Privacy in Blockchain

Murat Osmanoglu

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- "I desire a society where all may speak freely about whatever topic they will. I desire that all people might be able to choose to whom they wish to speak and to whom they do not wish to speak. I desire a society where all people may have an assurance that their words are directed only at those to whom they wish. Therefore I oppose all efforts by governments to eavesdrop and to become unwanted listeners." (Cyphernomicon, Tim May)

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- "What if we could build a society where the information was never collected? Where you could pay to rent a video without leaving a credit card number or a bank number? Where you could prove you're certified to drive without ever giving your name? Where you could send and receive messages without revealing your physical location, like an electronic post office box? " (Privacy, Technology, and the Open Society, John Gilmore)

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  'Security Without Identification: Transaction Systems to Make Big Brother Obsolete', 1985

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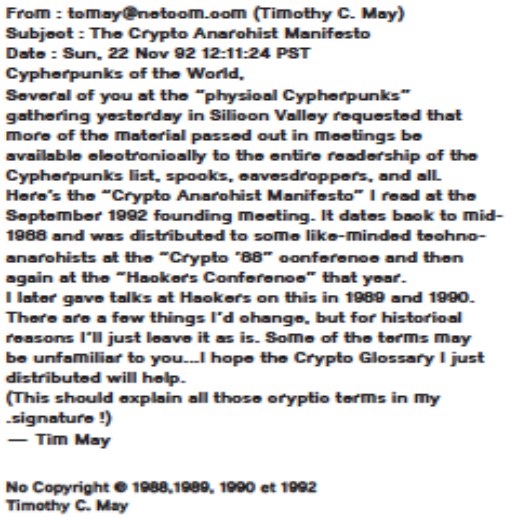
- in late 1992, three people: Eric Hughes (mathematicians from Berkeley), Tim May (businissman retired from Intel), and John Gilmore (computer scientist) were gathering to discuss some cryptographic and programing issues

Cypherpunks

- they later initiated a mailing list (the number of subscribers reached 2000 in 1997) to reach out some other cypherpunks outside of Bay Area.

- Timothy May published 'the Crypto Anarchist Manifesto' in 1992



From : tcmay@netcom.com (Timothy C. May)
Subject : The Crypto Anarchist Manifesto
Date : Sun, 22 Nov 92 12:11:24 PST
Cypherpunks of the World,
Several of you at the "physical Cypherpunks" gathering yesterday in Silicon Valley requested that more of the material passed out in meetings be available electronically to the entire readership of the Cypherpunks list, spooks, eavesdroppers, and all.
Here's the "Crypto Anarchist Manifesto" I read at the September 1992 founding meeting. It dates back to mid-1988 and was distributed to some like-minded techno-anarchists at the "Crypto '88" conference and then again at the "Hackers Conference" that year.
I later gave talks at Hackers on this in 1989 and 1990. There are a few things I'd change, but for historical reasons I'll just leave it as is. Some of the terms may be unfamiliar to you....I hope the Crypto Glossary I just distributed will help.
(This should explain all those cryptic terms in my .signature !)
— Tim May

No Copyright © 1988,1989, 1990 et 1992
Timothy C. May

THE CRYPTO-ANARCHIST MANIFESTO

Thimothy C.May

MANIFESTE CRYPTO-ANARCHISTE

Cypherpunk Manifesto

- Eric Hughes published *'A Cypherpunk's Manifesto'* in 1993, which can be considered as holy text of this movement.

"Privacy is necessary for an open society in the electronic age"

"Since we desire privacy, we must ensure that each party to a transaction have knowledge only of that which is directly necessary for that transaction.
"

"Privacy in an open society requires anonymous transaction systems."

"We cannot expect governments, corporations, or other large, faceless organizations to grant us privacy out of their beneficence"

"We must defend our own privacy if we expect to have any"

Privacy Issues

- each user can get all the transactions shared in the network
- it enables each user to validate integrity and authenticity of every transaction
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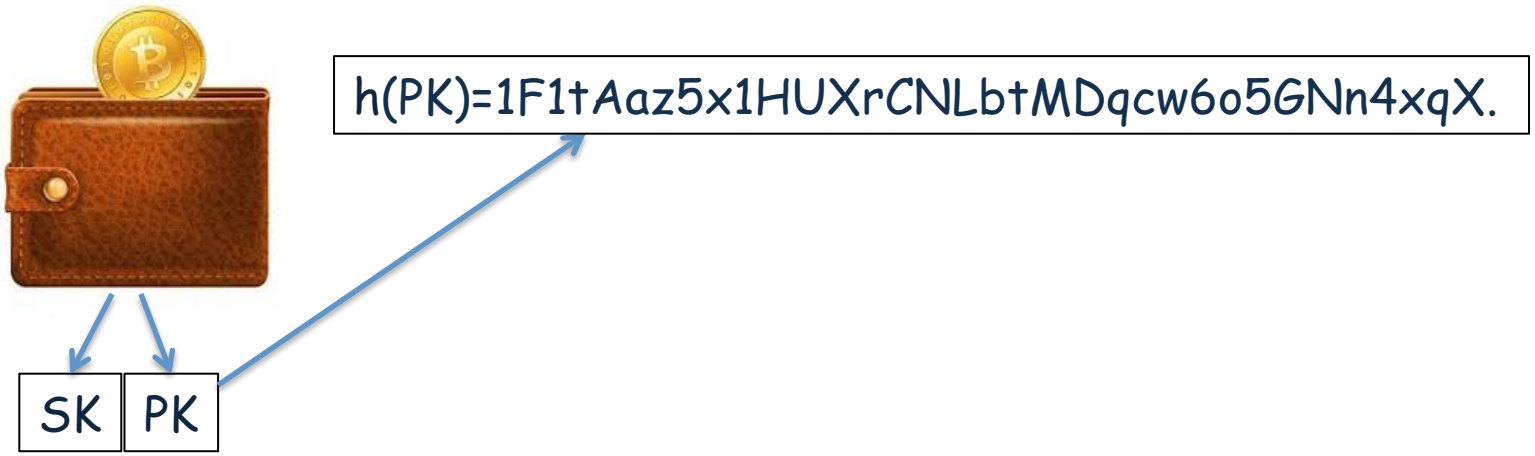

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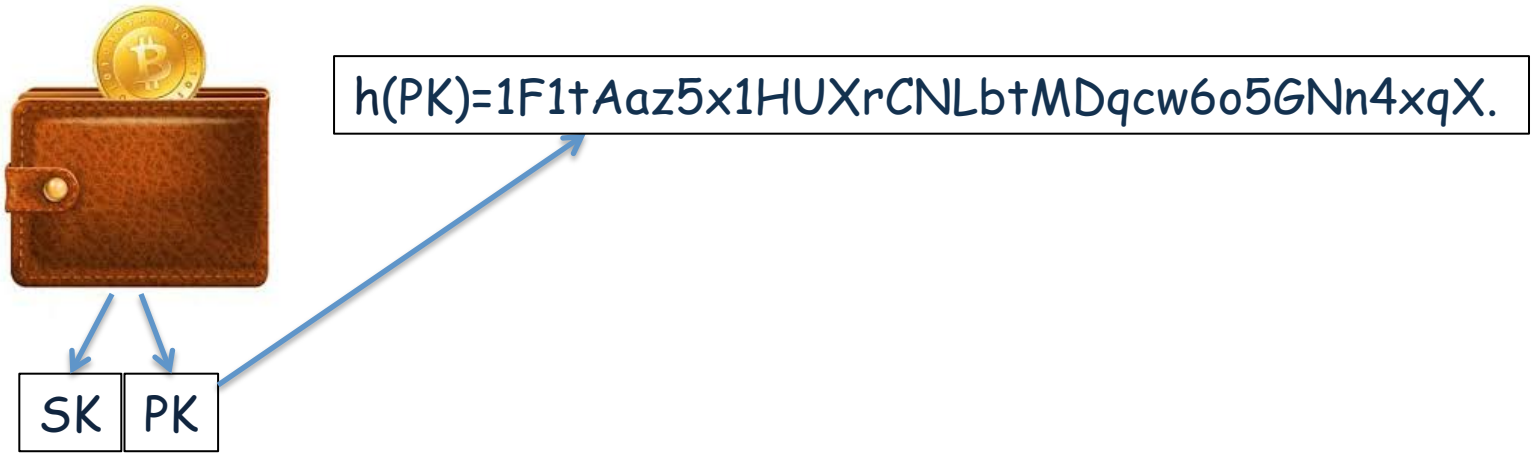

- Bitcoin even allows users to have more than one address and to use a new one for each transaction to improve privacy

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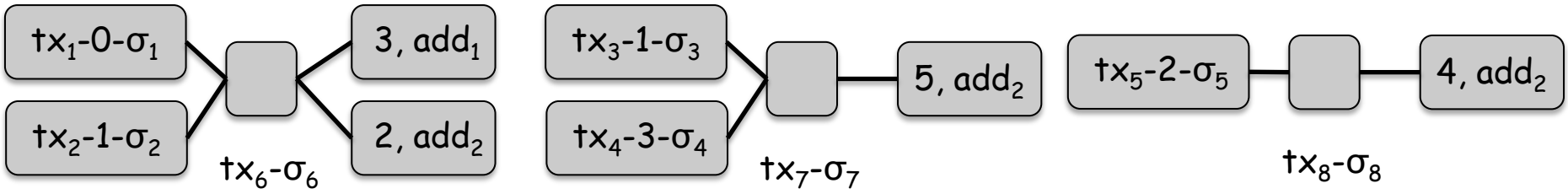
  - they obtained all the transactions recorded in bitcoin from January 2009 to July 2011 (1019486 txs between 1253054 addresses)
  - they built two networks (transaction and user) based on the input-output relationship between transactions and re-use and co-use of the addresses

Privacy Issues

- the transfer of an amount bitcoin ownership rights from one address to another one
- each tx consists of two main fields :
  - input : unspent transaction outputs claimed by the sender from previous transactions (previous transaction id, index, scriptsign)
  - output : instructions for claiming the sent bitcoins (value, scriptpublickey)
- if the transaction output not spent before, and the signature is valid, the transaction considered as valid



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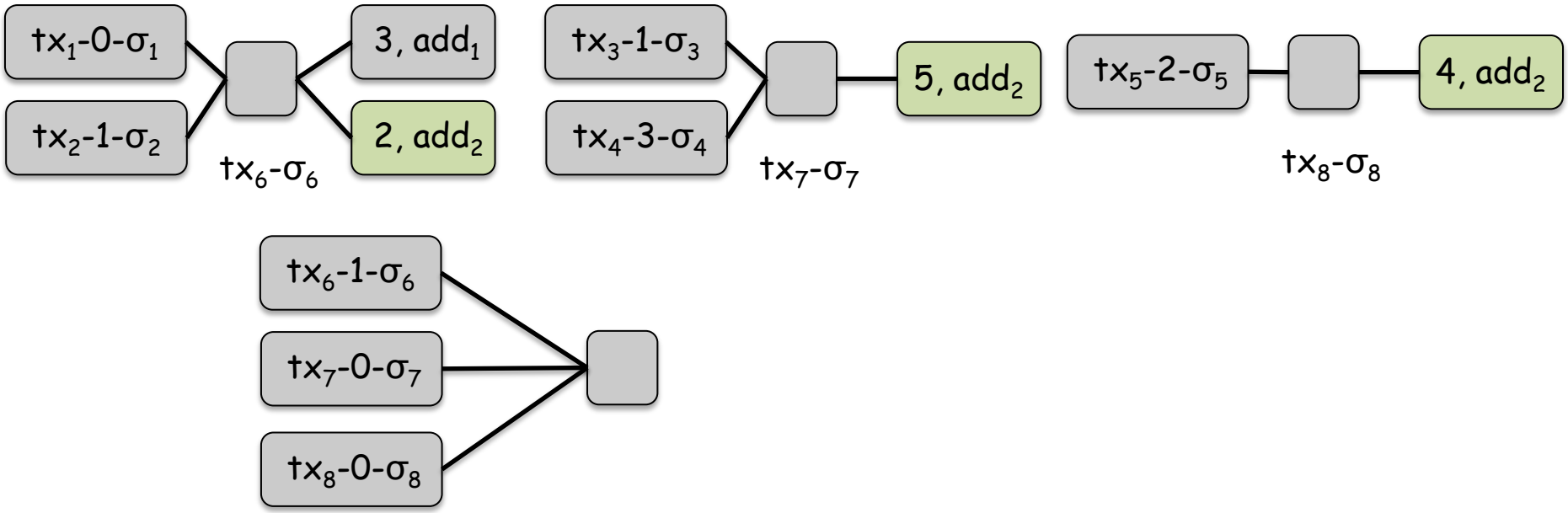

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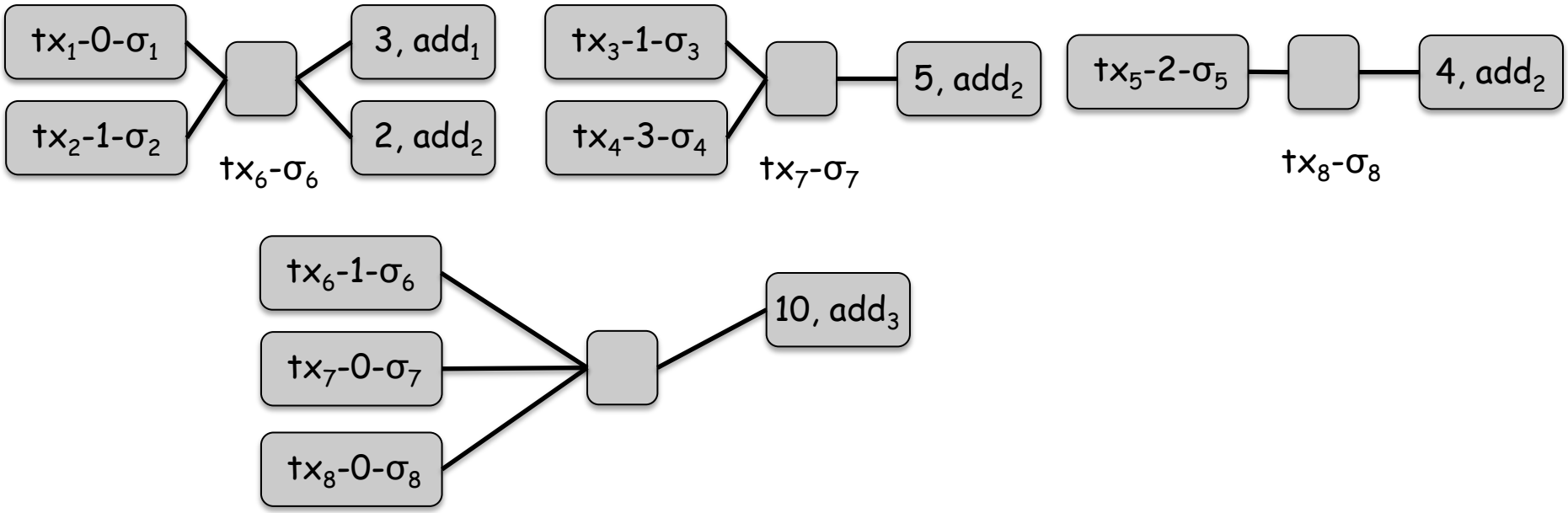

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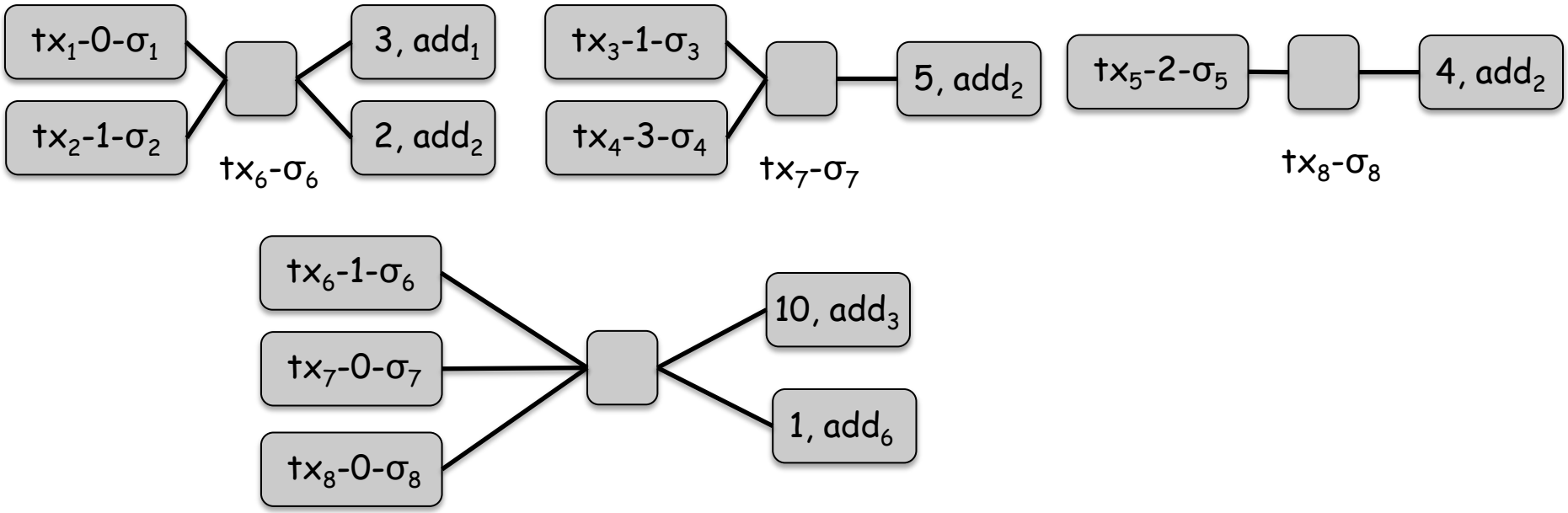

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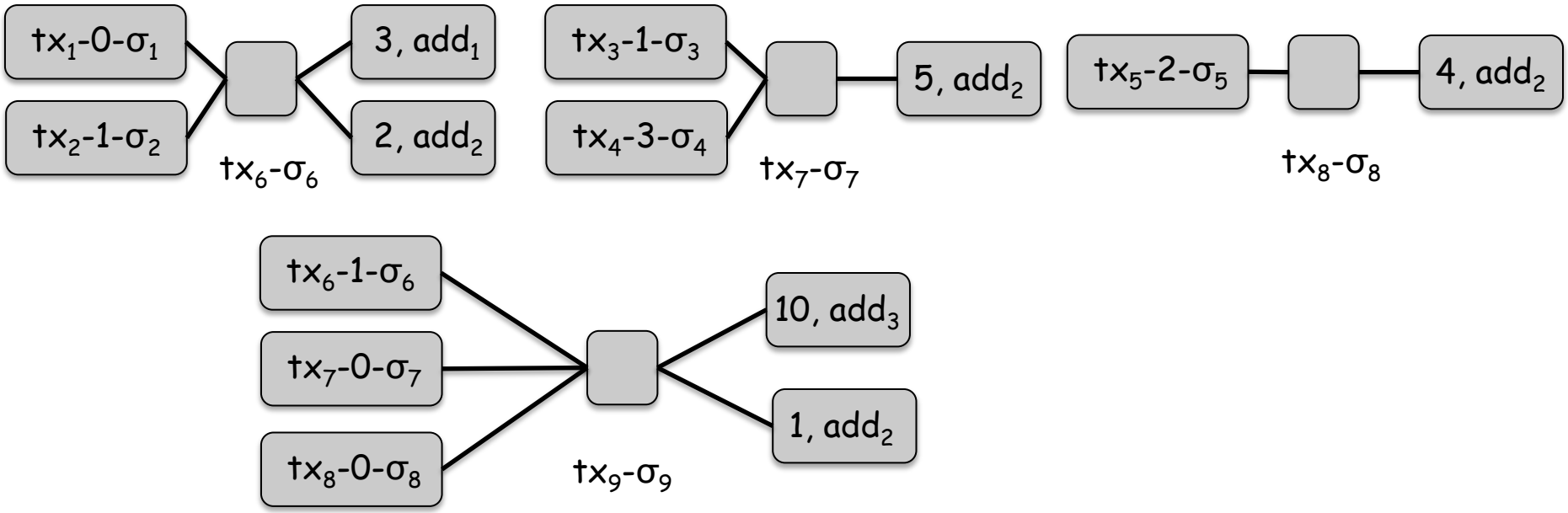
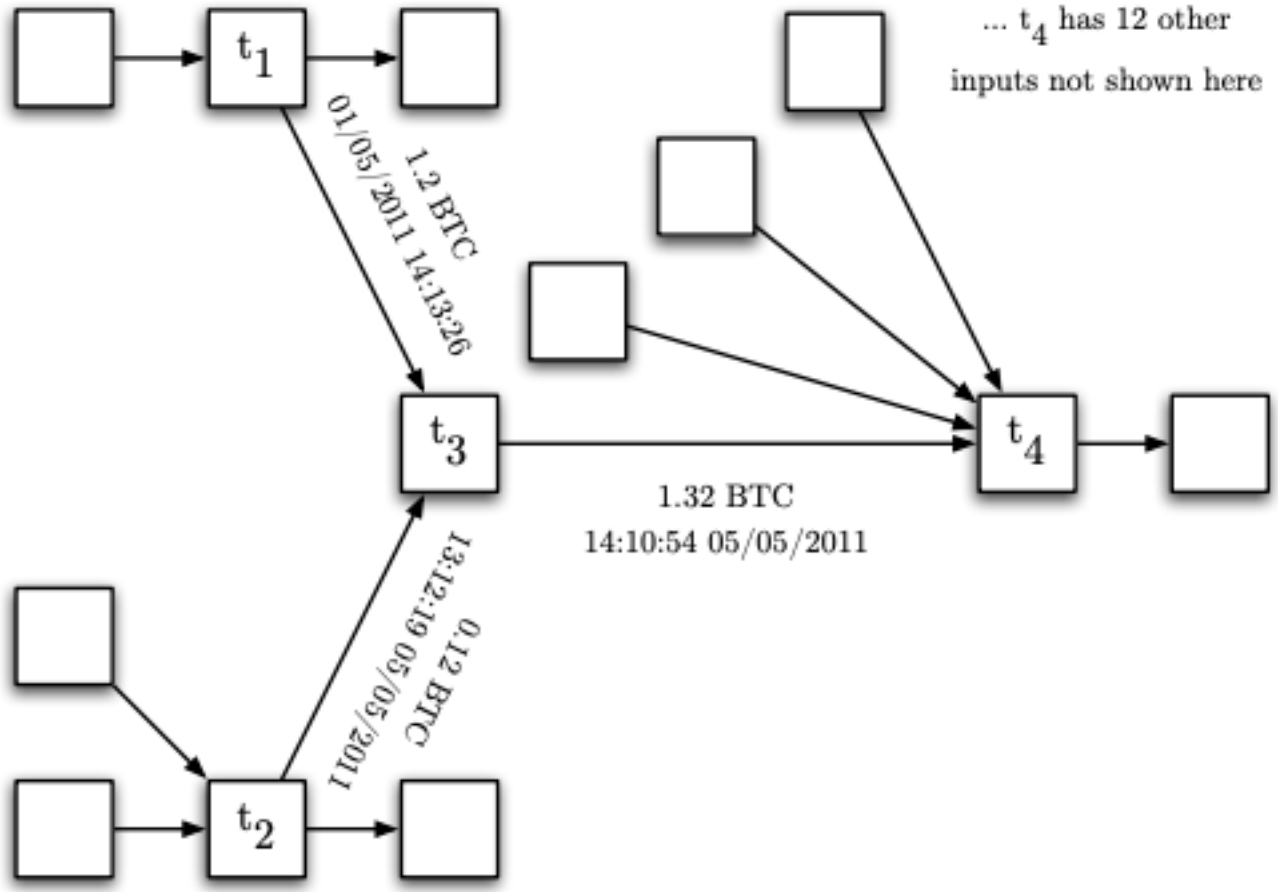


Privacy Issues

- analyze the study proposed Reid and Harrigan [1]
- a sub-network of transaction network



Privacy Issues

- analyze the study proposed Reid and Harrigan [1]
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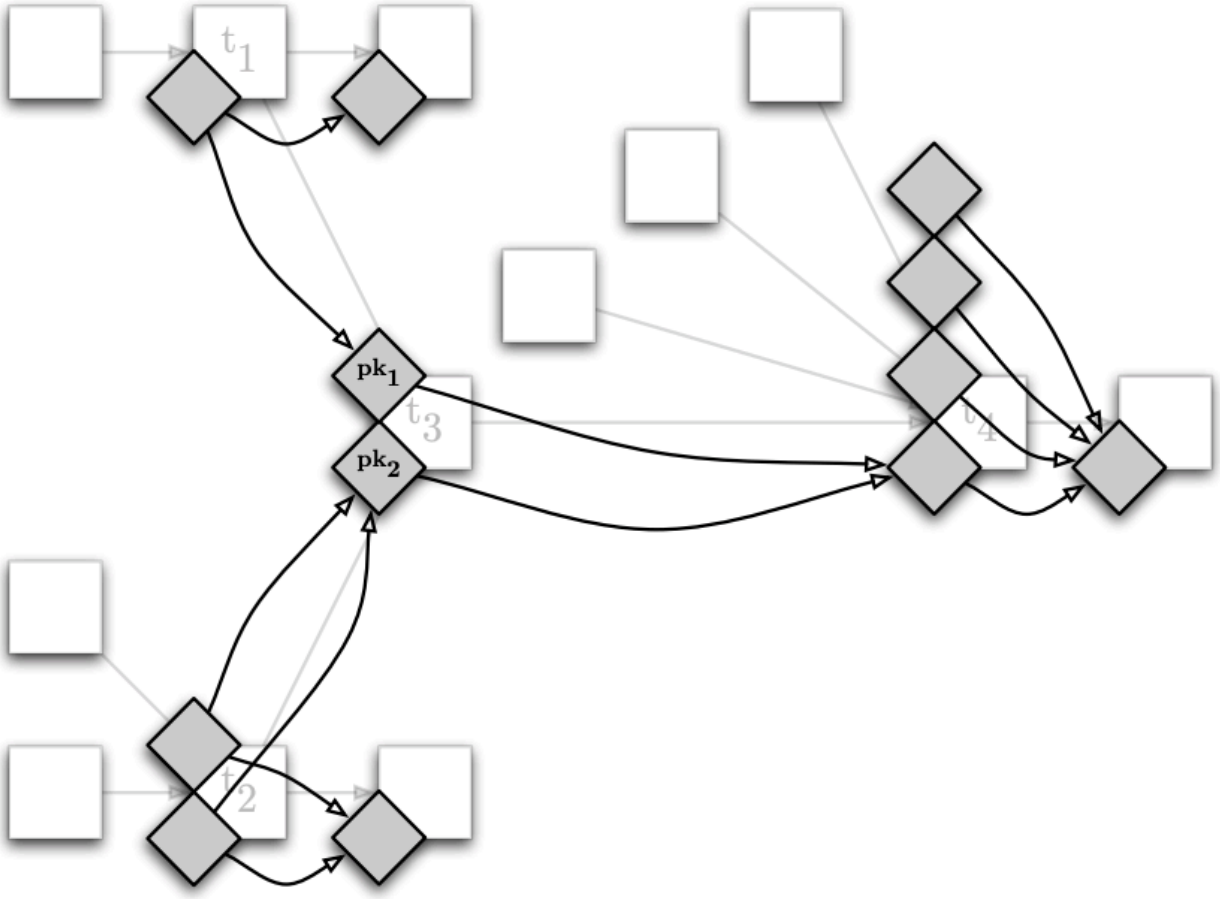

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- some findings:
  - user network has cyclic structure (it is expected to just contain Bitcoin flows between one-time addresses keys that were not connected to other addresses)
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  - a tx frequently has single input from a larger tx, or multiple inputs from smaller txs
  - a tx frequently has two outputs: one for payment, one directing to user's other address
- data obtained from different Internet sources such as twitter posts, bitcoin forums etc. (they usually post one of their addresses) used to link an address to a real identity
  - utilizing user network, they can even link public addresses to some other address belonging to same users

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- attacker broke into allinvain's Slush pool account and changed the payout address as his address

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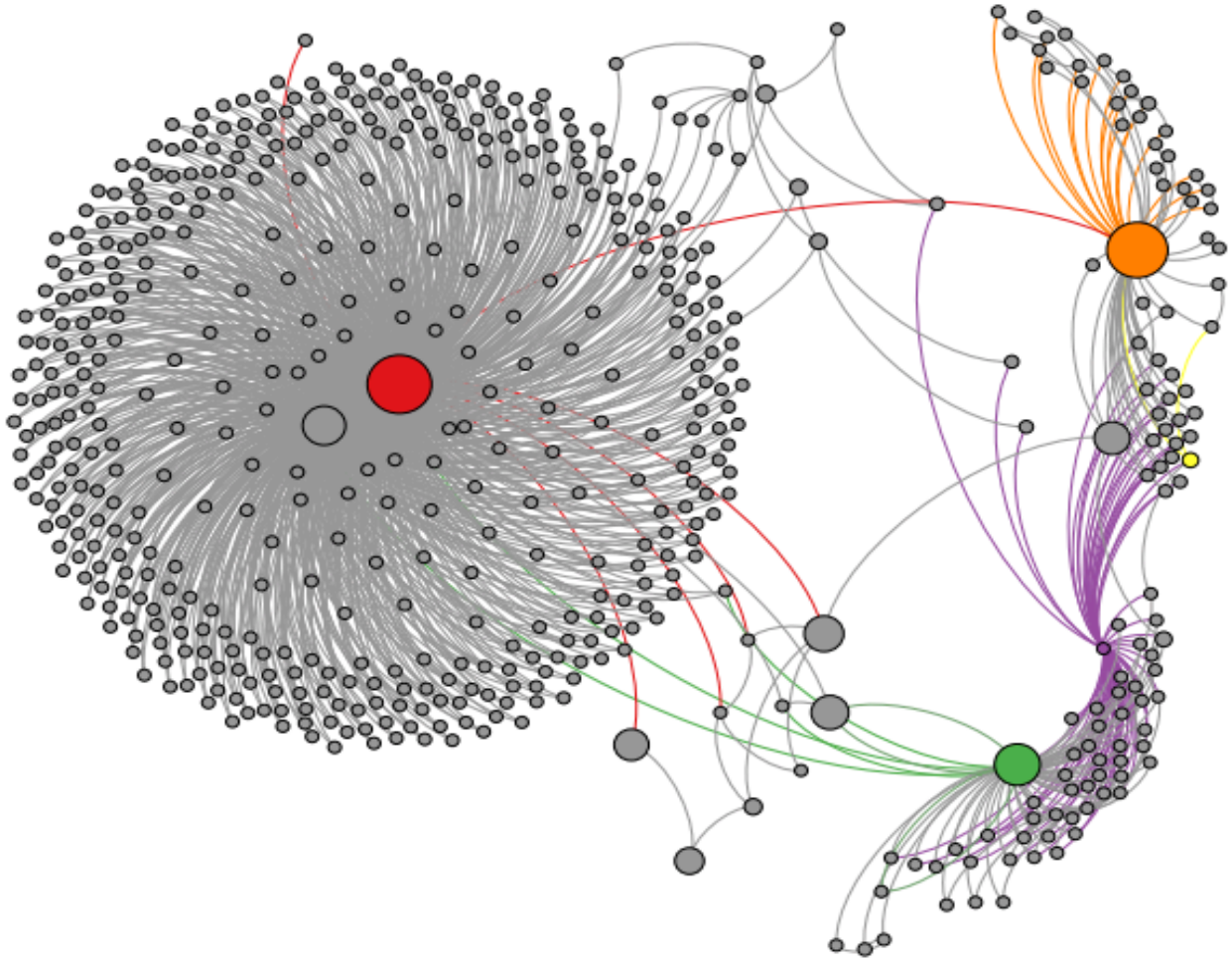

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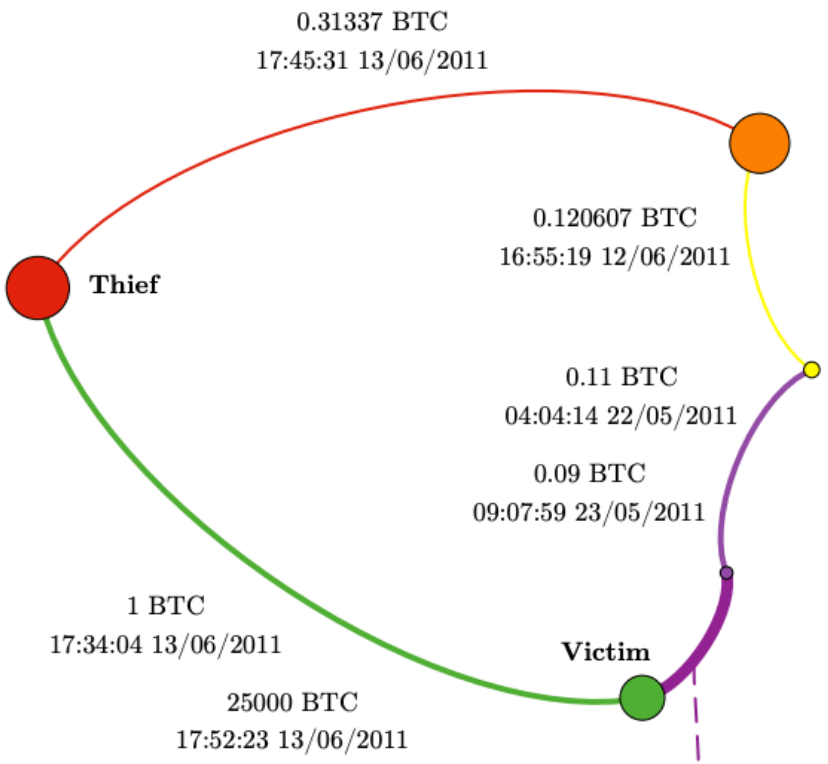

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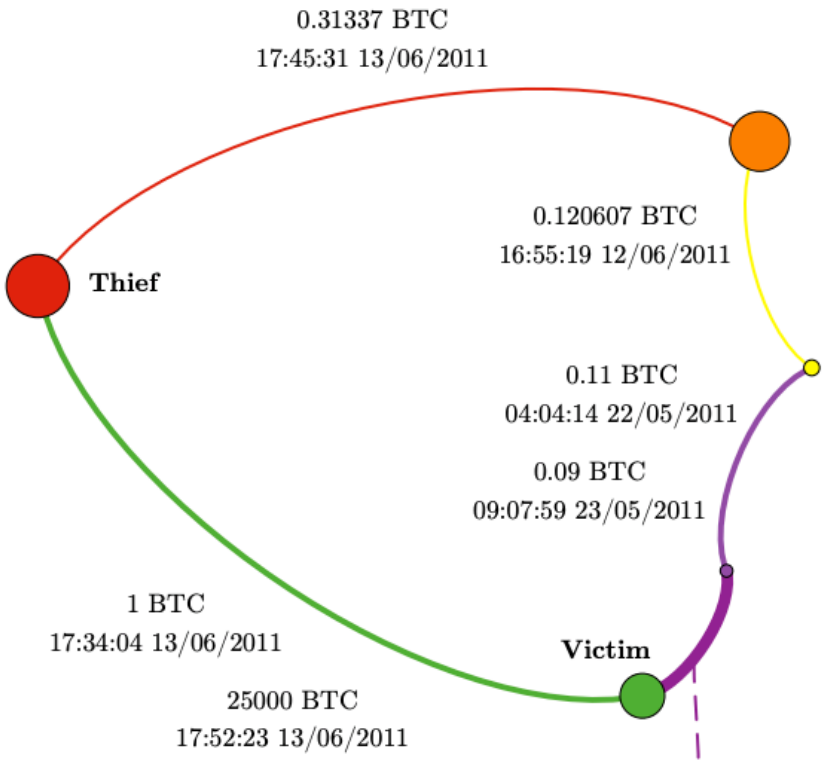
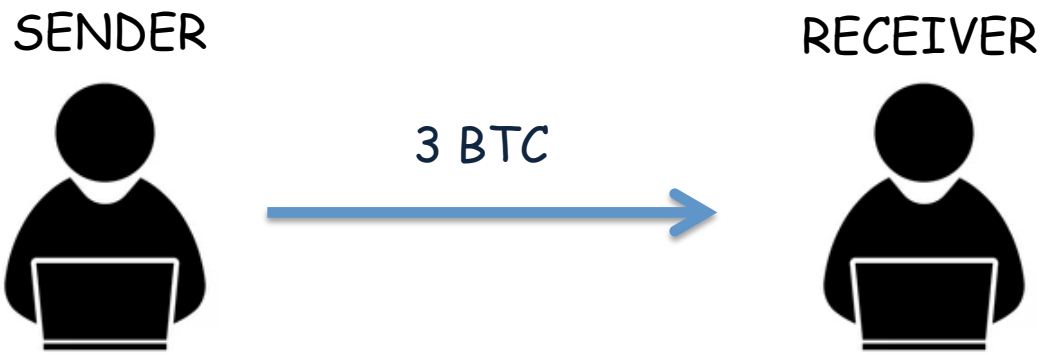


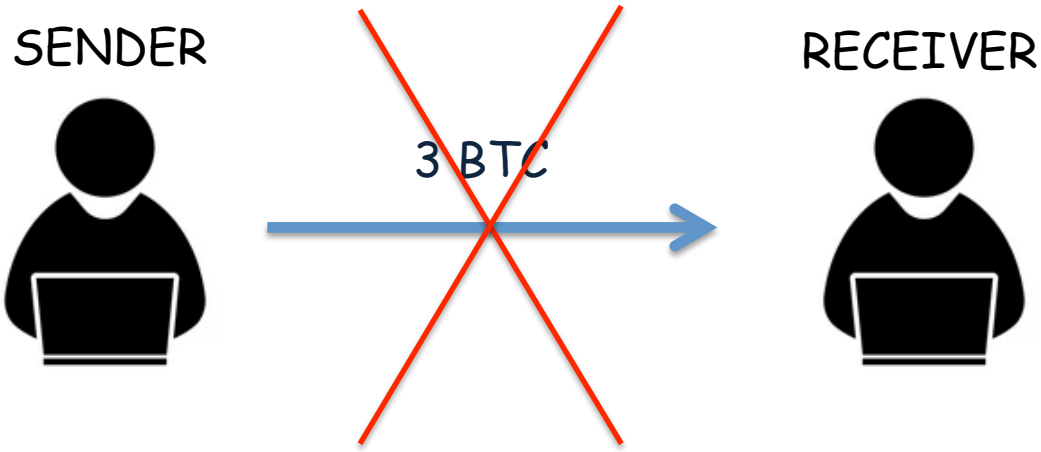
he even tried to associate the thief with the hacker group LulcSec by creating a transaction from hacker to that group

Privacy Enhancing Techniques



Privacy Enhancing Techniques

- break the link between source and destination address



Privacy Enhancing Techniques - Mixing

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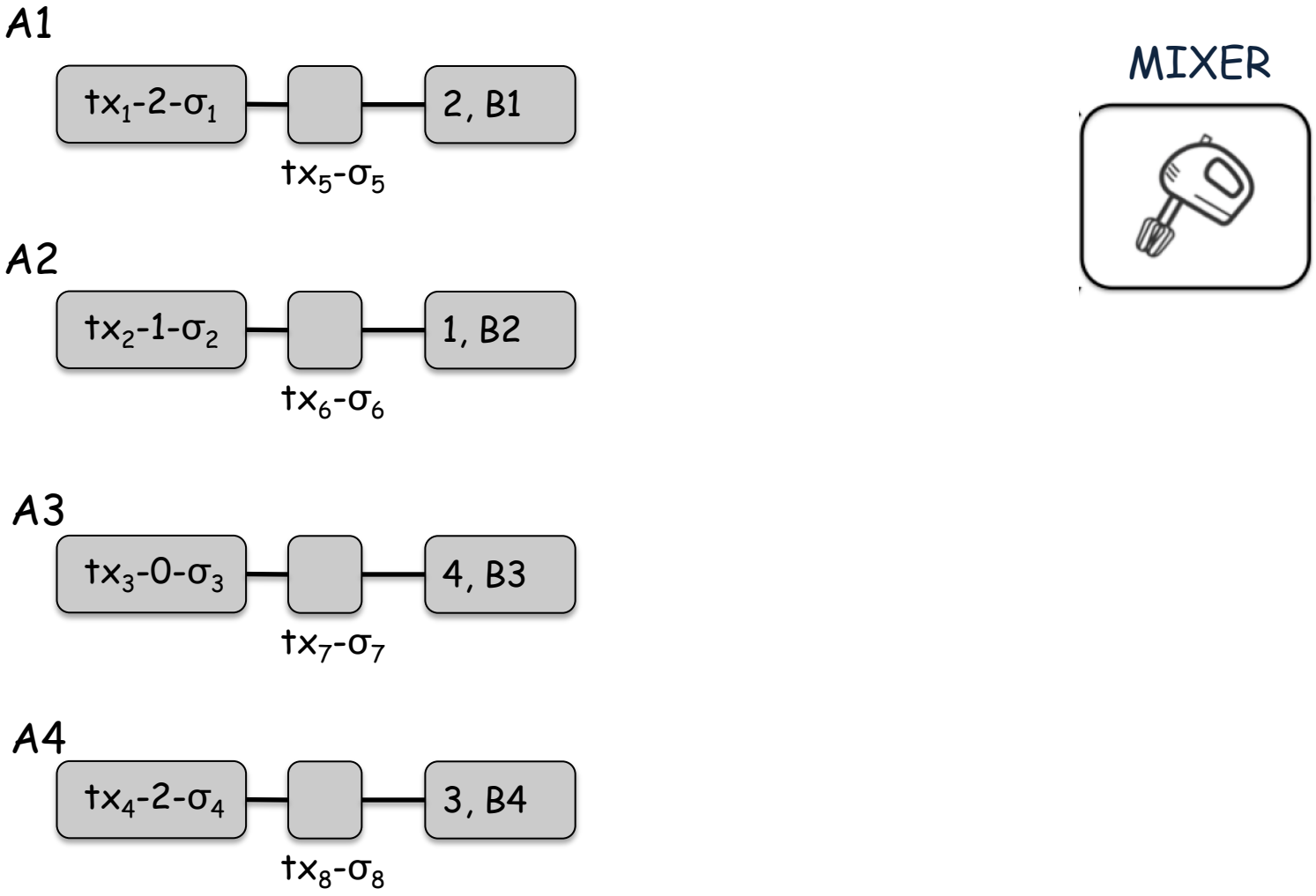

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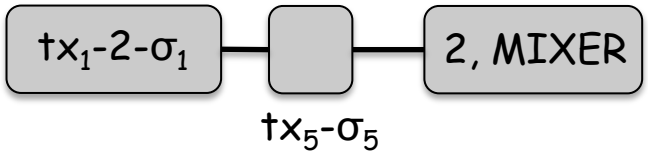

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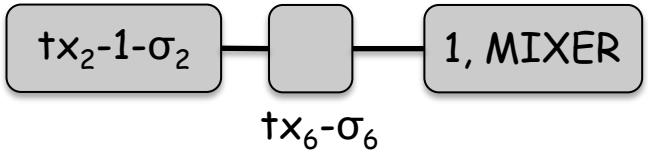

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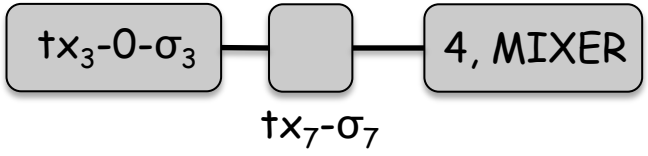

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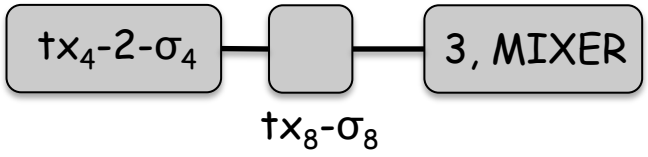

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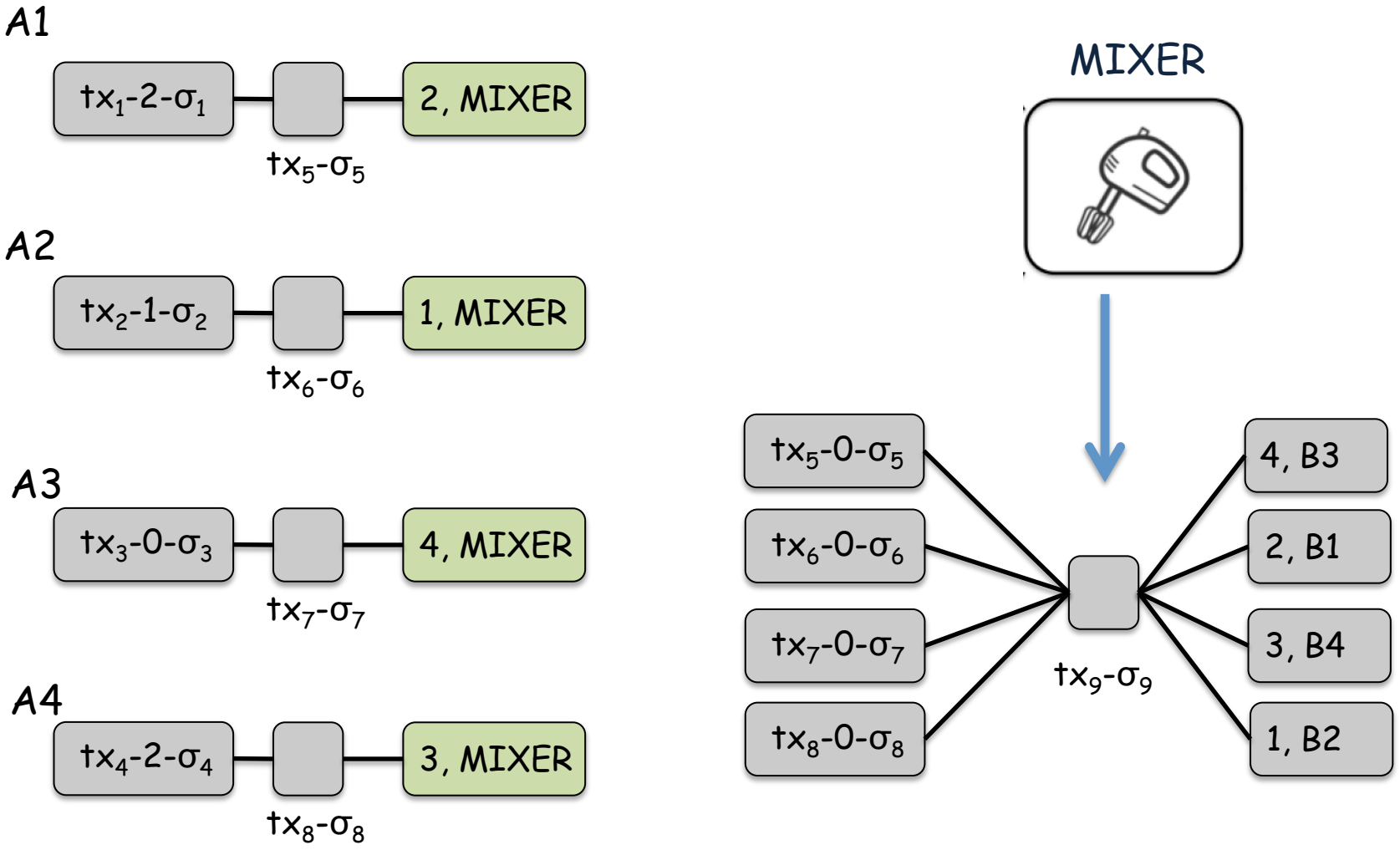

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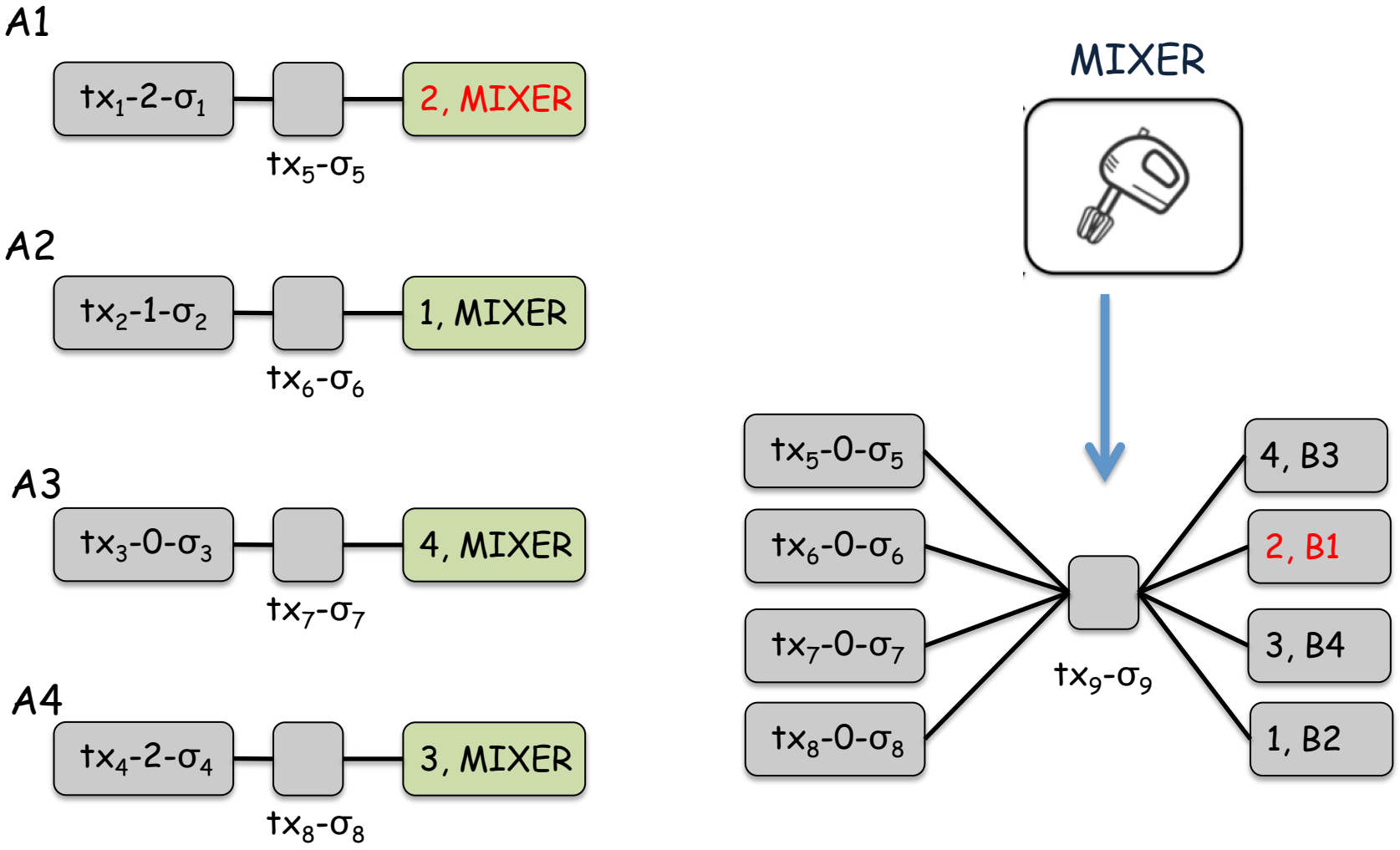

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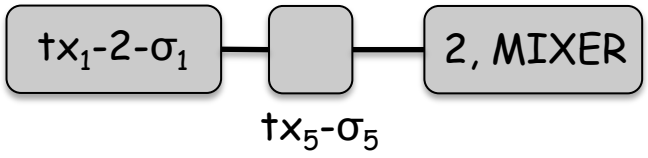

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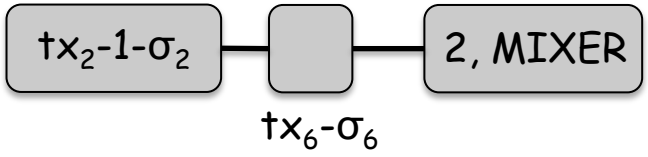

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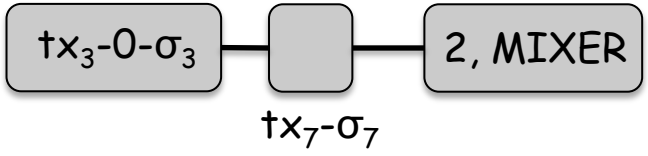

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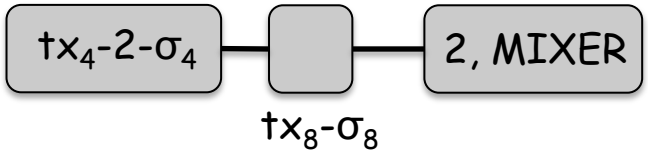

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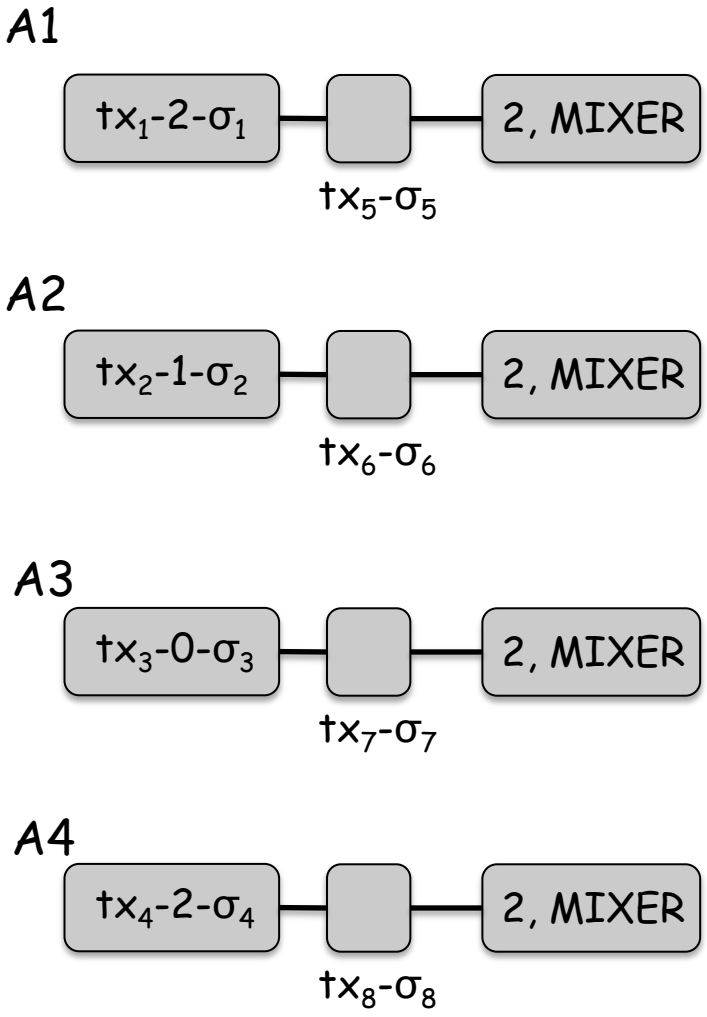

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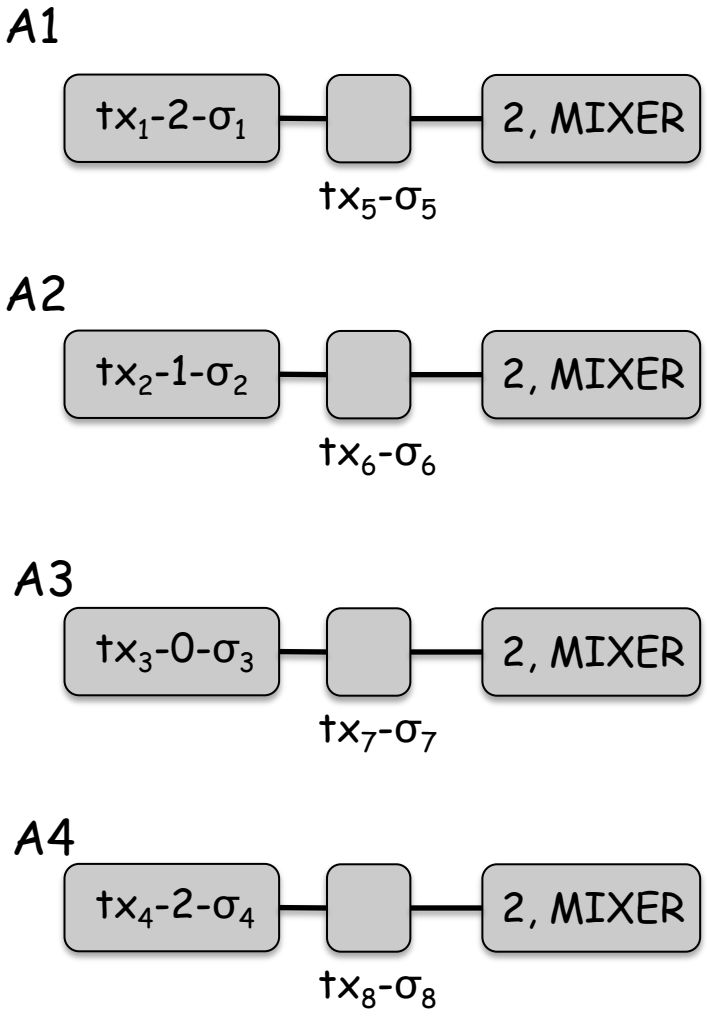

- transaction amount should be same to be indistinguishable
- mixer should be trusted
  - it can steal the money
  - it knows all the senders and receivers addresses, it can reveal that information

Privacy Enhancing Techniques - Mixing

Mixcoin

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- mixer may reveal the sender's and receiver's address

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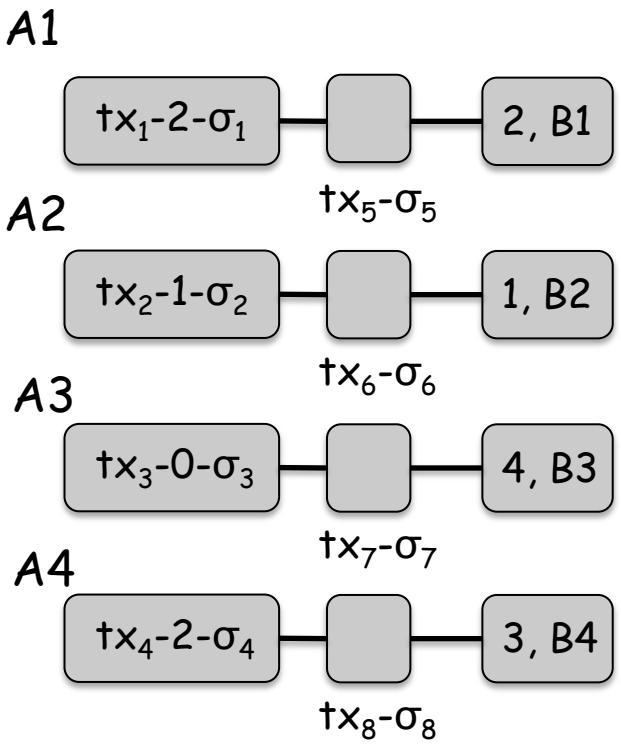

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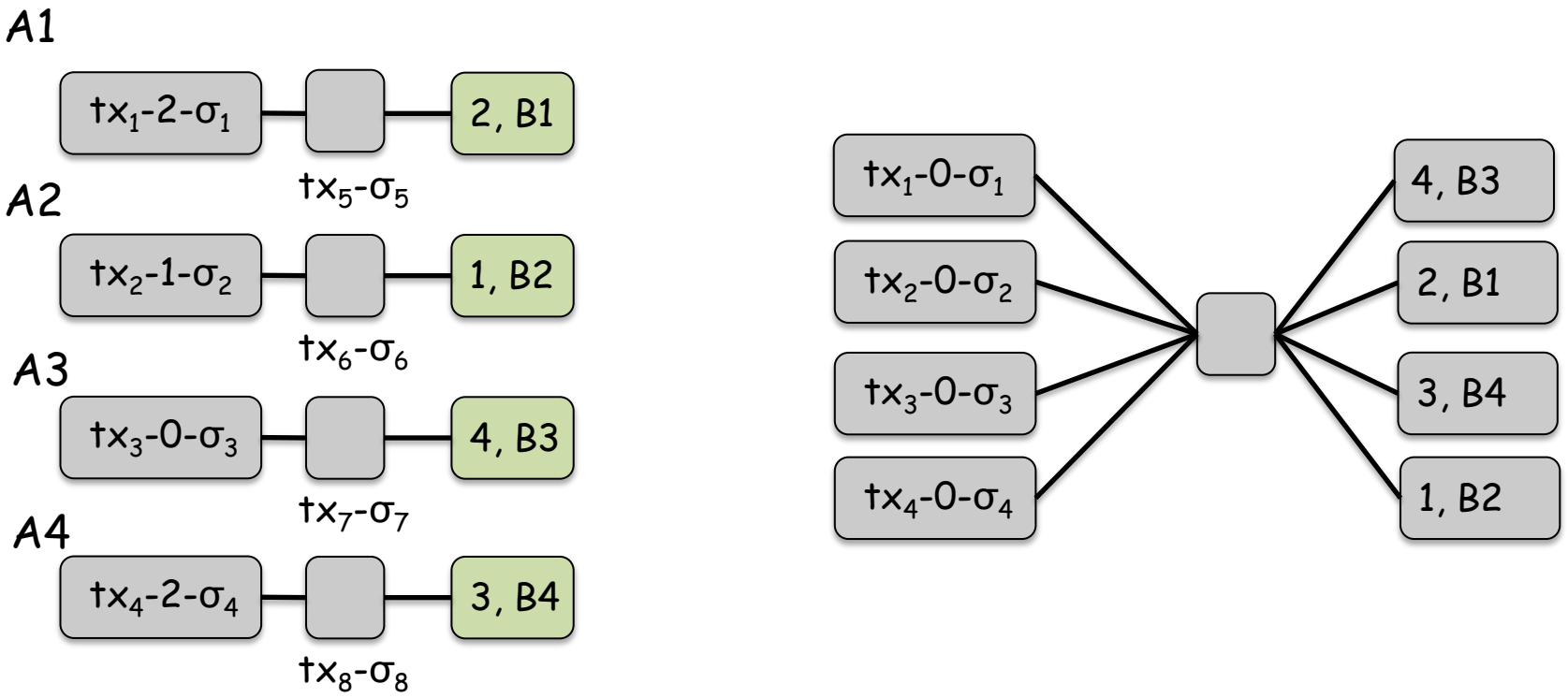

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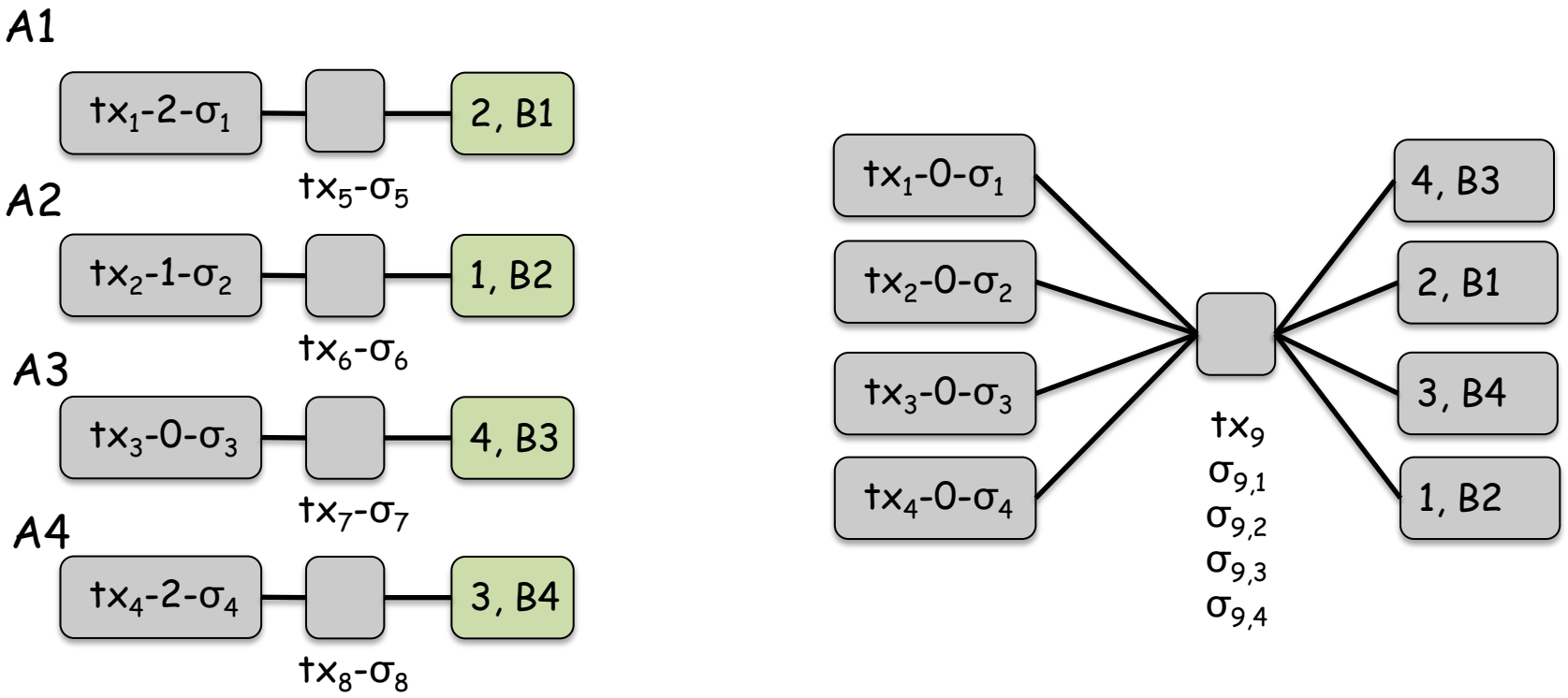

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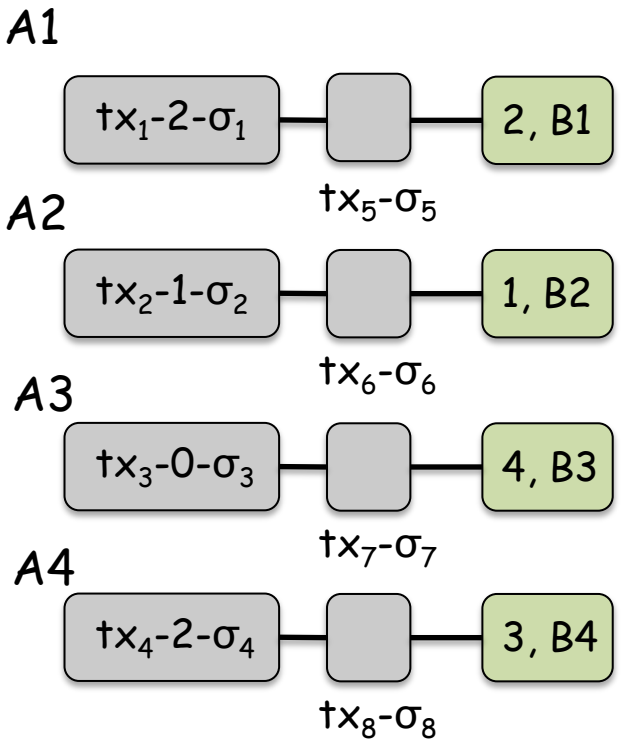
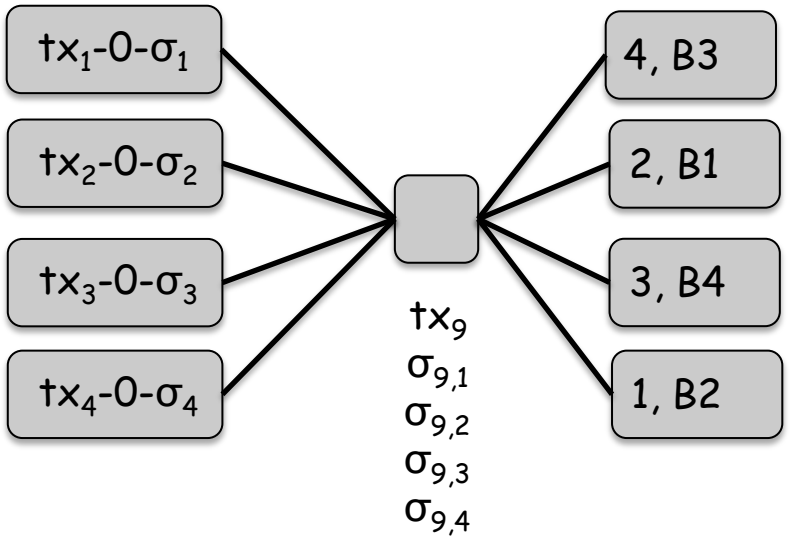


- insiders can reveal the link of each transaction



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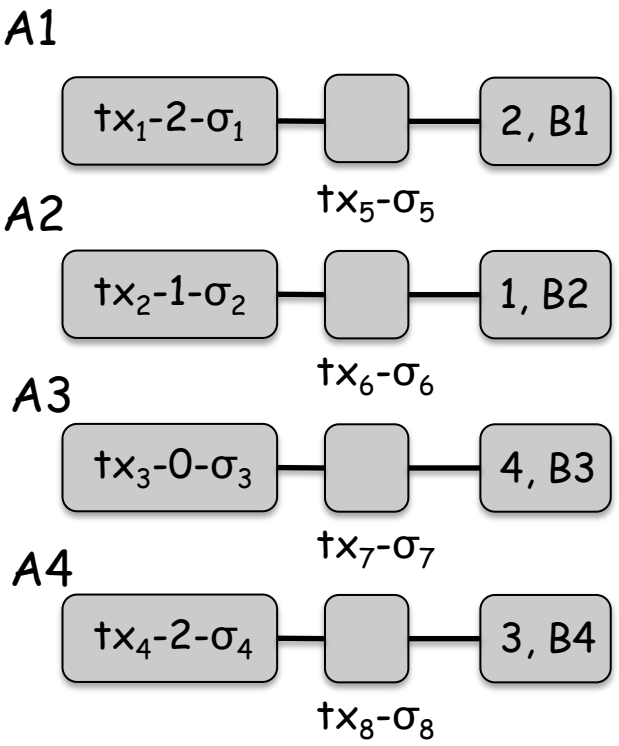

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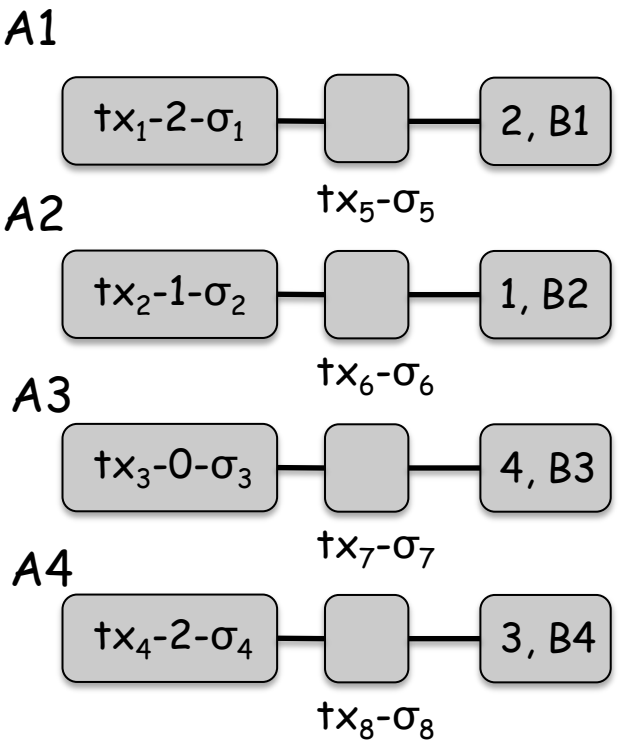

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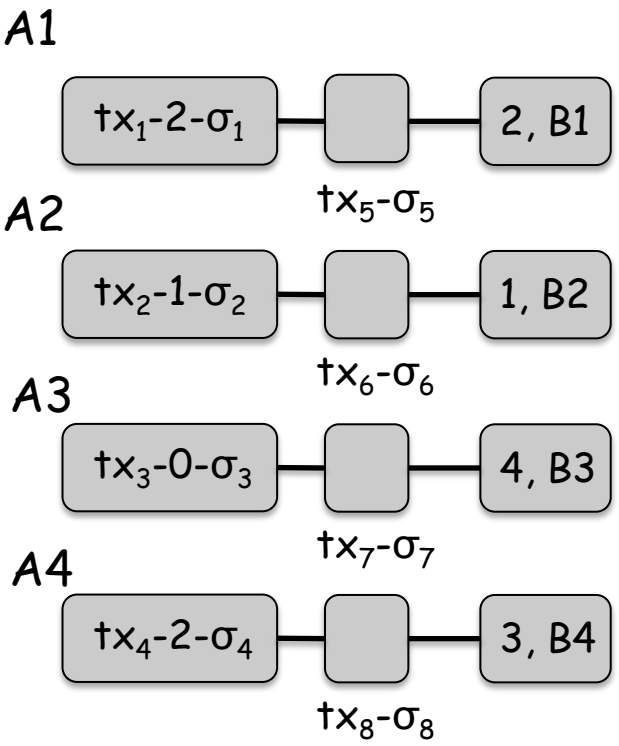

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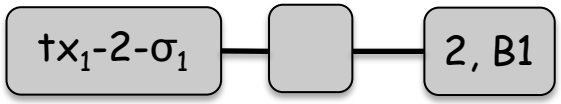
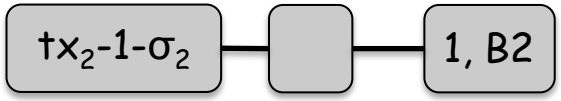


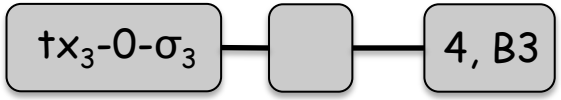
tx_5-σ_5

A2



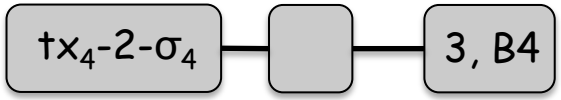
tx_6-σ_6

A3



tx_7-σ_7

A4



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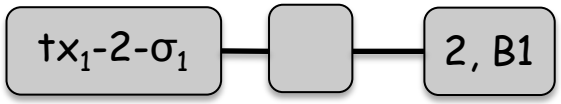

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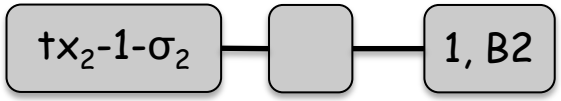

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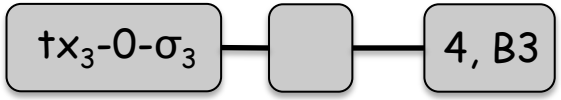

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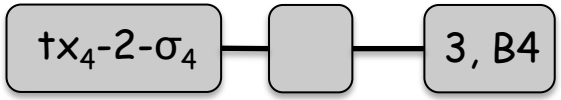

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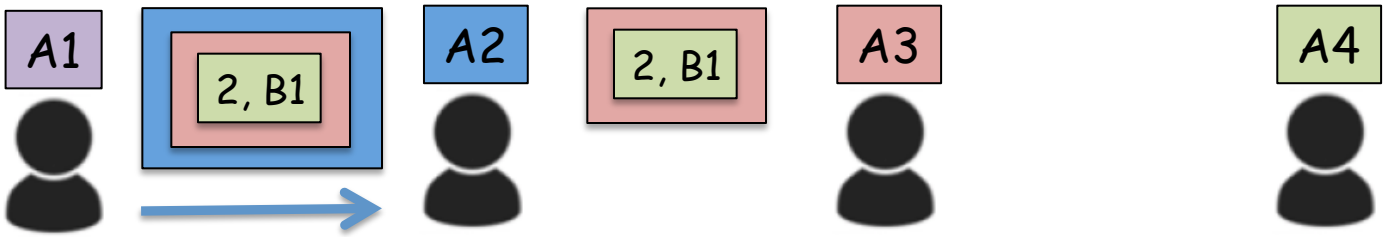

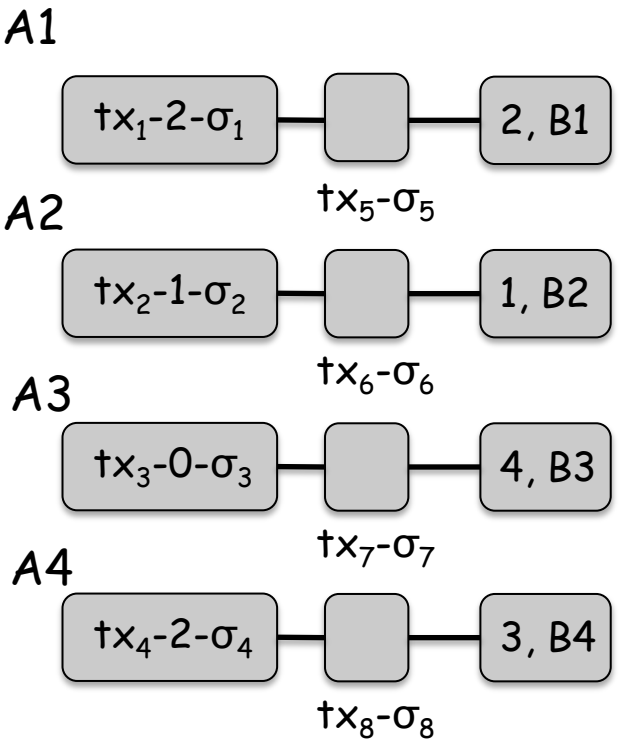

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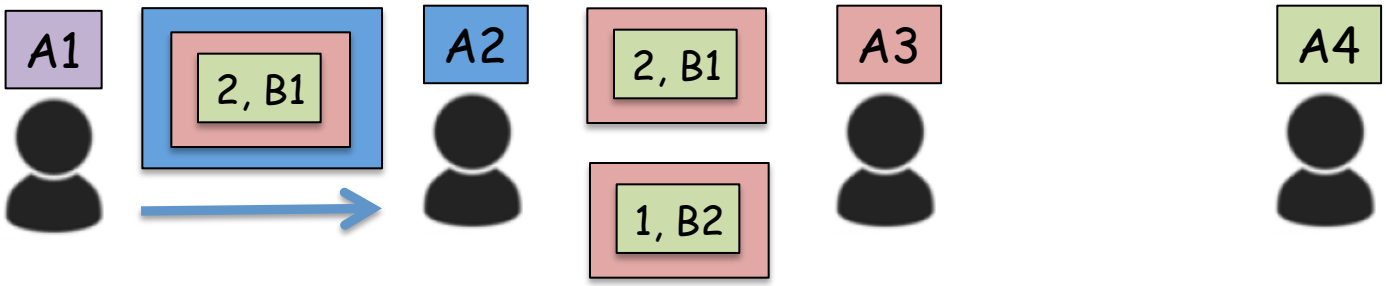

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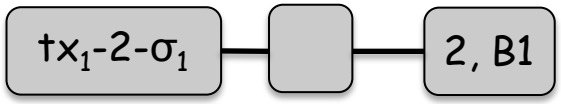

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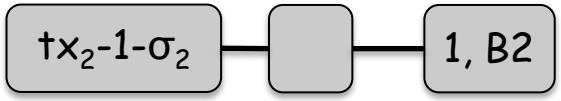

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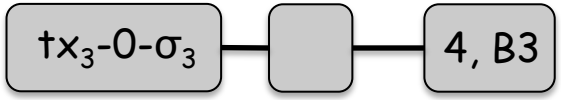

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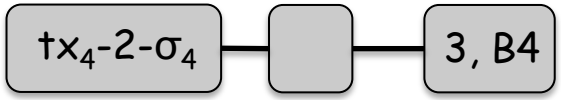

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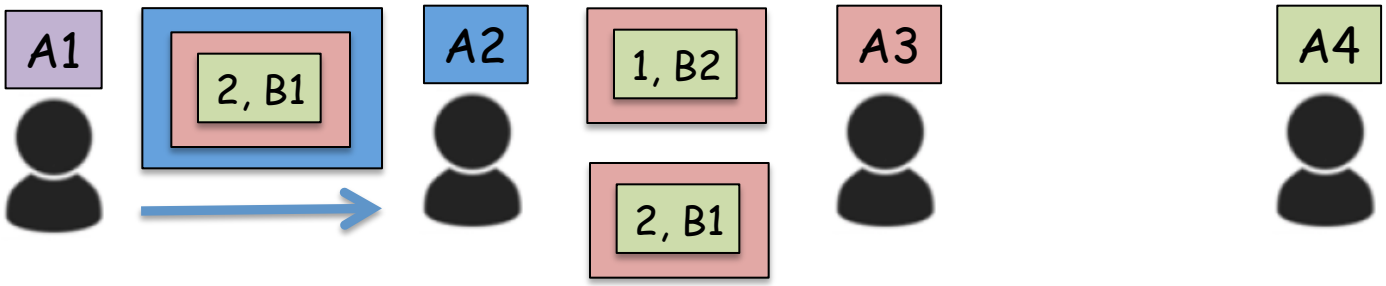

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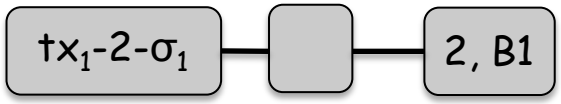

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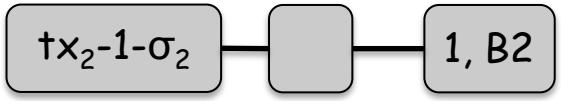

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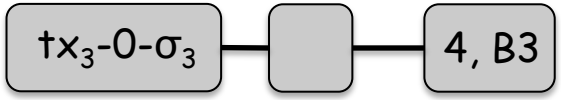

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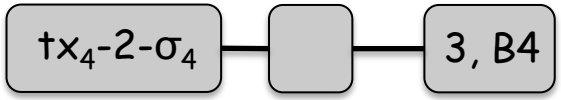

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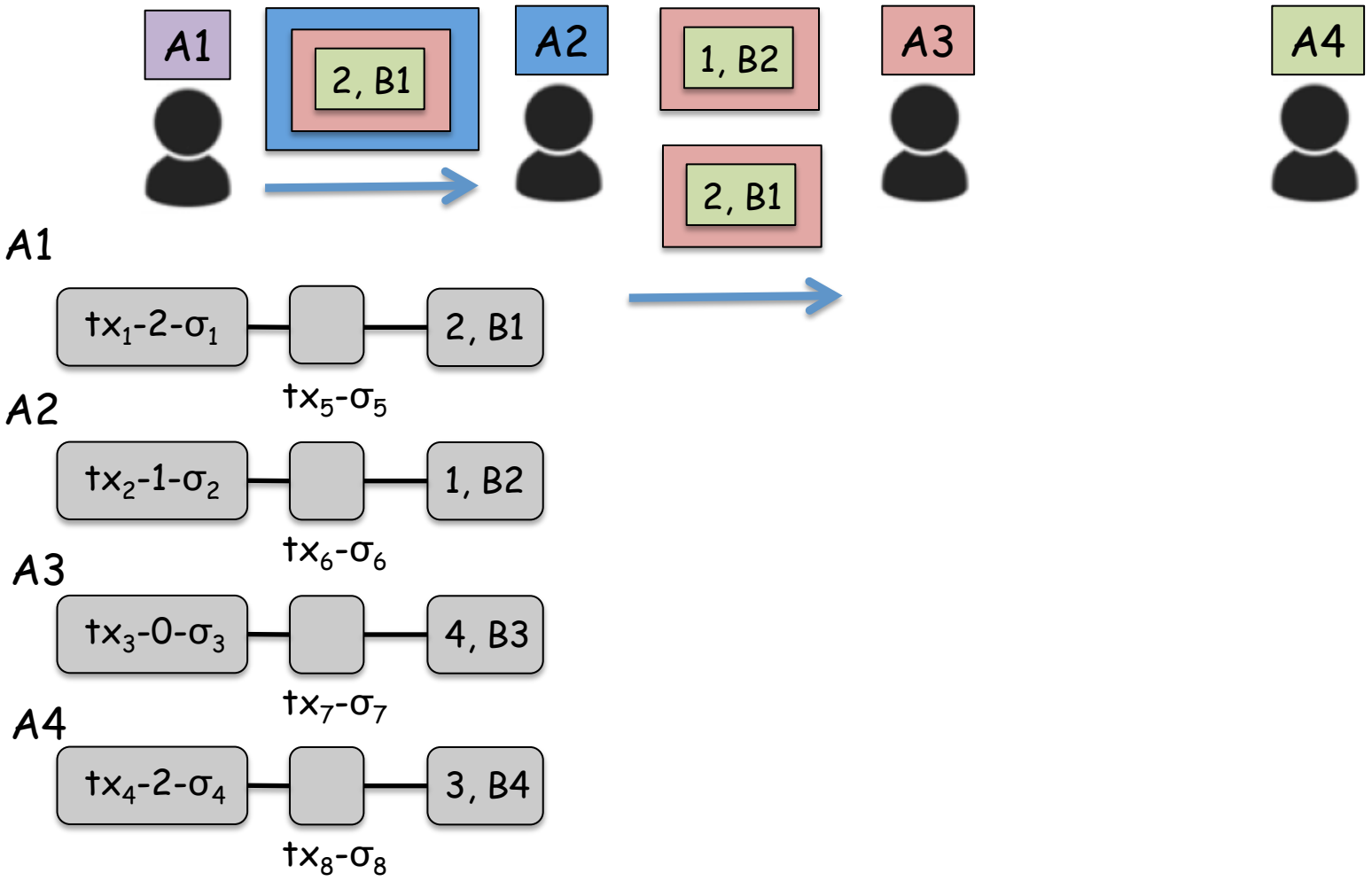

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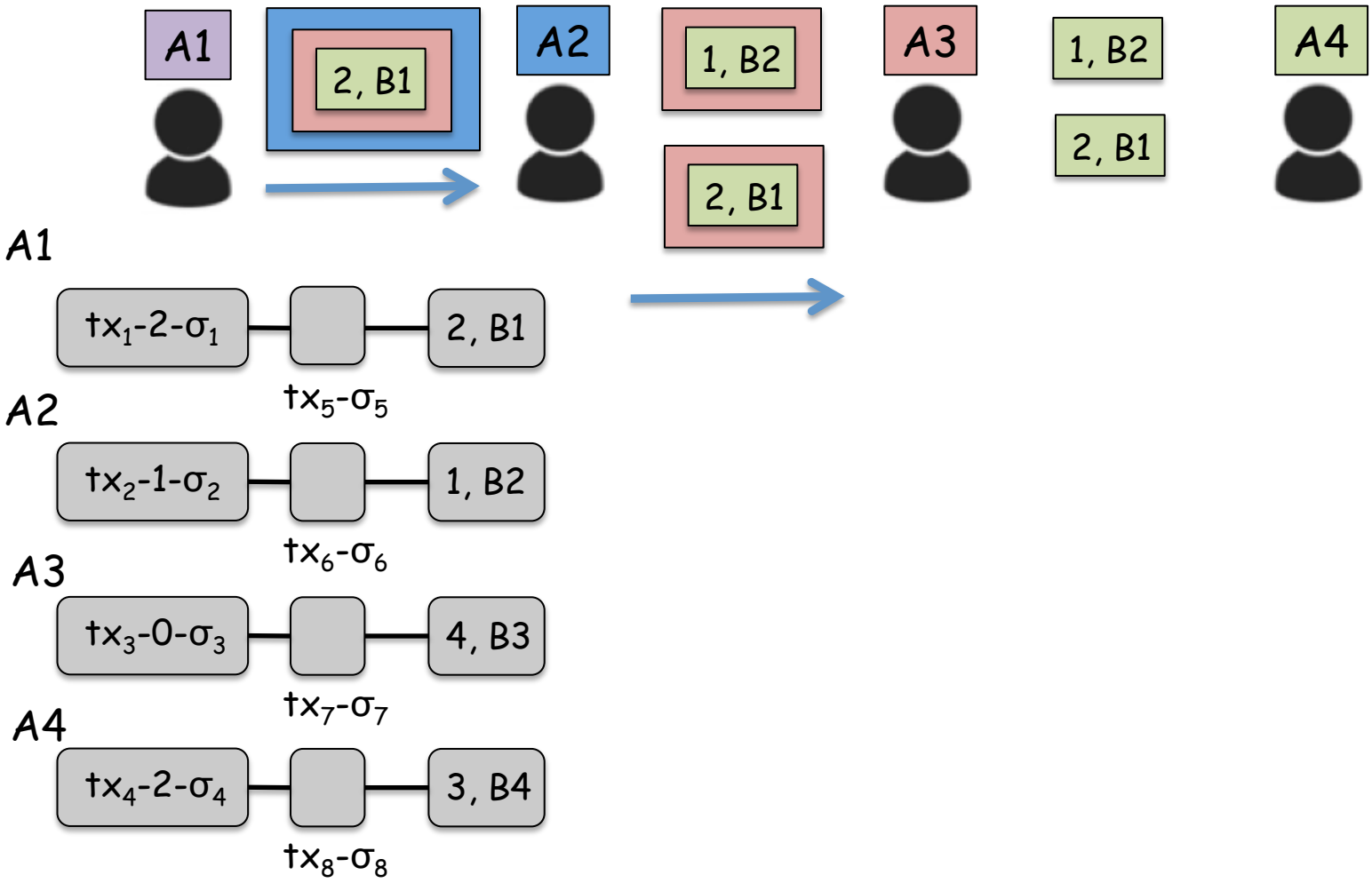

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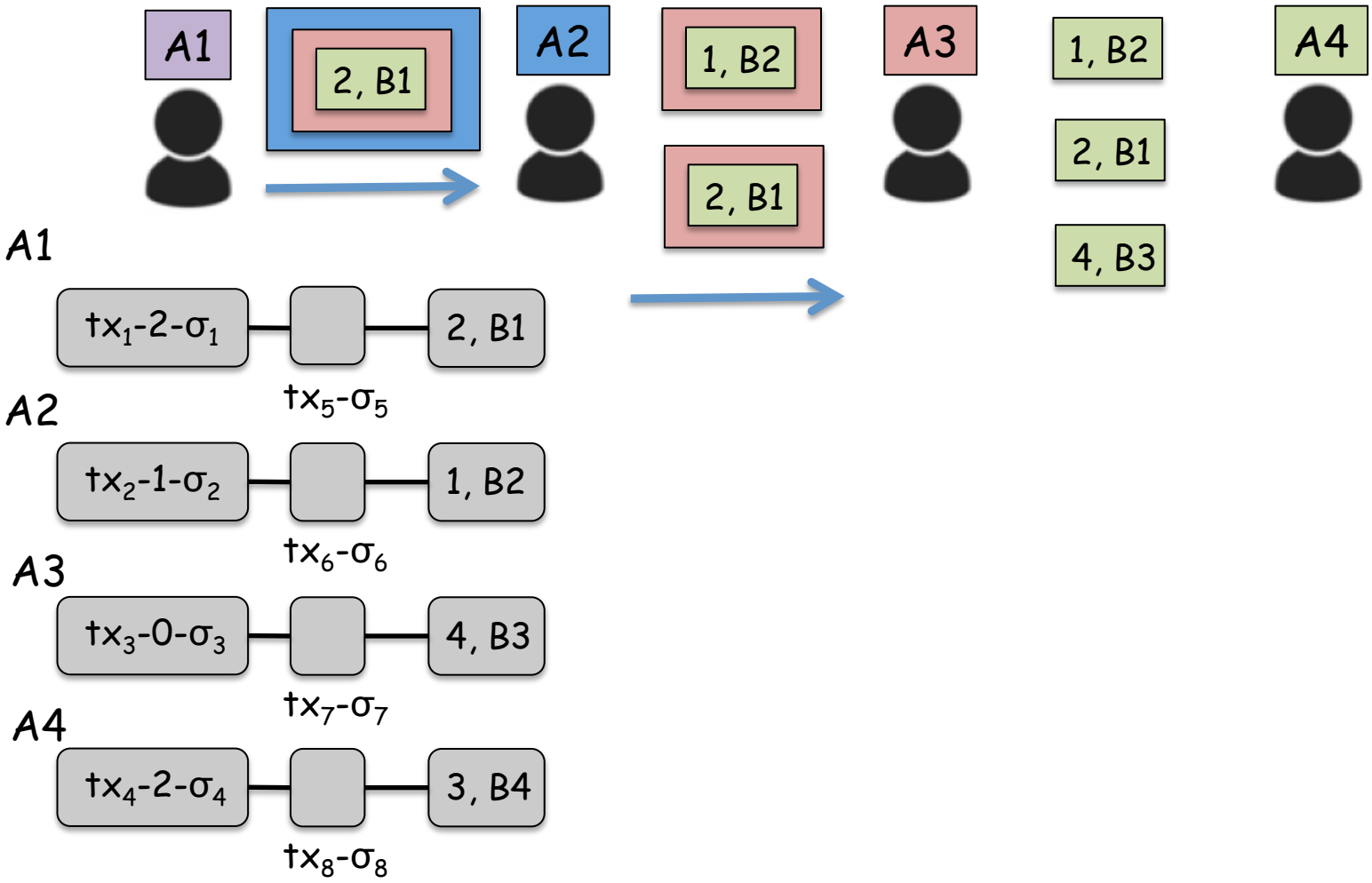

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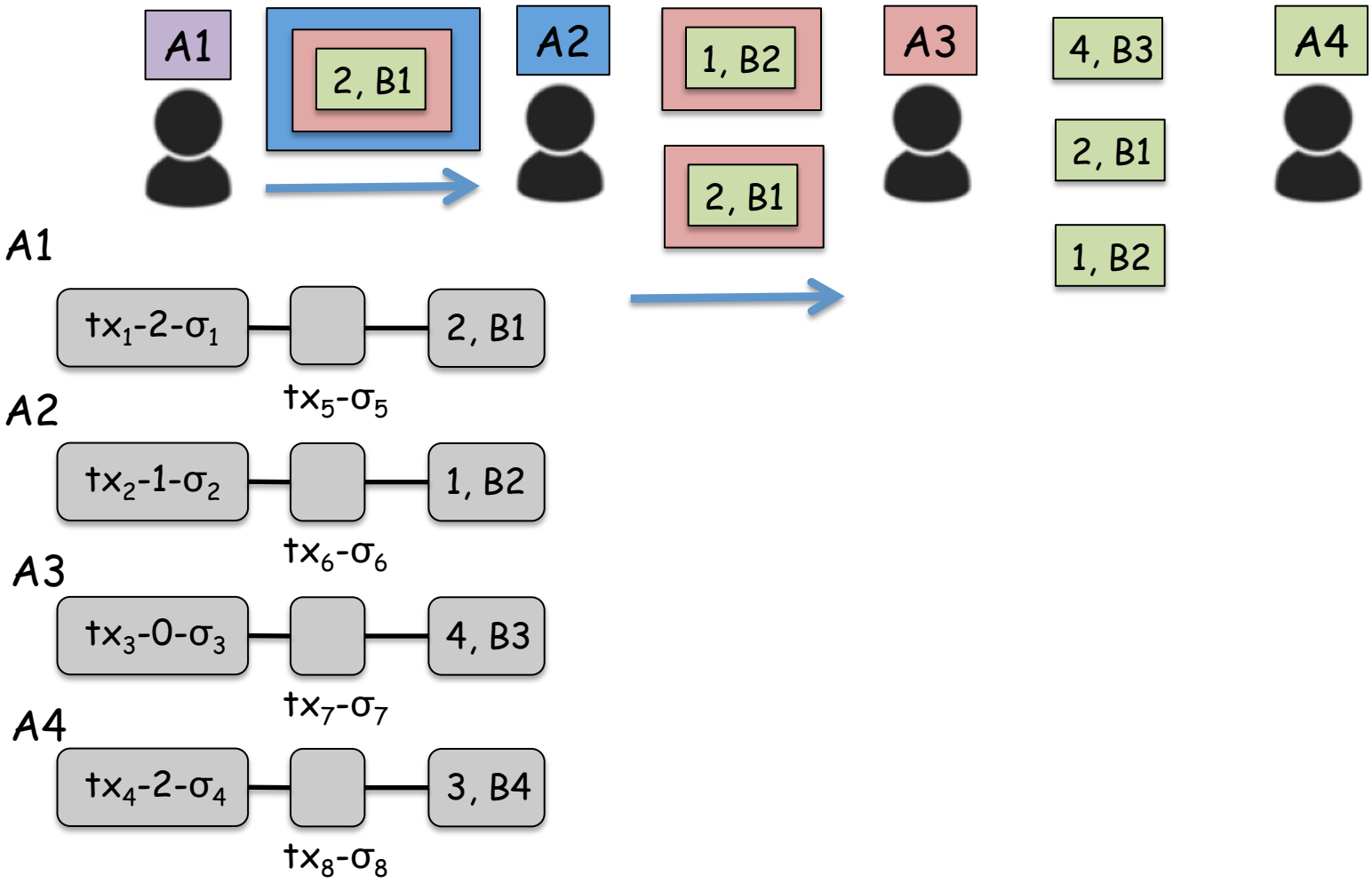

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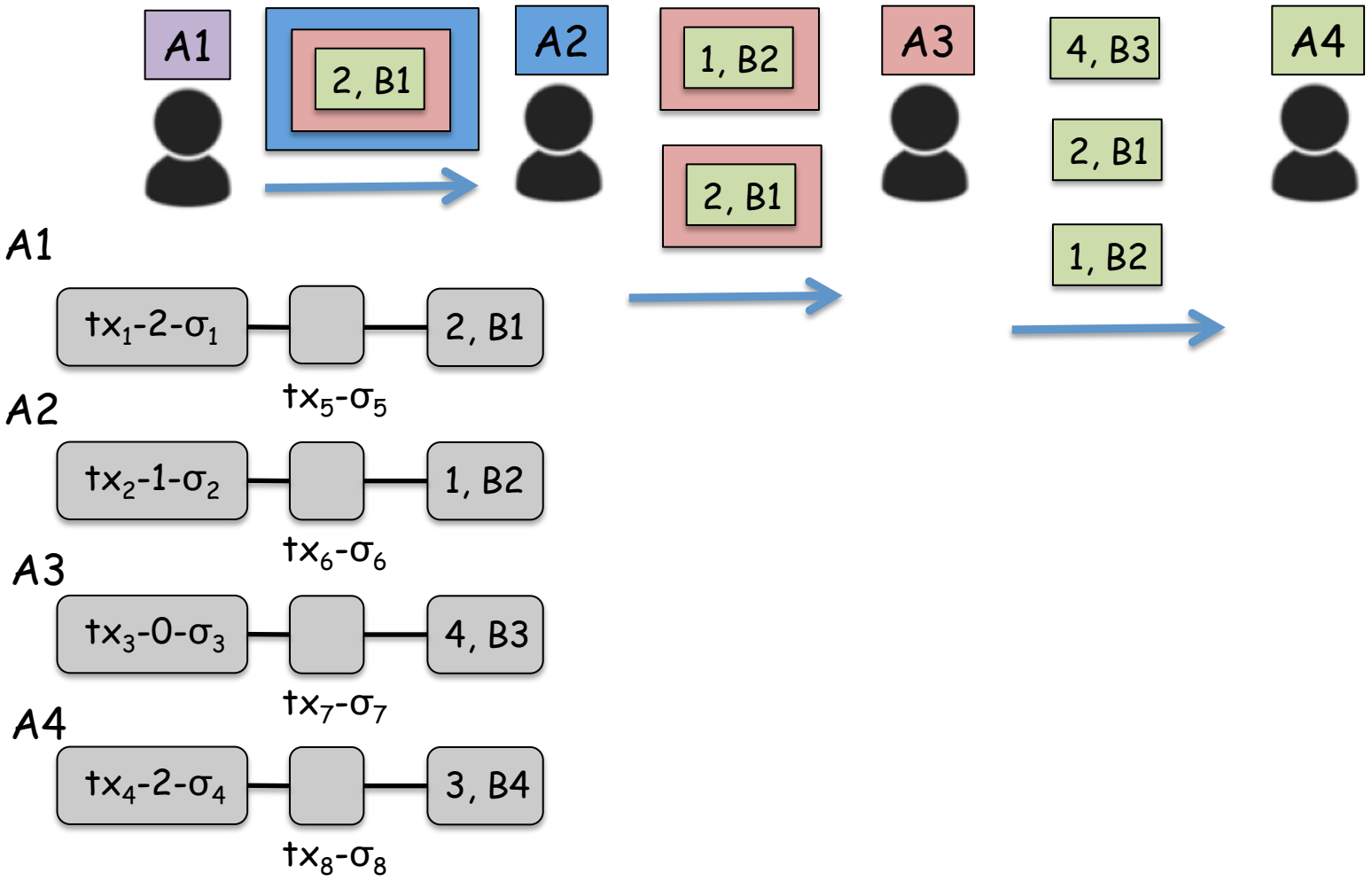

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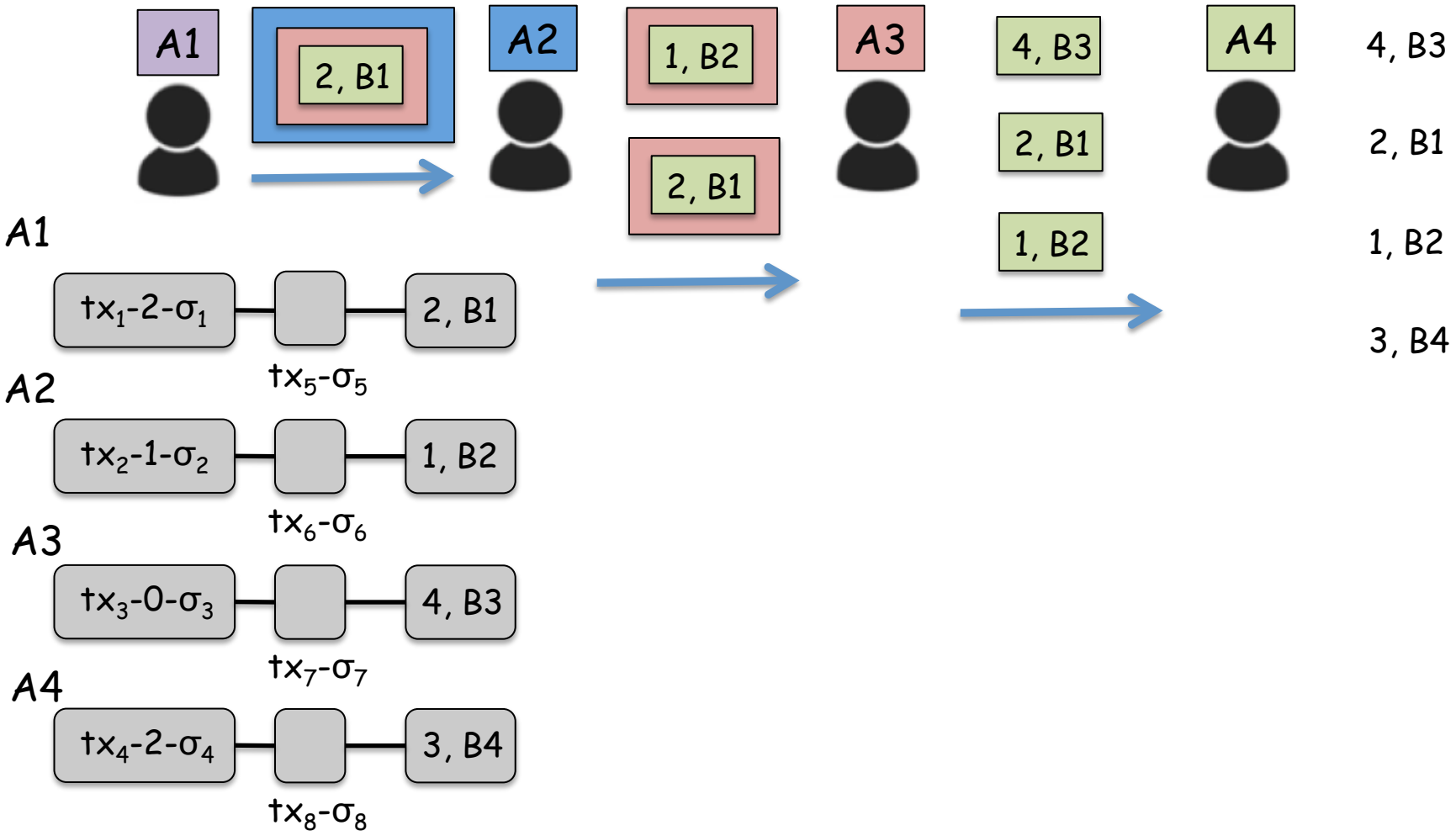

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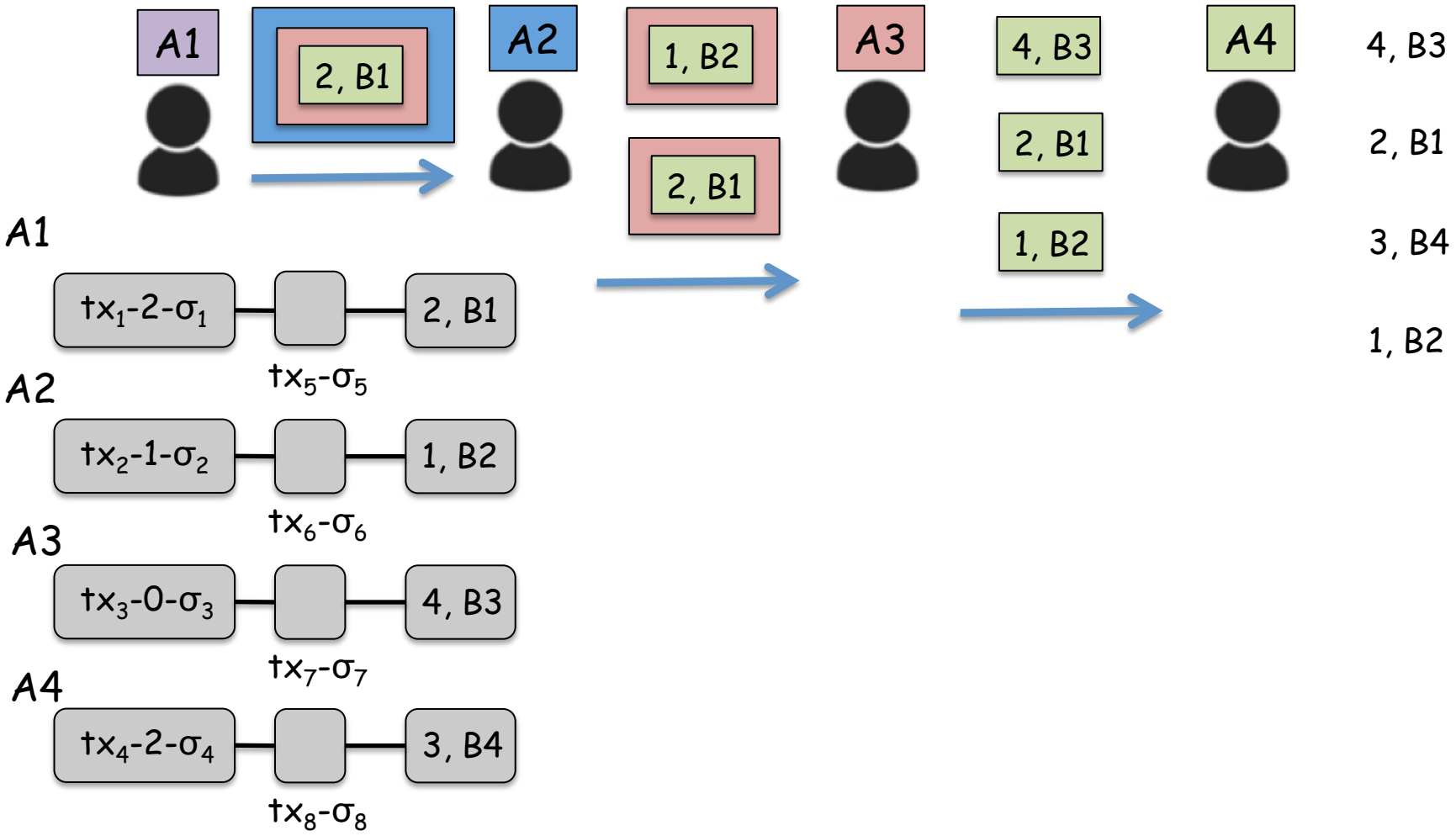

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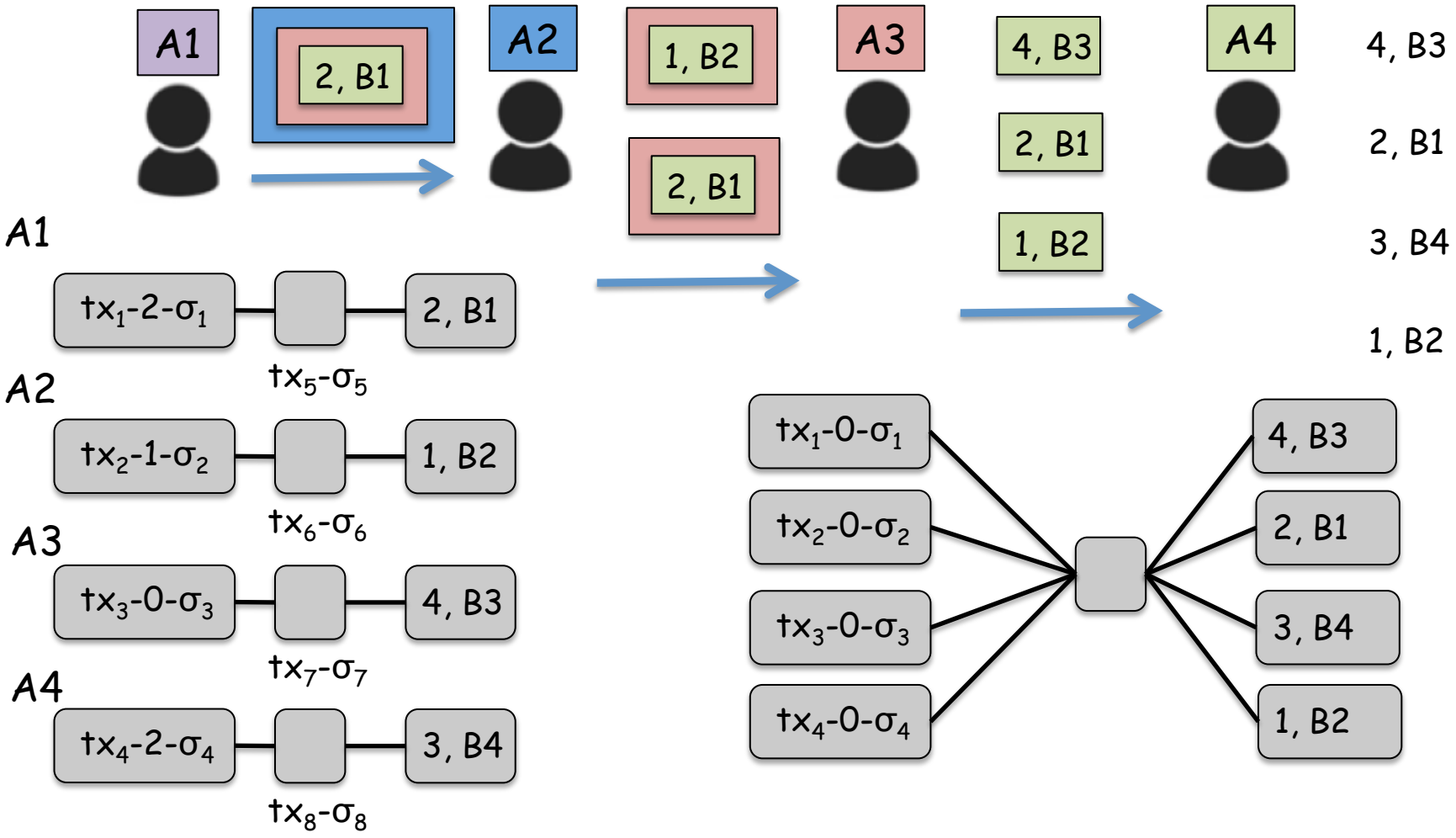

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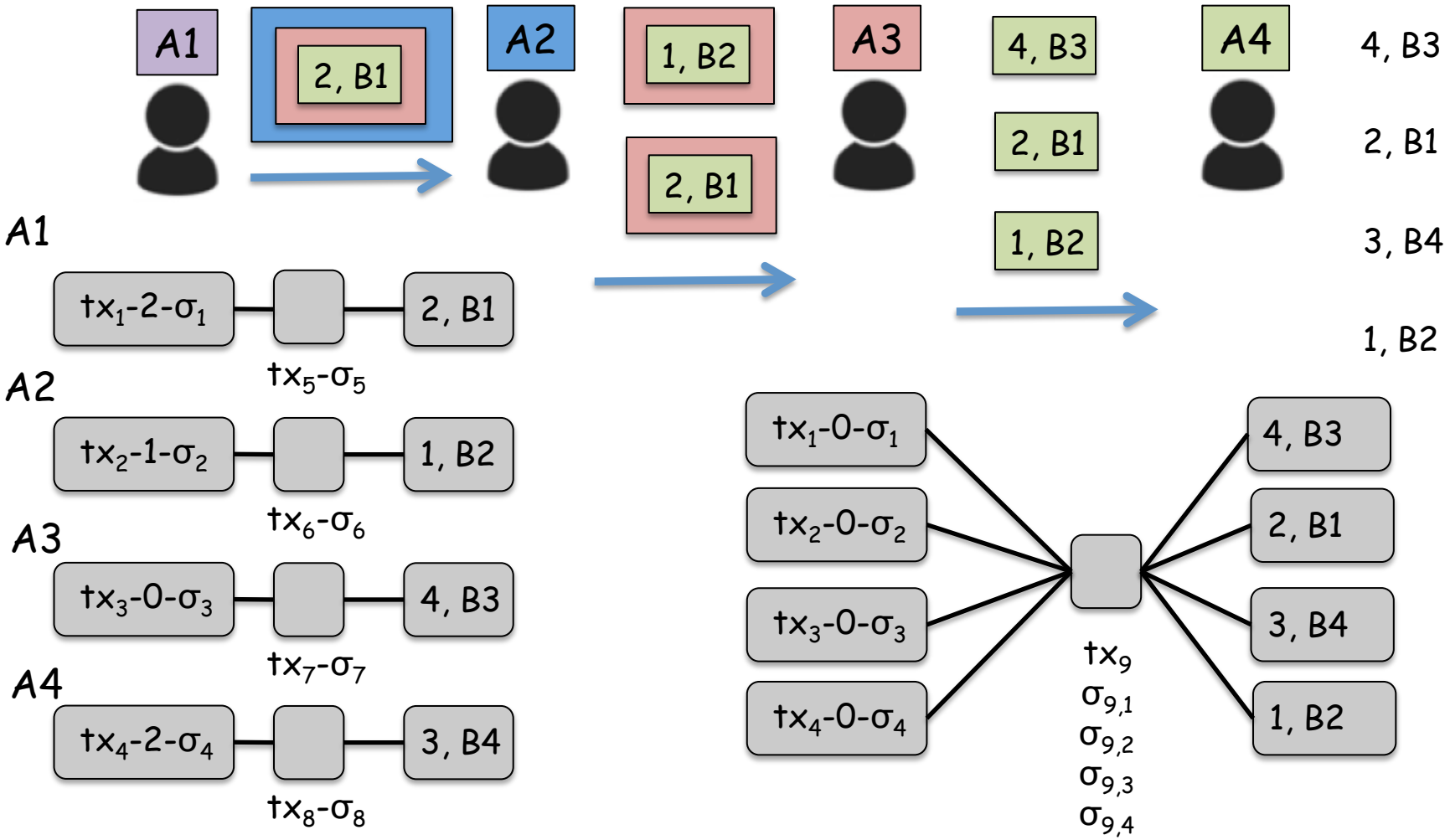
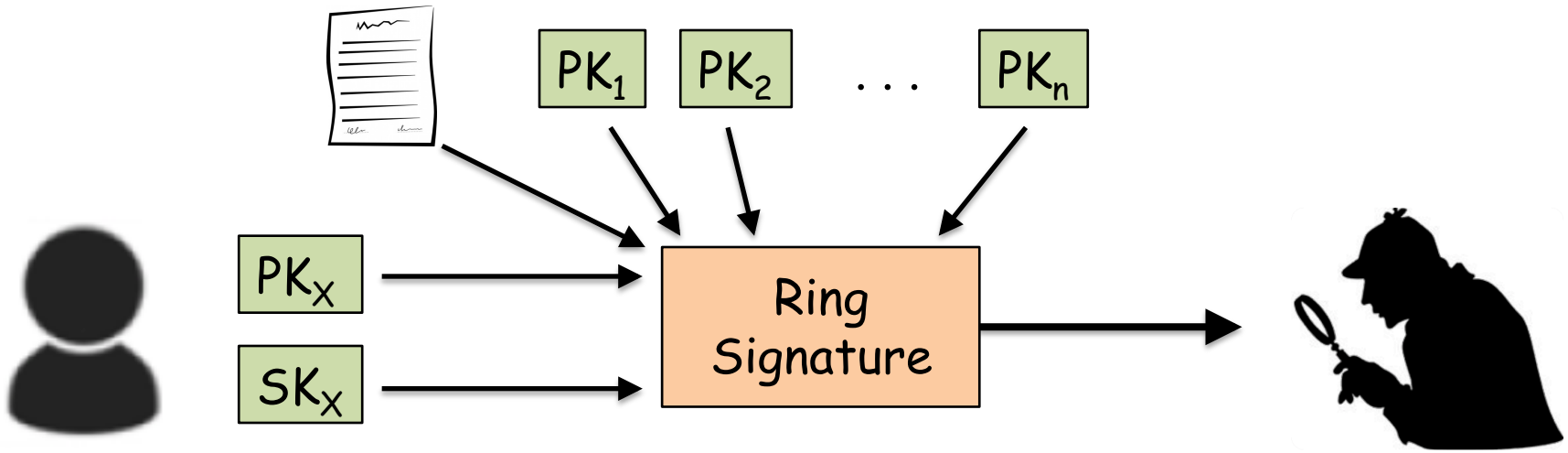


Privacy Enhancing Techniques - Ring Signatures

- introduced by Rivest et al. [5] in 2001



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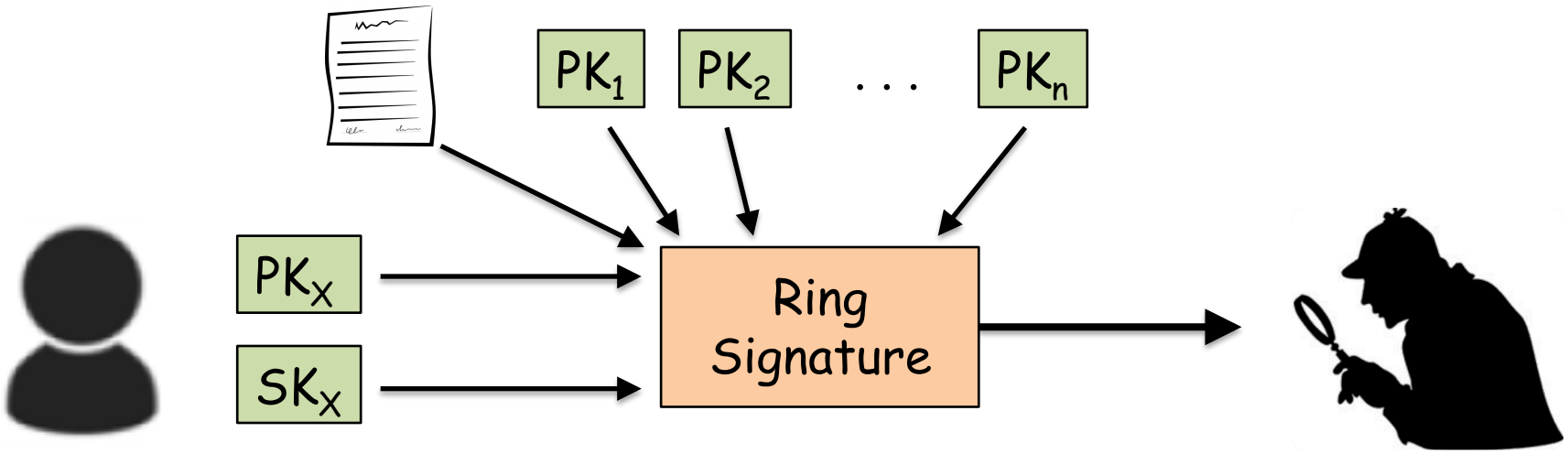

- verifier can tell that one member from the set {PK_1, PK_2, …, PK_n, PK_X} signed the message, but cannot tell which one the actual signer

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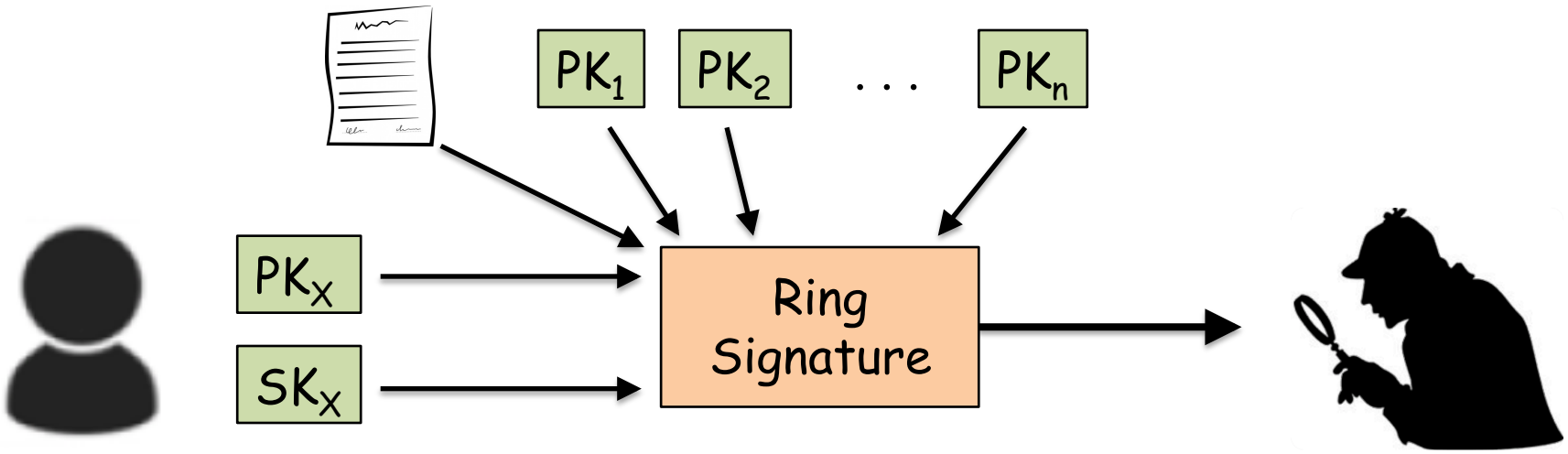

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  - one can vote for two different candidate without being detected

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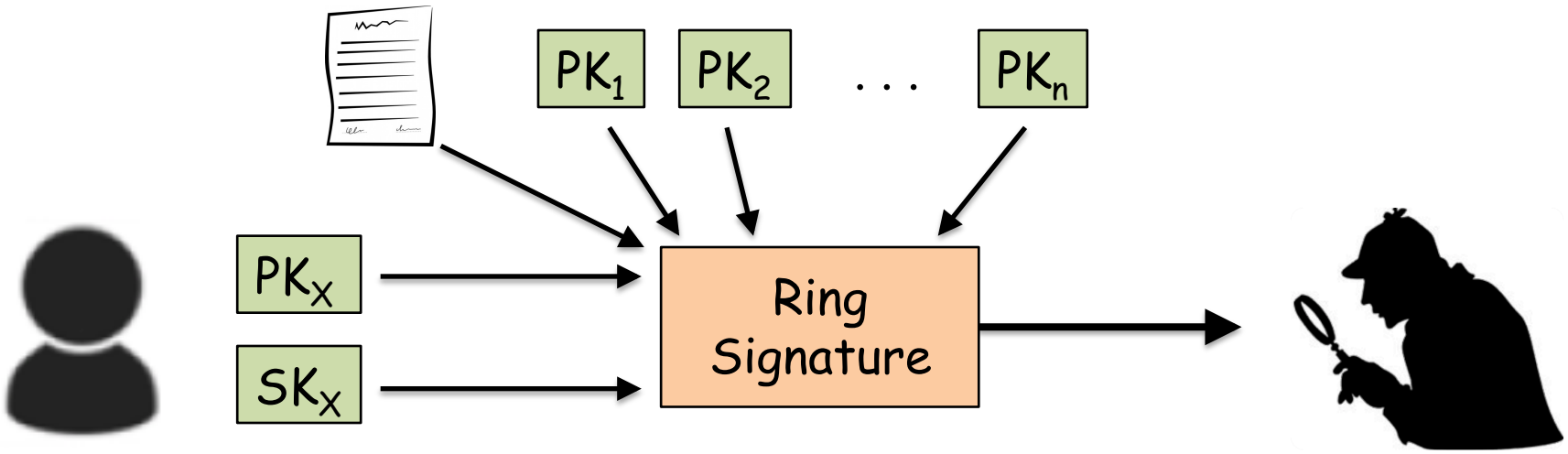

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- assume you designing a voting scheme using ring signatures
  - one can vote for two different candidate without being detected
  - traceable ring signatures, introduced by Fujisaka and Suzuki [6] in 2007, enabling us to detect if two signatures produced by same user

Privacy Enhancing Techniques - Ring Signatures

CryptoNote

- introduced by van Saberhagen [7] in 2013

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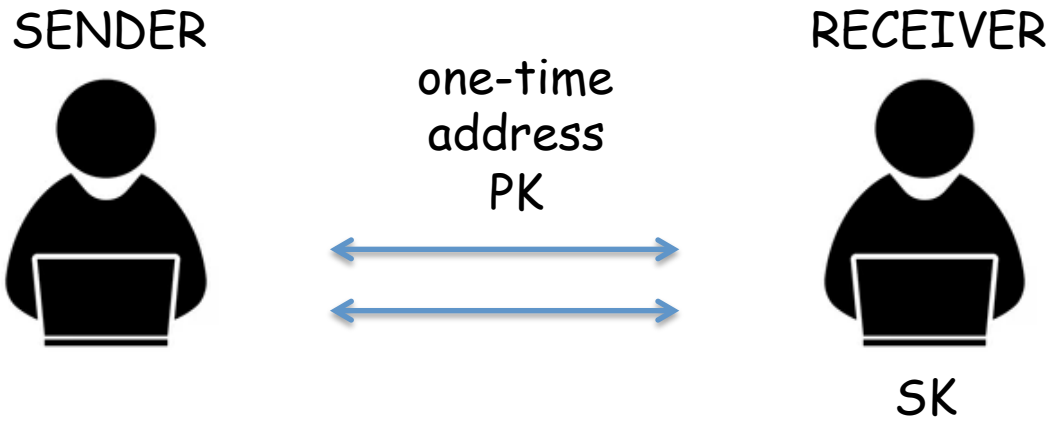

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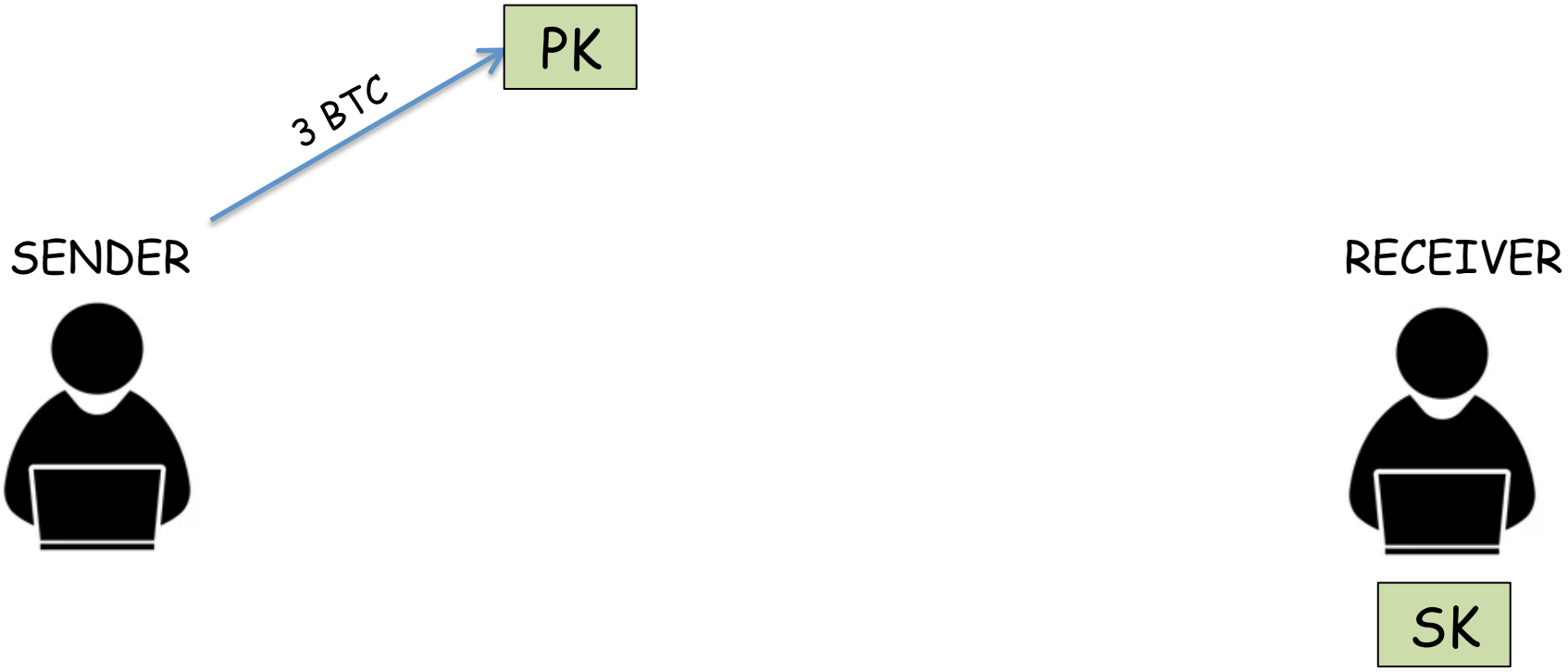

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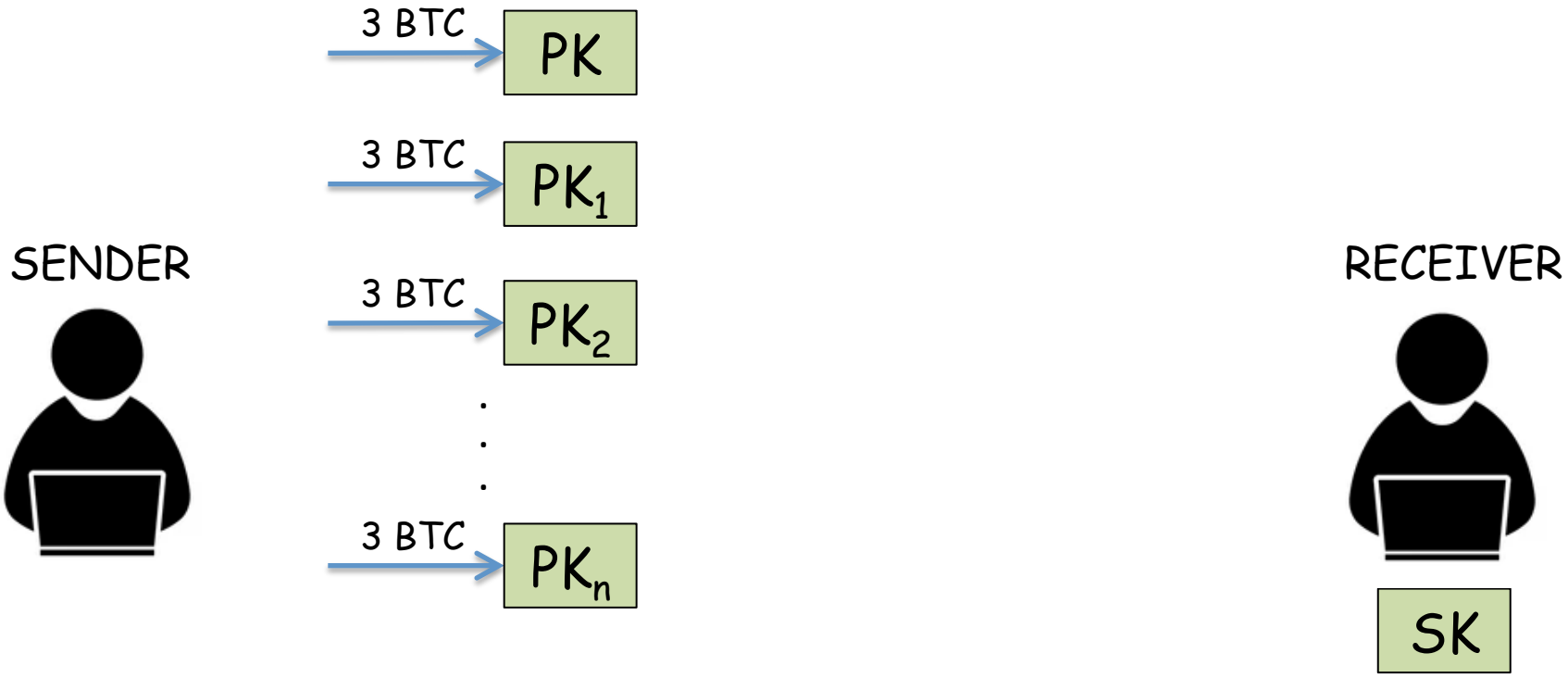

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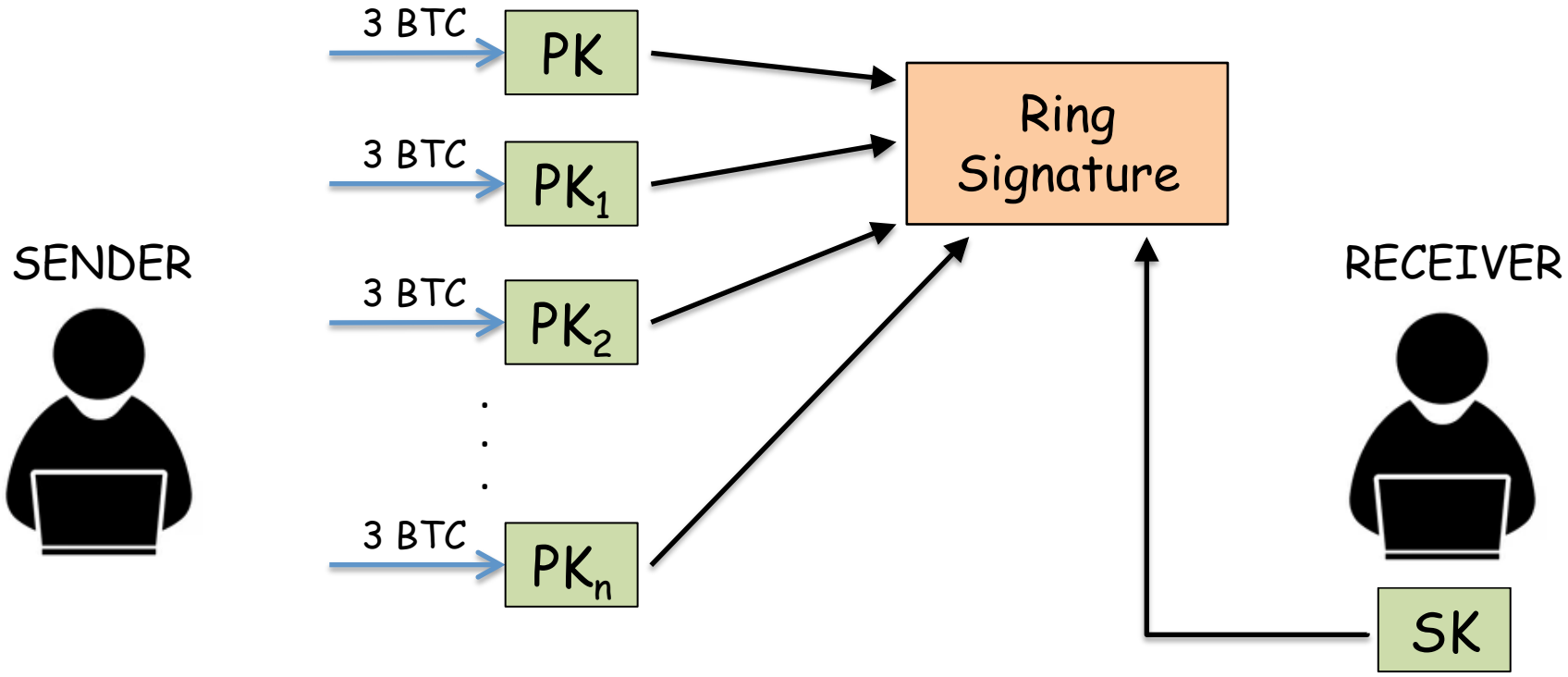
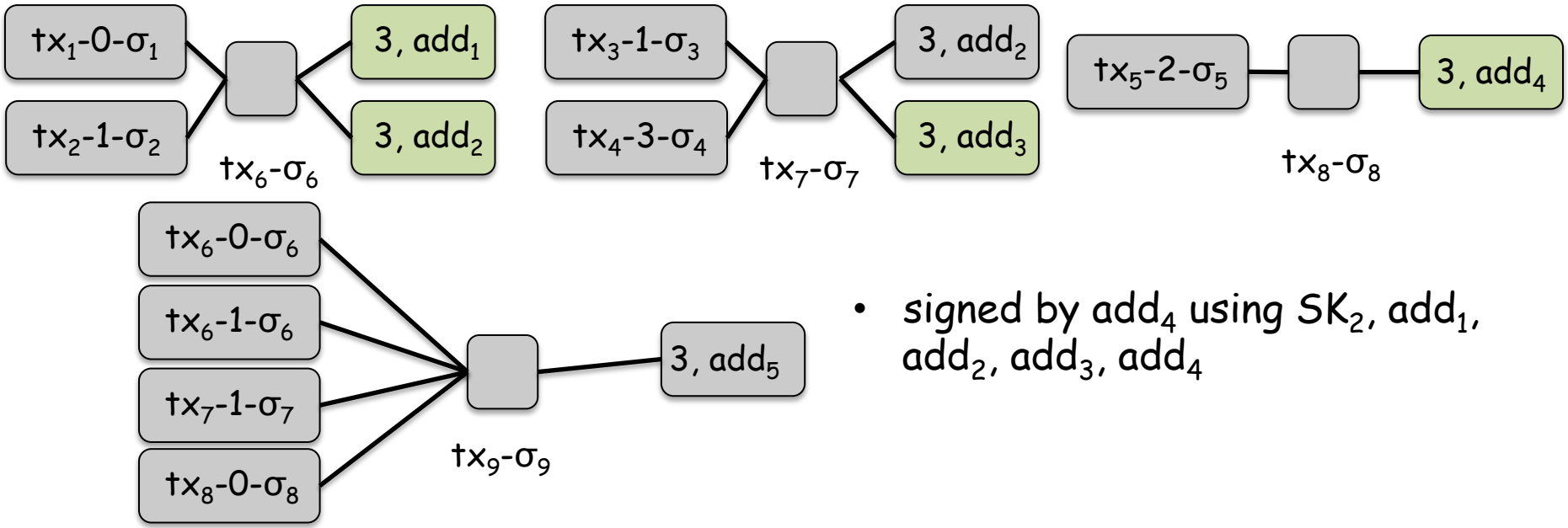


Privacy Enhancing Techniques - Ring Signatures

- the transfer of an amount bitcoin ownership rights from one address to another one
- each tx consists of two main fields :
  - input : unspent transaction outputs claimed by the sender from previous transactions (previous transaction id, index, scriptsign)
  - output : instructions for claiming the sent bitcoins (value, scriptpublickey)
- if the transaction output not spent before, and the signature is valid, the transaction considered as valid



- signed by add_4 using SK_2, add_1, add_2, add_3, add_4

Privacy Enhancing Techniques - Ring Signatures

CryptoNote

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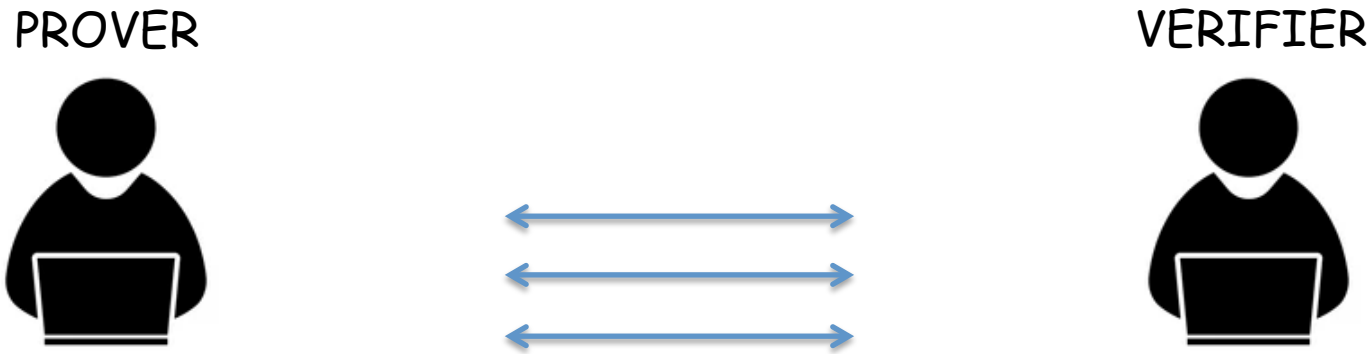
- Kumar et al. [8] analized Monero network to examine the untreacibility characteristics of CryptoNote

  - 93% of all transaction output amounts appear only once in the network
    (cannot be combined with others to form ring signatures)

  - users mostly use small number of transaction outputs to avoid high fees

Privacy Enhancing Techniques - Zero Knowledge

- introduced by Goldwasser et al. [9] in 1985



- allows one party (prover) to convince another party (verifier) that a statement is true without revealing any information other than this fact

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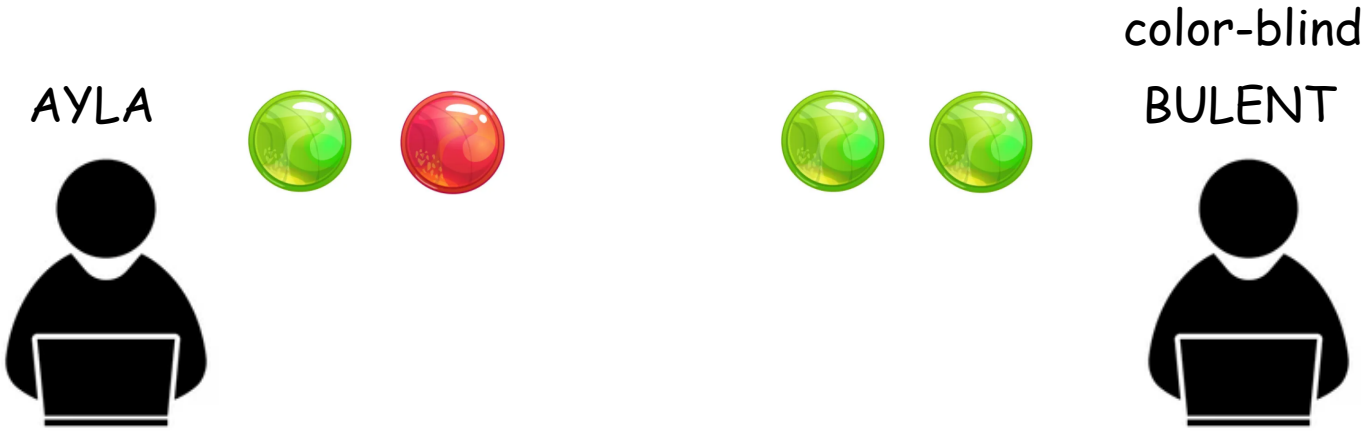

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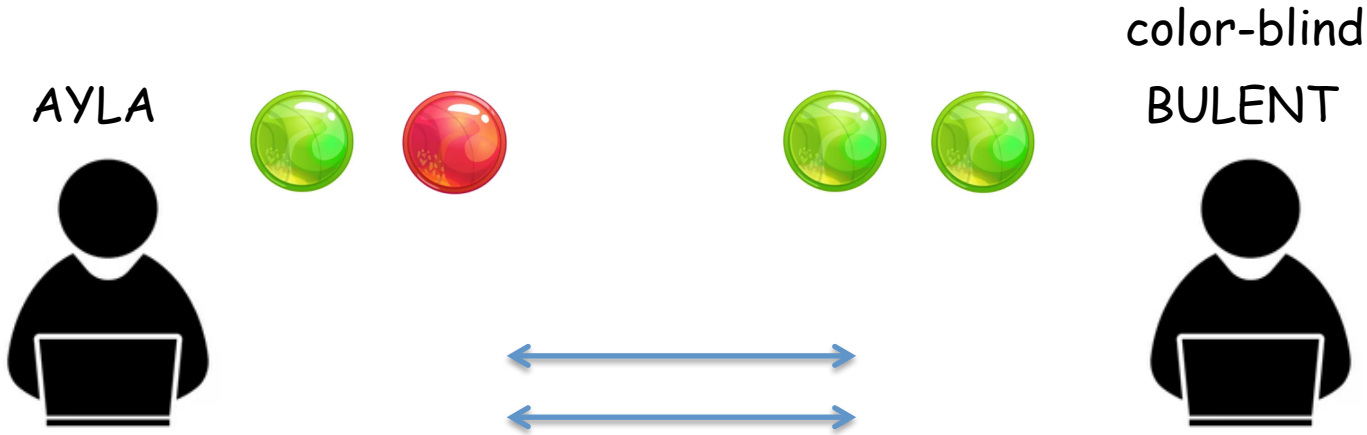

Ayla wants to convince Bulent they are in diffferent colors without revealing which one is red and which one is green

they seem completely identical to Bulent

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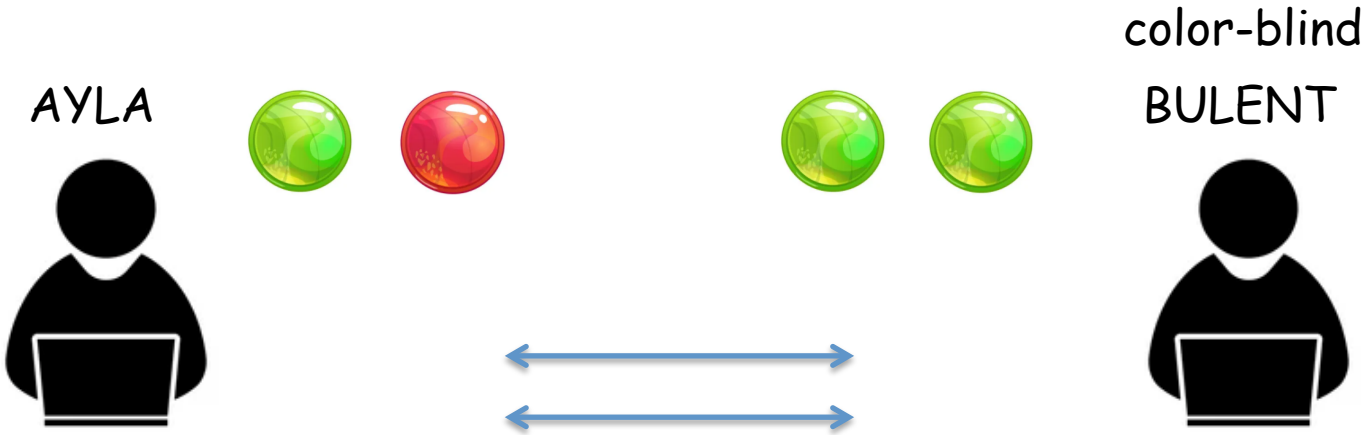

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he thinks they are actually distinguishable

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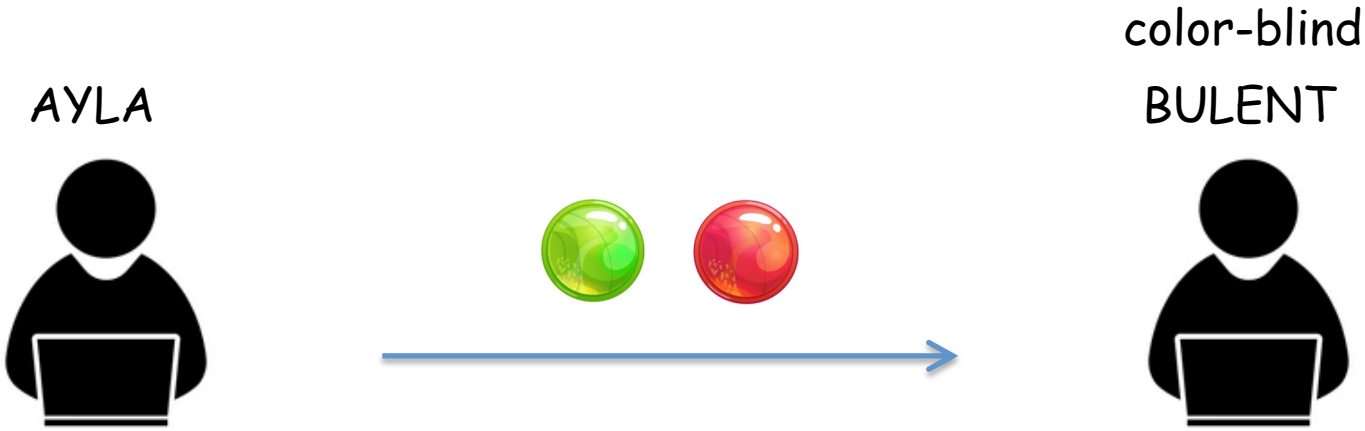

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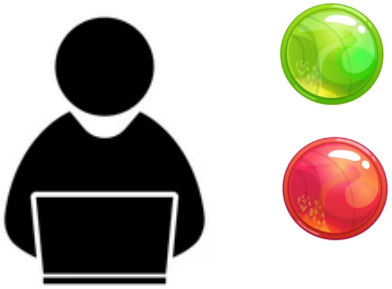
AYLA

color-blind

BULENT



he either switching the balls, or keeping them in same hands

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"Did I swtich the balls ?"

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- assume Ayla doesn't know which one green and which one is red
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$1 / 2 = 0.5$

$1 / 2^2 = 0.25$

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$1 / 2 = 0.5$

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$1 / 2 = 0.5$

$1 / 2^{10} = 0.00097$

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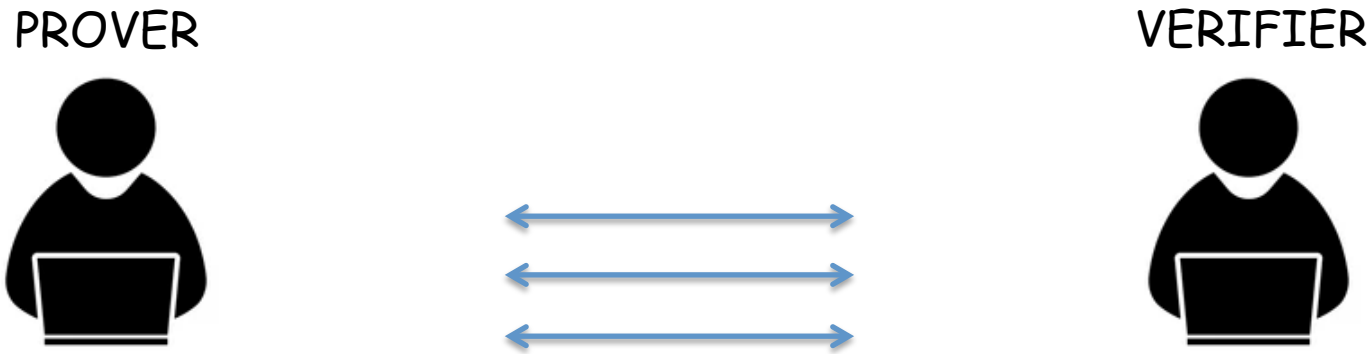

- allows one party (prover) to convince another party (verifier) that a statement is true without revealing any information other than this fact
- Completeness : if the statement is true, the honest verifier will be convinced by the honest prover
- Soundness : if the statement is false, no cheating prover can convince the honest verifier that it is true
- Zero-Knowledge : the verifier learns anything other than the statement is true

Privacy Enhancing Techniques - Zero-Knowledge

ZeroCoin

- introduced by Miers et al. [10] in 2013

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R = 13eBhR3

13eBhR3

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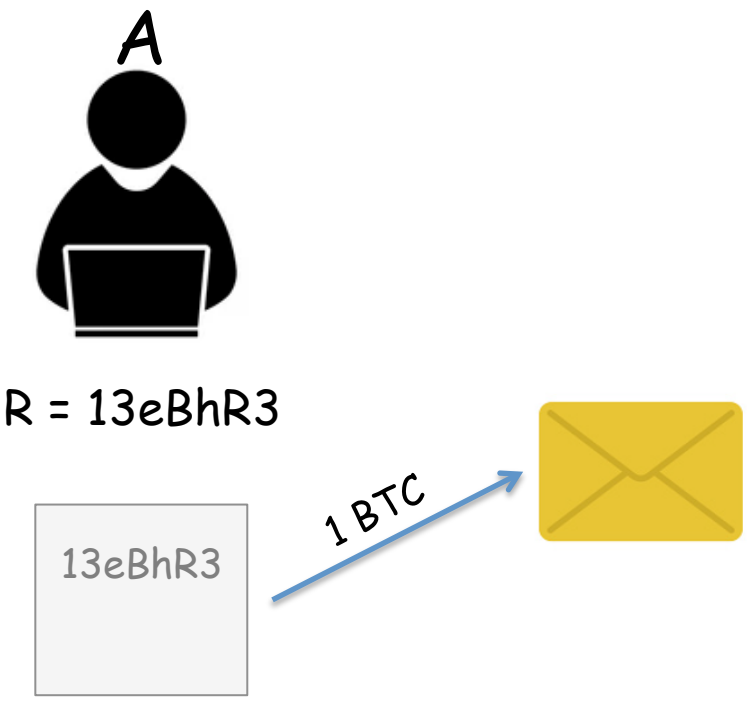

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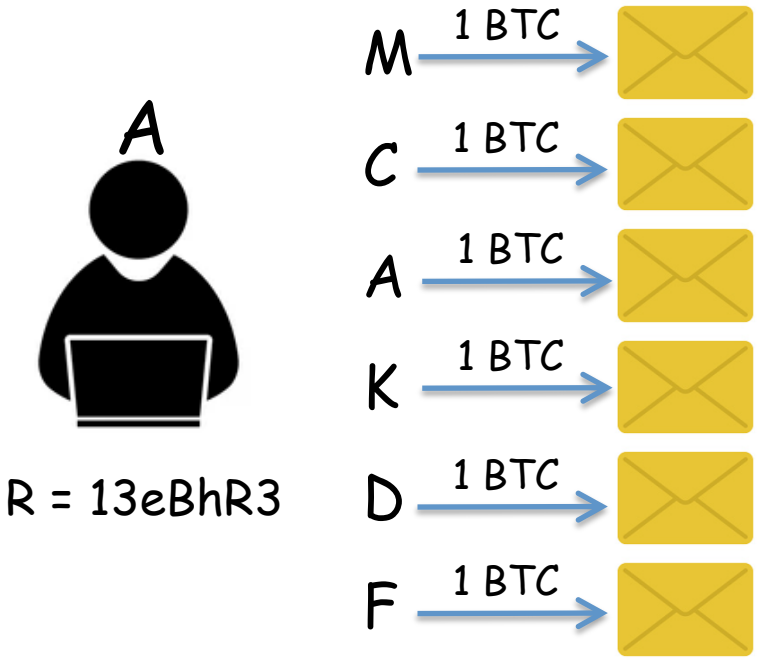

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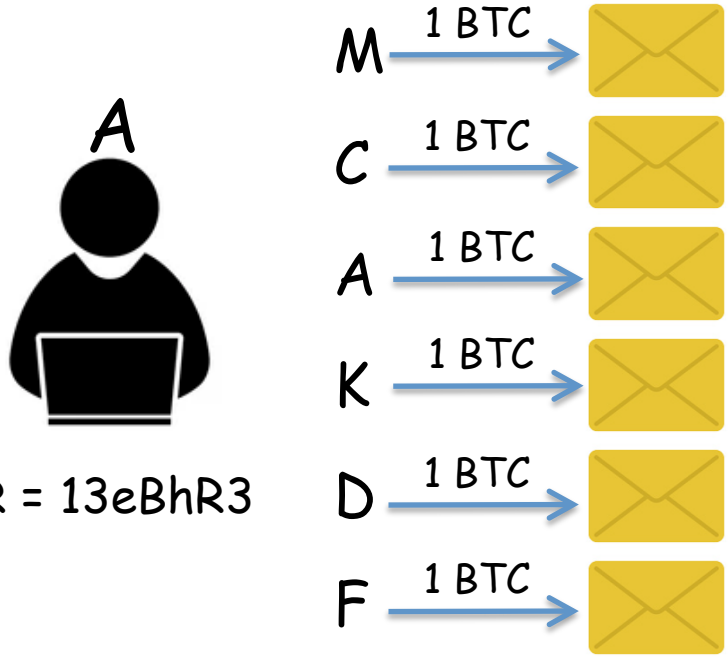

- R, proof

proof shows that on of the unclaimed zerocoins contains the serial number R

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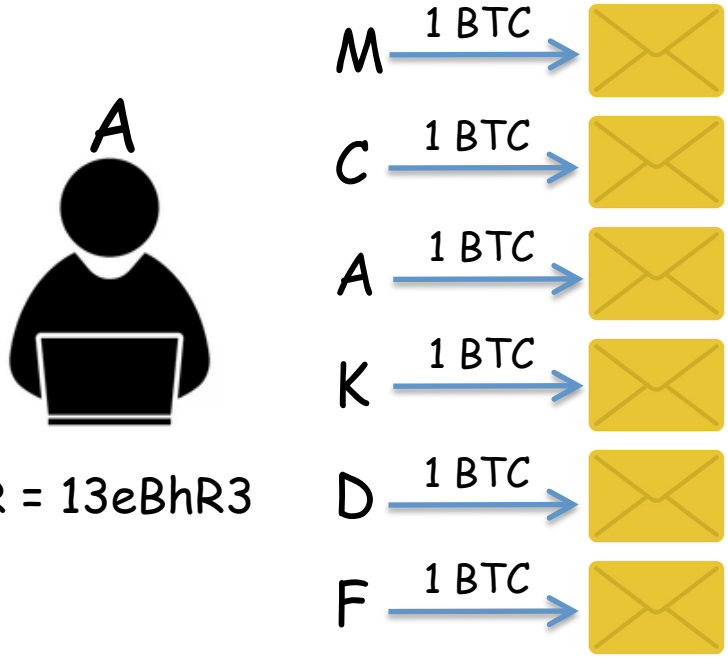

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proof shows that on of the unclaimed zerocoins contains the serial number R

- prover A tries to convince verifier (whole network) that one of the commitments contains R without revealing which one exactly containing R

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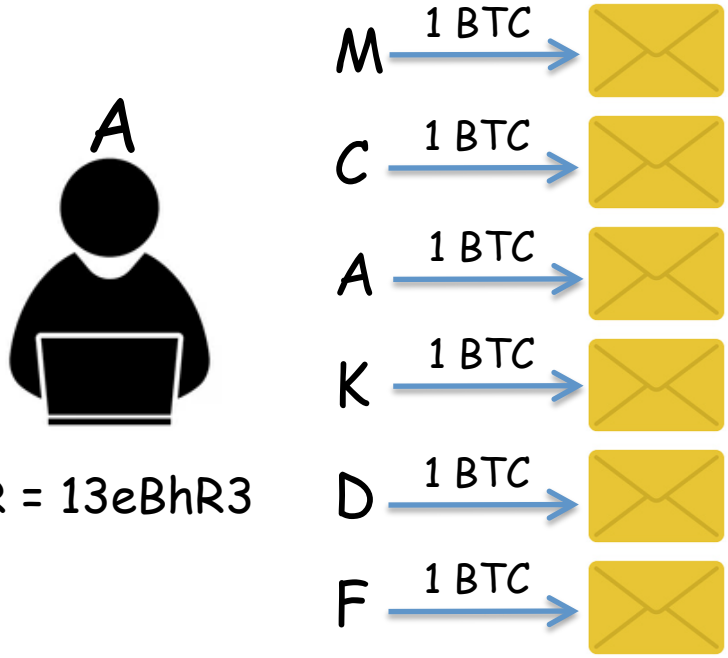

- R, proof

proof shows that on of the unclaimed zerocoins contains the serial number R

- prover A tries to convince verifier (whole network) that one of the commitments contains R without revealing which one exactly containing R
  - 'zero knowledge' prevents one to link this transaction to a specific address

Privacy vs Accountability

- attractive tools for criminals to perform illegal activities

Privacy vs Accountability

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Cryptocurrencies + Add to myFT

Monero emerges as crypto of choice for cybercriminals

Untraceable 'privacy coin' is rising in popularity among ransomware gangs, posing problems for law enforcement

"Justin Ehrenhofer, member of the monero developer, estimates that about 10 or 20% of ransoms are paid in monero, and that figure will probably rise to 50% by the end of the year"

Privacy vs Accountability

- attractive tools for criminals to perform illegal activities
- Singapore exchange Bittrue hacked in June 2019, over $4 million stolen

  "Bittrue working with Houbi, Bittrex to freeze stolen cryptocurrencies and accounts associated with the hack"

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- Singapore exchange Bittrue hacked in June 2019, over $4 million stolen

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- Japan exchange Liquid hacked in August 2021, over $97 million stolen

  " stolen funds converted to Ether using Uniswap and Sushiswap, then Ether laundered through Tornado Cash"

Privacy vs Accountability

- attractive tools for criminals to perform illegal activities

Tornado Cash

"Tornado Cash has been used to launder more than $7 billion worth of virtual currency since its creation in 2019. This includes over $455 million stolen by the Lazarus Group"

"Tornado Cash was subsequently used to launder more than $96 million of malicious cyber actors' funds derived from the June 24, 2022 Harmony Bridge Heist"

THANK YOU

- for details

Murat Osmanoglu, and Ali Aydın Selcuk. "Privacy in blockchain systems", Turkish Journal of Electrical Engineering & Computer Sciences (2022)

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