Privacy II

Murat Osmanoglu

Privacy Enhancing Techniques - Ring Signatures

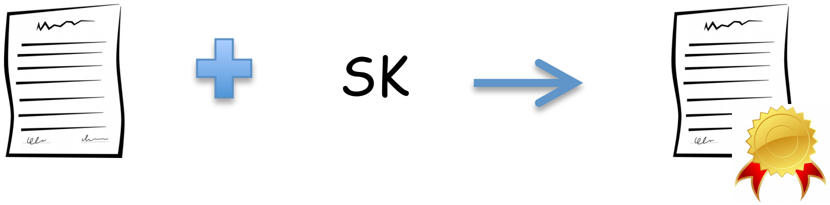
Digital Signatures

PK, SK

Privacy Enhancing Techniques - Ring Signatures

Digital Signatures

PK, SK



SK

Signature

SIGNING ALGORITHM

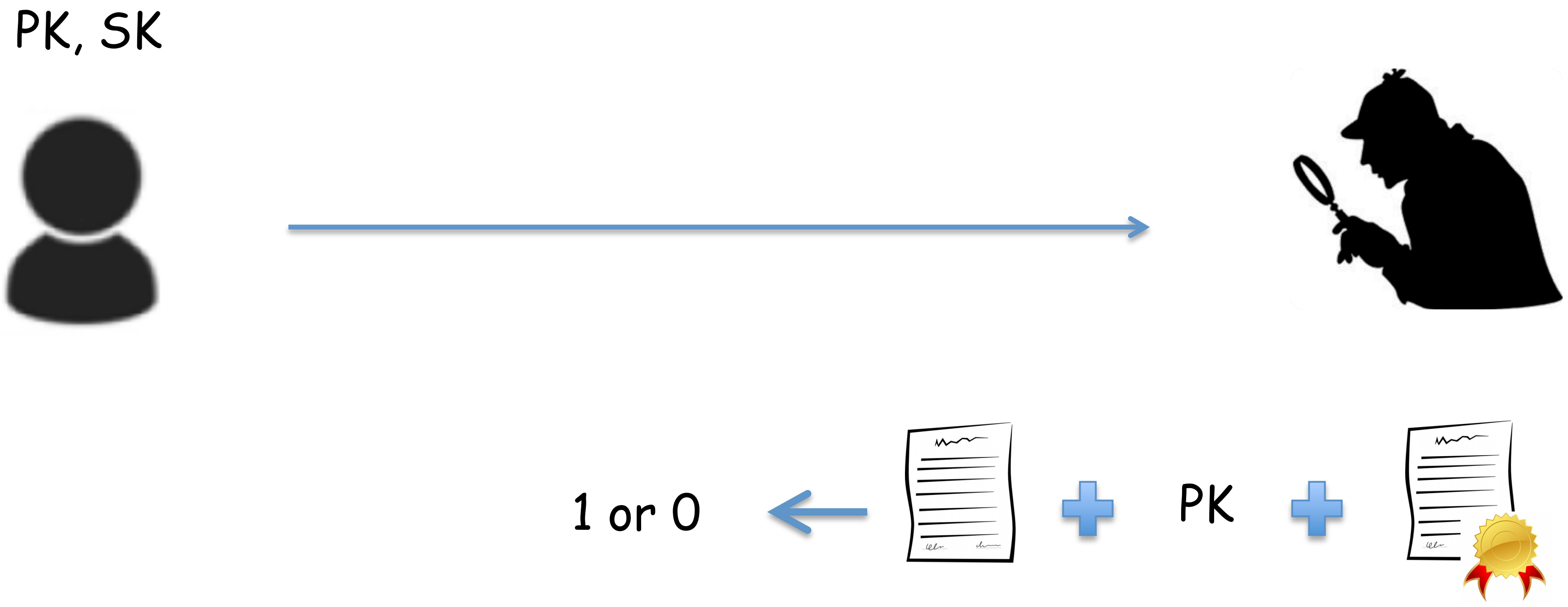
Privacy Enhancing Techniques - Ring Signatures

Digital Signatures

PK, SK

Privacy Enhancing Techniques - Ring Signatures

Digital Signatures



PK, SK

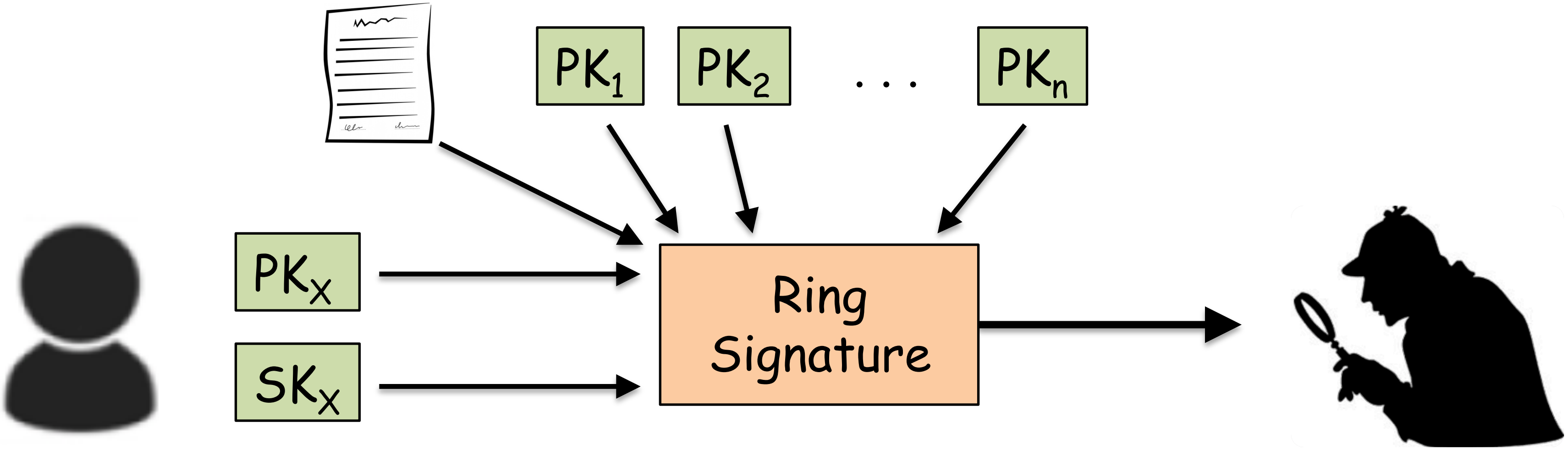
1 or 0

PK

VERIFICATION ALGORITHM

Privacy Enhancing Techniques - Ring Signatures

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



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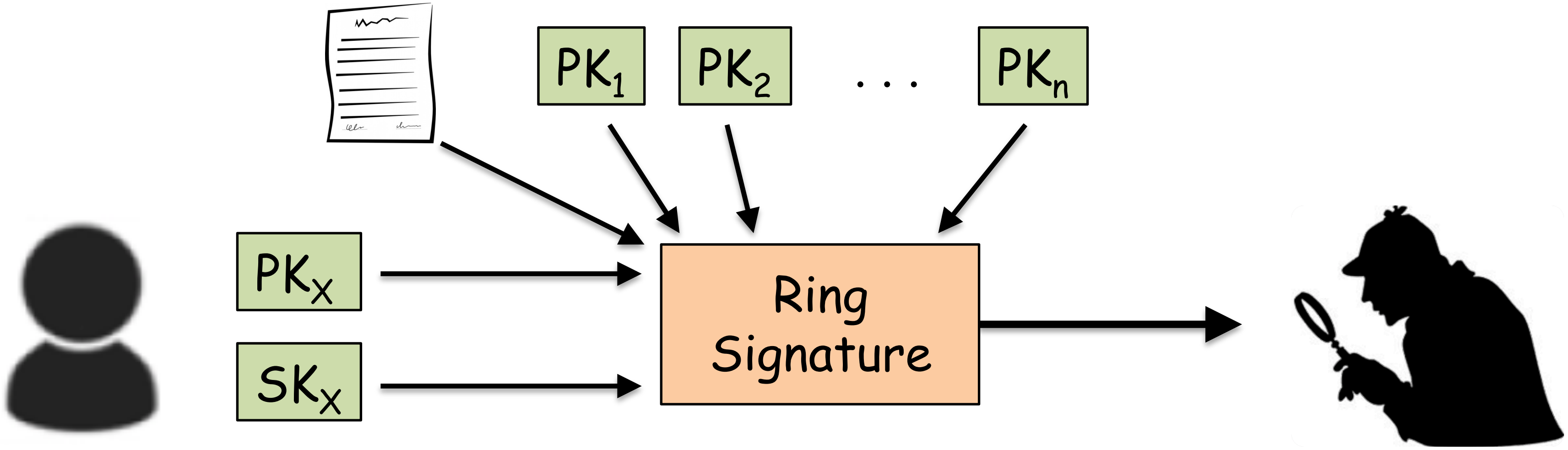

PK_1

PK_2

. . .

PK_n

PK_X

SK_X

Ring Signature

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

Privacy Enhancing Techniques - Ring Signatures

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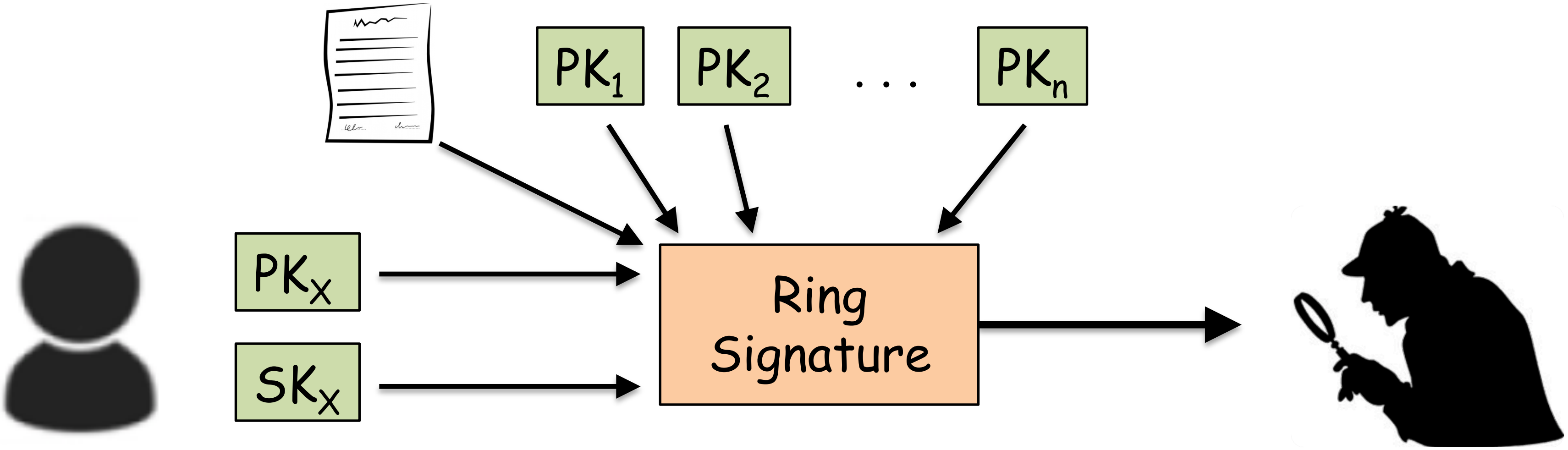

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- assume you designing a voting scheme using ring signatures
  - one can vote for two different candidate without being detected

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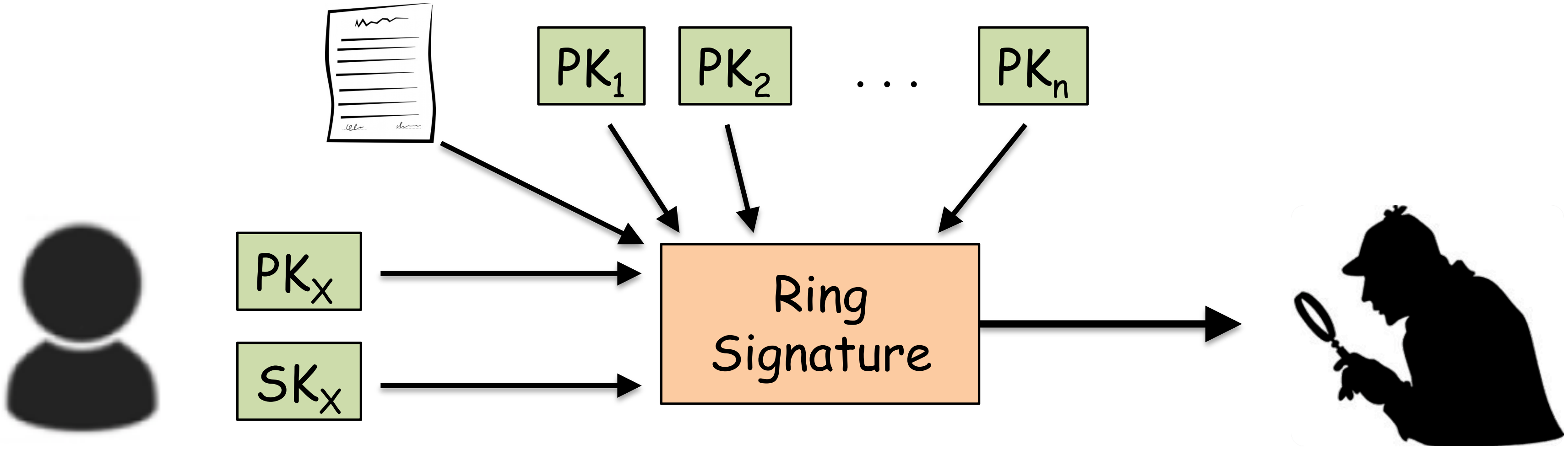
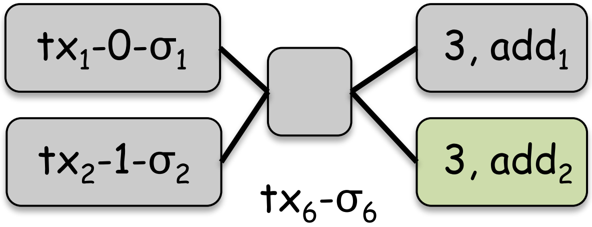


- verifier can tell that one member from the set {PK_1, PK_2, …, PK_n, PK_X} signed the message, but cannot tell which one the actual signer

- 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

- 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



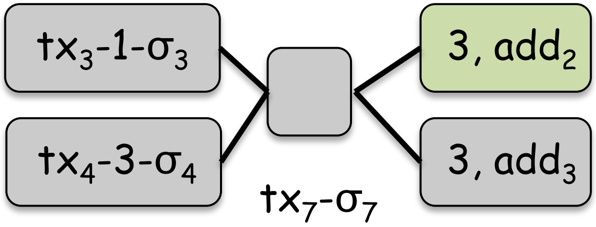
tx_1-0-σ_1

tx_2-1-σ_2

3, add_1

3, add_2

tx_6-σ_6



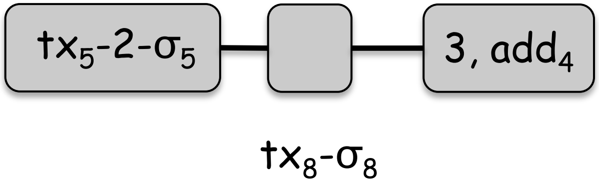
tx_3-1-σ_3

tx_4-3-σ_4

3, add_2

3, add_3

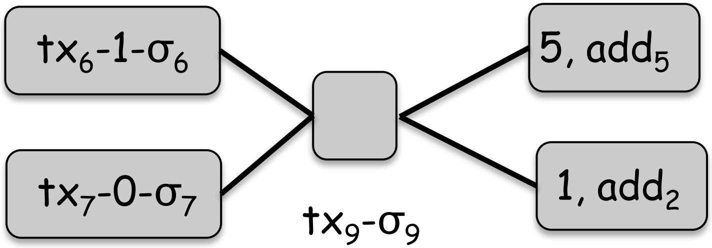
tx_7-σ_7



tx_5-2-σ_5

3, add_4

tx_8-σ_8



tx_6-1-σ_6

tx_7-0-σ_7

5, add_5

1, add_2

tx_9-σ_9

- signed by add_2 using SK_2

Privacy Enhancing Techniques - Ring Signatures

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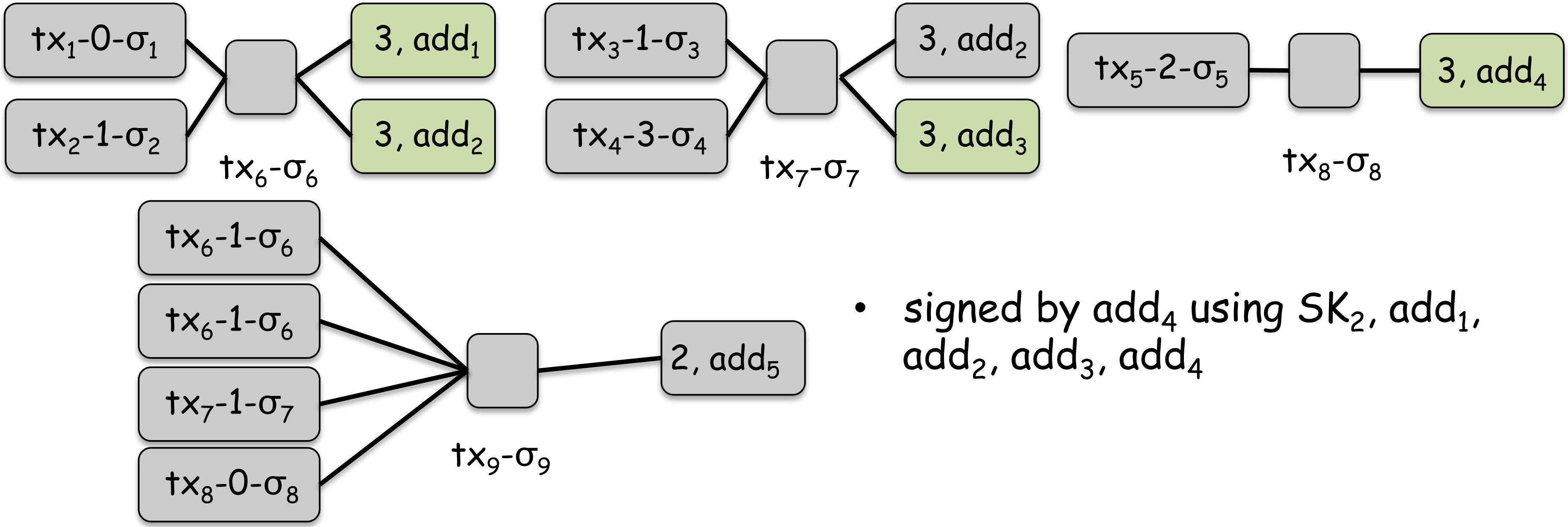

- signed by add_4 using SK_2, add_1, add_2, add_3, add_4

Privacy Enhancing Techniques - Ring Signatures

CryptoNote

- introduced by van Saberhagen [7] in 2013

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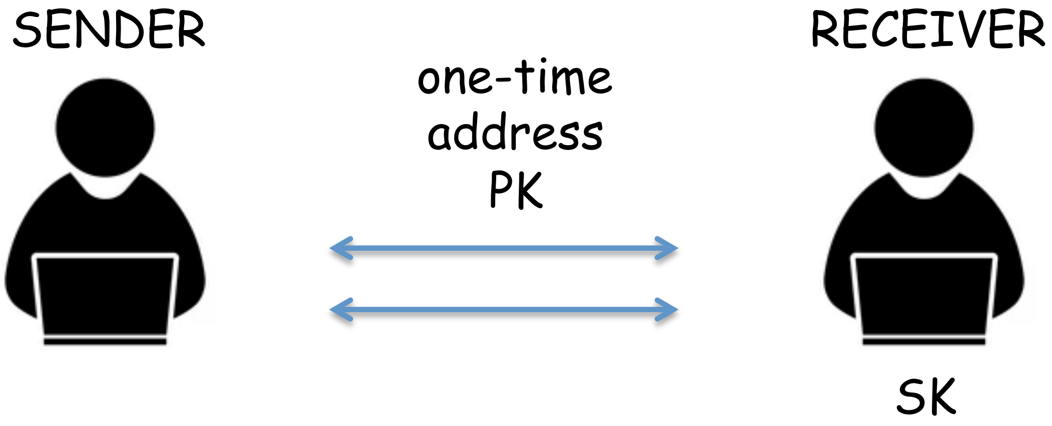

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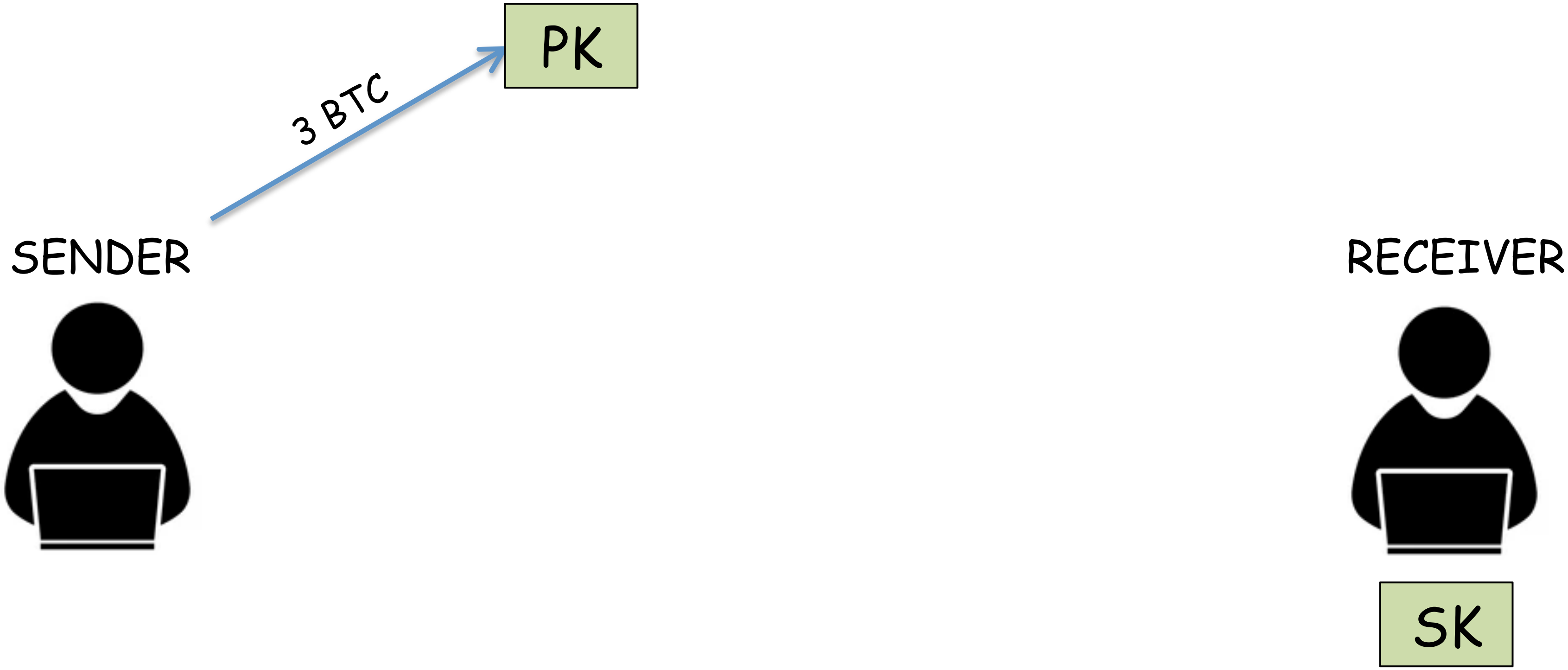

PK

3 BTC

SENDER

RECEIVER

SK

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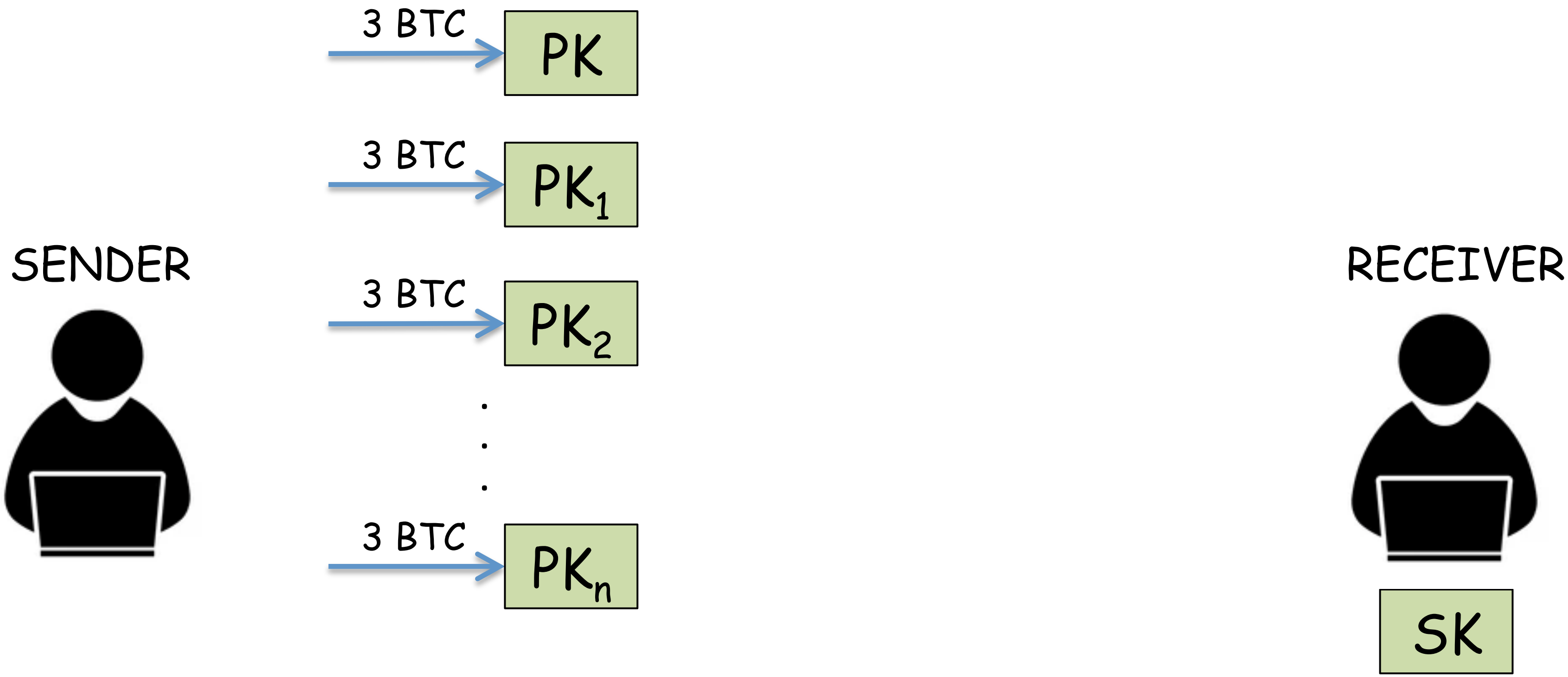

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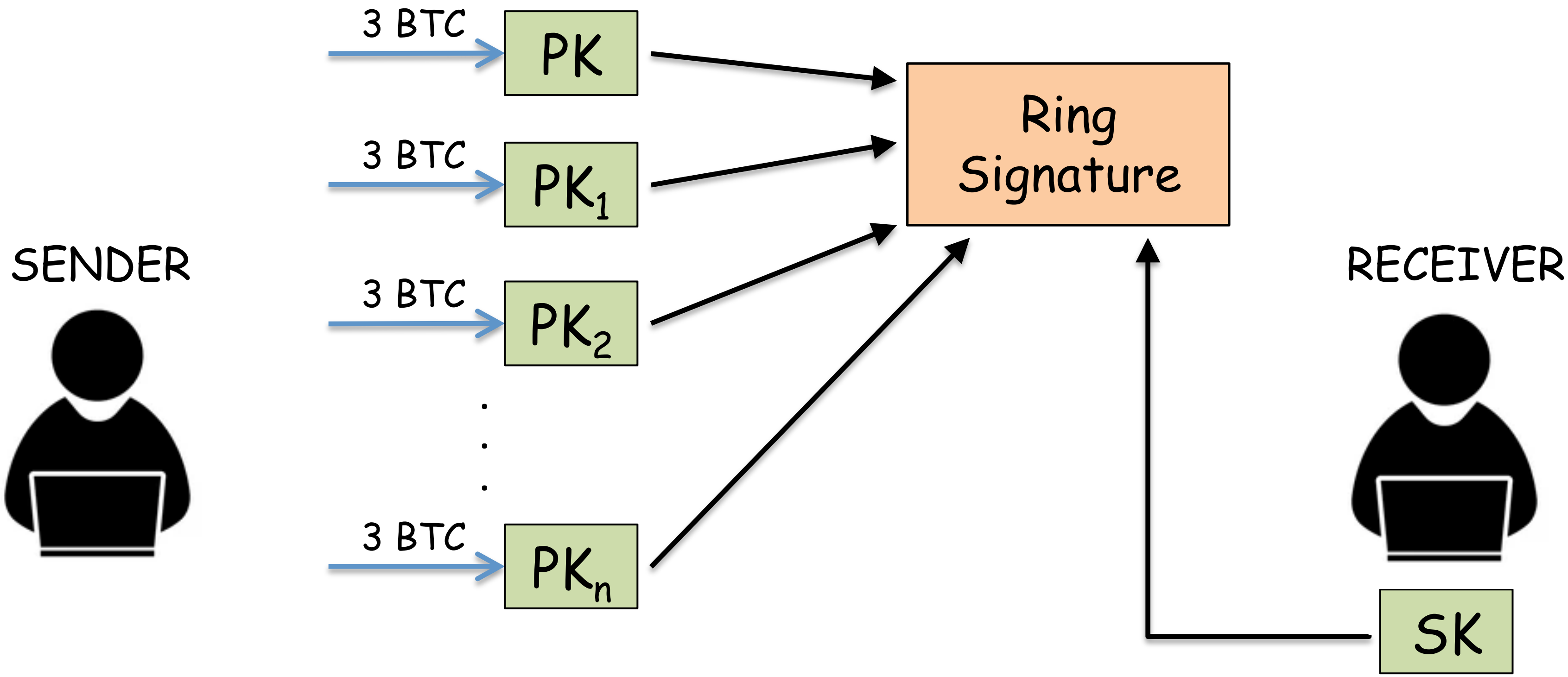


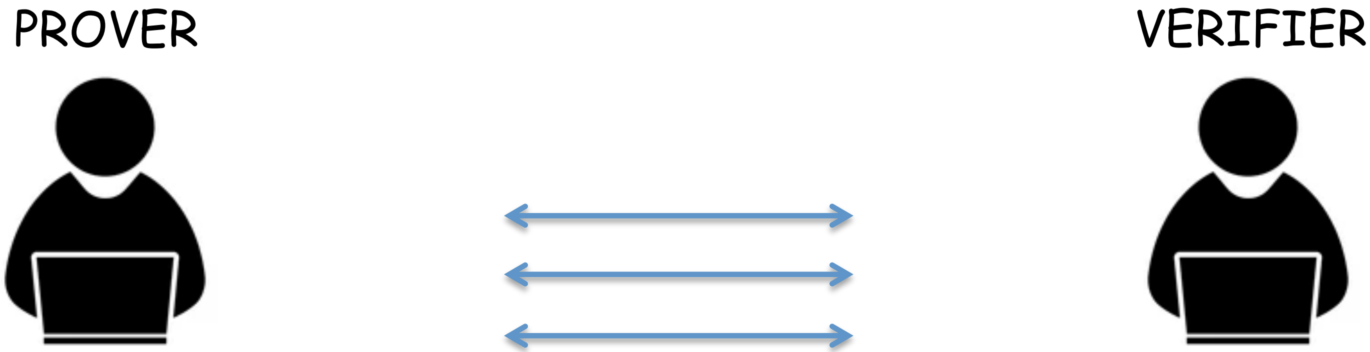
Privacy Enhancing Techniques - Ring Signatures

CryptoNote

- introduced by van Saberhagen [7] in 2013
- 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



PROVER

VERIFIER

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

Privacy Enhancing Techniques - Zero Knowledge

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AYLA

color-blind

BULENT

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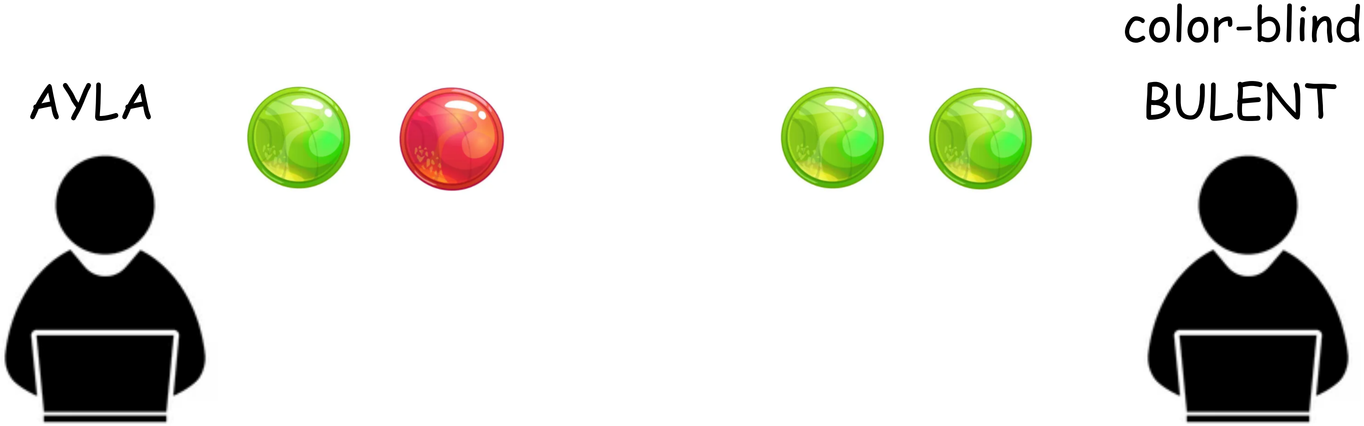

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they seem completely identical to Bulent

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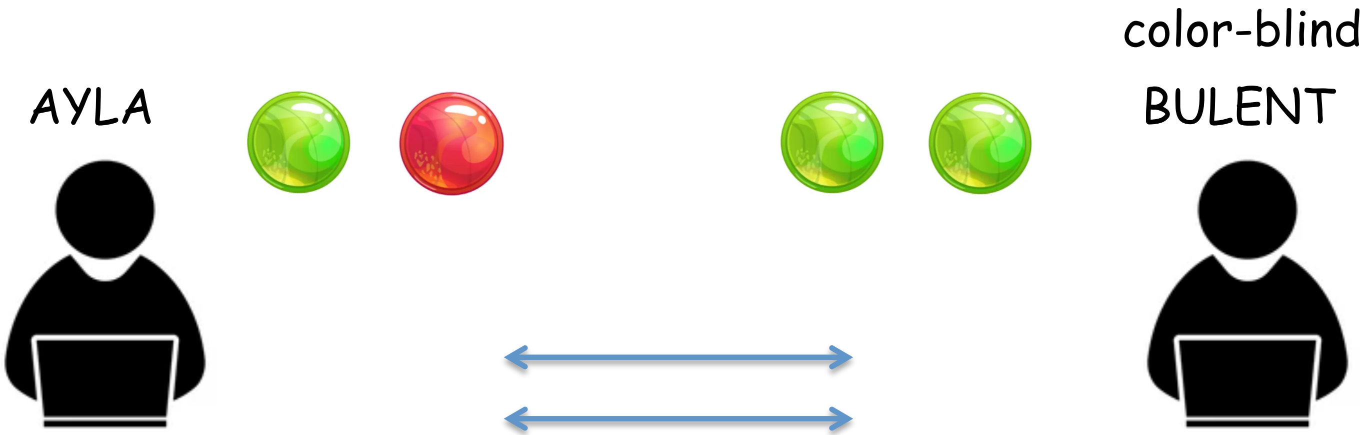

Ayla wants to convince Bulent they are in diffferent colors without revealing which one is red and which one is green

they seem completely identical to Bulent

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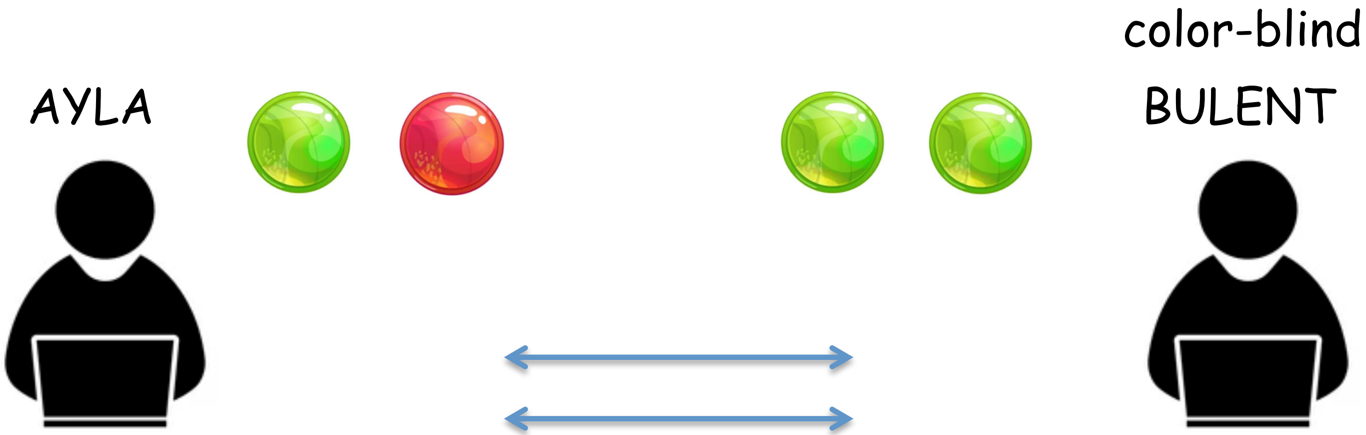

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they seem completely identical to Bulent

he thinks they are actually distinguishable

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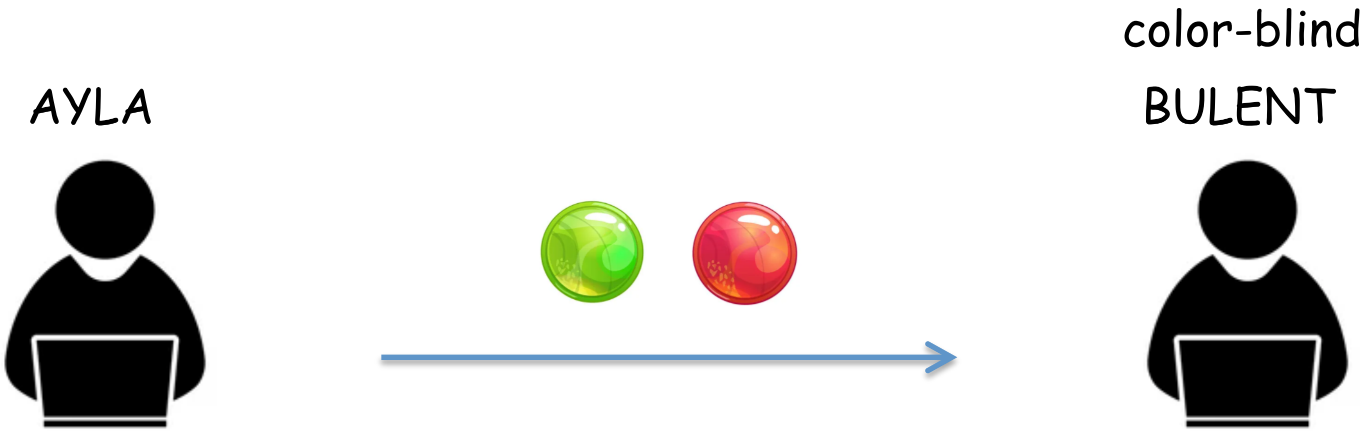

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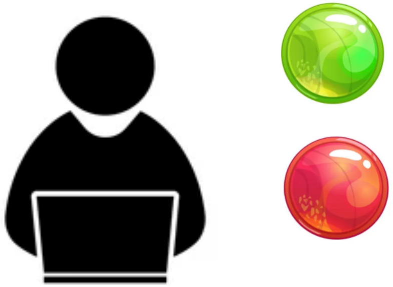

he either switching the balls, or keeping them in same hands

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“Did I swtich the balls ?”

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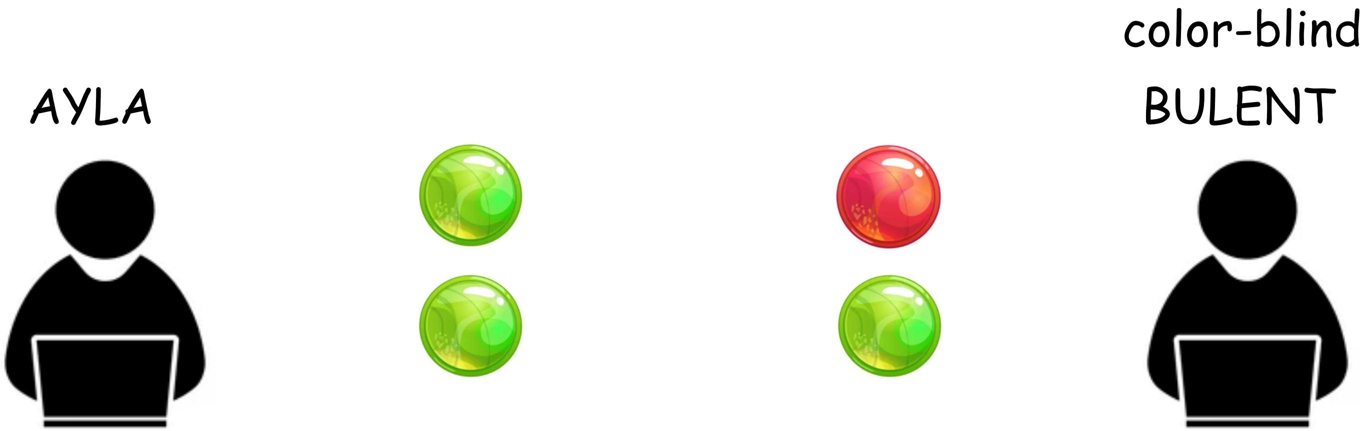

"Did I swtich the balls ?"

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- assume Ayla doesn't know which one green and which one is red

- what would be the probability that Ayla correctly guess whether he switched or not ?

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1 / 2 = 0.5

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- what would be the probability that Ayla correctly guess whether he switched or not ?

$1 / 2 = 0.5$

$1 / 2^2 = 0.25$

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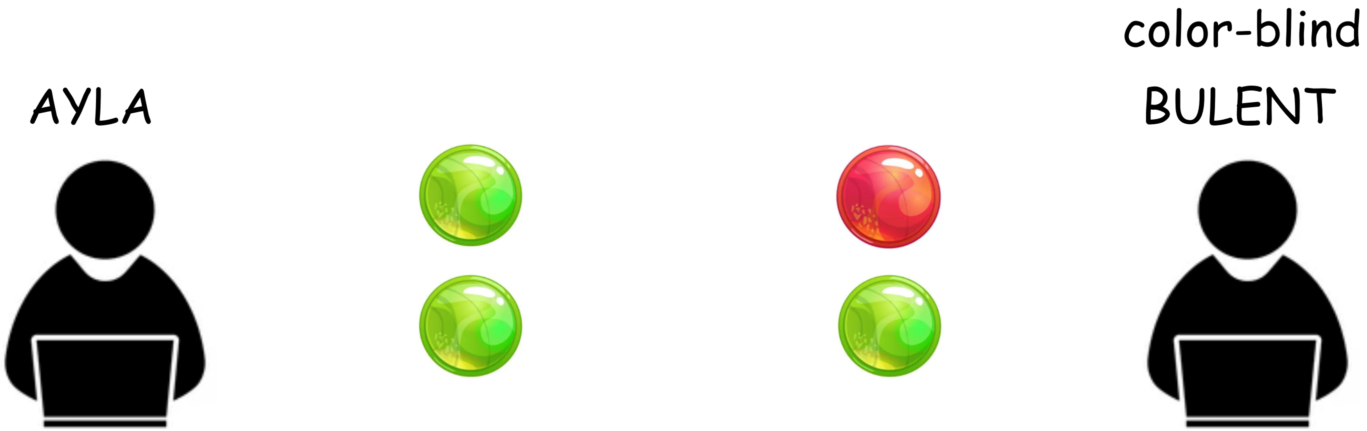

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$1 / 2 = 0.5$

$1 / 2^5 = 0.03125$

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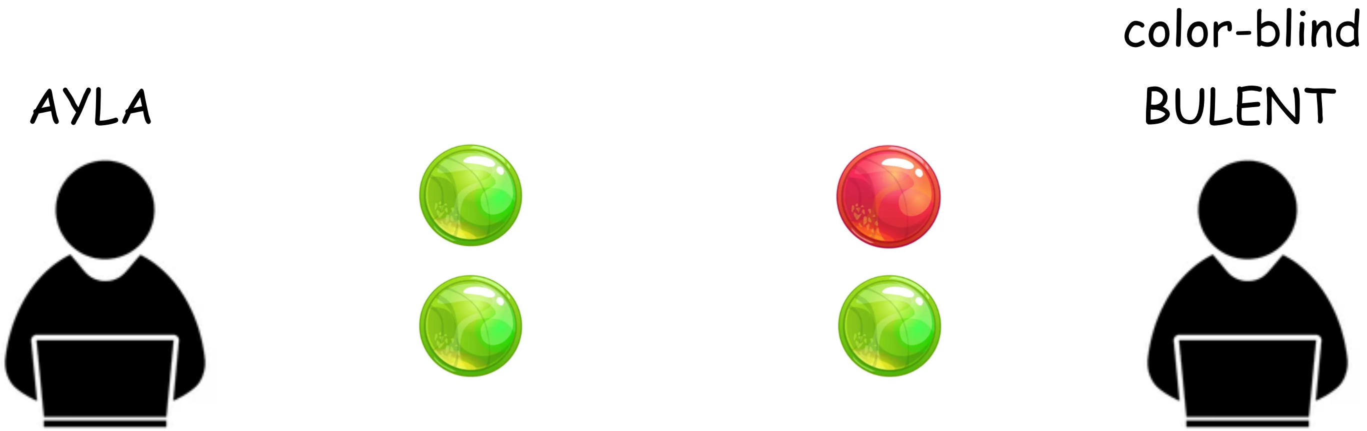

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- what would be the probability that Ayla correctly guess whether he switched or not ?

$$1 / 2 = 0.5$$

$$1 / 2^{10} = 0.00097$$

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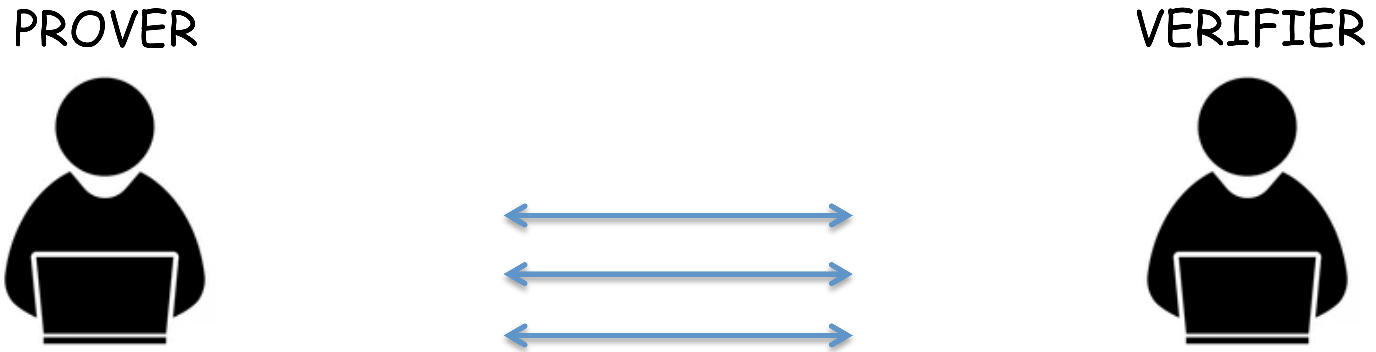

- allows one party (prover) to convince another party (verifier) that a statement is true without revealing any information other than this fact
- Completeness : if the statement is true, the honest verifier will be convinced by the honest prover
- Soundness : if the statement is false, no cheating prover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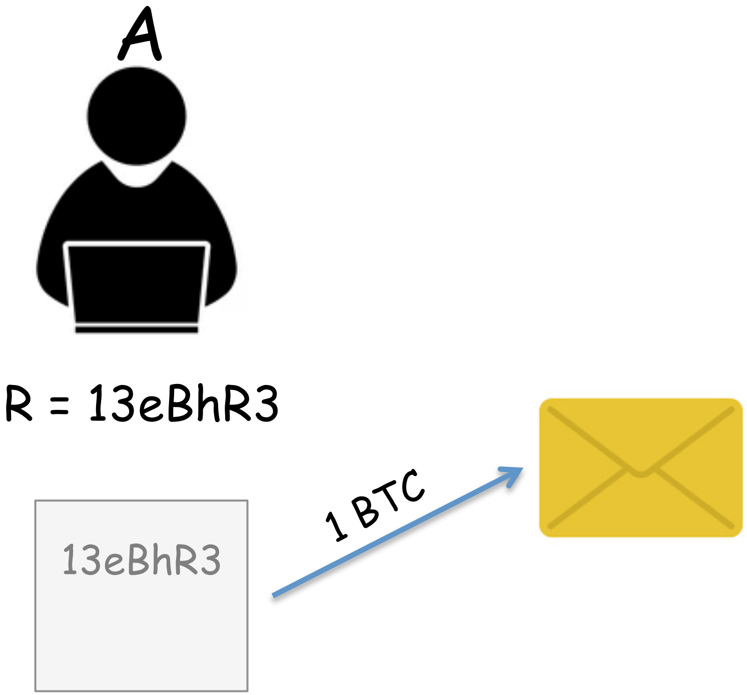

A

R = 13eBhR3

13eBhR3

1 BTC

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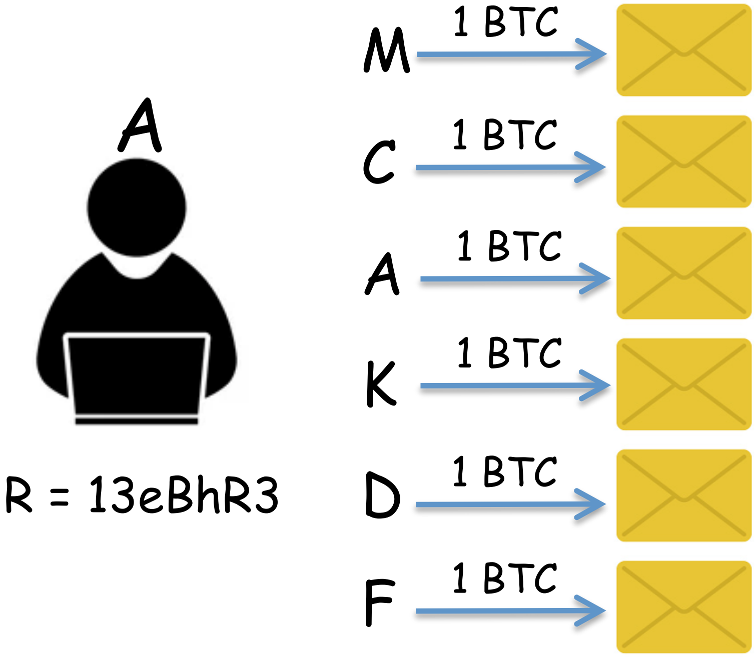

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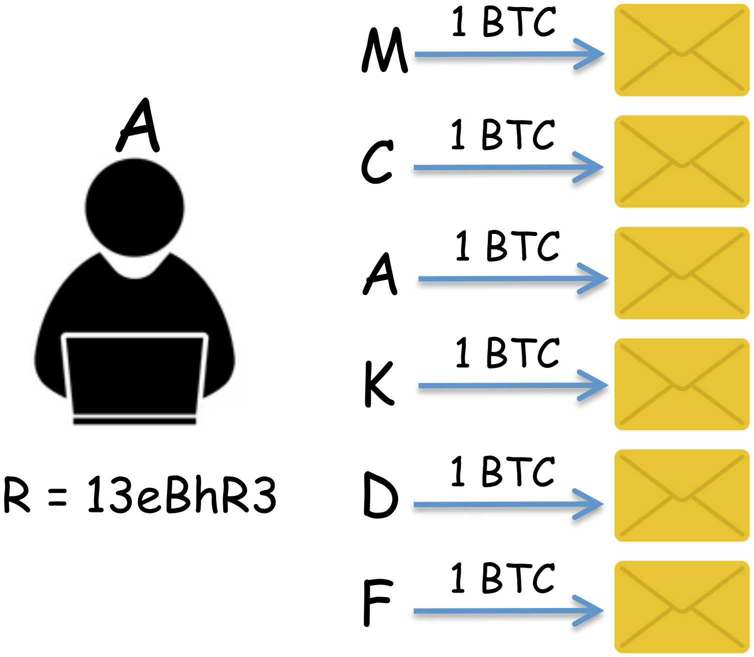

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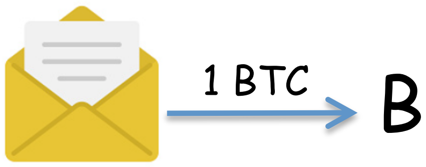

- R, proof

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

Privacy Enhancing Techniques - Zero-Knowledge

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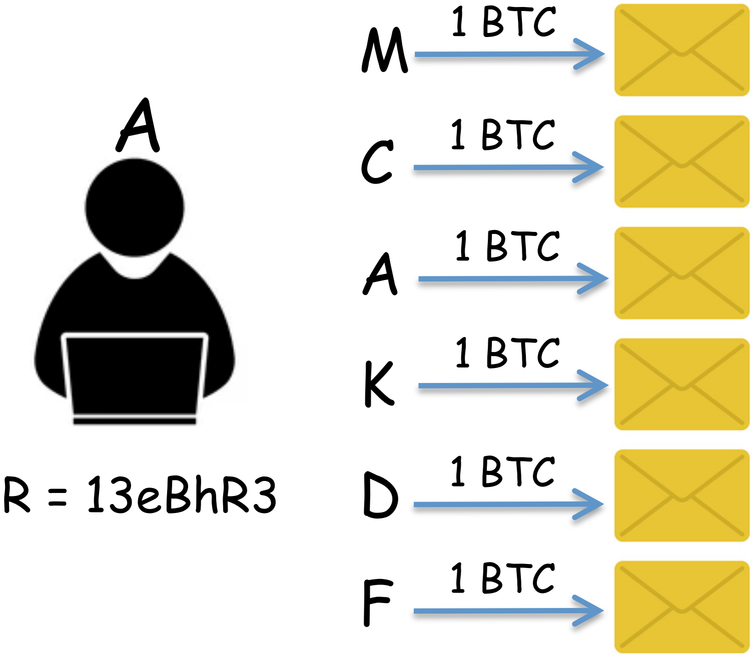

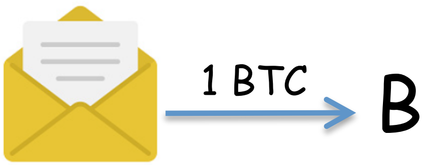

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proof shows that on of the unclaimed zerocoins contains the serial number R

- 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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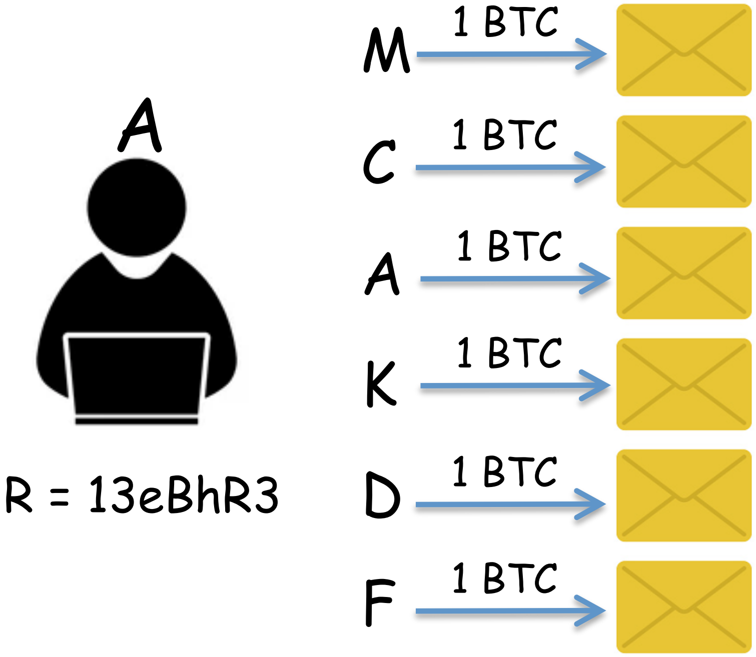

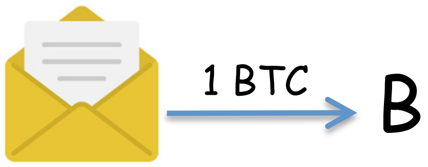

- R, proof

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  - ‘zero knowledge’ prevents one to link this transaction to a specific address

Privacy Enhancing Techniques

Privacy vs Accountability

Privacy Enhancing Techniques

Privacy vs Accountability

- attractive tools for criminals to perform illegal activities
- introducing serious concerns for regulatory authorities
- 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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- 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"

References

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