PROVING MORE OBSERVATIONAL EQUIVALENCES WITH PROVERIF

Vincent Cheval[(1)] & Bruno Blanchet[(2)]

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(2) INRIA Paris-Rocquencourt, France

19 March, 2013

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Vincent Cheval[(1)] & Bruno Blanchet[(2)]

(1) School of Computer Science, University of Birmingham, UK

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Context

Most communications take place over a public network

It is important to ensure their security

Symbolic model

Alice

Attacker

Bob

- We assume perfect cryptographic primitives
- Messages are represented by terms

$$\{N\}_{\mathsf{pk}(k)} \qquad \langle N, M \rangle \qquad \mathsf{adec}(\{N\}_{\mathsf{pk}(k)}, k)$$

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The attacker can

- intercept all messages
- transmit or modify messages
- test equality between messages

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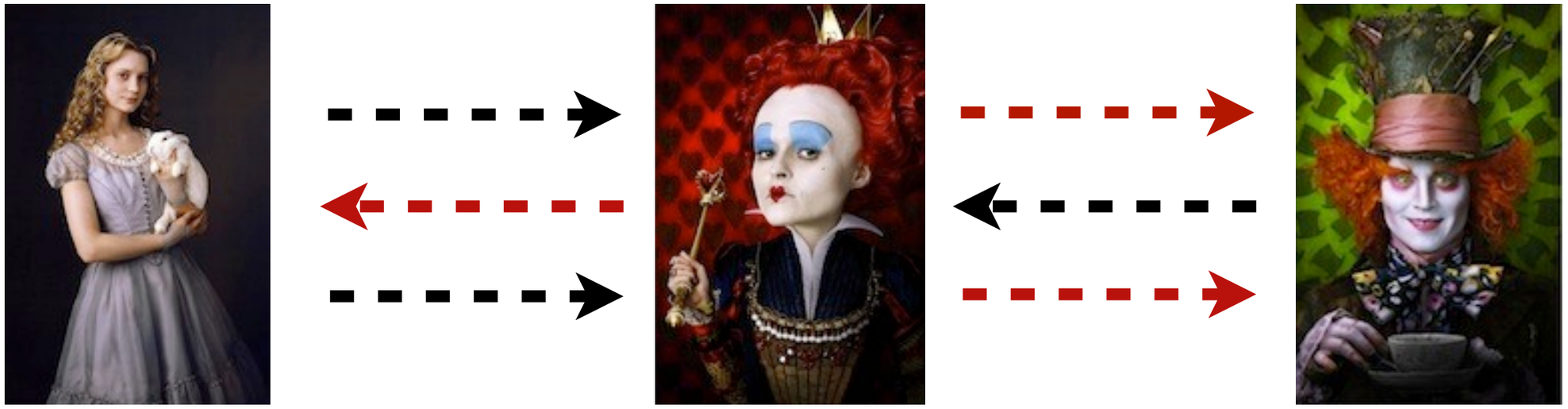
Symbolic model

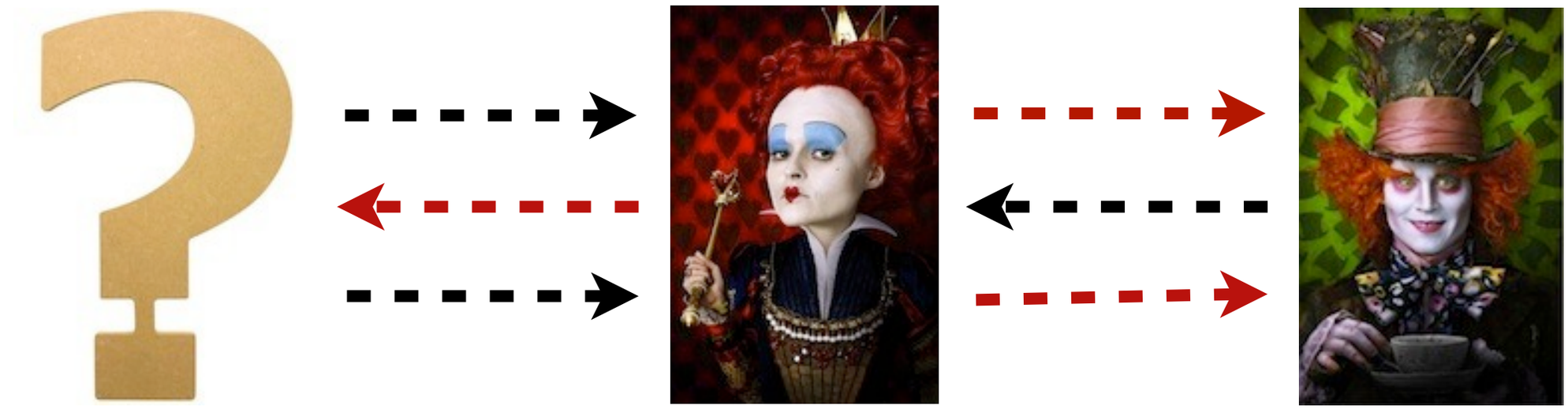


Security properties:

- Reachability properties
- Equivalence properties

Security properties

Equivalence properties: anonymity



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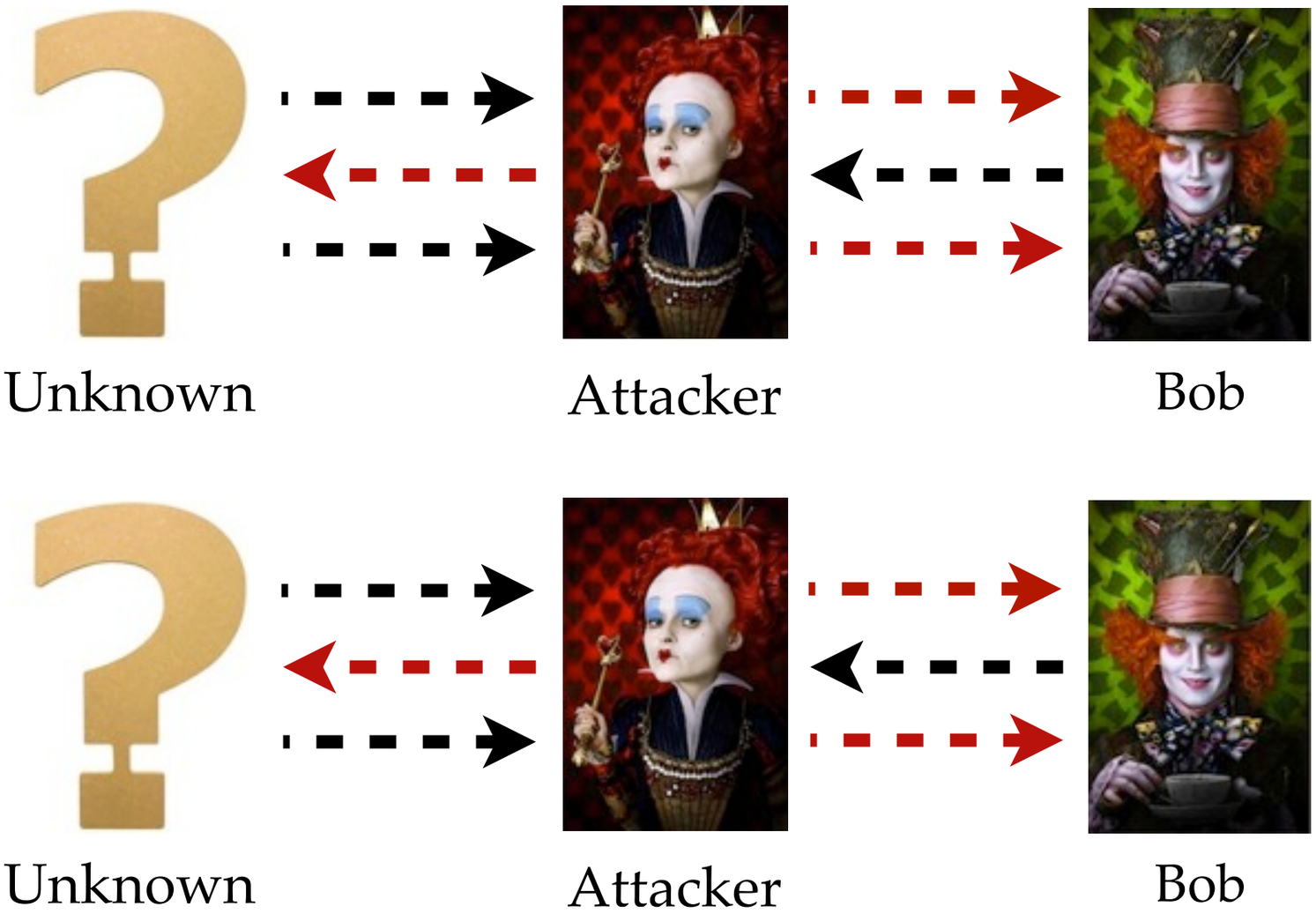
Equivalence properties: anonymity



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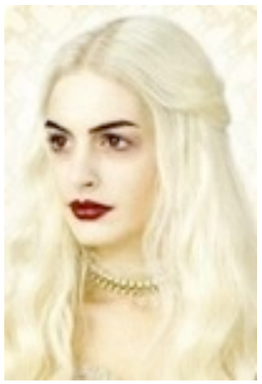


Charlene

Unknown

Attacker

Bob

Alice

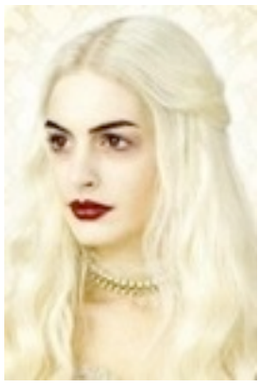
Unknown

Attacker

Bob

Security properties

Equivalence properties: anonymity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Unknown

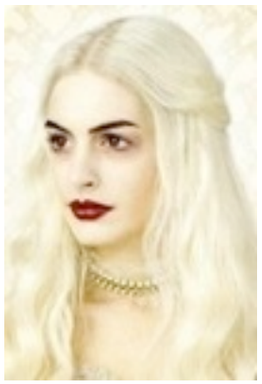

Attacker


Bob

Can the intruder distinguish the two situations ?

Security properties

Equivalence properties: anonymity



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Attacker

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Unknown

Attacker

Bob

Observational equivalence

Proverif

ProVerif was first an analyzer for reachability properties based on Horn clauses.

- Handle reachability and equivalence properties
- Cryptographic primitives described by equational theory and/or rewriting rules
- Handle processes with replication
- Possible false attack
- Does not always terminate

Examples

Private authentication protocol

Examples

Private authentication protocol

$$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$$

Alice

Bob

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$$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$$

$\mathsf{pk}(k_A)?$

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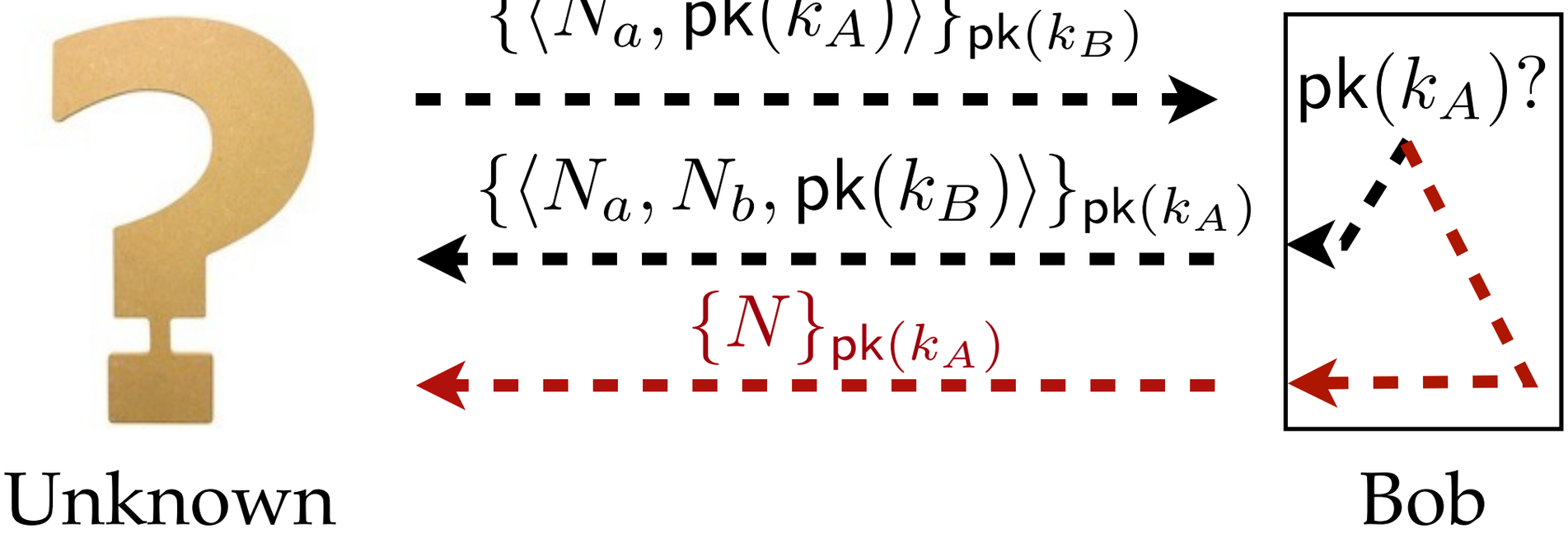
Examples

Private authentication protocol

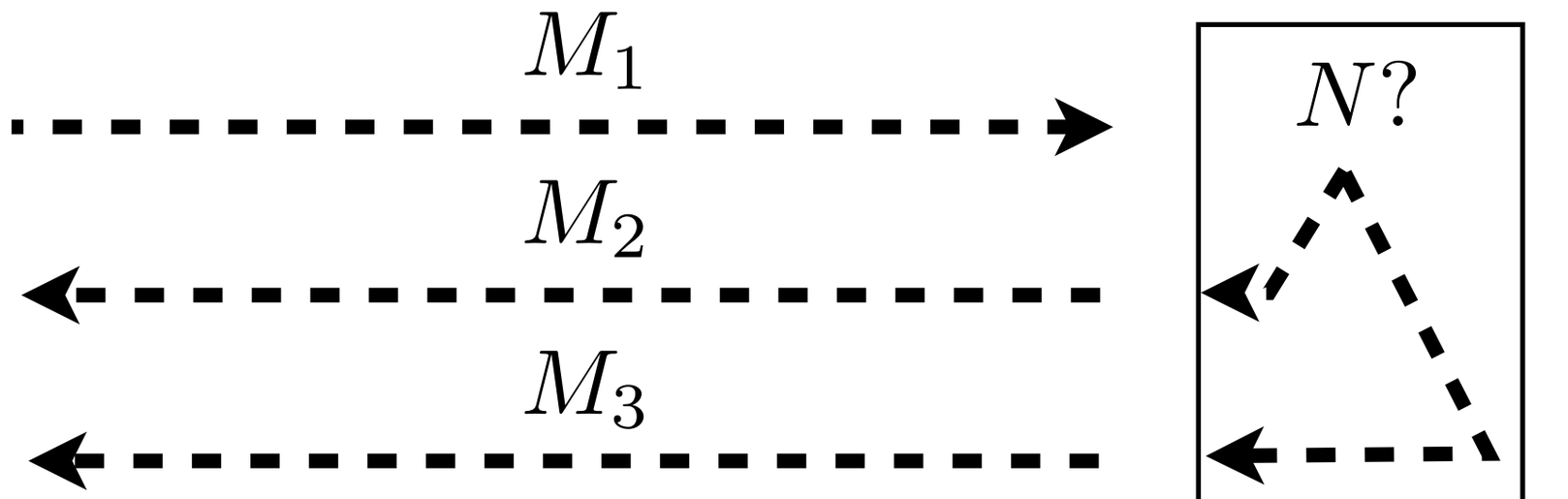


Processes

$$
\begin{aligned}
P, Q := \quad & 0 \\
& \mathsf{in}(c, x); P \\
& \mathsf{out}(c, M); P \\
& P \mid Q \\
& !\, P \\
& \mathsf{new}\ a; P \\
& \mathsf{let}\ x = D\ \mathsf{in}\ P\ \mathsf{else}\ Q
\end{aligned}
$$

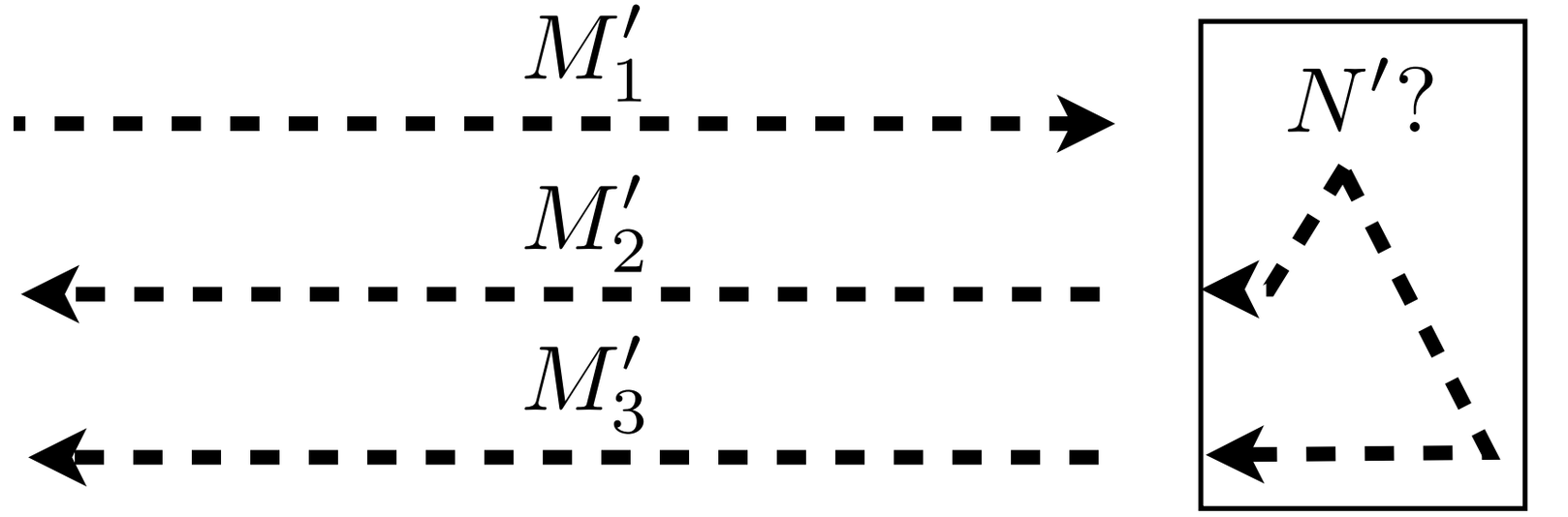
Biprocesses

Alice



Bob

Charlene



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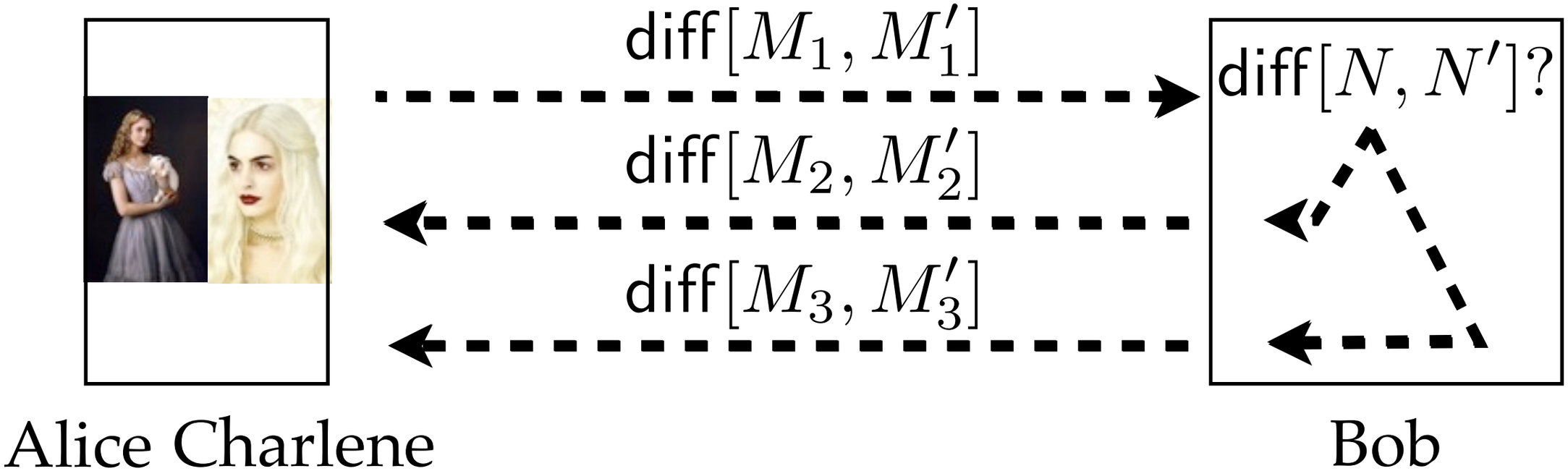
Biprocesses



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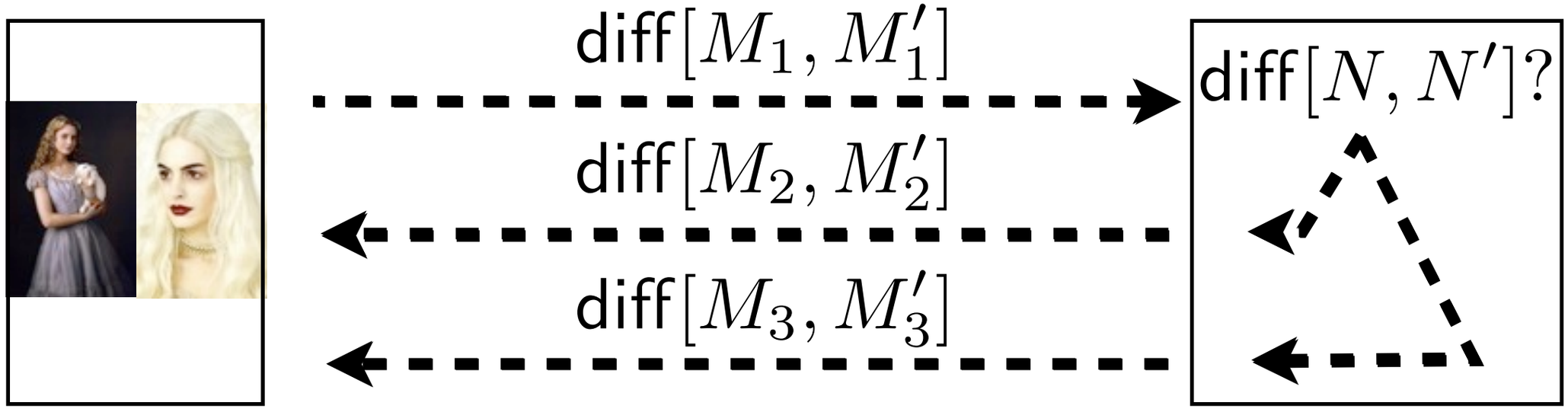

Equivalence too strong: possible false attack

Motivation

The private authentication protocol

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$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$

$\{\langle x, y\rangle\}_{\mathsf{pk}(k_B)}$

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$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$

$\{\langle x, y\rangle\}_{\mathsf{pk}(k_B)}$

$\mathsf{pk}(k_A) = y$

Bob

Charlene

Bob

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$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$

$\{\langle x, y\rangle\}_{\mathsf{pk}(k_B)}$

$\{\langle x, N_b, \mathsf{pk}(k_B)\rangle\}_y$

$\mathsf{pk}(k_A) = y$

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$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$

$\{\langle x, y\rangle\}_{\mathsf{pk}(k_B)}$

$\mathsf{pk}(k_A) = y$

$\{\langle x, N_b, \mathsf{pk}(k_B)\rangle\}_y$

$\{N\}_{\mathsf{pk}(k_A)}$

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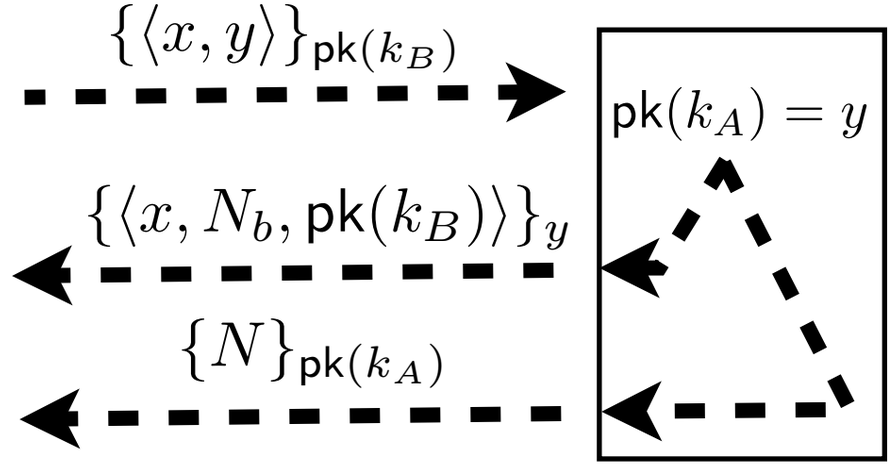
The private authentication protocol

$\{\langle N_a, \mathsf{pk}(k_A)\rangle\}_{\mathsf{pk}(k_B)}$



Alice

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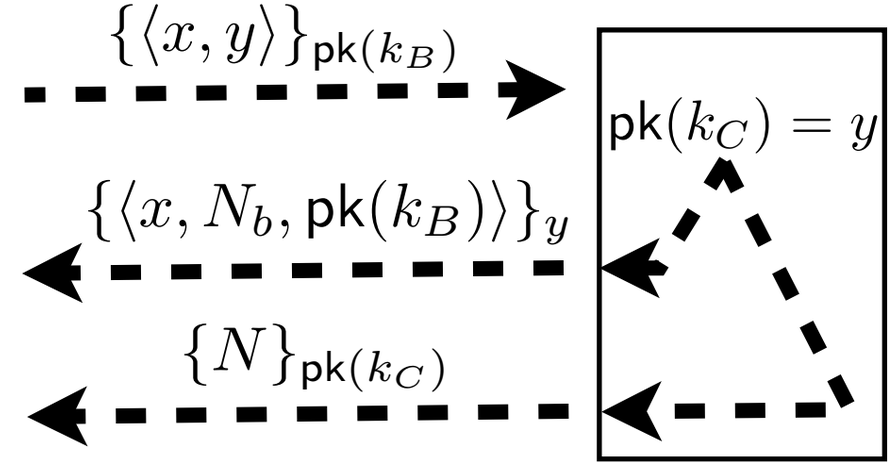
$\{\langle N_c, \mathsf{pk}(k_C)\rangle\}_{\mathsf{pk}(k_B)}$



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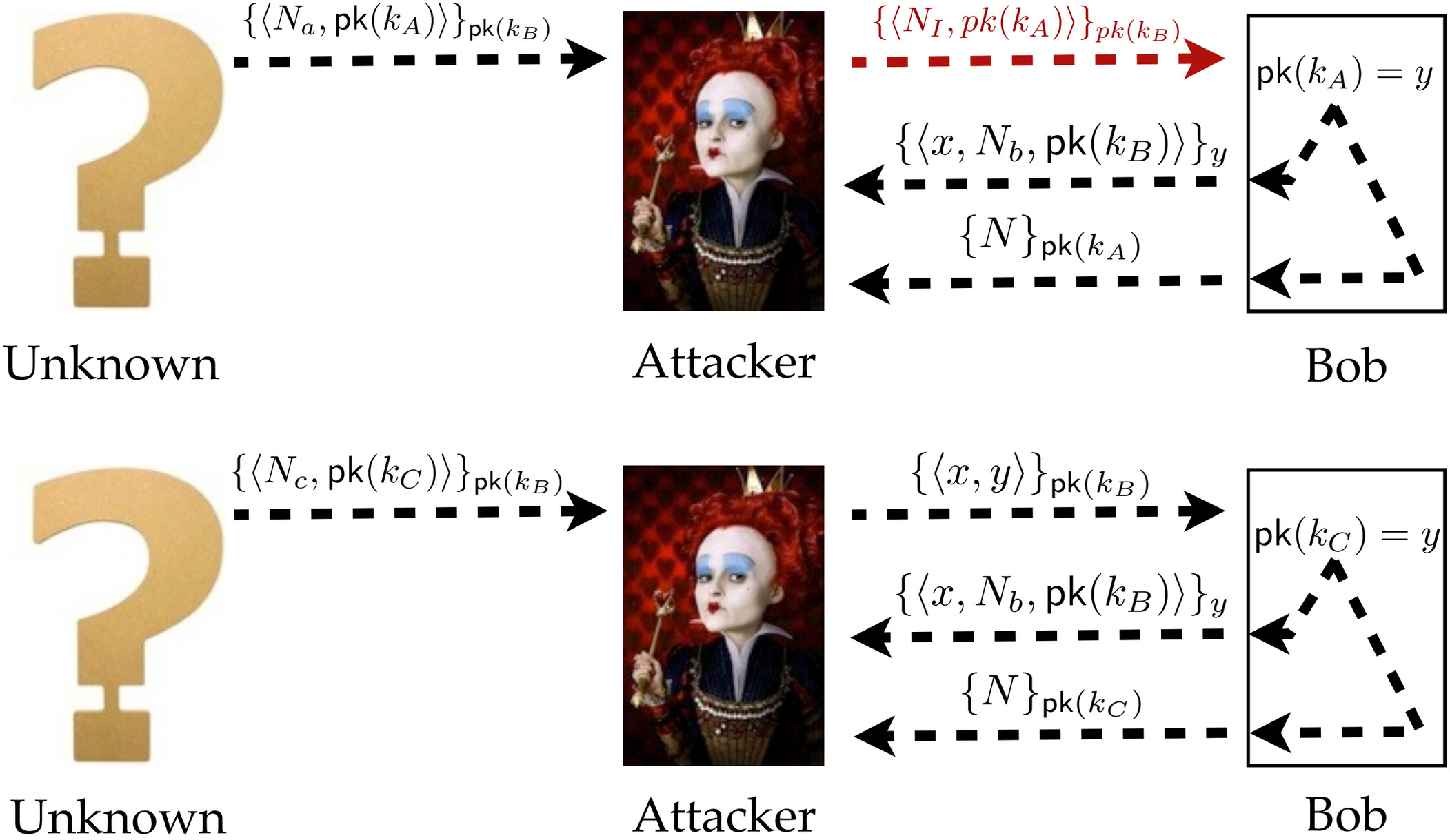

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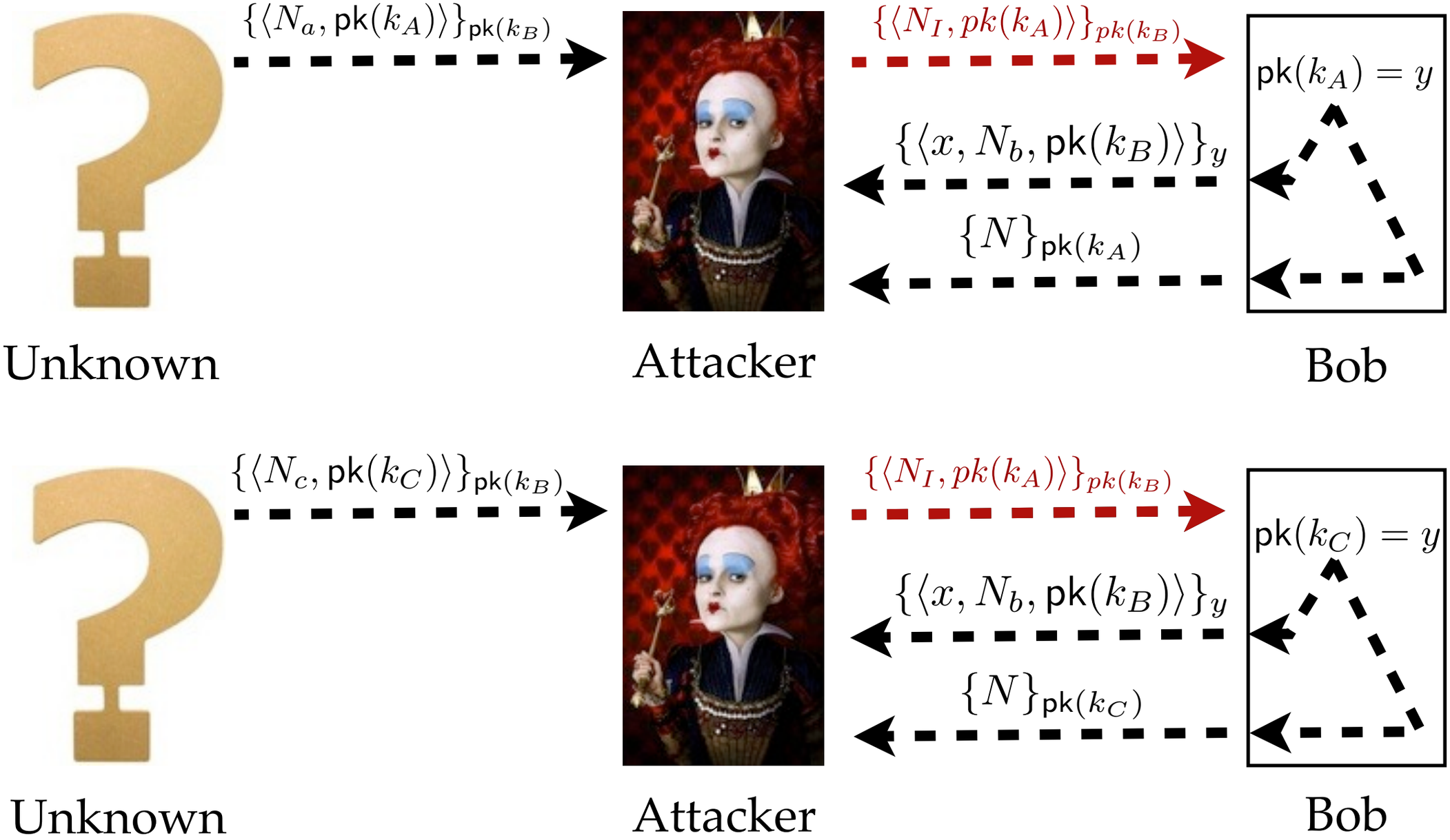

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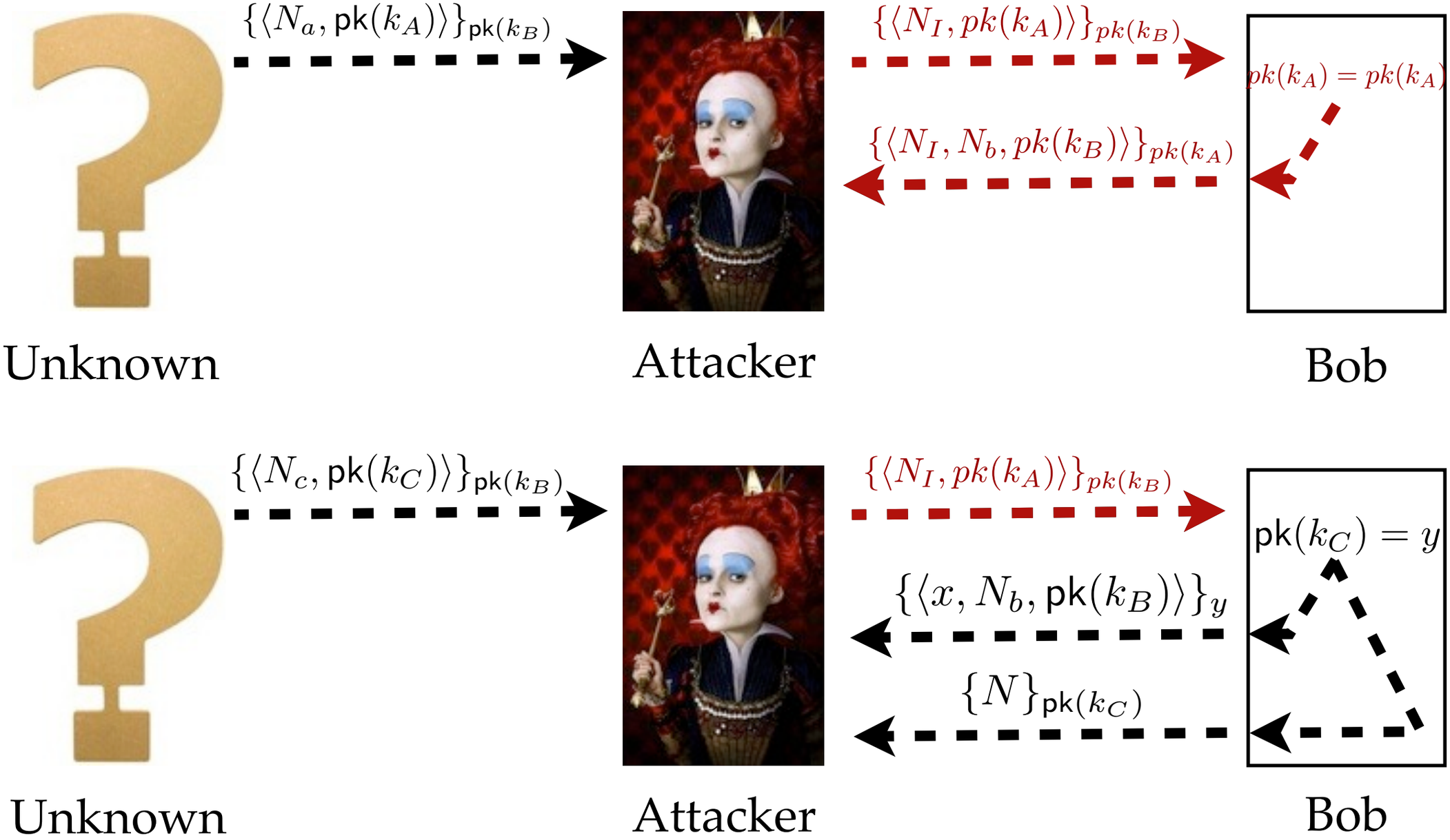

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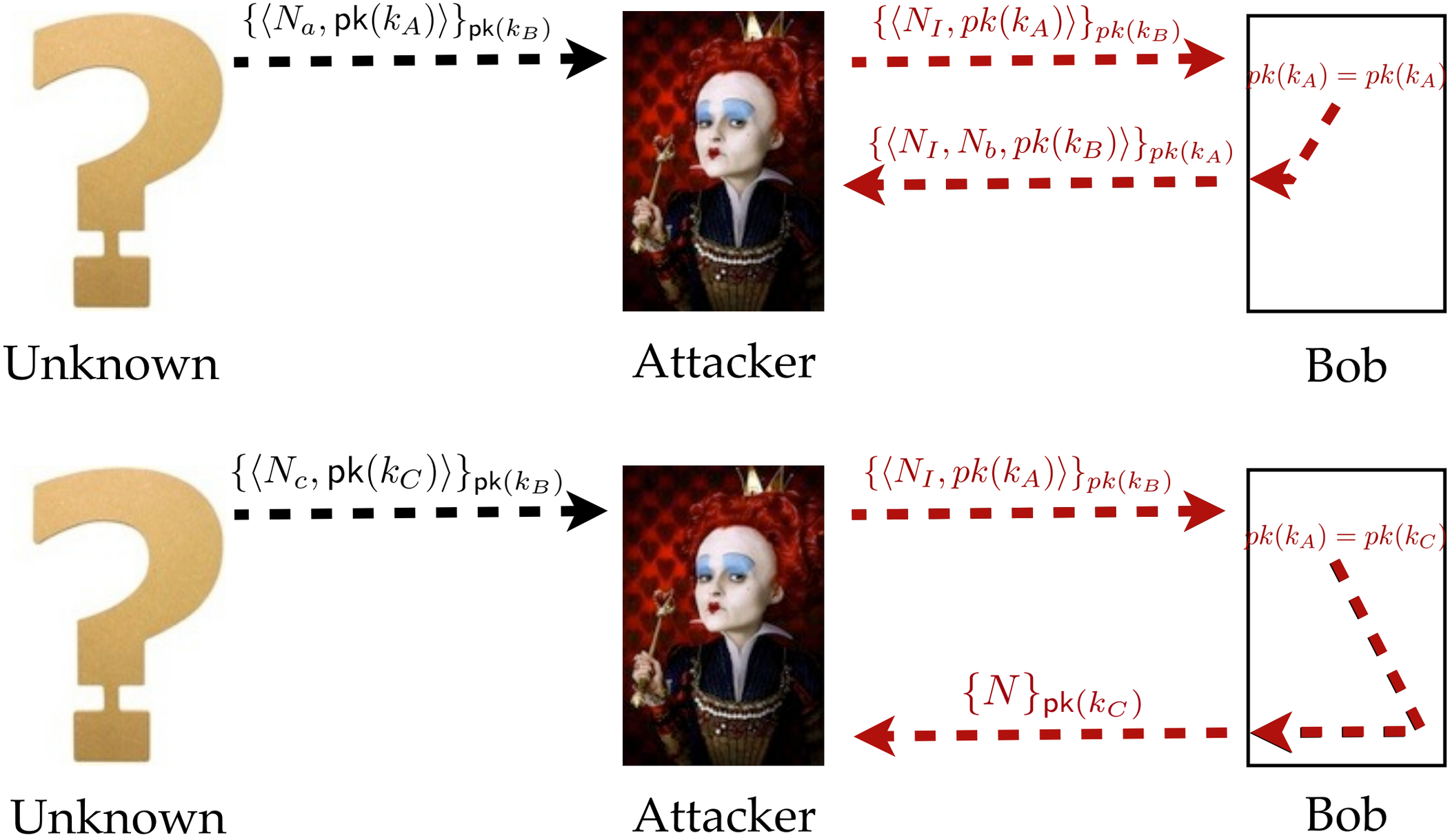

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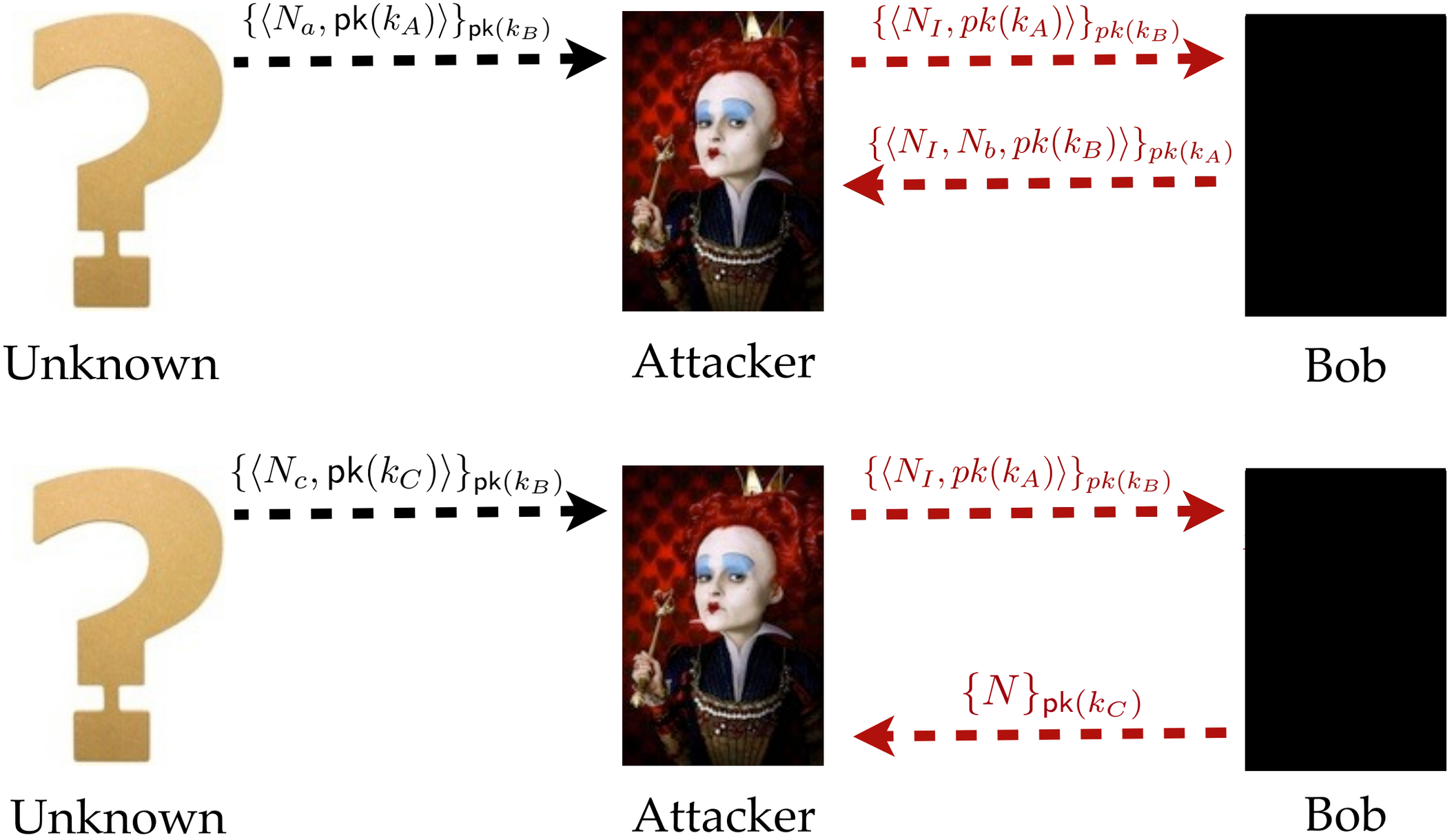

Contribution

Introduction of destructors with tests between terms

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The *If-then-else* destructor:

$$\mathsf{ifthenelse}(x, x, z, t) \to z$$

$$\mathsf{ifthenelse}(x, y, z, t) \to t \quad \text{with} \quad x \neq y$$

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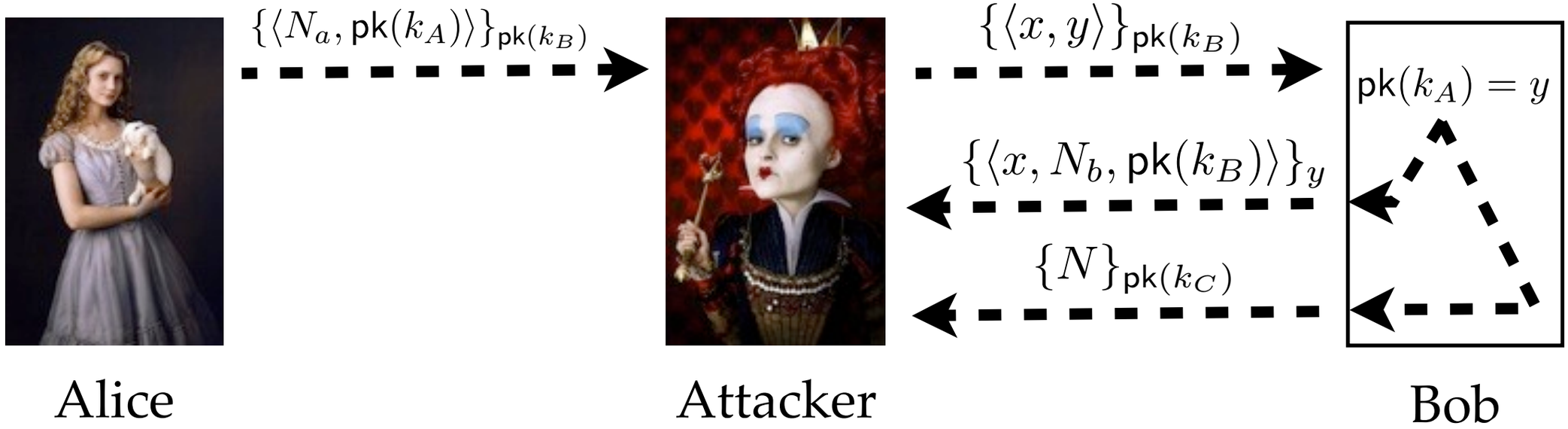

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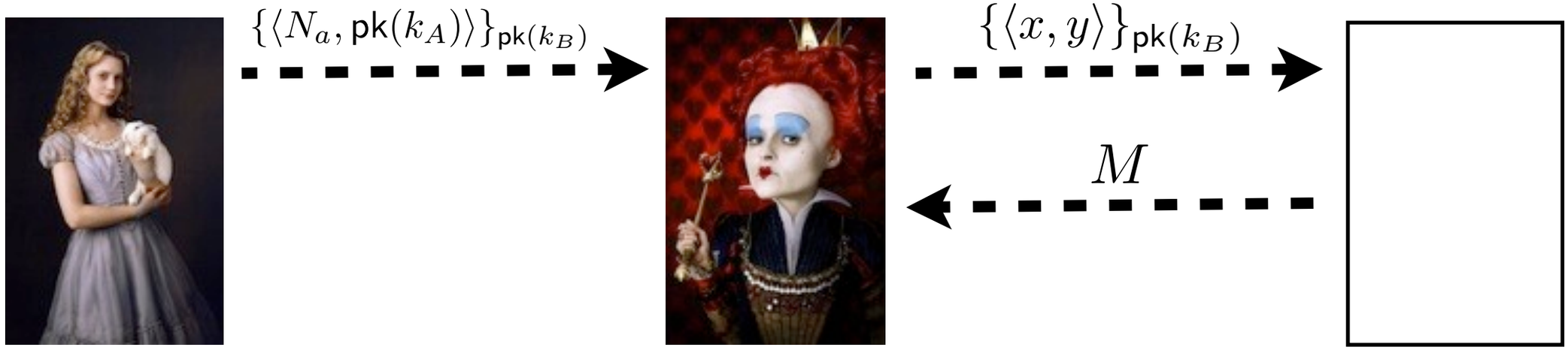

$$M = \mathsf{ifthenelse}(y, \mathsf{pk}(k_A), \{x, N_b, \mathsf{pk}(k_B)\}_y, \{N\}_{\mathsf{pk}(k_A)})$$

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Automatic transformation: $simpl$

For all processes P, $simpl(P) \approx P$

Implementation

Beta release:

ProVerif version 1.87beta6

http://prosecco.gforge.inria.fr/personal/bblanche/proverif/

Content:

- Rewrite rules with tests
- Automatic transformation of biprocesses
- Equivalence between processes with different control structures

Results:

- Prove anonymity for private authentication protocol (unbounded number of sessions)