Authentication in pervasive and social computation

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and
Oxford University

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with thanks to Cathy Meadows, Mike Mislove, John Mitchell, Bill Roscoe

Introduction
Model
Timed authentication
Symbolic guessing
Social authentication
Trust & reputation
Location authentication
Conclusions and future work

Outline

Introduction

Model of network computation

Authentication with timed channels

Symbolic model with partial information and guessing

Authentication with social channels

Trust & reputation

Deriving location authentication protocols

Conclusions and future work

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Introduction
- Problem of security engineering
- Approach: Protocol derivations
- Example: Deriving CR
- Task

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Problem of security engineering

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Verified protocols often fail

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Bull's protocol

- *Isabelle:* secure for $E(k, m; n)$
- *Ryan & Schneider:* not for $E(k, m; n) = n \oplus H_k(m)$

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IPSec GDoI

- *IETF MSec WG:* secure, verified
- *Cathy & Dusko:* GDoI_PoP attack

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MQV

- *NSA:* "MQV is critical for national security of US"
- *Krawczyk:* MQV insecure

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Thesis: Informal reasoning is error prone.

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Thesis: Informal reasoning is error prone.

Antithesis: Formal reasoning hides some attacks

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Problem of security engineering

Thesis: Informal reasoning is error prone.

Antithesis: Formal reasoning hides some attacks, and becomes error prone as it gets complicated.

Derivational approach

Thesis: Informal reasoning is error prone.

Antithesis: Formal reasoning hides some attacks, and becomes error prone as it gets complicated.

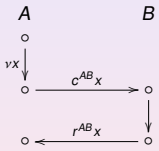
Synthesis: Incremental formalization:
Do not try to say all at once.

Derivational approach

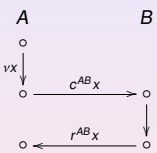
Problem
Incompleteness is the central concern in security engineering.

Solution
Protocol derivations manage it interactively.

Example: Deriving authentications

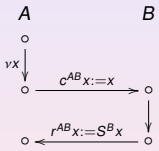


Example: Deriving authentications



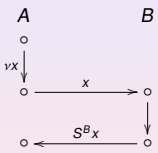
$$A:\ (\nu x)_A\Big(\langle\langle c^{AB}x\rangle\rangle_A \quad \triangleright \quad ((r^{AB}x))_A$$
$$\Longrightarrow\ \langle\langle c^{AB}x\rangle\rangle_A \triangleright ((c^{AB}x))_B \triangleright \langle\langle r^{AB}x\rangle\rangle_B \triangleright ((r^{AB}x))_A\Big) \quad \text{(cr)}$$

Signature-based challenge-response (CRS)



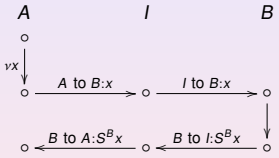
$$S^Bt = S^Bu \implies t = u \qquad \text{(sig1)}$$
$$V^B(y,t) \iff y = S^Bt \qquad \text{(sig2)}$$
$$\langle\langle S^Bt\rangle\rangle_X \implies X = B \qquad \text{(sig3)}$$

Signature-based challenge-response (CRS)

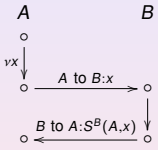


$(sig1\text{-}3) \wedge (B \text{ honest}) \vdash (cr)_{[c^{AB}x:=x,\ r^{AB}x:=S^B x]}$

Problem

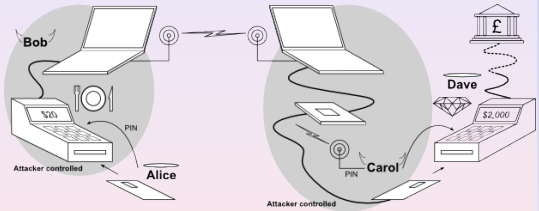


Signature-based challenge-response (CRS)

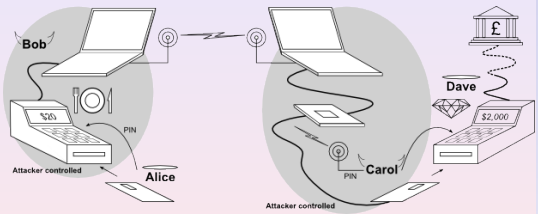


$(sig1\text{-}3) \wedge (B \text{ honest}) \vdash (cr)_{[c^{AB}x:=x,\ r^{AB}x:=S^B(A,x)]}$
$\wedge$ "B to A : $S^B(A,x)$"...

Problem



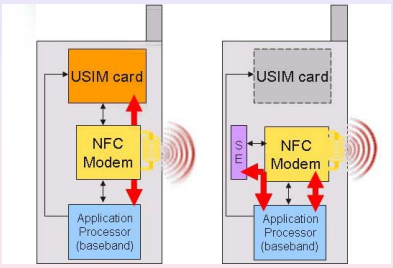
Problem



This becomes much easier with NFC phones!

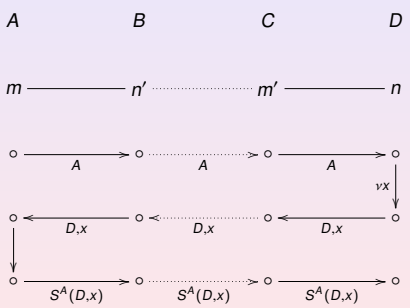
Near Field Communication (NFC)

Phone with a contactless smart card:



Secure Element (SE) is a miniSD flash memory, or a USIM card, or a separate microcontroller.

Agreement without proximity



Task

Study proximity authentication.

Outline

Introduction

Model of network computation
- Process model
- Network model

Authentication with timed channels

Symbolic model with partial information and guessing

Authentication with social channels

Trust & reputation

Deriving location authentication protocols

Conclusions and future work

Process model

terms $(\mathcal{T}, \sqsubseteq)$,

principals $(\mathcal{W}, \leqslant)$,

actions $\mathcal{A}$ generated by:

action	constructor	form
send	$\mathcal{W}^2 \times \mathcal{T} \overset{\langle\rangle}{\hookrightarrow} \mathcal{A}$	$\langle A \text{ to } B : t \rangle$
receive	$\mathrm{Var}^2_{\mathcal{W}} \times \mathrm{Var}_{\mathcal{T}} \overset{()}{\hookrightarrow} \mathcal{A}$	$(Y \text{ to } Z : x)$
match	$\mathcal{T} \times \mathrm{Op}_{\mathcal{T}} \times \mathrm{Var}_{\mathcal{W}} \overset{(/)}{\hookrightarrow} \mathcal{A}$	$(t/p(x))$
new	$\mathrm{Var}_{\mathcal{T}} \overset{(\nu)}{\hookrightarrow} \mathcal{A}$	(νx)
$\cdots$	$\cdots$	$\cdots$

Process model

processes $\mathbb{P} \xrightarrow{P} \mathcal{A} \times \mathcal{W}$ where
- $(\mathbb{P}, \triangleright)$ is a well-founded partial order
- $P_{\mathcal{W}}(p) \# P_{\mathcal{W}}(q) \;\Rightarrow\; p \# q$

runs $\big(P,\ \surd :\ \mathrm{recvs}(P) \longrightarrow \mathrm{sends}(P)\big),\ (x) \not\vdash \surd(x)$
- $\mathbb{P}^{\surd} = \mathbb{P} / \left(\surd(x) \triangleright (x)\right)$

Network model

A *communication network* consists of

network graph $\mathcal{N} = (L \underset{\varrho}{\overset{\delta}{\rightrightarrows}} N)$, where
- N is the set of nodes,
- $L = \sum_{N \times N} \mathcal{N}_{mn}$ is the set of links,
- $\mathcal{N}_{mn} = \langle \delta, \varrho \rangle^{-1}(m, n)$

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control assignment $\copyright : \mathcal{W} \longrightarrow \wp N$, satisfying

$$A \leqslant B \implies \copyright A \subseteq \copyright B$$
$$A \# B \implies \copyright A \cap \copyright B = \emptyset$$

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channel typing $\theta : L \longrightarrow C$,

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Model of network computation

Authentication with timed channels
- Timed challenge-response
- Distance bounding with two responses
  - Solution 1: Commitment
  - Solution 2: One-way response
- Distance bounding with two challenges
- Simple distance bounding

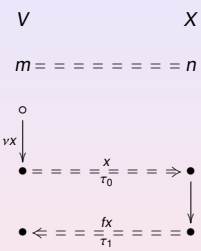
Symbolic model with partial information and guessing

Authentication with social channels

Trust & reputation

Timed challenge-response

Timed challenge-response



$$V : (\nu x)_V \Big(\tau_0 \langle x \rangle_V \triangleright \tau_1 (fx)_V \implies \exists X.\, d(V, X) \leq \frac{c}{2}(\tau_1 - \tau_0) \Big) \quad \text{(crt)}$$

Distance bounding protocols

Idea

Combine (cr) and (crt).

Distance bounding protocols

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Three families

Distance bounding protocols

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Combine (cr) and (crt).

Three families

- with **one challenge and two responses**:
  - $r^{VP}x$, satisfying (cr)
  - $f^{VP}x$, satisfying (crt)

Distance bounding protocols

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Combine (cr) and (crt).

Three families

- with **one challenge and two responses**:
  - $r^{VP}x$, satisfying (cr)
  - $f^{VP}x$, satisfying (crt)
- with **two challenges and one response**:
  - $c^{VP}y$ and $fr^{VP}(x,y)$, satisfying (cr)
  - x and $fr^{VP}(x,y)$, satisfying (crt)

Distance bounding protocols

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Combine (cr) and (crt).

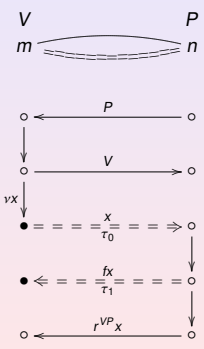
Three families

- with **one challenge and two responses**:
  - $r^{VP}x$, satisfying (cr)
  - $f^{VP}x$, satisfying (crt)
- with **two challenges and one response**:
  - $c^{VP}y$ and $fr^{VP}(x,y)$, satisfying (cr)
  - x and $fr^{VP}(x,y)$, satisfying (crt)
- with **one challenge and one response**:
  - x and $fr^{VP}x$, satisfying

$$V:\ (\nu x)_V\Big(\tau_0\langle x\rangle_V \quad \triangleright \quad \tau_1(fr^{VP}x)_V$$
$$\Longrightarrow\ \tau_0\langle x\rangle_V \triangleright (x)_P \triangleright \langle fr^{VP}x\rangle_P \triangleright \tau_1(fr^{VP}x)_V \qquad \text{(crp)}$$
$$\wedge \quad d(V,P) \le \tau_1 - \tau_0\Big)$$

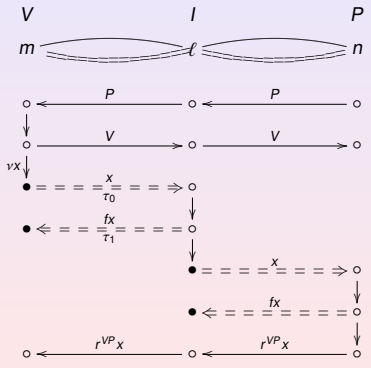
Distance bounding with two responses

Idea



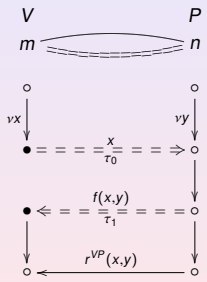
Distance bounding with two responses

Problem

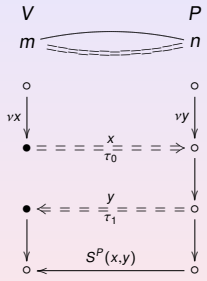


Distance bounding with two responses

Basic template



Brands-Chaum 1



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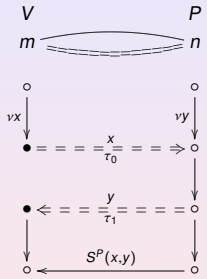
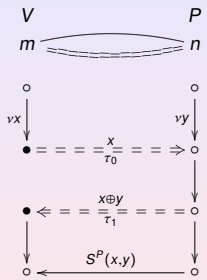
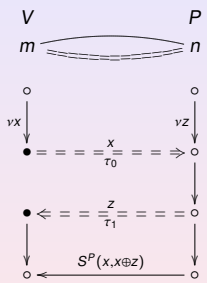


- V : P honest $\implies d(V,P) < \tau_1 - \tau_0$
- V : $\forall X.\ X$ responds $\implies d(V,X) + d(X,P) < \tau_1 - \tau_0$

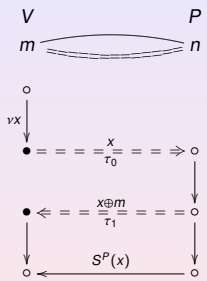
Discharge the honesty assumption?



P can still cheat



Brands-Chaum 2



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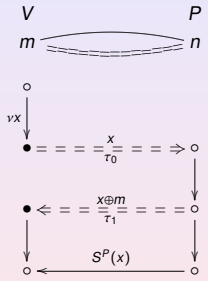
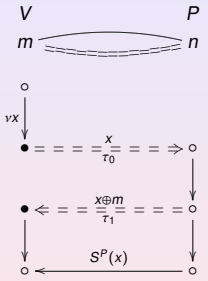


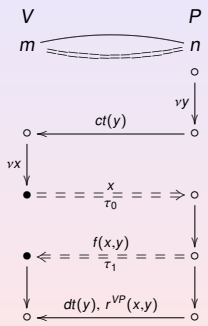
- Peggy cannot cheat

Brands-Chaum 2



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

Solution 1: 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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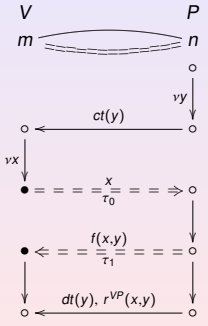
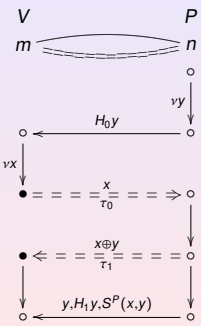
E.g.,

$ct(x) = H(x)$	$ct(x) = H_0(x)$	$ct(x) = E(x_0, x_1)$
$dt(x) = x$	$dt(x) = x::H_1(x)$	$dt(x) = x_0$
$ot(y,z) = z$	$ot(y,z) = z_0$	$ot(y,z) = D(z,y)$

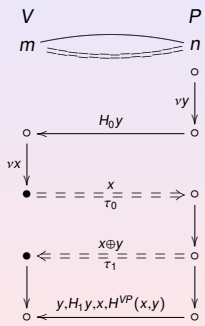
Solution 1: Commitment



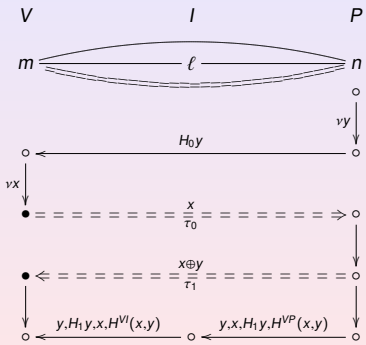
Brands-Chaum 3



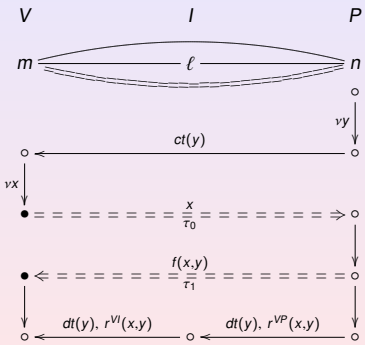
Čapkun-Hubaux



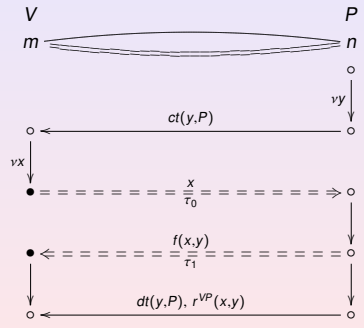
. . . but Peggy's identity can be spoofed



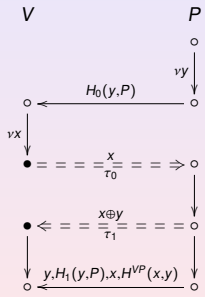
. . . and in general



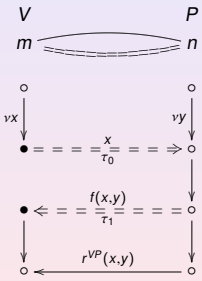
. . . so we need



Meadows et al

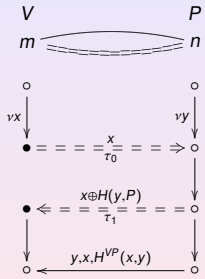


Solution 2: One-way response

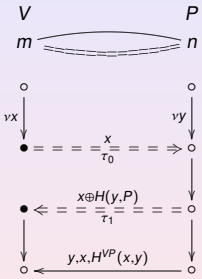


where $f^{VP}(x,-)$ is a one-way function for every x.

Meadows et bo

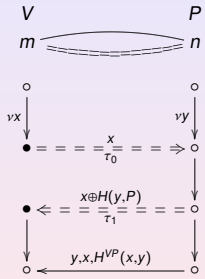


Meadows et bo



- $V:\ \exists X.\ d(V,X) < \tau_1 - \tau_0 \wedge X \sim P$

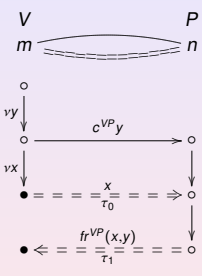
Meadows et bo



- $V:\ \exists X.\ d(V,X) < \tau_1 - \tau_0 \wedge X \sim P$
- $V:\ \forall X.\ X \text{ responds} \Longrightarrow d(V,X) + d(X,P) < \tau_1 - \tau_0$

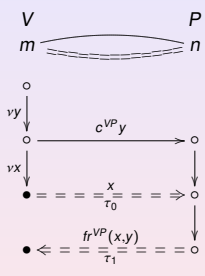
Distance bounding with two challenges

Idea



Distance bounding with two challenges

Idea

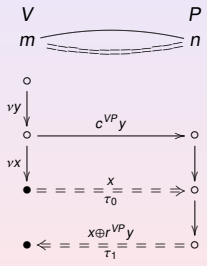


where

- $fr^{VP}(x,-)$ satisfies (cr) for all x
- $fr^{VP}(-,y)$ satisfies (crt) for all y

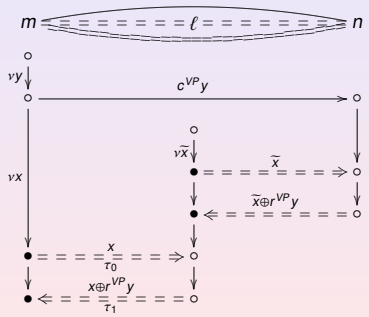
Distance bounding with two challenges

Try



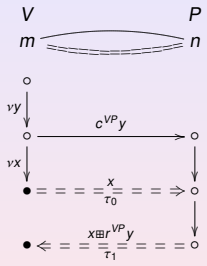
Distance bounding with two challenges

Problem



Distance bounding with two challenges

Idea 2: Find $\boxplus$

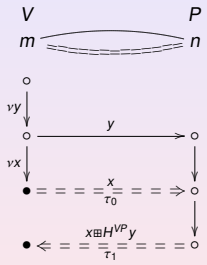


where

- r^{VP} satisfies (cr)
- $x \boxplus (-)$ is one-way function for every x
- $(-) \boxplus y$ satisfies (crt) for every y

Hancke-Kuhn

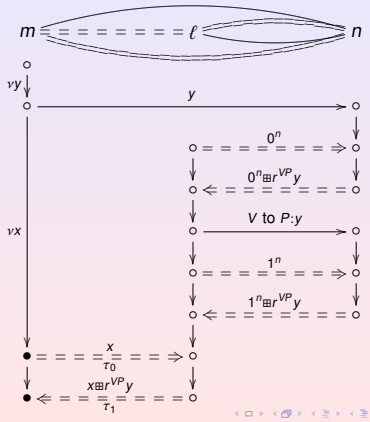
Candidate



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

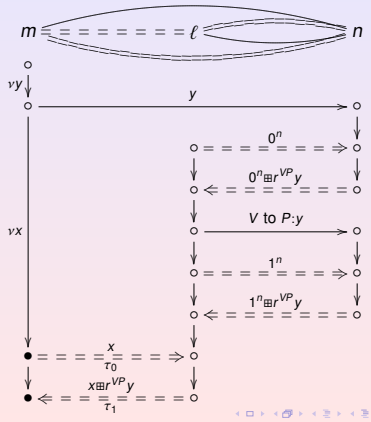
Hancke-Kuhn

Problem



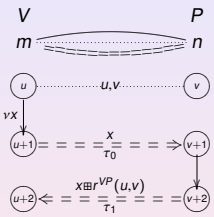
Hancke-Kuhn

Problem: $a \boxplus z, \overline{a} \boxplus z \;\vdash\; (-) \boxplus z$, for any a



Simple distance bounding template

Idea 3: Use **counters** to disable querying of $(-) \boxplus r^{VP} y$



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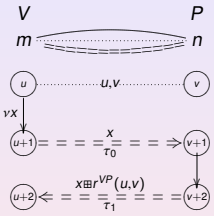

where

- r^{VP} satisfies (cr)
- $x \boxplus (-)$ is one-way function for every x
- $(-) \boxplus z$ satisfies (crt) for every z
- the counters u, v are public, but never reused

Outline

Introduction

Model of network computation

Authentication with timed channels

Symbolic model with partial information and guessing
- Algebra coding
- Guessing
- Base and dimension

Authentication with social channels

Trust & reputation

Deriving location authentication protocols

Algebra coding

- $\mathcal{T}$ be a term algebra over a clone T
- $\mathcal{L}$ a language over an alphabet Σ

Algebra coding

- $\mathcal{T}$ be a term algebra over a clone T
- $\mathcal{L}$ a language over an alphabet Σ

Definition

An *encoding* (or *implementation*) of $\mathcal{T}$ in $\mathcal{L}$ is a pair of maps

$$\begin{aligned} [\![-]\!] &: \mathcal{T} \to \mathcal{L} \\ \surd &: \mathcal{L} \rightharpoonup \mathcal{T} \end{aligned}$$

such that $\surd[\![t]\!] = t$.

Feasible algebra

Notation and terminology

- $\Sigma_\perp = \Sigma + \{\perp\}$, where $\perp \sqsubset s$ for $s \in S$

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- $\alpha \sqsubseteq \beta \iff |\alpha| \leq |\beta| \wedge \forall i \leq |\alpha|.\ \alpha_i \sqsubset \beta_i \vee \alpha_i = \beta_i$
- $\mathcal{F} \subseteq [\mathcal{L}_\perp \Rightarrow \mathcal{L}_\perp]_{\sqcup\uparrow}$, a submonoid of *feasible* maps

Feasible algebra

Definition

An algebraic operation $\varphi \in T$ is called *feasible* if the partial map

$$\begin{array}{rcl} [\![\varphi]\!] : \mathcal{L} & \rightharpoonup & \mathcal{L} \\ [\![t]\!] & \mapsto & [\![\varphi t]\!] \end{array}$$

can be extended to a feasible map.

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can be extended to a feasible map.

Example

Hohenberger-Rivest: pseudo-free groups

Derivability

Definition

For $\alpha_1, \ldots, \alpha_n, \beta \in \mathcal{L}_\perp$ define the *derivability* relation

$$\alpha_1, \ldots, \alpha_n \vdash \beta \iff \exists f_1, \ldots f_n \in \mathcal{F}.\ \bigsqcup_{i=1}^{n} f_i \alpha_i \sqsupseteq \beta$$

Derivability

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For a multiset of terms $s_1, \ldots, s_n, t \in \mathcal{T}$, we abbreviate

$$s_1, \ldots, s_n \vdash t \iff [\![s_1]\!], \ldots, [\![s_n]\!] \vdash [\![t]\!]$$

Frequency distribution

Assumption

Suppose that $\mathcal{L}$ is given with a probability measure

$$\mathrm{Prob} \ : \ \mathcal{M}(\mathcal{L}) \longrightarrow [0,1]$$

Frequency distribution

Assumption

Suppose that $\mathcal{L}$ is given with a probability measure

$$\mathrm{Prob} \ : \ \mathcal{M}(\mathcal{L}) \longrightarrow [0,1]$$

For simplicity, take

- $\mathcal{L} = \{0,1\}^*$
- $\mathcal{M}\{0,1\}^* = \left[\alpha^\uparrow \subseteq \{0,1\}^*\right]$
  - where $\alpha^\uparrow = \{\xi \in \{0,1\}^* \mid \alpha \sqsubseteq \xi\}$
- $\mathrm{Prob}(\alpha^\uparrow) = 2^{-|\alpha|}$

Derivability with guessing

Guessing a term

- $\mathrm{Prob}(t|A) \ = \ \frac{\mathrm{Prob}\left([\![t]\!]^\uparrow \cap A^\uparrow\right)}{\mathrm{Prob}(A^\uparrow)}$

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  - where $\|\alpha\| = |\alpha \restriction_\Sigma|$

Derivability with guessing

Guessing a term

- $\mathrm{Prob}(t|A) = \frac{\mathrm{Prob}\left(\llbracket t \rrbracket^{\uparrow} \cap A^{\uparrow}\right)}{\mathrm{Prob}(A^{\uparrow})}$
- $\mathrm{Prob}(t|\alpha) = \frac{\mathrm{Prob}\left(\llbracket t \rrbracket^{\uparrow} \cap \alpha^{\uparrow}\right)}{\mathrm{Prob}(\alpha^{\uparrow})} = \begin{cases} 2^{\|\alpha\|-\|\llbracket t \rrbracket\|} & \text{if } \alpha \sqsubseteq \llbracket t \rrbracket \\ 0 & \text{otherwise} \end{cases}$
  - where $\|\alpha\| = |\alpha\restriction_{\Sigma}|$

Definition

For $\alpha_1, \ldots, \alpha_n, \beta \in \mathcal{L}_{\perp}$ and $\delta \geq 0$ define

$$\alpha_1, \ldots, \alpha_n \vdash_{\delta} \beta \iff \exists f_1, \ldots f_n \in \mathcal{F}.\ \mathrm{Prob}\left(\beta \mid f_1\alpha_1, \ldots, f_n\alpha_n\right) \geq \delta$$

Base and dimension

Base

Let $\varphi \in T$ be an algebraic operation and $B = \{b_1, \ldots, b_k\} \subseteq \mathcal{T}$. Define

- $\varphi[B]_{\delta} = \left\{t \in \mathcal{T} \mid t, B, \varphi(B) \vdash_{\delta} \varphi(t)\right\}$

Base and dimension

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- $\mathrm{base}_{\delta\epsilon}(\varphi) = \left\{B \in \wp_{<\omega}\mathcal{T} \mid \mathrm{Prob}\left(\varphi[B]_{\delta}\right) \geq \epsilon\right\}$

Base and dimension

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Dimension

- $\dim_{\delta\epsilon}(\varphi) = \bigwedge_{B \in \mathrm{base}_{\delta\epsilon}(\varphi)} |B|$

Examples

eXclusive OR

Refine $b, b \oplus c \vdash x \oplus c$ for all $b, c, x \in \{0,1\}^{\ell}$ to show

- $\mathrm{base}_{\delta\epsilon}(- \oplus c) = \begin{cases} \{0,1\}^{*} & \text{if } \epsilon \leq 2^{-k} \wedge \delta \leq 2^{\ell-k} \\ \{0,1\}^{k} & \text{if } \epsilon > 2^{-k} \wedge \delta \leq 2^{\ell-k} \end{cases}$
- $\dim_{\delta\epsilon}(- \oplus c) = \begin{cases} 0 & \text{if } \epsilon \leq 2^{-k} \wedge \delta \leq 2^{\ell-k} \\ 1 & \text{if } \epsilon > 2^{-k} \wedge \delta \leq 2^{\ell-k} \end{cases}$

Examples

One-way XOR

For $\Sigma = \{0, 1, \ldots, n-1\}$ and $d = d^{(0)}::d^{(1)}::\ldots d^{(n-1)} \in \Sigma^{n\ell}$ define

$$\begin{array}{rcl} (-) \boxplus d : \Sigma^{\ell} & \longrightarrow & \Sigma^{\ell} \\ z & \mapsto & \left[d_1^{(z_1)}, d_2^{(z_2)}, \ldots, d_{\ell}^{(z_{\ell})}\right] \end{array}$$

Examples

One-way XOR

Refine
$0^\ell, 1^\ell, \ldots, (n-1)^\ell, 0^\ell \boxplus d, \ldots, (n-1)^\ell \boxplus d \vdash x \boxplus d$
to show

$$\dim_{\delta\epsilon}(- \boxplus d) = \begin{cases} 1 & \text{if } \epsilon \in \left[0, 2^{-nk}\right] \\ 2 & \text{if } \epsilon \in \left(2^{-nk}, 2^{(1-n)k}\right] \\ \vdots & \\ i+1 & \text{if } \epsilon \in \left(2^{(i-1-n)k}, 2^{(i-n)k}\right] \\ \vdots & \\ n & \text{if } \epsilon \in \left(2^{-k}, 1\right] \end{cases}$$

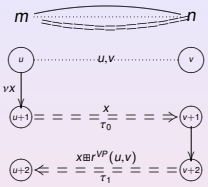
Upshot

Proposition

For all $\delta, \epsilon \geq 0$, and any $A \subseteq \mathcal{T}$ holds

$$|A| < \dim_{\delta\epsilon}(\varphi) \implies \mathrm{Prob}\big(t \in \mathcal{T} \mid t, A, \varphi(A) \vdash_\delta \varphi(t)\big) < \epsilon$$

Corollary



satisfies

$$V: (\nu x)_V\Big(\tau_0\langle x\rangle_V \triangleright \tau_1(fr^{VP}x)_V \implies \tau_0\langle x\rangle_V \triangleright (x)_P \triangleright \langle fr^{VP}x\rangle_P \triangleright \tau_1(fr^{VP}x)_V \wedge d(V,P) \leq \tau_1 - \tau_0\Big)$$

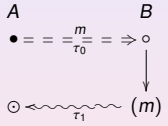
with probability $1 - 2^{-|x|}$.

Outline

Introduction
Model of network computation
Authentication with timed channels
Symbolic model with partial information and guessing
Authentication with social channels
- Social channel and its use
- Social commitment
- Authentication before decommitment
- Authentication after decommitment
- Socially authenticated key exchange
- Security homology

Trust & reputation

Preliminary example: a timed social protocol



Social channel bandwidth

- $\sigma : \mathcal{T} \longrightarrow \mathcal{T}$: a short digest (hash) function

Social channel bandwidth

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such that

- $\sigma\sigma t = \sigma t$
  - "The digest does not change short terms."

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Social channel bandwidth

- $\sigma : \mathcal{T} \longrightarrow \mathcal{T}$: a short digest (hash) function

such that

- $\sigma\sigma t = \sigma t$
  - "The digest does not change short terms."
- $\forall s\ \exists t.\ s \neq t\ \wedge \sigma s = \sigma t\ \wedge\ s \vdash t$
  - "For every term s, it is feasible to find a different term t with the same digest."

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Social actions

- $\ll B$ to $A : \beta \gg$ — B shows an action β to A

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Social actions

- $\ll B$ to $A : \beta \gg$ — B shows an action β to A

axiomatized as follows:

- $\ll B$ to $A : \beta \gg \implies A : \beta_B$
  - "If A sees B perform β, then A knows that B has performed β."

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- $\ll B$ to $A : \beta \gg \triangleright \ll C$ to $A : \gamma \gg \implies A : \beta_B \triangleright \gamma_C$
  - "If A sees β_B before γ_C, then she knows that β_B occurred before γ_C."

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Social actions

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axiomatized as follows:

- $\lessdot B$ to $A : t \gtrdot \implies \sigma t \in \Gamma_A$
  - "If B shows A a term t, then A sees the digest σt."
- $\lessdot B$ to $A : t \gtrdot \implies A : \exists u.\ \sigma u = \sigma t \wedge \lessdot A$ to $B : u \gtrdot_B$
  - "If B shows A a term t, then A knows that B has shown her some term with the digest σt."

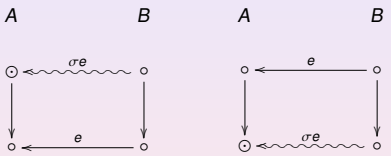
Social actions

Graphic notation

- $\beta_B \rightsquigarrow \odot_A$ represents $\lessdot B$ to $A : \beta \gtrdot$
- $\circ_B \overset{\sigma t}{\rightsquigarrow} \odot_A$ represents $\lessdot B$ to $A : t \gtrdot$

Socially authenticated key distribution

Bob announces his public key



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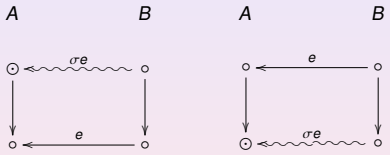
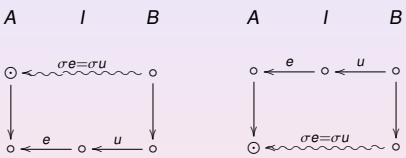


- $e, \sigma e \in \Gamma_A$
- $A :\ B$ honest $\implies \exists u.\ \sigma u = \sigma e \wedge \langle B$ to $A : u \rangle_B$

Socially authenticated key distribution

. . . but Ivan may have replaced it



- $e, \sigma e \in \Gamma_A$
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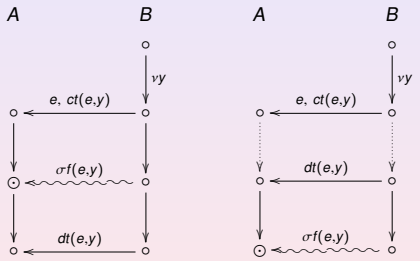
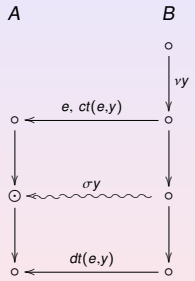
Social commitment

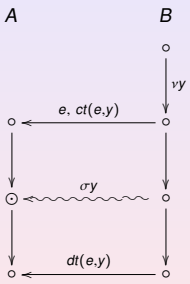


Authentication before decommitment



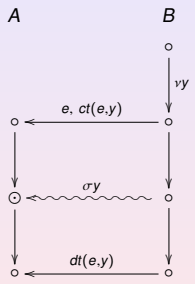
- $A:\ \exists y.\ \sigma y = s \wedge \lessdot B \text{ to } A : s \gtrdot_B$

Authentication before decommitment



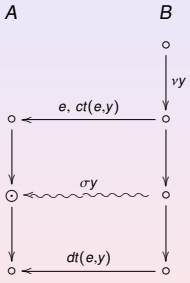
- $A:\ B \text{ honest} \Longrightarrow \exists y.\ \lessdot B \text{ to } A : \sigma y \gtrdot_B$

Authentication before decommitment



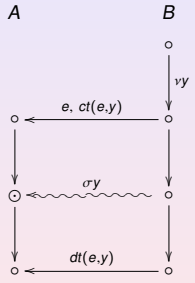
- $A:\ B \text{ honest} \Longrightarrow \exists u \exists y.\ \langle u, ct(u,y)\rangle_B \trianglerighteq \lessdot \sigma y \gtrdot_B$

Authentication before decommitment



- $A:\ B \text{ honest} \Longrightarrow \exists u.\ (\nu y)_B \trianglerighteq \langle u, ct(u,y)\rangle_B \trianglerighteq \lessdot \sigma y \gtrdot_B$

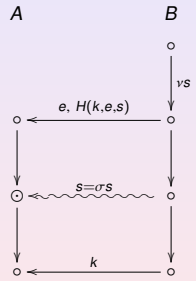
Authentication before decommitment



- $A:\ B \text{ honest} \Longrightarrow (\nu y)_B \trianglerighteq \langle e, ct(e,y)\rangle_B \trianglerighteq \lessdot \sigma y \gtrdot_B \trianglerighteq \langle dt(e,y)\rangle_B$

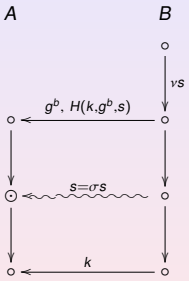
Authentication before decommitment

Wong-Stajano template



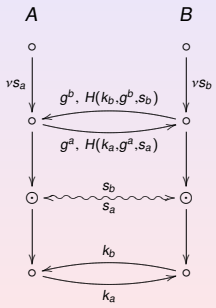
Authentication before decommitment

Wong-Stajano-$\frac{1}{2}$



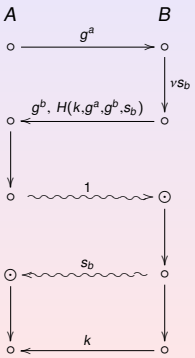
Authentication before decommitment

Wong-Stajano

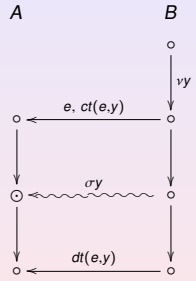


Authentication before decommitment

Wong-Stajano 3



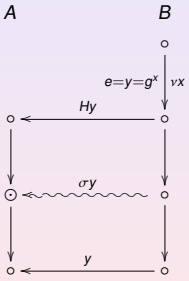
Authentication before decommitment



- $A:\ B$ honest $\Longrightarrow (\nu y)_B \trianglerighteq \langle e, ct(e,y)\rangle_B \trianglerighteq \ll\sigma y\gg_B \trianglerighteq \langle dt(e,y)\rangle_B$

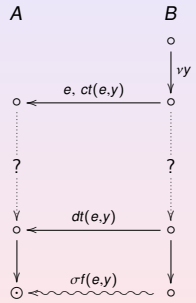
Authentication before decommitment

Hoepman-$\frac{1}{2}$

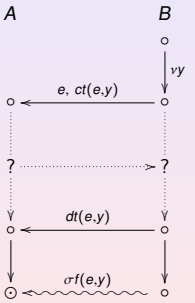


- $A:\ B$ honest $\Longrightarrow (\nu x)_B \trianglerighteq \langle H(g^x)\rangle_B \trianglerighteq \ll\sigma(g^x)\gg_B \trianglerighteq \langle g^x\rangle_B$

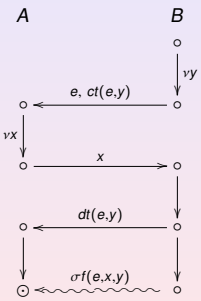
Authentication after decommitment



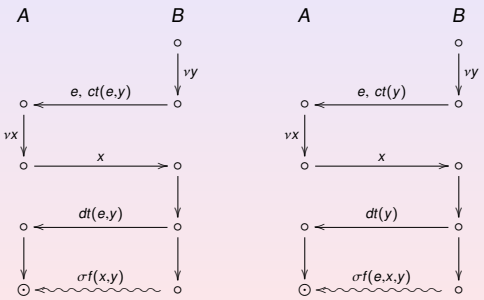
Authentication after decommitment



Authentication after decommitment

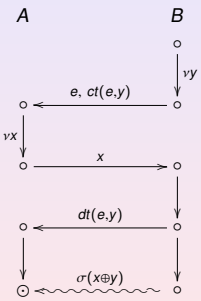


Authentication after decommitment



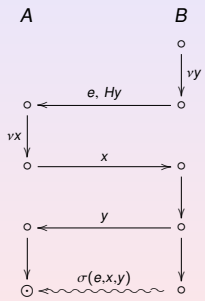
Authentication after decommitment

Vaudenay: SAS-$\frac{1}{2}$



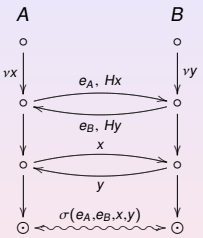
Authentication after decommitment

Nguyen-Roscoe: HCBK-$\frac{1}{2}$



Mutual authentication after decommitment

Nguyen-Roscoe: HCBK (2-party)



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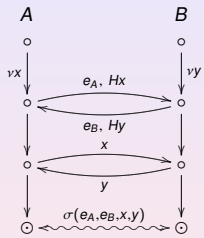

Assumption: Initiator establishes the order

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Mutual authentication after decommitment

Nguyen-Roscoe: HCBK (2-party)

$$\Big((\nu x)_A\ \langle e_A, Hx\rangle_A\ (u_1,u_2)_A\ \otimes$$
$$(\nu y)_B\ \langle e_B, Hy\rangle_B\ (v_1,v_2)_B\Big)\ ;$$

$$\Big(\langle x\rangle_A\ (u_3)_A\ (u_1,u_2/e_B,Hu_3)_A\ \prec\sigma(e_A,e_B,x,u_3)\succ_A\ \otimes$$
$$\langle y\rangle_B\ (v_3)_B\ (v_1,v_2)/e_A,Hv_3)_B\ \prec\sigma(e_A,e_B,v_3,y)\succ_B\Big)$$

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Multi-party authentication after decommitment

Nguyen-Roscoe: HCBK

Assumptions (to be discharged)

- agreed ordering of the principals

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Assumptions (to be discharged)

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  - all principals must digest at the same payload

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Multi-party authentication after decommitment

Nguyen-Roscoe: HCBK

Assumptions (to be discharged)

- agreed ordering of the principals
  - all principals must digest at the same payload
- social protocol to compare the digests

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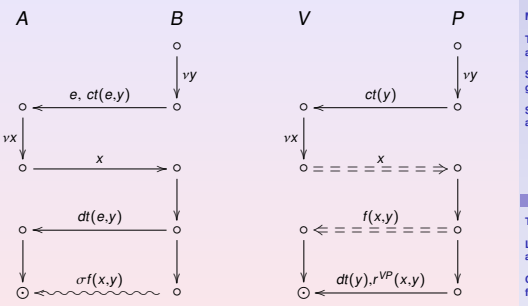
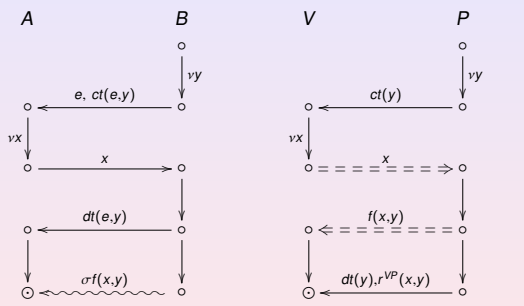
Structural similarity — conceptual difference



Structural similarity — conceptual difference



Social authentication is not challenge-response:
x on the left is not a challenge, but a binder, analogous to y.

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Trust and reputation

NOT PRESENTED

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Deriving location authetication: Mobile IP

NOT PRESENTED

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  - E2E model does not suffice

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- bootstrap distance, proximity, routing. . .

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  - derivational approach *sine qua non*

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- space security for pervasive and social computation
  - E2E model does not suffice
- bootstrap distance, proximity, routing. . .
  - derivational approach *sine qua non*

Future work

- embed Social Web 2.0 in physical space
  - enable the export of authenticated social links
  - make the Web into a social channel
- **electronic pheromones**

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