Achieving optimal anonymity in transferable e-cash with a judge

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Africacrypt 2011

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[2] Orange Labs
[3] University of Bristol
[4] Gemalto
[5] ST-Ericsson

Outline of this talk

1. Electronic cash
2. Commuting signatures
3. Our instantiation

Electronic Cash

should have the same properties as physical cash

- Unforgeability
- Anonymity
- (Transferability)

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- Unforgeability $\Rightarrow$ Bank *signs* serial number of coin
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Digital signatures are a digital equivalent of hand-written signatures

User produces key pair

- uses signing key to produce signatures
- publishes verification key to verify signatures

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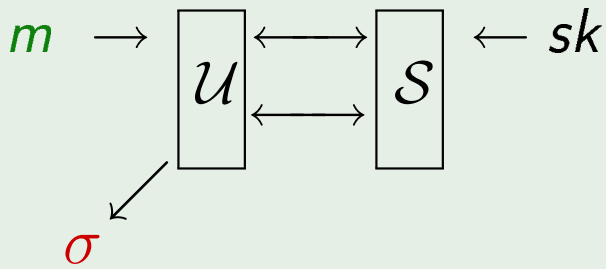
A **blind signature scheme** allows a *user* $\mathcal{U}$ to obtain a signature on a message hidden from the *signer* $\mathcal{S}$



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Double-spending

Unlike physical money, data can be copied

$\Rightarrow$ need mechanisms to trace double-spenders

Protocol

- Withdrawal: A user withdraws a coin c from the bank
- Spending: The user spends the coin with a merchant
- Deposit: The merchant deposits the coin at the bank

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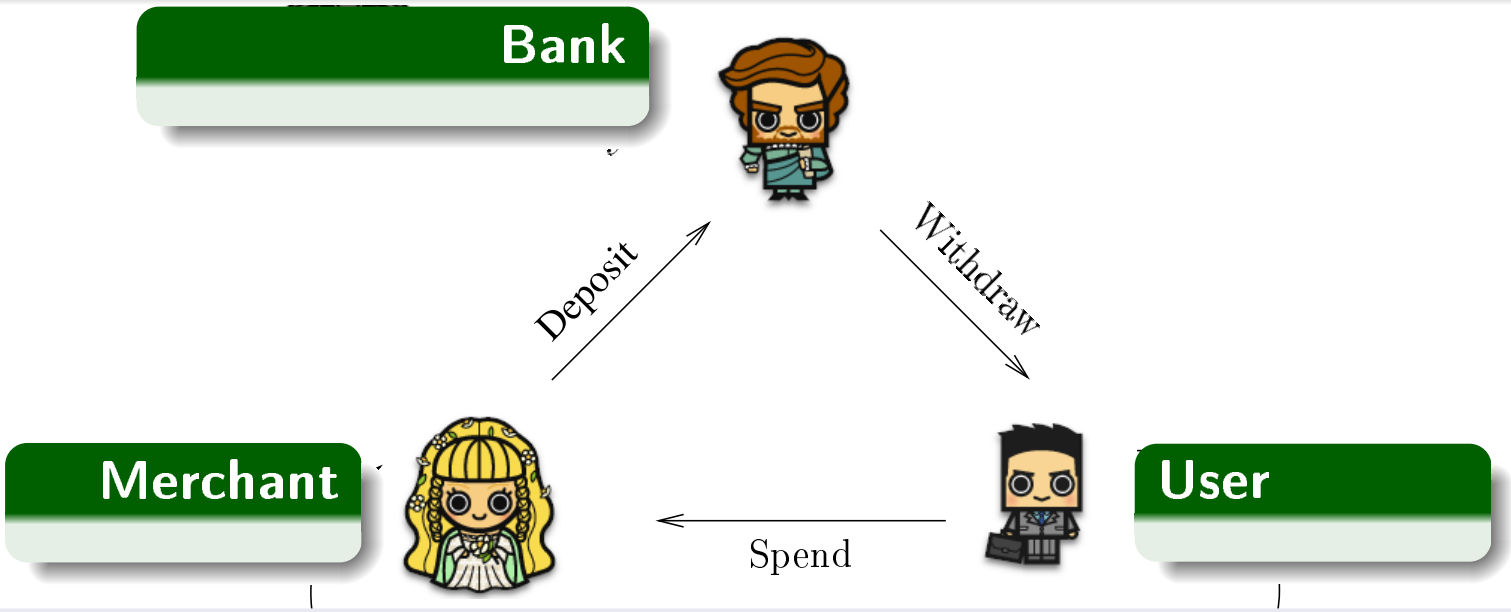

Classical protocol

Protocol

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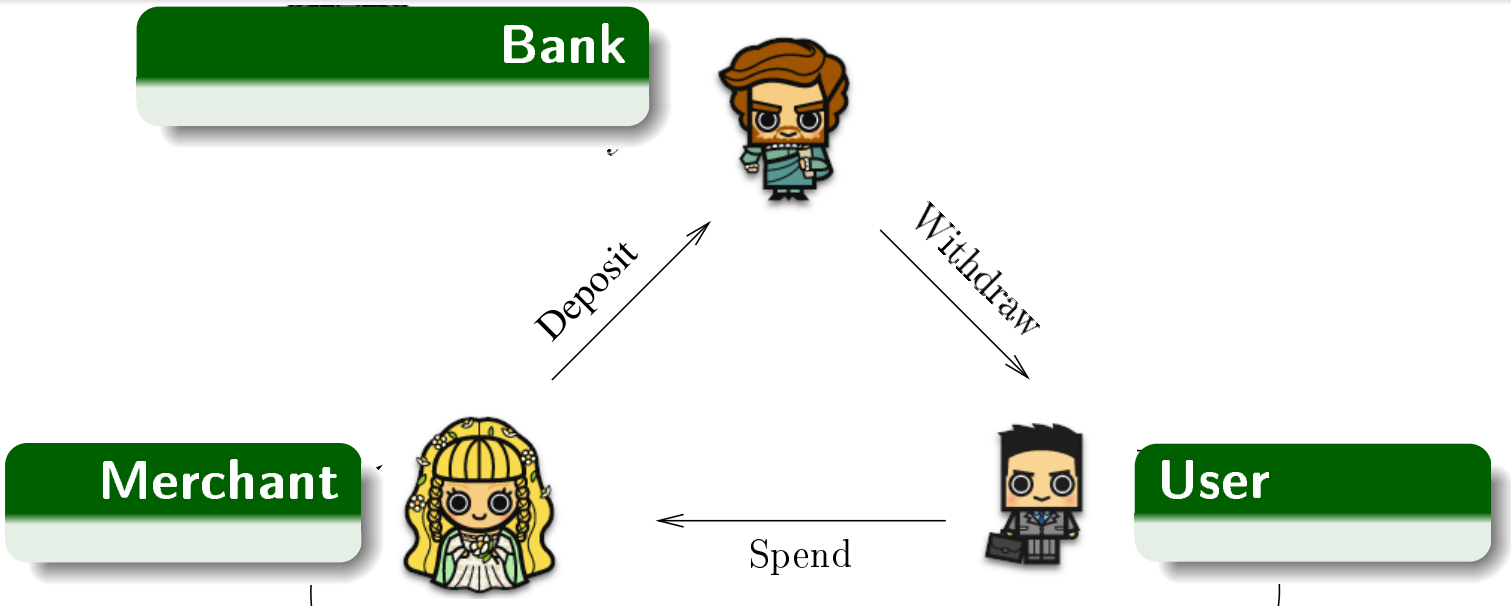

Transferable e-cash

A user can transfer a coin (offline) to other users before spending it

Anonymity in transferable e-cash

- Weak anonymity — Spender & receiver not identifiable
- Strong anonymity — User anonymous w.r.t. the bank

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Stronger anonymity in transferable e-cash [Canard-Gouget'08]

[FA] Observe then receive:
- Adversary can impersonate the bank,
- cannot link a coin he receives to a previously (passively) observed transfer

[PA] Perfect anonymity:
- Adversary can impersonate the bank,
- the adversary cannot tell whether he has already owned a coin he receives

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Impossible to achieve

Bank must link coins to detect double-spending

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[PA_1] Spend then observe:
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[PA_2] Spend then receive:
- The bank is *trusted*;
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Unforgeability

- No coalition of users can spend more coins than they withdrew (without being detected)

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Exculpability

- The bank—even when colluding with malicious users—cannot wrongfully accuse an honest users of double-spending

Ideas for our instantiation

Need to hide coin from previous owner [PA_2]

- Instead of signature $\Rightarrow$ Proof of knowledge of signature
  $\Rightarrow$ Proof of knowledge of proof ...
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  When receiving a coin, user picks new part of serial number

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- Spender commits to transfer
  Sender signs part of the serial number

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- Spender commits to transfer
  Sender signs part of the serial number
  $\Rightarrow$ Exculpability
  $\Rightarrow$ need to sign encrypted value

Commuting signatures and verifiable encryption I

- Signature $M \xrightarrow{sk} \Sigma$ Verification: vk, M, Σ

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Proof adaptation:

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Sign M given $\boxed{M}$: $\boxed{M} \xrightarrow{sk} \Sigma$ (crossed out)

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- Commuting signature and verifiable encryption

Sign plaintext then encrypt $\iff$ encrypt then sign plaintext

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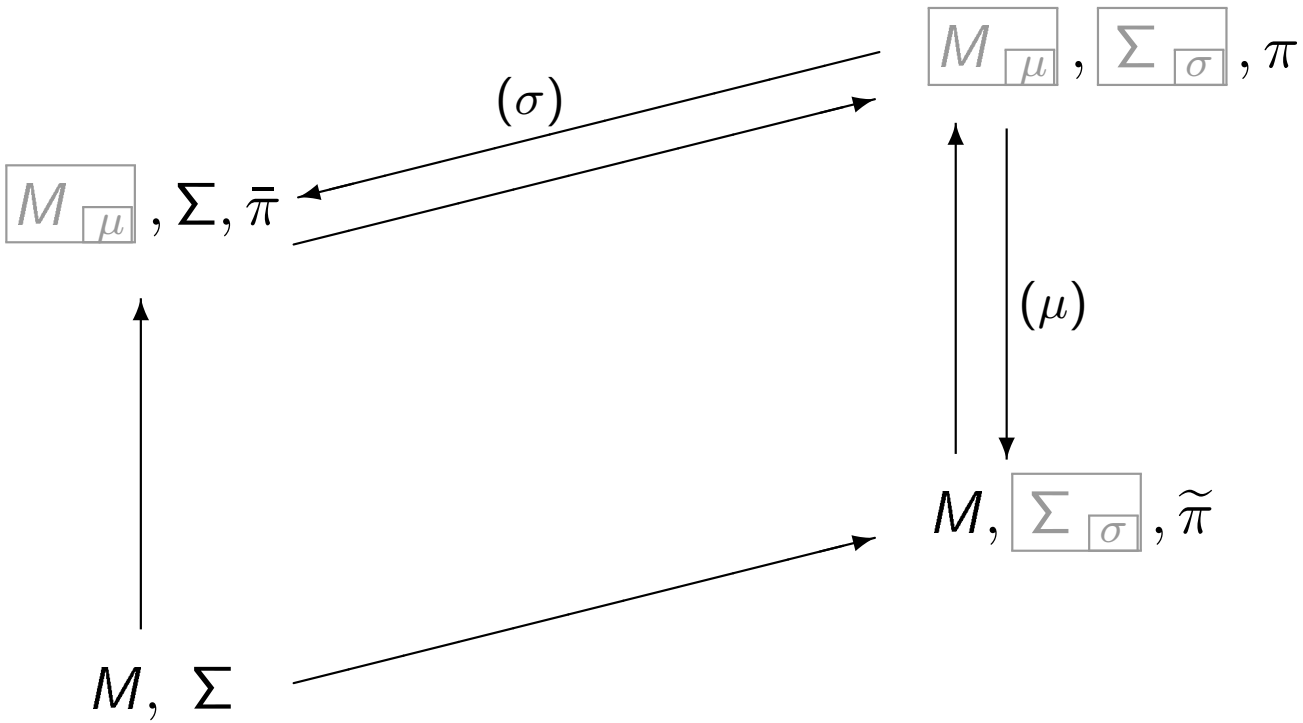
Commuting signatures and verifiable encryption II



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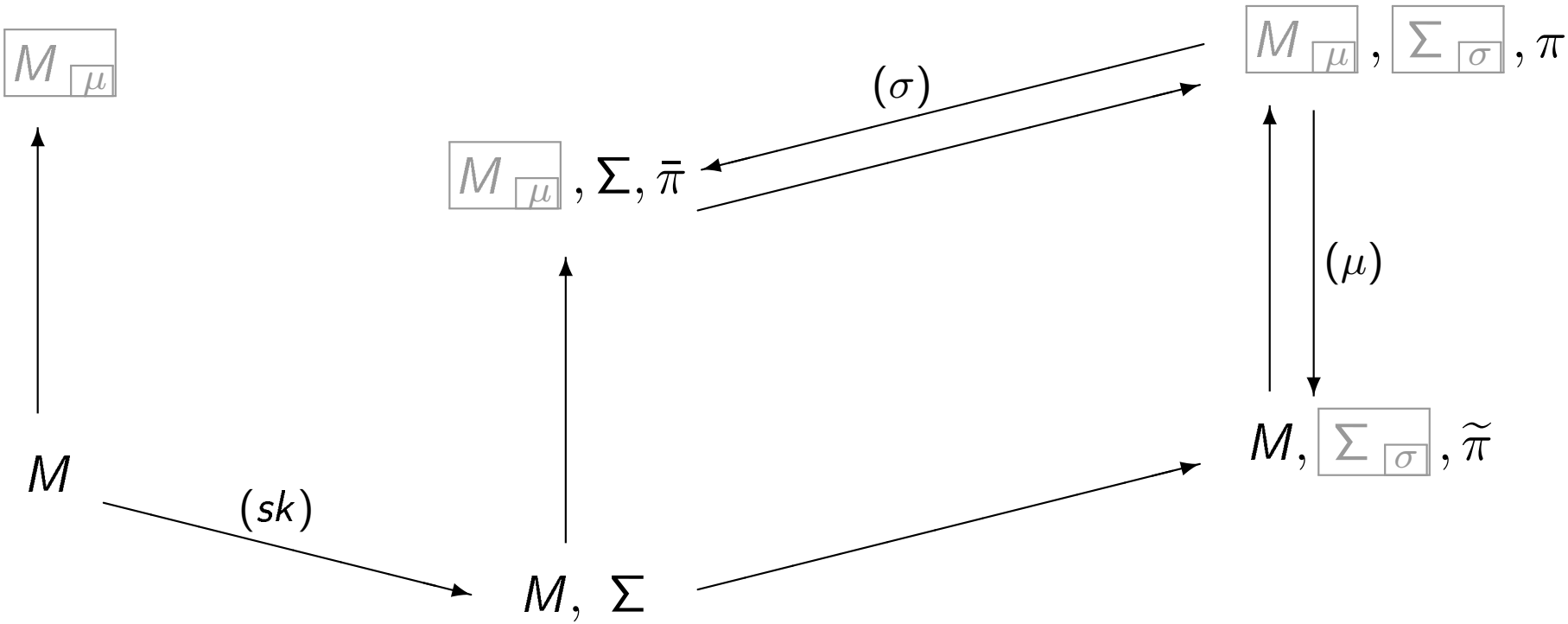

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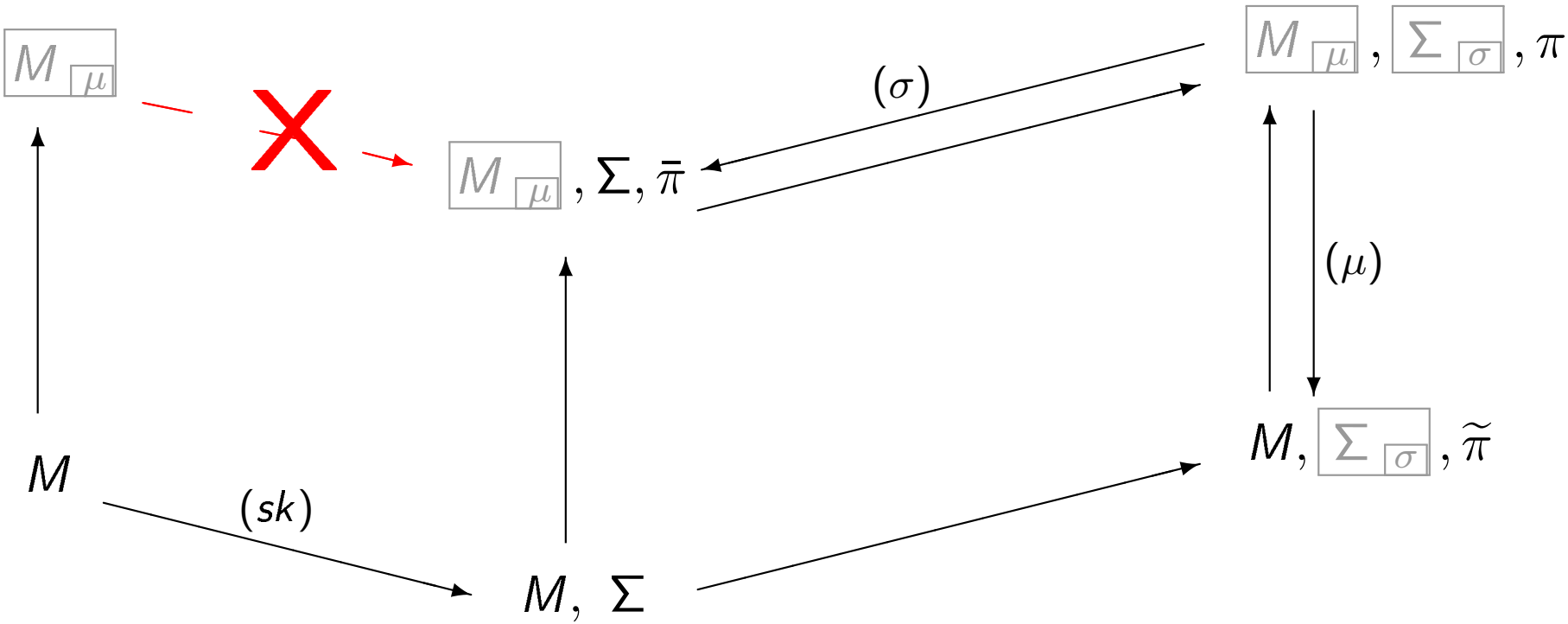

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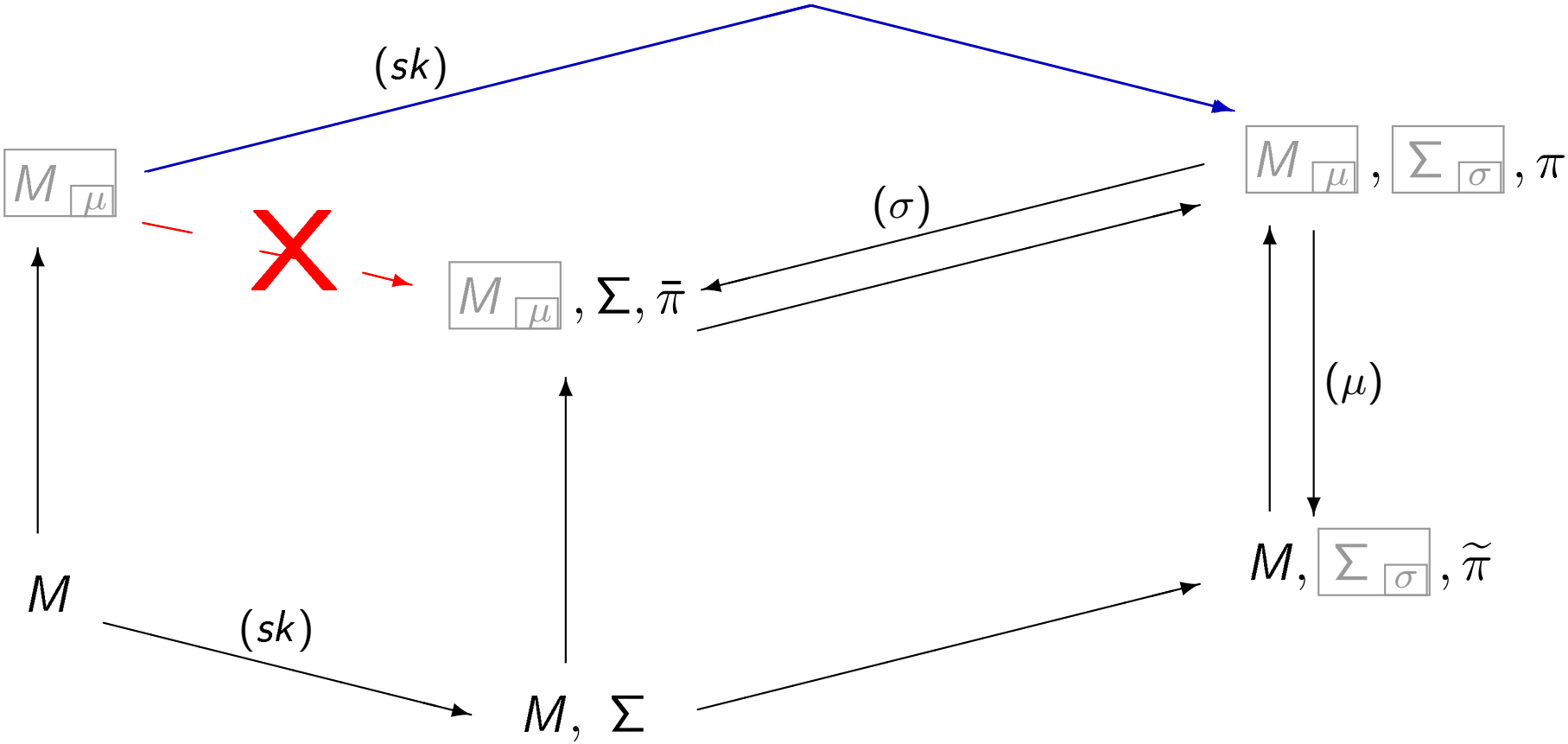


Commuting signatures and verifiable encryption II

Instantiation

- given in [F'11]
- using pairing-friendly groups,
- Groth-Sahai proofs [Groth-Sahai'08]

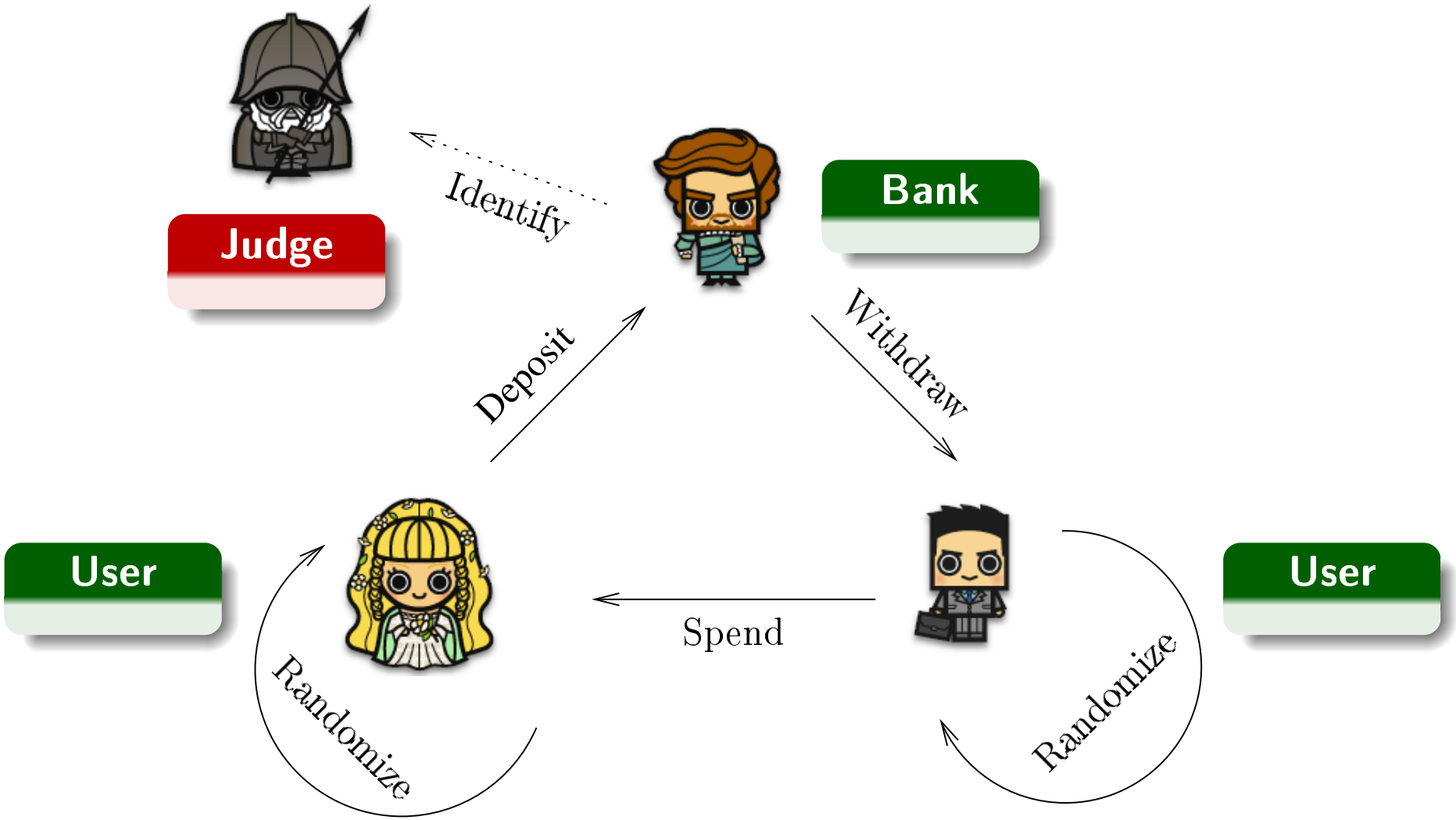
  which have been shown to be randomisable by [Belenkiy-Camenisch-Chase-Kohlweiss-Lysyanskaya-Shacham'09]
- and automorphic signatures [Abe-F-Groth-Haralambiev-Ohkubo'10]

1 Electronic cash

2 Commuting signatures

3 **Our instantiation**

Introducing the judge



Introducing the judge

Bank

$\boxed{n_1}$, $\boxed{pk_1}$

$\boxed{\Sigma_0}$, π_0

Σ_0 is signature on n_0, n_1, pk_1 under pk_B

User1

Judge

Introducing the judge

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User1

$\boxed{n_2}$, $\boxed{pk_2}$

$\boxed{coin}$

$\boxed{\Sigma_1}$, π_1

Σ_1 is signature on n_1, n_2, pk_2 under pk_1

User2

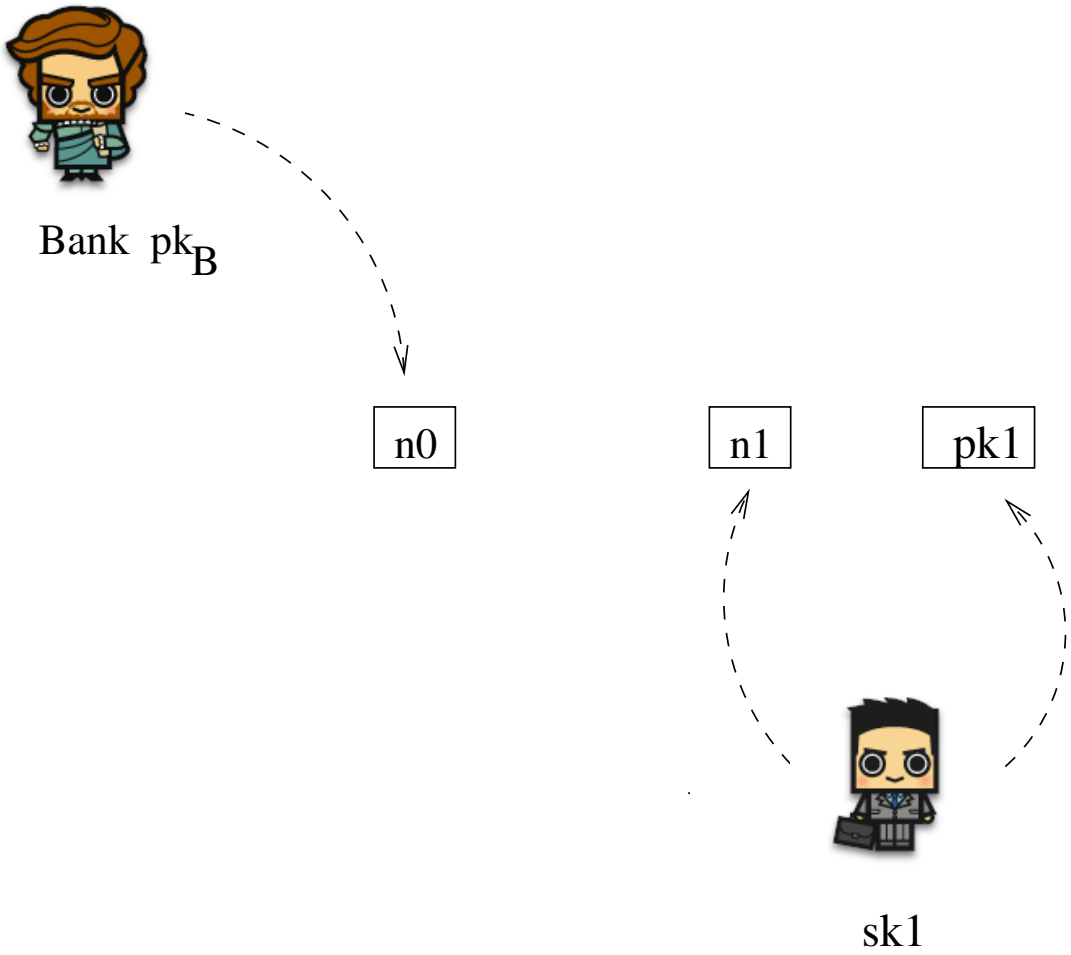
Judge

The form of a coin

Bank pk_B

sk1

The form of a coin



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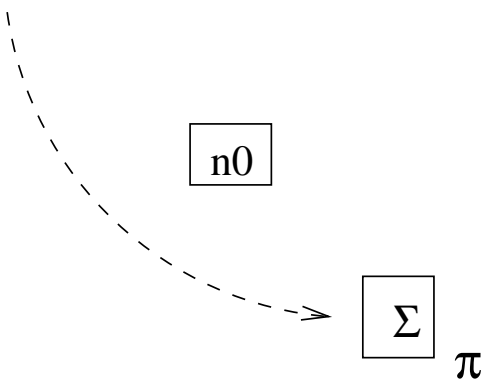

sk1

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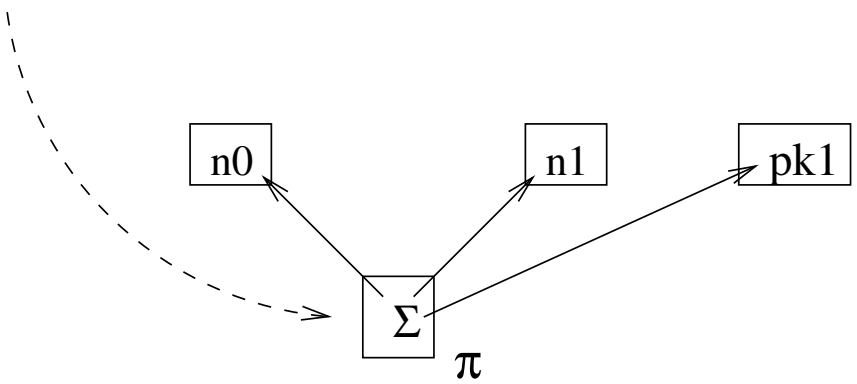

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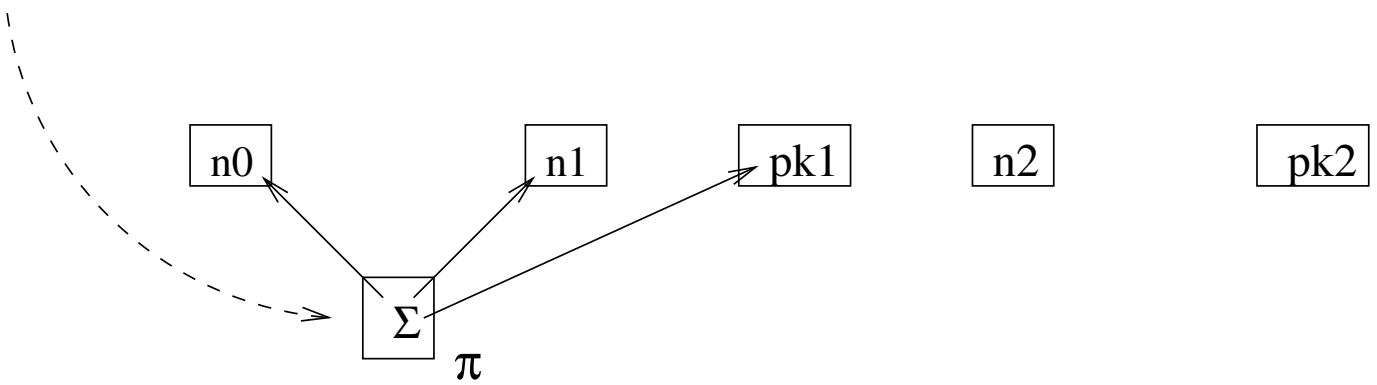
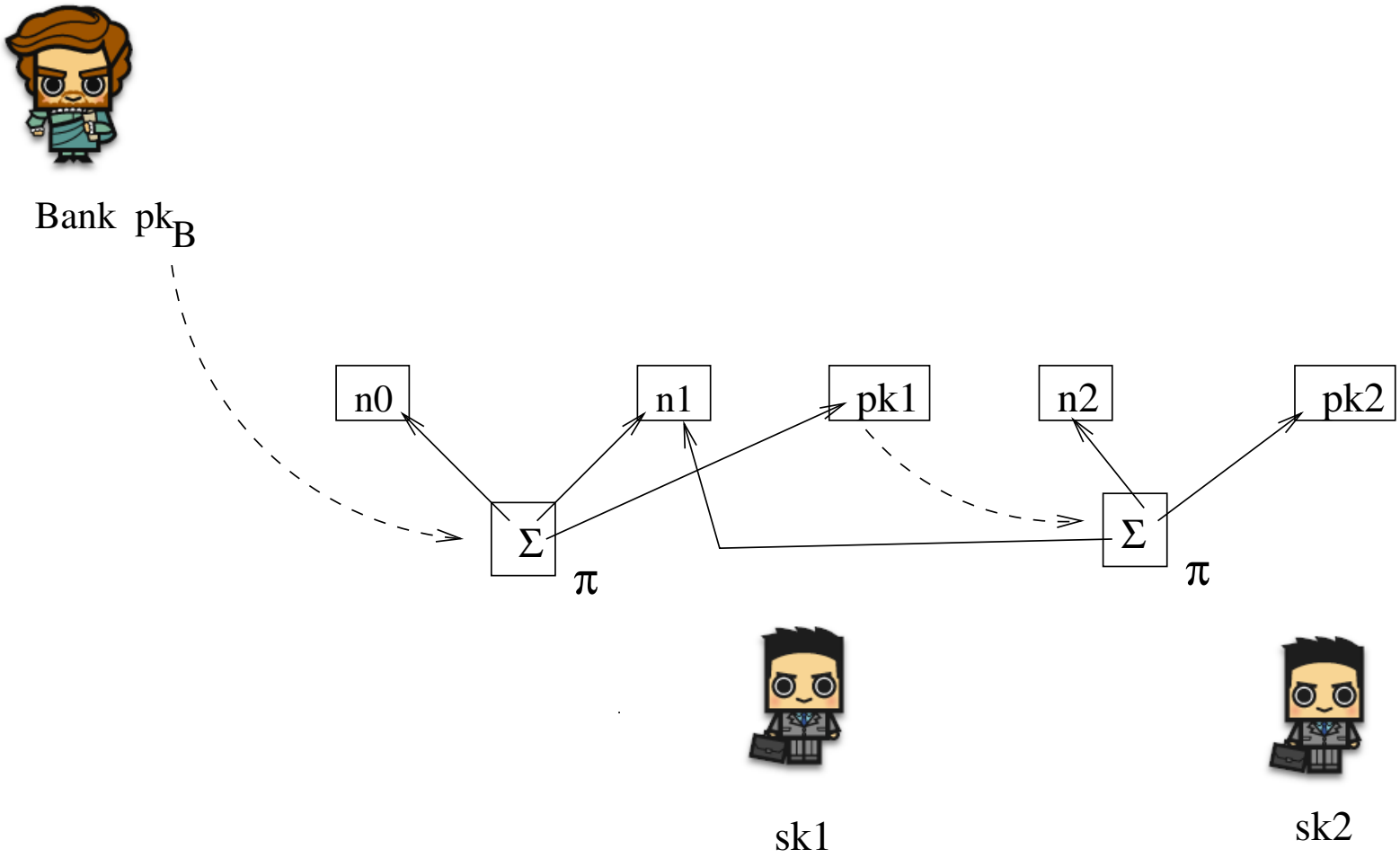


sk1

sk2

The form of a coin



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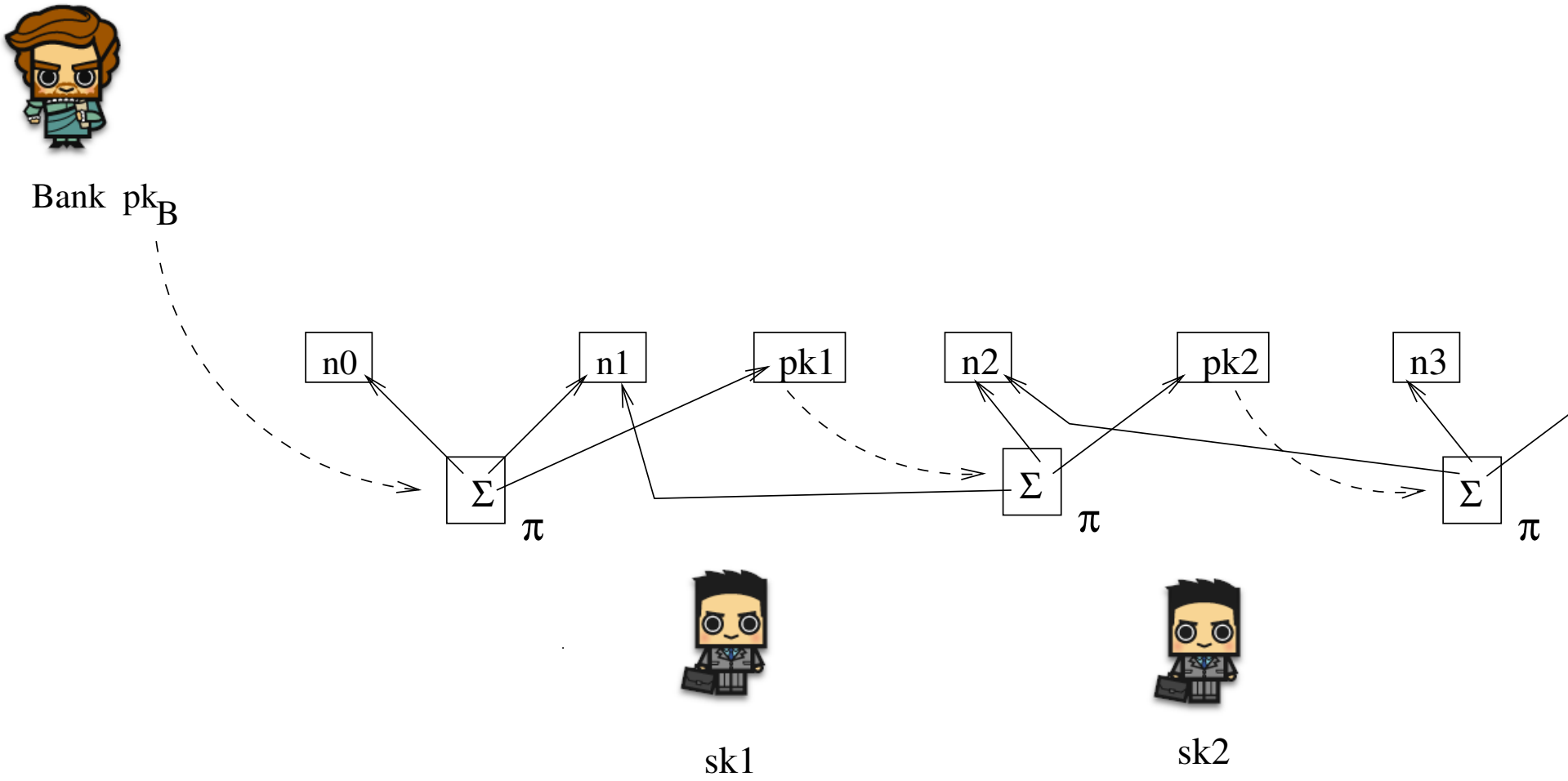

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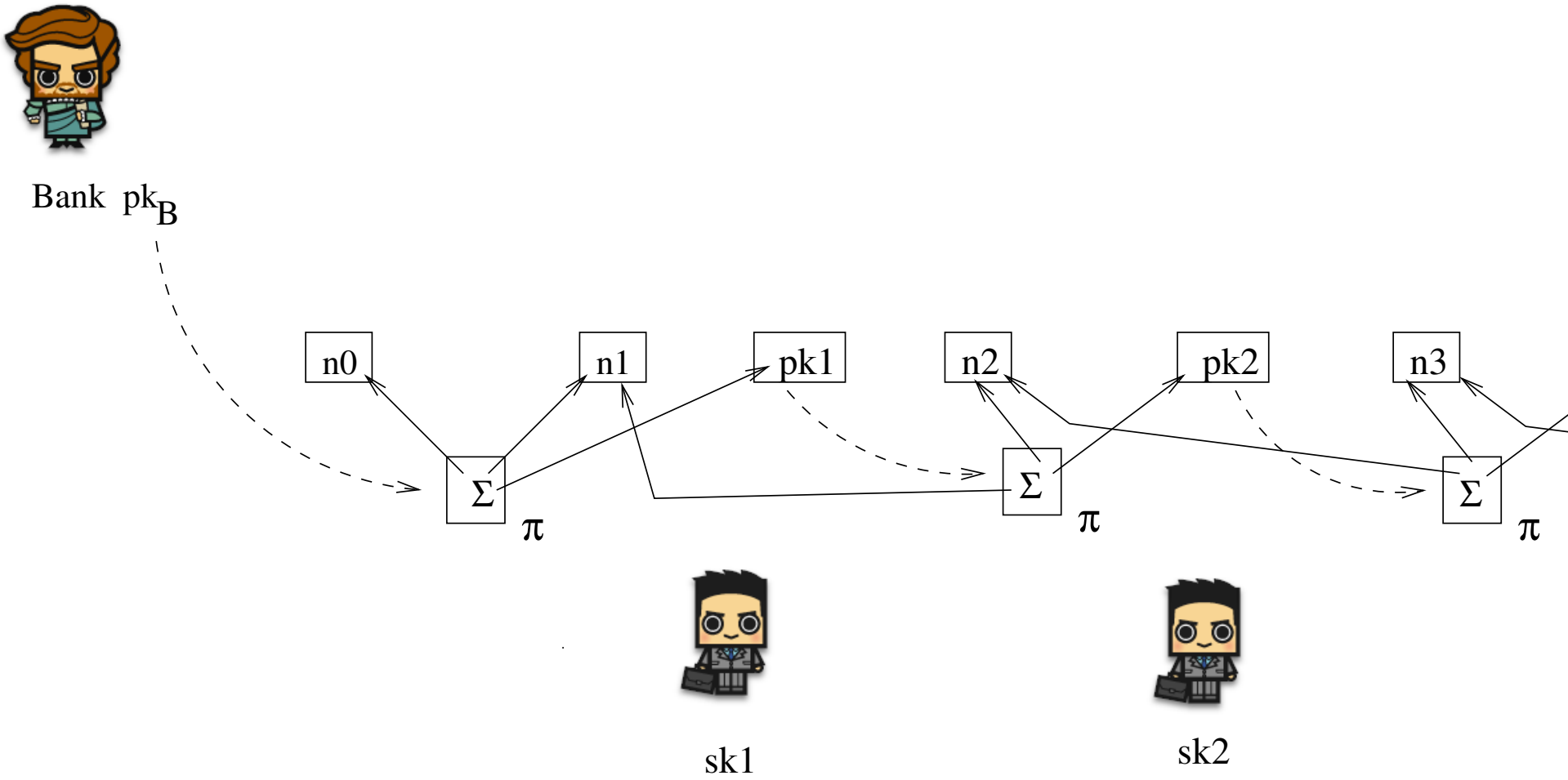

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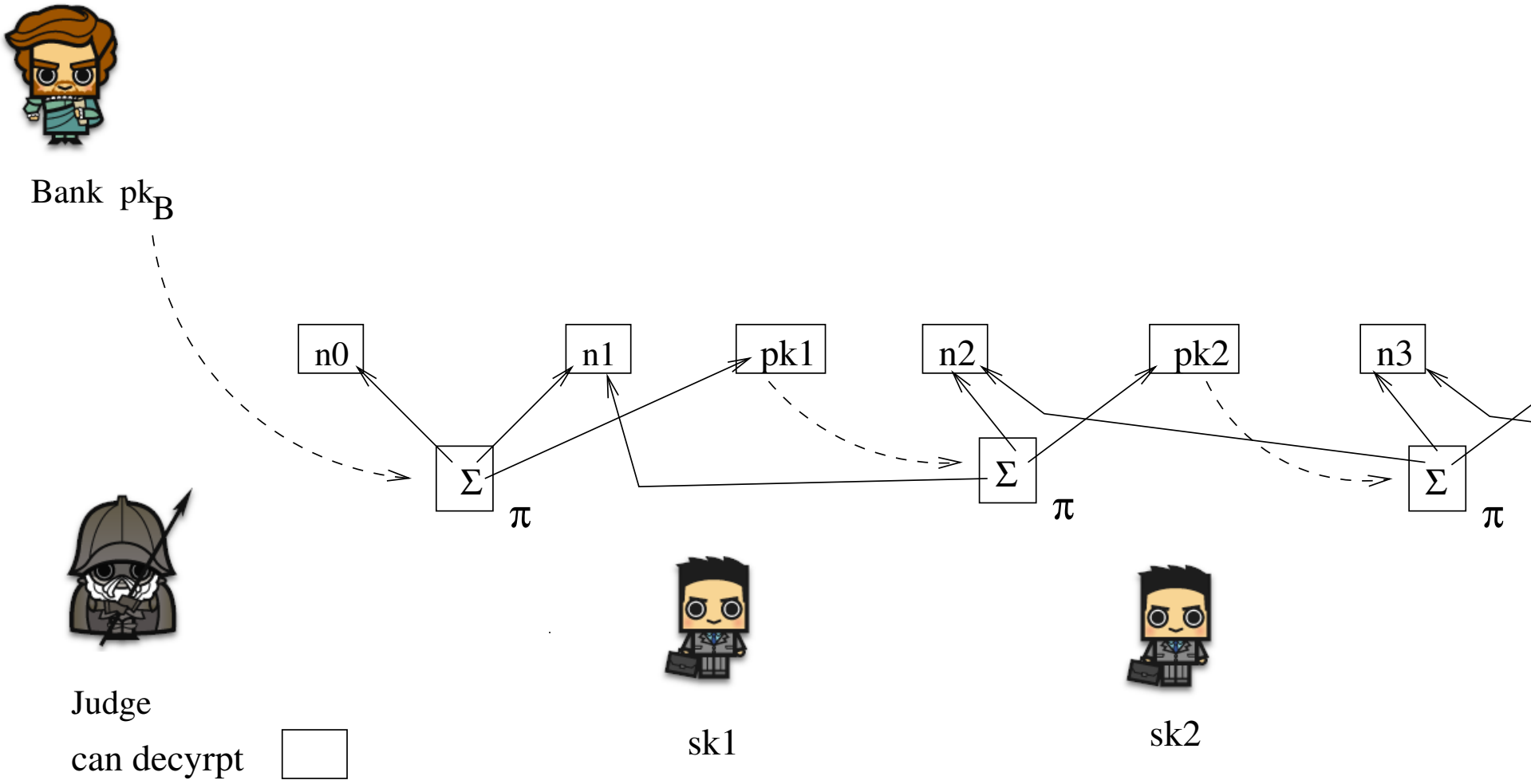

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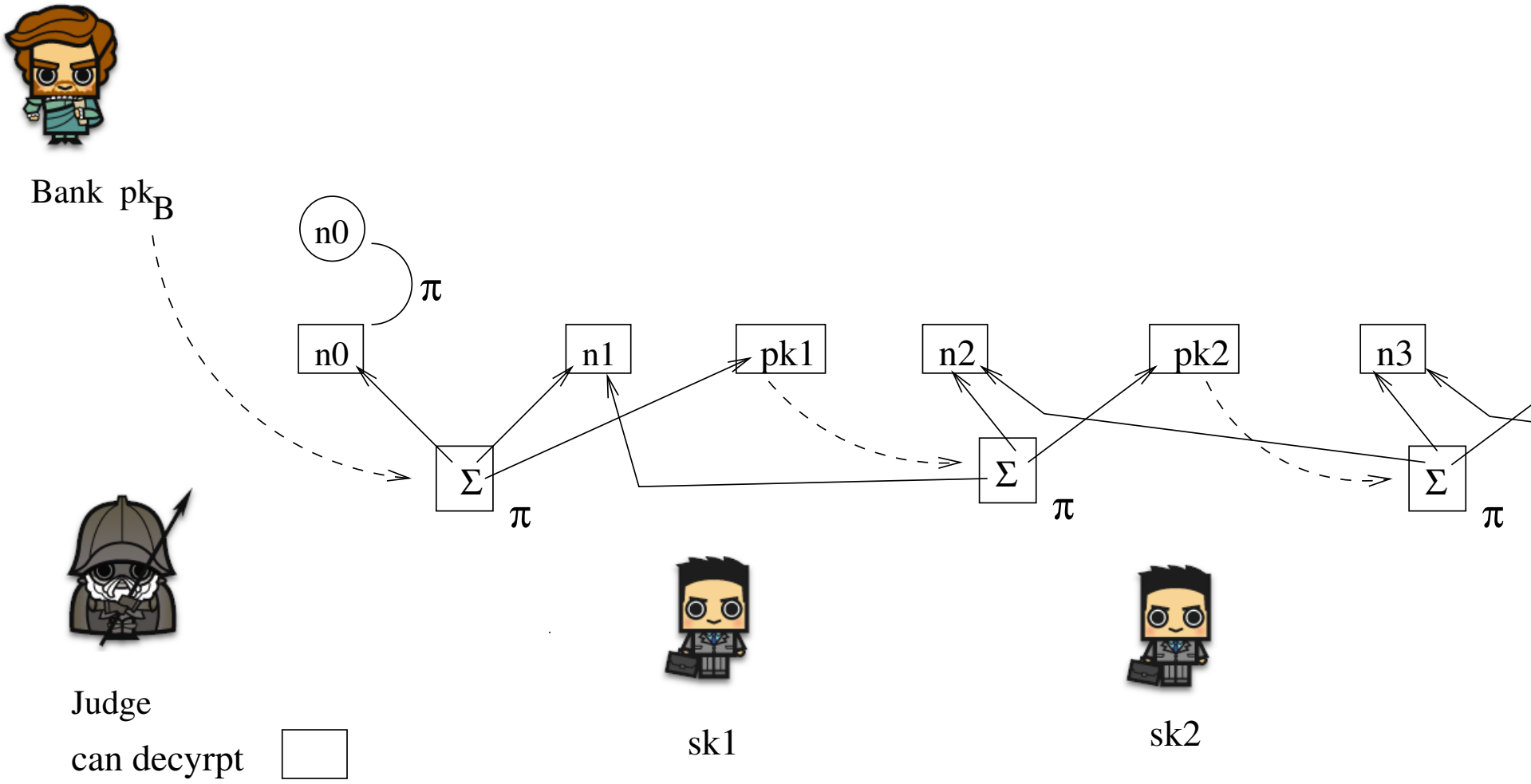

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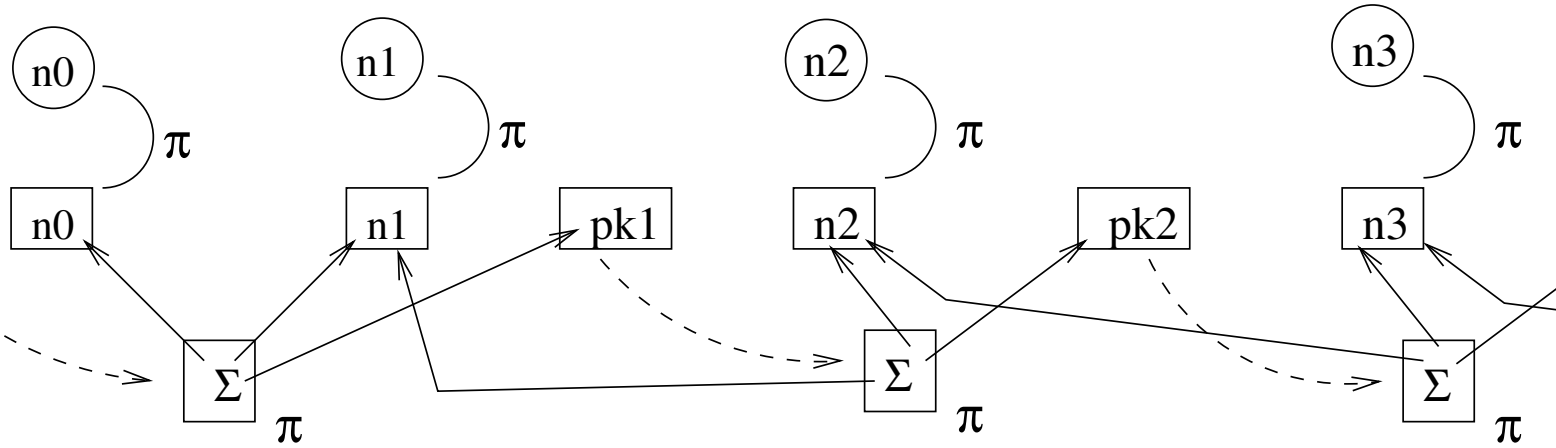


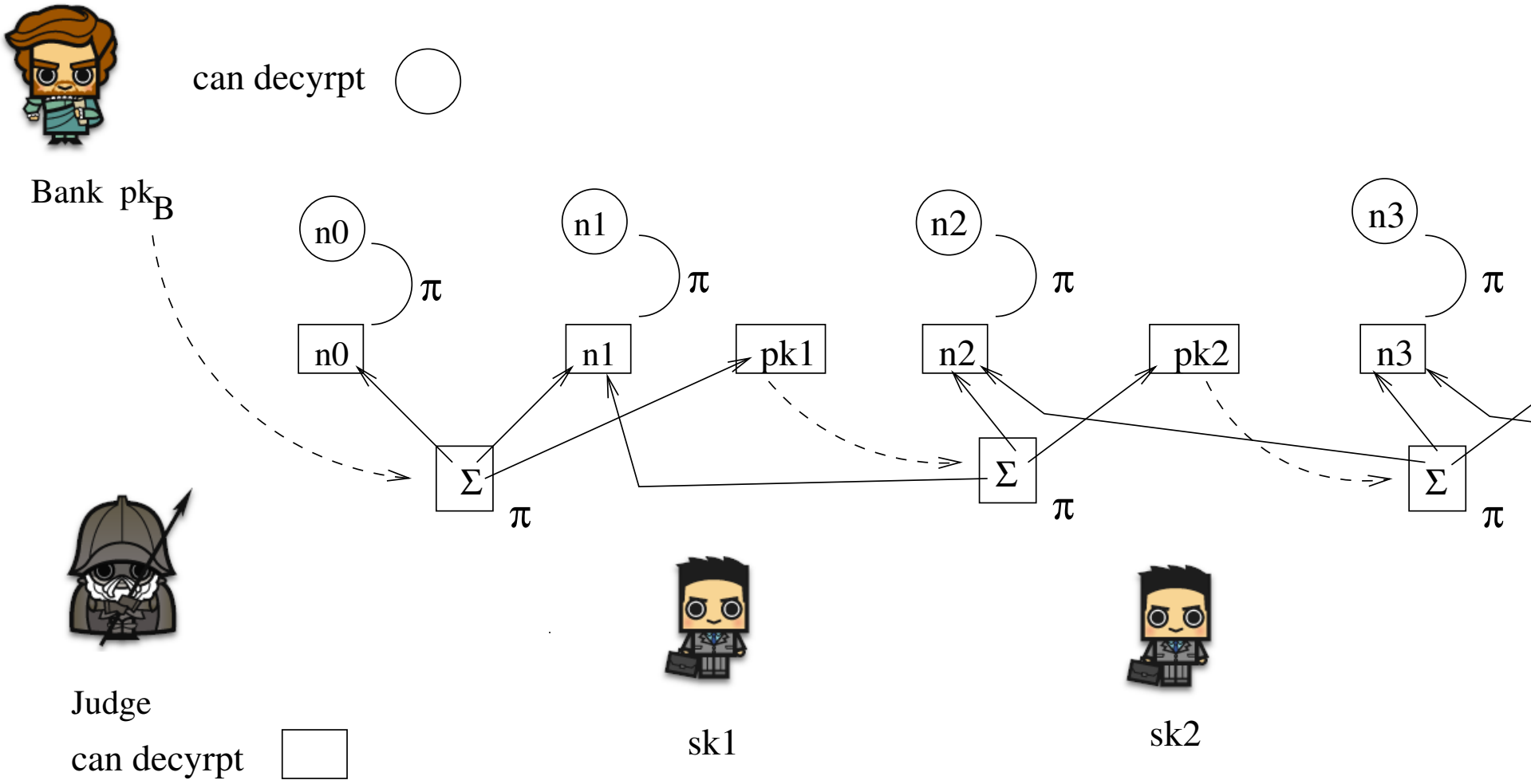
Judge

can decyrpt

sk1

sk2

The form of a coin



Conclusion

By introducing a trusted third party to trace users, we constructed the first *efficient* transferable e-cash scheme achieving all considered security notions

Thank you! ☺