Specifying authentication protocols for pervasive and social computation

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Outline

Deriving distance bounding authentication protocols

Deriving social authentication protocols

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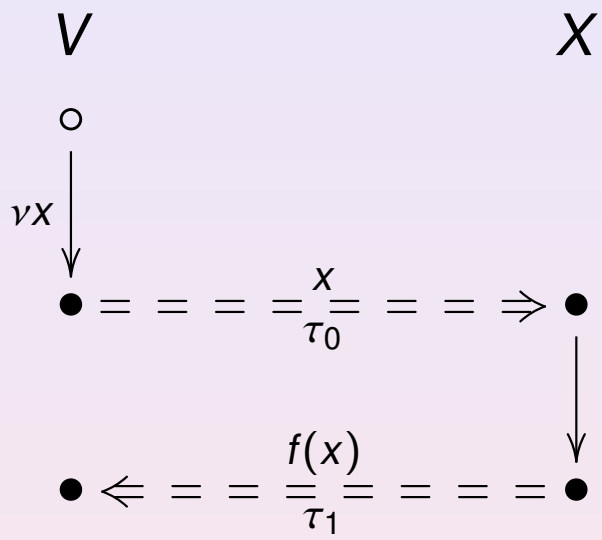
Deriving distance bounding authentication protocols

- Timed challenge-response
- Binding timed response and crypto response
- Binding timed response and crypto challenge
- Mixing timed channels

Deriving social authentication protocols

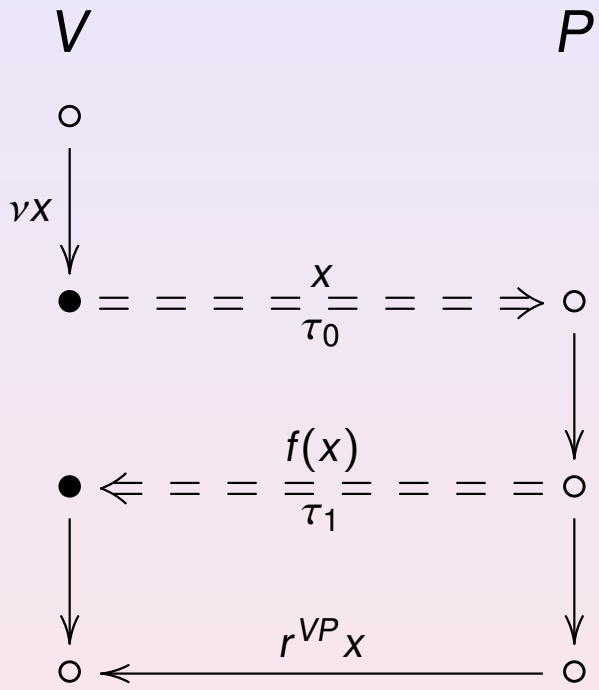
Timed challenge-response



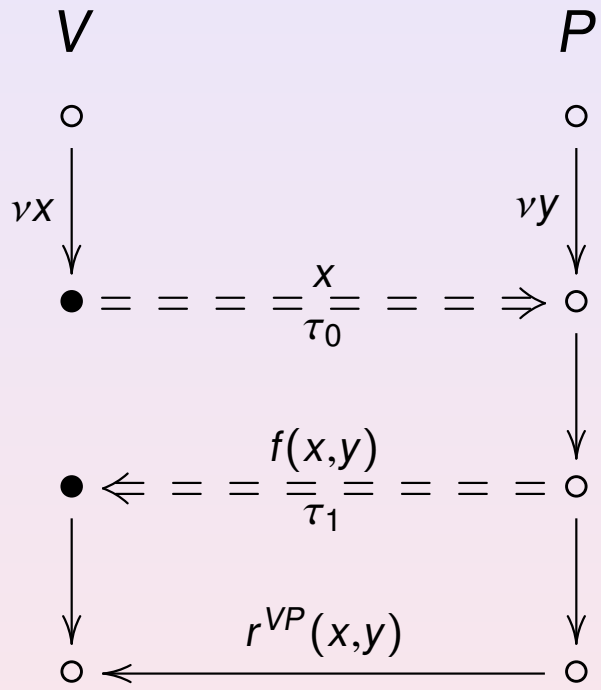
supports the axiom

$$V:\ (\nu x)_V\Big(\tau_0\langle x\rangle_V < \tau_1((x))_V \Longrightarrow \exists X.\, d(V,X) \le \tau_1 - \tau_0\Big)$$

Combining timed response and cryptographic response

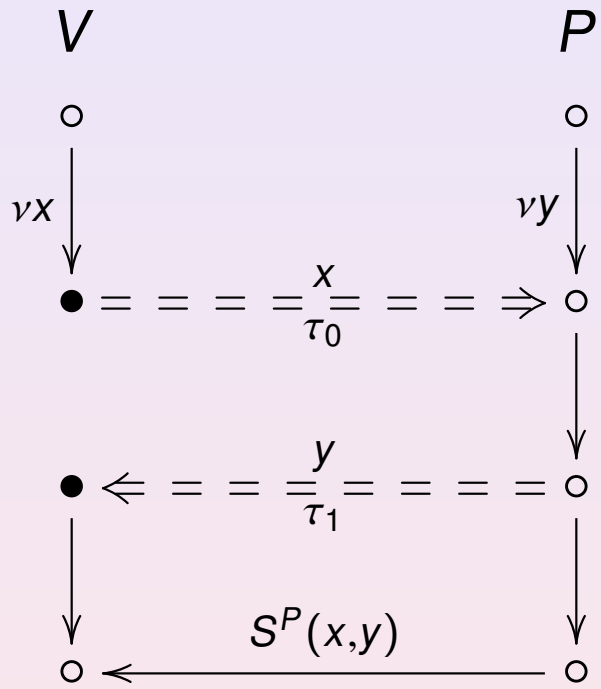


Binding timed response to cryptographic response



Binding timed response to cryptographic response

Brands-Chaum 1



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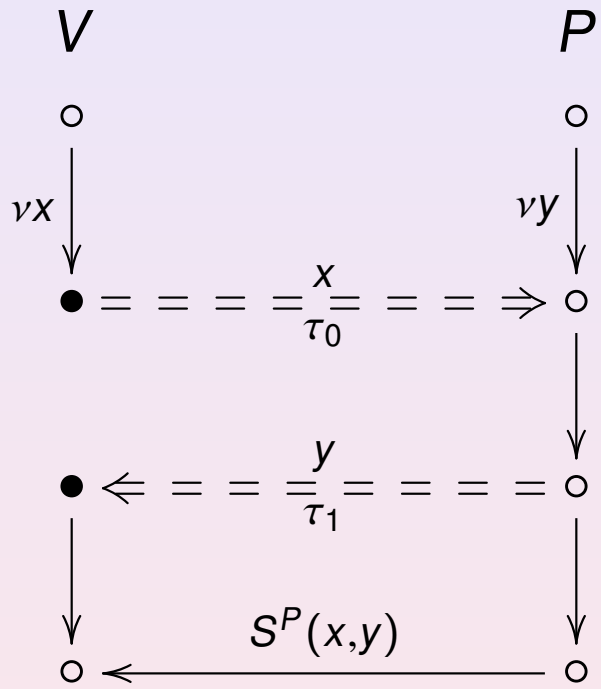
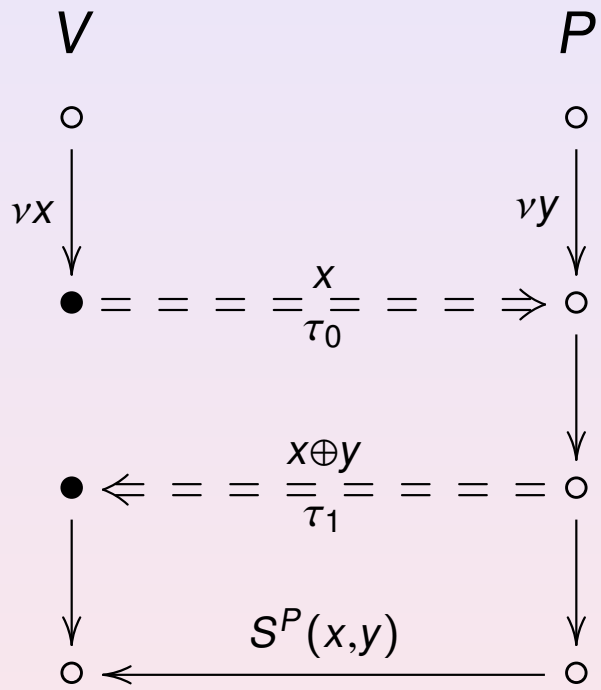


- V : P honest $\Longrightarrow$ $d(V,P) < \tau_1 - \tau_0$
- V : $\forall X.P$ responds to $X \Longrightarrow d(V,X)+d(X,P) < \tau_1 - \tau_0$

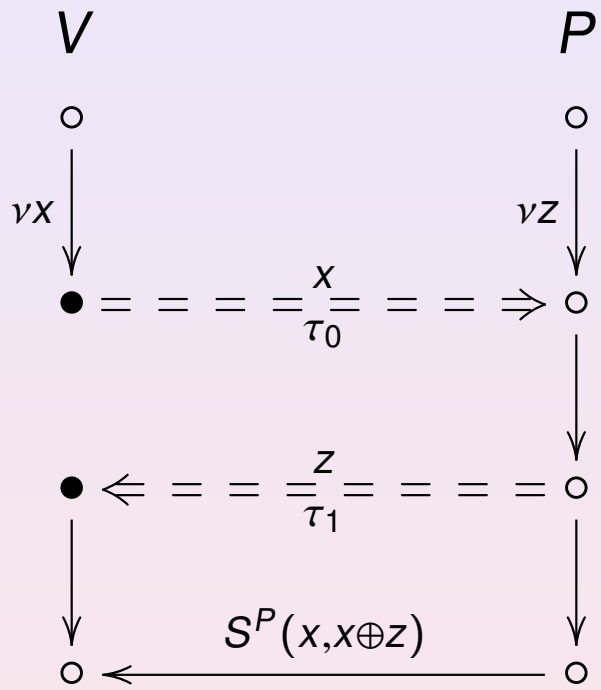
Binding timed response to cryptographic response

Discharge the honesty assumption?



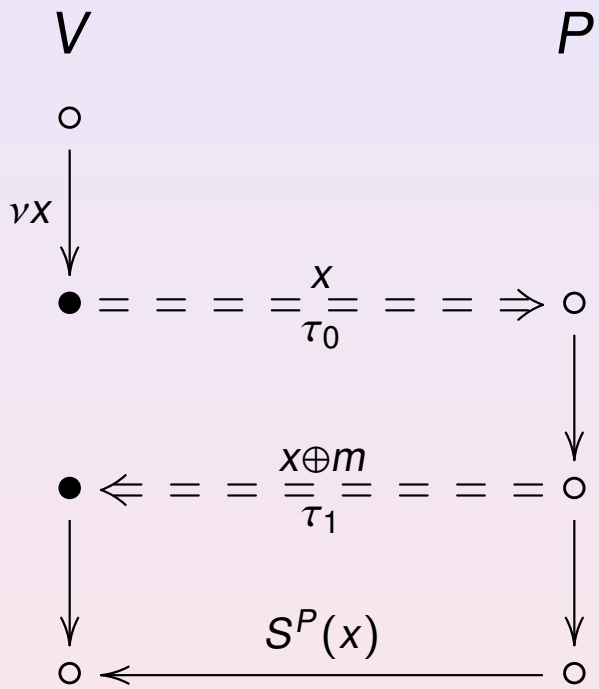
Binding timed response to cryptographic response

P can still cheat



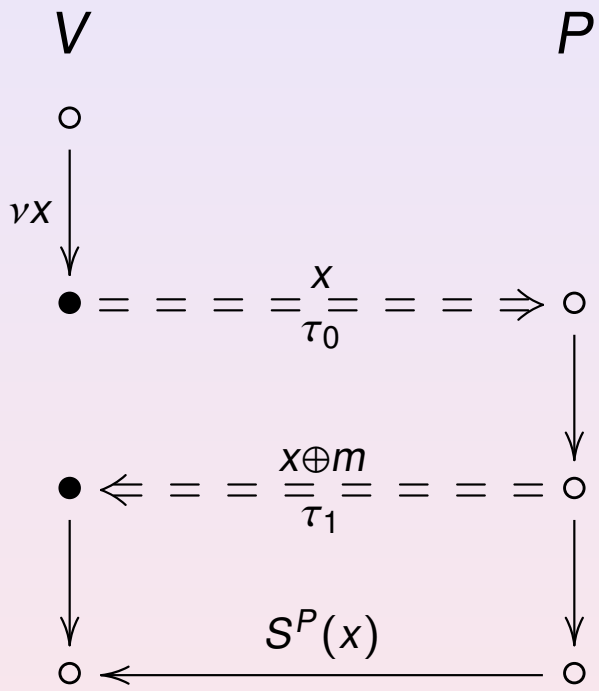
Binding timed response to cryptographic response

Brands-Chaum 2



Binding timed response to cryptographic response

Brands-Chaum 2



- Peggy cannot cheat

Binding timed response to cryptographic response

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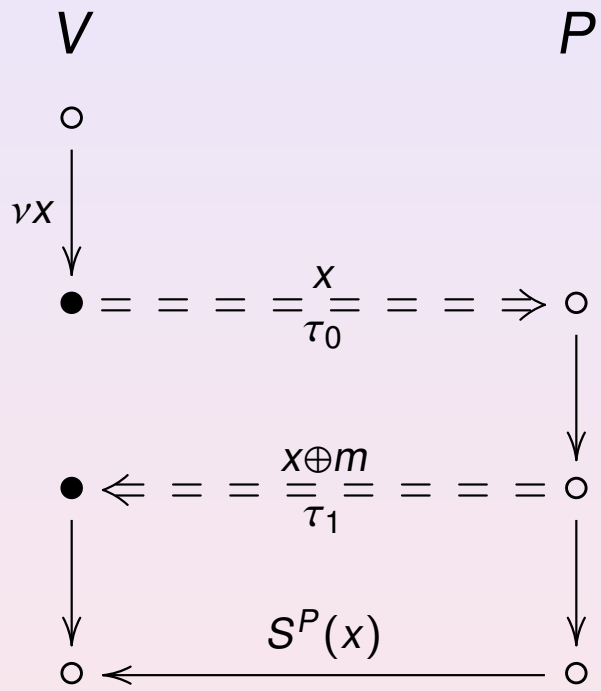
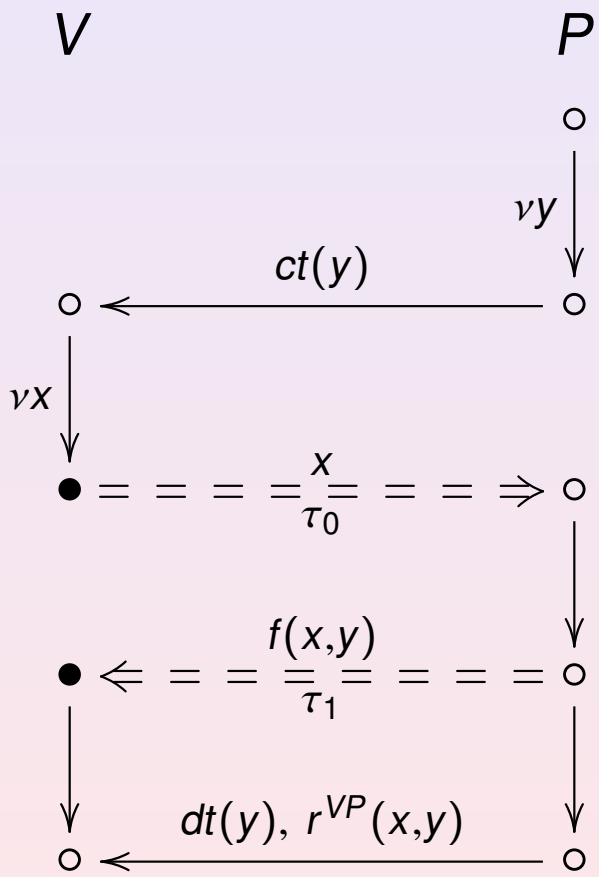


- Peggy cannot cheat
- Ivan can impersonate her, and relay $S^P(x)$

Binding timed response to cryptographic response

— with commitment



Digression: Symbolic commitment

Definition

A *commitment schema* consists of three publicly known functions over the space of messages $\mathcal{T}$,

- *commitment* $ct : \mathcal{T} \longrightarrow \mathcal{T}$,
- *decommitment* $dt : \mathcal{T} \longrightarrow \mathcal{T}$, and
- *open commitment* $ot : \mathcal{T} \times \mathcal{T} \longrightarrow \mathcal{T}$,

such that

- ct is a one-way collision-free function,
- $ot\,(ct(x), dt(x)) = x$.

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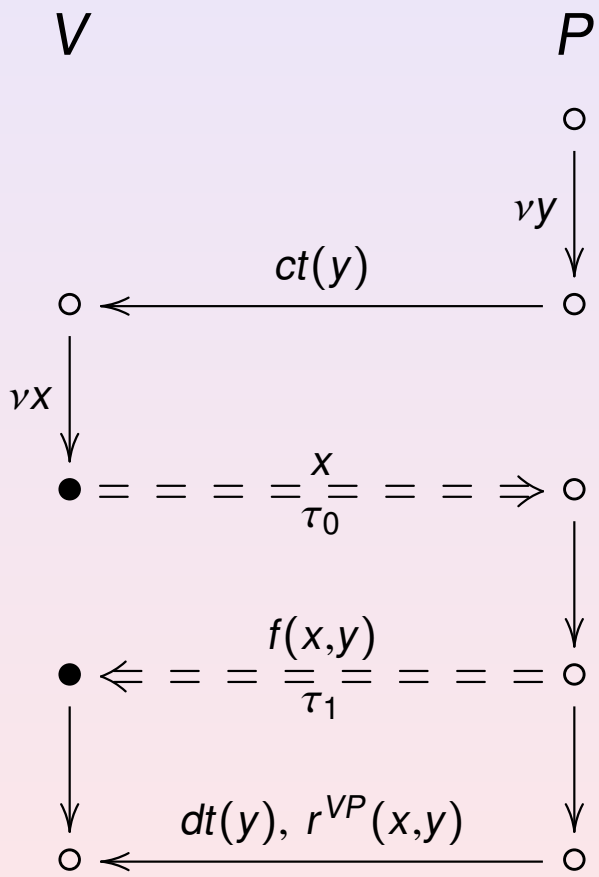
E.g.,

$$ct(x) = H(x) \qquad ct(x) = H_0(x) \qquad ct(x) = E(x_0, x_1)$$
$$dt(x) = x \qquad dt(x) = H_1(x)::x \qquad dt(x) = x_0$$
$$ot(y,z) = z \qquad ot(y,z) = z_1 \qquad ot(y,z) = D(z,y)$$

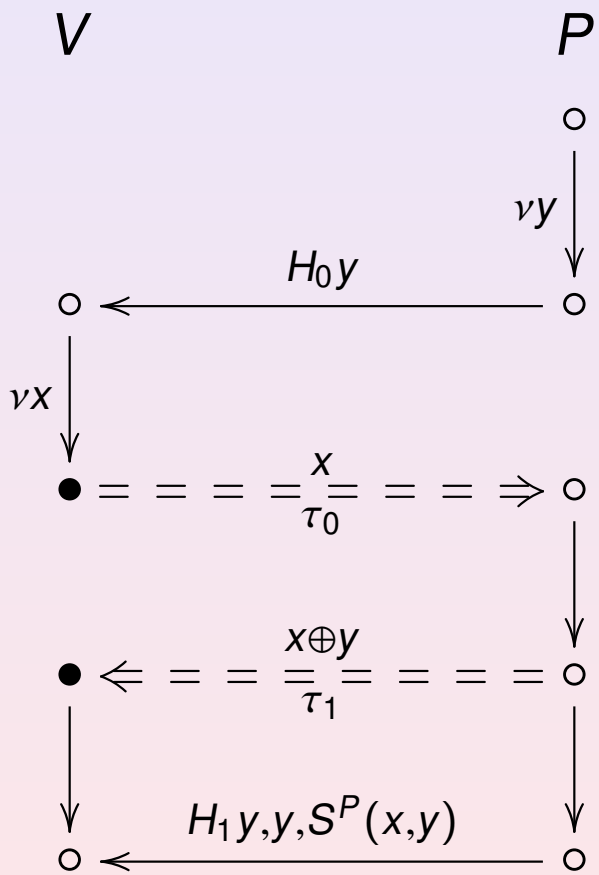
Binding timed response to cryptographic response

— with commitment



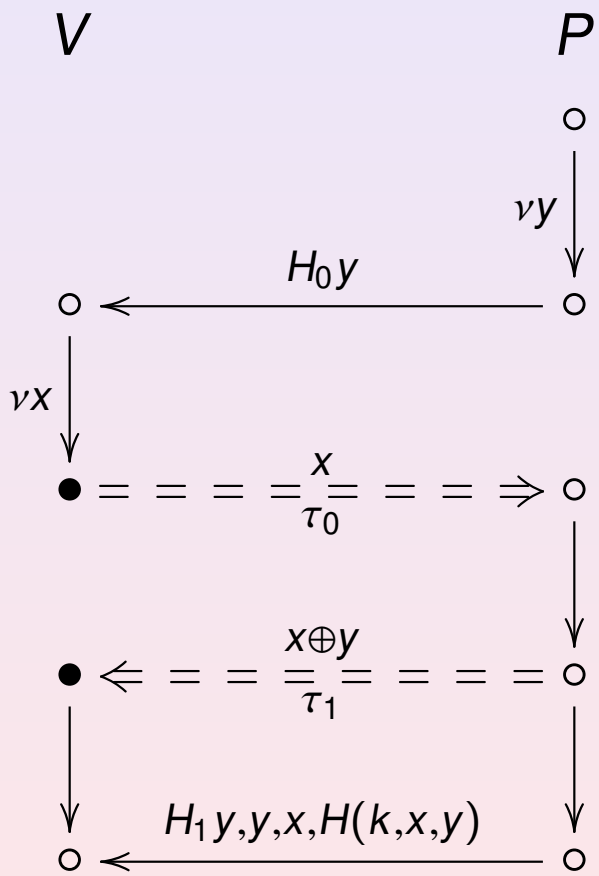
Binding timed response to cryptographic response

Brands-Chaum 3



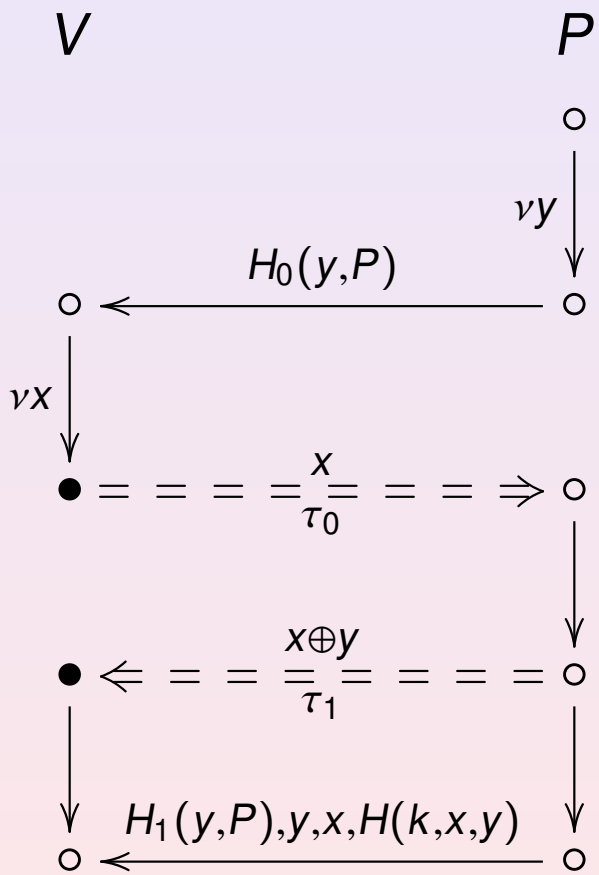
Binding timed response to cryptographic response

Čapkun-Hubaux



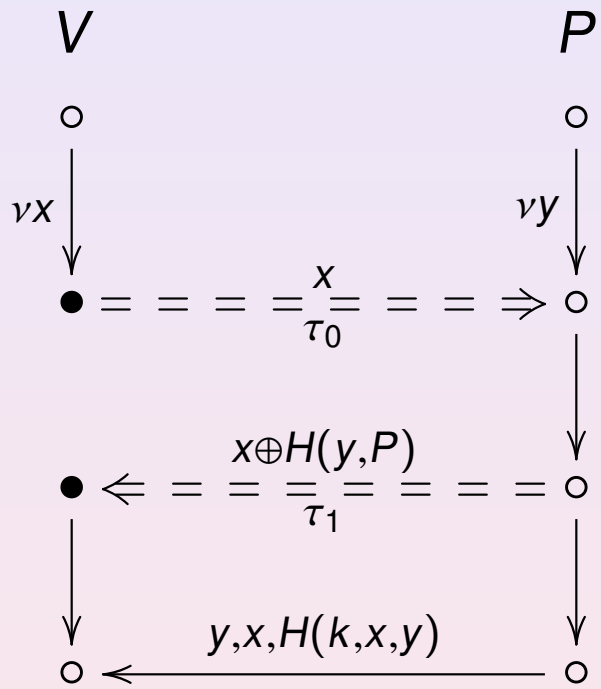
Binding timed response to cryptographic response

Meadows-Syverson



Binding timed response to cryptographic response

Meadows-P-Syverson



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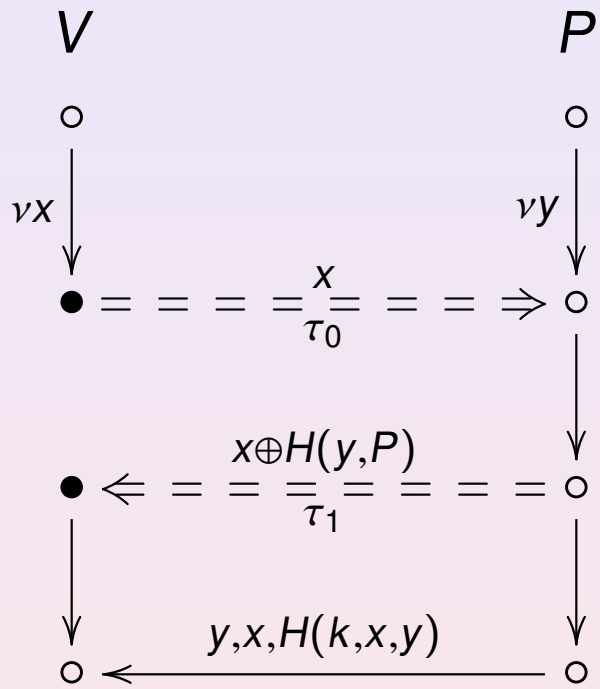
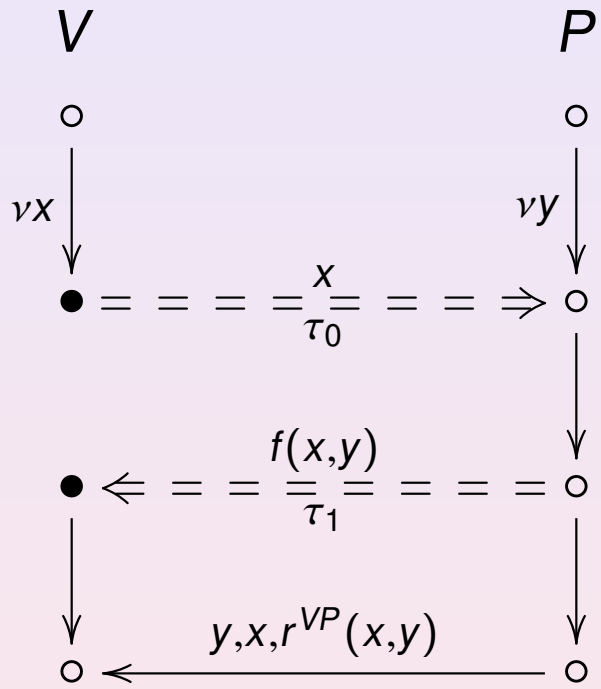


- $V:\ d(V,\widetilde{P}) < \tau_1 - \tau_0$
- $V:\ \forall X.P$ responds to $X \Longrightarrow d(V,X)+d(X,P) < \tau_1 - \tau_0$

Binding timed response to cryptographic response

. . . and in general



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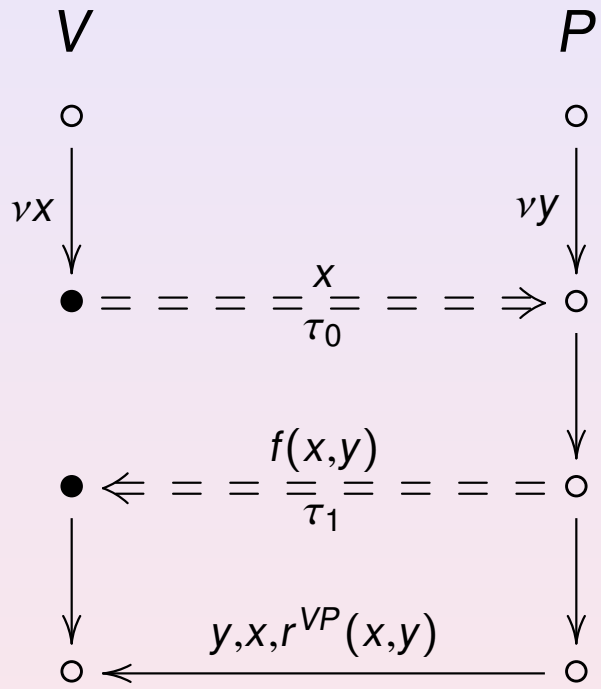
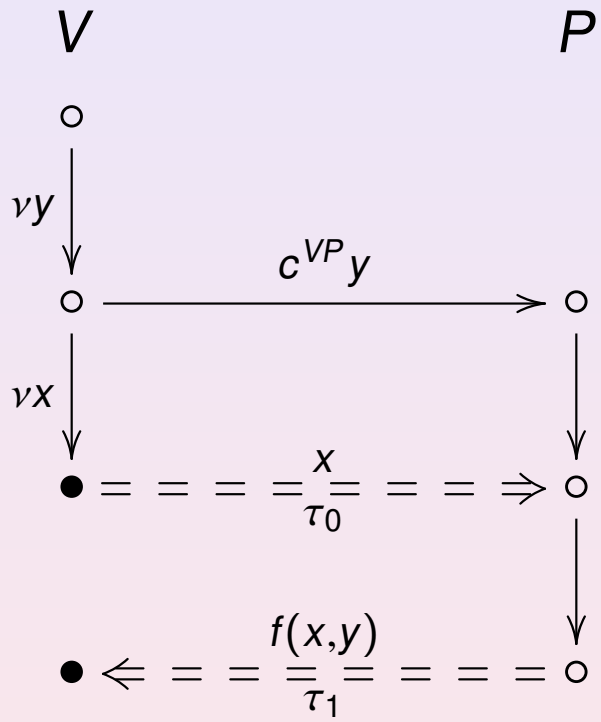


- $f(x, y)$ one-way function in y
- only P could generate $r^{VP}(x, y)$.

Binding timed response and cryptographic **challenge**



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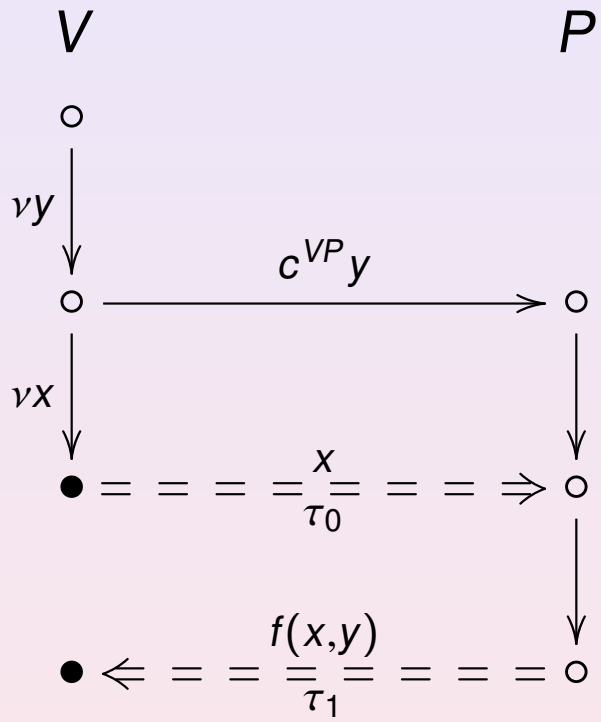
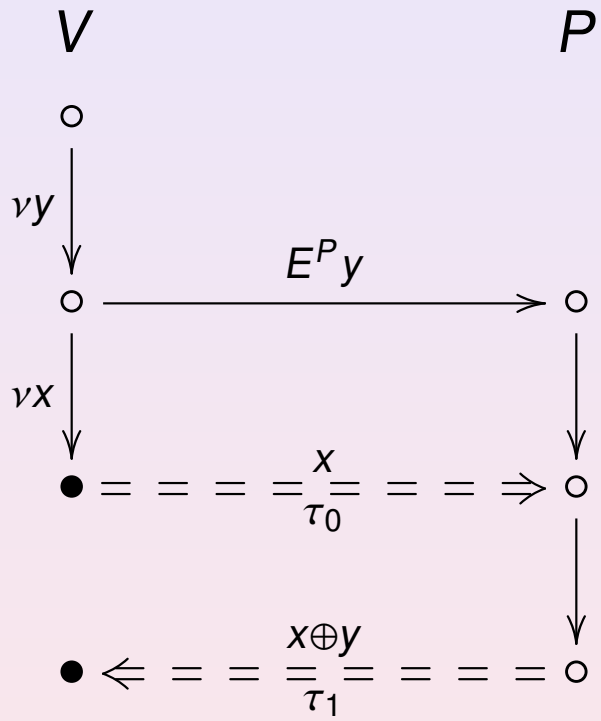


(more convenient when P is a smart card)

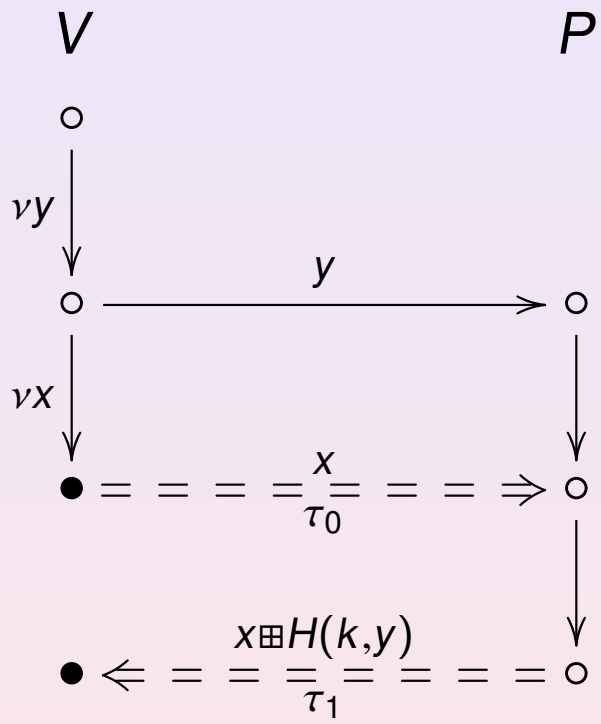
Binding timed response and cryptographic challenge



(if P has a public key)

Binding timed response to cryptographic challenge

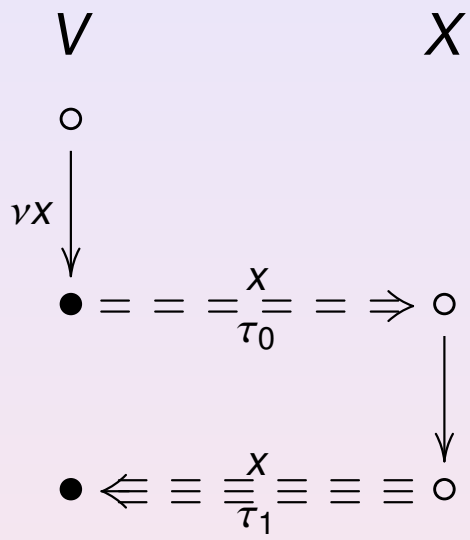
Hancke-Kuhn



$$x \boxplus z \;=\; [z_i^{(x_i)}] \quad \text{where } z = z^{(0)}::z^{(1)}$$

Mixing different kinds of timed channels

ECHO: Sastry-Sankar-Wagner



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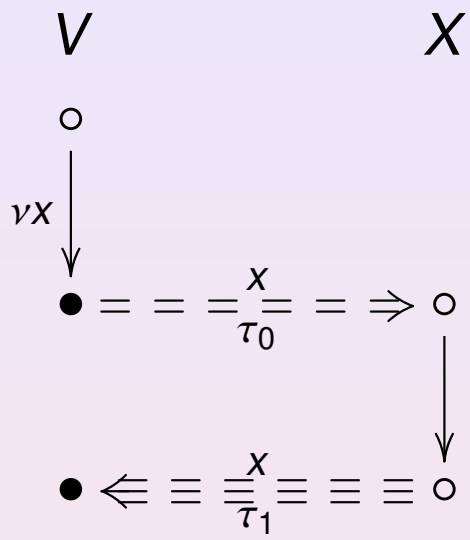

$$V:\ (\nu x)_V\Big(\tau_0\langle\langle x\rangle\rangle_V < \tau_1((x))_V \Longrightarrow \exists X.\ d(V,X) \le (\tau_1-\tau_0)\frac{c+s}{cs}\Big)$$

- where c is the speed of light and s the speed of sound

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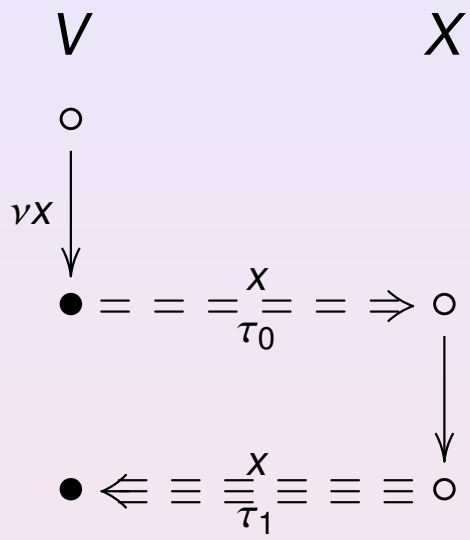

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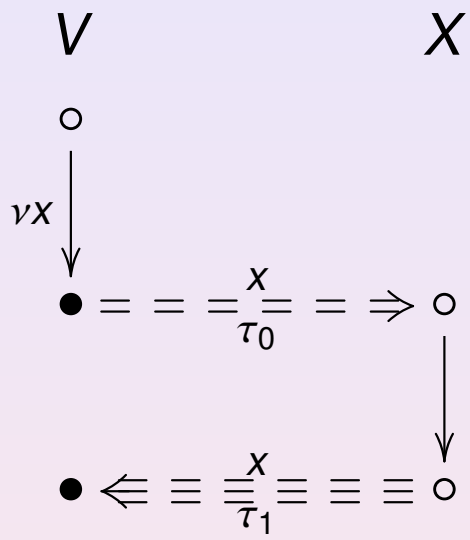

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- where c is the speed of light and s the speed of sound
- the reasoning boils down to (crt)), because $s \ll c \implies \frac{c+s}{cs} \approx 1$
- **pro:** measuring longer response times requires less precision
- **con:** s less robust, due to the influences of the environment

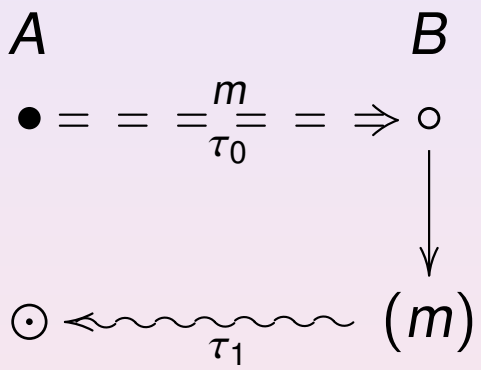
Outline

Deriving distance bounding authentication protocols

Deriving social authentication protocols

- Social channel basics
- Socially authenticated key distribution
- Socially authenticated key exchange

Preliminary example: a timed social protocol



Social actions

- $<\!\!\cdot\vartheta\cdot\!\!>_{B\to A}$ — B displays ϑ for A to see
  - where ϑ may be a term t, or an action β

Social actions

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  - where ϑ may be a term t, or an action β

such that

- $\langle\!\langle \beta \rangle\!\rangle_{B \to A} \implies A : \beta_B$
  - "If A observes an action β, then A knows that this action has occurred."
- $\langle\!\langle \beta \rangle\!\rangle_{B \to A} < \langle\!\langle \gamma \rangle\!\rangle_{C \to A} \implies A : \beta_B < \gamma_C$
  - "If A observes an action β_B before γ_C, then she knows that β_B really occurs before γ_C."
- $\langle\!\langle \beta(t) \rangle\!\rangle_{B \to A} \implies \sigma t \in \Gamma_A$
  - "If A observes an action with a term t, then the digest σt of that term becomes an element of A's environment."
- $\forall T \in \Theta \forall t \in T \exists u \in T.\ u \neq t \ \wedge \ \sigma u = \sigma t$
  - "For every sufficiently large set of terms T and every $t \in T$ it is feasible to find a different term $u \in T$ with the same digest."

Social actions

Graphic notation

- $\odot_A \beta(t)_B$ is represented by $\beta_B \overset{\sigma t}{\rightsquigarrow} \odot_A$
- $\langle\!\langle \sigma t \rangle\!\rangle_{B \to A}$ is represented by $\circ_B \overset{\sigma t}{\rightsquigarrow} \odot_A$

Social actions

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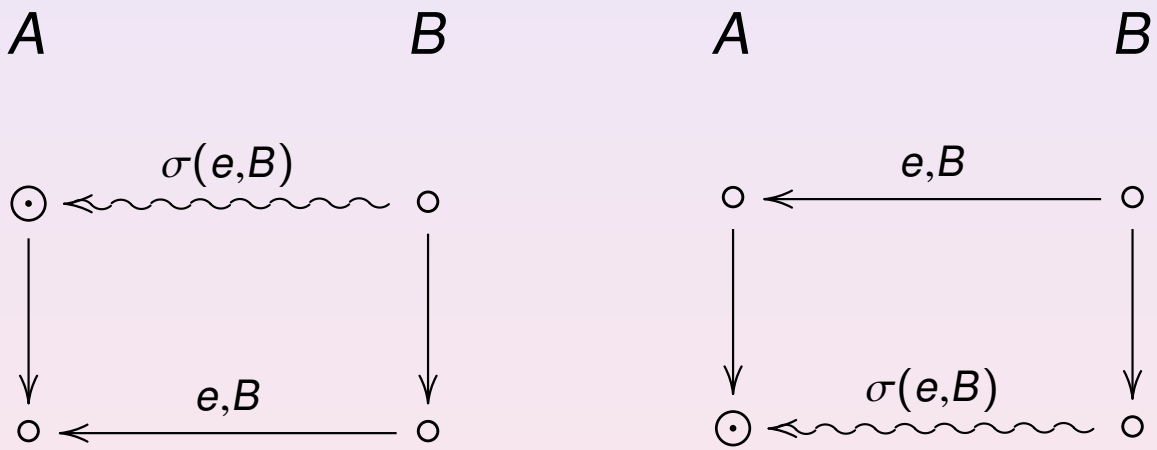
(σ annotations are redundant; a useful reminder.)

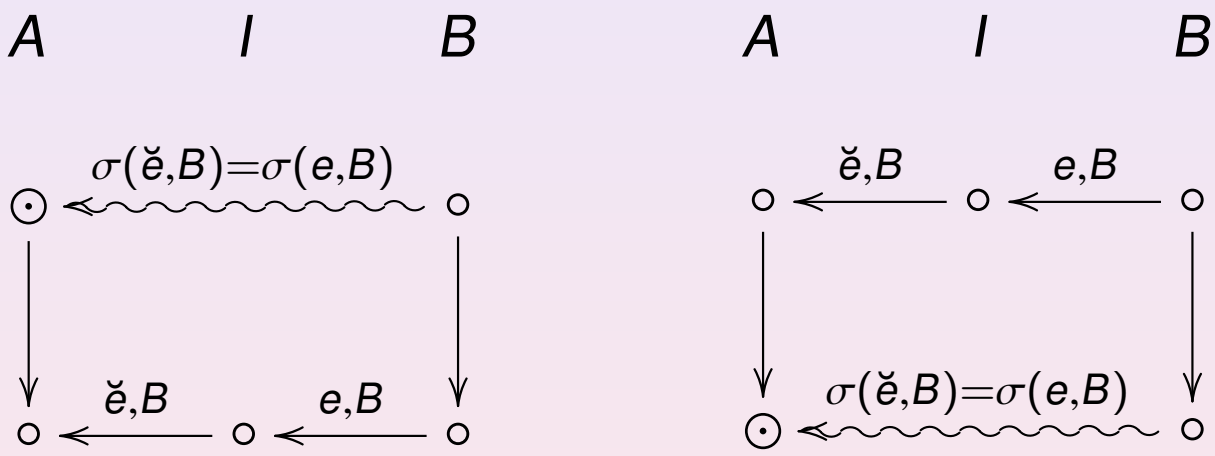
Socially authenticated key distribution

Bob announces his public key e from $B(d, e)$

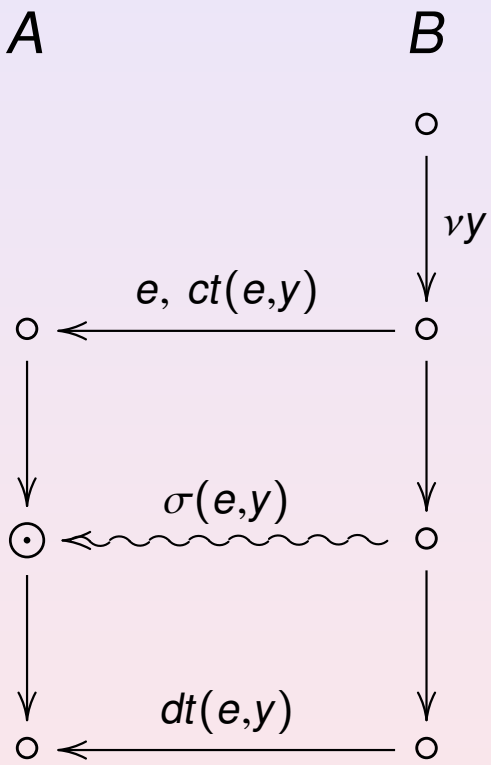


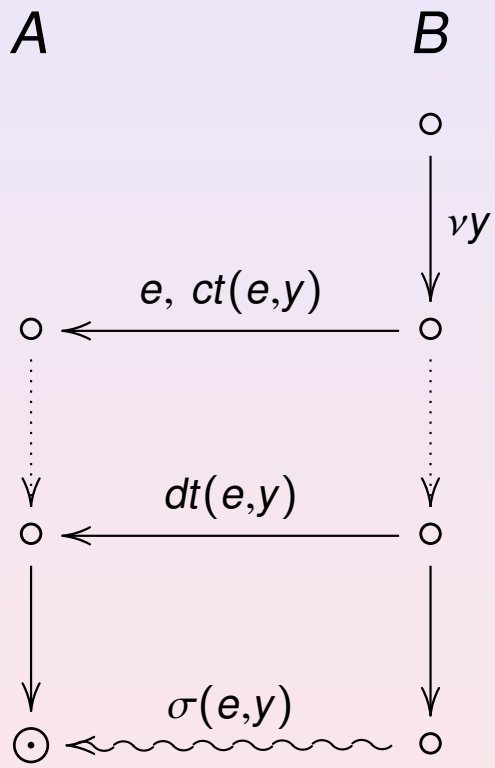
Socially authenticated key distribution

Ivan replaces it with $\check{e}$ from $I(\check{d}, \check{e})$



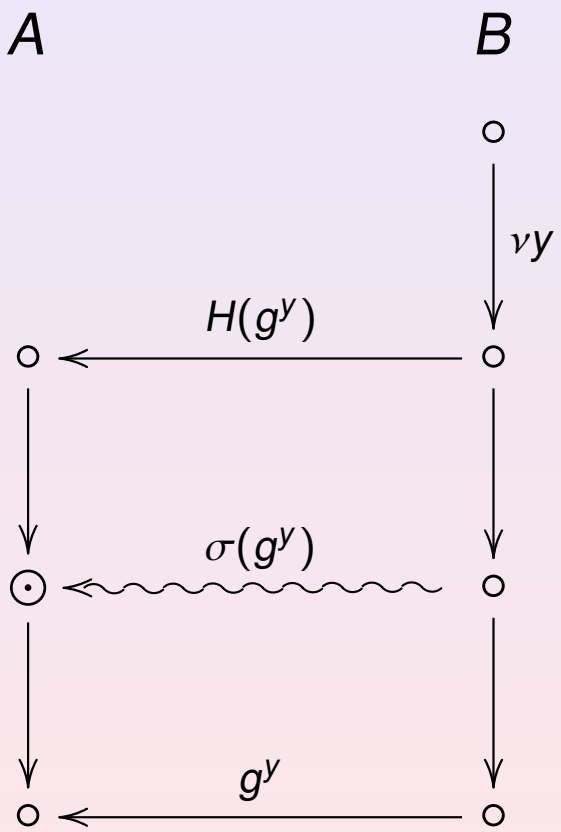
Social commitment





Authentication before decommitment

Hoepman



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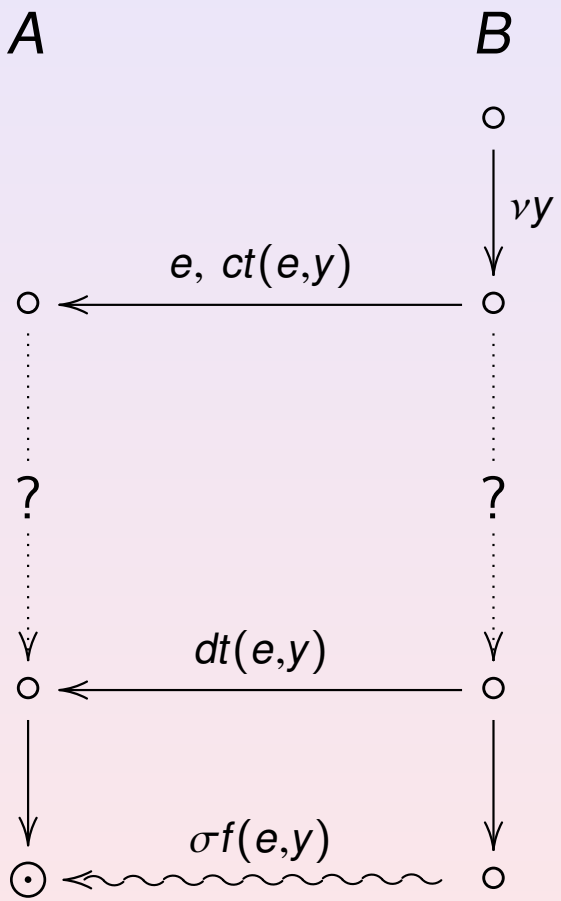

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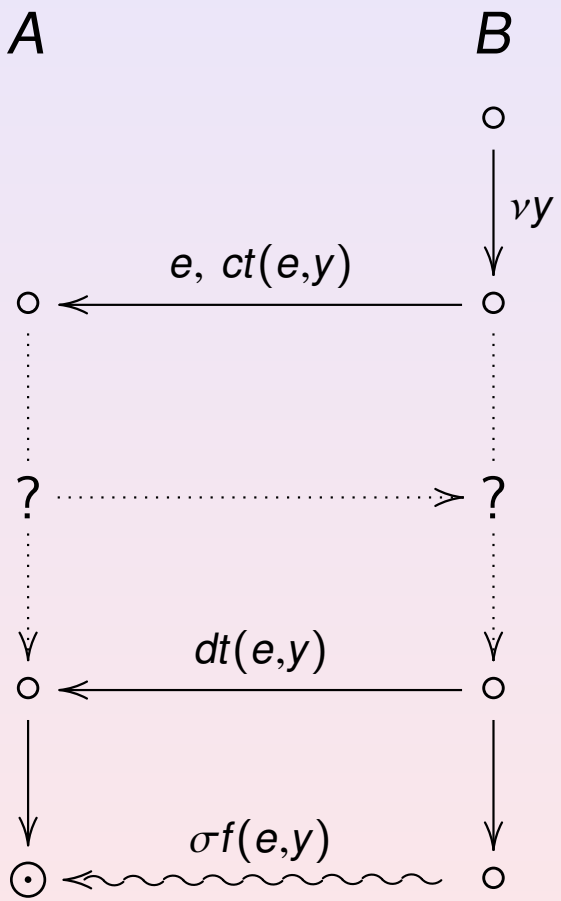
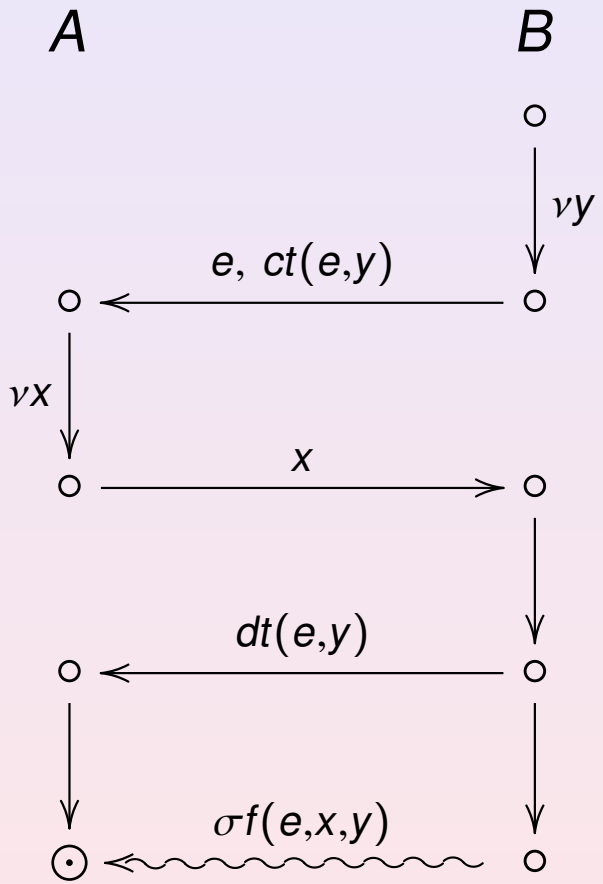
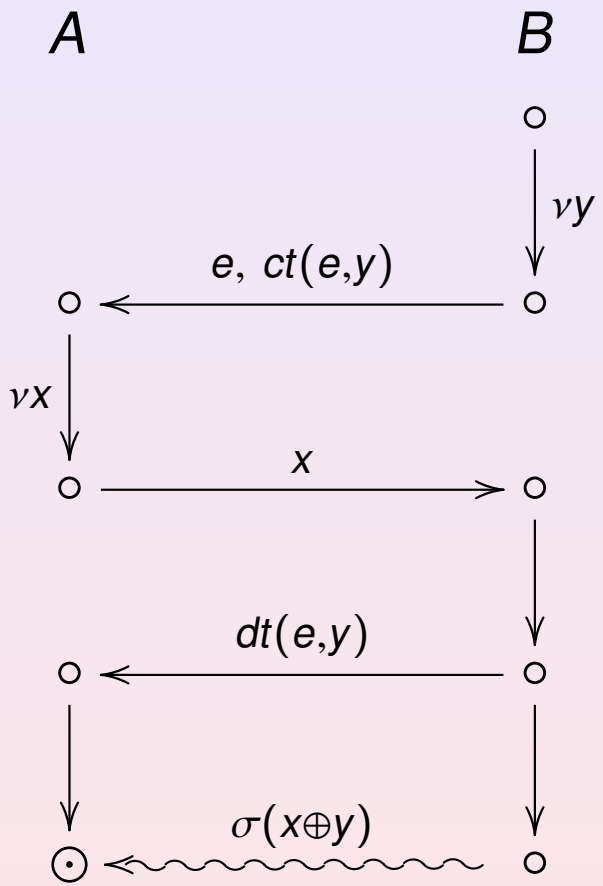


Authentication after decommitment

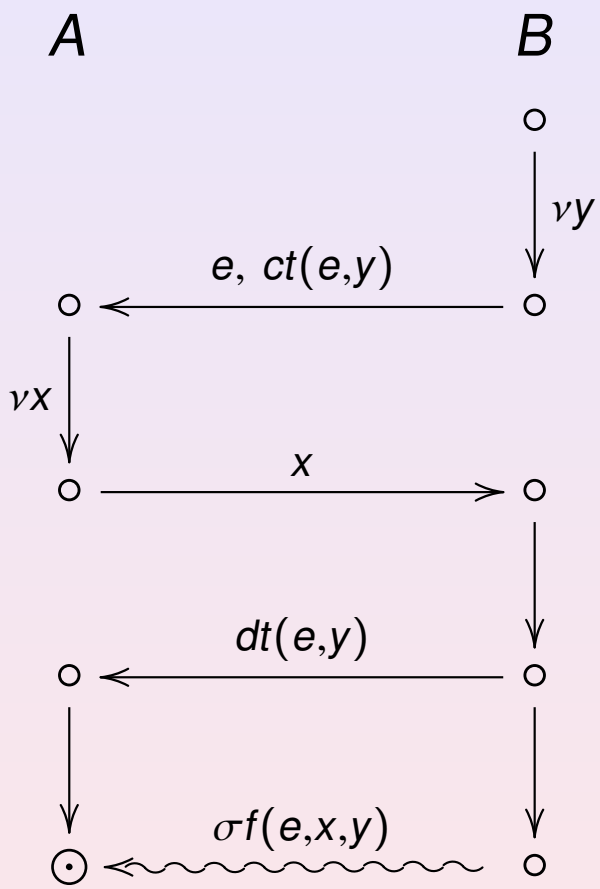


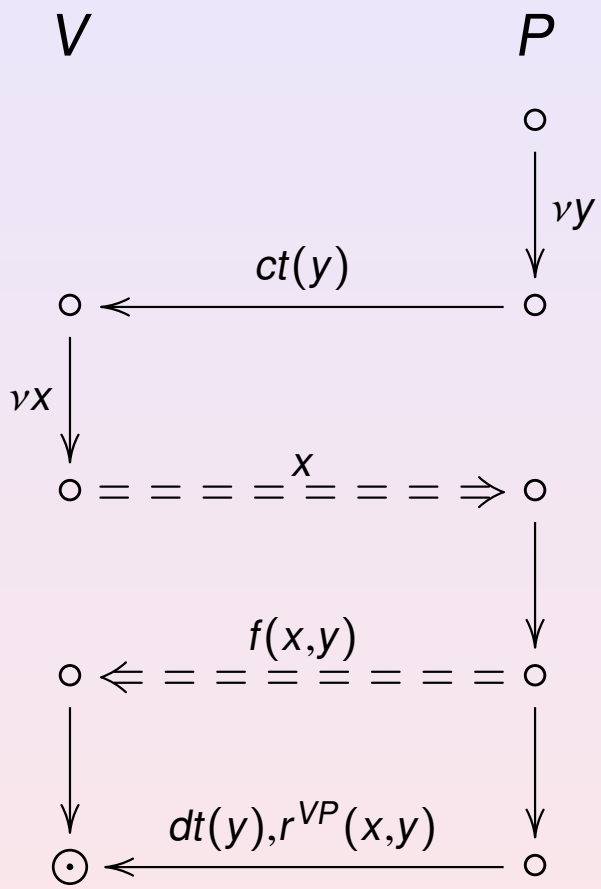
Authentication after decommitment

SAS: Vaudenay



Structural similarity — conceptual difference





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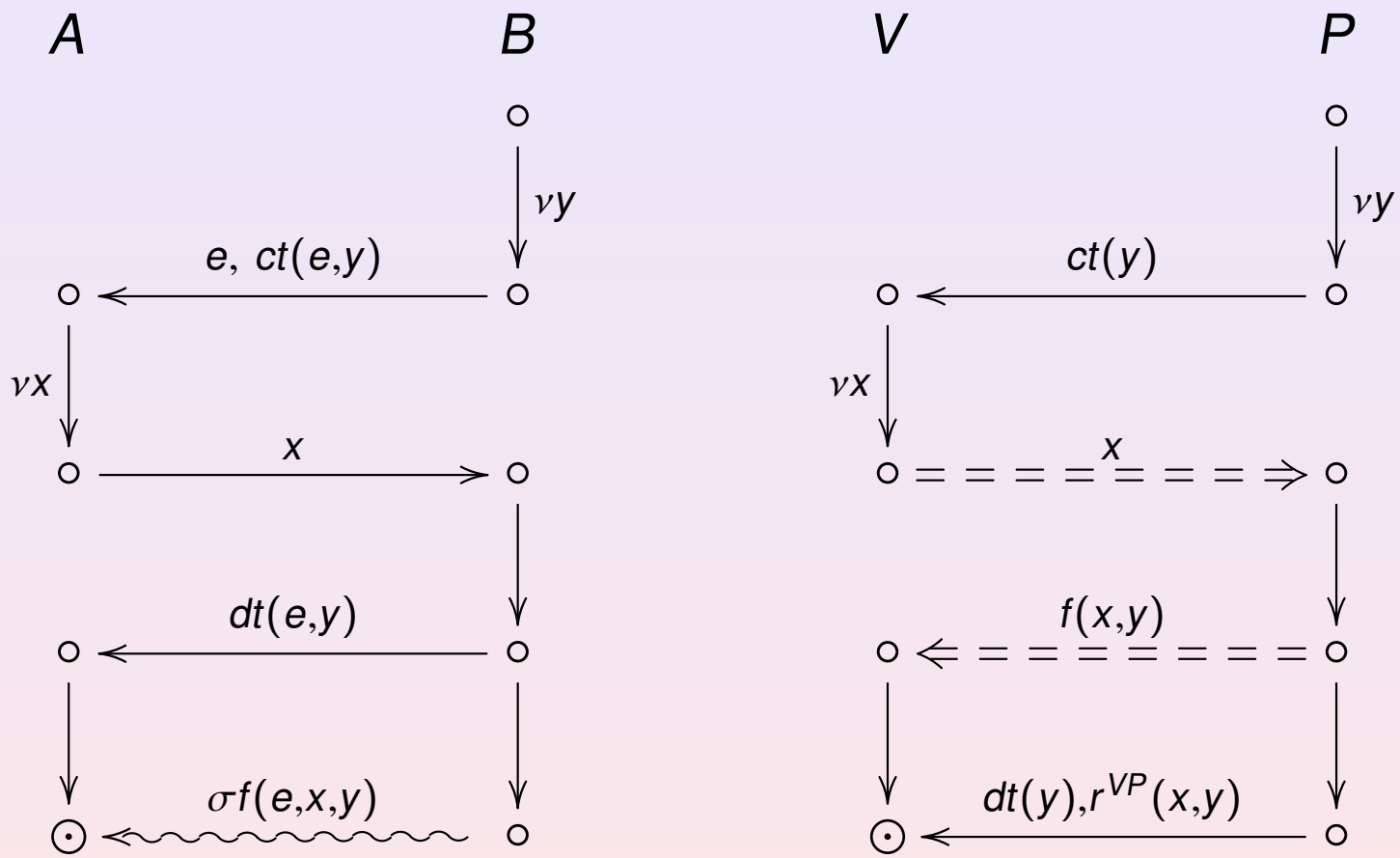
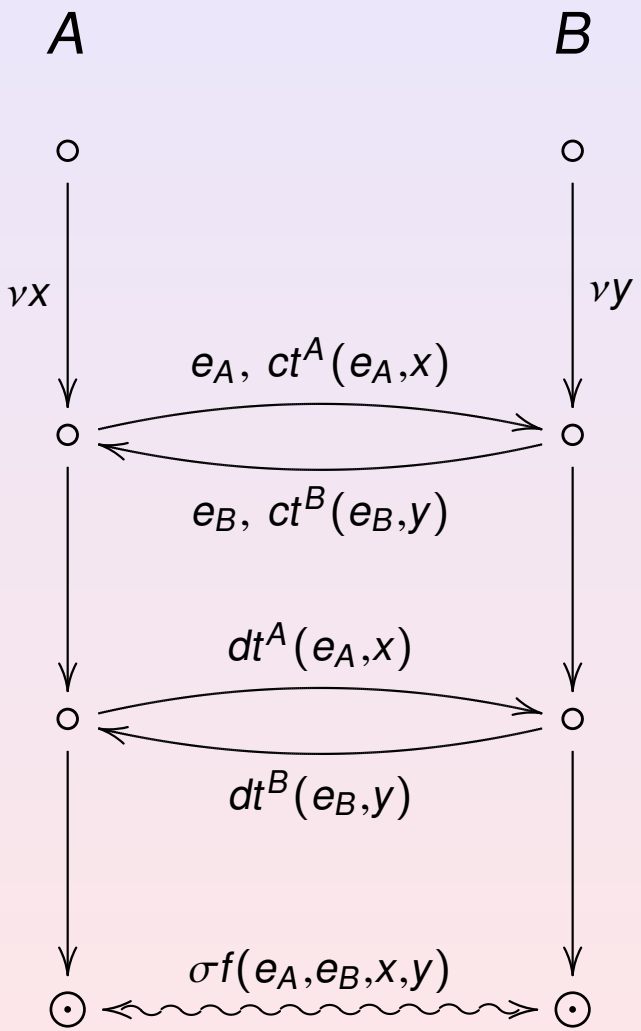


Social authentication is not challenge-response:

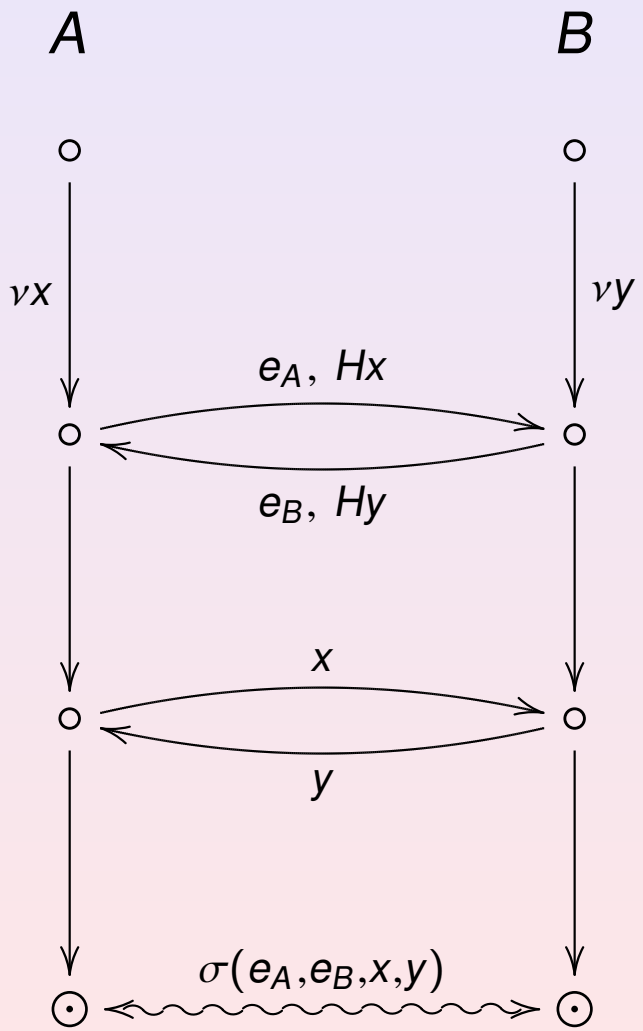
x on the left is not a challenge, but a binder, analogous to y.

Mutual authentication



Mutual authentication

HCBK: Nguyen-Roscoe



Mutual authentication

HCBK: Nguyen-Roscoe

$$\Big((\nu x)_A \ \langle e_A, Hx \rangle_A \ (u_1, u_2)_A \ \otimes$$

$$(\nu y)_B \ \langle e_B, Hy \rangle_B \ (v_1, v_2)_B \Big) \ ;$$

$$\Big(\langle x \rangle_A \ (u_3)_A \ (u_1, u_2 / e_B, Hu_3)_A \ \prec \sigma(e_A, e_B, x, u_3) \succ_A \ \otimes$$

$$\langle y \rangle_B \ (v_3)_B \ (v_1, v_2) / e_A, Hv_3)_B \ \prec \sigma(e_A, e_B, v_3, y) \succ_B \Big)$$