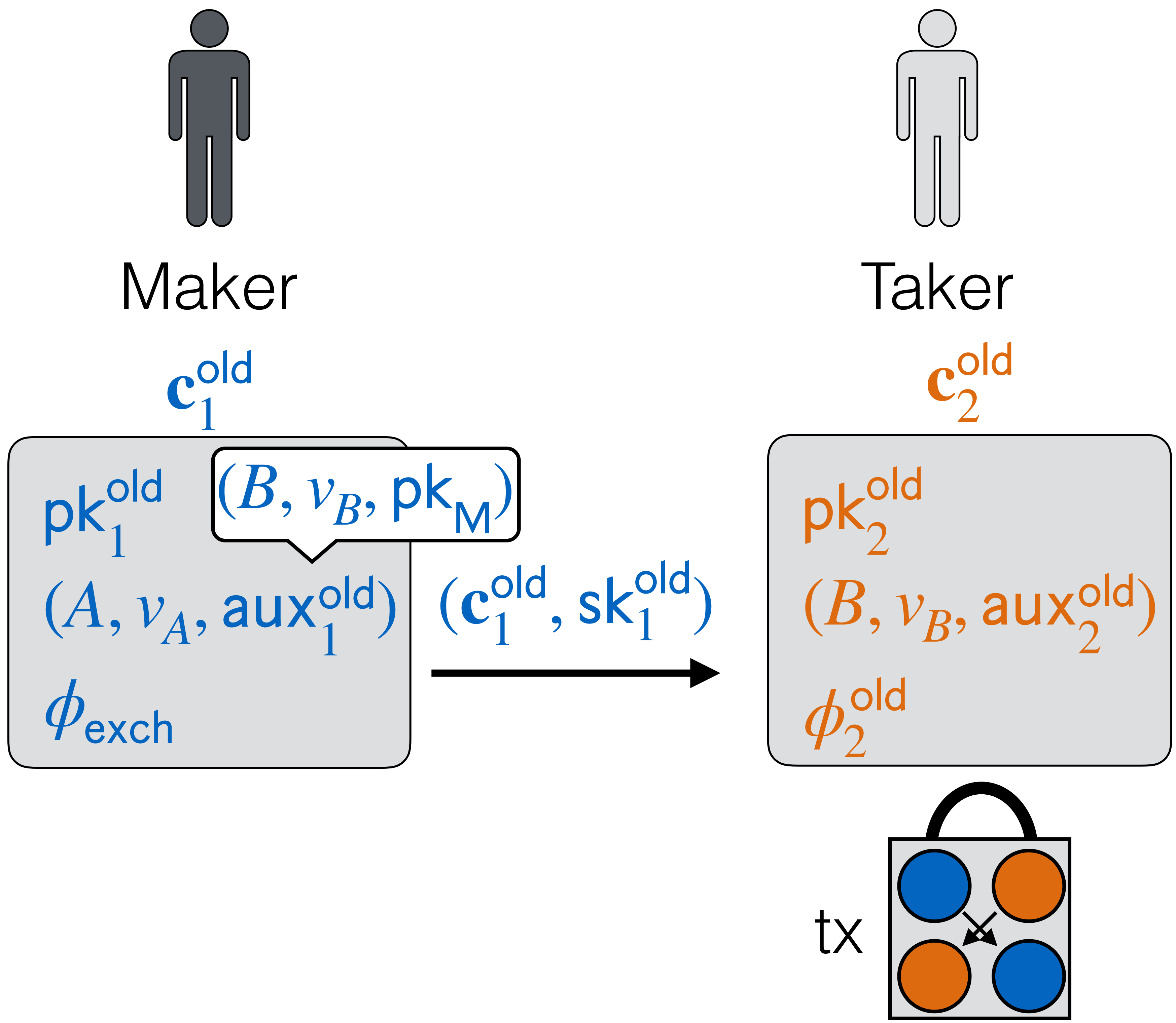

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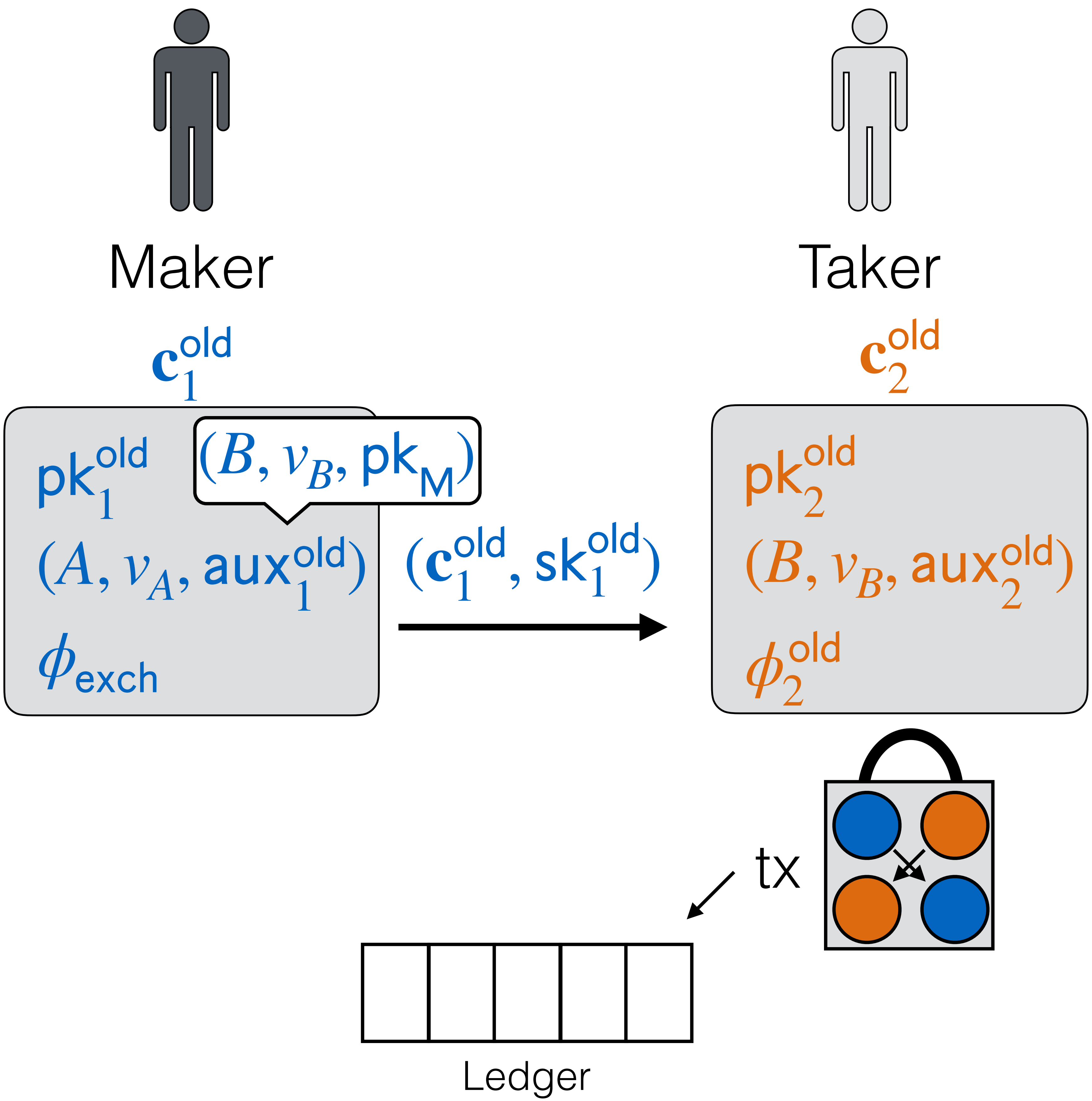

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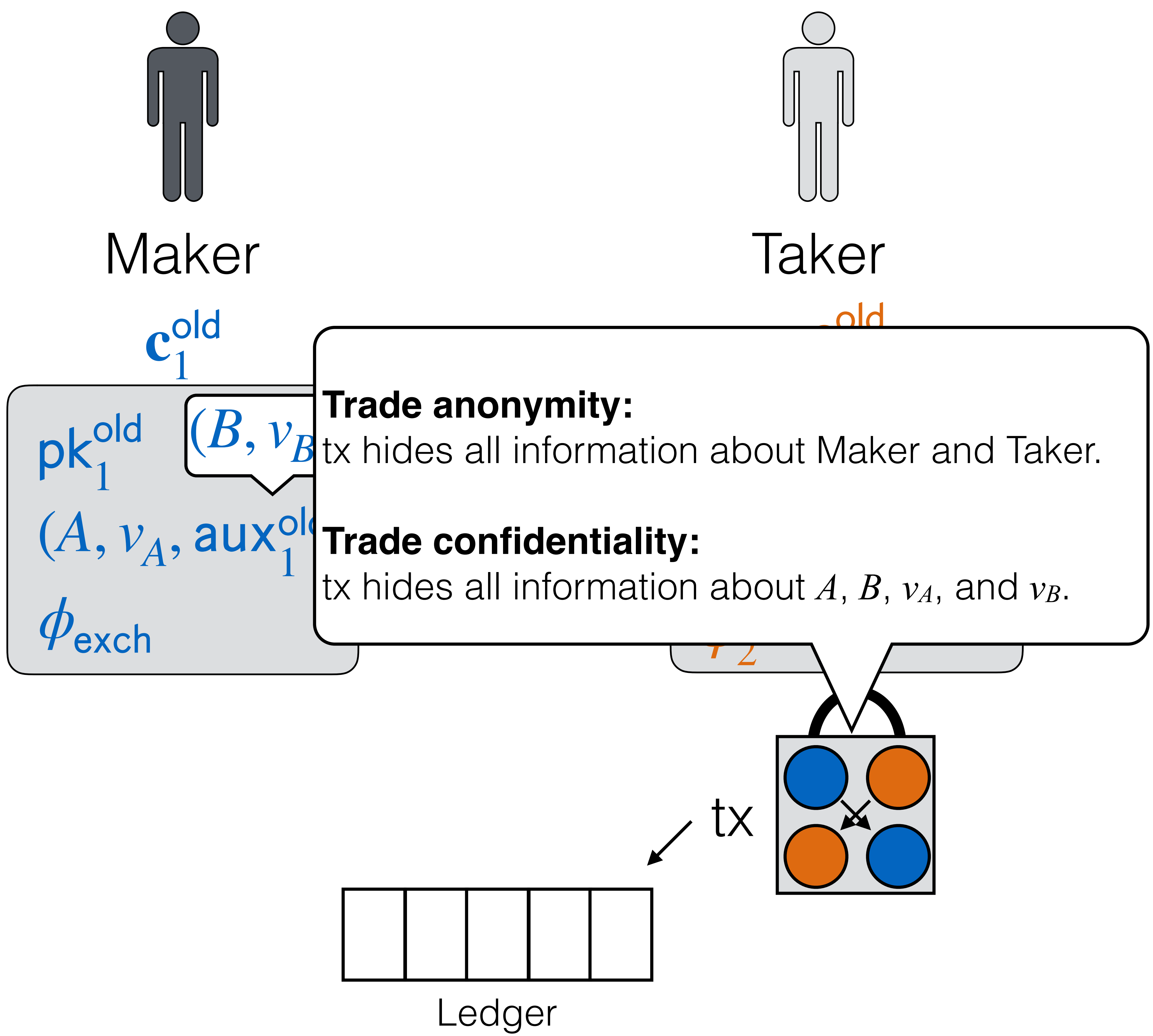

Private user-defined assets

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Custom access to private user-defined assets

Private user-defined assets

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Private DEX

But what if you want a user-defined asset with a different (custom) policy?

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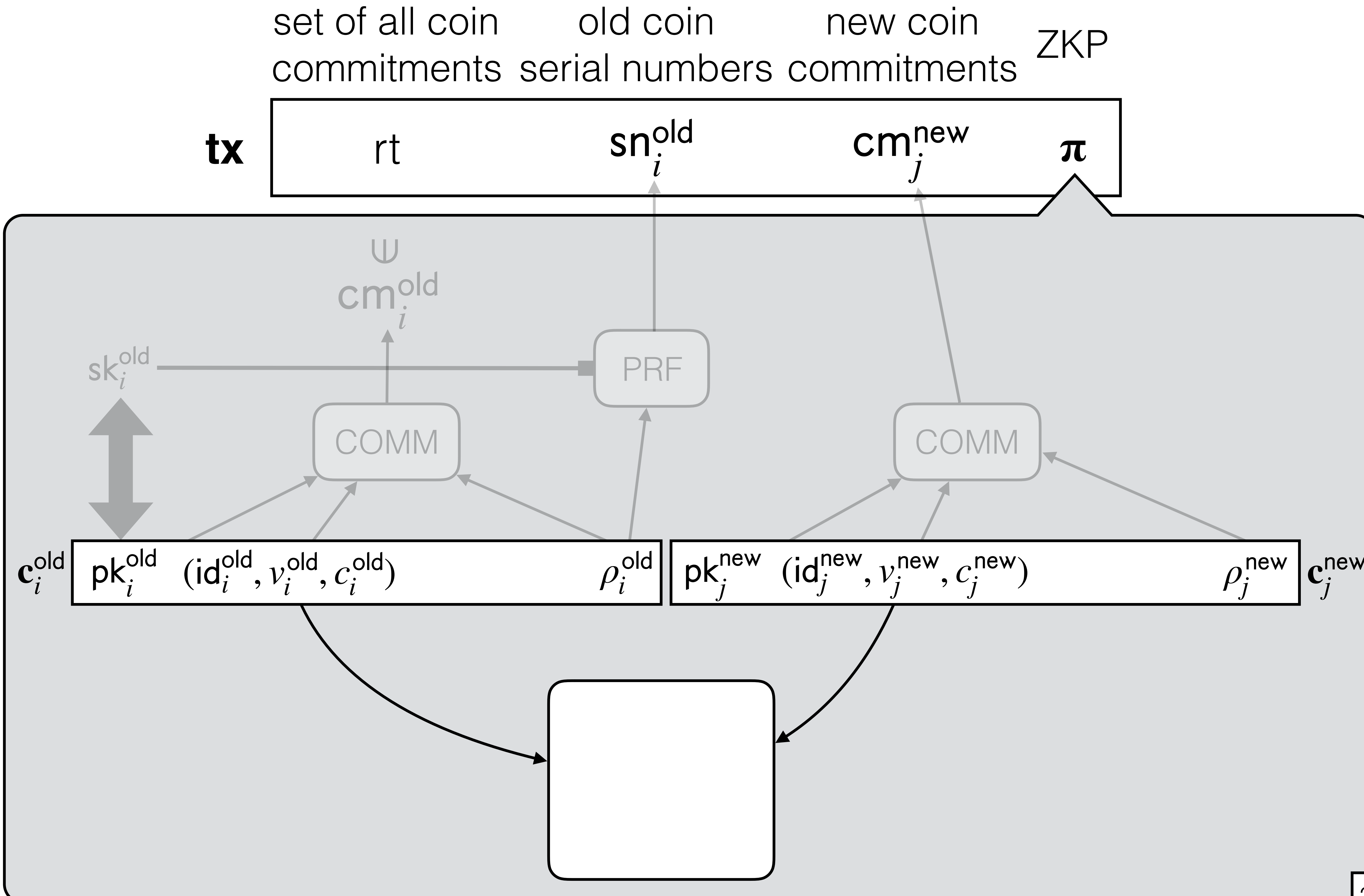
For example,
simple ERC-20 tokens require only value-conservation.
other tokens, like stablecoins, need to also implement blacklists and whitelists.

Birth predicates



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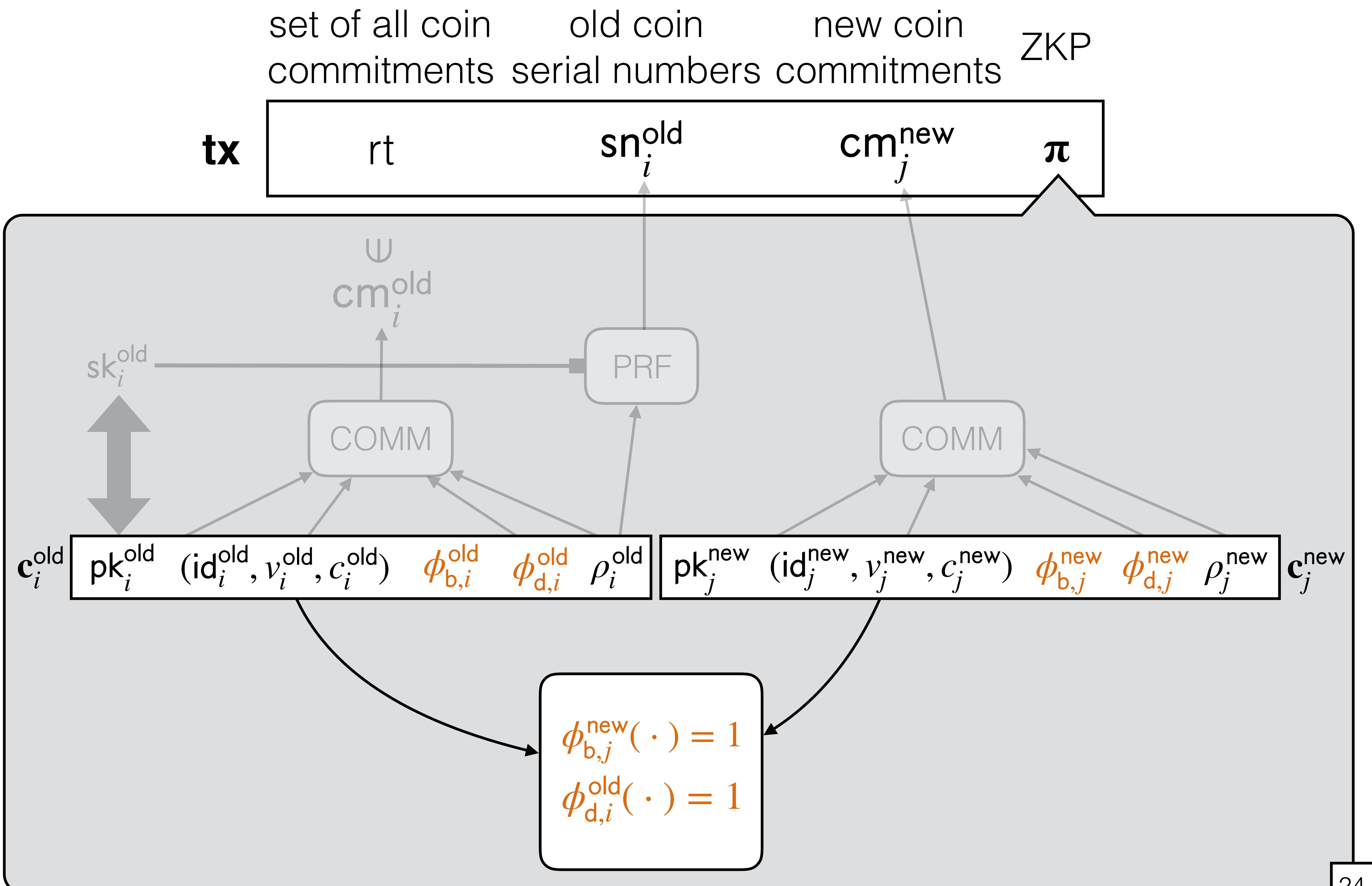

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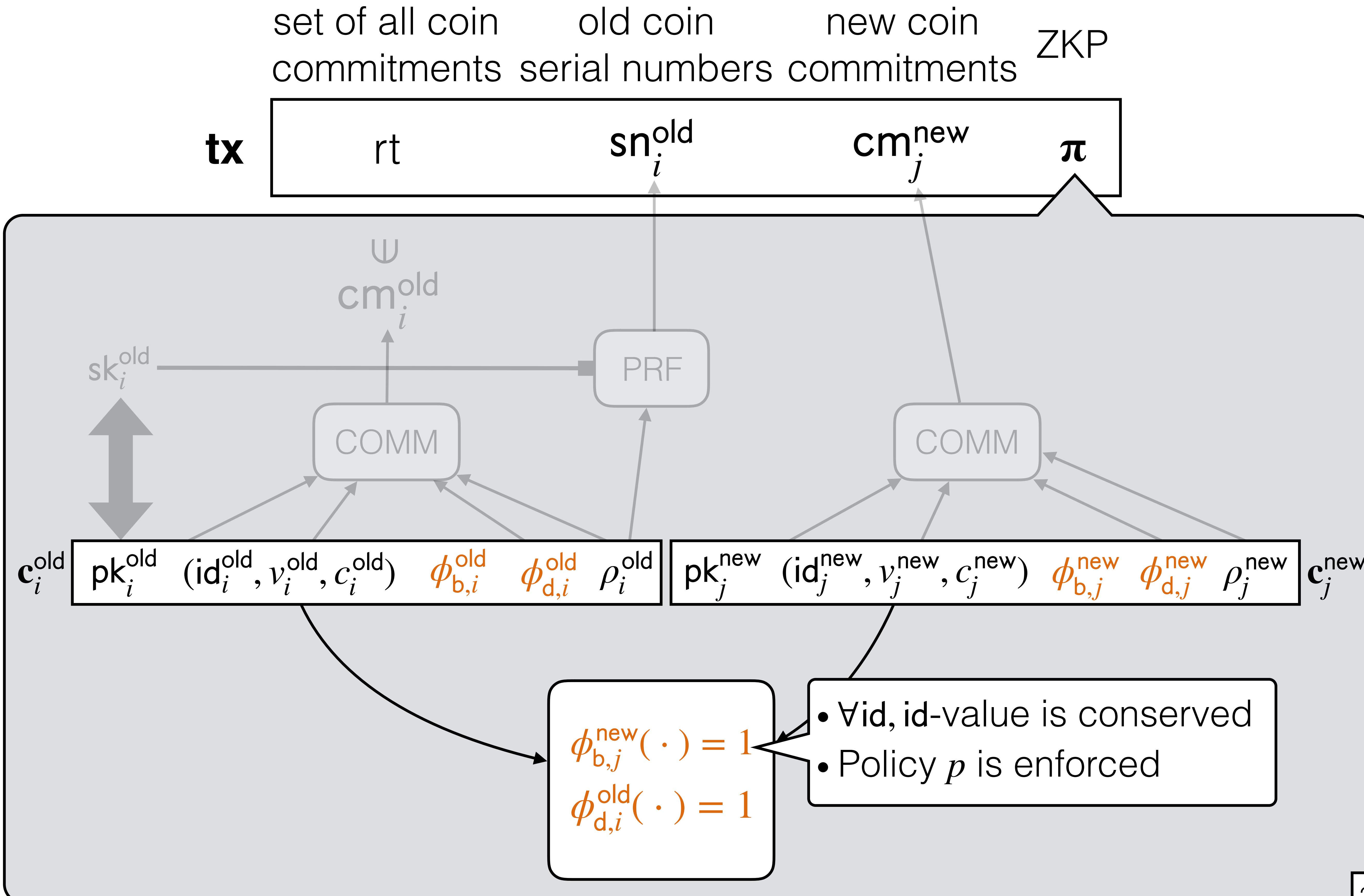
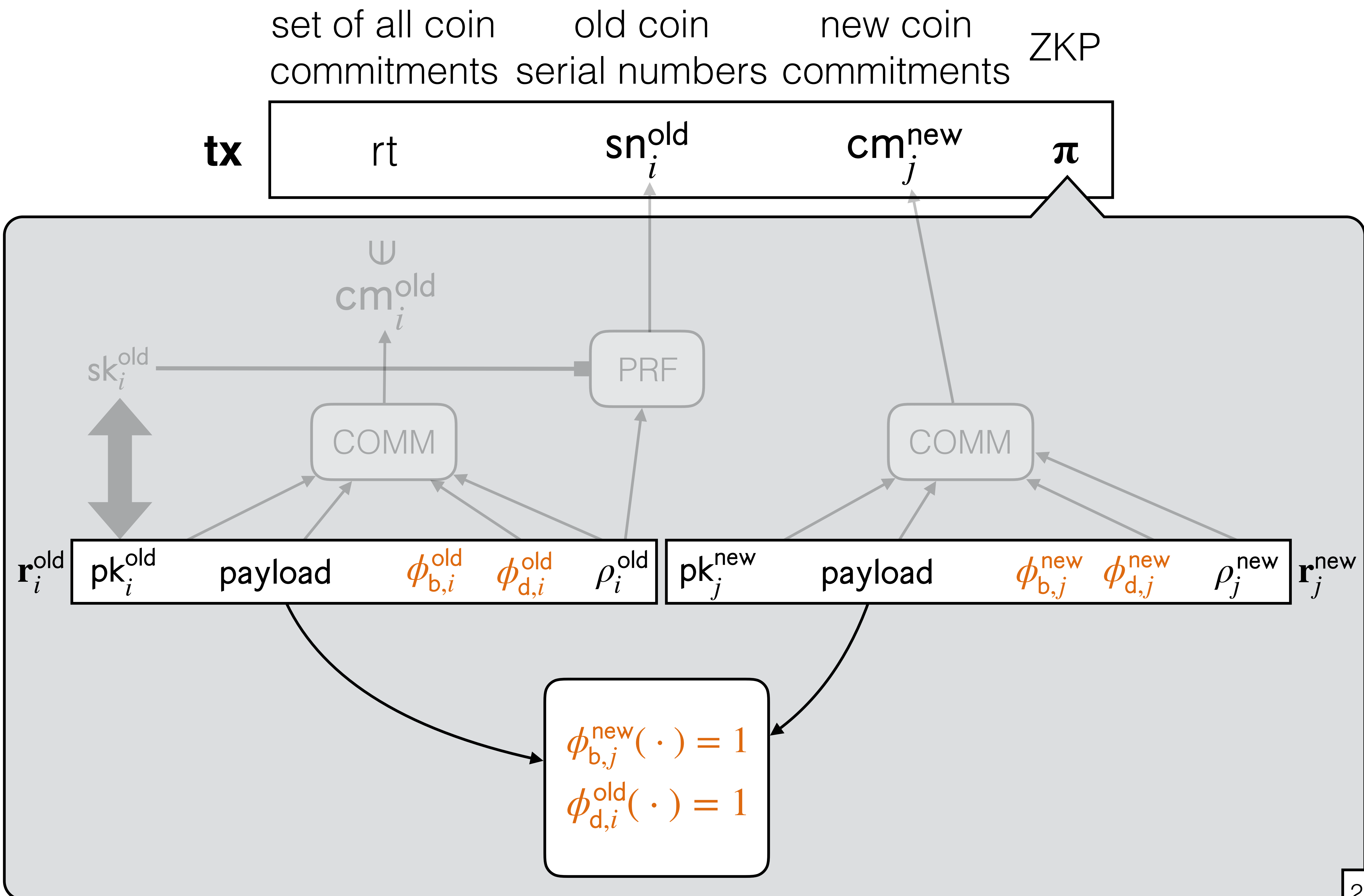
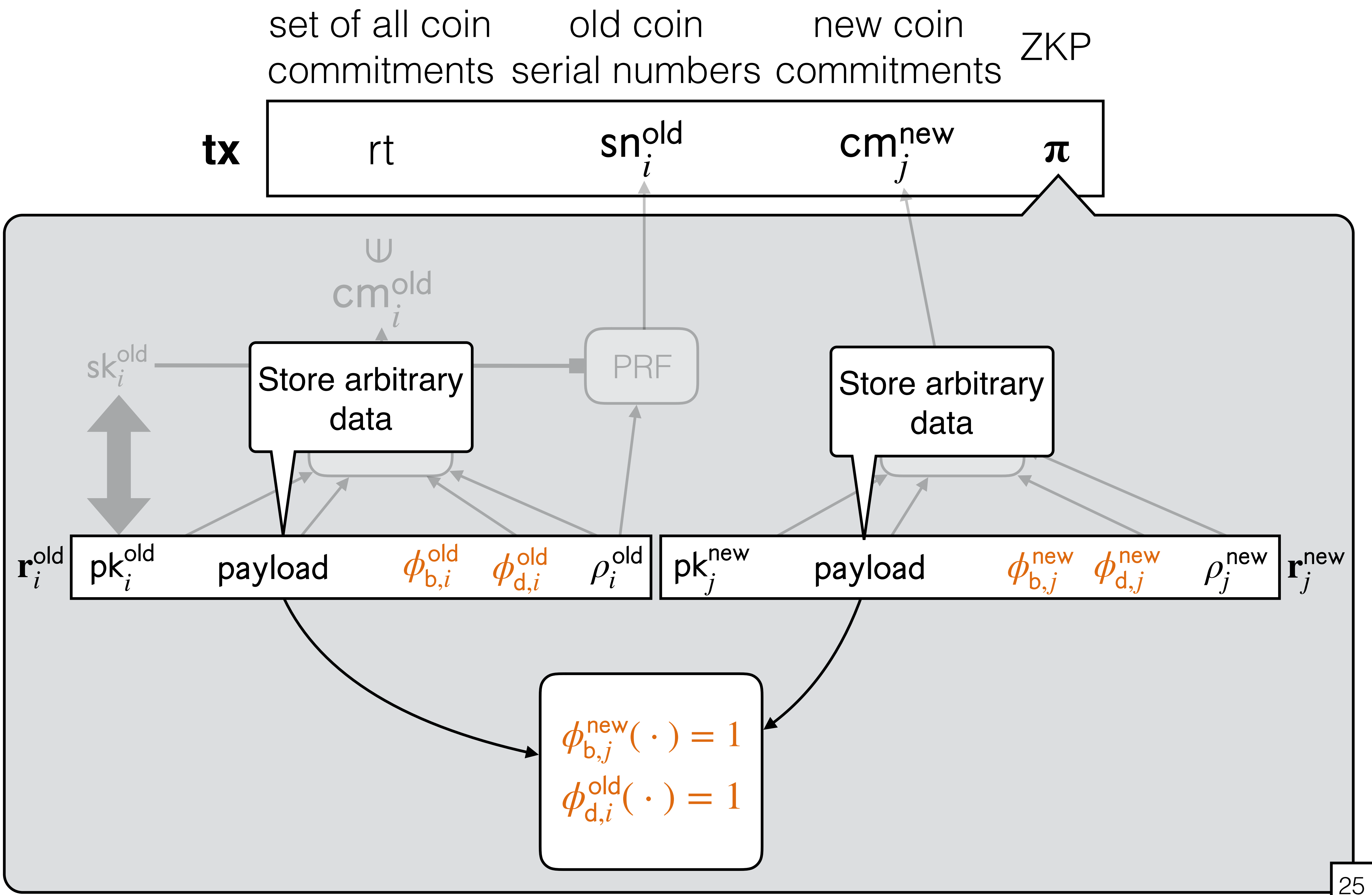


Supporting arbitrary data and computation



Supporting arbitrary data and computation



ZEXE

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Modeling: Records Nano-Kernel

minimalist shared execution environment that defines rules for computing on *records* (units of data)

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crypto primitive that realizes a ledger-based RNK where txs reveal NO information about computations

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Thanks!

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