Malleable Proof Systems and Applications

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Non-malleable cryptography

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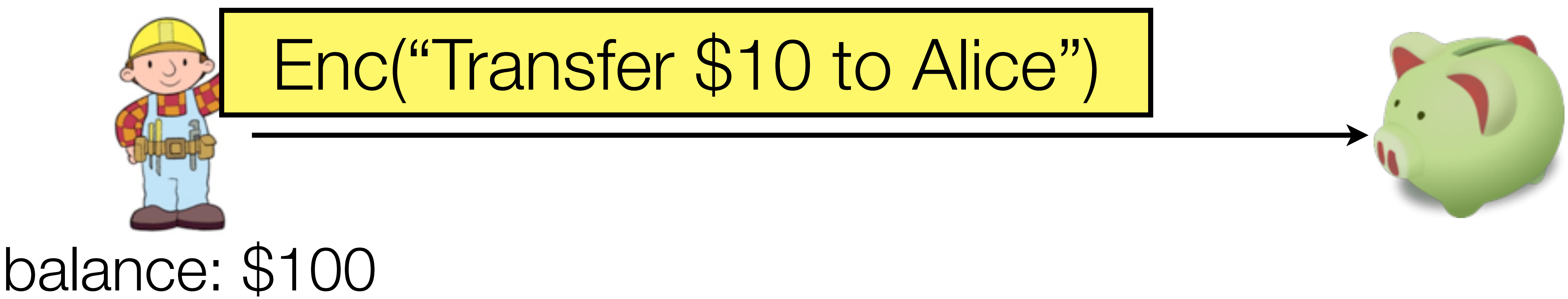

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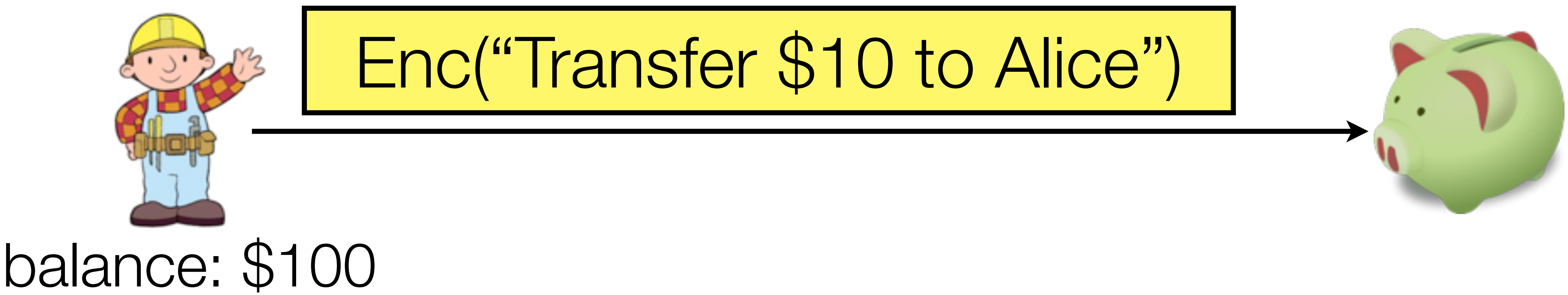

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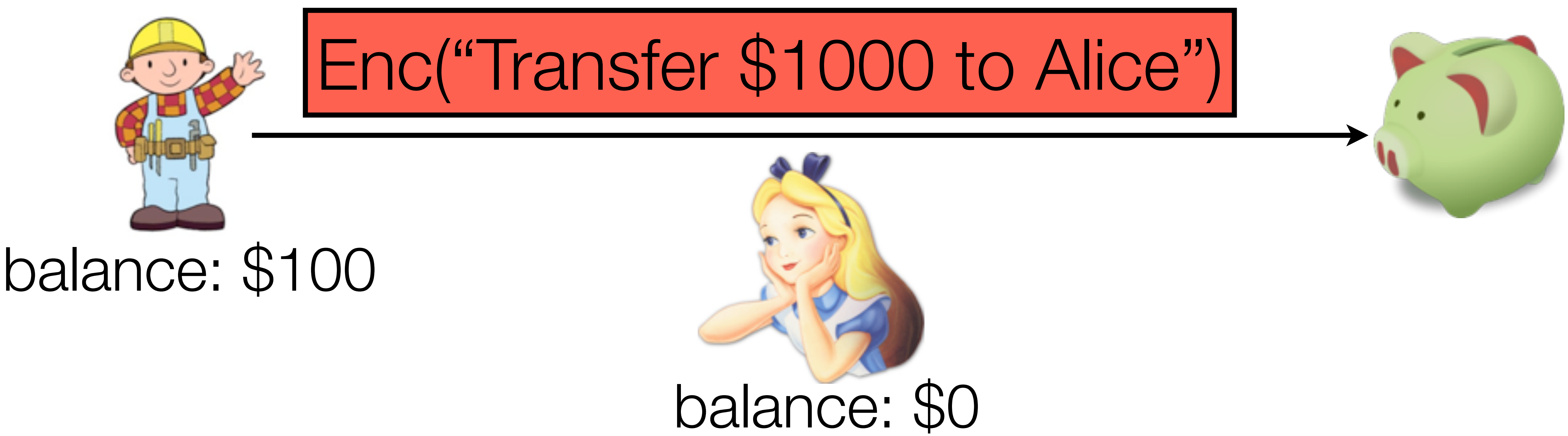

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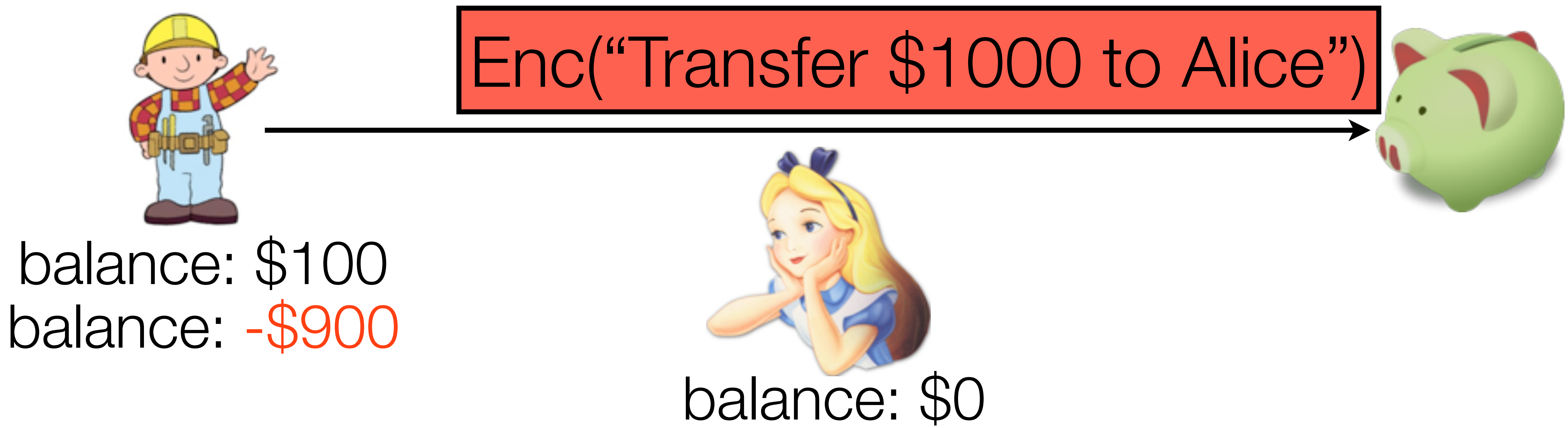

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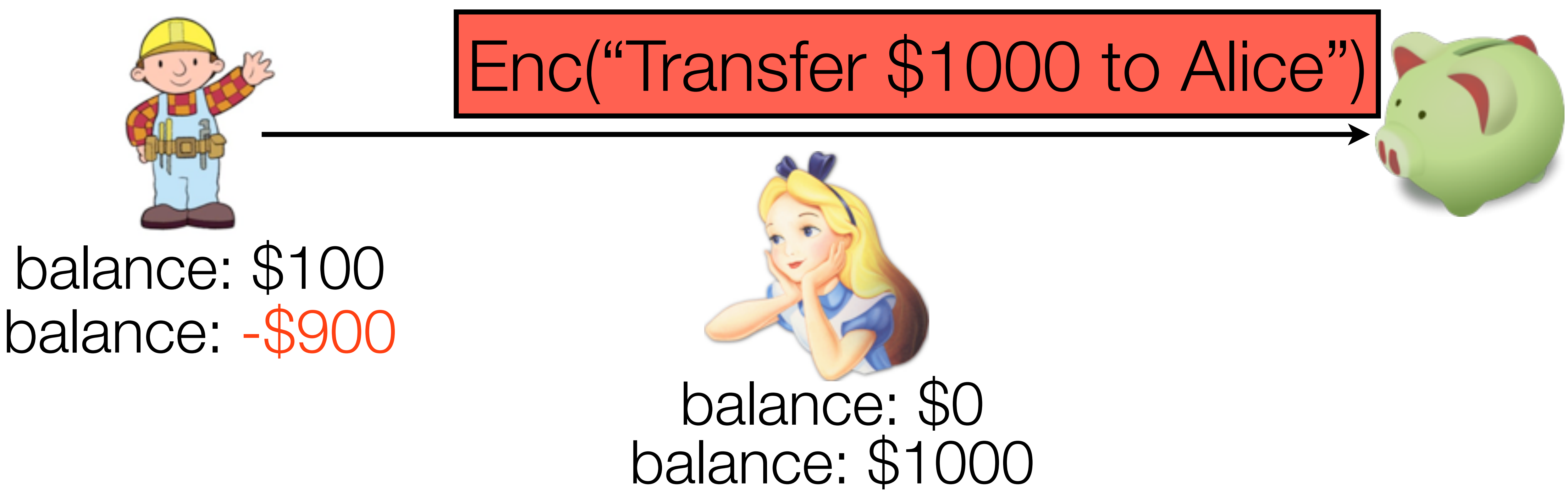

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?!?!?!

Enc("Transfer $1000 to Alice")

balance: $100
balance: -$900

balance: $0
balance: $1000

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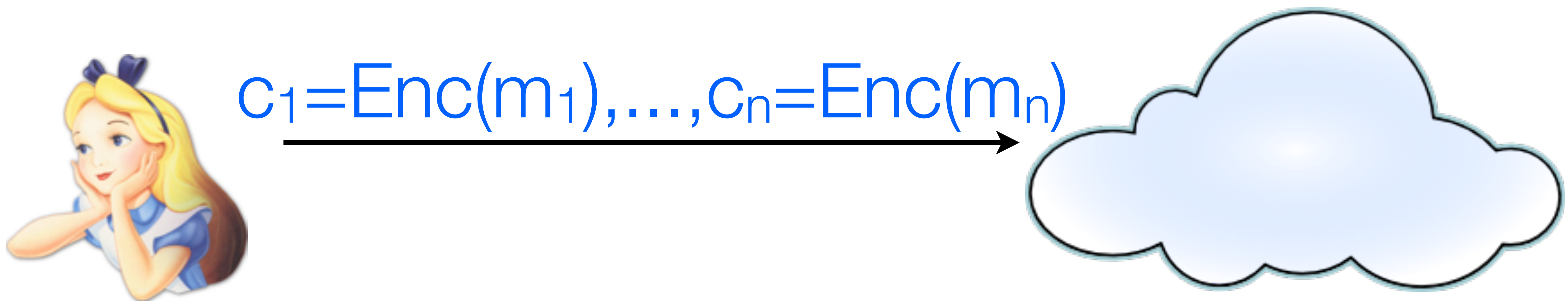

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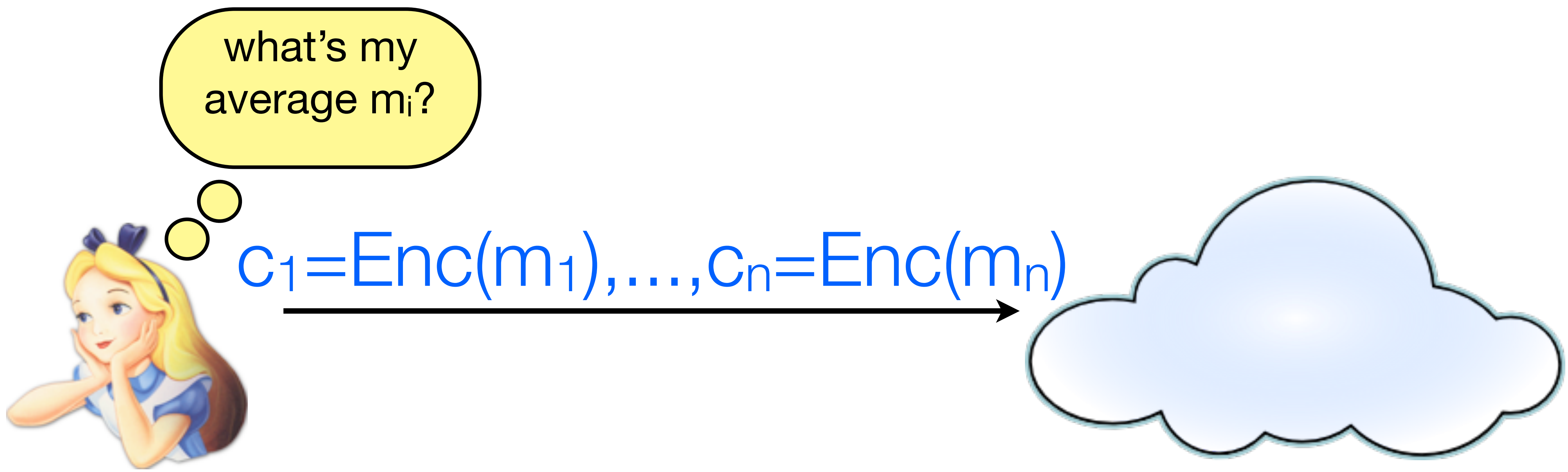

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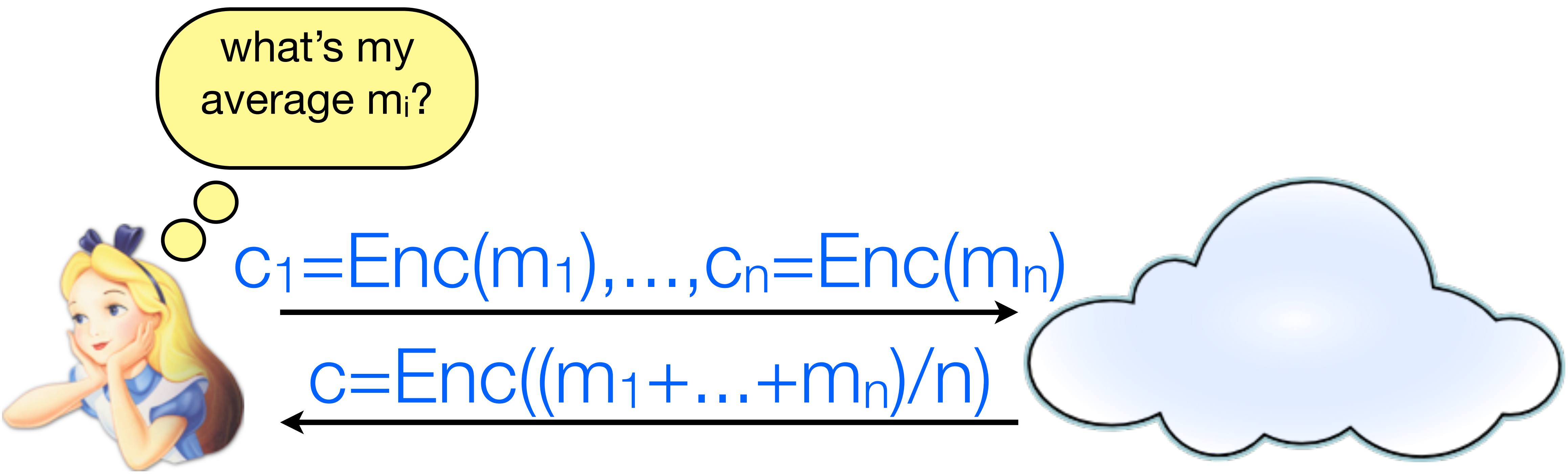

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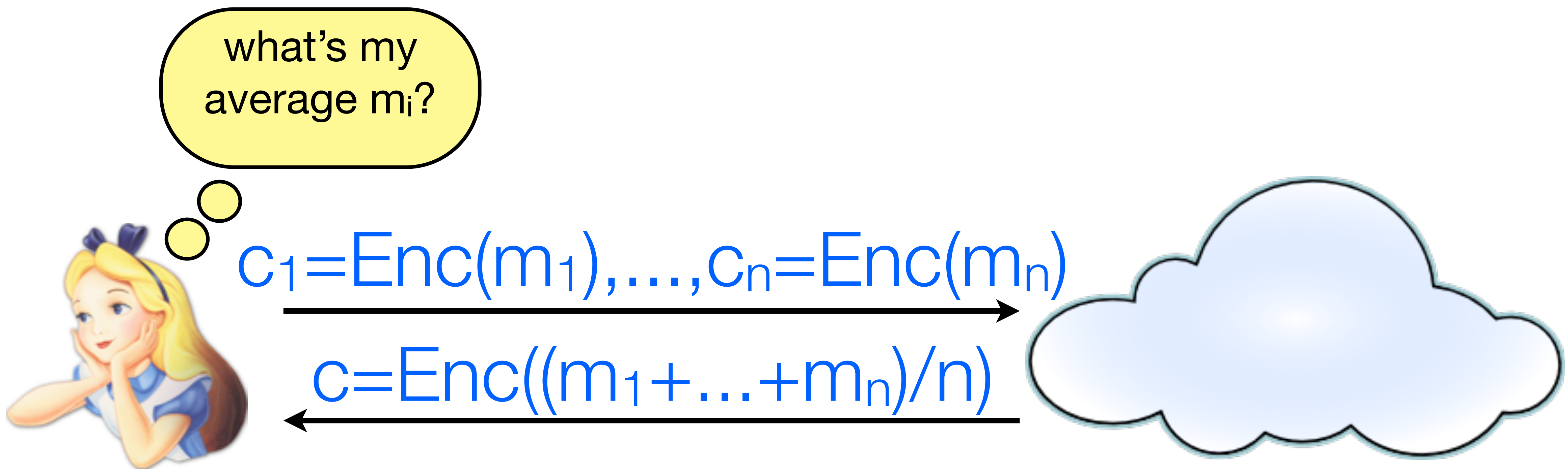

Has applications in cloud storage, outsourcing computation, search on encrypted data, etc.

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Methods for controlling malleability can provide a compromise between functionality and security [PR08,BSW12]

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In this work:

- Introduce notions of uncontrolled and controlled malleability for proofs
- Give two applications: CM-CCA security and compact verifiable shuffles
- Examine malleability within existing proof systems

Outline

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Definitions

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cm-NIZK construction

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Applications	Conclusions

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Definitions

Zero knowledge
Malleability
Controlled malleability
Derivation privacy

cm-NIZK construction

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Notions of malleability for proofs

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If we want zero knowledge, need to make sure proofs are malleable only with respect to operations under which the language is closed

- E.g., with bits, we run into trouble if we try to use $T = +$

Reconciling (controlled) malleability with soundness

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- Even more, simulation-sound extractability [G06] says that in fact we can always pull out a witness from any proof output by the adversary
- Our definition goes one step further: either we can pull out a witness, or it was derived from a simulated proof under a transformation in $\mathcal{T}$

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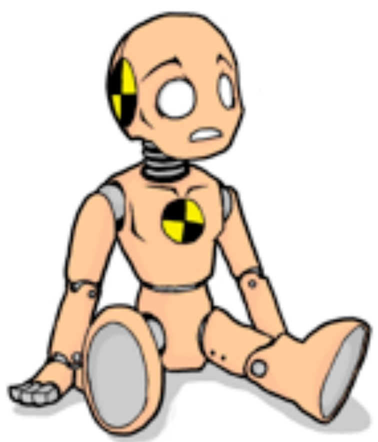

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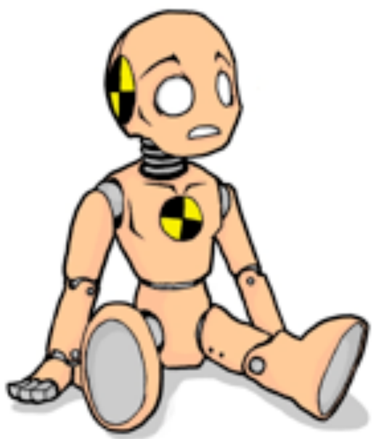

σ, τ_s, τ_e

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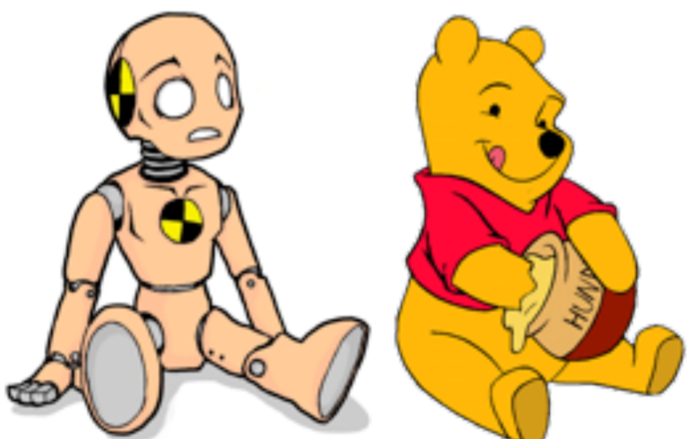

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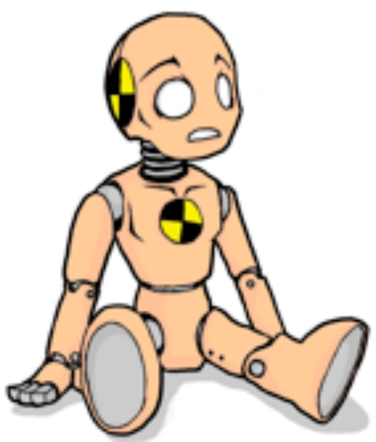

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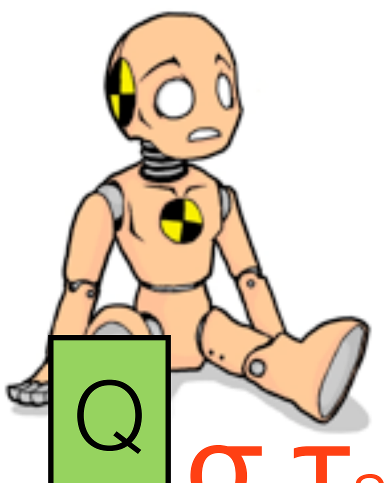

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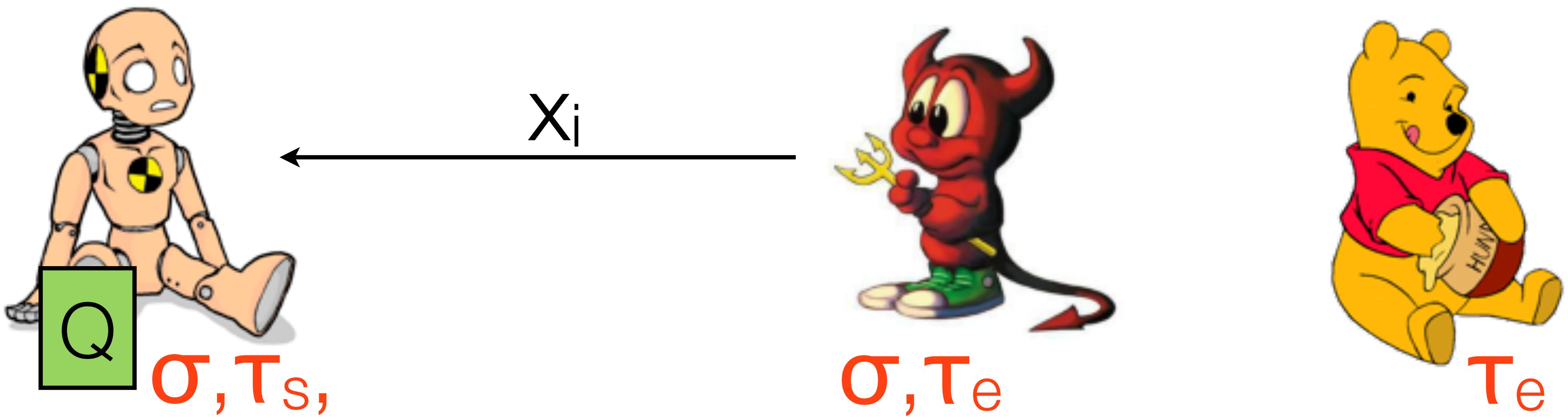

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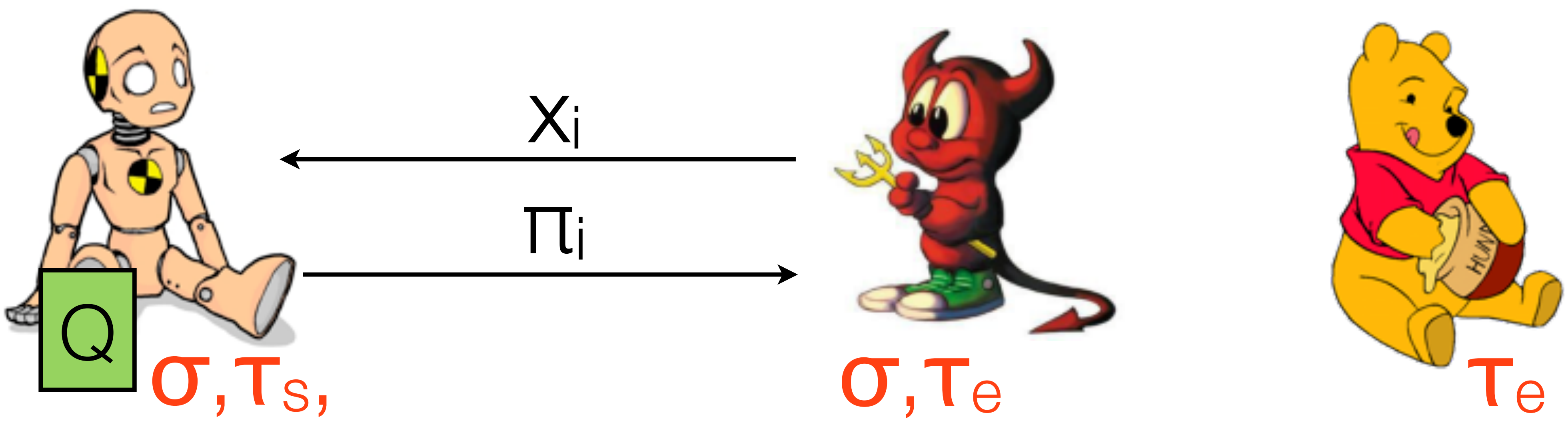

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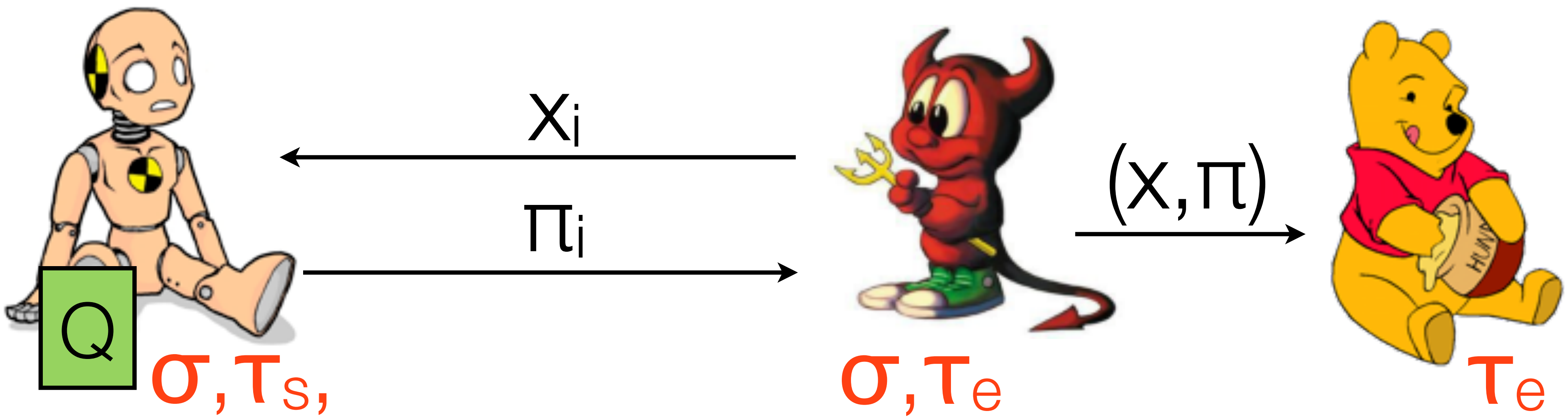

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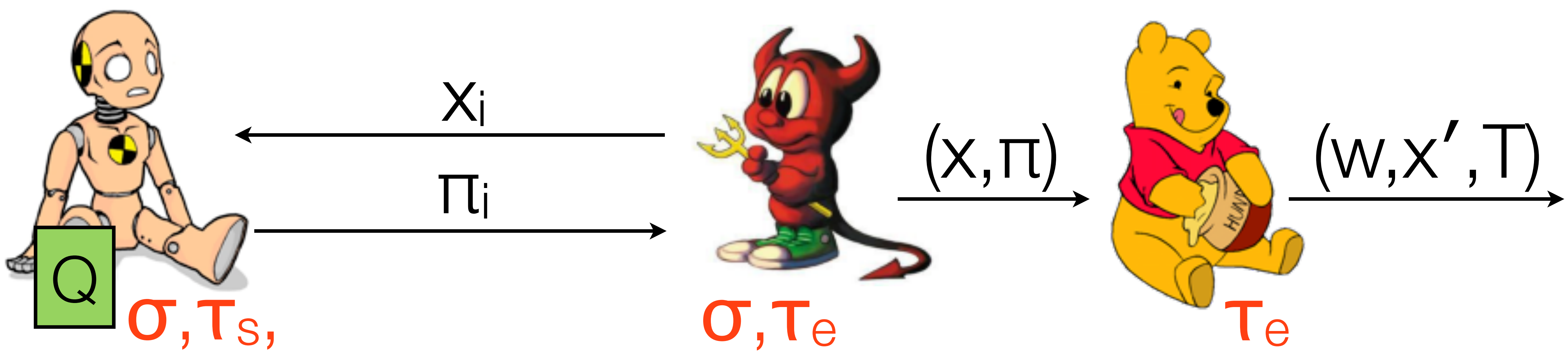

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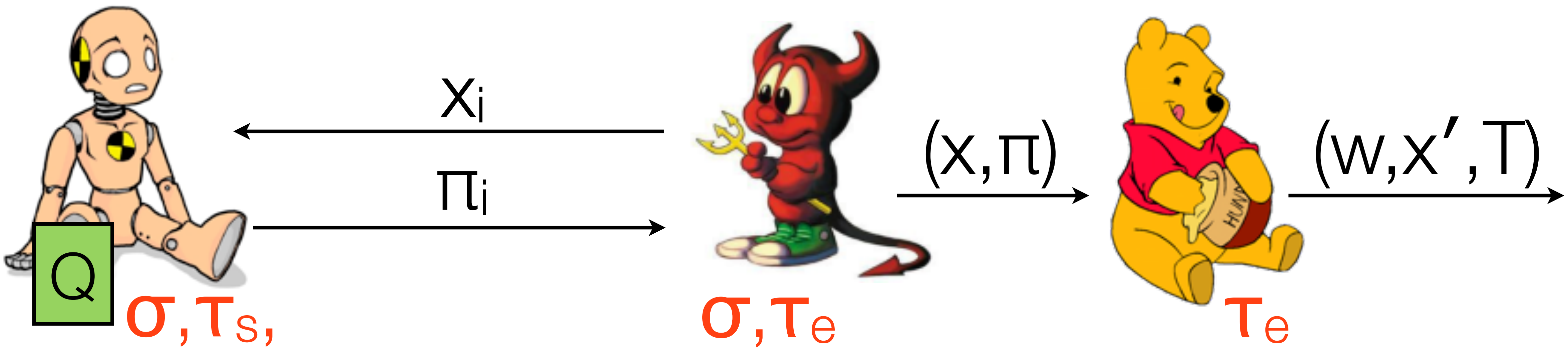

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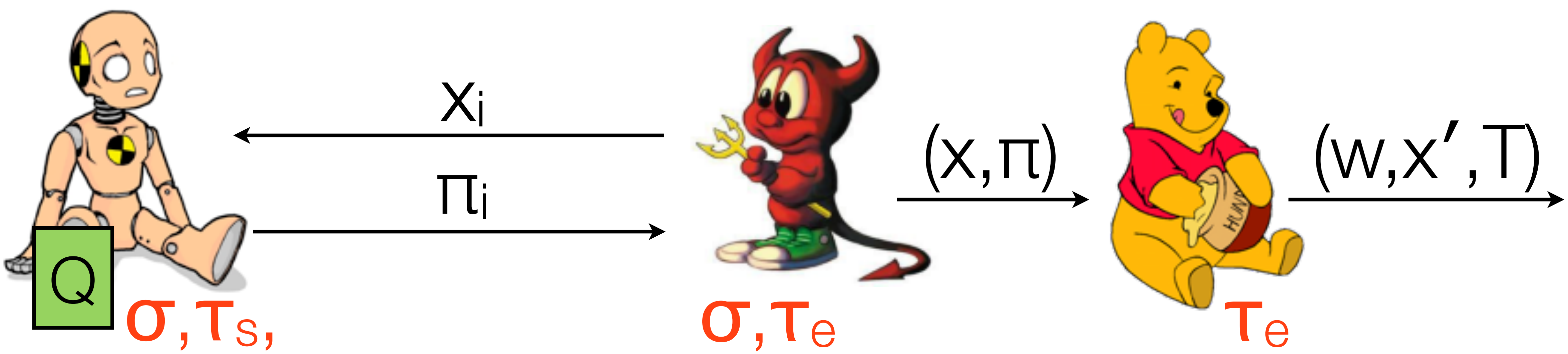

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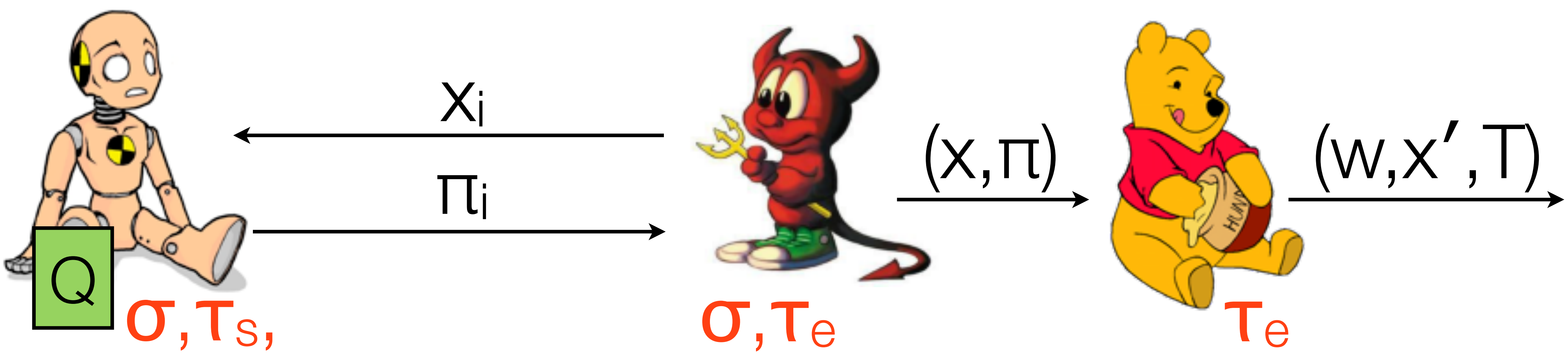

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(like function privacy for encryption)

If a proof is zero knowledge, CM-SSE, and strongly derivation private, then we call it a cm-NIZK

Outline

Definitions

cm-NIZK construction

Generic construction

Efficient instantiation

Applications

Conclusions

How to construct cm-NIZKs

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We will combine malleable NIWIPoKs with unforgeable signatures

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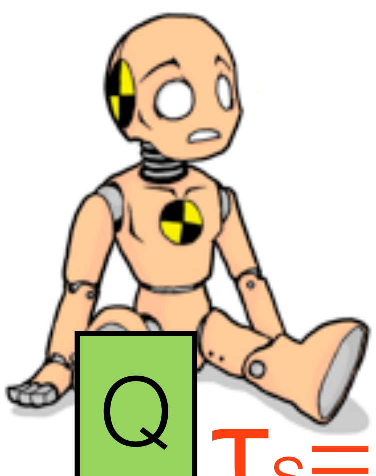

τ_S=sk

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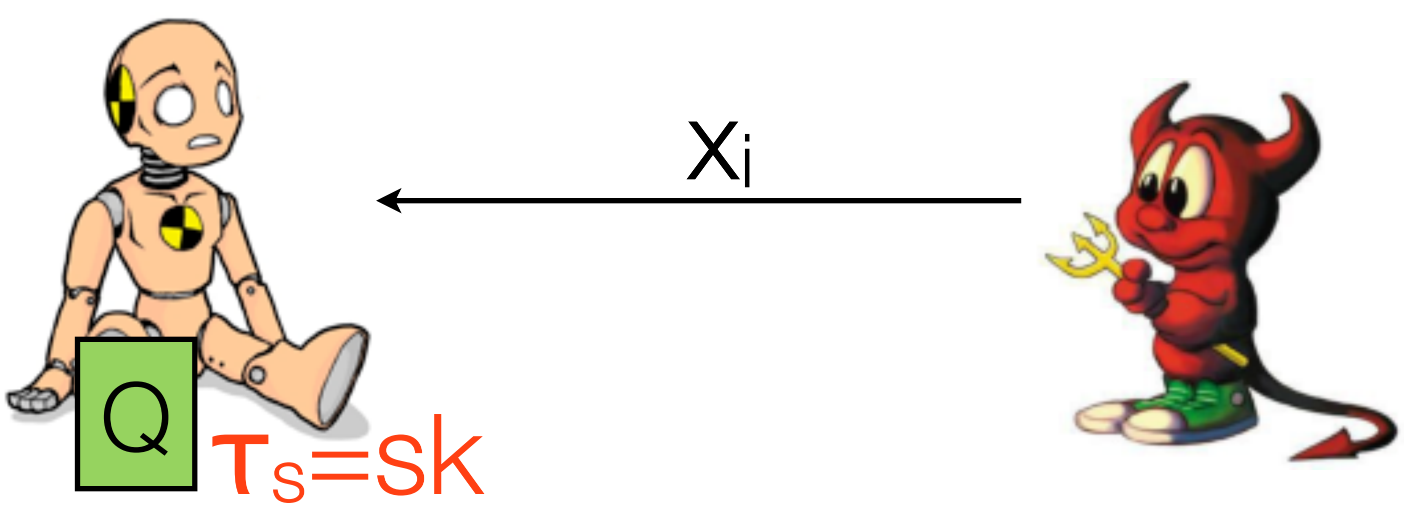

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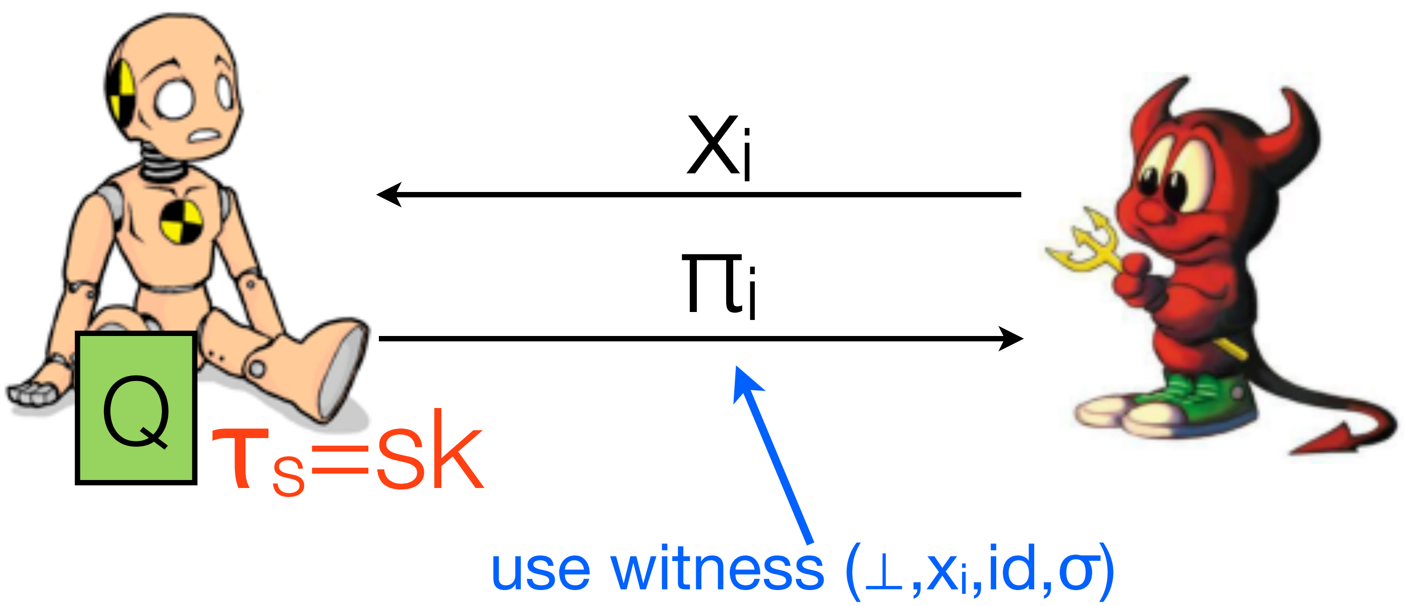

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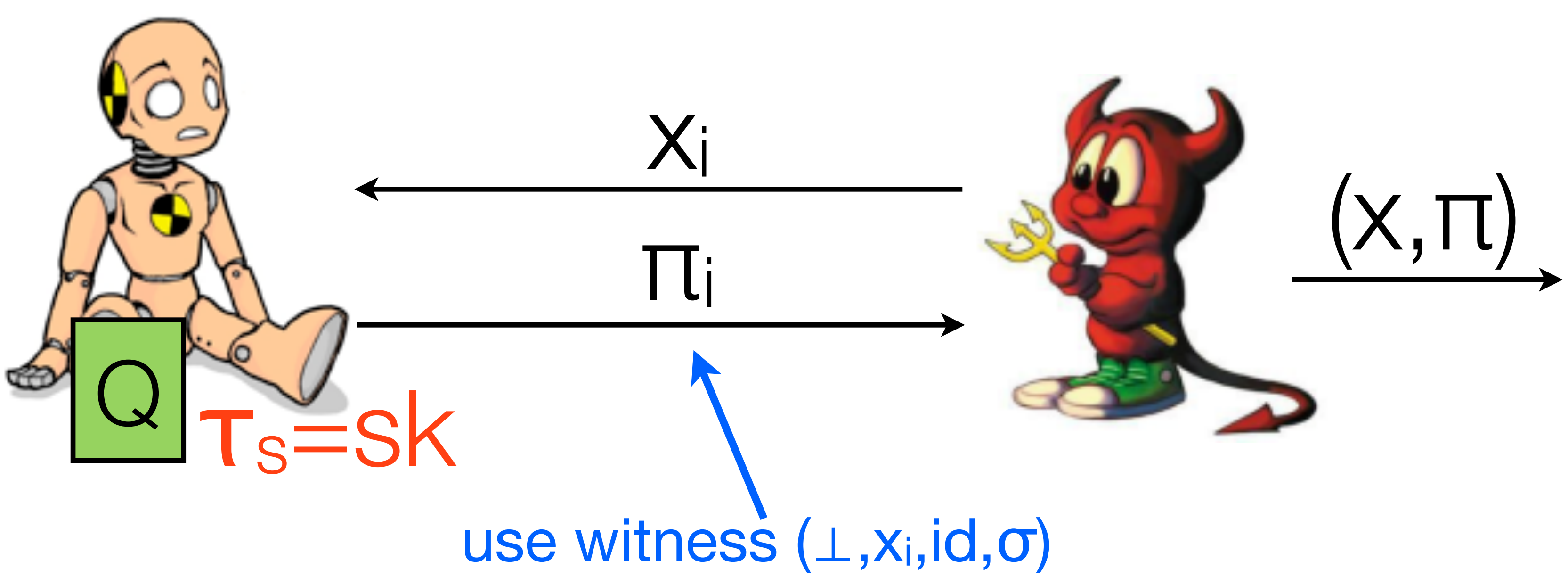

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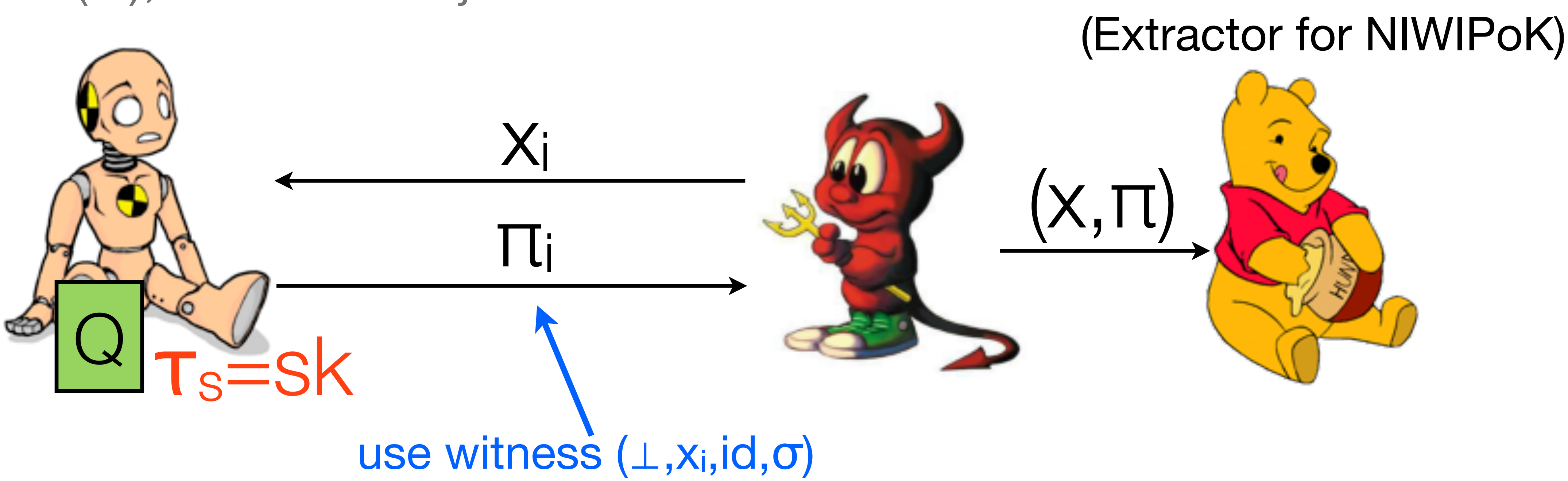

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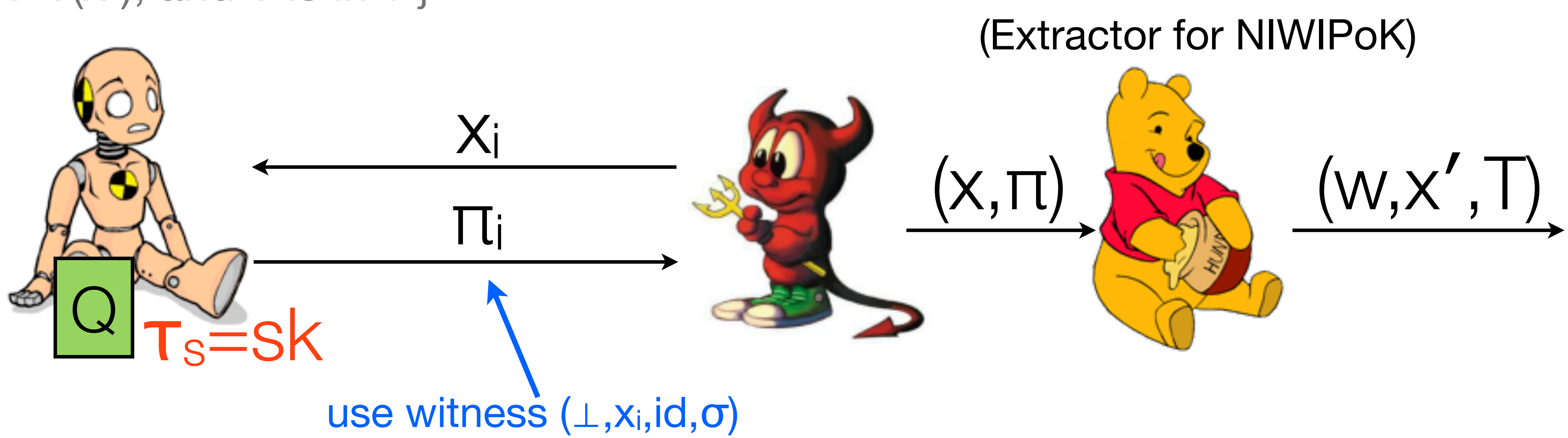

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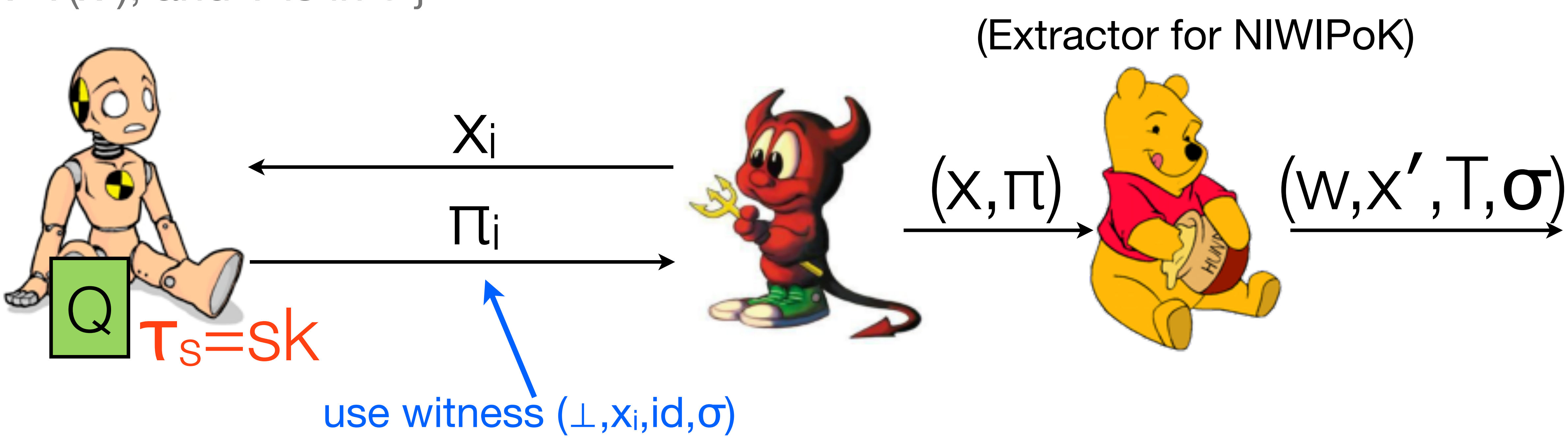

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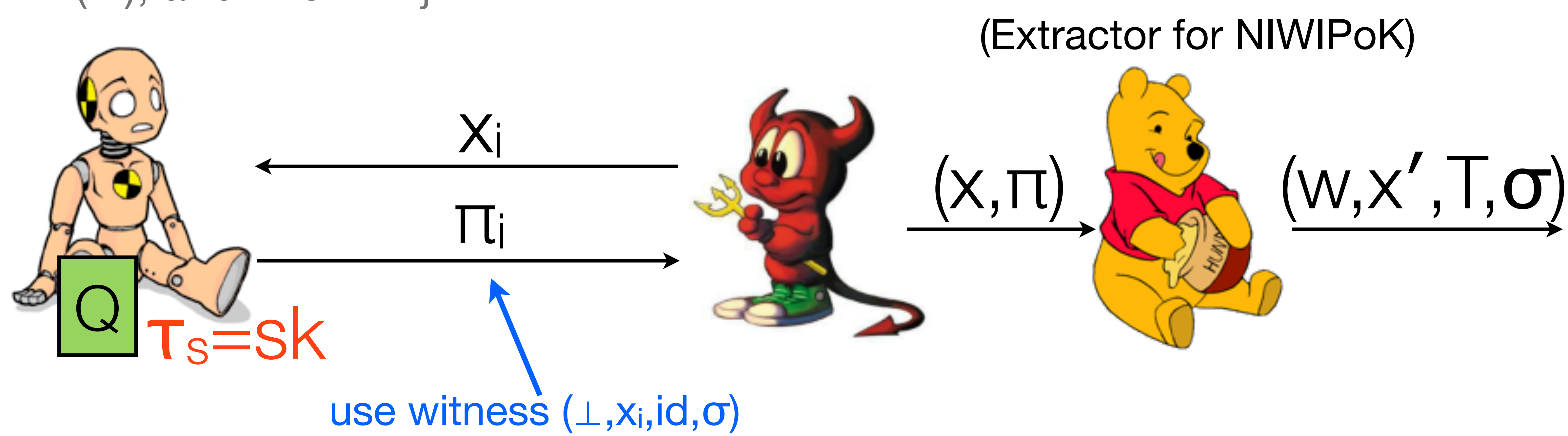

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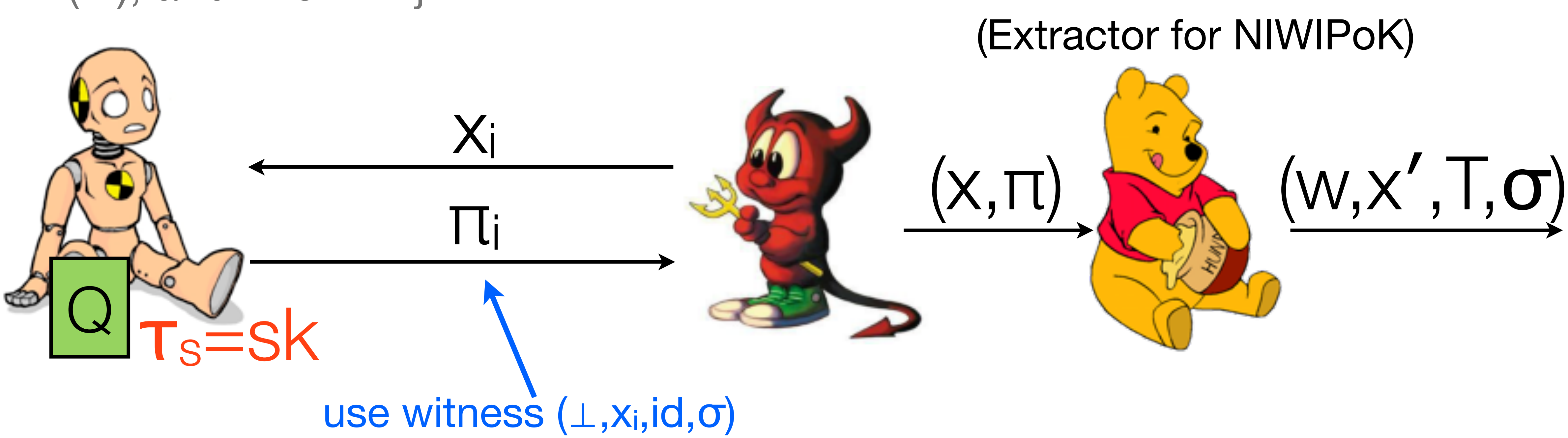

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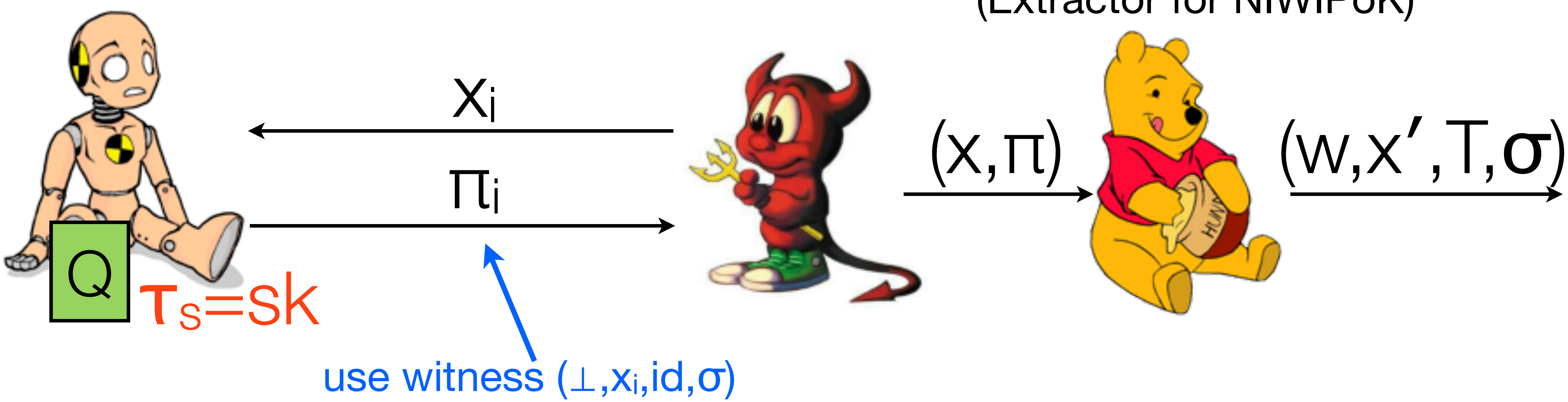
(Extractor for NIWIPoK)



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How to construct cm-NIZKs

We will combine malleable NIWIPoKs with unforgeable signatures

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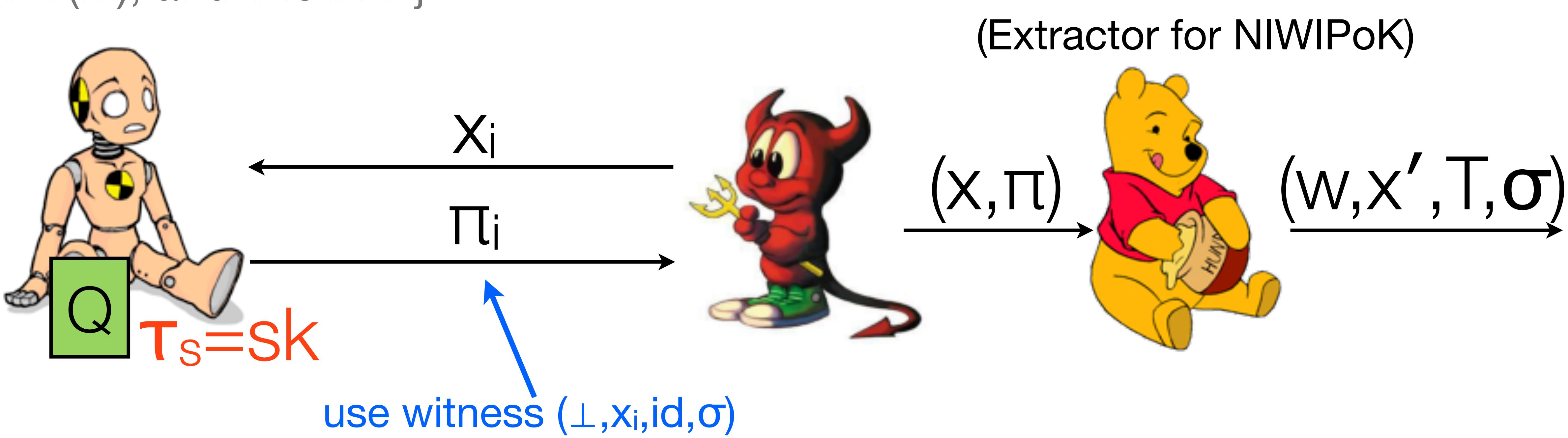

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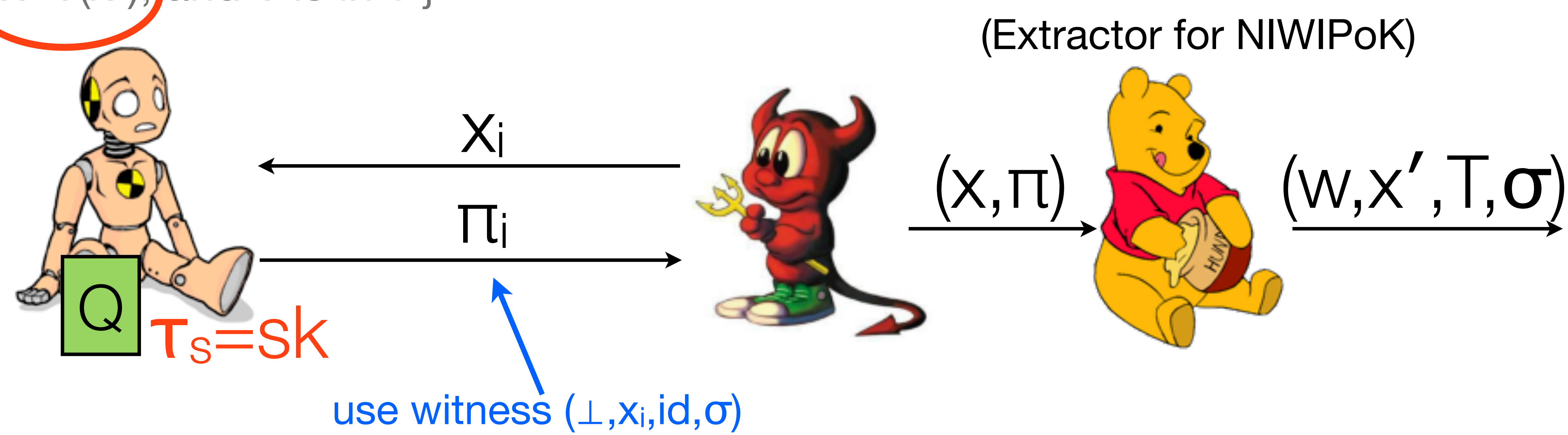

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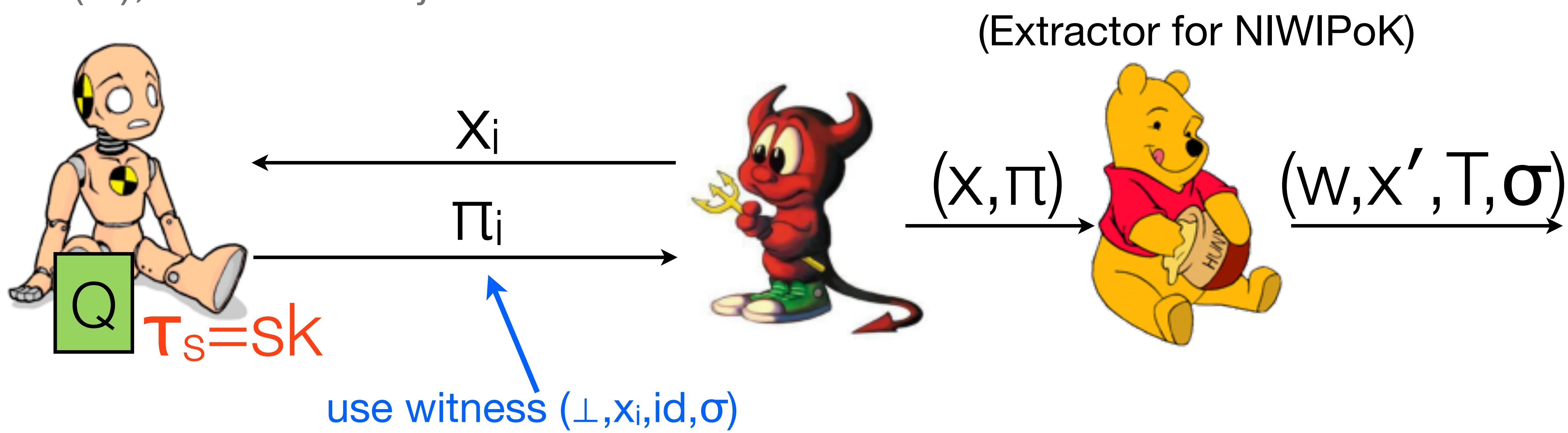

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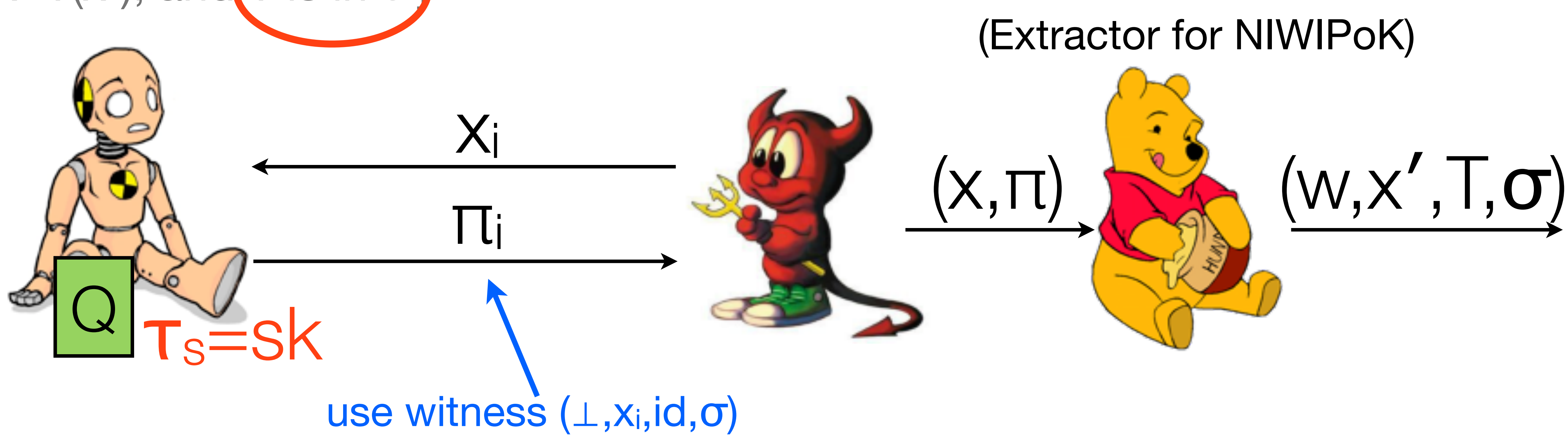

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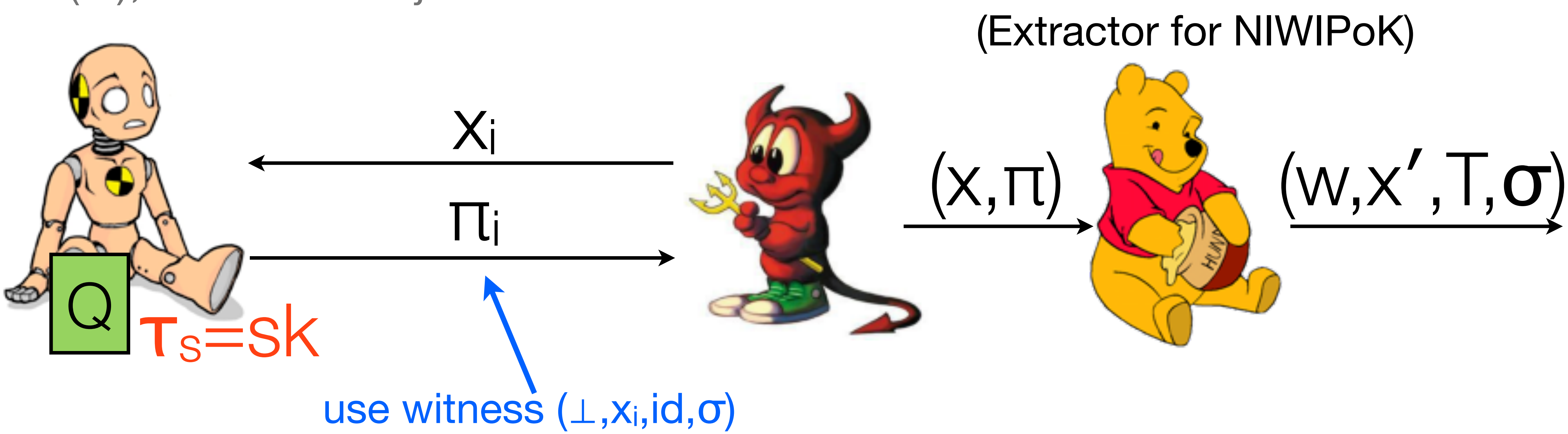

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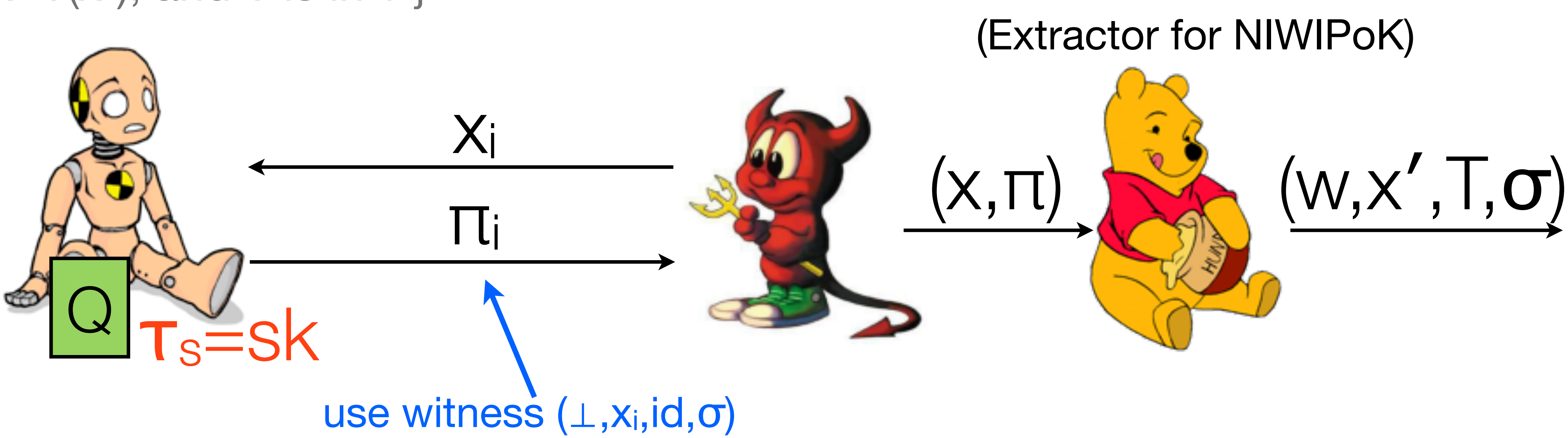

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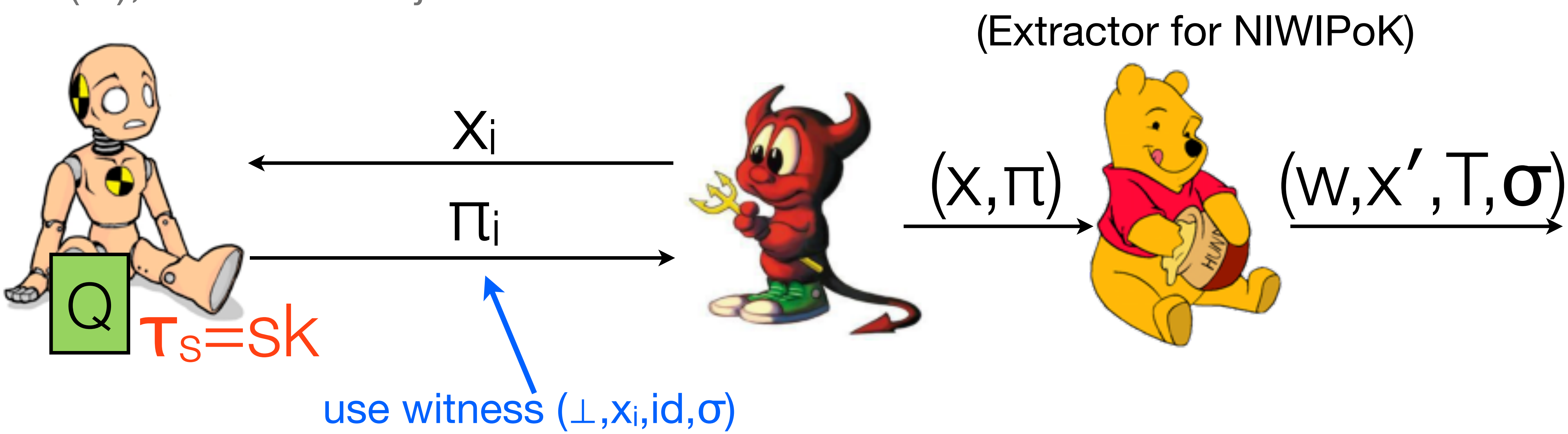

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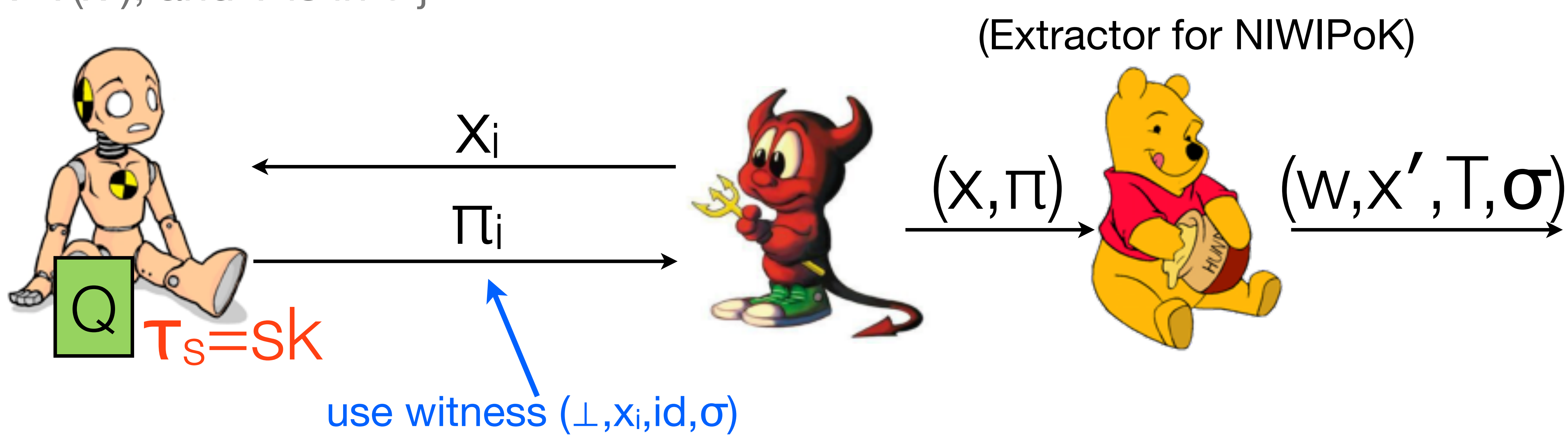

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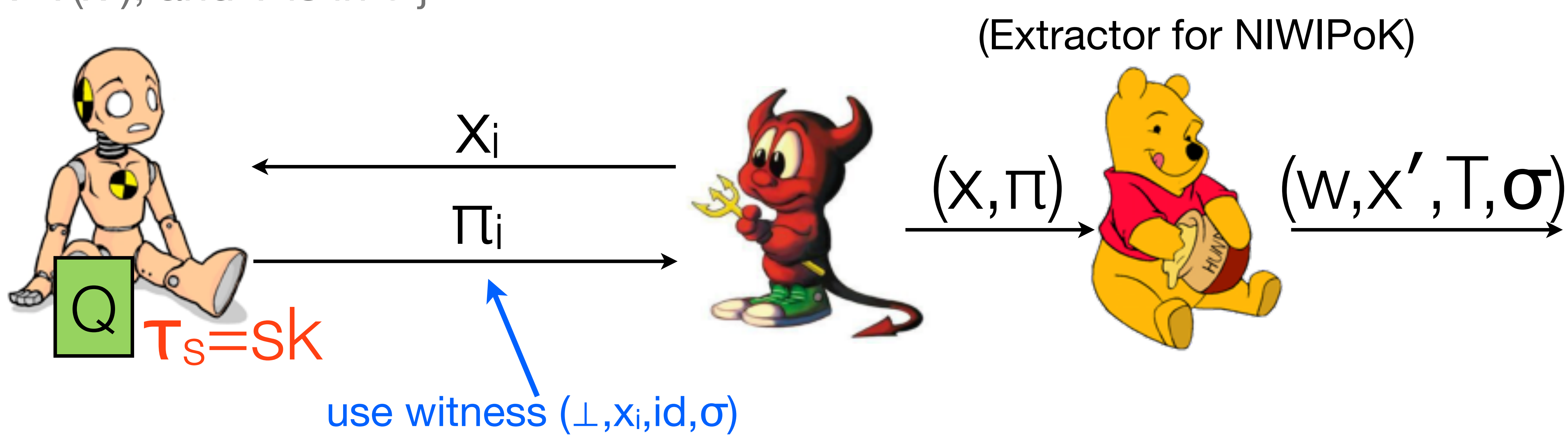

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In the paper, we examine the many ways in which GS proofs are malleable

Outline

Definitions

cm-NIZK construction

Applications

Boosting encryption security

Compactly verifiable shuffles

Conclusions

CM-CCA security

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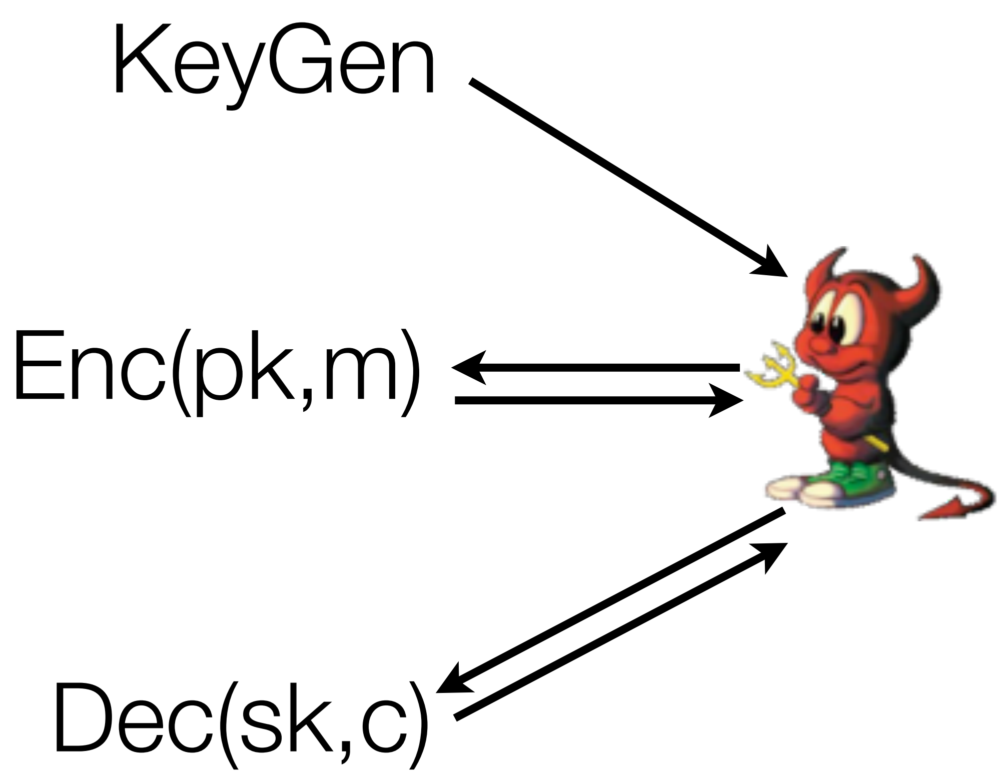

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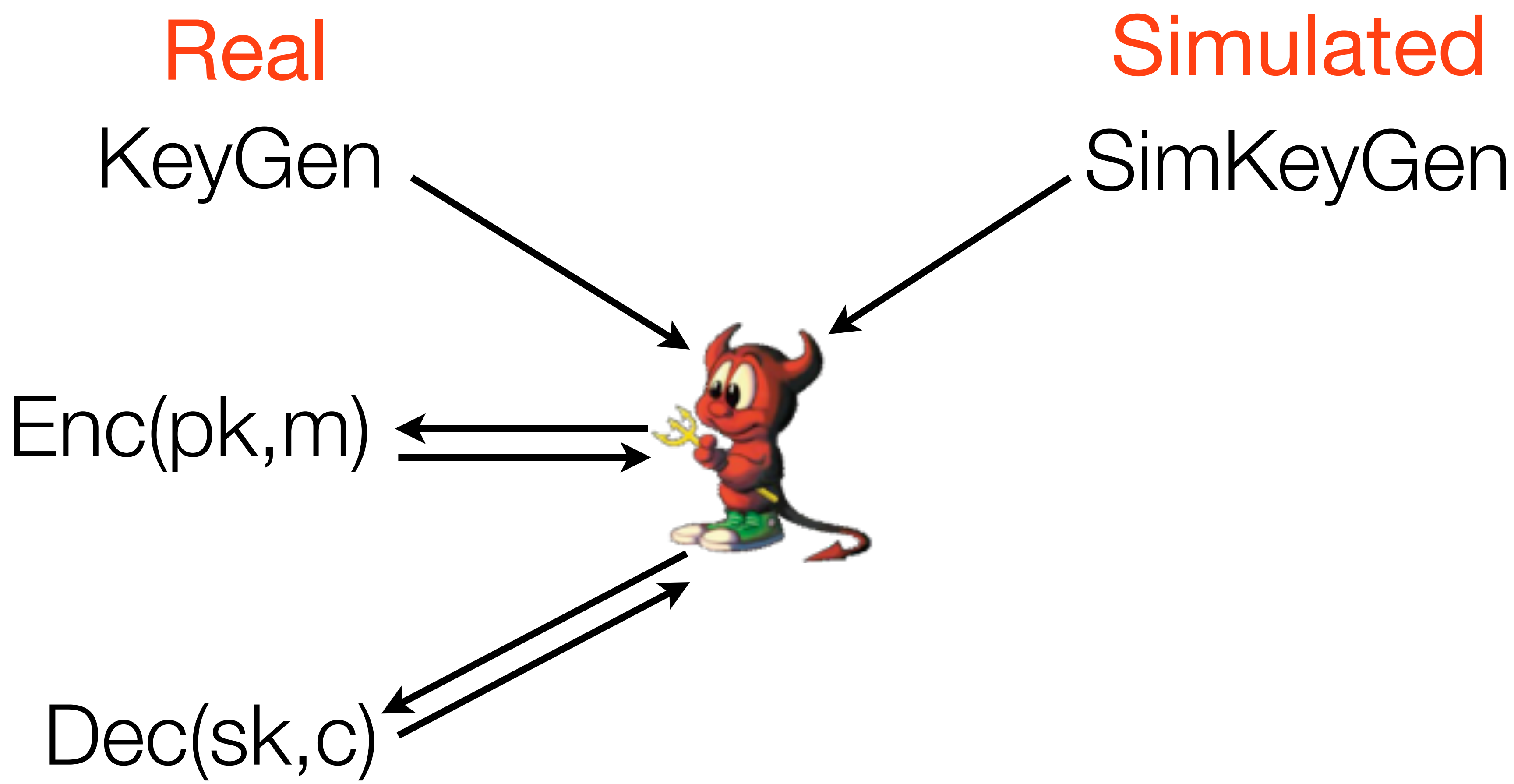

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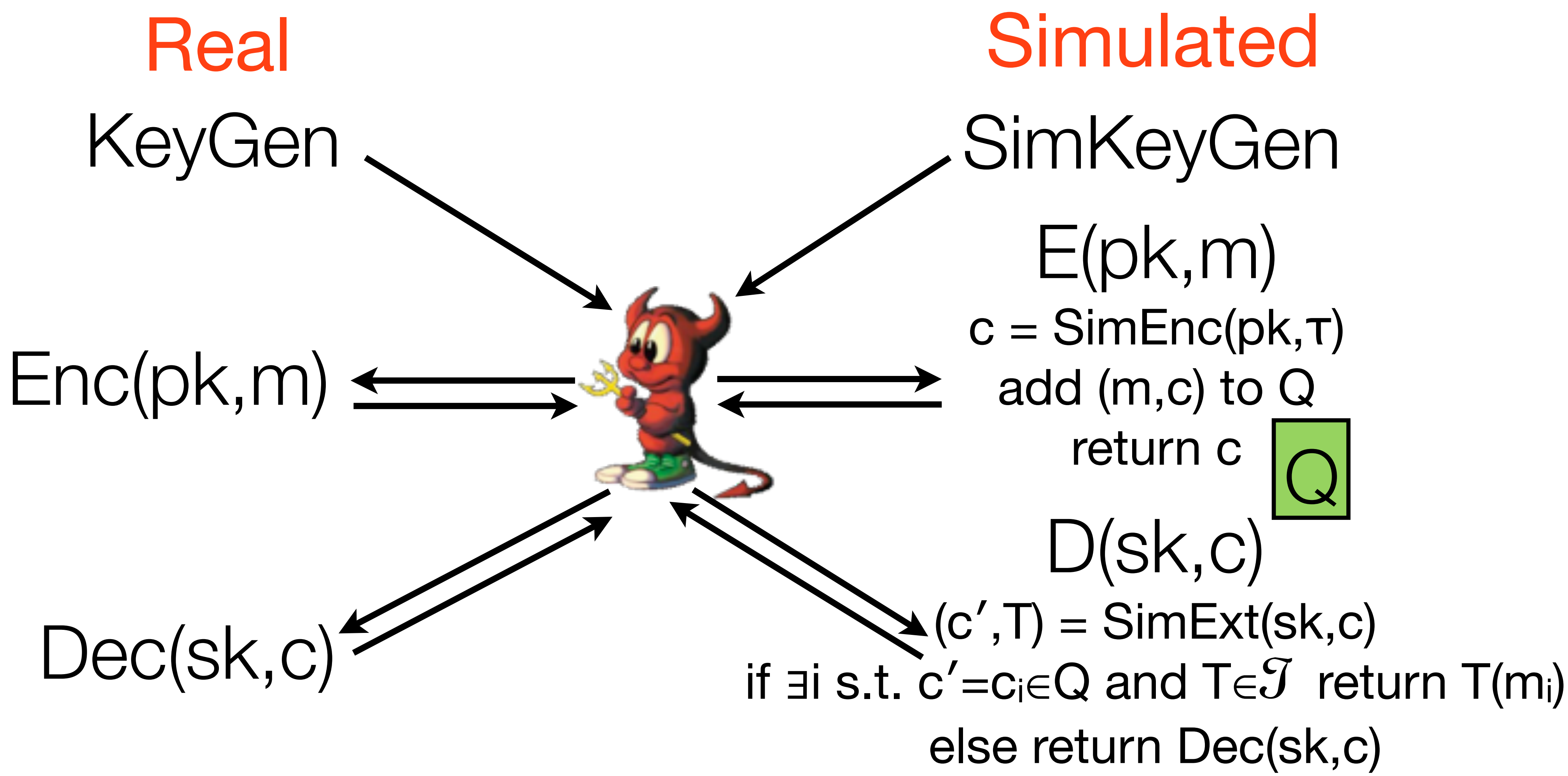

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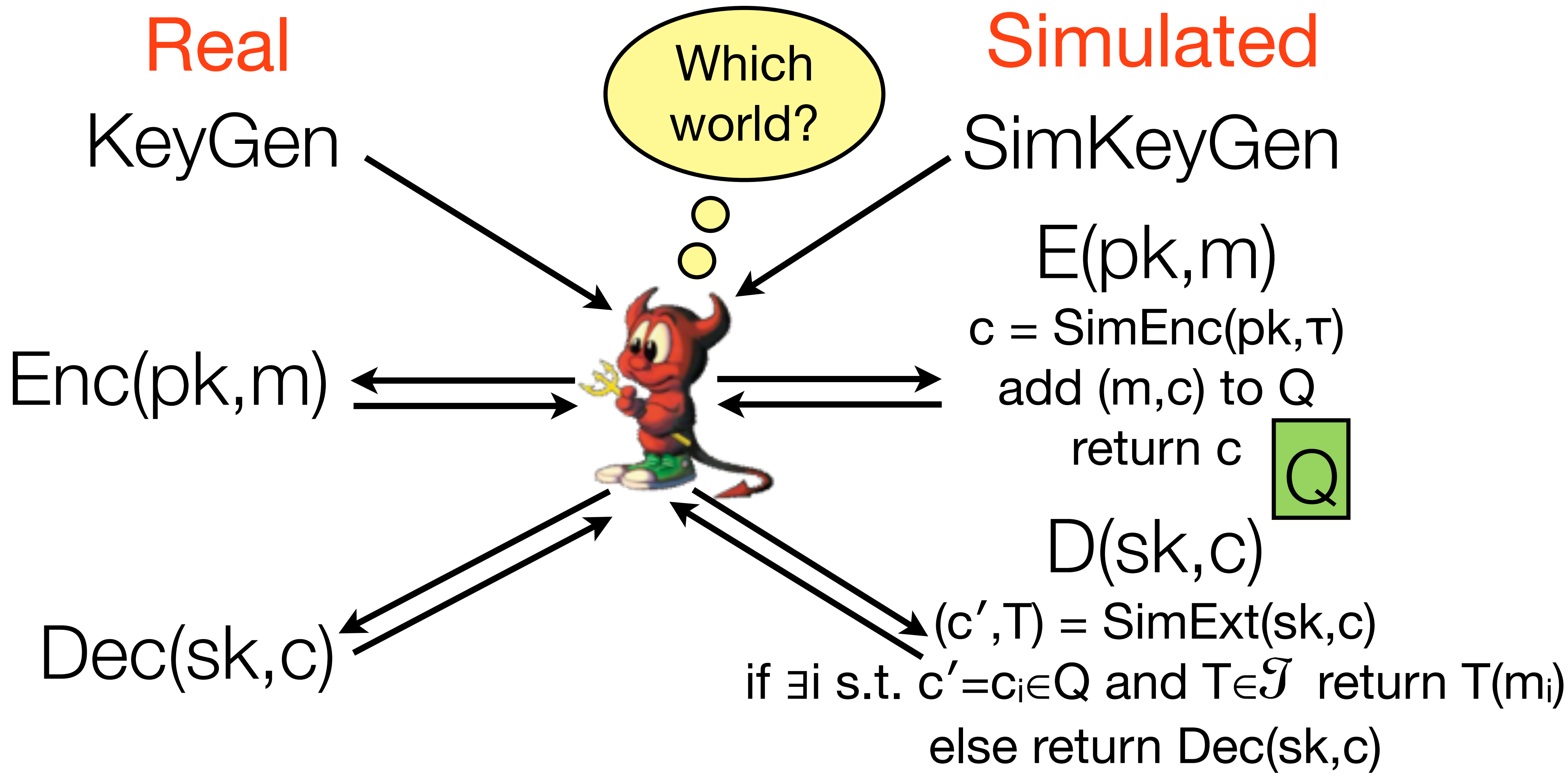

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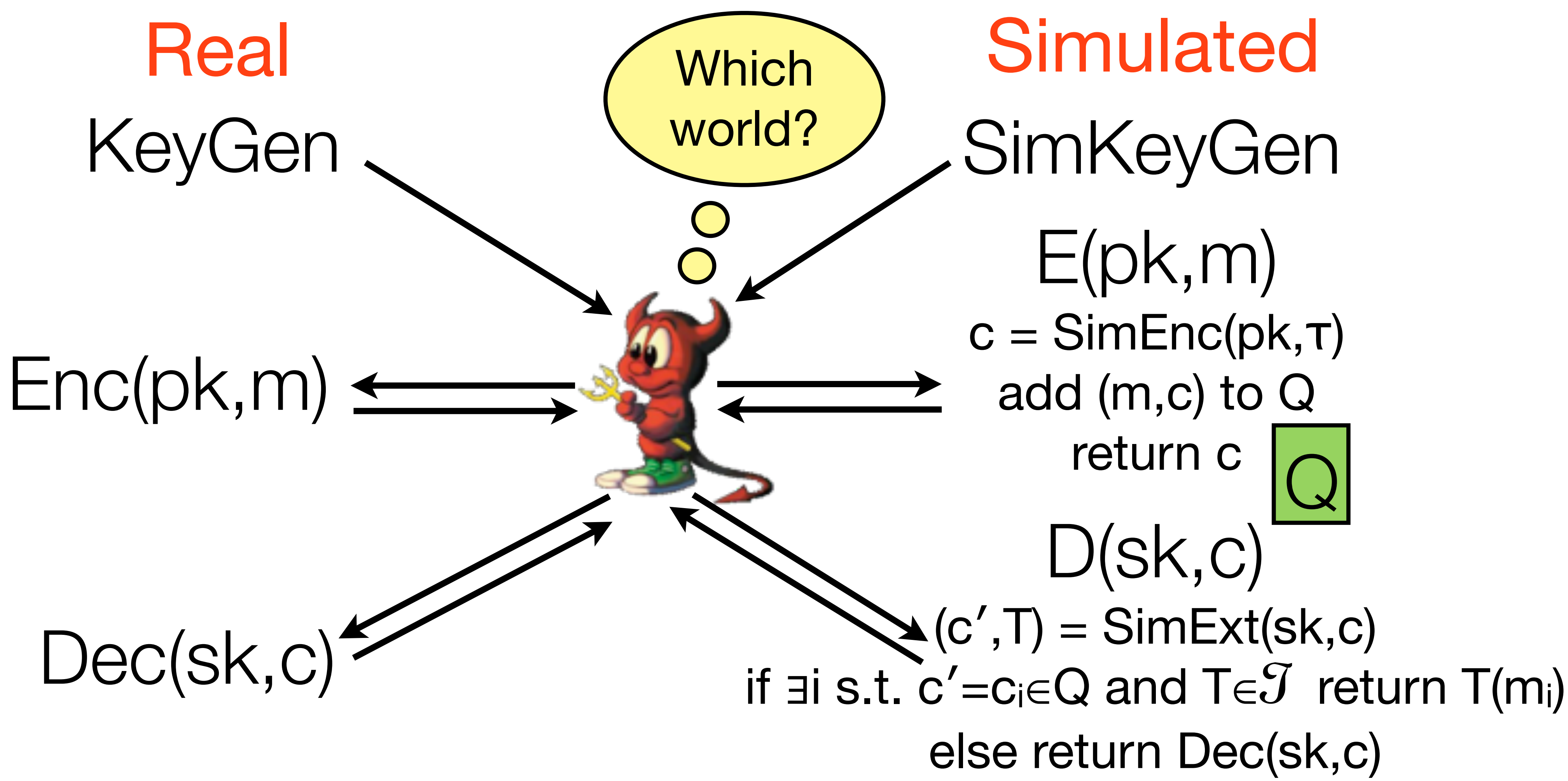

Give a generic construction for achieving CM-CCA-secure encryption: just define Enc(pk,m) = (c,π), where c is IND-CPA-secure and π is a cm-NIZK

A shuffle

A shuffle

c_1
c_2
c_3
c_4
c_5

Users encrypt their individual values to yield a public set of ciphertexts $\{c_i\}$

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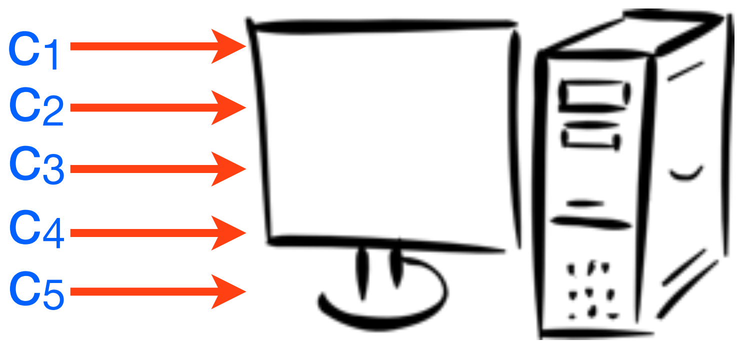

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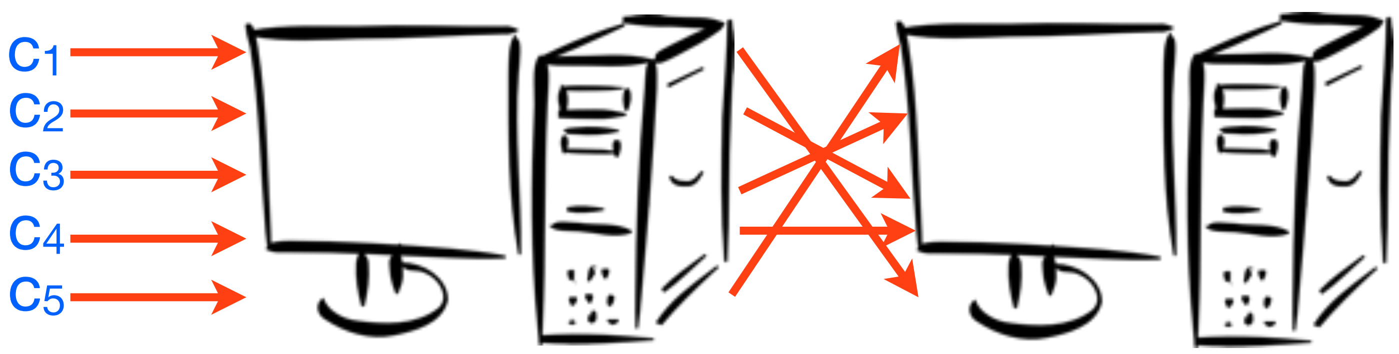

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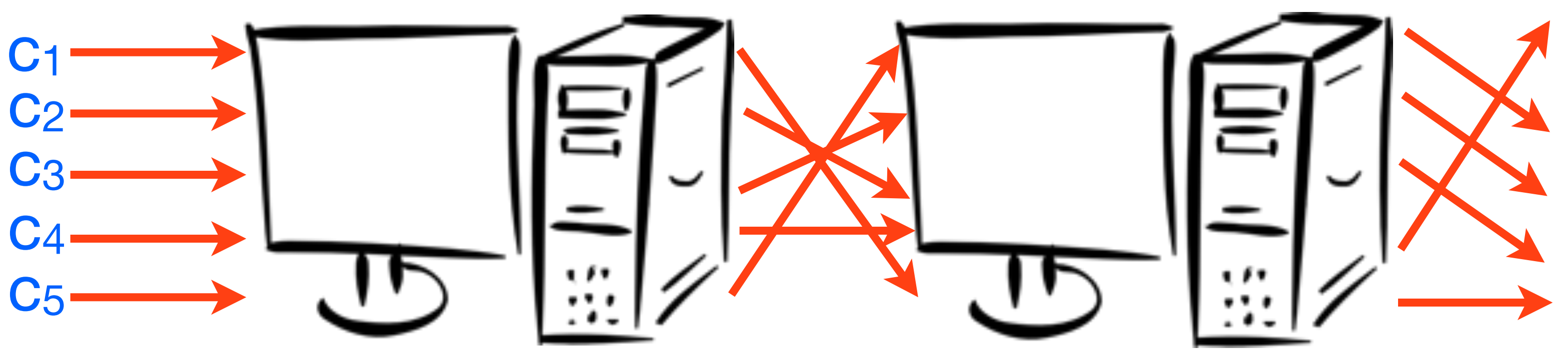

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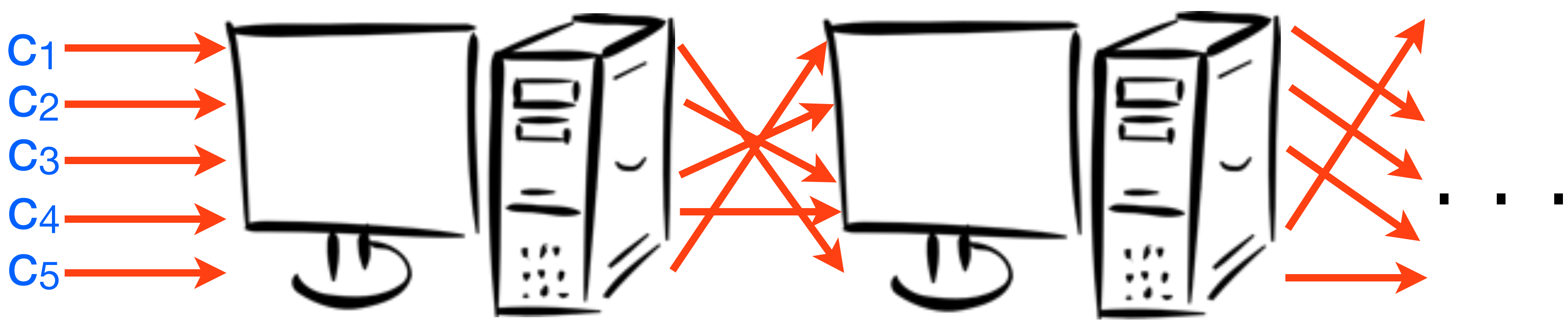

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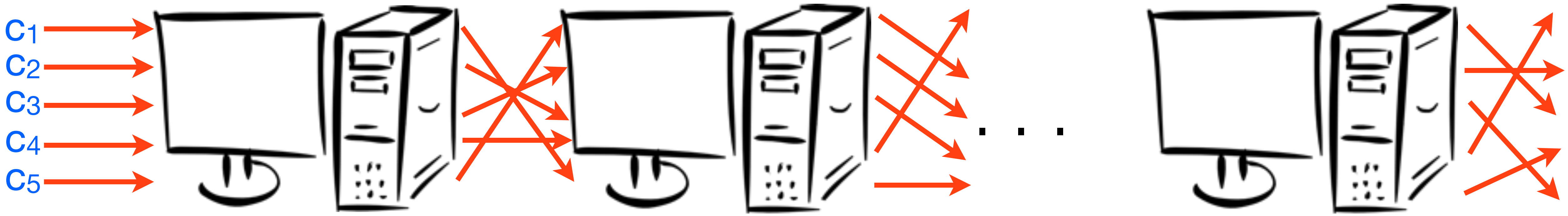

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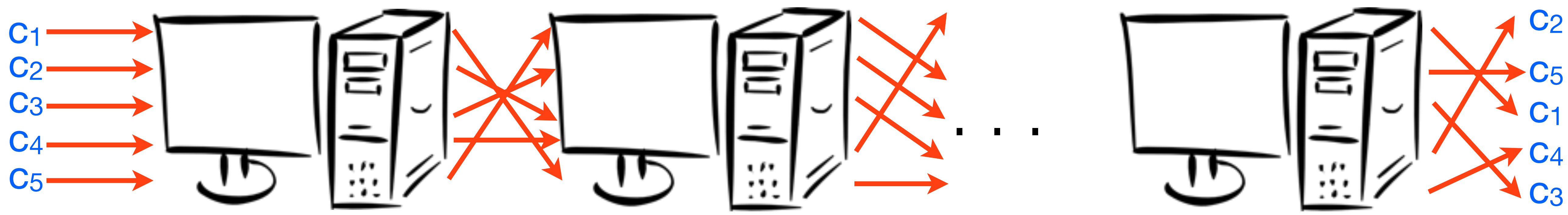

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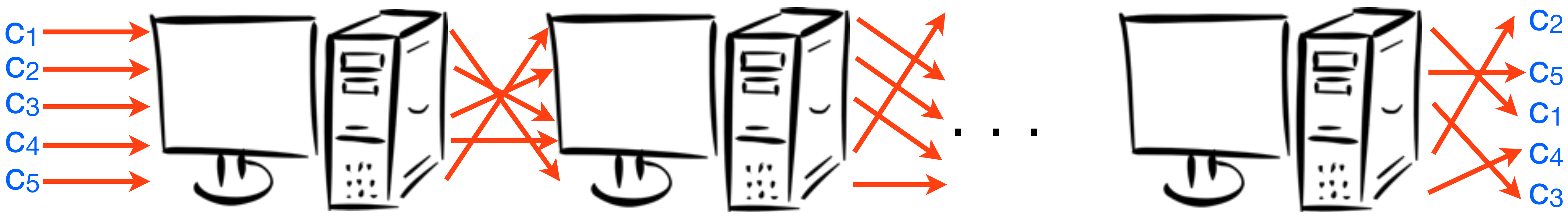

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Because values are shuffled, decryption won't reveal whose vote is whose

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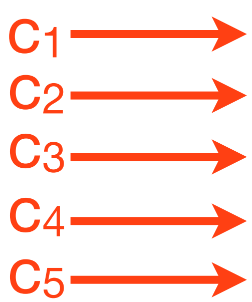

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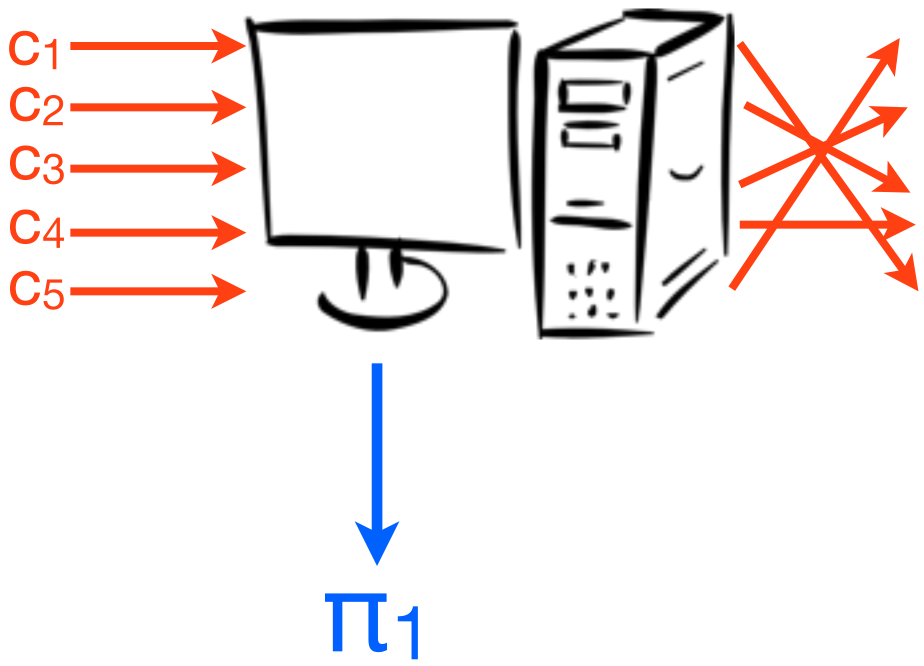

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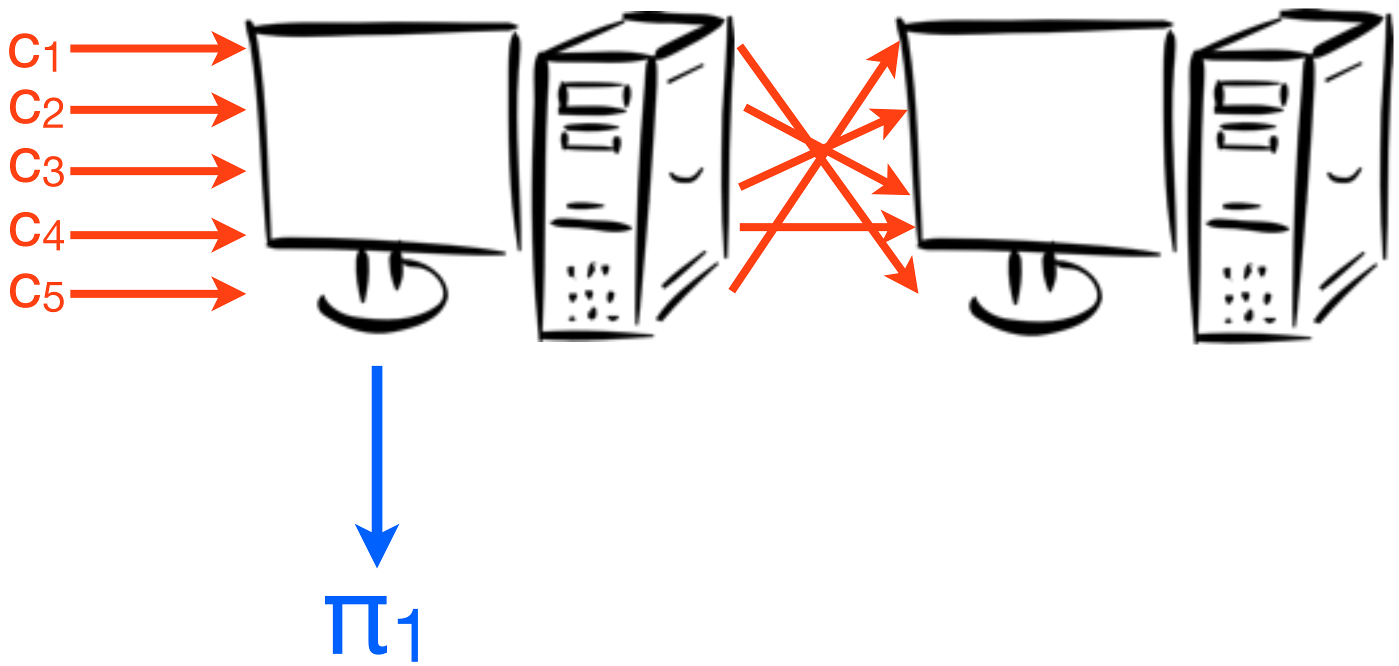

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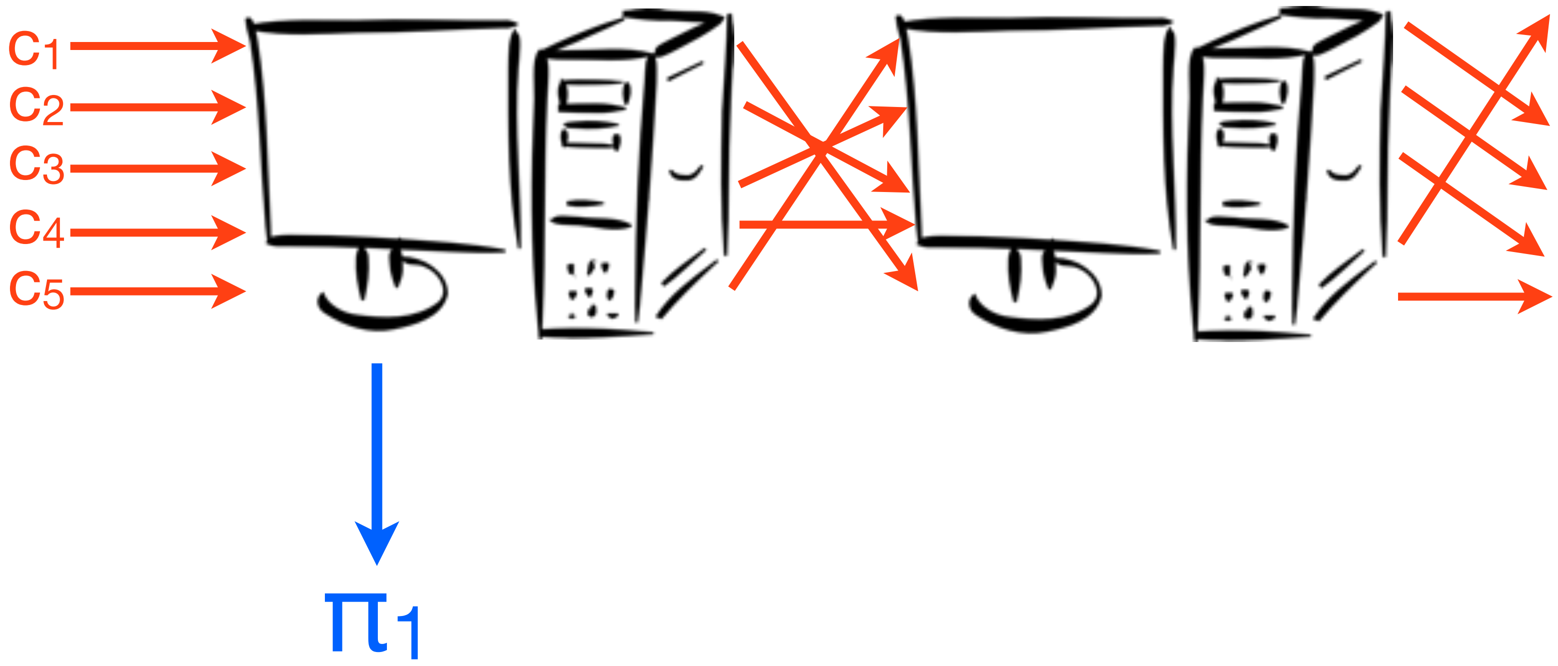

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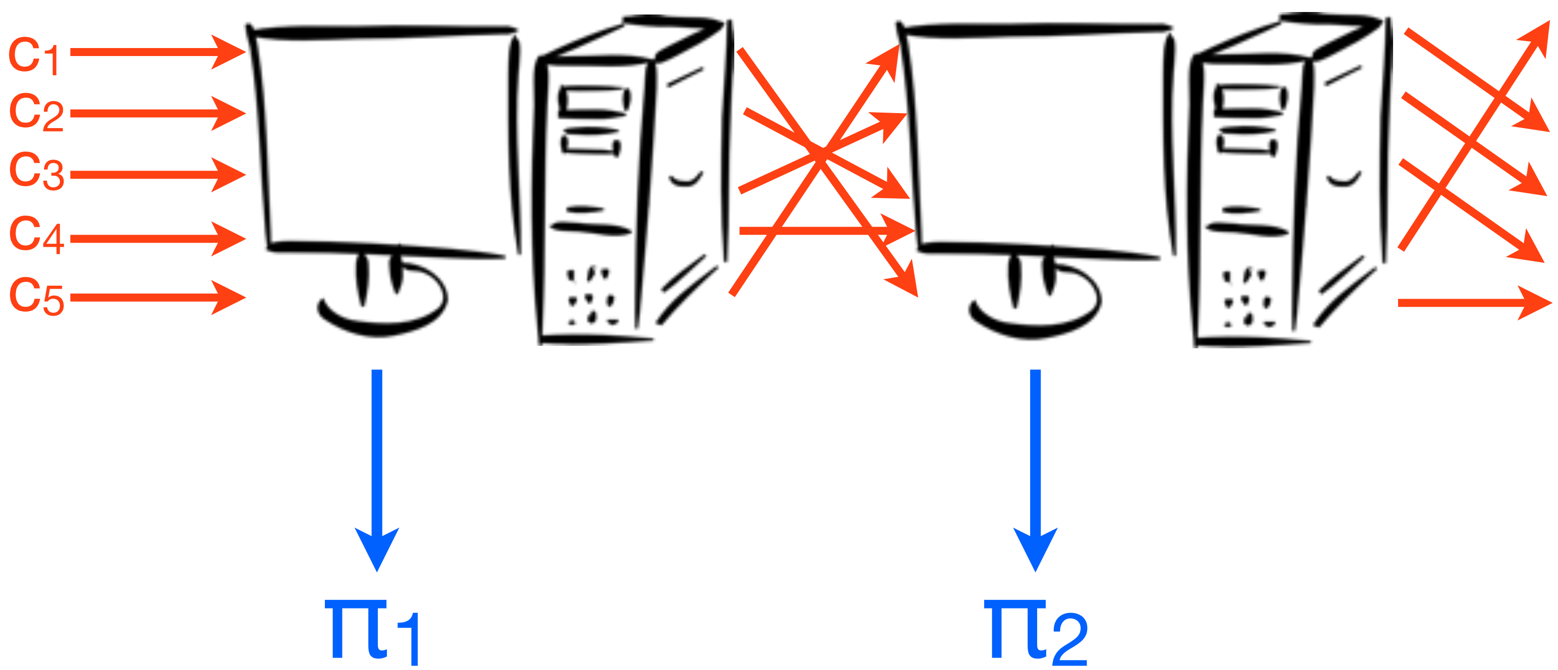

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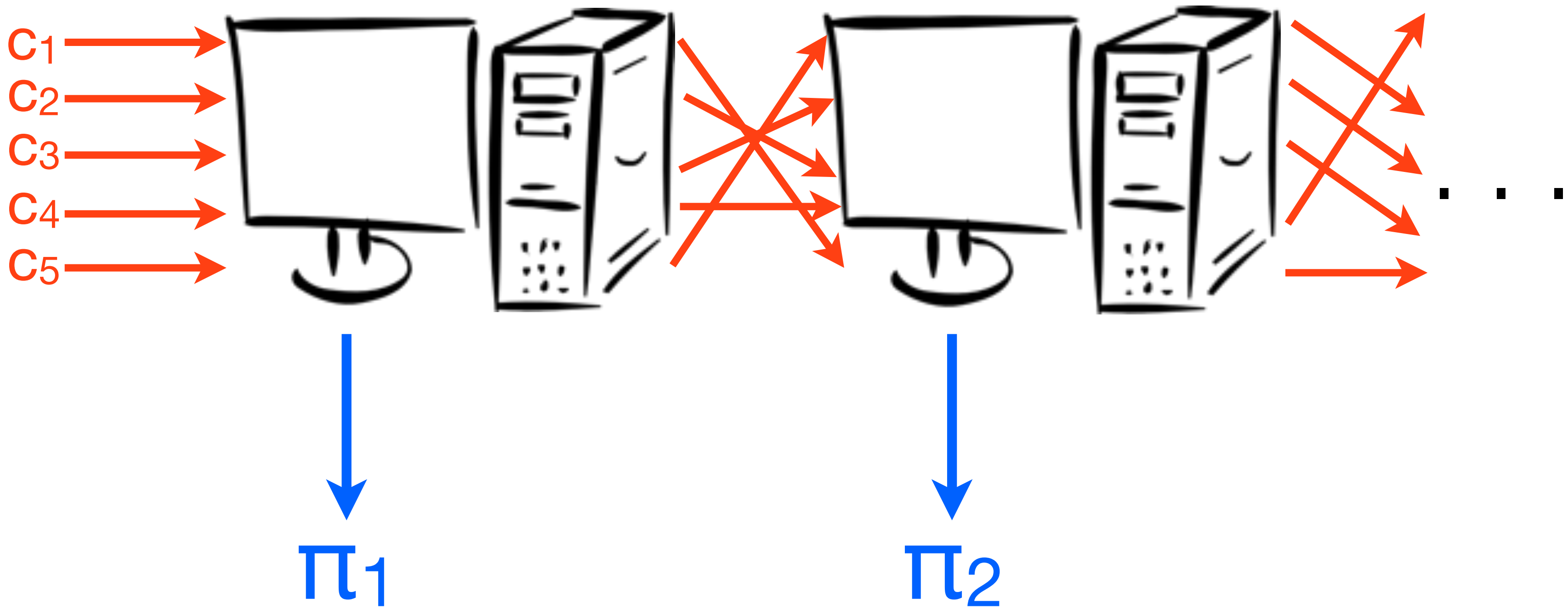

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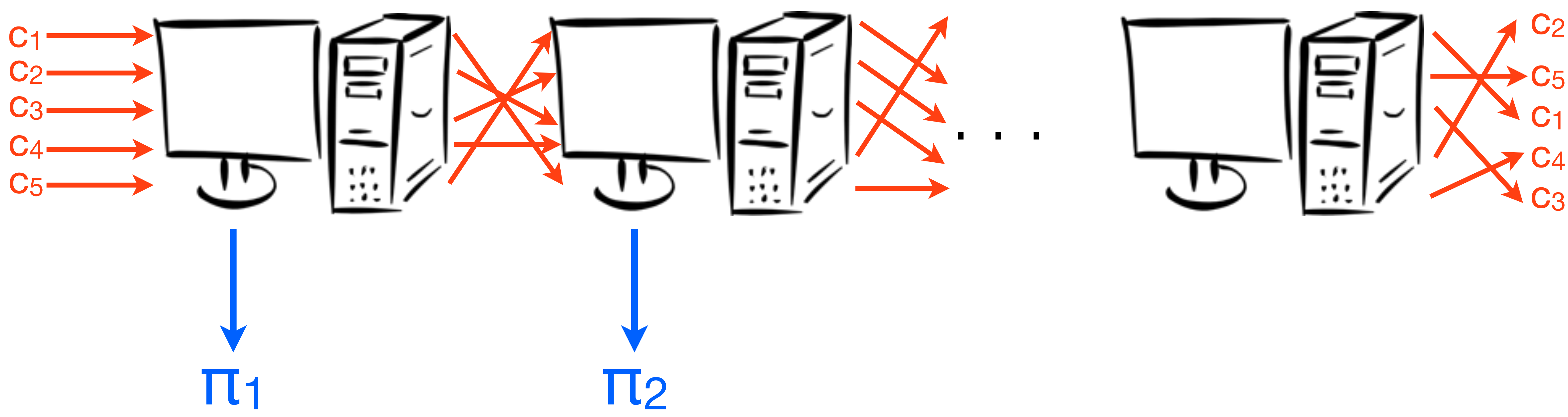

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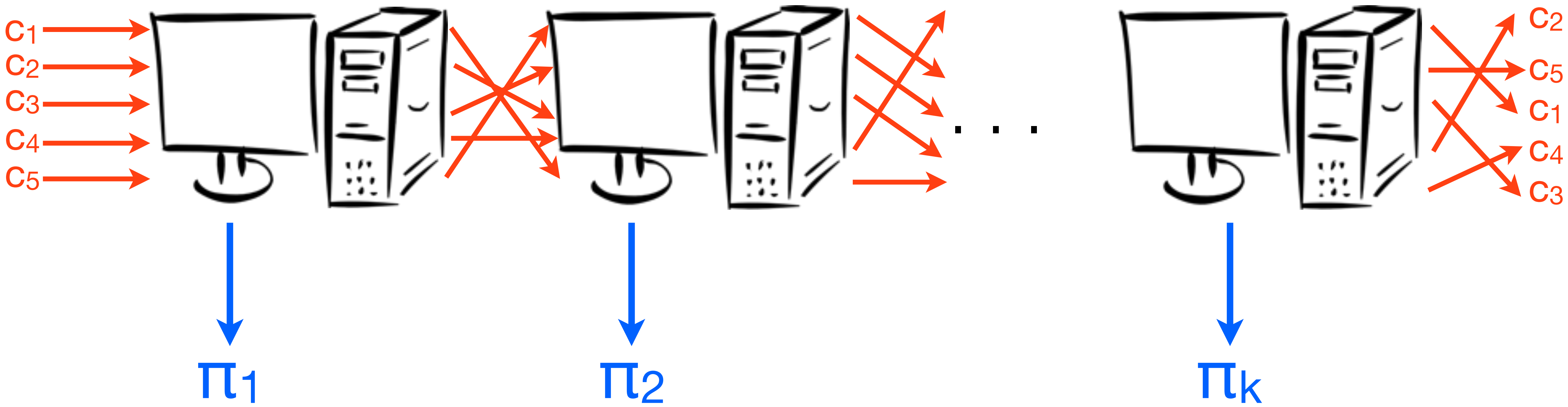

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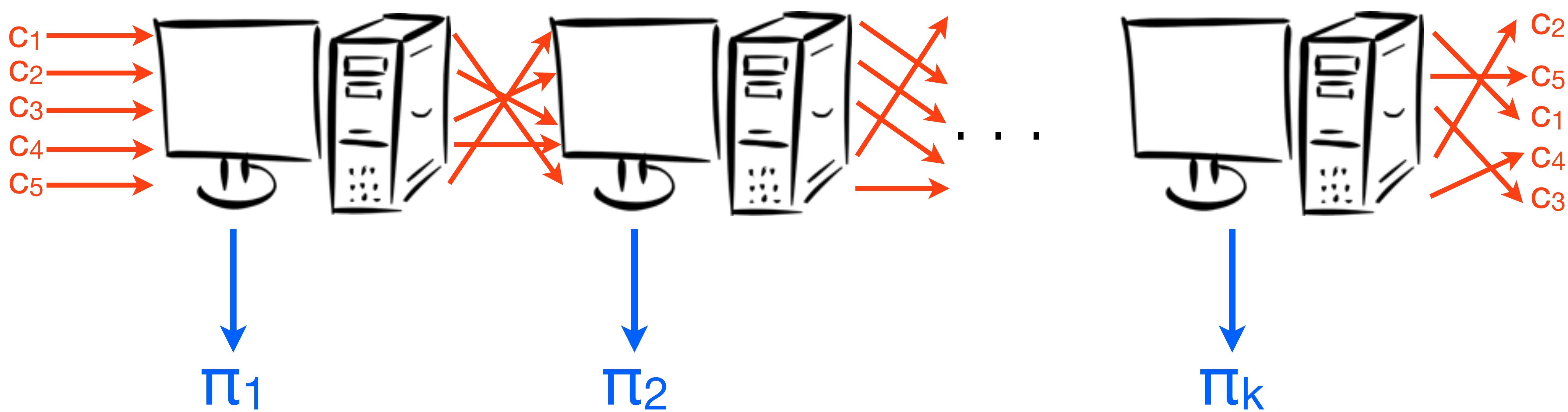

Each server now proves that it is honestly shuffling the ciphertexts, and so the shuffle is said to be verifiable

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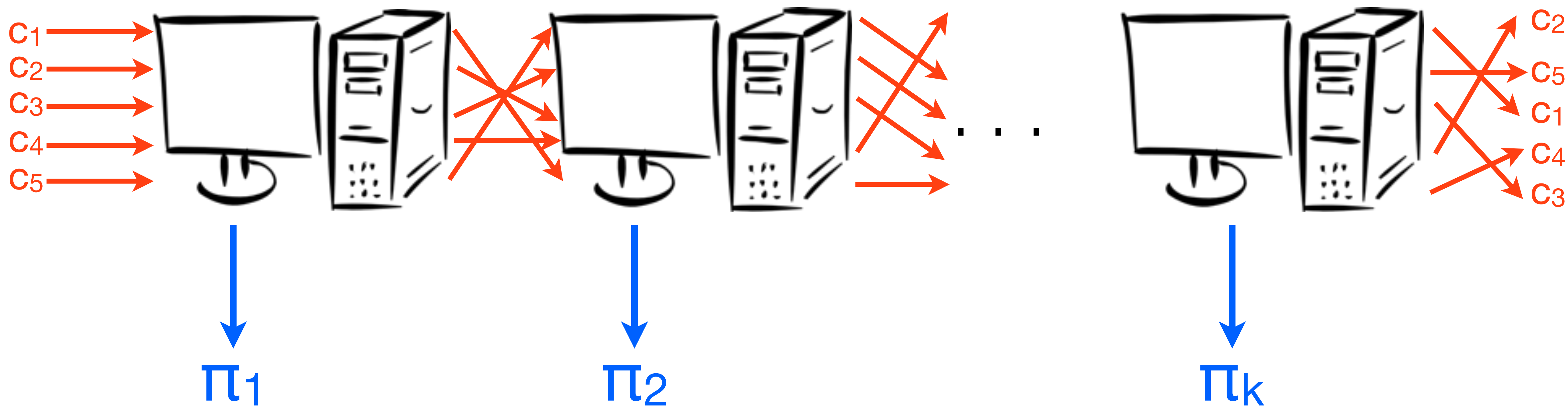

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New problem: The size of this proof grows with the number of mix servers

Using malleability to shrink the overall proof size

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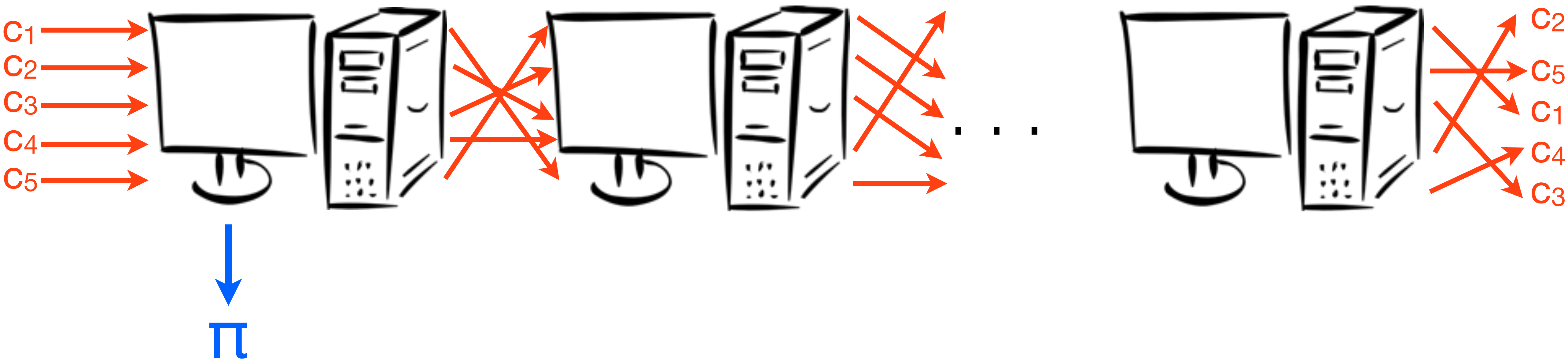
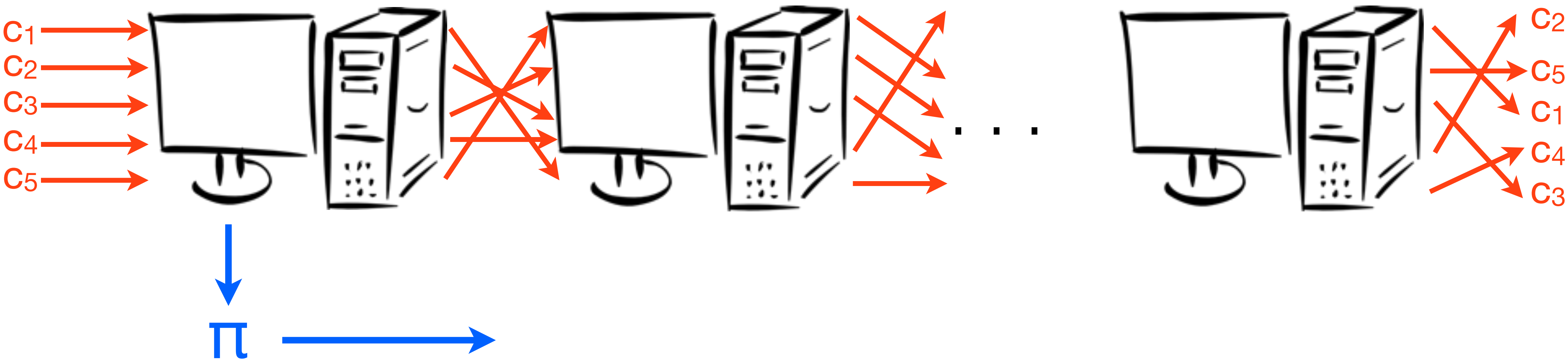


Initial mix server still outputs a fresh proof π, but now subsequent servers will "maul" this proof using permutation ϕ_i, re-randomization R_i, and public key pk_i

Using malleability to shrink the overall proof size



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$T_2 = (\phi_2, R_2, pk_2)$

$\pi \longrightarrow \pi^{(2)} = \mathrm{Eval}(T_2, \pi)$

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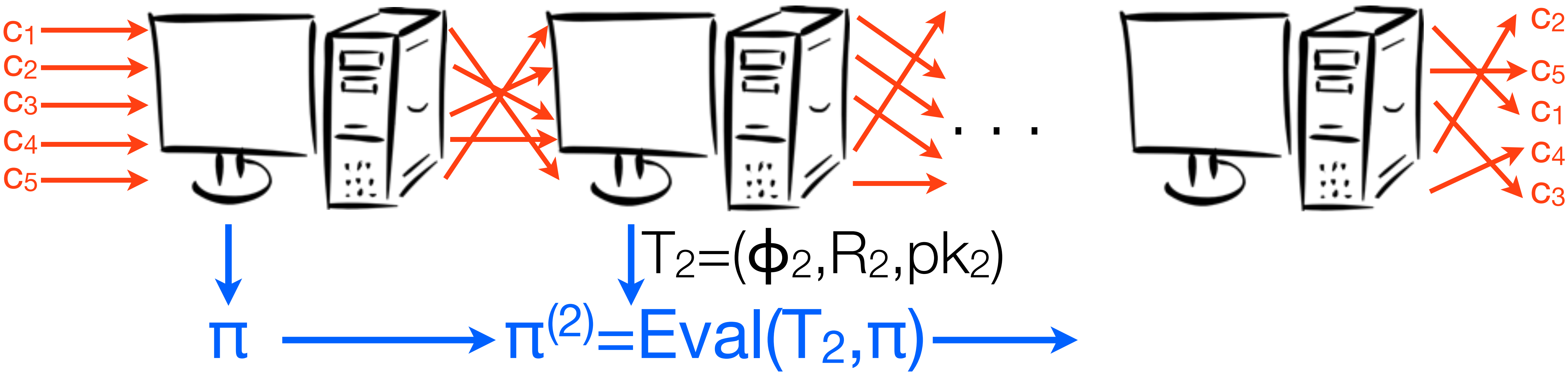

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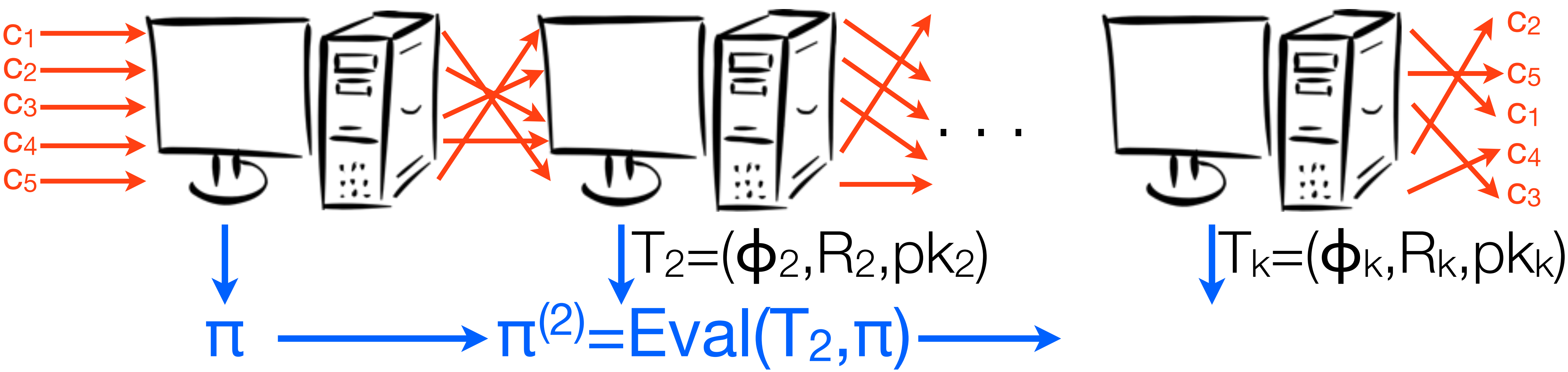

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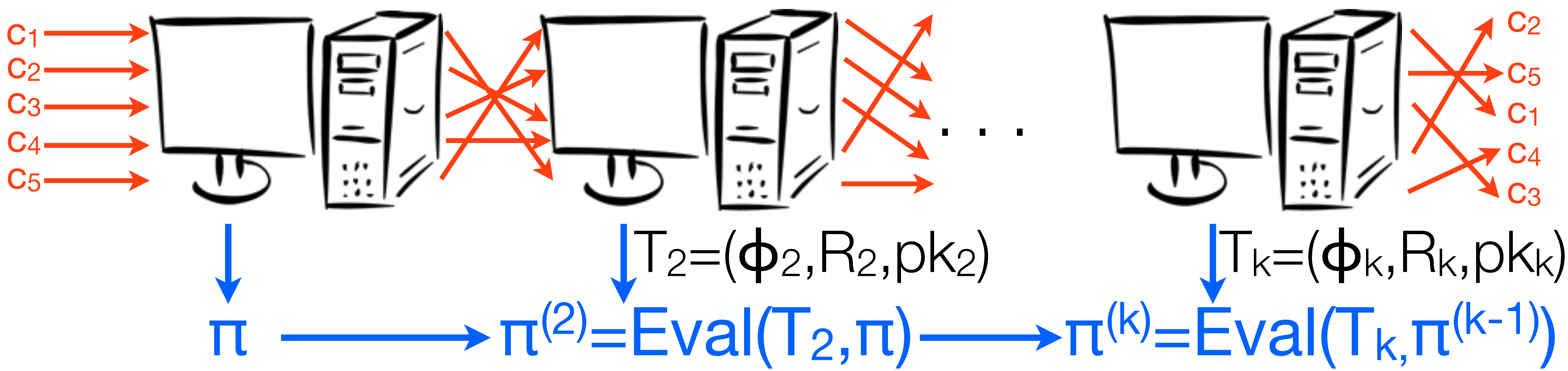

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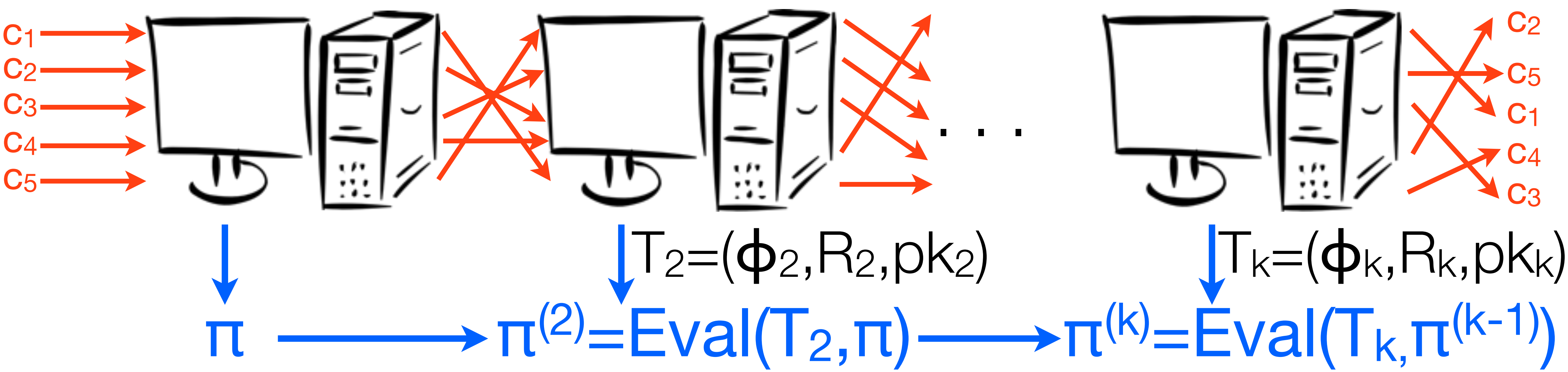

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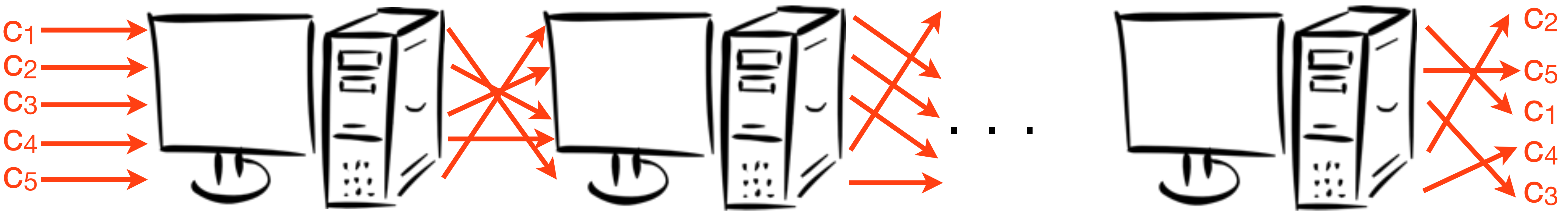

$T_2=(\phi_2,R_2,pk_2)$ $T_k=(\phi_k,R_k,pk_k)$

$\pi \longrightarrow \pi^{(2)}=\mathrm{Eval}(T_2,\pi) \longrightarrow \pi^{(k)}=\mathrm{Eval}(T_k,\pi^{(k-1)})$

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So if there are n ciphertexts and k servers, proof size can be $O(n+k)$ vs. $O(n*k)$

- This bound isn't just theoretical: in this paper we get $O(n^2+k)$ but in a recent result we use new methods to achieve $O(n+k)$

Outline

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cm-NIZK construction

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Thanks!
Any questions?