The Anatomy of a Crypto Protocol

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Symposium for Mitchell Wand
24 Aug 2009

Protocols coordinate distribute systems

Despite malicious adversaries

Allow principals to

- Agree selectively on values
- Undertake commitments involving those values
- Coordinate state changes

Application-specific crypto protocols

Three claims

- Central to secure distributed systems
- Analysis uses two basic principles: authentication tests
  - Formalized in a small denotational semantics
  - Analysis tool CPSA
- Authentication tests also suggest systematic protocol design methods

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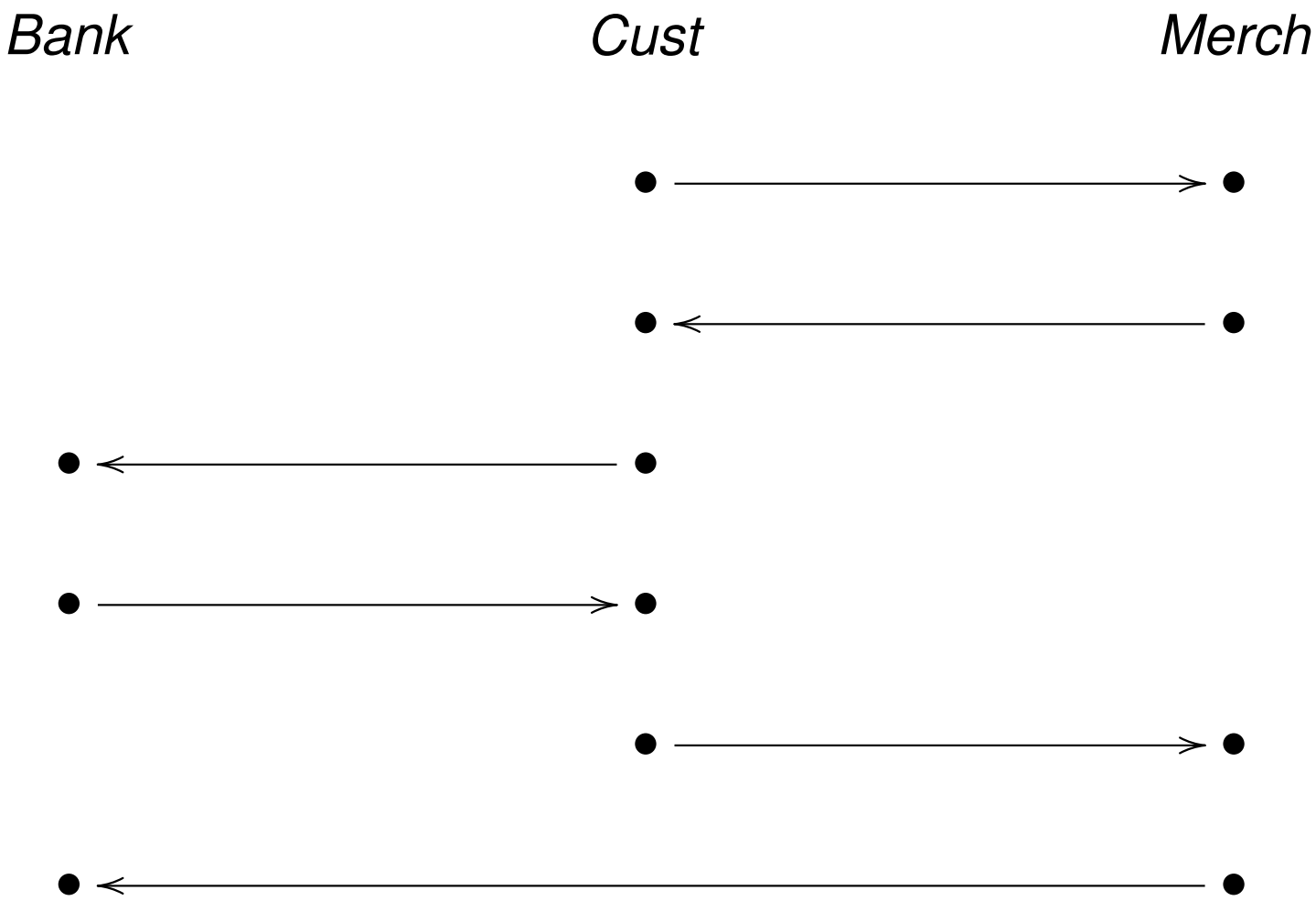

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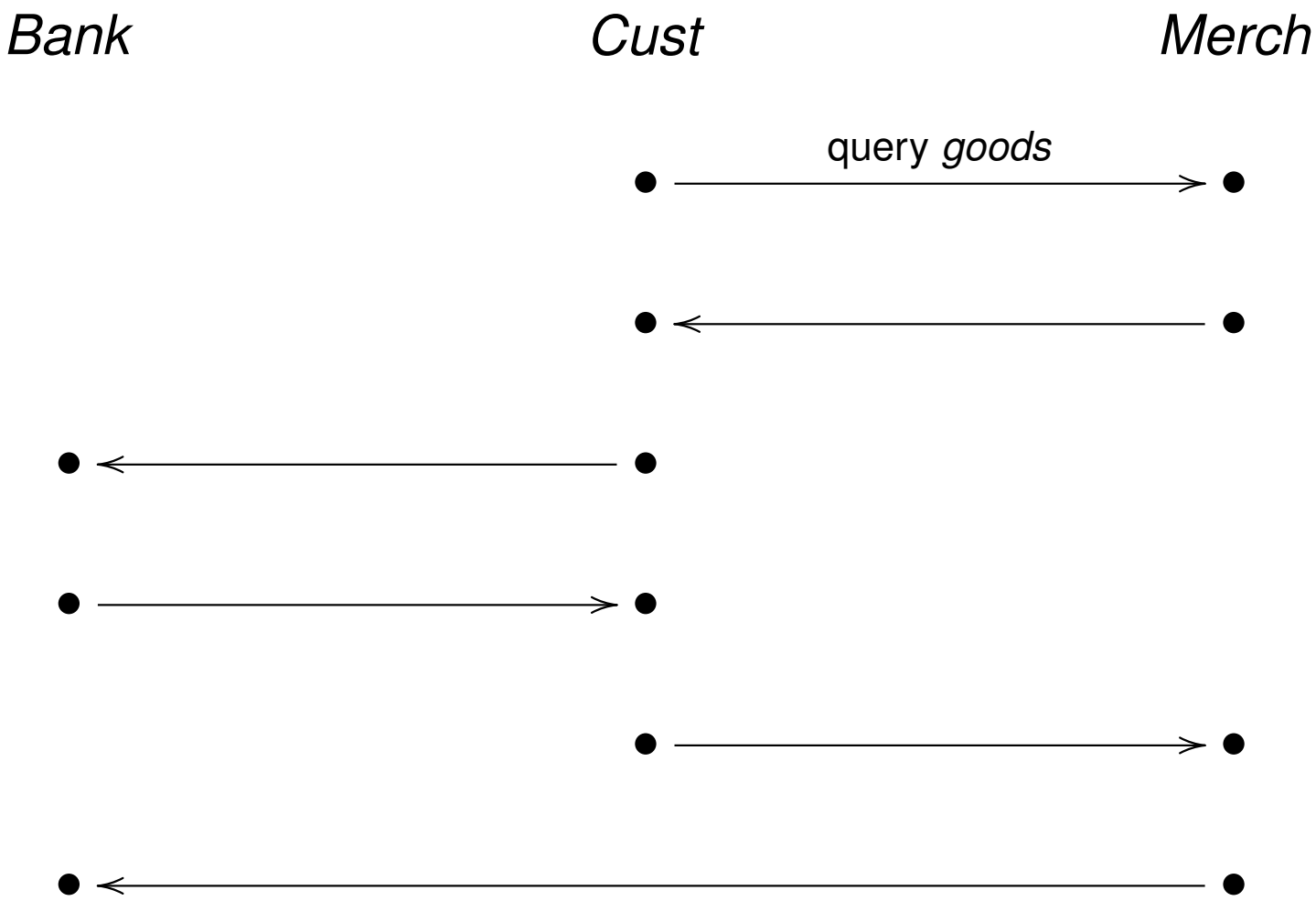

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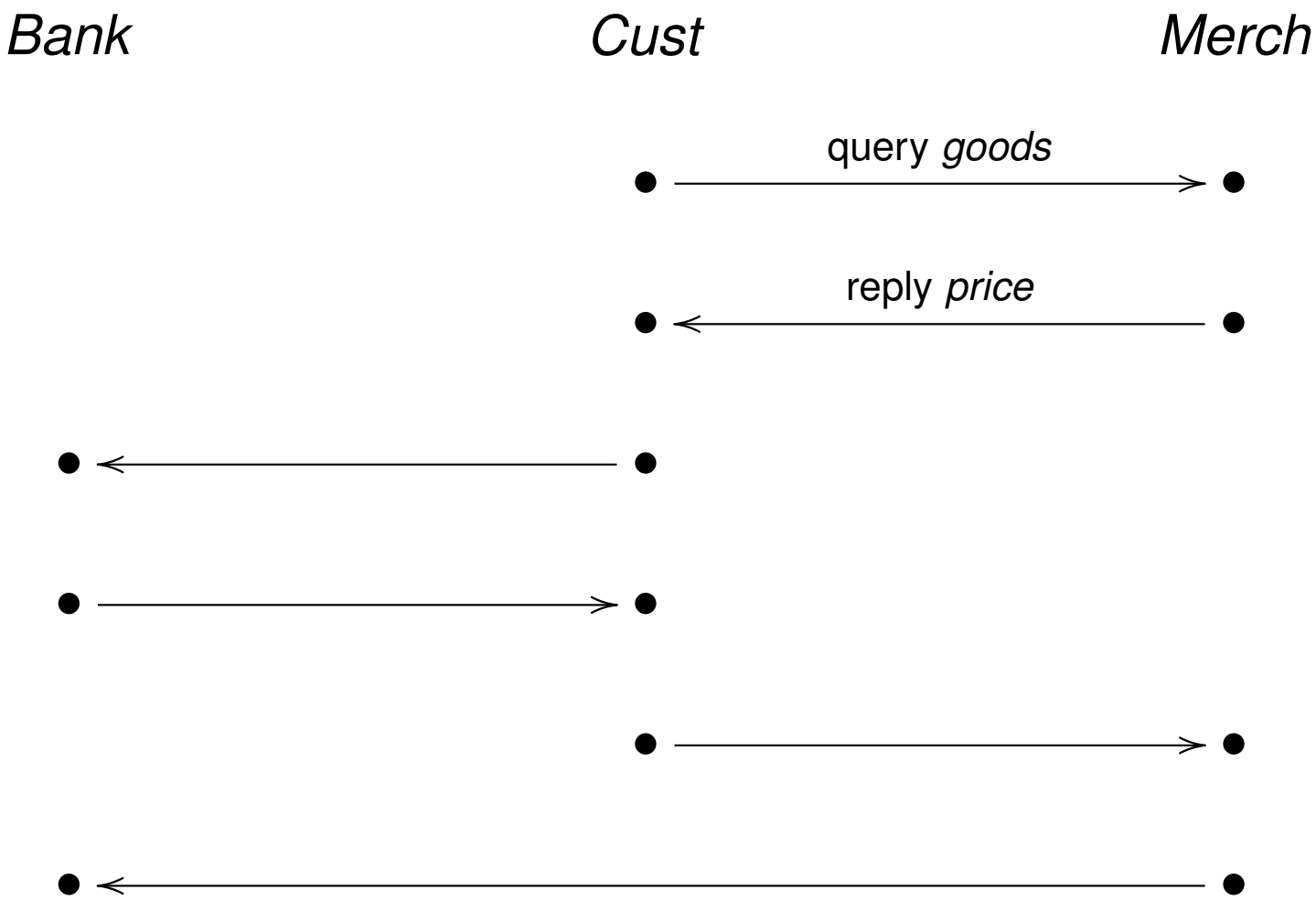

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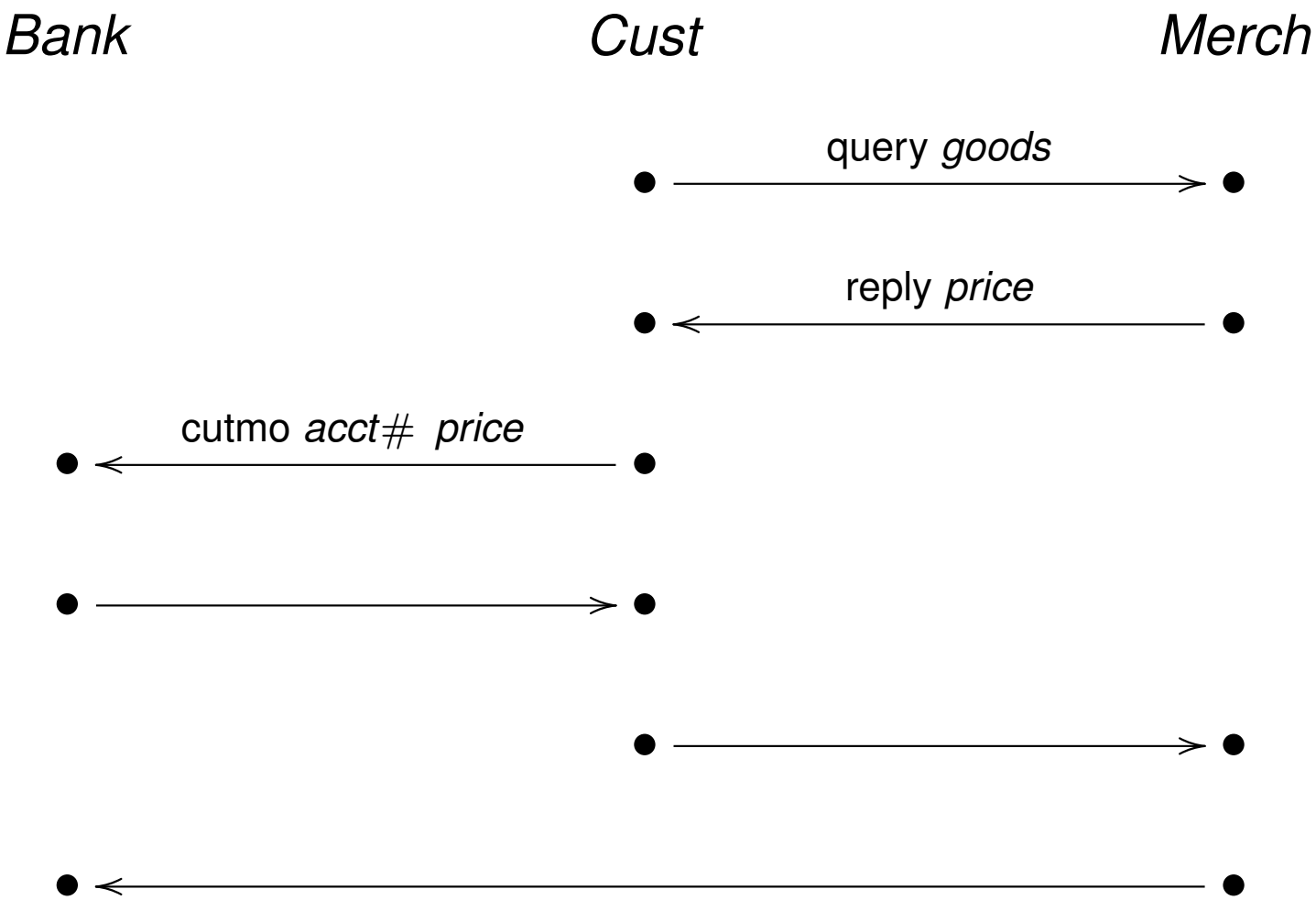

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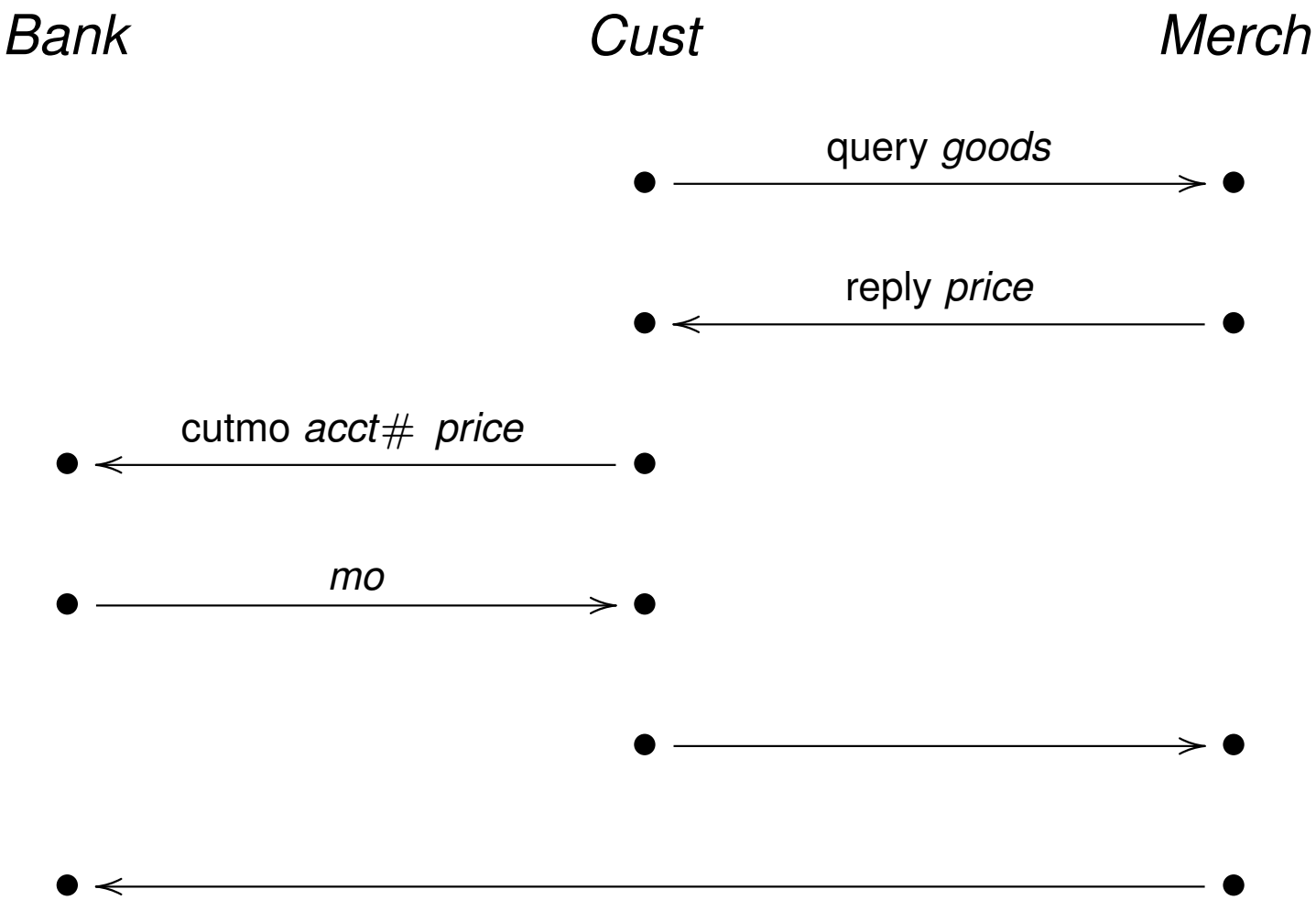

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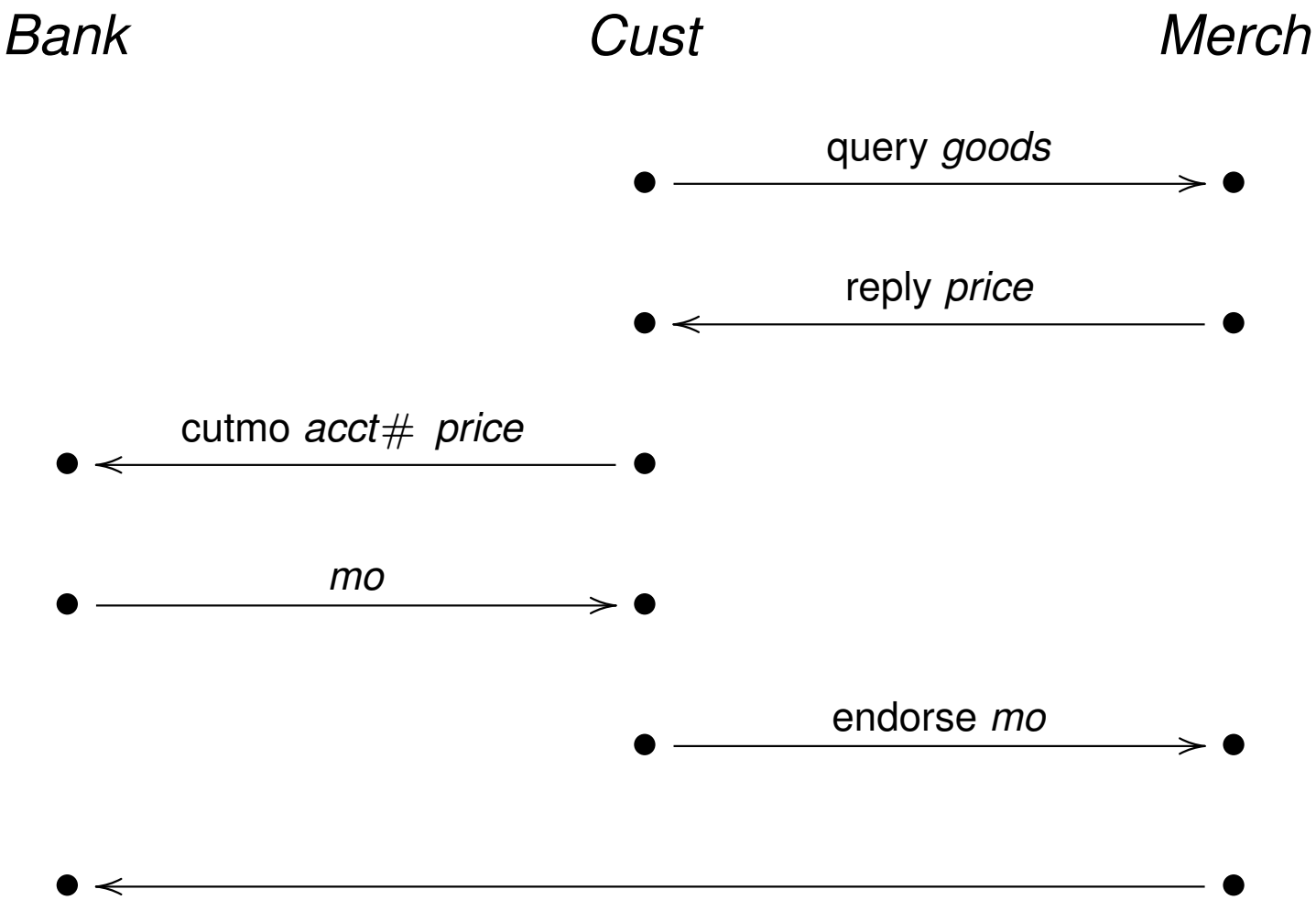

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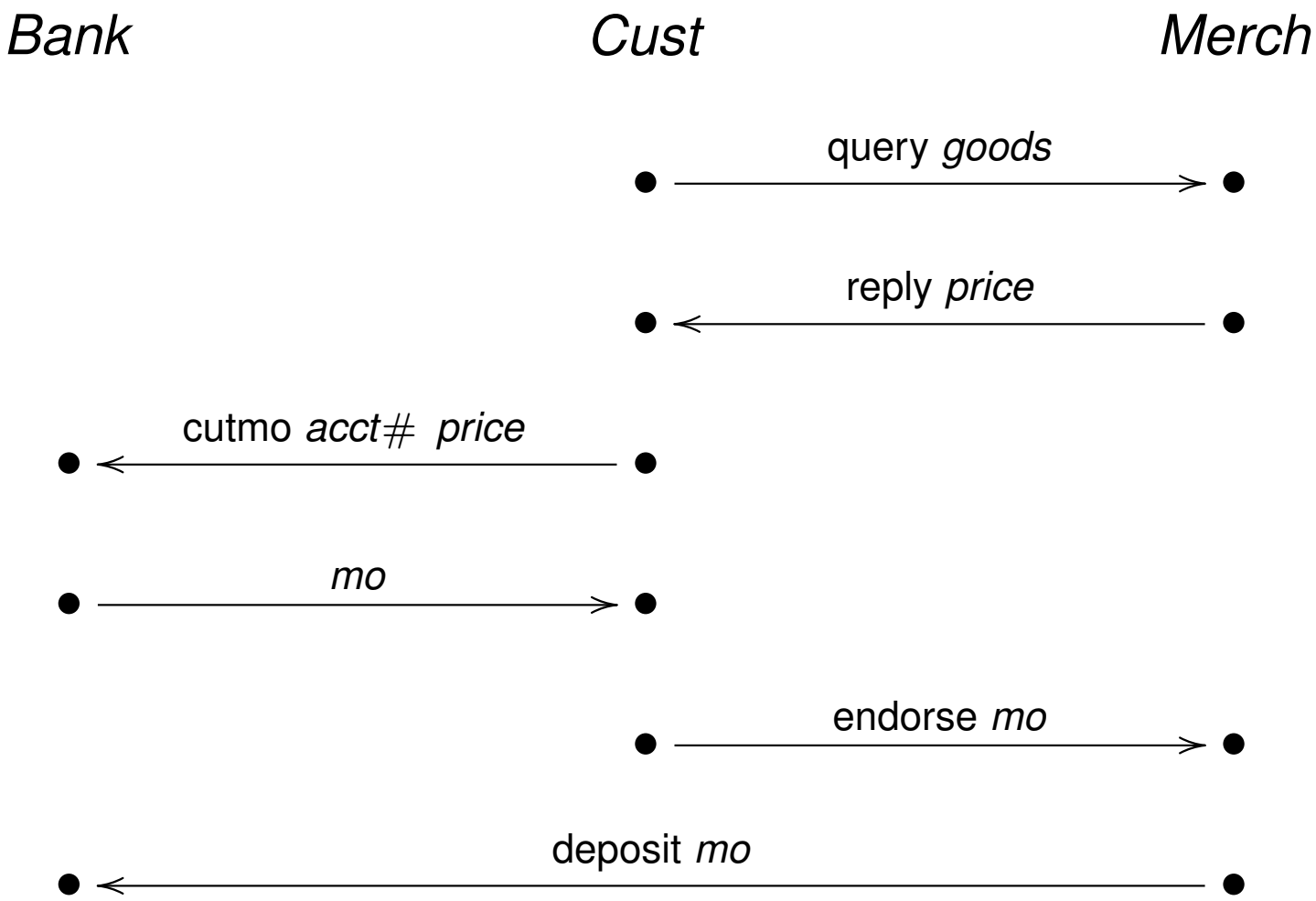


EPMO Goals

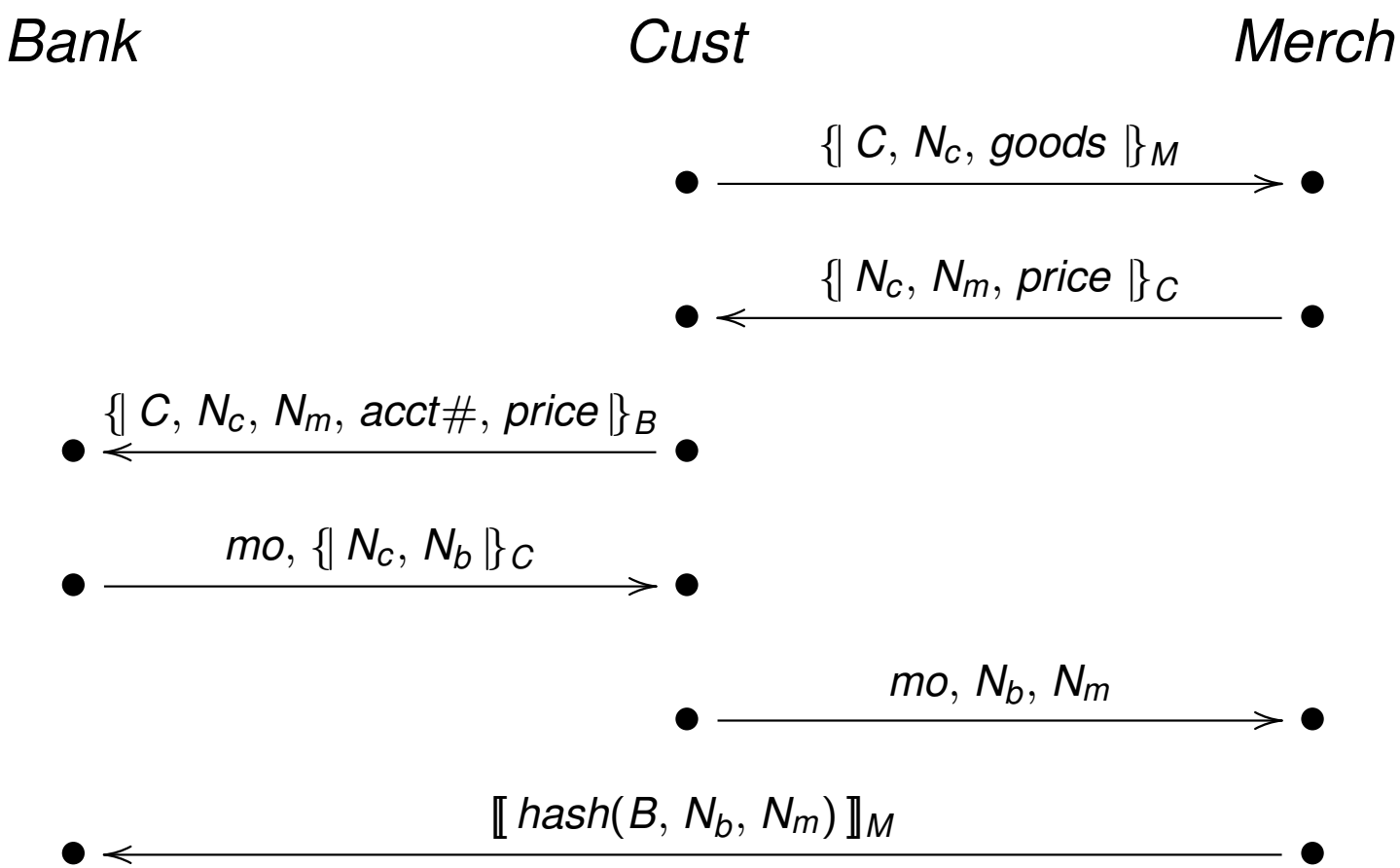
- *Cust*, *Merch*, *Bank* agree on:
  - principal identities
  - *price*
- *Cust*, *Merch* agree on *goods*
- *Cust*, *Bank* agree on *acct#*
- Beyond that, full confidentiality

$EPMO_1$

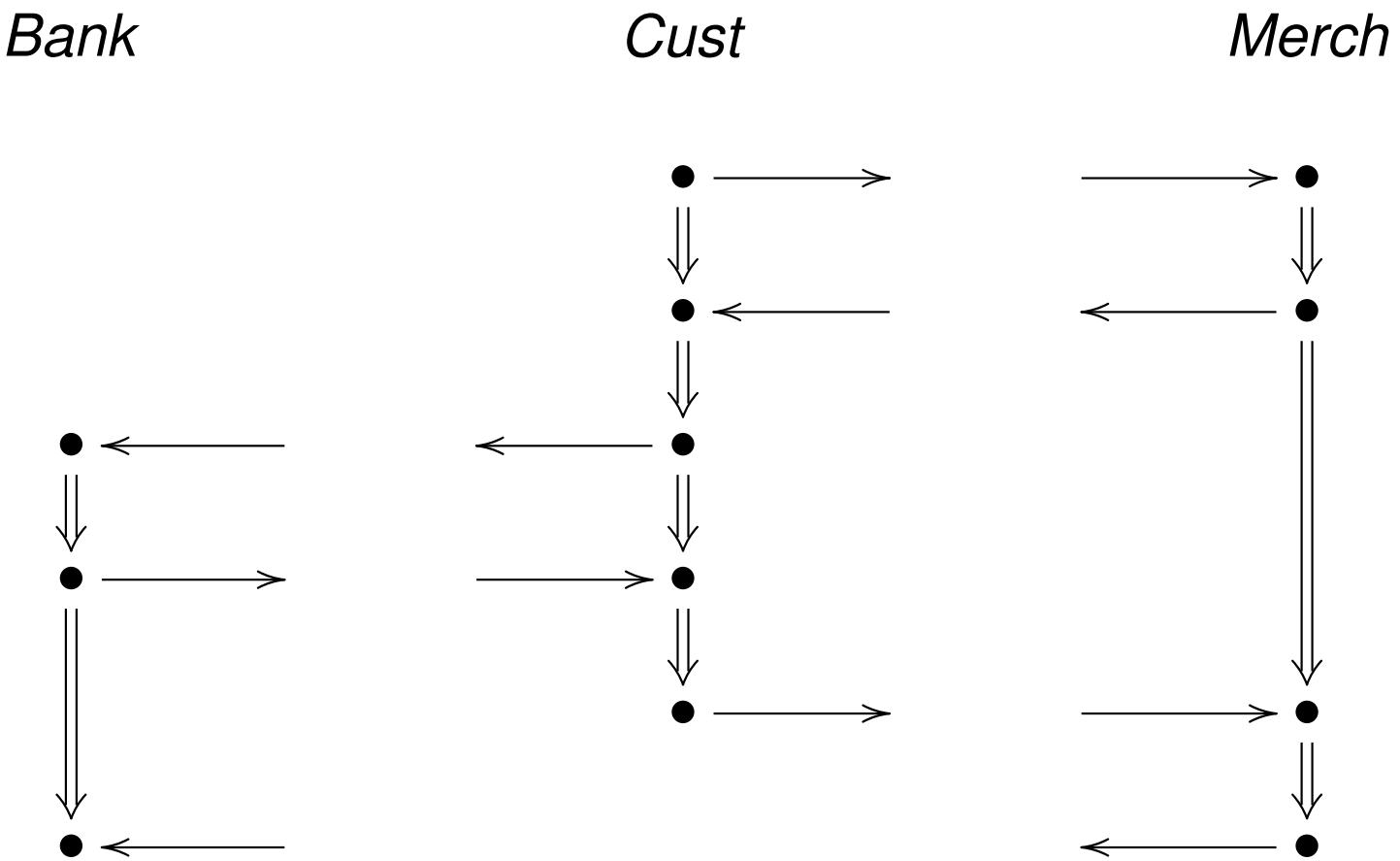
$\{\!|\ -\ |\!\}_P$ means encr. with P's public key

$[\![-]\!]_P$ means digital signature

$mo = [\![\, hash(C,\ N_c,\ N_b,\ N_m,\ price)\,]\!]_B$

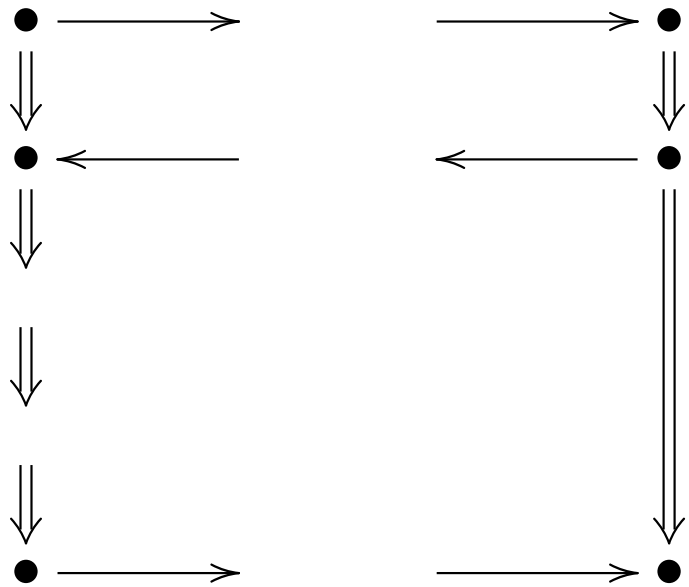


The Strand Space point of view

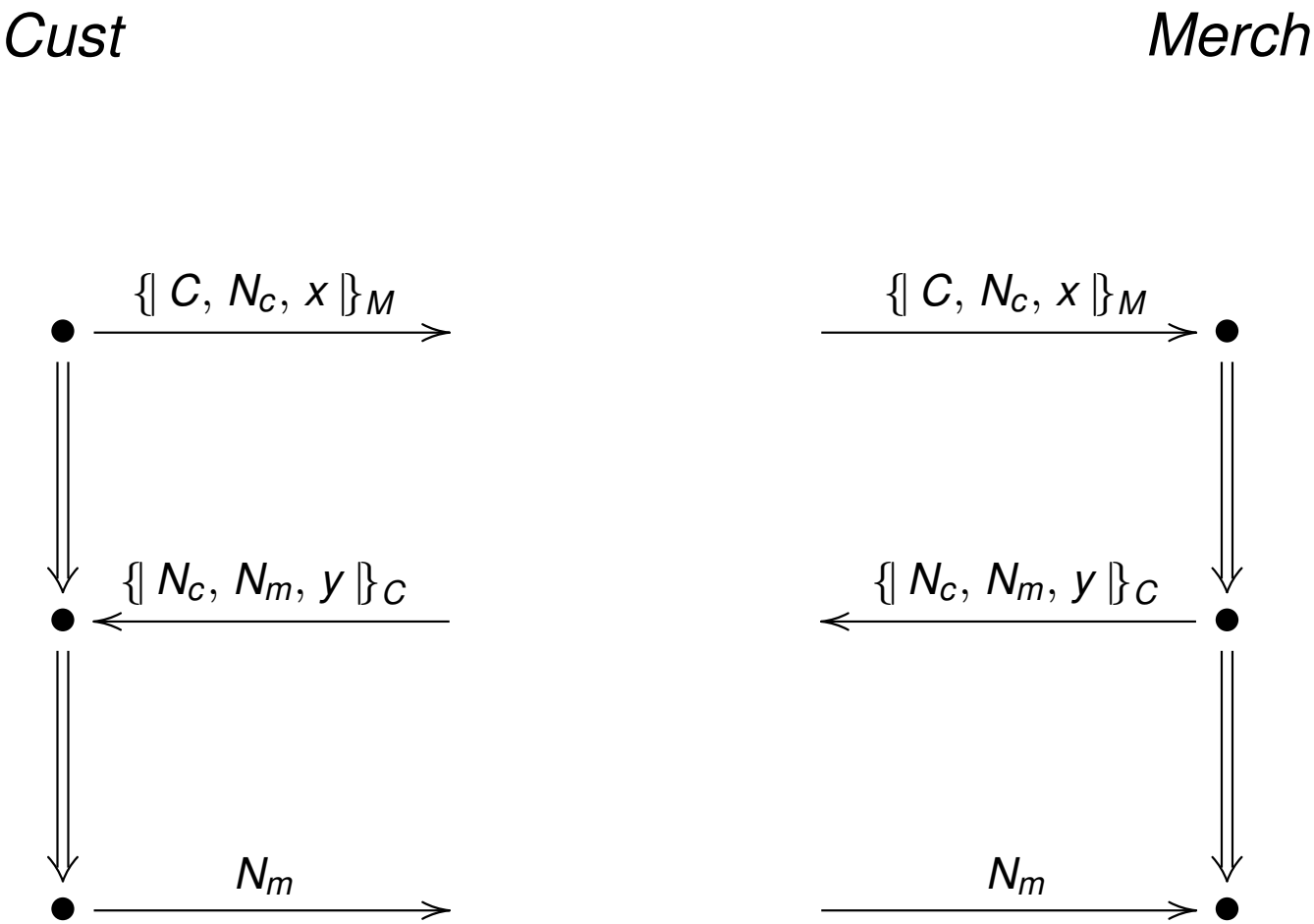


Simplification: Customer-merchant subprotocol

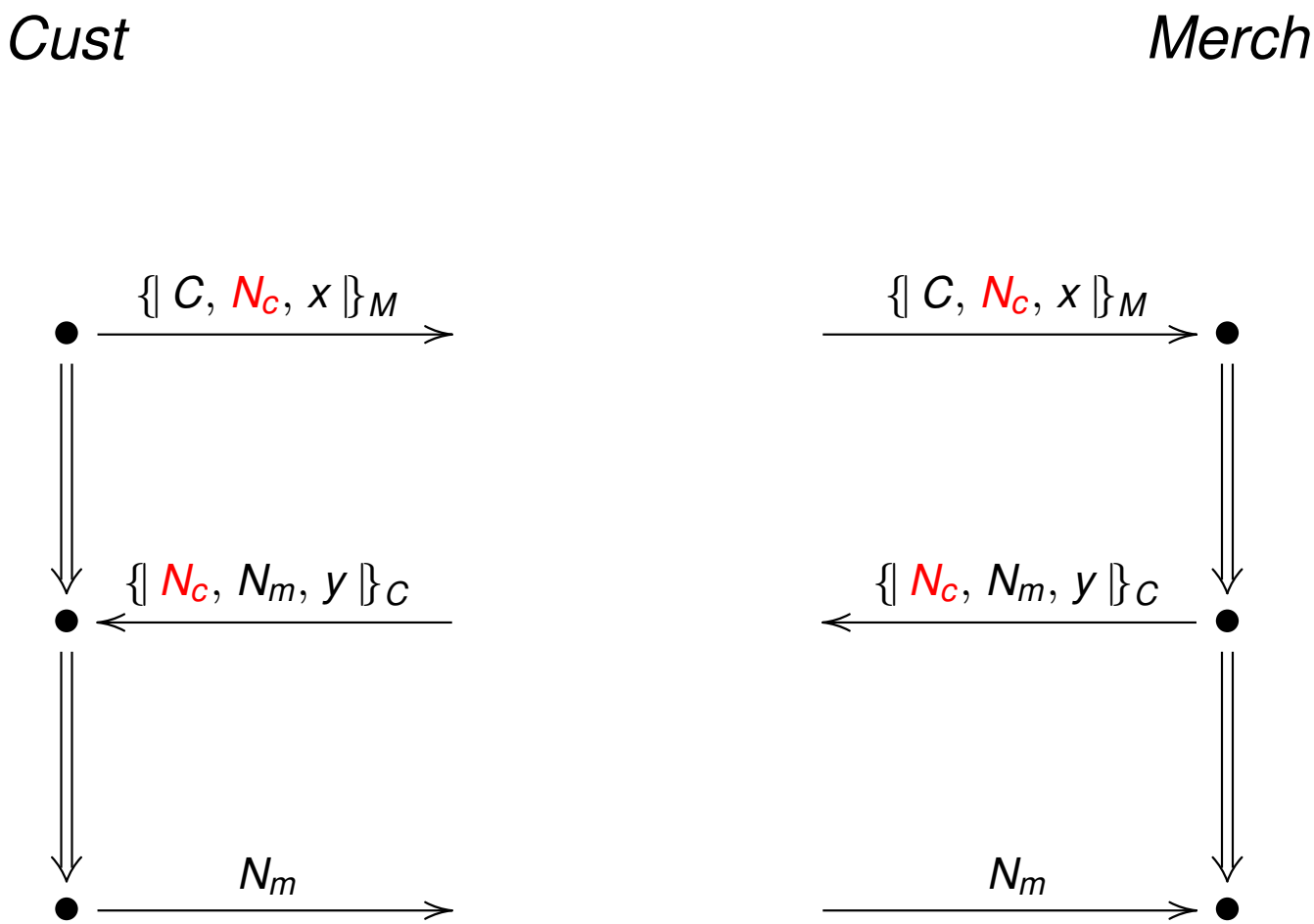
Bank *Cust* *Merch*



$EPMO_1$ customer-merchant subprotocol



$EPMO_1$: How customer tests merchant



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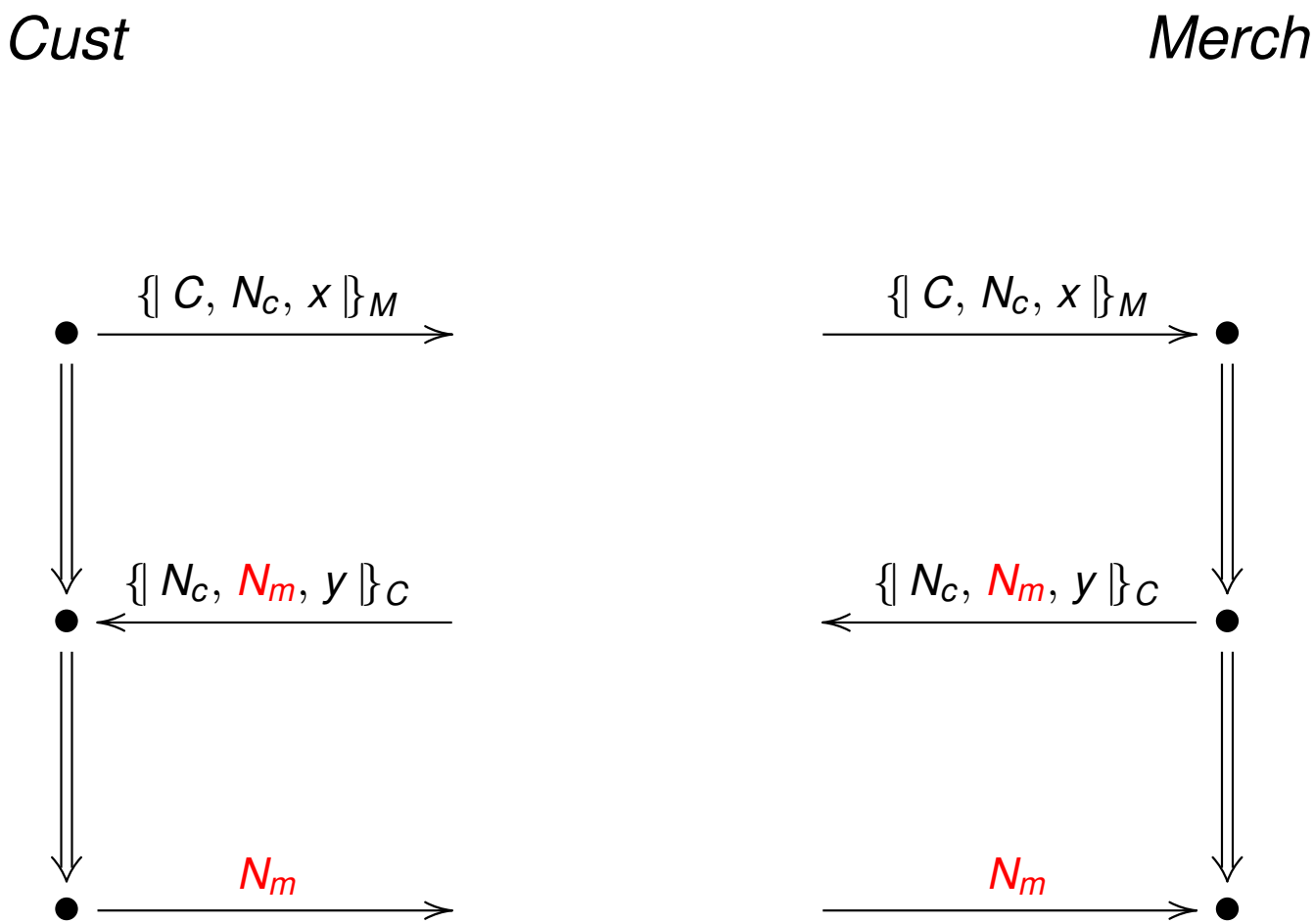
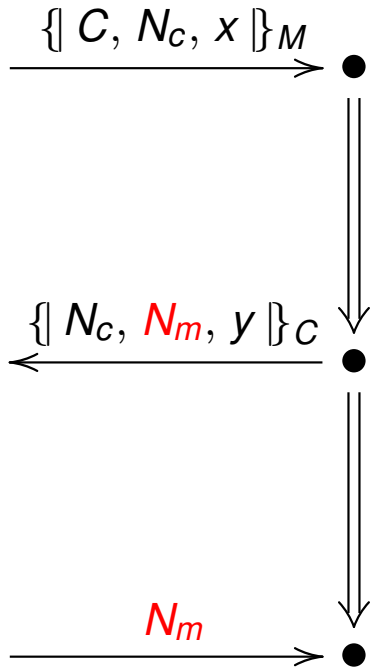


Nonce sent encrypted

Authentication test pattern

- When a freshly chosen value N is:
  - Sent inside encryption
    $$\{\!|\ \cdots N \cdots\ |\!\}_K$$
  - Received later outside this form
- Infer: either
  - Decryption key K^{-1} is compromised, or else
  - A regular participant received
    $$\{\!|\ \cdots N \cdots\ |\!\}_K$$
    and retransmitted N in another form

$EPMO_1$: What does the merchant learn?



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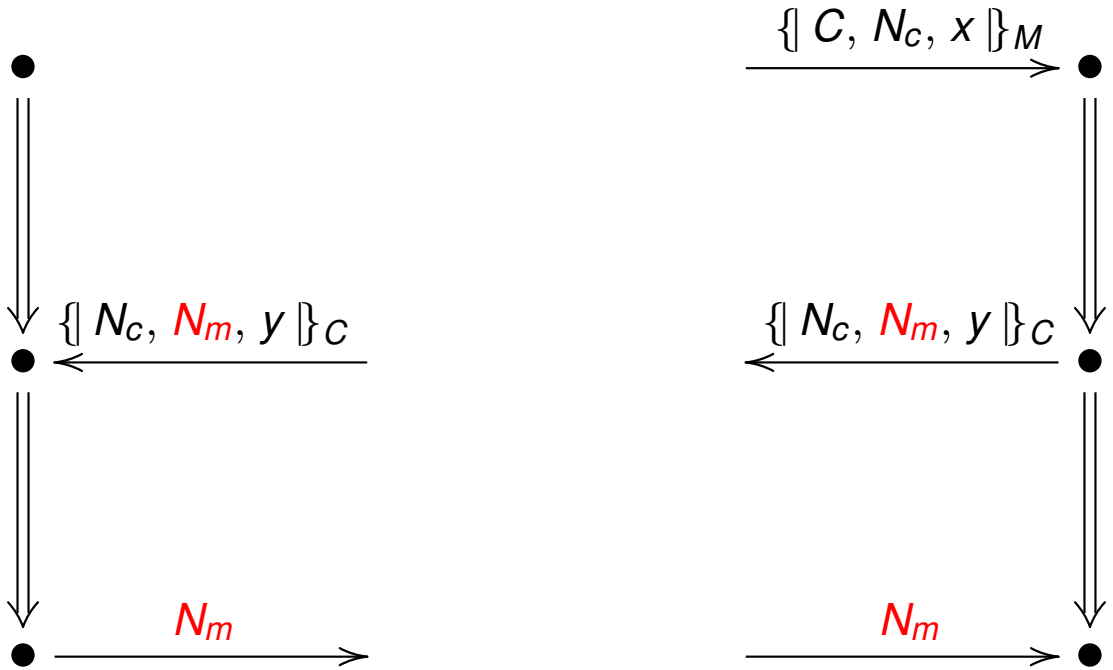
If N_m freshly chosen, C's decryption key uncompromised



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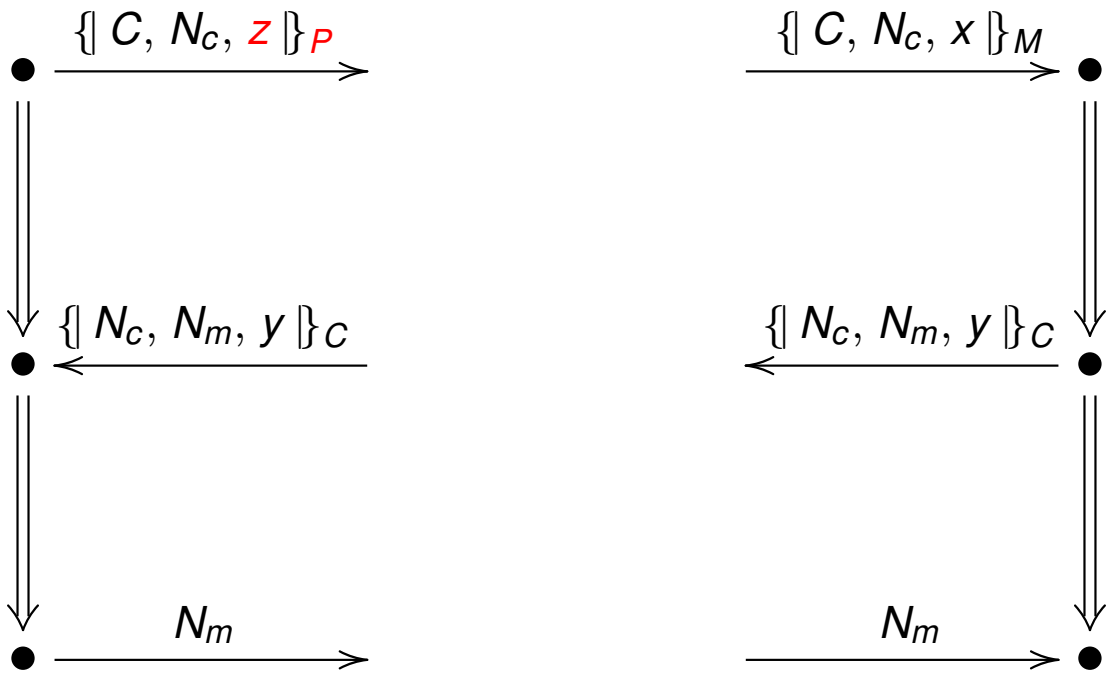
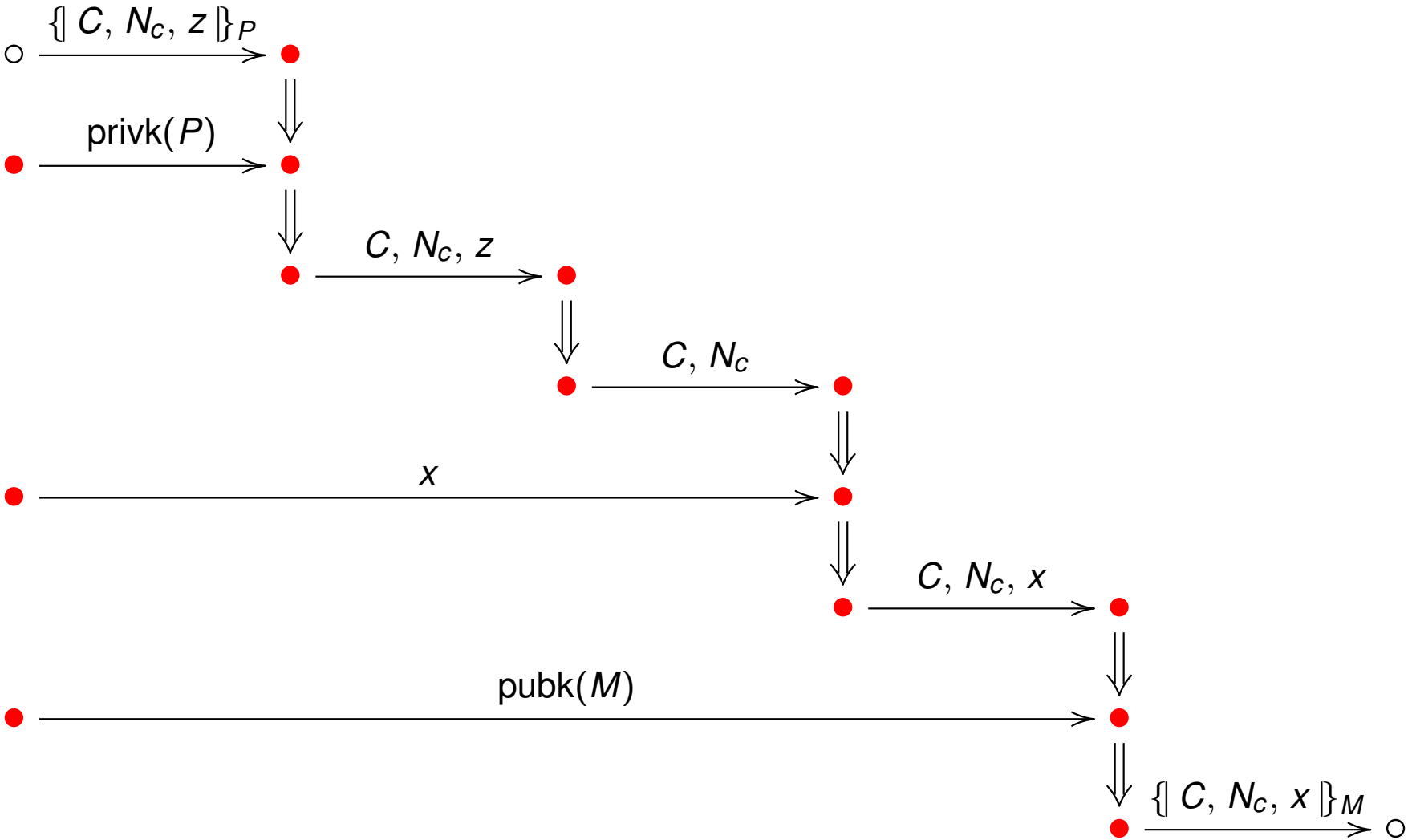


$EPMO_1$: How this is possible



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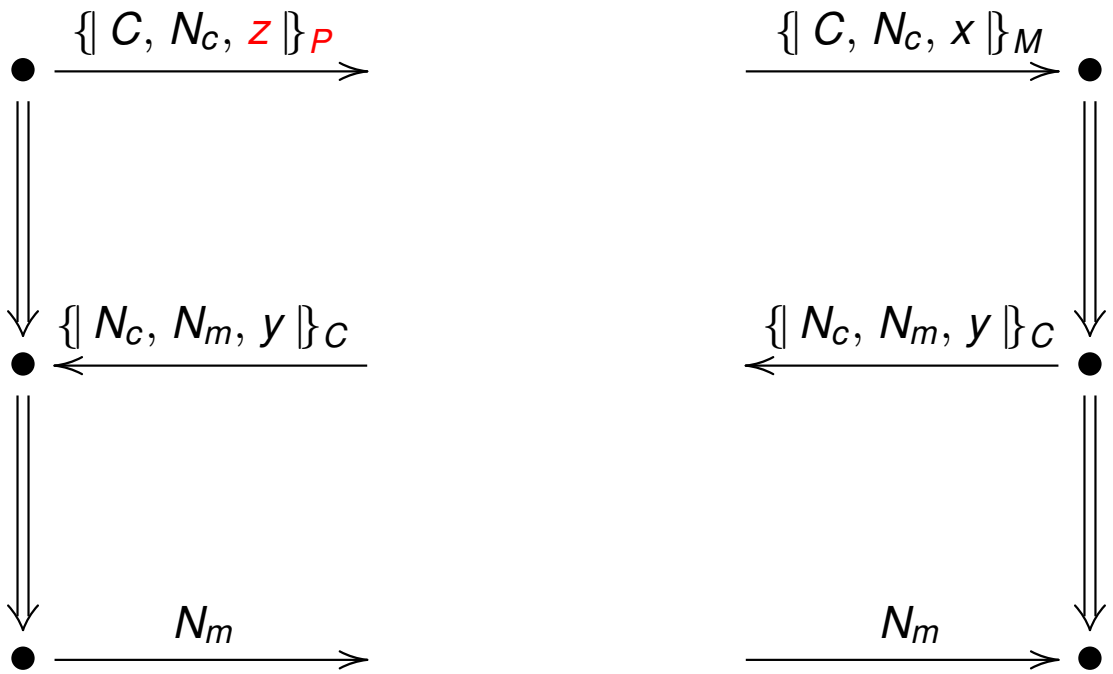
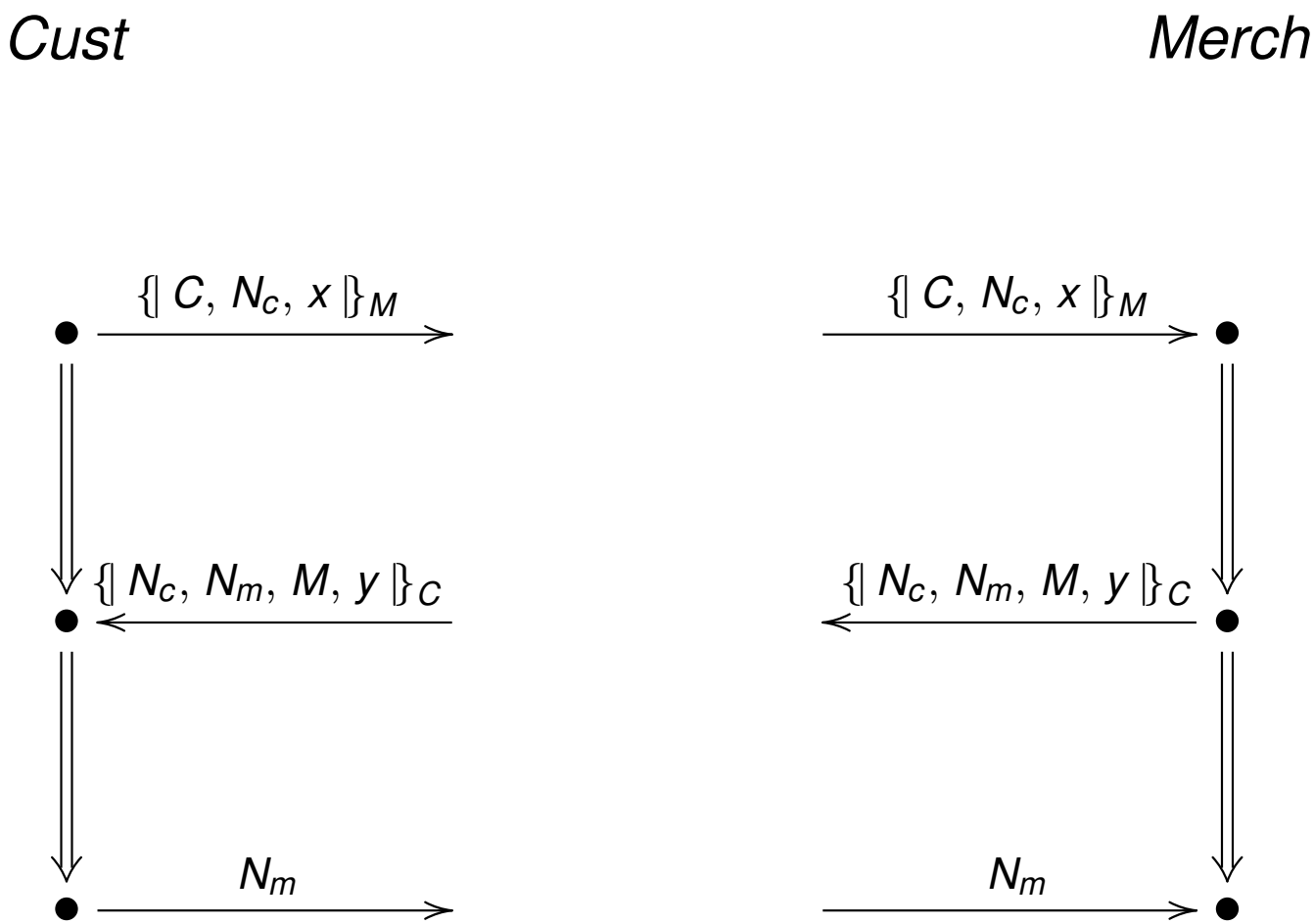


$EPMO_2$ customer-merchant subprotocol



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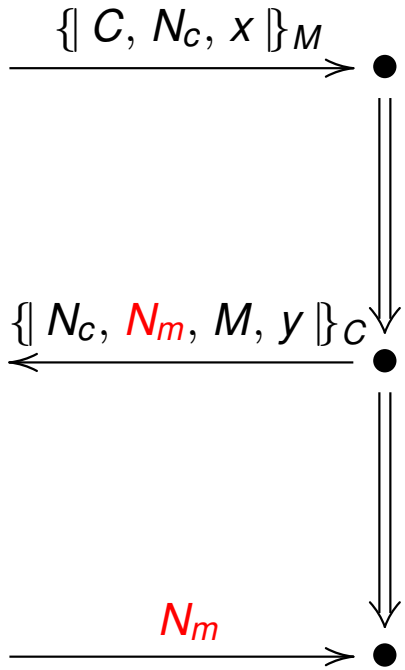

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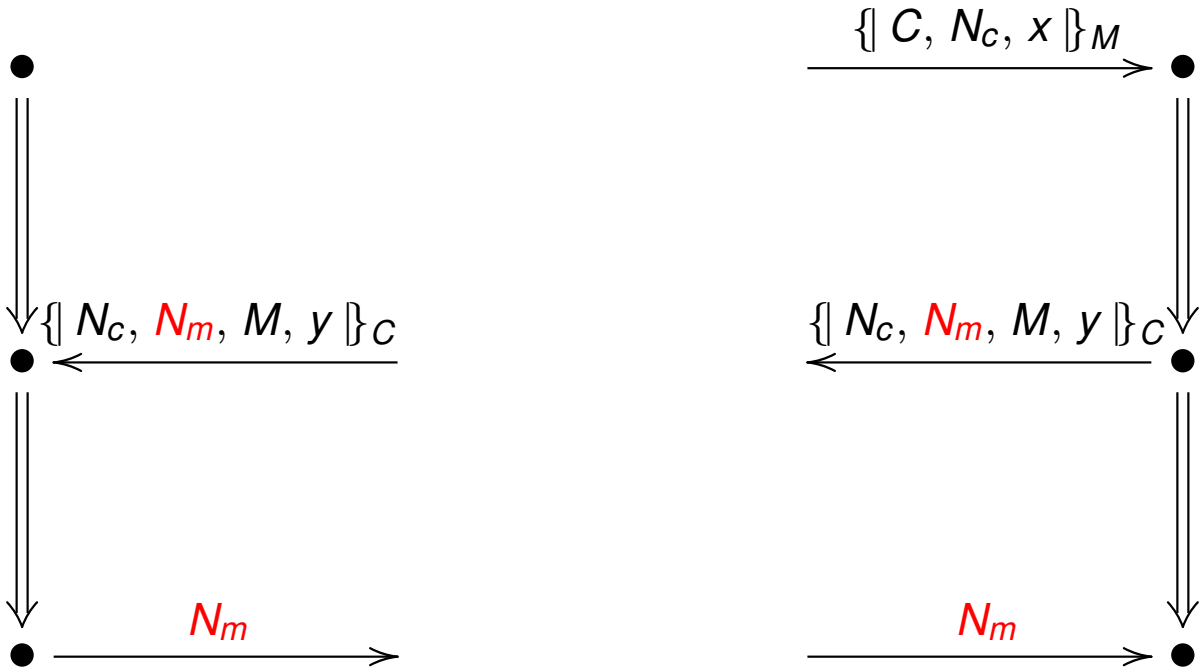

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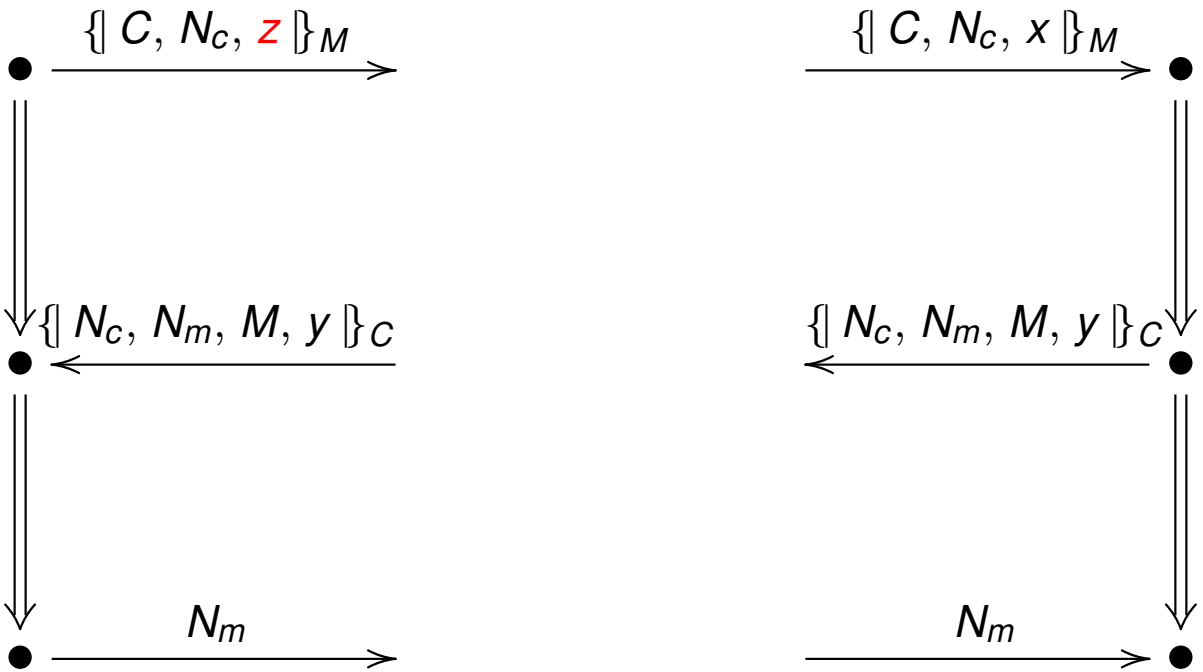

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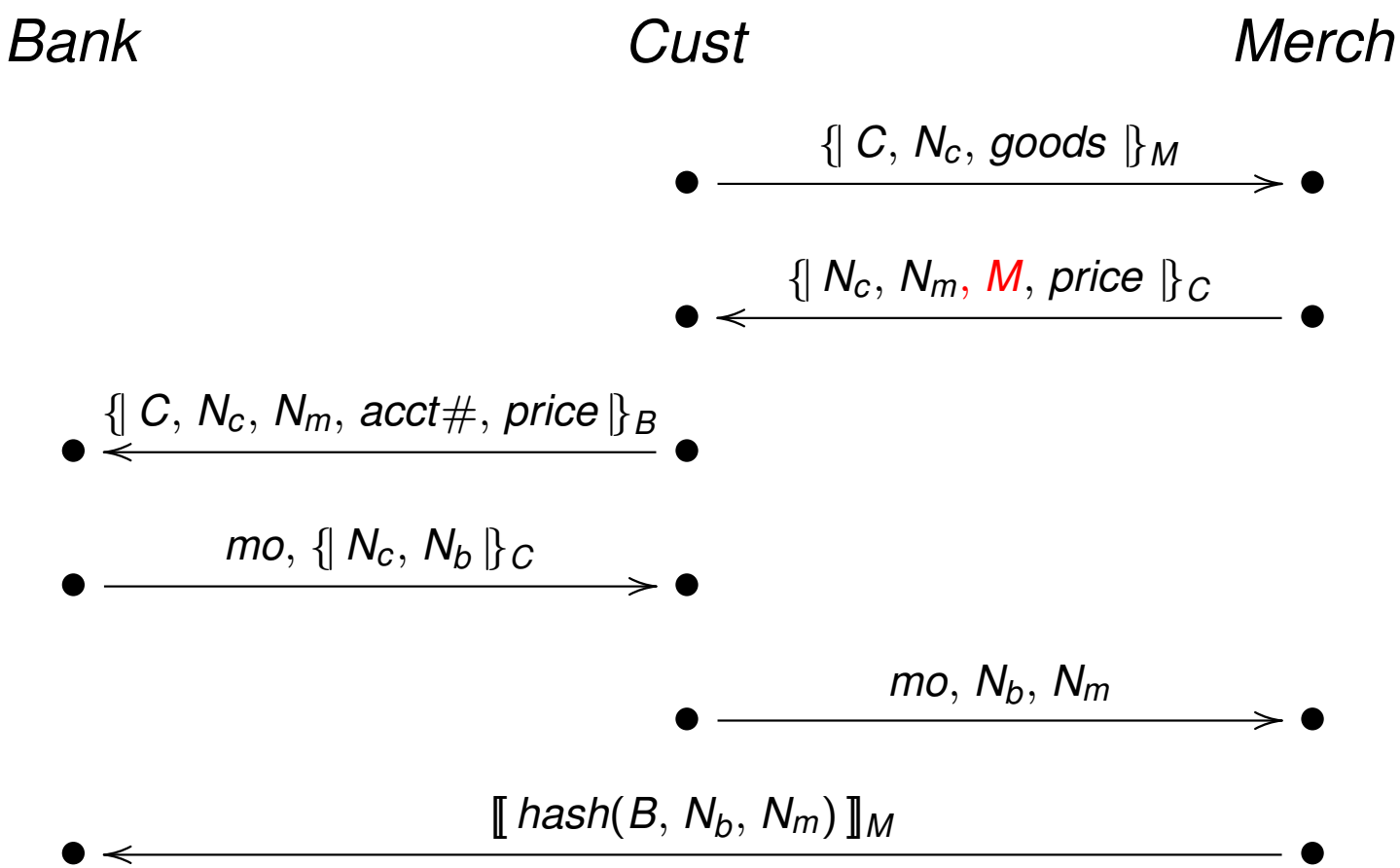

Small denotational semantics

For crypto protocols

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$\mathbb{A}$ is realized iff every test in $\mathbb{A}$ is solved

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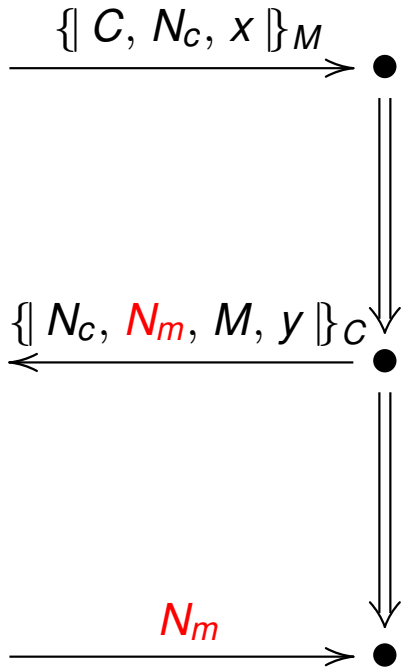

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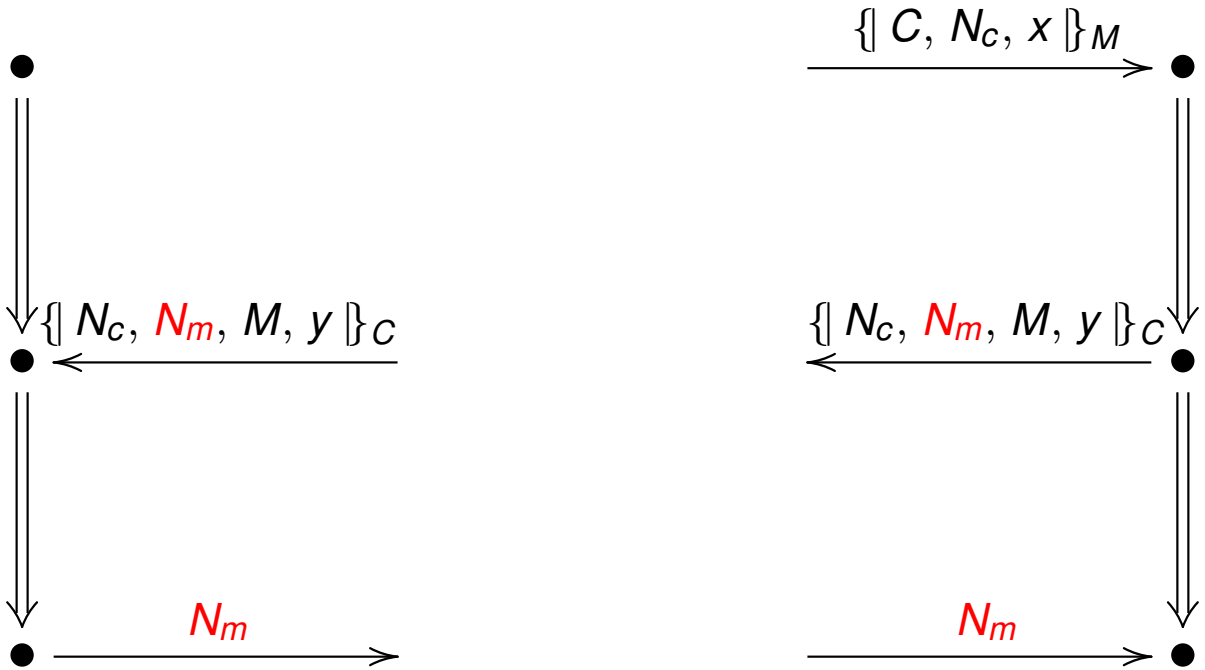

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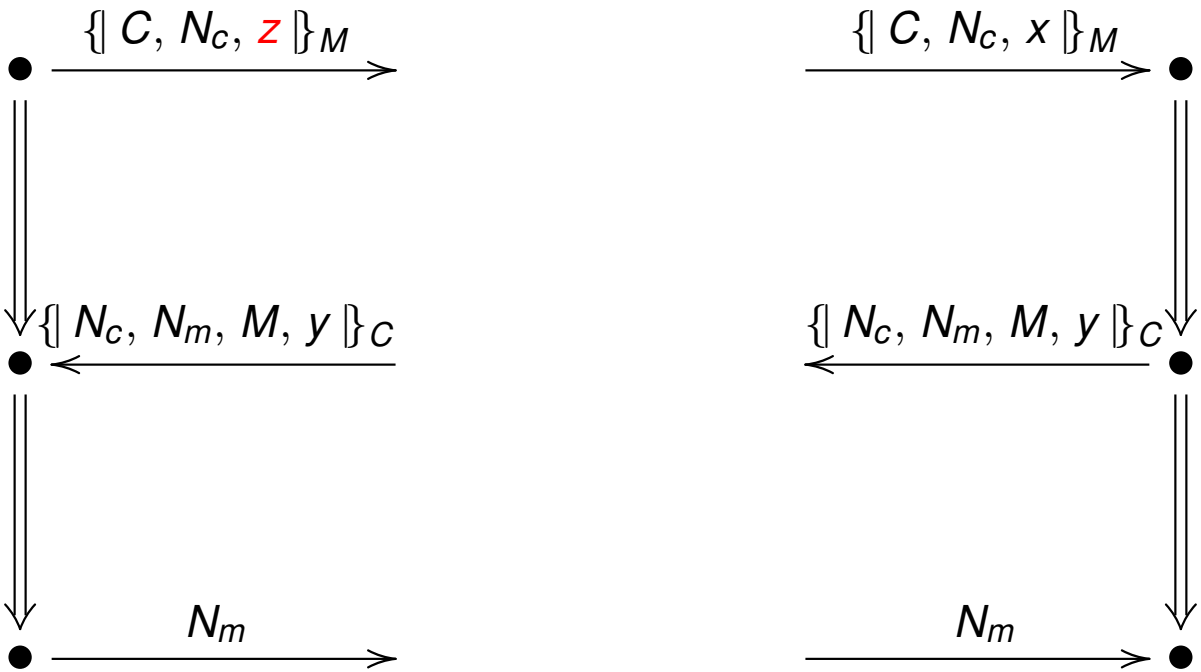

Three key facts

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- Suppose $\mathbb{A}_0 \mapsto \mathbb{A}$ and $\mathbb{A}$ is realized.
  Then for some realized $\mathbb{A}_1$,

$$\mathbb{A}_0 \rightsquigarrow^* \mathbb{A}_1 \quad \text{and} \quad \mathbb{A}_1 \mapsto \mathbb{A}$$

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