Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Informatik
Computer Science

# Characterization of Secure Human-Server Communication

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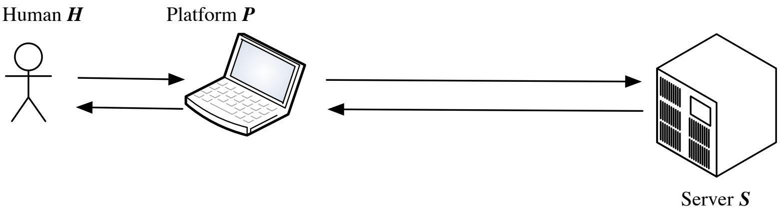
# Motivation

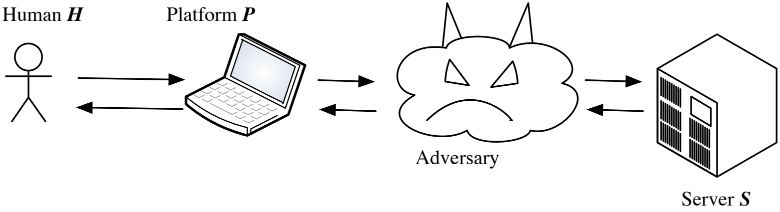
Remote (Internet) voting:




- Uncontrolled environment
- Broader attack surface
- No inherent voter privacy

# Motivation

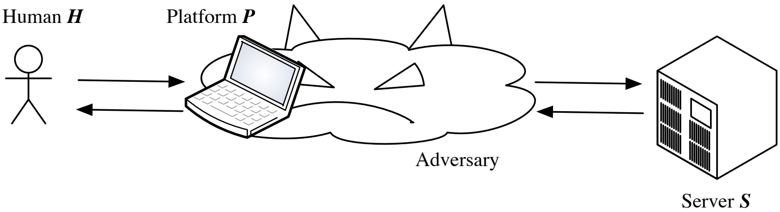
Cryptographic Internet voting protocols:




- Ballot casting assurance ✓
- Receipt freeness ✓
- Coercion resistance ✓

# Motivation

The Secure Platform Problem (SPP):




- Client-side multi-purpose platforms used
- Emerging malware infections
- General problem in electronic communication applications

# Research Questions

- What are possible approaches to solve the SPP?
- How to model these approaches and how to verify their security properties?
- What are necessary conditions to achieve specific security properties?

# Outline

State-Of-The-Art

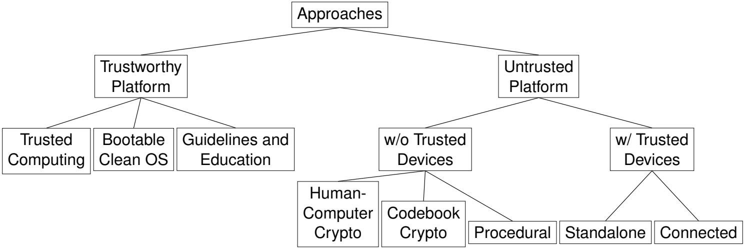
Human-Interaction Security Protocols

Characterization of Secure Human-Server Communication

Case Study

Conclusion

# Taxonomy of Solution Approaches



# Security Ceremonies [UPn03, Ell07]

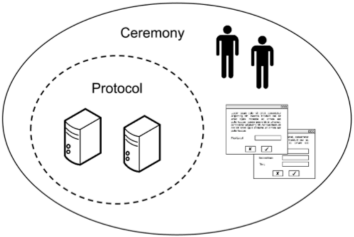
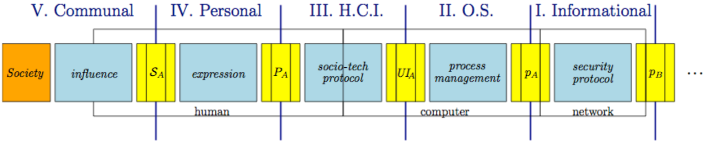



Figure: Security ceremonies. (Source: Carlos et al.)

- Nothing out-of-band
- “Special” Network connections
- Human nodes with different capabilities

# Formal Modeling of Security Ceremonies

- Bella and Coles-Kemp [BCK11, BCK12]:




- Meadows and Pavlovic [PM12, MP13] :
  Procedure Derivation Logic, Logic of moves
- Carlos et al. [CMPC12, CMPC13] :
  Weakening DY-adversary in Bluetooth-Pairing

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# Multiset Term Rewriting

- A rewriting theory $R$ consists of rewriting rules $l \rightarrow r$
- The symbol $\rightarrow$ indicates that an expression matching the left side can be rewritten to the one of the right side
- Tamarin uses labeled multiset rewriting rules. A labeled multiset rewriting rule is a triple $(l, a, r)$, denoted by $l{-}[\ a\ ]{\rightarrow}r$

## Examples

$\neg\neg A \rightarrow A$ represents a rule for double negative elimination in logic.
$A, A, B{-}[\ \ ]{\rightarrow}C, D, D, E$ is a multiset rewriting rule in Tamarin syntax.

# Traces of a Protocol

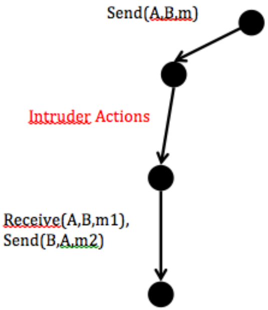
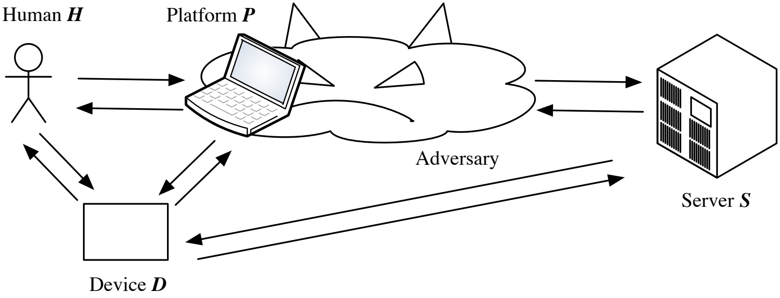


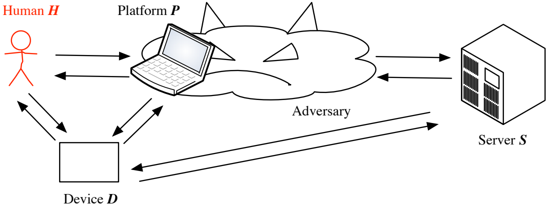

Figure: A specific trace of a protocol.

# Human-Interaction Security Protocols (HISP)



# Modeling HISPs

## Human Model

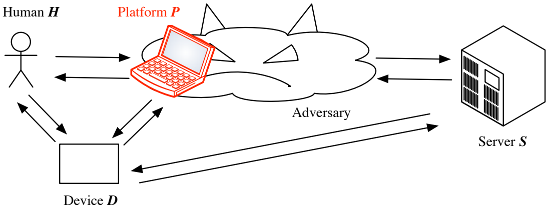



### Human capabilities

- Pairing of terms
- Projection of terms

# Modeling HISPs

## Dishonest Agents

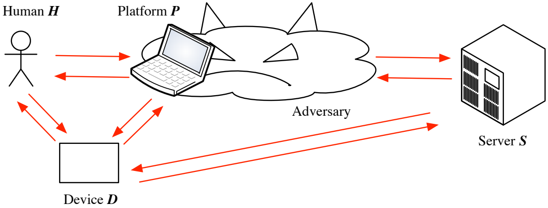



### Dishonest agents

- Leak all information, i.e., the current state
- Adversary controls them, i.e., updates the current state

# Modeling HISPs

Standard Dolev-Yao adversary and channel abstraction:




## Channels as assumptions

- Insecure
- Confidential
- Authentic
- Secure

# Modeling HISPs

Security goals

- Authentic channels
- Confidential channels
- Secure channels

between $H$ and $S$.

# Modeling HISPs

Security goals

- Authentic channels
- “Discriminating” authentic channels
- Confidential channels
- “Discriminating” confidential channels
- Secure channels
- “Discriminating” secure channels

between *H* and *S*.

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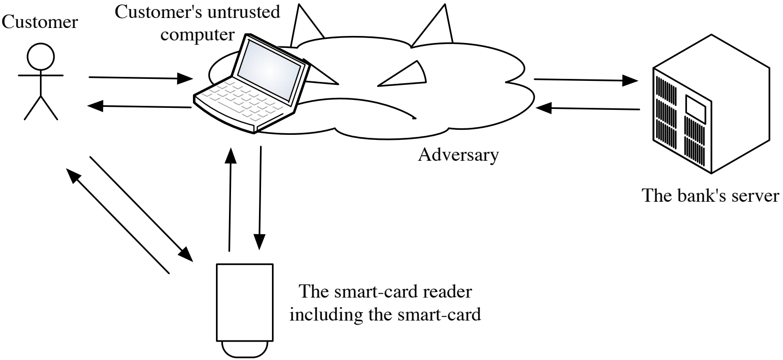
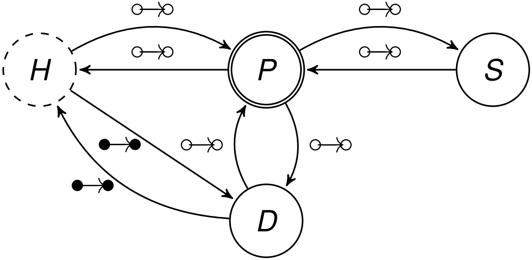
# Just One Example



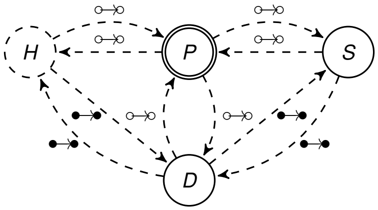
# Communication Topology Example



# Communication Topology Model

## HISP communication topology $(V, E, \eta, \mu)$

- $V = \{H, D, P, S\}$
- $\eta(H) = (\Sigma_H, \emptyset, \text{honest}), \eta(D) = (\Sigma, K_D, \text{honest}), \ldots$
- $\mu(H, P) = \mu(P, H) = \mu(D, P) = \circ\!\!\rightarrow\!\!\!\!\!/\,\circ, \ldots$



# Conditions for Secure Channel from *H* to *S*

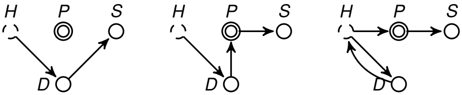



Figure: All minimal HISP topologies for which there are protocols providing a secure channel from *H* to *S*.

# Conditions for Secure Channel from *S* to *H*

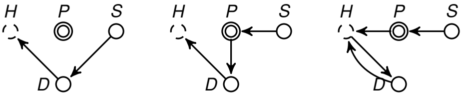



Figure: All minimal HISP topologies for which there are protocols providing a secure channel from *S* to *H*.

# Conditions for "Discriminating" Secure Channel from *H* to *S*

All minimal graphs for a "discriminating" secure channel from *H* to *S*:

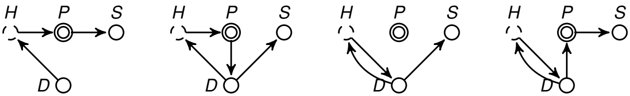



Figure: The edge from *D* to *H* and all acyclic paths from *H* to *S*.

# Conditions for "Discriminating" Secure Channel from *H* to *S*

"Discriminating" secure channels from *H* to *S*:

| | $(D,H) \notin E \wedge (H,D) \notin E$ | $(D,H) \notin E \wedge (H,D) \in E \wedge (D,S) \notin E^+$ | $(D,H) \notin E \wedge (H,D) \in E \wedge (D,S) \in E^+$ | $(D,H) \in E$ |
|---|---|---|---|---|
| $\mathrm{dauth}(\mathcal{R},H,S)$ | no (Lemma 1) | no (Lemma 2) | yes (Lemma 4) | yes (Lemma 6) |
| $\mathrm{dconf}(\mathcal{R},H,S)$ | no (Lemma 1) | no (Lemma 2) | yes (Lemma 4) | yes (Lemma 6) |
| $\mathrm{dsecure}(\mathcal{R},H,S)$ | no (Lemma 1) | no (Lemma 2) | yes (Lemma 4) | yes (Lemma 6) |

# Conditions for “Discriminating” Secure Channel from $S$ to $H$

All minimal graphs for a “discriminating” secure channel from $S$ to $H$:

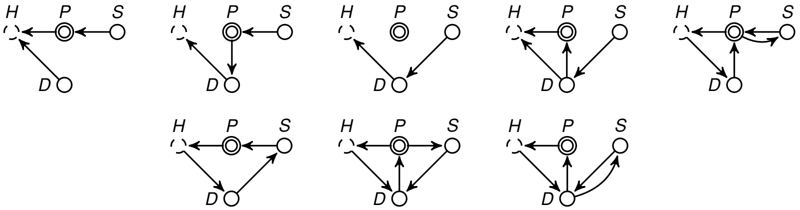



Figure: The edge from $D$ to $H$ and all acyclic paths from $S$ to $H$.

# Conditions for “Discriminating” Secure Channel from $S$ to $H$

Discriminating secure channels from $S$ to $H$:

| | $(D,H) \notin E \wedge (H,D) \notin E$ | $(D,H) \notin E \wedge (H,D) \in E \wedge (D,H) \notin E^+$ | $(D,H) \notin E \wedge (H,D) \in E \wedge (D,H) \in E^+$ | $(D,H) \in E$ |
|---|---|---|---|---|
| $\mathrm{dauth}(\mathcal{R},S,H)$ | no (Lemma 1) | no (Lemma 3) | yes (Lemma 7) | yes (Lemma 5) |
| $\mathrm{dconf}(\mathcal{R},S,H)$ | no (Lemma 1) | no (Lemma 3) | if $(H,S) \in E^+$ (Lemma 8) | yes (Lemma 5) |
| $\mathrm{dsecure}(\mathcal{R},S,H)$ | no (Lemma 1) | no (Lemma 3) | if $(H,S) \in E^+$ (Lemma 8) | yes (Lemma 5) |

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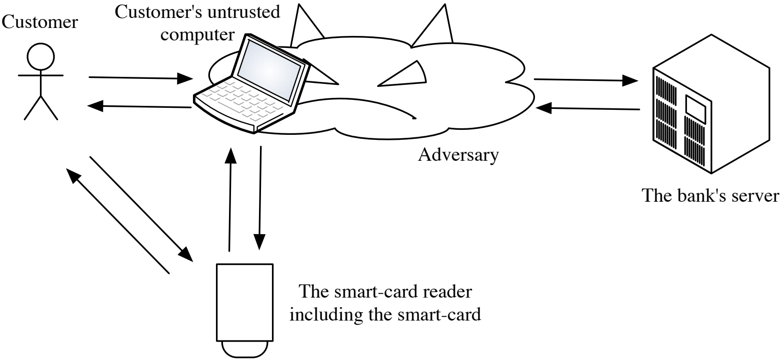
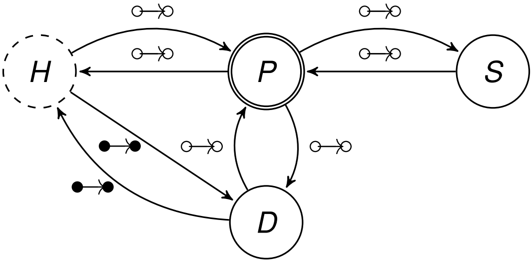
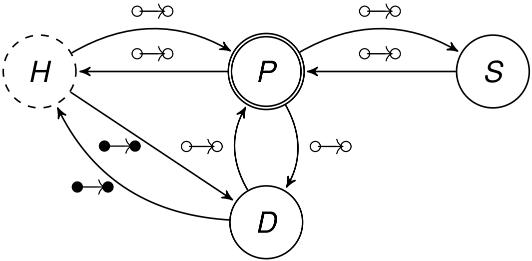
# Smart-Card-Based Transaction Authentication

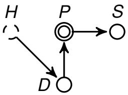


# Communication Topology



# Communication Topology




Authentic channel from *H* to *S* possible. ✓

# Transaction Authentication Protocols

Protocol Transauth a

$$H : \mathrm{knows}(\langle D, PIN \rangle)$$
$$D : \mathrm{knows}(\langle ltkD, PIN \rangle)$$
$$S : \mathrm{knows}(\langle H, D, \mathrm{pk}(ltkD) \rangle)$$
$$H \circ\!\!\rightarrow\!\!\circ P : m$$
$$P \circ\!\!\rightarrow\!\!\circ D : m$$
$$D \bullet\!\!\rightarrow\!\!\bullet H : m$$
$$H \bullet\!\!\rightarrow\!\!\bullet D : PIN$$
$$D \circ\!\!\rightarrow\!\!\circ P : \{m\}_{ltkD}$$
$$P \circ\!\!\rightarrow\!\!\circ S : \langle m, \{m\}_{ltkD} \rangle$$

# Transaction Authentication Protocols

Protocol Transauth a

$$
\begin{array}{rl}
 & H : \mathrm{knows}(\langle D, PIN\rangle) \\
 & D : \mathrm{knows}(\langle ltkD, PIN\rangle) \\
 & S : \mathrm{knows}(\langle H, D, \mathrm{pk}(ltkD)\rangle) \\
H \circ\!\!\rightarrow\!\!\circ & P : m \\
P \circ\!\!\rightarrow\!\!\circ & D : m \\
D \bullet\!\!\rightarrow\!\!\bullet & H : m \\
H \bullet\!\!\rightarrow\!\!\bullet & D : PIN \\
D \circ\!\!\rightarrow\!\!\circ & P : \{m\}_{ltkD} \\
P \circ\!\!\rightarrow\!\!\circ & S : \langle m, \{m\}_{ltkD}\rangle
\end{array}
$$

Protocol Transauth b

$$
\begin{array}{rl}
 & H : \mathrm{knows}(\langle D, PIN\rangle) \\
 & D : \mathrm{knows}(\langle ltkD, PIN\rangle) \\
 & S : \mathrm{knows}(\langle H, D, \mathrm{pk}(ltkD)\rangle) \\
H \circ\!\!\rightarrow\!\!\circ & P : m \\
P \circ\!\!\rightarrow\!\!\circ & D : m \\
D \bullet\!\!\rightarrow\!\!\bullet & H : \langle m, vc\rangle \\
H \bullet\!\!\rightarrow\!\!\bullet & D : \langle PIN, vc\rangle \\
D \circ\!\!\rightarrow\!\!\circ & P : \{m\}_{ltkD} \\
P \circ\!\!\rightarrow\!\!\circ & S : \langle m, \{m\}_{ltkD}\rangle
\end{array}
$$

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# Conclusions

- Complete characterization of necessary and sufficient conditions for the existence of security protocols that provide secure channels between a human and a remote server using an insecure network and a dishonest platform.
- Extensible and applicable on different levels of abstraction
- Efficient tool support (Tamarin)
- No bisimulation, i.e., no strong secrecy verification (yet)
- Basis for more specific models (e.g., human behavior)

# Future Work

- More detailed model and channel properties
  - Resilience as assumption
  - Verifiability as goal
- Human error modeling

# References

Giampaolo Bella and Lizzie Coles-Kemp, *Seeing the full picture: the case for extending security ceremony analysis*, Proceedings of 9th Australian Information Security Management Conference (Security Research Centre, Edith Cowan University, Perth, Western Australia), 2011, pp. 49–55.

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Marcelo Carlomagno Carlos, Jean Everson Martina, Geraint Price, and Ricardo Felipe Custódio, *A proposed framework for analysing security ceremonies.*, SECRYPT, 2012, pp. 440–445.

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UPnP Security Working Group, *UPnP™ security ceremonies design document*, October 2003.

# Questions

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